EVTS ENHANCED VFR TRANSPORT SYSTEM

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OVERVIEW

EVTS, an acronym for Enhanced VFR Transport System, is a concept study performed by the National Aerospace Laboratory NLR, Technical Research Laboratory for Applied Physics and Science TNO and Aerospace Software and Technologies Institute ASTI. EVTS is based on the idea of flying VFR (Visual Flight Rules) under IMC (Instrument Meteorological Conditions) by using aircraft equipped with the latest avionics technology and operated under new procedures. The idea behind this is that the VFR airspace and uncontrolled airfields have spare capacity that can be used without burdening ATC (Air Traffic Control). The EVTS concept can be used to open up this capacity to apply it in the personal air transport on-demand market.

To enable flying VFR under IMC technically, special means are required to provide information on separation, attitude information and navigation verification. For this purpose state-of-the-art avionics technology is used which offers the pilot devices that give him information about aircraft position and attitude, other traffic, dangerous terrain and bad weather conditions. Using this avionics technology (see figure 1) the pilot can fly VFR under IMC while safety is not diminished.

EVTS technology offers also the possibility to take-off and land under bad visibility conditions even on airfields that are not equipped with an instrument landing system or local air traffic control. Since this principle should also work during deteriorating weather conditions, more destinations can be reached regardless the local weather condition on these airfields. This implies that VFR flights can operate in a more efficient way.

Operationally, EVTS introduces usage of VLJ’s (Very Light Jets) or ever smaller ones. Those aircraft are designed to fly 200-250kts at relatively low altitudes and can operate on both controlled and uncontrolled airfields, combined with single pilot operations and the “sense-and-avoid” principle instead of the “see-and-avoid” principle. This allows flying in unused airspace outside airspace used by large jets, whenever you want, wherever you want in a relatively cheap manner.

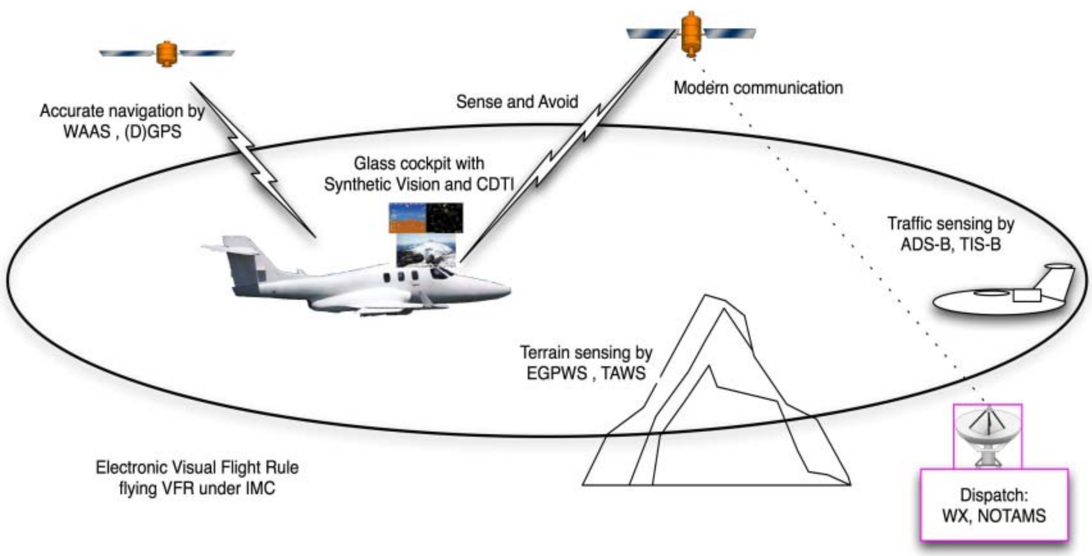

FIG 1. EVTS using state-of-the-art avionics

In this paper it will be shown that from a technical point of view EVTS is within reach. Also operationally EVTS is achievable. With regards to costs EVTS can compete directly with currently used forms of (air) transport such as a standard airliner, a train or a car. On the other hand EVTS demands a few very important adjustments: change of regulations with respect to aircraft and airspace use, and changes to flight crew licensing.

1. BACKGROUND

Since several years individual air transport can rely on an increasing popularity. This has several reasons:

- "value of time" of people increases
- traffic-jam problem of car traffic from and to major airports (hubs) and cities.
- trend towards on-demand market
- individualization and globalization
- security hassle at major airports
- price drop of individual air transport

The capacity of IFR airspace and large airports is becoming a problem. A trend is visible where a new form of point-to-point transport is used as an additional kind of air transport:

- scheduled flights from small airports
- business jets
- lease/subscription constructions

Related research
These developments have lead to several studies on personal air transport. One of the most important studies performed in this area is SATS (Small Aircraft Transport System). Other important studies are GAP (General Aviation Propulsion) and SAI (Silent Aircraft Initiative). These studies have already led to new type of aircraft and operations: Development of small jets (VLJ's) like for instance the Eclipse500 and the arrival of companies like Net-Jets are good examples.

Small Aircraft Transport System (SATS)
The SATS project [1] was a five-year, $69 million research and development program conducted through a public-private partnership jointly managed by NASA, the Federal Aviation Administration (FAA) and the National Consortium for Aviation Mobility (NCAM). The purpose of SATS was to enable expanded use of smaller airports and smaller aircraft for public transportation. Within the five year period, SATS operational capability was demonstrated in four major areas:

1. HVO (Higher Volume Operations) in non-radar airspace and at non-towered airports.
2. Lower landing minimums at minimally equipped landing facilities.
3. Increase single-pilot crew safety and mission reliability.
4. En Route procedures and systems for integrated fleet operations.

One very important outcome was that these new capabilities can fourfold the capacity of uncontrolled airfields without diminishing safety [2].

General Aviation Propulsion (GAP)
The goal of the GAP Program is help revitalize the U.S. General Aviation Industry through the development of revolutionary affordable propulsion systems for general aviation light aircraft. The engines developed in this program will play a key role in the revitalization effort [3].

Silent Aircraft Initiative (SAI)
SAI [4] is a Cambridge MIT project with many international partners. This goal of the project is to design a functionally silent airplane - one which is no louder than the ambient urban noise outside airport boundaries. The SAI aims to provide technical and economic analyses for an innovative, competitively differentiated aircraft which enhances the United Kingdom aerospace industry and regional/national economies. Four areas are looked at more specifically:
1. Airframe
2. Engine
3. Operations
4. Economics

This project is still going on.

European projects
IFATS (Innovative Future Air Transport system) [5] is a European research project that focuses on more autonomy of aircraft where you have guidance and control on the ground.

EPATS (European Personal Air Transport System) is a research project funded by the EU that focuses mainly on the need of small forms of air transport in particular in Poland where you have large isolated areas without good infrastructure.

At the moment and in the near future there are all sorts of small projects but none of them (yet) have the magnitude of SATS.

2. EVTS - CONCEPT

The question remains: Why should you fly VFR under IMC? The main reason is that sustainable extra capacity is created, without large changes in infrastructure. Keep in mind that EVTS is not meant as a substitute for the existing travel modes but more as an additional extra mode of transport.

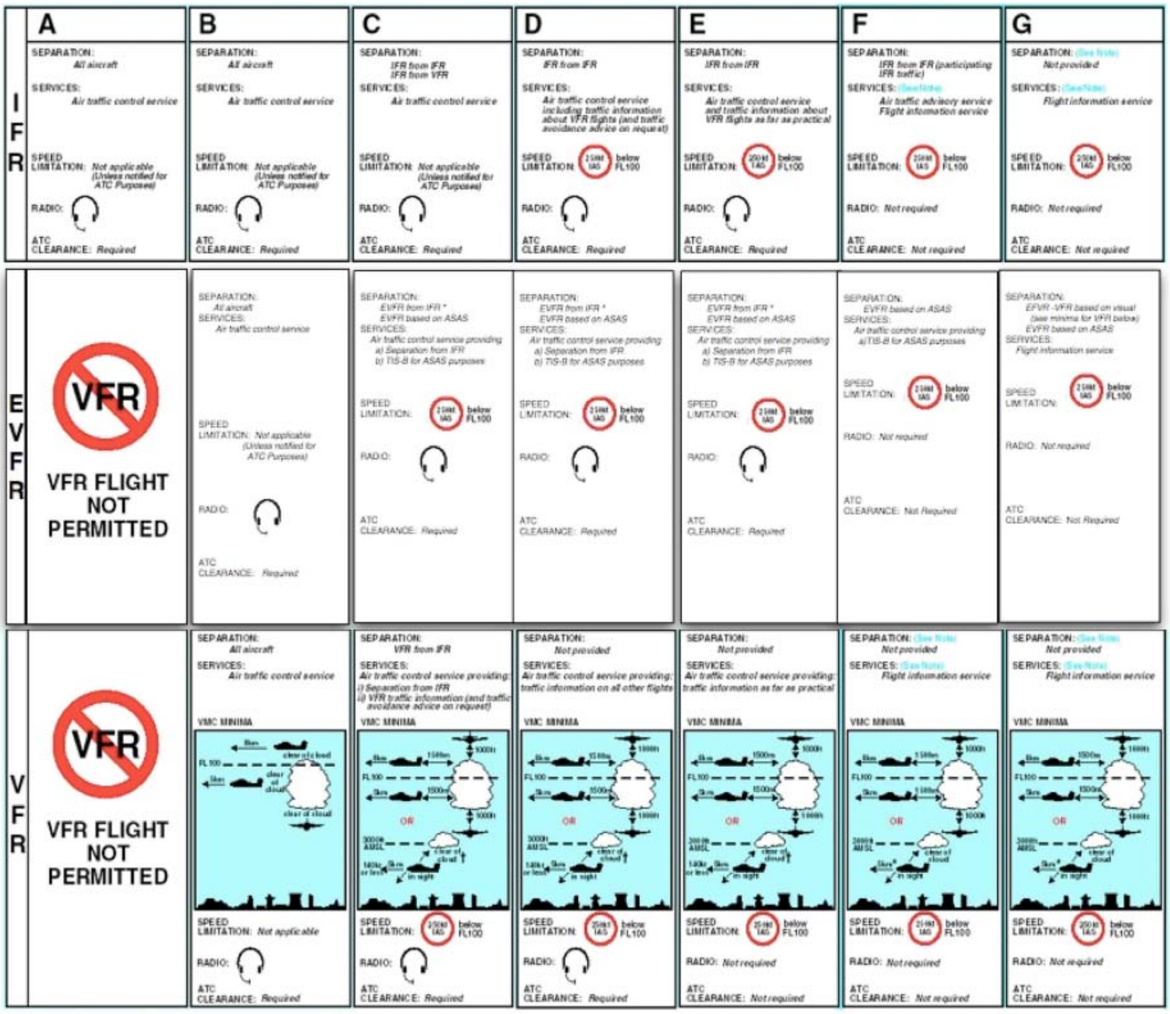

FIG 2. Airspace classes for IFR, EVFR (EVTS) and VFR

2.1. Airspace capacity increase

According to ICAO (International Civil Aviation Organization) standards the airspace can be divided into 7 kinds of airspace (A-G) (Fig. 2). These classes of airspace have different levels of ATC support and visibility criteria. VFR airspace (in Europe) is limited to FL 195 (=19500 ft). Everything above is always IFR airspace.

For EVTS visibility criteria are not the main issue anymore. This means that the available VFR airspace increases for those VFR flights that are limited to class G. Other classes (up to class B) can now be used. EVTS is not restricted to VFR airspace only. You can also fly an EVTS aircraft into IFR airspace but in that case you have to be under control of ATC, your aircraft has to be instrument rated and the pilot needs to have an instrument rating.

Eventually this means that to operate an EVTS aircraft under VFR you have to be in class B-G below FL195.

2.2. Airfield capacity increase

The number of usable airfields will increase dramatically as is shown by the following graph (Fig. 3). This is because various aircraft types have different runway requirements. Small (propeller) aircraft can use almost all airfields. Having EVTS enables these aircraft to fly from those airfields under low visibility conditions, making them economically feasible destinations/origins.

Using EVTS and flying with propeller aircraft will roughly provide double the number of airports as with standard business jets and roughly six times the number available to an airline traveller (less than 200 airports within Europe).

Of course flying with a small amount of passengers has a dramatic effect on passenger capacity (1,4 passengers average on business flight versus +100 passengers on an airliner), but even today looking only at VFR flights an average GA airport with one runway has a capacity of roughly 150.000 movements. If two thirds of these flights were used for passenger travel it would mean 0,66 x 150.000 x 1,4 = 140.000 passengers per airport. Having 6 airports against one major airliners airport would increase the number 6-fold = 840.000 passengers. These can be added to the number of passengers travelling on regular airliners (eg. Schiphol with 44million per year), without hardly any penalty to the infrastructure.

Potential airfields		
Jet IFR	621	100%
VLJ IFR	675	109%
Prop IFR	708	114%
Jet IFR/VFR	776	125%
VLJ IFR/VFR	967	156%
Prop IFR/VFR	1274	205%

FIG 3. Number of accessible airfields per type of aircraft and flight rule

Using EVTS with state of the art synthetic vision could make VFR landings feasible until CAT I conditions (cloud base at 200 ft, RVR 800 ft). In the future aircraft equipped with and Enhanced Visual Flight System could be allowed to do landings up to CAT II (cloud base 100 ft, RVR 100 ft).

2.3. EVTS benefits

When the EVTS concept is introduced it will generate several benefits:

- There will be an extra point-to-point transport system for persons and goods that will not compete with current air transport systems such as business jets.
- Next to the existing 10% (~200) of the most used airports in Europe other airports such as uncontrolled airports can be used under IMC, hence more airports can be used.
- Opening up remote areas in Europe with a small transport infrastructure.
- Much better use of VFR airspace resulting in an increase in airspace capacity
- Reduced operating costs.
- Decrease of travel times for distances between 300-1000 km (see Fig. 4)

2.4. EVTS pillars

EVTS will be based on the following three pillars:

1. Creation of a representation of the outside world using a Synthetic Vision System (SVS) and an Airborne Conflict Management system (Fig. 1 and 5)
2. Economical valid construction and certification methods
3. Aircraft systems and flight procedures for optimal safety

In the next chapters those three pillars will be described.

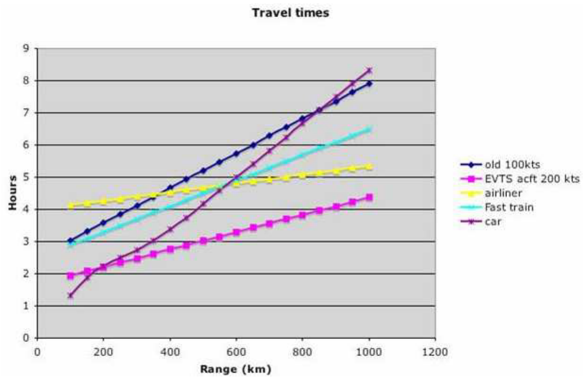

FIG 4. Range versus travel time (door to door)

3. EVTS - TECHNOLOGY

The EVTS technology has to make it possible to fly VFR under IMC. Therefore special systems are introduced to provide information on separation from other aircraft and the ground, attitude information and navigation verification.

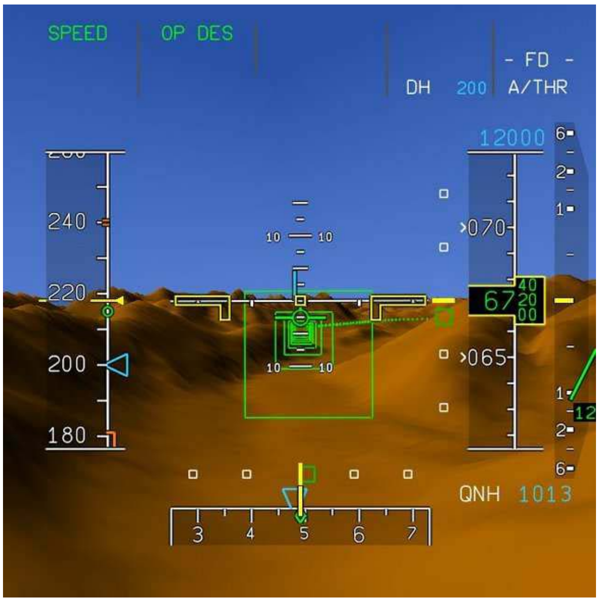

FIG 5. Example of an SVS display with Tunnel-in-the-Sky

These systems will be acceptable when safety is not diminished. At the moment flying VFR is relatively safe. But when more aircraft will start flying VFR safety will become an issue. To be able to have at least the same safety level as today new technology is necessary. This new technology can be implemented in two ways:

- Technically: for instance new avionics
- Operationally: for instance new rules

3.1. EVTS technical aspects

At the moment a new generation of avionics suites enters the cockpit. These new avionics suites use new systems that could enable pilots to fly VFR under IMC and improve safety ate the same time. For instance:

- SVS displays or 3-D EFIS displays for an overall improved situational awareness (Fig. 5).
- Improved terrain awareness with EGPWS (Enhanced Ground Proximity Warning System) or TAWS (Terrain Awareness Warning System).
- Improved runway awareness with systems like RAAS (Runway Awareness and Advisory System).
- Improved navigation with systems like WAAS (wide Area Augmentation System) and (D)GPS (Differential Global Positioning System).
- Improved guidance with HITS (Highway-In-The-Sky) or other Tunnel-In-The-Sky symbology.
- Improved weather radars and new up-linked weather data services for an accurate weather picture
- Improved traffic information with ADS-B (Automatic Dependent Surveillance Broadcast), TIS-B (Traffic Information Services Broadcast) or FIS-B (Flight Information Services Broadcast) and CDTI (Central Display for Traffic Information).

At the moment these kinds of avionics suites [6] are being certified for EASA (European Aviation Safety Agency) CS-23 type of aircraft and will be certified in the future for EASA CS-25 type of aircraft. A clear trend is visible towards certification of terrain databases used in EGPWS and TAWS avionics suites. They have proven to be reliable and accurate. This means that when flying VFR keeping separation from the ground or special obstacles on the ground is within reach.

ASAS

With regards to keeping separation from other traffic the new generation displays do not offer any solution (yet). With TCAS (Traffic Collision and Avoidance System), ADS-B or other systems like that the pilot is only provided traffic information and no information on how to keep separation from other traffic. In order to make this possible you would need a system like ASAS (Airborne Separation Assurance System). ASAS gives the pilot information what to do in order to keep separation from other traffic.

NLR has done extensive research in this area since 1996 [7]. Main idea behind ASAS is that - with or without ATC - aircraft should be able to keep separation from other traffic all by them selves. ASAS is based on the standard separation criteria and will give information to maintain these criteria. This is done by giving the pilot information about:

- Resolutions: required heading, (vertical) speed or altitude to avoid 'loss of separation'.
- No-go areas or bands giving directions where not to go.
- Position of the 'conflicts' (='loss-of-separation' within 5 minutes) giving more detailed data where the problem is.
- Other information regarding separation time or distance.

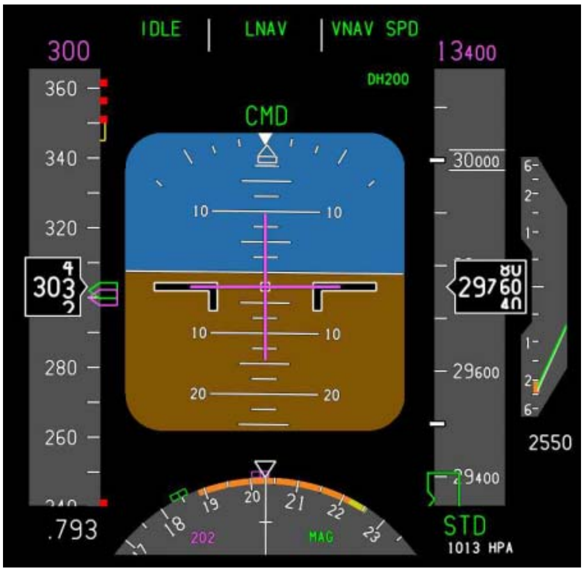

FIG 6. Example of a PFD with ASAS information

The PFD in Fig. 6 shows that the pilot has to change its heading to 185 degrees or to descend with more than 2000 fpm. This PFD accompanies the ND shown in Figure 7 that gives a lateral presentation of the situation. In the ND one can see that although the intruder aircraft is coming from the left, the pilot has to steer to the left to avoid problems.

FIG 7. Example of an ND with ASAS information

The research showed that by using this ASAS system safety was not diminished even in scenarios with three times the current traffic density.

At the moment NLR is still involved in many ASAS related projects.

3.2. EVTS operational aspects

Operational aspects of EVTS can be divided into two parts:

- Flight operations with respect to certification & regulation
- Operations with respect to cost

EVTS and ASAS operations

How ASAS is implemented operationally is determined by the level of (air traffic) control. Four modes of control can be distinguished:

ASAS-Awareness

When ASAS is in awareness mode, ATC is responsible for separation. The pilot will have to keep separation but ATC will be responsible. In this mode ASAS is only used for awareness and not used to maintain separation.

ASAS-Spacing

When ASAS is in spacing mode, ATC is responsible for separation. The pilot will have to keep separation with only one aircraft. In order to do this he will get his clearances from ATC.

ASAS-Separation

When ASAS is in separation mode, the pilot is responsible for separation with only one aircraft. In order to do this he will get his clearances from ATC.

ASAS-Self-separation

When ASAS is in self-separation mode, the pilot is responsible for separation with all aircraft. ATC will only monitor air traffic.

Current air traffic situation is almost equal to ASAS-Awareness. When an aircraft is equipped with an ADS-B transceiver the pilot is able to see all ADS-B equipped aircraft and TIS-B aircraft.
Therefore it is very easy to make separation more autonomous and go to the next ASAS mode: ASAS-Spacing. ATC is still responsible but aircraft can do separation tasks.
When ASAS has proven itself higher levels of autonomy can be allowed so that eventually VFR flights can be combined with ASAS-Separation or ASAS-Self-separation.

EVTS certification & rules

The biggest problem encountered when introducing EVTS is regulations. So a very important question is: Is EVTS possible within current regulations?

YES: EVTS aircraft can be certified under EASA CS23 (a.k.a. JAR-STD 23) but will need a STC (Supplemental Type Certificate). This STC is required to prove that the extra EVTS avionics work according to certification standards.

NO: According to JAR-OPS 1 and JAR-FCL one can not fly VFR under IMC and one can not take-off/land from /to ‘uncontrolled’ airfields under IMC. Furthermore in Europe it is not possible and/or custom to fly aircraft commercially with only one pilot. In the US different rules apply where in most cases it is allowed to fly jet and propeller aircraft commercially with only one pilot.

Important: there is a dilemma for EVTS: According to current standards EVTS can only be used under IFR: this means controlled flight when the EVTS special features are used. But EVTS has to be able to fly under all flight rules. Bottom-line for this to be achieved is that the JAR-OPS 1 has to be adapted or extended.

EVTS costs aspects

In order to be able to say anything about costs several scenarios have been analyzed with certain EVTS-like aircraft types like the Adams A500, an Eclipse500 and a LearJet40 [8]. The Adams A500 is a prop which is relatively cheap but slow and lacks luxury. The Eclipse500 is a jet, is relatively cheap and fast but lacks the luxury of a large business jet. The LearJet40 is expensive, fast and luxurious. With all three aircraft it is possible to fly EVTS.

Props can usually take-off from short runways. Jets are usually faster. When we look at figure 3 we can see that with jet+IFR about 600 airfields can be reached. If you are flying Prop+IFR/VFR you can land on almost 1300 airfields in Europe. This means that EVTS – that uses VFR as starting point - can be most beneficial when props or very small jets are used that are equipped with the EVTS technology. The fact that jets are faster means that they can usually not take-off from short runways, which makes them less suited for EVTS. If jets could take-off from short runways these jets may be used for EVTS. But keep in mind that EVTS is most beneficial for low altitudes, because that is where the unused airspace is. Jet engines usually don’t perform economically at low altitudes (below FL195).

When looking more closely at the cost aspect two business scenarios were studied:

- ‘Easy taxi’ scenario where the cheapest form of on-demand air transport is pursued. This scenario aims for the average aircraft passenger. Trips are shared with other passengers. Departure time is less important. Operations only on those airfields with the largest demand to prevent empty legs. The price per ticket should be very low somewhere between

€500 en €600. An aircraft that is suitable for this scenario is for instance the Adams A500.

- 'Business class just got better' scenario that targets the intercontinental business traveller. This traveller does not want to wait and does not want to share his flight with other passengers. For this traveller a VLJ is waiting (e.g. Eclipse500). Reliability and accuracy are very important. The price per ticker can be around €1500.

Both scenarios demand large investments and a long persistence but are achievable. EVTS will make both scenarios simpler and has a positive effect on feasibility, because EVTS reduces costs and increases the capacity by:

- The assumption to use only 1 pilot instead of 2 pilots. The self-fly passenger is an option.
- Very low route charges
- Low airport fees
- Larger accessibility of more airfields
- Better use of airspace.

If you take scenario 1 including all the EVTS benefits the price per hour for an EVTS aircraft would be around €500.

Suppose the value of time of an average business traveller is around €200 per hour. In that case we can demonstrate in following example that it will pay off to use EVTS:

Ski holiday in the Alps:

- Per EVTS aircraft this would cost for 4 hours flying = €2000.
- By car/train it will cost per person €250 + 8 hour drive x €200= €2050. (Hourly cost = €200) You will loose 4 hours anyway. To compare the car/train with the aircraft you have to subtract 4 hours. So the cost will be €2050 – 4 x €200 = €1050.

This means that when you hire this aircraft for 2 persons the EVTS aircraft can compete with a car/train. This is besides the fact that you would be 4 hours earlier at your destination!

EVTS new developments

In the (near) future new developments will take place that will influence EVTS in an advantageous way. Below a few examples are given

Example 1

At the moment STC's are issued for SVS-like (Synthetic Vision Display) EFIS displays for EASA CS23 aircraft. Developments such as ADS-B, TIS-B, FIS-B, TAWS etcetera will be common good within the near future. This means that technically EVTS is already possible. Although you have to keep in mind that ASAS is not yet possible but may be within 10 to 15 years.

Example 2

In case of IMC one flies IFR: that means under control of ATC. With EVTS avionics (ASAS) one can maintain separation by themselves: ATC is not necessary anymore to keep separation. Although EVTS aircraft can fly VFR they will have an ADS-B transceiver (or similar kind of equipment) on board in order to remain visible for ATC and other traffic. This principle is called 'Sense & Avoid'. In the future this principle could replace 'See & Avoid' which is currently the standard.

Example 3

At this moment flying VFR is only possible in small part of the airspace. But there is a visible trend towards 3 kinds of airspace (Fig. 8). Above FL195 everything will be ICAO class C airspace. Below FL195 and above FL 115 or 95, it will be an airspace in which aircraft are always known to ATC. Below FL115 or 95, airspace can be of any class. Eventually this means more available airspace for EVTS.

The final shape of this airspace will be determined within the SESAR (Single European Sky ATM Research) project, which a very large EU project that pursues a Single European Sky (SES). This new airspace lay-out will be ready and implemented in 2020.

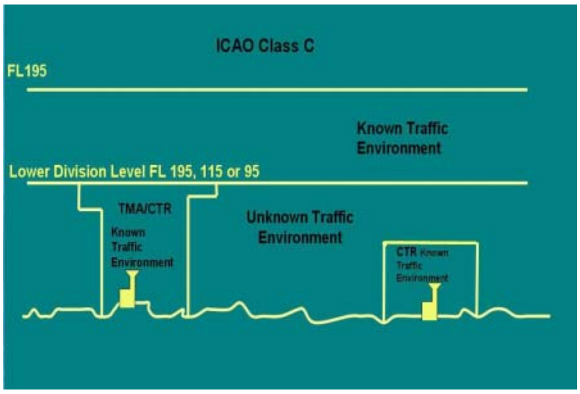

FIG 8. Proposed airspace layout by SESAR/Eurocontrol

Example 4

Introduction of FUA (Flexible Use of Airspace). FUA implies more efficient use of the total airspace (civil+military), where 4D navigation is applied. With regards to EVTS this can be an advantage, because more airspace will be available.

Example 5

Within SATS research has been done into HVO (Higher Volume Operations): This means more operations within uncontrolled areas. During IMC an SCA (Self-Controlled Area) is established around the airfield. Aircraft are sequenced automatically. Aircraft that enter this SCA must have ASAS or similar kind of separation tool on board. EVTS aircraft satisfy this requirement.

EVTS challenges

Not all EVTS aspects have been studied within the EVTS project. There will be issues that have to be looked into such as:

- Environmental issues
- Passenger comfort
- Icing

Environmental aspects may become a problem when EVTS is really gaining success. In that case EVTS will lead to an enormous amount of extra aircraft taking off and landing on airfields that will increase noise and emission levels.

Passenger comfort is not an issue when flying high above clouds at (generally) turbulence-free altitudes. But EVTS focuses on flying at low altitudes which means more clouds and turbulence encounter likelihood resulting in less passenger comfort.

Furthermore flying through clouds means more icing problems. Extra attention has to be paid to de-icing systems in the EVTS aircraft.

4. EVTS – FUTURE STEPS

It is understood that EVTS can not be ready tomorrow. A step-by-step approach is foreseen:

- Introduce new state-of-the-art technology: This is easy since this kind of avionics is already present in the newest GA aircraft. Make all aircraft (everything that flies) electronically visible: that is the key to success.
- Introduce single pilot operations on propeller aircraft in Europe. This makes the commercial operations cheaper.
- Make the transition from ‘see-and-avoid’ to ‘sense-and-avoid’. ‘Sense-and-avoid’ links better with current technology.
- Start with ASAS. ASAS is technically ready but is also something that has to be used internationally. ASAS is part of the SESAR project.
- Start with landings on VFR airfields up to CAT I conditions (more than minimum criteria). This does not require IFR.
- Use current airspace structure. The airspace structure is something that can only be changed on international level within a large project such as SESAR.
- Introduce HVO. This is mainly an ATM issue but require also amendments of the regulations.
- Make it possible for EVTS Aircraft to land under CAT II (technically) conditions. Question is: How do we do this under VFR instead of IFR?
- Introduce single pilot operations for small jets. One has to make amendments to the current JAR-OPS 1.

5. CONCLUSION

The EVTS concept can provide a significant capacity increase for the personal air transport on-demand market. EVTS is certainly viable. New and future developments provide a more favorable image for EVTS. Introduction of ASAS and the ‘Sense & Avoid’ principle are very important to succeed. Adjustment or amendment of JAR-OPS 1 is the biggest challenge.

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ABBREVIATIONS & ACRONYMS

IFR / VFR

Instrument Flight Rules (IFR) are a set of regulations and procedures for flying aircraft without the assumption that pilots will be able to see and avoid obstacles, terrain, and other air traffic; it is an alternative to visual flight rules (VFR), where the pilot is primarily or exclusively responsible for see-and-avoid. Since navigation and control of the aircraft under IFR is done by instruments, flying through clouds is allowed; under VFR it is not.
Commercial traffic (a flight carrying paying passengers or cargo) operates under IFR almost exclusively.

IMC / VMC

Instrument meteorological conditions (IMC) is term that describes weather conditions that normally require pilots to fly primarily by reference to instruments, and therefore under Instrument Flight Rules (IFR), rather than by outside visual references under Visual Flight Rules (VFR). The weather conditions required for flight under VFR are known as Visual Meteorological Conditions (VMC). IMC and VMC are obviously mutually exclusive. The boundary criteria between VMC and IMC are known as the VMC minima.

ADS-B	Automatic Dependent Surveillance Broadcast
ASAS	Airborne Separation Assurance System
ATC	Air Traffic Control

ATM	Air Traffic Management
CDTI	Central Display for Traffic Information
CTA	Controlled Terminal Area
CTR	Control Tower Region
DGPS	Differential GPS
EASA	European Aviation Safety Agency
EGPWS	Enhanced Ground Proximity Warning System
EPATS	European Personal Transportation System
EU	European Union
EVFR	Enhanced Visual Flight Rules
EVTS	EVFR Transportation System
FIS-B	Flight Information Services Broadcast
FUA	Flexible Use of Airspace
GA	General Aviation
GPS	Global Positioning System
HITS	Highway In The Sky
HVO	Higher Volume Operations
ICAO	International Civil Aviation Organization
IFATS	Innovative Future air Transportation system
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
JAA	Joint Aviation Authorities
JAR-FCL	Joint Airworthiness Regulations Flight Crew Licensing
JAR-OPS	Joint Airworthiness Regulations Operations
NLR	National Aerospace Laboratory the Netherlands
RAAS	Runway Awareness and Advisory System
RVR	Runway Visual Range
SATS	Small Aircraft Transportation System
SCA	Self-Controlled Area
SES	Single European Sky
SESAR	Single European Sky ATM Research
STC	Supplemental Type Certificate
SUA	Special Used Airspace
SVS	Synthetic Visual system
TAWS	Terrain Awareness Warning System
TCAS	Traffic Collision and Avoidance System
TIS-B	Traffic Information Services Broadcast
TMA	Terminal Manoeuvring Area
TNO	Technical Research Laboratory for Applied Physics and Science
TUD	Technical University of Delft
UAV	Unmanned Aerial Vehicle
VFR	Visual Flight Rules
VLJ	Very Light Jet
VMC	Visual Meteorological Conditions
WAAS	Wide Area Augmentation System