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Agenda Item 2: Report on Activities and Future Plans of Working Groups/Project Teams and Other Groups

LDACS White Paper – A Roll-out Scenario

Prepared by PT-T Participants Thomas Boegl (Rohde & Schwarz), Mathias Rautenberg (Rohde & Schwarz), Bernhard Haindl (Frequentis AG), Christoph Rihacek (Frequentis AG), Josef Meser (Frequentis AG), Pierluigi Fantappie (Leonardo), Noppadol Pringvanich (IATA), John Micallef (SITA), Klauspeter Hauf (DFS), John MacBride (UK NATS), Philippe Sacre (Eurocontrol), Bart van den Einden (Eurocontrol), Thomas Gräupl (DLR), and Michael Schnell (DLR)

(Presented by Rapporteur of PT-T)

SUMMARY

LDACS (L-band Digital Aeronautical Communications System) is a secure, scalable and spectrum efficient data link with embedded navigation capability and thus, is the first truly integrated CNS (Communications, Navigation, and Surveillance) system recognized by ICAO. During flight tests the LDACS capabilities have been successfully demonstrated. LDACS standards are currently developed within ICAO to pave the way for a successful roll-out in the near future.

In the attachment of this paper is the LDACS White Paper providing a brief LDACS overview as well as a roll-out scenario to bring LDACS into operations with involvement by all stakeholders and supported by a viable business case.

ACTION BY THE MEETING
The Meeting is invited to note the information provided in the White Paper attached to this paper.

(8 pages)

LDACS White Paper – A Roll-out Scenario

Acknowledgement

This White Paper has been developed by Project Team Terrestrial (PT-T) of the ICAO Communications Panel (CP) Data Communications Intrastructure Working Group (DCIWG). It has been presented to DCIWG at its Third Meeting in October 2019.

1. Status Quo – Connectivity from and to flight decks of civilian airliners

Aircraft are currently connected to ATC (Air-Traffic Control) and AOC (Airline Operational Control) via voice and data communications systems through all phases of a flight. Within the airport terminal, connectivity is focused on high bandwidth communications while during en-route high reliability, robustness and range is the main focus. Voice communications may use the same or different equipment as data communications systems. In the following the main differences between voice and data communications capabilities are summarized.

Voice communications today

Voice links are used for air-to-ground and air-to-air communications. The communication equipment is either ground-based working in the HF or VHF frequency band or satellite-based. All voice communications are operated via open broadcast channels without any authentication, encryption or other embedded protective measures. The use of well-proven communication procedures via broadcast channels helps to enhance the safety of communications by taking into account that other users may encounter communication problems and may be supported, if required. The main voice communications media is still the analogue VHF DSB-AM (Double Side-Band Amplitude Modulation) communications technique, supplemented by HF SSB-AM (Single Side-Band Amplitude Modulation) and satellite communications for remote and oceanic areas. DSB-AM has been in use since 1948, works reliably and safely, and uses low-cost communication equipment. These are the main reasons why VHF DSB-AM communications is still in use, and it is likely that this technology will remain in service for many more years. This however results in current operational limitations and becomes impediments in deploying new ATM (Air-Traffic Management) applications, such as flight-centric operation with point-to-point communications.

Data communications today

Like for voice, data communications into the cockpit is currently provided by ground-based equipment operating either on HF or VHF radio bands or by legacy satellite systems. All these communication systems are using narrowband radio channels with a data throughput capacity of some kilobits per second. While the aircraft is on ground some additional communications systems are available, like AeroMACS, which can deliver broadband communication capability.

The data communication networks used for the transmission of data relating to the safety and regularity of the flight must be strictly segregated from those providing entertainment services to passengers. This leads to a situation that the flight crews are supported by narrowband services during flight while passengers have access to inflight broadband services. The current HF and VHF data links cannot provide broadband services now or in the future, due to the lack of available spectrum. This shortcoming is becoming a limitation to enhanced ATM operations, such as Trajectory-Based Operations (TBO) and 4D trajectory negotiations.

Satellite-based communications are currently under investigation and enhanced capabilities are under development which will be able to provide inflight broadband services and communications supporting the safety and regularity of the flight. In parallel, the ground-based broadband data link technology LDACS is being standardized by ICAO and has recently shown its maturity during flight tests.[1] The LDACS technology is scalable, secure and spectrum efficient and provides significant advantages to the users and service providers.

It is expected that both – satellite systems and LDACS – will be deployed to support the future aeronautical communication needs as envisaged by the ICAO Global Air Navigation Plan (GANP). Both technologies have their specific benefits and technical capabilities, which complement each other and they are the main components of the multilink concept within the Future Communications Infrastructure (FCI).

2. LDACS – a modern aeronautical data link

The development of LDACS was initiated by already identified bandwidth limitations within aeronautical data link systems using VHF communication channels. The first research work focused on a VHF data link waveform as it was assumed to be the most cost-effective way to increase the bandwidth and enhance the capabilities of already fielded data communication systems with minimum effort.

During this first initiative, named B-VHF (broadband VHF), it could be shown that the implementation of a broadband VHF data communications system would not be advisable due to challenges during the transition period. Action Plan 17, undertaken jointly by the FAA and EUROCONTROL, thus determined that the L-band is the most suitable band to support future communication needs. In the wake of Action Plan 17, the scalable B-VHF technology was adapted and transferred into the aeronautical L-Band between 960 MHz and 1164 MHz. This led to the development of the LDACS data link technology. During this process, the capability of LDACS has been enhanced to meet the requirements of the FCI. Now, LDACS has achieved a level of maturity where it could be operationally deployed within some years.

Scalability is the key for fielding with low risk

LDACS is a scalable data link technology. This important feature allows a step-by-step deployment along with already fielded systems with very low risk. LDACS can initially be fielded to complement existing infrastructure and eventually replace legacy VHF data links. Standard IP interfaces will allow easy integration into the existing communications infrastructure.

This scalability also allows different deployment concepts. For example, LDACS deployment could be introduced locally, where most needed, to supplement VHF data links with the high-capacity broadband LDACS data link with the same communication service range. Another deployment concept could be a complete LDACS ground infrastructure, provided and operated by a system provider.

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[1] Flight tests have been performed by DLR under the MICONAV Project, supported by the German Federal Ministry for Economic Affairs and Energy. In addition to DLR and consortium leader Rohde & Schwarz GmbH & Co. KG, BPS GmbH and iAd GmbH are partners within the consortium.

To support future services, LDACS can provide data throughput from 550 kbit/s up to 2.6 Mbit/s depending on the chosen adaptive coding and modulation scheme. This is 50 to 200 times higher than the throughput of the currently operated VDL Mode 2 system. LDACS also manages service priorities and, thus, guarantees bandwidth, low latency, and high continuity of service for safety-critical applications while also accommodating airline AOC services. Additionally, LDACS can provide secured private communications for aircraft operators and ANSPs (Air Navigation Service Providers).

Communications and navigation at the same time

In addition to the communications capability, LDACS also offers a navigation capability. Ranging data, similar to DME (Distance Measuring Equipment), is extracted from the LDACS communication links between aircraft and LDACS ground stations. This results in LDACS providing an APNT (Alternative Position, Navigation and Timing) capability to supplement the existing on-board GNSS (Global Navigation Satellite System) without the need for additional bandwidth. Operationally, there will be no difference for pilots whether the navigation data are provided by LDACS or DME. This situation is analogous to ILS (Instrument Landing System) with GBAS (Ground-Based Augmentation System) being an alternative means for precision approaches with minimal impact to flight procedures, pilot interfaces and training.

Unlike today, LDACS provides enhanced data transfer capacity suitable to enhance DFMC GBAS[2] through providing additional augmentation information. LDACS also supports future cyber-security measures for GBAS, such as authentication and information integrity, which will be beneficial in enhancing the resilience and security of this critical flight navigation application. In addition to GBAS, LDACS provides secured and increased throughput capacity paving the way for future navigation applications, such as curved precision approaches and full 4-D trajectory operations.

Embedded spectrum efficiency

Spectrum is a scarce and valuable resource especially within the aeronautical L-band where already many services of high importance are allocated. LDACS is highly spectrum efficient because it was designed to be placed within those parts of the L-Band where no other service could be allocated until now.

This valuable feature was achieved by designing LDACS in a way that it can be co-located with DME in the L-band. For this approach, LDACS uses interference mitigation algorithms to cope with interference coming from DMEs. In addition, LDACS out-of-band radiation has been minimized to protect DME and other existing L-band systems. This feature which is new for a data link system gives LDACS unique capabilities to support an efficient spectrum allocation process.

LDACS is designed as a cellular system. Thus, the well-known co-channel interference problems of VDL Mode 2 are avoided by assigning different frequencies to neighboring LDACS cells.

[2] GBAS precision approach and landing system uses a data link to transfer augmentation messages from GBAS ground stations to the aircraft navigation equipment, enhancing accuracy and navigation integrity to each GBAS precision approach. Each GBAS message is specific to each GNSS frequency, e.g. L1 for GPS. In a dual-frequency, multi-constellation (DFMC) GNSS environment, several GNSS frequencies for multiple satellite constellations will be processed and all augmentation messages will then be transferred to the aircraft increasing the amount of data broadcast. In equatorial regions with high ionospheric and tropospheric activities, the capability to process and broadcast DFMC GBAS messages is important to support better mitigation of ionospheric and atmospheric errors.

Security is embedded within LDACS

Aviation will require secure exchanges of data and voice messages for managing the air-traffic flow safely through the airspace all over the world. The main communication method for ATC today is still an open analogue voice broadcast within the aeronautical VHF band. Currently, the information security is purely procedural based by using well-trained personnel and proven communications procedures. This communication method has been in service since 1948. Future digital communications waveforms will need additional embedded cyber-security features to fulfil modern information security requirements like authentication and integrity. These cyber-security features require sufficient bandwidth which is beyond the capabilities of a VHF narrowband communications system.

For voice and data communications, sufficient data throughput capability is needed to support the cyber-security functions while not degrading performance. LDACS is a mature data link technology with sufficient bandwidth to support cyber-security. From the very beginning of the development process cyber-security for LDACS has been addressed by design and meets the cyber-security objectives as standardized by ICAO.

3. Additional value for stakeholders and end users

In the following, the additional value LDACS delivers is reflected from three different stakeholder and end user perspectives: airlines and airspace users, ANSPs, and CSPs (Communication Service Providers).

Airlines and airspace users

With larger bandwidth and higher throughput, LDACS provides better support to AOC data traffic and is a technical enabler for connected aircraft operations. The large bandwidth coupled with data prioritization capability enables LDACS to reliably transfer large amount of essential operational data, such as graphical weather information, without interrupting the transfer of safety-critical ATC data traffic. These technical features are also beneficial for frequent transfers of large engine and maintenance data – resulting in recurring values to airlines by supporting better fleet management and reducing aircraft turn-around times.

Due to its secured air-to-ground connection, LDACS is suitable for operational-essential applications, such as EFB (Electronics Flight Bag). By meeting ICAO-standardized security requirements, LDACS reduces cyber-security risks by providing a secured connectivity to flight deck and other safety-critical avionics such as flight control and FMS (Flight Management System). These cyber-security features are essential for today's flight operations and are necessary enablers for advanced ATM and connected aircraft applications such as business trajectory negotiation and 4D trajectory-based operations.

Air Navigation Service Providers

Future operational concepts in ATM are based on the availability of a capable and reliable data communication infrastructure that connects aircraft and ATM ground system. This connectivity provides pilots and air traffic controllers with timely information on the intent of a flight and the services available through the ground system.

LDACS provides the capacity needed with a guaranteed quality of service on a secured communication link that enables the implementation of services like secure ADS-C (Automatic Dependent Surveillance – Contract) EPP (Extended Projected Profile), full TBO and ATS/B2 CPDLC (Controller Pilot Data Link Communications). LDACS is also expected to serve the emerging ATS/B3 services. As a capable data communication trunk, LDACS is therefore the prerequisite to integrate the aircraft into a SWIM environment and enables the implementation of promising future concepts like flight centric ATM.

LDACS is foreseen to become the main terrestrial component in the FCI multilink infrastructure covering all phases of the flight. Once deployed, it will provide ATC and AOC services at and around airports during taxiing, take-off, approach and landing as well as en-route.

Communication Service Providers

The value chain for digital communications service provision spans multiple stakeholders. As CNS services are gradually entering the purview of regulated Air Navigation Services, it will become increasingly important to address the interfaces between the various actors in the communications service provision chain in order to continue assuring high levels of service for ATC.

ATM is undergoing a fundamental transformation in concept. It is becoming increasingly reliant on an arsenal of automation tools to assist the air traffic controllers and flight crew achieve better levels of operational safety and productivity, while allowing for increasing traffic levels. This ultimately provides a business benefit for airlines and ANSPs. This increasing level of automation relies on air-ground data carried via the CSP networks.

At the present time, air-ground connectivity for ATC purposes is provided through ATN-enabled VHF media, and additionally through the ACARS network over several other media. These are largely narrowband media run over aviation-specific OSI-based networks – the Aeronautical Telecommunications Network (ATN). This setup has presented significant challenges at institutional and engineering levels, but has so far been manageable considering the present levels of demand for ATC related data.

This situation is set to change with the shift of ATM into the domain of big data. The gradual but certain introduction of new streaming-like data link services beyond the classic CPDLC services, such as TBO, will place unprecedented levels of demand on the capacity of the air-ground connection as well as on its integrity, as the operational concept leans more onto automated functions with data taking a primary role. A technology upgrade to terrestrial broadband capability in protected aeronautical spectrum is therefore a logical step forward to future proof the CSP networks while serving the operational needs of both airline and ANSP clients. LDACS provides a viable means to serve this need as it has some essential attributes including protected aeronautical spectrum allocation, resilience to cyber-security risks, native Internet Protocol (IP) capability, and aviation standards in the pipeline.

In leaping forward, the multiple stakeholders in the CSP chain alluded to above need to work collectively to define a transition roadmap. This roadmap should cleary articulate the business benefit and the value added for the ANSPs from the new applications made possible by a scaleable and flexible terrestrial broadband infrastructure and can be used to complement emerging broadband satellite capability. Such a transition may commence with local deployments demonstrating early operations of ATS/B2 and ATS/B3 applications including TBO.

4. Flight tests have proven the capabilities and maturity of LDACS

In March 2019, an LDACS flight test campaign was conducted within the German National Project MICONAV at the DLR research airport in Oberpfaffenhofen, near Munich. Several flights were performed at different altitudes up to FL 350. During these flights, all the major capabilities of LDACS were successfully validated in real practical scenarios by using industrial LDACS demonstration equipment in the aircraft and in four LDACS ground stations. Capabilities demonstrated included high-rate, low-latency data transmission secured by post-quantum cryptography, authenticated GBAS broadcast (secure GBAS) and handovers between LDACS ground stations.

The results of the flight campaign proved that LDACS is a mature technology for aeronautical communications and navigation. Flight test data is contributing to the validation of ICAO SARPs (Standards and Recommended Practices). This makes LDACS the first truly integrated CNS system recognised by ICAO.

5. **An LDACS roll-out scenario**

The LDACS data link provides enhanced capabilities to existing communications infrastructure enabling them to better support user needs and new applications. The deployment scalability of LDACS allows its implementation to start in areas where most needed to improve immediately the performance of already fielded infrastructure. Later the deployment is extended based on operational demand. An attractive scenario for upgrading the existing VHF communication systems by adding an additional LDACS data link is described below.

Enhancing VHF communication systems with LDACS technology

When considering the current VDL Mode 2 infrastructure and user base, a very attractive win-win situation comes about, when the technological advantages of LDACS are combined with the existing VDL mode 2 infrastructure. LDACS provides at least 50 time more capacity than VDL Mode 2 and is a natural enhancement to the existing VDL Mode 2 business model. **Table 1** shows that a VDL Mode 2 system combined with LDACS technology would be mutually beneficial. The advantage of this approach is that the VDL Mode 2 infrastructure can be fully reused. Beyond that, it opens the way for further enhancements which can increase business efficiency and minimize investment risk.

Bringing LDACS on-board without additional antenna or avionics box

The introduction of a new technology like LDACS does not automatically mean that the infrastructure of the aircraft has to be heavily modified. The reuse of existing space, antennas and interfaces is essential in this context. In the following, it is shown, how LDACS could be fitted into the avionics bay and how LDACS can support the multi-frequency approach as currently developed for VDL Mode 2 systems.

The multi-frequency approach enables VDL Mode 2 to use several VHF frequencies instead of one to alleviate the short- and midterm capacity bottleneck for VDL Mode 2 users. With this enhancement, the VDL Mode 2 radio is able to basically switch to any frequency, also outside the VHF- and especially within the L-band. As a consequence, LDACS can support the VDL Mode 2 system by supplementing the existing narrowband VDL Mode 2 data links with high-capacity broadband LDACS data links in L-band. To implement this, it is attractive to create a multi-mode LDACS/VDL radio combined in a single avionics box which contains both VDL Mode 2 and in addition LDACS. The previous VHF only antenna can be replaced by a dual-band VHF-/L-Band antenna with the same footprint. A single antenna cable can be used and the multi-mode LDACS/VDL radio incorporates a diplexer to serve both bands simultaneously.

Technical challenges when combining two radios into a single multi-mode LDACS/VDL avionics box, like heat dissipation or limited input current, can be easily resolved by avoiding simultaneous transmission of LDACS and VDL Mode 2. The simultaneous transmission of LDACS and VDL Mode 2 is not required as LDACS transmission alone can provide enough data throughput for all foreseen usages. On the receiving end however, the multi-mode LDACS/VDL radio will be capable to simultaneously listen to data from both VDL Mode 2 and LDACS. Simultaneous listening to the VHF- and L-band allows for detecting the available ground infrastructure. If LDACS is available, the transmitter is configured to LDACS, otherwise, the transmitter is configured to VDL Mode 2.

Table 1: Mutual benefit through combining VDL Mode 2 and LDACS in a combined avionics box

	LDACS (current situation)	VDL Mode 2 (current situation)	Combined Avionics VDL Mode 2 / LDACS (expected situation)
Applications and Services[3]	CPDLC, ADS-C and future applications and services	CPDLC, ADS-C	CPDLC, ADS-C and future applications and services
Spectrum Availability	very good	limited	very good
Number of Available Channels	very high	medium to low	very high
User Data Rate per Channel	very high	low	very high
Existing Service Provider	not yet available	available	available
Existing Infrastructure	not yet available	available	available
Existing Users	not yet available	available	available
Security	built-in feature	not available	built-in feature
Voice Capability	built-in feature	not available	built-in feature
Navigation Capability	built-in feature	not available	built-in feature
Capacity for long-term Growth	very high	none	very high

This deployment approach allows gradual introduction of LDACS with immediate use and revenues. LDACS ground infrastructure is introduced first, where most needed to supplement VDL Mode 2 with the high-capacity broadband LDACS data link. Successively, more and more LDACS ground infrastructure can be deployed. In the long term, when LDACS ground infrastructure has been rolled-out completely, the frequency allocation mechanisms of the multi-mode LDACS/VDL radio will automatically select only the L-band channels of LDACS. As soon as the transition from VDL Mode 2 to LDACS is completed, VDL Mode 2 infrastructure can be decommissioned and VHF spectrum made available for other aeronautical applications.

6. Summary

LDACS is a secure, scalable and spectrum efficient data link with embedded navigation capability and thus, is the first truly integrated CNS system recognised by ICAO. During flight tests the LDACS capabilities have been successfully demonstrated. A viable roll-out scenario has been developed which allows gradual introduction of LDACS with immediate use and revenues. Finally, ICAO is developing LDACS standards to pave the way for a successful roll-out in the near future.

— END —

[3] LDACS is capable of supporting all existing VDL Mode 2 applications. It will also support future, more stringent applications and services, such as full 4D trajectory, trajectory-based operations and additional AOC traffic.