



World Meteorological Organization

COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATIONS

OPAG IN SITU TECHNOLOGIES AND INTERCOMPARISONS

Expert Team on Aircraft-based Observations

16 – 19 April, Geneva, Switzerland

FINAL REPORT

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MEETING AGENDA

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- 4.1. Work Programme Deliverables
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- 5.1. WMO Constituent Body Reform and New Vision for the future of environmental measurements within WIGOS and the new CIMO Structure
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7. Actions and Report of the Session

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EXECUTIVE SUMMARY

The second session of the CIMO Expert Team on Aircraft-based Observations took place over 16-19 April, 2018 at the WMO headquarters in Geneva, Switzerland. This was the 2nd meeting of the team during the current inter-sessional period of CIMO ahead of the upcoming session of CIMO in October, 2018 (CIMO-17), with the first session having been held in December 2015 in conjunction with the CBS Expert Team on Aircraft-Based Observing Systems second session.

The chief focus for the session was for the team to report on progress and to undertake planning to finalise activities and tasks from its work plan ahead of CIMO-17 and to also determine requirements and recommendations for reporting to the commission.

The Chair of the team reported that the team had made good progress since its first session, in particular highlighting advancements made on the development and maintenance of guidance materials and technical reports on aircraft-based observations, including a draft Instruments and Observing Methods report on the performance of the WVSS-II water vapour sensor. Other achievements included, coordination of the development of AMDAR onboard software for Boeing B777 aircraft, its deployment in E-AMDAR aircraft to support provision of data over Africa and other data-sparse areas and developing plans and strategies for expansion of water vapour and turbulence monitoring as a component of the AMDAR observing system.

During the meeting, team members reported progress made on other activities and tasks within the ET-AO work plan, including research and analysis of AMDAR air temperature bias, attendance and interaction with relevant aviation bodies and fora, investigations and reporting on the viability of Unmanned Aerial Vehicles (UAV) for provision of upper-air observations and the maintenance of reporting and encoding formats.

The participants used a significant part of the meeting to address and advance several existing and some new proposed activities in, or proposed to be included in the work plan, including some proposed new activities relating to UAV observations.

The meeting was pleased to receive a presentation from representatives of the Panasonic Avionics Corporation on their developing capability to derive aircraft-based observations through their Inflight Entertainment System connectivity with satellite communications.

An important outcome of the meeting was the development of proposed terms of reference for an inter-programme expert team on aircraft-based observations, which was expected to be formed from the amalgamation of the two existing CIMO and CBS expert teams on aircraft-based observations.

GENERAL SUMMARY

1. Organisation of the Session

1.1. Opening of ET-AO-2 Session

The second session of the CIMO Expert Team on Aircraft-based Observations commenced at 9:30 am on the 16 April, 2018 at Geneva, Switzerland and was opened by the Chair of the team, Mr Stewart Taylor, United Kingdom of Great Britain and Northern Ireland. The meeting participants were welcomed to WMO on behalf of the Secretary-General by the Director of Observing and Information Systems, Mr Fernando Belda and Mr Etienne Charpentier, Chief of the Observing Systems Division. Mr Belda highlighted the expectation that the structure of WMO would likely be significantly changed at the upcoming session of Congress (Cg-18, 2019) with the number and structure of WMO technical commissions also reduced and reorganised with a view to both modernising and improving the efficiency of WMO activities. He suggested that the team might consider the implications of this change on the Aircraft-Based Observations Programme (ABOP) and particularly the possibility for the CBS and CIMO expert teams to work more closely together or even to be merged. Mr Belda also stressed the importance to WMO of the developing collaboration with the International Air Transport Association (IATA) and the benefits this might bring as a result of a closer relationship with the aviation industry. Mr Charpentier also highlighted several important aspects of the team's work programme, including the development and expansion of turbulence and water vapour measurement as a component of the AMDAR observing system and the need to consider relevant input to the upcoming session of CIMO in October 2018.

1.2. Adoption of the Agenda

The participants agreed to adopt the proposed agenda as outlined above.

1.3. Working Arrangements/Schedule of Session

The team agreed to the arrangements and schedule for the meeting in accordance with that proposed in document 1.3(1), with the meeting conducted partly in plenary to discuss and deliberate on the content and decisions within documents submitted to the Document Plan and also within groups, later during the meeting, so as to plan and advance key aspects of the team's Work Plan.

2. Report of the Chair

The Chair made a presentation to the meeting on the status of the ET-AO Work Plan highlighting the achievements and progress that had been made in particular since the first session of the team, which was held in conjunction with the Commission for Basic Systems Expert Team on Aircraft-Based Observing Systems in December, 2015 in Casablanca, Morocco.

The Chair reported since 2014 (Decision at 16th Session of CIMO), ET-AO has continued to be a component of the Aircraft-based Observations Programme (ABOP) in co-operation with CBS ET-ABO. A regular discussion within the ET-AO membership along with collaborative dialogue with CBS ET-ABO ensures appropriate assignment of ABOP developments and objectives.

The last full ET-AO meeting was held in conjunction with CBS ET-ABO in Casablanca 7-11th December 2015. Since then, there have been several ET-AO WebEx sessions with extensive use of email and telephone contact within the Membership about Work Plan activities and Budget reviews.

Since the first session, the Chair had attended several ABOP meetings representing ET-AO and various aviation related meetings that had relevance to ET-AO activities, including:

1. AEEC Data Link Systems Sub-Committee, London 26-27th July 2016.

2. CBS ET-ABO Workshop (RA IV), Panama 17-18th August 2016.
3. AEEC Data Link Systems Sub-Committee (WebEx) 29-30th November 2016.
4. WMO ABOP Management Meeting, NOAA Silver Spring 14-16th February 2017.
5. CBS ET-ABO-3 and Workshop (RA V), Jakarta 22-25th May 2017.
6. AEEC Data link Users Forum (DLUF), Brussels 12-13th September 2017.
7. IATA Drones Lab (UAVs), Barcelona 3-4th October 2017.
8. AEEC Systems Architecture and Infrastructure (SAI), Brussels 17th October 2017 (NOTE: attendance cancelled due to illness)
9. IATA and WMO Workshop (RA VI), Budapest 7-8th December 2017.
10. WMO ABOP Management Meeting, NOAA College Park 12-14th March 2018.
- 1) In plans:
11. IATA and WMO Workshop (RA II), Hong Kong 29-30th May 2018.
12. IATA and WMO Workshop (RA III), Buenos Aires, 5-6th December 2018.

2.1. Status of Work Plan

The Work Plan and associated Budget for ET-AO activities were reviewed and updated during December 2017 in collaboration with the CBS/ET-ABO and approved by CIMO in January 2018.

During the reporting period, several of the Work Plan tasks have been completed with others advanced closer to completion (tasks are evaluated using % values). The completed tasks include realisation of the B777 software now providing valuable data over Africa, Indian Ocean and eastern Pacific regions, the drafting of an IOM report on validation of the WVSS-II sensor and integration of WVM and Turbulence Reporting into ABOP Strategy and Implementation Plans (A-SIP). Other tasks that are still ongoing will be reviewed during the meeting to determine requirements and plans for their completion.

The meeting agreed that there was a requirement for the expert team to take a more active role in coordinating activities and tasks relating to Unmanned Aerial Vehicles (UAV) and in particular the transition of such systems from the research domain to operations. In doing so, it would be important to consider how best to take advantage of partnerships with other UAV users and operators outside the meteorological domain and also to facilitate the provision of data from voluntary or cooperative sources under the so-called "crowd sourcing" model. This matter is discussed in more detail under item 3.9.

Under agenda item 4, the team would undertake a complete review of the work plan and under item 5, determine the requirements of the team for reporting to CIMO.

2.2. Interaction with CBS ET-ABO

The meeting agreed that a primary decision of the team was to make a recommendation to CIMO on the possibility and means to collaborate more closely with CBS and other technical commissions, agreeing that an amalgamation of the CIMO ET-AO and CBS ET-ABO appeared to be a likely outcome. This matter is discussed and reported on in more detail under items 4 and 5.

2.3. Update on IATA and WMO Collaboration on AMDAR (IWCAP)

Mr Dean Lockett, the Secretariat, made a presentation to the meeting on the status and progress made in relation to the developing collaboration between WMO and IATA on the future operation of the AMDAR observing system and programme. In particular, the meeting was informed that:

- The development of the draft proposed Concept of Operations for the IATA-WMO Collaborative AMDAR Programme (IWCAP) had progressed over 2017 with an initial draft completed in 2017, following the recommendation by ET-ABO (May 2017) to endorse the collaboration and the subsequent formation of a Working Arrangement between the two organizations undertaken in July 2017 to define the terms and process under which the collaboration would be developed.
- The WMO Regional Association VI (Europe) had made the decision to endeavour to form the initial operational regional programme under the IWCAP, subject to the final decision of WMO Congress to approve the collaboration and the IWCAP in 2019 (Cg-18), with operations to commence in 2020 after a development period over 2019.
- Following consideration of relevant materials submitted by the CBS Implementation and Coordination Team on Integrated Observing Systems (ICT-IOS), CBS had also endorsed the further ongoing development of the IWCAP and its Technical Conference in March 2018 and made the decision to form the Task Team on the IATA-WMO Collaboration on AMDAR (TT-IWCA). The team would take primary responsibility for coordinating the further development of the relevant documentation and the processes for implementing the IWCAP leading up to the subsequent meetings of WMO Executive Council (EC-70, June 2018) and Congress (June 2019).

The current proposed Concept of Operations was described to the participants, along with the expected process and key milestones leading to the ultimate decision by WMO Congress on whether to proceed with the establishment of the collaboration with IATA.

The meeting agreed that the outcome might have a significant impact of the future work plan of the team and its activities related to the AMDAR observing system, although that depended to a large extent on the contribution and role of IATA and its various working groups and bodies under the collaborative programme.

3. Progress Reports and Status of ET-AO Work Plan

3.1. Status Report on WP Task 3 - AMDAR Temperature Bias

Dr Siebren De Haan, the Netherlands made a presentation to the meeting on the progress made in relation to the investigation into and analysis of air temperature bias in the AMDAR observing system that has been an ongoing concern of the programme and data users for many years. The key findings, outcomes and recommendations from this work would be provided within a developing paper titled, *AMDAR Temperature Bias and the Exploitation of Mode-S EHS Registers*. In describing the progress made, Dr De Haan explained that:

- Knowledge about the error characteristics was crucial for correct interpretation of the observation and the presence of biases, which are manifested as persistent constant differences between observation and model, are detrimental to Numerical Weather Prediction performance.
- The signature of the temperature bias from AMDAR observations was being investigated and characterized, by assuming that the observed total bias consists of a flight phase depending part, a Mach number related part, and a constant part.

Dr De Haan expected that the final version would be ready for consideration and review by the team and later for publication as an IOM report by early in the 4th quarter of 2018.

3.2. Update on WP Task 5 - Planning & Implementation of Water Vapour Measurement (WVM)

Dr Axel Hoff made a presentation to the team on the status and progress made in planning and implementing water vapour measurement in the ABO programme. Dr Hoff informed the meeting that:

- 148 aircraft (USA: 139, Europe: 9) of the worldwide AMDAR fleets had been equipped with the Water Vapour Sensing System (WVSS-II), which is based on a Laser absorption air sampling method. The densest coverage based on 139 Boeing aircraft is over the continental USA. In comparison, the 9 Airbus A320 units over Europe provide a correspondingly smaller density of profiles. Around the world, 23 units of WVSS II were also in use for research applications. Quality control results have shown that humidity derived from WVSS-II to be of very high quality, with biases measured with reference to the first guess fields of numerical models to be consistently in the range of a few percent of relative humidity only. Additionally, these sensors a long record of stable and reliable operation for many years now, demonstrating very little need for operational intervention, replacement or recalibration.
- About 400 aircraft worldwide had been equipped with the Panasonic Avionics Corporation (PAC), Tropospheric Airborne Meteorological Data Reporting (TAMDAR), which uses capacitive sensors to measure and report Relative Humidity. This system sends its data via a satellite connection (IRIDIUM or other Ku-band satellites) to the central data management hub of Panasonic which, subject to a contractual arrangement with a partner NMHSs can receive these and other meteorological data for national applications exclusively.
- In Germany, Deutscher Wetterdienst (DWD) was working with the Lufthansa group on the formulation of a possible joint project that might lead to the installation of WVSS II on 50 to 100 Lufthansa aircraft to support the provision of humidity data to improve weather forecasting and services and also contribute to detailed study and analysis into their viability and utility as an input to various aircraft flight safety and management applications. An additional aspect of the project would be to test the use of the aircraft satellite connectivity to facilitate data relay as an alternative to the use of the Aircraft Communications and Reporting System (ACARS), with the potential to make aircraft to ground data transfer significantly cheaper.

The meeting discussed the issue of humidity measurements derived from the E-AMDAR AMDAR/WVSS-II programme, where it was possible to derived humidity measurements greater than 100%, which were likely indicative of the presence of solid state water in the measured air sample and might be retained and utilised by data users. It was believed that, in the USA, such values of > 100% were methodically reduced to 100%, although it was not clearly understood where and how this data adjustment was being made prior to data being transmitted on the WMO Information System, Global Telecommunications System.

Dr Hoff also provided a brief presentation of results from the ongoing testing of 2 WVSS-II units on-board the UK Met Office and the Natural Environment Research Council (NERC), Facility for Airborne Atmospheric Measurements (FAAM) aircraft, informing the meeting that, as previously planned, the 2 sensors had exchanged deployment places early in 2018 on the aircraft to test the exposure location and method as a factor in the quality of derived data. The testing had demonstrated that the two sensors were consistent across all mixing ratios down to around 0.05 g/m³, below which the sensor capabilities were known to be limited.

The meeting agreed with the following recommendations and actions:

1. WMO Members should be encouraged to increase their efforts to work with airline partners to increase the installation of humidity sensors and extend the coverage of ABO humidity measurement.

2. The upcoming cooperation between WMO and IATA should aim to assist and encourage the respective memberships of the two organisations to also collaborate on the expansion of water vapour measurement with a major focus on reducing costs through aviation industry cooperation on standardisation of relevant sensors, software and implementation processes. In addition to measuring the benefit and impact of water vapour measurement by meteorological applications, this initiative should also focus on possible benefits and applications for aircraft safety and flight management. [**Action:** Secretariat to ensure CBS TT-IWCA incorporates this in ConOps, end-2018]
3. A calibration check of the two WVSS-II sensors on the FAAM aircraft was requested to be made. [**Action:** Chair/ET-AO, request by end-2018, results by end-2018]
4. CBS/ET-ABO to be requested to consider and formulate a position on requirements for processing WVSS-II humidity data to handle +100% humidity values. [**Action:** Secretariat to convey to ET-ABO, Jul 2018]

A more detailed summary on the status of ABO water vapour measurement is provided in [Annex II](#).

3.3. Update on WP Task 6 - Planning & Implementation of EDR Turbulence

Dr Greg Meymaris provided the meeting with a report on the status and progress made in the planning and implementation of turbulence as a component of the ABOP. The meeting was informed that:

- Unexpected turbulence encounters are a leading source of occupant injuries. Costs from injuries, aircraft damage, inspection and maintenance, and delays are significant. Because turbulence is often invisible to both pilots and remote sensing devices (e.g. radar), in situ aircraft observations are a critical piece of the turbulence mitigation puzzle.
- There are now three known versions of operational in situ turbulence reporting algorithm, which report eddy dissipation rate (EDR). Technically, EDR (defined as the cube root of the eddy dissipation rate) is what is generally reported.
- Under Task 6 of the ET-AO work plan, the team had now developed and incorporated the "EDR Implementation Plan" within the wider ABOP Strategy and Implementation Plan" that focuses on EDR reporting as part of the AMDAR program – See Annex 3 of the A-SIP¹.
- The team was now focusing on task 7 of the work plan which was to: Undertake the actions based on the strategies developed within the EDR Implementation Plan.
- At the current time, there were essentially two solutions available to support EDR derivation according to the National Centres for Atmospheric Research (NCAR) defined algorithm. The first was being facilitated by NCAR by integrating and tuning of the NCAR-provided software for Aircraft Condition Monitoring System (ACMS) avionics systems, available via a UCAR Tech Transfer package. The second solution had been facilitated by deployment of the NCAR algorithms within the Electronic Flight Bag (EFB), which receives the required input data via WIFI in the cockpit of the aircraft.
- For each aircraft model/avionics system application of EDR monitoring, a calibration/tuning process of the software was required to ensure sufficient data quality.

¹ Available at: <https://my.alfresco.com/share/s/LrBlaciORTqvnI5b2oZavA>

- Care must be taken to ensure EDR reporting does not interfere with the normal reporting of AMDAR or other ABOP related data.
- A list of airlines and systems installed is provided in Annex III

The team agreed on the following:

- A log of avionics and aircraft for which turbulence applications had been developed should be maintained as a component of the ET-AO work plan Task 10. [**Action:** ET-AO]
- The upcoming meeting of the AEEC DataLink Users Forum (DLUF) in September 2018 should be used to promote the development of turbulence monitoring as a component of the AMDAR observing system and under the IATA-WMO collaboration. [**Action:** Chair/ET-AO, Sep. 2018]

A more detailed summary of the status of EDR implementation is provided within [Annex III](#).

3.4. Update on WP Task 10 - Developments with AMDAR Software

Interaction with Avionics Applications Developers

Mr Dean Lockett, the Secretariat, provided a brief presentation on the status of work plan task 10 and the coordination of the development of AMDAR Onboard Software (AOS). This is an ongoing task to interact with commercial avionics developers towards a more standardised approach to AMDAR Onboard Software (AOS) availability, to enable easy retrofit or factory-floor/line-fit delivery of AOS in support of the AMDAR programme. Such development should be based on the AMDAR Onboard Software Functional Requirements Specification². The actions related to this task are:

- 1) Approach Teledyne Controls re AOSFRS implementation
- 2) Approach other avionics vendors
- 3) Follow up during Q1/2017
- 4) Continue discussions with vendors

Also related to this activity are the 2 other sub-tasks under task 10: i) Development of Generic AMDAR Onboard Software Modules and ii) Avionics Vendors Conference.

While the Secretariat and Chair of ET-AO have had informal meetings and teleconferences with Teledyne (Geneva, Switzerland, 2013 and 2014) on the possibility of supporting AOS, a way forward with a business case for the avionics vendor has not been found. Some ad hoc discussion has also taken place with representatives of Honeywell with a view to a similar arrangement for standardised availability of AOS for suitable data acquisition systems.

More recently, the team had adopted the approach to progress this task through the concept of the Generic AOS Modules and the idea to host an Avionics Vendors Conference. However, despite plans over the past couple of years to hold such a conference, other priorities have prevented this task from being significantly advanced.

The development of the collaboration with IATA potentially offers the team an alternative approach to this task by seeking to involve IATA in the approach to avionics vendors and developers, many of which are IATA members. It is recommended that the team might consider an appropriate strategy and steps for such an approach.

Other Issues Relating to AMDAR Onboard Software

² See : [AMDAR Onboard Software Functional Requirements Specification: \(Version 1.1, 2 June 2014\)](#), IOM Report- No. 115

A database of known AOS implementations by WMO Members has been compiled and is available via the WMO website³. This metadata will eventually become a part of the Aircraft-Based Observing System metadata repository within OSCAR/Surface.

Guidance on AOS development is also available in WMO-No. 1200, Guide to Aircraft-Based Observations, Appendix F.

The CBS Expert Team on Aircraft-Based Observing Systems (ET-ABO) has instigated consultancy work to update the AMDAR Coverage & Targeting for Future Airline Recruitment Report. The work commenced in April 2018 and is expected to be concluded in Q4 2018. Within the Description of Work (Annex 1), there are several aspects relating to AOS, including:

- Provision of prospective target airline information relating to avionics and communications systems deployed.
- A requirement to take into account potential availability of existing AOS for target fleets.

The team agreed on the following actions:

1. The ET-AO should develop a new strategy to attempt to steer the aviation/avionics vendor community towards provision of off-the-shelf AMDAR Onboard Software availability for key avionics/communications platforms, taking into account the likely collaboration with IATA on AMDAR. [ET-AO, Next inter-sessional period]
2. To review the description of work from the study and provide guidance on expectations from the work of the consultant. [ET-AO, During ET-AO-2]

3.5. Update on WP Task 15 - AMDAR and WVSS Inter-comparison Study

Dr Siebren De Haan, provided feedback to the team on the status of Task 15 to develop a strategy for AMDAR and WVSS-II inter-comparison, advising that data collection was underway and that a report would be produced later in 2018.

Dr De Haan expected to summarise the analysis of the inter-comparison and provide a proposed draft version for consideration and review by the team and later publication as an IOM report by early in the 4th quarter of 2018.

3.6. Update on WP Task 16 - Validation of WVSS Paper

Mr Bryce Ford, the Association of Hydro-Meteorological Equipment Industry (HMEI), provided a summary of the status of Task 16 of the work plan. The draft Instruments and Observing Methods (IOM) report provides a complete history of the testing and validation of the WVSS-II system for use as a component of an AMDAR observing system. The meeting and the ET-AO was invited to review, update and finalise the IOM with a view to its publication in the 3rd quarter of 2018. [**Action:** ET-AO to provide final version of IOM for CIMO review, Jul. 2018]

Mr Ford also made a presentation on the updated results of long-term testing of the stability of two WVSS-II units used in a non-operational test environment, which demonstrated that the sensors operated with no intervention over periods of 8 years of continuous operation. The data for this analysis was based on testing of two units in a continuous non-flight test environment at the manufacturers facility, with periodic testing of the 4-point calibration performed. This update extends the previously documented test period from 5 years to 8 years. The results showed that there was no need to routinely calibrate the sensors and that recalibration should be undertaken only in response to detection of a significant issue from data quality monitoring. Previous analysis of operational units deployed in the USA AMDAR programme through comparison of the sensor performance to Numerical Weather Prediction over a period of 5 years has previously been documented by SpectraSensors, and is consistent with these results. More detail on the updated non-operational testing and the original

³ [List of AMDAR Onboard Software by Avionics & Programme](#) (Version: August, 2016)

operational analysis was available in the report by SpectraSensors Inc., *Long Term Tests and Operational Evaluations of the Water Vapor Sensing System, WVSS-II*, Document Number: 01023-71246, Revision B.

3.7. Update on WP Task 17 - Review & Update of Regulatory Material

Mr Lockett presented document 3.7 to the meeting, summarising the status and progress made by the team in maintaining WMO regulatory and guidance materials related to aircraft-based observations. In particular, the ET-AO was proposing an update to WMO-No. 8, Part II, Chapter III, Aircraft-Based Observations. The team agreed that the chapter should be submitted to the CIMO Editorial Board for review and finalisation for submission to the CIMO session in October 2018. [**Action:** the Secretariat to coordinate provision of the proposed update to CIMO/Editorial Board and the CIMO session in October 2018]

3.8. Update on WP Task 18 - Representation at Aviation Forums/Meetings

Mr Stewart Taylor provided the meeting with a summary of the various aviation forums and meetings that had been attended to support the ongoing process of ET-AO coordination with and outreach to the aviation industry on ABO-related standards and programme development. In particular, Mr Taylor noted that the key activities associated with Work Plan Task 18 were:

- Developing and maintaining a list of aviation committees and contact points,
- Membership of RTCA and, where applicable, aviation groups,
- Review of aviation groups and regulatory bodies to determine any developments relevant to ABO.

In relation to these activities, the Secretariat had compiled a list of known WMO member representatives to aviation groups and forums on the ABOP Google Sites wiki. This included membership of several Airlines Electronic Engineering Committee AEEC and Radio Technical Commission for Aeronautics (RTCA) groups and committees that reported back to WMO ABO expert teams.

A list of groups of at least potential interest for the work of ET-AO is provided within [Annex IV](#).

The team agreed that it should consider representation at the following meetings to be held later in 2018:

- AMC and AEEC General Session: April 23-26th Miami.
- EFB User Forum: May 15-17th Miami. This is being held jointly with IATA EFB Task Force.
- SAI SC: June 14-15th Memphis.
- AEEC DLUF: September 18-19th Brussels. It should be noted that ABOP had to cancel attendance at the last DLUF (February 13-14th Miami) and missed an opportunity to raise the issues of AMDAR in the discussions regarding ACARS over Internet Protocol (IP). At the February meeting, several organisations provided information on their proposals for implementation of ACARS over IP.

3.9. Update on WP Task 21 - UAV Technology

Mr Taylor presented document 3.9 to the meeting, providing a summary of developments in the area of Unmanned Aerial Vehicles (UAV) in both aviation and for meteorological applications and his attendance at several events and forums where this matter was addressed. Within the work plan of the team under Task 21, the monitoring of the UAV market with regards to Task 21 of the ET-AO Work Plan was an ongoing activity. Mr Taylor reported that:

- Several advances have been made with regards to UAV developments to host meteorological payloads, the integration of UAVs into shared airspace and the wider promotion of societal and environmental benefits of the use of UAVs e.g., emergency services.
- Over the past decade or so, there had been a continued expansion of the use of UAVs by both professionals and enthusiasts and therefore the opportunities for meteorological data provision via such platforms had also increased, particularly if appropriate partners with similar interest and a suitable business case could be identified.
- While the use of UAVs for operational meteorological data collection was clearly viable and presented a great opportunity in the development and expansion of the ABO programme, there were also clearly many aspects that needed to be addressed in order to move forward, including: airspace management, safety and data policy and management with partners. However, the relevant regulatory bodies were already pro-active and advanced in relation to the regulatory and safety aspects.

Summary of development areas

It was agreed that the ET-AO would continue to keep abreast of developments in this area, in particular through keeping a watch on the activities of relevant bodies and organizations such as:

- Regulatory bodies – FAA, ICAO, SESAR
- UAV hardware and software – manufacturers and sales companies
- NMHSs – use of UAVs in research and development
- Airlines – use of UAVs for maintenance work
- Public Services – use of UAVs by Emergency Services, Border control and Coastguards
- Universities – research work.

A more detailed summary of activities and developments relating to UAVs is provided within [Annex V](#).

In discussing this matter further the team reached the following conclusions:

- It was clear that UAVs might play a greater role in the provision of upper-air meteorological observations in the future, particularly if this technology might be transitioned to operations and also if the concept of “crowd sourcing” could be harnessed through partnerships with both the private industry and the public at large.
- Several NMHSs were investigating the possibility to utilise UAVs as a component of their operational observing systems, including the Bureau of Meteorology, Australia and the Met Office, UK.
- In order to determine possibilities, requirements and expectations of Members, the team should request CIMO to consider the possibility to approve the team to hold a WMO sponsored workshop on the operational use of UAVs and drone technology, perhaps taking place in early 2019.
- The team might undertake an activity to coordinate a pilot project, possibly conducted in collaboration with a research institution, to test the viability and requirements for

several private operators of UAV systems to contribute data to a central data reception and processing centre.

It was agreed that, during the session, the team would develop the concepts and terms of reference for the above two proposed activities.

The following actions were agreed:

1. The Chair and the Secretariat to make a recommendation to CIMO that the team should undertake a workshop on UAV systems in 2019.
2. The Chair and the Secretariat to make a recommendation to CIMO that the team should conduct a pilot project on operational provision of upper-air data from private and public UAV systems.
3. The Chair and the Secretariat to recommend to CIMO that the upcoming upper-air inter-comparison event conducted by CIMO (2019/2020) should consider the possibility to include UAV systems.

3.10. Update on WP Task 22 - Reporting and Encoding Requirements

The meeting discussed matters relevant to Task 22 of the work plan relating to reporting and encoding requirements for ABO. It was agreed that there were no outstanding issues relating to the AMDAR BUFR Template (3 11 010) and this task could be considered and indicated as completed.

It was reported that the Aircraft Derived Data project under EUMETNET and in collaboration with the Single European Sky ATM Research (SESAR) Joint Undertaking, would likely transition to operation during the next programme phase and that this would lead to the development of a BUFR format for exchange of high resolution ABO data. The team agreed that it would be important to include a task on the transition to operation of ADD from the Mode S system including the coordination of encoding formats. [**Action:** Chair to include new task in work plan on Mode S, ET-AO-2]

4. Update and Planning of Work Programme

4.1. Work Programme Deliverables

The meeting agreed to work on various aspects and tasks of the work plan in groups to further plans and outputs associated with their completion and ahead of a review of the full work plan and budget in plenary. These groups addressed the following tasks and activities:

1. Review and update of proposed IOM on WVSS-II validation (item 3.6)
2. Terms of Reference for inter-programme/inter-commission team on ABO
3. Review of IATA-WMO Collaborative AMDAR Programme ConOps
4. Review Vision for the future of environmental measurements with respect to ABO.
5. Review description of work for update of study on target airlines for AMDAR, WVM and turbulence with respect to task 10.
6. UAV research project aimed at testing the crowd-sourcing concept
7. Workshop on use of UAVs in operational meteorology (with 2 central themes of crowd-sourcing and taking research systems to operations)

8. ABO input to CIMO upper-air inter-comparison

Reports and output of the work from each of these groups is provided in [Annex VI](#).

4.2. Revision of Work Plan and Budget 2018

The meeting undertook a review of the work plan and associated budget based on the recent outcomes and progress made and on the deliberations and decisions made during the meeting. The proposed revised updated work plan is provided within [Annex VII](#).

4.3. Review of ET-AO Terms of Reference (ToR)

In light of the agreement in relation to the presentation made by the Secretariat within item 5.1 and the recommendation to be made to CIMO to consider the formation of an Inter-Programme Expert Team on aircraft-based observations and observing systems, the team agreed on proposed Terms of Reference for such a team as provided within [Annex VI](#).

5. Reporting to CIMO

5.1. WMO Constituent Body Reform and New Vision for the future of environmental measurements within WIGOS and the new CIMO Structure

Mr Dean Lockett, the Secretariat, made a presentation to the meeting on the current activities under the WMO Executive Council to review the current structure of the WMO constituent bodies under the expectation that a significantly revised structure will be proposed to WMO Congress in 2019 (Cg-18). Given that a primary aim and expectation of the restructure will be a reduction in the number of WMO technical commissions and a minimal number of working groups so as to increase and improve efficiencies in WMO activities, it was agreed that the team should consider the possibility of, and requirements for a single working group on aircraft-based observations under the new WMO structure. To this end, the meeting considered the ongoing activities and tasks of both the CBS Expert Team on aircraft-based observations and systems for consideration by the CBS and CIMO technical commissions.

The meeting recommended that either of these two technical commissions could appropriately be responsible for the instigation of such a team but that both commissions should have oversight of its work plan and associated activities, while also seeking input and collaboration with other relevant commissions and WMO programmes.

5.2. Requirements for Reporting to CIMO

In addition to the expected reporting of outcomes and achievements of the work of the ET-AO, the Chair should report specifically and request decisions on the following proposed activities:

1. The holding of a workshop and the undertaking of a pilot project on UAVs – see agenda item 3.10; and,
2. The recommendation to amalgamate the WMO expert teams on aircraft-based observations into a single inter-programme expert team on aircraft-based observations – see agenda items 5.1 and 4.3

5.3. Recommendations to CIMO

See item 5.2 above.

6. Any Other Business

Presentation and Discussions with Panasonic Avionics Corporation

During the meeting, the participants were provided with a presentation by Mr Jeff Rex and Mr Bill Edgar from Panasonic Avionics Corporation (PAC) regarding the latest developments in

relation to the Tropospheric Airborne Meteorological Data Reporting (TAMDAR) system and other activities relating to and relevant to aircraft-based observations. Of interest to the meeting was that:

- In addition to continuing to maintain and expand its TAMDAR network which now is deployed on over 300 aircraft, PAC was an active participant and provider for the "Connected Aircraft" concept which aims to provide commercial aircraft, including both crew and passengers with in-cabin and inflight WIFI and air-to-ground data communications via satellite systems.
- PAC offers two possible solutions for this via both a higher frequency (Ku-band) option providing broadband connectivity over a large part of the globe, whilst also offering connectivity via the Iridium satellite constellation offering narrower bandwidth with a global coverage.
- PAC also provides many airlines with their In-Flight Entertainment (IFE) passenger service system that can also potentially facilitate the demonstrated provision of aircraft-based observations of air temperature and wind as a service to NMHSs and other customers. In this regard the Ku-band communications offers best opportunities for AMDAR data communications with over 2000 PAC systems now installed on larger, chiefly international, long-haul aircraft.
- PAC have developed a solution to provide AMDAR-like data via the IFE systems which can provide data at up to 4 times the frequency of reporting traditional AMDAR data and at a much-reduced cost.

The meeting agreed that the team should follow up with PAC subsequent to the meeting with the aim to discuss a possible collaboration with WMO and its member NMHSs for provision of IFE ABO data. [**Action:** ET-AO, the Secretariat, 2nd half 2018]

Liquid Content from B787 Rosemount Icing Sensor

Mr Douglas Body made a short presentation to the meeting on the recent information and discussions that had taken place with and between various stakeholders relating to the possible derivation of a measure of liquid water content as a possible output from the Rosemount Icing Sensor currently deployed on Boeing B787 aircraft. Mr Body informed the meeting that:

- An engineer from Qantas had contacted the Bureau in late 2017 about the Rosemount sensor deployed on B787 aircraft, which was comprised of dual platinum resistance sensors for both wet and dry conditions and reported a "delta voltage". Based on this, it was considered possible that a "delta temperature" might be derived and used as a proxy measurement of liquid water content.
- While this might not allow a consistent or accurate derivation of water vapour or humidity, it was thought that it might still potentially be a useful measurement to report from these aircraft within an AMDAR application.
- Qantas has developed a special message to downlink the values for analysis. Contacts from British Airways are also looking into this matter.

It was agreed that the ET-AO should continue to monitor developments and outcomes related to this activity. [**Action:** ET-AO to monitor developments relating to water content from B787 Rosemount icing sensor, Ongoing]

7. Actions and Report of the Session

It was agreed by the meeting that the Secretariat would produce a draft report of the session and submit to the team for review by email following the meeting.

8. Closure of Session

After thanking the Secretariat and participants for their contributions to the meeting, the session was closed by the Chair around mid-afternoon of the 19 April, 2018.

ANNEX I – LIST OF PARTICIPANTS

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ANNEX II – SUMMARY OF CURRENT STATUS OF ABO WATER VAPOUR MEASUREMENTS

1. Introduction

The USA National Oceanic and Atmospheric Administration’s National Weather Service (NOAA/NWS) does its aircraft-based Water Vapor Measurement (WVM) program within WMO Region IV. All WVM data is being made available on the GTS in real-time. Additionally some Relative Humidity reports are acquired by NOAA/NWS for internal use, but are not shared on the GTS due to contractual limitations with regard to distribution.

2. The Aircraft with Humidity Instruments

There are two different kinds of measurement systems in use. Some aircraft of the AMDAR fleets have been equipped with the instrument type WVSS-II, which is a laser based Water Vapor Sensing System. The systems’ output is fed into AMDAR’s data infrastructure. Via the data flow of ACARS the measurements are sent directly to the corresponding NMHS who is allowed to feed the data into the GTS/WIS.

The U.S. WVM network implementation with WVSS-II is a Public Private Partnership between NOAA/NWS, Rockwell Collins/ARINC, and partner airlines, United Parcel Service and Southwest Airlines. There are currently 139 WVSS-II equipped aircraft operating in the U.S. network. All WVM data in the U.S. Network is distributed by NOAA/NWS to the GTS in real-time. Figure 1, courtesy of NOAA/ESRL/GSD, shows a global coverage of ABO data with WVM over a typical 24-hour period (7th of March 2018).

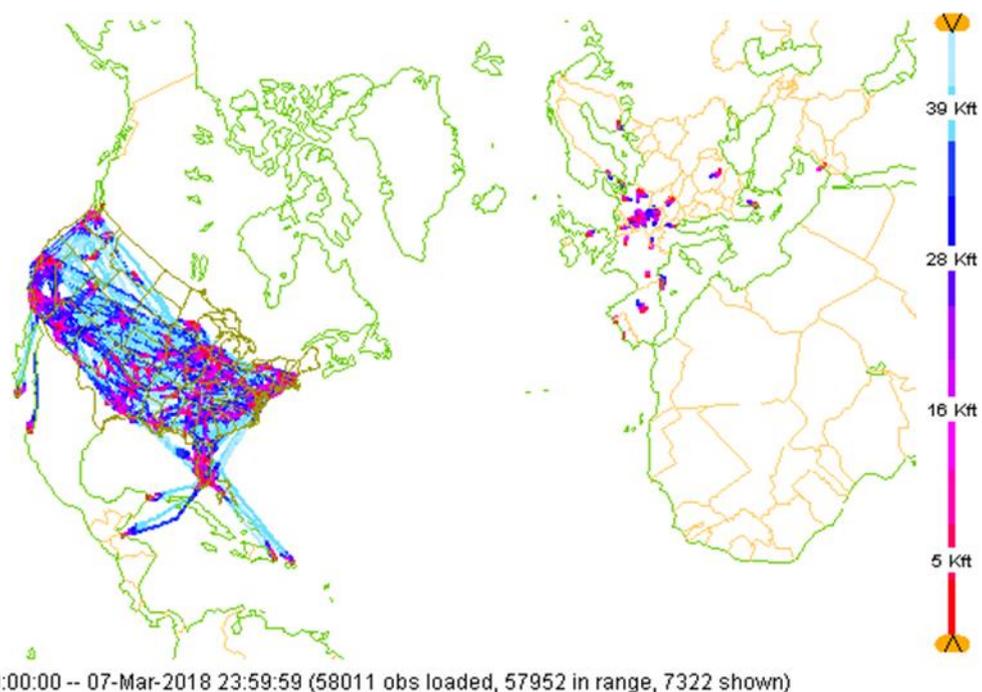


Fig 1: Global coverage of WVM data from WVSS-II equipped aircraft in a typical 24 hour period (7th of March 2018).

Courtesy of NOAA/Earth System Research Laboratory/Global Systems Division (NOAA/ESRL/GSD)

In May 2017 the U.S. Federal Aviation Administration (FAA) has accepted the Supplemental Type Certification (STC) for the A320 family configuration of WVSS-II, held by Lufthansa

Technik. The A320 family configuration includes the A319, A320, and A321 aircraft types. The STC for the A320 family configuration of WVSS-II previously was approved by the European Aviation Safety Agency (EASA), and then was submitted for review by the FAA. The FAA approval of the A320 family STC for WVSS-II increases the potential WVSS-II fleet in the U.S. by over 700 aircraft. With the A320 configuration STC approved by the EASA and the FAA, it is now the most widely accepted configuration of WVSS-II.

About 400 aircraft implementations have the TAMDAR equipment onboard, which uses capacitive Relative Humidity sensors. This system sends its measurement values via a satellite connection (IRIDIUM or Ku-band of other communication satellites) to the central data management hub of Panasonic which provides data to NMHSs contracted to exclusively receive and use the data.

Table 1 gives an overview of the equipped aircraft and the covered regions. Southwest Airlines as well as United Parcel Service are under contract of ARINC belonging to Rockwell Collins. They provide the data to the National Weather Service of NOAA. Lufthansa is contractually linked to DWD belonging to the European [grouping](#) EUMETNET.

Airline	Qty.	Aircraft Types	Covered Area	Data accessible by	Sensor Type
Southwest Airlines	139	Boeing B737-300, B737-700, B737-800	Continental USA, Caribbean, and Central America	all GTS/WIS users	WVSS-II within AMDAR
United Parcel Service		Boeing B757-200PF	Continental USA and Central America	all GTS/WIS users	
Lufthansa	9	Airbus A320 Type Family: A319, A320, A321	Primarily Europe with some flights to Russia and Middle East.	all GTS/WIS users	
Iceland Air	about 400	TBD	Coverage of the Airline around Iceland	Exclusively IMO	TAMDAR (Panasonic)
Regional US airlines		TBD	Continental USA and Alaska	Exclusively NOAA	
Other Airlines		TBD	TBD	Exclusively the contract partners	

Table 1: Overview of the humidity sensor equipped aircraft. "TBD" = to be determined

2.1. The Amount and the Density of Aircraft-based Humidity Observations

The biggest total amount and density of airborne humidity observations is done over the continental USA. The WVSS-II fleet yields about 60,000 observations per day being approximately 1,200 profiles. The coverage is very good. Over the northwest section of the USA the profiles' density is a bit less.

Over Europe the daily amount is about 3,000 observations corresponding to a number of 90 profiles per day. Up to now the sampling activation of the humidity aircraft is not controllable. Hence, the biggest amount of profiles is over Frankfurt and Munich as being the

main hubs of Lufthansa. Lufthansa is working on modified concepts in the communications infrastructure.

Region	Observations per day		Profiles per day	
	AMDAR	TAMDAR	AMDAR	TAMDAR
USA	about 60,000	TBD	approx. 1,200	TBD
Europe (without Iceland)	3,000		90	
Iceland		TBD		TBD

2.2. The Quality of Aircraft-based Humidity Observations

The measurement results of the European aircraft instrumented by WVSS-II are continuously checked against the first guess of the numerical model IFS operated by the ECMWF.

The humidity biases are consistently in a range of a few percent of relative humidity. A small overall tendency to a few percent below the reference may be a property of the sensor principle as well as of the model. Even the principle of the radiosonde measurements may play a role. Those measurements are the biggest part of input into the assimilation and herewith the biggest statistical weight in the reference.

However, the small mean deviations to the model's reference fields are an extremely good result.

2.3. Perspectives

2.3.1. WVSS-II units on the FAAM Research Aircraft

Two units of the WVSS-II are still operated on the research aircraft of FAAM. The instruments have different inlet/outlet probes. The first one is the conventional "Air Sampler" being in use on all AMDAR aircraft instrumented with WVSS-II. The other one is a total air temperature (TAT) housing having an especially adapted inlay. The TAT housing has its intake orifice beyond the air flow's boundary layer of the aircraft's fuselage. The comparisons between these units and other reference sensors on-board lead to the assumption of systematically different thermodynamic effects of the inlet/outlet gadgets in higher altitudes beyond 400 hPa (see Vance et al. 2015). The swapping of the WVSS-II units between the inlet/outlet probes now has been done. A report in the near future will help to decide how far each inlet's aerodynamics has an influence on the measurement results under very cold and dry conditions.

2.3.2. Usability of the Water Vapour Data On-board for Flight Operation and Flight Safety

Between DWD and Lufthansa Technik (LHT) a Memorandum of Understanding has been concluded. It concerns about a possible use of an onboard humidity measurement for an in-situ icing warning and possibly for an economic use of the de-icing energy. Moreover, LHT is working on concepts about the aircraft's communications infrastructure. AMDAR data including turbulence and humidity could be part of these concepts. DWD [endeavours](#) to get the LHT concept in compliance with the latest AOSFRS and/or ARINC 620.

The first step is to equip a large number of Airbus A320 aircraft with WVSS-II. This will be a basis for getting useable statistics about the humidity measurement results in comparison with icing events. Possibly in a second step, the indication in the cockpit about an icing risk being derived from the humidity measurement and other parameters is envisaged.

The usability of the humidity measurement for flight operational purposes immediately on the carrying aircraft itself may get to be the bedrock for having that functionality as standard equipment.

Another very interesting feature of the LHT concept is the use of the satellite connection for the AMDAR data transfer instead of the old VHF ACARS network. This would lead to a faster and cheaper data flow to the NMHSs.

Glossary

ACARS	Aircraft Communications Addressing and Reporting System
AMDAR	Aircraft Meteorological Data Relay
ARINC	Aeronautical Radio Incorporated (since 2013 belonging to Rockwell Collins)
DWD	Deutscher Wetterdienst (German Weather Service)
ECMWF	European Centre for Medium-Range Weather Forecasts
EUMETNET	Grouping of 31 European National Meteorological Services
E-AMDAR	EUMETNET-AMDAR
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FAAM	Facility for Airborne Atmospheric Measurements
GTS	Global Telecommunication System
IFS	Integrated Forecasting System (operated by ECMWF)
IMO	Icelandic Meteorological Office
IRIDIUM	Satellite System for Communication
LHT	Lufthansa Technik AG
NOAA	National Oceanic and Atmospheric Administration, USA
NMHS	National Meteorological and Hydrological Service
TAMDAR	Tropospheric Airborne Meteorological Data Reporting (Panasonic)
TAT	Total Air Temperature (kinetic energy is totally converted into inner energy)
VHF	Very High Frequency (30 - 300 MHz)
WIS	WMO Information System
WVM	Water Vapour Measurement
WVSS-II	Water Vapour Sensing System Number Two (SpectraSensors, Inc.)

ANNEX III – STATUS OF TURBULENCE/EDR IMPLEMENTATION

Task 6

Several airlines outside of the US have been identified to partner for a trial. Development activities are occurring concurrently with all but are at different stages of development. Current partners are Aer Lingus, Air France, Lufthansa, and Qantas. Lufthansa and Aer Lingus are pursuing EFBs as the deployment platform (Air France has shown some interest in this approach as well). Deployments otherwise have been to the Aircraft Condition Monitoring System (ACMS) or similar. This tends to require fairly technical work by either the ACMS providers (e.g. Boeing, Honeywell, Teledyne, etc.) or, in some cases, by the Airline (or an affiliate). There are advantages and challenges with both approaches.

ACMS implementations have the standard approach up to this point, in part, because it was the only viable way to deploy the software. It is difficult to deploy on an ACMS, depending on the provider/manufacture, and is sometimes impossible. In most cases, the provider's/manufacture's involvement is required. This presents some airlines with a cost barrier. Once it is deployed, the EDR software can then operate fairly trouble free, but updates go through the same challenges. Advantages are that in some cases, the EDR option can become an available option for airlines with configurations that have already been implemented.

Electronic Flight Bags (EFBs) are becoming more widely used, with some able to connect to an Aircraft Interface Device (AID), which has some access to data on the on-board databus. If one can access the right data fields (parameters) at high enough sampling rates, and send them to an EFB, then the EFB becomes an attractive computing platform due its far more open nature and possible connectivity to broadband-style downlink. The main challenge is that this is still brand new territory with many unknowns, including the significant issue of data availability of the algorithm inputs.

Coordination assistance continued with Air France and Boeing regarding costs of EDR software. It appears that AF will have some B787 with the EDR software operational.

Task 7

Currently EDR reporting airlines within AMDAR:

- Delta Airlines:
 - Teledyne ACMS -916: B737NG, B767-300/400 [work done by Delta]
 - Boeing ACMS AIMS-2: B777 [work done by Boeing]
- Southwest Airlines: Teledyne -916 B737NG [work done by Teledyne]
- United Airlines: Boeing ACMS AIMS-2: B777, B787 [work done by Boeing]
- Xiamen Airlines: Teledyne ACMS -916(?): B737NG [work done by Delta and Xiamen]

This constitutes roughly 1000 aircraft that are EDR equipped and reporting. EDR reporting numbers are included in the [AMDAR Newsletters](#).

Current list of compatible avionics:

- Boeing AIMS-2 (B777, B787)
- Teledyne ACMS -916 (B737NG, N767-300/400)
- Honeywell ACMS -50(?) (B737NG - no longer currently active)

Current list of compatible aircraft types:

- B737NG (Teledyne -916; Honeywell -50(?))
- B767-300/400 (Teledyne -916)
- B777 (Boeing AIMS-2)

- B787 (Boeing AIMS-2)

There are a number of implementations currently under active development:

- Air France: Boeing ACMS AIMS-2: B787
- Delta Airlines: Teledyne ACMS: A321, A330 [work done by Delta]
- Qantas: Teledyne ACMS: A330 [work done by Qantas/Airdatec/Teledyne]
- Lufthansa: EFBs: A330 or B747.
- Aer Lingus: EFBs: A320 or A330

The current strategy for extending EDR software availability is to work with ACMS manufacturers where possible to increase the available aircraft types/ACMS configuration. Furthermore, investigations are underway to develop implementations on EFBs, which could enhance the ability to increase availability.

EFB Implementations

Currently, two airlines are actively working on EFB implementations: Aer Lingus and Lufthansa. The way an EFB implementation works is through the use of an AID which allows the EFB to receive avionics data. The C-code EDR software library is integrated into an app on the EFB, which receives the required input data, computes the EDR, and then reports the EDR. An aircraft with a broadband-type connection to the ground can use this to report EDR, and other AMDAR data, to the ground.

Both airlines are still in an early phase of development, where the first task is to determine whether the data that is available to the EFB meets algorithm requirements. High-rate (8 Hz) input data has been recorded and analysed from both airlines. As usual, this involves some iteration, which is the current status.

Some issues discovered so far:

- Data normally available on the ACMS are not necessarily available via the AID. There are concerns that this may actually become more problematic in the future.
- There are a number of different types of EFBs, possibly complicating sharing efforts.
- On some types of EFBs, it may be difficult or impossible to have an app that constantly runs in the background.
- For some portable EFBs, there will need to be some careful configuration management in case the same EFB is used on different aircraft types.

RTCA Participation

Several members of the ET-AO team were also on the RTCA SC-206 SG-4 EDR Guidelines committee. The task of the SG-4 team was to write an EDR Guidelines document, DO-370, (initially planned to be an EDR MOPS document; Minimum Operational Performance Standard), as well as supplementary testing materials, with the intent that it would be invoked by the FAA as an aviation circular (AC). The purpose of the EDR Guidelines document was to create test procedures and guidance to ensure comparability of both existing and future EDR algorithms. While ideally, the result would have been test procedures and guidance to ensure operational comparability of *implementations*, this proved unfeasible. By ensuring comparability of EDR algorithms, this strongly limits the ways that implementations could be non-comparable to tuning and data quality issues. The document was formally released in January 2018.

EDR in MODE-S/ADS-Wx

DO-260C and DO-181F are expected to be published in 2019, and changes proposals for inclusion of ADS-Wx parameters are due in June 2018. There is some work underway to add EDR to ADS-B/Wx reporting.

ANNEX IV – AVIATION GROUPS & FORUMS OF INTEREST FOR ABO INTERACTION

- 1) AEEC Systems Architecture and Interfaces (SAI) Sub-Committee – investigation on the application of new technologies, review of avionics manufacturer proposals for new systems and equipment and promotion of standards to meet airline and supplier requirements. The SC also includes work on the ADS-B Programme.
- 2) AEEC Electronic Flight Bag (EFB) Users Forum – a unified forum for airlines, system integrators, hardware/software providers, regulators and **other interested parties** to present and discuss issues of interest to EFB users. Issues include communications interfacing, operational usage and encouragement of harmonised standards and regulations. This is relevant to current ET-AO work with airlines regarding EDR reporting and ACARS downlinking using EFB.
- 3) AEEC Air Ground Communications System (AGCS) Sub-Committee – to ensure current and emerging satellite air-ground communication systems are aligned with airline operational requirements. The AGCS SC is developing and maintaining satcom standards – providing ATI with global air-ground communications capabilities that support character-orientated protocols e.g. ACARS as well as bit-orientated protocols of ADS.
- 4) AEEC Internet Protocol Suite (IPS) for Aeronautical Safety Services – development of industry roadmap. ACARS is aviation unique and somewhat antiquated in the modern communications world. There is a need to modernise this infrastructure to provide robust systems common to both Air Traffic Services (ATS) and aeronautical operational communications (AOC). This project is expected to advance data communications with airline benefits in the form of greater data communications performance compared with ACARS and ATN.
 - a. It should be noted that both AGCS SC and IPS have overlaps with ACARS migration to Internet Protocol (IP) developments.
- 5) Avionics Maintenance Conference (AMC) – normally holds meeting jointly with AEEC General Session. Through AMC Membership, airlines can influence and determine future directions in system design and improved standards of maintenance for avionics. Recent discussions include the ADS-B Mandate and aircraft connectivity via satellite. Also at AMC, several updates to ARINC standards are discussed including satcom connectivity and ACARS over IP.
- 6) Global Aircraft Tracking (GAT) Working Group – preparation of Standards including ground-based and space-based ADS-B and datalink services. The goal is to propose solutions that can positively identify and track aircraft with minimum impact on aircraft production and retrofit. This is where AMDAR should be promoted.

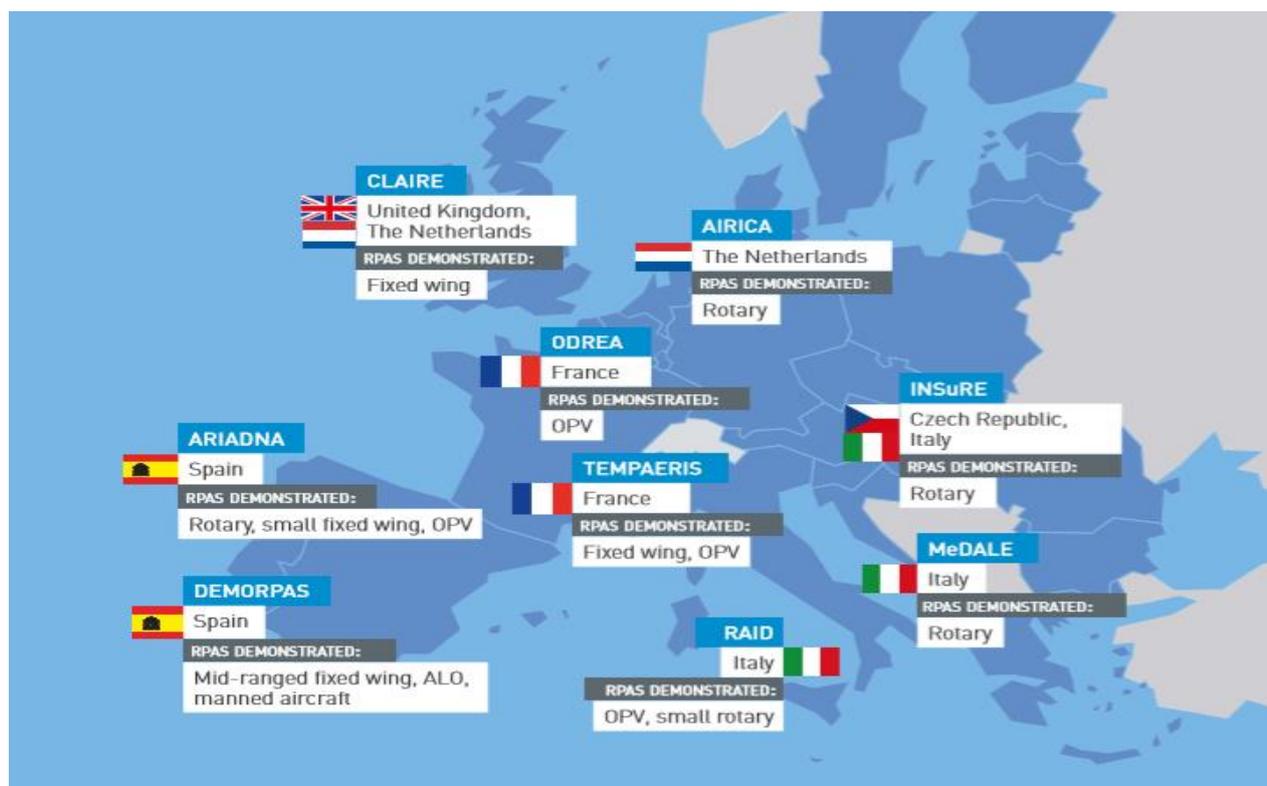
ANNEX V – SUMMARY OF DEVELOPMENTS AND ACTIVITIES RELATED TO UAVS

SESAR published a report describing the increase in the use of UAVs. Ten years ago drones or remotely-piloted aircraft systems (RPAS) were not part of the SESAR Definition Phase as it was impossible to predict at that time the exponential growth of these unmanned aircraft. In line with the European Commission's "Roadmap for the integration of civil RPAS into the European aviation system", the SESAR Joint Undertaking launched its first RPAS activity, the co-funding of nine demonstration projects, these are shown in the graphic below and described in the reference documents [Reference4]. The projects aimed to fly RPAS in non-segregated airspace in order to test what was possible within the current regulatory environment using existing technology.

Building on these demonstration activities and taking input from a wide range of aviation stakeholders, the SESAR JU has since defined how drone research should be conducted in SESAR 2020 in accordance with the 2015 European ATM Master Plan, which captures the research of these aircraft for the first time.

These projects could provide scope for meteorological payloads to be added. Looking towards the future, 7 million consumer leisure RPAS are expected to be operating across Europe and a fleet of 400 000 is expected to be used for commercial and government missions by 2050. RPAS are clearly changing the landscape of aviation and this market has the potential to generate significant and wide-reaching value for Europe.

In the SESAR 2020 Industrial Research programme, RPAS become a new class of airspace user in all concepts so that RPAS issues can be studied alongside those for manned aviation.



- The **ICAO UAS Toolkit**, published in 2016, is under review to take into account developments since initial publication.
- The **UAS Test Centre**, Denmark has increased membership to 165 drone related member companies since 2013.
- In **Russia**, a UAV company has sold over 2000 units to military and civilian customers including orders from Russian Ministry of Emergency Situations.

- In **Kansas, US** [Reference 6] a shared airspace with UAVs and manned aircraft has been deployed.
- **Airlines** are now utilising small UAVs for maintenance work. There could be the opportunity to discuss with the airline and Airport Authorities to make use of UAVs during curfew hours for boundary layer observations prior to morning operations.

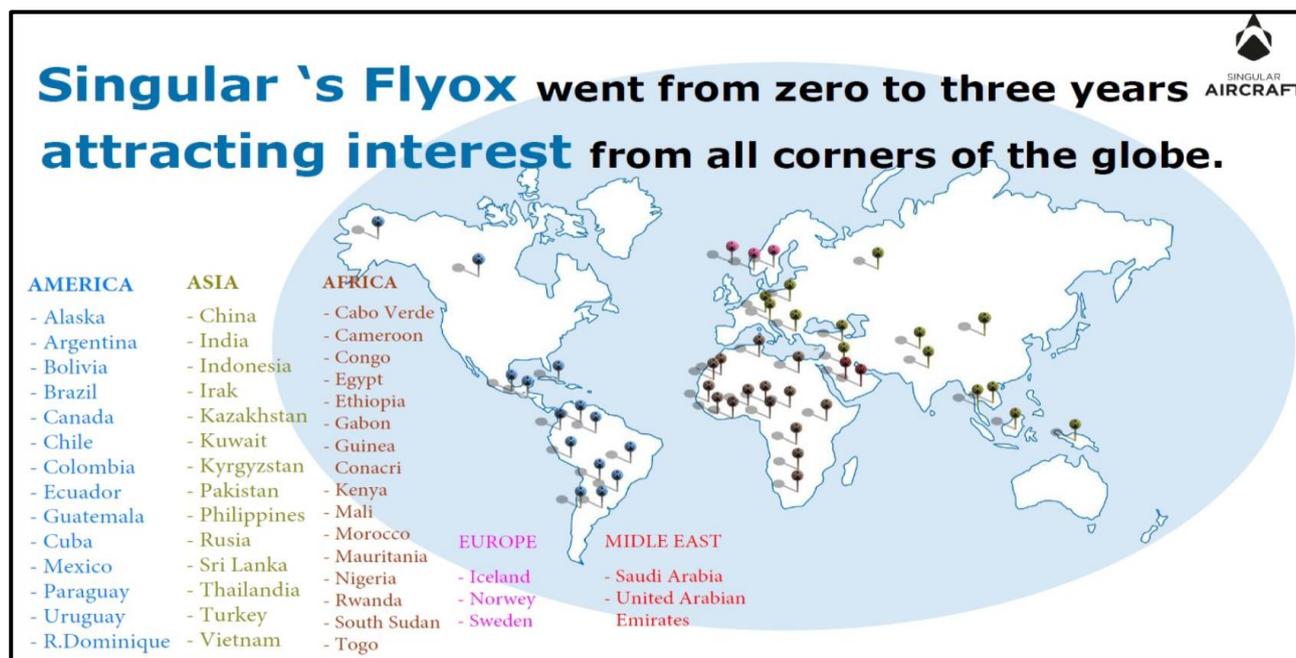
As part of the Task within the Work Plan, several mailshots are now being received which provide updates with regards to UAV developments.

Meetings relating to UAV and ET-AO Work Plan

There are now a few annual conferences and seminars relating to the development of UAVs mainly attended by manufacturers, regulatory bodies, UAV commercial users and enthusiasts.

One meeting attended by Chair ET-AO was the initial **IATA Drones Lab**, Barcelona Oct 2017. This was a very informative meeting and several networking opportunities were discussed. These included humanitarian work in Africa (UNICEF, Wings for Aid) delivering medical supplies and equipment to areas in need. During the meeting, there was discussion of ET-AO possibly presenting to the 2018 IATA Drones Lab meeting.

Another UAV manufacturer, **Singular Aircraft**, has a growing network of customers around the globe – with areas of interest to WMO ABO network expansion (e.g. Africa and Indonesia). The graphic below illustrates the customer coverage for their “Flyox” UAV.



Also in 2017, there was the “**Big Drone Show**” in Canada – this was billed as the largest gathering of UAV professionals and enthusiasts.

ET-AO Work Plan

For 2018, there will also be the **Commercial UAV Show**, London 14-15th November. The Chair ET-AO was contacted by the organisers in January 2018 and invited to speak at the show to present ABO and possible use of UAVs.

With the potential to develop a UAV network providing meteorological data, ET-AO are also looking at the possibility of holding a CIMO Workshop on UAVs.

ANNEX VI – SUMMARY OF OUTPUTS FROM GROUP SESSIONS

ET-AO-2 Breakout Groups

Session 1	Wed 18th AM	Scope
2. Terms of Reference for inter-programme/inter-commission team on ABO	D Lockett	Obtain the ToR for ET-AO and ET-ABO and develop a consolidated set of ToR for a proposed CIMO/IPET-ABO
8. ABO input to CIMO upper-air inter-comparison (Germany, 2019/20)	S Taylor A Hoff D Arodi	Explore ideas for ABO participation (consider UAV, AMDAR, WVSS) • 1-page concept note for consideration of ET-AO
3. Review of IATA-WMO Collaborative AMDAR Programme ConOps	B Ford D Body G Meymaris S de Haan	Review the CONOPs wrt ET-AO and provide recommended response from ET-AO
Session 2	Wed 18th PM	
1. Review and update of proposed IOM on WVSS-II validation (item 3.6)	D Body A Hoff	a. Undertake full review b. Make recommended changes to text c. Identify recommendations to the ET-AO
4. Review Vision for the future of environmental measurements wrt ABO.	D Arodi B Ford A Hoff	Review the Vision in CIMO-MG/Doc 3.2 wrt ABO activities identifying any issues/omissions/additions
6. UAV research project aimed at testing the crowd-sourcing concept	S Taylor Xu J D Arodi	Develop a project outline aimed at a possible university based project to test an end-end crowd-sourcing concept for data delivery from a group of UAV/drone providers including: – data telemetry from the UAV platform (wind, temperature and WVM?) – simple ground-based reception to iphone or similar device – internet transmission via an app – reception at a central hub – quality management
Session 3	Thu 19th AM	
7. Workshop on use of UAVs in operational meteorology	S Taylor Xu J	1-page concept note for a WMO workshop in partnership with a NMHS host – participants (manufacturers and NMHSs) – scope, themes and topics (include 2 above) – etc
5. Review description of work for update of study on target airlines for AMDAR, WVM and turbulence wrt task 10	G Meymaris B Ford S Taylor Xu J	Review DoW wrt work program of ET-AO b. Identify any desirable outcomes wrt ET-AO work program particularly focussing on AOS availability, turbulence implementation, WVM implementation

Review and update of proposed IOM on WVSS-II validation (item 3.6)

The draft IOM was reviewed by group members and plans for finalising a revised version made, to be completed and forward to the Secretariat by end-June 2018 by Mr Doug Body and Mr Axel Hoff.

Terms of Reference for inter-programme/inter-commission team on ABO

A draft proposed Terms of Reference for an Inter-Programme Expert Team on Aircraft-Based Observations, taking into account the ongoing tasks and activities of both the CBS/ET-ABO and CIMO/ET-AO (see summary table below) was developed and finalised by the team as below.

- 1) Develop and manage the work plan and associated activities of the expert team, including the budget for associated expenditure of the AMDAR Trust Fund in line with its Terms of Reference.
- 2) Oversee and report to the Commission on the programmatic, scientific, technical development and operation of aircraft-based observing systems, including AMDAR, Mode-S, ADS and other commercial systems, particularly with respect to instruments and methods of observation under the WMO Integrated Global Observing System (WIGOS).
- 3) Coordinate and report to the Commission on the development, scientific testing, validation and intercomparison of existing and new methods of observation for aircraft-based observing systems, including Unmanned Aerial Vehicles (UAVs), humidity, turbulence and inflight icing.
- 4) Organize and conduct the development, maintenance and provision of technical standards and specifications associated with aircraft-based observations and according to user requirements.
- 5) Oversee the international and regional aspects of management of aircraft-based observational data, including data quality and development and maintenance of the aircraft-based observations component of the WIGOS Data Quality Monitoring System.
- 6) Review outcomes of the Testbed(s) and/or Lead Centre(s) assigned to this Expert Team, and coordinate inclusion of guidance material in IOM reports and WMO-No. 8, Guide to Instruments and Methods of Observations.
- 7) Compile and review updates and new material on aircraft-based observations and observing systems for inclusion in WIGOS and other WMO regulatory and guidance documents, including WMO-No. 8, Guide to Instruments and Methods of Observations, and WMO-No. 1200, Guide to Aircraft-Based Observations.
- 8) Conduct and provide support for training and outreach activities of the Commission and WMO to support the development of aircraft-based observing systems and the use of aircraft-based observations.
- 9) Work in collaboration and cooperation with other teams of the Commission and WMO on the above activities as appropriate and as necessary.

Key Work Plan Activities and Requirements for Expertise

ToR	Task/Activity	Description	Requirements for Expertise
1	Develop, maintain and coordinate activities associated with the work plan of the expert team	<ul style="list-style-type: none"> Develop and maintain planning and budgeting documents 	<ol style="list-style-type: none"> Planning and budgeting skills Meeting coordination skills Ability to chair meetings
2, 5	Development and maintenance of global AMDAR and aircraft-based observations programmes at the regional and global level and under the IATA-WMO collaboration: <ul style="list-style-type: none"> AMDAR UAV ADS Mode S Commercial systems 	<ul style="list-style-type: none"> Collaborate with regional associations on requirements for observations Contribute to planning and budgeting processes Develop the functions and procedures of the data quality monitoring system and its associated WIGOS centres Liaison with relevant aviation bodies, committees, international organisations, etc 	<ol style="list-style-type: none"> ABO expert in each WMO region Representatives of regional WIGOS/ABO work groups ABO data quality managers Observing system and network design
4, 6, 7	Development and maintenance of ABO standards and guidance for developing and operational aircraft-based observing systems	<ul style="list-style-type: none"> Development of requirements, practices and procedures for observing system operation Coordinate and undertake the writing of regulations, technical reports and guidance 	<ol style="list-style-type: none"> Technical writing skills Analysis of test results and reports
2, 4, 5	Oversight of international centers and systems associated with aircraft-based observations <ul style="list-style-type: none"> Lead Centre for ABO Global Data Centre for ABO Global ABO Monitoring Centres Regional Data Processing Centres Oscar/Surface 	<ul style="list-style-type: none"> Oversight and coordination of ABO metadata management Development of operational procedures and processes Oversee operation of ABO centres, including data processing, monitoring and lead centres. 	<ol style="list-style-type: none"> Program and systems management Data quality management
3, 6	Coordination of testing and inter-comparison activities associated with developing aircraft-based observing systems	<ul style="list-style-type: none"> Coordinate development and input to relevant inter-comparison activities Develop and advise on requirements for inter-comparison and impact test of aircraft-based observations 	<ol style="list-style-type: none"> Inter-comparison planning and coordination Analysis of test results and reports Technical report writing
8, 9	Coordinate and undertake activities in ABO capacity development and training	<ul style="list-style-type: none"> Development of training materials and information Conducting workshops and seminars 	<ol style="list-style-type: none"> Training material development skills Technical training/teaching

Review of IATA-WMO Collaborative AMDAR Programme ConOps

Several team members undertook a review of the draft Concept of Operations for the IATA-WMO Collaboration on AMDAR and provided the following feedback & questions for consideration.

- Why is scope limited to AMDAR and not inclusive of other systems?
- Uniform cost burden? – The aim should be to implement a fair and equitable cost framework that may well not be “uniform”.
- Under the collaboration WMO and IATA should instigate a research program to demonstrate the benefits to the airlines of the availability of AMDAR data and resulting improvements to aeronautical met.
- Metrics should be established early so as to eventually be able to measure quantitatively the benefit of the program to airlines and the ATI.
- Programme development must be based on a competitive tender process at the regional/global level.
- For turbulence and EDR – need to assure that research institutions are not locked out from data use. Want some say/control over algorithm standards.
- KPIs for programme development should be developed.

Review Vision for the future of environmental measurements wrt ABO.

The group reviewed the Vision based on the version contained in the CIMO-MG/Document 3.2 and were happy that the vision well-represented requirements for ABO. Some minor comments were:

- 1) Suitable KPIs for ABO should be added – e.g. number of observations per day on the GTS.
- 2) Some items in the vision should be better referenced to relevant documents and requirements, e.g. for items like minimata convention.

Review description of work for update of study on target airlines for AMDAR, WVM and turbulence wrt task 10.

The group reviewed the Scope of Work for the consultancy work and provided the following feedback:

- Close guidance of the consultant required throughout to ensure that deliverables are suitable for ongoing use by the programme.
- For turbulence, study should focus on technical capabilities of aircraft and avionics – data from anywhere is of value. Larger fleets should be targeted. Airlines users require real-time in situ data for flight operations.

UAV research project aimed at testing the crowd-sourcing concept

The group discussed the concept of utilising "crowd-sourcing". This is defined as "obtaining information or input into a project by using the services of a large number of people typically via the Internet".

During discussion it was agreed that this could be a project developed by a university or an NMHS. The group suggested two options;

1. Develop a full blown data routing process to include;
 - a. data communications,
 - b. data processing unit and formatting of data,
 - c. quality control and management (rating of data),
 - d. visualisation – web based map and graphics, and
 - e. data user access, forum for discussion.
2. Develop a web based application to receive data
 - a. UAV user provides data – manual text, ftp, iphone/tablet,
 - b. Web page shows location, time and meteorological measurements
 - c. Forum for discussion.

The first option would require the development of a data processing system to;

- Receive data – various formats – via various media.
- Process to a defined data format – allows uniformity of data received. Also allows data to have same QC.
- Provide a rating of the data against a baseline – perhaps have the latest background fields for measured parameters.
- Method of providing NMHS data users with this upper air information
- Sort data by altitude to provide user boundary layer, medium level and upper atmosphere data (these criteria would be agreed)
- Provide a forum for discussion on the data.



The second option would be to develop a data repository to receive data from UAV users;

- Web based application (similar to Met Office WOW, <http://wow.metoffice.gov.uk/>). This would allow users to provide UAV data under defined parameters e.g location (google maps), type of data (e.g. rotary, fixed wing), altitude areas (e.g. low level/boundary, medium and upper layers).

Development of either of the options would need to be carefully assessed and aligned to budget.

Workshop on use of UAVs in operational meteorology (with 2 central themes of crowd-sourcing and taking research systems to operations)

The group discussed and identified the requirements to host a WMO/CIMO organised Workshop with the theme of "Utilising UAVs for Operational Meteorology".

Several factors would need to be put in place. These include;

Identify host e.g. MeteoFrance (Toulouse), DWD, DMI and/or UAS Denmark (<https://www.uasdenmark.dk/>).

Meeting duration e.g. 2-3 days (but need to be aware of "buy-in" from invitees).

Logistics e.g. major hub airport, hotel accommodation, transportation to/from venue.

Invitees e.g. NMHS and Research Institutes with interest in UAVs, UAV Manufacturers, UAV Service Providers, UAV Users (Public Service areas – Fire, Police, Coastguards, Humanitarian etc), Regulatory Bodies – ICAO, FAA, etc and UAV Conference organisers.

Scope: UAVs as meteorological (and atmospheric science) observing platforms. Workshop would initiate discussion and collaboration with stakeholders.

Bring together developments relating to observations from UAVs in support of operational meteorology.

Themes; Presentations and discussions with keynote speakers.

- Current research and application of UAVs in meteorology,
- CIMO activities with respect UAV developments,
 - o crowd sourcing of data,
 - o inter comparison of upper air measurements,
- Regulatory update – issues, legislation and developments
- Benefits
 - o Airport and airline operations, forecasting
 - o Emergency services – feedback of data quality
 - o NWP - profile and "medium" level upper air data in data sparse regions and model verification

If the venue allowed, there could be a demonstration/field experiment of UAV against balloon launch – this would require early notification to invited UAV manufacturers.

ABO input to CIMO upper-air inter-comparison

The team also discussed this in plenary and agreed that a recommendation should be made to CIMO that ABO systems should be considered for inclusion in the upper-air inter-comparison, including possibly AMDAR, Mode S and UAV systems, whilst acknowledging that the first two will be difficult to coordinate but might be facilitated through comparison based on "chance collocation".

ANNEX VII – REVISED WORK PLAN OF THE ET-AO

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
1	1)	Coordinate with CBS ET-ABO on Work Plan & Budget	Ch-ET-AO, SO/ARO	<ol style="list-style-type: none"> 1. Representative of ET attended ET-ABO-2 (2015) and ET-ABO-3 (2017); 2. Co-ordinate with CBS ET-ABO on Work Plans & Budgets. To be compiled & approved on at least an annual basis. 3. Regular Work Plan WebEx sessions to be held. 4. Plan 2017 and 2018 webex sessions. 5. Status report of all Work Plan Tasks to be updated Q1/2018 6. ET-AO to keep informed on WMO Constituent Bodies review. Liaise with ET-ABO on possible merging of ETs 	<ol style="list-style-type: none"> 1. Harmonised Work Plan & Budget for the ABO Program. 2. Report to ET-AO 3. Chair ET-AO will provide feedback on Work plan to ET-ABO and CIMO MG. 	Q4 2014	Ongoing	N/A	<ul style="list-style-type: none"> • Chair attended ET-ABO-1 • ET-AO-1 held jointly with ET-ABO-2 Dec 2015 • Chair attended ET-ABO-3, May 2017 (as well as RA II Workshop) • Chair attended WMO AMDAR Workshop RA VI, Budapest Dec 2017 • WebEx Session with ET-AO Members arranged Dec 2017. • Chair to attend IWCA and AMDAR Workshops planned for 2018/2019 • Provide input to WMO regarding possible merging of two ABO ETs 			

CBS/OPAG-IOS/ET-AO-2, Final Report, Annex VII, p. 2

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
2	2)	Meeting of ET-AO	Ch-ET-AO, SO/ARO	<ol style="list-style-type: none"> 1. Meeting of ET-AO, Q1 2015 2. Plan and hold meeting of ET-AO-2 April 2018 (prior to CIMO Session). 3. Prepare Report to CIMO Q1/2018 	<ol style="list-style-type: none"> 1. Work Program advancements ; 2. Report with recommendations to CIMO 3. Report provided to CIMO Q1 2016 ahead of CIMO MG Meeting Apr 2016. 4. Report to CIMO Q1/2018 	Q4 2014	Q1 2018	100	<ul style="list-style-type: none"> • Meeting of TT-AO-1 held 18-20 Feb 2014. • ET-AO-1 held Dec 2015 • Webex sessions to review Workplan planned during 2017. • Schedule WebEx sessions Q1/2018 (prior to CIMO Session). • ET-AO-2 scheduled Apr 2018 (Geneva) 		(15 WMO RB)	
3	3)	Investigate AMDAR Temperature Bias	S.d.Haan	<ol style="list-style-type: none"> 1. Review of relevant reference material 2. Consultation with avionics/sensor experts 3. Provide update to ET-AO Q1/2017 Status Report due Q1/2018 4. 	<ol style="list-style-type: none"> 1. Report to ET-AO and CIMO 2. CIMO IOM Report 3. Meeting to be arranged with avionics vendors 2017/18 – as required. 4. Draft paper to be available to ET-AO for presentation at ET-ABO-3 (May 2017) 5. Report for CIMO MG for next Session 	Q1 2014	Q1 2018	60	<ul style="list-style-type: none"> • May require funding to complete a study on onboard issues, such as deicing. Ref: WMO AMDAR Panel Aircraft Observing System Data Management Workshop, Section 5.1, • Paper “AMDAR Temperature Bias & Exploitation of Mode-S EHS registers” will be finalized for review during July/Aug 2018. 		Via 10	

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
4	3)	AMDAR and water vapor measurement (WVM) integration into existing avionics and airframes	A.Hoff, G.Meymaris, S.Stringer, B.Ford, SO/ARO	<ol style="list-style-type: none"> Drafting and review of plan. Finalise plan as part of the ABOP Strategy & Implementation Plan (A-SIP) Issue to ET-AO/ABO for final comments. Co-ordinate with SO/ARO dissemination of Plan 	Strategic Plan	2012	Q4 2017	100	<p>This needs to be harmonized with the A-SIP. Ref: WMO AMDAR Panel Session 15 Fin. Rep. 4.2.1. Incorporate:</p> <ul style="list-style-type: none"> •Ownership of STCs •Collaboration on STC costs •Integration into airframes AMDAR Software requirements. Some elements of the IP will be delivered during 2016/17 – thus delaying completion of deliverable. <ul style="list-style-type: none"> • Incorporated into A-SIP 			
5	3)	AMDAR and water vapor measurement (WVM) as standard accessory on commercial aircraft	A.Hoff, G.Meymaris, S.Stringer, B.Ford, SO/ARO	<ol style="list-style-type: none"> Drafting and review of plan. Finalise plan as part of the ABOP Strategy & Implementation Plan (A-SiP) Issue to ET-AO for comment Co-ordination with ET-ABO with regards IATA collaboration. 	Strategic Plan	2012	Q1 2017	100	<p>Incorporate:</p> <ul style="list-style-type: none"> •Formulation of IP into WMO Project, perhaps in collaboration with ICAO. Discussions with ET-ABO/ICAO ongoing <p>Ref: WMO AMDAR Panel Session 15 Fin. Rep. 4.2.1. Some elements of the IP will be delivered during 2016/17 – thus delaying completion of deliverable.</p> <ul style="list-style-type: none"> • Incorporated into A-SIP 			

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
		WVM Implementation	A.Hoff	1. Report on WVSS-II air intake assessment (FAAM) 2.	IOM Report	Q1 2016	Q2 2017	40	<ul style="list-style-type: none"> Awaiting report information from Met Office/FAAM – ET-AO to contact MO for update. Initial comments received from FAAM, report will be available end 2018 due resource issues. 			
			A.Hoff, B.Ford	Compile document on WVSS STC and candidate fleets for implementation.	WIGOS TR	Q1 2016	Q1 2017	50	<ul style="list-style-type: none"> Initial information collated for documentation 			
			SO/ARO	WMO Letter to PRs of Operational Programs re participation in AMDAR/WVM and AMDAR/EDR.	Letter to PRs	Q2 2016	Q1 2017	0	<p>Dependent on publishing of IOM under Task 16. This should also have a focus on requesting participating airlines to consider WVM and also to request WVM capability on future ordered aircraft.</p>			
			D.Body, A.Hoff, B.Ford	<ul style="list-style-type: none"> Undertake study on use of AMDAR/WVM for aircraft icing prediction & management. Identify airline to look at possible development 	<ul style="list-style-type: none"> Report to ET-AO Test of WVM data use in cockpit. 	Q1 2016	Q4 2017	40	<ul style="list-style-type: none"> ET-AO to ask AMDAR participating airlines if this could be a beneficial tool for operations. DWD are working with Lufthansa to investigate possibility of WVSS data for improvements to weather forecasting along with airline benefits e.g. icing prediction 			

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
			D.Body, A.Hoff, B. Ford	<ul style="list-style-type: none"> Reinvigorate interaction with airframe manufacturers re integration of WVM from factory floor. Encourage WMO Members to increase efforts on installation of WVM systems on their respective airlines. 	Manufacturers aware of requirement for integration of WVM.	Q1 2016	Q4 2018	20	Considerations: <ul style="list-style-type: none"> Letter from WMO to key aircraft manufacturers. Letter from WMO to IATA and/or airlines. Meetings with aircraft manufacturers – as required. Discussions with Airbus (facilitated by E-AMDAR) have renewed interest in the WVSS as part of sensor suite for aircraft orders. Airbus now testing WVSS on A320 and A350. Discussions with Qantas/Boeing on possible humidity measurements from B787. ET-AO to monitor developments relating to water content measurements from Rosemount sensors. 		Via 10	

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
6	3)	Turbulence (EDR) Implementation in AMDAR - Develop IP for EDR	G Meymaris, S.Taylor, T.Farrar, SO/ARO	<ol style="list-style-type: none"> 1. Drafting and review of plan. 2. Teleconferencing of collaborators. Liaise with NCAR on software requirements; 3. Identify possible airline partner for trial. 4. Follow up with Boeing and Air France on EDR implementation costs – also look at EDR Package available from NCAR 5. Investigate EDR reporting capability using IFE (e.g. GoGo). 	EDR IP	Q3 2013	Q2 2017	100	<p>Possibly include:</p> <ul style="list-style-type: none"> • A trial program with a European airline. The E-AMDAR Team discussing possibility with Air France. Delay in discussing with airline. Discussions in 2016/17 with Air France and Boeing proved cost prohibitive. • Need to revisit Boeing cost to implement EDR on European airline. • New possibilities using IFE and EFB – to be followed up. <p>Ref: WMO AMDAR Panel Session 15 Fin. Rep 4.2.2.</p> <ul style="list-style-type: none"> • E-AMDAR airlines (Air France, Lufthansa and Aer Lingus) are proceeding with developments relating to EDR measurements using EFB. • Airbus, UK Met Office and EasyJet are collaborating on turbulence data provision, with E-AMDAR liaising with the UK Met Office (on behalf of ET-AO) 			

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
7	3)	Turbulence (EDR) Implementation	G Meymaris	In collaboration with ET-ABO, undertake activities as required to facilitate AMDAR EDR monitoring program.	EDR monitoring program operational	Q2 2015	Q4 2018	25	<i>This Task will follow on from Task 6.</i> Sub-tasks below.			
			G.Meymaris	Develop & Maintain Implementation Plan documents: <ul style="list-style-type: none"> List of compatible avionics systems. List of compatible aircraft types. List of target participating programmes/airlines. 	IP Documents	Q1 2016	Q4 2017	80	<ul style="list-style-type: none"> A list of avionics and aircraft that can support EDR implementation to be populated and maintained (as part of Task 10) 			
			SO/ARO	Based on IP documents, contact PMs re participation in AMDAR/EDR.	PMs aware of IP and feedback received and reported to ET-AO	Q3 2016	Q3 2016	100	<ul style="list-style-type: none"> Sub Task completed 			
			G.Meymaris	Develop a plan & strategy for extension of EDR software availability.	Wider availability of EDR software for different aircraft models.	Q3 2016	Q2 2017	30	<ul style="list-style-type: none"> This aligns with sub task above reference IP Documents ET-AO will follow up with airlines with IFE capabilities 			
			G.Meymaris	<ol style="list-style-type: none"> Participate in Avionics Vendors Conference for promotion of EDR applications dev. Identify meetings to target during 2017/2018. Proactive contact with avionics vendors 2018 	Avionics vendors aware of requirements for EDR applications integration. Addition of an airline (outside of US) to implement EDR reporting	Q3 2016	Q4 2017	40	<ul style="list-style-type: none"> ET-AO to promote development of global turbulence monitoring – as both part of AMDAR observing system and the IWCA. As mentioned in task 6 above, a European airline has been identified for EDR implementation. 		Via 10	

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
			G.Meymaris, S.Taylor, SO/ARO	1. Participate in RTCA/SG4, EDR MOPS for EDR Standardisation. 2. Active in EDR discussions within RTCA	1. Contrib. to FAA EDR MOPS 2. Documentation input provided to RTCA	Q1 2016	Aligned with EDR MOPS schedule	Ongoing	<ul style="list-style-type: none"> ET-AO presence at these for a will ensure ABO community represented. 		Via 18	
			S.Taylor, G.Meymaris	Develop Strategy & Imp. Plan for E-AMDAR participation in EDR IP	Plan produced.	Q1 2016	Q4 2018	2540	<ul style="list-style-type: none"> Development of AFR B777 also includes implementation of EDR (note AFR currently reporting DEVG). Airline /Boeing will collaborate to achieve during 2016. Discussions during 2016 with AFR/Boeing. Continuing discussion with Boeing and also with Airbus since Q2 2017. Lufthansa and DWD (TeFiS Project) are collaborating on installing EDR on ~30 aircraft (all fleet types). This project "stalled" for time being, to be revisited during 2017. Investigate IFE possibilities Development of turbulence monitoring continues in Europe. 		Via 18	

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
8	3)	Study on Current & Future Comms & Technology Impact on AMDAR	SO/ARO, S.Taylor, D. Arodi.	<ol style="list-style-type: none"> Write Statement of Work Identify consultants SSA in place Monitor progress Study to be published as a IOM report. 	<ol style="list-style-type: none"> Kick off webex with consultant (Sep 2014). Study and recommendations produced. Two sections to cover Executive Summary and Technical terminology. 	Q3 2013	Q1 2015	100	<ul style="list-style-type: none"> Monthly status reports received. Regular Webex sessions held with consultant during 2014. Webex held Jan 2015. SSA consultancy completed. IOM with WMO Publications for Final approval IOM published 			
9	(4)	Update and maintain the AOSFRS	D.Body	<ol style="list-style-type: none"> Develop Version 1.1A as markup to version 1.1 for publication on the WMO Website. 	AOSFRS Maintained	Q4 2014	N/A	Ongoing	<ul style="list-style-type: none"> No current requirement for updates identified Version 1.1 issued. Record of amendments included in document. 			
10	4)	AMDAR Software Development & Availability	S.Taylor, SO/ARO	<ol style="list-style-type: none"> Approach Teledyne Controls re AOSFRS implementation; Approach other avionics vendors Follow up during Q1/2017 Continue discussions with vendors 	Integration of AMDAR into avionics systems.	Q3 2013	N/A	Ongoing	<p>Work towards availability of AMDAR software as a catalogue item of delivery for avionics systems.</p> <p>ET-AO agreed on more proactive approach possibly involving face to face meetings necessitating travel of Members.</p> <p>Promotion of concept at aviation meetings (e.g. AEEC DLUF 2016/2017)</p> <ul style="list-style-type: none"> A database of known global AOS implementations is available on the WMO AMDAR website. 		Via 18	

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
			ET-AO, SO/ARO	Development of Generic AMDAR Onboard Software Modules: 1. Determine viability of project. 2. Develop Description of Work and requirements. 3. WMO Tender for job. 4. Initiate contact with Avionics Vendors on this topic.	Suite of generic AOSFRS-compliant modules for deployment with participating airlines and avionics vendors.	Q3 2014	Q4 2018	20	<ul style="list-style-type: none"> Initial discussions with vendors. Honeywell and Teledyne contacted. Other vendors and aircraft manufacturers to be contacted (Q1 2015). After discussions throughout 2015 the concept has been put on hold pending further contact with vendors. Revisit during 2017 Chair discussed this again with Honeywell at AEEC DLUF Sep 2017 Progress has been slow with avionics vendors reluctant to allocate resources with other operational priorities. 		Via 18	

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
			Ch-ET-AO, SO/ARO	<p>Avionics Vendors Conference with AEEC in Q4 2016</p> <ol style="list-style-type: none"> Ch-ET-AO to approach meeting and conference organisers in AEEC to make request. LoA with AEEC required? New strategy to be investigated with a view to meeting or individual approach to vendors. 	Conference/Meeting with Avionics Vendors to be Held	Q1 2016	Q4 2018	20	<ul style="list-style-type: none"> Fallback will be to arrange alternative event staged at appropriate vendor venue in Q4. Not realized during 2016 Look at Avionics meeting during latter half of 2017. Look to extend attendees to airlines as well This has not been realized in 2017 – look to hold in 2018 possibly in collaboration with ET-ABO & IATA. Again during the last 6 months planning for Avionics Vendor Conference has been put on hold. ET-AO-2 discussed this matter and Chair will raise at upcoming Aviation for a (AEEC DLUF Sep 2018). 	0 (15K)15K		16k (moved from 2018)

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11	4)	Boeing 777 AMDR Software Dev.	Ch-ET-AO, Ch/ET-ABO, SO/ARO,	<ol style="list-style-type: none"> 1. Finalise negotiations with AFR and KLM in consult. with E-AMДАР & Meteo-France 2. Review quotation; 3. Provide advice on specifications and requirements. 4. Finalise agreement with stakeholders on costs. 5. Finalise implementation and software roll out. 6. Look to provide software to other airlines. 	B777 AMДАР Software application	2012	Q4 2016	100	<ul style="list-style-type: none"> • Combined action with ET-ABO • Agreement signed with AFR for S/W develop. Dec 2014 • AFR, LSY and E-AMДАР coord. Integ. of B777 to optimizer Jan 2015. • Project imp. delayed – expect completion in 2016 • AFR data available from 1st Feb 2016. • The development of BAW B777 for E-AMДАР was finalized in 2016 as well. • Both AFR and BAW fleets currently providing data in support of WMO Regional Programmes. • KLM B777 schedule may not provide cost/benefit in data coverage – E-AMДАР may look at A340 family • RA II contact informs Cathay Pacific interested in the B777 software Q3 2017. <p>Ref: WMO AMДАР Panel Session 15 Fin. Rep 4.4.7.</p>			

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12	4)	Develop and specify standard for AMDAR Data Optimisation System	D.Body	<ol style="list-style-type: none"> Determine requirements (consult with FPs); Draft specification; Conduct review; Publish spec. 	Addition to WMO guidance material.	Q4 2014	Q4 2016	100	<ul style="list-style-type: none"> Develop a functional specification that can be included in the Manual on WIGOS or in CIMO Guide. Guidance has been developed. Will be added to the Guide to GOS. COMPLETED			
13	5)	Monitor & Review reports from WVSS testing	A.Hoff	<ol style="list-style-type: none"> Review reports. Report to TT-AO-1 Provide summary report on DENCHAR test results. Provide ET-AO and ET-ABO with updates. 	<ol style="list-style-type: none"> Report to CIMO. Updates to ETs. 	Q3 2013	N/A	Ongoing	Ref: WMO AMDAR Panel Session 15 Fin. Rep 4.2.1.			
14	5)	Monitor & report on impact assessment results of TAMDAR humidity & other parameters by MetOffice	ET-AO	<ol style="list-style-type: none"> Review reports and analyse results. Report to ET-AO-1. Provide updates to ET 	Report to CIMO	Q3 2013	Q4 2017	60	<ul style="list-style-type: none"> Delay to installation of TAMDAR on FAAM aircraft, now scheduled for Oct 2014. TAMDAR sensor installed and Panasonic completing onboard calib. Data will be collected from campaigns from March 2015. Awaiting results from Met Office Report due end 2018 			

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			A.Hoff	Determine status of reporting of DWD & ECMWF on WVM Impact studies & compile a brief summary report for publication.	Newsletter Article or WIGOS TR	Q1 2016	Q4 2017	60	<ul style="list-style-type: none"> Newsletter Article produced. Combined report from ECMWF/DWD to be provided by July 2018. 			
15	3)	Develop & Implement plans for AMDAR & WVSS inter-comparison	S.d.Haan	<ol style="list-style-type: none"> Determine requirements; Analyse options; Draft Plan; Implement & report (IOM). Assess data from DLH WVSS aircraft 1 year data 	AMDAR & WVSS Inter-comparisons Plan	Q4 2013	Q2 2017	40	<ul style="list-style-type: none"> This task was delayed whilst awaiting WVSS installation on DLH aircraft. All 9 aircraft will be operational Q1 2016. Dataset of DLH aircraft now available Draft report has been initiated and expected Q4 2018. 			
16	6)	Prepare a paper on the status of WVSS-II validation	B. Ford & Collaborators	<ol style="list-style-type: none"> Prepare outline and scope Identify contributors Research and draft Review Publish 	IOM Report	Q3 2013	Q3 2017	95	<ul style="list-style-type: none"> Provide a summary on all scientific and operational aspects of the WVSS-II sensor and prepare a paper to be published as an IOM report. Upon review by CIMO requires some changes and additional material. After further iteration, document will be reviewed by ET-AO Q2 2016 IOM document reviewed by ET-AO-2 (Jul 2018) and will be put forward to Editorial Board for publication 			

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17	6)	Review & Update Aircraft-based Obs Reg. Mat. In CIMO Guide	ET-AO	<ol style="list-style-type: none"> 1. Review current status of material and identify requirements for update; 2. Coordinate & undertake update; 3. Review and complete; 4. Provide to CIMO Editorial Board. 	CIMO Guide on Aircraft-based Observations updated.	Q1 2014	Q4 2018	75	<ul style="list-style-type: none"> • Need to plan for review of current chapter to be completed (if necessary) by Q4 2017 for input to process to have approved by CIMO-2018 • Minor updated made by A.Hoff. • S. Taylor to provide input to new section on UAVs. • Final iteration Dec 2017 • ET-AO propose update to WMO-no.8, Part II, Chapter III be forwarded to CIMO/Editorial Board and also to the upcoming CIMO Session Oct 2018. 			

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18	7)	Attend meetings of relevance to AMDAR Technical Dev.	ET-AO, SO/ARO	<ol style="list-style-type: none"> Develop list of aviation committees and reps on P&C wiki. Membership of RTCA 	Meetings attended. Reports produced for CIMO and Secretariat	Q2 2013	N/A	Ongoing	This may include: <ul style="list-style-type: none"> Meeting with avionics vendors; SO/ARO & S.Taylor met with A.Hoff in Dec 2013 in Offenbach for Task 19. Met Expo (Madrid September 16) AEEC led meetings 2017 (DLUF and AMC) Attendance at DLUF in US Feb 2018 and Europe Sep 2018. ET-AO unable to attend Feb 2018 DLUF due to resource issues. The Sep 2018 DLUF will be an important opportunity to discuss plans i.e. IWCA, AMDAR modules, ACARS/IP and turbulence/WVM developments. 	3.1 (10K)	5K	
			Ch-ET-AO, SO/ARO	Undertake a review of AEEC, RTCA, SESAR and other bodies to determine critical committees and work groups requiring ET-AO representation	<ol style="list-style-type: none"> Nomination of members to key committees and work groups. Update of list on wiki. 	Q1 2016	Q2 2017	30	<ul style="list-style-type: none"> List commenced on WMO ABOP wiki. ET-AO to review and update/populate lists. 			

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No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
19	4)	Maintenance of AEEC ARINC 620 Specification	S.Taylor, SO/ARO, A. Hoff	1. As necessary, work with AEEC DataLink Systems Sub-Committee to maintain the Met. Report in the ARINC 620 standard.	Met. Report V6 defined in the AEEC ARINC 620 spec.	Q4 2013	Q4 2014	100	<ul style="list-style-type: none"> Will require travel support for work team and to attend AEEC meetings D.Lockett attended AEEC DLK SSC, June 2014 (1.2K) Met Rep. v6 incorp. into ARINC620-8 (published Dec 2014). AEEC led meetings 2017 		Via 18	

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
20	4)	Interaction with AEEC AOC	ET-AO, SO/ARO	<ol style="list-style-type: none"> 1. Review existing documents and reports to determine requirements for ET-AO 2. Seek membership of AOC and attend meetings 	Liaison with Aviation Industries. Report to ETs where appropriate.	Q2 2014	N/A	Ongoing	<ul style="list-style-type: none"> • SSC and AOC are trying to harmonize requirements for data link in A633 and A620. • ET-AO should determine any implications for AMDAR. • This Task is related to Task 18 and any funding is captured there. • Chair tried to add ABO to AMC Session (1-4 May). May be useful to attend as networking opportunity. • Possible attendance at AMC and other AEEC Meetings • Chair has contacted AEEC with regards discussions within several Aviation sub-Committees e.g. Internet protocol Suite (IPS), Electronic Flight Bag (EFB), Systems Architectures Interfaces (SAI) and Air-Ground Communications Systems (AGCS). 		Via 18	

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
21	3)	Study of UAV technologies.	Ch-ET-AO	<ol style="list-style-type: none"> 1. Investigate possible applications of UAV/UAS developments for reporting of meteorological parameters. 2. Attend meetings of relevance 3. Chair will follow up with vendors Q2/2017 4. Keep up to date with Aviation developments (FAA/EASA) regarding UAV and shared airspace 5. 	<ol style="list-style-type: none"> 1. Reports to ET-AO and CIMO. 2. Mission Report from UAV Conference (Oct 2014). 3. Prepare report for ET-ABO-3 4. Mission Report from IATA Drones Lab (Oct 2017) 	Q3 2014	N/A	Ongoing	<ul style="list-style-type: none"> • Ch-ET-AO attended UAV Conference Oct 2014. (1.4K) • UK Met Office are investigating UAV technology for meteorological research. • Ch-ET-AO invited to visit UAV vendors – to be arranged during first half of 2015. • Visit to UAV vendors delayed to 2016 • UAV meeting identified (Brussels March 16) • Met expo (Madrid September 16). Obtain feedback from MO attendee • Chair attended IATA 1st Drones Lab Conference, Barcelona Oct 2017. Possible invitation to present ABO at the 2nd Conference 2018 • Look to collate list of UAV research and operational use by WMO Members. • List of UAV usage by 3rd parties to be also included where possible. • 			

No.	ToR	Task Description	Person(s) Responsible	Action(s)	Deliverables / Outcome	Comm.	Deadline for Delivery	Status (%)	Comments	2017 Budget Expend.	2018 Budget Estimate	2019 Budget Estimate
			Ch-ET-AO	<ol style="list-style-type: none"> Possible CIMO Workshop on UAV use for met. Reporting in 2018. 	<ol style="list-style-type: none"> Host a UAV vendors conference as soon as possible 2019. Report to CIMO from Conference. Possible development of UAV data processing system or Web Portal. 			10	<ul style="list-style-type: none"> Recommend to CIMO that ET-AO should undertake UAV Workshop. In parallel, a recommendation to CIMO regarding a Pilot Project on potential provision of upper air data from NMHSs and public/private UAV systems. This will also include possible development of data processing system or Portal. 			20k (moved from 2018)
22	4)	Reporting and Encoding Requirements	A.Hoff	Make assessment of whether there is a requirement for reporting of True Heading within the AMDAR BUFR Template	Report to ET-AO and ET-ABO	Q1 2016	Q2 2017	100	<ul style="list-style-type: none"> Requires analysis of the BUFR template. J.v.d.Meulen can assist. ET-AO agreed Task completed as no outstanding issues. 			
			S.de.Haan	Investigate any additional metadata requirements to support heading derivation for ADD	Report to ET-AO and ET-ABO	Q1 2016	Q2 2016	100	<ul style="list-style-type: none"> Needs to be completed so that requirements can be met in the new guidance for the GttG. Being compiled by ET-ABO. ET-AO agreed Task completed as no outstanding issues. 			

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23		Developments with Mode-S (EHS)	S de Haan	<ol style="list-style-type: none"> 1. Monitor the progress of ADD with regards transition from development to operational use. 2. 	<ol style="list-style-type: none"> 1. Provide information on Mode-S data coverage and utilize to complement AMDAR networks. 2. 	Q2 2018	Q3 2019	0	<ul style="list-style-type: none"> • New Task agreed by ET-AO-2 • 			

ANNEX VIII – LIST OF ACTIONS FROM ET-AO-2

Item No.	Agenda Item	Action	Who	By When	Comment
1	3.2	Encourage Member to increase their efforts to work with airline partners to increase the installation of humidity sensors and extend the coverage of ABO humidity measurement.	ABOP, ET-AO	Ongoing	Consider follow-up action upon publication of the IOM report on WVSS-II validation.
2	3.2	IATA-WMO Collaboration on AMDAR to aim to assist and encourage the respective memberships of the two organisations to collaborate on the expansion of water vapour measurement with focus on reducing costs through aviation industry standardisation and promotion of benefits.	Secretariat	Jan 2019	
3	3.2	Request calibration check of the two WVSS-II sensors on the FAAM aircraft is undertaken asap.	Ch/ET-AO	Results by end-2018	
4	3.2	Consider and formulate a position on requirements for processing WVSS-II humidity data to handle +100% humidity values.	Ch/ET-AO to request action by ET-ABO	Jul. 2018	
5	3.3	A log of avionics and aircraft for which turbulence applications had been developed should be maintained as a component of the ET-AO work plan Task 10.	ET-AO, G. Meymaris	Ongoing	
6	3.3	The upcoming meeting of the AEEC DataLink Users Forum (DLUF) in September 2018 should be used to promote the development of turbulence monitoring as a component of the AMDAR observing system and under the IATA-WMO collaboration.	Chair/ET-AO	Sep. 2018	
7	3.4	The ET-AO to develop a new strategy to attempt to steer the aviation/avionics vendor community towards provision of off-the-shelf AMDAR Onboard Software availability for key avionics/communications platforms, taking into account the likely collaboration with IATA on AMDAR.	ET-AO	End-2018	Ch/ET-AO to update the work plan
8	3.6	ET-AO to provide final version of IOM for CIMO review.	ET-AO, the Secretariat	Jul. 2018	

Item No.	Agenda Item	Action	Who	By When	Comment
9	3.7	Coordinate provision of the proposed update to CIMO/Editorial Board and the CIMO session.	the Secretariat	Oct. 2018	
10	3.8	Team to be represented and promote AMDAR at the upcoming AEEC DLUF meeting	Ch/ET-AO	Sep. 2018	
11	3.9	Recommendation to CIMO that the team should undertake a workshop on UAV systems in 2019.	Ch/ET-AO, the Secretariat	Oct. 2018	It is highly recommend that any such WMO sponsored workshop be held in conjunction with an existing UAV forum, such as something associated with http://www.auvsi.org/ This will provide much greater visibility and interaction with the UAV community at such an event, than a WMO only workshop on the topic.
12	3.9	Recommend to CIMO that the team should conduct a pilot project on operational provision of upper-air data from private and public UAV systems.	Ch/ET-AO, the Secretariat	Oct. 2018	
13	3.9	Recommend to CIMO that the upcoming upper-air inter-comparison event conducted by CIMO (2019/2020) should consider the possibility to include UAV systems.	Ch/ET-AO, the Secretariat	Oct. 2018	
14	3.10	ET-AO work plan to include a task and activities on Mode S, including development of encoding formats.	Ch/ET-AO	ET-AO-2	
15	4.1	Work plan to be updated accordingly base on outcome of ET-AO-2 breakout group sessions.	Ch/ET-AO	Jul. 2018	
16	5.2	ET-AO Report to CIMO to include recommendations on UAVs and on the ToR for an IPET on ABO	Ch/ET-AO	Oct. 2018	
17	6	Follow up with PAC to discuss a possible collaboration with WMO and its member NMHSs for provision of IFE ABO data.	ET-AO, the Secretariat	2 nd half 2018	
18	6	Continue to monitor developments and outcomes related to B787 icing sensor activity.	ET-AO	Ongoing	

