Selected Information on European Union Research and Development Programmes and Projects focused on Reducing Emissions from Air Transport

Odabrane informacije o istraživačkim i razvojnim programima i projektima Europske Unije koji su usredotočeni na smanjivanje emisija zračnog prometa

Ivan Koblen
ALES a.s., Trenčín, Branch Office in Bratislava: Regus Business Centre
Bratislava, Slovakia
e-mail: koblen@ales.sk

Stanislav Szabo
Technical University of Košice
Faculty of Aeronautics
Slovakia
e-mail: stanislav.szabo@tuke.sk

Katarína Krnáčová
Technical University of Košice
Faculty of Aeronautics
Slovakia
e-mail: krnacovakat@gmail.com

UDK 504.3:656.7
Stručni članak / *Professional paper*
Rukopis primljen / *Paper accepted*: 12. 11. 2013.

Summary

The paper in the introductory part informs on the structure of jet engines emissions and introduce some facts regarding the timing progressive development in the area of aviation emissions reducing. The second part of the paper is focusing on introducing selected information concerning strategies and goals of the international aviation organizations (especially ACARE and IATA) as well as the European Commission in reducing emissions from air transport issue, including principle information on EU Emissions Trading System and its relationship toward aviation emissions inclusion and ambitious goals specified in document Flightpath 2050 regarding environmental impact of aviation. Authors shortly present the EU Framework programmes for research and technological development, including the newest Horizon 2020 research and innovation programme, whereby are focusing on the selected aviation research projects under the 7th FP as are REACT4C, DREAM and ALFA-BIRD projects. The part of paper is dealing with Clean Sky Joint Technology Initiative and introduction of six Integrated Technology Demonstrators – projects objectives and developed technologies to significantly increase the environmental performances of aircraft and air transport. In this regard authors pay also considerable attention to description of Clean Sky 2 programme mainly from its scope and key elements point of views. The last part of the paper is focused on the selected issue concerning the SESAR programme underlining the key environmental achievements

KEY WORDS

air transport
aviation
reducing emissions
research and development
european union
programmes
projects

Sažetak

Članak u uvodnom dijelu informira o strukturi emisija zračnog prometa i uvodi neke čimbenike koji se tiču progresivnog razvoja u području smanjenja emisija avijacije. Drugi dio članka usredotočuje se na uvođenje odabranih informacija koje se tiču strategija i ciljeva međunarodnih avijacijskih organizacija (posebno ACARE i IATA), kao i Europske Komisije o smanjenju emisija avionskog transporta, uključujući i princip informacija o EU ustavu emisija i njegovu odnosu prema emisijama avijacije i ambicioznim ciljevima određenim u dokumentu Flightpath 2050, a koji se tiče ekološkog utjecaja avijacije. Autori ukratko predstavljaju EU Okvirne programme za istraživanje i tehnološki razvoj, uključujući i najnoviji Horizon 2020 istraživački i inovacijski program, kojim se usredotočuju na odabrane istraživačke projekte iz avijacije prema Sedmom okvirnom programu i REACT4C i Dream i ALFABIRD projekte. Dio članka bavi se Inicijativom zajedničke tehnologije za čisto nebo i uvođenjem šest integriranih tehnoloških demonstratora – ciljeva projekta i razvijenih tehnologija kojim bi znatno povećali ekološke izvedbe letjelica i zračnog prijevoza. U vezi s ovim, autori posvećuju znatnu pažnju opisu programa Čisto nebo, većinom zbog njegova cilja i ključnih elemenata točke gledišta. Zadni dio članka usredotočuje se na odabrana pitanja koja se tiču SESAR programa podcrtavajući ključna ekološka postignuća.

KLJUČNE RIJEČI

zračni promet
avijacija
smanjenje emisija
istraživanje I razvoj
Europska Unija
programi
projekti

INTRODUCTION / *Uvod*

Air transport plays a key role in the economic prosperity and lifestyle. Economy benefits of air transport depends especially on ability to quickly and safely to transfer people and products. Aviation contributes to our quality of life - allowing us to visit friends and relatives, to travel, to experience new places, to shrink the borders of the world.

However, air transport also has environmental impacts, i.e. contributes to environmental pollution – primarily noise and atmospheric emissions. The role of aviation within sustainable economic and environmental policy development, impact of the emissions from air transport not just for the aviation industry, but on the economic, social and environmental wellbeing of the European Union and its Members states as a whole is currently the subject of intensive research activities and debates. Due to these facts it is also a subject of intensive research and development activities under the joint research programmes and projects in the framework of EU.

Aircraft jet engines emissions / *Emisije strojeva lebdjelica*

Aircraft jet engines, like many other vehicle engines, produce carbon dioxide (**CO_2**), water vapor (**H_2O**), nitrogen oxides (**NO_x**), carbon monoxide (**CO**), oxides of sulphur (**SO_x**), unburned or partially combusted hydrocarbons (also known as volatile organic compounds (**VOCs**)), particulates, and other trace compounds. A small subset of the VOCs and particulates are considered hazardous air pollutant (**HAPs**). Aircraft jet engine emissions are roughly composed of about 70% CO_2, a little less than 30% H_2O, and less than 1% each of NO_x, CO, SO_x, VOC, particulates, and other trace components including HAPs. Aircraft emissions, depending on whether they occur near the ground or at altitude, are primarily considered local air quality pollutants or greenhouse gases, respectively. Water in the aircraft exhaust at altitude may have a greenhouse effect, and occasionally this water produces contrails, which also may have a greenhouse effect.

About 10% of aircraft emissions of all types, except hydrocarbons and CO, are produced during airport ground level operations and during landing and take-off. The bulk of aircraft emissions (90 %) occur at higher altitudes. For hydrocarbons and CO, the split is closer to 30% ground level emissions and 70% at higher altitudes.

Jet engines emissions are products of their combustion process:

- CO_2 – Carbon dioxide is the product of complete combustion of hydrocarbon fuels like jet fuel. Carbon in fuel combines with oxygen in the air to produce CO_2 .
- H_2O – Water vapor is the other product of complete combustion as hydrogen in the fuel combines with oxygen in the air to produce H_2O.
- NO_x – Nitrogen oxides are produced when air passes through high temperature/high pressure combustion and nitrogen and oxygen present in the air combine to form NO_x.
- HC – Hydrocarbons are emitted due to incomplete fuel combustion. They are also referred to as volatile organic compounds (VOCs). Many VOCs are also hazardous air pollutants.
- CO – Carbon monoxide is formed due to the incomplete combustion of the carbon in the fuel.
- SO_x – Sulfur oxides are produced when small quantities of sulfur, present in essentially all hydrocarbon fuels, combine with oxygen from the air during combustion.
- Particulates – Small particles that form as a result of incomplete combustion, and are small enough to be inhaled, are referred to as particulates. Particulates can be solid or liquid.

The special category is Ozone – O_3. It is not emitted directly into the air but is formed by the reaction of VOCs and NO_x in the presence of heat and sunlight. Ozone forms readily in the atmosphere and is the primary constituent of smog. For this reason it is an important consideration in the environmental impact of aviation.

Globally, air transport contributes to the greenhouse effect and at a regional level aviation contributes to acidification, eutrophication and to the formation of tropospheric ozone by emissions of air pollutants.

Environmental responsibility is one of the most important areas for the aviation industry. Well before the Kyoto Protocol the aviation industry was working hard to reduce its emissions.

The fuel consumption of jet aircraft has been a major design consideration and between the Comet 4 of 1958 and the Airbus A380 of 2003 engine fuel consumption had been reduced by over 40% and when translated into a fuel burn per seat this had dropped by over 70%.[1] According to the International Aerospace Industries Association (ICCAIA) technical developments since the 1960s mean today´s new aircraft emit 50% less carbon monoxide and 90% less smoke and unburned hydrocarbons than they did 50 years ago. NO_x levels have also been cut, and modern aircraft now emit 40% less NO_x than in 1981. As a result of these efficiency increases, aircraft can often have a smaller impact on local air quality around airports than road traffic. The International Civil Aviation Organization (ICAO) sets standards for NO_x emissions and regularly tightens these for each new generation of aircraft. However, there is still work to be done and the aviation industry has a number of projects underway to futher reducing of air emissions. [2]

The European Union has a significant opportunity to create conditions for reducing the negative impact of human activities on the environment and it plays a very important role in the area of air emission reducing. One of its tools is the research and development. The EU has chosen aeronautics as one of its research and development priorities with the aim of minimising the environmental impact of aircraft. The EU realizes in this domain several development programmes and projects. The aim of these programmes/projects is to deliver the real results and tools for reducing the negative environmental impact of the air transport development. Since the pilot phase in 1990-1991 under the Second Framework Programme, more than 350 research projects have been funded at a total cost of 4 billion euros. About 30% of this research work has taken the form of activities aiming at reducing the environmental impact of aircraft, in particular CO_2 and NO_x. In addition, research into better understanding the climate impact of aviation has been investigated through the “Global Change and Ecosystem Programme” of the Sixth Framework Programme. A stronger orientation towards “greening” air transport and a greater focus on its impact on climate change was a priority in the terminate Seventh EU Framework Programme.

INTERNATIONAL AVIATION ORGANIZATIONS AND EU STRATEGIES AND GOALS IN THE REDUCING EMISSIONS FROM AIR TRANSPORT ISSUE / *Međunarodne avijacijake organizacije i EU strategije i ciljevi u smanjenju emisija od zračnog prometa*

ACARE

Looking to the medium and long term, aero engine manufacturers are very conscious of the need to improve fuel efficiency and reduce emissions. They are all putting forward new designs, some of which are more radical than others. The need for reduced emissions led to the Advisory Council for Aerospace Research in Europe (**ACARE**) setting targets for new aircraft technology by 2020, compared to a benchmark of large civil aircraft from 2000:

- reducing CO_2 emissions by 50 per cent per passenger kilometre.
- reducing NOx emissions by 80 per cent.
- reducing perceived aircraft noise by 50 per cent.
- The aircraft and engine manufacturers have all committed themselves to these targets
- and are looking at new solutions to achieve them.

IATA

In June 2007 the International Air Transport Association (IATA) laid out its environmental vision to mitigate greenhouse gas emissions from aviation:

- Build a zero-emissions commercial aircraft within 50 years
- Adopt a four-pillar strategy to achieve this vision:

1. Improved technology
2. Effective operations
3. Efficient infrastructure
4. Positive economic measures.

The four-pillar strategy was adopted by the global aviation industry, as well as ICAO states, in 2007. In June 2009, IATA airlines took a landmark decision to adopt a set of ambitious targets: [3]

- A cap on aviation CO_2 emissions from 2020 (carbon-neutral growth),
- An average improvement in fuel efficiency of 1.5% per year from 2009 to 2020,
- A reduction in CO_2 emissions of 50% by 2050, relative to 2005 levels.

These collective goals were endorsed by the aviation industry in the joint industry submission to ICAO in September 2009.

The European Commission / *Europska komisija*

Strategy for reducing the climate change impact of aviation / *Strategija za smanjenje utjecaja avijacije na klimatske promjene*

The Commission adopted a Communication in September 2005 setting a strategy for reducing the Climate change impact of aviation. The Communication (accompanied by an impact assessment) concluded that a comprehensive approach was necessary. Most elements of this were already in train but needed to be strengthened, They include:

- giving research into „greener" technology highest priority in the 7th Framework Programme for Research and Technical Development,
- improving the efficiency of European Air Traffic Management (**ATM**) through Single European Sky ATM Research (**SESAR**) initiative
- removing legal obstacles to the taxation of aviation fuel to facilitate more consistent transport energy taxation policy
- working in ICAO on developing more stringent technical design standards to reduce aircraft emissions at source

EU ETS

Since the beginning of 2012, emissions from international aviation are included in the EU Emissions Trading system (EU ETS). Like industrial installations covered by the EU ETS, airlines receive tradeable allowances covering a certain level of CO_2 emissions from their flights per year. The legislation, adopted in 2008, applies to EU and non-EU airlines alike. Emissions from flights to and from Iceland, Liechtenstein and Norway are also covered. The EU's legislation on aviation emissions is compatible with international law. This was confirmed by the European Court of Justice on 21 December 2011 in a legal case brought by some US airlines and their trade association against the inclusion of aviation in the EU ETS.

In October 2013 the EU's hard work paid off when the ICAO Assembly agreed to develop by 2016 a global market-based mechanism (MBM) addressing international aviation emissions and apply it by 2020. Until then countries or groups of countries, such as the EU, can implement interim measures. In response to the ICAO outcome and to give further momentum to the global discussions, the European Commission has proposed amending the EU ETS so that only the part of a flight that takes place in European regional airspace is covered by the EU ETS. The change would apply from the beginning of 2014 until the planned global MBM enters into force.

Flightpath 2050

The document/report „Flightpath 2050" is a principle Europe's Vision for Aviation elaborated by the High Level Group on Aviation Research and approved by both EC Directorate-General for Research and Innovation and Directorate-General for Mobility and Transport.

The chapter „Protecting the environment and the energy supply" contents the fundamental visions and goals towards the environmental impact of aviation. Document notes that „ in 2050, the effect of aviation on the atmosphere is fully understood. A combination of measures, including technology development, operational procedures and market-based incentives mean that its environmental impacts have been mitigated at a rate outweighing the effects of increasing traffic levels. The public is informed, understands and is convinced that the aviation sector has made the utmost progress in mitigating environmental impacts and therefore considers that air travel is environmentally sustainable. Substantial developments in vehicle and engine have combined and built upon each other to yield a truly new generation of European air vehicles and equipment with significantly improved and continuously improving fuel and noise efficiency. In parallel the air traffic control system is optimised to provide the best trajectories for fuel and time efficiency and associated atmospheric emissions and also to address noise. Noise projection on the ground is also reduced. Revenues from the Emissions Trading Scheme (ETS) have been used to supplement funding for research, technologies, products and fuel innovations providing Europe with a sustainable aviation.

The Flightpath 2050 defines the following ambitious goals in this area: [4]

1. In 2050 technologies and procedures available allow a 75% reduction in CO_2 emissions per passenger kilometre to support the ATAG Target (i. e. Carbon-neutral growth starting 2020 and a 50% overall CO_2 emission reduction by 2050) and a 90% reduction in NOx emissions. The perceived noise emission of flying aircraft is reduced by 65%. These are relative to the capabilities of typical new aircraft in 2000.

2. Aircraft movements are emission-free when taxiing.
3. Air vehicles are designed and manufactured to be recyclable.
4. Europe is established as a centre of excellence on sustainable alternative fuels, including those for aviation, based on a strong European energy policy.
5. Europe is at the forefront of atmospheric research and takes the lead in the formulation of a prioritised environmental action plan and establishment of global environmental standards.

THE EU FRAMEWORK PROGRAMMES FOR RESEARCH AND TECHNOLOGICAL DEVELOPMENT / *EU okvirni programi za istraživanje i tehnološki razvoj*

Framework Programmes for Research and Technological Development are the main European Union instrument for coordination of the research and development activities. These multi-annual programmes were established in 1984. Primary strategic objective of these Framework programmes is to strengthen scientific and technological base of European industry and to encourage international competition in the mutual facilitation of research that supports EU policies.

7th Framework Programme for Research and Technological Development / *Sedmi okvirni program za istraživanje i tehnološki razvoj*

The last programme - by end of 2013 the terminate programme - is the 7th Framework Programme for Research and Technological Development (FP7), which has been implemented for seven years period from 2007 until 2013. The programme has a total budget of over € 50 billion. This represents a substantial increase compared with the previous Framework Programme FP6 (41% at 2004 prices, 63% at current prices), a reflection of the high priority of research in Europe [5].

This money have been spent (for the most part) on grants to research actors all over Europe and beyond, in order to co-finance research, technological development and demonstration projects. Grants are determined on the basis of calls for proposals and a peer review process, which are highly competitive. Participation in the FP7 is open to a wide range of organizations and individuals, with individual conditions of funding vary for different groups of countries (member states, partner countries, third countries).

The Specific Programmes constitute the four major building blocks of FP7: [5]

- Cooperation
- Ideas
- People
- Capacities

Research in the field of transport is included in the Cooperation programme, and it is allocated more than 4 billion Euros. Transport is one of Europe's strengths - namely air transport contributes to the EU GDP share of 2.6% with 3.1 million jobs, but also to transport accounts for 25% of all CO2 emissions in the EU [6].

The amount of 960 million Euros was allocated from the budget for research in transport for Collaborative Research focused on reducing the environmental impact of aviation, as well as on the efficiency, competitiveness and safety of the air transport system. Another €800 million is dedicated to the Joint Technology Initiative Clean Sky, also focusing on environmental aspects. Note that from this same Transport budget, another €350 million has been contributed towards financing the SESAR Joint Undertaking [7].

Figure 1 shows a comparison of the amounts set aside for research in the field of aviation during the last Framework Programmes. Bold figures represent average amounts attributable to research in the field of aviation for one year and the figures in brackets the total amount allocated in individual FP. Increasing amounts of value indicates awareness of the need for research to reduce emissions.

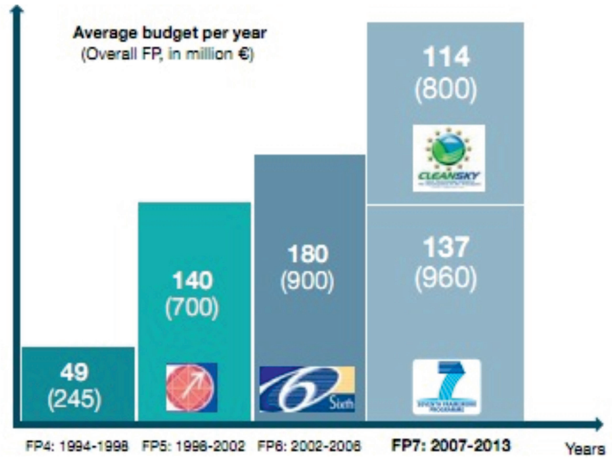

Figure 1 The budget for the aviation in Framework Programmes [5]
Slika 1. Budžet za avijaciju prema Okvirnom programu

The Selected aviation projects under the 7th Framework Programme / *Odabrani avijacijski projekti po Sedmom okvirnom programu*

REACT4C - Reducing Emissions from Aviation by Changing Trajectories for the Benefit of Climate

The main objectives of REACT4C are:

- to explore the feasibility of adopting flight altitudes and flight routes that lead to reduced fuel consumption and emissions, and lessen the environmental impact
- to estimate the overall global effect of such ATM measures in terms of climate change

The objectives are achieving mainly by a numerical approach, which combines atmospheric models of different complexity, ATM tools of planning flight trajectories, including models to calculate aircraft emissions, and tools for aircraft pre-design [7].

DREAM - valiDation of Radical Engine Architecture systems

- The main result of the project will be:
- The initial development of new open rotor Technologies.
- Novel concepts (vibration damping, structures and active control).
- The demonstration of the operation of alternative fuels.
- Demonstrate the potential of open rotor to greatly reduce CO2 emissions and still achieve acceptable levels of community noise [7].

The Figure 2 shows the new technology of Open rotor developed by project DREAM.

Figure 2 Open rotor [7]
Slika 2. Otvoreni rotor [7]

ALFA-BIRD - Alternative Fuels and Biofuels for Aircraft Development

The main challenge in the project work is developing fuels that meet the very strict operational constrains in aviation (e.g. flight in very cold conditions), and are compatible with current civil aircraft, which is a must due to their long lifetime of almost 50 years.

Project develops the whole chain for clean alternative fuels for aviation. The most promising solutions will be examined during the project, from classical ones (plant oils, synthetic fuels) to the most innovative, such as new organic molecules. Based on a first selection of the most relevant alternative fuels, a detailed analysis of 4 new fuels is performed with tests in realistic conditions. The 4 fuels selected are FSJF, FT-SPK, a blend of FT-SPK and 50% naphthenic cut, and a blend of FT-SPK and 20% hexanol [8].

Horizon 2020

Horizon 2020 is the key tool and financial instrument implementing the Innovation Union (conclusions of the 4 February 2011 European Council and to the European Parliament's Resolution of 12 May 2011 on the Innovation Union) a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness. Running from 2014 to 2020 with a budget of just over €70 billion, the EU's new programme for research and innovation is part of the drive to create new growth and jobs in Europe and to deliver the new ideas for the future.

Horizon 2020 combines all research and innovation funding currently provided through the Framework Programme for Research and technical Development, the innovation related activities of the Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation and Technology (EIT).

Horizon 2020 will focus resources on three distinct, yet mutually reinforcing, priorities, where there is clear Union added value. These priorities correspond to those of Europe 2020 and the Innovation Union: [9].

- **Excellent Science**,
  This will (among other things):
  - support the most talented and creative individuals and their teams to carry out frontier research of the highest quality by building on the success of the *European Research Council*;
  - fund collaborative research to open up new and promising fields of research and innovation through support for *Future and Emerging Technologies* (FET);

- **Industrial Leadership,**
  This will (among other things):
  - build *leadership in enabling and industrial technologies*, with dedicated support for ICT, nanotechnologies, advanced materials, advanced manufacturing and processing
  - provide Union wide support for *innovation in SMEs*.

- **Societal Challenges.**
  - Among these challenges it notes as one key *Societal Challenge*: *smart, green and integrated transport*.

The European Aeronautics sector, as provider of almost half of the worldwide fleet, is of sovereign importance to the European Union and its Member States. It helps to meet economical and society's needs by:

- Ensuring competitive mobility solutions for passengers, freight and public services;
- Minimising aviation's impact on the environment through key innovations in products and services;
- Providing highly skilled jobs, generating significant economic growth and creating wealth;
- Significantly contributing to the balance of trade and European competitiveness;
- Supporting Europe's knowledge economy through substantial R&D efforts and deep supply chains.

Continued long-term public-private investment has made the European Aeronautics industry globally competitive, allowing it to drive the innovation agenda in many areas, including environmental performance. But the new challenges highlight the need for more accelerated innovation and for more far-reaching solutions.

The aeronautical sector is a critical player in reaching the goals set out in Horizon 2020, and through research and innovation programmes, projects and activities solved under the Horizon 2020 mechanisms can deliver key outcomes spanning two of the key pillars defined in Horizon 2020 - *Societal Challenges* and *Industrial Leadership*:

- *Creating resource efficient transport that respects the environment***.** Aeronautical research and innovation in Horizon 2020 must *finish the job* of achieving the ACARE SRA goals as set for 2020;
- *Ensuring safe and seamless mobility***.** New concepts will allow the air transport system meet the mobility needs of citizens: more efficient use of local airports, faster connections and reduced congestion;
- *Building industrial leadership in Europe*. Aeronautical research and innovation projects will help protect and develop highly skilled jobs in Europe.

THE CLEAN SKY JTI / *Čisto nebo JTI*

Clean Sky is the most ambitious aeronautical research programme ever launched in Europe. Its mission is to develop breakthrough technologies to significantly increase the environmental performances of airplanes and air transport, resulting in less noisy and more fuel efficient aircraft, hence bringing a key contribution in achieving the Single European

Sky environmental objectives.

The Clean Sky JTI (Joint Technology Initiative) started in 2008 and represents a unique Public-Private Partnership between the European Commission and the industry. It is managed by the Clean Sky Joint Undertaking (CSJU) until 31 December 2017 [10].

With EC funding of €800 million and an equal contribution from European aeronatical industry (mostly in kind), €1 600 million has been invested in RTD work during 2008 – 2013 [10].

The objective of this unique public-private partnership is to speed up technological breakthrough developments and shorten the time to market for new solutions tested on Full Scale Demonstrators. It targets very significant environmental gains: 30% reduction in CO2, at least 6 dB less perceived noise per operation and 60% less NOx emissions versus a 2000 reference. *Clean Sky* aims to mature and integrate technologies into system level architectures, such as (full) engines, electrical systems, structures and innovative wings, and validate these through large-scale demonstration.

Speeding up new, *greener design* as part of Clean Sky is essential to protect our environment. It should be kept in mind that aircraft have a 30-year service life, and that new aviation design takes more than a decade to develop. The accelerated research process that Clean Sky offers represents an unprecedented opportunity for rapid progress in the introduction of green technology into aviation.

Clean Sky is structured into six Integrated Technology Demonstrators (**ITD**):

GRA - Green Regional Aircraft

This demonstrator will bring the future green regional aircraft and will meet demanding weight reduction, energy and aerodynamics efficiency, an high level of operative performance, in order to be compliant regards to pollutant emissions and noise generation levels. To achieve these so challenging results, the aircraft will be entirely revisited in all of its aspects [10].

The design of this Green Regional Aircraft shows the Figure 3.

Figure 3 Green Regional Aircraft [10]
Slika 3. Zeleni regionalni avion [10]

SFWA - Smart Fixed Wing Aircraft

Project objectives:

- 10% reduction of the aircraft drag,
- 20% reduction of fuel burn,
- Reduction of aircraft noise by up to 10 dB through engine noise shielding configurations.

Technologies developed:

- An all new, smart wing design with a robust "laminar performance" under typical flight conditions.
- Passive and active flow control technologies, to be implemented in the smart wing.
- A new blade and pylon design aiming at integrating the CROR engine at high aerodynamic efficiency and low noise and vibration levels.
- A new rear empennage design meant to address certification, noise and handling quality issues with advanced engine concepts [10].

The Figure 4 shows the shape of the Smart Fixed Wing Aircraft.

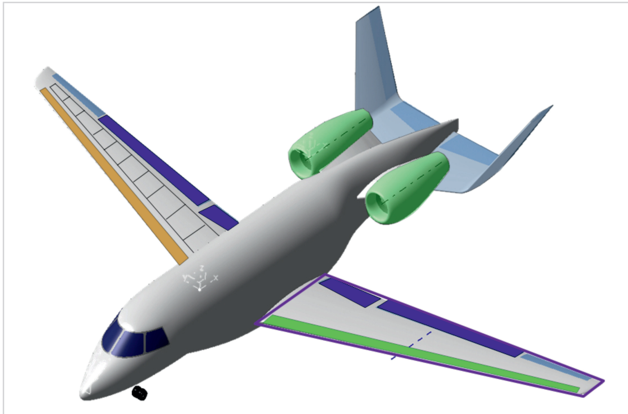

Figure 4 Smart Fixed Wing Aircraft [10]
Slika 4. Pametni avion fiksiranih krila [10]

GRC - Green RotorCraft

This demonstrator consists from seven projects, which present the technological changes for the greener rotorcrafts [10].

- Blades (GRC1)
- Reduced drag (GRC2)
- Electrical systems (GRC3)
- Diesel engine (GRC4)
- Flight path (GRC5)
- Eco-Design for rotorcraft (GRC6)
- Input to TE (GRC7)

The Figure 5 shows the design of Green Rotorcraft designed by GRC demonstrator.

Figure 5 Green RotorCraft [10]
Slika 5. Zelena rotirajuća letjelica [10]

SAGE - Sustainable and Green Engine

The demonstrations will prepare new solutions for the complete range of the market, with engines for the narrow body fleet, high thrust engines for wide body aircraft, regional aircraft engines and helicopter engines. For fixed-wing aircraft, a particular focus will be put on the novel engine architectures (open-rotor and geared-fan engine) that offer opportunities for step change reductions in CO2 emissions relative to current turbofans in the narrow-body and regional markets.

A range of technologies to reduce weight, noise and NOx emissions from more conventional engines will also be demonstrated [10].

The demonstrations have the three projects focussed on turbofans, geared turbofans and turboshafts engines. The design of turboshaft engine shows the Figure 6.

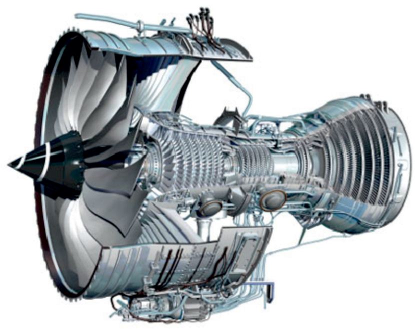

Figure 6 Turbofan engine [10]
Slika 6. Stroj s turbopuhalom [10]

Systems for Green Operations

Two domains have been identified in the Systems for Green Operations as major contributors to the achievement of the green challenges: [10]

1. *The Management of Aircraft Energy* (*MAE*), which includes the two focus areas of "All-Electric Aircraft Equipment Systems Architectures" and "Thermal Management"
2. *The Management of Aircraft Trajectory and Mission* (*MTM*), which includes the two focus areas of "Management of trajectory and Mission" and "Smart Ground Operations".

Eco-design

Eco-Design will focus on green design and production, withdrawal, and recycling of aircraft, by optimal use of raw materials and energies thus improving the environmental impact of the whole products life cycle and accelerating compliance with the REACH directive.

Eco-Design is organized in the two major areas of EDA (Eco-Design for Airframe) and EDS [Eco-Design for Systems (small aircraft)]. [10]

The Clean Sky's key goal of delivering 'up to 75% of the vehicle technology gains' required is fully being met. The Clean Sky JTI is itself a successful demonstrator. It is successfully demonstrating the relevance of the instrument: pursuing integrated, high readiness technologies, connected to market needs, having the full European aeronautical sector working together to common objectives. Clean Sky successfully links major players of the European aeronautics industry and research organizations, SMEs and academia.

As of September 2013, more than 550 participants from 24 Member States are actively involved in the implementation of the Clean Sky Programme. Overall participation shows a very healthy mix of large industrial players (58%), SMEs (15%), academia and research organizations (27%). To date, 36% of the budget for Partners has been awarded to SMEs and over 60% of the SMEs participating in Clean Sky are first-time participants in the European Framework Programme. Through Clean Sky, many newcomers have found an easier entry point into the European Research Area, and created new links into "big industry". This is an important enabler for the strengthening and deepening of European supply chains.

Clean sky 2 / *Čisto nebo 2*

With the success of Clean Sky, it is necessary to build upon the achievements of the current programme to, inter-alia, reach the 50% decrease of CO2 and, beyond ACARE 2020 horizon, prepare for the even more ambitious targets as are specified in document Flightpath 2050.

Clean Sky 2 will be a natural continuation to progress achieved in *Clean Sky,* which will end upon completion of the 7th European Framework Programme (FP7). Close alignment in time and in content between projects of Clean Sky 2 to its predecessor will allow for a seamless transmission of technical progress. Depending on the technology readiness level (TRL) reached at the end of Clean Sky, and on the results of the demonstrators, several technologies will achieve sufficient maturity to become available for development activity towards future aeronautical products whereas others will need to be strengthened through a further step of maturation within a Research and Innovation environment. For some of the most innovative and promising technologies worked on in Clean Sky, the preparation of the associated demonstrators shows that a higher level of integration will be needed. This next step - demonstrating representative full-scale vehicle architectures - should give the required confidence to market players to invest in break-through innovation.

The renewed ACARE SRIA (Advisory Council on Aviation Research in Europe, Strategic Research and Innovation Agenda) was completed in 2012, with ambitious goals for a sustainable and competitive aviation sector. These include a 75% reduction in CO2 emissions, a 90% reduction in NOx and 65% in perceived noise by 2050 compared to 2000 levels, and 4 hour door-to-door journey for 90% of European travellers. These substantial emissions reductions and mobility goals require radically new aircraft technology inserted into new aircraft configurations. Building on the substantial gains made in Clean Sky, Clean Sky 2 aims at meeting the overall high-level goals with respect to energy efficiency and environmental performance shown below (Table 1) :

Table1 Clean Sky 2 aims in the reducing aviation emissions area
Tablica 1. Čisto nebo ima za cilj smanjiti emisije u prostoru od avijacije

Emissions parameter	Clean Sky 2 as proposed * /
CO2 and Fuel Burn	-20% to – 30% (2025/2035)
NOx	-20% to – 40% (2025/2035)

Remark: */ Baseline for these figures is best available performance in 2014
Source: [10]and authors

The proposed Clean Sky 2 Programme aims to accelerate the introduction of new technology in the 2025-2035 timeframe (as illustrated on Figure 7). By 2050, 75% of the world's fleet now in service (or on order) will be replaced by aircraft that can deploy Clean Sky 2 technologies. Based on the same methodology as

Figure 7 The new aviation technology in the framework of Clean Sky 2 Programme [10]
Slika 7. Nova avijacijska tehnologija u okviru Programa Čisto nebo 2 [10]

applied in the Clean Sky economic case in 2007, the market opportunity related to these programmes is estimated at ~€2000 Bn. The direct economic benefit is estimated at ~€350-€400bn and the associated spill-over is of the order of €400bn.

The Horizon 2020 period will be decisive for delivering the innovations defining this century's fleet and its environmental footprint. Clean Sky 2 results will be applicable to 75% of the world fleet needing replacement9 up to 2050, and Clean Sky 2 technology will be able to address aviation emissions totalling over 70% of the worldwide civil air fleet.

Taking into these facts the Clean Sky 2 Programme has been prepared. This Programme consists of four key elements:

- Three Innovative Aircraft Demonstrator Platforms (IADPs) for achieving the higher level of integration of technologies into vehicle level demonstrators (for **Large Passenger Aircraft, Regional Aircraft and Fast Rotorcraft**),
- Three Integrated Technology Demonstrators (ITDs) and focused technology streams for **Airframes**, **Engines** and **Systems,**
- The Technology Evaluator (TE), assessing the environmental and societal impact of the technologies developed in the IADPs and ITDs;
- Two Transverse Activities (Eco- Design, Small Air Transport), integrating the knowledge of different**.**

Participation in Clean Sky 2 can be three-fold:

- Leaders
- Core Partners through Calls for Core Partners – similar to Associates in Clean Sky today
- Partners through Calls for Proposals (CfP) - similar to CfP in Clean Sky today

By pursuing joint European research on breakthrough innovations and demonstrating new vehicle configurations in flight, Clean Sky 2 will enable investors to develop and introduce game-changing innovations in timeframes otherwise unachievable, and create an '*Innovation Urgency*'. In doing so, Clean Sky 2 will significantly contribute to the Innovation Union, create high-skilled jobs, increase transport efficiency, sustain economic prosperity and drive environmental improvements worldwide, reinforcing Europe's role in leading the fight against Climate Change by positively contributing to lower emissions through technological advancement whilst enabling mobility to be sustained. Innovative new approaches instilled through Clean Sky 2 will underpin step-change advances in the performance of the next generations of aircraft expected to berequired from 2025, by mastering the technologies and the development risks.

Concerning Clean Sky 2 timeline, during the Q4 2013 will be providing the finalization of the Joint Technical Proposal post evaluation and adoptation of the regulation targeted. In Q1 2014 will be announced the Call for Core Partners and since beginning of Q2 2014 Clean Sky2 Programme will start.

THE SESAR PROGRAMME / *SESAR program*

The SESAR (Single European Sky ATM Research) programme is one of the most ambitious research and development projects ever launched by the European Community. The programme is the technological and operational dimension of the Single European Sky (SES) initiative to meet future capacity and air safety needs.

Given the complexity of the programme, a legal entity was founded by the European Commission and EUROCONTROL, to coordinate and concentrate all relevant research and development efforts in the Community.

The mission of this legal entity – the SESAR Joint Undertaking is to develop a modernised air traffic management system for Europe. This future system will ensure the safety and fluidity of air transport over the next thirty years, will make flying more environmentally friendly and reduce the costs of air traffic management.

SESAR aims at developing the new generation air traffic management system capable of ensuring the safety and fluidity of air transport worldwide over the next 30 years [11]. It is composed of three phases: [11]

- The Definition phase (2004-2008)
- The Development phase (2008-2013)
- The Deployment phase (2014-2020)

The total estimated cost of the development phase of SESAR is € 2.1 billion, to be shared equally between the Community, EUROCONTROL and the industry (€700 million Community, €700 million EUROCONTROL, €700 million industry) [11].

The SESAR programme comprises 16 work packages, which deals with the Operational activities, System development activities, System wide information and Management transverse activities [11].

The SESAR initiative to reduce the negative impact of aviation on the environment has set the following main objectives: [11]

- By implementing the SESAR concept in 2020, ATM-related CO2 emissions should be reduced by 10% per flight (against a 2005 baseline);
- Improve the management of noise emissions and their impacts through better flight paths, or optimised climb and descent solutions;
- Improve the role of ATM in enforcing local environmental rules by ensuring that flight operations fully comply with aircraft type restrictions, night movement bans, noise routes, noise quotas, etc.

SESAR realises already today environmental benefits through live trials or changes in real operations. Some examples of green procedures per domain of flight are introduces in text bellow.

On the ground

The key achievement for ground is to minimise aircraft holdings and distance rolling on the ground. For example, in a number of airports Collaborative Decision Making (CDM) is already in place for organising departure sequences. The general idea is to have a target start time for each and every departure. This improves the predictability and allows a reduction of taxi-out and taxi-in times. Having the predictability and information single engine taxing out is allowed by absorbing any potential delays at the parking stand, minimum usage of the aircraft APU etc.

More examples of ground initiatives to reduce fuel:

- CDM for departures and arrivals;
- Implementation of DMAN (Departure management) and AMAN (Arrival Management) tools;
- Pre-Departure Sequences;
- Better weather information;

Green ground procedures are covered in SESAR work packages 6, 9, 11, 13, 14 and 15 and realised project is *Ground movements project at Roissy Charles de Gaulle airport* [11].

Green Take-Offs - Green Departures

There is a large variety of how to perform the environmentally most advantageous take-off. Today, much consideration is given to noise constraints. However, a noise abatement departure procedure that is logical for one aircraft can be completely erroneous for another aircraft. Both in terms of noise and emissions. This indicates the importance of data availability and flexibility in the system.

Aircraft taking off are per definition in the segment of the flight where they are at their heaviest, meaning that they burn most fuel/time. Aircraft often climb in a series of steps separated by periods of level flight, neither efficient nor environmentally friendly.

Examples of departures initiatives to reduce fuel:

- Continuous climb;
- Implementation of PBN procedures allowing unrestricted climbs;
- Better weather information.

Green departure procedures are covered in SESAR work packages 5, 7, 8, 9, 11, 13, 15 and realised project is *Continuous Climb Departures and Tailored Arrivals and Continuous Descent Approaches project in Paris* [11].

Green Cruise

Aircraft cruise differently, depending on factors such as airframe design, weight, range, weather conditions and the airspace they are flying in. Flight management systems onboard aircraft can determine the most efficient cruise altitude and speed to optimise fuel burn. ATM can assist in this process by enabling capacity in the en-route phase of flight to offer aircraft the cruise levels and speeds they request. Further efficiency gains also include route changes to take advantage of favourable wind conditions for example.

Examples of cruise/oceanic initiatives to reduce fuel:

- Direct routing;
- Better lateral and vertical profiles
- Choosing the right Cost Index

Green cruise procedures are covered in SESAR work packages 7, 8, 9, 10, 11, 13, 15 and realised projects are *Reduction of Emissions on the North Atlantic by the Implementation of ADS-B and NATCLM (North ATlantic "cruise Climb""Lateral deviation" and "Mach number" flight trials demonstration)* [11].

Green Approaches

A successful Green Approach starts already at the Top of Descent. The target is to use all potential energy of the aircraft and convert it to kinetic energy which keeps the aircraft flying during the descent. The descent planning is therefore the critical part where all the potential energy must be balanced versus the needed kinetic energy during the descent. If the descent is started to early aircraft engines must be used to energy during the descent. If the descent is started to late valuable energy is burnt (from fuel) and must later be eliminated by the use of drag increasing device. The opportunities for fuel burn and emissions reduction in the descent phase through the reduction of ATM interference in planning of the descent is therefore crucial. It includes using sophisticated arrival management tools to better sequence aircraft ensuring shortest possible track distance, correct track distance information and minimal holdings. The aim is to allow all aircraft to descend uninterrupted from top of descent without using additional thrust, which burns fuel.

Examples of green approach initiatives to reduce fuel:

- Continuous descent operations;
- Idle reverse at landing;
- Implementation of PBN procedures allowing unrestricted climbs .

Green approach procedures are covered in SESAR work packages 7, 8, 9, 10, 11, 13, 15 and realised projects are

Continuous Descent Approach procedure using RNP-AR in Stockholm (MINT) and Continuous Descent Approach procedures in Madrid [11].

CONCLUSION / *Zaključak*

Research and development of new technologies is a fundamental European Union tool in the fight against the negative effects of air transport. Within the EU, there are implemented and still made a large number of research and development activities that are integrated into various EU programs and initiatives.

The main instruments for funding research in Europe are Frameworks programmes. The last one - the 7th Framework Programme for Research and Technical Development - is terminated by end of 2013. HORIZON 2020 as a new EU programme for research and innovation for the period 2014-2020 combines all research and innovation funding currently provided through the Framework Programme for Research and Technical Development, the innovation related activities of the Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation and Technology (EIT).

The biggest European aviation research program devoted to the environment is Clean Sky program. It is a joint initiative by the EU and industry, focused on the design of new aviation technologies - aircraft, engines, aircraft systems - to significantly increase the environmental performances of airplanes and air transport, resulting in less noisy and more fuel efficient aircraft, with reducing quantity of emissions. The proposed new Clean Sky 2 Programme aims to accelerate the introduction of needed technology in the 2025-2035 timeframe. Clean Sky 2 will be a natural continuation to progress achieved in Clean Sky. Close alignment in time and in content between projects of Clean Sky 2 to its predecessor will allow for a seamless transmission of technical progress.

The main aim of Single Euroepan Sky (SES) initiative of the European Commission is to provide a framework to meet future safety, capacity, environmental and efficiency needs at a European level . Very important part of SES initiative is Single European Sky ATM Research (SESAR) programme. The effort, projects and activities of the EU, EUROCONTROL and aeronautical industry in the SESAR programme framework have been focused also on environmental programmes/projects toward reducing of emissions from air transport area.

The ambition of the authors was to provide some selected, comprehensive and understandable information regarding the European Union research and development programmes and projects focused on reducing emissions from air transport and to underline the importance of this issue for the future air transport development. The key role in the processes and activities in relevant research and innovation programmes and projects in this area as well as from the fulfillment of challenging goals and needs in this area have European aeronautics industry and research organizations, SMEs and academia.

REFERENCES / *Literatura*

[1] Fuel and air transport, Report for the European Commission prepared by Air Transport Department, Cranfield University, URL: <http://ec.europa.eu/transport/modes/air/doc/fuel_report_final.pdf>

[2] http://www.enviro.aero/airquality.aspx

[3] www.iata.org

[4] http://ec.europa.eu/transport/modes/air/doc/flightpath2050.pdf

[5] http://ec.europa.eu/research/fp7

[6] http://ec.europa.eu/research/fp7/pdf/fp7-factsheets_sk.pdf

[7] http://ec.europa.eu/research/transport/pdf/projectsynopsesen.pdf

[8] http://www.alfa-bird.eu-vri.eu/

[9] http://ec.europa.eu/research/horizon2020/index_en.cfm

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

[11] http://www.sesarju.eu

[12] http://ec.europa.eu/clima/policies/transport/aviation/

[13] http://ec.europa.eu/transport/modes/air/environment/climate_change_en.htm

[14] http://www.eurocontrol.int/content/single-sky-europe

[15] http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/aeprimer.pdf

[16] http://www.ipcc.ch/index.htm#.Un_0y3BLOWY