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Ensuring 2050 European Aviation Safety and Security Goals: Are We Doing the Right Research?

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1. Abstract

According to EASA and other aviation safety organisations [1], air transport is acknowledged today as the safest global mode of transport; and certainly, as indicated in the report of IATA [2], the low accident rates registered in the past three decades bears this out.

Evolution and growth of the industry in the next 30 years requires us to continue reducing the accident rate to satisfy the expected demand [1] , [2]. The European strategy for aviation Flightpath 2050 has identified 6 safety and security goals for the region by 2050: i) Ultra-low accident rate in commercial flight; ii) Weather hazards and risk mitigation; iii) Integrating drones in manned airspace; iv) Comprehensive and unobtrusive security measures; v) Resilience to external and internal threats; and vi) High-bandwidth data resilient to cyberattacks.

This paper studies the progress made towards achievement of these 6 safety and security goals, and proposes measures for closing the gap that remains as well as those for avoiding limiting barriers.

2. Introduction

Air transport has grown significantly in recent years, with almost 4.1 billion passengers and 62.5 million tonnes of cargo transported in 2017 [3]. It plays a key role in social and economic development, contributing 3.0 trillion dollars to GDP (Gross Domestic Product) and approximately 67.7 million jobs in 2017 [4]. Ensuring viability and vitality of the sector requires exceptional safety figures [5]. The accident ratios currently experienced in commercial air transport are difficult to improve. According to the ICAO figures [3], only one out of every 2.4 million commercial flights had an accident in 2017. However, steady development of air transport requires us to continue reducing the accident rate to satisfy the expected demand [1], [2].

In the European Union, the Advisory Council for Aeronautics Research in Europe (ACARE) plays a key role in the long-term strategy for research aimed at ensuring and increasing flight safety and security of the European aviation industry [6]. The European strategy for aviation Flightpath 2050 proposes the following safety and security goals for the region by 2050:

- **Ultra-low accident rate in commercial flight:** The European air transport system has less than one accident per ten million commercial aircraft flights.
- **Weather hazards and risk mitigation:** Weather and other hazards from the environment are precisely evaluated and risks are properly mitigated.
- **Integrating drones in manned airspace:** The European air transport system operates seamlessly through interoperable and networked systems.
- **Comprehensive and unobtrusive security measures:** Efficient boarding and security measures allow seamless security for global travel with minimum passenger and cargo impact.
- **Resilience to external and internal threats:** Air vehicles are resilient by design to current and predicted on-board and on-the-ground security threat evolution.

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- **High-bandwidth data resilient to cyberattacks:** The air transport system has a fully secured global high bandwidth data network, hardened and resilient by design to cyber-attacks.

The Flightpath safety goals for 2050 are very ambitious when compared to the current commercial operations. To achieve these extremely exigent goals and levels of safety, the European industry must master a wide range of technologies and collaborate on their integration into design and development of the Air Transport System.

On the initiative of the partners of the European Union funded-project PARE (Perspectives for Aeronautical Research in Europe) research is being conducted to determine the level of progress, gaps and barriers for each of these objectives and to develop recommendations for their elimination.

This paper presents the outcomes of the research carried out so far by the project. It identifies the progress made towards each of the previous 6 safety and security Flightpath goals, and the gap remaining and limiting barriers. It extrapolates on the current rate of progress, and proposes measures for closing the gap either through accelerated continuous progress, or through a quantum jump in progress. These measures contemplate on:

i) evolutionary technologies;
ii) breakthrough technologies;
iii) ideas currently at low TRL that reach higher TRL in time for application before 2050; and
iv) new ideas not known at present, but feasible by 2050.

3. Methodology for benchmark of progress from the state of the art towards the 23 Flightpath 2050 goals.

EU aerospace research towards Flightpath 2050 goals faces several challenges. Available research shows that these goals cannot all be achieved only using evolutions of currently available technologies. For example, noise and emissions reductions can be achieved only if sufficient efforts are made for new technologies to mature. The transition from technology availability to technology uptake in a product or system is influenced by many factors; besides technology maturation, certification, sustainability and cost-effectiveness. There are also factors of a non-technological nature such as market expectations, new products or improvements being developed.

The ambitious goals set for Flightpath 2050 can only be achieved through equally ambitious strategies and actions. Basic research can play a key role here. The timeframe to 2050 leaves scope to mature what is now low Technology Readiness Level (TRL) basic research to promising high TRL demonstrations and feasible solutions to meet aviation targets. This requires the consideration of new and breakthrough technologies often originating in universities, SMEs and small laboratories, identifying the most promising among a multitude of new ideas, some of which may be ahead of their time.

In this work we analyse the benchmark of progress from the state of the art towards the 23 Flightpath 2050 goals following a three stage process, as illustrated in figure 1.

- In the first one, for each goal project partners have analysed the state of the art of technical developments regarding aviation safety based on the outcomes of relevant R&D projects and initiatives (from Clean Sky, SESAR, H2020 or other projects). The projects are selected considering their contribution to the goals and are assessed using the available sources of information, such as program of work and reports, possibly supplemented by individual research, questionnaires, interviews or dedicated workshops. This analyses is used to synthesise the current level of progress towards the goal.
- Then a benchmark of progress from the state of the art towards the 23 Flightpath 2050 goals is constructed. The benchmark is based on the assessment of technology‘s maturity. The specific methodology for assessing technology maturity is detailed in the following paragraphs.

- Finally a set of recommendations are issued aiming at speed up the progress towards the safety and security ACARE goals.

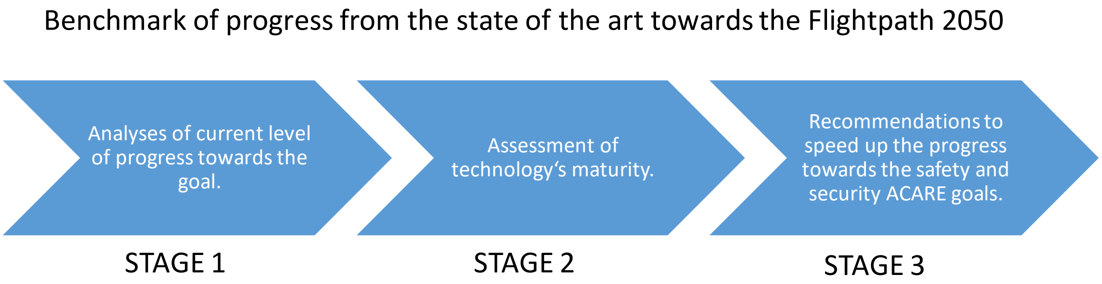

Figure 1. Three stage process to benchmark of progress from the state of the art towards the Flightpath 2050 goals.

Technology maturity is the degree to which a certain technology is capable of producing the results that are expected. For most of the researchers, the terms “technology maturity” and “technology readiness” are synonyms and therefore are used interchangeably. There are not plenty of metrics and tools developed to measure how ready a technology is. The most universally accepted methodology for assessing the upward slope of this curve is the Technology Readiness Level (TRL) scale [7]. There are actually several versions of the original NASA-developed TRL scale (around 40 years ago), depending on the application (software, manufacturing, etc.), but all rate a technology based on the amount of development completed, prototyping, and testing within a range of environments from lab (or "breadboard") to operationally relevant (figure 2). The lowest level, TRL 1, indicates that information already learned from basic scientific research is taking its first step from an idea to a practical application of a lesson learned. For example, after learning that hydrogen and oxygen can be combined to generate electricity, some would suggest an idea for building a machine to do just that. A technology that has achieved TRL 9 is one that has been incorporated fully into a larger system. It has been proven to work smoothly and is considered operational. The distance between TRL 1 and TRL 9 often amounts to years of research studies, prototype modelling, component building and testing, integration of tested components into other systems, and more tests in the laboratory and the real world.

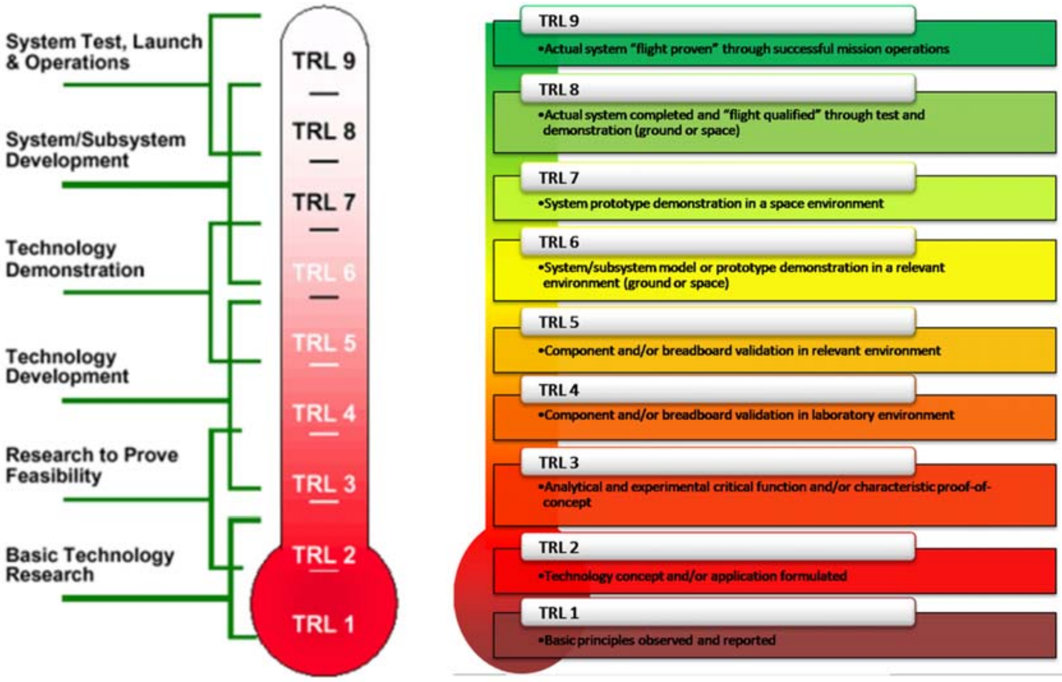

Figure 2. Technology Readiness Level (TRL) scale

A comprehensive approach and discussion about TRLs has been published by the European Association of Research and Technology Organisations (EARTO) [8]. Horizon 2020 has selected the TRL scale as an indicator to better position the requested projects in the program (as expressed in the Horizon 2020 annual work programs), despite extensive criticism of the adoption of TRL scale by the European Union was published in The Innovation Journal, in that "concreteness and sophistication of the TRL scale gradually diminished as its usage spread outside its original context (space programs)" [9]. The International Standard ISO standard 16290 was published in 2013 [10] and as a result, TRL are now globally harmonized. The TRL descriptions are provided in [10]: TRLs are used to quantify the technology maturity status of an element intended to be used in a mission. Mature technology corresponds to the highest TRL, namely TRL 9, or flight proven elements.

Research in air transport takes time and this, in part, is determined by the stringent safety requirements prevalent in this sector. The elements of the phased research programme comprise a range of Technology Readiness Levels. The present approach establishes an approximate relation between the given qualitative TRL and the years it will take to introduce the technology into service (the -Years to Maturity- for a current TRL) as depicted in figure 3 for different aviation technological domains. So far this estimate is solely based on historical data and does not account for the influences of e.g. financial incentives, administrative restrictions or supports, availability of resources and so forth.

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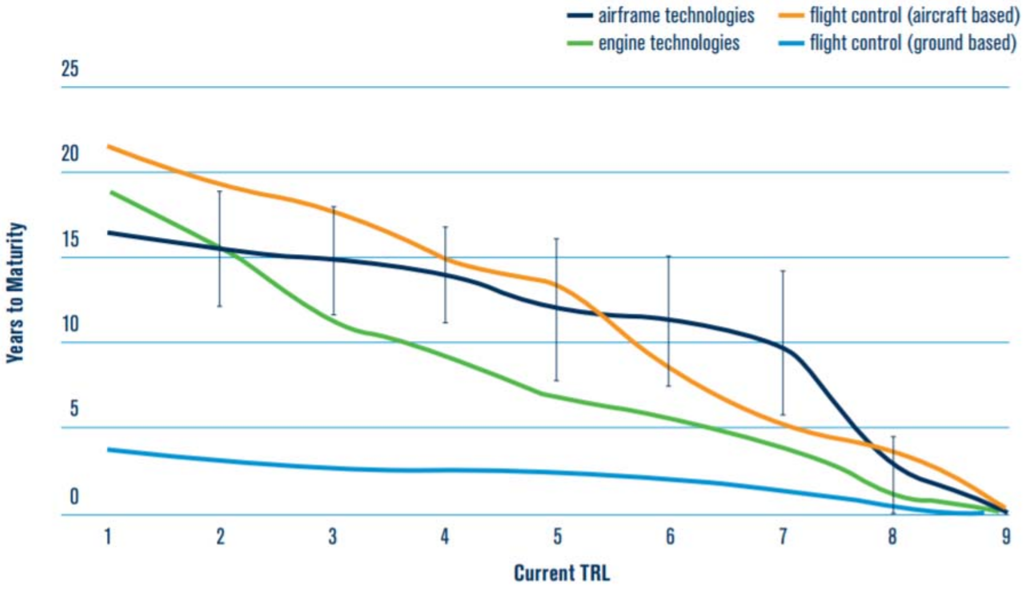


Figure 3. Maturation Timeline for Technology Readiness Level [11]

In this project we used a Technology Readiness Level Calculator developed by NYSERDA (https://www.nyserda.ny.gov/). This tool is a standard set of questions implemented in Microsoft Excel that produces a graphical display of the TRLs achieved. This tool is intended to provide a snapshot of technology maturity at a given point in time. The methodology of a balanced approach to assessing the readiness of projects as a whole – the Technology Project Readiness Level (TPRL) methodology, was originally proposed in [12]. As a starting point for the development of such a methodology, a unified method for assessing the level of readiness of technology TRL 13] and the StageGate® method [14] were used. The decisions made in the development of the software allow to create a full-fledged information system on its basis and integrate it into existing information systems designed to process information on scientific and technological projects.

4. Ultra-low accident rate in commercial flight

*** Flightpath 2050 goal 14: "European air transport system has less than one accident per million commercial aircraft flights"**

Keeping Aviation as the safest mode of transport, is the aim of goal 14. The global rate of accident in commercial aviation has remained well below 0.5 fatal accident per million departures since 2006. EASA MS AOC holders show a lower rate of fatal accidents than the rest of the world. In the last decade, there have been 12 fatal accidents involving operators from the EASA Member States, with only 1 in 2016. To improve existing safety levels relevant measures have been put in place lastest years:

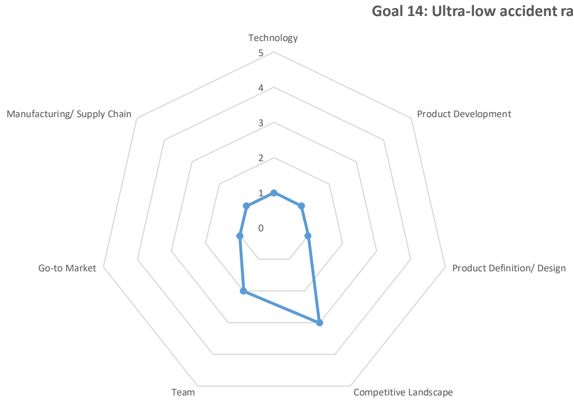
i) **Safety Management System (SMS);**
ii) **Data-driven approach** to the identification and prioritization of actions of the European Plan for Aviation Safety (EPAS); and
iii) **Risk-based Oversight (RBO)**.

The safety target in the goal 14 can be achieved by strengthening the cradle-to-grave safety chain of aviation:

(i) aircraft design based on the most reliable scientific methods, validated and tested in the more stringent conditions;

(ii) meeting comprehensive certification standards in all aspects related to operations and safety;
(iii) control of the supply of raw materials, documentation of fabrication processes and production quality checks;
(iv) qualification of all human actors, including pilots, maintainers and air traffic controllers;
(v) provision and maintenance of all support systems and equipment at the required standards;
(vi) strict implementation of safety rules and procedures;
(vii) reporting of incidents, without identification or blame, before they become accidents;
(viii) swift implementation of protective measures once a potential hazard has been identified;
(ix) continuous search for best practices and their timely implementation;
(x) use of existing and development of new monitoring, fault tolerant and adaptive systems and emergency intervention strategies.

NYSERDA (TRL/CRL) Calculator results for analysis and assessment of ACARE Challenge 4 Goal 14 **-** Ultra-low accident rate in commercial flight- are shown in figure 4 grounding on the results of the 1st year PARE report [15].



Technology	Project works is beyond basic research ad technology concept has been defined.
Product Development	Initial product/market fit has been defined
Product Definition /Design	One or more initial product hypotheses have been defined
Competitive Landscape	Comprehensive market research to prove the product/system commercial feasibility has been
Team	Solely Technical or non-technical founder)s) running the company with no outside assistance
Go to Market	Initial business model and value proposition have been defined
Manufacturing /Supply Chain	Potential suppliers, partners and customers have been identified and mapped in an initial value chain

Figure 4: NYSERDA (TRL/CRL) Calculator results for analysis and assessment of ACARE Challenge 4 Goal 14 —Ultra-low accident rate in commercial flight.

5. Weather hazards and risk mitigation

*** Flightpath 2050 goal 15: "Weather and other hazards from environment are precisely evaluated and risks properly mitigated"**

Atmospheric conditions continue to be a major factor in aircraft operations, although much progress has been made in flying safety through what were in the past hostile scenarios. Costs resulting from extreme weather for aviation in Europe (cancellations and time costs for passengers) was **606 million euro in 2010.** From 2003 to 2007 **weather was a cause or contributing factor in 1740 accidents, a 20,1% of total,** being the most often causes wind (50%) and visibility. The number of accidents due to the weather has steadily decreased until the present time, reaching historical minimum in 2011. Severe weather related accidents and incidents can be attributed to the following hazards:

i) In-flight icing;
ii) Severe air turbulence (convective cloud origin);
iii) Hail damage;
iv) Lightning strike;
v) Low visibility due to fog or precipitation;

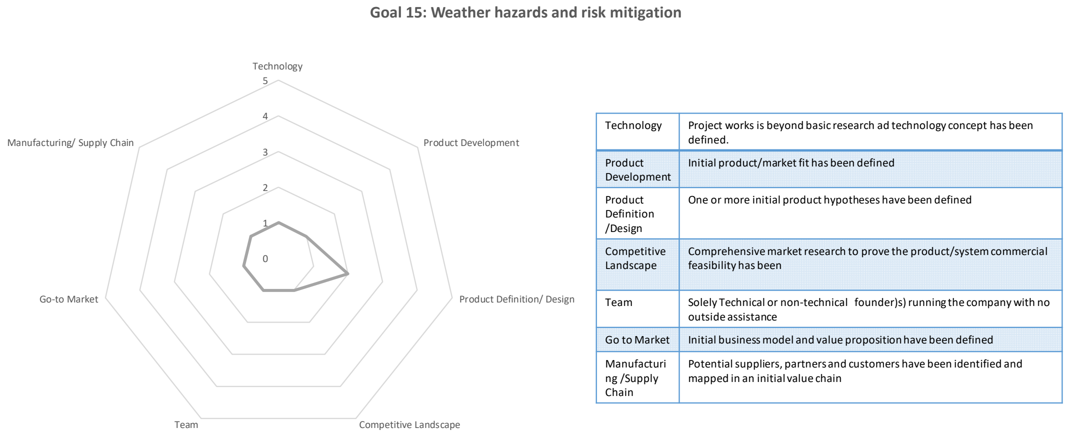
vi) Strong low level/surface winds and windshear.

As safety progresses former hazards are overcome and new ones are discovered, that were previously hidden behind other events. For example windshears or microbursts must have been the cause of accidents in the past of aircraft flying through storms, but were identified clearly only 3 decades ago, as other safety hazards were overcome. General weather predictions and on-board sensors like weather radar are basic indicators of potential hazards; laser Doppler radar is a good complement not generally fitted to airliners. The information from flights of preceding aircraft on similar routes can also be a useful warning. An example is a windshear associated with a microburst: (i) a toroidal vortex lies above the ground; (ii) it creates a down flow through its core; (iii) the following horizontal flow changes from head wing to tail wind as an aircraft flies under the core; (iv) the combination of down flow and tailwind can lead to stall and/or crash. The wind shear is most readily detected by LIDAR that measures wind speed; it can be detected by the weather radar if the microburst is associated with rain. The indications of an aircraft that has recently flown a similar path are a warning for the safest option of wind shear avoidance.

The prevention and mitigation of weather hazards requires:

i) supplementing **meteorological data** by information from ground based or airborne weather radars or lidars and flight reports;
ii) **system-wide information** sharing among all aviation stakeholders and stakeholders collaborative decision making processes;
iii) simple, unambiguous and **standardised products** and **business cases** to tailor MET info to the user's needs ;
iv) **early warning** of the flight concerned on the type and severity of the hazard likely to be encountered;
v) accurate **assessment of the risk**, survival tactics and timely decision of avoidance if appropriate;
vi) combine different hazards when and where appropriate: seamless, and in aviation sector;
vii) develop **impact scenarios** for various stakeholders, and
viii) training of pilots and air traffic controllers on mitigation strategies.

NYSERDA (TRL/CRL) Calculator results for analysis and assessment of **ACARE Challenge 4 Goal 15** - Weather hazards and risk mitigation - are shown in figure 5 grounding on the results of the 1st year PARE report [15].



Technology	Project works is beyond basic research ad technology concept has been defined.
Product Development	Initial product/market fit has been defined
Product Definition /Design	One or more initial product hypotheses have been defined
Competitive Landscape	Comprehensive market research to prove the product/system commercial feasibility has been
Team	Solely Technical or non-technical founder)s) running the company with no outside assistance
Go to Market	Initial business model and value proposition have been defined
Manufacturing /Supply Chain	Potential suppliers, partners and customers have been identified and mapped in an initial value chain

Figure 5: NYSERDA (TRL/CRL) Calculator results for analysis and assessment of ACARE Challenge 4 Goal 15 — Weather hazards and risk mitigation.

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6. Integrating drones in manned airspace

*** Flightpath 2050 goal 16: "The European air transport system operates seamlessly through interoperable and networked systems allowing manned and unmanned air vehicles to safely operate in the same airspace"**

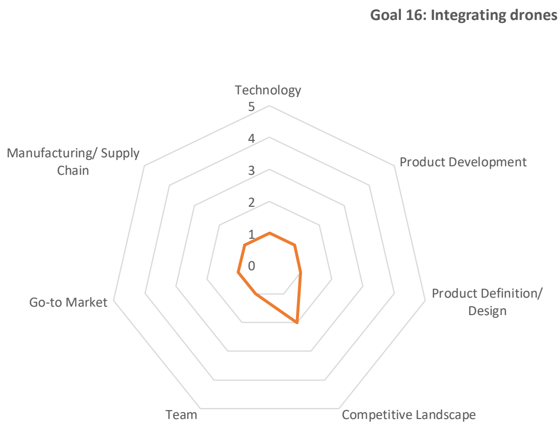
In relation to **goal 16**, **the number of drones within the EU has multiplied over the last 2 years.** Analysis of RPAS occurrences in the European Central Repository identified **584 occurrences of all severity levels,** of which 37 had been classed as accidents (2011-2015), none of them involved fatalities; and 4 with minor injuries. 63% of occurrences are related to **Airborne Conflict**, particularly, **airspace infringements** and **proximity** of drones to other aircraft. The highest number of occurrences took place in D and G class airspace. **The Key Risk Areas** identified by EASA from the reported occurrences are:

i) Airborne Conflict;
ii) Aircraft Upset;
iii) System Failures, and
iv) Third Party Conflict.

The EASA **regulatory framework** for the safe operations of drones in Europe currently addresses the issue of collision between drones and aeroplanes. A combination of measures are envisaged such as: operate in visual line of sight, fly under 150 m height above ground, be equipped with identification and geo-limitation functions and be registered. Although there has been an increasing trend, the **collection of data on UAS occurrences is still in its infancy** and there is still a lot of work to be done to ensure the correct application of taxonomy terminology related to UAS.

Further actions taken at the European Union level will need to occur rapidly given the pace of global development in drones, especially as the US and China are already. Much of what still needs to be done include technology (detect and avoid, Datacom), air traffic management, security & cyber reliance along with the availability of authorized & safe testing environments. These improvements need to be completed within a window of opportunity limited to the **next 5-10 years**. One of the keys is the technology related to air traffic management in such a way that the demand of UAVs on all areas of airspace highlights the critical nature of air traffic management.

NYSERDA (TRL/CRL) Calculator results for analysis and assessment of **ACARE Challenge 4 Goal 16** - Integrating drones in manned airspace- are shown in figure 6 grounding on the results of the 1st year PARE report [15].



Technology	Project works is beyond basic research ad technology concept has been defined.
Product Development	Initial product/market fit has been defined
Product Definition /Design	Mapping product/system attributes against customer needs has highlighted a clear value proposition
Competitive Landscape	Secondary market research has been performed and basic knowledge of potential applications and competitive landscape have been identified
Team	No team or company in place (single individual, no legal entity)
Go to Market	Initial business model and value proposition have been defined
Manufacturing /Supply Chain	Potential suppliers, partners and customers have been identified and mapped in an initial value chain

Figure 6: NYSERDA (TRL/CRL) Calculator results for analysis and assessment of ACARE Challenge 4 Goal 16 — Integrating drones in manned airspace.

7. Comprehensive and unobtrusive security measures

**** Flight 2015 goal 17: "Efficient boarding and safety measures allow seamless security for global travel with minimum passenger and cargo impact. Passengers and cargo pass through security controls without introduction"***

Regarding **goal 17**, high-priority risk areas in the coming years include the strengthening of security to be applied to all phases and processes associated with the carriage of persons, their cabin and hold baggage, cargo, mail, courier and express parcels; and protecting against cyber-attacks and threats.

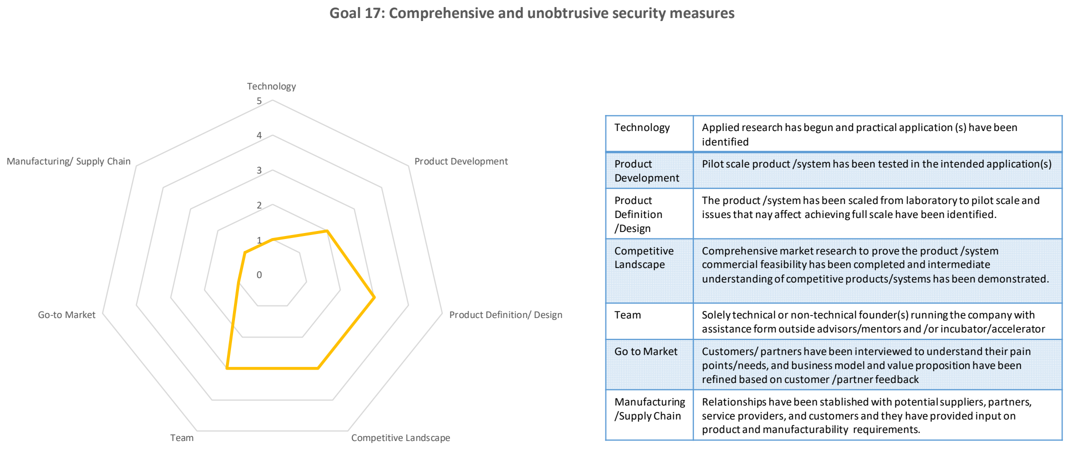
ICAO registered 1**0 acts of unlawful interference in 2015 and 21 in 2014. Advanced screening technologies** allow for effective threat detection while reducing the burden for passengers. Several **advanced passenger and baggage screening technology** begun to be deployed in 2010: Advanced Technology X-ray, Bottled Liquid Scanners, Advanced Imaging Technology, Boarding Pass Scanners, Enhanced Metal Detectors, Chemical Analysis Devices, Explosive Trace Detectors, and the use of risk-based algorithms to screen passenger more efficiently and quicker.

Collection and transmission of advance passenger information (API) and passenger name record (PNR) data are recognised as facilitators for developing a "**checkpoint of the future**", while acknowledging the importance of protecting passengers' privacy. In 2010 more than 180 States issued machine readable passports (MRPs) in conformity with ICAO specifications.

A more integrated approach to aviation safety and security is needed. Aviation security requires a cross-functional approach that ensures appropriate coordination with facilitation, aviation safety, air navigation and other relevant fields. More real-time sharing of critical information between States and industry, and between aviation security professionals and partners who have a need to know should be encouraged. The seven Strategic Focus Areas identified by ICAO should remain as a solid foundation for addressing current and future aviation security challenges:

i) *Addressing new and existing threats*;
ii) *Promoting innovation in aviation security*;
iii) *Sharing of information*;
iv) *Promoting global compliance and establishing* sustainable *aviation security oversight capability of States*;
v) *Improving human factors and security culture*;
vi) *Mutual recognition of aviation security processes, and*
vii) *Emphasizing the importance of aviation security worldwide*.

NYSERDA (TRL/CRL) Calculator results for analysis and assessment of ACARE Challenge 4 Goal 17 - Comprehensive and unobtrusive security measures – are shown in figure 7 grounding on the results of the 1st year PARE report [15].



Technology	Applied research has begun and practical application (s) have been identified
Product Development	Pilot scale product /system has been tested in the intended application(s)
Product Definition /Design	The product /system has been scaled from laboratory to pilot scale and issues that nay affect achieving full scale have been identified.
Competitive Landscape	Comprehensive market research to prove the product /system commercial feasibility has been completed and intermediate understanding of competitive products/systems has been demonstrated.
Team	Solely technical or non-technical founder(s) running the company with assistance form outside advisors/mentors and /or incubator/accelerator
Go to Market	Customers/ partners have been interviewed to understand their pain points/needs, and business model and value proposition have been refined based on customer /partner feedback
Manufacturing /Supply Chain	Relationships have been stablished with potential suppliers, partners, service providers, and customers and they have provided input on product and manufacturability requirements.

Figure 7: NYSERDA (TRL/CRL) Calculator results for analysis and assessment of ACARE Challenge 4 Goal 17 — Comprehensive and unobtrusive security measures.

8. Resilience to external and internal threats

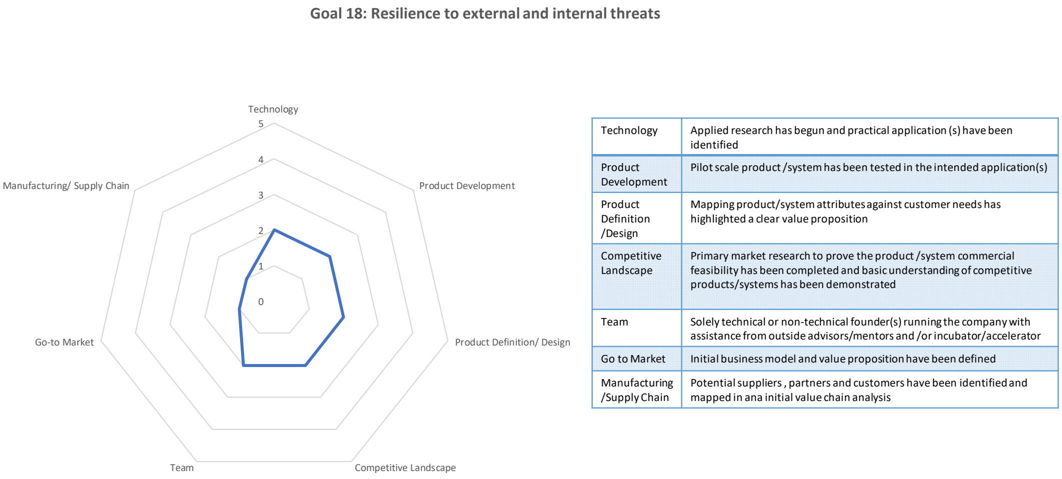
**** Flightpath 2050 goal 18: "Air vehicles are resilient by design to current on-board and on the ground security threat evolution, internally and externally to the aircraft"***

Being resilient is the aim of **goal 18.** The EU is facing one of the **greatest security challenges in its history** and **security** has become a major factor in civil and commercial aviation. In recent decades, **the number of threats to aviation security has grown significantly**. Current and emerging threats have been clustered into the following eight threat categories:

i) Improvised Explosive, firearms, close range destructive threats;
ii) Chemical, Biological, Radioactive, Nuclear and Explosive threats;
iii) Ground-to-air threats;
iv) Ground-to-ground threats;
v) Cyber threats;
vi) Electromagnetic threats;
vii) Sabotage, seizure and hijacking; and
viii) Bluff threats and threats from social media.

Currently, aviation security is primarily based on the **preventive phase and is inflexible to new threats.** This is also **mirrored in the research landscape** for aviation security. Most projects concentrate on preventive measures such as the detection of CBRNE-substances. Security concepts should aim at involving different measures at different stages of the passengers' travel. To be resilient to the evolving threat situation, aviation security should be based on the **complete resilience cycle** of "prepare, prevent, protect, respond and recover". This should enable stakeholders to "learn and adapt" instead of exclusively be ruled by reactive, strict and inflexible regulations. An **Aviation Security Research Roadmap** has been developed to provide the European Commission and the Member states with clear guidelines for future R&D activities responding to operational and economic market needs while being attentive of the acceptance by citizens.

NYSERDA (TRL/CRL) Calculator results for analysis and assessment of ACARE Challenge 4 Goal 18 - Resilience to external and internal threats – are shown in figure 8 grounding on the results of the 1st year PARE report [15].



Technology	Applied research has begun and practical application (s) have been identified
Product Development	Pilot scale product /system has been tested in the intended application(s)
Product Definition /Design	Mapping product/system attributes against customer needs has highlighted a clear value proposition
Competitive Landscape	Primary market research to prove the product /system commercial feasibility has been completed and basic understanding of competitive products/systems has been demonstrated
Team	Solely technical or non-technical founder(s) running the company with assistance from outside advisors/mentors and /or incubator/accelerator
Go to Market	Initial business model and value proposition have been defined
Manufacturing /Supply Chain	Potential suppliers , partners and customers have been identified and mapped in ana initial value chain analysis

Figure 8: NYSERDA (TRL/CRL) Calculator results for analysis and assessment of ACARE Challenge 4 Goal 18 — Resilience to external and internal threats.

9. High-bandwidth data resilient to cyberattacks

**** Flightpath 2050 goal 19: "The air transport system has fully secured global high bandwidth data network, hardened and resilient by design to cyber-attacks"***

In relation with **goal 19**, so far there have been no major reports of jamming of civil aircraft communications or cyberattacks on air traffic infrastructure. However, some isolated incidents from the past indicate that it can happen: (i) a Tornado aircraft flying over Radio Free Europe in southern Germany may have suffered loss of control due to high power radio transmissions interfering with on board systems; (ii) the Iranian television showed an American UAV intact (except for undercarriage) that did an emergency landing (US version) or was remotely diverted (Iranian version).

The following are some of the **main threats** identified in cybersecurity:

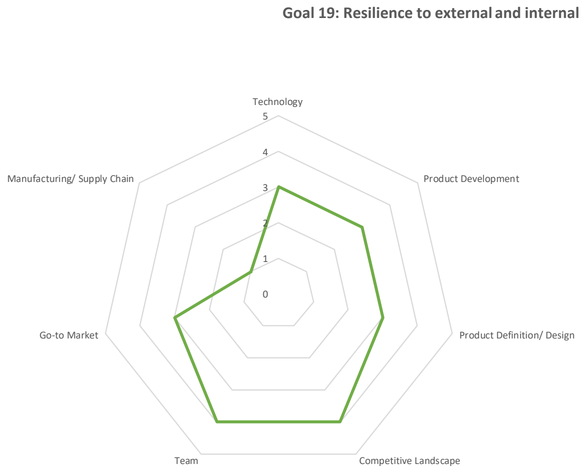
i) phishing threats;
ii) Jamming attacks;
iii) Remote hijacking;
iv) DDoS attacks, and
v) Wi-Fi-based attacks.

The **vulnerabilities** that need to be taken into account are: (i) in a large, complex interconnected system there are many entry points for cyber intrusion and many links to spread the cyber-attack; (ii) the weakest node may be the preferred entry point, for example small suppliers of equipment or codes well protected by large industries or government bodies.

Currently, **there is no common vision, or common strategy, goals, standards, implementation models, or international policies defining cybersecurity for commercial aviation**. Ensuring a secured aviation system and staying ahead of evolving ICT threats is a shared responsibility, involving governments, airlines, airports, and manufacturers. Three specific studies have been developed in this report covering key topics: i)the current state of the triple technological, operational and societal/human dimension of the cybersecurity problem in aviation;

ii) current guidelines for cyber protection and security, and iii) the blockchain as favourites technologies for cyber-security.

NYSERDA (TRL/CRL) Calculator results for analysis and assessment of **ACARE Challenge 4 Goal 19** – High-bandwidth data resilient to cyberattacks- are shown in figure 9 grounding on the results of the 1st year PARE report [15].



Technology	Preliminary testing of technology components has begun, and technical feasibility has been established in a laboratory environment
Product Development	Demonstration of a full scale product /system prototype has been completed in the intended applications (s)
Product Definition /Design	The product/ system has been scaled from laboratory to pilot scale and issues that may affect achieving full scale have been identified
Competitive Landscape	Competitive analysis to illustrate unique features and advantages of the product/system compared to competitive products/system has been completed
Team	Balanced team with technical and business developments/ commercialization experience running the company with assistance from outside advisors/mentors
Go to Market	Market and customer /partner needs and how those translate to product requirements have been defined and initial relationships have been developed with key stakeholders across the value chain
Manufacturing /Supply Chain	Relationships have been established with potential suppliers, partners, service providers, and customers and they have provided on product and manufacturability requirements

Figure 9: NYSERDA (TRL/CRL) Calculator results for analysis and assessment of ACARE Challenge 4 Goal 19 — High-bandwidth data resilient to cyberattacks.

10. **Conclusions and recommendations**

This paper presents the outcomes of the research carried out by the European Union funded-project PARE to determine the level of progress, gaps and barriers in the implementation of the safety and security goals for the year 2050. We have analysed the progress made towards each of the 6 safety and security Flightpath goals, extrapolated the current rate of progress, and proposed measures for closing the gap.

In this work we analyse the benchmark of progress from the state of the art towards the 23 Flightpath 2050 goals following a three stage process that includes: i) analyses of the state of the art in technical developments; ii) benchmark of technology maturity; and iii) proposal for recommendations.

In this project we used a Technology Readiness Level Calculator developed by NYSERDA to evaluate Technology maturity. Most of expected solutions for reaching the goals are assessed according to the levels TRL3-TRL4 – technology development and validation stages. Table 1 summarises the recommendations made by PARE project based upon the analysis performed.

ACARE Safety and Security Goal	Recommendations
GOAL 14: *Overall, the European air transport system has less than one accident per ten million commercial aircraft flights.*	***Recommendation 14:*** *Consider accident causes by order of statistical occurrence and for each class identify and implement appropriate safeguards.*

GOAL 15: *Weather and other hazards from the environment are precisely evaluated and risks are properly mitigated.*	***Recommendation 15.1:*** *Use the atmospheric data collected by airline flights to augment other weather data sources and better plan flight profiles and operations.* ***Recommendation 15.2:*** *Promote low-cost basic research on flight in adverse weather conditions (wind, rain, ash clouds, lightning, icing, storms and weather fronts) and select promising advances for demonstration.*
GOAL 16: *The European air transport system operates seamlessly through interoperable and networked systems allowing manned and unmanned air vehicles to safely operate in the same airspace.*	***Recommendation 16.1:*** *Assess the evolution of air traffic capacity in Europe compared with the growth of air transport to identify the spare capacity available to other users like UAVs.* ***Recommendation 16.2:*** *Establish the qualifications required of operators of UAVs and other aircraft compared with airline pilots and air traffic controllers to ensure that aviation remains the safest means of transportation.* ***Recommendation 16.3:*** *Define the design, production, certification and maintenance procedures for UAVs and other aircraft to preserve or improve on the safety levels of current airliners that operate in the same airspace.* ***Recommendation 16.4:*** *Explore the increased use of partially available airspace to enable the expansion of operations by new types of aircraft.* ***Remark 16.4:*** *Since congested airspace offers limited opportunities for new operators, largely unused ou less congested airspace could be exploited by suitably designed new vehicles like UAVs.*
GOAL 17: *Efficient boarding and security measures allow seamless security for global travel, with minimum passenger and cargo impact. Passengers and cargo pass through security controls without intrusion.*	***Recommendation 17:*** *Develop non-intrusive passenger screening methods and foolproof luggage checking that allow fast flow through registration, border and boarding procedures.*
GOAL 18: *Air vehicles are resilient by design to current and predicted onboard and on the ground security threat evolution, internally and externally to the aircraft.*	***Recommendation 18.1:*** *Design aircraft and establish procedures to (a) prevent unauthorised entry into the cockpit, (b) allow remote take-over up to safe landing in the case of an identified flight anomaly while (c) designing the system to be immune to the most sophisticated hacking.* ***Remark 18.1:*** *Threats to aircraft can come not only from hijackers but also from crew disabilities and in some cases of both remote control may the only solution, although it opens other risks like hacking or interference that must be weighted.* ***Recommendation 18.2:*** *Set up an independent observatory of external risks to aircraft overflights to advise airlines or failing that warn passengers.* ***Recommendation 18.3:*** *Design a worldwide airliner flight monitoring system and accident data recorders to ensure that accident/incident data is available regardless of time and location of occurrence.*
GOAL 19: *The air transport system has fully secured global high bandwidth data*	***Recommendation 19.1:*** *Assess the evolution of bandwidth requirements required to cope with increasing telecommunication*

network, hardened and resilient by design to cyber-attacks	*needs associated with improved navigation, on-board systems monitoring, passenger connection and other services.* ***Recommendation 19.2:*** *Establish evolving standards for protection against cyberattacks, with different levels, the highest for flight systems and the lowest but non-trivial for ticketing, bearing in mind the risk of intrusion from lower levels.*

As future work, to improve this assessment, a more sophisticated scheme will be designed taking in mind *Technology Project Readiness Level* (TPRL) methodology. The advantage of TPRL methodology is the fact that when assessing the level of preparedness of projects, not only the criteria characterizing a certain level of readiness (TRLX as is accepted by the TRL method) are used, but also the documents on the basis of which these criteria are fulfilled. This includes calculation of the numerical parameters of the model, which is based on the expert evaluation of the quality of the supporting information on the results of the projects presented in the project documentation. Such model will allow to monitor the effectiveness and progress of projects within the current level of technological readiness at small time intervals, or the rating of projects when making decisions to provide them with support.

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