The PARE project: pre and post-covid-19 prospects

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Abstract. The Advisory Council for Aeronautical Research in Europe (ACARE) has provided guidelines for aeronautical research to the European Commission embodied in its Framework Programs and produced a Strategic Research and Innovation Agenda setting out the challenges for aeronautics in the coming decades. Specifically, the report Flightpath 2050 lists 23 goals organized into 5 groups. The main motivation for the project PARE - Perspectives for Aeronautical Research in Europe is to assess the progress towards each of the 23 ACARE goals, the gap remaining and to propose measures leading to their achievement. The project has formulated 35 PARE objectives supporting the 23 ACARE goals; they are collected together in a set of 58 Recommendations for Aeronautics Research in Horizon Europe (section 1). Among the chapters in the PARE yearly report is chosen as example that on emerging technologies relevant to aviation (section 2). The final 3rd year PARE report also addresses new issues that emerged after the start of the project, for example the effects of the covid-19 pandemic on aviation (section 3).

1. 58 PARE recommendations for aeronautics research in horizon Europe

The ACARE (Advisory Council for Aeronautical Research in Europe) [1] has provided guidelines for aeronautical research to the European Commission embodied in its Framework Programs. ACARE has produced a SRIA (Strategic Research and Innovation Agenda) [2] setting out the challenges for aeronautics in the coming decades. More specifically the report Flightpath 2050 [3] lists a set of 23 goals organized into 5 groups. The main motivation for the project PARE (Perspectives for Aeronautical Research in Europe) is to assess the progress towards each of the 23 ACARE goals, the gap remaining and to propose measures leading to their achievement. To 23 ACARE goals in five areas, the PARE project adds five supporting areas, leading to 35 PARE objectives that complement the 23 ACARE goals in a set of 58 Recommendations for Aeronautics Research in Horizon Europe.

The five areas grouping the 23 ACARE goals are: (i) meeting social and market needs; (ii) maintaining and extending industrial leadership; (iii) protecting the environment and the energy supply; (iv) ensuring safety and security; (v) prioritizing research, test facilities and education. The five supporting areas grouping the 35 PARE objectives are: (vi) long-range air transport and related markets; (vii) emerging aviation technologies; (viii) cooperation beyond Europe´s borders; (ix) attracting young talent to aeronautics; (x) increasing the participation of women. Each of these 10 areas is the subject of a chapter in an extensive background document, the PARE second Year Report, available on line at [4].

Each of the 58 PARE Recommendations for Aeronautics Research in Horizon Europe [5] has a similar structure consisting of eight elements: (a) statement: text of the ACARE goal or PARE objective concerned; (b) recommendation(s): one or several brief statement(s) of the action(s) to be taken; (c) rationale: current situation and future prospects motivating the recommendation(s); (d) stakeholders: institutions that could contribute to the implementation at academic, research, industrial, regulatory and operational levels in national and international contexts; (e) relevance: expected impact of the initiative; (f) priority: justification of the priory rating on a scale from three asterisks (top) to zero asterisks; (g) justification: reference to the section of the PARE report containing detailed supporting information. The few highest priorities are given to the issues that could have the greatest impact on the future of aviation in Europe. The more numerous lower priorities remain as essential contributions to the balance and completeness of the European aeronautical activity.

The 58 PARE recommendations have been classified in an hierarchy with 4 levels of priority. The present paper will illustrate the overall review of the PARE project with a brief mention of the recommendations with the highest priorities. The highest priority has been assigned to 4 out of 23 ACARE goals and 4 out of 35 PARE objectives, addressing: (i) the global competiveness of the European aeronautical industry, not only for long-range air transport, but also in other sectors where it leads (like helicopters) or lags (like drones); (ii) the challenges of airspace capacity and environmental impact that could become impediments to the future growth of aviation; (iii) the strengthening of institutional cooperation in aeronautical clusters covering all stages of development from basic research to product innovation and market penetration and operational utilization; (iv) the enhancement of safety and security through high certification and operational standards, that support the unique position of aviation as the safest mode of transport regardless of location on the globe.

The latest 2nd year version of the PARE report adds to the 1st report a first outline of two "What If ?" studies concerning two topics that could change the landscape of commercial aviation as we see it now: (i) the possible emergence of a middle-of-the-market aircraft (MMA) category, intermediate between the two main current categories short long-haul single/twin aisle small/large; (ii) the possible emergence of a strong Chinese or Sino-Russian aircraft sector and its implications for regional and global aircraft markets including the Airbus-Boeing duopoly. The What If? study on the MMA focuses on such issues as the current size of the market and the extent to which it could grow with the availability of more efficient aircraft for long thin routes that could expand with low cost carriers. The What If? Study on Chinese or Sine-Russian cooperation takes into account the magnitude of the internal market and its implications for the international market, it could consider the major role played by equipment suppliers (engines, systems, avionic (s) that account for a large fraction of the value of current aircraft, for different airframe integrators.

The main conclusions of PARE 2nd year report have been presented in a collection of articles accessible to the general public [6]. Each article addresses one chapter of the PARE second year report, in terms of key findings, conclusions and recommendations.

As an example are given next the 8 highest priority recommendations of PARE for Aeronautics in Horizon Europe.

1.1. ACARE Goal 1

ACARE GOAL 1: "An air traffic management system is in place that provides a range of services to handle at least 25 million flights a year of all types of vehicle, including unmanned and autonomous systems that are integrated into and interoperable with the overall air transport system with 24 hour efficient operation of airports. European air space is used flexibly to facilitate reduced environmental impact from aircraft operations."

Recommendation***: A broad and deep research effort must be maintained concerning all aspects of Air Traffic Management (ATM) that can contribute to increase airspace capacity with equal or greater safety.

Rationale: The growth of air transport puts increasing demands on air traffic capacity with undiminished safety. The foreseen operation of UAVs in manned airspace will increase the demand for capacity. As capacity limits are approached there are more delays that cause inconvenience to passengers and increase emissions and fuel costs. Together airport noise and air traffic capacity could become the two main bottlenecks for the growth of aviation.

Stakeholders: EU, MS, AN, AP, AR, AI, RC, UA.

Relevance: The air traffic capacity must increase with undiminished or improved safety to accommodate traffic growth and UAVs without incurring major delays.

Priority: Air traffic capacity could potentially become an obstacle to the growth of aviation and past experience shows that approaching capacity limits can cause major disruption in terms of flight delays and operating costs and emissions.

Justification: PARE report Section 2.1 and Topics T2.1 and T2.2.

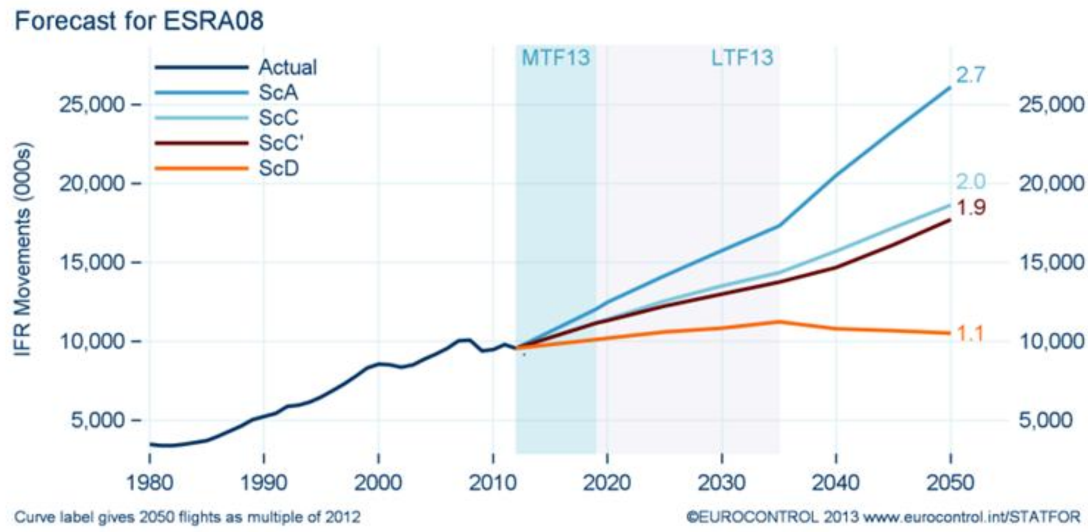

Figure 1. EUROCONTROL scenarios for 2050. *Source: http://bit.ly/2T69SJL*

1.2. ACARE Goal 6

ACARE GOAL 6: "The whole European aviation industry is strongly competitive, delivers the best products and services worldwide and has a share of more than 40% of the world market."

Recommendation 6***: Maintain a broad-based application-oriented research and development activity covering all sectors relevant to the global competitiveness of the European aircraft industry.

Rationale: The importance of the aeronautical industry to the prosperity of Europe is well documented. Since aeronautics is a synthesis of advanced technologies it requires a mastery of all of them to remain competitive.

Stakeholders: EU, MS, AI, RC, UA, AN, AA, AP, PA.

Relevance: taking as an example the market for airliners with more than 100 seats, maintaining the Airbus share of 50% of the world market will require technological leadership in a broad range of technologies.

Priority: This is the core of the aircraft market worldwide. The problems of the Airbus A380 with the passenger infotainment system and those of the Boeing 787 with the lithium-ion batteries show that even seemingly secondary aspects can cause major disruption.

Justification: PARE report Section 2.5 and Topic T2.8.

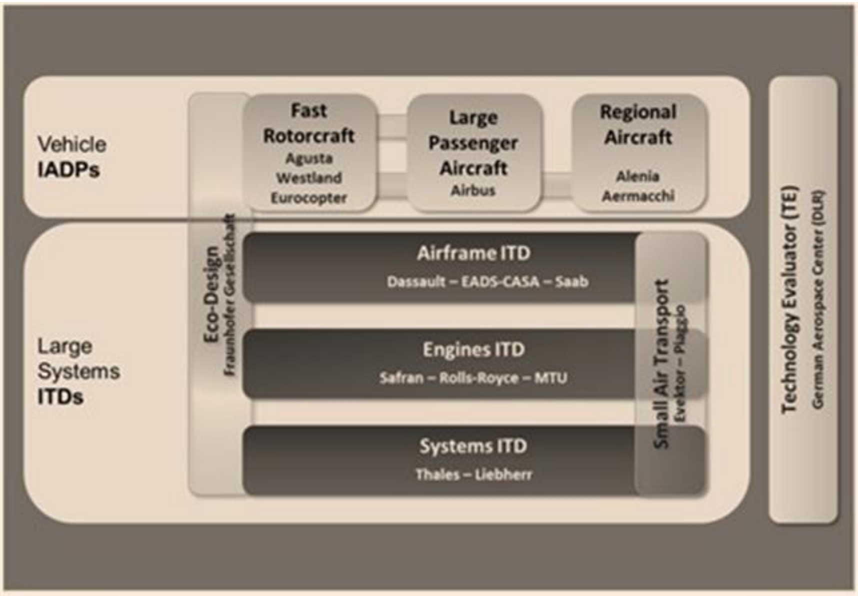

Figure 2. Structure of the Clean Sky 2 Programme. *Source:* http://bit.ly/31hHOpE

1.3. ACARE Goal 9

ACARE GOAL 9: "In 2050 the technologies and procedures available allow a 75% reduction in CO2 emissions per passenger kilometre 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".

Recommendation 9.1***: Support a broad research effort to reduce aircraft noise (a) at the source (b) through operating procedures and (c) taking into account psychoacoustic effects.

Recommendation 9.2*: Besides struggling with short term solutions to an increasingly pressing noise problem a modest effort should be made towards a long-term definitive solution: aircraft inaudible outside airport boundaries.

Recommendation 9.3**: Formulate a set of trade-offs between (a) different types of emissions (CO2, NOx, particles and water vapour) in (b) local airports and global cruise flights.

Recommendation 9.4: Besides struggling with short-term emissions problems put a modest effort towards a long-term definitive solution: the hydrogen-powered aircraft.

Rationale: The growth of air transport at a rate of 3 to 7% per year, leads to flights increased to the double by 2030, and triple by 2050; in order to avoid increased noise exposure near airports and emissions in cruise, the corresponding reductions must be made per flight. Noise is dominated by the engine at high thrust at take-off and by aerodynamics at approach with the engine at idle: thus, the full range of noise sources needs to be tackled, the operating procedures optimized, and psychoacoustic effects accounted for in order to succeed in this major challenge. The requirements for low emissions of CO2, NOx, particles and water vapour near airports and in cruise are sometimes contradictory and a reasonable compromise needs to be defined to guide engine design. The 'definitive' solutions to aircraft noise and emissions, such as aircraft inaudible outside airports and hydrogen propulsion that emits only water vapour, are far away but deserve a modest effort to establish how they might be viable.

Stakeholders: EU, MS, AI, RC, UA, AN, AR, AP.

Relevance: Tolerance to airport noise is reducing and court or other actions to limit airport operations are likely to increase if overall noise exposure cannot be contained. Aviation should have a non-increasing and preferably decreasing role in global emissions.

Priority: It is very challenging to contain total noise exposure at airports and failure to do so could limit airport operations and become a bottleneck for the growth of aviation. Emissions are a major local and global environmental concern and aviation should be an example of positive action. Beyond the pressing short-term issues of noise and emissions, a modest effort should be made to assess and mature in out-of-the-box long-term solutions.

Justification: PARE report Section 4.1 and Topics T4.1 and T4.2.

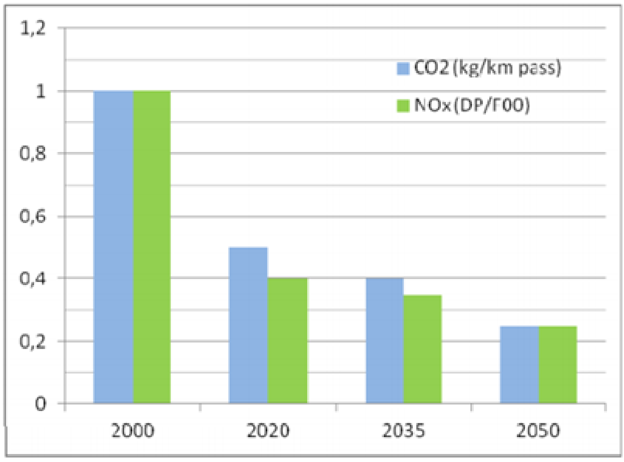

Figure 3. ACARE CO2 & NOx goals calendar (using CAEP6 margin for NOx). *Source: http://bit.ly/2GNvntU*

1.4. ACARE Goal 21

ACARE GOAL 21: “Creation of a network of multidisciplinary technology clusters based on collaboration between industry, universities and research institutes”.

Recommendation 21***: The creation of multidisciplinary technology clusters requires a balanced and proportionate support of 4 levels of projects: (a) basic (3-5%); (b) collaborative industrial (15-17%); (c) large-scale demonstrators (20-30%); joint undertakings (50-60%).

Rationale: A balanced aeronautical research programme should have 4 levels: (i) 50-100 basic research UA up to 1M€ each exploring up to TRL3 all sorts of novel promising ideas; (ii) 20-40 industrial research projects (4-10€) joining AI, RC, UA develop further the more prospects; (iii) 5-10 large scale demonstrators (20-100 M€) to reach practical scale on the best results at lower level; (iv) 1-2 joint undertakings (Clean Sky and SESAR) lead by industrial shorter term applications (1-2) B€. The EU FP Programs have shifted from one end to the other and should be rebalanced.

Stakeholders: EU, MS, AI, AN, RC, UA, AR, AP, CA.

Relevance: The technology clusters could provide the filtering of results up the basic-industrial-demonstration-development chain. The basic projects as sources as new ideas should be based on peer review by UA as the ERC. The three higher levels would be based on selection by industry to ensure the focus of larger investments.

Priority: Only a balanced allocation of resources at all 4 levels can promote the new ideas and links to practical application that can sustain competitiveness from the present to the future.

Justification: Section 6.2 and Topic T6.1

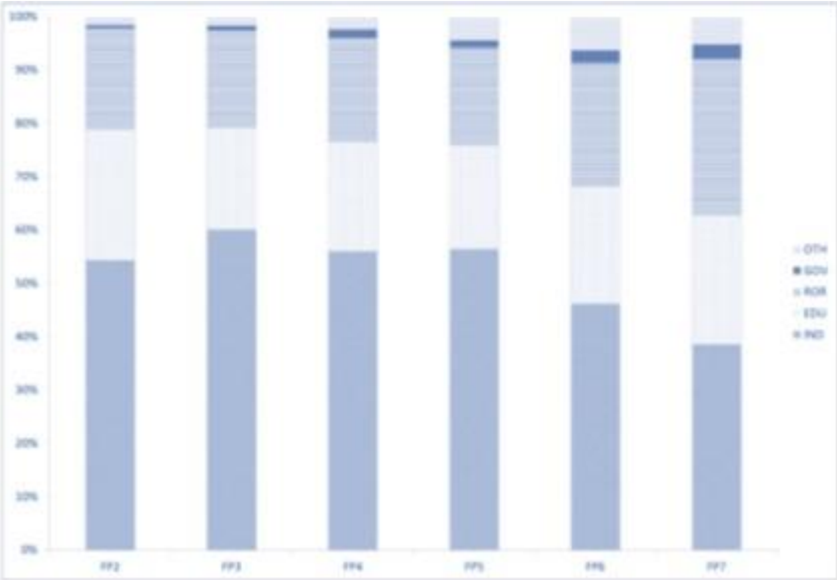

Figure 4. 1 Relative shares of the different organization types to aerospace EU funded projects. *Source: https://www.econstor.eu/bitstream/10419/88569/1/77397654X.pdf*

1.5. PARE Objective 27

PARE OBJECTIVE 27: Maintain the EU leadership in the world helicopter market.

Recommendation 27***: Ensure that Europe keeps at least abreast of developments in high-power high-speed helicopters/convertibles with enhanced hot-and-high lift capabilities.

Rationale: The USA has started a major program FVL (Future Vertical Lift) to design helicopters/convertibles with (i) twice the range, (ii) 50% higher speed, (iii) over twice the hover payload in demanding hot and high conditions, using engines with double power but similar fuel consumption, size and weight. Although it is the military program it could have civil spinoffs: (i) double-range for off-shore oil exploration; (ii) higher speed for medical emergencies and executive transport; (iii) greater payload for rescue and transport missions. All this could challenge the position of Europe with over 50% of the world helicopter market.

Stakeholders: EU, MS, AI, RC and UA.

Relevance: The FVL program in the USA is justified by the need to counter threats from near peer adversaries in Europe and elsewhere: hence it is relevant to the defence of Europe. The implications in the civil market could be to reverse the tables passing dominance from Airbus Helicopters and Agusta-Westland to Bell and Sikorsky. The FVL contenders are the Valor tilt-rotor from Bell and Defiant dual rotor plus pusher-propeller helicopter from Sikorsky; Europe has analogues in the Augusta-Bell AB609 and Airbus X3 that holds the world helicopter speed record, and competitive turboshaft engines from Turbomeca and Rolls-Royce.

Priority: There is a need for a program with a minimum investment to ensure that Europe does not fall behind. It is not necessary to match the massive US funding of FVL. The result of FVL could be as expensive as the Bell V-22 Osprey with small effect on the market, or it could like the RAH-66 Comanche lead to no significant production after years and billions of investment. The aim here is to safeguard against potential surprise breakthroughs that could change the European leading market position without making large speculative investments.

Justification: PARE report Section 7.6 and topics 7.5 and 7.6.

Figure 5. Military helicopters (H145 (ACH), (ACH) Latest model). *Source: Various manufactures*

1.6. PARE Objective 28

PARE OBJECTIVE 28: Provide a European alternative to the drones used in Europe with the potential to also enter the world market.

Recommendation 28***: Leverage the technological capabilities demonstrated in several prototype drones into a coherent European Programme covering all levels, to satisfy internal needs and complete in the world market.

Rationale: The market for MALE (Medium Altitude Long Endurance) drones is a sad example of lack of coordination in Europe: (i) of several prototype programs (Taranis in the UK, Mako in Germany, Hammerhead in Italy, Neuron Multinational led by France) none has yet reached operational status; (ii) in the meantime several European nations have bought American drones; (iii) in the international market China has emerged as the major competitor of the US through lower prices and less export restrictions.

Stakeholders: EU, MS, AI, RC, UA.

Relevance: Europe has the technology to develop all classes of UAVs that are increasingly relevant to a wide range of defence and civil missions, so the issue is one of coordination in the allocation of resources.

Priority: There must be an end to the European dependence on foreign UAVs, and a move to enter the international market since there is the technology to achieve both targets.

Justification: PARE report Section 7.6.

Figure 6. nEUROn drone in flight. *Source: http://bit.ly/2MGqUwO*

1.7. PARE Objective 29

PARE OBJECTIVE 29: Keep the EU at the forefront of progress in the electrification of aircraft.

Recommendation 29***: Make a thorough assessment followed by support measures on (a) emerging electric systems and propulsion technologies, (b) their potential to satisfy mission requirements and (c) the likely evolution of both.

Rationale: Although the automobile sector may lead to the electrification of transport vehicles, the specific needs of aeronautics and fast technological evolution will have increasing importance from drones to airplanes.

Stakeholders: EU, MS, AI, RC, UA, AR.

Relevance: Small electric drones, emerging electric air taxi, more electric airliners with bleedless engines and advances in electric propulsion and systems all point towards increasing electrification.

Priority: Progress in electrification is rapid and although the major market impact could be years away those caught unprepared may take a long time to catch-up.

Justification: PARE report Section 8.1.

Figure 7. Aurora's electric vertical take-off and landing (eVTOL) aircraft PAV prototype. *Source: http://www.aurora.aero/pav-evtol-passenger-air-vehicle/*

1.8. PARE Objective 38

PARE OBJECTIVE 38: Promote harmonized certification standards worldwide as already exist in other sectors to ensure the growth of aviation as the safest mode of transport.

Recommendation 38***: Strengthen the cooperation of EASA/FAA on common certification standards and their adoption worldwide to avoid duplication or degradation in specific regions.

Rationale: The coordinated and mutually accepted certification by either the FAA and EASA is a major breakthrough in avoiding costly duplication and preventing misuse of certification as a trade barrier. The Russian example of local certification is being followed by China, whose aircraft have faced long delays and major difficulties in obtaining EASA or FAA certification. Resorting to 'local certification' leads to lower safety standards that can affect not only locals but also Europeans travelling in those countries. The export of such EASA/FAA uncertificated aircraft could damage the unique overall safety record of aviation.

Stakeholders: The EU and MS, possibly with US coordination, since there is a common interest in supporting EASA/FAA standards.

Relevance: The EU and MS could insist on cooperation with China and Russia being conditional on progress towards worldwide certification standards. Although aircraft not certificated by EASA or FAA cannot operate in Europe, US or other developed regions their use as cheap unsafe transport elsewhere cannot be encouraged and puts European visitors at risk.

Priority: It is prudent to prevent the emergence of a parallel market of local or third world aviation with degraded safety standards that are already lower elsewhere than in Europe/US. Will require diplomatic and negotiation skills.

Justification: PARE report section 9.2 and topics 9.6 and 9.7.

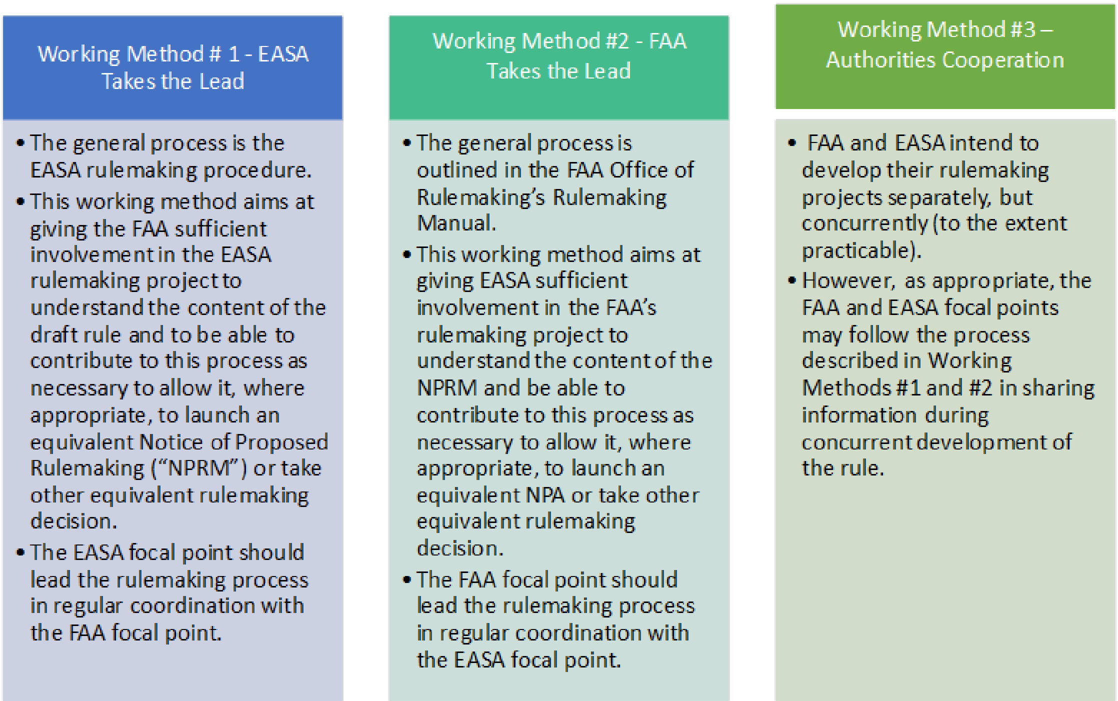

Figure 8. FAA and EASA rulemaking agreement foresee 3 possible working methods. *Source: http://bit.ly/2YLOjzk*

2. Emerging technologies relevant to the progress of aeronautics

The main aim of the project PARE (Perspectives for Aeronautical Research in Europe) is to assess the progress made towards achieving the 23 ACARE goals in the Flightpath 2050 document and to propose relevant measures as a set of recommendations based on an extensive report. One of the 15 chapters of the report concerns ten emerging technologies addressed in the present section 2: electrification, additive manufacturing, efficient production 4.0, telecommunications, 5G networks cybersecurity, big data, artificial intelligence, new materials, nanotechnologies and nanotube structures.

The guiding objectives for the aeronautics research program of the European Union have been established by ACARE (Advisory Council for Aeronautical Research in Europe) in a number of documents, most notably the 23 ACARE goals in Flightpath 2050. The main aim of the product PARE (Perspectives for Aeronautical Research in Europe) is to assess the progress made so far towards those goals and suggest measures to close the remaining gap. This assessment forms the first part consisting of chapters 2 to 6 of the PARE yearly report [4].

The second part of the report addresses major topics: (chapter 6) long-range air transport; (chapter 7) emerging technologies; (chapter 8) cooperation beyond Europe’s borders; (chapter 9) attracting young talent; (chapter 10) increasing the participation of women. The second part of the report have lead to the formulation of a set of 35 PARE objectives whose implementation supports the achievement of the 23 ACARE goals. The 23 ACARE goals and 35 PARE objectives have been collected in a set of 58 Recommendations for Aeronautics Research in Horizon Europe available as chapter 1 of the PARE report and as a brochure.

The third part of the PARE report consists of 6 chapters: (i) two “what if” studies on the Boeing MMA aircraft (chapter 12) and prospects for the Chinese aircraft industry (chapter 13); (ii) case study on the Boeing B737Max accidents (chapter 14); (iii) effects of the covid-19 pandemic on aviation, on a global level (chapter 14) and in the case of a specific airline; (iii) topics relevant to the New Green deal of the EU, namely cleaner and more efficient propulsion (chapter 17), Decarbonization of aviation (chapter 18) and alternative sustainable fuels (chapter 19). This section 2 focuses on chapter 8 on emerging technologies.

2.1. Emerging Technologies

The PARE yearly report is a rather comprehensive document covering most aspects of aviation, and the PARE session at CEAS 2020 selects a few of the most technology oriented chapters. Even a single chapter 8, on emerging technologies is more than can be presented in detail in a single presentation. Among the emerging technologies relevant to aviation, including those arising from other sections, 10 are mentioned:

-electrification
- hydrogen propulsion
-additive manufacturing
-efficient production 4.0
-telecommunications
-G5
-cybersecurity
-big data
-artificial intelligence
-new materials
-nanotechnologies
-nanotube structures

Each of these topics could support a presentation or session by itself, and thus a very brief account is given here, with just three elements for each:

- what is the long-term promise?
- how far have we reached?
- what are the main challenges?

The following are just a few highlights on each of 10 technologies.

2.2. Electrification

Electrification in aviation is mentioned mainly in 3 contexts: (i) electric or hybrid propulsion; (ii) more electric aircraft with replacement of other systems; (iii) electric towing and taxying to reduce emissions at airports. Concerning electric propulsion can be considered (a) solar power, (b) battery power and (c) hybrid propulsion.

2.2.1. Solar powered aircraft

- Promise: long/infinite endurance as a sensor/relay platform operating as an alternative to satellites much closer to earth.
- Achievement: round the world piloted flight with many stops and many unmanned flights.
- challenges: large wing area to collect modest solar energy, operation above clouds, battery weight to fly at night, time to climb, vulnerability to weather, light structure and small payload.

2.2.2. Battery *powered aircraft*

-promise: low/no emissions low-cost transport like urban V/STOL.
-achievements: small drones, light planes.
-challenges: low energy density of current batteries: low power-to-weight and power-to-volume ratio; range limited to about 500 km with current battery technology; improvements dependent on new solid-state batteries with better energy density but challenging on cost and large scale production

2.2.3. Hybrid regional aircraft

-promise: lower emissions and costs up to 1000 km range.
-achievements: demonstrator programs being pursued.

-challenges: using cruise optimized efficient engines backed by battery power for other stages of flight; having enough electric power reserve for climb, airport diversion; integration issues that become more difficult for long-range aircraf

2.3. Long-range aircraft

-promise: turbine engine driven alternator that supplies electric energy to efficient distributed propulsion.

-achievements: high-power generators and electric motors with high-efficiency (>93%) driving propellers.

-challenges: tens of MW of power imply thousands of volts and ampere; high voltage can lead to sparks and electromagnetic interference; large currents imply energy losses and difficulties with heat dissipation; 'superconducting cables' without electrical resistance require criogenic temperatures if they provide a viable energy transport; energy transport issues may be avoided by distributed integrated power-propulsion units.

2.4. Hydrogen propulsion

-promise: hydrogen combustion produces water vapour mostly, with a significant reduction in environmental effects.

-achievements: pressurized hydrogen is used in conventional engines and fuel cells, for example in cars; liquid hydrogen is used in cryogenic rocket propulsion

- challenges: pressurized hydrogen requires heavy tanks that take long to fill; aviation will need liquid hydrogen supply to turbines or fuel cells. Significant reliability and safety challenges operating at very low temperatures, about 20 K.

2.5. Additive manufacturing

-promise: local manufacture of spare parts with no need for stocks or awaiting deliveries

-achievement: manufacture of complex pieces in a slow process with quality constraints

-challenges: moving from small scale slow production to fast large scale production; quality issues depending on number of layers; limited choice of base materials; quality, repeatability and certification; access to all design information needed.

2.6. Efficient Production 4.0

-promise: approach/match the productivity of high-rate production chains using just-in-time and other efficiency enhancements.

-achievements: works in the automotive and other industries.

-challenges: adaptation to lower production rates of aviation, with greater complexity and higher quality standards; large investment in facilities, machinery, software and training; transition from and compatibility with traditional production methods.

2.7. Telecommunications

-promise: larger data rates through increased bandwidth without signal degradation, loss, interference or interruption.

-achievement: impressive progress moving to higher frequencies with benefits (more bandwidth, smaller antennas).

-challenges: signal generation, propagation and processing; minimizing interference, degradation, interruption or loss of signal; cyber and intrusion issues.

2.8. 5G

-promise: It is going to be widely available with high data rates so why not use it in aviation?

-achievement: could it be part of the solution for Air Traffic Management (ATM) of drones and urban air transport.

-challenges: there are stringent requirements for safe ATM on quality and continuity of signal: no interruption, saturation or interference from other services.

2.9. Cybersecurity

-promise: secure, hacker-resistant data files, communications and systems

-achievements: easier to list spectacular failures. Needs parallel monitoring, early detection of anomalies, isolation of affected sectors, reassignment of compromised functions to units operating correctly, elimination of intrusions, requalification of affected parts; much better if cyber resistance is designed-in from the outset'.

-challenges: there is no 100% protection of software by software. Encryption cannot be decoded if used only once; protection of systems at many levels: design, production, operations, communications, marketing, subcontracting all of which can be paths for intrusion.

2.10. Big data

-promise: to make good used of vast amounts of available data.

-achievements: improvements in fault prediction, detection and isolation, predictive maintenance, incorporation of operational experience in procedures and design

-challenges: processing large amounts of data in an efficient way; finding the relevant pieces of data in a large set; interpreting and exploiting the results reliably.

2.11. Artificial Intelligence

-promise: perform tasks much faster than humans, without errors, in complex environments.

-achievements: fast, error-free execution of tasks based on extensive training with high-quality data sets covering all possible occurrences in a given scenario.

-challenges: AI has no imagination: cannot deal with situations it was not trained for; quality of results depends on abundance of quality training material; training material must cover extensively every possible occurrence; large investment in data collection and validation, needs large number of realistic simulations, requires reliable independent validation.

2.12. New materials, nanotechnologies and nanotube structures

-promise: contributions to the efficiency of large 'big bird' aircraft, eventually making possible small 'insect size' drones.

-achievements: very diverse: composite, ceramic materials and alloys, fluidic control, micromechanical devices, etc.

-challenges: many specific to the technology; example: nanotube structures: could have the same strength with a fraction of the weight by being mostly hollow with a nanotube lattice. The nanotubes tend to coalesce rather than organize a lattice, even in laboratory conditions. Transition to production another challenge.

3. Effects of the covid-19 pandemic on aviation

The PARE project started on October 1, 2017 and its planned 3-year duration has been extended by 3 months up to December 31, 2020 taken into account three major events that have occurred in the meantime: (a) the New Green Deal policy of the European Union with a strong focus on reducing the environmental impact of aviation; (b) the emergence of the covid-19 pandemic as the biggest crisis in the history of aviation; (c) the B737Max crisis, following two accidents, whose serious consequences have been further complicated and dwarfed in scale by the covid-19 pandemic. Thus, the PARE final 3rd year report adds additional chapters to cover these subjects.

The PARE 2nd year report, besides an introduction (chapter 1) and conclusion (chapter 18) consisted of: (i) five chapters 2 to 6 corresponding to the 5 groups of 23 ACARE Goals; (ii) five chapters 7 to 11 on the 35 PARE objectives supporting the 23 ACARE Goals and leading to the 58 PARE recommendations for aeronautical research in Horizon Europe; (iii) two "what if" studies as chapter 12 and 13. The PARE final 3rd year report adds the following chapters: (Chapter 14) The two Boeing B737 Max Accidents and their consequences; (chapter 15) Regional and international airline operation pre-and post covid-19 pandemic in the case of one airline, namely PARE partner SATA; (chapter 16) General assessment of the effects of the covid-19 pandemic in all sectors of aviation; (chapter 17) Efficient propulsion with low-noise and emissions; (chapter 18) Decarbonization of aviation by 2050; (chapter 19) Sustainable fuels for the New Green Deal. The conclusion becomes chapter 20 in the PARE final 3rd report that is preceded by an executive summary.

Thus chapter 14 relates to the topic (c) the B737Max crisis, the new chapters 15 and 16 to the topic (b) of the effects of the covid-19 in aviation and chapters 17 to 19 to the topic (a) of the New Green Deal objectives of the greening of aviation. As an example of the PARE final 3rd report is chosen the chapter 14 global effects of covid-19 as the biggest crisis in the history of aviation.

3.1. The impact of the covid-19 pandemic on society in general and aviation in particular.

Towards the end of the duration (2017-2020) of the PARE project occurred the covid-19, the biggest crisis in the history of aviation. Although these dramatic events could not be predicted at the time the PARE proposal was formulated and support as a Coordination and Support Action (CSA) of the Aeronautics Program of the European Union, the resources of the project team allow a rapid comparative analysis of the pre and post covid-19 situation; the effects on aviation are considered in the broader context of the coronavirus pandemic considering a sequence of 16 aspects: (i) the origin of the pandemic, either natural or out of a laboratory (ii) analogy with other historic calamities, like previous pandemics, world wars, natural disaster or weapons of mass destruction; ; (iii) medical aspects related to protection, treatment and vaccination; (iv) social effects, including quarantine, unemployment, economic decline and telecommunications; (v) effects on air services, including airline passengers, air cargo, aircraft leasing, airports, Air Navigation service Providers and business aviation; (vi) effects on industry, including aircraft manufacturers, first-tier suppliers, down the tiers 2 to 4 of the supply chain, Maintenance, Repair and Overhaul (MRO) sector, used aircraft market and business aviation; (vii) financial bail-out schemes in the U.S. under the Congress CARES bill for keeping employment, maintaining internal flights, supporting airports and rescuing industry over a 6 month period without long-term objectives; (ix) the opposing choices made by different governments for supporting (or not) the aeronautical sector; (x) the policies of different governments in Europe concerning support to aviation, including Germany/Lufthansa, France- The Netherlands/AirFrance-KLM, Italy/Alitalia, Britain-Spain/ British Airways-Iberia, and the case of Low Cost Carriers)LCCs); (xi) the example of France as a comprehensive support package for aeronautics, consisting of military/defence contracts, and support for industry and Research and development (R & D) sectors; (xii) The essential role of the European Union in providing global financial stability, as well ass support for research and coordination measures to open the market; (xiii) the recovery for passenger travel, distinguishing the short and long haul and including the long-term level; (xiv) the focus on on-board and airport health measures to gain passenger confidence and protect aircraft crews, in particular cabin attendants; (xiv) the need for pandemic planning, learning the lessons of covid-19 in case of future pandemics, including the aspects of isolation and confinement, marshaling of support and back-up reserves; (xiv) the measures to ensure survival and recovery of all key players. Including airlines, industry and suppliers. The sections and subsections refer to the chapter 16 of the PARE final report where more detailed supporting evidence is provided.

3.2. Origin

The covid-19 pandemic has caused the biggest crisis in aviation history turning several years of continuous growth into an almost total grounding in the short time span of a few months (section 16.1). The official Chinese version, the pangolin in remote forests, as the carrier with transmission through bats to people (subsection 16.2.1) who eat them; the press has reported a rather different story (subsection 16.2.2) of origin in a laboratory working on biological weapons of mass destruction near Wuhan, where the outbreak stated.

3.3. Analogies

Several analogies have made with the covid-19 pandemic (section 16.3) including; (subsection 16.3.1) earlier historic pandemics with much higher death rates; (subsection 16.3.2) word wars which caused much larger number of deaths with attempts to occupy territory; (subsection 16.3.3) natural disasters, like earthquakes, volcanic eruptions, floods, fires and tsunamis of much more limited geographical or temporal extent; (subsection 16.3.4) biological weapons of mass destruction with no known cure leading to diseases whose spread is extremely difficult to contain.

3.4. Medical aspects

The basic medical aspects to be taken into account in the context of the effects on aviation (section 16.4) that include: (subsection 16.4.1) the means of protection against the transmission of the coronavirus via water droplets; (subsection 16.4.2) the treatment and healing leading to deaths mainly in elderly people with previous ailments; (subsection 16.4.3) the prospects for developing a vaccine which should have a high effectiveness and a lasting effect, without undesirable secondary consequences and be available in larger quantities at moderate cost.

3.5. Confinement

Without a cure or vaccine available the main way to counter the spread of the infection and avoid overwhelming the available medical resources (section 16.5) is confinement; (subsection 16.5.1) quarantining in infected cases and work at home to avoid contagion at work; (subsection 16.5.2) avoiding large gatherings in confined spaces through teleconferences. These precautions cannot be easily applied to essential services such as supply of medicines and food at pharmacies and supermarkets.

3.6. Social Effects

The social and economic effects of covid-19 include some of the most undesirable records (section 16.6) such as: (subsection 16.6.1) the deepest economic recession for a long time, due to the decline of industrial production and most services; (subsection 16.6.2) the highest unemployment level due to the paralisation of the economy; (subsection 16.6.3) increased budget deficits and debts attempting to mitigate business and job losses. Only a few sectors like informatics have benefited from the lockdown (subsection 16.6.4) with larger number of people staying longer at home and like meetings replaced by teleconferencing.

3.7. Effects on Air Services

Aviation is one of the worst hit sectors (section 16.7) in almost every area: (subsection 16.7.1) airlines have high fixed costs and no revenue from suspended flights, exhausting existing liquidity and leading to bankruptcy in a few months unless a rescue package is provided; (subsection 16.7.2) the air cargo sector becomes essential in the fast delivery of urgent medical supplies and protection equipment, but this hardly compensates the general decline due to reduced economic activity; (subsection 16.7.3) aircraft leasing, which has grown from 4% to 35% of the market in two decades faces a sharp reversal between high demand from airlines needing additional aircraft to zero demand from the same airlines having most of their fleet grounded; (subsection 16.7.4) airports lose revenues from cancelled flights and lack of passengers, and cannot balance fixed costs, just as Airlines; (subsection 16.7.5) a similar situation applies to ANSPs (Air Navigation Service Providers) with no flight charges to cover costs with personnel like ATCs (Air Traffic Controllers) and navigation ground infrastructure. The only niche sector with growth prospects is business aviation (subsection 16.7.6) that is the only alternative to cancelled airline flights with reduced health risks.

3.8. Effects on Industry

The decline in airline traffic (section 16.7) has an equally massive effect on industry (section 16.8) with losses everywhere without a single exceptional niche: (subsection 16.8.1) airlines finding themselves unexpectedly with grounded or oversize fleets may not make new orders, and be forced into cancellations or delayed deliveries all of which mean less revenues for aircraft manufacturers to add to production slowdown or shut-down; (subsection 16.8.2) first- tier suppliers, like aero engine manufacturers, are even worse adding to (i) the loss of production of engines for new aircraft also (ii) the reduction in maintenance and spares revenue due to reduced flying; (subsection 16.8.3) down the supply chain the effect (i) of reduced aircraft production may be amplified for smaller companies with less resources and high dependence on the aeronautical market; (subsection 14.8.4) the Maintenance; Repair and Overhaul (MRO) sector is hit as first tier supplies by (ii) reduced flying leading to less regular servicing and postponement of major work; (subsection 16.8.5) used aircraft prices have a sharp drop as airlines dispose of surplus aircraft, starting with the oldest, less efficient and more polluting models. The prospects for survival (subsection 16.8.6) are: (i) worse for small suppliers of services that can be taken up by high tiers with excessive work force; (ii) better for unique small suppliers needed for recovery and large companies that cannot be allowed to fail.

3.9. Bail-out under the U.S. CARES bill

The dire situation caused by covid-19 was addressed in the U.S. by the CARES (Coronavirus Air Relief and Economic stability) Bill passed by Congress, which included aviation (section 14.9) besides other sectors. Substantial sums were made available setting conditions lasting only for 6 months such as: (subsection 16.9.1) no dismissal or pay cuts for employees; (subsection 14.9.2) no reduction in domestic flights; (subsection 14.9.3) support to airports. In spite or because of the large sums involved, the rules of allocation lead to widespread controversy about unequal treatment in all cases airlines, airports and employment. The CARES act was less controversial on (subsection 16.9.4) bailouts for industry, although the size of the 60 B$ Boeing fund did raise some eyebrows. However the biggest issue is after spending 80B$ with airlines and airports for six months, what happens (subsection 16.9.5) after October 1, 2020: worker lay-offs and route cancellations or another large subsidy without long-term prospects?

3.10. Opposing Alternatives

Unlike the U.S. that applied blanket temporary rules lasting 6 months other countries took a longer term view, with a case-by-case analysis, leading for airlines (section 14.10) to (subsection 14.10.1) a rescue package in case of flag carriers with strong or not so strong records, sometimes with environmental and other conditions, mostly in developed countries with strong economies; (subsection 14.10.2) bankruptcies of major airlines and flag carriers with poor performance records mainly in developing with weak indebted economies already in financial strain before aggravation by the covid-19 pandemic.

3.11. Government Policies

In Europe government policy towards rescuing airlines differed by country (section 16.11) with significant contrasts (subsection 16.11.1) the 9 B$ rescue of Lufthansa by the German government involved strict conditions on reduction of fleet size and loss of airport slots, leaving an open road to increased or decreased state control towards nationalization or privatization; (subsection16.11.2) France and the Netherlands agreed on a 80:20 split of a 7 B$ rescue for Air France-KLM; (subsection 16.11.3) Italy provided Alitalia with an ambitious rescue plan assuming far better performance in the future than that achieved in the past; (subsection 16.11.4) British Airways-Iberia have protested against government travel restrictions, besides receiving limited support. The Low Cost Carriers (LCCs) may survive on their own, with lay-offs, salary reductions and limited support (subsection 14.11.5) trying to ramp-up services and recover revenues as quickly as possible.

3.12. Comprehensive Support

A good example of comprehensive rescue package for the aerospace sector is provided (section 16.12) by France: (subsection 16.12.1) the collapse of the civil market can be partially compensated for industry also active in the defense sector by keeping or expanding military contracts that are stable in the long-term, as long as economic conditions allow; (subsection 16.12.2) the industry support includes not only the large Original Equipment Manufacturers (OEMs) but also smaller companies down the supply chain whose products and skills are essential for post covi-19 recovery; (subsection 16.12.3) supporting research and technology for 20-30% more eficient airliners in the 2030-2035 time frame keeps the design and development active and ready to support future competitiveness.

3.13. Support of the European Union

Comprehensive and well-coordinated support programs for the aerospace sector, at a national level like in France and Germany, becomes most effective together with initiatives at the level of the European Union (section 16.13), for example: (subsection 16.13.1) the overall covid-19 cohesion fund strengthens national economies, enabling the support of several sectors including aeronautics; (subsection 16.13.2) the aeronautical and space programs of the EU support continued competitiveness and initiatives like electrification an hydrogen economy and cleaner environment; (subsection 16.13.3) EU-wide measures on deconfinement and health rules, even with local exceptions are essential to accelerate recovery of the aviation sector from the covd-19 crisis.

3.14. Recovery Prospects

The prospects for recovery of the aeronautical sector from the covid-19 crisis are (section 16.14) different for: (subsection 16.14.1) a faster V-shaped ramp-up for regional and short-haul flights among regions with almost simultaneous deconfinement; (subsection 16.14.2) the uncoordinated deconfinement measures at world-wide level harm long-hall travel, that will remain at low-level longer until global deconfinement leads to an abrupt U-shaped recovery. Besides the uncertainty of when short-hall (2021?) and long-hall (2023?) traffic recovers there the major question (subsection 16.14.3) of ultimate recovery level in the range from full (100%) to partial (down to 70%?) due to changed habits, like more teleconferencing instead of professional travel.

3.15. On-board Health

The post covid-19 recovery of aviation depends not only on coordinated deconfinement between travel destinations but also on non-board health (section 16.15) provided by anti-pandemic measures, like (subsection 16.15.1) directed air conditional air flows and hospital grade virus filters. The airport screening and passenger compliance with health protection measures are essential to regain trust in air travel (subsection 16.15.2). Bearing in mind that flight crew, in particular cabin attendants, fly often with a large number of passengers, their health protection deserves particular attention (subsection 16.15.3).

3.16. Pandemic Planning

Although most countries have emergency planning for natural disasters (fires, floods, earthquakes, etc...) there appears to be little planning for a pandemic, that has far greater consequences, countered in the case of covi-19 by an assortment of improvised measures often later and not fully effective. The Covid-19 may not be last pandemic the world will see, and pandemic planning (section 16.16) should cover at least the following aspects: (subsection 16.16.1) isolation and confinement measures to limit the geographical spread, to ensure that a minimum of affected population is supported by a maximum of healthy population; (subsection 16.16.2) using all the resources of the healthy population to help, recover and cure the affected population; (subsection 16.16.3) making sure medical and other essential services and resources are not overwhelmed by having pre-planned reserves, facilities and ability to ramp-up rapidly production of protective equipment and treatments.

3.17. Survival and Recovery

As one of the worst pandemics affecting mankind, and the biggest crisis in aviation history, covid-19 has challenged the survival and recovery prospects (section 16.17) of all sectors, namely: (subsection

16.17.1) airlines with reduced passenger demand met by a fraction of the fleet, with remaining aircraft parked, or stored or likely to be disposed of, until traffic recovers sufficiently; (subsection 16.17.2) aircraft manufacturers facing cancellations, delayed deliveries and a lack of new orders for several years until airlines need additional or replacement aircraft; (subsection 16.17.3) industry in all tiers 1 to 4 of the supply chain with high investment to increase production at low prices before covid-19 facing an abrupt slowdown due to the pandemic

3.18. Conclusion

In conclusion (section 16.18) although the evolution (second wave?) and recovery (full or partial, when?) from the covid-19 pandemic is unpredictable, its effects have shown that better planning is needed to avoid comparable disruption in the future.; the aeronautical section should plan to rapidly convert to support the fight against the pandemic, and then recover quickly. The government interventions during the covid-19 pandemic have differed around the world, and support for the aeronautical sector is no exception. In the U.S. the CARES bill provided large sums with temporary rules whereas in Europe smaller support was made conditional on economic and environmental performance and innovative technology for higher competitiveness.

Conclusion

This paper has highlighted a sample of the topics covered in more detail in the PARE final 3rd year report: (topic 1) the 58 PARE recommendations for Aeronautical Research in Horizon Europe; (topic 2) the emerging technologies most relevant to progress of aviation; (topic 3) the covid-19 pandemic as the biggest crisis in the history of aviation.

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