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PJ18W2 4DSKYWAYS

SOLUTION 53B: IMPROVED PERFORMANCE OF CD/R TOOLS ENABLED BY REDUCED TRAJECTORY PREDICTION UNCERTAINTY

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Abstract

The PJ.18-Wave 2 4DSkyways project continued research on Trajectory Management (TM) to enable the deployment of the SESAR Trajectory Based Operations (TBO). Solution 53B improves the separation management processes both of the Executive Controller and the Planning Controller by improving the accuracy of the conflict detection and resolution tools at their disposal. The solution is for the en-route and TMA operational environments and introduces adaptations of HMI when needed.

Solution PJ.18-W2-53B built on the work performed in Wave 1 solutions PJ.18.06a, PJ.10-02a1, PJ10.02a2, and the PJ31 "DIGITS" project. Work under the solution-project then defined and validated the improvement of more advanced (in comparison to activities conducted in Wave 1 PJ.18-06a and PJ.10-02a2) Conflict Detection and Resolution tools that are derived from the improvement of ground Trajectory Prediction (TP) with the use of ADS-C data in TMA and En-route environment. In addition, this solution increases the TP improvements for Planned and Tactical predicted trajectories) with the use of Mode-S data and more accurate (more granular spatial and temporal) MET data.

The solution achieved V3 maturity level at the end of SESAR 2020 Wave 2.

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1 Purpose

This document provides the contextual note for SESAR Solution PJ18-W2-53B for V3. It provides all the information in terms of scope, main operational and performance benefits, and relevant system impact from the validation exercises belonging to PJ18-W2-53B, Improved Performance of Conflict Detection & Resolution Tools (CD&R) Tools Enabled by Reduced Trajectory Prediction Uncertainty, mainly focused on the improvement of CD&R tools, as well as Trajectory Prediction improvements (TP) with the use of ADS-C data

Below the list of V3 validation exercises providing information in this Contextual Note:

- **PJ.18-W2-53B-V3-EXE-008** conducted by AIRBUS-BULATSA-ENAV, investigated further improvement of CD&R and Conformance monitoring tools with the use of multiple data resources and available weather information, enhancing TP.
- **PJ.18-W2-53B-V3-EXE-009** conducted by DFS and Indra with Airbus support (PAS@ATM simulator), which focused on the development of additional TP improvements using further elements of Automatic Dependent Surveillance – Contract Extended Projected Profile (ADS-C EPP) and more recent weather information and adverse weather areas (AWAs), also assessing the impact on conflict tools and separation management.
- **PJ.18-W2-53B-V3-EXE-010** conducted by MUAC and Indra, performed validation of planned trajectories TP and Meteorological (MET) data quality improvements based on the use of ADS-C EPP opportunities.
- **PJ.18-W2-53B-V3-EXE-011** conducted by PANSA and Indra built on the outcomes of 18-06a activities and aims to further investigate TP improvements using EPP. It also validated tactical separation tools improvements.
- **PJ.18-W2-53B-V3-EXE-012** conducted by Skyguide, validated the improvement of the TP to be used in either Planning or Tactical phases and CD&R tools enriched with downlinked airborne data (ADS-C data).

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2 Improvements in Air Traffic Management

Solution PJ.18-W2-53B (V3 completed) is for Improved Performance of CD&R Tools Enabled by Reduced Trajectory Prediction Uncertainty,. This solution addresses the improvement of conflict detection and resolution tools that are derived from the improvement of ground Trajectory Prediction (TP) with the use of advanced data from ATS B2 ADS-C reports messages as defined in the EUROCAE standard ED-228A and improved meteorological data.

The accuracy of today's ATC predicted Trajectories is limited by the lack of information about, amongst others, Airspace User's preferences or Meteorological data. This limited accuracy implies an uncertainty on future Aircraft position, which increases for longer look-ahead horizons. In addition, as the Density/Complexity of Airspace increases, it is more difficult to design a Conflict-free Ground plan in a mid-term look-ahead horizon. Tactical intervention is then needed to solve a significant number of Conflicts, further contributing to the overall Mid-term uncertainty.

The improvements of ground TP in Solution PJ.18-W2-53B address the use of ADS-C data to reduce uncertainty in the Trajectory Prediction, the core ADS-C parameters used (when available) are gross mass, speed schedule, Top Of Climb (TOC) and Top Of Descent (TOD) altitudes, turning manoeuvre strategy, turn radius, EPP predicted profile, preferred speeds and the predicted speeds at route points, in particular:

- The use of ADS-C reported Actual Mass, together with the actual Mode-S TAS in order to improve the initial conditions of the Predicted Trajectories;
- The use of ADS-C reported Speed Schedule, EPP Predicted Speeds and stable Mode-S IAS/Mach to improve the Target Speeds along the different Phases of the flight;
- The use of the EPP profile to calibrate the BADA performance model, by comparing ADS-C reported EPP Vertical Profile with an equivalent Ground computed Profile to identify Performance Coefficients to be used in Ground Trajectory computation;
- Improvements in the calculations of turning manoeuvres thanks to the use of turn radius and the turning strategy (overfly vs fly-by);
- The implementation of catch-up manoeuvres (modelling the interception of an aircraft in descent with its optimal descent profile), not depending on EPP data.

In addition, the solution encompasses the handling of more granular MET data to improve the trajectory prediction. The changes on the Trajectory Prediction are applicable to all Ground Computed Trajectories, and this includes ad-hoc what-if Trajectories that can be created to assess Conflict Resolution actions.

The Conflict detection and resolution (CD&R) is improved thanks to the better prediction provided by the ground TP taking into account ADS-C reports and the use of derived aircraft performance in the detection envelope computation, this aims at reducing the number of false [low probability] conflicts and allow the better identification of actual conflicts. Furthermore, the improved TP should provide a more reliable sector sequence (particularly for vertically evolving flights in complex airspace), easing the burden of coordination and transfer between sectors.

3 Operational Improvement Steps (OIs) & Enablers

The following table gives the OIs and enablers addressed by PJ.18-W2-53B.

OI Steps ID	OI Steps Title	Enabler ID	Enabler Title	OI Step/Enabler Coverage
CM-0209-b	Improved Separation Management with the use of Aircraft Data in Conflict Detection and Resolution Tools in En-Route Predefined and User Preferred Routes environments	A/C-37a	Downlink of trajectory data according to contract terms (ADS-C) compliant to ATN Baseline 2 (FANS 3/C)	OI step • Full Enabler • Required • Use
		A/C-48a	Air broadcast of position/vector (ADS-B OUT) compliant with DO260B	Enabler • Optional • Use
		ER APP ATC 167	ATC Planned Trajectories improvement with new ADS-C reports, and surveillance information	Enabler • Required • Develop
		ER APP ATC 200	ATC Improvement to receive and use more granular MET forecasts	Enabler • Required • Develop
		ER APP ATC 149a	Air-ground data exchange to support i4D – Extended Projected Profile (EPP)	Enabler • Optional • Use
		ER APP ATC 214	Conflict Detection envelope trajectories improvement with new ADS-C reports	Enabler • Optional • Develop
CM-0212[1]	Improved Separation Management with the use of Aircraft Data in	A/C-37a	Downlink of trajectory data according to contract terms (ADS-C) compliant to ATN Baseline 2 (FANS 3/C)	OI step • Full Enabler • Required • Use

[1] Enablers assigned via Change Request 07135.

	Conflict Detection and Resolution Tools in the TMA	A/C-48a	Air broadcast of position/vector (ADS-B OUT) compliant with DO260B	Enabler • Optional • Use
		ER APP ATC 167	ATC Planned Trajectories improvement with new ADS-C reports, and surveillance information	Enabler • Required • Develop
		ER APP ATC 200	ATC Improvement to receive and use more granular MET forecasts	Enabler • Required • Develop

Table 1: SESAR Solution PJ18-W2-53B Scope and related OI steps and enablers

4 Background and validation process

Solution PJ.18-W2-53B builds on the work performed in Wave 1 solutions PJ.18-06a, PJ.10-02a1, PJ10.02a2, and the PJ31 "DIGITS" project. It defines and aims to validate the improvement of more advanced (in comparison to activities conducted in Wave 1 PJ.18-06a and PJ.10-02a2) Conflict Detection and Resolution tools that are derived from the improvement of ground Trajectory Prediction (TP) with the use of ADS-C data.

Solution PJ18-W2 SOL53B, Improved Performance of CD&R Tools Enabled by Reduced Trajectory Prediction Uncertainty, in the en-route and TMA operational environments has been carried out in performing several validation exercises:

In total, five exercises were conducted inside the PJ18-Wave 2 SOL53B:

- PJ.18-W2-53B-V3-EXE-008 (BULATSA and AIRBUS), the validation exercise is focused on higher automation-level conflict detection and resolution tasks in pre-tactical and tactical-time horizon enabled by using improved Trajectory predictions. Trajectory based operations are in the focus of the development of Tactical Encounter Solver Assistant (TESLA) tool. Combining data from various sources such as EPP, Mode-S, planned trajectory, ATCOs system inputs, etc. into complex algorithm. This results in numerous system calculations of possible trajectory predictions ("What-If" and "What-Else") for any specific aircraft and compare them with all other trajectory predictions for all other aircraft. Thus reducing the uncertainty and indicating to ATCOs possible conflicts and ranked ("What-next") conflict free resolutions.

- PJ.18-W2-53B-V3-EXE-009 (DFS and Indra), the validation exercise was aiming to improve operational performance when using the planning trajectory. This was expected to be achieved via a reduced uncertainty in trajectory prediction, allowing a reduction in false conflict notifications in CD&R tools. Lower uncertainty could be obtained by certain modifications and additional information input. The exercise is covering OI Step CM-0209-b (Improved Separation Management with the use of Aircraft Data in Conflict Detection and Resolution Tools in en-route Predefined and User Preferred Routes environments).

  DFS and Indra (supported by Airbus, PAS@ATM simulator) developed and validated additional TP improvements using further elements of ADS-C EPP to what was done in PJ.18-06a and more recent weather information. The impact on conflict tools and separation management was assessed. A higher performance may enable operational concept modifications in future studies.

- PJ.18-W2-53B-V3-EXE-010 (MUAC, LVNL and Indra), the exercise validated trajectory prediction improvements based on the use of ADS-C EPP opportunities defined in the PJ.18-W2-53B TS and it evaluated the operational impact of the TP enhancements. The main objective of the exercise was to validate the enhancement of the ground trajectory prediction using ADS-C input from the aircraft.

  The ADS-C meteo data (temperature and wind) from the aircraft. was also used as an additional input to the weather forecast the Royal Dutch Meteorological Institute (KNMI), in order to evaluate if the quality of the forecast can be improved using this input.

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Through a separate activity (led by LVNL), the exercise also validated the enhancement of the ground trajectory prediction using ADS-C input from the aircraft using inferred vertical performance data from EPP data in the process of deriving Trajectory Management solutions consisting of descent speed advisories.

- PJ.18-W2-53B-V3-EXE-011(PANSA and Indra), the validation exercise is focussed on the planned trajectory prediction (TP) improvements, with the usage of ADS-C Mass, Better selection of speeds using ADS-C data and Mode-S data, implementation of catch-up manoeuvres and BADA calibration.

- PJ.18-W2-53B-V3-EXE-012 (Skyguide), the Validation Exercise has been performed through real time simulations using an ATC real time simulator with a traffic generator providing a high-fidelity aircraft and FMS behaviour (Airbus Defence and Space / GENETICS). A new TP has been developed taking into account ADS-C EPP data for BADA calibration and turning manoeuvres adjustments. CD&R has been enriched with thinner detection envelopes around the aircraft predicted trajectory thanks to aircraft performance extracted from ADS-C EPP reports. From recorded exercises data, comparison between legacy TP, new TP, EPP and tracks has been made with specific analysis tool. Operational/Human performance/Performance (flight efficiency, capacity…) and Safety… aspects, real time simulations have been measured with quantitative and qualitative data collection.

5 Results and performance achievements

The following section provides an overview of the combined findings generated by each validation exercise.

From the five validation exercises performed in the frame of Solution PJ18-W2-53B, the following overall consolidated conclusions have been drawn, considering the main concepts for improvements addressed in the Solution. Validation activities were focused on the Trajectory Prediction, and Conflict Detection & Resolution tools performance improvement through the use of ADS-C data and at a lower level, on the use of WTQ (Wind, Temperature, QNH) Grid data and weather forecast.

The Trajectory Prediction using airborne data (ADS-C EPP, speed schedule) feeding Trajectory Management tools and improvement of Conflict Detection & Resolution tools (e.g. envelopes of detection) has demonstrated benefits to the operations in term of Operational Efficiency, Capacity, Safety, Human Performance as well as environmental and cost efficiency.

5.1 Conclusions on SESAR Solution maturity

Solution 53B addresses the improvement of conflict detection and resolution tools that are derived from the improvement to ground trajectory prediction with the use of advanced data from ATS-B2 ADS-C reports messages and improved meteorological data. The consolidation of the results from the five validation exercises (table 12) shows that most validation objectives and success criteria are achieved.

The project concludes that Solution 53B is feasible from the operational and technical integration perspectives. The Solution 53B maturity gate, held at the SJU on the 13th of June 2023, concluded that the Solution has achieved V3 maturity. The project makes a number of important recommendations at section 5.2 for industrialisation and deployment (including recommendations to address specific partner concerns), and for additional research and development for future work outside the scope of the solution.

5.2 Conclusions on concept clarification

At the solution level, the overall validation results confirm the operational feasibility of improving conflict and detection tools with the use of advanced data from ATS-B2 ADS-C reports messages and improved meteorological data.

Generally, ATCOs expressed strong positive opinions towards both the concept and usability of the trajectory prediction and CD&R tools. They believe that implementation of such tools will have positive effect on their job satisfaction.

The use of advanced CD&R tools, using on-board data/aircraft derived data, is compatible with the existing procedures and current operational methods in the TMA and ENR airspace.

ATCOs were able to handle very high traffic levels (2035 forecast traffic level) without degrading safety, this shows the high benefit of having more reliable information with both enhanced Trajectory Prediction tool and Conflict Detection & Resolution tools.

Areas for further development and fine tuning were identified. For example, some functions (e.g. Descent When Ready, Level Constraints…) including some automation need additional study to be fully integrated in the concept.

5.2.1 Conclusions regarding Trajectory Prediction improvements with ADS-C

- The use of ADS-C EPP data downlinked from the aircraft in the ground trajectory prediction tools is confirmed to be feasible from the operational and technical integration perspectives.
- There is a positive effect of the use of the ADS-C EPP data. More precise trajectory predictions taking into account ADS-C EPP data, provide greater accuracy and reduced uncertainty regarding the future positions of the equipped aircraft.
- The Trajectory Prediction accuracy is improved thanks to the calibration process (based on ADS-C EPP data). More precise 2D/3D trajectory calculation is demonstrated.
- Trajectory Management tools: the display of ADS-C EPP trajectory with information such as TOC/TOD, ETOs… and type of turns (FlyOver, Fly-By) allow the ATCOs to get an advanced knowledge of aircraft intentions and performances, therefore, to be more precise in their analysis for conflicts resolution and trajectories optimisation.

5.2.2 Conclusions regarding Conflict Detection & Resolution Tools improvements

- The use of the ADS-C EPP in CDR tools is confirmed to be feasible from the operational and technical integration perspectives. the enhanced CD&R tools using downlinked aircraft data are more reliable than current CD&R tools based only on ATM system's information (planned trajectory and clearances).
- Advanced Trajectory Prediction performance, using ADS-C EPP data appears to be a valid enabler for Conflict Detection & Resolution tools improvement.
- With the use of advanced Trajectory Prediction and ADS-C EPP data, thinner and more reliable detection envelope can be designed for Conflict Detection & Resolution tools. Conflict detection is therefore more accurate and reliable, supporting better resolution options. This improves ATCO's performance and in particular situation awareness.
- Advanced Conflict Detection & Resolution Tools, using aircraft derived data (e.g. ADS-C EPP), are compatible with the existing procedures and current operational methods in the TMA and ENR airspace.
- ATCOs rely on having less "false" conflicts and therefore improve their conflict solving.
- Overall, the results of the validation exercises show that the benefits of using ADS-C/EPP data in the ground Trajectory Prediction and the CD&R tools are clear and achievable.

These conclusions are caveated with the following points:

- Degraded modes have not been fully addressed in the exercise runs. In particular, the validation exercises have only considered the full loss of ADS-C EPP data and not corrupted ADS-C/EPP data.

Potential "corrupted" data must be considered of paramount importance as the results of conflict detection tools could be altered, failing to detect some conflicts.

- Higher variability of cost indexes was not part of the validation exercises. The effects of this high variability can have an impact on conflict detection and resolution and this has to be further studied.

5.2.3 Conclusions regarding the use of improved meteorological data for TP and CD&R

- Use of WTQ Grib data improvements
  - An improved meteorological model with a finer granularity of wind, temperature and QNH information was used in the TP calculation with more accurate and more frequent WTQ grid data updates (GRIB2 of ICON-EU, a DWD weather product). It is demonstrated that it can be processed with the given set-up, therefore increasing the accuracy of the Trajectory Prediction.
- Use of weather forecast from ADS-C reports improvements (not part of the solution 53B)
  - The quality of the ADS-C meteo data (temperature and wind) from the aircraft is confirmed and shows great potential for weather forecast improvement.
  - The use of ADS-C meteo data (temperature and wind), downlinked from the aircraft, as an additional input to the weather forecast improves the evaluation of the quality of the forecast model.

These improvements are caveated with the following point:

- The use of airborne derived MET data in the TP of the ground system and CD&R tools has not been validated as part of the scope of solution 53B. The meteo integration between air and ground systems (wind, temperature…) needs further validation as some exercises were performed in a standard meteo environment (no wind, standard temperature), the difference in weather data between the ground and the airborne has an impact on the trajectory calculation by the ground and airborne systems and therefore on the CDRs (EPP data deviation compared to flown trajectory).

5.3 Conclusions on technical feasibility

Each set of Solution PJ18-W2-53B exercises validated different sets of functionalities on various platforms. The overall conclusion is that solution functionalities are considered technically feasible.

Detailed conclusions on technical feasibility are provided below:

- It has been demonstrated that ADS-C EPP data can be processed and used for trajectory prediction and CD&R tools. In addition, the consideration of more accurate and up-to-date wind and temperature data further reduces the error on vertical profile in trajectory prediction.

- The amount of ADS-C EPP data can be processed with the provided technical performance of the equipment.

- More accurate and more frequent WTQ grid data (GRIB2 of ICON-EU, a DWD weather product) can be processed as well with the given set-up.
- The technical implementation of the Trajectory Prediction taking into account ADS-EPP data did not reveal deficiencies. The ADS-C contracts (periodicity and on event contracts) have to be smartly set-up in order to avoid too many ADS-C EPP messages used for the Trajectory Prediction and the CD&R tools.

5.4 Conclusions on performance assessments

The execution of the validation exercises belonging to Solution PJ.18-W2 SOL53B confirms a positive effect of the use of the ADC-S/EPP and Met data for trajectory prediction and conflict detection and resolution tools. More precise trajectories, enhanced with the EPP data, provide greater accuracy and reduced uncertainty regarding the future positions of the EPP equipped aircraft. Increased trajectory accuracy and use of ADS-C EPP data (for envelope calculation) contribute to improve conflict detection and provision of conflict resolutions.

These results lead to reduced workload and improved situational awareness of the ATCOs. Therefore, the beneficial outcomes for the KPI related to capacity, safety and cost efficiency have been measured. In addition, improvements in operational efficiency and environmental impact have been also demonstrated.

Results and main conclusions in the following key performance areas are summarised below:

Human Performance

Overall, the exercises report a positive effect on their performance when using the functionalities under validation, with improvements in ATCO's situational awareness and workload.

The acceptability and suitability with the use of new improved tools and associated operating methods was rated as good level and the level of task performance appears to be increased

EXE011 reported some limitations on the exercise setup and the conflict detection and resolution tools under validation that could have impacted the human performance rating of new functionalities. The exercise allowed demonstrating that the EPP data transmitted from the aircraft might be operationally feasible, but a limited benefit to Human Performance was recorded (more details can be found in Appendix D.3.5.3.

Airspace Capacity

Three of the exercises of SOL53B were able to measure the impact on the airspace capacity:

- EXE008 concluded that, for a 30% EPP equipage rate, the capacity increase could be 3.21% for En-route and 7.95% in the TMA; and for a 50% EPP equipage rate, the capacity increase could be 5.11% for En-route and 9.04% in the TMA.
- EXE012 concluded that the capacity increase could be of 5% for solution 53B (alone) and up to 7,5% combined with solution 56 considering that these two solutions are increasing their respective benefits if combined (and with 80% flights equipped with EPP).

- EXE011 assessed the impact on airspace capacity, but the results could not provide a quantitative increment of capacity.

Overall, the increased capacity offered by solution implementation allows to manage the expected traffic level/complexity at horizon 2035 (based on 2035-extrapolation scenario traffic load).

Operational Efficiency and Environment

Two of the exercises of SOL53B were able to measure and/or observe some operational efficiency and environment gains for the solution:

EXE008 concluded that here is an improvement in the fuel burn, track distance flown by aircraft and CO2 emissions for the TMA sector. In contrast, the results for ENR show negligible improvement of the above parameters.

EXE012 reports that qualitative gains have been clearly reported by ATCOs. There is no measured positive or negative impact regarding 2D efficiency from a quantitative perspective (no clear trend). In parallel, 3D quantitative flight efficiency gains are demonstrated with better flight profiles in climb, in cruise and descent.

Cost Efficiency

Based on the expected increase in the capacity, same number of ATCOs can handle more aircraft in sectors and therefore increase the number of flights controlled by an ATCO then improve ATM Cost Efficiency.

For airspace users, trajectories can be more optimised thanks to a better Trajectory Prediction and enhanced CD&R tools allowing more optimised conflict resolutions. With capacity gains and a better trajectory management by ATCOs, flights have the possibility to more frequently fly at optimum cruise flight levels and are longer maintained at their RFL.

EXE011 assessed the impact on cost efficiency and the results showed that from an ACTOs perspective the tool under validation does not have a positive impact on possible cost efficiency (more info on EXE011 can be found in Appendix D in this VALR).

Safety

Based on quantitative and qualitative results (data logs) the level of safety is maintained with the use of the new functionalities while traffic has been increased.

The obtained results from EXE011 do not show any trends of decreasing safety, but in order to provide more certain conclusions, further investigation is recommended.

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6 Recommendations and Additional activities

A detailed list of recommendations is provided in this section.

6.1 Recommendations for next phase

6.1.1 Recommendations for future research and development

The following recommendations to be considered for future SESAR solutions

REC-01: Aircraft downlinking corrupted but credible ADS-C data was not considered in 53B. The impact that this has is in confidence that the controller can have in the predictions provided by the tools. Future SESAR solutions involving automation (i.e. those planned in ATC-TBO) will require ATCOs to have heightened trust in tools and tools predictions than 53B. Therefore, to improve the confidence needed for these solutions (where they rely on downlinked trajectory data) it is recommended to validate degraded modes for conflict detection and resolution tools due to corrupted ADS-C EPP data. In particular, such a validation would benefit from the use of live data.

REC-02: To validate the impact of cost-index variations on conflict detection and resolution tools.

REC-03: The use of airborne derived MET data in the ground trajectory prediction and conflict detection & resolution tools was not part of the solution 53B. However, it is considered that it could bring benefits. Therefore, further study of this is recommended.

REC-04: To further validate the vertical evolution clearance with level constraint function which was judged to be extremely promising by ATCOs in the Skyguide-led exercise 012, taking into account FMS capabilities and What-if tool improvements, etc.

REC-05: Descent When Ready (with automation) and Level Constraints topics are found very promising by the ATCOs, however their behaviour has to be further analysed and some FMS capabilities have to be also studied in order to cope with the objective of these functions. This has to be addressed in the next phase of SESAR activities (SESAR 3) (advanced versions and working methods, HMI and automation). Furthermore, the naming "Descent When Ready" is not appropriate in this case and this should be more "Descent as FMS plan".

REC-06: Sequencing merging is not part of solution 53B. However, to achieve the full potential and the benefits of the CD&R tools, advanced sequencing functionality must be developed and incorporated. Even though, the provided conflict resolutions ensure safety, they often don't correspond with ATCO's plan. Therefore, the ATCOs might not use them. The sequencing functionality is primarily needed for the TMA sector, where orderly flow of landing aircraft must be maintained.

REC-07: An information on the Figure of merit associated with conflicts (conflicts between ATN-B1 flights, ATN-B1/ATS-B2 flights and ATS-B2/ATS-B2 flights) is recommended for awareness of ATCOs. A code or colour code adapted to tools / conflict detection process characteristics (envelopes adaptation according to aircraft equipment) could allow ATCOs to adapt the margin / buffer for separation in their way of controlling (analysis of the conflict and resolution as well).

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REC-08: The catch up from below manoeuvre function in solution 53B implements a 1000ft/min or 500ft/min descent rate catch up from below assumption. This is not typical of all aircraft types and could be made more accurate in the future. For future R&D it work it is recommended to consider using the EPP input instead of a standard 1000/500ft/per min in TP for catch up from below manoeuvres in potential combination with downlinked ROD (rate of descend).

6.1.2 Recommendations for industrialisation and deployment

REC-01: To test degraded modes for conflict detection and resolution tools due to corrupted ADS-C EPP data. In particular, testing would benefit from the use of live data. This testing should take full consideration of the strong caveat on degraded modes expressed in Section 5.2.2 of this Contextual Note that addresses a specific partner concern.

REC-02: Aircraft behaving differently than expected by the ground TP due to a delay in the downlink of an updated EPP when the aircraft changes its speed profile mid-flight is a concern that has been expressed and should be considered in the industrialisation and deployment activities of the solution.

REC-03: The results show that the use of airborne data (ADS-C EPP and speed schedule) in the ground system greatly improve ground tools. Operational benefits from ATC part and also from airborne part can be achieved in the short/medium term. However, it relies on a minimum airborne equipage rate that shall be sufficient for operational benefits. It is therefore recommended that the airborne equipage forecast shall be evaluated quickly in order to enable efficient deployment planning.

REC-04: To continue to evaluate the impact of the FMS mode (selected or managed) on the use of ADS-C EPP data in ground tools.

REC-05: A more detailed study of ADS-C contracts to be established and reliability/usability of downlinked data must be carefully studied.

REC-06: Considering the validation results of the joint Solution 53B and 56 exercises, the simultaneous implementation of ADS-C EPP and CPDLC ATS-B2 is highly recommended.

REC-07: Concerning Descent When Ready function, it is necessary to develop a new monitoring function on the descent profile permanently checking that initial Descent conditions considered for conflict detection are still valid and warn the controller if not.

REC-08: To get optimal use of ADS-C EPP data in the Trajectory Prediction tools, the calibration process has to be made with the vertical EPP profile performances. This data is available in the ADS-C EPP report during the climb phase. Therefore, the ATC ground system shall be able to get this data even if the flight in cruise when arriving in the airspace. These ADS-C EPP data shall be made available when required by the ATC ground system. This would be possible with an ADS-C Common Service. This ADS-C Common Service shall be the primary source to get ADS-E EPP data.

REC-09: When implementing advanced visualization of flight trajectory and EPP report (type of turns, TOC/TOD and vertical profile), to efficiently support ATCOs actions, a particular attention must be paid on displaying data in due time and without ambiguity e.g.:

- distinction between cleared and predicted trajectory parts (e.g. colour coding)
- easy identification of flight phase considered by FMS (e.g. TOC/D display - more restrictive speeds in climb, cruise and descent) and adapted units (e.g. speed in MACH / CAS / IAS)

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REC-10: It is recommended to share the ADS-C data on a near real time and continuous and regular manner with the European meteorological community via preferably EMADDC and for EMADDC to perform quality control. The obtained and quality controlled observations can be used by the meteorological community including MET ANSPs to improve the quality of meteorological nowcasts and forecasts for aeronautical purposes such as TP performance, and for operational use by aeronautical meteorological forecasters. Especially the good quality of the temperature observations at lower level has added value for aeronautical meteorological service provision.

REC-11: It is recommended that more parameters are added to the ADS-C dataset, such as roll angle and True Airspeed (TAS). This will enable the meteorological community to calculate wind and temperature information for the ADS-C messages where meteorological information is missing and can be used for verification if the data is present. Adding roll angle will allow for improved validation and input quality control of the data by the meteorological community c.q. EMADDC. From a meteorological perspective, the inclusion of magnetic heading, on top of the included true north heading, would be beneficial for EMADDC to improve the calculation of the specific aircraft correction being used in the derivation of wind and temperature information by EMADDC.

REC-12: Where possible, airlines operating ATS B2 equipped aircraft, should endeavour to carry the most actual descent winds to facilitate the least amount of speed variation in the descent due to FMS adjustments to maintain the planned path. This will facilitate better profiles for validation and is also a beneficial step towards the future concept, yielding more fuel savings.

REC-13: To consider the creation of an enabler for the provision of ADS-C MET data from the ADS-C Common Server to MET Service Providers.

7 Actors impacted by the SESAR Solution

- ATC ENR planner controllers
- ATC ENR executive controllers
- ATC TMA planner controllers
- ATC TMA executive controllers
- Airspace Users
- ANSPs

8 Impact on Aircraft System

In order to perform this kind of improvements, aircraft should be equipped with ADS-C functionality, to be able to downlink Extended Projected Profile (EPP) messages to ATC Ground system.

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9 Impact on Ground Systems

- Ground systems must be updated with all the functionality needed to support the new improvements, concerning trajectory prediction using ADS-C reports, BADA model, Conflict Detection Tools, Enhanced Tactical Conflict Resolution proposals, new planned conflict resolution approach, as well as implementation of WTQ Grib data and **weather forecast**

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10 Regulatory Framework Considerations

For the improvements that take benefits from EPP data, it is critical that EPP standards and/or the use of EPP data by the Ground systems, are mandated in order to rapidly increase the equipage rate. CP1 AF6 Implementing regulation NO 716/2014 requires a certain proportion of aircraft to be equipped with ADS-C EPP capability by 2026 and all European ground systems to be ADS-C capable by 2025.

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11 Standardization Framework Considerations

Applicable standards covering ATN Baseline 2 are:

- Safety & Perf Req. Std. for Baseline 2 ATS Data Com, EUROCAE ED-228A
- Interoperability Req. Std. for Baseline 2 ATS Data Com, EUROCAE ED-229A
- EUROCAE Interoperability Requirements Standard For Baseline 2 ATS Data Communications, Fans 1/A Accommodation (Fans 1/A – Baseline 2 Interop Standard), ED-230A
- EUROCAE Interoperability Requirements Standard For Baseline 2 ATS Data Communications, ATN Baseline 1 Accommodation (ATN Baseline 1 – Baseline 2 Interop Standard),ED-231A

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12 Solution Data pack

The Data pack for this Solution 53B - D.2.2. - SESAR Solution 53B Data Pack for V3 includes the documents:

- D2.2.101 - SESAR Solution 53B SPR-INTEROP/OSED for V3
- D2.2.106 - SESAR Solution 53B CBA for V3
- D2.2.102 - SESAR Solution 53B TS/IRS for V3
- D2.2.105 - SESAR Solution 53B VALR for V3

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