GA COLLISION RISK -

INTEROPERABILITY OF ELECTRONIC CONSPICUITY SYSTEMS

Case Studies: D-3.1

Version control

Version	Approved by and when	Remarks
1.0		For review to EASA
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1. Introduction and background

Airborne collision risk involving non-commercially used small airplanes represent a key priority in EASA's annual safety review and for the development of safety actions at EU level in the European Plan for Aviation Safety (EPAS). Given the diversity of the so-called electronic conspicuity devices, these are mostly not interoperable with each other, meaning that aircraft may or may not be electronically visible to each other. Here the lack of harmonized technical standards addressing the performances of such devices, the data transmission protocols and formats as well as the radiocommunication spectrum usage prevents their widespread use in Europe. In addition, the requirements set for electronic conspicuity of manned aircraft for U-space operations (SERA 6005 (c)) entered into force in 2023 and will impact on the possible choices for General Aviation (GA) pilots regarding the installation of such devices.

The main outcome of the study is the provision of a comprehensive roadmap for the development of technical standards addressing the interoperability of electronic conspicuity systems for General Aviation, contributing to the reduction of aircraft collision risks. E-conspicuity is not to be seen as a collision avoidance system; rather, its purpose is to enhance pilots' situational awareness throughout Europe, spanning all altitudes, while catering to diverse needs within the aviation community. It is crucial to note that E-conspicuity is not designed to aid in surveillance to support Air Traffic Control (ATC). Instead, E-conspicuity is meant to supplement Flight Information Service (FIS) and Search and Rescue (SAR) operations by providing supplementary data.

From April 4th, 2023, to May 7th, 2023, an online survey was conducted for end-users to evaluate current e-conspicuity system usage, the satisfaction regarding conspicuity and its needs and constraints. The exceedingly high number of >2.000 participants emphasizes the importance of this study. One of the main findings of this study is the lack of end-user information and in this context a great deal of uncertainty regarding installation, usage, constraints, and opportunities of existing e-conspicuity systems. Furthermore, the survey showed that the systems must be made interoperable to obtain a traffic picture that is as complete as possible. Since the existing e-conspicuity solutions have emerged from different areas of aviation (e.g., powered aviation, glider, hang glider) several incompatible frequencies, transmission ways and protocols are used.

Following the survey, two extensive workshops were conducted that brought together high-profile experts from various sectors of General Aviation. The workshops, conducted as part of the ongoing efforts to advance and enhance general aviation, set the stage for the case studies.

The first workshop focused on presenting survey results and developing potential criteria for interoperability and deriving system combinations. The determined system combination incorporates the systems ADS-B, ADS-L 4 SRD 860, ADS-L 4 Mobile, FLARM, Mobile Applications, and ground-based applications (see Figure 1). This combination was crafted with the involvement of numerous experts and is the first basis for interoperable e-conspicuity systems in Europe.

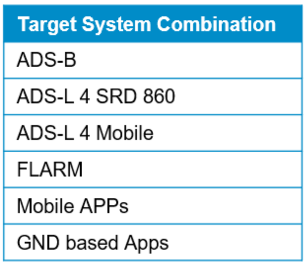
In between the workshops several technical meetings were conducted to identify how the different transmission paths can be made interoperable. One result was that interoperability can only be achieved by merging the transmission ways (e.g., multilink devices and networks). The already deployed solutions cannot simply be replaced and the different transmission paths have specific characteristics, qualities, and constraints. Therefore, they must be examined individually in the following project steps.

The second workshop focused on the identification of interoperability levels, deriving needs, constraints, and requirements for implementation. Logically following the previous results, the focus here is on the transmission paths 1090 MHz, SRD 860 spectrum and mobile network.

The following three case studies provide a comprehensive insight into the developments and innovations stemming from the two workshops and the mentioned technical meetings. Following the approach of the workshops, the case studies are also separated into the different transmission paths. Therefore, three main case studies (Deliverable 3.1) are developed each with a different focus based on technical, operational, and regulatory feasibility, the constraints, and costs. Case study one will focus on 1030/1090 MHz systems, case study two on SRD860 and case study three will concentrate on mobile transmission. This framework is easily expandable to include further and future transmission paths like satellite communication bands or UAT frequencies and also future developments. Interoperable systems integrate information transmitted through different channels with varying protocols, sometimes utilizing ground networks and relay functions.

The goal of the case studies is to assess the feasibility, constraints and costs of the proposed interoperability requirements while considering the currently deployed electronic conspicuity solutions for General Aviation, identify the suitable deployment scenarios and the coordination actions required amongst the different actors.

In Deliverable 3.2 the assessment of additional benefits for airspace and ground users through harmonized data exchanges, including the availability of additional data for search and rescue operations, the investigation of safety events and safety trends, as well as the reuse of traffic data for training purpose will be outlined (see Figure 2 for overview).



Target System Combination
ADS-B
ADS-L 4 SRD 860
ADS-L 4 Mobile
FLARM
Mobile APPs
GND based Apps

Figure 1: Target system combination
Source: Derived in first workshop

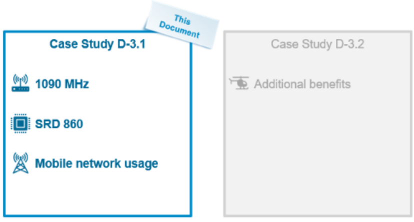


Figure 2: Overview deliverables

2. Case study approach and assumptions

The considerations for the case studies have been prepared in conjunction with previous parts of this project and should not be published as a stand-alone document.

The elaborated interoperability levels (workshop two) will not be part of this document but will be included in the final report. Nevertheless, the applicable and necessary derived requirements from the second workshop will be proofed in the sense of the task description.

In this discussion, three primary case studies are thoroughly examined and categorized according to the three main transmission paths of the target system combination: 1090 MHz, SRD 860, and mobile network. An additional case study delves into the supplementary advantages for airspace users, emphasizing the utilization of the traffic data for training, incident, and accident analysis, and addressing other specialized aspects. The combined target system as elaborated in the second workshop is shown in Figure .

A fundamental prerequisite guiding this exploration is the maximized (re-)use of existing equipment. Therefore, the connection between the existing systems of 1090 MHz, SRD 860 and mobile network solutions is the prime focus of this case studies, unless the restricted upgradability of legacy systems prevents this. In those cases, an exchange to a new system is recommended.

As ADS-B is one of the feasible ways to be electronically visible in U-Space Airspace regarding to SERA 6005 c, it is part of this case studies and the upgrade of older Mode-S systems to ADS-B is a way to realize this. Older parts of the 1090 systems (Mode S) do not send out an aircraft position. Thus, the focus in the 1090 MHz case study will be the upgrade from Mode S to ADS-B as this enables the broadcast of the aircraft´s position.

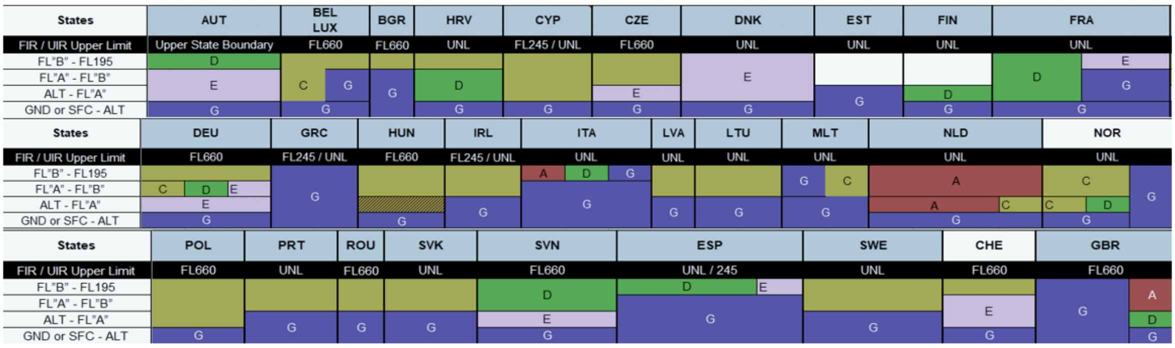
Another option listed in SERA 6005 c is the use of UAT. In Europe, the use of the UAT frequency (978 MHz) is limited and partly not possible. The exemption of the frequency is very time consuming, and a widespread usage is likely to be a medium to long term project. For this reason, no further consideration will be given here, although all possibilities for utilization are being monitored.

Regarding to SERA 6005 c, ADS-L is another way to be electronically visible in U-Space likewise. ADS-L is a new protocol which was derived from ADS-B. It is a slightly different and smaller version of the standardized ADS-B protocol, but as an advantage a timestamp was added. Semantically both protocols are not fully compatible. ADS-L is integrated in the target system combination in two ways, the transmission on SRD 860 frequencies and on mobile networks. It can be seen as an attempt to create a single protocol for the interoperable communication. The status of the ADS-L specification used here is issue one, released in Dec. 2022, no final version has been released yet. Changes in this specification, especially in terms of mobile network usage or relay function may affect the overall considerations. Despite the specification of ADS-L not being finalized, it is considered a deployed technology for the task at hand. The ADS-L 4 Mobile specification remains undetermined at this point, awaiting further developments.

This approach allows for precise demonstration of feasibility, constraints, and costs, avoiding ambiguities that a user-based perspective might entail, particularly with Multilink devices. Multilink solutions with combined transmission methods will be introduced and evaluated later in the form of suitable deployment scenarios.

Airspace dependency cannot be conclusively determined across Europe due to varying airspace structures, thus limiting the assessment to a technical evaluation of electronic visibility. One of the major problems and a hotspot is the airspace E, where IFR and VFR traffic meets, sometimes without knowledge of each other. As soon as interoperability and thus conspicuity is technically established, this problem is also minimized. Therefore, no avoidance rules or airspace dependencies are considered here, as this is primarily a technical realization.

The lack of harmonised application of airspace structures in Europe[28] is well illustrated in the below picture[29].



States	AUT	BEL LUX	BGR	HRV	CYP	CZE	DNK	EST	FIN	FRA
FIR / UIR Upper Limit	Upper State Boundary	FL660	FL660	UNL	FL245 / UNL	FL660	UNL	UNL	UNL	UNL
FL"B" - FL195	D						E			D E
FL"A" - FL"B"	E	C G	G	D						G
ALT - FL"A"						E		G	D	
GND or SFC - ALT	G	G		G	G	G	G		G	G

States	DEU	GRC	HUN	IRL	ITA	LVA	LTU	MLT	NLD	NOR
FIR / UIR Upper Limit	FL660	FL245 / UNL	FL660	FL245 / UNL	UNL	UNL	UNL	UNL	UNL	UNL
FL"B" - FL195		G			A D G			G C	A	C G
FL"A" - FL"B"	C D E				G					
ALT - FL"A"	E		▨	G		G	G	G	A C	C D
GND or SFC - ALT	G		G						G	G

States	POL	PRT	ROU	SVK	SVN	ESP	SWE	CHE	GBR
FIR / UIR Upper Limit	FL660	UNL	FL660	UNL	FL660	UNL / 245	UNL	FL660	FL660
FL"B" - FL195					D	D E			G A
FL"A" - FL"B"						G		E	
ALT - FL"A"		G	G	G	E		G		D
GND or SFC - ALT	G				G			G	G

Figure 3: Airspace Structure in Europe
Source: Best Intervention Strategy for “Airborne Collision Risk,” EASA

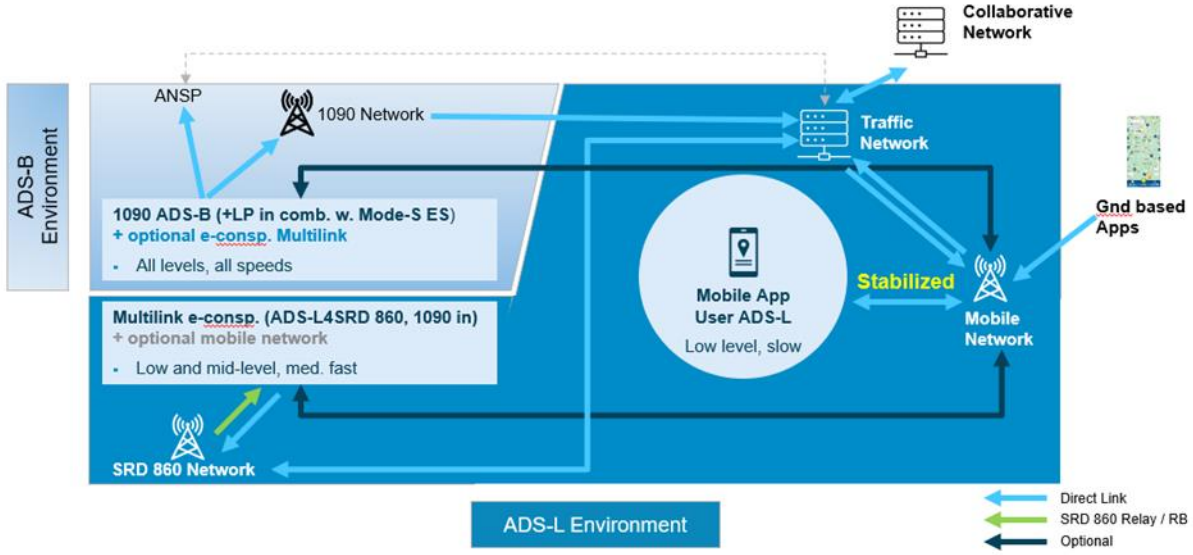


Figure 4: Target near future view of electronic conspicuity
Source: Second workshop

Figure shows the connection between the different system parts and the planned network structures. This scheme will be the basis for the case study discussions. A ground traffic network connects the ADS-B environment with the planned ADS-L parts via SRD 860 and mobile network usage. There are already working networks on community base as well as commercial ones. One additional advantage of using the networks is the integration of ground-based applications, e.g., for the display of model aircraft and paraglider starting and landing sites.

3. Case studies

3.1. Requirements for interoperability

Based on the results of the second workshop the following proposed requirements will be assessed in terms of feasibility, constraints, and costs in all case studies. An evaluation matrix is developed from the main requirements and constraints identified, which is used to determine the suitability of the various transmission paths. The complete compilation of all derived requirements can be found in the documentation of the second workshop.

The following content describes the main requirements for the separate transmission ways as well as the common requirements for interoperability.

The main common requirement is the (re-)use of existing (cockpit) equipment and the affordability of solutions for the widespread user base. This includes the elimination or at least minimization of license fees. The utilization without airframes must be considered in the same way as a fixed installation in cockpits. There must be upgrade and (financially supported) exchange programs to setup multilink devices in conjunction with already installed systems. In the same manner existing ground networks should be updated and used to support the traffic system. Connections to peripheral equipment, e.g., for transmission of altitude or (actual) used frequencies (to reach the pilot), should be set up as well as interfaces to certified equipment, e.g., ACAS systems. Thus, compatibility must be achieved also for other cockpit systems, like audio. For all transmission paths a sufficient reception should be ensured, e.g., by external antennas. One major problem that causes pilots to stay away from e-conspicuity usage is the missing encryption and anonymization. This should also be addressed with the setup of new solutions.

All solutions together must have a simple, easy to use human-machine-interface. Pilots must understand how to use the system and what they see. The indications and warnings should stay close to standards and the prioritization of information must be clear. Pilots must know the constraints and limits and realize that “see and avoid” will remain the basic principle of flying, it is just supported by technology. The usage of e-conspicuity systems must not interfere or degrade the pilot´s scan. A conformity management must be enabled as the user is responsible to have his device updated.

In the 1090 MHz area the upgrading of existing Mode-S transponders to ADS-B (connection with certified and non-certified positioning sources) was identified as well as the addition of an e-conspicuity system with display to visualize the traffic data. ADS-B traffic should be displayable in all new e-conspicuity systems, regardless of the Source Integrity Level (SIL). Therefore, affordable GNSS sources must be available on the market, preferably included in small e-conspicuity solutions with GNSS interface. In the upgrade process the premise of not degrading TCAS performance must be kept in mind.

In terms of SRD 860 it has turned out that the ADS-L protocol should be enabled here first. The SRD 860 frequency band is free to use and several systems with different protocols, transmission power and ranges use it. There is a high number of e-conspicuity users in this transmission path. The specification of the ADS-L protocol and the interoperability of the mentioned systems has already started in this section.

For the mobile network usage in e-conspicuity systems special attention must be paid to the antenna installation. The main goal is to achieve a stable connection to the network without disturbances of the ground mobile network. Thus, measures for using the best suitable frequencies and portable mobile routers (or mobile phones) with external antennas should be taken. Optional mobile connection should be integrated into existing e-conspicuity devices, as technically feasible. Minimum requirements to e-conspicuity apps, as well as data volume and data quality for transmitted traffic data must be defined. Furthermore, recommendations and specifications for mobile devices in terms of e-conspicuity must be determined. Mobile national and international roaming should be achieved to ensure gapless and stable reception in Europe, also while cross border flying.

To combine the different transmission paths, the usage of traffic networks is inevitable (see also Figure). Therefore, the fusion and sharing of traffic data should be mandated. The merging and conversion of different data sources to the various transmission paths requires a filtering and validation process, which must be defined in quantity and quality. It must also be assured that the most integer dates are always used, e.g., if two or more information about one target exist.

A relay functionality should be enabled to supply airspace users who are out of direct reception range. Feeding in data from ground-based applications, e.g., for showing model airplane activities and hang-gliding sites are required to defuse and avoid hotspots. A technical infrastructure for the needed network must be defined. This includes the ownership and operation.

The usage of e-conspicuity data by ANSPs must be enabled to achieve a mostly complete traffic picture and relieve services like the Flight Information Service. Thus, interfaces for the ANSPs must be integrated into the network and quality parameters for the usage must be defined.

The most important applicable requirements for the evaluation process in the case studies are summarized in the following matrix:

	Interoperability Requirements	Assessment
Feasibility	A/C Usage (high, low, slow, fast)	
	Ease of installation (Technical) (upgrade to ADS-B in+out)	
	Ease of installation (Regulations) (upgrade to ADS-B out)	
	Usability w/o airframe, mobility	
	Air - Air direct communication	
	User acceptance (e.g. survey)	
	Flight area dependency (cross border)	
	Range	
	Possibility for anonymization	
	Sensitivity for obscuration	
	Traffic network required	
Benefits	Fulfilment of SERA 6005C	
	Use of existing equipment	
Constraints	Credits ANSP (e.g. airspace usage)	
	ADS-L compatibility	
	Latency stable (e.g. timestamp)	
	Transmission safety (spoofing, encryption)	
Costs	Installation costs (only ADS-B upgrade)	
	Annual costs	
	Infrastructure for traffic network	

Figure 5: Assessment matrix for transmission paths
Source: Own graphic

3.2. Case study 1 – 1090 MHz

3.2.1. Outline

This case study will focus on 1030/1090 MHz systems, specifically systems using the 1090 answer and broadcast frequency, as the 1030 MHz frequency is used for interrogations from secondary surveillance radar stations and TCAS systems. The inclusion of ADS-B in the Target System Combination is a crucial aspect of this analysis, with Mode S being among the systems still under investigation. ADS-B plays a significant role in improving air situational awareness by continuously and precisely transmitting aircraft positions and data.

Both frequencies are integral to commercial aviation, given that Traffic Collision Avoidance System (TCAS) relies on Mode S transponders, and Airborne Collision Avoidance System (ACAS X) will operate with ADS-B. A disturbance or excessive stress of the 1090 MHz frequency leading to a degradation of TCAS performance must be avoided under all circumstances. In General Aviation the Mode-S transponder was mandated with only small exemptions in the year 2008. As the Mode-S Downlink Format (DF) does not integrate a position information, an upgrade to ADS-B (with integrated position) is a very accessible step to improve the traffic information. ADS-B has the advantage of enabling ATC services and conspicuity simultaneously, a standardized protocol and a worldwide usage.

The aim must be to shift as many Mode-S users as possible to ADS-B. The additional load on the frequency for this shifting must be evaluated but is assessed to be little. To clarify, this consideration is not about adding further, new transponders, but about retrofitting or exchanging existing ones. Every new transponder would increase the frequency load in any case. A distinction between the ADS-B-out and ADS-B-in function must be made as there is no traffic display only with ADS-B-out.

1090 MHz systems are also multilink capable, as demonstrated previously (e.g., electronic conspicuity systems with ADS-B-in functionality). The following points outline the scenario/use case and address the crucial issues that need to be explored, encompassing technical, operational, and regulatory feasibility, constraints, cost considerations, and recommended actions to be taken.

3.2.2. Feasibility

Existing Mode S and ADS-B systems are already in place. They transmit on the frequency of 1090 MHz; the interrogation frequency of 1030 MHz is not used for electronic conspicuity systems in General Aviation. The precise localization of a Mode-S transponder system by measuring phase shift and transit time difference is only possible with very expensive TCAS systems, SSR radar. The only way to bring the position information of a Mode-S target into General aviation cockpits is via traffic networks with multilateration, like FlightRadar24 or ADS-B-exchange. In contrast to Mode-S transponders, ADS-B-out systems broadcast their information automatically including a precise GNSS position. For this reason, ADS-B-out is one of the authorized ways to make manned aviation conspicuous in U-Space (SERA 6005 (c))

Therefore, the ADS-B-out function is very important for electronic conspicuity and a major part in the complete traffic picture. The aim must be to upgrade as many Mode-S transponders with the ADS-B-out function as possible without overloading the frequency. This also enables the reception, merging and display of surrounding traffic with affordable reception stations on the ground (e.g., traffic networks, isolated applications).

In order to indicate ADS-B-out transmitting traffic in the cockpit directly (air-air communication), an ADS-B-in system with a display is necessary. Otherwise, an e-conspicuity system with ADS-B included in the traffic data should be used.

The upgrade from Mode-S to ADS-B should preferably be carried out by adding an e-conspicuity system with GNSS-interface. This approach ensures an efficient and streamlined upgrade process for enhanced performance and functionality.

The ADS-B-out function is firmly connected with a Mode-S transponder unit, standalone systems are only known with low power solutions, which are not authorized in EASA member states. A Mode-S system can be upgraded to ADS-B-out by connecting a GNSS source, but the transponder must be prepared for this. The focus is on upgrading only existing systems, avoiding additional installations in other user groups such as SRD 860 or mobile network users. The expected additional load to the 1090 frequency is low. According to a survey of manufacturers, more than 75% of existing systems can be upgraded very easily (see Figure). As not all manufacturers answered the survey, the number might be even higher.

For those users owning a non-upgradable system, two options should be initiated. One way is the allowance of an additional low power ADS-B-out system in firm connection with the authorized Mode-S part in EASA member states. The other way is the initiation of financially supported hardware exchange programs. Both ways are steps of the later introduced action plan and e-conspicuity roadmap.

The position of a Mode-S transponder can also be determined via multilateration (MLAT). This would mean no change to the aircraft equipment, but a greater effort on the ground, as many receiving stations would have to be networked. There are already some networks that can do multilateration. This solution would also make non-upgrade willing aircraft owners conspicuous when they switch their transponder on, and it might serve as an interim solution until the retrofits are completed.

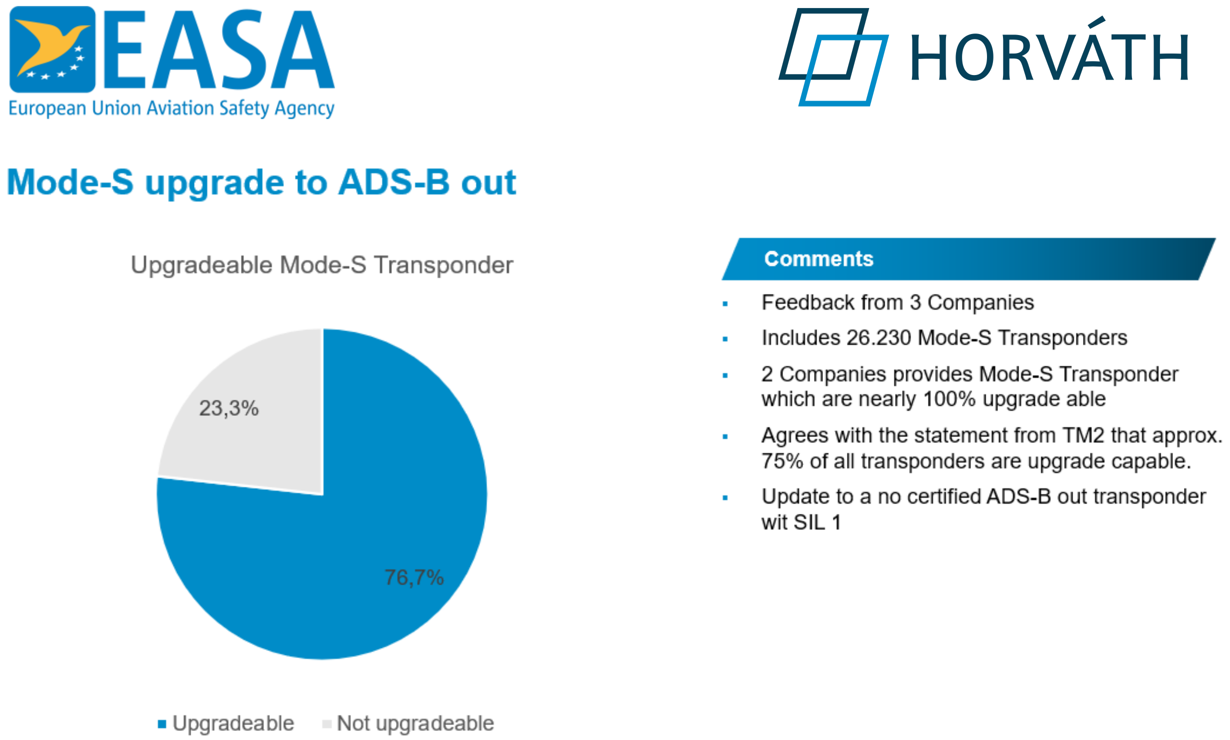
One factor influencing the visibility of ADS-B traffic on e-conspicuity systems is the source integrity level (SIL). The used SIL in ADS-B range from 0-3 and is coded in two bits of the Downlink Format (DF) in the ADS-B message. The receiver detects the quality of the source sending. Simply adding a basic GNSS source to an existing, upgradable Mode-S transponder will lead to SIL=0. The e-conspicuity systems with ADS-B-in which are already available will show all ADS-B targets, regardless of the SIL. ANSPs and certified systems in commercial aircraft make the ADS-B visibility dependent on the type of use. Mostly a SIL between 1 and 3 is demanded. SIL0 meets the requirements for SERA 6005 (c).

The ADS-B and Mode S transponders achieve the best (direct) transmission range of all airborne systems, and the use of antennas outside is deemed mandatory due to the high transmission power (up to five hundred watts). The transmission takes place in a frequency range protected for aviation but can hardly be protected against spoofing.

In the medium term it is conceivable that some use of airspace may depend on the usage of ADS-B or similar systems, so an upgrade of Mode-S transponders is advisable.

In the above considerations the main focus was on achieving the ADS-B-out function. The reception of ADS-B information is much easier, as it is not firmly connected to the usage of a transponder and in most cases uncertified equipment may be used. The information might be received in newer e-conspicuity systems directly or via network, e.g., via ADS-L4SRD860 or ADS-L4Mobile. A transmission and reception of ADS-L via 1090MHz is currently not possible, as the 1090MHz devices require certification, are not easily upgradable and it will increase the frequency congestion significantly. At present, ADS-L cannot be displayed in certified devices such as those used in commercial aviation. A further investigation should be initiated to determine the reception of ADS-L in such devices.

For integration of ADS-B and Mode-S traffic information in traffic network ground reception stations are needed. In Germany, approximately thirty antennas with ADS-B functionality have already been installed by Deutsche Flugsicherung (DFS), but the obtained data is not shared publicly, and it is solely used for the upper airspace. Furthermore, Germany has excellent coverage with ADS-B antennas in many areas due to the requirement for "Bedarfsgerechten Nachtkennzeichnung (BNK)" of wind turbines. There are also simpler and significantly cheaper solutions installed by communities feeding the data into traffic networks. The newest combined receiver stations can merge all transmission paths and protocols mentioned in these case studies.



Mode-S upgrade to ADS-B out

Comments

- Feedback from 3 Companies
- Includes 26.230 Mode-S Transponders
- 2 Companies provides Mode-S Transponder which are nearly 100% upgrade able
- Agrees with the statement from TM2 that approx. 75% of all transponders are upgrade capable.
- Update to a no certified ADS-B out transponder wit SIL 1

Figure 6: Survey about upgradable Mode-S transponders
Source: First workshop

	Interoperability Requirements	Assessment
Feasibility	A/C Usage (high, low, slow, fast)	independent
	Ease of installation (Technical) (upgrade to ADS-B in+out)	medium complex
	Ease of installation (Regulations) (upgrade to ADS-B out)	regulated, limited
	Usability w/o airframe, mobility	not usable
	Air - Air direct communication	yes
	User acceptance (e.g. survey)	medium, due to requirements
	Flight area dependency (cross border)	none
	Range	high
	Possibility for anonymization	none
	Sensitivity for obscuration	insensible
	Traffic network required	partly
Benefits	Fulfilment of SERA 6005C	yes
	Use of existing equipment	yes
Constraints	Credits ANSP (e.g. airspace usage)	not fully established
	ADS-L compatibility	no
	Latency stable (e.g. timestamp)	no
	Transmission safety (spoofing, encryption)	low
Costs	Installation costs (only ADS-B upgrade)	medium-low
	Annual costs	high
	Infrastructure for traffic network	professional high, community low

Figure 7: Assessment Matrix for 1090 MHz
Source: Own graphic

3.2.3. Costs

User related costs:

In case of an upgradeable existing Mode-S transponder system, the connection of the transponder to a GNSS source with interface (mostly NMEA or GDL90) must be established. In most cases this can be done with existing equipment, so the costs on user side will be less than 250€ for the installation. In this case you have enabled the ADS-B-out function with a SIL=0, but you have no traffic information displayed.

If there is no further GNSS source installed, the best way to supplement the system is the integration of an electronic conspicuity system with GNSS interface. The advantage will be the option to display all received traffic data besides enabling the ADS-B-out function. The costs for this option may vary depending on the features of the chosen e-conspicuity system between 500 and 2.500€. Suitable upgrade scenarios will be discussed at the end of these case studies.

If there is no possibility of upgrading the existing Mode-S transponder, a new ADS-B-out system, an additional low power device might cost around 500€, assuming the authorization of EASA member states. Support programs to exchange the hardware to ADS-B-out might lower the costs for a new system below 1.000€. In this case also the installation of a new e-conspicuity system uniting all transmission paths should be considered.

Usually, a one-time registration fee and an annual fee applies when using a transponder in aircrafts. As we assume here that the transponder is already installed and is solely to be upgraded, we do not consider these fees here. The fee only applies for the transmission on 1090 MHz, reception on this frequency is free of charge.

Infrastructure costs:

The price of receiving stations in the BNK area is around 30.000€ in terms of size, and operation costs around 3.000€ per year. There are also high costs for the integration into the network. The costs of the DFS receiving systems and their operation are estimated to be much higher. In the community sector, simple installations can be used which are often raised by clubs or private individuals to use the network. The costs for these installations usually amount to less than 500 €. The establishment and operation of a traffic network is necessary for the provision of the MLAT function and for the transfer of traffic data to other transmission channels. Further investigations are necessary on this topic.

3.2.4. Conclusion

In summary, it can be concluded that upgrades from existing Mode-S transponders to ADS-B are a straightforward way to significantly improve the visibility and the traffic picture. In this scenario, no new 1090 MHz users shall be "created", only existing devices should be upgraded to send out their exact position via ADS-B.

The existing hardware is simply upgradable in most cases by installing a GNSS source, e.g., electronic conspicuity systems with GNSS interface. Alternative solutions like supported exchange programs and the release of additional low power ADS-B solution should be established. The 1090 traffic data should be fed into connected traffic networks to supply aircrafts using other transmission paths, e.g., with the ADS-L protocol. Transmission and reception of ADS-L on 1090 MHz is currently not possible. The hardware changes are too complex due to license and approval requirements.

Receiver stations may be realized by the combination of professional and community facilities. This can also clear the way to accurately locate Mode-S transponders via MLAT that are not updateable or should not be updated.

3.3. Case study 2 – SRD860

3.3.1. Outline

This case study will focus on systems transmitting and receiving in the SRD 860 frequency band. SRD 860 in common is a low power frequency band which is unprotected and used by several applications of all kinds. It is not restricted to aviation use. The emitting power is limited, depending on the frequency used, between 25mW and 500mW. For example, the FLARM technology uses two frequencies, switching in a fixed interval, with an output power of 10-25mW, depending on the system. PilotAware on the other hand uses a different frequency to FLARM which allows a higher transmission power up to 500mW.

The SRD 860 devices were developed to serve the needs of certain aviation communities like glider pilots or hang glider pilots, but it has found its way into many General Aviation cockpits. There is a high number of SRD 860 system users in Europe, which was also evident in the survey of this project. Therefore, the FLARM system was identified as one part of the target system combination in the first workshop.

Over the course of time, these devices have been further developed and interoperability with other systems and transmission paths has been partially established. As the FLARM technology is also built into the hardware of other manufacturers under licence, for example, there is an abundance of devices, which are often combined with 1090 systems components. An extension to include mobile data communication is possible in newer devices, but a protocol specification must be developed.

In comparison to ADS-B which delivers a position, FLARM transmits a predicted future flight path and has a timestamp. The installation of FLARM devices is approved as a standard change or minor change, depending on the device. There are different payment models for the license fees for SRD860 devices. In case of FLARM devices this is included in the purchase price, in case of PilotAware annual license fees are due.

Some ground networks for SRD860 are already built, e.g., OGN and the PilotAware network (mostly in Great Britain), so a connection to the mobile transmission path on the ground is already possible. Relay stations with broadcasting functions on the SRD frequencies are currently not in use in EASA member states.

There are both fixed and mobile solutions in the SRD860 section. Due to the exceptionally low transmission power the reception quality is very sensitive to obscuration. It is strongly recommended to install external antennas, if possible, to improve reception.

SRD 860 technologies are the most suitable ones to establish communication with the new ADS-L protocol. The devices are easy to upgrade and need no certification. Combinations with ADS-B in functionality are already in use. Thus, the specification for ADS-L4SRD860 is currently in development with the help of important stakeholders in SRD860 technologies. Both direct communication between the aircraft and communication to and from the ground with ADS-L are planned. Various channels in the SRD860 band are to be used for this purpose including an additional one with increased data speed. Questions regarding the requirements for the network, its structure and its operation must be clarified urgently for successful deployment.

3.3.2. Feasibility

SRD 860 devices can communicate directly (air-air) with each other and to the ground. Due to the low transmission power the range of SRD 860 in case of FLARM may be between 3km - 20km, ideally. Obscuration is the biggest impact on the achievable range. The installation of external antennas, wherever possible, is strongly recommended. Ground receivers with well-positioned antennas can also receive more distant transmissions. Using the PilotAware frequency with its higher approved transmission power increases the range up to 50km - 100km.

The integration of ADS-L as common protocol is a major step in achieving interoperability. A team of stakeholders and experts is finalising the second version of the ADS-L4SRD860 specification. At this stage it can be said, that in case of ADS-L4SRD860 three frequencies will be used for the transmission, the two FLARM frequencies (M-band) and the PilotAware frequency (O-band). The last one shall be used as well with an HDR channel, which enables higher data rates as the other ones. This also allows the integration and transmission of additional data like weather information.

As one major requirement is the use of existing SRD 860 devices, the reception of the additional frequency must be enabled. Therefore, so called SDR (software defined radio) receivers must be integrated into the systems allowing concurrent monitoring of multiple frequencies. These receivers have a simple hardware design, but a higher power consumption as they are listening to several frequencies simultaneously. According to an initial assessment only existing devices younger than 10 years might be upgradable for ADS-L. To continue the use of older FLARM systems without ADS-L for example, the FLARM protocol will be transmitted in parallel to ADS-L and other protocols.

As the SRD 860 devices do not need authorization, upgrades will be simple on the regulation side. The U-Space compatibility will be achieved with the use of ADS-L as described in SERA 6005c. SRD 860 data is currently not used by ANSPs, not even for information services like FIS in Germany. The project survey showed clearly that this data may relieve ANSP information services and radio frequencies.

The establishment of a network is necessary to achieve a more complete traffic picture. It will allow the processing and dissemination of more distant traffic despite of the small SRD 860 transmission range, and it will also enable the transfer of traffic information received on other transmissions paths. This network shall include relay function between ground and aircrafts as well as between airspace users. Receiving networks as OGN may be used as a basis for this development, but the quality and quantity of the transmission data must be specified. The future use of UAS as "flying" network stations should be examined in detail.

	Interoperability Requirements	Assessment
Feasibility	A/C Usage (high, low, slow, fast)	independent
	Ease of installation (Technical) (upgrade to ADS-B in+out)	easy for newer systems
	Ease of installation (Regulations) (upgrade to ADS-B out)	easy
	Usability w/o airframe, mobility	possible
	Air - Air direct communication	yes
	User acceptance (e.g. survey)	very high
	Flight area dependency (cross border)	independent
	Range	low, but sufficient
	Possibility for anonymization	yes
	Sensitivity for obscuration	high
	Traffic network required	partly (relay fct)
Benefits	Fulfilment of SERA 6005C	with ADS-L upgrade yes
	Use of existing equipment	yes, except legacy hardware
Constraints	Credits ANSP (e.g. airspace usage)	none
	ADS-L compatibility	yes
	Latency stable (e.g. timestamp)	yes
	Transmission safety (spoofing, encryption)	possible
Costs	Installation costs (only ADS-B upgrade)	low
	Annual costs	provider-dependent, low
	Infrastructure for traffic network	low

Figure 8: Assessment Matrix for SRD 860
Source: Own graphic

3.3.3. Costs

User related costs:

The simplest improvement for reception with SRD 860 devices is the optimal installation of reception-optimized antennas. Under certain circumstances, this may not incur any costs at all if only the position of the antenna in the aircraft needs to be improved. Good external antennas, if needed, are in the range of up to 200€, but show a vast improvement compared to the initial state.

The costs for an upgrade from SRD860 devices to ADS-L are relatively low on the user side in the case of newer and updateable devices. The costs for an upgrade from the manufacturer usually amount to less than 500€ and are limited to software solutions.

The limit for non-upgradeable legacy hardware will be around 10 years of age. Costs for a hardware upgrade to be able to use the new frequencies and relay functions have not yet been determined, as the specification of ADS-L4SRD860 has not yet been finalized. In this case, however, it will be more worthwhile to replace the hardware with a newer version. To this end, financially supported replacement programs should be sought from the manufacturer as the costs for a new device is between 500€ and 2.500€, depending on the device class and equipment. There are no registration and authorization costs for a SRD 860 installation. The annual costs and license costs depend on the business model of the manufacturer.

Future devices could integrate various technologies, such as FLARM, PilotAware, additional services and mobile phone usage, which can then be activated with various cost models. Free use is ruled out due to the high development and operating costs. The only remedy here would be financial support from the state or aviation associations.

New SRD860 devices have the advantage of being able to receive ADS-B directly in most cases and even Mode-S in some cases.

As there are already mobile devices, e.g., for paragliders, these will also be upgradeable to ADS-L with a software update.

Infrastructure costs:

The costs for SRD860 receiving stations are reasonable low. The OGN network which mainly works with FLARM, FANET and PilotAware data already showed that an affordable network can be set up within the pilots' community. OGN is a receiving only network in contrast to the PilotAware network, which already includes a broadcast function on SRD 860 band. For the realization of an ADS-L network which receives and transmits traffic and other data a more complex installation is necessary. Network Servers must be installed, preferably with the integration of 1090 MHz receivers and a mobile connection. The first devices for this are currently under development. One device manufacturer estimated the cost of a transmitting and receiving station for ADS-L at 5.000€ per station. This clearly exceeds the costs of pure receiving stations in community networks. Since the successful, nationwide introduction of ADS-L requires the establishment of a network, the requirements for data quality and quantity as well as financing and operation must be clarified as a matter of urgency.

3.3.4. Conclusion

SRD860 devices are immensely popular in general aviation, both permanently installed in the cockpit and as mobile devices, e.g., for paragliders. Due to their used frequency, they have a short range and can communicate both air to air and air to ground.

Utilizing the existing and new SRD860 technology to implement ADS-L is certainly the best and easiest way to achieve interoperability through this new protocol. Existing systems can be upgraded and retrofitted up to a certain age. Although the combination of different technologies and frequencies from the SRD860 frequency band enables the technical implementation of transmit, receive, and relay operation, it also poses major technical challenges.

First and foremost, the specification of the ADS-L protocol for SRD860 must be completed and the specification for ADS-L4Mobile must be initiated in parallel. This is the basis for the development of devices for general aviation.

Financially the SRD860 devices have no registration and authorization costs and little licensing costs. Upgrades to ADS-L will be affordable, but the full new functionality of ADS-L will be only available to new devices.

3.4. Case study 3 – Mobile network usage

3.4.1. Outline

This case study will focus on the transmission of e-conspicuity messages via the mobile network path, which means - in technical terms - using a public land mobile network (PLMN) for packet data communication between the participants of the e-conspicuity system.
As the project survey showed, there is an uprising number of e-conspicuity applications already using mobile networks. Therefore, it is essential to examine the technical details carefully to ensure consistency and understanding.

Several technical meetings in this project have taken place on this topic which have shown existing problem areas while utilizing the mobile network in lower airspace.
The case study three shall address the problem areas and sketch solutions.

The biggest advantage of this transmission path is that almost every airspace user owns a mobile phone or tablet that could be used for transmission of e-conspicuity messages. The already existing e-conspicuity applications on the market are very affordable. This results in very low overall costs for users. As well as for the SRD860 devices no authorization or registration of devices is necessary.

Although there may be integrated mobile radio solutions in permanently installed e-conspicuity devices in the future, mobile network is the predestined transmission path for using a mobile e-conspicuity device for paragliding, for example. Existing e-conspicuity devices using other transmission paths may be enabled to use the mobile network by retrofitting appropriate modems or by the external connection of mobile network devices.

Detailed problem aeras were already identified in the technical meetings and workshop two:
- partly unstable reception,
- disturbances of the ground mobile network by aerial usage,
- high dependence of the reception on the flight conditions (altitude, speed),
- legal/contractual uncertainties about the contract with mobile network operators,
- international and national roaming issues and
- the lack of a business case for aerial usage for mobile network providers.

In summary this means that transmission and reception of e-conspicuity messages via the mobile network path should currently be considered as a complementary option.
An improvement in the operating and reception conditions of the user devices, e.g., through outside fuselage antennas, optimization of the frequency range used and ground-side optimization by the mobile communications providers should be investigated further.

Direct communication between two airspace user who only use mobile network communication is not possible without a server infrastructure behind the mobile network. A server infrastructure is essential to make the mobile network transmission path work for e-conspicuity. On the other hand, a centralized server infrastructure can also be linked to many different traffic information sources if they are collected and combined in a ground network.

A good example for this, among others, is the Safesky App, which combines about fifteen different traffic data sources and connects an existing mobile network device via the mobile network transmission path.

Another advantage of the mobile network transmission path is the possible integration of Ground Based Applications like the FlyDMFV App for model flying. This app feeds model flying activities as activated model airfields or single flying sites into the traffic system. These can then be transmitted to users of the system and displayed on e-conspicuity solutions. The app can also be extended to hang glider take-off and landing fields and other hazard zones under certain circumstances.

For the sustainable and successful use of the mobile network for transmission of e-conspicuity messages, recommendations and specifications regarding the usable devices and the quantity and quality of data must be defined, i.e., limitation of data to a predefined area around the location of the user. ADS-L is a suitable common protocol here, but the specification of ADS-L4Mobile must be driven forward promptly. The question of network infrastructure and operation is the same here as with the ADS-L4 SRD-860 and will happen most probably combined.

3.4.2. Feasibility

One of the most important limitations when using mobile network in the air is the strong dependence on altitude and speed. From altitudes of three hundred metres above ground on and speeds above 200 km/h, a stable and reliable connection cannot be assured. This is partly due to the design and structure of the mobile phone network itself. Although planned and built as a network for users on the ground (i.e., by tilting antennas downward to the ground), ground reflections of the high frequency signals lead to an unintentional existing mobile network coverage in the lower air space. Coverage height above terrain varies dependent on the topography of the terrain. The resulting network coverage in lower airspace through ground reflections can be used by a lower airspace user to communicate via the mobile network.

With regards to the moving speed of the user, mobile networks were designed to fit common ground transportation speeds. This also depends a little on the frequency band used.

To estimate the general feasibility of the mobile network path for e-conspicuity message transmission the following options are considered in more detail:

Standalone smartphone usage
Since smartphones have become part of our daily life, we can assume that every pilot has one available in flight. Low barrier entry into mobile network usage for e-conspicuity message transmission is a smartphone app.

Network reception quality with a smartphone can be limited due to small antennas and the unfavourable position inside the aircraft fuselage, making obstruction of the high frequency waves an issue for the reliable use. For slow and low-flying users, such as paragliders, the mobile network is already well usable today and might be the best and only solution by far. Still, for the use of smartphones inside of aircraft fuselages the reception quality may be optimized using a cradle with coupled external antennas as they are used in cars.

Another key factor for the quality of data transmission is the amount of data. The user must ensure that all unused apps, including those in the background, are not transmitting data anymore before the device is used for e-conspicuity. As the (core) e-conspicuity app also should work as a background app it is difficult to realize a reliable function on many phones. Some phones even prohibit the data transmission of apps in the background.

Existing e-conspicuity devices retrofit
To connect existing/installed e-conspicuity systems to mobile network communication a retrofit solution is needed:

Option A: Use smartphone mobile hotspot function via WiFi/Bluetooth or via USB cable as connection device
Option B: Use dedicated mobile network router (with outside fuselage antenna)

Keeping in mind that universal retrofit solutions are critical with regards to reliable functionality Option B seems by far more feasible but would include additional SIM card /data plan at additional cost (see below 3.4.3). A WiFi functionality of the router is highly recommended and often standard.

In future e-conspicuity systems a modem for mobile network communication may be integrated in parallel with receivers of other transmission paths.

The traffic included in the received e-conspicuity messages may be integrated into the device's internal traffic stream, processed, and filtered and then displayed together with the received traffic from other transmission paths. The received traffic messages may include additional information, as weather conditions or airport data. This payload is also intended to be included in the ADS-L protocol.

Apps need to be developed for both iOS / Android hardware to gain sufficient user acceptance. Technical disadvantages of the app solution need to be sorted out in a separate friendly user trial.

In summary there are options available to make the transmission of e-conspicuity messages feasible. But it should be kept in mind, that due to the client/server principle of the mobile network transmission path a server infrastructure collecting, calculating, and sending data is mandatory.
This would have several benefits as stated above, but results in a bigger investment for development and operation. There are already some of those networks in use. For the future development of a common network, there must take place a specification of data quality and quantity and of the interfaces between the server structure.

	Interoperability Requirements	Assessment
Feasibility	A/C Usage (high, low, slow, fast)	location dependent
	Ease of installation (Technical) (upgrade to ADS-B in+out)	easy
	Ease of installation (Regulations) (upgrade to ADS-B out)	independent
	Usability w/o airframe, mobility	easy
	Air - Air direct communication	not available
	User acceptance (e.g. survey)	high
	Flight area dependency (cross border)	difficult, tbd.
	Range	low-medium (only transmission)
	Possibility for anonymization	possible
	Sensitivity for obscuration	yes
	Traffic network required	mandatory
Benefits	Fulfilment of SERA 6005C	yes
	Use of existing equipment	yes
Constraints	Credits ANSP (e.g. airspace usage)	none
	ADS-L compatibility	yes
	Latency stable (e.g. timestamp)	yes
	Transmission safety (spoofing, encryption)	yes
Costs	Installation costs (only ADS-B upgrade)	mid range
	Annual costs	low
	Infrastructure for traffic network	mandatory / high

Figure 9: Assessment Matrix for Mobile Network Usage
Source: Own graphic

3.4.3. Costs

User costs:

In case of a smartphone usage hardly any hardware costs will appear, as it can be assumed that every pilot has a mobile phone. Little investments for a cradle with outside antennas should be foreseen.

The e-conspicuity application itself may be paid by annual fees, as is also the case with the Safesky app. Additional costs for data plan for mobile network contract need to be identified as soon as data traffic consumption of the app is clear. The costs should be within the normal range of a current data contract and most probably the user already has a contract including a data volume.

For an additional connectivity box (Option B from 3.4.2 Retrofit) a standard industrial mobile network router (4G/5G) with external antenna could be used as long as the manufacturer of the onboard finds a way of connection and an update solution to make use of mobile network with ADS-L. Costs for the router, antenna and installation range around 500-1.000€. The solution will significantly enhance mobile network reception in the lower airspace and can also be used for other applications like weather report.

Complete new devices with an integrated mobile network modem will be developed by the manufacturers if a larger number of users would like to have this. The additional costs for the new connectivity will not significantly increase the price of the devices in comparison to the actual ones.

Application and network costs:

Application development on both platforms (iOS/Android) depends on the complexity and costs 30.000-50.000€. This does not include trial periods for app testing and/or server architecture. The costs for the app development and user trials could be financed by CAA or EASA. Later service fee needs to be calculated separately.

The investor for the app development needs to decide whether they want to charge the user for download and/or subscription fee. Typical way forward with regards to commercial app developer fees range around 20-30€/year.

The costs for the essential traffic network with server structure (not the mobile network itself) are difficult to estimate as this part of the network will probably be integrated into systems of 1090MHz and SRD860 network parts. The development of a complete network and the determination and subsidization of costs and potential operators will be one of the main tasks for this area.

3.4.4. Conclusion

The preparation calls and discussions during the second workshop clearly indicated, that the use of mobile networks as transmission path for e-conspicuity messaging is not as dependable as indicated by service partners as SafeSky, already promoting a mobile network-based solution.

When it comes to the performance parameters for seamless connectivity it should be kept in mind:

- Mobile network data services are a shared resource service – overload situation can occur.
- Mobile network coverage in lower airspace is not an intended mobile network feature; it is a – so to speak – a waste product, using unintentional reflections for network coverage.
- Mobile network operators not really like network users in the air because they cause unintended neighborship relations between network cells.

Mobile network usage enablement onboard an aircraft / airspace user will significantly enhance e-conspicuity situational awareness, as it would make far more traffic visible, mainly from additional traffic information sources, currently not available for the user.

But the success of a solution using mobile network as a communication path for e-conspicuity messaging is based on the parallel setup of a server infrastructure for e-conspicuity message communication / re-broadcasting from and to the connected users.

EASA needs to enforce the development of ADS-L4MOBILE specification to make this available for manufacturers willing to invest in the development of an e-conspicuity message transmission hardware / retrofit solution.

EASA also needs to evaluate the expenses for a suitable server infrastructure development, installation, and long-term operation.

In opposition to air-to-air broadcasting communication of electronic conspicuity device users the communication via mobile networks / internet connection relies on a centralized data platform with the following functionalities:
a. Receiving e-conspicuity messages and other air traffic information sources,
b. Processing / filtering the messages for the user location,
c. Re-broadcasting them through several communication paths, i.e., mobile networks.

Without a suitable server infrastructure and a 24/7 operating/monitoring of the systems the communication path mobile network has no benefit for e-conspicuity message transmission.

3.5. Influence from unmanned aviation

Electronic conspicuity has been a focus need for unmanned aerial systems (UAS) from day one, since - according to air laws – UAS always must give right of way to manned aviation! For operations in u-space airspace, the requirements for and responsibility for the visibility of air traffic are clearly regulated.

To obey this law during an UAS mission beyond visual line of sight of the UAS pilot (BVLOS) it is mandatory to have any kind of “electronic situational awareness” since the UAS pilot cannot look through the UAS canopy.

Helpful but not sufficient are receiver stations for all common electronic conspicuity systems along the flight path of the UAS to fill data into a situational awareness map system for the UAS pilot. Companies in the drone industry already offer service packages for drone operators including receiver stations, transmission of the received data and calculation of a situational awareness visualization to enable the drone pilot to give right of way to manned aviation appearing in his operation aera, i.e., to become aware of an approaching rescue helicopter. Unfortunately, this will not bring all manned aviation to the awareness of the UAS pilot, for example aircraft equipped with just Mode-S transponders (see case study 1090MHz).

The European Aviation Safety Agency (EASA) is responsible for regulating the use of drones in the EU and has established a regulatory framework for Remote ID that requires most drones to be equipped with a Remote ID system (same as FAA/US).

Remote ID shall enhance drone operations' safety, security, and accountability, particularly in areas where drones may be operating near other aircraft or in sensitive locations. It is a system that allows drones to transmit identification and location information. This information can be received by other airspace participants, including authorities, pilots, and the general public. It is already mandatory for many UAS operation categories since 1st Jan 2024 and is currently integrated by leading manufacturers.

From a purely technical point of view, the Direct (Broadcast) Remote ID and Network Remote ID systems works as follows:

Direct (Broadcast) Remote ID:
In this method, the unmanned aircraft broadcasts its identification, location, and other relevant information using WIFI or Bluetooth. Nearby receivers, including other aircraft and ground stations, can pick up these signals to obtain information about the UAS. Due to the noticeably short range of the transmission (<2km), the benefits compared to manned aviation are questionable.

Network Remote ID:
With network remote ID, the identification and location data of UAS are transmitted over mobile network / the internet to a centralized database. Authorized parties, such as air traffic control, law enforcement, and other stakeholders, can access this information through the network. The Network Remote ID traffic messages may be

integrated in the network systems mentioned in the case studies via the ADS-L protocol. This also means for EASA that integration or data exchange and format/protocol mapping needs to be elaborated between network remote ID database and e-conspicuity database / server infrastructure. Network Remote ID is also defined mandatory for the upcoming EU airspaces called U-space, where manned and unmanned traffic shall be integrated.

Focus groups of the unmanned aviation industry like the Joint Authorities for Rulemaking of Unmanned Systems (JARUS) are working on the digital information sharing subject for years already. Recently JARUS published a whitepaper intending to provide an outline for considering the impact of automation and digital information sharing across all aspects of aviation safety.

In summary, it underlines that digitalization, the sharing of digital information and e-conspicuity can enable safe flight operations, especially with high levels of automation. Electronic conspicuity will facilitate cooperation among aircraft for safe separation, as well as provide ground systems with safety support. Standardized digital information sharing will enable cooperative airspace and traffic management, ensuring all operators have access to information about airspace users and constraints. Human intervention will still be necessary for events unresolved by automation, with responsibility resting on the operator and leveraging aircraft technology.

An outlook into the future might be the vision of Enhanced Flight Rules (EFR), a digitized version of Visual Flight Rules (VFR), facilitated also by electronic conspicuity. As unmanned aviation evolves, there is a need for safe integration with manned aviation, emphasizing electronic conspicuities for all. This forward-looking approach represents significant innovation in unmanned aviation, particularly in response to the challenges posed by beyond visual line of sight (BVLOS) UAS operation.

Conclusion:
EASA’s approach for ADS-L specification and all efforts for harmonization with other protocols and already existing data formats like network ID now becomes a crucial starting point for a safe and fair interworking of manned and unmanned aviation without any airspace segregation and therefore for the interoperability as such.

3.6. Identification of suitable deployment scenarios & user matching

For the identification of suitable deployment scenarios different categories are proposed to enable a comprehensive and far-reaching dissemination of e-conspicuity systems and to provide all user groups with suggestions and pointers for solutions. The categories were differentiated here mainly by mobility, certification, and the financial outlay. The project survey has shown that there is a great deal of interest in improvement and a willingness to invest. The intended user groups, which are also integrated in the ADS-L protocol, are listed in Figure . However, these will be expanded in the future, e.g., to also identify hazard zones of ground-based apps such as model flying sites and take-off and landing sites for hang gliders.

3.6.1. Portable e-conspicuity solution – The 200€ solution

The portable solution is primarily intended to cater for users who do not want to spend a lot of money on an e-conspicuity device or who are not able to install a device (e.g., no fuselage). It will most likely consist of a mobile, app-based solution using an existing mobile phone. The costs will be limited to the application costs (purchase and annual costs) and potentially a cradle for fixing the device in the cockpit. In addition, solutions with outside antennas for reception optimization could increase the costs a little. In a mobile-app solution many different sources of e-conspicuity may be made available if the ground-side server system provides them. The ADS-L4Mobile protocol will help to realize this provision, even with additional information (e.g., weather). As the device itself is not fixed in the aircraft, no certification or change is required.

The advantages are of course the low entry costs and the use of a well-known, own equipment. Furthermore, such a solution is portable and can therefore also be used in several different aircraft. This solution is also able to meet the needs of paragliders and hang-gliders, who do not have a fuselage to install fixed devices. Easy updates and upgrades are possible via the internet on the ground and the pilot can even practice the usage it at home.

The disadvantage of this solution is the single usage of only one transmission path with all its weaknesses. No direct transmission and reception of the other transmission paths are possible in this solution. Those were explained in detail in the mobile network case study. Another disadvantage is that this solution cannot currently be displayed in commercial aircraft.

This solution may fit for paraglider, hang-glider and slow flying aircrafts and it may supplement already installed devices for all other users. If this system is the only one used, there is no visibility to pure 1090MHz users (mostly commercial aviation), as there is no rebroadcast system for ADS-L on 1090.

3.6.2. Uncertified e-conspicuity solution – The 1.500€ solution

The uncertified solution will be a device or a combination of devices which combine the different transmission paths described in the case studies. The core device collects the traffic data from the various receiving units and processes it so that it can be shown on a display. The display can then be either one offered by the manufacturer or even a user's mobile phone/tablet. The transmission paths should combine ADS-L4SRD860 and ADS-B, including a transponder. This combination may be supplemented by the mobile transmission path. Ideally, all three options can be integrated in one receive and transmit box connected to external antennas. This could also be available as an upgrade for existing e-conspicuity systems if the appropriate interfaces are available. The installation is managed as a standard or minor change without a necessary certification.

The main advantages of this solution are the combination of the 1090MHz system and the associated possibility of using airspaces which require this and the direct transmission air to air.

The main disadvantage of this solution is the combination of different parts (core device, communication box, display) and the needed interfaces. All components must be kept updated to compatible versions; the failure rate could be higher than with integrated systems.

3.6.3. Certified e-conspicuity solution – The 5.000€ solution

The certified solution will be a completely integrated solution, combining all three transmission paths, the core unit and the communication and display parts in one device of one manufacturer. The display will show the traffic, navigation and further information like weather and may also be used for planning purposes. As this device will be fixed in the aircraft and potentially connected to other aircraft systems, it requires a certification and annual checks.

The main advantage of this solution is that the entire unit is perfectly integrated into the cockpit environment. The individual transmission paths are perfectly coordinated, and the reception is optimized for the specific aircraft. The traffic data is shown on a display together with additional information and flight planning and aircraft parameters. Inputs are made on just one system with a well-adapted human-machine interface.

The main disadvantage of this solution is clearly the price. Developing, coordinating, approving, and installing such a system is a major undertaking. Furthermore, annual inspections and fees are incurred. Upgrades to future technologies for such a well-integrated system are usually very time-consuming and expensive, if not impossible.

Due to the characteristics described, this system solution only makes sense for larger and more expensive airplanes and helicopters.

3.6.4. Specific solutions

There are still some user groups that will need more specific or special solutions for e-conspicuity. Hot air balloons for example may use a portable combined unit with radio and ADS-B capable transponder with a possible supplement of a low-level e-conspicuity solution. Weight and power consumption only plays a minor role here.

Other groups like parachutists, skydivers and wingsuit pilots and also model pilots shall use a ground-based app to mark the area of their operation. They may activate their area before start and close it after landing. The principle is shown by the FlyDMFV app. The same applies to the take-off and landing fields of hang gliders and paragliders. These areas will be integrated as a special aircraft category in the ADS-L protocol later.

For UAS operations Remote ID and Network Remote ID are provided in use cases where they must be made conspicuous. As there is no coordinated standard for the transmission, the protocol will most probably be ADS-L. Thus, these aircrafts can be integrated into the traffic messages.

Parameter	Values
Aircraft category	No emitter category information available
	Light fixed-wing (<7 031 kg / 15 500 lb)
	Small to heavy fixed-wing (≥7 031 kg / 15 500 lb)
	Light rotorcraft
	Heavy rotorcraft
	Glider / sailplane
	Lighter-than-air
	Ultralight
	Hang-glider
	Paraglider
	Parachutist / skydiver / wingsuit
	eVTOL / UAM
	UAS 'open' category
	UAS 'specific' category
	UAS 'certified' category
	Model plane
	Reserved

Figure 10: Evaluation of ADS-L aircraft categories
Source: SERA 6005

Concluding, it should be noted that all solutions and partial solutions should always keep the option open for the connection of further transmission technologies, such as UAT frequencies, satellite communication, etc.

4. Action plan for deployment of all use cases

In this chapter the recommended actions for EASA will be summarized. They consist of the one hand of general recommendations for actions that emerged from the workshops and the survey, and on the other hand of those that emerged from the examination of the individual transmission channels.

One of the most important steps is to establish a clear and understandable communication with the users and to demonstrate the topic of e-conspicuity as well as its benefits and limitations. The best starting point for this is the AERO 2024 trade fair in Friedrichshafen, where both end users and trade visitors will be confronted with the topic. At the same time, a description of how the chosen solution approach will be put into practice can be shared on that trade show. The input, questions and needs of the users will provide clear indications of the way in which the solutions need to be structured. A clear strategy and communication campaign involving all user groups must be setup.

The setup of the complete ADS-L specification (SRD860 and Mobile transmission, including payload) is currently under development, but must be finished as soon as possible to give manufacturers the opportunity for rapid implementation. They should be encouraged to implement ADS-L in their devices. The specification of ADS-L4-Mobile in particular must be tackled quickly. The clarification and definition of the additional information possible in the protocol will be a decisive argument to interest users in the new technology.

Several steps should be initiated with the knowledge gained from this study. The necessary network including server infrastructure, linkage of the different e-conspicuity messages etc. must be defined. Thus, the minimum requirements of the data quality and quantity should be outlined. Practical tests should be conducted, e.g., at an airfield, to assess the combination of the various transmission paths, as well as the establishment of and integration into a network and rebroadcasting on the various channels.

In terms of mobile network usage, studies should be initialized and stable aerial usage together with European network providers should be evaluated (Script with realistic data streams). Furthermore, it should be defined a minimum standard for the aerial usage of the mobile network and recommendations and specifications for mobile devices in terms of e-conspicuity.

In addition, research should be conducted into how high the load on the 1090MHz band is due to the ADS-B upgrades.

NAAs should be encouraged to join an “Acceptance Declaration” for the e-conspicuity solutions. It must be agreed upon that pilots will not be punished because of being conspicuous and making unintentional mistakes. In addition, the use of e-conspicuity data by ANSP (airspace and FIS) should be enabled.

To achieve broad acceptance by the various user groups, the usage of the intended e-conspicuity solutions special attention must be paid to the human machine interface, warnings, and theoretical and practical training. The user must feel safe and comfortable with his solution. Thus, guidelines for manufacturers must be setup.

For the financial view operational and technical assessments and detailed business cases for ground-based stakeholders and airspace users must be considered. Support programs, e.g., for upgrade or replacement programs of existing hardware must be setup with the help of state, communities, and manufacturers. The step towards renewal must be made bearable for the user.

5. Overall conclusion across all case studies

In the three case studies presented here, the transmission paths 1090 MHz, SRD 860 and mobile network were examined regarding the interoperability in e-conspicuity. Within the individual case studies, the interoperability requirements determined in the second workshop were checked for feasibility, constraints, and costs. In all considerations it must be clear that e-conspicuity shall support the situational awareness of pilots; it is not to be used as surveillance supporting ATC.

The individual transmission paths are not directly compatible and do not speak the same language, the protocol. Therefore, the only way to achieve interoperability is to optimize the individual paths and bring them together with a common language, e.g., ADS-L, in the network and through combined (Multilink) devices.

In the 1090MHz path, the best option is to convert as many existing Mode-S transponders to ADS-B as possible. This enables a significant increase in the number of users broadcasting their exact position. Pilots using an ADS-B out or Mode-S system alone are strongly recommended to upgrade to a combined e-conspicuity device or to supplement their system with one.

Combined solutions are already available in the SRD860 path, but manufacturers still need to complete the transmission modules for 1090MHz, O-band, mobile network usage and future transmission paths. The integration of ADS-L must be pushed further once the specification is available. The reception quality should be optimized with external antennas.

In the status the mobile network path should be seen as a complimentary option for e-conspicuity, as the usage is highly dependent on the current position, altitude, and flight speed. For low and slow flying traffic, it might serve also as a single solution if it is ensured that the transmitted traffic messages are also visible for all other airspace users. For the usage of the Mobile network path for e-conspicuity a server-based traffic network behind the mobile network is essential. EASA needs to enforce the development of ADS-L4MOBILE specification.

The influence of unmanned aviation was demonstrated, and the Direct Remote ID and Network Remote ID technologies were presented. The Network Remote ID should be integrated into the planned traffic network systems, e.g., via the ADS-L protocol, to be able to display the position data of UAS to the users.

In chapter 3.6 Identification of suitable deployment scenarios & user matching, the feasibility for different user groups was presented and checked. The boundaries between the exemplary systems are floating and the users can also find themselves in several parts. So, there is no clear, single solution for individual users.

Beside the technical challenges, a good, simple, and open communication must be established with users to demonstrate the benefits, possibilities, and the limits of e-conspicuity. This also includes the initiation of training to be able to operate the devices safely and effectively and to prevent overloading and a negative effect on attention.

A crucial criterion for successfully establishing electronic conspicuity in general aviation is the introduction of an e-conspicuity declaration for NAAs and ANSPs. This declaration is intended to stipulate that a rule violation committed without intent or purpose and made visible through e-conspicuity will not be penalized. Dealing with it in this way (a kind of “Just Culture”) is the only way to achieve wide distribution among users.

On the financial side, support programs should be initiated to support costs for app development, replacement programs for older hardware components and upgrades to existing e-conspicuity devices. These can be provided by associations, the government or manufacturers, or a combination of these.

Developments in communication technology and frequency utilization should be monitored, particularly regarding the integration of additional communication channels. interfaces for the connection should be kept open from the outset for all solutions.

6. Table of illustrations

7. List of abbreviations

ACAS-X	Airborne Collision Avoidance System X
ADS-B	Automatic Dependent Surveillance - Broadcast
ADS-L	Automatic Dependent Surveillance - Light
ATC	Air Traffic Control
ANSP	Air Navigation Service Provider
BNK	Bedarfsgerechten Nachtkennzeichnung
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
DFS	Deutsche Flugsicherung GmbH (German ASNP)
DF	Downlink Format
EASA	European Union Aviation Safety Agency
EFR	Enhanced Flight Rules
EPAS	European Plan for Aviation Safety
FIS	Flight Information Service
FLARM	Portable Collision Avoidance System
GDL	Garmin remote-mount broadband transceiver
GNSS	Global Navigation Satellite Service
JARUS	Joint Authorities for Rulemaking of Unmanned Systems
MLAT	Multilateration
NAA	National Aviation Authority
NMEA	National Marine Electronics Association (NMEA Format for position transmission)
OGN	Open Glider Network
PLMN	Public Land Mobile Network
SAR	Search and Rescue
SERA	Standardized European Rules of the Air
SIL	Source Integrity Level
SRD	Short Range Device
TCAS	Traffic Collision Avoidance System
UAS	Unmanned Aircraft System
USB	Universal Serial Bus
USP	Unmanned Traffic Management Service Provider
VFR	Visual Flight Rules