PERSPECTIVES FOR AERONAUTICAL RESEARCH IN EUROPE

PARE

CHAPTER 6

Prioritizing Research, Testing Capabilities and Education

Final Report

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Chapter 6 – Prioritizing Research, Testing Capabilities and Education

The continuation of the success of the European aeronautics sector in the long term requires a joint research strategy (section 6.1), implemented through industry-research-academia cooperation (section 6.2), with access to test and development facilities (section 6.3) the whole supported by a steady influx of young talent (section 6.4).

6.1 European Research and Innovation Agenda

*Flightpath 2050 goal 20: "European research and innovation strategies are jointly defined by all stakeholders, public and private, and implemented in a coordinated way with individual responsibly".

Aviation is recognized as one of the top five advanced technology sectors in Europe. Thus, it is generally acknowledged that research infrastructures are extremely important to the aviation industry and the scientific community working on aeronautics. Europe has the world's leading research infrastructure covering the entire aviation system from wind tunnels through simulation facilities to test aircraft. Industrial customers (i.e. aircraft manufacturers) make commercial use of facilities for developing and enhancing their products during limited test periods. This contributes to making the facilities available for scientific research to other users who need them for limited periods. This situation benefits the numerous research projects conducted under national or EU programmes on both fixed and rotary-wing aircraft and is conducive to improving basic knowledge (of such matters as flow stability, transition, wakes, vortices and the combustion process) through tests directly funded by research establishments to improve fuel efficiency and reduce noise.

European research is defined, organised and funded in a coherent and coordinated, dynamic and agile way avoiding duplication and inefficiency. It is prioritised towards initiatives resulting from strategic roadmaps defined and agreed by all European stakeholders, satisfying actual needs (industry pull) and potential future demands (technology push). The start of the EU aeronautics programme in the framework programme FP2 with a budget of 36 M€ and its steady growth one hundred-fold to a budget of 3.6 B€ in H2020 testifies to the success and the growing importance of this initiative. It was pioneering in supplementing without duplication national, bilateral and multilateral cooperation on an occasional basis among larger nations, by systematic cooperation accessible to all EU member states, bringing more talent to the European pool. The growth of the aeronautics program has seen a shift from (i) basic to (ii) industrial, (iii) demonstration and (iv) integration activities. This growth should be considered as an efficient element of integral European transport system growth that "provides completely safe, secure and sustainable mobility for people and goods". A single European transport area should ease the movements of citizens and freight, reduce costs and enhance the sustainability of European transport. Technological innovation can achieve a faster and cheaper transition to a more efficient and sustainable European transport system by acting on three main factors: vehicles' efficiency through new engines, materials and design; cleaner energy use through new fuels and propulsion systems; better use of network and safer and more secure operations through information and communication systems. The synergies with other sustainability objectives such as the reduction of oil dependence, the competitiveness of Europe's transportation (aviation, automotive, railway and maritime) industry as well as health benefits, especially improved air quality in urbanistic conglomerates, make a compelling case for the EU to step up its efforts to accelerate the development and early deployment of clean vehicles (aircraft, cars, trains, etc.).

On a separate track, the European Research Council (ERC) has sponsored high-quality research in basic science, including mathematics and physics, with some underrepresentation of engineering. Fundamental and applied research in various scientific disciplines (such as fluid mechanics, materials, structures and systems) and the development of sub-components and components (like engines) and aeronautical end-products (including fixed-wing aircraft and rotorcraft) has always been associated with extensive design, computation, testing, optimisation and validation activities. This complex process calls for the systematic use of various research facilities, such as aerodynamic wind tunnels, combustion and structural testbeds, material elaboration apparatus, clusters of small computers (or conversely high-end super-computers), air traffic management and air traffic control simulators, flight simulators, and research aircraft. These facilities, used for different disciplines and specialities, differ greatly in their size and range of application but are often linked to one another through a complex immaterial network that transforms basic scientific knowledge into competitive products while integrating environmental, safety and security requirements. Formal pan-European networks have been established to improve overall efficiency by exchanging best practices and progressively specialising in fields of application. Examples are AT-One for Air Traffic Management, DNW, and ESWIRP for wind tunnels.

The gap between the Joint Research Initiatives (JRI) "Clean Sky" and "SESAR" focused on industrial application and the ERC focused on fundamental research needs to be filled by a Basic Research Programme (BRP). The call for "exploratory research" ideas in SESAR is a first step towards filling the void in basic research and needs to be expanded and extended to all areas of aeronautics. Both Joint Undertakings (JUs) Clean Sky and SESAR ensure the medium-term competitiveness of the European aeronautical sector; the supply of new ideas and prospects to ensure longer-term competitiveness depends on a Basic Research Program linking the human resources of academia, industry and research establishments.

As envisaged, for example by the CSI, to reach the goals expected by 2050 with respect to the realization of new generations engines (see Figure 6.1), the research outputs of the Next Decade European Aeronautics Research Programme can be divided into near-term (i.e. exploitable within the 2020–2029 timeframe), mid-term (i.e. exploitable within the 2030–2039 timeframe) and far-term (i.e. exploitable within the 2040–2049 timeframe) [1]. However, highly-innovative radical technologies can be expected as a result of fundamental research and the exploration of novel concepts. Subscale and ground demonstrators, in conjunction with numerical and experimental research, will be required to develop further understanding of the underlying principles.

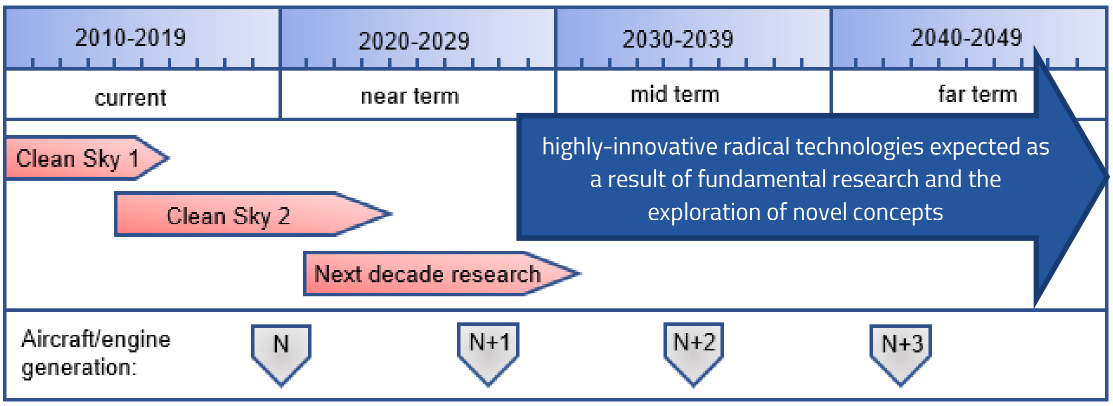


Figure 6.1 Timeline for Aeronautics Research Programmes on new generation engines. Adapted from [1]

In view of the next EU Framework Program, different organizations are preparing position papers indicating the priorities to be addressed and supported. In particular, the European Commission has formed a High-Level Group to draw up a vision and strategic recommendations to maximise the impact of the future European Union (EU) research and innovation (R&I). The Group has elaborated a report entitled "LAB – FAB – APP Investing in the European future we want" [2] containing series of recommendations aimed at maximising the impact of EU Research & Innovation Programmes for post-2020 EU programme. The report is based on the results of the interim evaluation of Horizon 2020, on a collection of documents and on issue papers prepared by the Commission services and feedback received from a range of European-level stakeholder organisations.

The summary of recommendations is shown in Figure 6.2. As it can be easily recognized, the main messages are to support innovative ideas and invest in education.

According to this strategic vision to maximise the impact of future European Union (EU) research and innovation (R&I), EREA, the Association of European Research Establishments in Aeronautics, has issued recommendations for an impactful aviation research programme in the next Framework Programme, which takes into account those of "LAB-FAB-APP" report of the High Level Group. The EREA position paper [3] has stressed that it is essential to support, develop and maintain test infrastructures for new products and innovative solutions and invest on the human capital source to bring in new ideas for the technological base of the European Industry. For supporting and keeping one of the most flourishing EU industries and because of the long cycles characterizing research in aviation, the investment in Research and Innovation is crucial and requires the necessary support from public funding through Grants up to TRL 6. To ensure proper flow through the innovation chain, a certain degree of continuity is required. EREA therefore fully supports multi-annual programming. FP9 should earmark a larger portion of the funding for Collaborative Research on TRL levels 1 to 4-5, which will keep the invaluable innovation and human capital source for one of Europe's most strategic sectors vibrant and bring in new ideas for the technological base of the European Industry.

Summary of recommendations

The following recommendations are aimed at maximising the impact of future EU research and innovation programmes. Each of them is exemplified by a key action.

1. Prioritise research and innovation in EU and national budgets
   Action: double the budget of the post-2020 EU research and innovation programme.
2. Build a true EU innovation policy that creates future markets
   Action: Foster ecosystems for researchers, innovators, industries and governments; promote and invest in innovative ideas with rapid scale-up potential through a European Innovation Council.
3. Educate for the future and invest in people who will make the change
   Action: modernise, reward and resource the education and training of people for a creative and innovative Europe.
4. Design the EU R&I programme for greater impact
   Action: make the future programme's pillars driven by purpose and impact, fine-tune the proposal evaluation system and increase flexibility.
5. Adopt a mission-oriented, impact-focused approach to address global challenges
   Action: set research and innovation missions that address global challenges and mobilise researchers, innovators and other stakeholders to realise them.
6. Rationalise the EU funding landscape and achieve synergy with structural funds
   Action: cut the number of R&I funding schemes and instruments, make those remaining reinforce each other and make synergy with other programmes work.
7. Simplify further
   Action: become the most attractive R&I funder in the world, privileging impact over process.
8. Mobilise and involve citizens
   Action: stimulate co-design and co-creation through citizen involvement.
9. Better align EU and national R&I investment
   Action: ensure EU and national alignment where it adds value to the EU's R&I ambitions and missions.
10. Make international R&I cooperation a trademark of EU research and innovation
    Action: open up the R&I programme to association by the best and participation by all, based on reciprocal co-funding or access to co-funding in the partner country.
11. Capture and better communicate impact
    Action: brand EU research and innovation and ensure wide communication of its results and impacts.

Figure 6.2 List of recommendations of the High-Level Group

Source: [2]

However, with the increasing pressure deriving from the problems associated to environmental issues that is the object of public opinion attention, the EU has identified climate change as one of its future priorities. Therefore, it is expected that major efforts will be directed in FP9 towards competitive calls on this topic.

6.2 Industry-Research-Academia Clusters

*Flightpath 2050 goal 21: "Creation of a network of multi-disciplinary technology clusters based on collaboration between industry, universities and research institutes"

The creation of these technology clusters could be the result of 3 initiatives, two ongoing and one to be restored from the past:

A – The (iii) demonstration and (iv) integration activities existing in the JUs Clean Sky and SESAR;

B – The fundamental research in mathematics, physics and engineering existing in the ERC;

C – Restoring the (i) basic and (ii) industrial research that existed in the aeronautics programme since the beginning and lapsed with increasing scale.

European research and innovation strategies are jointly defined by all stakeholders, public and private, and implemented in a coordinated way with individual responsibility. This involves the complete innovation chain from blue-sky research up to technology demonstration. A network of multi-disciplinary technology clusters has been created based on collaboration between industry, universities and research institutes (EREA, PEGASUS, XNOISE, FORUM-AE, etc.). The sector is organised to sustain the full research and innovation chain. This includes mechanisms for small and medium enterprises (SMEs) to link with higher tier suppliers without any penalty for sub-contracting. Research work with achieved previously maturation in its TRLs is continued and intensified with particular emphasis on medium and high levels which are specifically focused on improving components for existing aircraft. Fundamental aeronautics research is coherent with more applied research and makes use of the European Research Council's scheme. In the short-term, attractive and efficient research, instruments are put in place, which ensures continuity between research on the promising breakthrough concept, their validation by focused RTD actions and finally their demonstration in an integrated environment.

The basic research programme in C may be a relatively modest budget item (up to 100 M€) but it can have a major effect on long-term competitiveness by linking A and C. It would be possible to imagine the clusters around any or all of the 14 main aeronautical technologies: flight physics, aerodynamics, propulsion, structures, materials, production, control, avionics, telecommunications, computation, electrics, noise, emissions and operations.

Harmonisation between technology evolution in aviation and in other correlated sectors enables spin-in from and cross-fertilisation with innovations in other sectors, such as communications (mobile web, travel search engine providers). It also incentivises the aeronautical world to be more adaptive to the very fast evolution of IT technologies (c.f. the current aeronautical evolution on 10-year time scale versus IT technology evolution on a yearly time scale).

The contribution of the EU aeronautics programs from FP2 to FP8 (Horizon 2020) deserves special focus (Key Topic T6.1). The main figures related to the R&D projects funded within the eight FPs are summarized in Table 6.1.

In particular, the description is split into two separate parts. The first one is devoted to the already finished FPs, i.e from FP2 to FP7, for which analyses are assessed based on available results and information. The second part is specifically focused to the analysis of data concerning the still running Horizon 2020 (H2020)

General statistics on funded aerospace R&D collaboration network							
European Framework Programs	FP2	FP3	FP4	FP5	FP6	FP7	FP8 (H2020) (**)
Years	1987-1991	1990-1994	1994-1998	1998-2002	2002-2006	2007-2013	2014-2020
Number of Projects	390	714	241	196	255	217	1194
Number of Participants	2171	4066	2301	2385	3899	2791	8035
Average number of participants	5.6	5.7	9.5	12.2	15.3	12.9	6,7
Budget (M€)	36	71	245	700	850	2300 (*)	>3600

Table 6.1 General information concerning the aerospace sector funded from FP2 to FP8 in the time-period 1987 to 2019.

Adapted from: a) D. Guffarth, M. J Barber, (2013): The European aerospace R&D collaboration network, FZID Discussion Paper, No. 84-2013; b) Aeronautics in the EU Framework Programme DG RTD-H.3 - Aeronautics November 2006.

(*) Budget 2007-2013: Aeronautics (Collaborative Research +JTI) and SESAR

(**) Figures in this column are obtained by own elaboration based on available data extracted from CORDIS database - April 2020 (keywords: aerospace OR aeronautics OR aviation).

KEY TOPIC T6.1 – EU AERONAUTICS PROGRAMS SINCE FP2

PROGRAMS from FP2 to FP7

The aerospace industry is characterized by a high R&D intensity, technological complexity, long product life cycles, and so on. To support the huge costs associated with the development of new products in this demanding industrial sector, the European Union has funded numerous transnational, collaborative R&D projects, within the European Framework Programmes (FPs). The proposals are submitted by self-organized consortia composed by at least two independent legal entities established in the different EU Member States and an associated State. Since their initiation in 1984, eight FPs have been launched up to the currently running one, named Horizon 2020, launched in 2014.

The main fields of interest developed within the EU framework programs from FP1 to FP7, are described by Guffarth et al. [4]. They consulting the EUPRO database[1], have inspected more than 2000 projects dedicated to the aerospace sector and mapped each of them into one or more of 25 thematic categories as shown in Table 6.2.

Moreover, as shown in Figure 6.3, the fraction of the projects funded in each FP have been associated to the different categories. In the early FPs A rather uniform distribution among the different categories can be noticed. Four categories have increased the relative importance from FP4 until FP7: SAT (satellite and space topics), RSY (quality and safety systems, non-destructive detection and repair systems, maintenance and their facilities), OMP (optimization of manufacturing processes and supply chains, existing product

[1] EUPRO database is developed and maintained by Austrian Institute of Technology, Innovation Systems Department by standardizing raw data on EU FP research collaborations collected from the CORDIS database

improvements) and SIM (simulation, numerical models, computer-aided systems for air traffic management or aerodynamic application).

Thematic Categories	
Code	**Thematic explanation**
AER	Aerodynamic, flows and aero thermic
ALO	Alloys and coatings, glazed materials and paints
CEG	(technical) ceramic and glasses
CHE	Chemical processing (incl. petrochemicals)
COM	Composite materials
ELE	Electric and electronic (incl. cables and conductors)
FCH	Fuel cells, batteries, liquid hydrogen, cathodes and membranes
FOR	Forming, moulding, winding, sintering and grinding
LIT	Rare-earth materials (e.g. lithium)
LSO	Lasers, sensors and optics
MET	Metals (steel, aluminum, copper, titanium,...)
MIN	Mining (incl. all auxiliaries)
OMA	Other materials (e.g. rubber, leather, resins, wood, concrete, biomaterial,...)
OMP	Optimizing manufacturing processes, production and products (incl. cost reduction)
OTH	Others
PLA	Plastics and polymers
REC	Recycling and environmentally friendly product improvements and processes
ROB	Robotic systems, e.g. for production, inspection, ...
RSY	Quality and safety systems (incl. repair systems, non-destructive detection, maintenance, etc.)
SAC	Sawing and cutting
SAT	Satellites and space topics
SIM	Simulation, numerical models, computer-aided systems, informatics
SUR	Surfaces
TXT	(technical) textiles
WEL	Welding, soldering, brazing

Table 6.2 Thematic categories used to classify the EU funded projects related to the aeronautic sector.

Source: D. Guffarth, M. J Barber, (2013) [4].

A significant observation, which can be resumed by relating the data in Figure 6.3 with the historical development of the aeronautic industry, concerns the composite material sector (COM). It can be noted that projects belonging to this category were among the most relevant in FP2 and FP3, which have been in place between the mid-1980s to the mid-1990s. During this period, many R&D efforts have been devoted to the development of new composite materials in response to the aircraft manufacturers demand to reduce its weight in order to decrease fuel consumption and increase the aeroplane flight range.

It has to be reminded that until the mid-1990s the percentage of composite materials employed was around 10% of the total aircraft weight and limited to non-structural parts. This percentage has sensibly increased up to the present figures. In fact, both the Boeing 787 and the Airbus A350 recently introduced in the aircraft market (in 2011 and 2015, respectively) are now composed with about 50% in weight of carbon fibre reinforced materials. This demonstrates that there has been an industrial application of such new technology has nearly 20 years lag with respect to the research and development phase.

The most relevant topics of FP4 concerning efficiency and optimization of aircraft design and procurement costs, (OMP and RSY in Table 6.2) were continued in FP5. Besides, specific goals concerning the reduction of aircraft noise and climate impact become of greater importance thus, explaining the increase of AER and REC categories. During the exploitation period of FP5, the improvement of aircraft operational capability is put in evidence by the increased number of projects dedicated to computer-aided systems (SIM).

In FP6, the significant percentages associated to categories like space (SAT), satellite-based information services (LSO) and data information models (SIM) signalled the growing importance recognized by the EU to the Galileo project, and to satellite telecommunications. As it concerns the aeronautic sector, the most relevant efforts have been associated to safety and security (RSY), cost reduction (OMP), improvement of the environmental impact with regard to emissions (REC) and noise (AER and OMP).

Within the FP7 the EU strategy concerning aerospace has been concentrated on the reduction of emissions and alternative fuels (REC), air traffic management (SIM), safety and security (RSY) and efficient aircraft production (OMP).

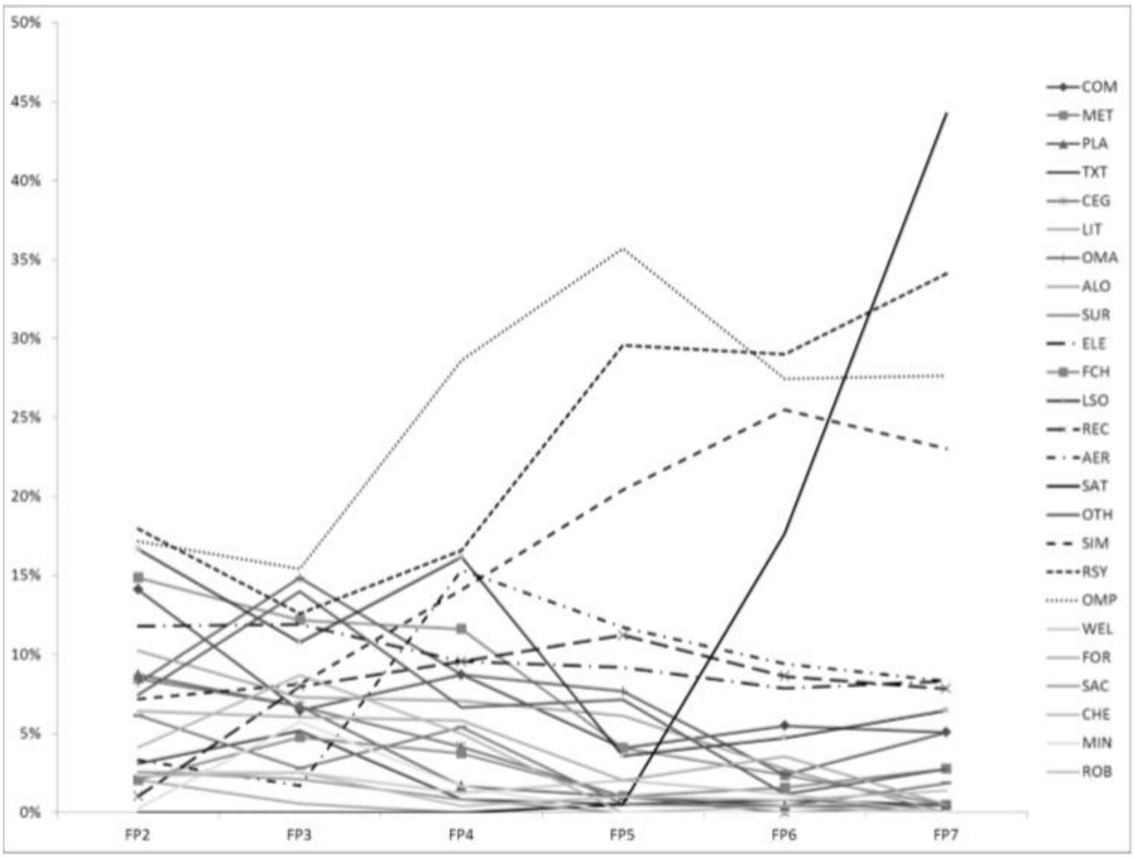


Figure 6.3 Thematic development of EU-funded aerospace R&D projects. [4].

Participation by Country

The graphs shown in Figure 6.4 provides a synthetic description of the relative involvement of the different EU countries in the FP projects. In particular, the diameter of the nodes is associated to the overall number of participants per country, whereas the links between the nodes provide the number of connections between the regions: the thickness of the links indicates the number of connections within the different FPs. Such graphs illustrate the evolution of the involvement of the EU countries from a uniform distribution in FP2 and FP3 towards a more concentrated one in FP5-FP7. Such change may be reasonably associated with the previously discussed evolution of the relative importance of the different categories and to the identification of a less fragmented and more specialized cooperation network.

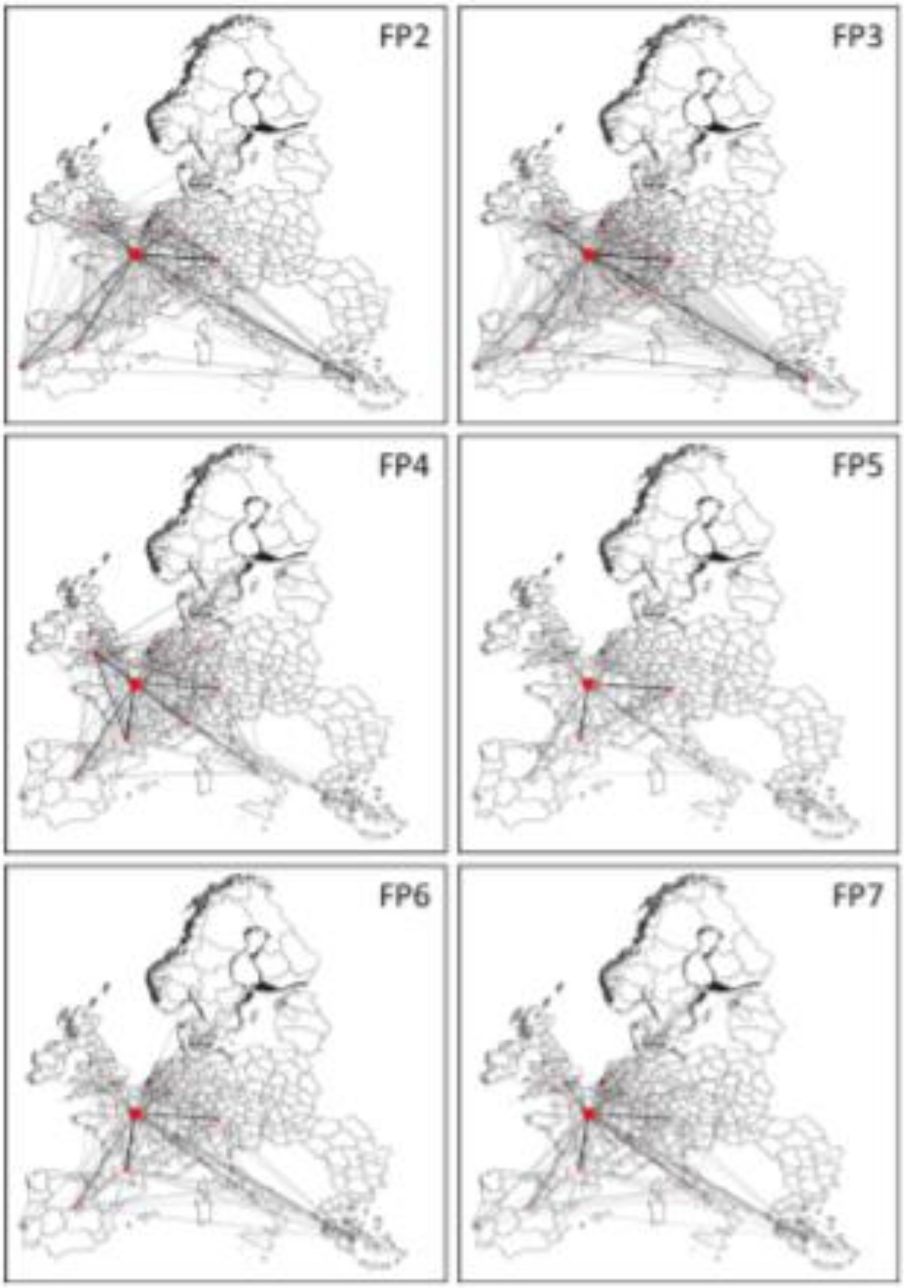


Figure 6.4 The European aerospace R&D collaboration network [4]

Participation by Section: Industry, Research, Academia

As it concerns the organization types participating to the EU funded projects the following categories can be considered: IND (industry), EDU (education and science facilities, like universities), ROR (research organizations, like the Fraunhofer Gesellschaft, Office National d'Etudes et de Recherches Aérospatiales (ONERA), Centro Italiano Ricerche Aerospaziali (CIRA), Deutsches Zentrum für Luft- und Raumfahrt (DLR), Netherlands Aerospace Centre: NLR, ...), GOV (government and other public authorities) and OTH (all other organizations).

Figure 6.5 illustrates the relative weight of such different organizations within the FP projects. As it concerns the industry IND, it can be noted that there is a presence between 50-60% almost constantly from FP2 to

FP5. In FP6 and FP7 a decrease to 45% and 38% respectively can be noticed. An opposite trend, closely related to the thematic development discussed before, is visible for the scientific organizations EDU and ROR since their shares, nearly constant from FP2 to FP5 with a percentage <40%, increased to 45% in FP6 and 53% in FP7. In particular, such a trend is related to the rising relevance of topics like satellite and space, environmental impact in FP6 and FP7 that demands a more prominent scientific effort and long development phase.

As indicated in [4] on the average by considering all FPs, "an industrial actor participated in a mean number of 3.2 projects, with a standard deviation of 14.6, a research organization in 3.0 (11.1) projects, and a university in 2.6 (6.1) projects. Overall organization types, the fluctuation seems to be high, since they participate on average in about three projects over 26 years. The enormous variation indicates strong heterogeneity within the different types".

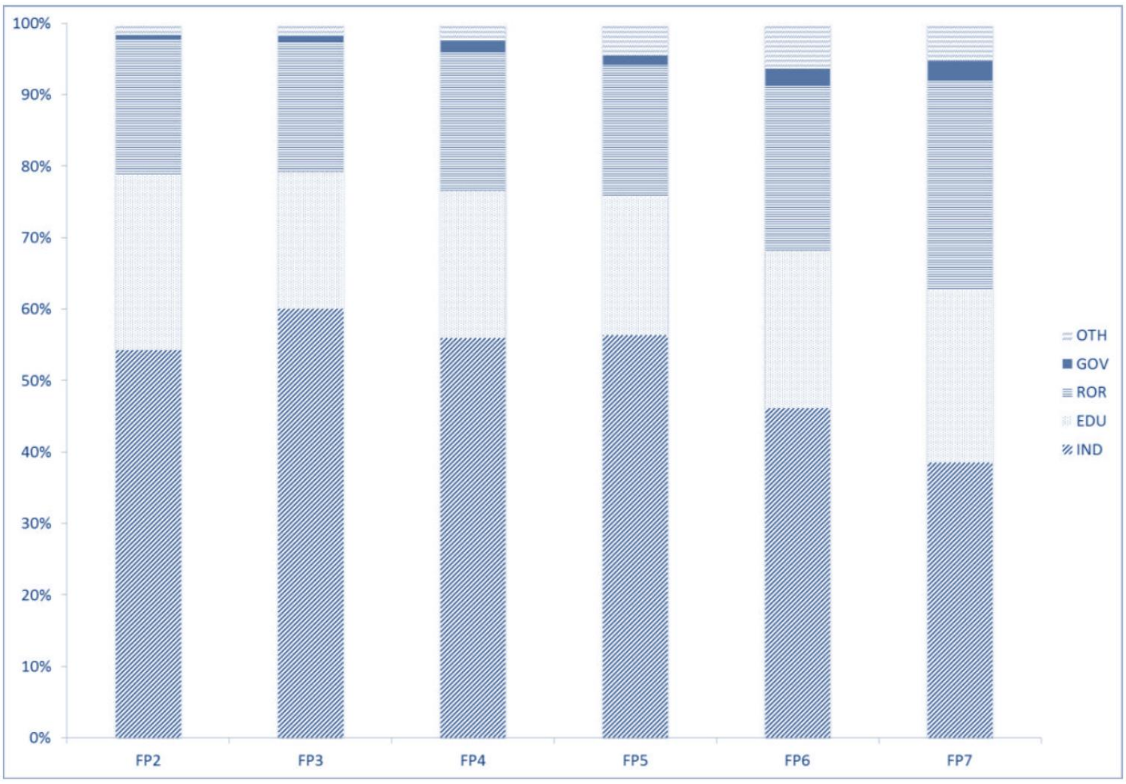


Figure 6.5 Relative shares of the different organization types to aerospace EU funded projects. [4]

Horizon 2020

Horizon 2020 is a still running FP and therefore complete and detailed analyses of the same kind illustrated in the previous sub-paragraph are not available yet. For this reason, a specific investigation has been performed by the PARE Consortium.

In particular, information concerning the projects associated to the aeronautic sector has been extracted from CORDIS database in May 2020. The following keywords have been adopted to perform the query among all the projects funded within the H2020 FP: aerospace OR aeronautics OR aviation (see Figure 6.6).

Before presenting some figures that may be derived the huge list of projects obtained in this way (1221), some cautions have to be kept in mind. In fact, not all the topics dealt with by the funded projects are strictly related to the aeronautic sector. However, at least a first approximation of the impressive effort undertaken by the EU to support the aeronautic sector can be obtained.

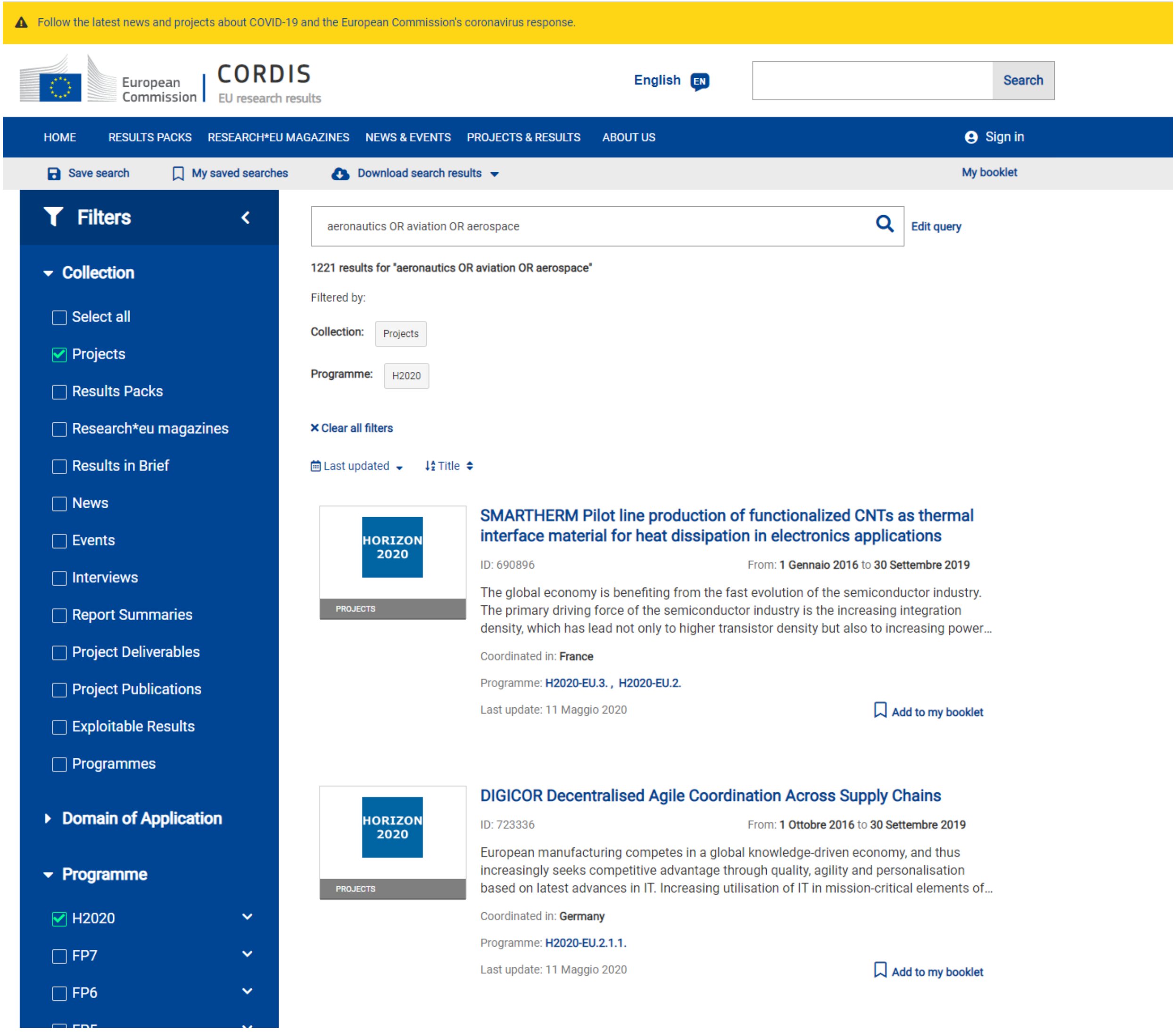


Figure 6.6 Extraction of projects funded in H2020 from CORDIS data base.

The main data summarising the efforts provided within the H2020 FP are shown in Table 6.3.

Total projects	1221
Total participants	8035
Total contribution	3.653.998.983 €
Mean contribution per participant	454.760 €
Mean contribution per project	3.060.301 €
Contribution to ended projects (11/05/2020)	1.790.379.719 €
Contribution to ongoing projects	1.863.619.263 €

Table 6.3 Main data summarising the efforts provided within the H2020 FP.
Source: Extraction on May 2020 from CORDIS database by using as keywords for the query: aerospace OR aeronautics OR aviation.

In Figure 6.7 an illustration of the distribution of projects per nation is presented. In particular, only the nations with more than 5 funded projects are shown.

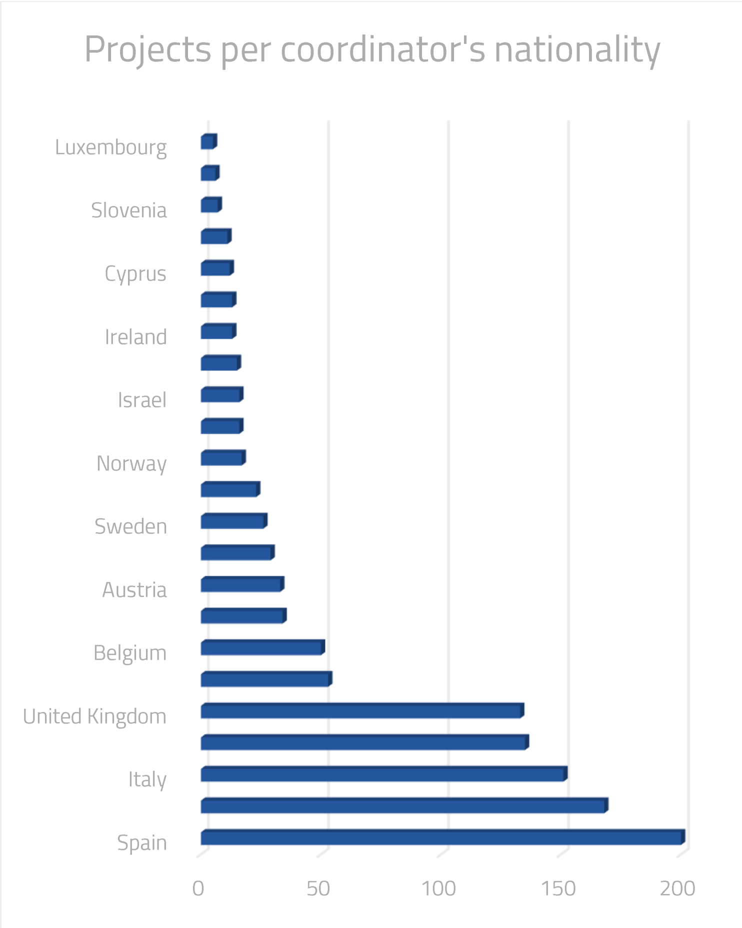


Figure 6.7 Number of projects funded in H2020 per coordinator's nationality. Only nations with more than 5 funded projects are indicated.

The Spain has the highest number (200) of funded projects whose coordinator is a national Institution. The nations that had a number of projects lower than 5 are listed in Table 6.4. Most of them are countries involved in the measure "Widening actions under the Spreading Excellence and Widening Participation part of Horizon 2020[2]".

Nation	# of projects
Lithuania, Romania	4
Slovakia, Ukraine	3
Estonia, Iceland, Latvia, Serbia, Turkey	2
Bulgaria, Croatia, Malta, Uruguay	1

Table 6.4 Number of projects per coordinator's nationality. Nations with less than 5 projects.

Source: Extraction on May 2020 from CORDIS database by using as keywords for the query: aerospace OR aeronautics OR aviation.

In Figure 6.8 the number of projects per coordinating organization and the amount of the total obtained contribution are displayed. Also in this figure, only the coordinators that have been granted more than 5

[2] The nations that had less amount of projects are listed below. It is possible to notice that the most of them are countries involved in the. The Member States currently eligible for "Widening actions under the Spreading Excellence and Widening Participation part of Horizon 2020" are: Bulgaria, Croatia, Cyprus, Czechia Estonia, Hungary, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Romania, Slovakia and Slovenia.

projects are indicated. The right axis shows the total received amount in logarithmic scale. It can be evidenced that the greatest sum (about 200M€) is for few large projects coordinated by Airbus.

In Table 6.5 the list of topics that have been financed for more than 40M€ is reported. The different topics have been grouped according to the different calls.

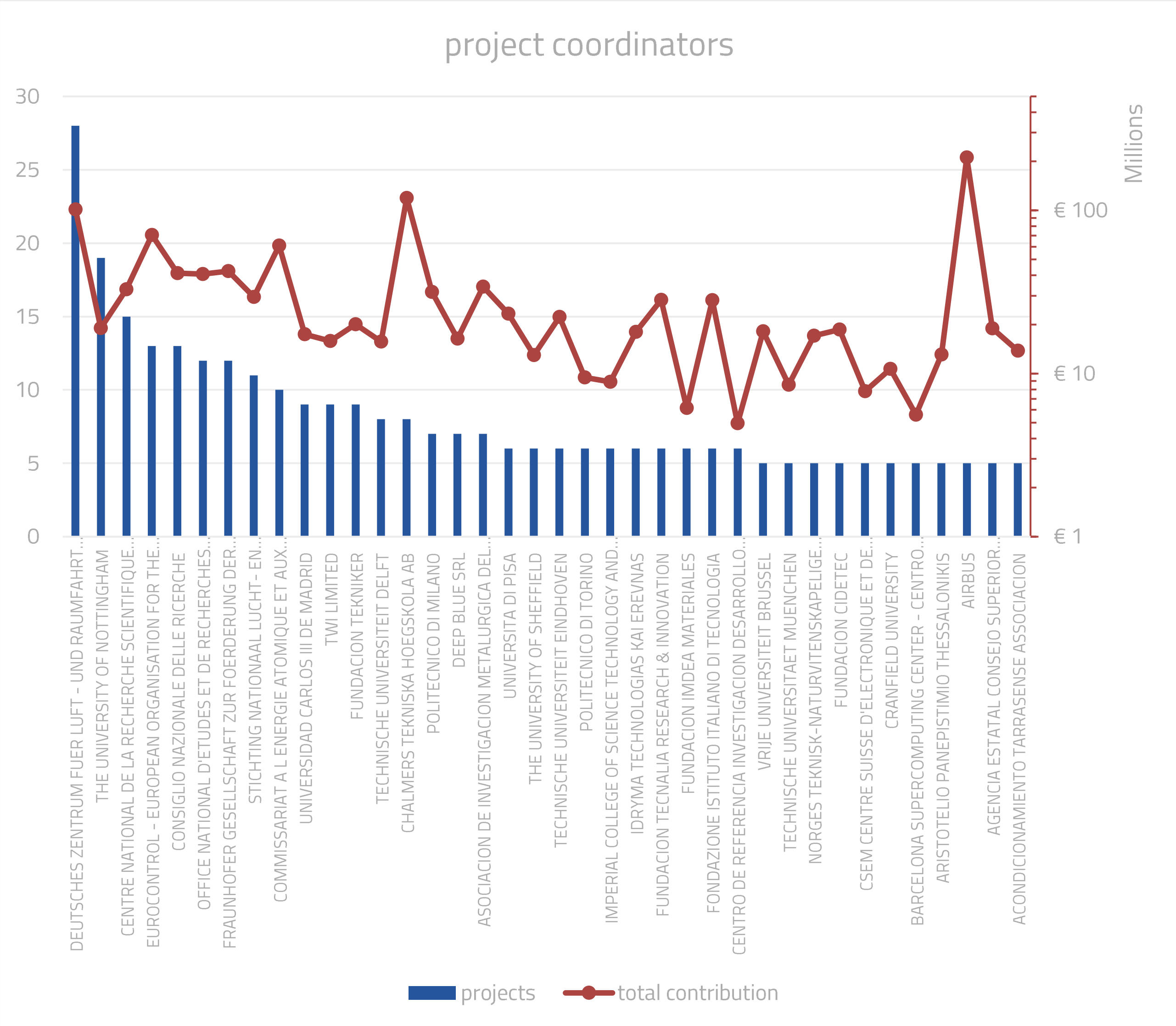


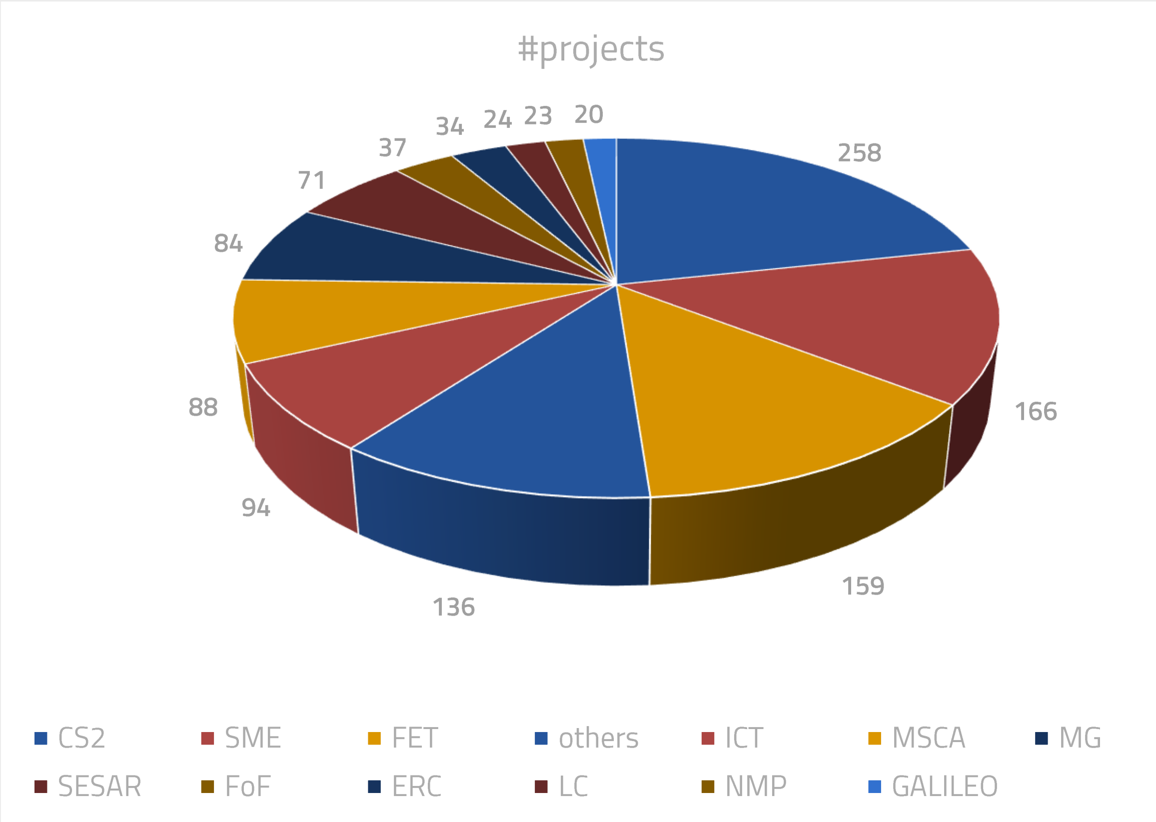
Figure 6.8 Number of projects per organization coordinating more than 5 projects and amount of the total obtained contribution.

The total amount assigned to the projects is in logarithmic scale.

Acronym	EU call	Description
FET	FET	Future and Emerging Technology
MG	MG	Mobility for growth
ICT	ICT	Information and Communication Technologies
CS2	JTI-CS2, CS2-GAM	Clean Sky2 calls
SESAR	SESAR	Single European Sky ATM Research
FoF	FoF+ DT-FoF	"Factory of Future", "Digital Transforming Factory of Future"
MSCA	MSCA	Marie Skłodowska-Curie actions
LC	LC	Low carbon
NMP	NMP and NMBP+DT-NMB	"Nanosciences, Nanotechnologies, Materials and new Production Technologies", "Nanotechnologies, Advanced Materials, Biotechnology, and Advanced Manufacturing and Processing", "Digital Transforming Nanotechnologies, Advanced Materials, Biotechnology"
SME	SMEInst+EIC-SMEInst+EIC-FTI+ IT-small	"Small and Medium Enterprises Instruments", "Enhanced European Innovation Council SMEInst", "Enhanced European Innovation Council-Fast Track Innovation", "small business innovation research for Transport"
GALILEO	GALILEO	European Union's Global Satellite Navigation System
ERC	ERC	European Research Council

Table 6.5 List of topics that have been financed within different calls in H2020 for more than 40M€.

In Figure 6.9 the number of funded projects (Fig. 6.9a) and participant entities (Fig. 6.9b) per EU call is reported. As it can be noticed, the highest number of funded projects and that of participants is observed for Clean Sky 2 (CS2) and Future and Emerging Technologies (FET) calls respectively. The lowest number of funded projects is within the GALILEO calls, whereas the lowest number of participants is associated to European Research Council calls.



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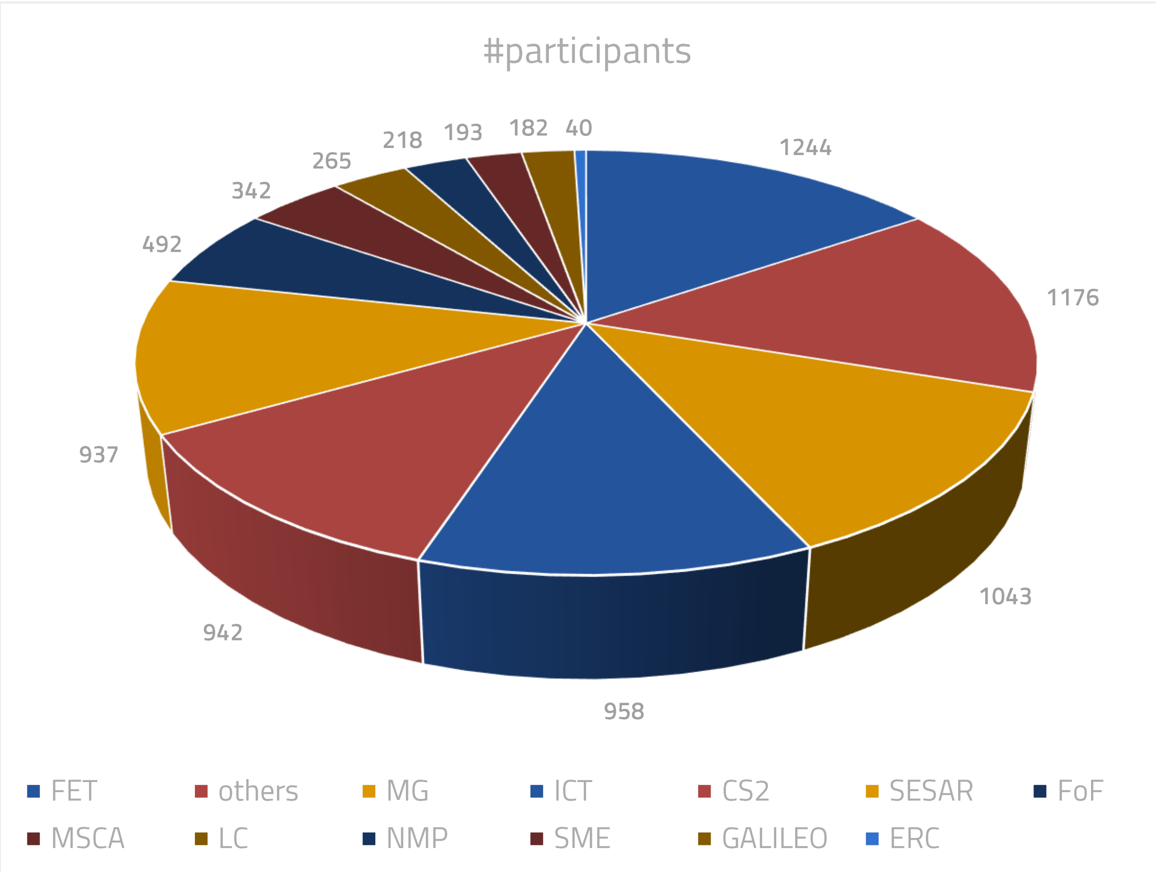


b

Figure 6.9 Number of funded projects (Fig. 6.9a) and participant institutions (Fig. 6.9b) per EU call

As evident from Figure 6.10, where the founding for call type is reported, the largest EU contribution is for projects funded within the Clean Sky 2 calls, indicating that the greatest efforts (about 842 M€) have been directed to sustain projects oriented to industrial applications. On the other side, the GALILEO and ERC projects focused on fundamental research are those with least financial support. The project with the largest funding (184.973.050 €) is CS2-GAM-2018-LPA - Large Passengers Aircraft with AIRBUS (France) as project coordinator and with 41 participants. The project with most participants is in the FET calls. It is the FETFLAGSHIP – Graphene with an EU contribution of 89.000.000€, 186 participants and whose coordinator is CHALMERS TEKNISKA HOEGSKOLA AB (Sweden).

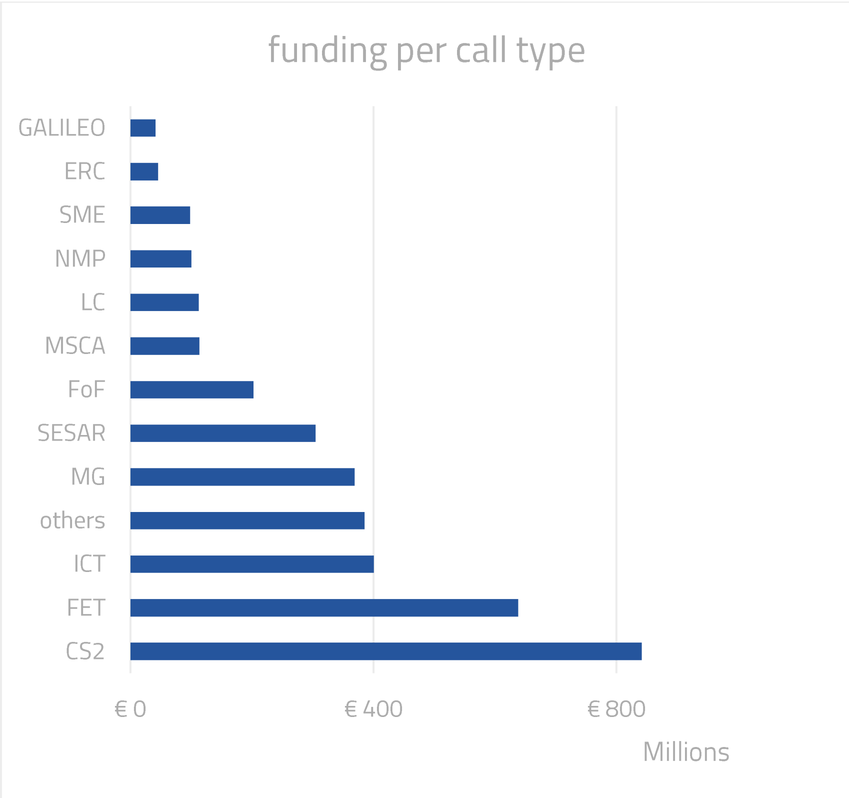
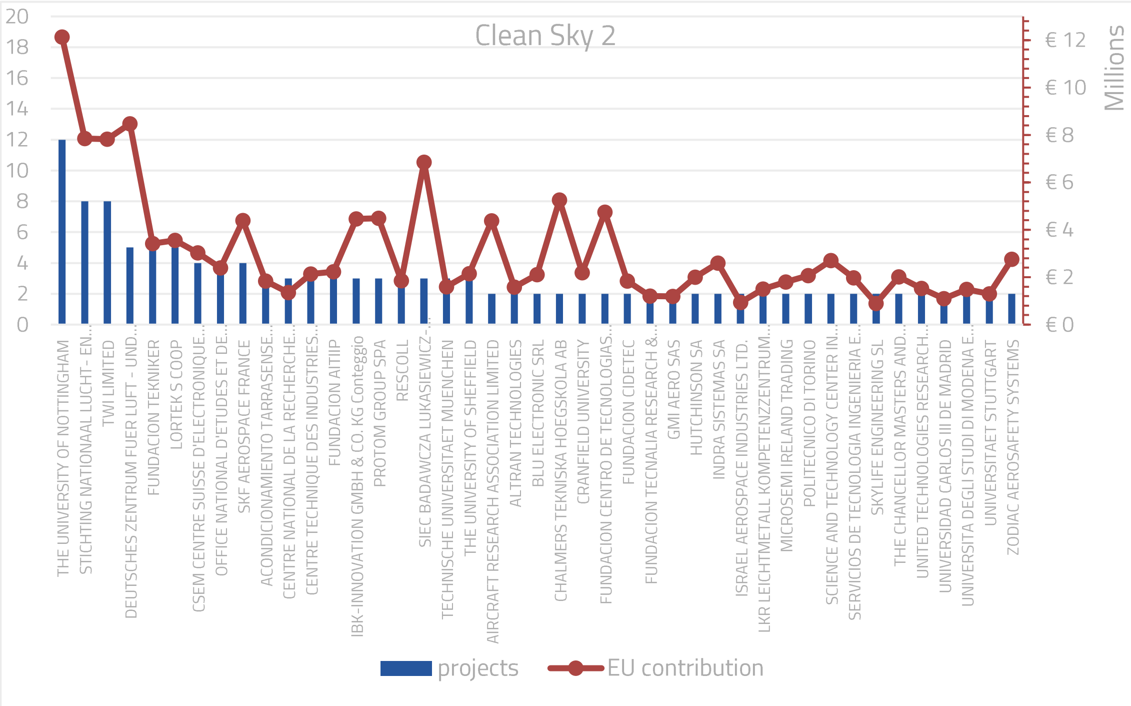


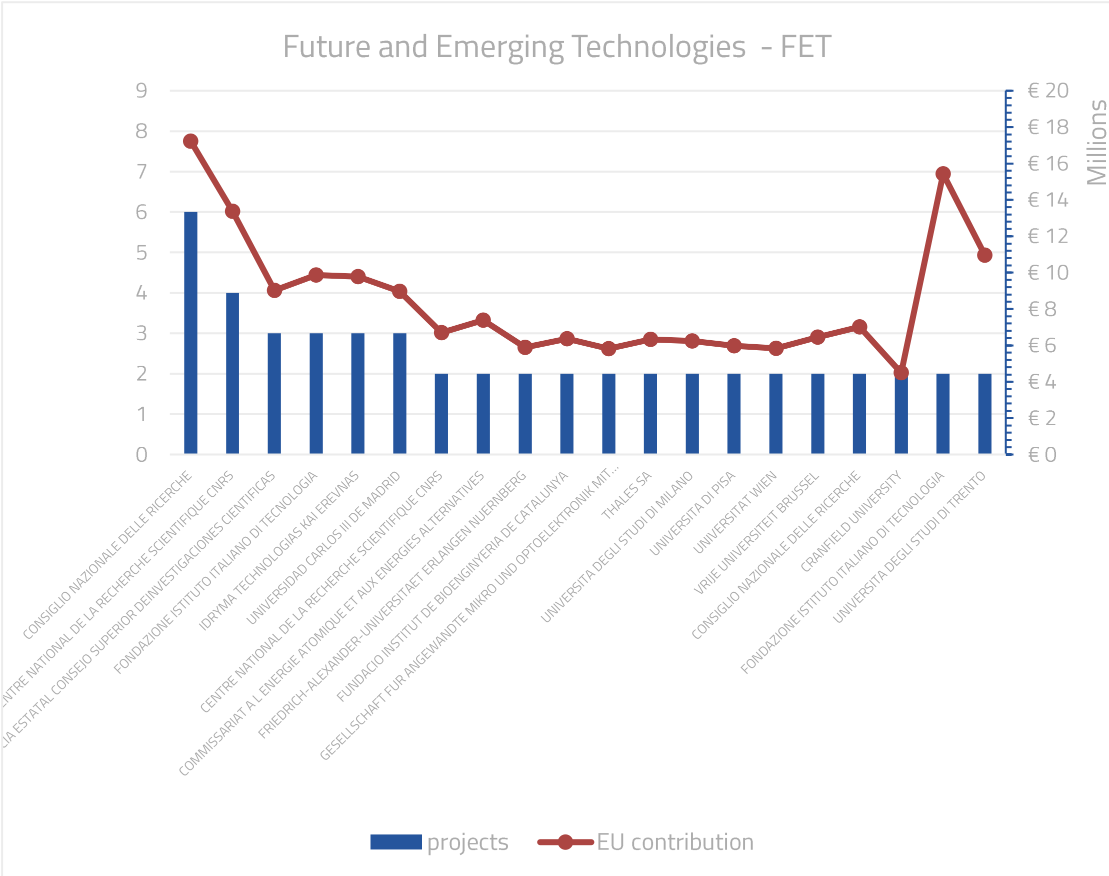
Figure 6.10 Funding per call type. For description about the meaning of the acronyms, refer to Table 6.5.

As it concerns the Clean Sky 2 and Future and Emerging Technology calls, a presentation of the institutions that have played a major role either in terms of occurrence as project coordinator or with regard to the budget of the projects is shown in Figure 6.11. Institutions involved at least 2 times as project coordinator have been considered. It can be noted that in CS2 the University of Nottingham (United Kingdom) has been the most frequent (12 times) project coordinator (left axis in the figure); the different consortia of such projects have received a total funding of about 12 M€. As it concerns the FET calls, the Consiglio Nazionale delle Ricerche (Italy) has been the most frequent (6 times) project coordinator (left axis in the figure); the different consortia of such projects have received a total funding of about 8 M€

A summary of the same information (occurrence as project coordinator and total budget assigned to the projects) for the other calls type is presented in Table 6.6.



a



b

Figure 6.11 Breakdown of the occurrence as project coordinator (left axis) and total project contribution assigned to the consortia (right axis) for projects financed within Clean Sky 2 calls (a) and Future and Emerging Technologies (b).

Project coordinator	Occurrence as projects coordinator	Total EU contribution for the projects
SESAR		
EUROCONTROL - EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION	10	€ 50.763.700
DEEP BLUE SRL	2	€ 1.196.867
LEONARDO - SOCIETA PER AZIONI	2	€ 58.710.781
Others, # 57	1	€ 194.304.616
MG		
DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV	3	€ 17.668.814
OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES	2	€ 10.621.804
AIRBUS	2	€ 2.372.388
DEEP BLUE SRL	2	€ 9.616.623
Others, # 75	1	€ 328.883.441
SME		
NORDIC RADAR SOLUTIONS APS	2	€ 1.543.625
ICEWIND EHF	2	€ 1.790.259
Others, #162	1	€ 94.860.882
MSCA		
THE UNIVERSITY OF NOTTINGHAM	4	€ 2.454.373
IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE	2	€ 287.182
FUNDACION IMDEA MATERIALES	2	€ 340.243
Others, # 80	1	€ 110.213.142
Others		
POLITECNICO DI MILANO	2	€ 14.040.039
UK RESEARCH AND INNOVATION	2	€ 3.499.848
MASARYKOVA UNIVERZITA	2	€ 784.867
NARODOWE CENTRUM BADAN I ROZWOJU	2	€ 799.964
TECHNOLOGIKO PANEPISTIMIO KYPROU	2	€ 799.625
THE CYPRUS INSTITUTE	2	€ 796.750
UNIVERSITY OF CYPRUS	2	€ 799.747
Others, # 122	1	€ 363.671.023

Table 6.6 List of occurrence as project coordinator and total budget assigned to the projects financed within different calls in H2020.

6.3 Test, Simulation and Development Facilities

*Flightpath 2050 goal 22:" Identification, maintenance and ongoing development of strategic European aerospace test, simulation and development facilities. The ground and airborne validation and certification processes are integrated where appropriate".

Research and development infrastructure is an indispensable tool to achieve a decisive competitive edge in developing sustainable aviation products and services that meet the needs of EU citizens and society. Appropriate core capabilities are available and accessible. Infrastructure and the associated workforce are vital assets, which are maintained and further developed in a focused, efficient and cost-effective manner. Suitable access to these facilities enables knowledge transfer across Europe and facilitates continuity from blue-sky research to innovation in products and services for the benefit of Europe. Strategic aviation infrastructure is of the highest quality and efficiency, providing the basis for world-class research and competitive product development while supporting education. It ranges from wind tunnels via iron and copper birds up to experimental aircraft and simulation capabilities for in-flight and airport operations. Infrastructure is organised in a network for the best usability of all stakeholders. The data quality and operational efficiency of European aviation infrastructure help industry to minimise risks and development costs and helps society to determine the impact of aviation in benefits such as fast transport as well as in penalties such as the impact on the atmosphere.

The days of duplication or multiplication of major aerospace test facilities are long gone, as shown by some good examples of the last few decades: (i) the joint Dutch-German aero-acoustic wind tunnel DNW; (ii) the joint British-French-German cryogenic pressurized wind tunnel ETW; (iii) the choice of CIRA to build an icing wind tunnel and an atmospheric re-entry simulation facility not existing elsewhere in Europe on a comparable scale. The rationalization of smaller-scale test facilities has diminished duplication and it may be time to look at updates, upgrades and new needs.

There is large-scale co-operation in science, code development and high-power computing. The main topics of this include:

- Improved and validated fluid dynamics, aerodynamic control, combustion, noise and thermal modelling based on high-performance computation, covering all needs for the aircraft and its engines, external and internal.
- Methods and tools facilitating the evaluation of aircraft and engine configurations.
- Results from the demonstration, allowing to assess not only improvements in vehicle development but also to verify and validate new modelling techniques.

A European aeronautical facility programme would logically consist of the following steps:

- List by industry and certification authorities of the test facilities needed for the foreseeable future and their appropriate specifications;
- comparison with the inventory of existing facilities in Europe to identify the needs (i) already met; (ii) to be met by upgrades or (iii) requiring new facilities;
- To devise a funding and implementation plan, associating each test facility with one or more technology clusters (section 6.2).

6.4 Young Talent and Women in Aviation

*Flightpath 2050 goal 23: Students are attracted to careers in aviation. Courses offered by European universities closely match the needs of the aviation industry, its research establishments and administration and evolve continuously as those needs develop.

The aviation community is committed to lifelong learning and continuous education thus promoting interest in the sector and stimulating innovation. Europe's students are attracted to careers in aviation and perform highly. Courses offered by European Universities are academically challenging and adapted continuously to support and match the evolving needs of the sector research (establishments) and administrations. **Educational policies across the EU motivate students to pursue further studies in science, technology and mathematics to ensure a steady supply of talent for a first-class workforce**. The aviation community engages actively with European students from the earliest age. Higher education is based on the adaptation of curricula based on the evolution of knowledge, language and (soft) skill requirements derived from ICAO. The curricula are designed based on a common understanding of the balance between multi-disciplinary and in-depth knowledge, such as, for example, common language recommendations, the T-shaped professional and the Conceive-Design-Implement-Operate (CDIO) philosophy. This ensures that **scientists of the future are capable of integrating interdisciplinary skills of a technological, human and social nature**. Also, more detailed requirements such as the inclusion of a flight test, hands-on experience, and a minimum amount of essential, aeronautics related knowledge are included.

The aviation sector in Europe will need a vast pool of human resources (Key Topic T6.3). The distribution by tasks may be comparable in Europe and the United States (Key Topic T6.4).

The European Parliament called on the Commission to provide **more support in FP9 'for young researchers,** such as pan-European networking tools and to reinforce funding schemes for early-stage researchers with less than two years of experience after PhD completion.

KEY TOPIC T6.2 – HUMAN RESOURCES NEEDED BY THE AERONAUTICAL SECTOR IN EUROPE

Goal 23 – Young talent and women in aviation is mentioned and analysed by several key institutions in the field of aeronautics, as presented in the following.

Flightpath 2050 - Goal 23:

"Students are attracted to careers aviation. Courses offered by European universities closely match the needs of the aviation industry, its research establishments and administration and evolve continuously as those needs develop. Lifelong and continuous education in aviation is the norm."

The attraction of young talent to aviation can be enhanced by:

- Demonstrating the progress in aerospace vehicles of all types: airliners, helicopters, fighters, launchers, satellites, rockets and drones;
- The availability of a dynamic and rewarding marketplace
- Highlighting the multidisciplinary nature of aerospace engineering as a synthesis of advanced technologies with working opportunities throughout Europe.

The pool of young talent can be enlarged by promoting greater participation of women in aviation through the dissemination of opportunities and successful case histories.

The EU is **approaching gender balance among doctoral students**. Overall, in 2016, women made up 47.9 % of doctoral graduates at the EU level, while in two-thirds of EU Member States the proportion of women among doctoral graduates ranged between 45 % and 55 %". Nevertheless, as shown by the data in Table 6.7, the proportion of women among doctoral graduates still varies among the different fields of education; in 2016, women doctoral graduates at EU level were over-represented in education (68%), but **under-represented** in the field of information and communication technologies (21 %) and the **fields of engineering** and manufacturing and construction (29 %). [5]

Country	Education	Arts and humanities	Social sciences, journalism and information	Business, administration and law	Natural sciences, mathematics and statistics	Information and Communication Technologies	Engineering, manufacturing and construction	Agriculture, forestry, fisheries and veterinary	Health and welfare	Services
EU-28	68	54	54	48	46	21	29	59	60	41
BE	68	44	61	47	38	0 (0/16)	32	62	63	83 (5/6)
BG	67	61	54	54	53	56 (10/18)	37	51	55	30
CZ	66	51	51	47	46	8	27	55	52	22
DK	-	53	54	-	37	-	32	61	63	-
DE	68	53	54	38	42	15	19	65	59	57
EE	82 (9/11)	79	57	68 (13/19)	54	13 (2/16)	36	55 (6/11)	64 (7/11)	-
IE	62	55	60	48	45	28	28	43	58	0 (0/1)
EL	72	55	54	37	58	14	36	37	52	63
ES	58	53	50	43	53	22	39	52	64	39
FR	60	59	50	52	43	27	32	-	51	30
HR	52	56	59	61	68	22	33	57	63	27 (3/11)
IT	81	58	60	51	53	25	37	59	64	-
CY	100 (7/7)	75 (6/8)	80 (12/15)	50 (6/12)	63	0 (0/4)	35 (6/17)	-	67 (2/3)	-
LV	63 (5/8)	87	65	55	53	25 (2/8)	38	33 (2/6)	83 (15/18)	100 (1/1)
LT	75 (12/16)	62	68	65	52	0 (0/6)	33	72 (13/18)	75	-
LU	40 (2/5)	64 (7/11)	68 (13/19)	31 (4/13)	50	16 (3/19)	7 (1/14)	-	-	-
HU	55	51	50	56	45	14	27	51	57	21 (3/14)
MT	-	50 (4/8)	0 (0/2)	0 (0/1)	40 (4/10)	0 (0/1)	33 (2/6)	-	56 (5/9)	-
NL	-	45	:	:	36	:	27	50	59	-
AT	76	53	54	47	38	17	26	54	58	36 (4/11)
PL	84	55	57	47	55	10	42	62	67	44
PT	71	51	63	48	62	28	37	64	74	51
RO	72	60	60	58	66	43	38	51	60	40
SI	84	69	72	67	60	24	32	56	72	37
SK	71	57	57	48	64	12	31	67	62	42
FI	74	59	68	53	49	18	32	63	63	47 (8/17)
SE	73	55	56	41	41	24	28	57	61	33 (3/9)
UK	67	51	51	43	46	24	26	57	59	-
IS	100 (3/3)	62 (8/13)	100 (3/3)	50 (2/4)	37 (7/19)	0 (0/1)	67 (6/9)	100 (1/1)	84 (16/19)	-
NO	64	58	64	49	40	15	27	56 (9/16)	61	38 (6/16)
CH	61	53	58	39	40	15	27	76	57	-
MK	70 (7/10)	64	25 (2/8)	65	53 (8/15)	17 (1/6)	32	71 (5/7)	60	50 (1/2)
RS	63	66	58	34	62	50	42	53	66	17
TR	54	40	42	40	52	44	36	36	69	34
IL	67	52	61	57	48	23	26	53	80	-

Table 6.7 Proportion (%) of women among doctoral graduates by broad field of study, 2016 [5].

More specifically, in 2017 at the EU level, women represented 53.1 % of the persons with tertiary education who were employed as professionals or technicians. In contrast, in science and engineering, women in the EU-28 were still a minority as they made up only 40.8 % of people employed as scientists or engineers.

Many European women are excelling in higher education, and yet, women represent only a third of researchers.

As they moving up the academic ladder, women are less represented. In the EU-28 in 2016, women represented 48% of doctoral students and graduates, 46% of grade C academic positions, 40% of grade B and 24 % of grade A academic position. The gap between women and men was wider in STEM (science, technology, engineering and mathematics); while women made up 37% of doctoral students and 39% of doctoral graduates, they held only 15% of grade A academic position. [5]

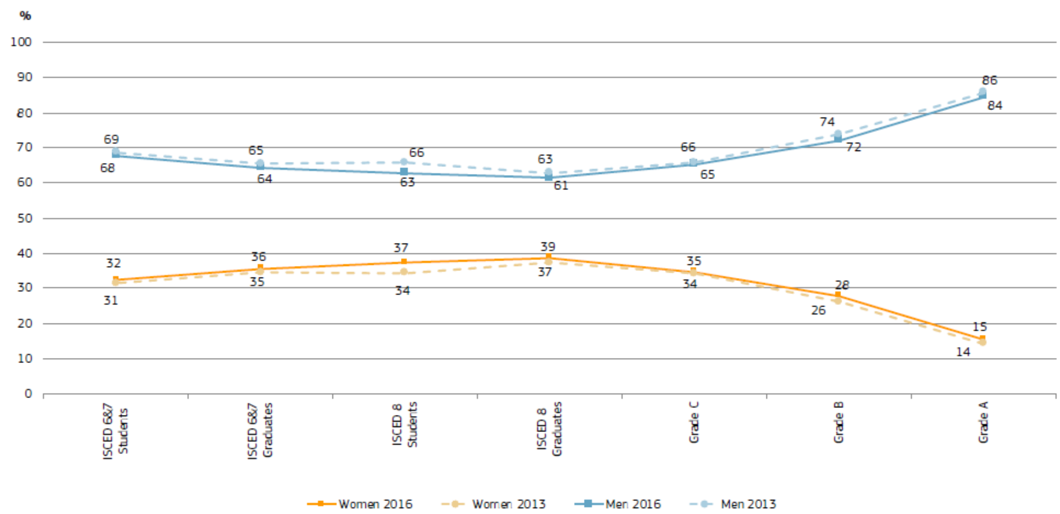


Figure 6.12 Proportion (%) of men and women in a typical academic career in science and engineering, students and academic staff, EU-28, 2013-2016 [5]

The best form of alignment of university courses with the needs of industry and research establishments is the joint research activities that point to the same future and link academic staff to the places where their students are going to be employed, creating synergies and longer-term links.

The cooperation among the IMT, EREA and PEGASUS in general and the technology clusters are further elements in the alignment of education, research and industry.

2017 SRIA

The SRIA challenge relevant for Goal 23 is dedicated to Infrastructure and Skills – aiming to ensure the preservation of Europe's research infrastructure requirements and encourage a sustained flow of competent, trained and motivated people.

ACARE has laid down the plan to establish a" fully integrated European aviation education system which will deliver the required high-quality workforce, with the skills and the motivation to be able to meet the challenges of the future. This requires a harmonised and balanced approach covering the entire scope from attracting talents over primary and secondary education to apprenticeship, academia and lifelong professional development". ACARE settles three action actions relevant for this analysis, indicated in Table 6.4:

- Action Area 5.6 – Provide world-leading education in aviation;

- Action Area 5.7 – Stimulate the involvement of stakeholders in education;

- Action Area 5.8 – Make aviation attractive to ensure inflow into educational programmes.

Action Areas	Target State 2050	Desirable Progress
5.6 - Provide world-leading education in aviation	European aviation education is world-leading, providing excellent support to the aviation sector. Programmes are harmonised with European accreditation schemes and a chartered aerospace engineer qualification.	By 2025, the means for harmonisation across European aviation education should be defined, with implementation following shortly after. European accreditation should be in place in 2035. As well, the qualification of the chartered aerospace engineer should also be available.
5.7 - Stimulate the involvement of stakeholders in education	Industry and research establishments are fully involved in educational programmes ensuring that students are better prepared for an aviation career. Industry is reaping substantial benefits from this collaboration, which extends to apprenticeships and life-long learning.	Internships, placements and subject matter for masters and doctoral students; staff exchanges; a greater number of industry-funded university chairs
5.8 - Make aviation attractive to ensure inflow into educational programmes	The image of the aviation sector is positive and attractive. A sufficient number of people flow into the educational programmes and choose an aviation career. This supports European aviation as a world leader.	Awareness programmes for schools should be in place from 2020 onwards By 2025 there should be a system of grants for outstanding students who wish to join aviation programmes from within and beyond Europe. A European XPRIZE in aviation should also be organised in 2025.

Table 6.8 Status relative to the ACARE Goal 23.

Analysing the scope in both Flightpath 2050 and SRIA it can be stated that both proposals are coherent and SRIA is complementary to the FP 2050. SRIA analyses several keys aspects and areas to be promoted until 2050. We can highlight the following:

- **Ensure a large inflow of talent into aviation educational programs:**
    - From primary through secondary to high education;
    - Attract talent from outside Europe;
    - Attract people from other sectors to pursue a career in aviation

   - Outreach to the general public.
- **Retain professionals at a later stage** – keeping them motivated and updated in terms of knowledge and skills.
- **Gender balance** – attract female students and encourage greater participation of women in conferences, events and competitions, not only to increase numbers, but mainly to bring new talents.

In terms of measures to be taken, the following are highlighted:

- **Implementation of awareness programmes:**
   - Careers must be visible attractive and progressive, with LLL possibilities and flexibility to change disciplines inside the sector.
- **Organisation and promotion of scholarships, grants and prizes;**
- **Promote diversity in types of education and training:**
   - Degree programmes must be interesting, appealing, of high quality and supported by modern facilities. Harmonised curriculum; Europe-wide standard for aviation education; Links with outstanding education institutes worldwide.
   - Professional education and re-training opportunities should be available on-line and on-site.
   - Include in the programmes the 21st Century skills – problem-solving, critical thinking and creativity.

ICAO also addresses the shortage of skilled aviation professionals. In 2009, ICAO also strongly addressed the shortage of skilled aviation professionals. The analyses made at that time highlighted that:

Statistics

- In the next 20 years, airlines will have to add 25,000 new aircraft to the current 17,000-strong commercial fleet.

- By 2026, 480,000 new technicians **will be needed** to maintain these aircraft and over 350,000 pilots to fly them.

- Between 2005 and 2015, 73% of the American air traffic controller population is eligible for retirement.

The underlying problem **was presented and simply stated in the following way:** "the demand for aviation professionals will exceed supply".

Factors that explain it include:

- **wholesale retirements in the current generation of aviation professionals;**
- **aviation professions not attractive enough to potential candidates;**
- **competition with other industry sectors for skilled employees;**
- **training capacity insufficient to meet demand;**
- **learning methodologies not responsive to new evolving learning style;**
- **accessibility to affordable training;**
- **lack of harmonization of competencies in some aviation disciplines, and**
- **Little awareness by the "next generation" of types of aviation professions available.**

Employment of aerospace engineers is projected to grow 2 percent from 2018 to 2028, slower than the average for all occupations[3]. Aircraft are being redesigned to cause less noise pollution and have better fuel efficiency, which will help sustain demand for research and development. Also, new developments in small satellites have greater commercial viability. Growing interest in unmanned aerial systems will also help drive

[3] Data do not take into account the effects of the crisis due to COVID-19.

growth of the occupation. However, growth in research and development activities will be tempered by a projected decline in employment of aerospace engineers in the manufacturing industry (Figure 6.13)[4]

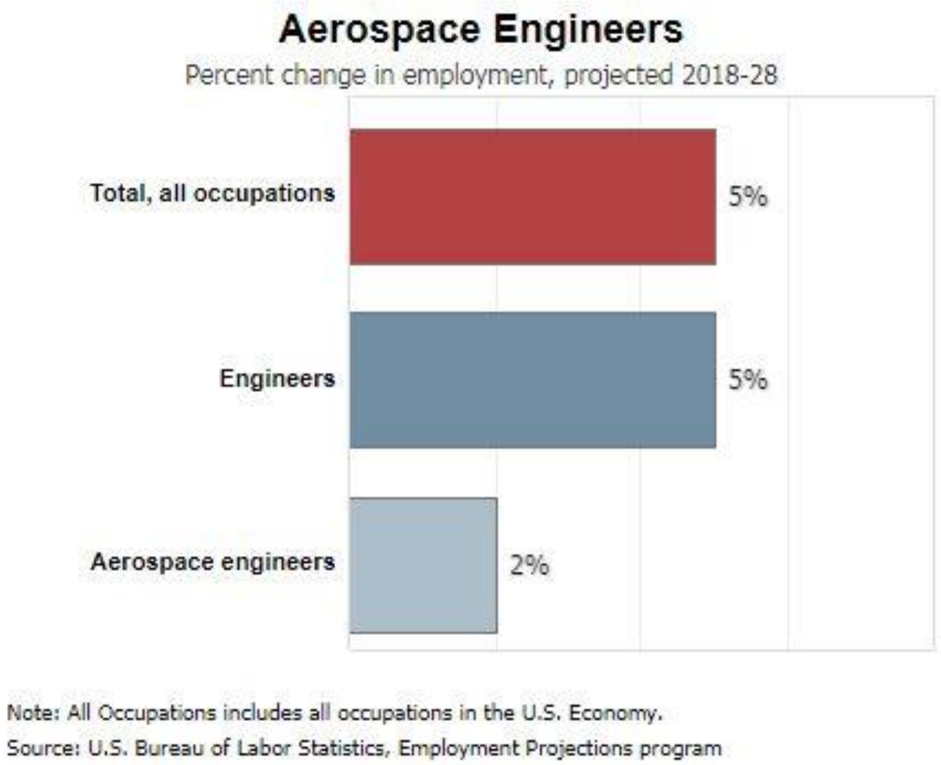


Figure 6.13 Growth for aerospace engineers in the years 2018-2028

ICAO stated then that solutions should be globally harmonized in nature and include human resource planning tools, accredited training and educational programmes adapted to the next generation, and wide-ranging cooperation among concerned stakeholders. Therefore, ICAO established the **Next Generation of Aviation Professionals Taskforce (NGAP)**, consisting of 29 representatives from industry, education and training providers, regulatory bodies and international organizations. Near-term objectives define included to inventory human resources planning data; identify and support initiatives to reach out to the next generation; and, find ways to harmonize training regulations. The Task Force also envisaged supporting initiatives relating to the next generation of aviation professionals.

The NGAP initiative was "launched to ensure that enough qualified and competent aviation professionals are available to operate, manage and maintain the future international air transport system. This is critical as a large contingent of the current generation of aviation professionals will retire, access to affordable training and education is increasingly problematic, and aviation competes with other industry sectors for highly skilled professionals. The lack of harmonized competencies in some aviation disciplines and a lack of awareness by the 'next generation' of the types of aviation jobs available further compounds the problem".

Under this initiative, several actions are in place, as presented in Figure 6.14:

[4] https://www.bls.gov/ooh/architecture-and-engineering/aerospace-engineers.htm#tab-6

NGAP actions timeline from 2009 to 2016

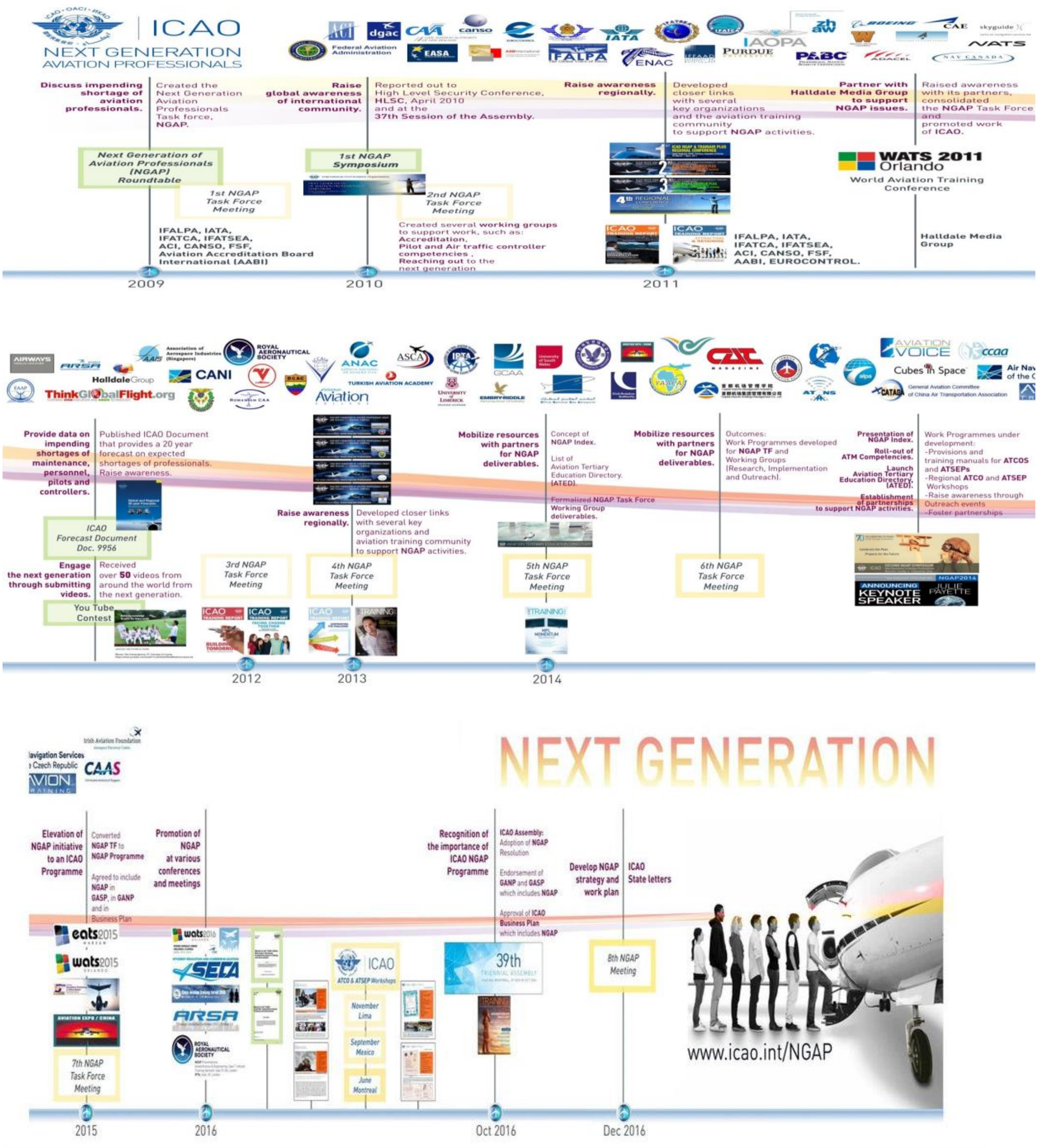


Figure 6.14 NGAP timeline New generation of Aviation Professionals task force.

As for the recent NGAP developments/actions by NGAP (2016 – 2017), we can mention the following:

- Established as ICAO Programme, inclusion in GANP & GASP, Assembly Resolution;
- Outreach activities and communications including:
    - Website; Newsletters; Training Reports.
    - Inclusion in Global and regional training conference programmes.
    - Collaboration with IPTA to promote best practices for pilot careers.

- Supported Dream Soar Initiative.
- NGAP Global Summit & Model ICAO Forum.
- New Fundamentals of the Air Transport System course.
- New Aviation Training and Education Directory.
- Updated aviation personnel forecasts
- New CBT manuals and regional workshops

In 2018 the International Civil Aviation Organization (ICAO) began to call for applications to the 2019 Young Aviation Professionals Programme (YAPP). The Programme, which is managed under ICAO's leadership, is a joint initiative with the International Air Transport Association (IATA) and Airports Council International (ACI). It provides a unique professional development opportunity; the candidates contribute to one or more of ICAO's Strategic Objectives under the mentorship of an ICAO subject-matter expert. Focusing on the inter-relationships between the work of ICAO and that of the airline and airport industries, they will also work in close collaboration with IATA and ACI experts.

Furthermore, in December 2018 ICAO welcomed a new **International Association of Aviation and Aerospace Education** the **ALICANTO** initiative as filling an important gap in air transport's global cooperation framework, through the collaboration of six respected international aerospace universities: Beihang University in China, Ecole Nationale de l'Aviation Civil in France, Embry-Riddle Aeronautical University in the United States, McGill University in Canada, Moscow State Technical University of Civil Aviation in Russia, and the University of the Witwatersrand in South Africa. ALICANTO was registered as a non-governmental, non-sectarian, non-partisan and nonprofit organization in Montréal, Québec. McGill University's Institute of Air and Space Law was chosen as the association's domicile.

The agreement underscores the key importance today of the overall NGAP programme in bringing together States, educational and training institutions, United Nations organizations, industry and other actors to address existing and future aviation personnel shortages.

The partnering universities further recognized that their aligned participation and input is critical in order to identify and implement effective approaches to attract, educate and retain the next generation of aviation professionals. The network of education institutions would aim to collaboratively develop initiatives to attract and prepare the next generation, as well as play a leading role to create, publish, distribute, and promote educational programs that serve the needs of the aviation industry and support the education and training of the next generation of aviation professionals.

ALICANTO is supported also by the Chinese Society of Aeronautics and Astronautics (CSAA), the Aerospace College Alliance of Sino-universities (ARCAS), the Partnership of a European Group of Aeronautics and Space Universities (PEGASUS), the Romanian Aeronautical Association/European Aviation Institute and the Directorate General of Civil Aviation of Turkey.

Reference State in 2010

In 2010, the skills shortages were a forthcoming threat and worries about skills shortages were widespread at a global scale in aviation. Red flags were raised by ICAO, IATA, ACARE.

In Europe, clearly, there were no guarantees that it would be possible to keep up with the changing world in a way that allowed the maintenance or increase of its technological position, as the demand for professional engineers and technicians was expected to grow in all levels of the value chain. The majority of the worries about skills shortages were directed mainly at engineering-related careers. It is well known that the major demographic trend in Europe is characterised by an ageing population and declining younger age cohorts. In 2010, the industry employment was already assisting to a concentration of age structures in the middle age range (35-50 years) and experiencing lower recruitment rates of youngsters – in part due to longer education and training periods – but also due to broad use of early retirement schemes. This demographic tendency, in addiction with lower proportions of qualified young people who were (and are) choosing for mathematics, physics and engineering careers was (is) a concern for the aerospace industry, not only in Europe but in all mature industrialized economies. Europe AI also faces challenges posed by the emerging economies who accessed the aircraft market and are not confronted either with the problem of an ageing society nor a decreasing interest in STEM study programmes. The longstanding dimension of the declining labour supply is also heightened by the circumstance that regional mismatches in the labour market cannot easily be adjusted. Cultural, linguistic, and legal differences among European members challenge companies' desires to move work and employees between countries. It was clear the need for education and training to coordinate multiple cultural traditions and institutions and make them work across borders, to develop transparently and recognised training courses and graduates. It's also relevant to mention that for the European AI is difficult to take advantage of the global market for highly skilled employees, since European characteristics - less open societies and language barriers – make Europe, in general, less attractive than the US, and most Member States are more restrictive.

Nevertheless, and as mentioned above, the labour shortages on the engineering level are not only a European but also a US concern. In 2014, in a study made by GAO (US Government Accountability Office), the analysis found mixed evidence about a current or possible future shortage of aviation professionals. There has been a steady decline in the number of engineering graduates in the US since a peak in the mid-1980s, but as the USA can rely on immigrants, the situation there is different. Aerospace engineers experienced a low unemployment rate—the most direct measure of a labour shortage—and increases in employment suggested that a shortage may exist. Until 2010, around half of all engineers with PhDs in the US workforce under the age of 45 were foreigners. Data provided less support for a shortage of aircraft mechanics; while the occupation has had a low unemployment rate, both employment and earnings have stayed about the same, suggesting that demand for this occupation has not outstripped supply. Industry and government are taking some actions to attract and retain qualified individuals in these occupations, but employers GAO interviewed remain concerned about future needs. GAO found that most of these employers had some challenges hiring personnel with the skills employers were seeking at the wage they offered. Employers reported taking a variety of actions, but few were raising wages. Several US agencies—the Federal Aviation Administration (FAA) and the Departments of Defence (DOD), Education, Labour (DOL), and Veterans Affairs—developed programs that assisted individuals interested in aviation careers. For example, in the academic year 2011–2012, Education disbursed approximately $1.6 billion in federal grants to students majoring in related fields. Still, most employers and stakeholders stated that maintaining a qualified workforce was difficult (Figure 6.15), in part because of a perception that fewer people are interested in aviation careers.

Figure 6.15 Need for aviation professionals in the US.

Since then, some initiatives were already put in place. Workforce mobility assumed growing importance for European AI. National cluster units and the new European Aerospace Cluster Partnership (EACP) established opportunities to develop and expand transnational education and training programmes. The Hamburg Qualification Initiative (HQI), or the PEGASUS (Partnership of a European Group of Aeronautics and Space Universities) are examples of successful transnational cooperation. The HQI has established an exchange in the field of training between the aviation clusters of Hamburg and the French aerospace valley of the regions Midi-Pyrénées (Toulouse) and Aquitaine (Bordeaux). The programme has evolved from the exchange of trainees to integrated transnational vocational training courses. The PEGASUS alliance created with the purpose to optimise the higher education services offered in the best interest of Europe both in terms of continuing to attract the best students and also to offer highly relevant educational and research programmes, also evolved to include also an industry and research alliance is also pursuing the interest to promote excellence and recognition seal of European aerospace Universities.

Data on higher education choices for Aerospace engineers from The Department of Education and Census Bureau show (Figures 6.16 and 6.17) that the most common major for Aerospace engineers is Engineering[5].

[5] https://datausa.io/profile/soc/aerospace-engineers

Figure 6.16 Most common major for Aerospace engineers in 2017 and 2018 (bachelor degree)

Figure 6.17 Most common major for Aerospace engineers in 2017 and 2018 (master degree)

As it concerns the skills required to aerospace engineers, data on the critical and distinctive skills necessary for Aerospace engineers from the Bureau of Labor Statistics, show that the most required skills are Science, Reading Comprehension, and Operations Analysis. The revealed comparative advantage (RCA) shows (Figure 6.18) that Aerospace engineers need more than the average amount of Science, Technology Design, and Operations Analysis.

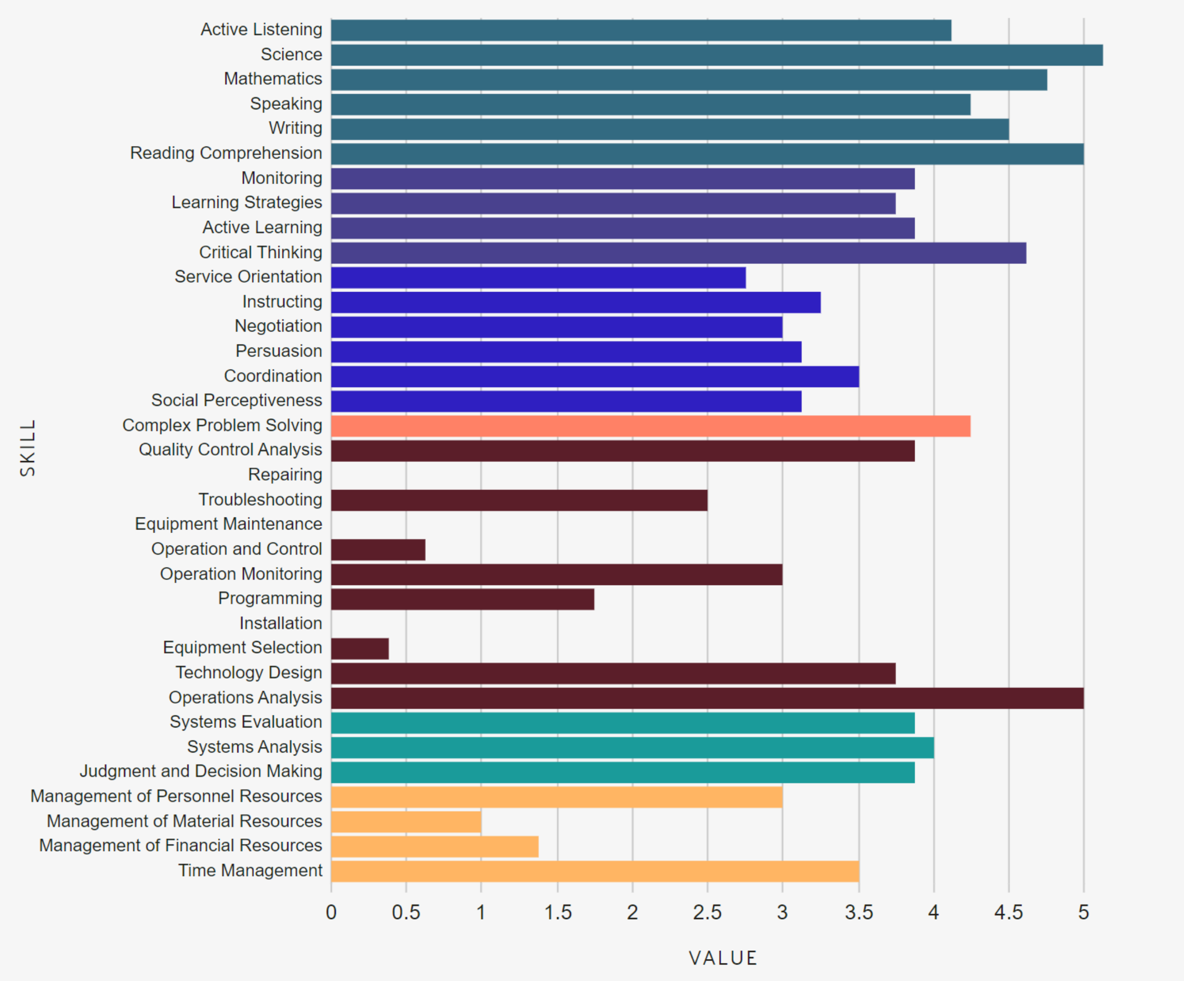


Figure 6.18 Most common skills for Aerospace engineers.

Present Status

The skills shortage is no longer a looming threat; it is a stark reality that many countries are facing.

In fact, U.S. airlines are in the early stages of a pilot shortage that could boost labour costs and even constrain growth. "Kids, get your pilots licenses because this could be the career of the 2020s and 30s" was published on LinkedIn.

The pilot profession is highly regulated to drive a high level of safety, with laws dictating the level of experience and proficiency a pilot must acquire before flying a commercial aircraft, as well as when and how a professional pilot may work. This constrained environment has always made it difficult for the industry to meet the ebbs and flows of demand. New regulations further constrain the availability of new pilots. Now, as demand for air travel grows rapidly many aviation insiders see the number of pilots in training and the future demand for commercial pilots diverging.

Leading airline executives are considering a new approach to the problem by forming partnerships with operators, training providers, and even regulators to shape the pipeline of pilots in training. New regulations introduced in 2013 make commercial airlines dependent on a set of aviation segments that provide the necessary experience but that are not elastic to growth in demand by the airlines and other career-employment companies. Even a perfectly efficient system could only provide the experience required for two-thirds of the pilots needed in the U.S. Further, the supply of military pilots will likely continue to shrink as military branches roll out programs to incentivize pilots to stay longer. As the pilot career pipeline becomes constrained, the commercial airline industry's demand for pilots is rising. Oliver Wyman's 2016-2026 Global Fleet & MRO Market Forecast expects the number of commercial aircraft in service in the U.S. to rise 7.7% during the next 20 years to 8,067. The forecast expects the number of commercial aircraft in the global fleet to rise 40% to 34,437 aircraft.

Boeing estimates U.S. airlines will demand about 95,000 pilots in the next 20 years as shown in Figure 6.19. Europe is expected to need 95,000 pilots, and Asia will likely need 226,000.

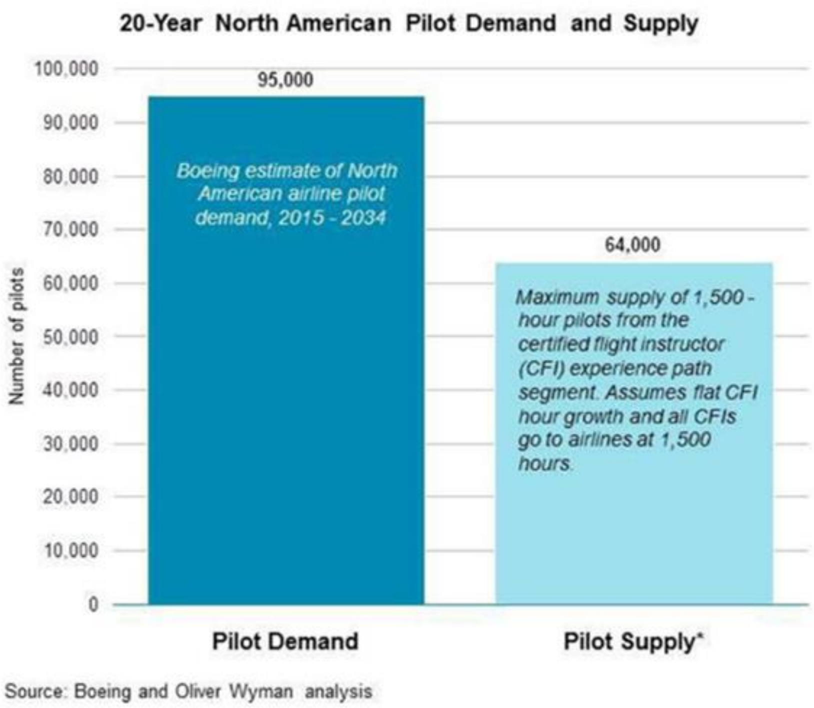


Figure 6.19 Forecast Pilot demand and supply in the next 20 years

Source: https://www.forbes.com/sites/oliverwyman/2016/01/28/pilot-shortage-threatens-to-slow-u-s-airline-growth/#67a9eb1f6b4f

Airline operators can follow several philosophies on managing the pilot pipeline. They must consider strategies to recruit pilots in a more competitive and constrained environment. This could entail developing programs with vocational or collegiate flight schools, developing more formalized feeder programs with regional partners, or financing the next generation of qualified pilots. However, these options are also costly. All pilot categories, except for rotorcraft only certificates, continued to increase. The number of student pilots increased from 72,280 in 2009 to 119,119 in 2010. By 2016, they totalled 128,501 and with no expiration of certificates jumped to 149,121 by the end of 2017. The number of active general aviation pilots (excluding students and ATPs) is projected to decrease about 22,600 (down 0.4%) over the forecast period. The ATP category is forecast to increase by 22,600 (up 0.7% annually). The much smaller category of sport pilots is predicted to increase by 3.3% annually over the forecast period. On the other hand, both private and commercial pilot certificates are projected to decrease at an average annual rate of 0.8 and 0.5 per cent, respectively until 2038 (Figure 6.20).

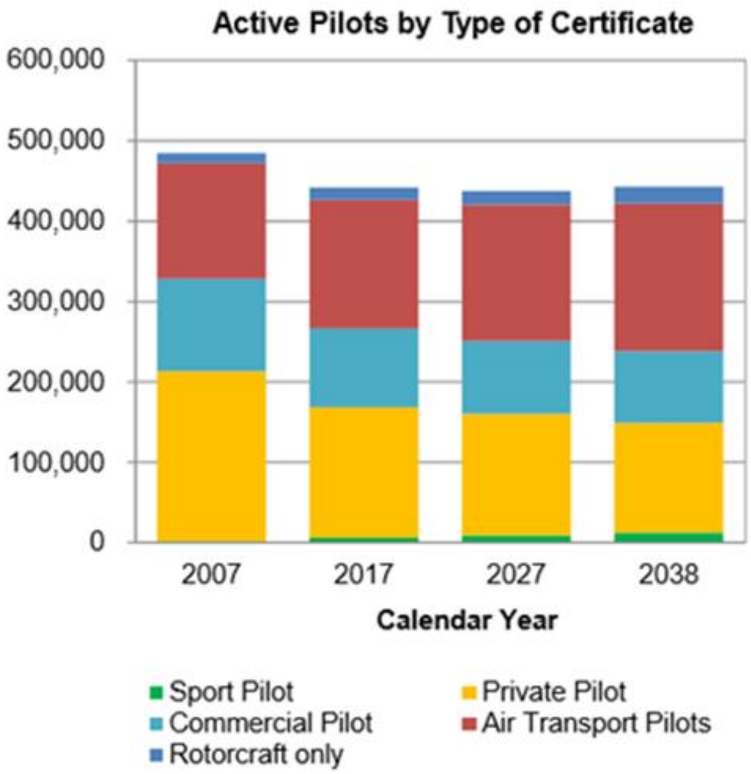


Figure 6.20 Forecast of private and commercial pilot certificates
Source: Forecast FAA 2018-2038

The industry must attract qualified engineers and skilled blue-collar workers, as well as pilots and technicians. However, the attraction of young talent to aviation has been enhanced by demonstrating the progress in aerospace vehicles of all types: airliners, helicopters, fighters, launchers, satellites, rockets and drones; and highlighting the multidisciplinary nature of aerospace engineering as a synthesis of advanced technologies with working opportunities throughout Europe. The pool of young talent has been enlarged by promoting greater participation of women in aviation through the dissemination of opportunities and successful case histories. The best form of alignment of university courses with the needs of industry and research establishments is the joint research activities that point to the same future and link academic staff to the places where their students are going to be employed, creating synergies and longer-term links. Over the coming decades, hundreds of thousands of new pilots, air traffi controllers, maintenance professionals and other skilled workers and managers will need to be recruited, and women in aviation, both young and old, will be critical to how effectively aviation meets these challenges. Part of the solution to achieve this goal is ensuring that girls and women are better aware of the personal and professional growth opportunities, which await them in the aviation sector.

For example, United Airlines launched a new program to recruit, train, and hire pilot candidates, taking a major step to address the looming pilot shortage, signing an agreement to purchase the Westwind School of Aeronautics in Phoenix, Arizona, and would integrate it as a key extension of its Aviate pilot development program. The Aviate program was launched as a recruitment and development program, offering a direct track to a job with the mainline airline for pilots in training. It is a primary training flight academy, it takes people with zero hours and builds them all the way up to the professional pilot credentials that are required to become an instructor, and eventually, an airline pilot. And during the course of that training, they get seven FAA certifications.

INITIATIVES WORLDWIDE TO ATTRACT YOUNG TALENT TO AEROSPACE

The "Australian Youth Aerospace Association" (www.ayaa.com.au) is composed and animated by young students from Aerospace and organises a set of activities that aim to engage and attract youth to aerospace-related careers. Among the different initiatives, the following ones can be evidenced:

- Aerospace Futures: a 3 days conference dedicated to exposing university students to opportunities in the aerospace industry. In this conference, students have the opportunity to be aware of the latest developments in AI; to better know the organisations involved in AI; to discover job opportunities in AI.
- AYA Forum: is a 5 days interactive conference dedicated to secondary students that aim to showcase the Aerospace Industry. Through this forum, students have the opportunity to gain a clear understanding of the pathways available for them after high school.
- RocketProjet: this action allows students to become rocket engineers for a day. It showcased both the theoretical and practical applications of modern rocketry.
- Australian Undergraduate week: a 5 days event is organised and includes hands-on space engineering activities; dissemination of PhDs and internships activities.

Women

The National Aeronautics and Space Administration (NASA) in the United States has two programmes that focus on attracting female talent. Through the NASA / Girls Scouts of the USA partnership, NASA scientists provide training sessions, led by NASA scientists, for girl scouts. Some 100 000 girls have participated in these sessions until May 2016. Under the "NASA G.I.R.L.S" programme, female NASA professionals provide online lessons in STEM fields to girls selected through a competitive process. Surveyed countries support many other programmes that foster interest in STEM careers, but these are not specifically targeted to women. Some countries also support initiatives to attract interest among male students in female-dominated professions. Germany, for example, funds a nation-wide network and information platform to support gender-sensitive career and life orientation for boys through the programme "New Paths for Boys and Boys' Day". The programme provides information and material to education and social work professionals, career advisers, human resource teams, education and training specialists, and parents. Nationwide conferences and meetings are also planned to facilitate exchanges between researchers and practitioners, as for example National Women in Engineering Day organized by the Women's Engineering Society (WES), a charity and a professional network of women engineers, scientists and technologists offering inspiration, support and professional development. It encourages the education of engineering and helps and support companies with gender diversity and inclusion, as well as achieve a diverse and inclusive workforce.

The aerospace and defence sector is characterized by strong volume growth with an estimated production of 25,000 aircraft in the next 20 years. That's why, the industry must attract qualified engineers and skilled blue-collar workers, as well as pilots and technicians*. According to Alix Partners (It's All About People, The Battle for Talent in the Aerospace and Defence Industry, January 2013)* European aerospace and defence industry is expected to require at least 12 500 engineers yearly[6]. The demand for highly skilled people is expected to increase dramatically. For example, the number of U.S. jobs that require complex interactions involving a high level of judgement has grown three times as fast as employment in general.

The International Civil Aviation Organization (ICAO) estimates that 350 000 new pilots and 480000 new technicians will be needed to keep these planes operational[7].

[6] https://legacy.alixpartners.com/en/Publications/AllArticles/tabid/635/articleType/ArticleView/articleId/ 466/Its-All-About-People.aspx

[7] https://icao.int/Newsroom/Pages/ICAO-Addresses-Shoortage-of-Skilled-Aviation-Professionals.aspx

CURRENT SITUATION

Europe

According to the Aerospace and Defence Industries Association of Europe (ASD), the figures for employment in 2015 - 2018 are the following (Table 6.9)[8] [6]:

	2015	2016	2017	2018
Employees in Aeronautics	551,000	543,000	559,000	561,000
Employees in Space	38,000	40,400	42,700	43,450

Table 6.9 Employment in Aeronautics and Space

The distribution by tasks is comparable in Europe and the United States. More detailed statistics are available from the United States Department of Labour, Bureau of Labour Statistics (Table 6.10 and Table 6.11).

HOUSEHOLD DATA- ANNUAL AVERAGES
Employed persons by detailed industry, sex, race, and Hispanic or Latino ethnicity
[Numbers in thousands]

Industry	2019					
	Total employed	Percent of total employed				
		Women	White	Black or African American	Asian	Hispanic or Latino
Air transportation	656	41.2	67.9	20.0	7.2	14.1
Aircraft and parts manufacturing	813	25.4	78.4	9.0	10.0	12.9
Aerospace product and parts manufacturing	54	29.6	87.5	5.6	6.1	11.1

Table 6.10 Aviation Employment in the US

Source: https://www.bls.gov/cps/cpsaat18.htm

[8] Aerospace and Defense Industries Key Facts Figures 2016, 2017, 2018 and 2019.

CATEGORY	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Pilot--Total	**52'740**	**46.463**	**42.694**	**39.187**	**39.287**	**39.322**	**39.621**	**40.621**	**41.316**	**42.218**	**36.808**
Student 1/	27'255	22.266	19.219	15.971	14.580	14.369	14.405	14.643	14.683	14.767	8.450
Recreational (only)	7	10	14	15	16	16	17	16	18	12	13
Sport	254	240	229	223	211	192	174	152	135	118	98
Private 2/	10'683	10.255	9.971	10.009	11.339	11.652	11.909	12.456	12.927	13.566	14.322
Commercial 2/	7'038	6.556	6.267	6.081	6.587	6.685	6.911	7.536	7.956	8.175	8.289
Airline Transport 2/	7'503	7.136	6.994	6.888	6.554	6.408	6.205	5.818	5.597	5.580	5.636
Pilot Total w/o Student Category 1/	**25'485**	**24.197**	**23.475**	**23.216**	**24.707**	**24.953**	**25.216**	**25.978**	**26.633**	**27.451**	**28.358**
Flight Instructor Certificates 4/	**7'957**	**7.335**	**7.105**	**6.848**	**6.669**	**6.521**	**6.386**	**6.371**	**6.350**	**6.359**	**6.362**
Remote Pilots 6/	**10'818**	**6.188**	**3.462**	**793**	N/Ap	N/Ap	N/Ap	N/Ap	N/Ap	N/Ap	N/Ap
Non-Pilot--Total	**215'905**	**203.725**	**195.993**	**187.914**	**183.259**	**174.000**	**166.294**	**160.452**	**155.918**	**150.019**	**147.052**
Mechanic 5/	7'573	7.133	6.855	6.536	8.419	8.151	7.917	7.729	7.487	7.215	6.980
Repairmen 5/	1'996	1.868	1.847	1.822	2.289	2.278	2.288	2.307	2.278	2.312	2.335
Parachute Rigger 5/	681	631	597	540	811	763	712	697	683	655	633
Ground Instructor 5/	5'340	5.085	4.924	4.772	5.907	5.889	5.869	5.853	5.880	5.894	5.860
Dispatcher 5/	4'389	4.086	3.867	3.615	4.503	4.326	4.115	3.930	3.744	3.530	3.381
Flight Navigator	0	0	0	1	1	1	1	1	1	1	1
Flight Attendant	194'578	183.519	176.471	169.170	159.703	150.941	143.701	138.223	134.114	128.646	126.034
Flight Engineer	1'348	1.403	1.432	1.458	1.626	1.651	1.691	1.712	1.731	1.766	1.828

Table 6.11- Estimated Active Women Airmen Certificates Held December 31, 2007-2016.

Source: Excel file 2016-civil-airmen-stats_US Dep of Transportation
https://www.faa.gov/data_research/aviation_data_statistics/civil_airmen_statistics/

Note: The term airmen include men and women certified as pilots, mechanics or other aviation technicians. This table (Table 2) represents data for females only. Data in the Pilot Categories does not directly correspond to the same category in Table 1 as glider and/or helicopter and/or gyroplane certs are not broken out separately. Data in the Non-Pilot Categories, as well as Flight Instructor Certificates, does directly correspond to the same category in Table.

- *1 / In July 2010, the FAA issued a rule that increased the duration of validity for student pilot certificates for pilots under the age of 40 from 36 to 60 months. This resulted in an increase in active student pilots to 14,767 from 8,450 at the end of 2009.*
- *2 / Includes those with an airplane and/or a helicopter and/or glider and/or a gyroplane certificate.*
- *3 / Glider and lighter-than-air pilots are not required to have a medical examination.*
- *4 / not included in the total.*
- *5 / historically, numbers represented all certificates on record. No medical examination required. In 2016, Federal Regulation required that airmen without a plastic certificate no longer considered active. Therefore, starting with 2016, those airmen with a paper certificate only were excluded.*
- *6 / Flight Attendants first reported in 2005.*
- *7 / Remote pilot certification started in August 2016. These numbers are not included in the pilot totals.*

NA Not available. Prior to 1995 repairmen were included in the mechanic category. Recreational certificate first issued in 1990. Sport certificate first issued in 2005

Potential Solutions

Potential solutions may be:

1. **Recruiting more creatively** - improving the recruiting process by institutionalising close cooperation between industry and science to attract talents:
   - Airbus is using Twitter accounts to talk to potential recruits and is holding international recruitment days where candidates are quickly down-selected from several hundred applicants[9].
   - Rolls-Royce supports PhD students, 25% of the graduates are recruited and many more remain in the network[10].
2. **Acting globally** - companies globalise their activities to attract the largest pool of talent while similarly benefitting from lower cost and international work-sharing:
   - Boeing Design Centre in Moscow, to benefit from the local pool of talents[11];
   - Airbus innovation units in Bangalore and Delhi (India), to benefit from the local pool of talents[12].
3. **Improving the working environment** - companies focus on improving the working environment:
   - UTC Re-Empower Program supporting experienced professionals returning to work after a career break[13].
   - BAE Systems has created an "Assignment Panel", a clearinghouse of openings in the company, so employees do not need to leave to find new challenges[14].
   - Northrop Grumman has implemented highly structured rotation system where top talents spend their first two years on four rotations, supported by a mentor[15].
4. **Improving knowledge transfer** from experienced to young employees - companies actively seek opportunities to improve knowledge transfer from older to younger employees. They use rotation programs as a lever to transfer knowledge and systematically offer part-time work for older people (e.g. BAE Systems has established a very aggressive mentoring programme to ensure that knowledge is being passed down from one generation to another[16]).
5. Improving the number of college graduates who have studied science, technology, engineering and mathematics. A good example of that kind action, undertaken by an aviation company's cluster, is the Aviation Valley Association Education Support Foundation[17]. The foundation main goal is popularizing science and education, developing scientific interests as a means for attractive discoveries and experiences. Some of the most important actions and projects conducted by the foundation:
   - **The Children's Technical University** includes activities for primary school pupils. These include interactive lectures, conducted using scientific experiments, aid, and exhibits. The topics of the lectures are adjusted to the age of the pupils. Topics from the fields of chemistry, physics, mathematics, civil engineering, biology, aeronautics and every other scientific subject related to the Technical University. Classes are taught by academic staff,

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[9] http://www.industryweek.com/recruiting-retention/boeing-and-airbus-fight-hell-aerospace-engineers; access: December 2017

[10] http://www.indianexpress.com/news/airbus-plans-innovation-unit-in-india/967419; access: December 2017

11 http://www.boeing.com/news/frontiers/archive/2005/september/mainfeature1.html; access: December 2017

[12] http://company.airbus.com/careers/jobs-and-applications/vacancies-in-india.html; access: December 2017

[13] http://www.utc.com/Careers/Work-With-Us/Pages/ReEmpower_Program.aspx; access: December 2017

[14] Economist Intelligence Unit 2011, Talent strategies and the competitiveness of the US aerospace and defence industry, p. 8

[15] http://www.northropgrumman.com/careers/Students-Entry-Level/Pages/default.aspx; access: December 2017

[16] https://www.baesystems.com/en-uk/our-company/corporate-responsibility/working-responsibly/investing-in-our-people/diversity-and-inclusion/developing/perfect, access: December 2017

[17] https://dolina-wiedzy.pl/fundacja/; access: December 2017

industry specialists, students, and other institutions offering institutions. Actions are conducted full-time in Rzeszow, Mielec, Debica, Ustrzyki Dolne and part-time (The Travelling Children's Technical University).

- **Flying Physics Project** - demonstrative physics lessons for middle school pupils held a few times a month in selected schools with the approval of the respective principal. Teachers are grouped in two-person teams that are didactically and substantively prepared. During the demonstrations, scientific exhibitions are used that are used to confirm the theoretical material present during a multimedia presentation.
- **Suggestion Project** - demonstrative physics lessons held for teenagers of secondary schools. They are conducted twice a month in selected schools with the approval of the respective principal. A topic that combines physics and aviation are conducted by two teachers working in a team that have the knowledge and ideas for interesting lessons, which can be a great foundation of knowledge, and it serves as a way to better prepare for the Matura exam.
- **Company and science picnics -** The foundation participates in several scientific events, during which it presents scientific exhibitions. This called the experiment zone, in other words, experiment stations that can be used to conduct simple experiments with the help of organizers and volunteers. In the experiment zone, there are also play stations dedicated to young children.
- **CEKSO Operator Training Centre and CEKSO 2 project** - In 2005, the Aviation Valley Association established a program that intended to increase the accessibility of professions related to the aerospace industry. The task of CESKO was coordinating training in technical in the Subcarpathian Voivodeship to suit the realistic needs of industry and creating a world-class Operating Training Centres in the long term. Cooperating under the CEKSO framework permits more extensive analysis of issues regarding implementing: new production management tools, new production technologies, and continuous improvement tools. Practical Training Centres, in accordance with their statutes, educate young future employees by appropriating the forms and educational contents to the employment needs of Aviation Valley companies. The institutions also train adults in the form of courses to meet the needs of companies.

  In 2015 new actions, named CEKSO 2, were implemented. The main principle was shortening the adaptation period of professional graduates and increasing their skills to adapt to the ever-changing needs of the aerospace company through:
    - Modifying secondary school curriculums;
    - Creating motivators for teachers and students;
    - Preparing teaching staffs.

In conclusion, to maintain EU leadership in aviation, to reach a sustainability and safety aviation, it is important to eliminate the barriers to women's participation in the workforce.

Furthermore, with respect to aviation gender equality, a priority emphasized by ICAO Member States, the Secretary-General of ICAO Dr. Liu emphasized that while "air transport connects people, cultures and businesses across the globe, and strengthens socio-economic development worldwide, at the same time it has not been very successful at providing an open, inclusive working environment for women." She called on the airline CEOs to make gender parity a personal priority, stressing that it must be driven from the top in any organization, and highlighted ICAO's new Gender Equality[18]

[18] https://www.icao.int/Newsroom/Pages/FR/Priorities-for-security-environment-privatization-and-gender-parity-raised-as-ICAO-Secretary-General-addresses-IATA-AGM.aspx

Our recommendations for future actions will stress the importance of involving women at all levels and dimensions of aeronautics research and in STEM. One of the Flightpath 2050 goals states that "Students are attracted to careers in aviation", whereas today the situation is rather unbalanced between men and women.

Women's values in PARE project should be synthesized as follows: the common denominator to attracting young talent and steering women to STEM, inside and outside school is to change the mentality and philosophy of intuitions, starting since childhood.

Potential solutions at European level in an open, creative cooperation environment are recruiting more creatively, improving the working environment, improving the number of college graduates who have studied STEM.

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[5] EU Publication, She figures 2018, published first time March 2019, https://ec.europa.eu/info/publications/she-figures-2018_en

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