Ukrainian Aeronautics Research and Technology Report 2018

Foreword

We would like to welcome you to the *Ukrainian Aeronautics Research and Technology Report 2018*.

Ukraine's aerospace sector spans the full spectrum of aerospace systems and components development and production with original equipment manufacturers, tier 1 and tier 2 suppliers, aircraft engine manufacturers, control systems manufacturers, R&D organisations and institutions, aeronautic universities, as well as aerospace small-to-medium sized enterprises. This is also reflected in the aerospace sector being a major contributor to the country's economy.

Ukrainian aerospace organisations possess unique skills and knowledge that can help Europe to address the challenges and goals identified in the ACARE Strategic Research and Innovation Agenda / Flightpath 2050 Report. Furthermore, following the signing of the Agreement for the Association of Ukraine to Horizon 2020 in March 2015, Ukrainian aerospace organisations are eligible to participate in the EU's Clean Sky 2 and H2020 Transport programmes on the same funding terms as those from EU member states. Equally, genuine commercial opportunities exist for European aviation organisations to help modernise Ukraine's aerospace sector.

This report is an updated and expanded version of the *Ukrainian Aeronautics Research and Technology Report 2010*, which was produced during the European Commission funded AERO-UKRAINE project (2009-2011, Seventh Framework Programme, Grant Agreement No 233640). This latest version of the report has been prepared under the European Commission funded AERO-UA project (2016-2019, Horizon 2020 Framework Programme, Grant Agreement No 724034). The main aim of the project is to provide strategic and targeted support for Europe-Ukraine collaboration in aviation research.

The AERO-UA project addresses its main aim via four high-level objectives:

- Identifying the barriers to increased EU-UA aviation research collaboration;
- Providing strategic support to EU-UA aviation research collaboration;
- Supporting EU-UA aviation research knowledge transfer pilot projects;
- Organising awareness-raising and networking between EU-UA stakeholders.

The project and this report are the collaborative efforts of the following consortium of European and Ukrainian partners:

- Intelligentsia Consultants (Project Coordinator), www.intelligentsia-consultants.com
- Fraunhofer Institute for Factory Operation and Automation, www.iff.fraunhofer.de
- Technology Partners, www.technologypartners.pl
- University of Manchester, www.manchester.ac.uk
- SE Ivchenko-Progress, www.ivchenko-progress.com
- Public Joint Stock Company "FED", www.fed.ua
- Ukrainian Research Institute of Aviation Technology, www.ukrniat.com
- National Academy of Sciences of Ukraine, www.nas.gov.ua
- National Aerospace University of Ukraine (KhAI), www.khai.edu

The consortium is supported by an Advisory Board involving Airbus, DLR, Ministry of Education and Science of Ukraine, Ukrainian State Air Traffic Services Enterprise and retired Director of EADS Jean-Pierre Barthélemy.

If you would like further information about the H2020 AERO-UA project and its events, please visit our project website: www.aero-ua.eu

We hope you enjoy reading this report and that it helps to strengthen future Europe-Ukraine aeronautics research and technology collaboration.

Giles Brandon
H2020 AERO-UA Project Coordinator
on behalf of the H2020 AERO-UA consortium

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Introduction

This report aims to provide a thorough description of the Ukrainian aeronautics research and technology sector as well as the barriers and support to aeronautics research collaboration between the EU and Ukraine.

The report is structured according to the following chapters:

- **Chapter 1** summarises the *State's role in the national aeronautics sector*.
- **Chapter 2** describes *the main aeronautics organisations (institutes of the National Academy of Sciences, higher education institutes, industrial organisations and clusters) and research and technology areas (from materials through to airports) in Ukraine.*
- **Chapter 3** examines *the barriers and support to aeronautics research collaboration between the EU and Ukraine based on feedback to an online survey from Ukrainian aeronautics experts as well as interviews with key Ukrainian aeronautics R&T decision-makers*.
- **Chapter 4** describes *past and current initiatives providing support to EU-Ukraine research collaboration in the field of aeronautics and some illustrative success stories.*
- **Chapter 5** provides *a high-level SWOT analysis of the aeronautics research and technology sector in Ukraine and defines a set of recommendations to strengthen aeronautics research and technology cooperation between the EU and Ukraine.*

1. The role of the State in the National Aeronautics Sector

The State plays an important role in the organisation and development of the aeronautics sector in Ukraine. In order to have an understanding of the State's role, it is vital to have a thorough description of the national governance system as well as the direct and indirect policy measures that influence the Ukrainian aeronautics industry and relevant research and innovation activities.

1.1 National Governance System

The **President of Ukraine**, as the guarantor of the Ukraine's sovereignty, territorial indivisibility, and the observance of the Constitution of Ukraine and human and citizens' rights and freedoms, acts in the field of research and technology activities in accordance with the Constitution and the legislation of Ukraine. The President has the power to issue decrees in different areas and they have to be considered by the Cabinet of Ministries. The President is Head of the National Security and Defence Council of Ukraine, which is responsible for determining the strategic national priorities in the science, technology and innovation spheres, mainly in the defence domain.

The **Verkhovna Rada of Ukraine**, as the single body of legislative power in Ukraine, is responsible for state regulation in the field of scientific and technology development. The Verkhovna Rada approves basic principles and focal points of national policy in the field of research and technology activities; adopts priorities of science and technology development, and national programmes aimed at research and technology development of Ukraine. To facilitate these activities, the **Committee on Education and Science** is established and operates within the Verkhovna Rada.

The **Cabinet of Ministers of Ukraine**, as the highest body of executive power in Ukraine, ensures the implementation of national science and technology policy and guarantees the development and strengthening of Ukraine's scientific and technical potential in all priority areas, including aeronautics. On the one hand, the Cabinet of Ministers of Ukraine submits to the Verkhovna Rada proposals for science and technology priorities; ensures development and implementation of national target science and technology programmes; approves the national target science and technology programmes according to the priorities adopted by the Verkhovna Rada; and takes measures to improve the national legislation in the field of research and technology activities. On the other hand, it determines and approves the responsibilities of the central executive bodies and regulates their coordination with the National Science and Technology Council of Ukraine. In this way, it ensures control over the establishment and operation of the public administration system in science, technology and innovation and therefore plays a very important role in aeronautics R&D.

The **National Science and Technology Council of Ukraine** is a permanent consultative and advisory body under the Cabinet of Ministers of Ukraine that was established in April 2017 to support reforms in research and innovation. The Council is responsible for ensuring effective collaboration between the research community, executive authorities and the economic sector in the frame of the development and implementation of a single national science and technology policy. The National Science and Technology Council of Ukraine operates in close collaboration with the Ministry of Education and Science of Ukraine and the National Academy of Sciences of Ukraine.

The **Ministry of Education and Science of Ukraine** (MESU) is the main central executive body in Ukraine, which is responsible for development and implementation of national policies in the fields of education and science; and research, technology and innovation. MESU has two main departments that influence the national and international aeronautics-related research implemented by Ukraine's leading universities.

Firstly, the Department of Scientific and Technical Development is responsible for science development in Ukrainian Higher Education Institutes (HEIs). It provides financial budget support to more than 140 HEIs to conduct basic and applied research and technology development. These funds are allocated in the frame of annual open calls, which are in line with the science and technology priorities adopted by the Verkhovna Rada. All applications are evaluated and successful projects are selected by MESU's Scientific Council that includes 23 panels including one dedicated to "Aerospace Engineering and Transport". In 2016, the total funding allocated by MESU to Ukrainian HEIs was 670 million hryvna.

Secondly, the Department of International Cooperation and European Integration is responsible for international education and research links with the Ministry and, specifically, for communication with

education and research establishments and agencies of the European Union. In the frame of these activities, the system of the National Contact Points (NCPs) was established in 2011 to support the participation of Ukrainian organisations in the 7th European Framework Programme for Research and Technological Development. In 2014, the Ministry reappointed some FP7 NCPs and appointed some new ones to serve as Horizon 2020 NCPs. Following the successful signing on 20 March 2015 of the Association Agreement between Ukraine and European Union for the participation of Ukraine in the European Union's Horizon 2020 Framework Programme for Research and Innovation, the Department is officially responsible for European Union-Ukraine cooperation in education, science, innovation and technology as well as Ukraine's participation in Horizon 2020.

The **National Academy of Sciences of Ukraine (NASU)** is the highest self-governing public research organisation in Ukraine. NASU is entitled to determine independently its research priorities and topics as well as to collaborate nationally and internationally. NASU annually reports to the Cabinet of Ministers of Ukraine on its R&D activities and the results it has achieved. As of 2017, NASU is comprised of 163 research institutes and more than 15,000 researchers, including 6,814 candidates of science (equal to PhD degree), 2,402 doctors of science, 186 academicians, 361 associates and 98 international members.

NASU's governing bodies - such as the General Assembly, Presidium, and Expert Council on fundamental research topic assessment - play a vital role in the development and implementation of coordinated research policy at the national level. They regularly advise governmental bodies on ways to improve the regulatory framework, provide financial support of research entities, nurture and encourage human resources.

The research activities of NASU institutes are mainly financed by the State and national companies and enterprises. However, international contractual research and technology transfer activities generated 114 million hryvna (approximately 3.9 million euro) profit in 2016. At least **10 of NASU's research institutes** are involved in research and innovation activities related to aeronautics. One of them - E.O. Paton Electric Welding Institute - is also the location of Ukraine's most successful technology park: Technopark "Paton Electric Welding Institute".

The **State Fund for Fundamental Research in Ukraine (SFFR)**, which celebrated its 25th anniversary in 2016, supports on a competitive basis fundamental research in the field of natural science, technical science (including aeronautics-related issues) and humanities that are carried out by Ukrainian research institutions, higher educational establishments, and scientists. The SFFR is officially managed by the Ministry of Education and Science of Ukraine. At the same time the SFFR Board, which is the primary management authority of the Fund, involves prominent researchers and executives from both Ukrainian HEIs and NASU research institutes.

The **Ministry of Economic Development and Trade of Ukraine -** Ukraine's main central executive body for industrial policy – has several responsibilities with respect to State regulation of Ukraine's aeronautics industry. Firstly, the Ministry determines the directions for the scientific and technical development of Ukraine's industry as well as develops and ensures the implementation of science and technology development programmes for specific industry branches including aeronautics.

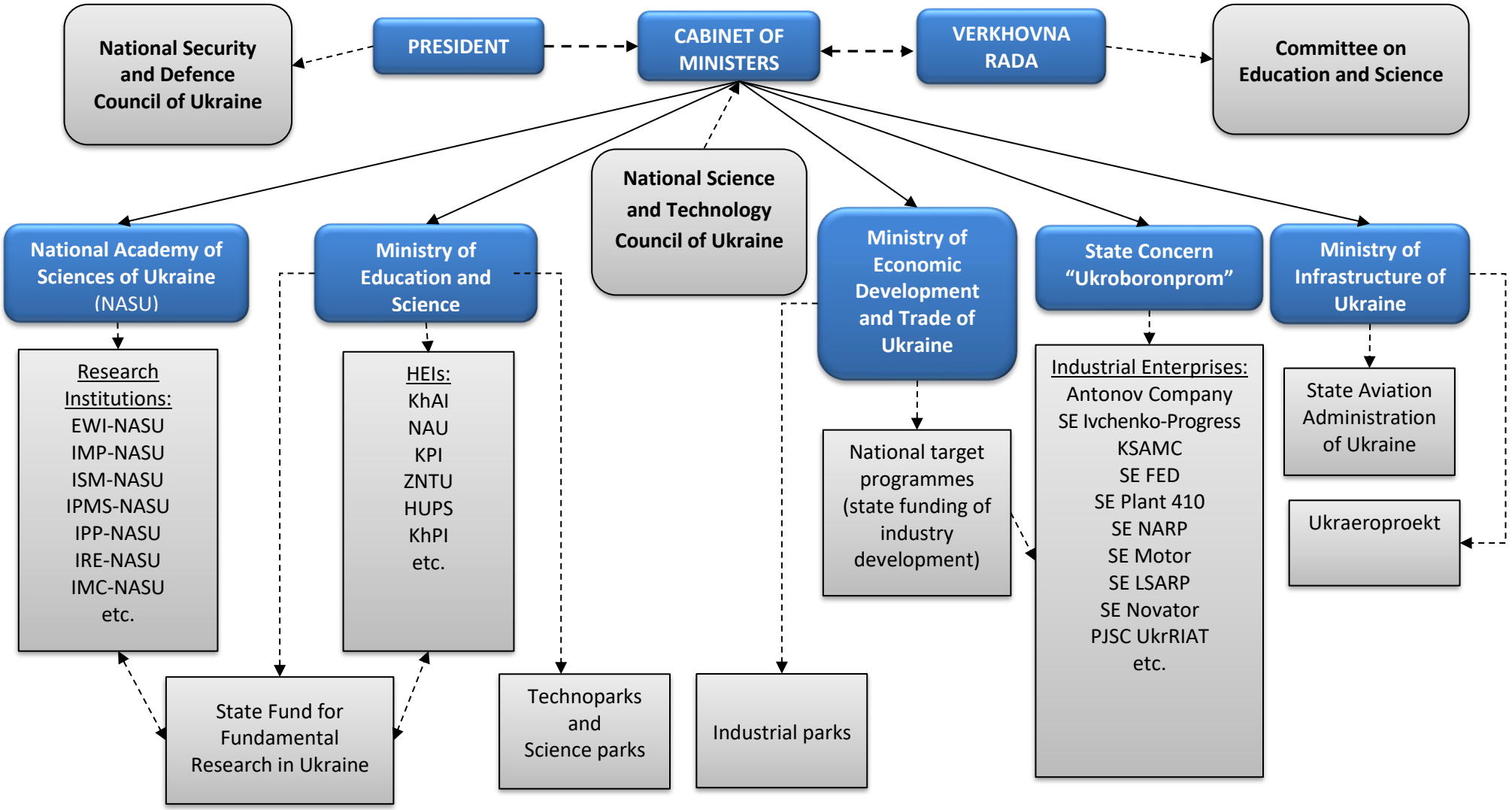
Secondly, the Ministry develops and organises the implementation of **national target programmes relevant to the needs of industry**, which creates a background for the development and manufacture of competitive products by Ukrainian industrial enterprises with the use of innovative technologies, equipment and materials. According to recommendations made by the Ministry of Economic Development and Trade of Ukraine, the national target programmes are funded by the Ministry of Finance of Ukraine using state budget funds. Since Ukraine became an independent country in 1991 there have been several national target programmes dedicated to aeronautics, such as "Programme of Ukrainian Aviation Industry Development" (1992), "State Complex Programme of Ukrainian aeronautics industry development for 2001-2010" (2001). Right now, the "Programme of Ukrainian Aircraft Industry Revival" is under development with the aim to facilitate the revival of batch production of aircraft and to boost the sector's growth.

Moreover, the Ministry has the power to initiate the creation of state integrated companies in the industrial sector and to make relevant proposals to the Cabinet of Ministers of Ukraine. In this way, the **State Concern "Ukroboronprom"** was created by decrees of the Cabinet of Ministers of Ukraine in 2010 with the aim to ensure efficient operation and management of state enterprises, which are involved in the development, production, selling and utilisation of military and special equipment.

Today, the **State Concern "Ukroboronprom"** is an association comprised of over 100 multidisciplinary enterprises from five key branches of the defence industry of Ukraine, including aircraft industry and aircraft maintenance. Ukroboronprom's members include Antonov Company, SE Ivchenko-Progress, SE Kharkiv State Aircraft Manufacturing Company, PJSC FED, SE Plant 410, SE NARP, SE Motor, SE LSARP, PJSC UkrRIAT and others. Among other issues, Ukroboronprom supports the members with the implementation of applied research in priority areas as well as the introduction of advanced technologies into production.

Concerning civil aviation matters and the use of Ukraine's air area, the **Ministry of Infrastructure of Ukraine** is responsible for the development of relevant state policy, while the **State Aviation Administration of Ukraine** is responsible for its implementation. The Ministry of Infrastructure coordinates and controls the activities of 17 companies in the aviation sector, including Ukrainian State Air Traffic Services Enterprise, SE Boryspil International Airport, SE International Airport "Lviv" named after Danylo Halytsky, and Ukrainian State Design and Technological Research Institute of Civil Aviation "Ukraeroproekt", which has the status of head industrial research organisation in the area of development of civil aviation ground infrastructure in Ukraine. Currently, Ukraeroproekt employs about 80 highly qualified specialists. Ukraeroproekt's main activities include engineering design of airfields, runways, service areas, and maintenance, repair and operations facilities; development of master plans for airports, aircraft manufacturing and repair plants, industrial entities; development of waste treatment, heat recovery, sewage treatment and other technologies; relevant R&D activities relevant to civil aviation infrastructure. Ukraeroproekt has developed the majority of civil aviation projects in Ukraine and worked together with the State Aviation Administration to renovate Ukrainian airports for the Euro 2012 football championship.

The role of the State in Ukrainian Aeronautics Research and Technology



1.2 Direct and Indirect Policy Measures influencing Ukrainian Aeronautics R&T

1.2.1 Importance of the aviation industry for Ukraine – historic outline

Aerospace has been long recognised as one of the strongest economic sectors of Ukraine, which is one of the few countries in the world possessing the full cycle of aerospace product development and manufacturing. Therefore, since Ukraine became independent in 1991, specific attention has always been paid by the Government to this high-tech sector.

In 1992 the Programme of Ukrainian Aviation Industry Development was initiated and approved by the President of Ukraine. It foresaw a set of measures for organisational and financial support to provide:

- Development and manufacturing of modern competitive cargo and passenger aircraft in Ukraine
- Organisation of batch production of such aircraft with the involvement of Ukrainian enterprises of defence and other industries
- Building, renovation and commissioning of necessary industrial capacities
- State funding of research activities, capital building, renovation, equipment and materials supply
- Organisation of head enterprise to coordinate all research and development activities in aeronautics filed in Ukraine
- Introduction of tasks on the development and production of aircraft products to public procurements and allocation of funding to assembly manufacturers.

This Programme was followed by the State Complex Programme of Ukrainian aeronautics industry development for 2001-2010. The Programme goals included:

- Creation of a globally competitive aviation industry to meet the internal demand of the country matching its strategic independence and increasing the export of Ukrainian aviation products.
- Assimilation of new types of competitive aviation products.
- Increase production and sales of aviation products which provide significant economic impact.
- Improvement of production structure, development of research potential and production capacities, and renovation of capital assets of aviation product manufacturers.
- Creation of conditions to accelerate innovation-driven development of the aircraft industry.
- Creation of a support system for Ukrainian aviation products sales.
- Widening of international cooperation and deepening of integration with CIS-countries and other foreign countries in aviation product manufacture and repair.
- Harmonisation of Ukrainian intellectual and production systems and regulatory environment with the relevant systems and procedures of leading foreign manufacturers of aviation products.

However, over this intervening period, the aeronautics R&D potential of Ukraine has decreased with the above mechanisms for stimulating innovation activities proving inefficient. In parallel, several critical aviation production facilities have become outdated, workforce capacities weakened, and Ukrainian aeronautic products have lost their competitiveness.

In 2008, after thorough investigation of the potential of aviation enterprises, the Cabinet of Ministers of Ukraine approved the *National strategy of the aviation industry development for the period to 2020***.** Its overall goal has been to create the necessary conditions for a competitive and sustainable Ukrainian aeronautics industry.

After the Ukrainian Revolution in 2013, the new government implemented a series of reforms. This led to some changes in the governance structures influencing the aeronautics sector (See Section 1.1). In 2017, in order to facilitate the revival of batch production of aircraft and to boost the sector's growth, the *Programme of Ukrainian Aircraft Industry Revival* has been developed and is currently awaiting approval of the Cabinet of Ministers of Ukraine.

1.2.2 Programme of Ukrainian Aircraft Industry Revival

The Programme's overall aim is to create the conditions for the development and extensive growth of the aircraft sector by improving the cost and competitiveness of aircraft products.

The Programme's specific goals include:

- To support Ukrainian manufacturers and to implement an import substitution policy
- To increase aircraft industry competitiveness and improve the investment climate, to create modern manufacturing facilities and introduce new technologies
- To make structural changes: privatisation of state enterprises and the creation of an integral management structure for the sector
- To develop new airplanes and helicopters and modernise existing types of passenger and cargo airplanes and helicopters, to modernise existing types of aircraft engines, and other aircraft products which will have a market demand
- To restructure, modernise and renovate aircraft batch production capacities, maintenance and repair centres for Ukrainian aircraft
- To form production capacities for the development, modernisation and batch production of helicopters, civil UAVs, other aircraft; to create an integrated centre for the development of advanced avionics equipment
- To develop and batch produce radically new technologies for aircraft, aircraft engines, assemblies and systems, and other aircraft products and parts
- To create favourable conditions for aircraft product marketing, and organisation of efficient sale strategies (including use of leasing)

The Programme is expected to be funded from the state budget, investment and innovation funds, loans, and the internal funds of enterprises. The aggregate projected amount of funding for the period of 2017-2022 is 64.5bn UAH (approximately 2.2bn euro).

A specific Action Plan has been developed to implement the programme, which aims to increase aircraft production output by up to 100 bn UAH and facilitate the development of new airplanes, helicopters, UAVs and modernisation of existing ones (AN-158, AN-178, AN-124, Mi-8, etc.) Also, the quality of manufacturing will be increased and international certification systems will be introduced. Other important targets over the period 2017-2020 include facilitating public-private partnerships and attracting investments to the sector; retaining at least 60,000 jobs and creating at least 8,000 new jobs; and increasing salaries in the field by a factor of 2-3.

The Action Plan for implementing the Programme of Ukrainian Aircraft Industry Revival includes the following main tasks with each one allocated to a responsible body (government bodies, ministries, public companies, etc.):

- Elaboration, approval and implementation of the State Target Research Programme for the development of the aircraft industry for 2018-2020
- Implementation of measures (including R&D, testing, certification activities) to replace Russian components in Antonov aircraft
- Introduction of leasing campaigns to stimulate the demand for Ukrainian aircraft
- Easing of credits of commercial banks for aircraft enterprises
- Facilitation of public procurement of defence aircraft products
- Deep modernisation of Mil helicopter production
- SE Antonov privatisation as well as the creation of an Antonov State Holding Company
- Optimisation and modernisation of Antonov aircraft production
- Facilitation of the production of helicopters and their assemblies by Motor Sich
- Facilitation of the development and start of batch production of new types of aircraft engine by SE Ivchenko-Progress
- Certification of Ukrainian aircraft engine in the European Union
- Amendment of relevant legislation acts to create more favourable conditions for aircraft enterprises
- Renovation of Antonov aircraft landing gear production at SE Yuzhmash
- Support to the implementation of the Law of Ukraine regarding mass expansion of products in relation to aircraft products
- Completion of unfinished AN-140 and AN-74 aircraft

1.2.3 Other direct and indirect policy measures influencing Ukrainian Aeronautics Sector

Measures relevant to aircraft industry

Law on the Development of the Aircraft Industry
This law[1] was approved and signed by the President in January 2010 and has been amended several times during 2012-2016. Among other provisions, the law provides privileges to the aircraft industry including specific conditions on import customs, exemption from land tax, favourable VAT rates, and preferential taxation on profits and foreign currency payments.

Law on the amendment of the Section "Transitional provisions" of the Tax Code of Ukraine concerning support for the aircraft sector
This law was signed by the President of Ukraine in December 2016[2] and temporarily (till 1 January 2025) exempts:

- Actors working in the aeronautics sector - from VAT for operations on import of relevant products and implementation of relevant R&Ds in customs area;
- Aircraft OEMs, aircraft engines OEMs - from income taxes with the requirement to use these funds for R&D, facility renovation and upgrade, and innovation activities;
- Aircraft OEMs, aircraft engines OEMs - from land taxes.

Measures relevant to research and development activities

Law on Innovation Priorities
This law determines the legal, organisational and economic foundations for the formulation of innovation priorities in Ukraine for 2011-2021[3]. The law describes two types of priorities – medium term and long-term strategic ones. Strategic priorities are for not less than 10 years. The list of strategic priorities includes the following:

1. Assimilation of new technologies for energy transportation, introduction of energy and resource-efficient technologies, and assimilation of alternative energy sources
2. Assimilation of new technologies for high technology development of the transportation system, rocket and space field, aircraft industry and shipbuilding, armament and military technologies
3. Assimilation of new technologies for materials production, their processing and joining, creation of nanomaterials and nanotechology industry
4. Technological upgrade and development of the agricultural sector
5. Introduction of new technologies and equipment for quality medical services, treatment, pharmaceuticals industry
6. Wide application of technologies for cleaner manufacturing and protection of the natural environment
7. Development of advanced information and communication technologies, robotics.

Law on Science and Technology Priorities
This law defines the legal, financial and organisational foundations for the formulation and realisation of science and technology priorities in Ukraine for the period to 2020[4]. Initially, seven specific priorities for science and technology were established:

- Fundamental research in key areas of science and technology to improve Ukraine's social, economic, political and human potential to ensure the country's global competitiveness and the sustainable development of society and the State
- Information and communication technologies

[1] The Law of Ukraine on Development of the Aircraft Industry approved by the President of Ukraine No 2660-III dated 12 July 2001, revision dated 1 January 2017 (http://zakon5.rada.gov.ua/laws/show/2660-14)
[2] The Law of Ukraine on amendment of the Section XX "Transitional provisions" of the Tax Code of Ukraine as for the support of aircraft sector approved by the President of Ukraine No 1795-VIII dated on 20 December 2016 (http://zakon2.rada.gov.ua/laws/show/1795-19)
[3] The Law of Ukraine on Priority areas of innovation activity in Ukraine approved by the President of Ukraine No 3715-VI dated 8 September 2011, revision dated 5 December 2012 (http://zakon2.rada.gov.ua/laws/show/3715-17)
[4] The Law of Ukraine on Science and Technology Priorities approved by the President of Ukraine No 2623-III dated 11 July 2001, revision dated 16 January 2016 (http://zakon2.rada.gov.ua/laws/show/2623-14)

- Energy efficiency
- Efficient use of natural resources
- Life sciences, new technologies of prophylactic and treatment of the most common diseases
- New substances and materials

Measures relevant to aviation infrastructure

Strategic plan of aviation transport development to 2020
This plan was approved by the Ministry of Infrastructure of Ukraine in 2015[5] and is aimed at ensuring the sustainability of the Ukrainian aircraft sector under conditions of increased competitiveness following integration to the Common Aviation Area (CAA); ensuring safety of flights; and harmonizing the standardisation system (regarding flight safety, personnel, maintenance, etc.) with the European Union. The plan defines the following strategic targets:

- Improvement of aviation infrastructure
- Assurance of affordable, high-quality and safe air transportation for citizens
- Intensification of international activities of Ukraine in the field of civil aviation
- Reformation of the civil aviation sector management system

The plan includes a list of specific tasks to be implemented and relevant key performance indicators to be monitored.

State target programme for airport development up to 2023
The aim of this programme, approved by the Cabinet of Ministers in 2016[6], is to satisfy national demand for development of the aeronautics sector; to harmonise aviation infrastructure with international standards; to facilitate Ukraine obtaining "transit country status" due to its unique geographical location; and to increase the efficiency of state-owned property management. It includes a set of specific actions to be realised till 2023 and the targets to be achieved:

- Twofold increase of passenger throughput with respect to 2015 (up to 24.3m in 2023)
- Twofold increase of passenger capacity of airports
- Shortened aircraft ground handling time (to 35-40 minutes)
- Facilitate private-public partnership in the area of airport operation
- Increase the share of low-cost airlines (up to 30% of all air transportation market)

The programme is financed from the personal funds of airport owners, credit funds, state funds, private investments, etc. The total estimated aggregate funding required for airport development to 2032 is over 8.6bn UAH (approximately 300m euro), including 1.2bn UAH of private investments.

State programme of civil aviation safety
The State programme of aviation safety was approved by the President of Ukraine[7] in March 2017 and has been developed in accordance with the standards and recommended practices of the Convention of international civil aviation and other applicable regulations, as well as accounts for the requirements of the United Nations Security Council. The programme defines measures, rules, practices and procedures for aviation safety assurance at all levels. It foresees the funding of these aircraft safety measures as being covered through airport charges.

[5] Strategic plan of aviation transport development to 2020 approved by the Order of the Ministry of Infrastructure of Ukraine No 546 dated 21 December 2015 (http://new.mtu.gov.ua/documents/444.html)
[6] State target programme for airports development to 2023 approved by the Resolution of the Cabinet of Ministers of Ukraine No 126 dated 24 February 2016 (http://zakon2.rada.gov.ua/laws/show/126-2016-%D0%BF)
[7] State programme of civil aviation safety approved by the Law of Ukraine on the State programme of civil aviation safety No 1965-VIII dated 21 March 2017 (http://zakon2.rada.gov.ua/laws/show/1965-19/page)

2. The National Aeronautics Research and Technology Sector

Obtaining accurate and up-to-date quantitative information specifically about the aeronautics research and technology (R&T) in Ukraine is quite difficult. For the overall aerospace industry (i.e. aeronautics and space), it is estimated over 68000 scientific and technical employees work across 39 plants and companies[8].

In broad terms, organisations conducting aeronautics research fall into one of three categories: institutes of the National Academy of Sciences of Ukraine, higher education institutes and companies (state or privately owned).

The **National Academy of Sciences of Ukraine** is comprised of about 200 research institutes and centres with most of them involved in natural and technical sciences. At least 10 institutes are involved in research and technology related to aeronautics. The research activities of the Academy are mainly financed by the State and it co-ordinates its activities with the Ministry of Education and Science.

In 2016, there were 657 **higher education institutes** from all levels of accreditation in Ukraine. Among them, 287 institutes and universities with level III-IV accreditation have research facilities and conduct research. However, the total research and technology costs in 2016 for all Ukrainian universities was only 670 million hryvnas (approximately 22.3 million euro). Nevertheless, there are 6 leading universities spread across the country - in Kyiv, Kharkiv, and Zaporizhzhya - conducting research related to aviation and aerospace. Altogether, there are about 30,000 aerospace students.

The major aeronautics **industrial organisations** are currently state owned e.g. SE Antonov (State Company), SE Ivchenko-Progress (State Enterprise) and SDO Yuzhnoye (State Design Office). With regard to research and technology, state owned companies rely heavily on the input and support of institutes of the National Academy of Sciences and several universities. Also, there are estimated to be a few hundred small-to-medium-enterprises (SMEs) involved in the aerospace sector with a significant number privately owned.

2.1 Main Organisations conducting Aeronautics Research and Technology in Ukraine

2.1.1 Institutes of the National Academy of Sciences of Ukraine

A list of website addresses for the following institutes can be found in Annex 2.

Frantsevich Institute for Problems of Materials Science of the National Academy of Sciences of Ukraine (IPMS-NASU) is Ukraine's leading research centre in the field of materials science and advanced technology of metal, ceramic and composite materials. It provides advanced scientific and engineering consultancy as well as contract research and technology services.

IPMS-NASU was set up in 1955 on the base of the laboratory for special alloys of the Ukrainian Academy of Sciences. Since then it has progressively widened its fields of research and customer base. IPMS-NASU's activities in new material development and commercial application are supported by a large pool of researchers in solid-state physics and chemistry, inorganic physical chemistry, and mechanics of deformable media.

Altogether, IPMS-NASU employs about 1700 people, including 70 doctors and more than 345 PhD. It is a large scientific and research complex, including Special Design Bureau with Pilot Plants, Computer Centre and Laboratory for Basalt Materials Production.

G.V. Kurdyumov Institute for Metals Physics of the National Academy of Sciences of Ukraine (IMP-NASU) is a leading research centre in the fields of metal physics, solid state physics and physical metallurgy in Ukraine. The institute employs 431 people, including 123 PhDs and 63 Dr. hab, whose research and development activities are conducted along four main directions:

[8] **Ukrainian Aviation Industry and Capabilities for Cooperation with the European Union**, Presentation, Oleg Bogdanov, Deputy General Designer, Antonov ASTC, 28 October 2009

- Atomic Structure of Metals and Heterophase Metallic Systems,
- Physics of Strength and Plasticity of Metals and Alloys,
- Electronic Structure and Electronic Properties of Metallic Alloys and
- Intermetallic Compounds, Nanoscale systems.

Its research related to aerospace applications is focused on structural materials such as high-strength aluminium alloys; wear-resistant superalloys for gas-turbine engines; functional materials such as shape memory alloys; as well as certain technologies such as electro-thermal treatment of titanium alloys, powder metallurgy manufacturing of titanium components and ultrasonic treatment of aerospace metallic materials. These R&D achievements are at different technology readiness levels but some have already been adopted by different enterprises, including Antonov.

V. Bakul Institute for Superhard Materials of the National Academy of Sciences of Ukraine (ISM-NASU) conducts research on novel mono- and polycrystalline superhard materials (synthetic diamonds, cubic boron nitride, composites and ceramics), which are widely used in the tool industry for machining metal and non-metal materials, as well as structural elements for instrument-making, electrical industry, space equipment, optics, and electronics. The institute cooperates with a number of Ukrainian enterprises including Antonov. The institute's staff of 420 employees includes 38 doctors, 81 candidates of sciences, and more than 100 young researchers and post-graduate students.

Physical and Technological Institute of Metals and Alloys of the National Academy of Sciences of Ukraine (PTIMA-NASU) conducts research on hydrodynamics, heat and mass transfer and crystallisation processes in order to prepare, process and solidify alloys to obtain novel cast metallic materials or final products. The institute also develops related manufacturing equipment and technologies. The institute cooperates with a number of Ukrainian enterprises including SE Antonov and JSC Motor Sich. The institute's staff of 400 employees includes two members of NASU, 25 doctors, 44 candidates of sciences, and over 50 young researchers and post-graduate students.

The Institute of High-Molecular Compounds Chemistry of the National Academy of Sciences of Ukraine (IHVS-NASU), is the leading scientific center of Ukraine for the development and research of different polymers, composites and derived materials. It was founded in 1958. The Institute conducts research and manufactures the newest methods of creating polymers in several key areas of polymer science: fundamental aspects of the chemistry of polymers, chemistry and chemistry of polymer composite materials, technology of functional polymers and composites based on them, creating a theoretical basis for the modification of polymeric materials and the study of polymers for medical purposes. The Institute's staff of 300 employees includes one academician and two corresponding members of the National Academy of Sciences of Ukraine, 18 doctors and 73 candidates of science, 5 professors and 50 senior researchers.

E.O. Paton Electric Welding Institute of the National Academy of Sciences (PEWI-NASU) is a multidisciplinary research institute which realises fundamental and applied research works, develops technologies, materials, equipment and control systems, rational welded structures and weldments, methods and equipment for diagnostics and non-destructive quality control according to the following directions:

- Advanced technologies of welding and joining of materials;
- Strength, reliability and life of welded structures;
- Technology of surfacing, coating and treatment of surface;
- Processes of special electrometallurgy;
- New structural and functional materials;
- Technical diagnostics and non-destructive testing;
- Automation of processes of welding and related technologies.

The E.O. Paton Electric Welding Institute is a head organisation of the Scientific-Technical Complex "The E.O. Paton Electric Welding Institute" of the National Academy of Sciences of Ukraine (STC PWI), which includes Design-Technological Bureau, Engineering Centres of high technologies, pilot workshops on explosion welding and treatment, and also a powerful production facility in the form of three pilot plants manufacturing welding equipment, consumables and using new technologies, which are capable to design, manufacture and deliver the pilot samples and batches of specialised equipment, welding and filler materials, welded structures and weldments.

A.M. Pidhorny Institute for Mechanical Engineering Problems of the National Academy of Sciences of Ukraine (IPMASH-NASU) is a well-known research centre in power and mechanical engineering. It has 14 scientific departments and plays an active role in the following activities: forming the energy strategy of Ukraine to 2030, and the concept of the State programme for ensuring technological safety in key branches of the economy; the regional programme "Resource"; the initiator of the Academic Scientific-and-Educational Complex (ASEC) for open-end training of researchers starting from school (academic lyceums) and through to post-graduate courses and Doctorate studies.

G. S. Pisarenko Institute for Problems of Strength of the National Academy of Sciences of Ukraine (IPP-NASU) was founded in 1966 on the basis of the Department of Strength of the Institute for Problems of Material Science of the Academy of Sciences of Ukraine. In the past, research efforts were concentrated on investigations of novel structures for rocket, aerospace, and propulsion engineering. Today, the institute's main concern is with the evaluation of the remaining life expectancy and safe operation of equipment used in nuclear and thermal power engineering, oil-, gas-, and product pipelines; aeronautic apparatus; oil-refining and chemical industries; and railway transport.

Institute of Technical Mechanics of the National Academy of Sciences of Ukraine and the State Space Agency of Ukraine (ITM-NASU and SSAU) was established in 1980 and provides scientific and technical support to the execution of projects of the National Space Programmes of Ukraine and coordinates R&D in space engineering under the supervision of the State Space Agency of Ukraine. Currently, the institute conducts fundamental and applied research in the following directions:

- Dynamics of mechanical and hydromechanical systems, launch vehicle systems, and rail and motor transport;
- Aero-thermo and gas dynamics of power plants and flying and space vehicles and their subsystems;
- Strength, reliability, and optimisation of mechanical systems, launch vehicles, and spacecraft;
- Mechanics of interaction of a solid with ionised media and electromagnetic radiation;
- Systems analysis of trends and prospects in space engineering.

"Transmag" Institute of Transport Systems and Technologies of the National Academy of Sciences of Ukraine (ITST-NASU) carries out research in the following areas:

- Dynamics and aerodynamics of high-speed vehicles, cars, trains;
- Development of computational fluid dynamics software based on the equations of compressible gas and incompressible fluid dynamics, turbulence, air ionisation, chemical kinetics;
- Aeroelasticity of aircraft structural elements;
- Aerodynamics of multi-element airfoils in different flight modes;
- Transonic and supersonic shock wave/boundary layer interactions;
- Electrodynamics and chemical kinetics of low-temperature nonequilibrium plasma;
- Flow separation control with plasma actuators, heat and mass transfer;
- Aircraft icing.

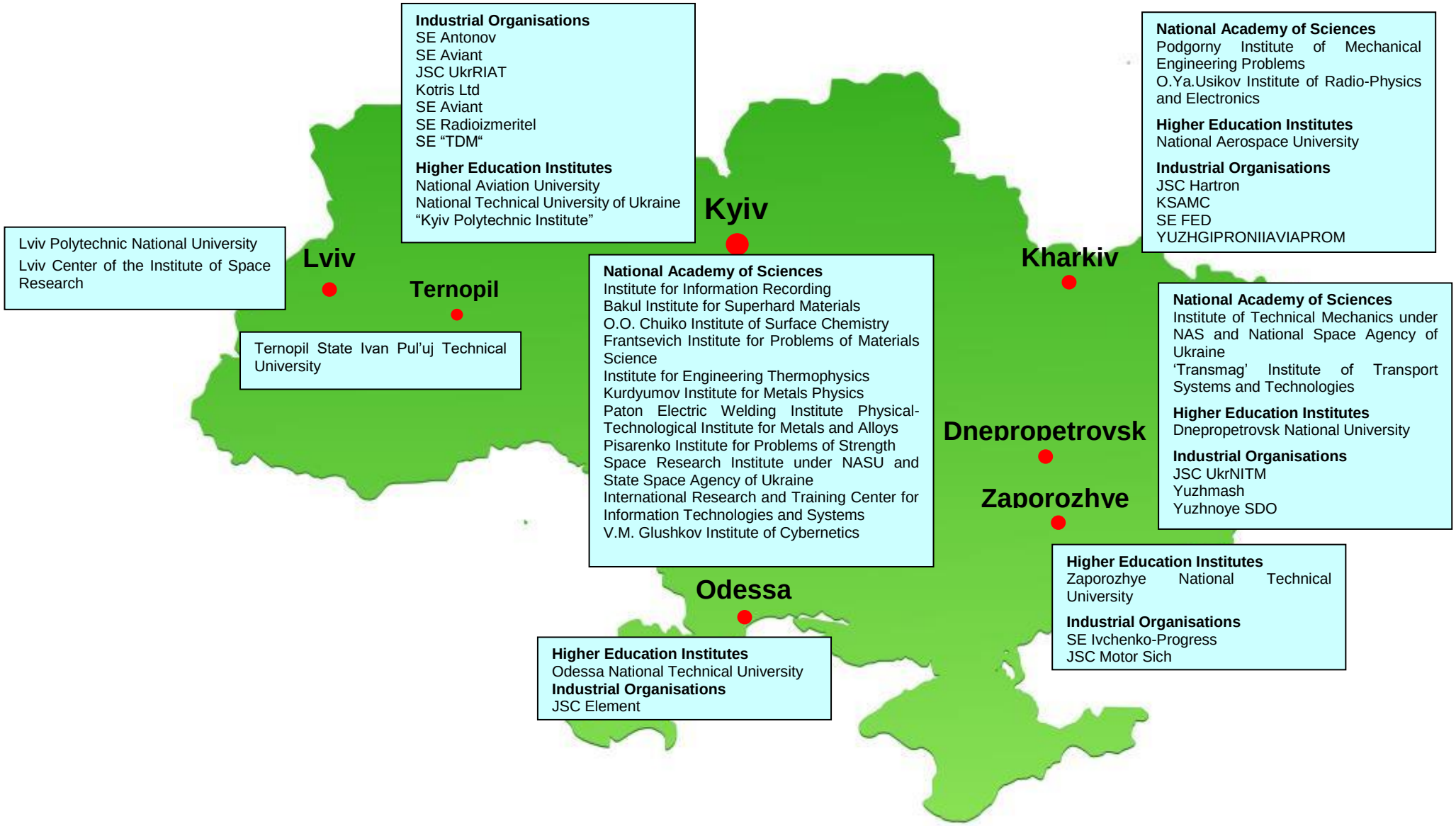
The institute's staff is comprised of 108 employees includes 7 doctors, 26 candidates of sciences, 19 young researchers and 5 post-graduate students.

Institute of Electron Physics of the National Academy of Sciences of Ukraine (IEP-NASU) has extensive experience in the field of radiation testing of materials and devices for aerospace engineering on a base of an electron accelerator microtron M-30. They have skilled staff and the necessary licenses to conduct such radiation test work using dosimetric/spectrometric apparatus in specialised labs. The institute cooperates with a number of Ukrainian enterprises including SDO Yuzhnoye.

Institute of Engineering Thermophysics of the National Academy of Sciences (ITTF-NASU) has a department dedicated to high-temperature thermogasdynamics, which is a leader in the field of gas turbine blade cooling. The department's 25 staff conduct research into swirling and vortex flows fundamentals, air-cooled gas turbine blades, heat transfer augmentation, internal blade cyclone cooling, novel oscillating film cooling, and high temperature heat exchangers.

O. Ya. Usikov Institute of Radio-Physics and Electronics of the National Academy of Sciences of Ukraine (IRE-NASU) was established in 1955 on the basis of the former Departments of Electromagnetic Oscillations and Radio Wave Propagation of the Kharkov Institute of Physics and Technology of NASU. The Institute has gained a reputation for its research achievements – especially concerning millimetre and submillimetre waves - in radio physics, vacuum electronics, quasioptics, microwave studies in solid-state physics and biophysics, radio wave propagation, and remote sensing of the earth from airborne and space-borne platforms. The institute cooperates with a number of Ukrainian enterprises including SDO Yuzhnoye. The institute's staff of 490 employees includes 41 doctors, 125 candidates of sciences, and over 100 young researchers and post-graduate students.

Organisations involved in Aeronautics Research and Technology in Ukraine



V.I. Vernadsky Institute of General and Inorganic Chemistry of National Academy of Sciences of Ukraine (IGIC–NASU) was founded in 1918 and performs research and design of new compounds, composites, protective and functional coatings used in engineering, microwave technology, chemical power sources, photoelectrochemical devices and sensors, sorption-membrane and electrochemical purification technologies. The institute collaborates extensively with local organisations (e.g. SE "Orizon-Navigation", KP "Kharkiv Design Bureau engine", NPO "Integral", "Plant Transistor" and "Metallokeram" Ltd) and has won numerous research grants (e.g. NATO "Science for peace", FP7, Horizon 2020, "Erasmus-Mundus" and STCU). The institute is comprised of 188 people including 108 researchers (18 doctors of science, 64 PhD, 3 doctoral students, 19 PhD students and graduate students).

Institute of Macromolecular Chemistry of National Academy of Sciences of Ukraine (IMC-NASU) was established in 1958 and carries out research into advanced areas of macromolecular chemistry: chemistry, physics and technology of functional polymers and polymer composites; theoretical fundamentals of polymer and polymer composite modification; and scientific tools for forming organic-inorganic polymers and composites based on natural compounds. In recent years, the institute has been involved in the development of optically-transparent coatings to increase the efficiency and life-time of photovoltaic devices as well as high-strength glue compounds for solar batteries used in space applications.

L.V.Pisarzhevskii Institute of Physical Chemistry of National Academy of Sciences of Ukraine (IPC-NASU) is one of the most well-known scientific centres in Ukraine carrying out fundamental and applied studies in modern physical chemistry. The Institute has six scientific departments, two laboratories and the production-technological complex for the state enterprises of "Radma", "Katek" and "Koloran". Its research is focused on fundamental problems of catalysis, chemistry of isotopes, chemistry of free radicals and mechanisms of chemical reactions, adsorption and adsorbents, physical chemistry of coordination compounds, photochemistry, physico-chemical methods and indicator agents to check leak-tightness. The institute cooperates with several Ukrainian enterprises including SE Antonov and SDO Yuzhnoye.

O.O. Chuiko Institute of Surface Chemistry of the National Academy of Sciences of Ukraine (ISC-NASU) was founded in 1986. The Institute carries out fundamental and applied research in the following areas:

- Chemistry, physics and technology of surface;
- Theory of chemical structure and reactivity of surface of solids, research into nature of active sites of surface, mechanisms of adsorption, chemical reactions, and transformations in surface layers;
- Biomedical problems of surface;
- Research into surface states, diffusion phenomena, charge and mass transfer, phase formations in nanostructures, collective interaction in assemblies of particles, size-quantised effects of systems, interaction with radiation;
- Technology of production of nanomaterials, highly disperse oxides, their modified forms, and composites on their basis.

ISC-NASU also runs the Kalush Experimental Plant (Ivano-Frankivsk region) to develop and produce nanoparticulate metal oxide fillers and their modified forms.

V.M. Glushkov Institute of Cybernetics of the National Academy of Sciences of Ukraine (GIC-NASU) conducts research on computer mathematics and discrete optimisation, mathematical theory of computing and artificial intelligence, system analysis and stochastic programming, mathematical reliability theory and the theory of programming. The institute provides high-performance supercomputing resources for institutes of National Academy of Science and serves the Ukrainian National Grid as a National Resource Centre. The institute cooperates with a number of Ukrainian enterprises including Antonov. The institute's staff of 540 employees includes 40 doctors, 132 candidates of sciences, and more than 90 young researchers and post-graduate students.

International Research and Training Center for Information Technologies and Systems under the National Academy of Sciences of Ukraine and Ministry of Education and Science of Ukraine (IRTC) conducts R&D in artificial intelligence, novel information and communication technologies and systems, automatisation problems, and the creation of an informational society in Ukraine. The institute

has 350 workers including: 30 doctors of science, 70 candidates of science and around 100 young researchers and postgraduates.

Institute for Information Recording of the National Academy of Sciences of Ukraine (IPRI-NASU) conducts research on physical fundamentals, principles, methods and systems of recording and transformation of information, theoretical foundations and applied methods for creating computer information-analytical systems, investigation and development of information protection methods in computer systems and networks, theoretical basis and applied methods of computer simulation, and creation of automated monitoring systems of plurality moving objects in real time. The institute cooperates with SDO Yuzhnoye. The institute's staff consists of 172 employees, including 83 scientific workers, 9 doctors and 24 candidates of sciences.

Space Research Institute under the National Academy of Sciences of Ukraine and State Space Agency of Ukraine (SRI-NASU and SSAU) was established in April 1996 on the basis of the Control Systems Department at V.M.Glushkov Institute of Cybernetics. It has five research departments employing nearly 100 staff. SRI-NASU and SSAU participates in the following national and international research projects:

- Near-Earth Space: POTENTIAL (on board SICH-2), IONOSAT-MICRO, RADIOASTRON, RESONANCE.
- Earth Observation: methodological support and development of information services.

SRI-NASU and SSAU represents Ukraine in international space organisations and working groups (e.g. COSPAR, CEOS and GEO). Ukraine's regional support centre for the United Nations Platform for Space-Based Information for Disaster Management and Emergency Response (UN-SPIDER) has been established on the basis of SRI-NASU and SSAU.

Lviv Center of the Institute of Space Research under the National Academy of Sciences of Ukraine and State Space Agency of Ukraine (LC-ISR) was established in 1996 as the leading centre of space instrumentation developments. Currently LC SRI employs over 100 experts in the design of equipment for electromagnetic measurements, information processing systems and ground facilities.

2.1.2 Higher Education Institutes

A list of website addresses for the following institutes can be found in Annex 2.

The National Aerospace University "KhAI" (KhAI) is a leading Ukrainian technical university and the only engineering University in Ukraine providing the full cycle of higher education in the field of aviation and aerospace engineering. Since the University's foundation in 1930, its history is closely connected with aircraft engineering and science global development. Today, over 12,000 students and 160 PhD students are trained at the University. 700 teachers (including more than 100 professors and doctors of science, 400 associate professors and candidates of science) and over 2000 teaching staff members are employed at KhAI.

KhAI is a member of the International Association of Universities (IAU/UNESCO), Partnership of a European Group of Aeronautics and Space Universities (PEGASUS), European Aeronautic Science Network (EASN), Magna Charta of European Universities (Magna Charta Universitatum), International Association of Technical Universities from CIS Countries, and Academic Association of Higher Education Institutions of CIS Countries. Being a well-known University, KhAI is also a globally recognised aerospace research centre. It is focused on innovative research across the aerospace industry, and has worked with Airbus, ONERA, Thales Alenia, Boeing, EOARD, IAI, AVIC, etc.

KhAI is involved in a diversified range of research activities: aerodynamics, including subsonic, supersonic, hypersonic fluid dynamics and wind tunnel tests; CAD/CAM/CAE design of aeronautic structures and elements, strength analysis and FEM simulation; aircraft structure full-scale structural

testing and durability studies; advanced coating development; high-strength composite structure design and simulation; aircraft manufacturing and assembly processes development, advanced manufacturing tools; aircraft propulsion, aircraft control systems; dependable embedded systems and fault-tolerant adaptive systems, unmanned aerial vehicles, remote sensing systems.

National Aviation University (NAU) was established in 1933 for the education and training of specialists in civil aviation. Since its establishment, over 200,000 specialists and master students have been trained at NAU. Today, NAU is one of the world's most powerful aviation higher educational institutions with more than 50,000 students including 1,200 international students from 49 countries studying all the necessary specialties for airports, airlines, design offices and other aviation organisations. The university consists of 15 institutes, 7 colleges, a technical school, 2 high schools, Centre for Air and Space Law, and European regional centres of International Civil Aviation Organisation (ICAO).

Research is concentrated in 4 research institutes, 7 research centres, and a number of research laboratories, which carry out research in the fields of integrated telecommunication technologies; design and ergonomics; unmanned aviation, airport ecological problems, operational reliability of aviation equipment information support of the operation of aviation transportation equipment; lubricants; aerodynamics; aircraft strength and resource, nanotribology; technical diagnostics; mechanics of materials and aerospace engineering structures, information security systems, etc.

National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (KPI) was founded in 1898. It is one of the oldest and largest technical universities in Europe and is ranked first in Ukraine. In the 2017 Webometrics Ranking of World Universities, KPI was placed 1593 out of 20,300 universities. It regularly holds the highest position amongst the best higher educational establishments of Ukraine. The university trains 25,000 students, postgraduates; doctorates as well as foreign students. It has 19 faculties, 9 educational and scientific institutes, several scientific and research institutes and educational centres.

KPI cooperates with technical universities from across the World countries, many international organisations (UNESCO, UNIDO, WIPO, NATO, EDNES, ICSU, CODATA, etc.), numerous well-known corporations (Siemens, Festo, Samsung, INTEL, etc.), and takes part in international educational, scientific projects and programmes.

KPI is involved in numerous research areas with several of them directly connected with aerospace: aerospace systems; energy, metal and composite materials, mechanical engineering; power engineering and power generating technologies, information processing, electronics, radio engineering and communications; technical systems diagnostics and administration. In 2014, KPI opened together with "Progresstech-Ukraine" LLC a joint education and research centre for aircraft technology. The centre is based in KPI's Institute of Mechanical Engineering and trains both young specialists and HEI academic staff in aircraft engineering education.

Zaporizhzhya National Technical University (ZNTU) consists of 6 institutes, 12 faculties and over 13,000 students. For over 110 years the university has been graduating thousands of professionals many of whom became leaders in the respective branches of industry, including aviation. ZNTU is a member of the Black Sea Universities Network. The university's departments carry out fundamental and applied research in different technology areas. It has world class scientific schools related to material science, welding processes and material science; machine construction; metal-

cutting processes; and aviation engine construction. Specifically, ZNTU has a Department of Aviation Engine Construction Technology, which closely works in research and education with the aero-engine industries in Zaporizhzhya such as JSC Motor Sich and SE Ivchenko Progress.

Ivan Kozhedub National University of Air Force (HUPS) Ivan Kozhedub Kharkiv University of Air Force is a multidisciplinary higher education institution with a highly qualified faculty, up-to-date education and material facility, developed infrastructure. The university was founded in 1930 and carries out educational activity for the training of military pilots, navigators, specialists in combat management of aviation, anti-aircraft missile troops, radio engineering troops, engineering aviation support, automated control systems and ground support of aviation flights, computer science and information technologies, metrology, energy, etc.

The university's research has been utilised in many government and industry programmes, in the creation and improvement of armaments and military equipment, its combat use and operation. The university's research and laboratory facilities support fundamental, applied and exploratory research in the fields of creating high-precision weapon systems, video information security, signal processing in radioelectronic systems, metrological support of radio electronic equipment and radio engineering systems.

National Technical University "Kharkiv Polytechnic Institute" (KhPI) was founded in 1885. According to QS World University Rankings, KhPI is ranked amongst the best 750 universities in the World. The university has research teams working in the fields of turbine machine building, material science, chemistry, lightning strike testing (research institute "Molniia"), ICT, energy saving and integrated technologies, Integrated manufacturing engineering technology, high-voltage electrophysics and engineering.

2.1.3 Industrial Organisations

A list of website addresses for the following companies can be found in Annex 2.

SE Antonov was founded in 1946 by the famous aircraft designer Oleg Antonov. More than one hundred types and modifications of various aircraft classes and purposes have been designed since the company's foundation. The characteristic advantages of ANTONOV aircraft include structural reliability and economic efficiency, flexibility of transport operations, ability to use unpaved airfields and easy maintenance. Due to these qualities, over 1500 Antonov aircraft have been exported to more than 70 countries all over the world. All in all more than 22,000 aircraft have been built.

Antonov AN-148
(Image courtesy of SE Antonov)

Nowadays, Antonov is engaged in designing and building new aircraft prototypes as well as modifications of earlier designs, the provision of operational and product support and engineering work on extending the service life of existing aircraft. Antonov also participates in international cooperation in the field of aircraft and equipment design and manufacture as well transit vehicle development.

Antonov has invested heavily in computer-aided-design equipment and skills thereby creating a powerful engineering and research potential. In-house wind tunnel facilities enable the testing of aircraft models. All aircraft types, including such giants as the Ruslan and Mriya, can be subjected to structural tests to determine their service lives in one of the world's largest fatigue test laboratories. Finally, Antonov completes the aircraft development cycle with flight test programmes to demonstrate compliance of the aircraft with airworthiness requirements and customer specifications.

An overview of the planes developed by Antonov over the past 60 years can be found in Annex 3.

Zaporozhye Machine-Building Design Bureau Progress State Enterprise Named After Academician A.G. Ivchenko (SE Ivchenko-Progress) has been designing a wide range of aero-engines to power aircraft and helicopters since 1945. During the past 65 years, more than 80,000 of Ivchenko-Progress' aviation piston and gas turbine engines, turbine starters, auxiliary power units and industrial application drivers have been manufactured. Aero engines designed by Ivchenko-Progress power 57 types of aircraft in 109 countries from Europe, Asia, Africa and America. The total operating time of its gas turbine engines exceeds 300 million hours.

Ivchenko-Progress was responsible for first introducing many new engineering designs in the USSR including:

- AI-20 turboprop engine with long service life;
- AI-25 bypass turbofan engine;
- D-36 three-shaft bypass turbofan engine with high bypass ratio;
- D-18T turbofan engine with a thrust over 20 tons (which powers the AN-225 and AN-124-100).

Similarly, Ivchenko-Progress has been responsible for numerous "world firsts" including:

- D-136 helicopter engine – the most powerful in the world helicopter engine;
- D-27 cruise turboprop-fan (open rotor) engine (which powers the AN-70);
- Unified gas generators for turboprops and turbofans of high reliability and low cost.

D-18T Engine from SE Ivchenko-Progress
(Image courtesy of SE Ivchenko-Progress)

Since the 1990s, the company's design team has been developing gas turbine drivers for industrial applications and special equipment. This line of activity covers 21 types of engines with a power range from 0.5 to 25 MW. Gas turbine drivers from the D-336 family (4 to 10MW) and the AI-2500 (2.5MW) are currently operating in more than 31 compressor and 3 power stations in Ukraine, Russia, Belarus, Azerbaijan, Turkmenistan, Uzbekistan, Bulgaria, Turkey and Iran. The operating time for some driver gearboxes has reached 30000 hours without the need for repair.

Today, the sphere of Ivchenko-Progress activities covers design, manufacture, test, development, certification, putting into series production and overhaul of gas turbine engines for aviation and industrial applications. The company has more than 60 design, quality and reliability certificates from international bodies including Bureau Veritas, EASA, Central Civil Aviation Administration of China, IAC AR and GosAviaSluzhba of Ukraine.

Notably, the research and test facilities of the company are amongst the most advanced in the world. They include 17 test benches and 78 rigs used for solving various problems related to engine testing, component development, certification, reliability and fuel-consumption.

An overview of the aero-engines developed by SE Ivchenko-Progress can be found in Annex 4

Motor Sich Joint Stock Company (JSC) is Ukraine's largest aircraft engine manufacturer which was founded in 1907. The company is engaged in development, production, testing, upgrade, repair and overhaul, and field maintenance of engines for multiple aircraft applications, as well as creation, upgrade and maintenance of helicopters and their components. Aircraft engines produced by Motor Sich JSC are installed in 88 aircraft types operated in more than 120 countries worldwide.

The company is engaged in a wide range of research and development activities in the fields of engine design and optimisation, engine manufacturing processes and techniques, material science, etc. One of the Motor Sich's subdivisions works on the development and upgrade of helicopters. Motor Sich JSC closely works with many national research entities, enterprises and universities, as well as participates in international collaboration in the frame of EU-funded programmes.

TV3-117VMA-SBM1V Engine

MSB-2 Helicopter Configuration

(Images courtesy of Motor Sich JSC)

PJSC "FED" is a company dealing with the development, serial production, maintenance, modernisation and repair of aircraft and general machinery units in Ukraine and abroad. The company's products are used on many different aircraft and helicopter in over 60 countries around the world. PJSC "FED" is a developer of unique technologies and manufacturing processes that are integrated in the world's most successful aeronautic programmes and projects. Serial products of PJSC "FED" are constantly updated based on operation experience in various regions of the world.

PJSC "FED" possesses robust R&D facilities and up-to-date technologies, such as precision plasma nitriding nanolayer nanocomposite coating deposition to enhance the operational characteristics of materials and parts, cutting and forming tools; high-speed processing of light, heat-resistant and titanium alloys; finishing and super-finishing treatment; honing of holes; finishing of spherical and flat surfaces; diffusion welding of bimetal designs; electron-beam welding in vacuum; and galvanic processes on a base of "clean technologies".

High-precision machine workshop (Image courtesy of PJSC “FED”)

PrJSC "Volchansk Aggregate Plant" is a private company whose activities include design, manufacture, serial production, repair and testing units for aeronautic, industrial gas turbine and automotive industries. The R&D department of the company develops hydraulic pumps and motors, oil fuel units for different aircraft and helicopter engines, actuators for flight control systems, fuel units for industrial gas turbine engines, and units for automotive hydraulic and pneumatic systems.

State Enterprise “PLANT 410 CA” is the authorised provider of a wide range of aircraft equipment maintenance, repair and overhaul services, particularly AN-24, AN-26, AN-30, AN-32, AN-72, AN-74 aircraft, MI-8MSB helicopters, and D-36 engines. The plant occupies 236,000 m^2 including 170,000 m^2 of production facilities. SE "Plant 410 CA" has overhauled about 7,000 aircraft and 40,000 engines for domestic and foreign customers from 50 countries since its establishment.

Yuzhnoye State Design Office (SDO) is one of the most well-known and recognised scientific and design companies in the world in the field of space technology development. The main areas of Yuzhnoye SDO activities are aerospace technology development and supervision of operation and manufacturing of aerospace technology (launch vehicle, rocket engines and their components, space systems, spacecraft and their components, ground segment and its components). Besides space rocket hardware, Yuzhnoye SDO develops high technology products for machine-building, power industry, transport, processing industry and other industries.

JSC ELEMENT is a certified developer and manufacturer of onboard and ground aviation electronics. In 2007 JSC ELEMENT obtained a license for the development, production, and related activities in aviation electronics and meteorological equipment. Specifically, JSC ELEMENT develops and manufactures pressure and vibration measurement transducers, onboard and ground aviation electronics, data collection and data processing systems for tests of gas turbine engines. The company works with Ukrainian and foreign companies and universities and has taken part in ambitious projects such as:

- development and manufacture of digital regulators, start and generation units, control and special test equipment for AI-450S aircraft engines;
- electronics for the AI-450S engine developed and produced by Ivchenko-Progress for the Austrian DA-50-JP7 DIAMOND aircraft;
- development and manufacture of software and hardware systems for testing Ai-222 and Ai-322 aviation engines developed and manufactured by Motor Sich JSC for the Skyrizon Company (China).

Aviation company VECTOR LLC develops light multi-purpose helicopters. The company’s development team has over 20 years of experience in aeronautics and many of their engineers were involved in the development of the Ukrainian helicopter KT-112 "Angel". Currently, the company works on the development of the twin-engine multi-purpose helicopter "Bumblebee". This helicopter has a wide range of applications including regional and municipal administration, naval aviation, oil and gas, mining, forestry and water, air ambulances, army, police, and emergency services. The company works with many European companies and seeks partners in the areas of production and investment.

JSC Ukrainian Research Institute of Aviation Technology (UkrRIAT) was established in 1964 - during the period of rapid development of the Soviet aircraft industry - as a Ukrainian branch of the Research Institute of Aviation Technology. The original purpose of UkrRIAT was to assist Ukrainian production plants with the introduction of new technologies and the mass production of new aircraft.

Today, UkrRIAT is a joint-stock company with just over half the shares owned by the State of Ukraine and the rest owned by legal entities and natural persons. Its key activities include:

- R&D, prototype and manufacturing processes development, engineering and consulting services in the field of technology and production engineering, repair, modernisation, utilisation of aircraft and aviation equipment and aviation material science;
- Examination/evaluation of the production of aviation and other high tech industries.

UkrRIAT's pneumatic tools for airframe assembly
(Image courtesy of UkrRIAT)

UkrRIAT is a key organisation in the field of material science and technology of aircraft production. UkrRIAT comprises of different specialists from production organisation, aircraft construction and machine-building. It also deals with resolving European and Ukrainian standards issues in the sphere of aviation technologies, systems and equipment. UkrRIAT also provides consultancy services concerning the application of Ukrainian aviation technology and products.

UkrRIAT has a long-term experience of cooperation with all the main players in the Ukrainian aviation sector (i.e. Antonov, Motor Sich, Ivchenko-Progress, NASU, etc.) UkrRIAT also collaborates with foreign companies such as Airbus, Evektor Aerotechnik and United Aircraft Corporation.

2.1.4 Clusters

The Ukrainian Aerospace Cluster "Mechatronics" was established in 2015 in order to build an effective system of interaction and communication between the Ukrainian aerospace industry and research and academic institutions. The Cluster is not a legal entity but acts on the basis of the Memorandum of Understanding signed by all the Cluster members. On January 2015, the Cluster registered 22 members involved in aerospace activities at all levels including leading industrial aerospace actors such as:

- **SE Antonov** – leading Ukrainian aircraft manufacturing and services company with particular expertise in the field of large cargo planes. Antonov has built a total of approximately 22,000 aircraft, and thousands of planes are currently operating in more than 70 countries
- **SE Kharkov Machinery Plant "FED"** – leading enterprise in the manufacture and repair of integrated drive generators, hydraulic devices and fuel control units for aviation, as well as products for other industries. Currently, "FED" products are distributed to over 60 countries around the World.
- **Kharkov State Aircraft Manufacturing Company (KSAMC)** – leading aircraft manufacturing company in Ukraine and one of the most famous aircraft manufacturers in the CIS. KSAMC has over 75 years' experience in the production of passenger, cargo and military aircraft. Currently, KSAMC manufactures airplanes for Antonov.
- **PJSC Hartron** – one of the leading design engineering bureaus in CIS countries and the only one in Ukraine, which develops and produces spacecraft and aerospace control systems.
- **JSC Motor Sich** – manufacturer of reliable aircraft engines and gas turbine power plants considered to be competitive on the World market. The company's products operate on aircraft and helicopters in over 100 countries worldwide.
- Design Bureaus, High Education Establishments and Research Organisations.

The Cluster's objectives include:

- Improving the competitiveness and economic potential of members of the Cluster by means of efficient cooperation throughout the entire life cycle of the Cluster's products
- Creation of broader access to innovations and new technological solutions, including technology transfer
- Creation of new high-skilled working places in various industries
- Reduction of transaction costs to create a basis for the implementation of cooperation projects and productive competitiveness
- Improving external-economic integration and growth of international competitiveness of Cluster participants through incorporation of the Cluster and its members o the global value-added chains
- Creation of the opportunities pool for launching of joint investment projects, including facilitation of Cluster members' access to financial resources
- Facilitation of scientific, production, organisational and financial cooperation within the Cluster.

Among the Cluster's joint projects are the development and production of aircraft high-lift systems with combined actuators; development of composite structures for advanced aircraft; development and production of light aviation of general and special purpose; precision plasma nitriding, nanolayer nanocomposite coatings; and development and production of inspection equipment. Also, the Cluster is a participant of the AERO-UA project and represented by PJSC FED.

2.2 Main Aeronautics Research and Technology Areas in Ukraine

2.2.1 Materials

Titanium
Titanium is a special metal gaining an increasing profile in the aeronautics sector. Titanium alloys have high strength-to-weight ratios and excellent corrosion resistance. In Ukraine, there are a number of institutes of the National Academy of Sciences involved in titanium research for aeronautics applications. For example, the research activities of Frantsevich Institute for Problems of Materials Science of the National Academy of Sciences of Ukraine (IPMS-NASU) include:

- Elaboration of silicon-strengthened titanium “steels” possessing increased high-temperature strength, oxidation resistance and ductility;
- Elaboration of advanced in situ reinforced Ti-matrix composites;
- Thermomechanical processing and powder metallurgy technology with high solidification rate in manufacturing Ti-based alloys to exert effect on formation, geometry and morphology of boride phase;
- Creating a scientific basis for elaborating silicon boride-strengthened Ti-based materials possessing increased values of Young modulus and high temperature strength;
- Studying effects of alloying, solidification rate, thermomechanical processing and boron addition technique on structure and mechanical properties of Ti-Si-X, Ti-B-X, Ti-B-Si-X (X = Al, Zr, Sn).

Transmission components made from novel titanium composites (tribotic)
(Image courtesy of IPMS-NASU)

Indeed, IPMS-NASU has been supporting Ivchenko-Progress with the development of advanced steels as well as scientific and technical documentation to manufacture blanks for high speed heatproof bearings for new generation aircraft engines.

Meanwhile, G.V. Kurdyumov Institute for Metals Physics of the National Academy of Sciences of Ukraine (IMP-NASU) is involved in the development of high strength titanium alloy production technology as well as the cost effective production of powder metallurgy titanium components. It has developed an integrated production technology that can produce beta-titanium alloy parts characterised by extremely high strength (UTS ≥ 1600 MPa) whilst keeping reasonable level of ductility (RE ≥ 8%). The production technology is based on a blended elemental powder metallurgy method in its simplest press-and-sinter approach, without application of pressure or deformation during or after sintering. A distinctive feature of technology is the employment of hydrogenated titanium powder instead of traditional titanium powder. Hydrogen has a major effect on synthesis improvement, providing production of alloys having 98.5-99.5% density, desired microstructure and chemical homogeneity, low impurity content and high mechanical properties. The production technology has been successfully used to produce high strength titanium springs for the Antonov 148 aircraft.

In recent years, Antonov's titanium development work has focused on its application in landing gear (e.g. now 80% relative volume of titanium alloys in AN-148 landing gear), high lift devices (using VT-22) and pipelines (using PT-7M).

Surface Engineering

Surface engineering is a major branch of materials science that deals with the way solid surfaces degrade through wear, corrosion and fatigue. Normally, the main aim of surface engineering is to increase the wear properties of a solid's surface to reduce its degradation over time. This can be accomplished by coating or altering its surface properties. Surface engineering is considered an enabling technology for the aerospace industry. It has been estimated that over 2 million components in a typical Airbus passenger jet require some form of surface engineering to enhance their properties.

Surface engineering related R&T in Ukraine is performed by several Ukrainian organisations. For example, International Center for Electron Beam Technologies (ICEBT) has worked on thermal barrier coating (TBC) projects for companies in the USA (General Electric, Pratt & Whitney, Chromalloy, Phygen), Canada (Cametoid) and China (BAMTRI, BIAM, Xian Aero-Engine). It has developed an electron beam physical vapour deposition (EB-PVD) system that enables the deposition of a multilayered graded nanostructured coating to be conducted in a single unit. It enables a major reduction in process time and cost as well as an improvement in the principal service properties of the coatings (thermal barrier, damping and erosion resistant). For graded thermal-barrier coatings, the EB-PVD system can:

- reduce ceramic layer thermal conductivity to 0.6 W/mK;
- improve adhesion strength with bond coat (more than 150 MPa);
- increase thermal-cyclic life-time 2-2.5 times compared with traditional TBC.

ICEBT's pilot-production EB-PVD unit
(Image courtesy of ICEBT)

For multi-layered graded erosion-resistant and damping coatings of 25-45 microns thickness deposited at high deposition rate (up to 1 micron/min), the EB-PVD system can:

- increase 10-15 times the erosion resistance (compared to Ti-6-4 alloy) due to application of B4C-based layer, stable up to temperature up to 600 C;
- increase damping characteristics and absence of coating influence on fatigue limit of the substrate being protected;
- reduce the cost by half.

ICEBT offers clients EB-PVD equipment, patent licensing and know-how concerning:

- Graded thermal-barrier coatings NiAl/YSZ for hot section components of gas turbines
- Graded nanostructured erosion-resistant and damping coatings on steel & Ti alloy items.
- Manufacturing of EB-PVD units in accordance with customer requirements.

In recent years, Antonov has been working with Paton Electric Welding Institute (PEWI-NASU) to develop a new metal deposition process for local surface repair of components made of Ti alloys. The

process offers several benefits: minimum thermal cycle effects on the structure of the base material, lower residual stresses in the base material and no wear effects up to a considerable depth.

Also, Ivchenko-Progress has been working extensively with PEWI-NASU to develop new types of high-temperature and heat-resistant coatings; ceramics materials; technologies to apply new coatings and materials to gas turbine engine components; technologies to recover parts made of titanium and high-temperature nickel alloys by welding and brazing methods; friction welding; wear-resistant coatings and associated deposition methods.

Meanwhile, Chuiko Institute of Surface Chemistry of the National Academy of Sciences of Ukraine (ISC-NASU) has been involved in several international projects with European partners dealing with:

- Environment-friendly hexavalent chromium free anticorrosion nanocoatings for corrosion protection of aluminium, magnesium and light alloys;
- Easy-to-clean and self-cleaning nanocoatings on the surface of metals and glass.

Similarly, V.I. Vernadsky Institute of General and Inorganic Chemistry of the National Academy of Sciences of Ukraine (IGIC-NASU) is specialised in electrochemical deposition of functional coatings on aluminium and its alloys using low-temperature melts and aqueous solutions. They have developed low-temperature melts (140-150°C) for depositing 1 μm thick layers of silicon on aluminium. Also, work is underway to develop wear-resistant corrosion resistant coatings of cobalt-tungsten alloys from aqueous solutions instead of using chrome.

Also, G.V. Kurdyumov Institute for Metals Physics of the National Academy of Sciences of Ukraine (IMP-NASU) is involved in the development of cobalt-based eutectic alloys (HTN-1 and HTN-2) with excellent heat and wear-resistance at high temperatures, high corrosion stability and good casting characteristics. The alloys can be used for nickel-based aviation alloy applications such as gas turbine blades. The HTN-61 alloy has been put into production at SE Ivchenko-Progress and JSC Motor Sich and is used in the engines D18T, D436T1, D436-148, AI222-25 for the AN-124, AN-225, TU-334, BE-200, AN-148, Yak-130 aircrafts. The HTN-62 alloy is currently being tested in the engine D18T.

Frantsevich Institute for Problems of Materials Science of the National Academy of Sciences of Ukraine (IPMS-NASU) is involved in investigating dispersion- and eutectic-strengthened structural materials (metallic, ceramics, ceramic metals). It recently completed an STCU project on new light eutectic alloys for coating based on cubic L12 aluminium intermetallics. IPMS-NASU is also deeply involved in the creation of detonation coatings based on titanium aluminide alloys and aluminium titanate ceramic sprayed from mechanically alloyed powders Ti—Al. It has developed the detonation coating gun “Dnepr-5MA” and established service centres to support its detonation coating technology in Japan, China, former Yugoslavia and Iran.

Lastly, G. S. Pisarenko Institute for Problems of Strength of the National Academy of Sciences of Ukraine (IPP-NASU) is involved in lifetime estimation of materials under fretting fatigue taking into consideration interference of electrical phenomena and complex stress states in the zone of contact and friction. Their development work has included studying the effect of various surface modifications and coatings on fretting fatigue of titanium alloys for dovetail joints for Ivchenko-Progress.

Composites

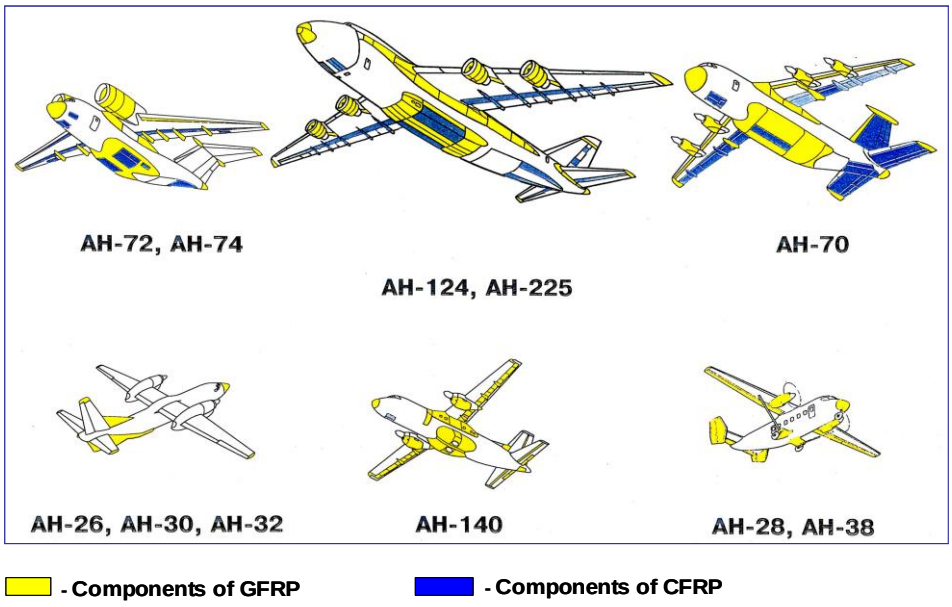
The aerospace industry’s demand for composites is advancing rapidly as a result of the drive for lighter, energy saving and environmentally friendly materials. The most widely produced composites are polymer composites with carbon fibre reinforced plastic (CFRP) being particularly popular.

Antonov has a centre dedicated to composite structures where it develops nonmetal structures based on carbon, glass, organic and hybrid fibres. The company works closely with Frantsevich Institute for Problems of Materials Science (IPMS-NASU), Podgorny Institute for Mechanical Engineering Problems (IPMASH-NASU) and Pisarenko Institute for Problems of Strength (IPP-NASU). Development work is focussed on:

- Investigations of high- and medium-stressed structures made of composite materials
- Investigations of resistance to fuel, flame and corrosion
- Investigations of atmospheric effects on strength and service life

- Development and introduction of processes for series production of integral structures

Composite material has been applied extensively to Antonov aircraft e.g. stabilizer of AN-70, engine nacelle of AN-148 and cargo door panels of AN-124.



Areas and type of composite material used in Antonov Aircraft (Image courtesy of Antonov ASTC)

The National Aerospace University "KhAI" has a strong team of experienced and young researchers who, in close cooperation with national and international research, academia and industrial partners, carry out intensive studies in the field of composites. A specialised composite material laboratory is equipped with all certified facilities and tools required for composite structures manufacturing (samples, sub-components, and small-scale components) and the static and dynamic testing of such structures.

KhAI's key fields of research in composites are:

- The mechanics of composite materials, including different aspects of mechanics of composite materials and structures and apply them to computational modelling and engineering problem solving.
- The optimisation of composite structures based on advanced FEM simulation as well as analytical models, optimisation algorithms, and customised software to simplify and accelerate typical structures design (panels, rods, shells, etc.).
- The innovative design solutions for composites (e.g. lattice and wafer components or hybrid composite-to-metal joints) to overcome existing barriers and expand composites application in aerospace structures
- The optimised production of composite structures with improved energy-efficiency and cost-efficiency through the development and the application of optimised / customised curing profile together with specifically designed self-heated tools.
- The rational maintenance of composite structures, including assessment of typical defects and failure modes and health monitoring of structural strength to schedule maintenance and develop high-quality repair processes with minimal time/costs and minimal impact on repaired structure.
- The reliable testing of composite structures with focus on high quality of structures assembly and repeatability of loading conditions. This is guaranteed through customised designed test jigs and fixtures.
- The composites characteristics modification through selection of specific additives (including nano-particles) to optimise material characteristics as well as the development of new productive and cost-efficient techniques for composites characterisation applying invariant-based theory.

Based on its expertise, KhAI offers the following high-quality services to the industry, research establishments and interested parties:

- Innovative design solutions for specific requirements.
- Multi-parametric design of composite structures for complex load cases.
- Advanced numerical simulation and strength analysis of composite structures.
- Development of energy-efficient manufacturing processes and tools for high-quality structures production.
- Health monitoring of damaged structures and development of efficient repair processes.
- Composite structures testing including full-scale tests of large 3D components.
- On-site/off-site customised training courses for in industrial enterprise staff.

Finally, Ivchenko-Progress has been working closely with IPMS-NASU to develop composites and manufacturing techniques in order to produce composite parts for aircraft gas turbine engines.

Nanomaterials

Nanomaterials have a high potential for application in several areas of aeronautics including lightweight structures designed for harsh environments and high temperatures as well as thermal and mechanical protection layers with excellent tribology characteristics for engine or landing gear parts.

Frantsevich Institute for Problems of Materials Science of the National Academy of Sciences of Ukraine (IPMS-NASU) has been successfully conducting international research projects concerning nanostructured materials with partners from Europe, India, Russia and USA since the 1990s. Its expertise and achievements include the following:

- Production of tens of particulate substances and compounds had been obtained on laboratory, pilot and industry scales;
- Development of a new concept of nanoparticle synthesis in nanoreactor considering wide number of possible reactors;
- Development of rate-controlled synthesis method appropriate for flexible control of nanoparticle size distribution;
- Development of new combined method for synthesis of nano-cubic boron nitride under shock–wave conditions in diffusion-controlled area of transformation from graphite-like BN;
- Development of pilot-scale manufacturing of single walled carbon nanotubes (SWNT) and multi walled carbon nanotubes (MWNT) by carbon oxide conversion reaction;
- Development of laboratory synthesis of nanorods, nanowires and other elongated nanostructures based on SiC, Si3N4, TiB2, BN.

Meanwhile, Podgorny Institute for Mechanical Engineering Problems of the National Academy of Sciences of Ukraine (IPMASH-NASU) can produce new nonoxide powder materials using new milling equipment operating in liquid nitrogen (77K / -196 0C). Using cryogenic milling, SiC, HfC, etc, powder materials can be produced with the following physical and chemical properties: chemical homogeneity of size composition, high dispersivity (up to 1 mkm), high purity, low sintering temperatures, high adhesion and without an oxide layer on the surface. New structural carbon-ceramic material based on SiC demonstrate significantly improved strength and thermal physics characteristics compared to traditional materials. For example, gas turbine engine combustion chambers produced from these materials have ultimate bending strength, ultimate tensile strength and ultimate compressive strength that are two times higher. Also, their high-temperature strength and heat-resistance are significantly increased.

G.V. Kurdyumov Institute for Metal Physics of the National Academy of Sciences of Ukraine (IMP-NASU) has developed power transformers based on nanocrystalline magnetic cores for medium-frequency, switch-mode power supplies for power electronics and telecommunications for aerospace applications. IMP-NASU has licenced production of the technology to Melta Ltd.

Transformers for frequency converters of HF melting and quenching plants of 125 kVA and 250 kVA power (Image courtesy of IMP-NASU)

V.I. Vernadsky Institute of General and Inorganic Chemistry of the National Academy of Sciences of Ukraine (IGIC-NASU) has been developing novel energy-saving additives for eco-friendly, bio-based lubricants. The additives are based on bio-ligands and metals found in biological systems. IGIC-NASU has studied the structure and tribology properties of the additives in etyllaurate solutions (vegetable oil). As a result of the additives penetrating the surface and near surface layers of friction zones, they are able to significantly reduce friction and wear compared to pure oil-based lubricants.

2.2.2 Manufacturing

Joining and Welding

Joining and welding are vitally important to the construction of reliable aircraft structures. Consequently, the development of improved joining and welding techniques, as well as new methods to assess the integrity of joints and welds, are of keen interest to aircraft manufacturers.

The E.O. Paton Electric Welding Institute of the National Academy of Sciences (PEWI-NASU) is world renowned for its welding development work. This institute's department of pressure welding conducts investigations into flash-butt welding, flash and resistance welding, friction and magnetically-impelled arc welding (for similar and dissimilar materials). Also, investigations concerning the physical-metallurgical processes involved in welding steels (including carbon and stainless) and alloys based on aluminium, titanium and nickel.

The institute's department of optimisation of welded constructions for new equipment's is involved in the optimisation of welded thin-sheet stringer panels and cases from aluminium and titanium alloys for the construction of new generation, wide-body aircraft. The main aim is to increase operation life by regulating deformation and minimising welding heat by means of ray and arc techniques and also by friction welding with mixing. The department has developed technologies and equipment for non-deformation welding of stringer panels from BT-1 and AMg6 alloys up to 2.5m in length and cases from AMg5 and AMg6 alloys with 0.5 – 4.0m diameters.

Frantsevich Institute for Problems of Materials Science of the National Academy of Sciences of Ukraine (IPMS-NASU) is deeply involved in the welding and soldering of inorganic materials: ceramics, oxides, nitrides, quartz glasses, glass ceramics, carbon reinforced materials and special functional materials (segneto- and piezoelectric materials, infra-transparent materials, etc). For such purposes, IPMS-NASU has developed special metallic soldering melts (adhesion–active solders), which can wet non-metallic materials.

Single-impact riveting tool developed at KhAI
(Image courtesy of KhAI)

National Aerospace University "Kharkov Aviation Institute" (KhAI) has extensive joining R&T experience from close cooperation with Antonov, Kyiv State Aircraft Plant and Kharkiv Aircraft Manufacturing Company. Also, KhAI has worked with numerous international aviation organisations. Within the STCU funded collaborative project "Composite Laminates Titanium Riveting Technology Development with Process Parameters Optimisation", KhAI worked with Boeing to develop technical knowledge and tools for pulse riveting of carbon-filled plastic aircraft structures. In a project with Evektor, KhAI was involved in the detailed study of composite parts machining and riveting, holes burnishing in aluminium structures, tightness bolts installation and torque box tanks press riveting.

Ukrainian Research Institute of Aviation Technology (UkrRIAT) has a long-term expertise in development of manufacturing processes for assembling airframe components including metal-composite stacks, as well as in manufacturing air-driven tools for the whole spectrum of processes used for joining airframe components. The processes and tools developed by UkrRIAT are widely used by aircraft manufacturers in Ukraine, Russia, China, and Iran.

Metal Forming and Machining
National Aerospace University "Kharkov Aviation Institute" (KhAI) has laboratories dedicated to metal forming, sheet and electrohydrodynamic stamping, and high-speed impulse technologies. Utilising these facilities, KhAI conducts the following research:

1. Development of methods for increased application of adaptable rigging (machining in modern machining centres).
2. Modern control of manufacturing processes and quality in sheet-stamping production.
3. Upgrading of press equipment for forming and sheet stamping in aircraft production.
4. Sheet stamping by means of high-speed cumulative influence of transmission medium.
5. Technology and equipment for high-speed (impulse) metal forming.
6. Development of enhanced high-lifetime plasma generators

Also, the Physical and Technological Institute of Metals and Alloys of the National Academy of Sciences of Ukraine (PTIMA-NASU) is involved in the development of magnetohydrodynamic and plasma technologies for processing high quality, liquid aluminium alloys – for ingots as well as sheet metal - for use in aircraft construction.

Meanwhile, Zaporozhye National Technical University (ZNTU) is involved in innovative machining technology and services to optimise modes of high-speed milling of shovels for compressors. By using its technology, Ivchenko-Progress has been able to improve production rates for aviation blades, shafts and disks by 50-55%. Specifically, ZNTU has developed manufacturing techniques for compressor blings for the high-pressure turbojet engine D-27 and researched the influence of technology twist extrusion on constructional durability of titanic alloys for compressor blades.

Similarly, G.V. Kurdyumov Institute for Metal Physics of the National Academy of Sciences of Ukraine (IMP-NASU) supplies portable ultrasonic equipment for surface engineering of details and constructive elements, in order to minimise surface roughness, enhance hardness, and redistribute residual stress. IMP-NASU has successfully cooperated with several Ukrainian plants of aircraft industry (Civil aviation plant 410, Kyiv mechanical plant and SE Antonov) in the ultrasonic surfacing of cylindrical parts (shafts and bolts), and mounting plates.

2.2.3 Numerical Simulation and Analysis

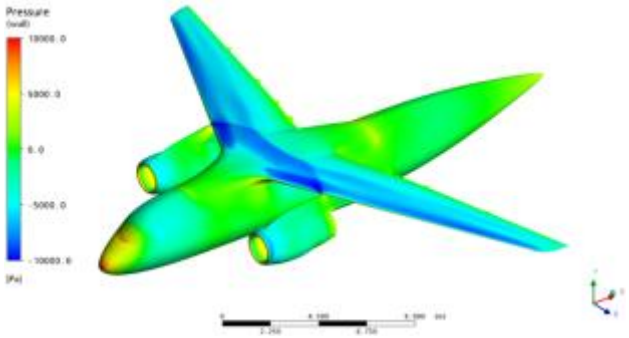
Fluid Dynamics

Podgorny Institute for Mechanical Engineering Problems of the National Academy of Sciences of Ukraine (IPMASH-NASU) has major experience in numerical simulation of viscous flows in aerodynamic passages, taking into account three-dimensionality, compressibility, flow separation, unsteadiness, influence of turbulence and other physical effects. It has developed its own computer simulation system – OPTIMUM – used for solving multilevel conditional-unconditional scalar and vector optimisation. OPTIMUM was used successfully to help design the aviation engines AI-25TLSh and D-436T1 for Ivchenko-Progress.

The department of information technology at the National Aerospace University “Kharkov Aviation Institute” (KhAI) is also heavily involved in fluid dynamics related work:

- numerical modelling of gas flows in complex form channels (including chemical reactions);
- design and test maintenance of aerodynamics objects: axial-flow and centrifugal blowers, axial-flow and centrifugal compressors, ejectors, heat-exchange devices, catalytic converters;
- numerical modelling of gas mixing at atmosphere and industrial plants (determination of pollutant gases hot spots, combustion and explosion of inflammable gases, risks assessment of man-caused emergency conditions);
- computational fluid dynamics, finite-difference and finite volume methods;
- computational multi-objective optimisation methods;
- 3D CFD codes, CAE-systems, CAD-systems, computational decision support systems on the basis of inverse problem quasi-solutions searching for turbomachines;
- technologies of flow separation control;
- computational methods of gas turbine engine diagnostic analysis.

V.M. Glushkov Institute of Cybernetics of the National Academy of Sciences of Ukraine (GIC-NASU) has a Supercomputer Aero & Hydrodynamic Virtual Lab, which provides computer aided design, engineering and simulation support to aircraft design agencies, engine builders, shipbuilding design institutes, power engineering companies and the chemical industry. The laboratory makes use of software packages such as Flowvision, ANSYS, OpenFoam and Nastran together with its own proprietary programmes to evaluate the structural integrity of constructions, simulate hydro-mechanical and thermo-mechanical processes, and solve large scale optimisation problems.



AN-148 lift computed by GIC-NASU’s Supercomputer Aero & Hydrodynamic Virtual Lab (Image courtesy of GIC-NASU)

Meanwhile, “Transmag” Institute of Transport Systems and Technologies of the National Academy of Sciences of Ukraine (ITST-NASU) has created a specialised computational fluid dynamics and

electrodynamics package based on the Navier-Stokes, Maxwell, Helmholtz, Boltzmann equations and differential turbulence models, in order to calculate steady and unsteady laminar and turbulent flows in the presence of plasma sources. Also, ITST-NASU has conducted turbulent flow analysis around three-element 30P30N air foils for cruising and landing configuration in a wide range of attack angles.

2.2.4 Structure

Antonov has one of Europe's largest structural testing facilities for conducting static, fatigue and simulated bird strike tests. It conducts research into the development of surface hardening processes; corrosion damage and its after effects; structural reliability and durability; and methods and tools for non-destructive testing of structures.

The National Aviation University (NAU) carries out fundamental and applied research within its aircraft strength and fatigue life laboratory. This includes fatigue testing according to ASTM standards (tension testing of metallic materials, measurement of fatigue crack growth rates and measurement of fracture toughness) and fatigue testing according to variable amplitude test programmes (TWIST/MiniTWIST, HELIX/FELIX and FALSTAFF).

The National Aerospace University "KhAI" has a stress test lab certified according to Ukrainian aviation regulations part 23, sections C and D; as well as airworthiness specifications JAR-VLA, sections C and D. The lab is used for examining the static and fatigue characteristics of materials, aircraft parts, and small aircrafts. Also, finite element analyses are conducted to define and predict airframe durability.

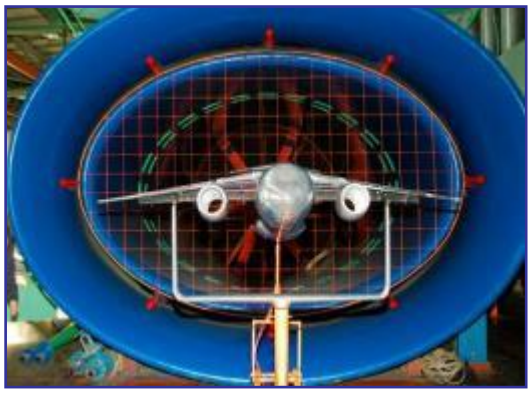
Over many years, G. S. Pisarenko Institute for Problems of Strength of the National Academy of Sciences of Ukraine (IPP-NASU) has been developing a general concept of Mode I fracture in plates and tubes subjected to monotonic loading– called the Unified Methodology - with much of the work focussed on express tensile fracture testing of thin-sheet metal for Antonov.

Meanwhile, E.O. Paton Electric Welding Institute of the National Academy of Sciences (PEWI-NASU) has developed a method of reducing fatiguing effects by means of electrodynamic treatment of cracks using electric current impulses. The method increases the operating life of aircraft where the cracks are below a critical length when first discovered. The equipment involved is compact and easy to use so aircraft can be simply treated at an airport.

Finally, Ternopil Ivan Pul'uj State Technical University (TSTU) has conducted several national projects to model and evaluate the influence of temperature and waveform loading on fatigue crack growth rates in transport plane wings.

2.2.5 Aerodynamics

Antonov develops new aerodynamic configurations for complete aircraft, wings, wing flaps, slats and other high-lift devices. Recent work has focused on improving the aerodynamic characteristics of its aircraft in cruise configuration and methods of increasing wing lift using engine power (by blowing on the upper and lower wing surface with the stream of a bypass turbo-jet engine or propfan).



Wind tunnel testing
(Image courtesy of SE Antonov)

The department of aerodynamics and acoustics at the National Aerospace University "Kharkov Aviation Institute" (KhAI) conducts fundamental and experimental research. KhAI's fundamental research includes wing in ground effect aerodynamics, adaptive airfoils, coanda effect, boundary layer, jet-controlled high-lift devices, wing and fuselage integration, and semi-empirical methods. KhAI's experimental research spans: aircraft of various configurations (TsAGI, Tupolev Design Bureau, Ilyushin Design Bureau and Antonov); wing-in-ground effect craft and amphibious aircraft (Beriev Design Bureau); UAV of various configurations for a wide range of Mach number (Yuzhnoye); and helicopters of various configurations. The department has the following facilities:

- Subsonic aerodynamics laboratory
  - Subsonic wind tunnel T-3 (velocity up 45 m/s; diameter of flow core 1.2 m; length of working section 2.3 m; initial degree of turbulence 0.06%)
  - Subsonic wind tunnel T-4 (velocity up 60 m/s; diameter of flow core 1.2 m; length of working section 2.3 m; initial degree of turbulence 0.08%)
- Supersonic aerodynamic laboratory equipped with supersonic wind tunnel T-6 (Mach number – 0.5÷4; cross section – 0.6x0.6 m; length of working section 1.3 m)
- Study wind tunnels T-5 (velocity up 35 m/s; diameter of flow core 0.6 m; length of working section 1.5 m)

Lastly, "Transmag" Institute of Transport Systems and Technologies of the National Academy of Sciences of Ukraine (ITST-NASU) has conducted numerous wind tunnel tests to evaluate high speed ground vehicle models (fuselages, fuselages with wings, and railway rolling stock).

2.2.6 Propulsion

An overview of the aero-engines developed by SE Ivchenko-Progress can be found in Annex 4

Ivchenko-Progress is continuously developing new aero engines for civil and military applications. The company investigates new materials, control systems, elements and components to help improve their gas turbine engines. The developed and evaluated ideas, technologies and materials are not only introduced in their new advanced engines, but also used to modify and improve the quality and performance of existing serially produced engines.

The company has several departments involved in research and technology of aero-engines. The compressor department carries out research, design, test and certification of compressors. In recent years, its development work has included:

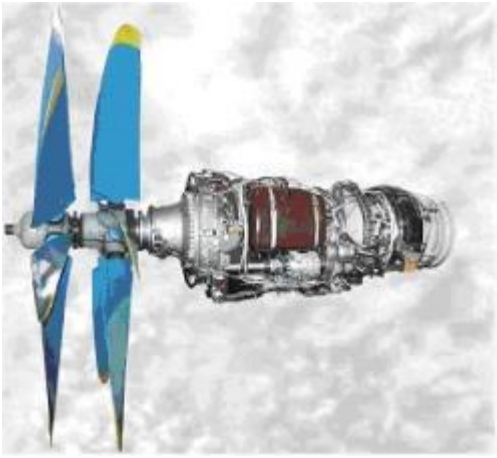
- One stage axial fans, multistage axial compressors of high and intermediate pressure and axial centrifugal compressors;
- High efficiency and high-pressure compressors of D-18T, D-436T1/TP, D-436-148, D-27, D-36, AI-222-25 and other aviation engines;
- Small-size centrifugal compressor with high pressure ratio AI-450M (400-470hp) aviation engine.

On the other hand, the combustion chamber research department has been working on:

- Development of new low-NOx-level fuel-burning technologies;
- Ensuring burning stability;
- Increasing altitude characteristics of engine starts;
- Implementation of new temperature-resistant ceramic materials and thermal barrier coatings;
- Minimisation of the combustor exit temperature profile.

Meanwhile, during the 1990s, the reduction gearbox department developed reduction gearboxes for the turboprop engines TV3-117VMA-SBM1 and AI-450, with gear meshings with a transverse contact ratio above two, which significantly increased their life time and reduced gear vibrations and noise. In the 2000s, the department has developed the main and tail reduction gearboxes for the light helicopters KT-112 and AK-1-3. In order to increase the contact durability of gear teeth, the department developed an antifriction coating. Research results have indicated the coating increases durability by up to 40%. It has now been implemented on reduction gearboxes for the aircraft engines AI-450, D-27 and TV3-117VMA-SBM1.

Moving on now to consider specific gas turbine engine developments, Ivchenko-Progress developed the world's first turbopropfan engine – the 14000 hp D-27. The engine is currently undergoing official flight testing on the medium-range military airlifter AN-70. Modified versions have also been developed: AI-127 (14500hp); a family of ultra-bypass turbojet engines (about 13); and AI-727 (9000-11000 kgf thrust) driven by a reduction gearbox for the AN-148T transport aircraft.



D-27 counter rotating open rotor propeller
(Image courtesy of SE Ivchenko-Progress)

Understandably, Antonov has expertise as well in counter rotating open rotors through its long term use of such propellers on the AN-22 aircraft and development of two-row counter-rotated propfans on the AN-70 aircraft.

For the new regional AN-140 aircraft, Ivchenko-Progress has developed the TV3-117VMA-SBM1 turboprop engines and AI9-3B auxiliary power unit. Work to further extend the service life and improve the reliability of these engines is currently being performed.

For the new passenger TU-334 and AN-148 aircraft, as well as the BE-200 amphibian, Ivchenko-Progress has developed the new-generation D-436 engine family (6400 to 8200 kgf thrust). Engine series production is executed in cooperation with JSC Motor Sich (Ukraine), FGUP Salut MMPP (Russia) and JSC UMPO (Russia). In November 2008, the D-436TP turbofan engine received EASA (European Aviation Safety Agency) airworthiness approval - the first from an ex-Soviet country - and ensuring that the BE-200ChS amphibian could enter the European market.

In recent years, the company has been developing a family of AI-222 turbofan engines with a thrust ranging from 2200 to 4500 kgf (afterburning version) for powering modern combat training airplanes. In 2009, the programme was completed and the acceptance report was signed for the joint state flight tests of a Russian Yak-130 combat trainer powered by AI-222-25 engines (2500 kgf thrust). Currently, the development of the AI-222-25F engine (4200 kgf thrust with afterburning power) is in its final phase. Also, work is now being carried out on the development of the AI-222-40 turbofan engine (3500-4150 kgf thurst based on the baseline engine core) for powering commercial aircraft.

For new aircraft and helicopters, turboprop and turboshaft versions of the AI-8000 are currently being investigated with a power of 7000-8000 hp.

A small-sized turboshaft engine, AI-450, rated at 465 hp has been recently designed for powering KA-226 helicopter. An experimental batch of engines was manufactured at JSC Motor Sich. Based on the AI-450 engine core, the AI-450MS auxiliary gas turbine engine is used to power the AN-148 regional aircraft. Also, a modified version, AI-450M, with a rear shaft output (400 - 465 hp) for upgrading MI-2M helicopter, is under development. It is currently undergoing bench testing and preparations for series production are in progress. Furthermore, an upgraded version, AI-450-2 (630-730 hp), to power helicopters of Ansat type, AI-450C (400-465hp) and AI-450C-2 (630-730 hp) turboprop engines are also being developed for light airplanes of Yak-18, Yak-152, SM-92T "Finist Turbo", EV-55 type, as well as,

modified versions of turbofan engines AI-450BP (409 kgf) and AI-450-2BP (560 kgf) for light multipurpose airplanes and UAVs.

By using the considerable experience gained in the development of the AI-222-25, AI-222-25F and D-27 engines, Ivchenko-Progress is currently developing the AI-9500F engine with a thrust of 9.5 tons for use in the power plants of light combat airplanes. Also, proposals to develop an advanced engine - AI-40 (3500-4500hp) - for powering commercial airplanes are being developed.

In order to increase the weight-lifting capability and efficiency of the AN-124-100 transport aircraft, a modified version of D-18T series 4 engines, with a maximum take-off thrust of 25830 kgf, is being developed. The new AN-124-100M-150 aircraft will be able to carry cargo of up to 150 tons.

Based on the AI-25TL engine, a modified version - AI-25TLSh – was recently developed as part of the upgrade of the Czech AeroVodohody L-39 trainer. The modified engine provides a combat mode of increased maximum thrust of up to 1850 kgf and will extend the service life of the L-39 aircraft by 10-15 years. In December 2008, the upgraded L-39 airplane with the modified engine successfully undertook the state flight tests. Today, the upgraded L-39 airplanes have entered the Ukrainian Air Force.

We now move on to consider other Ukrainian organisations involved in propulsion R&T.

The department of aviation engine design at the National Aerospace University “Kharkov Aviation Institute” (KhAI) has over 30 years of experience in turbine engine monitoring, diagnostics, numerical modelling and simulation. Its comprehensive research activities include:

- gas turbine engine parametric diagnostics;
- development of fast calculated multi-mode dynamic models of turbine engine;
- sensor fault detection procedures using information redundancy and engine subsystem mathematical modelling;
- development of combustor, including innovative design for further NOX reduction;
- development of analytical and experimental techniques for modelling the kinetics of combustion and related computational fluid dynamics;
- development of technologies for advanced combustor and injector systems with regard to NOx, soot and unburned hydrocarbon;
- lifetime depletion of critical gas turbine engine parts monitoring methods based on dynamics temperature and stress states identification;
- development of the fast calculating monitoring models of temperature and stress state critical turbine engine parts on steady-state and transient modes based on upper level computer models.

In the mid-1990s, the Institute of Technical Mechanics of the National Academy of Sciences of Ukraine and the State Space Agency of Ukraine (ITM-NASU and SSAU) successfully collaborated with the European Rocket Engine Development and Production Amalgamation, in order to theoretically explain and suppress cavitation self-oscillations observed in the liquid oxygen feed system of the VULCAIN liquid propellant rocket engines of the ARIANE-5 launch vehicle.

Finally, Podgorny Institute for Mechanical Engineering Problems of the National Academy of Sciences of Ukraine (IPMASH-NASU) has major experience in numerical simulation of viscous flows in aerodynamic passages, taking into account three-dimensionality, compressibility, flow separation, unsteadiness, influence of turbulence and other physical effects. It has developed its own computer simulation system – OPTIMUM – used for solving multilevel conditional-unconditional scalar and vector optimisation. OPTIMUM was used successfully to help design the aviation engines AI-25TLSh and D-436T1 for Ivchenko-Progress.

2.2.7 Safety

The International Research and Training Center for Information Technologies and Systems under the National Academy of Sciences of Ukraine and Ministry of Education and Science of Ukraine (IRTC) has developed an aircraft collision warning system, which enables closely approaching planes to avoid each other and then return to their original flightpaths. The system is believed to calculate reroutes that are 30% more efficient than those determined by similar systems.

E.O. Paton Electric Welding Institute of the National Academy of Sciences (PEWI-NASU) is involved in the development of methods and equipment for diagnostics and non-destructive testing. In particular,

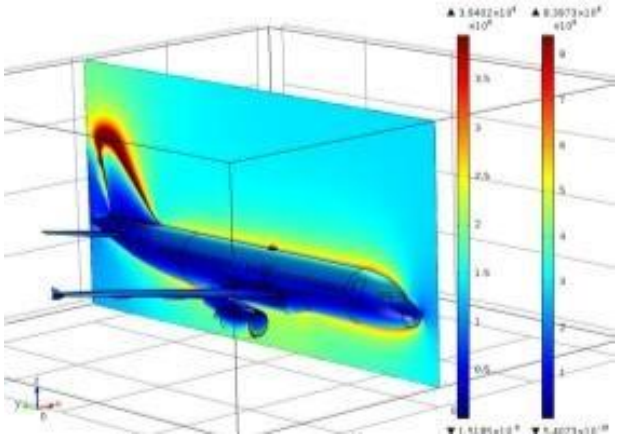
PEWI-NASU has created a range of acoustic emission test equipment – EMA systems - for diagnosis and prediction of the residual life of welded joints, materials, coatings and structures, which have been used by SE Antonov, SDO Yuzhnoye and Aerospatiale.

EMA-4 acoustic emission test equipment (4- and 16-channel modules)
(Image courtesy of PEWI-NASU)

The increased use of carbon plastics in aircraft is invoking increased interest in lightning strike protection of composite parts. Unlike metals, when struck by lightning, carbon plastics are subjected to damages which are accompanied with splitting and delamination in the form of trough breakdowns and consequently a separation of damaged layers by free-stream flows. On this topic, Frantsevich Institute for Problems of Materials Science of the National Academy of Sciences of Ukraine (IPMS-NASU) has been working with Antonov to develop knitted lightning protection meshes for composite parts. The meshes comprise of current-conductive layered reinforced coatings based on microwire composite cells that include nanostructure electric-conductive fillers. The meshes allow for repair and renewal of lightning damaged composite materials in structural elements of aircrafts.

In a related field, the National Aviation University (NAU) uses wind tunnel and equipment to research how sudden impacts during flights can affect the aerodynamic qualities of planes. NAU produces scale-down models of plane wings that contain the optimum number of sensors to register moment, degree and location of typical impacts. Based on past positive crew actions in similar situations, NAU has created a contingency plan rule base.

Finally, the R&D institute “Molniya” of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (KPI) performs computational simulations of the effects of different electromagnetic phenomena on aircraft, including lightning strikes where currents can reach 200kA.
The institute has undertaken such studies for all the key Ukrainian aircraft and airborne equipment manufacturers (e.g. SE Antonov, SDO Yuzhnoye and SE Polysvit).



Electric field simulation around an Airbus A320
(Image courtesy of KPI)

2.2.8 Systems

The department of aircraft control systems at the National Aerospace University "Kharkov Aviation Institute" (KhAI) has performed for many years various systems related projects for aerospace organisations. Its research and technology development activities include:

- development of aircraft control systems with the capability of active fault-tolerance;
- development of methods, models, algorithms of aircraft control system state deep diagnosing;
- development of methods, models of determining aircraft control systems diagnosability;
- development of methods, models, algorithms of aircraft control systems functions recovery after faults and airframe damages;
- experimental research of aircraft control systems using test benches and computer programmes.

Meanwhile, the electronic control and monitoring systems department at Ivchenko-Progress carries out development work on the following systems:

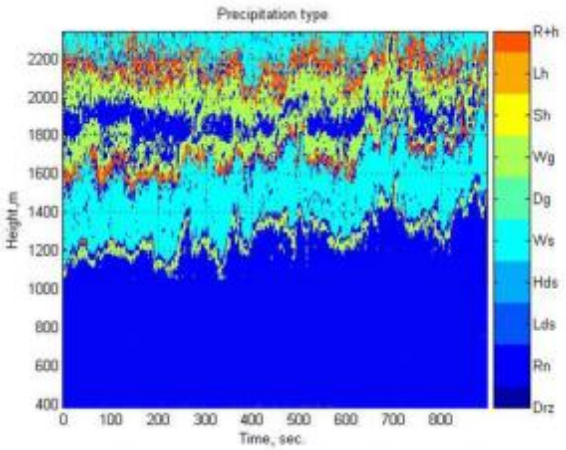
- Automatic control systems: electronic control systems; fuel systems; pneumatic systems; hydro-mechanical systems; test and control equipment; and bench control systems;
- Monitoring and diagnostic systems: on-board; on-ground; monitoring systems of vibrations; systems of representation of parameters; and signals of the engine.

2.2.9 Communications and Navigation

The radio-electronics department of the National Aviation University's (NAU) main research directions include:

- Remote detection and estimation of dangerous weather phenomena for aviation safety;
- Doppler-polarimetric radar;
- Surveillance systems including multilateration, secondary radar, automatic dependent surveillance-broadcast (ADS-B), and traffic and collision avoidance system (TCAS);
- Noise immune coding and cryptographic protection of information; and
- Compression of signals and images.

The department has conducted numerous research projects with IRCTR-TU Delft, Holland, and the Technical University of Hamburg-Harburg, Germany.



Radar hydrometeor type recognition (Image courtesy of NAU)

The R&T achievements of the O. Ya. Usikov Institute of Radio-Physics and Electronics of the National Academy of Sciences of Ukraine (IRE-NASU) include:

- Development of a series of new radiation sources operating in millimetre and sub-millimetre wavebands with wide potential for radar, communication systems, and defence applications;

- Design of pulse-mode magnetrons whose operation mode is called the "Kharkov 11", as well as continuous-mode magnetrons, klynotrons and reflection klystrons covering the wavelength range from 0.5 mm to 2 cm;
- Design of new sources of coherent radiation of in mm and sub-mm ranges: orotrons (diffraction radiation sources) of pulsed and continuous modes having champion parameters in terms of high stability, narrow spectrum, low noise and high power;
- Development of high-efficiency sources of far-infrared and optical band: dye lasers with a tunable frequency of induced emission;
- Development of full sets of the waveguide measuring devices (within the range from 1 mm to 10 mm), a set of quasi-optical wide-range measuring devices and components for measurements within the wavelength range from 0.1 mm to 1 mm.

Millimetre-wave airport radar
(Image courtesy of IRE-NASU)

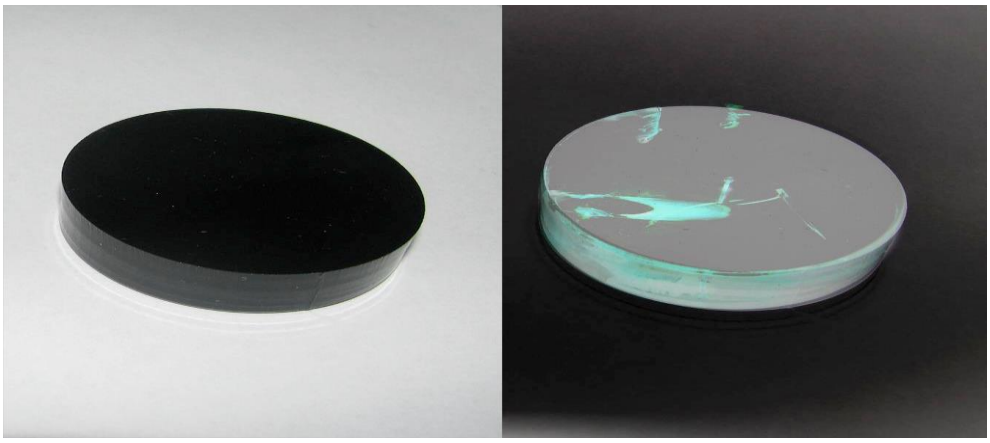
Also, the Institute of Technical Mechanics of the National Academy of Sciences of Ukraine and the State Space Agency of Ukraine (ITM-NASU and SSAU) is involved in the development of antenna and waveguide technology. The institute uses nickel and iron-nickel alloys and electroforming methods - metal crystallisation from the electrolyte cathode layer – to produce antennas that operate in high temperature, gravitation, and vibration conditions.

For aircraft flight information systems, Lviv Polytechnic National University (LP) develops radio-electronic equipment using digital signal processors (DSPs), field programmable gate arrays (FPGAs), and high-speed analogue-to-digital conversion devices (ADCs). Also, it develops specialised software for information and signal processing including application programmes, device drivers, DSP firmware, and FPGA configuration.

The department of instruments and systems of orientation and navigation at the National Technical University of Ukraine "Kyiv Polytechnic Institute" (NTUU KPI) is heavily involved in the development of signal processing methods and control algorithms for inertial navigation systems (including strapdown systems); researching the static and dynamic characteristics of vibratory gyroscopes; and development of intelligence system for flight information processing and decision making for aircraft engine rotary details.

2.2.10 Testing

The L.V.Pisarzhevskii Institute of Physical Chemistry of National Academy of Sciences of Ukraine (IPC-NASU) Is active in the development of fluorescent penetrant inspection techniques in which a fluorescent dye is applied to the surface of a non-porous material in order to detect defects that may compromise the integrity or quality of the part in question. In particular, IPC-NASU has been investigating the use of terahertz (THz) illumination and spectral analysis techniques to identify foreign impurities and defects.



Penetrant inspection testing: visible wavelength radiation (left) and THz radiation (right) (Image courtesy of IPC-NASU)

Scientific and Technical Enterprise “TDM” develops semiconductor sensors for temperature (thermo-resistors), mechanical tension (tenzoresistors, strain sensors) and magnetic field (Hall sensors) measurements across a wide temperature range 4,2 – 400 K. The firm’s sensors are small: Hall sensors – 1x1x0,5 mm, strain sensors – 1x8x0,4 mm, and thermo-resistors – 1x1x1 mm. Their sensors have high measurement sensitivity: temperatures – 100%/K, magnetic fields – 500 mV/Tl and mechanical tensions – 100 mkV/mln^{-1}.

Kotris Ltd has developed a hardware and software system called KAI-25F for aviation gas turbine engine testing with automated modelling and diagnosis features. KAI-25F is used for real-time synthesis and analysis of control laws and algorithms of automatic control systems during engine and laboratory tests. KAI-25F’s features include:

- automatic and hand remote engine control in process of engine tests and laboratory tests of hydromechanics;
- monitoring of the engine control system and hydromechanics measuring channels in process of motor tests;
- real-time simulation of gas turbine engine, hydromechanics and electronic digital control system algorithms and measuring channels.

JSC Element is one of Ukraine’s leading certified suppliers of electronic measurement systems, parameter monitoring systems and aviation engine control systems. It develops measuring transducers, aviation control and monitoring systems, programme and technical complexes of aviation engine testing, embedded real-time software, SCADA, monitoring and simulation systems, gas-turbine engine models, trend and correlation analysis. The firm has taken part in the development projects for Antonov AN-70, Antonov AN-148, Kamov Ka-226 “Sergei” and Tupolev Tu-334.

Meanwhile, the electronic control and monitoring systems department at Ivchenko-Progress carries out development work on the following systems:

- Automatic control systems: electronic control systems; fuel systems; pneumatic systems; hydro-mechanical systems; test and control equipment; and bench control systems;
- Monitoring and diagnostic systems: on-board; on-ground; monitoring systems of vibrations; systems of representation of parameters; and signals of the engine.

In the field of radiation testing of materials and devices for aerospace engineering, the Institute of Electron Physics of the National Academy of Sciences of Ukraine (IEP-NASU) has extensive experience utilising an electron accelerator microtron M-30. They use the equipment to conduct radiation tests on new materials and equipment requiring enhanced radiation resistance and effective systems of protection (active, passive) from sources of radiation (fast electrons, neutrons) in the external atmosphere, on-Earth or near-Earth space.

The R&D institute “Molniya” of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (KPI) studies the effects of powerful electromagnetic phenomena - such as lightning – on aircraft. It has an accredited laboratory (ISO/IEC 17025 standard) used for compliance testing of airborne equipment to DO-160G standard.

2.2.11 Airports

The centre of environmental problems of airports at the National Aviation University (NAU) conducts research into airport noise and air pollution reduction including:

- Semi-empirical methods for assessment of aircraft noise levels and noise exposure around airports;
- Methods for assessment of air pollution concentrations around airports;
- Methods for assessment of third party risk around airports;
- Numerical methods for optimisation of aircraft trajectories and flight scenario for minimum noise and air pollution impact around airports;
- Development of software tools for acoustic signal analysis and synthesis in aircraft cabins and its implementation in production.

3. Barriers to aeronautics research collaboration between the EU and Ukraine

In order to understand the barriers to aeronautics research collaboration between the EU and Ukraine, the AERO-UA project conducted:

i) an online survey of research groups and departments at Ukrainian aeronautics organisations
ii) interviews with key Ukrainian aeronautics R&T decision makers.

3.1 Online survey of Ukrainian aeronautics organisations

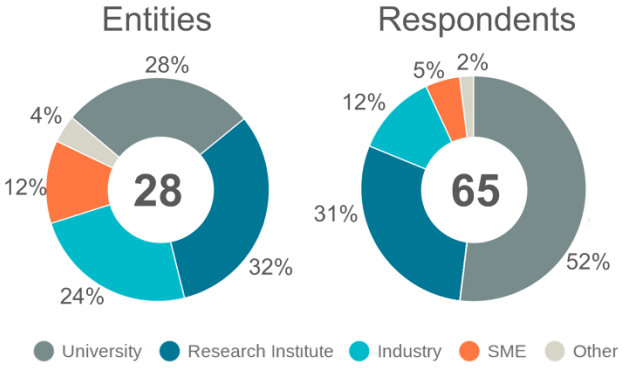
From December 2016 until April 2017, the H2020 AERO-UA project conducted an online survey of Ukrainian aeronautic actors aimed to understand Ukrainian involvement and expectations with respect to European aviation research collaboration as well as their perceived barriers to such collaboration. Specifically, the survey covered the following types of barriers:

- Barrier 1: Lack of motivation to collaborate with European partners,
- Barrier 2: Lack of awareness of European collaboration,
- Barrier 3: Lack of human resources or talent,
- Barrier 4: Lack of facilities, computer hardware and software,
- Barrier 5: International travel limitations,
- Barrier 6: Lack of funding,
- Barrier 7: Shortcomings in the research culture,
- Barrier 8: Legal and financial barriers, and
- Barrier 9: Specific barriers regarding EU framework programmes

The target audience for the AERO-UA survey included aeronautic experts affiliated with key stakeholder groups, specifically:

- **Academic entities** (research institutes and universities), which represent the key R&D actors and operate on the principles of ***academic freedom and proactivity***. Each academic organization involves several independent departments and/or research team that have different priorities and level of involvement in international cooperation. Normally, the administration supports and facilitates international collaboration initiated by research team(s) and gets involved at the stage of official documents signing (e.g. memorandum on cooperation, grant agreement, contract, etc.)
- **Business entities** (big industry and SMEs), which are the key end-users of new technologies and innovations. In Ukraine, big industry has a ***highly-centralised, vertical management*** structure, in which all decisions - including international collaboration - are taken at the level of Director or the Board of Directors. In the case of both bottom-up and top-down mechanisms of initiation of international collaboration, the time and effort required to make a final decision is quite high due to these bureaucratic transactions. Big industry also realises a very strict policy concerning distribution of information thus information dissemination can be slow. As for SMEs, they are normally led by a single person or small group of persons - thus less bureaucratic and more open for international cooperation - but have limited human resources.

Over 600 Ukrainian actors in the aeronautics sector were invited to participate in the survey and 65 respondents from 25 different entities completed the questionnaire. The breakdown of respondents is shown in the neighbouring figure. In total, respondents form 8 research institutes, 7 universities, 6 big industrial enterprises and 4 SMEs provided their opinion and ideas as for European-Ukrainian aeronautic cooperation prospects (see details in the table below).



In line with the above described Ukrainian scenario of decision-making and allocation of responsibilities in academic and business entities, 23% of the survey respondents completed the questionnaire “on behalf of the organization in the whole”. These respondents represented all business entities (industry and SMEs), which took part in the AERO-UA survey and provided a single response per organization, plus just several academic entities (research

institutes and universities), in which the top officials provided their overall high-level opinions in addition to the research group representatives. The other 77% of respondents belong to the academic community and responded “on behalf of a research department or a research team”.

Also, it worth mentioning the high-level profile of Ukrainian aeronautic experts who participated in the AERO-UA survey. 83% of respondents have doctoral degrees (either Candidate or Doctor of Science) and 65% of respondents have 5+ years of professional experience in such areas as aircraft design, production, operation, maintenance, repair and overhaul, as well as aeronautics-related R&D and education.

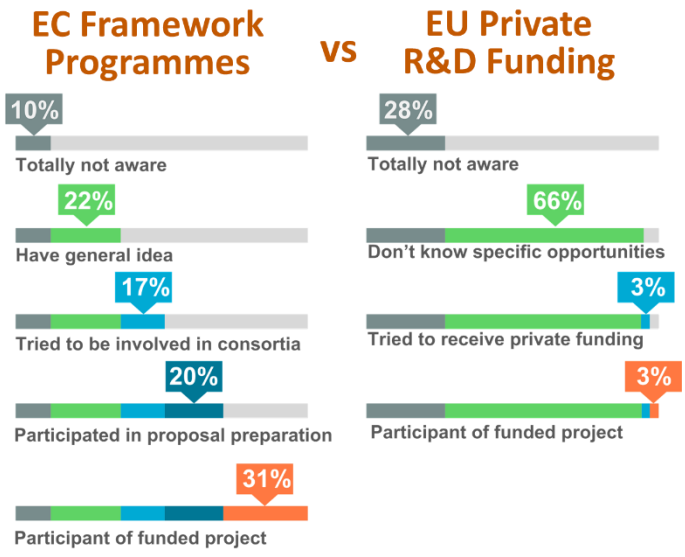
Ukrainian organizations participated in the AERO-UA survey

Research Institutes	Universities
• Ukrainian research institute of Aviation Technology (UKRRIAT) • E.O. Paton Electric Welding Institute, NASU • G.S. Pisarenko Institute for Problems of Strength, NASU • G.V. Kurdyumov Institute for Metal Physics, NASU • Frantsevich Institute for Problems of Materials Science, NASU • O.Ya Usikov Institute for Radio Physics and Electronics, NASU • Institute of Macromolecular Chemistry, NASU • Institute of transport systems and technologies, NASU	• National Aviation University • National Aerospace University "KhAI" • National Technical University of Ukraine "Igor Sikosky Kyiv Polytechnic Institute" • Zaporizhzhya National Technical University • Kozhedub National University of the Air Force • National technical university "Kharkov Polytechnic Institute" • Kharkiv National University of Radioelectronics
Big industry	**SME**
• ANTONOV Company • SE "Ivchenko-Progress" • PJSC "Volchansk aggregate plant" • JSC "MOTOR SICH" • PJSC "FED" • PJSC "Dnepropetrovsk aggregate plant"	• MPS Development • JSC "Element" • LLC "Science and technical center of general aviation" • Ukrainian Aircraft Corporation

The survey data was then thoroughly analysed by KhAI and, in the following sub-sections, a summary is presented of the results, analyses and suggestions concerning: Ukrainian involvement and expectations with respect to European aviation research collaboration as well as perceived barriers to collaboration.

<u>Involvement in European aviation research collaboration</u>

Overall, 90% of all the survey respondents were aware of the EC framework programmes (FP7, H2020) with 68% having tried at least to be involved in a proposal and 31% having participated in a funded project. In the case of EU private funding for R&D, 97% of the respondents were completely unaware or at least unaware of specific opportunities. Just 3% of respondents had participated in a project financed with EU private funding.

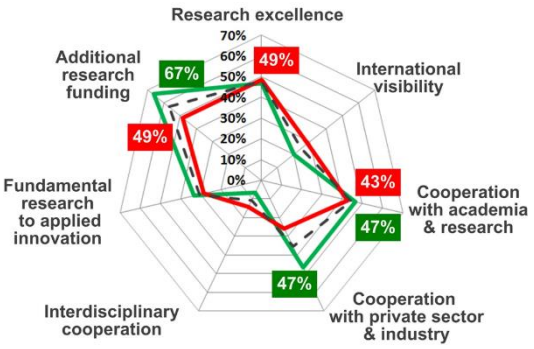


When the survey data was separated between academic entities (NAS research institutes and universities) and business entities (industry and SMEs) and analysed, the level of participation in EU funded projects was similar for both entities (31%

and 27%). However, 71% of respondents from academic entities indicated they had tried at least to be involved in a proposal, whereas only 55% of respondents from business entities said this was the case.

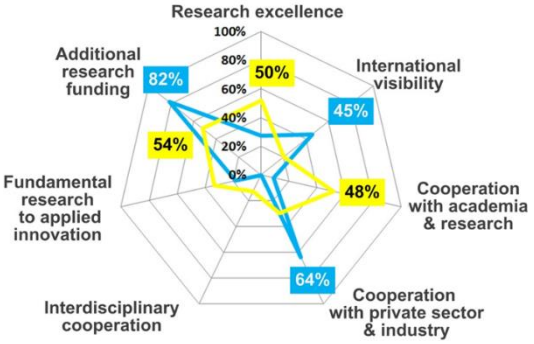
Expectations with respect to European aviation research collaboration

Based on the adjacent graph - which distinguishes between survey respondents with international experience (green) and without international experience (red) – the top 3 expectations with respect to European aviation research collaboration were as follows.



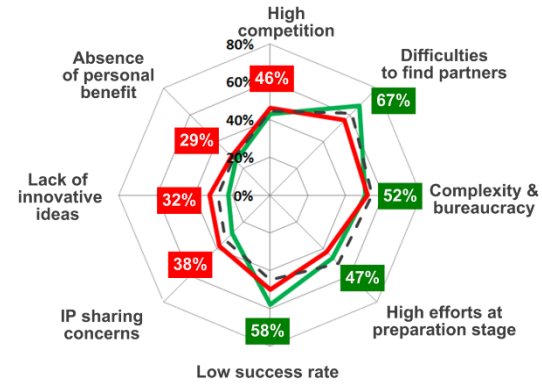
- Survey respondents with international experience: additional research funding (67% of survey respondents with international experience), cooperation with academia and research (47%) and cooperation with sector and industry (47%).
- Survey respondents without international experience: additional research funding (49%), improvement in research excellence (49% of survey respondents without international experience) and cooperation with academia and research (43%).

When the survey data was split between academic (yellow) and business entities (blue) as shown in the adjacent graph, the leading expectation for both entities was additional research funding (54% and 82% respectively). Other top priorities sought by academic entities were an improvement in research excellence (50%) and the establishment of cooperation with academic and research organizations (48%). As for business entities, their other top priorities were cooperation with the European private sector and industry (64%) and improvement in their international visibility (45%).



Barrier 1: Lack of motivation to collaborate with European partners

Based on the adjacent graph - which distinguishes between survey respondents with (green) and without international experience (red) – the top 3 factors contributing to a lack of motivation to collaborate with European partners were as follows.



- Survey respondents with international experience: difficulties to find partners (67% of survey respondents with international experience), low success rate (58%) and complexity and bureaucracy (52%).
- Survey respondents without international experience: high competition (46% of survey respondents without international experience), IP sharing concerns (38%) and lack of innovative ideas (32%).

When the survey data was split between academic and business entities and analysed, there were some differences in the top 3 factors contributing to a lack of motivation to collaborate with European partners.

- Survey respondents from academic entities: difficulties to find partners (64% of survey respondents from academic entities), low success rate (58%) and the complexity and bureaucracy of the EU's framework programmes (52%).
- Survey respondents from business entities: high competition (64% of survey respondents from business entities), low success rate (50%) and difficulties to find partners (48%).

In the feedback from the survey respondents, they made the following suggestions to reduce this barrier:

- Include aviation collaboration as a priority in the EU/UA Association Agreement.
- Reduce the administrative bureaucracy and maximize the freedom to collaborate (e.g. make it easier to reallocate project funding).

- Increase the remuneration for Ukrainian staff involved in EU projects.
- Create Project Offices in Ukrainian academic institutes to provide support and consultations.

Barrier 2: Lack of awareness of European collaboration

Based on the neighbouring table of results - covering all survey respondents – the top 3 factors contributing to a lack of awareness of European collaboration were: low awareness of partner search instruments (47% of all survey respondents), low awareness of collaboration opportunities (55%) and low awareness of legal and/or financial issues (52%).

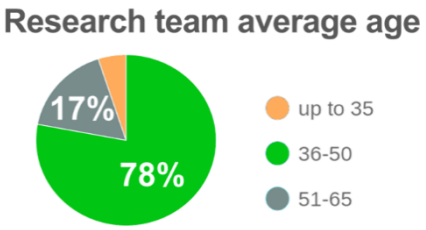
When the survey data was separated according to academic entities (NAS research institutes and universities) and business entities (industry and SMEs) and analysed, the top 3 factors contributing to a lack of awareness of European collaboration were the same.

In the feedback from the survey respondents, they made the following suggestions to reduce this barrier:

- The Ministry of Education and Science, National Academy of Sciences and/or H2020 National Contact Points should produce a monthly e-digest with timely information of EU aviation research calls and EU collaboration opportunities.
- Intergovernmental dialogue should take place between the EU and Ukraine concerning EU aviation research collaboration.
- Information exchange meetings should be organised for EU and Ukrainian stakeholders.
- A “white paper” should be produced with a list of Ukrainian aviation research initiatives.
- Workshops should be organised on how to prepare and submit proposals to EU calls.

Barrier 3: Lack of human resources or talents

The results for all survey respondents revealed that the vast majority of their research staff (95%) were over 35 years old.



Furthermore, 62% of all survey respondents felt there was a need to recruit additional research staff. The top 3 reasons given for recruiting were to: involve young talented researchers (70%), enlarge the research team (55%) and cover new competencies and expertise (50%).

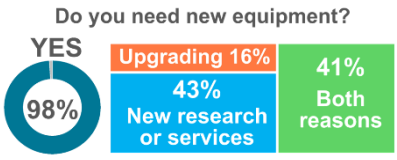
When the survey data was split according to academic entities and business entities, both sets of respondents expressed the need for additional staff (academic: 63% and business: 55%). However, the main reason given for business entities was to cover new competencies and expertise (83% of business respondents) whilst the main motivations for academic entities were to involve young talented researchers (79% of academic respondents) and to enlarge the research team (62%).

In the feedback from the survey respondents, they made the following suggestions to reduce this barrier:

- Provide more administrative freedom to universities with respect to recruitment issues.
- Provide higher salaries for qualified researchers and young researchers (MSc, PhD students)
- Provide objective criteria for the quality assessment of research (e.g. publications)

Barrier 4: Lack of facilities, computer hardware and software

The results for all survey respondents revealed that the vast majority (98%) feel they need new equipment, in order to do new research or provide new services (43%), to replace obsolete facilities (16%), or for both reasons (41%).



However, the condition of currently available facilities is considered much better by respondents from business entities than from academic entities. The majority of respondents from business entities felt their existing equipment can be used for advanced research: only 9% expressed having a lack of computer facilities and 17% indicated having a lack of required software. On the other hand, 28% of

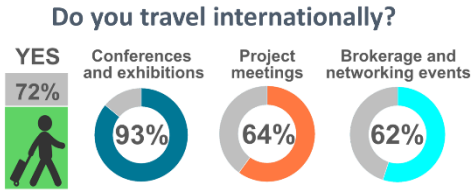
respondents from academic entities mentioned that their equipment is obsolete and cannot be used for advanced research. Furthermore, 46% expressed having a lack of computer facilities and 53% indicated having a lack of required software.

In the feedback from the survey respondents, they made the following suggestions to reduce this barrier:

- Provide Ukrainian state funding for upgrade of research infrastructure (with a 5-year depreciation period).
- Sign agreements between the Ministry of Education and Science, National Academy of Sciences and aviation industry to provide access to each other's research infrastructure.
- Provide information about EU research infrastructure available to Ukraine.
- Allow funding from EU projects to be used for upgrading research infrastructure.

Barrier 5: International travel limitations

72% of all survey respondents confirmed they travelled internationally. However, 53% of all respondents travelled only once a year or less often and 80% of all respondents felt their international travel was limited by a lack of funding.



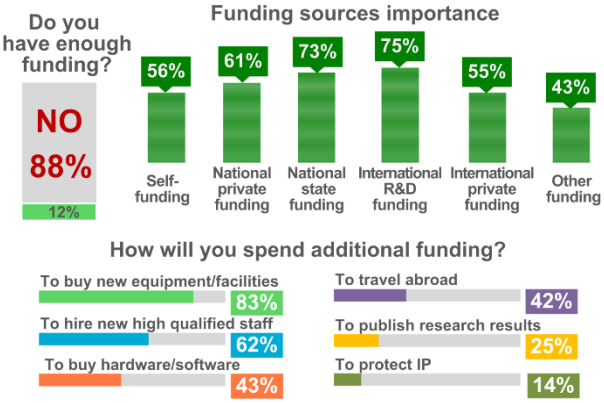
While respondents from both academic and business entities confirmed their possibility to travel internationally (70% and 82% respectively), business respondents travel far more frequently (56% travel at least every 3 months) than academic respondents (61% travel once per year or less often). For academic respondents, the main barrier to international travel was a lack of funding (87%). For business respondents, the main barrier was related to a lack of language skills (63%).

In the feedback from the survey respondents, they made the following suggestions to reduce this barrier:

- Establish a national programme – for example, under the State Fund for Fundamental Research - to enable Ukrainian researchers to visit international conferences.
- Encourage businesses to provide English language courses to their employees.

Barrier 6: Lack of funding

88% of all survey respondents were not satisfied with the level of funding available to perform advanced research. Furthermore, 83% of all respondents indicated they would spend additional funding to buy new equipment/facilities and 62% indicated they would hire new qualified staff. When the data was divided between academic and business entities, a similar set of results was observed.

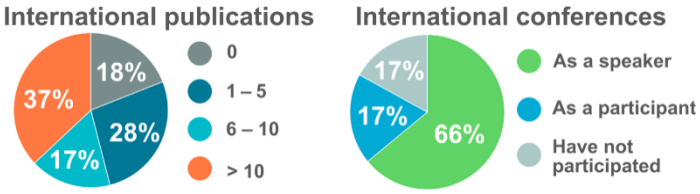


In the feedback from the survey respondents, they made the following suggestions to overcome this barrier:

- Ensure government implementation of Ukrainian Law that 1.7% of GDP be invested in science.
- Change Ukraine's tax system to allow tax exemptions for industry investment in research and innovation.
- Eliminate the state's limitations on tender applications.
- Be creative in the funding mechanisms offered in Ukraine (co-funding, public-private partnerships and venture capital).
- Provide specific funding opportunities for EU-Ukraine aeronautics collaborative research projects in H2020 and Clean Sky 2.

Barrier 7: Shortcomings in the research culture

The results for all survey respondents revealed that 82% have published in international peer-reviewed journals, 66% have attended international conferences as a speaker, and 51% were involved in associations and societies. Furthermore, 74% of all respondent's organisations have their website in English and 88% having an English-speaking person in their team.



When the data was divided between academic and business entities, there were no significant differences for international publications, international conferences and involvement in associations and societies. On the one hand, 100% of the respondents from business entities indicated their company websites were available in English, but just 73% had an English-speaking person in their team. On the other hand, only 67% of the respondents from academic entities indicated their institute websites were available in English, but 92% had an English-speaking person in their team.

Barrier 8: Legal and financial barriers

Based on the neighbouring table of results - covering all survey respondents – the top 4 factors contributing to legal and financial barriers were: lack of resources to co-fund projects (63% of all survey respondents), specific Ukrainian financial regulations (63%), procedures of projects/contracts approval by governmental bodies (50%), and inconsistency between UA and EU financial accounting practices (44%).

In general, academic entities were more sensitive to legal and financial barriers than business ones:

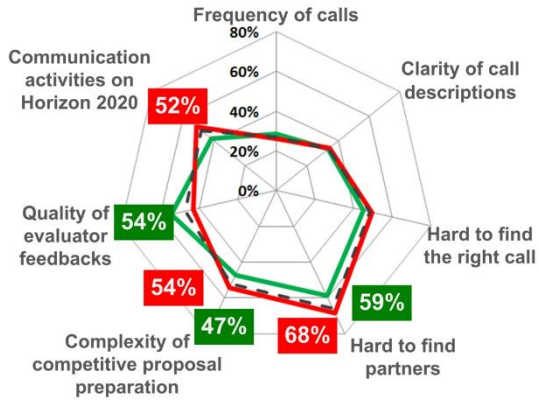
- Lack of resources to co-fund projects: 69% of academic respondents versus 33% of business respondents
- Specific Ukrainian financial regulations: 64% versus 58%
- Procedures of projects/contracts approval by governmental bodies: 52% versus 42%
- Inconsistence between EU and UA financial accounting practices: 45% versus 38%

In the feedback from the survey respondents, they made the following suggestions to overcome these barriers:

- Harmonise the legal systems between the EU and Ukraine in research and innovation.
- Reduce and/or eliminate Ukrainian government "red tape" bureaucracy concerning research and innovation e.g. need for currency conversion (euros to Hryvnia), payment time limits and State Treasury involvement.
- Provide greater freedom to research groups/institutions on how they use project funds.

Barrier 9: Specific barriers regarding EU framework programmes

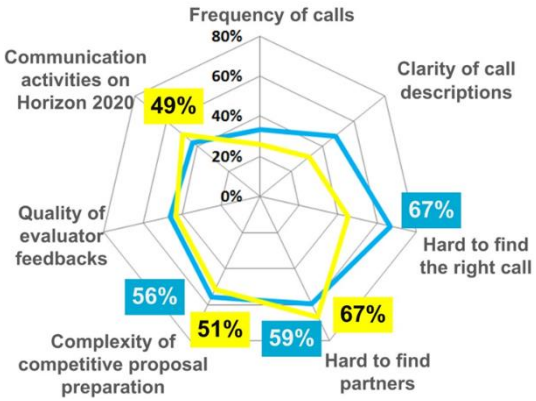
Based on the adjacent graph - which distinguishes between survey respondents with (green) and without international experience (red) – all the survey respondents struggle to find partners (59% and 68% respectively) and to prepare competitive proposals (47% and 54%% respectively). Furthermore, respondents with international experience have problems with the quality of evaluators' feedback (54%) whilst those without international experience need more information about H2020 (54%).



In the feedback from the survey respondents, they made the following suggestions to overcome these barriers:

- Increase the activities of the national contact points (info-days, networking sessions and proposal-writing workshops).
- Appoint national representatives to lobby on behalf of the interests of Ukraine's aviation industry.

Looking at the survey data from the perspective of academic and business entities shown in the adjacent graph, both groups struggle to find partners (67% and 59% respectively) and to prepare competitive proposals (51% and 56% respectively). Specifically, academic entities need more information about H2020 (49%) whilst the largest problem for business entities is the identification of appropriate calls (67%).



3.2 Interviews with key Ukrainian aeronautics R&T decision makers

To further understand current and future perspectives for aeronautics R&T in Ukraine as well as barriers to EU-Ukraine cooperation, the AERO-UA project conducted interviews with key Ukrainian aeronautics R&T decision makers at SE Ivchenko-Progress, PJSC "FED", Ukrainian Research Institute of Aviation Technology (JSC UkrRIAT), National Aerospace University (KhAI), Frantsevich Institute for Problems of Materials Science (IPMS-NASU), Karpenko Physico-Mechanical Institute (IPM-NASU) and G.S. Pisarenko Institute for Problems of Strength (IPS-NASU). The key points from these interviews are summarised in the following sub-sections.

3.2.1 SE Ivchenko-Progress[9]

Ivchenko-Progress's current aeronautics research and technology (R&T) priorities are:

1. Creation of aircraft engines of any type and dimensions.
2. Creation of aircraft reduction gears, having no world analogues.
3. Creation of ground-based commercial plants on the basis of aircraft engines.
4. Development of innovation designs, techniques, materials, design styles, manufacturing and test methods that increase the safety and decrease the environmental hazard and the costs.
5. Creation of nozzle guide vanes and turbine retainers made of ceramic matrix composites.
6. Investigation of thermal-barrier ceramic coatings on turbine blade and nozzle guide vanes.
7. Investigation of abradable coatings.
8. Investigation of wear-resistant coatings on labyrinth rings.
9. Experimental investigation of turbine blades radial clearances.
10. Computational-experimental investigation of turbine struts thermal state.
11. Computational-experimental investigation of advanced schemes of convection-film cooling of turbine blades (penetration cooling).
12. Computational-experimental investigation of gas flow in GTE outlet ducts of complicated shape.
13. Numerical investigations of low Reynold's number influence on turbine cascades efficiency using up-to-date transient turbulence models.
14. Numerical investigations and optimization of inter-turbine ducts.
15. Numerical investigations of gas flow in turbine air-gas channels with attached cavities.
16. Development of heat-resistant and thermal-barrier coatings, ceramic materials for combustion chamber parts. Mature development through elaboration of technology for their application, manufacture and repair; functional test as a part of turbine or combustions chamber of a GTE with a service life not less than 25000 hours at a gas temperature 1800K.
17. Computational-experimental optimization of low-emission combustion chamber performance to ensure compliance with the current and advanced ICAO requirements to harmful emissions.
18. Development of new and modernization of existing thrust vectoring nozzles with variable areas at nozzle throat and exit sections.

[9] Based on information received from Igor Kravchenko, Director of SE Ivchenko-Progress, 29 August 2017

Meanwhile, the company's aeronautics R&T priorities over the next 5 – 10 years are expected to be:

1. Creation of high-performance aircraft engines of 5th generation (increase and optimization of thermo-gas-dynamic cycle parameters, increase of effectiveness of all engine components, decrease of fuel consumption).
2. Development and implementation of technologies for turbine blades 3D printing.
3. Implementation of technologies for thermal-barrier ceramic coatings application on turbine and combustion chamber parts.
4. Increase of service life and reliability.
5. Decrease of weight and DOCs.
6. Decrease of harmful emissions and noise.
7. Increase of competitiveness.
8. Certification of engines designed by Ivchenko-Progress SE on the European market.
9. Development of activities on the creation of aviation engines for small aircraft.

The main sources of influence on Ivchenko-Progress's R&T priorities are:

- Customers' requirements.
- Modern world trends in aviation propulsion engineering.
- Government policy.
- Our own strategic goals and tasks.

Ivchenko-Progress considers its main R&T strengths compared to European and other international organisations as being:

- Wide experience in creation of aircraft engines of all types and dimensions.
- Most powerful in the world helicopter engine, D-136.
- D-18T engine powering the world's largest load-carrying aircraft: AN-225 and AN-124-100.
- First in the world cruise turbo propfan (open rotor) engine, D-27, powering the AN-70 aircraft (which excels on performance attributes the A400M aircraft being developed by EADS).
- Differential coaxial (epicyclic) reduction gear of high reliability for engine rated to 14000 hp.
- Unified gas generators for turboprops and turbofans of high reliability and low cost.
- The experimental-design bureau carries out all production activities related to aircraft engine creation from designing up to certification and service support.
- The cost of Ivchenko-Progress SE products is lower than that of European companies keeping the same level of quality.

The main areas where Ivchenko-Progress is interested to collaborate are as follows:

- Small-size centrifugal compressors of high compression ratio (perspective design, fabrication technique, new materials).
- Highly effective low-noise fans.
- Low-emission combustion chambers.
- Strength investigations.
- Highly effective small-size cooled contra-rotating turbines.
- Advanced distributed systems of automatic control.
- Advanced onboard and on-ground monitoring & diagnostic systems, up-to-date algorithms and methods of troubleshooting and maintenance on condition, logistics.
- Advanced materials (new coatings, alloys, other types of materials, like ceramic composite materials, Ti-Al alloys, thermal-barrier ceramic coatings).
- 3D printing technologies for engine parts.

Response of Igor Kravchenko, Director of SE Ivchenko-Progress, to the question "What prevents Ukraine from cooperating more closely with the EU in the field of aviation research?", April 2017

"Ukraine's cooperation with EU countries in the field of aviation research can be useful and mutually beneficial, using the example of SE Ivchenko-Progress.

At present, Ukrainian standards, according to which we work, are mostly harmonised with international (European and American) standards. And the certificates issued by Ukrainian administrations

correspond to the European level. But, for this to be not only a Ukrainian certificate, the State Aviation Service of Ukraine needs to integrate more with European organizations. And, to be competitive in the world market, at least at the first stage, we need preferential terms, as well as recognition of Ukrainian certificates by the European community and American standardisation agencies. This would be the most optimal solution. But, given that we currently have an agreement to work towards recognition of Ukrainian certificates, we will continue to improve our comprehensive product testing to comply with the customer's requirements.

Therefore, of course, the cooperation of our enterprise with European partners can be useful and mutually beneficial. The entire aviation world is being integrated. Through cooperation with Austrian, Czech, German and other companies, we create joint products. If these products are produced jointly and supplied to the market jointly, then integration will take place, as well as certification and market processes. By exchanging experience, we certainly raise our Ukrainian level and integrate into the European aviation system to be competitive in the world market. The main thing is to find a buyer in those countries in which the European community is interested."

3.2.2 PJSC "FED"[10]

PJSC "FED"'s current aeronautics research and technology (R&T) priorities are:

- Development and production of fuel system units.
- Development and production of aviation engines automatic control systems.
- Development and production aircraft energy saving system units.
- Development and production of flight control system units.
- Development and production of aircraft hydraulic system units.

PJSC "FED"'s anticipated aerospace R&T priorities of over the next 5-10 years are:

1. Development of highly efficient, endurable plunger pumps and gear pumps for aviation engines of all types.
2. Development of stand-alone and combined actuators.
3. Development of automatic control systems with full authority (FADEC) for turbo-shaft and turbo-prop engines with hydro-mechanical unit (HMU) and hydro-mechanical redundancy
4. Development of automatic control systems with full authority (FADEC) for medium-thrust engines with partial-authority HMU;
5. Development of automatic control systems with electrically actuated fuel metering units;
6. Development of automatic control systems with distributed architecture;
7. Increasing life period, enhancing robustness and service life;
8. Improving competitiveness.

The main sources of influence on PJSC "FED"'s R&T priorities are:

- Current world trends of aviation components manufacturing
- Requirements and interests of Customers, Suppliers and Partners/
- Policy of the State.
- Objectives and tasks, as well as PJSC "FED"'s Quality Assurance policy.

PJSC "FED" considers its main R&T strengths compared to European and other international organisations as being:

- Extensive experience in development, repair and service maintenance of aviation components and other machine-building components.
- Participation in aerospace Cluster "Mechatronics" which incorporates leading production companies and scientific-educational complex of aerospace industry of Ukraine.
- Development and practical implementation of multicomponent coatings (mono and multi-layer, nanostructural, gradient) to improve operating characteristics of components.
- Application of complex forms of ion-condensed materials.

[10] Based on information received from Prof. Viktor Popov, Chairman of the Board of PJSC "FED", 7 September 2017

- Development of aerospace science, technologies, machine building and instrument-making industry.
- Development of fundamental, exploratory and applied research of priority trends of advanced science.
- Organization, coordination and control of development and implementation of innovative projects.
- New system of education and training of highly qualified specialists.

The main areas where PJSC “FED” is interested to collaborate are as follows:

- Complex monitoring of technical condition of aviation components, trend analysis of identifying of defects during component operation.
- Electrical-hydraulic two-stage converters.
- Electrical-hydraulic rotatory-type converters.
- Fast-computing dynamic element-by-element unit models.
- Stand-alone, combined, complex electrical-hydraulic actuators.
- Electromechanical actuators.
- Automation of assembly/disassembly of aviation components.
- Visualization of aviation components assembly process.
- Application of composite materials in manufacturing of casings of aviation components (engines).

3.2.3 Ukrainian Research Institute of Aviation Technology (JSC UkrRIAT)[11]

UkrRIAT’s current aeronautics research and technology (R&T) priorities are:

1. Different types of high-loaded joints for airframes including those based on composites.
2. Development and production of hand-held pneumatic tools for aircraft manufacturing.
3. Increasing the effectiveness of aircraft production.
4. Development of programs and forecast-analytical materials for the aircraft industry and other hi-tech industries.
5. Development of normative documentation (standards) in the field of aircraft industry, other Hi-Tech branches covering the whole life cycle of the item.
6. Technological design of the aircraft and aircraft manufacturing capacities.
7. Forecasting, estimating and determining labour and material costs for aircraft production.
8. Development of efficient manufacturing processes, methods and means for manufacturing high-loaded joints of the airframe components including metal-composite ones.

They are also expected to be the company’s priorities over the next 5+ years.

The main sources of influence on UkrRIAT’s R&T priorities are:

- Customer needs and requirements,
- Aircraft industry development trends,
- UkrRIAT’s experience and competence in aircraft technology and its own vision of domestic and international aviation trends,
- Governmental orders.

UkrRIAT considers its main R&T strengths compared to European and other international organisations as being:

- Deep knowledge of the Ukrainian aircraft industry,
- Ability to identify the appropriate Ukrainian partner for international organisations looking to establish joint projects for aircraft, space and defence.

The main areas where UkrRIAT is interested to collaborate with European and other international partners are as follows:

[11] Based on information received from Prof. Volodymyr Kryvov, Director General of JSC UkrRIAT, 31 August 2017

- Engineering and technical assistance to aircraft factories in the development of serial production of new technologies.
- Development and implementation of manufacturing processes and means of mechanization for high-life-time and high-loaded joints including metal and composite components.

Response of Prof. Volodymyr Kryvov, Director of JSC UkrRIAT, to the question "What prevents Ukraine from cooperating more closely with the EU in the field of aviation research?", April 2017

"The main barrier to closer cooperation is the lack of readiness of those who fund European aviation projects and research programmes to organise a system to ensure the efficient participation of Ukrainian specialists and researchers in these projects and programmes.

Another problem is the absence of classifiers to categorise Ukrainian researchers (individually) and organisations for participation in European projects and research programmes.

One more problem is the absence of an organisational structure authorised by the European funding body to coordinate research activities implemented by Ukrainian specialists (UkrRIAT is ready to take on this role).

Besides all the issues mentioned above, the absence of distinct, timely and up-to-date information from the relevant EU bodies impedes the development of cooperation"

3.2.4 National Aerospace University "Kharkiv Aviation Institute" (KhAI)[12]

KhAI's current aeronautics research and technology (R&T) priorities are:

1. Research in theoretical and experimental aircraft aerodynamics.
2. Research in aeronautic composite structures design and manufacturing.
3. Research in efficient unmanned aerial systems development.
4. Development of efficient processes for aeronautic structures manufacturing.
5. Research in smart systems for aircraft navigation, radio positioning and control.
6. Improvement of aircraft design and testing methods.

Meanwhile, the university's aeronautics R&T priorities over the next 5 – 10 years are expected to be:

1. Theoretical and experimental research in aircraft aerodynamics.
2. Improvement of theoretical and experimental approaches to aerodynamic investigation of aircraft.
3. Improvement of composite structure design approaches, manufacturing technologies, testing and quality control.
4. Investigation and feasibility study of new areas of UAVs application, development of relevant components, and their integration to on-board and on-ground systems.
5. Improvement of theoretical and experimental methods of strength, durability and lifetime analysis for aircraft components and products.
6. Development and implementation of impact (impulse) technique in mechanical treatment of hard-to-machine metal and composite materials;
7. Advanced joints for aircraft structures development.
8. Development of new technologies and methods for functional coatings deposition to aircraft components
9. Development of smart control systems for UAVs and their swarms.

The main sources of influence on KhAI's R&T priorities are:

The Ukraine government's plan to reform the field of research, which foresees the creation of a new system of research governance in the country and the creation of a series of institutions. The reform also foresees changes in the research funding system. All these reforms require the creation of a distinct regulatory environment, which currently is under development, and will lead to changes in research

[12] Based on information received from Olexandr Gaydachuk, Vice-Rector of Science, National Aerospace University "Kharkiv Aviation Institute", 7 September 2017

organisational structure at all levels. It is difficult to predict how these reforms will influence the quality of research activities, their acceleration or deceleration.

KhAI considers its main R&T strengths compared to European and other international organisations as being:

- Deep and old scientific tradition, long-term experience;
- Capability and tendency to produce own scientific results based on initial data formulated by its own models and methods and their experimental validation;
- Opportunity for advanced training of scientific personnel in specific research area;
- Tendency towards original and non-traditional approaches to solving new problems.
- Successful experience of participation in international programs and projects.
- Track record of cooperation with several high-tech aerospace industrial companies.

The main areas where KhAI is interested to collaborate are as follows:

- Theoretical and experimental research in aircraft aerodynamics.
- Improvement of theoretical and experimental methods of strength, durability and lifetime analysis for aircraft components and products.
- Creation of unmanned aircraft complexes
- Technologies and systems for aircraft manufacturing.
- Smart systems for aircraft navigation, radio positioning and control

3.2.5 Frantsevich Institute for Problems of Materials Science (IPMS-NASU)[13]

IPMS-NASU's current aeronautics research and technology (R&T) priorities are:

1. Enhancement of specific characteristics of the materials used in aviation and space, especially weight reduction;
2. Increase in the use of composite materials with improved characteristics, especially composites reinforced by high modulus carbon fibres, carbon nanotubes;
3. Creation of new materials with enhanced corrosion resistance for elevated temperatures;
4. Development of new technologies of joining of metals with polymer-based composites reinforced by carbon fibres and carbon fabrics.

Expected priorities in scientific and materials research activity in the field of aviation for the next 5-10 years:

1. Development of new technologies of monitoring of strength deformed state and degree of defectiveness of metal and composite elements of aviation constructions by acoustic emission, optical digital, vibration methods.
2. Development of the technologies of monitoring of degradation of aluminium alloys under long service period.
3. Development and implementation of new cost and energy efficient metal-, ceramic- and polymer composites for various aviation applications
4. New materials working in the conditions of essential noise and vibration loads.

IPMS-NASU considers its strong competitive sides in the field of aviation compared to European and other international organizations are:

- Materials with high specific strength;
- Composite Al-SiC materials;
- Al sandwich panels and foamed granules;
- Heat resist metal-based materials;
- Anti-friction polymer-based materials;
- Materials for lightning protection;
- Shielding materials for protection from electromagnetic radiation;
- Ceramic fuel cells.

[13] Based on information received from Prof. Sergey Firstov, NASU academician, Deputy Director of IPMS-NASU, 15 November 2017

The main areas of cooperation:

- Aluminium based alloys, especially aluminium alloys with scandium additives with yield strengths about 700-740 MPa, ultimate tensile strength about 800 MPa, and at the same time plasticity of 9-14 %; high stability after thermal treatment alloys and powders of Al-Fe-Cr-(Ti, Zr) containing quasicrystals with σB > 300 MPa at 300°C; ceramic and metal sintered composites Al (D16) – SiC with σ0,2 = 400 – 464 MPa, σB = 530 – 600 MPa and articles from high porosity foamed Al.
- Heat resistant metal based alloys, especially high entropy alloys Nb(Cr-Ti-Al-Zr-Si) with ρ = 6,35 g/cm^3; T_{work} = 1000 °C; σ0,2 = 860 MPa, dispersion hardened powdered (Ni-Cr-Al-Y2O3) σ0,2 = 687 MPa; σB = 100 5 MPa; δ ≤ 5,1% (800°C); σ0,2 = 51 MPa; σB = 56 MPa; δ ≤ 22,3% (1200°C), high modulus titanium alloys reinforced by Si and B on the base of Ti-Si-X and Ti-B-X, (X = Al, Zr, Nb, Sn) with strength 1,5 times higher at 600-750°C in comparison with traditional ones, new aluminides Ti2,17Ta0,77Al1,06 (analogue O-phase of Ti2NbAl) with compression strength at 700°C – 1500 MPa, at 800°C – 1000 MPa.
- Ultra-high temperature constructional ceramics on the base of Zr(Hf)B2-SiC with bending strength 150-200 MPa at 1800°C.
- Ceramic solid oxide fuel cells.
- Polymer based composites reinforced by soldered-knitted meshes for lightning protection and reinforced by carbon nanotubes and SiC nanofibers for antifriction aviation applications

3.2.6 Karpenko Physico-Mechanical Institute (IPM-NASU)[14]

IPM-NASU's current aeronautics research and technology (R&T) priorities are:

1. Development of the production technologies for high strength and crack resistant welded joints for the Al-Cu-Mg- and Al-Zn-Mg-Cu-based alloys.
2. Creation of the methods and tools for determination of degradation tendencies for heat strengthened aluminium based alloys and its monitoring during service period.
3. Technology to detect hidden defects in multi-layered aviation structures especially under rivet heads by methods of eddy current defectoscopy, electronic speckle-interferometry (ESI) and digital correlation of images (DCI).
4. Evaluation of stress-deformed states for the fuel tank shells of the launch vehicles by ESI and DCI methods.
5. Analysis of the geometry sizes of fatigue zone before destruction, cyclic and static plastic zones near holes and cuttings of the elements of aviation constructions manufactured from Al- and Ti- based alloys by the methods of phase shift laser interferometry; evaluation of fatigue durability for the construction elements with holes.
6. Investigations of the hydrogen influence on the surface of titanium alloys for aviation applications by the methods of shift phase laser interferometry.

Expected priorities in scientific and materials research activity in the field of aviation for the next 5-10 years:

1. Development of high strength welding alloy Al-Mg- (Sc, Zr, Hf)-(Er, Tb) with nano-dispersive hardening and enhanced resource characteristics for the long service periods.
2. Development of the hybrid optical and digital systems for diagnostics of layered and cellular composite structures for the monitoring of the damages and surface defects using ESI and DCI methods.
3. Investigations by ESI and DCI methods of strength and life time of composite elements of aviation constructions and joining between metal and composite under static, shock and cyclic loadings.
4. Creation of the special optical and digital correlation system for the diagnostics of the closed bolted and rivet joints "metal-composite" and evaluation of their deformation and ovalisation.
5. Creating a portable phase shift interferometer which give the possibility to evaluate the parameters of the roughness of the reliefs for smooth surfaces in real time, to determine the geometrical parameters of fatigue zone of pre-damage and plasticity zones near holes and cuttings in the elements of aviation constructions manufactured from aluminium and titanium alloys.

[14] Based on information received from Prof. Zinovii Nazarchuk, NASU academician, Director of Karpenko Physico- Mechanical Institute of NASU, 15 November 2017

IPM-NASU considers its strong competitive sides in the field of aviation compared to European and other international organizations are:

- Detection and evaluation of the properties of gas saturated layers of titanium alloys by eddy current method for the working frequencies more than 100 MHz.
- Combining the experience in design and creation of hybrid optical and digital systems of diagnostics of the element of constructions during their deformation and damage under static and dynamic loadings.
- Using of new high-speed methods of phase shift laser interferometry, ESI and DCI for the reproduction of surface relief and the fields of tangential and normal surface displacement and deformation and also creation of the models of the hybrid optical and digital diagnostic systems on their base for the work in laboratory and field conditions.

The main areas of cooperation:

- Structure mechanics of fatigue damage of the aviation materials and their welded joints.
- Eddy current structure and defectoscopy for aviation materials and construction elements.
- Investigation of the displacement and deformation fields for composite surfaces and reproduction of the reliefs of their surfaces by methods of digital holography, ESI and DCI.
- Lengthy experience of developing composite materials;
- Extensive experience of applying materials science research to the development of pilot and production technologies;
- Achievement of world-class results in materials science.

3.2.7 G.S. Pisarenko Institute for Problems of Strength (IPS-NASU)[15]

IPS-NASU was founded in 1966 by G. S. Pisarenko, Academician of the National Academy of Sciences of Ukraine. One of the main directions of scientific investigation in the field of strength of materials and structures has been the development of methods and facilities to enhance the reliability and lifetime of elements and structural assemblies of aeronautical engineering under extreme thermomechanical loading. In this field, IPS-NASU cooperates fruitfully with the leading Ukrainian state enterprises such as Antonov, Ivchenko-Progress, Motor Sich, etc.

Today, IPS-NASU has over 100 scientists dealing with the problems of strength and lifetime of existing and developed materials, as well as structural elements considering factors peculiar to real operation conditions.

IPS-NASU enjoys a high standing in both European and world scientific spaces. Numerous joint scientific projects have been implemented. IPS-NASU's scientists actively participate in international conferences. Investigations of crack growth resistance of large-sized structural elements of aluminium alloys have been performed within the framework of the international projects with "Antonov".

Currently, IPS-NASU is actively involved in the H2020 AERO-UA project. Furthermore, IPS-NASU has a certain experience of bilateral cooperation with EU institutions.

Nevertheless, IPS-NASU is highly interested in extending its involvement in international grants for the execution of scientific and research activities, which are privately or nationally funded as well as EU funded joint educational projects (for instance, Tempus, Erasmus).

IPS-NASU's main expectations with respect to scientific and research cooperation in the field of aeronautical engineering with European partners are the following: adoption and implementation of best practices in the institute's laboratories, enhancement of cooperation with scientific and research institutions and business structures in these fields, as well as an increase in the number of applied investigations within the general scope of scientific and research activities at the institute.

IPS-NASU has a high potential to participate in European aviation projects since it has many highly-qualified specialists to perform scientific investigations. However, the institute lacks young scientists and the mean age of the institute's employees is 50. Also, it is a challenge to win European aviation projects due to the high competition from experienced European aerospace organisations.

[15] Based on information received from Prof. Valeriy Kharchenko, Director of G.S. Pisarenko Institute for Problems of Strength, 1 June 2017

4. Initiatives to support EU-Ukraine research collaboration in aeronautics

4.1 EU funded initiatives

Formal cooperation between Ukraine and the European Commission in aeronautics can be traced back to at least 1998 when the Partnership and Cooperation Agreement (PCA) came into force[16]. This agreement provided a framework for political relations and cooperation. Aeronautics was addressed either directly or indirectly in several articles: Article 64 “Transport” and Article 65 “Space” defined several areas including modernisation and development of airport and air navigation infrastructure and promotion of joint research and technology programmes.

The first participation of a Ukrainian organisation in an aeronautics RTD project funded by the EU’s framework programmes for research and technological development occurred during the fifth framework programme (FP5, 1998-2002). The large project - called SILENCE-R – was dedicated to aircraft noise reduction and it was coordinated by SNECMA (France) with the support of fifty consortium partners including the National Aviation University (Ukraine).

In July 2002, an “Agreement on Cooperation in Science and Technology” between the European Community and Ukraine was signed. It established a base for further growth and enhancement of collaboration between scientists. This agreement stipulated that cooperation could be implemented in research areas including fundamental studies, technology development and demonstration activities. Furthermore, the European Research and Sixth Framework Programme Conference (Brussels, November 2002) opened a new possibility for Ukrainian scientists within European Research.

In August 2003, the National Information Centre for Ukraine-EU S&T Cooperation (NIP Ukraine) was established by the Ministry of Education and Science of Ukraine. It was based on the Kyiv Centre for S&T and Economic Information to support the integration of the Ukrainian scientific community to the European research area by facilitating access of the scientific community of the country to the framework programmes. NIP Ukraine closely cooperates with the Ministry of Education and Science of Ukraine, National Academy of Sciences of Ukraine and National Space Agency of Ukraine.

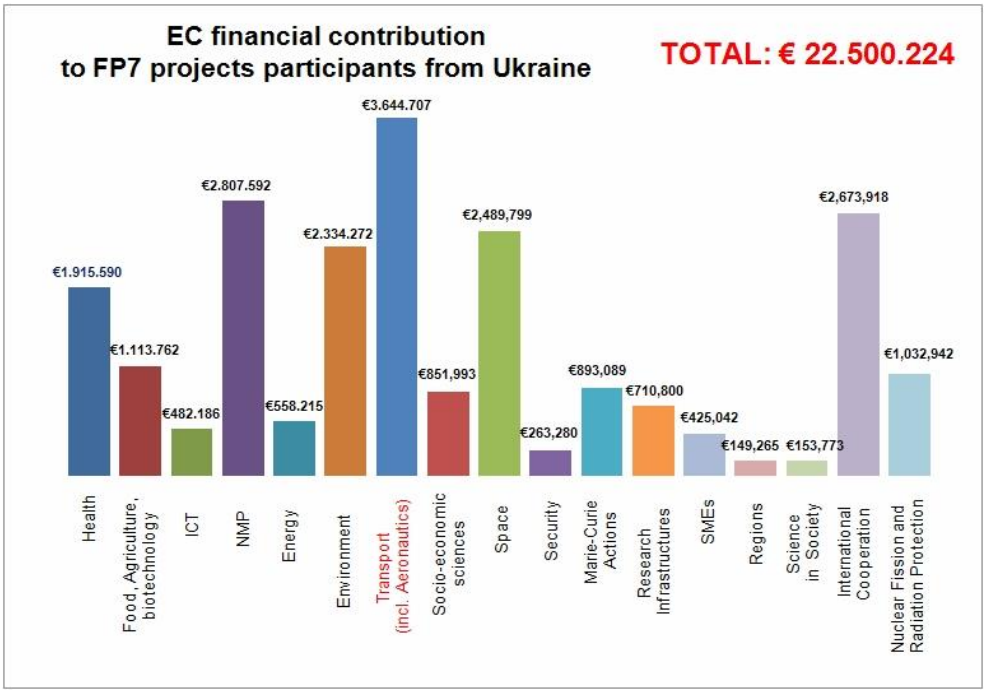
Since 2005, EU-Ukraine cooperation activities have been largely defined by the bilateral EU-Ukraine European Neighbourhood Policy Action Plan[17], which is based on the PCA. The Action Plan sets out an agenda of political and economic reforms with short and medium-term priorities. It contains several articles pertaining to aviation.

Six and seventh framework programmes for research and technological development

All the above policy initiatives have helped to nurture the participation of Ukrainian organisations in the sixth and seventh framework programme (FP6 and FP7). Notably, there were six FP6 projects and fifteen FP7 projects - focused on aviation RTD - involving a total of twenty-five Ukrainian participations (including industrial organisations, higher education institutes and research institutes). Indeed, Ukrainian participants enjoyed most success with the FP7 Transport (including Aeronautics) programme: 3.64 M€ of EC financial contribution was won, which represents 16.2% of the total EC financial contribution of 22.5 M€ won by Ukrainian participants across the whole of the FP7 programme (see figure overleaf).

[16] Partnership and Cooperation Agreement between the European Communities and their Member States, and Ukraine, http://trade.ec.europa.eu/doclib/docs/2003/october/tradoc_111612.pdf

[17] EU/Ukraine European Neighbourhood Action Plan, DG External Relations, http://ec.europa.eu/world/enp/pdf/action_plans/ukraine_enp_ap_final_en.pdf



In June 2011, a network of National Contact Points (NCP) for FP7 was established in Ukraine. This network aimed to further facilitate the integration of the Ukrainian research community into the European Research Area. It included 25 NCPs for 14 thematic areas, legal and financial issues and international cooperation. The organisations hosting the NCPs included higher education institutes (controlled by the Ministry of Education and Science, Youth and Sport of Ukraine), research institutes (controlled by the National Academy of Sciences of Ukraine) and non-governmental and governmental organisations (e.g. State Space Agency).

Association Agreement

In March 2014, an Association Agreement was signed between the EU and Ukraine which established a political and economic association between the EU, Euratom, its 28 Member States and Ukraine.[18] In the agreement Ukraine has committed to make economic, judicial, and financial reforms to converge its policies and legislation to those of the EU. In return, the EU has agreed to provide Ukraine with political and financial support, access to research and knowledge, and preferential access to EU markets. Notably, the agreement includes several articles with respect to science and technology including:

Article 372: Cooperation will include the exchange of information on each other's policies and programmes and the relevant opportunities for cooperation and joint projects, including participation of Ukrainian entities in the relevant Space and Transport themes of the next EU Framework Programme for Research and Innovation Horizon 2020.

Article 374: The Parties shall develop and strengthen their scientific and technological cooperation in order to contribute both to scientific development itself, and to reinforce their scientific potential for contributing to the resolution of national and global challenges.

Article 376: Cooperation shall take place particularly through:

- *(a) exchange of information on each other's science and technology policies;*
- *(b) participation in the next EU Framework Programme for Research and Innovation Horizon 2020;*
- *(c) joint implementation of scientific programmes and research activities;*
- *(d) joint research and development activities aimed at encouraging scientific progress and the transfer of technology and know-how;*
- *(e) training through mobility programmes for researchers and specialists;*
- *(f) the organisation of joint scientific and technological development events/measures.*

[18] Association Agreement between the EU and Ukraine http://trade.ec.europa.eu/doclib/docs/2016/november/tradoc_155103.pdf

Horizon 2020

In accordance with this agreement, the Ukrainian government has undertaken the following measures to support the implementation of Horizon 2020 Programme in Ukraine:

- In December 2013 the Ministry of Education and Sciences of Ukraine together with the National Academy of Sciences of Ukraine established a network of Horizon 2020 National Contact Points which comprise of former (FP7) NCPs and newly selected ones (30 in total). This NCP network is revised and updated each year taking into account evolving needs and opportunities. As of May 2017, the network consisted of 38 national and 6 regional contact points (RCPs) covering all the thematic areas of Horizon 2020 programme. The network includes both higher education institutes and research institutes, and their contact points are governed and funded by the Ministry of Education and Sciences and National Academy of Sciences respectively. Two NCPs and one RCP are dedicated to the Societal Challenge "Smart Green and Integrated Transport" of the Horizon 2020 programme.
- In March 2015 the participation of Ukraine in the EU framework programme for research and innovation Horizon 2020 - with the status of associated country - was signed between the EU and Ukraine. Ukrainian research institutions, universities and businesses became automatically eligible for funding and participation in Horizon 2020 programme under the same conditions as EU Member States. The agreement opened a wide range of new opportunities across the whole research and innovation value chain, from fundamental research up to close-to-market activities.
- A Peer Review of the Ukrainian Research and Innovation System took place from May to December 2016. The Peer Review report contains seven headline policies to inspire the design and implementation of reforms. The report explains the rationale for each policy and contains thirty more detailed recommendations on the reforms to be achieved. Recommendations are made on a range of issues including reforming the science, technology and innovation (STI) system in order to improve efficiency and results; increasing government investment in R&D; revamping STI institutions, funding and procedures; and improving international cooperation. The Ukrainian national authorities have expressed their strong political commitment to the Peer Review recommendations and will be responsible to follow-up the implementation of these recommendations.
- In December 2016 the Cabinet of Ministers of Ukraine established a "Coordination Centre" to work on more effective solutions to the problems encountered during the implementation of projects funded under H2020 in Ukraine.

During the first three years (2014-2016) and 274 calls of the Horizon 2020 programme, 383 Ukrainian organisations participated in the preparation of 604 proposals (808 participations) requesting a combined EC contribution of 236.95 M€. Out of these many submitted proposals, 61 proposals were successfully selected for funding involving 67 Ukrainian organisations (80 participations) with a combined EC contribution of 11.95 M€. In particular, 24 proposals with 36 Ukrainian participations were submitted to aeronautics-related calls resulting in two successfully funded projects. These two projects involve six Ukrainian organisations (seven participations) with a combined EC contribution of 0.53 M€.

Today, besides the Horizon 2020 programme, Ukraine is also eligible to participate in a number of other EU programmes that foster RTD cooperation such as the Erasmus+ programme[19] - which supports education, training, youth and sport - as well as the Cross-Border Cooperation: Hungary-Slovakia-Romania-Ukraine Programme[20].

Science and Technology Center in Ukraine

The Science and Technology Center in Ukraine (STCU)[21] is an intergovernmental organisation established in 1993 with the objective of preventing the proliferation of expertise related to weapons of mass destruction (WMD) from former Soviet countries. The STCU receives funding from the EU and the United States in order to provide grants and funding for RTD projects employing WMD scientists and engineers. By April 2016, the STCU had received $275 million in approved project funding and managed over 1700 collaborative research projects involving approximately 21,000 scientists and technicians from its five partner countries (Azerbaijan, Georgia, Moldova, Ukraine and Uzbekistan). This includes numerous aeronautics research projects such as "Heterogeneous composite-to-composite and

[19] http://ec.europa.eu/programmes/erasmus-plus/node_en
[20] http://www.huskroua-cbc.net
[21] http://www.stcu.int

composite-to-metal heavy loaded joints (P296)" involving the National Aerospace University (KhAI) and EOARD and "Modern methods of welding and production of the constructions from aluminium and lithium alloys" involving Paton Electric Welding Institute and Boeing. Through the STCU Partner Program, private companies, academic and nongovernment organisations, and government agencies may contract research and technology work to Ukrainian as well as Azeri, Georgian, Moldovan and Uzbek scientists and institutes.

European Aviation Safety Agency
In June 2017, the European Aviation Safety Agency (EASA) and the State Aviation Administration of Ukraine (SAAU) launched a three-year cooperation project to support the implementation in Ukraine of EU airworthiness rules and thus prepare the country for participation in EASA's activities[22]. The launch followed the signing in January 2017 of an arrangement between the EC and SAAU on convergence of certification systems.

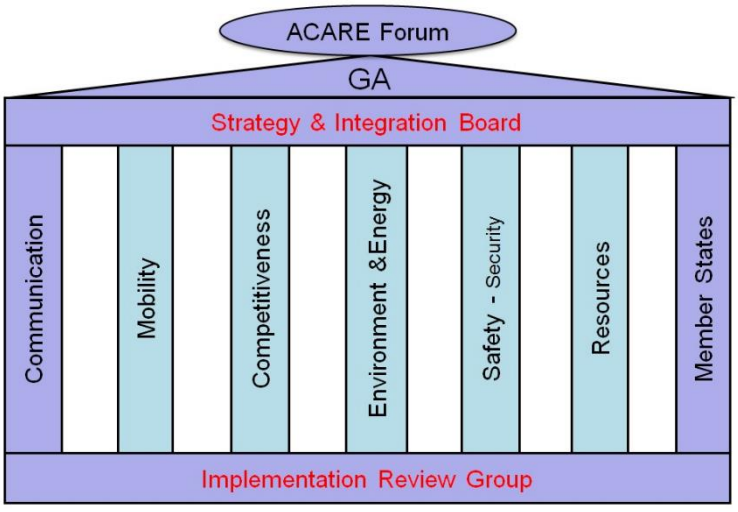
4.2 Industrial led initiatives

A large potential exists for collaboration between the Ukrainian aeronautics industry and its European counterpart, however it is currently underexploited. For both partners, increased research cooperation would be useful for two reasons:

- Participation in European research projects, or in bilateral developments with leading European companies, would help to gain first-hand information on advanced developments;
- Could act as a first step to business-to-business industrial co-operation.

In order to increase interaction between Ukrainian and EU industry, there are a number of European initiatives which Ukrainian companies should consider contacting.

ACARE
The Advisory Council for Aeronautics Research in Europe (ACARE)[23] provides a network for strategic research in aeronautics and air transport so that aviation satisfies the needs of society and secures global leadership for Europe. ACARE is essential in bringing together the right stakeholders to turn the air transport vision in Europe into reality. ACARE has been in existence since 2001 and comprises European public and private stakeholders – from industry, research laboratories and academia - who collaborate on a common purpose to develop challenging improvements for aeronautics and air transport in Europe.



ACARE maintains a governance structure to develop and review strategic options, priorities and objectives through a General Assembly (GA) and Strategy and Integration Board. Supporting groups provide forums to review implementation, infrastructure and communication needs on a regular basis.

[22] https://www.easa.europa.eu/newsroom-and-events/press-releases/easa-launches-airworthiness-convergence-project-ukraine
[23] www.acare4europe.com

In June 2017, ACARE launched an updated Strategic Research and Innovation Agenda (SRIA)[24], which provides a strategic roadmap to guide the future direction of public and private research towards the achievement of the EU's 'Flightpath 2050' Vision.

Thanks to Ukraine being an associate country to H2020 and the efforts of the AERO-UA project, Victor Shulepov (UkrRIAT) was successfully appointed in November 2017 by the Ministry of Education and Science to become the Ukrainian observer eligible to participate in meetings of the ACARE General Assembly.

ASD

The Aerospace and Defence Industries Association of Europe's (ASD)[25] represent the interests of larger aerospace companies and national associations in Europe. The association is divided into two distinct groups of the aeronautical industry: the company members and the national association members. The main role of the association is to be the voice of the industry, representing 3,000 companies and more than 847,700 people. The ASD association seeks to act as a single voice to promote the best interests of the industry in dialogue with the EU Institutions and other stakeholders, to contribute to shape effective policy and legislation at European and global level, to promote international cooperation and dialogue with other international associations and organisations, to raise awareness about the benefits of the sector to a large variety of audience (politicians, decision-makers, businesses, media, general public, NGO's and other stakeholders), to act as the central intelligence hub for expert knowledge on industry related issues.

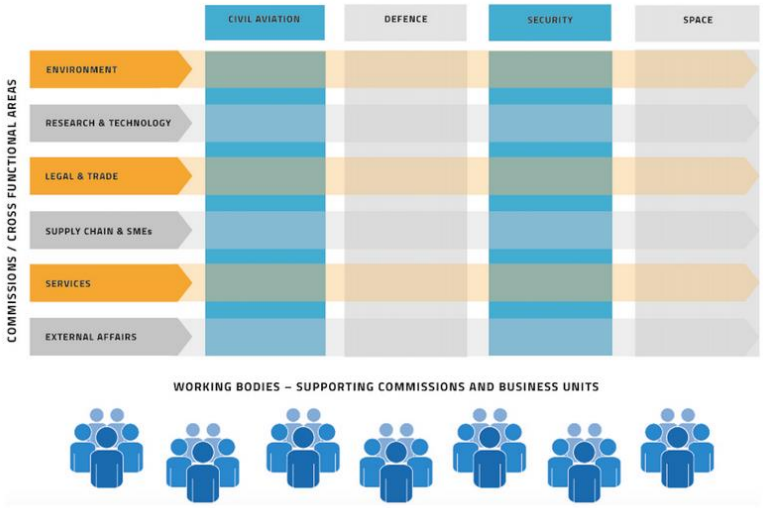
The following table shows the members of ASD:

Direct Company Members	National Association Members
Airbus	Austrian Aeronautics Industries Group
BAE Systems	Austrian Defence Industry Association
Dassault Aviation	Advancing UK Aerospace, Defence & Security Industries
FICANTIERI	AED Portugal (DANOTEC)
GKN Aerospace	Association of Finnish Defence and Aerospace Industries
Indra	Agoria
Leonardo	Italian Industries Federation for Aerospace, Defence and Security
MBDA	Association of Aviation Manufacturers of the Czech Republic
NAVAL GROUP	Defence and Security Industry Association of the Czech Republic
Rolls Royce	Association of Polish Aviation Industry
SAAB	Bulgarian Defence Industry Association
SAFRAN	German Aerospace Industries Association
Thales	Federal Association of the German Security and Defence Industry
	Belgian Security and Defence Industry
	CIDEF
	Defence and Aerospace Industries Association in Denmark
	Norwegian Defence and Security Industries Association
	French Aerospace Industries Association
	Hellenic Aerospace and Defence Industries Group
	Netherlands Aerospace Group
	Netherlands Defence Manufacturers Association
	Swedish Aerospace Industries
	Swiss Aeronautical Industries Group
	Turkish Defence Industry Manufacturers Association
	Swedish Security and Defence Industry
	Spanish Association for Defence, Security and Space Technology Companies

The day-to-day work of ASD is conducted within a framework of working bodies, made up of experts from among the membership and supported by staff of the Secretariat. Strategically located in the heart of Brussels, the ASD team is responsible for major items of policy work, create and maintain close links

[24] http://www.acare4europe.org/sites/acare4europe.org/files/attachment/acare-strategic-research-innovation-volume-1-v2.7-interactive-fin.pdf
[25] http://www.asd-europe.org

with the European Institutions and international organisations. ASD works closely together with its members in four Business Units (Civil Aviation, Defence, Security and Space) that are sector focused and six Commissions (Environment, R&T, Economic Legal & Trade, Services, Supply Chain and External Affairs) that address cross-functional areas.



For Ukrainian industrial organisations active in any of the four business units, it is highly recommended to get in touch with the ASD team member responsible for the respective business unit.

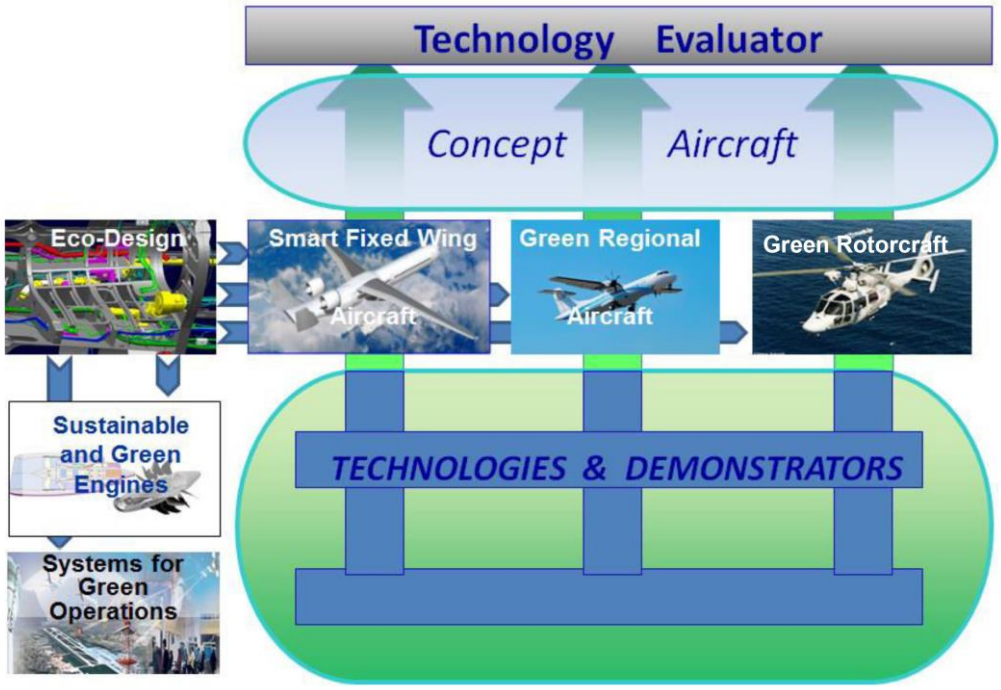
Clean Sky Joint Undertaking

The Clean Sky Joint Undertaking (CSJU)[26] is a public-private partnership between the European Commission and the European aeronautics industry that coordinates and funds research activities to deliver significantly quieter and more environmentally friendly aircraft. The CSJU manages the Clean Sky 2 programme - funded by the EU's Horizon 2020 programme - which aims to be the main contributor to the EU's Flightpath 2050 goals set by ACARE. These goals are:

- A 75% reduction in carbon dioxide (CO2) emissions.
- A 90% reduction in mono-nitrogen oxides (NOX).
- A noise reduction of flying aircraft of 65%.
- Mitigate the environmental impact of the lifecycle of aircraft and related products by designing and manufacturing aircraft to be recyclable

Clean Sky is built upon six different technical areas called Integrated Technology Demonstrators (ITDs), where preliminary studies and down-selection of work will be performed, followed by large-scale demonstrations on ground or in-flight, in order to bring innovative technologies to a maturity level where they can be applicable to new generation "green aircraft". The Clean Sky programme is shown schematically in the following figure:

[26] http://www.cleansky.eu



The CSJU publishes biannual work plans which contain details of RTD priorities and the deadlines for call for proposals. Because Ukraine is an associate country to H2020, Ukrainian aeronautics organisations are able to participate in Clean Sky 2 funded projects on the same terms as those from EU member states.

SESAR Joint Undertaking

The SESAR Joint Undertaking (JU)[27] is a public-private partnership between the European Commission and representatives from the military, civil users of airspace, air navigation service providers, equipment manufacturers, airports, bodies representing staff in the air traffic management sector and scientific institutions and the scientific community.

SESAR JU manages the Single European Sky Air Traffic Management Research 2020 (SESAR 2020) programme, which aims to develop a modernised air traffic management system for Europe to ensure the safety and fluidity of air transport over the next decades, make flying more environmentally-friendly and reduce the costs of air traffic management. It supports the Single European Sky and EU Aviation Strategy vision to offer passengers safer, cleaner and more affordable flights.

With a budget of €1.6 billion up to 2024, SESAR 2020 supports projects to deliver solutions in four key areas, namely airport operations, network operations, air traffic services and technology enablers. The research projects are categorised into three strands: Exploratory research, Industrial research and validation and Very large-scale demonstrations. These strands have been designed as an innovation pipeline through which ideas are transformed into tangible solutions for industrialisation. SESAR 2020, which is co-funded by the EU's Horizon 2020 programme, publishes both open and closed calls. Calls relating to exploratory research and very large-scale demonstrations are open, while only SESAR Joint Undertaking members can apply for industrial research calls.

Because Ukraine is an associate country to H2020, Ukrainian aeronautics organisations are able to participate in CESAR 2020 funded projects on the same terms as those from EU member states.

4.3 Academic and Public Research led initiatives

Ukrainian researchers have a strong reputation for their creativity, upstream ideas and conceptual design abilities. Thus, Ukrainian universities and research establishments would not only benefit but also be of significant value to research projects in technological readiness levels (TRL) 1-3 i.e. from basic technology research through to technology development. Participation of Ukrainian entities, either

[27] https://www.sesarju.eu

in EU funded research projects or bilateral co-operations, would lead to win-win situations, as both sides have significant knowledge, expertise and human resources to share.

To increase interactions between Ukrainian and EU universities and research establishments, there are a number of networks which Ukrainian research organisations and researchers should consider contacting.

EASN

The European Aeronautics Science Network (EASN)[28] is the academic representative in the Advisory Council for Aeronautics Research in Europe *(*ACARE*)* and the European Commission. Its members include academics, university labs and universities from several European countries. EASN currently connect to several thousand academia and research staff throughout Europe. EASN has mapped the European universities according to their geographical distribution and the areas of expertise.

EASN Regional structure
(Source: www.easn.net)

PEGASUS Network

The Partnership of a European group of aeronautics and space universities (PEGASUS)[29] provides a European portal for higher education services for aerospace. The twenty founding institutions of PEGASUS had previously collaborated for some years in an ad-hoc manner - largely supported by EU funding - and decided to work more closely together in a manner that better satisfied the needs of their students and aerospace companies across Europe.

One of the first actions taken by the PEGASUS partners was to define diplôme/postgraduate level requirements enabling the granting of a European certificate in the education and training of aerospace engineers, and an award in recognition of an individual student's multi-national experience. All PEGASUS partners have agreed on a specific curriculum description format, enabling an immediate understanding of the level of education provided by the partners. Admission to PEGASUS is based on a set of criteria, focusing on two fundamental keywords: quality and international co-operation, all related to the higher education offered in aeronautical / aerospace engineering at European level.

Today, more than 2000 aeronautical engineers graduate from the member institutions of PEGASUS each year. Furthermore, PEGASUS' close relations with industry have enabled the establishment a set of Airbus international industrial placements dedicated to students of PEGASUS institutions.

[28] European Aeronautics Science Network (EASN), www.easn.net
[29] PEGASUS Network, www.pegasus-europe.org

Distribution of current PEGASUS network members
(Source: www.pegasus-europe.org)

EREA Network

The Association of the European Research Establishments in Aeronautics (EREA)[30] was established in May 1999 with the main aims:

- to promote and represent the joint interests of its members;
- to intensify the co-operation between its members, aimed at further integration of their activities in the field of civil, military and space-related aeronautics;
- to improve and intensify the co-operation of EREA and its members with third parties in the field of aeronautics;
- to facilitate the ultimate goal of the Members of an integrated management of joint activities, thereby contributing to Europe's role as a global player in aeronautics.

The association's full members are AFIT, AIT, CEIIA, CIRA, CSEM, DLR, ILOT, FOI, INCAS, INTA, NLR, ONERA, TsAGI, VKI and VZLU. The association provides a forum for liaising with the European Commission, European industry (e.g. ASD) and other interested research organisations on aeronautical and security research issues.

4.4 Success Stories

Since the EU's fifth framework programme for research and technology development (FP5), numerous Ukrainian actors (industrial, academic, public research) have participated in aeronautics related collaborative research projects with European partners. The following is a selection of success stories from this experience.

FP6 CESAR Project

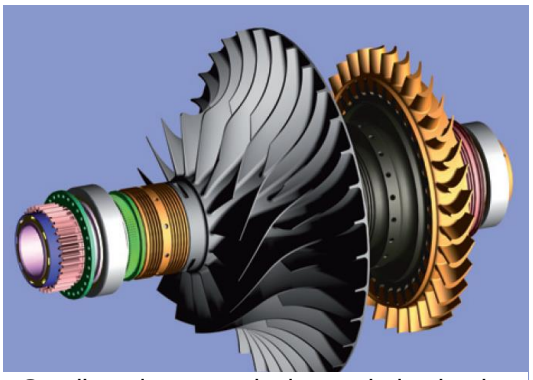
CESAR (Cost-Effective Small Aircraft) project (September 2006 to February 2010) was a cooperative project, in which 40 enterprises and organisations from 13 countries, including Ukraine, took part. Its mission was to develop a small, commercial aircraft competitive at world market with improved technologies that significantly reduce time to market for the aircraft, reduce development, operation and maintenance costs, while improving safety, environmental impact and passenger comfort. CESAR sought to provide the necessary technological and theoretical data for the advanced wing, a competitive and environmentally friendly power-plant and new technologies for major aircraft systems to reduce aircraft operating costs and improve safety.

Ivchenko-Progress State Enterprise was responsible for the development of an integrated power-plant. The following achieved objectives by Ivchenko-Progress SE were:

[30] www.erea.org

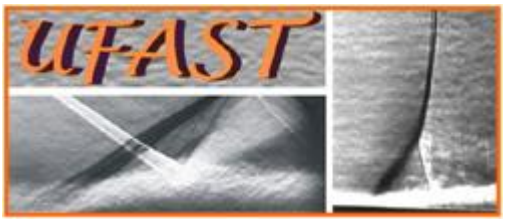
1. Weight of power plant was reduced by about 6 - 8%.
2. Fuel consumption was decreased by 2 - 3%.
3. Overall dimensions of the power plant were decreased.
4. Service life of the engine and its systems was increased by 10 - 15%.
5. Maintenance costs were decreased by 7 - 9%.
6. Increased reliability and safety.

Participation in this project was the prerequisite for further participation of the company in other EU-funded activities, like FP7 ESPOSA and AERO-UKRAINE projects.



Small engine rotor design optimisation by Ivchenko

FP6 UFAST Project

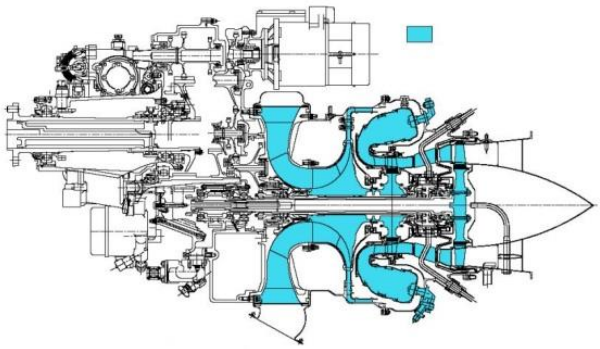


The 'Unsteady effects in shock wave induced separation' (UFAST) project (January 2005 to May 2009) focused on both theoretical and experimental work in the area of unsteady shockwave boundary layer interactions (SWBLI).

The project improved knowledge and expertise by conducting reference experiments based on unsteady effects. The three configurations were selected (Transonic interaction, Nozzle flow, Oblique shock reflection) and this implied a high number of flow cases. Three different experiments were designed for each configuration. The Podgorny Institute for Mechanical Engineering Problems (of National Academy of Science Ukraine / RES) took part in different types of experiments with regards to nozzle flow, including nozzle, curved channel, AJVG, etc. The initiative also sought to improve existing numerical modelling methods that can increase understanding of complex physical phenomena. New methods of turbulence modelling, especially for shock dominated flows, were developed by the consortium.

FP7 ESPOSA Project

ESPOSA (Efficient Systems and Propulsion for Small Aircraft) was a cooperative project (October 2011 to June 2016). 41 enterprises and organisations from 15 countries, including Ukraine, took part. The purpose of the project was to increase and improve of a base (existing) turboprop engine through modelling and demonstrator. Ivchenko-Progress SE first managed the subproject of developing and optimising components of the advanced base engine1 (BE1/BE2). In a second phase, Ivchenko-Progress SE managed the design of the base engine 2 (BE2/BE2+). Through modelling and validation of the demonstrator engine, the project confirmed that engine 2 can be selected on a small 9-seat GA aircraft.



BE2 - Baseline Engine 2 based on AI 450 engine of Ivchenko-Progress SE

Foreseen applications

FP7 WASIS Project

The Composite Fuselage Section Wafer Design Approach for Safety Increase in Worst Case Situations and Minimising Joints (WASIS) project was initiated and based on an idea of the Ukrainian partner National Aerospace University "KhAI", thanks to its long-term experience with both lattice composite structures and metal-to-composite joining. The project (January 2011 to June 2016) aimed to develop innovative full-composite aircraft fuselage structure based on lattice stiffening concept and innovative hybrid joining elements. The target was to incorporate several cost-saving features to meet future environmental demands and to improve design and manufacturing cost and productivity.

The project consortium was coordinated by Fundacion Cidaut (Spain) and included 10 other European partners (including the Italian aircraft manufacturer Piaggio Aero Industries). The project results showed that the proposed solution offers both cost efficiency and significant weight reduction.

Since completing the project, KhAI successfully continued collaboration with some of the project partners, which resulted in several joint proposal applications and projects in the field of aircraft composite structures.

WASIS consortium at ECCM16 in Seville, Spain

Full-Scale Wafer Fuselage Section Mock-up

FP7 AERO-UKRAINE Project

The main aim of AERO-UKRAINE was to facilitate research cooperation between aeronautics actors from the EU and Ukraine. The project covered a wide range of activities: assessing and publicising the aeronautics collaboration potential between the EU and Ukraine; raising awareness and understanding of EU aeronautics collaborative research; supporting participation in FP7 aeronautics research.

Consortium has created a short brochure describing the possibilities of the involvement into the FP7 projects and providing some practical information through examples.

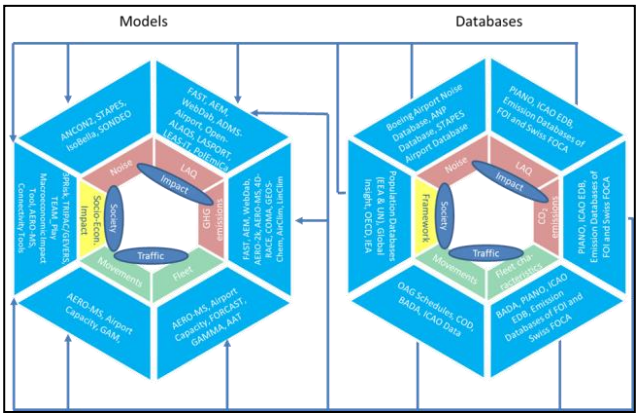
The project has also organised several FP7 awareness raising events in Ukraine and EU, where representatives of EC, ACARE; major R&T organisations like AIRBUS, DLR and many more attended. It contributed to establishing the Ukrainian aeronautical NCP and to appointing KhAI as Ukrainian transport NCP which includes aeronautical NCP.

FP7 TEAM_PLAY Project

The TEAM_Play project (December 2010 to March 2013) created a modelling framework to combine and advance European modelling capabilities to support the European perspective in the international policy arena. Modelling of aviation's sustainability has become more complex and requires broader assessments, including environmental and socio-economic impacts.

During the project, the National Aviation University (NAU) developed the following models:

The IsoBella model was designed to calculate noise levels/indices at specific points and/or noise contours (for several types of level/indices) for airport flight scenarios under consideration. The model was further enhanced with environmental factors models: PolEmiCa (Local Air Quality model) and 3TPRisk (Third Party Risk model). Today, IsoBella is almost adapted with the ANP database, supervised by EUROCONTROL at www.aircraftnoisemodel.org (version 2.0 currently is available). The data requirements to allow the tool suites to be run are very similar for about all aviation environmental modelling purposes.



H2020 AERO-UA Project

AERO-UA is a 3-year coordination and support action that started on 1 October 2016 and is funded by the European Commission under the Smart Green and Integrated Transport Challenge of the Horizon 2020 Programme. The project aims to stimulate aviation research collaboration between the European Union and Ukraine through strategic and targeted support. AERO-UA focuses solely on Ukraine due to the country's huge aerospace potential and comparatively low level of aviation research collaboration with the EU.

The AERO.UA project will achieve its overall aim via four high-level objectives:

1. Identifying the barriers to increased EU-UA aviation research collaboration;
2. Providing strategic support to EU-UA aviation research collaboration;
3. Organising awareness-raising and networking between EU-UA stakeholders; and
4. Supporting EU-UA aviation research knowledge transfer pilot projects.

AERO-UA Project Consortium

5. Analysis and recommendations to support EU-Ukraine cooperation

5.1 SWOT analysis of the Ukrainian aeronautics R&T sector

The following table summarises the main strengths (S) and weaknesses (W) of the Ukrainian aeronautics R&T sector and the expected opportunities (O) and threats (T) from the external environment over the next 5+ years.

SWOT Analysis of Ukrainian Aeronautics Research and Technology Sector

Strengths (S) and Weaknesses (W) of Ukrainian Aeronautics Sector	Opportunities (O) and Threats (T) from the External Environment
Strengths S1. Long and successful experience in aerospace R&T and production S2. Full cycle of aerospace development, production and maintenance S3. Presence of national aircraft and gas turbine engines OEMs S4. Large number of well qualified and skilled aerospace scientists and engineers S5. Specialised know-how linked to unique Ukrainian aerospace products (e.g. super-cargo planes, counter rotating open rotors, rocket launchers and small satellites) S6. Historical global presence on different markets	**Opportunities** O1. Ukraine's association to the H2020 programme O2. Expected approval of Programme of Ukrainian Aircraft Industry Revival 2017-2022 O3. Participation in European aerospace networks aimed at higher education institutions, public research organisations and industry (e.g. EASN, EACP, EREA, CEAS) O4. Growth of the global aviation transportation market O5. Creation of new R&D and production sites to substitute Russian aircraft components O6. Tax exemptions for actors working in aeronautics sector (aircraft OEMs, aircraft engines OEMs) O7. Expected signature of agreement to join European Common Aviation Area
Weaknesses W1. Outdated aerospace R&T infrastructure at higher education institutes and institutes of the National Academy of Sciences W2. Ageing aerospace research staff at higher education institutes and institutes of the National Academy of Sciences W3. Lack of government funds for board aeronautics research support W4. Inadequacy of legal and regulatory control of aircraft sector, regarding R&D, industry and relevant infrastructures W5. Insufficient experience of international R&T cooperation beyond ex-Soviet countries W6. Lack of knowledge and experience of EC's research framework programmes (e.g. low participation in FP7, Horizon 2020 aviation calls and Clean Sky 2) W7. Insufficient marketing know-how	**Threats** T1. Continued "brain-drain" of talented young aerospace scientists and engineers T2. Loss of large market for aerospace products export and deep research ties due to sanctions against Russia T3. Increasing international competition in aerospace field T4. Continued political instability in Ukraine T5. Global economic crisis

5.2 Recommendations to strengthen EU-Ukraine aeronautics R&T cooperation

The following recommendations have been formulated by considering current barriers (see Sections 3 and 5.1) and opportunities for EU-Ukraine aeronautics R&T cooperation (see Sections 4 and 5.1). These recommendations are separated according to four different levels of decision-maker or group.

Level of Decision-Maker or Group	Recommendations
1. Ukrainian Government 	**a) Implementation of the Funding Law** The Ukrainian government passed a funding law in November 2015 which stipulates that 1.7% of GDP is to be allocated to science. However, currently, the government is only allocating 0.48% of GDP (2016) which is about four times less than that foreseen by law. The government needs to adhere to this commitment. **b) Research Spending Freedom** As part of the Ukrainian Law "About Higher Education", Ukrainian universities have the right to have accounts outside the State Treasury, thereby giving the universities freedom to be financially autonomous in how they spend funds. However, currently, the law is being blocked by the Ukrainian government. The Ukrainian government needs to allow this law to be implemented. **c) Ukrainian Co-Funding for H2020 Projects** Ukraine is committed to co-funding H2020 projects with up to 15% of the budget allocated by the EU. Without this co-funding budget, Ukrainian partners in H2020 projects will miss up to 15% of the project's planned budget. The Ukrainian government must not only allocate this budget but also ensure it is distributed to the Ukrainian partners. **d) Ukrainian H2020 National Contact Points (NCPs)** The Ministry of Education and Science needs to increase the funding support for Ukrainian NCPs and to require the NCPs to conduct a greater number of H2020 information sessions, networking events and proposal-writing training workshops. **e) Reducing Ukrainian Bureaucracy** Researchers and institutes are looking for simplified rules, consistent rules and commitments which are delivered. It would greatly help if the government could eliminate or simplify the current rules related to the State Treasury, currency exchange rules, payment terms rules, tender rules, etc. **f) Harmonising of the Aviation Laws and Certification Procedures between the EU and Ukraine** Ukraine started the process to harmonise its aviation laws and certification procedures with the EU in January 2017[31]. It must ensure it completes the harmonisation process in five years or less. Poland went through a similar harmonisation process with the EU when it passed its Aviation Law in 2011. The impact of this harmonisation has been to greatly facilitate cooperation between Polish and European aviation enterprises in areas of trade, transportation, product development and manufacturing.[32] **g) Harmonising the Science and Technology Innovation System between the EU and Ukraine** The Ukrainian government needs to harmonise its Science Technology and Innovation system with the EU system, thereby allowing Ukrainian partners to work smoothly with both systems as recommended by the European Commission (http://ec.europa.eu/research/iscp/index.cfm?pg=ukraine): The Horizon 2020 PSF Peer Review took place from May 2016 to December 2016. The Peer Review report contains seven headline policy messages to inspire the design and implementation of reforms. The report explains the rationale for each

[31] http://www.rusaviainsider.com/ukraine-to-harmonize-aircraft-certification-system-with-eu-standards/

[32] Report on the Innovativeness of the Aviation Sector in Poland in 2010, Tadeusz Baczko et al, Warsaw 2011, http://www.innovation-in-aviation.pl/en/report

	policy message and contains thirty more detailed recommendations on the reforms to be achieved. Recommendations are made on a range of issues including reforming the STI system to boost efficiency and impact; increasing government investment in R&D; revamping STI institutions, funding and procedures, and improving international cooperation. The Ukrainian national authorities have expressed their strong political commitment to the Peer Review exercise and will be responsible for the follow-up to the review and implementation of the resulting recommendations. **h) Ukrainian expertise Involved in EU Activities** There needs to be consistent, reliable and sustained involvement of Ukrainian expert representation at different EU levels such as the H2020 Programme Committees and National Contact Points (NCP). Changing representation creates considerable barriers and communication hurdles. **i) Intergovernmental Committee for Aeronautics** Many government entities are involved in aeronautics but there is no intergovernmental committee dedicated to aeronautics. Consequently, there is no common strategic research agenda for aeronautics - comparable to the ACARE strategic research agenda - and the government entities often act in different directions. An intergovernmental committee needs to be established which would be responsible for creating a common strategic research agenda for aeronautics as well as key performance targets. **j) Ukrainian Aviation Government Agency** The Ukrainian government lacks an agency dedicated to aviation. It should establish such an agency whose responsibilities would include permanently representing Ukrainian interests and competencies in Horizon 2020 and Clean Sky 2 as well as in subsequent EU R&D programmes.
2. European Commission 	**a) EREA and PEGASUS Recommendations** The European Commission needs to allocate more appropriate funding to early-stage, low-Technology Readiness Level projects within Clean Sky and SESAR. The funding rate for such projects is currently very low. The European Commission needs to harmonise and permanently set: the rules in the grant agreements, the quality and consistency of proposal reviews, the scope of calls for proposals need to be more clearly focused scope thereby facilitating higher potential success rates. **b) Ukraine Oriented Topics** Since the EU desires more Europe-Ukraine research collaboration, the H2020 work programmes should also include specific Ukrainian research interests in the calls for proposals, order to create more Ukrainian interest and involvement. **c) Funding** As stated in the following link, the EU budget for future research programmes (i.e. FP9) should be significantly increased to cover the anticipated needs of research: https://horizon-magazine.eu/article/next-eu-science-fund-should-be-doubled-size-pascal-lamy_en.html#.WVohz_xXuPQ.linkedin **d) Bureaucracy** As recommended by EREA and PEGASUS, a simplification of submission procedures, reduction of the time required to prepare proposals and clearer objectives in calls for proposals will help to increase the success rate of Ukrainian partners, and thereby increase the interest of Ukrainian partners in collaborative research. **e) ERASMUS+** Promote exchange of higher education students between EU universities and Ukrainian universities and increase the awareness of the Ukrainian universities and research interests through EU students. This awareness will be further disseminated by those “former” students in the private and public sector. The ERASMUS+ program should have a special focus on the aerospace Ukrainian universities listed in Annex 2.

3. Ukrainian Partners 	**a) Top Down Responsibility** The National Contact Points (NCPs) should regularly share prospective and actual opportunities for Europe-Ukraine collaborative research, proposal submission processes, project implementation procedures and, last but not least, Ukrainian success stories as motivators. This is currently supported by ncp.khai.edu **b) Ukrainian Partner Long Term Commitment** Ukrainian partners need to be committed to such collaboration on the long term. It requires involvement at different levels of H2020 regulations; regularly following-up on aeronautics related calls; and long term / sustained commitment in day-to-day, week-to-week, month-to-month, and year-to-year activities related to research projects. For this purpose, Ukrainian partners should establish their own EU project support offices. All Ukrainian partners need to continually promote their expertise, excellence and competence in aeronautical research and innovation. This requires recruiting and/or training staff to have the necessary English-language skills. Additionally, they should also consider expanding the scope of their research outside aeronautics, as there may be other good opportunities for funding their fundamental research. Perseverance is an essential requirement for Ukrainian partners to be successful in EU research collaboration. **c) Ukrainian Aerospace Cluster "Mechatronics"** The Ukrainian cluster was established in 2015. The cluster's members must continue to show strong support for the cluster's goals of improved integration and competitiveness. The investment in time and effort will pay off as shown by the Aviation Valley cluster in south east Poland, where the cluster has been instrumental in aligning the research and education activities of local universities with the needs of industry, especially SMEs.[33] **d) Seek Foreign Direct Investment** The Ukrainian aviation sector has a strong need for investment in new R&D and production facilities. The Ukrainian partners should seek ways to attract foreign direct investment for this purpose. For inspiration on how to do this, they should examine the numerous recent examples in the Polish aviation sector.[34]
4. EU Partners 	**a) Ethics** It is essential that EU partners consider Ukrainian partners with a mutual level of respect for their competence, expertise and ethics, in order for the Ukrainian partners to feel like equal partners and to be motivated in joining Europe-Ukraine collaborative research projects. **b) Conferences and Trade Shows** EU partners should consider presenting papers at conferences or at least attending conferences or trade shows which are organised in Ukraine, particularly in aerospace and related fields. This will increase awareness of Ukrainian expertise and further increase the networking between partners. **c) Sharing Success Stories** EU partners should consider promoting more aerospace research collaboration and success stories with Ukrainian partners on their company website or newsletter but also on the Wikipedia page of their company. This will increase the awareness of UA partner's expertise. Ideally, circular references between partners website should be created.

[33] Report on the Innovativeness of the Aviation Sector in Poland in 2010, Tadeusz Baczko et al, Warsaw 2011, http://www.innovation-in-aviation.pl/en/report

[34] Report on the Innovativeness of the Aviation Sector in Poland in 2010, Tadeusz Baczko et al, Warsaw 2011, http://www.innovation-in-aviation.pl/en/report

Annexes

Annex 1. Bibliography and Other Information Sources

ACARE, www.acare4europe.com

AeroSpace and Defence Industries Association of Europe (ASD), www.asd-europe.org

Association Agreement between the EU and Ukraine, http://trade.ec.europa.eu/doclib/docs/2016/november/tradoc_155103.pdf

Clean Sky 2, www.cleansky.eu

CEARES, www.slotconsulting.eu/references/projects/ceares/

Cordis website, http://cordis.europa.eu

EREA, www.erea.org

EU/Ukraine European Neighbourhood Action Plan, DG External Relations, http://ec.europa.eu/world/enp/pdf/action_plans/ukraine_enp_ap_final_en.pdf

European Aeronautics Science Network (EASN), www.easn.net

European Commission's website, Research & Innovation, International cooperation section, http://ec.europa.eu/research/iscp/index.cfm?pg=ukraine

Ministry of Education and Science of Ukraine, http://mon.gov.ua

National Academy of Sciences of Ukraine, www.nas.gov.ua

Partnership and Cooperation Agreement between the European Communities and their Member States, and Ukraine, http://trade.ec.europa.eu/doclib/docs/2003/october/tradoc_111612.pdf

PEGASUS Network, www.pegasus-europe.org

Report on the Innovativeness of the Aviation Sector in Poland in 2010, http://www.innovation-in-aviation.pl/en/report

SESAR 2020, www.sesarju.eu

Ukrainian Aeronautics Research and Technology Report – 2010, An initiative of the FP7 Aero-Ukraine project http://www.intelligentsia-consultants.com/docs/Ukrainian_Aeronautics_R&T_Report_2010.pdf

Verkhovna Rada of Ukraine, http://rada.gov.ua

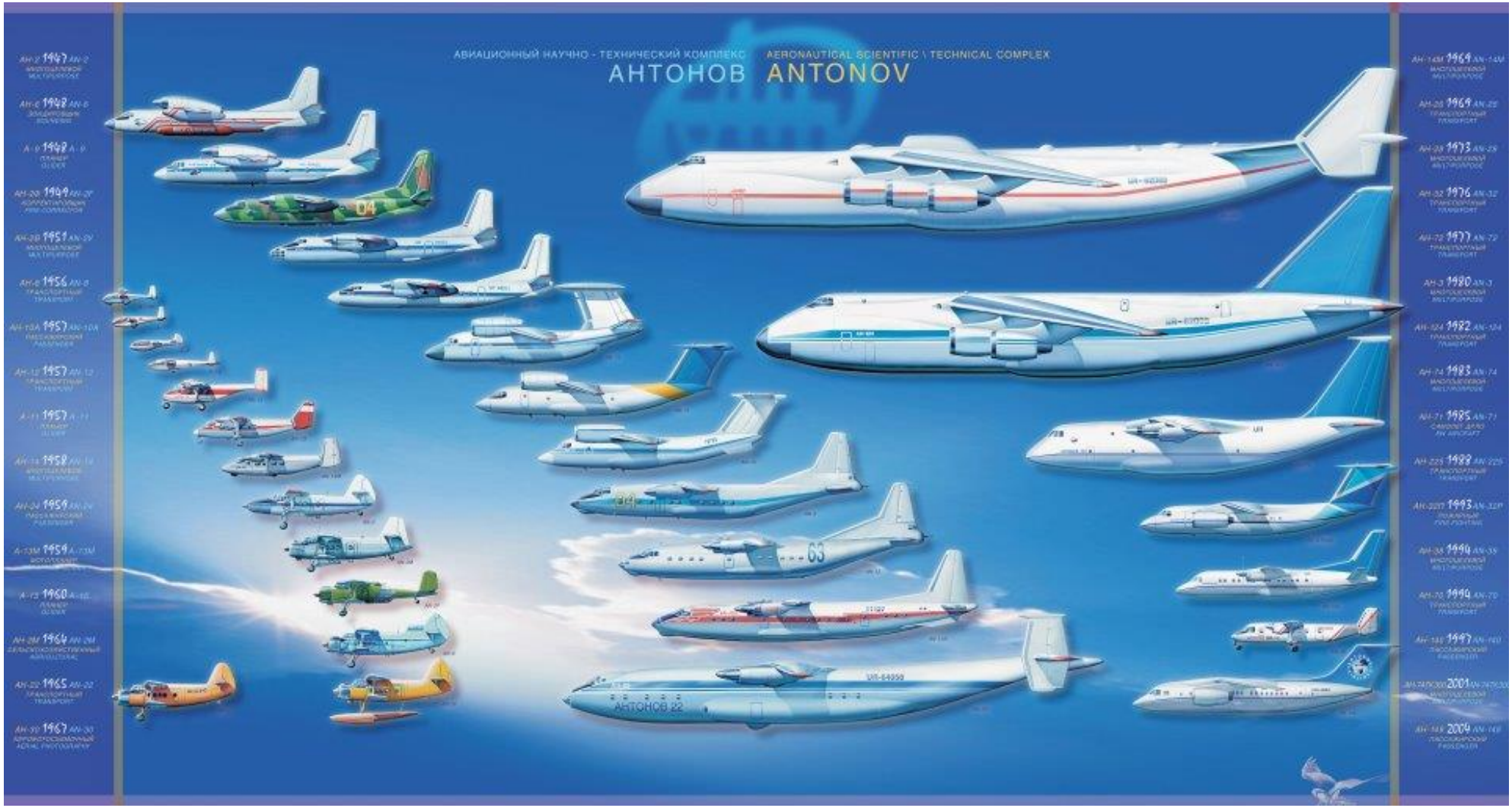
Annex 2. Ukrainian Organisations involved with Aeronautics

Type of organisation	Name of organisation (in English)	Website
Government and legislative bodies		
Legislative bodies		
	Verkhovna Rada of Ukraine, Committee on Education and Science	www.rada.gov.ua
Executive authorities		
	Cabinet of Ministries of Ukraine	www.kmu.gov.ua
	National Science and Technology Council of Ukraine (under the Cabinet of Ministries of Ukraine)	N/A
	Ministry of Education and Science of Ukraine	www.mon.gov.ua
	National Academy of Sciences of Ukraine	
	Ministry of Economic Development and Trade of Ukraine	www.me.gov.ua
	Ministry of Infrastructure of Ukraine	www.mtu.gov.ua
	State Aviation Administration of Ukraine (under the Ministry of Infrastructure of Ukraine)	www.avia.gov.ua
	National Security and Defence Council of Ukraine	http://www.rnbo.gov.ua/en/
	State Concern “Ukroboronprom”	http://ukroboronprom.com.ua/uk/
Industrial entities		
	SE Antonov	www.antonov.com
	SE Ivchenko-Progress	www.ivchenko-progress.com
	JSC “MOTOR SICH”	www.motorsich.com
	PJSC "FED""	www.fed.com.ua
	PrJSC "Volchansk Aggregate Plant"	www.vza.com.ua
	SE "Plant 410 CA"	www.arp410.com
	Yuzhnoye State Design Office	www.yuzhnoye.com
	JSC ELEMENT	www.element.od.ua
	Aviation company VECTOR LLC	www.ak-vector.com
	Kharkiv State Aircraft Manufacturing Company	
	PJSC "HARTRON"	www.hartron.com.ua
	SSPE "Kommunar Corporation"	www.tvset.com.ua
	SE Kharkiv Aggregate Design Bureau	khadb.kh.ua
	R&D SDB "POLISVIT"	www.tvset.com.ua/branches/polisvit/
	PJSC "Dnepropetrovsk aggregate plant"	www.aodaz.com.ua
	PJSC "Mukachevsky plant "Tochprilad""	http://tochprilad.com
	JSC "Radar"	http://radar.net.ua
	SE "Novator"	http://novator-tm.com
	JSC "CONNECTOR"	www.connector.com.ua
	JSC "Elektronprylad"	www.electronprylad.com.ua
	SE "Orizon-Navigation"	http://orizon-navigation.com
	PJSC "AVIACONTROL"	www.avionika.com

	SDP SE "ARSENAL"	www.arsenalcdb.com.ua
	LTD "Aerocopter"	www.aerocopter.com.ua
	LTD “Kotris”	www.kotris.kiev.ua
	SE "Nikolaev Aircraft Repair Plant "NARP""	www.narp.ua
	SE "Lutsk Repair Plant "MOTOR""	www.motor-lutsk.com.ua
	SE "Lviv State Aircraft Repair Plant "LSARP""	www.lsarp.com.ua
	SE "Chuguev Aircraft Repair Plant"	http://charz.com.ua
	SE "Odessa Aircraft Plant"	www.avirs.ua
	SE "Zaporizhya State Aircraft Repair Plant "MiGRemont""	www.migremont.zp.ua
R&D and educational institutions		
National Academy of Sciences of Ukraine		
	Frantsevich Institute for Problems of Materials Science, NASU	www.materials.kiev.ua/science/home.jsp
	G.V. Kurdyumov Institute for Metal Physics, NASU	www.imp.kiev.ua
	V.N.Bakul Institute for Superhard Materials, NASU	www.ism.kiev.ua
	Physical and Technological Institute of Metals and Alloys, NASU	www.ptima.kiev.ua
	The Institute of High Molecular Compounds Chemistry, NASU	http://ihvs.kiev.ua/
	E.O. Paton Electric Welding Institute, NASU	www.paton.kiev.ua
	A.M. Pidhorny Institute for Mechanical Engineering Problems, NASU	http://ipmach.kharkov.ua/
	G. S. Pisarenko Institute for Problems of Strength, NASU	www.ipp.kiev.ua
	Institute of Technical Mechanics of the National Academy of Sciences of Ukraine and the State Space Agency of Ukraine	www.itm.dp.ua
	“Transmag” Institute of Transport Systems and Technologies, NASU	http://www.itst.org.ua/
	Institute of Electron Physics, NASU	http://iep.org.ua/
	Institute of Engineering Thermophysics , NASU	www.ittf.kiev.ua
	O. Ya. Usikov Institute of Radio-Physics and Electronics, NASU	http://ire.kharkov.ua/
	V.I. Vernadsky Institute of General and Inorganic Chemistry, NASU	www.ionc.kar.net
	L.V.Pisarzhevskii Institute of Physical Chemistry, NASU	www.inphyschem-nas.kiev.ua
	O.O. Chuiko Institute of Surface Chemistry, NASU	www.inphyschem-nas.kiev.ua
	V.M. Glushkov Institute of Cybernetics, NASU	www.icyb.kiev.ua
	International Research and Training Center for Information Technologies and Systems under NASU and Ministry of Education and Science of Ukraine	www.irtc.org.ua
	Institute for Information Recording, NASU	www.ipri.kiev.ua
	Space Research Institute under NASU and State Space Agency of Ukraine	www.ikd.kiev.ua

	Lviv Center of the Institute of Space Research under NASU and State Space Agency of Ukraine	www.isr.lviv.ua
	Institute of Macromolecular Chemistry, NASU	www.macromol.kiev.ua
Other		
	Ukrainian research institute of Aviation Technology (UKRRIAT)	www.ukrniat.com
	Ukrainian State Designing Technological and Scientific Research Institute of Civil Aviation “Ukraeroproekt”	www.ukraeroproject.com
Universities		
	National Aerospace University “KhAI” (KhAI)	www.khai.edu
	National Aviation University	www.nau.edu.ua
	National Technical University of Ukraine "Igor Sikosky Kyiv Polytechnic Institute"	www.kpi.ua
	Zaporizhzhya National Technical University	www.zntu.edu.ua
	Ivan Kozhedub Kharkiv University of Air Force	www.hups.mil.gov.ua
	National Technical University “Kharkiv Polytechnic Institute”	www.kpi.kharkov.ua
Research Support Intermediaries		
	H2020 NCP system	www.h2020.com.ua
	Smart, Green and Integrated Transport H2020 NCP	https://ncp.khai.edu

Annex 3. Aircraft produced by SE Antonov
(Image courtesy of SE Antonov)



Annex 4. Aero-engines produced by SE Ivchenko-Progress (Image courtesy of SE Ivchenko-Progress)

Annex 5. Targeted Questionnaire in the frame of AERO-UA project

Targeted Questionnaire in the frame of AERO-UA project

Barriers to aeronautic research collaboration between EU and Ukraine partners

The Partners of AERO-UA project, funded by the European Commission under Horizon 2020 Programme, reaching out representatives of aeronautics-related research and industrial organisations of Ukraine to respond to this online survey.

This online survey allows to express your opinion regarding barriers to aeronautic research collaboration with EU partners and also to recommend any activities to remedy the current situation and to make such collaboration more accessible and efficient.

Summarised survey results will be brought up for expert discussion with the representatives of research and industrial community, governmental bodies, as well as other stakeholders. Recommendations developed by the experts will be further communicated to the relevant national authorities of Ukraine and EU in order to stimulate collaboration and establish targeted cooperation in the field of aeronautics.

The process of completing this online survey is estimated to 30 minutes.

All the AERO-EU Consortium Partners would like to thank all respondents for your time and consideration for completing accurately this online survey.

Section 1:	Personal Profile	
1.1	First Name, Last Name	
1.2	Contact Email Address	
1.3	Education / Research degree	☐ MSc ☐ Candidate of Science (PhD) ☐ Doctor of Science ☐ Other (please, specify)
1.4	Organisation name	
1.5	Department or Laboratory Name	
1.6	Position	
1.7	Length of employment	☐ Under 1 year ☐ 1-5 years ☐ 6-10 years ☐ 11-25 years ☐ 25+ years
1.8	Are you responding	☐ On behalf of organisation as a whole ☐ On behalf of specific department/unit of organisation

Section 2: Organisation Profile

2.1	Organisation Type	☐ Higher education establishment ☐ Research Institute ☐ Design Bureau ☐ Industry ☐ SME ☐ Other (please, specify)					
2.2	Organisation Address						
2.3	Organisation Website Address						
2.4	Number of employees	☐ 1 to 10 ☐ 101 to 500		☐ 11 to 50 ☐ 501 to 1,000		☐ 51 to 100 ☐ over 1,000	
2.5	Organisation activities (multiple choice)	☐ Aircraft Design ☐ Aircraft Production ☐ Aircraft Maintenance, Repair and Overhaul (MRO) ☐ Aircraft Operation ☐ Aeronautics-related R&D ☐ Aeronautics-related Education ☐ Other (please, specify)					

Section 3: Awareness, Experience and Expectations regarding European Aviation ResearchCollaboration

3.1 Please, indicate your level of awareness of possible ways of European aviation research collaboration, relevant experience and interest to participate in such collaboration.

		AWARE or this opportunity	HAVE PARTICIPATED	INTERESTED to participate
	Publicly funded collaborative R&D projects of the European Framework Programmes (FP6, FP7, Horizon 2020, Clean Sky JU, CESAR JU)			
	Privately funded collaborative R&D projects			
	Collaborative R&D projects funded by the national funds of EU countries			
	Collaborative educational projects funded by the EC (e.g. Tempus, Erasmus)			
	Collaborative educational projects funded by the national funds of EU countries			
	European scholarships and research exchange programmes			
	Other (please, specify)			

3.2	Please, indicate your level of awareness of European Framework Programmes (FP6, FP7, Horizon 2020) (multiple choice)	☐ I am not aware of any European Framework Programmes ☐ I have heard of EU Framework Programmes, but not in details. ☐ I have attempted to be part of consortium without success. ☐ I participated in proposal preparation and submission, but project was not funded. ☐ I am participating/have participated in funded project.
3.3	Please, indicate your level of awareness of European privately	☐ I am not aware of any European privately funded research projects ☐ I have heard of such possibilities, but not in details. ☐ I have attempted to receive private funding without success.

	funded research projects	☐ I am participating/have participated in a privately funded research project (please specify).
3.4	Are you aware about NCP (National Contact Point) network in Ukraine, its activities and services?	☐ YES, I am aware about NCP(s) and use their services ☐ YES, I am aware about NCP(s) but have never used their services ☐ NO, I am not aware
3.5	What are your expectations regarding European aviation research collaboration? (up to 3 options)	☐ Improve research excellence in my unit/organisation ☐ Improve international visibility ☐ Strengthen cooperation with academia and research ☐ Strengthen cooperation with private sector and industry ☐ Strengthen interdisciplinary cooperation ☐ Drive fundamental research to applied innovation ☐ Funding of projects that could not be (sufficiently) funded by national programmes ☐ Other (please, specify)

Section 4: Barriers to EU-UA aviation research collaboration

4.1 Lack of motivation to collaborate with European partners

4.1.1 To what extent the following factors affect your motivation to collaborate in aviation research at European level?

	Not at all	To some extent	To large extent	Fully	I do not know
High competition with European organisations					
Difficulties to find partners					
High cost, time or workload at preparation stage					
Low success rate in competitive programmes (e.g. EU FPs)					
Competitive programmes complexity and bureaucracy					
Concerns about sharing valuable knowledge (IP) with partners					
Lack of innovative ideas					
Absence of personal benefit					

4.1.2	Are there any other factors that affect your motivation to collaborate in aviation research at European level?	Open non-compulsory question

4.2 Lack of awareness of European collaboration

4.2.1 Please, indicate a level of your awareness on the following aspects

	Very poor	Poor	Good	Very good	I do not know
European/global state-of-the-art in your specific research area/topic					
Opportunities available for European aviation research collaboration					
How to find partners					
Rules of participation in specific competitive programmes (such as H2020)					
Rules/peculiarities of preparation of proposals for competitive programmes or bids/contract offers for private funding					
Legal and/or financial aspects of implementation of international projects/contracts in Ukraine					
How to protect my knowledge and IP					

4.2.2

Is there any other knowledge which you are missing and which prevents you from collaboration in aviation research at European level?	Open non-compulsory question

4.3 Lack of human resources or talent

4.3.1	Please, assess research potential of your unit/organisation at European	☐ High (we have all necessary high-qualified specialists to perform advanced research) ☐ Medium (we have a number of high-qualified specialists, but

	level?	*some competencies are lacking*) ☐ Low (*qualification of our specialists is too low to perform advanced research)* ☐ I can't assess
4.3.2	Please, assess an average age of your unit/organisation?	☐ up to 35 ☐ 35-50 ☐ 50-65 ☐ 65+
4.3.3	Does your unit/organisation have time to look for collaboration opportunities and to perform work in the frame of European projects, grants, contracts?	☐ YES ☐ NO, all our staff is fully loaded
4.3.4	Do you need extra people to do some research?	☐ YES (*please, specify the reason(s)*) ☐ To enlarge team to cover research load ☐ To involve young talented researchers to the team ☐ To cover new competences and expertises ☐ Other, please specify ☐ NO
4.4 Lack of facilities, computer hardware and software		
4.4.1	Please, assess the state of your unit/organisation facilities	☐ Our facility and equipment are at state of the art level, can be used to perform advanced research ☐ Our facility and most of our equipment are modern/upgraded, in general the state of facilities allows performing advanced research ☐ All or significant part of our facility and equipment are obsolete and cannot be used to perform advanced research
4.4.2	Do you need other/extra/new facilities?	☐ YES - > (*please, specify the reason(s) - multichoice*) ☐ To replace obsolete facilities

		☐ To do new research or to provide new services ☐ Other –> *please, specify* ☐ NO
4.4.3	Do you have access to external facilities?	☐ YES - > (*please, specify the mechanism(s) – open, non- compulsory question*) ☐ NO
4.4.4	Does your unit/organisation is fully equipped with modern computer facilities?	☐ YES ☐ NO
4.4.5	Do you have required licensed software to perform advanced research?	☐ YES ☐ I do not require specific software to perform my research ☐ NO - > (*please, specify the reason(s) and list the software(s) you are missing or need upgrade – open non-compulsory question)*
4.5 International travel limitations		
4.5.1	Do the members of your unit/organisation travel abroad for research collaboration purposes?	☐ YES -> *please, specify the purposes* ☐ To attend conferences/exhibitions ☐ To participate in networking or brokerage events, meet potential partners ☐ To participate in project meetings ☐ Other - > *please, specify* ☐ NO
4.5.2	How often the members of your unit /organisation travel abroad for research collaboration?	☐ More often than once per 3 months ☐ Once per 3 months ☐ Once per 6 months ☐ Once per year ☐ Less often than once per year
4.5.3	What are the main reasons preventing the members of your unit /organisation from travelling	☐ Absence of a valid passport to travel abroad ☐ Lack of funding ☐ Any visa problems

	abroad for research collaboration? (*multiple choice*)	☐ Language problems ☐ Security reasons ☐ Any other issues -> please, specify
4.6 Lack of funding		
4.6.1	Does your unit/organisation have enough funding to perform advanced research?	☐ YES ☐ NO
4.6.2	What are predominant sources of R&D funding for your unit/organisation?	☐ Self-funding ☐ National public funding ☐ National private funding ☐ International public funding ☐ International private funding ☐ Other - > please, specify
4.6.3	Which are the most important types of expenditures for your team? (up to 3 options)	☐ To hire new high qualified staff ☐ To purchase or upgrade hardware and software ☐ To acquire new equipment/facilities or renovate existing ones ☐ To travel abroad ☐ To publish research results ☐ To protect IP ☐ Other - > please, specify
4.7 Inadequacy of research culture		
4.7.1	Have the members of your research unit/organisation published papers in international peer-reviewed journals, in the last 3 years:	☐ YES - > (*please, specify how many*) ☐ NO - > (*please, specify the reason(s) – open non-compulsory question)* ☐ No need in publishing ☐ Lack of opportunities and/or funding to translate articles in English ☐ Lack of funding to pay for publication ☐ We submitted few papers but they were not accepted

		☐ Other (*please, specify*)
4.7.2	Have the members of your unit/organisation participated in international conferences abroad, in the last 3 years:	☐ YES, as speaker ☐ YES, as attendee ☐ NO - > (*please, specify the reason(s) – open non-compulsory question)*
4.7.3	Are members of your unit/organisation affiliated to any Engineering Societies?	☐ YES - > (*please, specify Engineering Societies – open non- compulsory question)* ☐ NO - > (*please, specify the reason(s))* ☐ not aware of any? ☐ none meeting your interest? ☐ is it cost? ☐ is it because you are not allowed to join? ☐ other reason? ☐ Not applicable
4.7.4	Does the affiliation to these Engineering Societies give you access to collaborative research projects?	☐ YES *(please, specify)* ☐ NO
4.7.5	Does your organisation have website in English?	☐ YES ☐ My organisation has website only in Ukrainian/Russian ☐ My organisation does not have a website ☐ Other - > please, specify
4.7.6	Does your organisation have LinkedIn profile in English?	☐ YES ☐ My organisation has LinkedIn profile only in Ukrainian/Russian ☐ My organisation does not have a LinkedIn profile ☐ Other - > please, specify
4.7.7	Does anyone in your team is **fluent** in **professional** English?	☐ YES ☐ NO
4.7.8	Does your organisation have a	☐ YES

	long-term Research Strategy?	☐ NO ☐ I do not know
4.7.9	Are the research priorities managed in your organisation by the administration or some internal committee/body?	☐ YES ☐ NO ☐ I do not know
4.7.10	Are your research topics in line with EU priorities?	☐ YES ☐ NO ☐ I do not know

4.8 Legal and financial barriers

4.8.1 Towhat extent the following legal and/or financial barriers have ever affected or may affect your participation in European Aviation ResearchCollaboration?

		Not at all	To some extent	To large extent	Fully	I do not know
	Procedures of collaborative or bilateral projects/contracts approval by State service of export control of Ukraine					
	Inconsistency between Ukrainian and European financial accounting practices					
	Specific Ukrainian financial regulations (e.g. currency exchange regulation, salary/reimbursement rates, impossibility for government-owned institutions to command own financial resources, etc.)					
	Lack of resources to co-fund projects/grants by the organisation					
4.8.2	Are there any other legal and/or	Open non-compulsory question				

	financial barriers that have ever affected or may affect your participation in European Aviation Research Collaboration?					
4.9 Specific barriers regarding EU Framework Programmes						
4.9.1 To what extent the following aspects prevent you from participation in European Framework Programmes?						
		Not at all	To some extent	To large extent	Fully	I do not know
	Frequency of calls for proposals (once per year)					
	Clarity of the calls for proposals description					
	Ease of finding the right call for my proposal					
	Ease of finding partners for my proposal					
	Complexity of competitive proposal preparation					
	Quality of the feedback from evaluators					
	Communication activities on Horizon 2020 in my country					
4.9.2	Are there any other barriers that prevent you from participating to European Framework Programmes?	Open non-compulsory question				
4.10 Specific barriers regarding EU Privately Funded Research Collaboration						
4.10.1 To what extent the following aspects prevent you from participation in European Privately Funded Research Collaboration?						

		Not at all	To some extent	To large extent	Fully	I do not know
	Complexity in finding private funding sources					
	Competition with other interested European organisations					
	Necessity to demonstrate previous experience and background					
	Lack of adequate programmes and types of financial support					

4.10.2	Are there any other barriers that prevent you from participating to European Privately Funded Research Collaboration?	Open non-compulsory question
4.11 OTHER		
4.11.1	Are there any other barriers in European aviation research collaboration, which are not covered by the questions above?	*Open, non-compulsory questions*

Section 5: Measures to improve EU-UA research collaboration

5.1 Recommendations

5.1.1 Could you propose any measures that can help to overcome one or several of the following barriers?

□ Lack of motivation to collaborate with European partners	*Describe measure(s) you propose*
□ Lack of awareness of European collaboration	*Describe measure(s) you propose*
□ Lack of human resources or talent	*Describe measure(s) you propose*
□ Lack of facilities, computer hardware and software	*Describe measure(s) you propose*
□ International travel limitations	*Describe measure(s) you propose*
□ Lack of funding	*Describe measure(s) you propose*
□ Inadequacy of research culture	*Describe measure(s) you propose*
□ Legal and financial barriers	*Describe measure(s) you propose*
□ Specific barriers regarding EU Framework Programmes	*Describe measure(s) you propose*
□ Specific barriers regarding EU Privately Funded Research Collaboration	*Describe measure(s) you propose*
□ I cannot propose any recommendation	

5.1.2	Could you propose any additional measures that can help to overcome other barriers to EU-UA aviation research collaboration?	*Open, non-compulsory question*

Section 6: Your suggestions and proposals to AERO-UA consortium partners

Open, non-compulsory question

All theAERO-EU Consortium Partners would like to thank you for your time and consideration for completing accurately this online survey.

We are convinced that valuable information that you provided could help to draw relevant conclusions regarding existing barriers to EU-UA aviation research collaboration, as well as to develop efficient measures to overcome these barriers.

Please visit regularly AERO-EU Consortium webpage (www.aero-ua.eu) for project updates and public results.