Project no: ASA6-CT-2006-044549

Project acronym: EPATS

Project title: European Personal Air Transportation System Study

Instrument: Specific Support Action

Thematic Priority: Integrating and Strengthening the European Research Area

Title of report:

D3.2 EPATS Airports General Requirements including Safety and Environmental Issues

Organization name of lead contractor for this deliverable: **NLR**

Date of report preparation: May17th, 2008	Date of report issue: June 13, 2008
Deliverable: D3.2 EPATS Airports General Requirements	Version/Status: **V1** (draft: a,b,c; final: 0,1,2,3)

Approval Status (date, signature)			
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Project coordinator organization name: INSTITUTE of AVIATION	Duration: 18 month

Project funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	**X**
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Abbreviations

4D	Three dimensional plus time
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance - Broadcast
ALS	Approach Lighting System
AOPA	Aircraft Owners and Pilots Association
APP	Approach ATC service
APU	Auxilarry Power Unit
A-SMGCS	Advanced Surface Movement Guidance and Control System
ASAS	Airborne Separation Assurance System
ATC	Air Traffic Control
ATM	Air Traffic Management
ATPL	Air Transport Pilot Licence
CAT (Cat)	Category
CDA	Continuous Descent Approach
CFR	Code of Flight Regulations
CPL	Commercial Pilot Licence
CONOPS	Concept of Operations
CRI	Critical Review Items
CRM	Crew Resource Management
CS	Common Standards
DME	Distance Measurement Equipment
EASA	European Aviation Safety Agency
ECCAIRS	European Co-ordination Centre for Accident and Incident Reporting
EEC	Eurocontrol Experimental Centre
EFIS	Electronic Flight Instrument System
ELT	Emergency Locator Transmitter
EPATS	European Personal Air Transportation System
ES	Extended Squitter
FAA	Federal Aviation Administration
FADEC	Full Authority Digital Engine Control
FAR	Federal Aviation Regulations
FCL	Flight Crew Licensing
FDM	Flight Data Monitoring
FMS	Flight Management System
FOQA	Flight Operations Quality Assurance
FP	Framework Programme
FSF	Flight Safety Foundation
GA	General Aviation
GAO	Government Accountability Office
GBAS	Ground Based Augmentation System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPU	Ground (electrical) Power Unit
GPWS	Ground Proximity Warning System
HUD	Head Up Display
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules

ILS	Instrument Landing system
IMC	Instrument Meteorological Conditions
JAA	Joint Aviation Authority
JOEB	Joint Operations Evaluation Board
LAAS	Local Area Augmentation System
LAHSO	Land After and Hold Short
LOFT	Line Oriented Flight Training
MFW	Maximum Fuel Weight
MFD	Multi-Function Display
MOR	Mandatory Occurrence Reporting
MSL (msl)	Mean Sea Level
MTOW	Maximum Take Off weight
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NBAA	National Business Aviation Administration
NDB	Non-directional Beacom
NLR	National Aerospace Laboratory
NLR-ATSI	NLR Air Transport Safety Institute
NM	Nautical Mile
NOTAM	Notice to Airman
PAPI	Precision Approach Path Indicator
PFD	Primary Flight Display
PPL	Private Pilot Licence
P-RNAV	Precision Area navigation
R&D	Research and Development
RVSM	Reduced Vertical Separation Minimum
RW	Runway
SATS	Small Aircraft Transportation System
SBAS	Space Based Augmentation System
SCA	Self Controlled Airspace
SESAR	Single European Sky ATM Research
SFCS	Specific Fuel Consumption
SID	Standard Instrument Departure
SMS	Safety Management System
SRM	Single pilot Resource Management
SSA	Specific Support Action
STAR	Standard Terminal Arrival Route
TAA	Technically Advanced Aircraft
TCAS	Traffic Collision Avoidance System
TFM	Traffic Flow Management
TMA	Terminal Manoeuvring Area
TMU	Traffic Management Unit
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VHF	Very High Frequency
VLJ	Very Light Jet
VMC	Visual Meteorological Conditions
VMCG	Minimum Control Speed Ground
VOR	Very High Frequency Omni-directional Range
WAAS	Wide Area Augmentation System
WP	Work Package

1. Project and report objectives

1.1. Project objectives

The EPATS (European Personal Air Transportation System) [1] focuses on the future Highly Customer Oriented and Time, and Cost Efficient Air Transport System. It fills niche between Surface and Scheduled Air Transport. Future mobility cannot be satisfied only through investments in hub and spoke, or rail - and highway systems.
This future EPATS system will provide a wide choice of transportation mode - and **the wider use of small aircraft, served by small airports, to create access to more communities in less time.**
The goal of the EPATS proposal is to demonstrate the needs and potential of small aircraft business development and to propose recommendations for the introduction of this new European Air Transportation System in the context of the European Research Areas.

The SSA EPATS Study project is addressing the following issues:
- The potential new market for personal aviation up to 2020 [2].
- The potential impact of this new way of transport on the European ATM, and **airport infrastructures**, as well as the **environmental and safety** issues involved [7].
- The EPATS general specification and R&D Roadmap [11]

The study is carried out by a Consortium supported by representative experts of the EPATS stakeholder community.

The deliverables of these studies will be reports containing a joint vision of the personal air transportation system in Europe to 2020 and proposals for developing this new small aircraft business at a European level.

1.2. Report objectives

This Report relates to Deliverable D3.2 EPATS Airports General Requirements including Safety and Environmental Issues and reflects the work done on Future Airports Parameters (Work package 3, [1].

EPATS WP3 Objectives:

1. Identify the issues to be solved that are related to the required airside infrastructure for the various types of airport to accommodate EPATS aircraft.
2. Identify environmental and safety issues for EPATS.

<u>The work on EPATS task 3.2 Future European airports parameters</u> ***(NLR)*** consists of a specification of the main characteristics of EPATS airports (general requirements, chapter 3 of this report) and the identification of the R&D issues (see Recommendation chapter 6 of this report) to be solved that are related to the required airside infrastructure for the various types of airport to accommodate EPATS aircraft. Use is made of available input from other work packages:

- The expected EPATS traffic volumes in 2020 [2],[3],[6],[7]

- Expected number of EPATS type of aircraft (e.g. MTOW, max. number of passengers per aircraft, piston, turboprop, jet etc.) [4]
- Envisaged traffic routes. This is an expected output from WP1, WP2 [6]
- EU [12], US [13], Eurocontrol [16] and ICAO strategy document [14, 15]

The work on EPATS task 3.3 Environmental and safety aspects ***(NLR)*** studies the consequences for:

- Environment: (chapter 4 of this report)
  Identify in what way EPATS traffic figures, taking into account approach and departure procedures, will affect noise and emission levels in communities surrounding the airport
- Safety (chapter 5 of this report)
  Identify the factors to be investigated that affect ATM safety when EPATS traffic is introduced in the ATM system.

This analysis is also reported in this document, see chapter 4 and 5.

The security problem of operations with EPATS aircraft from small and regional field with minimum facilities is not discussed in this report. Regulatory aspects are covered lightly along the topics as discussed.

The consequences of the EPATS evolution for Air Traffic Management are explained in EPATS deliverable D3.1 – ”EPATS ATM General requirements & related issues to be solved” (EEC) [8].

1.3. Terminology

In this report there is no difference between ”airport”, ”airfield” or ”aerodrome” (ICAO term). Airports may be civil, military or combined military/civil airports. An airfield is called controlled when aerodrome control service is supplied from an aerodrome control tower. The United States of America call controlled airfields ”towered airports” and not-controlled airfields ”non-towered airports”. If an airport is called international, custom facilities are present.

1.4. The EPATS project

EPATS is a study funded by the European Commission that focuses on the future highly customer oriented, time- and cost efficient air transport system. The concept is characterised by reducing the door-to-door travel time, using small, regional airports and small aircraft at low costs, that are capable in operating in all weather conditions. EPATS will improve mobility, accessibility and economic equity through Europe’s suburban, rural and remote areas. It would provide a safe, secure and comfortable alternative to other modes of transportation, including current air travel and high speed trains. The new, emerging technologies and advanced small light aircraft open up a new market for business/corporate aviation and air taxi services[1].

It is estimated that 100,000 EPATS aircraft will be flying in European airspace by 2020. They will partly replace the current general aviation aircraft types. The acquisition cost of small aircraft like the Very Light Jet (VLJ) is currently in the order of a few million euro’s. The mass production of these aircraft is a characteristic associated with this market (related to the low

aircraft acquisition cost), resulting in a potential large number of small aircraft entering the aviation system.

The goal of the EPATS study is to demonstrate the needs and potential of small aircraft business development and to propose recommendations for the introduction of EPATS in the context of the future European Research Areas. In order to provide recommendations for further research and development in the form of an R&D roadmap, the EPATS project analyses:

- The potential new market for personal aviation up to 2020;
- The potential impact of this new way of transport on the European Air Traffic Management (ATM) and airport infrastructure, as well as the environmental and safety issues;
- The efficiency, technology and operational aspects of such an air transport system; and
- Aircraft specifications.

The study is carried out by a consortium supported by representative experts of the EPATS stakeholder community. The deliverables will be reports containing a joint vision on the personal air transportation system in Europe by 2020 and proposals for developing this new concept at an European level.

The concept of EPATS is mainly based on [2, 11]:

- Using the already existing local and regional airports network (more than 2000), especially located on the periphery of European main transportation infrastructure in the areas with low level of accessibility indicator;
- Using a potential enabled by the opening of Single European Sky and conducted research in the area of management and air traffic control by e.g. SESAR;
- Using new technologies concerning aerodynamics, materials, propulsion, communication, navigation and control based on satellite systems;
- Adjusting aircraft fleet and operational structures to interregional passengers flow, local demand and society needs;
- Increasing economic efficiency of interregional air transport by creating small carriers and private aircraft owners friendly legal and economic conditions, promoting unification, standardization and integration of maintenance networks; and
- Including remote interregional communication networks areas (with low accessibility) into public transport financing.

EPATS is a complex collection of systems, procedures, facilities, aircraft and people. They work together as one system to ensure safe and efficient operation. The system includes:

- Network of all existing and future airports and airfields in Europe satisfying the EPATS requirements, i.e. an EPATS-compliant airport meets a set of desired characteristics appropriate for the community’s transportation demand and requirements;
- Pistons, turboprop and jet aircraft, having a capacity from 4 to 19-seats, fulfilling the requirements of FAR-23 or CS-23 and FAR 135 operating regulations;
- Air traffic management and control systems adapted to intensified air traffic generated by the EPATS. They include: radio, TMU and TFM, weather, radar, navigation and en route sites;
- Flight Service Station;

- Internet-based passenger travel booking and demand optimisation, offering transport capacity adjusted to the demand at the lowest price/performance ratio;
- Aircraft maintenance and management companies; and
- Aircraft owners and users associations.
- Aviation authorities;
- Air Navigation Service Providers;
- Flight training schools; and
- Research centres.

Moreover, the system surroundings include public transport powers (adequate local government units), aviation authorities, air traffic managers, aviation schools, aviation industry with its research and development centres. The system aims to operate in the public transport infrastructure framework.

The goal of the EPATS study is to demonstrate the needs and potential of small aircraft business development and to propose recommendations for the introduction of this new European Air Transportation System in the context of the future European Research Areas. The EPATS project studies the market, efficiency, technology and operational aspects if such an air transport system to provide recommendations for direction of further research and development.

2. EPATS concept of operations

The development of an European Personal Air Transportation System and its consequences for the airport infrastructure can be better envisaged if we try to define the EPATS better with the knowledge of the other studies. Three basic components of the transportation system are:

- The expected type of EPATS aircraft,
- Avionics
- EPATS operational use.

These are discussed in the next paragraphs.

2.1. EPATS aircraft

There are three aircraft categories defined for EPATS based on engine type: pistons, turboprops and jets [11],[17]. Each category includes single- and multi-engine aircraft. All EPATS aircraft have to comply with FAR-23 or EASA CS-23 requirements. EPATS aircraft are small aircraft with a take-off weight of less than 5,700 kg for normal category and 8550 kg for commuter category, equipped with advanced avionics (see section), with capabilities for all-weather operations, which can be flown both IFR and VFR, and by a single pilot or a crew of two[1]. The aircraft will be used as scheduled commuter, business, corporate, air taxi, charter, individual owner/operator flight. The EPATS concept does not involve the traditional air carriers. An EPATS aircraft operator can be, amongst others, an scheduled small carrier, on demand air-charter, air taxi service operator with a fleet of a dozen or hundreds of aircraft , a medium-sized corporation, a private, public-private, fractional ownership company, or an individual owner.

2.1.1. Piston aircraft

The EPATS roadmap envisions that the cheapest *single-engine* aircraft will partially replace cars for travelling a distance of 300-500 km and above. These aircraft will be flown Visual Flight Rules (VFR), often with pilots (owners) only having a private pilot license. However, the aircraft will meet EPATS requirements and have an Instrument Flight Rules (IFR) capability for commercial operations and versatility. The aircraft can accommodate up to 3 passengers and a single pilot. *Twin-engine* aircraft will operate as an air-taxi with comparable costs to a car taxi. These will be used for one day business trips on routes connecting remote, peripheral regions with distances around 300-700 km. The aircraft may be piloted in VFR/IFR conditions by a single commercial licensed pilot carrying up to 5 passengers. It is forecasted that the current dominant position of piston aircraft (70% of all general aviation) will gradually decline as they will be phased out in favour of turbines and jets due to the expected income rise of the population [17].

[1] Current regulations in Europe require a crew of two pilots when commercial operations (e.g. air taxi) are conducted, refer to section 5.6.3.

2.1.2. Turboprop aircraft

Turboprop aircraft with 9 to 19-seats, operated by small carrier companies, will serve direct and regular connections between peripheral regions on distances between 300-1,500 km, which are characterized by low intensity of traffic (5,000-10,000 passengers yearly). These aircraft will also provide charter service on routes with low, irregular flow of passengers (e.g. tourism, seasonal travel, sports or cultural events, etc.). Costs of travel using these aircraft should be comparable with costs of travelling by low-cost carriers and should be available to most of the citizens [17]

2.1.3. Jet aircraft

In the small jet aircraft category, two main types are envisioned:

- *Very Light Jets (VLJ):* small jet aircraft with 3-6 seats, which will be mainly used in business and air taxi operations, providing regional and executive air transport for upper time value passengers. (They could also be used for recreational or private flights for wealthiest peoples.)
- Jet aircraft with 7-9-seats will operate across Europe as a corporate and business airline charter or regularly scheduled flights between cities deemed profitable [17].

In particular the advent of VLJs gets much attention recently. For several years, a number of aircraft manufacturers have been designing and testing VLJs and the production and delivery of VLJs is increasing. Examples of VLJs are the Eclipse 500, Cessna Mustang, Diamond Aircraft D-Jet and Embraer Phenom 100. The first air taxi operations with VLJs have already started in the United States (e.g. the DayJet company in Florida). The typical VLJ weighs 5,000 kg or less and is equipped with advanced avionics, automated engine and systems management, autopilot and advanced FMS, and are designed for single pilot operations. A typical VLJ’s performance profile includes flight levels 150-280, but these jets are capable of higher flight levels as well. The VLJs have a typical climb performance of 2,000-3,000 feet/minute, cruise at Mach 0.6, and their range is 900-1,300 NM. They are capable of operating from airports with paved 3,000-5,000 feet runways. These aircraft have capabilities for Instrument Flight Rules (IFR), Cat 1 landing and Reduced Vertical Separation Minimum (RVSM). They are priced at 2-4 million US$ (2006).

2.2. EPATS aircraft avionics

The typical avionics suite of the EPATS aircraft includes [17] a subset of:

- Dual 8.33 kHz VHF radio, System Wide Information Management, dual datalink, World wide Interoperability for Microwave Access (Twin Turboprop and Twinjet) and optional Broadband Services for Twin Jet
- Dual GNSS with Satellite Based Augmentation System and dual DME
- RVSM for Twin Jet
- P-RNAV FMS for Single Engine and Twin Engine Piston Aircraft; 4D RNAV FMS for Turboprop and Twin Jet
- ILS receiver

- ADS-B In/out 1090ES for Single Engine and Twin Engine Piston Aircraft
- Enhanced ADS-B for Twin Turboprop and Twin Jet
- Moving map navigation displays, with terrain, traffic and weather information;
- Traffic Advisory System for all aircraft types and TCAS II for higher class Twin Turbojet and Twin Jet
- Emergency Locator Transmitter 406 MHz
- Terrain Avoidance Warning System class B for all aircraft types and class A for higher class Twin Turbojet and Twin Jet
- Flight Data Recorder and Cockpit Voice Recorder for the higher class Twin Turbojet and Twin Jet
- Lightning detection for Single Engine and Twin Piston, Weather Radar for Twin Turboprop en Twin Jet
- Integrated Flight Deck (Primary Flight Display /Multi Functional Display /audio/Auto Pilot)
- Head Up Display / Synthetic Vision System / Enhanced Vision System optional for the higher class Twin Turboprop and Twin Jet
- Electronic Flight Bag: airport charts, and information, airport taxi display;
- Full authority digital engine control (FADEC)

This list is giving an overview but is not intended as compulsory for any type of EPATS aircraft.

2.3. EPATS Typical Flight Operations and Numbers

From the market potential study [2, 6, 7] the following typical flight operations are evident. It is partially supported by NASA Small Aircraft Transportation System Concept Of Operations SATS CONOPS [18]. Flights take place in the 2020 European Single European Sky ATM Research (SESAR) scenario within a network centric air traffic management (ATM) and negotiated flight plans. This represents a major shift from the current airspace based system to a future trajectory based system. Large amount of self-separation will be up to aircraft.

2.3.1. EPATS ATM infrastructure

EPATS aircraft, above all VLJs, will fly in the European airspace and share the same airspace with commercial air traffic and large corporate and business aircraft. For example, VLJs are capable of flying at FL300+. In these populated level bands they fly between commercial air traffic at a significant slower speed. The disparity in climb speeds of VLJs is even greater. It is expected that some type of segregation is required and will be implemented to separate EPATS air traffic from the traditional air traffic. Dedicated SIDs/STARs and parallel en-route offset airways may be required for VLJs [Ref. 53]. FAA and Eurocontrol are currently studying the impact of VLJ operations on the airspace system.

The level of ATC provision at airports served by EPATS aircraft will differ: some may be controlled airfields, others could be uncontrolled. Likewise, the availability and quality of air traffic control service provision, ATC systems and safety nets will vary across airports. This applies to runway incursion alert systems, Advanced Surface Movement Guidance and Control Systems (A-SMGCS), availability of approach and ground radar, and minimum altitude

warning system. Such systems may be available at large and some regional airports, but most likely not at the smaller airfields.

The identification and description of aspects related to ATM is subject of WP3.1 and report D3.1 [Ref. 1].

2.3.2. A typical EPATS flight

Before the flight(s):

- The typical EPATS passengers in this example are business men/women travelling having a meeting at place more than 300 km away from their home or business. He/she wants to save time and to avoid hotels and overnight stays. Therefore he/she avoids the large airports with its long and nasty check in and security procedures, not even talking about the road traffic jams around the large airports. In a typical case there is no large airport near by
- The passenger looks into travel and transport information resources (internet based) for an attractive transport means short before he actually wants to travel. Short before means less than one day before the travel.
- The passenger buys his ticket that guarantees him travel between departure and arrival airport at times that are optimal for that passenger. He prefers to return on the same day. Even a one day trip with several destinations is possible.
- The transport providing company, hereafter called air taxi, optimises the size of the aircraft, the passengers and the destinations per day.
- The airtaxi company arranges flight crew and flight preparations.

On the day of the flight:

- The airtaxi company takes care to send the EPATS aircraft in time to the airport of departure, probably a small airport close to the passenger home or business.
- When waiting for the passengers, the usual pre-flight checks are executed by the pilot(s) Small problems can be solved by local facilities or spare parts on board.
- Using the ATM network linked flight planning computer at airport operations, the pilot enters the flight plan with the desired route. The pilot negotiates a satisfactory flight plan and he accepts and files it.
- Weather up to and including cat II Autoland is not delaying the flight due to excellent avionics and airport infrastructure.
- The passenger takes care to arrive on time at the small regional airport for departure.
- Other passengers join the flight as a result of the optimisation process of the airtaxi company.
- The regional airport is not controlled or remotely controlled, which means that the flight is VFR and safeguarded by e.g. Ground and Airborne Separation Assurance Systems, or IFR with Procedural Control. If needed the pilot informs the ATM system to meet the departure slot or to ask for slight a slight delay.
- The EPATS aircraft takes of on time, is flying VFR in class G airspace, special EPATS airspace or IFR in between regulated traffic and under control of traditional ATS.
- During large portions of the flight, the aircraft will be in managed airspace under ATC control. This will be very much like standard IFR flights conducted present day, with an

airborne separation assistance system (ASAS). Self separation with other aircraft occurs under special circumstances for example in free flight areas or where there is a lack of ground surveillance.

- The passenger arrives on time at the destination. He/she calls for car taxi transport, attends the meeting and returns at the remote airport in time for the return flight.
- If time allows the airtaxi performs other flight services in between (result of the flight optimisation process by the air taxi company), otherwise the airtaxi waits for the passenger(s).
- The return flight is executed and due to the advanced avionics no delay is experienced.
- The airtaxi returns to its home base or stays on the regional field for another day of operations.
- In case of aircraft problems or other sorts of delay, alternative transport is offered. A spare airtaxi or spare parts can be flown in, or e.g. in Cat III weather conditions, the transportation is done by other means.

The EPATS study gives estimations of a couple of 100.000 additional aircraft to be operated for air taxi and private purpose [7] in 2020. To stay on the conservative side, this airport study takes an of 100.000 EPATS aircraft to analyse where potential problems may arise in the coming 12 years. In comparison there are already about 50.000 General Aviation aircraft in Europe but data on actual use is not available This figure includes mainly gliders, ultralight, agricultural, … GA FAR JAR-23 Normal Category aircraft constitutes about 10.000 units. They are probably not used frequently. Well known is the fact that the larger European airports show policy to restrict access for General Aviation to their airport with exception of some business flight operations.

The mobility study in the EPATS project [6] gives information which city to city connections could be preferred by EPATS users. The emerging EPATS connections and the situation in 2020, however, are difficult to predict, because this emerging transport system will promote local economy such that low use connections have a good chance to grow. Therefore in this airport study we will only perform simple estimations and extrapolations to find the bottlenecks on airport infrastructure.

If we assume that about 1000 of the 2000 available small regional airport will attract EPATS and that we have the aforementioned 100.000 EPATS aircraft, we will see about 100 aircraft hosted per airport on average The EPATS aircraft is supposed to be used at least once per day. It implies about 200 movements per day per airport. If we assume on average another 50 to 100 visiting EPATS aircraft per day per airport, we are confronted with up to 400 movements per airport per day on average. These numbers will be taken in the next chapters to find bottlenecks for the air transportation by EPATS and areas for further investigation.

Some EPATS airport may host large air taxi operators with central maintenance and repair. There the estimations are higher and special infrastructure will be needed. The next chapters and the recommendations cover this type of ”airbases”.

For large airports the rules of slot allocation apply. We call these airports full-co-ordinated. It seems that the numbers of EPATS aircraft are still too low to require also slot allocation for smaller regional EPATS airports.

3. Airport infrastructure for EPATS

3.1. State of the art

There are over 2300 airports in Europe [5]. All major large airports are very tight scheduled and some are large hubs. Major airport flight schedules are based on regular flights and big airlines flying big planes. When the EPATS aircraft will fly on these major airports they will cause problems, for instance capacity and wake turbulence. The EPATS may constrain the airport capacity in total number of passengers transferred. A typical EPATS aircraft can only transfer a maximum of 19 passengers at a time while a Boeing 747-400 can transfer over 400 passengers. The latter is much more interesting for the major airports. Therefore the major airports will not promote airplanes like the EPATS aircraft. Expectedly, the EPATS aircraft will only fly on the smaller airports.
In Europe about 2000 of such smaller airports exists with varying levels of (quality of) infrastructure [5]. The passengers have the benefits of quick access to air transport without the disadvantage of the major airports. Nowadays General Aviation and sport use these smaller airports. If the EPATS aircraft start flying on these smaller airports, the airports have to meet some requirements (chapter 3.2). The smaller airports usually have almost no accommodation. The people who visit these airports are the pilots and some aviation enthusiasts. The introduction of the EPATS aircraft creates a new user group for the smaller airports and will change the economy and vision. The smaller airports will get an opportunity to grow. This will create new markets around the airports and it will favour the local economy. Restaurants, hotels and taxi-services get a lot of new customers. What an airport needs to satisfy the passengers is described in Airport operations chapter 3.3.
With the introduction of the EPATS aircraft a new transport system will be created. In the future many EPATS aircraft will fly in Europe. This development will change Europe in certain ways. These consequence are discussed in chapter 6.1.

Airport infrastructure includes:
- The landside (terminals, connectivity to other means of transport, passenger services, catering),
- Airside (runway, taxiways and apron),
- The navigation systems,
- Landing systems infrastructure (ILS, PAPI/VASI, GPS based landing systems),
- Runway and taxiway design and layout, including runway lighting system, signs, markings, runway crossings, location of exits.

Services delivered at the airport which play a role in flight operations (and flight safety) include:
- Aircraft servicing (parking, maintenance, repair)
- Fuelling,
- Anti-ice/de-icing service,
- Emergency response and rescue service,

- Cargo loading,
- Bird and wildlife control,
- Maintenance of runways/taxiways, runway and taxiway; runway friction measures
- Weather information provision

Smaller and regional airports will probably not offer all services and means. They mostly have just one runway, one taxiway to and one taxiway from the runway connecting parking areas. Often an extra grass strip is present for glider and traditional general aviation.

The level of ATC services at smaller airports may differ. Some may be controlled airfields, others could be uncontrolled. Likewise, the availability and quality of systems and safety nets at ATC/Tower will vary across airports. This applies to Runway Incursion Alert Systems, Advanced Surface Movement Guidance and Control System (A-SMGCS), availability of Approach and Ground radar, beacons and Autoland systems. The lack of airport infrastructure and ATC services has to compensated by design and operation of smart avionics in the EPATS aircraft.

3.2. Airport requirements

Requirements for design and operation of airports are given in ICAO Annex 14 [19] and guidance Document 9157[20]. The aviation world sticks together with rules and regulations. Therefore an airport has to meet certain requirements before an airplane can use an airport. When an airport complies with the requirements it may get a certificate (3.2.1).
If a terrain is going to be used as an airport, it needs to be nominated as an airport by national authorities. Above mentioned ICAO references apply and also local regulations for instance to define environmental limits for airport operations. The airport proprietor, the air traffic services and the chief airport operations should be known.
Every airplane has it own performance characteristics. Depending on these characteristics of the airplane the infrastructure (runways and taxiways) requirements can be determined (3.2.2).
When flights are executed during night or with bad visibility lights are required (3.2.3).
To make an airport save and operational in most conditions some systems could be installed to serve the EPATS aircraft (3.2.4).

3.2.1. Certification of airports

The certification process for airports is describing the certification of organisations, aircraft, infrastructure and personnel. It is one of the basic tasks of the national Civil Aviation Administrations. The aim of certification is to describe airport conformance with requirements and to verify conformance with requirements. Guidance can be found in ICAO Doc. 9774 – Manual on Certification of Airports [21]. Certification of airport is important due to privatisation of airports. Since November 2003 states have to certify their *international* airports. An airport can ask for certification if a Safety Management System (SMS) is in use. The SMS is required since November 2005.

When European airports host scheduled or commercial traffic, they most probably need a certificate. An example is given for the United States of America. In the USA airports can obtain a FAA certificate. Airports need to carry out a self evaluation process and to report it to

the FAA. When the airport is FAA certified, it categorises the airport on several issues: Aircraft Rescue & Fire fighting, Bird & Wildlife, Hazards, Self-inspection Procedures, Airport Condition Assessment/Reporting, Control of Hazards from Construction, Snow Removal Plan and Emergency Plan. The FAA expects that the airports maintain there condition. To supervise the airport the FAA will plan scheduled and unscheduled quality control visits.
The EPATS aircraft has a projected maximum capacity of 4 to 19 passengers. The FAA is issuing a final rule on airport certification for scheduled air carrier operations in aircraft with 10 to 30 seats [22]. In Europe there is not yet a harmonised system for airport certification except for the ICAO Annex 14 and relevant ICAO Documents.

The Europe Union intends to create regulations for airport certification to improve the safety. The last 15 years the flights in Europe more than doubled. With 100.000 extra EPATS aircraft in 2020, European airspace will be loaded with double traffic figures.. The main goal of the European Union for the future is to work out safety prescriptions (EASA) to maintain the safety at airport level in Europe at the same level as today (2007), or to make it even better.

3.2.2. Airport Infrastructure
The infrastructure of an airport exists of runways and taxiways to get to or from a parking place or hangar, terminal, other runways or other facilities.

Runways
The runway requirements are different for each type of airplane. They depend on some factors: airport elevation, the temperature of the hottest month in summer, runway gradient, and the aircraft configuration. Because of the relatively low weight of EPATS aircraft they do not need much runway. The Eclipse 500 needs a takeoff distance 2.279ft (700m) (at MSL and MTOW) and a landing distance 2.155ft (657m) (at MSL and landing weight 4600lbs). One size bigger, the business jets that can carry up to 19 passengers, needs a longer runway of 6560ft (2000m).
The runway properties depend of the category of airplane. The category will be defined with a character and a number. The character depends on the wingspan. The number depends on the approach speed (see Table 3-1). The runway properties depend only of the character (see Table 3-2). Because probably all EPATS aircraft fall in category I and II the runway width needed is 100ft.
From the survey in [4] it may be concluded that a large part of airports in Europe have runways with dimensions suitable for EPATS aircraft.
The estimated number of up to 400 movements per airport per day can be accommodated by a single runway although this amount may require control of traffic by ATC especially when traffic shows up in peaks.

Taxiways
Taxiways are used to get to and from a hangar, terminal, runway, or other facility. Most of the time taxiways are paved but on the smaller airports taxiways can be made of gravel or grass. For small aircraft the taxiways does not needed to be paved. Although the better taxiways are the faster the airplanes can taxi. This will increase the throughput capacity of an airport. Some busy airports make use of so called high speed taxiways to allow the airplane to taxi with a speed up to 60 kts.

Taxiways should be well indicated preferably according to ICAO standards.

Table 3-1 Aircraft classification standards

FAA Aircraft Approach Categories		
Approach Category	**Approach Speed (Knots)**	**Typical Aircraft Type**
A	Less than 91	Beech Bonanza, Cessna 150, Cessna 172
B	91 but less than 121	King Air, Citation I & II, Falcon 50
C	121 but less than 141	Lear 25, Gulfstream III
D	141 but less than 166	Gulfstream II and IV, B-747, B-777

FAA Wingspan Design Groups		
Design Group	**Wingspan (Feet)**	**Typical Aircraft Type**
I	Less than 49	Beech Baron 58, Cessna 150, Cessna 172
II	49 but less than 79	Beech King Air C-90, Gulfstream I, Falcon 50
III	79 but less than 118	B-727, B737, DC-9
IV	118 but les than 171	A-300, B-757, B-767, L-1011, DC-10
V	171 but less than 197	B-747, B-777
VI	197 but less than 262	Lockheed C-5A

Table 3-2 Runway properties

ITEM	AIRPLANE DESIGN GROUP			
	I	II	III	IV
Runway Length	Depends on airplane configuration			
Runway Width	100 ft 30 m	100 ft 30 m	100 ft 30 m	150 ft 45 m
Runway Shoulder Width	10 ft 3 m	10 ft 3 m	20 ft 6 m	25 ft 7.5 m
Runway Blast Pad Width	120 ft 36 m	120 ft 36 m	140 ft 42 m	200 ft 60 m
Runway Blast Pad length	100 ft 30 m	150 ft 45 m	200 ft 60 m	200 ft 60 m
Runway Safety Area Width	300 ft 90 m	300 ft 90 m	400 ft 120 m	500 ft 150 m
Runway Safety Area Length Prior to Landing Threshold	600 ft 180 m	600 ft 180 m	600 ft 180 m	600 ft 180 m
Runway Safety Area Length Beyond RW End	600 ft 180 m	600 ft 180 m	800 ft 240 m	1,000 ft 300 m
Runway Object Free Area Width	800 ft 240 m	800 ft 240 m	800 ft 240 m	800 ft 240 m
Runway Object Free Area Length Beyond RW End	600 ft 180 m	600 ft 180 m	800 ft 240 m	1,000 ft 300 m

Source: Federal Aviation Association

3.2.3. Airport lighting and markings

On an airport no mistakes can be allowed, therefore everything has to be clear. Every section on the airport has its own colored lights or surface markings. In the following chapters the lights will be described and the basic markings of three sections. At first the approach, secondly the runway and at last the taxiway will be described. It will be evident that turning on/off the lights requires control service at the airport or remote control. If a controller or operator is present, pilots may ask for adjustment of the light intensity. EPATS aircraft will use mainly small regional fields that are probably not controlled. It would mean that all passive guidance to assist pilots should be of high quality and conforming ICAO standards. It would mean that systems should become available to switch on airport lighting remotely, on request of EPATS pilots to support flight during low visibility and night conditions.

Approach lighting

VFR flights just use the standard runway markings for landing. Normally an Approach Lighting System (ALS) is installed on airports that support IFR flights. This system makes sure the pilot can see the runway correctly in case of bad visibility. ALS consists of a series of light bars and strobe lights that extends outward from the runway end.
There could be a system called Precision Approach Path Indicator (PAPI) or Visual Approach Slope Indicator (VASI) at an airport. This systems tells the pilot if the glide path is correct. The light boxes of the PAPI system are located besides the runway. The normal glide slope of an airplane is 3 degrees. When this is the case the pilot sees equal red and white lights. When the airplane flies too high the lights are all white. If the airplane flies too low all lights are red. With this system the pilot can easily see if his approach is correct.

Runway lighting

When a runway is equipped with lights this is done with three different colours. Green lights indicate the start or approach end threshold of the runway. The departure end threshold is marked by red lights. Lights along the edges of the runway are white, changing to amber near the departure end of the runway. The centreline of the runway is indicated with white lights. To distinguish the centreline lights from the lights along the edges of the runway the interval between the centreline lights is less.

Taxiway lighting

Taxiways are identified with alphanumeric sign colored black and yellow. These signs are located along the taxiways. When available the taxiways are edged with blue lights. Sometimes the center line is lighted with green lights.

Markings

The runway has ICAO specified markings painted on the runway. The beginning and the end is marked with a threshold. The runway edges are marked with a continuous white line. The centreline is marked with a striped white line. The pilot may see the runway better when the lights are turned off.
The markings of taxiway center lines are continuous yellow lines. When a taxiing airplane arrives near the runway for take-off, it should stop at a prescribed distance to keep the runway free including ILS protection zone if present. Yellow painted bars and eventually stop bars with red lights protect the runways for incursions.

Parking

Parking places and stands should be indicated clearly using stand numbers and clear landside airside separation marks. A small airport will occupy an area of about 1 km long and about 500 m wide (one runway configuration). Aside of the runway a lot of space is thus available for safe parking. A rule of thumb for estimation the space needed to park an aircraft is to take three times the rectangle made by wing span and length of the fuselage. It will allow park in and taxi out on own engines.
Small hangars may be wanted for maintenance and winter weather protection. If properly heated they will prevent icing and there is no need then to invest in expensive de-icing.

3.2.4. Airport systems

Airport systems are required to increase the operational reliability and punctuality of EPATS aircraft. An airplane can fly under Instrument Flight Rules (IFR) and Visual Flight Rules (VFR). What is necessary for an airport to support IFR flights is explained in the next paragraphs. The development of the navigation equipment for approach, landing and taxiing will deliver new systems to navigate and taxi more accurately. Accurate weather forecast is important for safe and efficient EPATS flight preparations. Airports can anticipate on weather forecasts and take precautions to increase the operational periods. During winter snow removal and de-icing may be required. For parking and maintenance electrical power is needed from e.g. a ground power unit. All these aspect will be discussed in next paragraphs including the need to have enough fuel available for each sort of EPATS aircraft.

IFR/VFR

An aircraft can fly under two flight rules: under VFR and under IFR. Which one is used depends on the weather conditions and the airspace in which the flight takes place. Requirements for onboard equipment and pilot qualifications are much higher for IFR than for VFR. The pilot is required to have an instrument rating for IFR flights, and a minimum equipment level on board and on ground is specified: Very High Frequency (VHF) Omni-directional Range beacon (VOR), Non Directional Beacon (NDB), Distance Measuring Equipment (DME) and Automatic Direction Finder (ADF) receivers, Secondary Surveillance Radar (SSR) and transponders, Very High Frequency (VHF) communication receivers as to allow navigation, communication and surveillance in low visibility conditions. These systems ought to be present near or on the airport as is possibly an Instrument Landing System. If an airport is not equipped with the traditional CNS systems, it could be cost beneficial to wait for operational certification of newer systems, see e.g. next paragraph.
With the upcoming advanced avionics and especially new airborne separation assistance operations and means (ASAS), it seems that there will be a time that free flight operations are safe and possible. Well equipped EPATS aircraft would fly in IMC but without control from air traffic service providers. Aircraft approaching non controlled airports in IMC would separate themselves from each other during approach and landing, while aircraft on ground would be informed about actual runway use for landing or other aircraft taxiing or taking off. This concept of free flight operations is still far from being applied in Europe. It is, however, not that futuristic because during VMC and absence of tower control it is common practice for general Aviation using the see and avoid principle.

Navigation

It is expected that the advanced cockpit automation of an EPATS enables single pilot operations. The integrated moving map makes it possible to navigate all over the world and on airports. The EPATS avionics is probably equipped with Differential GPS that works together with Local Area Augmentation Systems (LAAS). A LAAS sends a reference signal to the GPS system. With this reference the GPS position can be determined an accuracy of less than 1 meter. It is very likely to be certified for use as ILS cat I landing device. LAAS can typically be used when the airplane is within 20 miles range from the airport with LAAS. In the near future GPS, and especially Differential GPS with high accuracy positioning, will be available world wide (WAAS). On board area navigation (RNAV), traffic collision alerting (TCAS) and airborne separation (ASAS) are techniques that already exist to favour a transition to user preferred routing and more free flight type of operations.

Meteorology

Weather services for aviation is mostly a task accomplished by the national weather authority. They provide Terminal Aerodrome Forecast (TAF's) and METeorological Airdrome Report (METAR's) messages to the airports. Accurate weather information and forecasting is a very important factor in preparing and executing safe flights. It would imply that sufficient quality of information is available, e.g. on internet facilities for flight preparation. The EPATS aircraft will probably be equipped with access to Satellite Weather services. This provides an up to date weather forecast 24x7. With this system and information on board the pilot knows what the weather is without the need for communication with the ATC.

Ice prevention

An external de-icing system is needed on the airport when icing conditions occur. Small regional airport may not be equipped with de-icing facilities. A simple method to prevent ice accreditation is parking in a hangar. The smaller size of EPATS aircraft makes inside parking easier. Compared to flight operations on large airports the pilots flying EPATS on small and regional airport are probably the only ones to perform ice and snow inspection and removal.

Snow removal

In case of heavy snow runways and taxiways can become unavailable. Snow removal vehicles are needed to clean the runway or taxiway and make it save again to taxi, take-off or departure. If a snow removal system is not available delays can occur in case of heavy snow.

Ground Power Unit

When parked, aircraft may need electrical power supply from a ground power unit (GPU). The GPU provides the EPATS Aircraft with the required electrical power. All board systems can be operated for a long period without running the engines. Updates and maintenance can be carried out. If no GPU is available, an Auxiliary Power Unit (APU) onboard could supply the electrical power for start-up and systems running when the airplane is parked. An APU will make the EPATS aircraft more expensive and heavier. Using an APU results in more pollution and a shorter range. It is more likely that the smaller EPATS aircraft have their own batteries with enough power to turn on the engines that take over electrical power supply when running.

Fuel

All larger airports have fuel supply facilities. The EPATS aircraft engines will run probably on normal fuel. Because the EPATS Aircraft is supposed to fly to smaller airports normal jet fuel will not always be available. Therefore the range (and design of the fuel tanks) must be calculated with precaution taking into account refuelling on places other than the airport of departure and the airport of arrival. Smaller airports without fuel tankers may serve EPATS aircraft with a fuel station with easy access for the variety of EPATS designs.

3.3. Other airport facilities

Some basic services must be available to make an airport secure and comfortable for passengers. For the safety and national interest security and customs services are needed (see3.3.1). The airport must have a good connectivity and some extra facilities are necessary (chapter 3.3.2).

3.3.1. Security and customs

The EPATS study is too small to work out the consequences of EPATS and security of flying. This paragraph just gives some examples of promising technology to verify passenger identity. Europe is lucky to have the Schengen regulation for cross country flying for a large part of Europe. The Schengen treaty implies however to provide extra security measures on the borders of the Schengen – Non-Schengen area. But security checks have to be done anyhow. Large

airports have their facilities for security and customs. There are already biometric checks to automate the process of secure boarding and to make it less time consuming. The passengers can identify their self with a fingerprint and iris-scan. These methods are very reliable. It has much potential for smaller and regional airfields. Passengers using EPATS would make themselves known to the biometric checking system. Remains to problem to check that all passengers and crew pass the security and customs.
Luggage and freight must also be checked. No efficient and low cost methods exist to take care of this security and customs checking.

3.3.2. Connectivity and passenger facilities

It is very important to have a good transport infrastructure near the airports. A fast aviation system has no use when the infrastructure around the airport causes delay. The passengers will reach the airport with public transport, cab or own transportation depending on what is available. When the passengers choose for own transportation there must be enough car parking. There should be also some other facilities like a waiting-room were the passengers can wait until their flight will dispatch. In this waiting-room facilities like internet, food and drink will be appropriate. With the internet the passengers can require information about the public transport, cabs or hotels for instance. Most airports are located near a city were hotels and restaurants are available. When the airport is not near a city it is an option to build these facilities on the airport.

4. Environmental effects and EPATS

Eurocontrol (SESAR) goal is to reduce the environmental impact per flight with 10 %.

This section will discuss the most important environmental effects of EPATS and gives an indication of important subjects for further research. The discussion about the environment will be divided into two separate subjects: noise and emissions.

The impact on the environment depends on the number of aircraft and the different aircraft types used to carry out the air traffic within the EPATS system. First a short overview of the assumptions used for this chapter will be given and after that the impact on noise and gaseous emissions will be discussed.

Ref [11] gives two different estimations for the amount of EPATS aircraft. Both are calculated in the same manner, but the outcomes differ due to different assumptions. Both studies analyse the number of passenger kilometres per year of car travels longer than 300 km. After that, it is assumed that a percentage of these travels will be done by EPATS aircraft in the future so that an estimation of the number of passenger kilometres by EPATS aircraft is found. Then an average amount of passenger kilometres per aircraft is assumed which results in an estimated number of aircraft needed. Method one only uses aircraft with four seats, while the second method does not specify the number of seats.

Table 4-1 summarizes both methods; the table gives the amount of passenger kilometres by car over a distance larger than 300 km, the percentage that will be flown in the future, the expected amount of passenger kilometres flown, the assumed average amount of yearly passenger kilometres per aircraft and finally the assumed amount of aircraft needed.

Table 4-1: Estimation of the number of EPATS aircraft

Method	Pas.km_car	% expected	Pas.km_ac	pas.km/ac	number of ac
1	$825 \cdot 10^9$	25 %	$210 \cdot 10^9$	$540 \cdot 10^3$	388000
2	$825 \cdot 10^9$	10 %	$82.5 \cdot 10^9$	$1 \cdot 10^6$	82500

It should be noted that the values in the table are taken from [11] and have not been corrected for rounding errors. Furthermore the amount of passenger kilometres per year is the current value, while this value might change in the future. The most important conclusion from this table is the fact that the predicted number of aircraft for method one is almost 5 times higher that for the second method.

The fact that the first method only assumes aircraft with four seats may lead to an overestimation of the number of aircraft, since in reality larger aircraft will be used between city pairs with a high number of passengers.

In the description of the second method it is assumed that an aircraft will make approximately one flight each day. In practice this would mean that aircraft will mostly fly less during the weekends and make 7 flights during the working week. Assuming 365 flights per year means that method one assumes an average flight length of 370 km. This is on the low side since the minimum trip length equals 300 km, while flights of more than 1000 km are also possible. An increase of average flight length can lead to an increased value of the amount of yearly passenger kilometres and a lower number of aircraft needed. Finally the percentage of 25 % is optimistic since this percentage currently equals 0.1 % ([11]).

These facts indicate that the first method probably leads to an overestimation of the number of aircraft. However, it is clear that a more accurate estimation of the traffic is needed for detailed analyses of the environmental impact of the EPATS concept. Due to the comments on the first method, the remainder of this document will use the results of the second method. Downside of the second method is that no information is given about the fleet mix, so this will also require more detailed research.

If the average amount of flights per day carried out by EPATS aircraft equals 82500, this means that this value will be higher during the working week. Assuming that no flights take place during the weekend means that the average number of flights during a working week will approximately be 115500.

Since every flight leads to one start and one landing; approximately 231000 flight movements have to be accommodated at all the airports. These flight movements have to be divided over 2567 airports, however since the busiest airports are already congested, it is assumed that the busiest 67 airports are not used for EPATS traffic. This means that the other airports have to accommodate an average value of 92 aircraft movements per working day per airport or approximately 24000 flight movements per year per airport.

However, the traffic will not be evenly divided over these 2500 airports, which means that the busier airports will need the capability to handle at least two or three times more traffic; this means that some airports will have to deal with up to 280 aircraft movements each day. Since most traffic will occur in the early morning and the end of the afternoon, a sufficient amount of capacity is needed to accommodate all air traffic.

4.1. Noise

If the number of aircraft movements on local airports increases due to the introduction of the EPATS concept, this will have an effect on the noise load in the vicinity of these airports. For that reason it is important to make sure that the increased noise load will not become a limiting factor for the EPATS concept.

4.1.1. Noise production

The amount of noise produced by air transport depends on several parameters. First of all the type of aircraft or more specific the type of engine is important. One of the new technologies that will be used for the EPATS concepts are the so-called very light jets (VLJ) as a

replacement of the older generation light jet aircraft. Since the VLJs are light and since they use modern engines they are expected to be quiet and fuel efficient. This section will compare the noise production of a VLJ, light jets, piston aircraft and turboprop aircraft.

Comparing different aircraft types is difficult because a lot of factors contribute to the noise production. For a good comparison all aircraft should have comparable weight (except for VLJ since these aircraft are designed to be lighter compared to other small jet aircraft), year of design (engines became quieter during the years), maximum range (the longer the range, the more fuel will be needed, which means that the weight of the aircraft increases) and number of passengers (to find the noise production per passenger).

All noise data presented here are obtained from [30]. Table 4-2: Comparison of noise production of different aircraft types

Aircraft + type	year	MTO W	pa s	range	LA TO	LA APP	LA TO corr	LA APP corr
Cessna Citation Encore (J)	1998	7634	11	7634	58.3	83	54.9	79.6
Mitsubishi MU300 Diamond I (J)	1996	7394	7	2744	71.9	77.2	70.4	75.7
Cessna Citation 525 CJ (J)	1998	4853	5	2408	60.3	81.7	60.3	81.7
Piper PA-42 Cheyenne (TP)	1977	5125	6-9	3015	70.3	77.1	67.7	74.5
Beech Super King Air B200 (TP)	1981	5670	13	3251	68.8	77.8	64.7	73.7
Cessna 421C (P)	1976	3103	8	2756	61	74	59.0	72.0
Beech Bonanza A36 (P)	1970	1633	3-5	1291	67.8	64	67.8	64.0
Eclipse 500 (VLJ)	2007	2719	5	2408	54.9	72.8	54.9	72.8

shows noise data for several aircraft, furthermore the maximum take-off weight (MTOW) in kilograms, year of introduction (year), maximum number of passengers (pas), range in kilometres and aircraft type (P = piston, TP = turboprop, J = jet and VLJ = very light jet) are given. The noise values (LA) are given for take-off (TO) and approach (APP); the noise values are estimations, given in dB(A).

Table 4-2: Comparison of noise production of different aircraft types

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Eclipse 500 (VLJ)	2007	2719	5	2408	54.9	72.8	54.9	72.8

The table was completed using data from [24], [25] and [26]. Except for the Beech Bonanza A36 all aircraft have two engines; the Beech Bonanza A36 is a single engine aircraft. Some of the aircraft in the table are over 20 years old, so it should be noticed that the current generations of comparable aircraft will probably be quieter.

The Eclipse 500 (VLJ) can best be compared with the Cessna Citation 525 CJ. Both aircraft are jet aircraft and have the same range and passenger capacity. Comparing the estimated noise levels of both aircraft clearly shows that the weight reduction and new engines result in a reduction of the noise production.

The take-off noise levels show that the Eclipse 500 has the lowest estimated noise level. Only the Cessna Citation Encore has a comparable noise level if the number of passengers is taken into account, even though the Encore has a longer range. The noise produced with 2.2 take-offs of an Eclipse 500 (the Encore has a passenger capacity that is 2.2 times as large as the passenger capacity of the Eclipse 500) leads to an estimated take-off noise level of 58.3 dB(A), which is equal to the take-off noise level of the Encore. The noise level of aircraft *x* (a/c_x), normalized to the number of passengers of the Eclipse 500, is calculated using the following formula with a correction factor c_1:

$$LA_{a/c\_x\_corr} = 10 \cdot \log\left(c_1 \cdot 10^{\frac{LAa/c\_x}{10}} \right), \text{ where } c_1 = \frac{N_{pas\_Eclipse}}{N_{pas\_a/c\_x}}$$

Comparing the noise levels (corrected for the number of passengers) of all jet aircraft shows that the Mitsubishi MU300 Diamond I is the jet aircraft with the best noise characteristics for the approach. Comparing the estimated noise level of this aircraft with the Eclipse 500 shows that the approach noise level of the Eclipse 500 is 4.4 dB(A) less compared to the MU300. These results show that the use of VLJs instead of the current generation of light jets should be recommended in order to decrease the noise impact of air traffic.

Comparing the Eclipse 500 with turboprop and piston aircraft shows that the Eclipse 500 is the quietest aircraft during the take-off. As discussed earlier only the Cessna Citation Encore shows comparable noise characteristics during take-off. Furthermore, there are some aircraft with better or comparable approach noise characteristics (corrected for the number of passengers). First of all the Beech Bonanza A36 with a single piston engine has a lower approach noise

level. The same holds for other single piston engine aircraft described in [30]. One of the reasons for this lower noise level might be the lower weight of single piston aircraft.

Comparing the approach noise characteristics of the Eclipse with the Cessna 421C (two piston engines) and the Beech Super King Air B200 (two turboprop engines) shows that the 421C is 0.8 dB(A) quieter, while the B200 is 0.9 dB(A) noisier if the number of passengers is taken into account.

From this paragraph it can be concluded that using VLJ instead of regular light jets is desirable in order to reduce the noise impact. Furthermore the use of single and twin piston engines and turboprops gives better or comparable noise characteristics during the approach, while the VLJ produces less noise during the take-off. The higher noise production of VLJs during the approach can be a reason to allow the use of single and twin piston aircraft. Another advantage of piston aircraft is the fact that the operating costs of piston aircraft are lower compared to VLJs.

4.1.2. Possible solutions for noise reduction

Due to the high traffic density at large European airports, several methods to reduce the noise impact of air traffic have been developed over the years. If the traffic density at local airports increases due to the implementation op EPATS, the increased noise load might lead to resistance against the EPATS concept. For that reason several solutions can be implemented in order to reduce the noise load on local communities.

First of all the noise production should be incorporated in the design of aircraft that will be used for the EPATS concept. If the engines become quieter, the noise production and the amount of people affected by the aircraft noise will decrease.

A second way to lower the noise impact is to design noise abatement routes. These routes are designed in such a way that they circumnavigate densely populated areas near the airport. Especially when the airport is located near one or more towns, the use of noise abatement routes has to be considered.

The use of silent approach and take-off procedures can lead to a further decrease in noise impact. An example of such a silent procedure is a continues descent approach (CDA). If this procedure is used the aircraft will have an idle thrust setting during the largest part of the approach (except for the final part of the approach) which leads to a reduction in the noise production. For a take-off the use of a derated thrust procedure will lead to a reduction in the noise levels near an airport. However it should be noted that a lower thrust setting leads to a more gradual climb profile so that the noise load further away from the airport will increase due to the lower altitude of the aircraft.

If the large amount of extra aircraft caused by the EPATS concept leads to congestion at regional airports, it is important to make sure that the circuits around these airports are designed in such a way that they can handle the additional traffic in a safe way and that traffic in these circuits leads to a minimum amount of noise hindrance.

Finally it should be noted that flights arriving and departing during the night will lead to an increase in the resistance against air traffic. For this reason the traffic should be managed in such a way that the majority of the flights takes place during day time.

Summarizing the above, it is clear that the EPATS concept leads to an increase in traffic at all participating regional airports. This means that attention has to be paid to limit negative effects of the additional noise production. The most effective way to achieve this is designing aircraft that are as silent as possible.

If the increase in noise production requires additional measures, several options can be considered such as redesigning routes and circuits, using different procedures limiting the number of flights during evening and night time. What options give the best result depends on several factors that differ for each airport, such as the population density near an airport and the number of runways.

4.2. Emissions

Every flight will lead to a certain amount of emissions. What pollutant gasses are emitted and the quantity of the emissions inventories of the different pollutants depends on several factors such as the type of propulsion and the amount of fuel used.

In general emissions are divided into local and global emissions. Local emissions are emissions around an airport emitted below 3000 ft, while global emissions are all emissions produced by air transport. The local emissions have an effect on the local air quality while the global emissions contribute to global effects such as the greenhouse effect and the depletion of the ozone layer.

Air transport leads to the emission of different gasses; the most important ones are listed here:

- CO_2 (carbon dioxide)
- H_2O (water vapour)
- NO_X (nitrogen oxides)
- SO_X (sulphur oxides)
- CO (carbon monoxide)
- HC (hydrocarbon)
- PM_{10} (particulate matter 10µm or less)
- $PM_{2.5}$ (particulate matter 2.5µm or less)

All these pollutants will have a different effect on the environment. Also the altitude where the emissions take place can influence the effect of some pollutants. First of all CO_2 is a greenhouse gas, which means it contributes to global warming.

Water vapour also is a greenhouse gas; this greenhouse effect is mainly caused by the contrails that are formed when water vapour is emitted in the air. Most of the formation of these contrails takes place above 8 km. To reduce the effect of H_2O emissions it is recommended to make sure that the cruise altitude of aircraft has a maximum value of approximately 8 km.

NO_X has several effects on the environment; first of all it is a greenhouse gas and furthermore NO_X emissions can cause ozone destruction when the emissions take place at an altitude above approximately 10 km. When emitted at low altitude, NO_X emissions contribute to smog formation. Finally NO_X emissions at low altitude cause acid rain.

The production of SO_X leads to global warming and also contributes to acid rain. Both CO and HC are produced due to incomplete combustion. For this reason their production mainly takes place at and near airports where aircraft use low thrust settings (during taxiing and landing). HC is a greenhouse gas and is toxic; the same holds for CO emissions, however, these effects are less severe than for HC emissions.

The production of small particles is a complex process that depends on several parameters such as engine setting, speed, atmospheric conditions and the use of wheel brakes. These particles have a negative impact on the health and trigger cloud formation. This means that these particles have an indirect contribution to the greenhouse effect.

As discussed earlier, the propulsion type has a large impact on the emissions. The use of current aircraft fuels leads to all emissions described above. If biomass fuels are used the net production of CO_2 pollution can be eliminated. Biomass fuels are fuels, which are produced from biological sources. Although combustion of these fuels produces CO_2, the effect on the environment is significantly reduced, since the biological sources (plants) for the fuel use CO_2 from the air to grow.

If hydrogen is used to propel aircraft, this will eliminate the CO_2 emissions at the cost of an increase in H_2O emissions (approximately 2.6 times higher compared to current aviation fuel). If electrical propulsion is used this will eliminate the NO_X emissions due to the fact that no combustion is needed for this type of propulsion.

Finally it should be noted that the production of the fuel used for the EPATS aircraft has to be done in an environmental friendly way in order to achieve a reduction of emissions. If the production of hydrogen or electricity leads to CO_2 pollution; the use of these propellants will not lead to a decrease in emissions. Also the production of batteries for electric propulsion will lead to emissions.

4.2.1. Global emissions

The most important method to reduce global emissions is to decrease the fuel consumption. This can be done by flying as efficient as possible. One of the goals of EPATS is to use an ATM system that leads to more efficient flights to decrease flight time and costs. If such an ATM system is implemented, this will also lead to lower global emissions (less CO_2, H_2O and NO_X emissions).

In order to achieve a reduction of the effects of global emissions, a change of the current propulsion system can be considered. If flights are carried out at altitudes below 7 km, this will reduce the effect of water vapour emissions. So, especially if hydrogen is used, flying at low altitude should be considered.

In order to make a good comparison between different types of aircraft, information about the emission indices (amount of emitted pollutant per kilogram fuel used) for the different pollutants is needed. However, obtaining all emission indices for a set of different aircraft is outside the scope of this chapter. For this reason only a comparison of the specific fuel consumption (SFC) will be given. The amount of fuel used is directly linked to the amount of CO_2, H_2O and SO_X emissions. For the other emissions the engine setting also has an impact on the emissions inventories; a lower thrust setting leads to a reduction in NO_X emissions for example.

Table 4-3 gives an overview of the SFC of several aircraft. The table compares the same aircraft as Table 4-2: Comparison of noise production of different aircraft types

Aircraft + type	year	MTOW	pas	range	LA TO	LA APP	LA TO corr	LA APP corr
Cessna Citation Encore (J)	1998	7634	11	7634	58.3	83	54.9	79.6
Mitsubishi MU300 Diamond I (J)	1996	7394	7	2744	71.9	77.2	70.4	75.7
Cessna Citation 525 CJ (J)	1998	4853	5	2408	60.3	81.7	60.3	81.7
Piper PA-42 Cheyenne (TP)	1977	5125	6-9	3015	70.3	77.1	67.7	74.5
Beech Super King Air B200 (TP)	1981	5670	13	3251	68.8	77.8	64.7	73.7
Cessna 421C (P)	1976	3103	8	2756	61	74	59.0	72.0
Beech Bonanza A36 (P)	1970	1633	3-5	1291	67.8	64	67.8	64.0
Eclipse 500 (VLJ)	2007	2719	5	2408	54.9	72.8	54.9	72.8

, furthermore two aircraft types are added in order to show the fuel consumption of current generation piston and turboprop aircraft. Since the noise characteristics of these aircraft are not known, they are not considered in the noise comparison in the previous paragraph. The SFC will be given in kilograms of fuel used per passenger kilometre (kg/pas.km). Due to a lack of data the SFC values were calculated by dividing the maximum fuel weight (MFW) in kilograms by the maximum range of the aircraft times the number of available passenger seats. If more than one value is given in the column with passenger capacity the highest value is used.

Table 4-3: Comparison SFC of different aircraft types

Aircraft + type	year	MTOW	pas.	range	MFW	SFC

Cessna Citation Encore (J)	1998	7634	11	3313	2449	0.067
Mitsubishi MU300 Diamond I (J)	1996	7394	7	2744	2228	0.116
Cessna Citation 525 CJ (J)	1998	4853	5	2408	1461	0.121
Piper PA-42 Cheyenne (TP)	1977	5125	6-9	3015	1757	0.065
Beech Super King Air B200 (TP)	1981	5670	13	3251	1653	0.037
Cessna 421C (P)	1976	3103	8	2756	647	0.029
Beech Bonanza A36 (P)	1970	1633	3-5	1291	225	0.035
Eclipse 500 (VLJ)	2007	2719	5	2408	765	0.064
Piper PA-46 Mirage (TP)	2006	1967	6	2491	364.8	0.024
Beech Bonanza G36 (P)	2007	1656	4-5	1391	201	0.029

To determine the values of the MFW of these aircraft [24], [27], [28], [29], [25] and [11] were used. A fuel weight of 3.04 kg/gallon was used; this value was obtained using [24] where the fuel capacity is given both in gallons and in kilograms. Both the Bonanza G36 and the Piper PA-46 Mirage have a single engine.

The table shows that the Eclipse 500 is not the most fuel efficient aircraft, but it is more fuel efficient than all other jet aircraft, even the Cessna Citation Encore. This is remarkable since the Encore is a larger aircraft and in general larger aircraft have a high fuel efficiency compared to smaller aircraft. As discussed earlier, the Eclipse 500 can best be compared with the Cessna Citation 525 CJ. Compared to this aircraft the fuel efficiency is almost two times better due to the low weight and modern engines.

Comparing the Eclipse 500 with the three turboprop aircraft shows that the SFC of the Eclipse is comparable with the SFC of the Piper PA-42 Cheyenne. The SFC of the Beech Super King Air 200 is almost two times lower. Finally the SFC of the Piper PA-46 Mirage is more than 2.5 times lower. This shows that modern turboprop aircraft are much more fuel efficient than VLJs. Since turboprop aircraft have a much lower cruise speed than VLJs, they are best suited for travelling over relatively short distances.

Finally the comparison of a VLJ with piston aircraft shows that all aircraft equipped with piston engines have a better SFC. For this reason the use of aircraft with piston engines or turboprop engines should be considered for transport over relatively short distances. To decide whether piston or turboprop aircraft should be used; it should be investigated what aircraft has the best noise characteristics combined with high fuel efficiency.

The cruise speed of the Eclipse 500 equals 685 km/h [11], while the cruise speed of the Cessna 421C is equal to 446 km/h [25] and the cruise speed of the Beech Bonanza G36 equals 283 km/h [28]. For this reason VLJs are better suited for transport over longer distances than aircraft with piston engines. For distances below 600 km the use of a Cessna 421C leads to a delay of less than 30 minutes compared to the Eclipse 500, while the emissions per passenger kilometre are more than two times lower, if both aircraft carry the maximum number of passengers.

From this information it can be concluded that the Eclipse has a lower SFC compared to all other jet aircraft but that its SFC is higher than the SFC of turboprop aircraft and of aircraft with

piston engines. Since these aircraft have a much lower cruise speed, the use of piston and turboprop aircraft should be considered for transport over relatively short distances.

4.2.2. Local emissions

As discussed earlier, the EPATS concept will lead to an average increase in the number of flight movements with 92 aircraft per day per airport. At busy airports the number of EPATS flight movements per will be much higher. Especially during peak periods the required capacity can become a problem at busy airports.

The high number of aircraft during peak periods may lead to congestion problems. These problems will have a negative impact on the local emissions, since insufficient capacity leads to ground queuing and airborne holding. Furthermore an increase in flight time due to increased airborne holding means that aircraft have to take more fuel on board. The increase in weight leads to an increase in emissions and since more fuel is needed for airborne holding, the maximum range of the aircraft decreases.

To give a good indication of the impact of the EPATS concept on the local emissions, it might be useful to compare the emissions of a VLJ with a car. In this comparison the fact that aircraft passengers use a reference car to travel to their final destination should also be taken into account. The next paragraph will give a comparison of the EPATS concept with road transport.

4.2.3. Comparison with road transport

The idea behind the EPATS concept is that more people will use small aircraft instead of a car to travel over distances higher than 300 km. For this reason this paragraph will give a comparison between EPATS aircraft and road transport. Since EPATS is not meant to compete with transport by train, no comparison with rail transport will be given.

Figure 4-1 shows a comparison between a Toyota Avensis and four different aircraft. The left graph shows values if all seats are occupied, while the right graph shows the results if all vehicles have an average load factor (0.3 for the car and 0.6 up to 0.9 for the different aircraft). It should be noted that the fuel consumption of the car is an overall fuel consumption; if the average fuel consumption outside urban regions is used this would lead to a reduction of the specific fuel consumption of 16 %.

The SFC of the car is shown for an average fuel consumption and for only one reference car. The graph does not take any future developments in the aviation and automotive industry into account while cars are expected to become more environmentally friendly in the coming years for instance due to the development of hybrid cars. It is not in line with Task2.0 “Air Transport efficiency and its measures” point 5 “Impact on environment by costs externalities measurements” and sources data “The Social Costs of Intercity Passenger Transportation. A Review and comparison of Air and Highway” by David M Levinson, which is matter for further analysis. Furthermore the efficiency of a car will decrease if it is used on crowded roads with a high number of traffic jams. For this reason also the development of road traffic should be investigated to give a good indication of the SFC of road transport in the future.

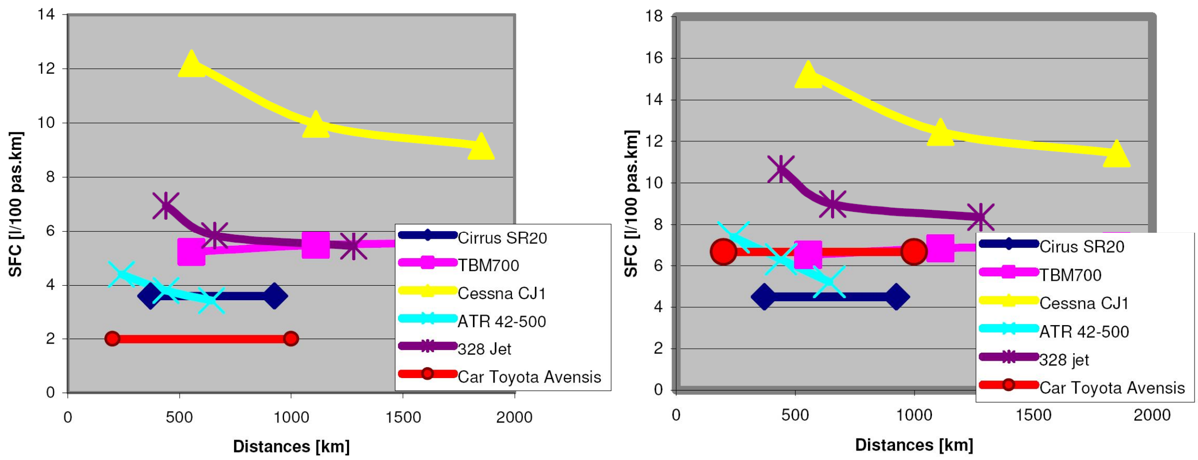

Figure 4-1: Comparison of specific fuel consumption of different transport modes [11]

The figure shows that the car is most fuel efficient if all vehicles are fully loaded. However the right graph shows that the load factor has a large impact on the amount of fuel used per passenger kilometre. For this reason it is of great importance that the load factor of the aircraft in the EPATS concept is as high as possible.

If the emissions of aircraft are compared to road vehicle emissions it should be noted that the cruise altitude of the aircraft plays an important role in the effect of the emissions. For example H_2O emissions of a car are not harmful while H_2O emissions at an altitude of 10 km contribute to the greenhouse effect. Only a small amount of jet will probably fly at altitudes of 8-10 km while expectations are that the most aircraft will flight below 6 km

Another advantage of using a car is the fact that no other means of transport will be needed, while an aircraft passenger has to be transported to and from an airport if his destination is not within a range of a few hundred meters from the airport. As discussed earlier it is important that cleaner and quieter aircraft are developed, also because of the fact that the automotive industry also develops cleaner cars.

4.2.4. Boundary conditions for the reduction of environmental effects

In order to make sure that the environmental load of the EPATS system does not become too high; some boundary conditions have to be satisfied. As was shown in Figure 4-1, it is important that the average load factor of all aircraft is as high as possible.

On the other hand the system has to be attractive for potential users. This means that it should not be a problem if a customer books his flight only one day before the flight. Furthermore the availability has to be high. There should only be a small chance that a passenger can not book an aircraft due to the fact that all seats are already booked or that no aircraft is available.

Another issue is the fact that the system has to be very flexible, since the demand per airport will vary each day. All together this means that the system has to offer affordable flights, while the availability has to be high. Since the demand is not constant, the system has to be flexible. This conflicts with the fact that the average load factor of all aircraft has to be as high as

possible. To deal with these problems an advanced booking system should be developed (which for instance makes use of online booking), in order to achieve an optimal load factor combined with good availability and flexibility.

5. Safety and EPATS

This section contributes to the EPATS project Work Package WP3 Task 3.3 S*afety aspects*. This part of the document describes the results of the identification and review of safety issues related to EPATS and provides recommendations for future R&D to address the identified safety-related problem areas. It gives an overview of safety aspects of EPATS in the areas of: aircraft manufacturing and certification; flight operations; training and qualification; airport and air traffic control; safety programs; and safety oversight. The information provided in the document is based on a review of collected information from literature, complemented with the knowledge and expertise of the NLR Air Transport Safety Institute. Data has been collected from various sources in Europe and the United States, including aircraft manufactures, regulators, Eurocontrol, and the Flight Safety Foundation.

The main identified safety aspects are summarised below:

- EPATS aircraft have a lower standard of airworthiness compared to larger commercial airliners, because different certification standards apply. We assume that JAR-23 Airworthiness will be enhanced to obtain the same safety level as JAR-25. Amendments should be proposed to EASA
- An area of possible risk is the (long-term) airworthiness of the new technologies, production techniques and materials. New technologies must be introduced step by step in order to minimize the risk
- Automation, advanced avionics and single pilot operations are major issues in the context of pilot workload, decision-making, monitoring and automation pitfalls, e.g. complexity, over-reliance.
- The introduction of high performance aircraft will increase the likelihood that relatively inexperienced pilots will be operating in a complex and challenging environment.
- The level of equipment, facilities and services provided at EPATS airports will not be of the same standard as at the international or large airports in Europe. Lack of services (e.g. bird control, de-icing) may degrade flight safety and restrict aircraft operations in certain conditions. The level of EPATS airport equipment, facilities and service should be adequate to the used actual technology and conditions and in any case should not degrade flight safety. There will be, however, a lot of simple airports in the next decades, that are attractive to be used for EPATS and they form a risk factor that should be envisaged.
- Problems can be expected in pilot-air traffic control communication and traffic sequencing.
- EPATS operators could benefit from airline oriented safety programs such as SMS, FOQA, safety occurrence reporting and analysis, but their implementation and application in EPATS need further study.
- Safety data reporting and collection of occurrences in the general aviation sector is nowadays not well covered, resulting in a lack of knowledge and awareness of general aviation safety and in particular EPATS safety issues in the future.
- Oversight of EPATS will pose a complex and resource intensive oversight process.

Recommendations for further research and development include:

- Analyse to what extent the current regulations are appropriate for certification of new designs and new technologies, production techniques and materials within EPATS.
- Research into automation that supports safe single pilot operations, in particular flight envelope protection and further automation of flight in EPATS aircraft. In addition, further research is proposed into intuitive displays and the effect of cockpit design, automation and advanced avionics on pilot workload, decision-making etc.
- The applicability and appropriateness of the current regulations for pilot qualification and pilot training programs shall be evaluated.
- The safe integration of EPATS aircraft in the air transport system of today has to be studied in more detail to identify and assess the risks of EPATS in the airport and ATM domain. The focus should be on air-ground communication and the effect of single pilot operations on ATC-pilot interaction.
- The safety implications of workload of air traffic controllers in EPATS.
- The tailoring and application of commercial aviation safety programs to EPATS operators and outsourcing of safety programs shall be studied.
- The identification of solutions to improve general aviation data collection and analysis.
- To deal with the challenge of safety oversight in EPATS, research shall address inspector resource planning and risk-based oversight and inspection programs.

5.1. The objective and scope

This section contributes to the EPATS project Work Package 3 Task 3.3 *Environmental and safety aspects*. The documents describes the results of the identification and review of safety issues related to EPATS and provides recommendations for future R&D to address the identified safety-related problem areas. The analysis is based on the current version of the EPATS envisioned concept of operations. The study considers the use of small, technically advanced aircraft (Appendix D) in EPATS for business, corporate and taxi flight operations only and does not take into account their use for recreational purposes. The information provided in the document is a review of collected information from a literature survey, complemented with the knowledge and expertise of the NLR Air Transport Safety Institute (NLR-ATSI). Data has been collected from various sources in Europe and the United States, including aircraft manufactures, regulators (FAA, EASA), Eurocontrol, and the Flight Safety Foundation (FSF).

5.2. Outline of the section

Chapter 1.4 will provide a description of the EPATS project to set the context of the identification of safety aspects. It describes the envisioned EPATS operational concept, the aircraft types (general specifications, capabilities and avionics) and the current and expected airport and air traffic management system infrastructure in Europe. Chapter 5.3 gives an overview of safety aspects of EPATS in the areas of: aircraft manufacturing and certification; flight operations; training and qualification; airport and air traffic control; safety programs; and safety oversight. Chapter 6.4 provides suggestions for future R&D to address the identified key safety issues.

5.3. Identification of safety aspects

This chapter presents an overview of safety aspects related to EPATS. Since industry and regulators are aware of the potential risks related to operating small, advanced aircraft and single pilot operations, initiatives are under way to mitigate these risks. Therefore, the directions regulators are considering with respect to regulations for the EPATS aircraft and operations will be discussed. The previous chapter defined the types of EPATS aircraft, equipment and operations that form the context of this chapter. The VLJ is one of aircraft types envisioned in the EPATS concept, but EPATS is not restricted to jet aircraft only. Technically advanced turboprop or piston engine aircraft (TAA)[2] will also be available for personal air transportation in EPATS. The developments and issues related to VLJs and TAAs, in particular in the United States, are applicable to EPATS as well. In this report we will draw upon the R&D, experience and developments in the area of VLJs and TAAs to identify safety aspects in EPATS. In order to structure the identification of safety issues we have grouped them in several areas:

- Aircraft manufacturing and certification;
- Flight operations[3];
- Training and qualification;
- Airport and Air Traffic Control;
- Safety programs; and
- Safety oversight.

5.4. Aircraft manufacturing and certification

Aircraft certification

Safety aspects related to EPATS aircraft will be considered as part of the certification process. Where airworthiness is concerned the EPATS aircraft are certified in accordance with FAR-23 or EASA CS-23. They will all have type certificates [Ref. 43]. In general, current policies and regulations adapted and amended to TAAs are deemed suitable for certification of these aircraft [Ref. 46]. FAA and EASA have established special provisions for certification of high performance Part 23 aircraft [Ref. 45]. A safety concern is the fact that the EPATS aircraft are certified in accordance with FAR/CS Part 23, which is a lower standard from an airworthiness perspective compared to FAR/CS Part 25, which is used for certification of large commercial aircraft. As a result, the safety level of EPATS aircraft will be less in some areas compared to airliners. For example, single engine accountability is not regulated in Part 23 in contrast to Part 25. This means that take-off and climb out performance with one engine failed (N-1) does not need to be taken into account. Likewise, structural requirements are different for Part 23 aircraft. JAR-23 should be revised in context of new technology and TAAs.As another example, minimal control speed ground (VMCG) tests do not have to be conducted and requirements for system failure probabilities (versus severity of the failure) are a factor 10

[2] A general aviation aircraft that combines some or all of the following design features: advanced cockpit automation system (moving map GPS/glass cockpit) for IFR/VFR flight operations, automated engine and systems management, and integrated auto flight/autopilot systems.

[3] Flight operations include functions such as passenger services, dispatch, ground operations, aircraft operations, aircraft loading.

lower than in Part 25. As regulators have recognized that the high performance Part 23 aircraft are going to be used in commercial air transport, special provisions or Critical Review Items (CRI) have been established to bring these aircraft closer to the standard of Part 25. Examples of CRIs are fuel tank crashworthiness, bird strike, speed margins, vibration and buffeting.

Manufacturing and airworthiness
A second safety aspect is manufacturing and related airworthiness regulations. We see new aircraft manufactures entering the VLJs/TAAs market with little experience. Aside these new start-ups, aircraft manufacturers of commercial aircraft and business jets have also started developing VLJs (e.g. Embraer and Cessna). The production lines have to output a considerable number of aircraft on a yearly basis since the high number of aircraft to be delivered is obviously related to the required low unit price. For instance, VLJ manufacturer Eclipse expects a delivery rate of two aircraft per day. This production rate and associated support is a significant effort for relatively small aircraft manufactures. Especially the high number of aircraft to be produced, low cost and weight drives new production processes and manufacturing techniques. An area of possible risk is the (long-term) airworthiness of the new technologies, production techniques and materials. We have gained a considerable amount of experience and knowledge in the past decades in behaviour of structures, materials and related production processes, which is reflected in current regulations. However, the industry has limited experience today regarding the long-term behaviour and effects of these new technologies etc. It is unclear to what extent the current regulations are appropriate for certification of new designs and new technologies.

EPATS aircraft are certified in accordance with FAR/CS Part 23, which is a lower standard from an airworthiness perspective compared to FAR/CS Part 25, which is used for certification of commercial airliners. As regulators have recognized that the high performance Part 23 aircraft are going to be used in commercial air transport, special provisions have been established. A second safety aspect is the area of manufacturing and airworthiness regulations. An area of possible risk is the (long-term) airworthiness of the new technologies, production techniques and materials. The question is whether the current regulations are appropriate for certification of new designs and new technologies.

5.5. Flight operations

In the area of flight operations we expect safety issues for EPATS operations that are comparable to VLJs and TAAs. The National Business Aviation Administration (NBAA) has collected a list of potential hazards for operations of VLJs and TAAs [Ref. 35]. The issues on this list are not restricted to VLJ operations and relevant for other EPATS aircraft as well. Although VLJs have a different performance envelope (higher speeds and flight levels) than turboprops, the latter category may encounter similar hazards in EPATS. Appendix B contains a detailed version of this table.

Table 5-1: List of hazards for VLJs [Ref. 35].

• Clear air turbulence/jet stream core or boundary encounters • Convective weather encounters • FMS programming and autoflight vs. manual flight control • High-altitude upset • Inadequate "land and hold short" (LAHSO) preparation • Inadequate crosswind takeoff/landing preparation • Inadequate exercise of "command" • Inadequate knowledge of high-altitude weather • Inadequate preparation for high-rate/high-speed climbs • Incorrect/less-than-optimum cruise altitude selection	• Jet blast damage behind larger jets during ground operations • Lack of pilot self-evaluations • Low-fuel arrivals trying to stretch range • Microburst/windshear encounters • Mountain wave encounters • Physiological effect of high-altitude operations • Recognizing single pilot "red flags" (as an alternative to below) • Single pilot adherence to checklists • VLJs misunderstood by ATC (pilot mitigations) • Wake turbulence encounters • Winter operations

Three major concerns for EPATS stand out in the area of flight operations and these issues are closely related indeed:
- Use of automation and advanced avionics;
- Single pilot operations; and
- Pilot training (see section 5.6)

The first two issues will be explained below, while the next section addresses pilot training and qualification in more detail.

Use of automation and advanced avionics:
- The advanced avionics in the EPATS aircraft help to reduce pilot workload and increase situational awareness, if used well by a well-trained pilot.
- Although EPATS aircraft offer increased safety and situational awareness by means of automation and advanced avionics, the drawback is the potential for over-reliance and over-confidence of pilots on automation and flying too much 'heads-down'. Oftentimes many (too many) options and features are available in avionics, while concern for human factors in design leaves room for improvement. In contrast to the business jets, commercial aircraft avionics have generally less features and are used in a strict procedural environment and a crew concept.
- EPATS aircraft, in particular VLJs, provide advanced avionics and aircraft performance that may challenge the (inexperienced) pilot with a non-airline/professional pilot or military training background 'to stay ahead of the aircraft'. Basically the EPATS aircraft require highly cognitive skills for operating automation, e.g. monitoring aircraft systems, operating the FMS, automation modes, mode changes, understanding the complexity of avionics, and handling failures. Advanced avionics require extra training and cognitive skills. Workload, planning, avionics complexity, decision-making, automation mode confusion etc. are examples of real issues that need attention through design and training of pilots.
- With the emergence of TAAs (glass cockpit general aviation aircraft) a few years ago, the aviation industry and FAA have launched initiatives to address training of both pilots and inspectors. It is important that pilots remain current in using the avionics. The lack of recent

experience is contributing to accidents and incidents according to NASA [Ref.55]. Training should cater for pilots from different backgrounds and experience levels, as we will see various types of pilots operating EPATS aircraft. It is remarked that training should not replace or correct inadequate or sub-optimal design from a human factors standpoint.

Single pilot operations:

- The EPATS aircraft are generally designed for single pilot operations, using the advanced avionics and automation. An obvious change is the lack of a second pilot, whose role can not be fully replaced by automation. The second pilot is pivotal in monitoring, cross-checking, decision-making and challenging the pilot flying, meanwhile sharing workload and supporting the pilot flying with 'administrative' tasks, e.g. R/T, programming the FMS, reading checklists, and assisting in failure handling. Technology remains 'passive' in the sense that it does not actively challenge a pilot.
- Single pilot Resource Management (SRM) is the single pilot version of Crew Resource Management (CRM). SRM should help the pilot to manage workload, flight planning, and decision-making.
- Medical and mental fitness will be an issue, especially in single pilot operations. For example, pilot incapacitation, fatigue and stress are safety aspects that should be addressed in training. Some manufacturers offer safety features such as an aircraft parachute system to mitigate pilot incapacitation or extreme emergencies.

Safety issues related to flight operations:

Automation/advanced avionics:

- Overreliance, over-confidence, 'heads-down' operation
- Lack of experience, knowledge of pilots and inspectors
- Complexity, understanding of advanced avionics (additional training) n
- Highly cognitive skills for operating automation

Single pilot operations

- Workload in non-normal situations
- No co-pilot: lack of challenging, decision-making, monitoring, workload sharing
- Medical and mental fitness

5.6. Training and qualification

Besides aircraft airworthiness certification, the regulators are also responsible for developing requirements and standards[4] with regard to certification of pilots, instructors and maintenance personnel. EPATS will introduce new aircraft and operations. Accordingly, many organisations have acknowledged the risk associated with relatively inexperienced pilots operating in complex, advanced aircraft, such as VLJs, possibly in single pilot operations. Therefore, training for EPATS aircraft and operations is a subject that will receive much attention across the aviation industry.

[4] Generally, the complexity of the aircraft and types of operation determine the level of qualification to must be met.

5.6.1. Pilot training

Additional pilot training required to prepare for advanced aircraft

The EPATS aircraft with advanced avionics and flight automation will introduce complexity compared to the general aviation and business aircraft with analogue instruments, ground based navigation and simple automation. Operating advanced aircraft requires additional knowledge, understanding of the systems, skills in monitoring and automation management, mode awareness and understanding how, when and when not to use automation, while maintaining manual flying skills [Ref. 49]. Training programs should thus be focused on automation management, workload management, cognitive skills, single pilot resource management, flight planning, judgement and decision-making [Refs. 53,54,55]. Although the automation and avionics may provide additional safety, the AOPA Air Safety Foundation states that "to actually obtain this available safety, pilots must receive additional training in the specific technically advanced aircraft systems in their aircraft that will enable them to exploit the opportunities and operate within the limitations inherent in their systems" [Ref. 47].

Particularly the introduction of the VLJ will increase the likelihood that relatively inexperienced pilots will be operating a high performance jet in a complex and challenging environment. Regulators should ensure that training standards, experience and medical standards are adequate to deal with this development [Ref. 38].

Different pilot experience levels

It is likely that pilots with a range of experience levels will operate the EPATS aircraft: some will transition from general aviation, others will come from the corporate or business aviation industry, air taxi operators or fractional ownership companies. There is also an interest in hiring retired former airline pilots, who bring experience, knowledge and airline training with them, which will benefit safety. We can expect EPATS air taxi operators to adopt similar approaches to pilot qualification as the air taxi operation business in the USA today. For example, the VLJ air taxi operator DayJet in the United States is looking for pilots with multi-engine aircraft experience and a minimum of 3,000 flights hours, which draws potential pilots from (retired) airline pilots, the charter and business/corporate sector. The DayJet's 25 days pilot training program consists of ground school and flight training according to the FAA Industry Training Standards scenario-based training. Another taxi operator, Linear Air in the United States, typically gets pilots from four groups: flight instructors, regional airline pilots, airline pilots nearing mandatory retirement and military pilots. The aforementioned mentioned minimum experience requirements for pilots employed in air taxi operations may not be the 'standard' for EPATS aircraft. Especially the smaller companies and individual owners could have relatively inexperienced pilots in the seats of EPATS aircraft.

5.6.2. Development of pilot training programs

Based on what we observe in the United States in the area of VLJ pilot training, it is likely that in EPATS aircraft manufactures, together with aviation insurance companies, regulators and flight crew training organisations, will establish training requirements and develop training programs in recognition of the need to prepare pilots for the EPATS aircraft and single pilot operations. Actually, the insurance companies will be the driving forces for these training

programs. The manufacturer's pilot training programs typically go a step further than the required type rating course. Unfortunately, if one buys for example a VLJ second-hand the manufacturer based training program will probably not be followed.

The training programs have to accommodate and address the various backgrounds, levels of experience and expertise of the student pilots. NBAA has introduced the concept of mentor pilot training for new pilots of VLJs upon completion of the pilot training program [Ref. 35]. The mentor pilot is an experienced pilot who will accompany the newly VLJ pilot during flights to gain supervised operating experience ("line-oriented flight training") [Ref. 57]. FAA encourages the use of simulation in pilot training with emphasis on scenario based training, although it is not required and FAA notes that today there are no special pilot training schools to conduct VLJ pilot training [Ref. 45]. In EPATS the mentor pilot and scenario-based training concepts could be applied as well.

5.6.3. Flight Crew Licensing regulations

Flight crew licensing regulations in EPATS will not be very different from today, except for additional regulations pertaining to VLJ pilot qualification and single pilot operations. One of the EPATS aircraft types is the VLJ, which is the newcomer in the market and enables a larger population of pilots to fly high-performance jets. EASA concluded that VLJ pilot qualification can be conducted under current rules [Ref. 44]. At this time, the JAA Joint Operations Evaluation Board (JOEB) has proposed requirements for Flight Crew Licensing (FCL) for VLJs, which will form the basis of future EASA rules. The current JOEB proposal includes at a minimum the following training to be completed at an approved type rating or flight training organisation:

- 16 hours in the aeroplane, plus 4 hours line oriented operations for low experience pilots; or
- 32 hours Full Flight Simulator (FFS), including 16 hours flying and 16 hours not flying.

The pre-entry requisite for the student includes a mandatory certificate of high performance aeroplane training. EASA will consider and implement the JOEB recommendations in the future and holds the opinion that with respect to pilot competence on complex aircraft types "a new approach to general aviation training systems is required – to at least commercial pilot standards" [Ref. 41]. EASA is going to develop the rules to cover multi-crew operations of VLJs, including training, skill tests, proficiency checking and recency requirements [Ref. 41,42].

It is assumed that an EPATS aircraft VLJ can be flown single pilot under VFR by the holder of:

- An Air Transport Pilot Licence (ATPL), plus the appropriate Type Rating;
- A Commercial Pilot Licence (CPL), plus the appropriate Type Rating;
- A Private Pilot Licence (PPL) with certificate of (JAR-FCL) High Performances Aeroplane Training and the appropriate Type Rating.

For conducting IFR flights, the pilots shall have a full Instrument Rating (IR).

In accordance with JAR-OPS 1, commercial air transport operations, such as a VLJ operating as an air taxi service, require a flight crew of two pilots (at least one with ATPL) if conducted as an IFR flight. Under VFR the commercial air transport flight can be operated by a single pilot if the pilot holds a CPL [Ref. 43].

5.6.4. Inspector training

Inspectors have to inspect EPATS aircraft, check flight instructors and pilot examiners, and participate in accident investigations. Therefore, not only the pilots, but also inspectors have to be prepared in a proper training program to transition to EPATS aircraft and operations. To illustrate the challenges that could be encountered in EPATS, we refer to effect of the advent of the VLJ in the United States recently. According to the FAA and the US Government Accountability Office (GAO) the introduction of VLJs in the National Airspace System means that FAA inspectors need additional training and qualifications [Ref. 45,46]. The FAA concluded that inspectors "may find themselves in uncharted territories when conducting an inspection or check ride" [Ref. 49]. For example, simulating failures in a proficiency checking flight may be different compared to traditional aircraft: simulating failures with advanced avionics is not as simple and effects on instrumentation and autoflight systems may be different in reality compared to simulation. The FAA developed a dedicated training program for operations inspectors when the TAA entered the general aviation market. Furthermore, the FAA maintenance and avionics inspectors have to receive additional training as well. Their training program was in still in development by mid 2007.

Safety issues related to training and pilot qualification:

Pilot training:

- Pilots must receive additional training in the EPATS aircraft to enable them to exploit the available system capabilities and operate within the limitations inherent in the systems.
- Training programs should focus on automation management, workload management, cognitive skills, single pilot resource management, flight planning, judgement and decision making.
- The introduction of the VLJ will increase the likelihood that relatively inexperienced pilots will be operating a high performance jet in a complex and challenging environment.
- Regulators should ensure that training standards, experience and medical standards are adequate to deal with this development.

Training programs:

- Pilots with a range of experience levels will operate EPATS aircraft. Training programs have to cater for the various backgrounds, experience and expertise of the student pilots.
- The mentor pilot and scenario-based training concepts from VLJs could be applied in EPATS.

Inspector training:

- Inspectors have to be trained and in EPATS aircraft and operations for inspections. Hence, inspector training programs are required in EPATS.

5.7. Airport and air traffic control – Safety aspects

The expected large number of EPATS aircraft and associated flights could lead to air traffic density and complexity related safety problems in the airspace and on the ground. Examples of expected safety issues are bird strike, separation assurance, wake turbulence, runway incursions, airspace incursions, approach and departure pattern deviations, and level busts. It is

remarked that the aforementioned issues are common today, but their frequency of occurrence and severity may change due to EPATS.

Airport safety issues
The airports served by the EPATS aircraft will mainly be the small and regional airports. The level of equipment, facilities and services provided at these airports will not be of the same standard as at the international or large airports in Europe. The airport infrastructure and availability of services for flight operations at the airport are relevant from a flight safety perspective. For example, bird control at the airport aims to reduce the likelihood of bird strike or bird ingestion and the availability of de-icing service is important in winter operations to prevent take-off with contaminated wing (risk of loss of control). If such services are unavailable at an airport, it may reduce flight safety and restrict operation in certain conditions. The absence of de-icing facilities would preclude operations to/from that airport in icing conditions for example.
Air traffic control safety issues
In the EPATS concept the following safety aspects relate to air traffic control (ATC) and pilot-controller interaction:

- *Communication problems*. In general, air-ground communication problems are an issue and occur on a daily basis. Examples are call-sign confusion, loss of communication, wrong frequency selected, using non-standard phraseology, misunderstanding of instructions, instruction issued to wrong aircraft etc. The potential consequences of these problems include altitude deviation, runway incursion, prolonged loss of communication, loss of separation, airspace infringement, and heading or track deviation [Ref. 50]. To what extent these scenarios will be exacerbated by workload associated with single pilot operations and by experience and level of training of EPATS pilots should be further analysed.

- *ATC instructions and traffic sequencing*. Safety issues may stem from pilot interaction with ATC. Air traffic controllers will have to learn how to acknowledge and deal with the performance and limitations of EPATS aircraft, which differs amongst EPATS aircraft and will not match current commercial and corporate aircraft performance. Misunderstanding of aircraft performance could result in improper sequencing, speed or altitude instructions etc. Comprehension by ATC of single pilot operations related workload and the specifics of EPATS operations may take time. Air traffic controller workload and airspace capacity will be substantial issues, as is wake vortex (when descending and climbing through levels for instance) [Ref. 59]. Moreover, there is at this moment no mandate for an Airborne Collision Avoidance System (ACAS) on-board the EPATS aircraft, although it is being considered by Eurocontrol. Soon, EPATS aircraft are required to have Mode-S transponders, which means that ACAS-equipped aircraft will be able to see them.
  Air traffic controllers will face the challenge of working in a further congesting air space, especially at and near smaller airports, where EPATS aircraft are expected to prevail because of their smaller size and shorter runway requirements [Ref. 39]. This could adversely impact workload and situational awareness of air traffic controller, which could result in loss of separation, communication problems etc.

EASA is concerned about the integration of the VLJs in today's air traffic system, amongst others in the area of accommodating VLJs at the higher flight levels of commercial air traffic (FL300-400) and in the complex and dense TMAs. EASA concluded that they needed to quantify and mitigate risk associated with potentially large number of these jets in the European airspace, the airport and ATM issues, single pilot operations in IFR and flight operations in such technically advanced aircraft [Ref. 44].

<u>Safety issues related to airport:</u>
- The level of equipment, facilities and services provided at EPATS airports will not be of the same standard as at the international or large airports in Europe.
- The airport infrastructure and availability of services for flight operations at the airport are relevant from a flight safety. Lack of services (e.g. bird control, de-icing) may degrade flight safety and restrict aircraft operations in certain conditions.

<u>Safety issues related to air traffic control:</u>
- The frequency and severity of the following events may increase due to EPATS: loss of separation, wake turbulence, runway incursions, airspace incursions, approach and departure pattern deviations, and level busts. To what extent these occurrences will be exacerbated in EPATS should be further analysed.
- Problems in communication, and ATC instructions and traffic sequencing in EPATS, in relation to single pilot operations, increased traffic and communication volume. The safe integration of EPATS aircraft in the air transport system of today has to be studied in more detail to identify and assess the risks of EPATS in the airport and ATM domain.

5.8. Safety programs

The majority of airlines have implemented programs to maintain and manage flight safety. Examples of these programs are Safety Management System (SMS), voluntary occurrence reporting programs, and Flight Operations Quality Assurance (FOQA). Technologies and strategies are available from the commercial air transport industry that could contribute to achie Iving and maintaining an acceptable level of safety in the EPATS concept. Such safety programs work well for airlines, but they have to be tailored to corporate, business and air taxi operators, flying EPATS aircraft. Many operators of EPATS aircraft will likely have a small fleet of aircraft which means that they could lack the resources for equipment and manpower to conduct such safety programs. In addition, small operators with a few aircraft do not benefit from the large amount of data and trend analysis of FOQA and occurrence data. For those reasons, it is yet unclear to what extent the commercial aviation safety programs can be successfully implemented in EPATS and would really provide meaningful feedback.

<u>Safety management</u>
Safety management is defined as the systematic management of all activities to secure an acceptable level of safety. Safety management should be both reactive and proactive. A *Safety Management System* (SMS) is the process that an operator has in place to proactively identify and manage risks and to ensure that safety is maintained at the desired level. In this process there are a number of key elements, like safety objectives set in the safety policy, monitoring

safety performance, identification of threats, conducting risk assessments, and taking safety actions (e.g. risk mitigation measures, safety promotion). FAA has issued an Advisory Circular AC-120-92 in June 2006 about the SMS concept and provides guidance to implement SMS on a voluntary basis. SMS is also beneficial for air taxi operators and corporate flight departments, therefore NBAA is promoting SMS amongst business aircraft operators.

In EPATS the commercial operators and corporate aviation departments could implement SMS voluntarily as along as there is no requirement for this in the regulations. Although we may see the outsourcing of safety management programs to manufacturers or to Aircraft Maintenance Company as we suggest, by the small(er) or individual operators, that action does not remove the responsibility of safety management by the operator. The question is to what extent the small, corporate companies and individual operators of EPATS aircraft can implement an effective SMS. What would an SMS look like in an organisation with just one plane? Whether outsourced or not, how can commercial aviation safety programs be effectively applied in EPATS? If outsourced, what processes are required to ensure that feedback from manufacturer to operator is timely and adequate and that actual follow-up actions by the operator are accomplished? It is recommended that these question are addressed in a future study. It is clear that the safety level of EPATS commercial and corporate flight in 2020 can not be lower than nowadays corporate flight operation which is near airliners level and should reach the airliners level . The accident rate data demonstrates that corporate aviation has an excellent safety record over the years measured. The corporate jet accident rate of 0.08 accidents per 100,000 departures compares favorably with the scheduled airline rate of 0.112 for hull loss and/or fatal accidents per 100,000 departures. See D1.1 “Total and fatal accidents rate by aircraft type and operators”

Safety data reporting, collecting and analysis

Reporting, collecting and analysing safety data is one pillar of aviation safety. Safety research, safety statistics and trend analysis, and risk assessments require good quality data and are dependent on data from the actual flight operations. Therefore, a database collecting accidents, incidents and occurrences in general aviation (including air taxi, corporate and business flights) would greatly improve the knowledge and awareness of EPATS safety issues.

Aside from *Mandatory Occurrence Reporting* (MOR) as required by the regulators, another important safety program is a *voluntary safety reporting program*[5], which pilots, cabin crew and maintenance personnel can use to report occurrences and concerns to the flight safety department of their organisation. Such data is a valuable source of information for identifying problems and trends and for providing feedback from operations to management.
Safety data collection of occurrences in the general aviation sector is nowadays not well covered. Data coverage and quality in general aviation is poor compared to commercial air transport operations. In particular, data on occurrences involving small, light, general aviation aircraft (e.g. Cessna 172) are not well reported and collected. Business and corporate aviation is generally well covered. The situation regarding general aviation data collection is much better

[5] In the United States the voluntary reporting program is called Aviation Safety Action Program (ASAP). In an airline Air Safety Reports (ASRs) are reports by pilots of unsafe occurrences and hazardous situations that occurred during operations.

in the United States than Europe. In the ECCAIRS database (European Co-ordination centre for Accident and Incident Reporting Systems) occurrences involving EPATS aircraft that have a maximum take-off weight of more than 2250 kg are collected (if reported of course). It is expected that VLJs will be covered by ECCAIRS.

Flight Operations Quality Assurance.
FOQA is the pro-active, systematic and non punitive system of monitoring flight data from normal operations. In a FOQA program flight data is recorded and regularly downloaded for monitoring and data analysis, in order to timely identify safety trends and exceedances, so that mitigating measures can be taken to correct identified problems to avoid accidents and incidents. In commercial air transport FOQA programs are standard practise today and have resulted in economic, safety and operations efficiency benefits for airlines.

FOQA programs for corporate aviation are beginning to emerge. The Flight Safety Foundation (FSF) and the Safety Committee of NBAA have initiated Corporate FOQA (C-FOQA) and conducted a demonstration project. Applying the airline oriented program to corporate aviation was not straightforward, in particular regarding data recording capabilities (e.g. installation and certification of quick access recorders) [Ref. 51]. Corporate aviation departments employ usually a few aircraft, which do not provide sufficient exposure for meaningful trend analysis.

A possible solution to this problem is the outsourcing of FOQA to an independent organisation. VLJ manufacturer Eclipse Aviation launched the idea of manufacturer-hosted safety programs [Ref. 52]. In this concept VLJ operators send on a regular basis flight data and voluntary occurrence reports to the aircraft manufacturer for aggregate data analysis across a large fleet of aircraft and operators. The manufacturer conducts trend analysis, provides feedback to the operators, and improves manufacturer related problems. However, manufactures do not have the authority to correct identified problems at operators. In that case, the manufacturer can inform the operator, who in turn should take action to mitigate the problem, e.g. by changing company operating procedures or providing additional pilot training. From the operator perspective there is concern about privacy and propriety information. Consequently, procedures and arrangements have to be set-up to ensure data protection, privacy, de-identification etc. According to Eclipse Aviation it is better to have a manufacturer-based safety program than to have nothing [Ref. 52].

Health and Usage Monitoring
The introduction of the digital avionics, sensors and systems on-board general aviation aircraft provide the opportunity to implement a health and usage monitoring program comparable to commercial aviation. A health and usage monitoring program is one of the application areas of Flight Data Monitoring. Such a program monitors aircraft systems performance, detects exceedances, and determines the condition of systems or parts to improve maintenance and ultimately safety. The programs can be used to conduct maintenance of a component based on its actual condition and wear (condition-based maintenance) in stead of a standard time interval. They also assist maintainers in fault detection and analysis, which makes maintenance more efficient and effective.

Safety programs issues:

- EPATS operators could benefit from airline oriented safety programs such as SMS, FOQA, safety occurrence reporting and analysis.
- The implementation and application of these safety programs in EPATS will not be straightforward due to the required resources and expertise, scale of operations and type of operations.
- The outsourcing of safety programs (e.g. manufacturer-hosted FOQA) runs into issues regarding privacy and propriety information, effectiveness, and responsibility for improvement action.
- Reporting, collecting and analysing safety data is one pillar of aviation safety.
- Safety data reporting and collection of occurrences in the general aviation sector is nowadays not well covered, resulting in a lack of knowledge and awareness of general aviation safety and in particular EPATS safety issues in the future.

5.9. Safety oversight

The introduction of new types of aircraft means that regulators need to identify, quantify and mitigate potential risks associated with new types of aircraft and their operation. The expected number of EPATS aircraft that will enter the market in the next decades and pace of change will bring challenges, and are sources of concern about new risks being introduced for which EASA and National Aviation Authorities need to prepare to maintain a high standard of safety oversight.

In the EPATS concept we envision many different operators and types of operations, ranging from commuter scheduled, on demand charter, air taxi companies operating a large fleet of small aircraft offering on-demand air taxi service to individuals owning and flying these aircraft for business or personal and recreational purpose. Up to 2,000 regional airports in Europe are suitable destinations in EPATS. How are regulators going to cope with the inspection and oversight of all these different aircraft types, operators, and operations across Europe at many regional airports?

It is not clear (yet) how EASA and the National Aviation Authorities will deal with oversight of EPATS aircraft and operators, maintenance organisations and training facilities. To get an idea of the potential impact of EPATS on safety oversight, we refer to the conclusion of the Government Accountability Office (GAO) in the United States regarding the impact of VLJs on FAA oversight. Given the fact that the VLJ is one of the EPATS aircraft types and that VLJ operations in the United States could be regarded a precursor of EPATS, it is likely that European regulators will face similar challenges as the FAA today in safety oversight of VLJs.

GAO stated that “the challenge of meeting its [FAA] performance target will be exacerbated by other challenges in human capital management, the acquisition and operation of new safety enhancing technologies, and new types of vehicles, such as very light jets, that may place additional workload strains on FAA inspectors and air traffic controllers. […] Finally, if predictions about new types of aviation vehicles are borne out, it will change the aviation landscape and will require new areas of expertise for FAA’s inspectors and controllers. For example, the industry predicts there may be as many as 5,000 to 10,000 VLJs operating in the national airspace by 2020, which would further congest the national airspace system especially

at and near smaller airports, where VLJs are expected to be prevalent because of their smaller size" [Ref. 39].

In general, there is concern with respect to limited resources and allocation of resources to meet certification, inspection and oversight demand as the number and rate of VLJs entering the NAS increases. A shortage of FAA inspectors, mainly due to retirement, could threaten FAA's ability to conduct safety oversight, but FAA plans to increase its inspector workforce [Refs. 39,46]. Since the VLJs are likely to operate from many smaller/regional airports across the United States (potentially 3000-5000 airports) the deployment of resources will be a challenge.

Safety oversight issues:
- Oversight of EPATS will pose a complex and resource intensive oversight process, since operators range from individuals operating an EPATS aircraft to air taxi operators operating a hundred VLJs across Europe from different countries to/from hundreds of airports.
- There is concern with respect to limited resources (or shortage) and allocation of resources to meet certification, inspection and oversight demand as the number and rate of EPATS aircraft entering the system.

6. Conclusions and Recommendations

6.1. Consequences for the future

The expected increase in EPATS aircraft and use (about 100.000 aircraft in 2020) will have consequences for airports, environment and safety, see the next paragraphs for the details as identified.
First the numbers. There are presently about 50.000 General Aviation aircraft in Europe (but only about 10000 FAR or JAR-23 normal Category certified aircraft). With an estimate of 2000 small airfields and airports, there are already about 25 GA aircraft on average per airfield. It may be private and sports aircraft, flying schools, police, ambulance and small business applications like aerial photography, advertisement and parajumping etc. If the 100.000 EPATS aircraft are distributed among the assumed 1000 economically attractive airfields, it would imply an increase to 100 or 125 aircraft per airfield on average in 2020.

The big difference will be that EPATS aircraft are assumed to be used at least once or twice a day, while present day GA aircraft are probably flown just a few hours per week or month. The intensified use of small airfields will require willingness of the surrounding population to accept more noise and pollution. It will also require more ATC control and service.

The numbers of EPATS aircraft are expected to grow gradually. In the beginning this EPATS will be rather expensive, but as large orders (thousands of the same type) will lower the price to an estimate of200 – 500 thousands Euro for pistons, 1- 1,5 million Euro for VLJ's, and 1,5 – 2,5 million Euro for turboprop commuter will become rather popular.

It is still an open question whether the countries in the European Union will be able to train and supply enough EPATS pilots (200000 pilots during 20 years). It could be, however attractive for business people to fly their own aircraft in business models like buy-in of hours or shared ownership. This will have safety aspects, that are discussed below.

With the present airport distribution over Europe, there will be enough infrastructure to accommodate the expected EPATS evolution. Some airports are not close to economic centres, making others close by economic activities more attractive. Some may need new, more or extended runways, but it seems reasonable that this aspect of the European infrastructure can be developed in time and in phase with the EPATS evolution.

The same applies to the airport facilities. Local economy should drive and have benefit from the evolution. As we still have 10 to 12 years to go, investors and governments can wait and see a couple of years, also because there is plenty of capacity already available and waiting for EPATS.

6.2. Airport Infrastructure Recommendations

The arrival of the EPATS will have a big influence on the existing airports, especially the small and regional airports. Because the EPATS aircraft is a small airplane it has fewer requirements for an airport. Therefore the airports can first watch the development of the EPATS before they make large investments. When the time is come the airports can make investments like ILS, de-icing, calamity prevention and accommodation to be a fully functional EPATS airport. With these systems the safety will be maintained and the efficiency will be optimal. VFR airports can expand to an IFR airport so flights can take place during the night or with bad visibility. For the airports that are not controlled it is an option to introduce remote control and surveillance. The crew of a different airport could control the necessary issues, like stop bars, with help of cameras and radio contact. When de-icing is not available a solution is to heat the hangars so no expansive de-ice equipment has to be bought. With this kind of solutions small airports can operate with the EPATS in a basic way.

All passengers, luggage and cargo must be checked easily and quickly. This requires a good security system. The existing security system as operated on large airports can be used or developed further.
The air taxi companies are emerging in Europe. An air taxi company will have more airplanes flying through Europe so it is good to have a home base. Airplane hangars will be available and all the necessary maintenance can provided on these bases. From here they fly to the airport were the passengers will depart from and bring them to their destination. Afterwards the airplanes can fly back to home base. We envision a home base of a dozen to hundreds of aircraft step by step in each NUTS 2 (260) and NUTS 3 (1100) regions

The EPATS study recommends and concludes on the following airport infrastructure topics:
Airports:

- It seems that Europe has enough small airports to accommodate 100.000 plus small aircraft
- Some economic growth centres will be places to create or modernise small airports, especially in areas where other more traditional means of transport are absent. The local economy will be the driving factor because it will have direct benefit.
- Each region NUTS 2 and NUTS 3 airport will have good chances become the home base of EPATS operators. These airports need more facilities and probably Air Traffic Control to service safe flight operations during peak hours. Examples in the US demonstrate that air taxi operators could service their own airport with tower control.
- EPATS aircraft may fly under rules that are neither IFR nor VFR. Their avionics may allow self separation as if EPATS are flying VFR. Research is recommended to what traffic quantities Self separating EPATS flights can be maintained on non-towered airports.

Runways and Approach / Departure:

- One runway per airport could accommodate up to 400 movements a day, which is the average rate estimated for 100.000 small aircraft, 1000 European airfields of interest and equal numbers of home based aircraft and visiting aircraft. Noise and environment may restrict the airport to lower numbers, but from air traffic and safety reasons 400 movements per runway are certainly possible
- Punctuality of air transport services will benefit from Autoland facilities, satellite based local area augmentation systems and extra beacons although the EPATS aircraft will

probably operate rather independently from VOR, NDB and DME. Satellite based Autoland systems still need certification. Autoland systems should be available on pilot demand either by calling the local airport operator or by remote ATC operations. Autoland will need additional certification if the airfield is not controlled and if a fire brigade is not available on the spot. In conclusion research is recommended on cheap and safe Autoland facilities for EPATS aircraft.

- EPATS operations during night and low visibility need approach lighting and runway lighting, preferably systems that can be ignited on pilot demand either by local airport operators or remotely. Research is recommended on remote control of airports, including approach and runway lighting.
- Quiet airports are also places where wildlife likes to live. Safe EPATS operations require protection against wildlife and birds. It is inevitable to take care of this aspect. Local airport operators could be trained to inspect the runway short before landing. Research is recommended on animal friendly protection of runways and taxiway against bird and wildlife.

Taxiways and parking:

- The existing 2000 small European airports possess probably sufficient taxiways with sufficient quality.
- Extra parking and hangars may be needed to host the extra 100 of EPATS aircraft on average per airport. Airfields with one runway and subsequent taxiway and aprons will occupy a rectangle of land with about 1 km length and about 500 m width. This should be enough space to create extra parking stands for engined taxi in and taxi out parking of about 100 extra small aircraft.
- Taxiway guidance (markings, painting, lighting) should serve the EPATS pilots according to ICAO standards and up to a level that taxi operations can happen uncontrolled and punctually. Research on certification of moving map cockpit displays is recommended.

Air Traffic Control and flight preparations

- Airports with low traffic will not need control. In comparison much of the VFR general aviation happens on uncontrolled airfields and procedures guarantee safe operations there.
- It will save the cost of personnel if airports are controlled remotely. Applied research and development is needed for optimal ways of remote airport control.
- The availability of meteo data for flight preparation is of utmost importance. Present day European meteo data systems are already available but may need further development and certification to allow use for flight preparation.

Airport facilities:

- The runway(s), taxiways and aprons should be free of snow and ice for safe operations. Local airport operators (services) should take care of this aspect of airport accessibility and reliability. Research is recommended to predict local ice forming and snow several hours before landing. Research and development is needed how to protect runways and taxiways longer against snow and ice than present day methods.
- The EPATS aircraft should be free of snow and ice before take off. Methods could be developed for simple removal of snow and ice on small aircraft. Off course indoor parking in heated hangars will solve the problem.
- Provision of electrical power would be needed, but if not available, EPATS aircraft could use there own battery power for starting up the engines.

- Various types of fuel should be available on small airports to prevent extra refuel stop overs. It might be futuristic but technology for in flight refuelling exist!
- Small repair and maintenance would benefit flight operational reliability.

Passenger facilities:

- Connectivity (car, public transport) is needed to fulfil the EPATS goal of spending as little time as possible in the transport system
- The need for restaurants, waiting room, parking and shops will grow with the traffic.
- Simple but secure check in and customs procedures are needed; biometrics is a candidate.

Statistics:

- Better statistical data is needed to track the EPATS evolution and consequences for airports.

Statistics on EPATS aircraft, number of flights, number of passengers and connections, number of pilots, hours of operation etc. will help to predict the future of EPATS better.

6.3. Environmental Recommendations

A disadvantage of the EPATS evolution is that people, who live near an airport, will revolt against enlargement of the airports. More airplanes mean more pollution and more noise inconvenience. But the quick development of the high efficient jet engines makes it possible that the engines are a lot quieter than the comparable piston and turboprop driven airplanes (For accurate measurements see appendices V). Eurocontrol (SESAR) goal is to reduce the environmental impact per flight with 10 %. A big advantage is that the EPATS will relieve the traffic on the highways. That will result in less traffic-jams and pollution.
The EPATS concept will lead to an average increase of 24000 aircraft movements per year per local airport. At busy airport this value will be even two or three times higher. This will have an impact on the environment; both on the production of noise and gaseous emissions. At least at some airports this increase in flight movements will conflict with the noise limits. For instance several airports in the Netherlands are not allowed to accommodate more than 10000 to 20000 additional yearly flight movements compared to the current situation due to noise restrictions. These figures hold for the current generation of small aircraft; if future aircraft become quieter this will lead to an increase in the allowed number of flight movements within the noise limits. Finally this increase in traffic may lead to congestion at busy airports during peak times.

To reduce the noise impact as much as possible, it is important to design aircraft that are as silent as possible. Besides the noise production, the fuel consumption also has to be as low as possible in order to reduce the emissions.
Comparing the noise production of several aircraft showed that the introduction of very light jets (VLJ) reduces the noise production per flight compared to regular jets and turboprops. The comparison to aircraft with piston engines showed that the VLJ has better noise characteristics during the take-off, while the approach noise characteristics are comparable.

Also the emissions of several aircraft types were compared. This showed that modern aircraft with piston and turboprop engines have lower emissions compared to VLJs. For this reason the use of these aircraft can be considered. Downside of these aircraft is the fact that their cruise speed is lower, which will lead to an increase in fight time. Therefore their use is only recommended for short trips. If piston or turboprop aircraft are used, it is desirable that the

noise production of these aircraft is taken into account in new designs, since they produce more noise during take-off compared to a VLJ.

Besides the engine type, also the fuel used has an impact on the emissions. The use of hydrogen will eliminate the emissions of CO_2 (as long as no CO_2 is emitted during the hydrogen production process) and electric propulsion will eliminate the NO_X emissions. If fuel types are used that lead to the emission of H_2O and/or NO_X, a cruise altitude of less than 8 km is recommended to reduce the effect of these emissions.

Finally the load factor of the EPATS aircraft is of importance since a high load factor is beneficial for the emissions per passenger kilometre. This requisite is in conflict with the flexibility and capacity criteria that have to guarantee an acceptable level of customer satisfaction.

This chapter gives an overview of the most important effects on the environment (both noise and emissions) of the EPATS concept. However this is only a short summary of these effects. To give a more detailed indication of the impact on the environment, additional research will be needed. The following list presents several suggestions for further research:

- First of all a good forecast of the expected traffic is needed. As can be seen in Table 4-1 the figures provided so far do not give a clear picture. For this reason more detailed information about the number of aircraft and the fleet mix is needed. Also the effect of delays due to congestion should be investigated. If an airport becomes congested it will be less beneficial to use an aircraft for transport to a location near this airport.
- If the amount of traffic is known, the next question to be answered is how these aircraft are divided over the available airports. First of all large hub airports can not accommodate a large number of EPATS flight movements since these airports are already congested. Furthermore the amount of traffic on the other airports will not be equal for each airport, but it depends on the amount of commercial activities in the vicinity of the airport for instance.
- Also the way the traffic is spread over a day is of interest since this will influence the accessibility of an airport. Most business passengers are expected to arrive early at their destination and leave at the end of the afternoon, which means that the traffic density will become high during these periods. If the traffic volume becomes too large this will lead to airborne holding (hence an increase in emissions and possibly noise) and delays on the ground. If these studies show that congestion might become a large problem, research will be needed on measures to decrease the congestion problem.
- As shown in Figure 4-1 the average load factor has a large impact on the amount of emissions per passenger kilometre. For this reason it is of great importance that a system will be developed that allows flexible and efficient use of the available aircraft. Such a system is needed to make sure that the average load factor will be as high as possible. On the other hand this system must be able to cope with the differences in demand that will occur. Since one of the goals of the EPATS concept is that passengers can book an aircraft a day in advance, there is only a limited amount of time to make a good planning of how much capacity is needed where and when. The chance that a passenger

must arrange another mode of transport due to a lack of availability of EPATS aircraft must be low in order to provide a sufficient level of service to the customers.
- To reduce the noise impact of the EPATS concept, research should be done to develop more silent aircraft.
- If an unacceptable noise impact is expected for a specific airport, research is needed to find the best way to improve the situation around the given airport.
- For travelling over short distances (up to 600 km) the use of aircraft with piston engines or turboprop engines can be beneficial. A trade-off should be made between these two aircraft types to estimate what type of aircraft gives the best combination of low noise production and fuel efficiency.
- To reduce the impact of the EPATS concept on emissions, research should be done to develop more fuel efficient aircraft. Also the potential of new propulsion methods should be looked into.
- Since every country has its own laws that prescribe the noise, emission and external safety limits; it might be useful to investigate whether large differences exist between different laws. This is of interest because these laws can limit the maximum capacity and might increase the need for additional measures to limit the environmental impact of air traffic.
- To reduce global emissions an ATM system that allows aircraft to fly direct routes between two points is desired. This will limit the flight time and reduce the amount of fuel used, thereby also decreasing the global emissions.
- Depending on the amount of H_2O and NO_X that will be emitted by all EPATS aircraft, it can be interesting to investigate whether it is possible to limit the maximum cruise altitude. To limit the effect of both gasses on respectively global warming and ozone depletion, a maximum altitude of approximately 8 km is suggested.
- To make a good comparison between the emissions of an aircraft and a reference car; information about the emissions of both the aircraft and the reference car will be needed. Since the EPATS concept is to be implemented in the future, the expected technological developments of both cars and aircraft should be taken into account in order to produce a realistic estimation of their emissions.
- To give a good estimate for the local emissions of a VLJ, the LTO cycle of a VLJ (for example the Eclipse 500) can be calculated. To obtain a realistic result, good estimates for the different times in mode are needed. The time in mode describes how long the final approach, taxiing, take-off and climb out take.
- In general, EPATS users will use a car to travel from the airport to their final destination. To give a good comparison between the emissions of road transport and the EPATS concept, the average number of passenger kilometres travelled by car between the airport and destination has to be known. Hereby it should be noticed that road transport will directly transport a passenger to the desired destination, which means that the total trip length will be shorter than for the EPATS concept.
- It can be useful to investigate the local air quality around several small airports and give an indication of the estimated contribution of the EPATS concept to the local pollution. This gives an idea of the impact of the EPATS concept relative to other sources of pollution around an airport, such as road transport.

6.4. Safety Recommendations

In the previous sections we have identified and reviewed safety aspects of EPATS aircraft and operation. In line with the objective of the EPATS project we will define in this chapter the recommendations for further research and development in order to address the safety issues in EPATS. The EPATS concept shows great resemblance to the Small Aircraft Transportation System (SATS) program in the United States. In 2006 the National Institute of Aerospace in the United States delivered a report describing the strategic goals for achieving the Small Aircraft Transportation System [Ref. 60]. A system of small aircraft operating to/from small airports across the United States is envisioned in SATS in order to provide a safe, reliable affordable and efficient transportation service to every community in the United States. However, additional research and improvements are required for SATS. The National Institute of Aerospace report defines the strategic research and development roadmap for SATS, including four priority areas: service reliability, weather safety, ease of operation and community compatibility. Since EPATS can be regarded as the European version of SATS, research requirements for EPATS will have a lot in common with the SATS R&D roadmap. The next sections provide an overview of recommendations for future R&D with the scope of flight safety. The reader is referred to Appendix C for a summary of the SATS R&D roadmap, which will be beneficial for EPATS as well.

6.4.1. Aircraft manufacturing and certification

Safety aspects related to EPATS aircraft manufacturing and certification yield the following recommendations:

- Analyse to what extent the current regulations are appropriate for certification of new designs and new technologies, production techniques and materials in EPATS.
- Conduct a safety study to determine the benefit of equipping EPATS aircraft with ACAS and GPWS.

6.4.2. Flight operations

Recommendations for R&D cover automation and single pilot operations:

- ***Research into automation that support safe single pilot operations***. Topics include the development of automated flight planning, resilient recovery of functionality, fly-by-wire with autopilot/auto-throttle, and pre-flight and weight and balance technology [Ref. 60]. In addition to that, research dedicated to the application in general aviation of sophisticated technologies, such as head-up display, synthetic vision, voice recognition and synthetic voice, is recommended.
- Conduct ***research and a feasibility study in the area of flight envelope protection and further automation of flight*** in EPATS aircraft. Autopilot with auto-throttle and auto-land capabilities could improve flight safety, especially in IMC conditions. Having an auto-throttle would reduce pilot workload in the approach for instance by less engine handling, monitoring and maintaining approach speed.
- The pitfall of advanced avionics and automation is the danger of over-reliance, mode confusion, too much head-down time, skill erosion, complacency etc. (section 5.5). In order to overcome these issues ***further research in intuitive displays and automation*** has to be performed. This should address the *human factors* in design, e.g. menu structure, information presentation, automation features, what is presented and what not, the

availability of options or features, and the identification of tasks that can be autonomously executed by avionics.

- The ***effect of cockpit design, automation and advanced avionics on pilot workload, decision-making*** etc., should be studied for a crew of two pilots, as well as in single pilot operations.
- Study how the advanced avionics and automation can be exploited to improve single pilot operations, e.g. situational awareness, pilot attention and decision-making in the absence of a co-pilot. In this context, the ***virtual co-pilot concept shall be further studied*** [Ref. 60]. A virtual co-pilot can support the flying pilot in monitoring, decision-making, flight planning etc., to reduce workload and enhance situational awareness. In [Ref.60] an extensive list of research items in this area are noted.
- ***Free flight or the Self Controlled Airspace*** (SCA) for small, remote airports is an area for further research. The Self Controlled Airspace was studied in the SATS program [Ref. 60] and could help to accommodate increased traffic volume at small, regional airports to allow single pilot operations in IMC. It is recommended to conduct research into systems, procedures and automation needed to safely introduce the SCA concept and to enable the effortless transition from small airport airspace to en-route airspace. The reader should refer to [Ref. 60] for specific suggestions for SCA research.

6.4.3. Training and qualification

To address the safety aspects in training and qualification of pilots and inspectors the following suggestions for further research are done:

- In cooperation with EPATS operators, manufacturers, training organisations and regulators ***the applicability and appropriateness of the current regulations and pilot training programs*** should be evaluated, and shortcomings and areas for improvement shall be identified, keeping in mind the high performance jets and single pilot operations. The focus should be on automation management, workload management, cognitive skills, single pilot resource management, flight planning, judgement and decision-making. Training of inspectors and maintenance personnel should receive attention as well.
- The implementation of ***Single pilot Resource Management*** (SRM) should be studied. Drawing upon the experience of Crew Resource Management, the SRM concept shall be further developed. Research should define the content of SRM, develop training tools and assess the effect of SRM on flight operation.

6.4.4. Airport and Air Traffic Control

Subjects for further research from a safety perspective in the area of airport and air traffic control are:

- The safe integration of EPATS aircraft in the air transport system of today has to be studied in more detail to ***identify and assess the risks of EPATS in the airport and ATM domain***.
- A ***risk assessment of wake vortex encounters*** by EPATS aircraft during en-route, climb, descent (manoeuvring in TMA) and in take-off and landing.
- A study about the impact of EPATS on ***air-ground communication problems***. It should focus on the identification of various problems, their frequency of occurrence and the consequences, especially ***in the context of single pilot operations***. Research should evaluate the potential and safety effects of air-ground data link communication and requirements in relation to single pilot operations and EPATS operations. In the SATS report, research areas

are identified for the safe integration of small aircraft in the ATM system [Ref. 60]. Their recommendations cover communication as well.
- An analysis of the ***effect of single pilot operations on ATC-pilot interaction*** and related safety issues shall be performed. For example, the impact of EPATS on communication problems, runway incursions, airspace infringements, level busts, deviations from flight paths etc. The analysis should take into account the increased number of movements by small aircraft and the growth of single pilot operations. Mitigating measures to prevent these issues in EPATS need further study, as well.
- The identification and review of safety implications due to increased ***workload of air traffic controllers*** as a result of handling more air traffic, in particular EPATS aircraft.
- Research into the current and future status of EPATS airports in Europe with respect to the availability and provision of services and level of equipment. A ***safety assessment of airport operations in EPATS*** and the implications for aircraft operations and on-board equipment (required equipment, standard and performance) should be conducted.

6.4.5. Safety programs

EPATS operators may benefit from several safety programs that are nowadays common practice in commercial aviation. Hence, the following research is proposed:
- ***The tailoring and application of commercial aviation safety programs to EPATS operators*** (notably air taxi operators, corporate and business aviation) should be studied. It shall consider the required resources (manpower, knowledge, equipment, costs etc.) and benefits of safety programs, like SMS and FOQA, in EPATS.
- Additional research is necessary to determine the consequence of and issues concerning the ***outsourcing of safety programs*** in the form of manufacturer-based programs for instance. Such a study should address the set-up, the advantages and disadvantages, and the cost-benefit of outsourced safety programs versus operator's "in-house" safety programs.
- Occurrence data reporting and collection of general aviation statistics should be improved. This issue falls under the responsibility of regulators (rulemaking/oversight/collecting) and operators (reporting). It is recommended to analyse current regulations with respect to general aviation occurrence reporting, the causes of the problems encountered in data reporting and collection, the available systems for data collection and storage. The analysis should support the ***identification of solutions to improve general aviation data collection and analysis***. As soon as quality data on general aviation safety becomes available, safety studies should be carried out to gain insight in the EPATS related safety problems and trends therein.
- Further research is required to ***tailor contemporary health and usage monitoring systems*** to general aviation, and to develop (trend) analysis techniques and tools in this context.

6.4.6. Safety oversight

In response to the challenge of safety oversight in EPATS, three recommendations are made:
- Research into ***resource planning*** is proposed to efficiently and effectively conduct oversight within EPATS. For example, optimisation strategies and available tools have to be identified.
- Secondly, the identification, quantification and analysis of risks associated with EPATS aircraft and operations are the first steps towards risk mitigation. A ***risk-based oversight***

and inspection program would help regulators to prioritise their limited resources on the most important safety-related issues. It is recommended to conduct research into risk-based oversight and inspection within EPATS, including the tools and techniques required for this activity.

Finally, the development of a dedicated ***training program for authorities and inspectors*** in EPATS aircraft and operations is a topic for research and development.

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Appendix A Certification rules for airports

(From EMMA D143, A-SMGCS related Certification Aspects, G. Mansfeld, S. Loth, DLR, March 2007 [23])

Besides the regulations for certification of aircraft and related parts there are also rules for certification of airports in the US. These rules are defined by the FAA in 14 CFR (Code of Federal Regulations) Part 121 and Part 139 "Certification of Airports; Final Rule" [22]

The summary of the rules are as follows:

> *This rule revises the airport certification regulation and establishes certification requirements for airports serving scheduled air carrier operations in aircraft designed for more than 9 passenger seats but less than 31 passenger seats. In addition, this rule amends a section of an air carrier operation regulation to conform with changes to airport certification requirements. This rule is necessary to ensure safety in air transportation at all certificated airports.*

Part 139 – Certification of airports consists of the following Subparts

<u>Subpart A: General</u>

The subpart is addressed to the applicability, the delegation of authority, definitions and methods and procedures for compliance.

Depending on the type of served air carrier operations, airports in the US are classified by the FAA for certification. Four classes are currently defined.

Class I airport:
: certificated to serve scheduled operations of large air carrier aircraft that can also serve unscheduled passenger operations of large air carrier aircraft and/or scheduled operations of small air carrier aircraft.

Class II airport
: certificated to serve scheduled operations of small air carrier aircraft and the unscheduled passenger operations of large air carrier aircraft. A Class II airport cannot serve scheduled large air carrier aircraft.

Class III airport
: certificated to serve scheduled operations of small air carrier aircraft. A Class III airport cannot serve scheduled or unscheduled large air carrier aircraft.

Class IV airport
: certificated to serve unscheduled passenger operations of large air carrier aircraft. A Class IV airport cannot serve scheduled large or small air carrier aircraft.

<u>Subpart B: Certification</u>

The subpart is addressed to the general requirements, the application for a certification, inspection authority, issuance and duration of a certificate, and exemptions and deviations.

The following paragraphs are included:

> *§ 139.101 General requirements.*
> *(a) Except as otherwise authorized by the Administrator, no person may operate an airport specified under §139.1 of this part without an Airport Operating Certificate or in violation of that certificate, the applicable provisions, or the approved Airport Certification Manual.*
> *(b) Each certificate holder must adopt and comply with an Airport Certification Manual as required under § 139.203.*

Subpart C: Airport Certification Manual

The subpart is addressed to the contents of an Airport Certification Manual and the amendments'.
§139.203

> (a) *Each certificate holder shall include in the Airport Certification Manual a description of operating procedures, facilities and equipment, responsibility assignments, and any other information needed by personnel concerned with operating the airport in order to comply with applicable provisions of subpart D of this part and paragraph (b) of this section.*
> *(b)*
> *Except as otherwise authorized by the Administrator, the certificate holder shall include in the Airport Certification Manual the following elements, as appropriate for its class:*

Manual Elements	Airport Certificate Class			
	Class I	Class II	Class III	Class IV
1. Lines of succession of airport operational responsibility	X	X	X	X
2. Each current exemption issued to the airport from the requirements of this part	X	X	X	X
3. Any limitations imposed by the Administrator	X	X	X	X
4. A grid map or other means of identifying locations and terrain features on and around the airport that are significant to emergency operations	X	X	X	X
5. The location of each obstruction required to be lighted or marked within the airport's area of authority	X	X	X	X
6. A description of each movement area available for air carriers and its safety areas, and each road described in § 139.319(k) that serves it	X	X	X	X
7. Procedures for avoidance of interruption or failure during construction work of utilities serving facilities or NAVAIDS that support air carrier operations	X	X	X	
8. A description of the system for maintaining records, as required under § 139.301	X	X	X	X
9. A description of personnel training, as required under § 139.303	X	X	X	X
10. Procedures for maintaining the paved areas, as required under § 139.305	X	X	X	X
11. Procedures for maintaining the unpaved areas, as required under § 139.307	X	X	X	X
12. Procedures for maintaining the safety areas, as required under § 139.309	X	X	X	X
13. A plan showing the runway and taxiway identification system, including the location and inscription of signs, runway markings, and holding position markings, as required under § 139.311	X	X	X	X

14. A description of, and procedures for maintaining, the marking, signs, and lighting systems, as required under § 139.311	X	X	X	X
15. A snow and ice control plan, as required under § 139.313	X	X	X	
16. A description of the facilities, equipment, personnel, and procedures for meeting the aircraft rescue and fire fighting requirements, in accordance with §§ 139.315, 139.317 and 139.319	X	X	X	X
17. A description of any approved exemption to aircraft rescue and fire-fighting requirements, as authorized under § 139.111				
18. Procedures for protecting persons and property during the storing, dispensing, and handling of fuel and other hazardous substances and materials, as required under § 139.321	X	X	X	X
19. A description of, and procedures for maintaining, the traffic and wind direction indicators, as required under § 139.323	X	X	X	X
20. An emergency plan as required under § 139.325	X	X	X	X
21. Procedures for conducting the self-inspection program, as required under § 139.327	X	X	X	X
22. Procedures for controlling pedestrians and ground vehicles in movement areas and safety areas, as required under § 139.329	X	X	X	
23. Procedures for obstruction removal, marking, or lighting, as required under § 139.331	X	X	X	
24. Procedures for protection of NAVAIDS, as required under § 139.333	X	X	X	
25. A description of public protection, as required under § 139.335	X	X	X	
26. Procedures for wildlife hazard management, as required under § 139.337	X	X	X	
27. Procedures for airport condition reporting, as required under § 139.339	X	X	X	X
28. Procedures for identifying, marking, and lighting construction and other unserviceable areas, as required under § 139.341	X	X	X	
29. Any other item that the Administrator finds is necessary to ensure safety in air transportation	X	X	X	X

Table A-1 Elements of Airport Certification Manual

Subpart D: Operations

The subpart is addressed to the operation of a certified airport. A detailed description of procedures for most of the elements of the Airport Certification Manual is given.

Appendix B Inventory of safety aspects

The following list of safety related issues associated with Very Light Jets and Technically Advanced Aircraft was collected by the National Business Aviation Administration [Ref. 35]:

Wake turbulence encounters
- At altitude and in the traffic pattern
- In-trail spacing and profile adjustments
- Best recovery configuration

Convective weather encounters
- Pre-flight weather analysis
- Alternate route identification
- Contract flight planning and/or dispatch interaction
- Circumnavigation fuel capability

Microburst/windshear encounters
- Area entrance rules or philosophy
- Pre-flight weather analysis
- Condition definition
- Best recovery methods
- Alternate airport identification
- Alternate fuel capability

Clear air turbulence/jet stream core or boundary encounters
- Pre-flight weather analysis
- Contract flight planning and/or dispatch interaction
- Aircraft configuration in various levels of turbulence
- Lower/higher altitude cruise capability
- Fuel burn impact

High-altitude upset
- Performance capability
- Coffin corner education
- Recovery methods from low-speed/high-speed stalls
- Straight/swept wing aerodynamics, as appropriate

Mountain wave encounters
- Thrust and speed adjustments
- Pre-flight weather analysis

Inadequate knowledge of high-altitude weather
- Winds aloft millibar charts
- Tropopause levels
- K index and lifted index chart
- CAT forecasts
- Icing levels
- Severe weather charts

Physiological effect of high-altitude operations
- Altitude chamber or nitrogen simulator training
- Personal health issues
- Medication interaction

Jet blast damage behind larger jets during ground operations
- Proper spacing on taxiways
- Advise/educate ATC
- Close proximity operations in icing conditions

Low-fuel arrivals trying to stretch range
- Cruise chart education
- Identification of maximum range and maximum endurance speeds
- Identification of suitable intermediate airports
- Altitude selection to reduce fuel consumption

Incorrect/less-than-optimum cruise altitude selection
- Contract flight planning and/or dispatch interaction
- Cruise chart education
- Wind/altitude trade capability
- Rule-of-thumb or toolkit approach to altitude/range/fuel burn predictions

Inadequate preparation for high-rate/high-speed climbs
- Course/altitude overshoots
- Excessive airspeed below 10,000 MSL or below Class B airspace
- High deck angles and reduced traffic vigilance
- Thrust-controlled vertical rate
- Toolkit approach to thrust/speed/rate control

Inadequate crosswind takeoff/landing preparation
- Speed adjustments for steady and gust components
- Roll and pitch airframe limits
- Flap selection criteria

- Maximum crosswind and gust limits

Inadequate "land and hold short" (LAHSO) preparation
- Minimum pattern size and programmed drag profile
- Advise/educate ATC

VLJs misunderstood by ATC (pilot mitigations)
- High speed in terminal airspace
- High speed to final approach fix
- Lack of respect for single pilot operation and associated work load
- Improper spacing behind heavier traffic
- Unreasonable requests for configuration or climb/descent performance

Single pilot adherence to checklists
- Overcoming old habits
- Patterns of discipline not developed
- Complacency resulting from simplicity of VLJs
- Degradation of systems knowledge

FMS programming and autoflight vs. manual flight control
- Reluctance to abandon autoflight/reluctance to use autoflight
- Inadequate FMS and/or autoflight skills
- Inadequate manual flight skills
- Raw data/manual flight and FMS/autoflight training

Inadequate exercise of "command"
- Inclusion of captain development training in program
- Inclusion of CRM/SRM training in program
- Inclusion of LOFT or scenario-based training in program
- Inclusion of judgment contrast debriefings in program
- Inclusion of command modeling in program

Recognizing single pilot "red flags" (as an alternative to below)
- POPE, which stands for:
  - Psychological (overload, inexperience, emotional)
  - Operational (aircraft-mechanical, weather, fuel, performance)
  - Physiological (fatigue, medical, pharmaceutical)
  - Environmental (time, external pressure, business)

Lack of pilot self-evaluations
- Use of available tools/personal minimums checklist
- PAVE, which stands for: Pilot, Aircraft, EnVironment, External pressure

Winter operations
- Airframe contamination

- Airport contamination: Takeoff, Landing
- Decision making

Appendix C SATS R&D

The SATS Research and Development (R&D) roadmap of the U.,S. National Institute of Aerospace indicates four priority areas for further R&D to introduce a safe, reliable and affordable personal air transportation system. These four areas are: Service Reliability, Weather Safety, Ease of Operation, Community Compatibility [Ref. 60].

Appendix C.1 Service Reliability - Self-Controlled Airspace

Importance of Self-Controlled Area (SCA)

- Visual-like free-flight procedures for operations during low visibility conditions to non-towered airfields outside of radar coverage will increase airport access by over 4-fold.

Modelling of Alternative SCA Concepts

- Concepts, procedures, and requirements modelling.

SCA Automation System Development

- SCA automation system development and flight tests.
- Cockpit automation tools to assure safety and low workload.
- Real-Time WAAS non-precision performance approach procedures for any runway end on demand.

SCA Systems Validation

- FAA ATC policy and procedures development/validation.

Appendix C.2 Weather safety - Real-Time Cockpit Weather Intelligence

Importance of Real-Time Weather

- Improved safety with accessibility and detailed knowledge of icing, convective activity, and turbulence.

Intuitive Weather Data Interpretation

- Examine the opportunity for fusion of weather information integrating data from appropriate sensors & forecasts.
- Real-time broadcast and receipt of aircraft weather sensors, and NWS weather component data.
- Automated assessment of significant weather data in relation to flight plan and alternate airports for intuitive interpretation and presentation.

Appendix C.3 Weather safety - Enhanced Weather Forecasting

Importance of Enhanced Weather Forecasting

- Imprecise current weather information at lower altitudes and remote areas has a major effect on the safety and productivity of General Aviation. When a broad area of severe weather is forecast, most General Aviation airplanes do not fly anywhere in that area.
- Current, low-altitude weather forecasting lacks fine-grid data to make the adequately refined forecasts that are needed along a specific flight path. Enhanced refined forecasts along a particular airways and free flight paths will improve operational safety and efficiency.

Fine-grid Forecast Models
- Develop analytical tools that enable the creation of predictive dynamic models of micro-climates.
- More detailed information about regional weather patterns and movements that affect microclimates.

Sensor Requirements
- Requirements for higher resolution weather satellites, and advanced ground and airborne weather sensors.
- Develop and install ground-based and on-board sensors for weather observation (e.g. wind vector, temperature, humidity, ice, and turbulence).

Prototype Model Assessment
- Coordinate with domain experts on forecasting models. Establish methods for merging NWS observations with new aviation data (e.g. when and where do models run, what is the path for observation data?).

Appendix C.4 Weather safety - Airport Weather Sensors

Importance of Airport Weather Sensors
- Develop advanced affordable sensors for general aviation airports that will enhance safety and reduce operating cost with more accurate and reliable weather reports.

Microelectronic Sensor R&D
- Design more accurate and affordable airport weather sensing.
- Design sensors to assess runway conditions (temp, ice, moisture).

Airport Weather Dissemination
- Requirements for digital ATIS and Net-Centric Weather Dissemination.

Slant Range Visibility Sensor R&D
- Develop and test integrated ceilometer & whole-sky-imager.
- Conduct algorithm development and validation.

Appendix C.5 Weather safety - Weather Enhanced Icing Safety

Importance of Icing Research

- The operation of a small aircraft can be severely limited by icing.
- The efficiency of the SATS vision would be enhanced by the development of affective low cost icing protective systems.

Icing Forecasting and Avoidance

- Improved forecasting with real-time icing information in the cockpit could provide pilots with timely icing avoidance information.

Icing Detection, Prevention, and Removal

- New methods of detection and lower cost methods of ice prevention and removal will save lives.

Appendix C.6 Ease of Operation - Intuitive Aircraft Operations

Importance of Intuitive Aircraft Operational Capabilities

- An integrated haptic system and intuitive displays will enhance aviation safety with aircraft performance envelope protection and improved pilot capabilities.

Intuitive Displays

- Assess adaptive behaviour of intuitive display symbology.
- Define requirements for advanced, affordable display media, such as HUD, head-worn displays, effective head-down displays, and synthetic voice/voice recognition.
- Evaluate dynamic flight path guidance.
- Develop automated flight planning capabilities.
- Develop emergency auto-land and resilient recovery functionality.

Advanced Controls

- Model haptic stimulus and response algorithms for IMC operations.
- Model fly-by-wire control laws with affordable fully-coupled auto-pilot.
- Automate pre-flight and weight-and-balance technology.

Training and Flight Test Experiments

- Develop and conduct simulation evaluations of advanced, intuitive operational capabilities.
- Conduct haptic system and envelope protection flight tests.

Appendix C.7 Community Compatibility - Small Aircraft Safety Improvement

Importance of Small Aircraft Safety Improvement:

- Develops acceptable methods to quantify safety of small aircraft at small airports.
- Imparts benefits derived from:
  a) aircraft health monitoring systems,
  b) pilot training, and
  c) flight safety systems analysis in all phases of flight.

Safety Enhancements from Health Monitoring Systems

- Examine the benefits derived from aircraft sensors and health monitoring systems.

Safety Enhancements from Pilot Training

- Evaluate the safety benefits derived from better pilot training.

Total System Safety Assessment

- Conduct safety assessments in all phases of flight.

Appendix C.8 Community Compatibility - Real-Time Safety Health Monitoring

Importance of Real-Time Aircraft Safety Health Monitoring

- Wide deployment of such systems will capture and analyze health status in-flight, enhance safety, improve dispatch reliability, and reduce maintenance cost and time.

Develop Structural Stress Sensors

- Develop low cost light weight, non-destructive, unobtrusive, wireless, embedded sensors for monitoring the aircraft structure.

Aviation Industry Collaboration

- Develop open standards and protocols for health monitoring systems.

Develop Integrated Health Monitoring Systems

- Define system functionality.
- Interface avionics, engine sensors, flight control stress sensors, data link communication, FMS, EFIS, and auto-pilot.

Appendix D NBAA Definitions

The National Business Aviation Administration (NBAA) has defined [Ref. 35]:

Technically Advanced Aircraft (TAA)
A general aviation aircraft that combines some or all of the following design features: advanced cockpit automation system (moving map GPS/glass cockpit) for IFR/VFR flight operations, automated engine and systems management, and integrated auto flight/autopilot systems.

Very Light Jet
Jet aircraft weighing 10,000 pounds or less maximum certificated takeoff weight and certificated for single pilot operations. These aircraft will possess at least some of the following features: (1) advanced cockpit automation, such as moving map GPS and multi-function displays; (2) automated engine and systems management; and (3) integrated autoflight, autopilot and flight-guidance systems.

Reactions on the Comments to the Report T3.1.: Analysis of the Impact of EPATS on the ATM Parameters – ATM impact assessment

The provided Comments on the Report T3.1. was dealing with three major issues. All of these are addressed in the followings.

Comment n. 1:

In fact the analysis assumed that the ratio of the IFR flights in 2005 from the total general and business traffic holds for EPATS, and therefore the same as given in the publications of the European Commission.
This assumption was considered to be reasonable in view of the followings:

- **lack of data**: while the task 3.1. was supported with the findings of the WP2 and therefore the future number of EPATS flights was accessible for 2020, no information was given for the baseline of the analysis (2007). In addition, EPATS, being a novel air transportation, offers no European statistical background. Therefore, the exact European EPATS records might only be available once modeling the demand for 2007, with for example survey techniques. On the other hand, due to the limited timeframe of the investigation, demand modeling (for 2007) was out of the scoop of the task 3.1. Seeing this drawback, the analyst took the records of general and business aviation, since these – relative to the rest of the airspace users – were found to be the closest to the characteristics of EPATS and therefore relevant to support this preliminary investigation. Anyhow, in view of all these limitations, the analyst agrees that further investigation might also focus on the establishment of the European EPATS statistical background (for 2007 or 2008).
- **European statistics**: the above mentioned ratio is based on European statistics and more particularly on the document titled "An Agenda for Sustainable Future in General and Business Aviation". Besides the fact that is a recent publication, the application of the mentioned US statistics (see list of comments) to the European context is not promising, since Europe – instead of having a unique territory with more or less the same attributes – consists of different countries, with numerous socioeconomic characteristics and country specific attributes, such as the presence of alternative transportation systems like the high speed trains or the complexity of the highway network. Furthermore, the geographical circumstances are also different (e.g. the distance between the cities) which might even influence the optimal airspace to fly or the propulsion system to use. This results again, in the inability to exploit the US records to the European market.

On the other hand, the analyst agrees with the fact that SESAR should take into account that a large majority of EPATS will rely on the see-and-avoid concept.

Comment n. 2: