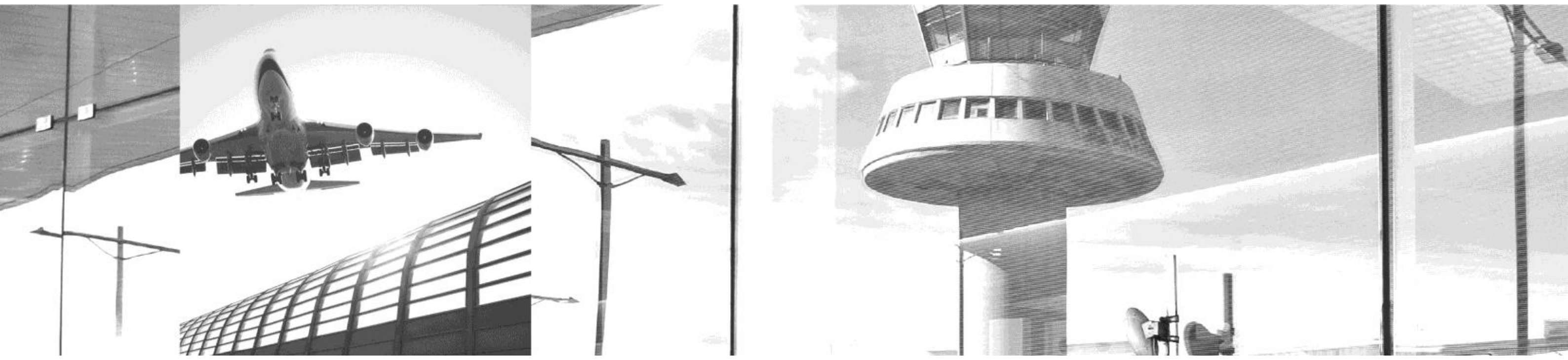

Applications of ADS-C

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1 Introduction

In July 2014, the Knowledge and Development Centre Schiphol (KDC) awarded a consortium consisting of MovingDot, Ferway and the National Aerospace Laboratory (NLR) a contract to study potential applications of the Automatic Dependent Surveillance-Contract (ADS-C) concept. The present report provides an overview of the results of this study.

1.1 Study purpose

The request for proposal by KDC [Ref. 1] included three main purposes of the study:

- Create an overview of the current and future Automatic Dependent Surveillance-Contract (ADS-C) equipage of aircraft operating at Schiphol. Aircraft with ADS-C operating on the Future Air Navigation System (FANS)1/A[1] network are part of the study;
- Determine which ADS-C data items are described in regulations, standards and guidance material (ICAO Standards and Recommended Practices (SARPS) or Documents (DOCS), Notices of Proposed Amendment (NPA) from The European Aviation Safety Agency (EASA) and EU Implementing Rules (IR)) are feasible to use for Schiphol traffic. Examples are: downlink of 4D trajectory information, aircraft state information (e.g. position, speed and heading) and meteorological information;
- Create an overview of potential applications of ADS-C with potential benefits to safety, efficiency and the environment.

1.2 ADS-C concept

Automatic Dependent Surveillance-Contract (ADS-C) is defined as a means for surveillance by which the terms of an ADS-C agreement will be exchanged between the ground system and the aircraft using a datalink. Specification under which conditions ADS contracts would be initiated and what data would be contained depends on the service. ADS contracts can be established using the FANS 1/A service or the Aeronautical Telecommunication Network (ATN) B1.

FANS 1/A uses the Aircraft Communications Addressing and Reporting System (ACARS) as datalink while ATN B1 uses the VHF Data Link Mode 2 (VDL2) where the latter datalink does not support ADS-C yet. The transfer of data via these datalink is carried out by a commercial service provider and is associated with costs for airlines.

ADS-C is conceptually capable of three types of message contracts:

1. A periodic contract (normal and emergency) in which certain information is requested to be sent at a specified rate;
2. An event contract in which certain information is requested at the occurrence of a specified event (or sequence of events);
3. A demand contract in which a one-time polling of the aircraft for specific information is requested.

[1] FANS 1 is used by Boeing, FANS A is used by Airbus Industry

There is a wide variety of data items available through ADS-C. This makes it possible to downlink for example aircraft state information, aircraft intent information and meteorological information. The information can be used, for instance, to verify the aircraft information with the ground systems information to detect discrepancies between Air Traffic Control (ATC) ground systems and Flight Management System (FMS). The exchange of state and intent information can also be used to enhance ATC radar trackers and planning tools. In particular, intent information may enhance the predictability of the operation and is a key ingredient to future Trajectory Based Operations.

1.3 Project approach

To achieve the study objectives as described, a project was set-up with three main groups of activities:

A. Technical analysis of ADS-C
B. Operational applications of ADS-C
C. Reporting of results

The aim of the first activity in group A is to get a general understanding of ADS-C applicable regulations and the available standards and guidance material. The result is an overview of all possible ADS-C data items with a brief description. In turn, as part of the second activity, the availability of ADS-C in aircraft operating at Schiphol is studied based on recent flight plan information. From ADS-C equipped aircraft, sample data is obtained and studied for the actual availability of individual data items. Next to the current equipage, main Schiphol operators and avionics manufactures are consulted to get a view of how the equipage rate may evolve within the next five years.

In activity group B the operational interest in ADS-C information is studied during interviews with operational experts and systems experts of Air Traffic Control the Netherlands (LVNL). Besides internal stakeholders from LVNL, technical experts from the Royal Dutch Airlines (KLM) and Royal Netherlands Meteorological Institute (KNMI) are interviewed. Together with the experts, an overview of the operational interest for both air traffic controllers and ground systems is created.

In plenary sessions, the results of activity group A and B are assembled leading to potential ADS-C applications including data quality and constraints. Finally these results are reported as part of activity group C. The interaction between the groups of activities is illustrated in Figure 1-1.

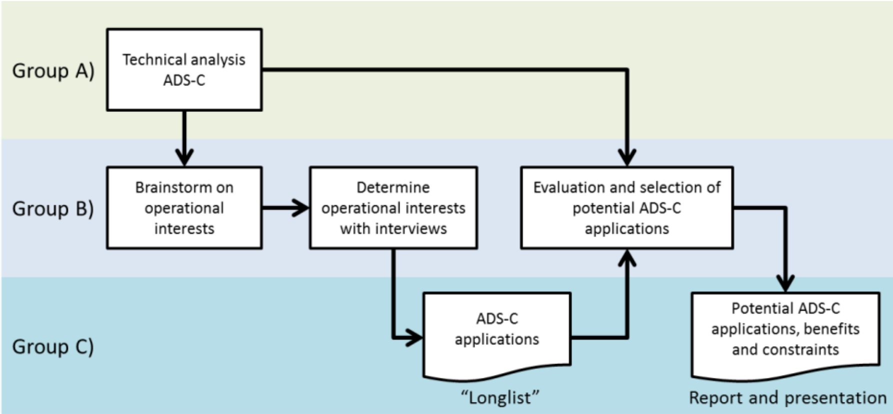

Figure 1-1 Project approach

1.4 Reading guide

The report structure adopts the so-called Pyramid principle [Ref. 2] where the main results and conclusion precede the detailed results and context information. By applying this principle the report will be as concise as possible, allowing the reader to choose the preferred level of detail in reading the report.

After the introduction in chapter 1, chapter 2 will cover the study's results, conclusions and recommendations. Chapter 3 describes the results from the operational interest in ADS-C following several interviews and plenary sessions. Chapter 4 will detail the technical analysis with, for example, the flight plan analysis and ADS-C sample data analysis. This chapter also covers the prediction of the ADS-C equipage level within the next five years. The report is concluded in chapter 5, with an overview of currently available ADS-C standards and guidance material.

2 Potential applications of ADS-C

2.1 Conclusions

The number of potential operational applications is limited by the low ADS-C equipage rate

Aeronautical Dependent Surveillance – Contract (ADS-C) is a surveillance protocol where the provision of aircraft state and intent and meteorological information is contracted between aircraft and Air Traffic Control (ATC). The number of potential operational applications of ADS-C for Air Traffic Control the Netherlands (LVNL) is limited by the current low ADS-C equipage rate of aircraft operating at Schiphol Airport. Measurements over a period of nine months showed that on average 16% of Schiphol inbound and outbound aircraft operating under Instrument Flight Rules (IFR) is equipped with ADS-C. This group consists primarily of wide-body aircraft. In the specific period from 04:00 till 06:30 hours (local time) the ADS-C equipage of inbound aircraft increases up to 80% because of a high number of incoming intercontinental wide-bodies.

No increase in ADS-C equipage rate expected in the next five years

Currently there is no active North-American or European regulation mandating ADS-C and it is also not foreseen within the study's time scope of 5 years. Standardisation material for ADS-C is readily available though. It consists of a number of Standards and Recommended Practices and other guidance material from the International Civil Aviation Organisation (ICAO) and several documents of the European Organisation for Civil Aviation Equipment (EUROCAE) and the Radio Technical Commission for Aeronautics (RTCA).

Main aircraft operators at Schiphol, like Royal Dutch Airlines (KLM), easyJet and Transavia do not plan to extend their ADS-C equipage rates unless regulations will force them to. KLM currently has its Boeing 747-400, Boeing 777 and Airbus A330 aircraft equipped with ADS-C while easyJet and Transavia with solely Airbus A320 and Boeing 737 aircraft, have no ADS-C equipage on board. From Delta Airlines, another major aircraft operator at Schiphol, no information was received.

Operational applications regardless of the low ADS-C equipage rate

In the present study, no operational applications have been identified that fulfil an urgent operational need for LVNL. Nevertheless, some applications with an operational interest were found. Two applications were identified that meet operational interest regardless of the low ADS-C equipage rate:

- The meteorological service provider can improve their weather model and weather report based on wind speed and direction and temperature information obtained from equipped aircraft;
- ADS-C can improve the sequencing process of wide-body aircraft during night transitions by Approach control (APP). During the early morning inbound peak with a high percentage of ADS-C equipped aircraft, a timely and accurate Fixed Projected Intent information (FPI) can be fed to the Arrival Manager (AMAN). The same holds for the state Information fed to the Cross Border Arrival Manager (XMAN).

Operational applications for an increased ADS-C equipage rate

Additionally, two other applications were identified that meet operational interest which, however, can only be addressed with an increased ADS-C equipage rate and further study:

- For APP, ADS-C may reduce workload by checking the selected ILS frequency for the assigned runway during parallel approaches and alerting the controller when necessary;
- For Tower control (TWR), ADS-C may reduce the number of mistakes with Standard Instrument Departures (SID) by systematically checking the correct SID selection in the FMS before take-off and alerting the controller when necessary.

2.2 Recommendations

It is recommended to further study the operational application of weather information because of the number of direct benefits regardless of the low equipage rate.

It is also recommended to further study the use of ADS-C FPI information in AMAN (Arrival Manager) and aircraft state information in XMAN (Cross Border Arrival Manager) for application especially during the early morning at Schiphol (04:00 – 06:30 hours (local time)) when night transitions are flown and the level of ADS-C equipped aircraft is high.

Furthermore, it is also recommended to establish a cost and benefit analysis for the setup of an ADS-C ground infrastructure to obtain the parameters that meet operational interest regardless of the low ADS-C equipage rate. Cost and benefits for aircraft operators should be an inherent part of the mentioned studies, because aircraft operators are charged for the exchange of ADS-C data.

Finally, it is recommended to actively monitor European research programs with ADS-C involvement. If ADS-C becomes the major SESAR (Single European Sky ATM research) surveillance data source, the potential benefit of applications addressing SID and runway selection will increase.

2.3 Main results

For Future Air Navigation Services (FANS) 1/A, which is at present the only operational ADS-C compatible datalink, the following ADS-C items are readily available in equipped aircraft. On the same ADS-C data items an initial analysis was performed based on sample data.

Table 2-1 Available ADS-C data items

Data group	Data item
Aircraft state information	Latitude, longitude, altitude, track, speed, vertical rate
Meteorological information	Wind speed and direction, temperature
Fixed Projected Intent (FPI) information	For a requested time interval ahead: Predicted aircraft position and predicted altitude
Intermediate Projected Intent (IPI) information	For multiple (up to 10) planned waypoints ahead: Position (bearing/distance), projected altitude and projected time interval

Table 2-2 illustrates the applications of ADS-C as a result of this study. The applications are listed per stakeholder, which can be a LVNL operational unit, department or another Air Navigation Service Provider (ANSP). After a brief description of the application, the potential effects on key performance areas as used by LVNL, which are safety, efficiency and environment, are identified. The results of the technical analysis concerning data availability and data quality are indicated in the last two columns. For data availability, the indicated percentage is the number of ADS-C filed flight plan as part of all filed flight plans for inbound or outbound IFR aircraft at Schiphol airport within a period of nine months. The data quality indication is the result of an initial analysis performed on limited data from Air Services Australia (ASA), because no data was available for the Amsterdam Flight Information Region (FIR). As a consequence the feasibility of the mentioned applications in the Amsterdam FIR could not be verified.

Table 2-2 Applications of ADS-C

Stakeholder	Applications	Potential effect	ADS-C item	Availability	Quality indication
ACC	Presenting the **predicted altitude** at coordination points can improve controller's situational awareness.	Safety, efficiency	Intermediate projected Intent	16%	Good
APP	Systematically checking the **correct runway selection** and alerting the controller for discrepancies, can reduce his workload.	Safety	Fixed projected Intent	16%	Good
TWR	Systematically checking the **correct SID** waypoints and a quick alert for the controller for discrepancies, can avoid SID mistakes.	Safety, efficiency, environment	Intermediate projected Intent	16%	No indication available
Technical systems	Delivering the predicted time at the runway threshold can enable improvement of the **sequencing of traffic on night transitions**.	Efficiency	Intermediate projected Intent	80%[2]	Good
Meteorological Service Provider	**Wind speed and direction and temperature information** can improve weather model and weather report.	Safety, efficiency	Meteorological information	16%	Good

[2] This percentage is based on the number of ADS-C filed flight plan in the time period between 04:00 till 06:30 hours (local time), which is a different time span than used for the calculation of the other percentages (24 hours).

3 Operational interests

In this chapter the ADS-C applications that can be of added value to ATC, Meteorological Service Providers and Airline Operators are described. It is important to note that from operational perspective this study can be seen as an extension of the KDC study "New applications of Downlink Airborne Parameters" (DAP study) [Ref. 3] into Mode S Enhanced Surveillance (EHS) that was published in January 2014. Many possible applications of ADS-C are comparable with the applications of the DAP study and are therefore not again substantially studied with regard to operational need. The main focus is put on applications based on aircraft intent information as requested by KDC.

In general, operational air traffic controllers (ATCO) welcome every application that provides them with an additional safety net. Every additional detected error is important, they argue. Human Factor-wise one has to wonder whether the implementation of an operational application, even if it leads to high safety benefit (SID control, track selection), is desirable as it will work for only 16% of air traffic. In this case, the risk that a controller fully relies on a system that does not work for 84% of the aircraft is real and present. On a sideline, it should also be noted that the value of 16% ADS-C equipage is an average rate over a long time period. During the day the ADS-C equipage rate will vary.

The following sections describe the results of the questioning of relevant LVNL units and departments, KNMI and KLM. For all the mentioned application, the required ADS-C data item(s) and the expected benefits for the Air Traffic Management (ATM) system in terms of safety, efficiency or environmental (SEE benefits) are described. For each application, an initial feasibility study has been performed based on literature research and a limited ADS-C sample data set provided by ASA because no data was available for the Amsterdam FIR. Note that this does not determine feasibility for Schiphol.

3.1 Area control (ACC)

Predicted altitude

At the crossing of routes or when entering new traffic areas like Terminal Approach Areas (TMA) or the sector of an adjacent centres, it is relevant for an ATCO to know whether an aircraft will meet the assigned flight level at a coordination point or at a waypoint with other flight level restrictions.

Rate of climb/descent is a parameter that the ACC ATCO currently estimates based on successive track updates resulting from the aircraft Mode S transponder. The rate of climb/descent is also used to estimate if certain specific climb/descent restrictions can be met.

Unchanged from the findings of the DAP study is that displaying the actual rate of climb/descent on the radar screen is faster and provides a better indication than the current ATCO estimate and can therefore lead to improved safety and efficiency. Identical to Mode S EHS, ADS-C cannot extract the controller preferred *selected* rate of climb. Instead, ADS-C can provide, for each programmed waypoint, the predicted altitude which is a relevant data item for specific coordination points at sector boundaries or the Initial Approach Fix (IAF) at the TMA boundary. The altitude predictions towards the IAF may prove to contribute to the ATCO's situational awareness of of the arriving aircraft intentions. Such possibilities need further exploration.

This ADS-C data item is part of the Intermediate Projected Intent (IPI) group, one of the defined ADS-C groups within FANS 1/A (see chapter 5). It should be noted that the accuracy of the predictions will, amongst others, depend on the operating method of the aircraft. ADS-C has been designed for oceanic control and has not been used much for tactical control. When the aircraft is under tactical control (vectoring), the flight path instructed by the ATCO deviates from the calculated FMS flight plan. Because the ATCO instructions cannot be predicted by the FMS, the FMS calculations during tactical control will be less accurate

The datalinks used for ADS-C have a variable update rate up to 64 seconds and a variable delay depending on the datalink. A downlink of the rate of climb/descent via ADS-C is therefore less interesting because the data has limited validity. There are simpler and faster methods based on Mode S Enhanced Surveillance or radar tracker algorithms available to obtain this particular information.

Contrary to the rate of climb/descent, the predicted altitude can be obtained via ADS-C only. This data items seems beneficial in both pre-tactical and tactical ADS-C. The variable update rate and delay may however limit the operational use in tactical ATC.

Required ADS-C data items	<u>Intermediate Projected Intent</u> Position (bearing/distance), projected altitude and projected time interval
SEE benefits	Safety, efficiency

3.2 Approach control (APP)

Check on Runway Selection

Verifying that the correct frequency of the Instrument Landing System (ILS) has been selected is important; particularly during parallel landing operations to reduce the risk that approaching aircraft converge to the same runway. Currently the ATCO has to check the correct setting of the ILS frequency via Radio Telephony (R/T). In FMS systems of modern aircraft, the ILS frequency is linked to the runway selection in the active flight plan/route in the FMS. If this runway selection could be downlinked via ADS-C, a check via R/T would become obsolete. The automatic verification of the selected frequency of the ILS during parallel approaches by means of the verification of the landing runway obtained via ADS-C can reduce the ATCO workload.

In the Fixed Projected Intent (FPI) data group, one of the defined ADS-C groups within FANS 1/A (see chapter 5), the coordinates of a waypoint at a projected time interval can be extracted. The final waypoint of each flight is the runway. Hence, with the request for a prediction of a sufficient time interval ahead, it is feasible to verify the runway entered into the FMS.

An initial examination of ADS-C sample data shows that the selected runway can indeed be found in the data. A further study of the aircraft operational manuals of the most common ADS-C equipped aircraft shows the following. The Airbus A330, Boeing 747-400 and Boeing 777 include the functionality to automatically tune the ILS frequency and course. The ILS frequency and course may also be entered manually, which will overrule the auto-tuning.

It can be concluded that ADS-C offers the possibility to verify the selected runway and, as a result of that, the selected ILS frequency. This is information that cannot be obtained with Mode S EHS.

Required ADS-C data items	<u>Fixed Projected Intent</u> Position, predicted altitude, projected time interval
SEE benefits	Safety, efficiency

3.3 Tower control (TWR)

Check on SID selection

The Standard Instrument Departures (SID's) of parallel runways are designed to guarantee divergence of flight tracks. Especially in parallel operations divergence with the correct SID flown is crucial. Because the SID is linked to the departure runway, there is a need at the TWR controller to have information on the correct runway and SID selection.

An automatic check on the selection of the correct SID may reduce the number of SID mistakes and thus improves safety. For Schiphol this could mean that ATCOs may use parallel departure operations under a wider range of meteorological conditions. Thus the check on SID selection does not only improve safety, but it could also improve efficiency and reduce environment impacts because higher priority preferential runway combinations with higher runway capacity can be used for a longer period of time.

The runway and SID selection can be derived from sequential waypoints. These waypoints are programmed in the FMS which can be accessed via ADS-C as part of the IPI group.

Examination of ADS-C sample data shows that FMS programmed waypoints are available in the data. Since the initial feasibility could only be tested using a limited dataset from ASA, it was not possible to study how these waypoints correlate with the published SID. Similarly, it was not studied how ADS-C performs prior to departure. For now it is assumed that a check on the selected runway and SID can be performed with the IPI. In Mode S EHS this information could not be directly found; divergence was determined by monitoring aircraft roll/track angle. Further research steps are needed to specifically verify the feasibility of the application at Schiphol.

Required ADS-C data items	Intermediate Projected Intent Position (bearing/distance), projected altitude and projected time interval
SEE benefits	Safety, efficiency, environment

3.4 Technical systems

The application of ADS-C data groups for machine-related purposes has been discussed with a LVNL ground system expert. In this interview the main topic touched is the interest for ADS-C information like aircraft state, intent and meteorological information within current planning tools at LVNL.

LVNL is about to implement its new arrival manager (AMAN), which is a tool that determines an arrival sequence and planning for Schiphol airport based on current aircraft state information and actual flight plans. The current planning horizon of AMAN is about 150 NM (14 minutes from the metering fix). It is assumed that 20 minutes will be the ultimate planning horizon for the Schiphol AMAN considering factors like available radar coverage, inter-centre coordination and the nature of pop-up traffic from nearby aerodromes. Future developments will involve cross border arrival managers (XMAN) where aircraft state and flight plan information is shared between adjacent ANSPs to reach a planning horizon of 200 NM or beyond.

Aircraft operating within (LVNL) radar coverage have a sufficient quality of state information. Outside this airspace currently limited aircraft state information is available in the form of an ETA sent by the Enhanced Tactical Flow Management Systems (ETFMS) of EUROCONTROL. However, state information downlinked from ADS-C can be used to provide more accurate estimates outside the radar coverage. Studies into the use of FANS data have shown that ADS-C can indeed supplement aircraft trajectory prediction in ground systems for the purpose of arrival management [Ref. 4].
In future, XMAN will consider availability of accurate estimates and planning information across borders. Several sources of aircraft state and intent information may be considered for use in this concept: downlinking ADS-C information or sharing it among ANSP's is candidate. This future development does however not preclude to already follow suit on several activities in the world where ADS-C data has been used. Initial use cases of ADS-C can serve as path finding activities for developments towards System Wide Information Management (SWIM). SWIM covers a complete change in paradigm of how information is managed along its full lifecycle and across the whole European ATM system[3].

ADS-C is considered more successful in pre-tactical ATC than in tactical ATC because of the variable message update rate (1-64 seconds) of ADS-C datalinks and the inaccurate FMS predictions during vectoring in the tactical phase. In the pre-tactical phase no general applications of ADS-C in AMAN

[3] https://www.eurocontrol.int/swim

are foreseen for this study's time scope. Specific applications of ADS-C following an operational need can be implemented in AMAN with limited effort.

Sequencing on night transitions

Because of a Controller–Pilot Data Link Communications (CPDLC) mandate over the Atlantic Ocean, Canada and several Chinese routes, KLM modified his wide-body aircraft with the FANS package of Boeing. This package included besides CPDLC also ADS-C. During the time period of the early morning at Schiphol (04:00 – 06:30 hours (local time)) when night transitions are flown, the traffic consists of mostly wide-body aircraft. Data analysis (see Section 4.1.2) showed that the ADS-C coverage in this period is up to 80% for inbound aircraft.

During night-time, traffic is less dense and therefore there is less need for active control by the ATCO's. Frequently, pilots can choose speed, the Top of Descent (TOD) and the rate of descent at their own discretion for flight efficiency reasons. This leads to a great diversity of speed and descent profiles. Due to the lack of a supporting planning Trajectory Predictor (TP) for such diverse profiles, the currently used expected approach times can hardly be achieved by the ATCO. The disadvantage of this diversity of flight profiles and lack of support tools is that predictability for the ATCO is negatively affected with respect to the vertical profile as well as time. This requires ad hoc intervention of the ATCO, resulting in inefficiencies due to deviations from continuous descent operations. Given better predictability, early control of speed may aid in sequencing the traffic at night and allows more aircraft to continue for a more optimal descent profile without being vectored.

The ADS-C FPI can be used in the AMAN-tool to improve the planning to create a more accurate sequencing and metering. State information can also be used by ACC as additional information from the XMAN tool to provide earlier and more accurate speed control.

The interviewed ATCO's endorsed this application, but added that, as a precondition that this application should be compatible with AMAN and that ADS-C non-equipped aircraft easily can be fit in the sequence without disturbing the other flight profiles.

In short, ADS-C can periodically provide accurate state information to the advanced trajectory management tools (AMAN, Speed and Route Advisor (SARA), XMAN) which can lead to an improved planning leading to better sequencing and metering for night transitions where currently no adequate supporting tool is present. Vertical profiles and estimate data can improve predictability for the ATCO with the large diversity of flight profiles at night-time.

Required ADS-C data items	Intermediate Projected Intent Position (bearing/distance), projected altitude and projected time interval
SEE benefits	Efficiency, environment

3.5 Meteorological Service Provider

The Royal Netherlands Meteorological Institute (KNMI) provides meteorological information to the LVNL. This information comprises primarily two categories:

- Weather conditions at surface level relevant for airport operations. This concerns information like visibility, cloud base, rain or snow probabilities etc.
- Winds and temperatures aloft. This information is used by the TP application of the ANSP to predict aircraft trajectories. Planning support and conflict detection tools in turn use this trajectory information for their functions.

KNMI has conducted substantial analysis [Ref. 5] of weather information that can be derived from the aircraft by means of aircraft state information provided through Mode S EHS and other sources. Observations made in the vicinity of Schiphol showed that, compared to Mode S EHS, ADS wind observations are of similar quality and ADS temperature observations are of better quality [Ref. 6]. The already available studies into the quality of the meteorological information group eliminates the need for additional analysis based on sample data.

Wind speed and direction and temperature

The ADS-C datalink application can provide, amongst others, meteorological information in what is called the meteorological information group. The aforementioned study by KNMI has revealed that the quality of wind-information is comparable to, and the temperature information is of higher quality than the information currently available from AMDAR. The KNMI therefore has expressed strong interest in being able to use this information source for their weather model processing.

KNMI expects that assimilating ADS-C sourced wind and especially temperature information will bring the following benefits for their products and their users:

Improvement of the weather model:

1) Supplementary source of weather observations to their current method of a daily balloon release into the atmosphere.
2) More accurate determination of the freezing level (also improves the weather report)
3) Verification of the winds aloft, improving forecasts up to 15 hours

Improvement of the weather report:

1) Winter season: additional source of information to determine the type of precipitation (rain, snow, freezing rain, etc.), aiding in model verification.
2) Summer season: in cases of doubt, the information will help to determine whether or not showers will develop.

LVNL ground system experts consider it feasible to share downlinked ADS-C information with KNMI. LVNL is currently sharing Mode S Enhanced Surveillance data with KNMI. In the upcoming release of AMAN there is no compatibility with high-resolution wind conditions from ADS-C yet. In the future, high-resolution wind information from the KNMI obtained via ADS-C can improve trajectory predictions for the LVNL AMAN.

Required ADS-C data items	Meteorological information Wind speed and direction, temperature
SEE benefits	Safety, efficiency

3.6 Airline Operator

KLM explains that it can communicate ADS-C information via ACARS. A communication service provider links ACARS equipment on the aircraft to the ground systems. Compared to information sent via Mode S EHS or ADS-Broadcast (ADS-B), the communication service providers charge airlines for data exchange.

KLM currently has no means to process ADS-C information yet. Hence, KLM was not in a position to provide this project with ADS-C sample data in the Schiphol context.

From KLM experts' point of view, no operational interest exists for intent information apart from the estimated time of arrival. Navigational state information and aircraft operator-related state information, i.e. aircraft and fuel status and estimated time of arrival, are already satisfactorily obtained via the Aeronautical Operational Control (AOC) datalink that uses the ACARS network too. The AOC datalink is able, from the KLM experts' point of view, to provide more functionality than ADS-C and is seen as an alternative. Standardisation of the AOC datalink for applications in ATS has never been accomplished though.

4 Technical analysis

In this chapter the potential of ADS-C is described from a technical point of view. The potential applications for ADS-C data are not only determined by the types of data and the frequency with which the data can be offered, but also by the equipage level of the fleet visiting Schiphol.

In the next section, the level of equipage is exposed based on individual flights and separately for a number of main Schiphol operators. After studying the present, a representation is given of interviews with the main stakeholders like airframe and avionics manufacturers and aircraft operators into the technical developments of ADS-C for the next 5 years. Then, the results of an initial analysis of ADS-C data quality are shown using a data sample provided by ASA. The chapter concludes with an overview of the required steps for LVNL to set up a ground infrastructure to implement ADS-C into their ATM system.

4.1 Equipage Schiphol fleet

4.1.1 Time frame analysis

An analysis was conducted to establish the ADS-C equipage of the current aircraft fleet visiting Schiphol. To this end, flights from 1-Jan-2014 till 10-Sep-2014 were selected. Of this period, all Flight Plan (FPL) messages concerning IFR (Instrument Flight Rules) flights to be operated to and/or from Schiphol airport were analysed. In the FPL message, the subfield "SSR equipment" will contain, amongst any other possible indicators, the indicator "D1" to signify ADS-C capability carriage.

The available flight plans were analysed first by considering them without any further criteria. The results of the 323,128 flight plans analysed are shown in Figure 4-1.

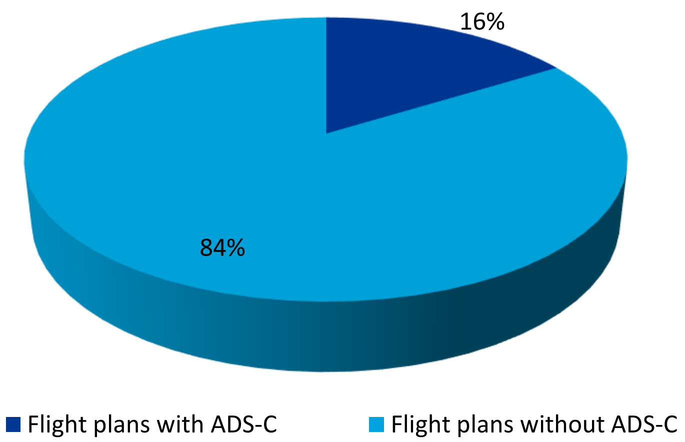

Figure 4-1 Flight plans indicating ADS-C equipage

When analysing the composition of the set of flight plans indicating that an aircraft is ADS-C equipped, practically all of these aircraft (98%) are of the wide-body category. Although most ADS-C equipped aircraft are wide-bodies, not all wide-body aircraft are ADS-C equipped (approximately

80/85% of wide-bodies). This needs to be taken into account when considering the options for ADS-C applications.

4.1.2 Early morning arrivals

The average ADS-C equipage level as found in the study of all flights visiting Schiphol is fairly low. Since many wide-body aircraft are ADS-C equipped, the early morning arrivals were mentioned by ATCO's as a period that could be of interest for ADS-C application where typically the majority of the arriving flights are wide-bodies. To verify this statement, the distribution of ADS-C equipage level during the day has been studied. The results are depicted in Figure 4-2. The underlying information, listed in Annex A, gives an impression of the distribution of the number of flight plans during the day.

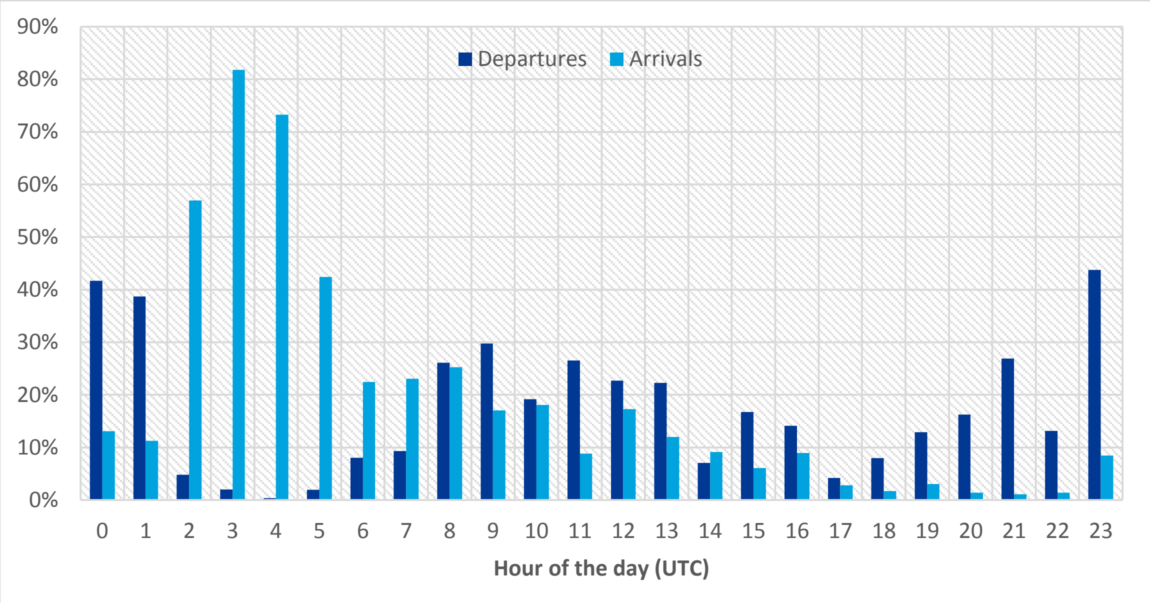

Figure 4-2 ADS-C equipage level distribution at Schiphol over the day

It is found in the figure that for the early morning period (from 04:00 until 06:30 hours (local time)), about 80% of the flights arriving at Schiphol are ADS-C equipped.

4.1.3 Main aircraft operators

According to the annual report Schiphol 2013[4] the top 5 aircraft operators at Schiphol on a total of 425.565 movements are listed:

[4] http://www.jaarverslagschiphol.nl/resultaten/top-connectivity/verkeer-en-vervoer/vliegtuigbewegingen

Table 4-1 Movements of top 5 aircraft operators with percentages of total movements

#	Airline operator	Percentage of total movements	Number of movements
1	KLM	50,7%	215.670
2	Transavia	6,4%	27.462
3	easyJet	5,9%	25.076
4	Air France	3,2%	13.517
5	Delta Airlines	2,7%	11.353

In the top 5 operators at Schiphol airport the ADS-C coverage is as follows:

Table 4-2 ADS-C equipage as percentage of total movements

#	Airline operator	Percentage of ADS-C equipped flights
1	KLM	9%
2	Transavia	0%
3	easyJet	0%
4	Air France	0%
5	Delta Airlines	2%

From this data it follows that the top 5 aircraft operators at Schiphol account for 69% of aircraft movements. As they account for a representative number of movements as well as ADS-C equipage, these aircraft operators were contacted and interviewed for their plans with ADS-C in the next 5 years. The results of these interviews are described in section 4.2.1.

4.2 Equipage developments in the next 5 years

4.2.1 Main aircraft operators

KLM

The KLM fleet[5], as of 31 December 2013, consisted of the following aircraft:

[5] www.airfranceklm.com

Table 4-3 KLM fleet description

Aircraft type	Number of aircraft
Long haul	
Boeing 747-400	22
Boeing 777	23
Airbus A330	16
Boeing MD-11	5
Medium haul	
Boeing 737NG	47
Regional	
Embraer E190	24
Fokker 70	26
Cargo	
Boeing 747-400	4

The KLM Airbus A330, Boeing 747-400 and Boeing 777 aircraft are equipped with ADS-C, i.e. 39% of its total fleet. With the planned introduction of the Boeing 787 and some additional Boeing 777s and the retirement of the MD-11 fleet, this percentage may slightly increase in the short/medium future.

Transavia

The Transavia fleet[6], as of 31 December 2013, consisted of the following aircraft:

[6] www.airfranceklm.com

Table 4-4 Transavia fleet description

Aircraft type	Number of aircraft
Medium haul	
Boeing 737NG	30

None of the Transavia aircraft are equipped with ADS-C, and it also not anticipated (including potential fleet replacements) that this will change in the short/medium future. Since there is no European mandate to have ADS-C capability, there is no incentive to install it on the Transavia fleet.

easyJet

The easyJet fleet[7], as of 30 September 2014, consisted of the following aircraft:

Table 4-5 easyJet fleet description

Aircraft type	Number of aircraft
Short haul	
Airbus A320 family	226

None of the easyJet aircraft are equipped with ADS-C, and it also not anticipated that this will change (including fleet expansion and replacement plans involving the A320neo) in the short/medium future.

Delta

No information was received about the ADS-C equipage of their fleet.

4.2.2 Airframe and avionics manufacturers

Current situation

Information about ADS-C was received from Boeing, Honeywell and Rockwell Collins. There is only one ADS-C capability currently fielded – FANS. It is defined in the RTCA DO-258A / EUROCAE ED-100A INTEROP document (Radio Technical Commission for Aeronautics, The European Organisation for Civil Aviation Equipment) It is currently used widely in oceanic airspace and some domestic airspace such as Australia, but it is not used domestically in the United States or Europe.

[7] www.corporateeasyjet.com – Annual report and accounts 2014

FANS-1/A-based ADS-C is available on all Boeing aircraft. On the long hauls (B-777, B-787, B-747-8), it is typically a basic function and on the rest it is optional. Retrofit is possible for those Boeing aircraft delivered without the capability, but this can be very expensive, especially if the aircraft does not have satellite communication (SATCOM) already. However, for domestic airspace, SATCOM would not be needed.

Honeywell provides FANS 1/A capability on every Boeing and Airbus aircraft except for the Boeing 737 which is provided by GE Aviation. Thales is an alternative supplier on the Airbus 320 family and Airbus A330/A340. Furthermore, FANS 1/A from Honeywell is available as an option on some Gulfstream business aircraft and Embraer regional aircraft. Many aircraft in the fleet have the capability in the aircraft systems but have not paid the aircraft manufacturers to have the feature enabled, typically for aircraft that operate mostly over mainland. For these aircraft it would be relatively inexpensive to turn the feature on, compared to aircraft that would need retrofit to newer avionics. However, some aircraft have older avionics that would need retrofit to have FANS capability, with varying cost required depending upon the age of the aircraft and how much needs to be upgraded to bring the avionics up to newer models.

Rockwell Collins is offering FANS 1/A capability on a number of business aircraft, i.e., several models of Bombardier, Gulfstream, and Dassault.

Near term future (initial Baseline 2) and more distance future (final Baseline 2)
There are new requirements published by RTCA and EUROCAE for (initial) Baseline 2 ATS Data Communications, including more sophisticated ADS-C capability with five more report types – including extended projected profile (EPP)[8] and time of arrival range and several new event types [Ref. 7]. Europe is planning a large-scale demonstration including initial Baseline 2 in the 2018-2019 timeframe, equipping about 100 in-service aircraft and some number of ground stations. Honeywell is working on several development prototype systems to prepare for full product development, including working with Airbus on the SESAR A320, and internal research on other product lines. Honeywell has no defined product introduction dates yet. RTCA SC-214 and EUROCAE WG-78 are defining final Baseline 2, with plans to publish it in 2016. The plan is to support additional services of Dynamic Required Navigation Performance (RNP), Advanced Flight Deck Interval Management, and ATC Winds. Baseline 2 final will likely introduce further capability to ADS-C to support these new services, such as RNP reporting. The United States are planning to field Baseline 2 final in the 2022-2025 timeframe. Honeywell was not aware of the schedule for Europe to transition from the large scale demonstration of Baseline 2 initial to full implementation of either Baseline 2 initial or final.

Boeing does not have plans for the short-term future to develop Baseline 2 capability.

[8] The new ADS-C EPP reports will contain aircraft trajectory predictions for up to 128 waypoints with details of predicted time, speed, altitude, etc. The new ADS-C EPP reports will provide richer aircraft predictions to the Air Traffic Controller and/or ground system.

4.3 ADS-C data quality

The ADS-C datalink application is part of the Air Traffic Services (ATS) datalink FANS or ATN package. Contrary to AOC datalink, ATS datalink implementations need to comply with strict regulations and standards. This leaves little room for airlines and/or aircraft manufacturers to implement specific parts or element of the datalink specification differently or not implement them at all. Hence, as experience with ADS-C in Oceanic Control centres has shown, quality and availability of ADS-C data has proven to be consistently high. In general, it can be assumed that whenever ADS-C carriage is reported, the information detailed in the ATS datalink specifications will be available. Some exceptions exist as will be further described in Section 5.3.

For this study, ASA provided example ADS-C downlinks. This ANSP has substantial experience with the use of FANS applications because of the large oceanic regions under their control. FANS is known to have many uses for oceanic control.

ADS-C has been designed for oceanic control and has not been used much for tactical control. When the aircraft is under tactical control (vectoring), the flight path instructed by the ATCO deviates from the calculated FMS flight plan. Because the ATCO instructions cannot be predicted by the FMS, the FMS calculations during tactical control will be less accurate. Use of ADS-C data in a tactical control operation like vectoring should therefore be considered with care.

The sample data from ASA demonstrated that well before actual arrival (about 45 minutes) the ADS-C downlinked information provided the landing runway programmed into the Flight Management Computer (FMC). The same downlink information also showed consistent reporting of the next few waypoints the FMC will use for lateral guidance. The first information element could assist in verifying if the correct landing runway is selected by the aircrew, the latter can potentially provide information about the SID that has been loaded prior to take-off (the actual downlinking of the departure waypoint after take-off was not available in the downlinks provided and could therefore not be verified).

4.4 ADS-C ground infrastructure

In an interview with an LVNL ground systems expert, the following activities were drafted which are required for the introduction of ADS-C downlink information in the LVNL ATM System:

a. Architecture impact analysis: The impact on the current system architecture as well as the required changes to facilitate this new information flow through the ATM System to both applications and the controller. An updated system architecture would be the result of this activity.
b. Based on the analysis in a), the hardware solution chosen will most likely require network components to be acquired either off-the-shelf or custom-made.
c. Appropriate changes to current applications or new applications and their human machine interfaces. Depending on the functionalities selected, these may need to be made in the TWR system and/or the APP/ACC System (AAA (Amsterdam Advanced ATC

system), and in future: iCAS (iTEC Centre Automation System)). Other system functionalities will be impacted in the Communication (COM) and/or Surveillance (SUR) infrastructure.

5 ADS-C standards and regulation

5.1 Introduction

As part of this study, an analysis of available standards and regulations was performed in order to describe the current level of development concerning ADS-C and the possible future developments. Regulations are legal norms created by a governing body and are intended to shape a desired conduct. In case of the European Union, regulations are legal acts that become immediately enforceable as law in all member states simultaneously. Standards and recommended practices for air navigation and infrastructure are produced by the International Civil Aviation Organisation (ICAO). Standards concerning civil aviation equipment are often produced jointly by Eurocae and the RTCA. The analysis also included an inventory and functional description of the available ADS-C messages and message blocks.

Regulations did not provide much information about ADS-C. The reason for this is that the international focus is currently on services from the Eurocontrol LINK 2000+ Programme. The most applicable regulation document of the European Commission is the *Data Link Services Implementing Rule* (EC Reg. No. 29/2009) which states:

"A significant number of data link services have been defined by the International Civil Aviation Organisation (hereinafter ICAO) and by the European Organisation for Civil Aviation Equipment (hereinafter Eurocae). Only those which have been sufficiently validated at Eurocontrol level should be the subject of mandatory introduction, based on the standards defined by these organisations."

Adhering to this statement, the Special Condition on ATN B1 Data Link installation of EASA refers to abovementioned implementing rule and only considers the services for Data Link Initiation Capability (DLIC), ATC Communications Management (ACM), ATC Clearances (ACL) and ATC Microphone Check (AMC). These are all LINK 2000+ services that have been standardised by Eurocae/RTCA.

In the same way FAA Advisory Circular 20-140B for LOA 056: Airworthiness requirements for aircraft with an installed data link system intended to support air traffic services, also refer to the Eurocae/RTCA documentation.

Summarizing, the regulation material for ADS-C does not exist yet as only CPDLC services are currently in the process of being regulated.

Standardisation material for ADS-C is readily available, though. All in all, it consists of a number of ICAO Standards and Recommended Practices (SARPs) and several Eurocae/RTCA documents. The documents that were considered in this study are:

Table 5-1 Relevant ICAO Standards and Recommended Practices (SARPs)

ICAO documents
Annex 10: Aeronautical Telecommunications (Vol. III: Communication Systems)
PANS-ATM
Annex 2: Rules of the Air
Annex 11: Air Traffic Services (ATS)
Doc 9705: Manual of Technical Provisions for the ATN
Doc 9694: Manual of ATS Data Link Applications
GOLD: Global Operational Data Link Document

Table 5-2 Relevant Eurocae/RTCA documents

EUROCAE/RTCA documents
ED 100A: FANS 1/A INTEROP
ED 110B: ATN B1 INTEROP
ED 154A: FANS 1/A - ATN B1 INTEROP
ED 122: SPR for D/L in Oceanic & Remote Airspace

5.2 Overview of studied reference material

Before going into the details described in these standards, it should be noted that the Eurocae/RTCA documentation shows that FANS 1/A is the service collection that is currently available in most aircraft and includes ADS-C. ATN B1, however, which is the preferred service for continental airspace defined by ICAO, does currently only cover the Link2000+ services mentioned above. ATN should thus be seen as a future development for which standards are defined, but which does not consider ADS-C yet in regulation or implementation activities. This has a number of consequences in terms of data availability, which will be highlighted later. First, a look will be taken at the ICAO documentation, though, which focuses on ATN as the communication service for ADS-C.

Annex 10: Aeronautical Telecommunication contains a general ADS application description (chapter 3.5.2.1) and several ATN related requirements (chapters 3.4.22 and 3.5.2.1.1). In summary, it describes the ADS-C application as a service with an airborne and ground component, where the airborne ADS application component is capable of automatically providing data derived from on-board navigation systems to the ground component. It also mentions five types of contract that can be established between ground and airborne systems. The ATN is seen as the communications service for ADS-C.

ICAO DOC 4444 PANS-ATM (Procedures for Air Navigation Services - Air Traffic Management) goes a bit further by describing the contents of ADS-C reports, however, following the descriptions of the ATN, meaning that some of the contents will currently not be provided by aircraft systems. Chapter 13 of this document is an extensive section about ADS service provision. In particular, it describes functional requirements for ADS-C ground system capabilities and the use of ADS-C in the provision of ATS.

Annex 2: Rules of the Air merely addresses requirements concerning ADS-C equipped aircraft in case of interception and unlawful interference.

Annex 11: Air Traffic Services includes several procedure-related requirements for emergencies and transfer of control (chapters 2.23, 3.6, 6.2.3) and a general requirement for automatic recording of surveillance data that also mentions ADS-C (chapter 6.4.1).

ICAO Doc 9694: Manual of ATS Data Link Applications is a rather old document (from 1999) with Part III describing several general aspects of ADS-C. Generally, the document has the same high-level contents as chapter 13 of the PANS-ATM concerning ADS use, but it contains additional information regarding reliability, availability and integrity as well as data communication and message details.

ICAO Doc 9705: Manual of Technical Provisions for the ATN is also an older document (from 2002). ADS is described in Sub-Volume II, chapter 2.2.1 and contains a general application description with several requirements, an abstract service description, formal message definitions, protocol definitions, communication requirements, user requirements (contract and communication details), and conformance requirements (protocol details). ADS report forwarding is described in chapter 2.2.2.

The few paragraphs above only give a rough description of the contents of the ICAO literature that contains standards and requirements for ADS. Since the documentation is rather old and somewhat incoherent, ICAO in recent years started working on the so-*called ICAO Global Operational Data Link Document*, briefly called GOLD. Edition 2 of this document was published in 2013. GOLD addresses data link service provision, operator readiness, controller and flight crew procedures, performance-based specifications and post-implementation monitoring and analysis standards. It facilitates uniform application of SARPs from Annex 2/10/11, PANS-ATM, and regional SUPPs (Doc 7030). The GOLD standard has the status of ICAO regional guidance material. It comprises material that is supposed to assist the user in the application of the SARPs and PANS.

The studied EUROCAE documents do not address ADS-C directly, but set down interoperability requirements for FANS 1/A and ATN B1 in which ADS-C is one of the data link service elements (ED 100 and ED 110). ED 154 concentrates on differences between ATN and FANS. ED 122 looks at Safety and Performance Requirements (SPR) in oceanic and remote airspace and addresses specific services in use in these regions. ED 120, which is the corresponding SPR document for continental Airspace did not contain any details about ADS-C.

5.3 Details of standards describing ADS-C

The following paragraphs will highlight some of the most important elements and properties of ADS-C. The main source for operational requirements was the GOLD standard, because it follows current practice and the more realistic service provision via FANS1/A, and the PANS-ATM as it offers the most complete set of requirements. Technical details and requirements were taken from the Eurocae documents.

In almost all ICAO documents the following definitions concerning ADS-C are given:

ADS-C Agreement

A reporting plan, which establishes the conditions of ADS-C data reporting (i.e. data required by the air traffic services unit and frequency of ADS-C reports which have to be agreed to prior to using ADS-C in the provision of air traffic services). The terms of the agreement will be exchanged between the ground system and the aircraft by means of a contract, or a series of contracts

Automatic Dependent Surveillance - Contract (ADS-C)

A means by which the terms of an ADS-C agreement will be exchanged between the ground system and the aircraft, via a data link, specifying under what conditions ADS-C reports would be initiated, and what data would be contained in the reports.

Up to five separate ground systems may request ADS contracts with a single aircraft (ICAO GOLD, chapter 2.2.6) and an equipped aircraft must be capable of supporting ADS-C agreements with at least four ATC unit ADS-C ground systems simultaneously (PANS-ATM, chapter 13.4.3.4). For communication, ADS-C makes use of FANS 1/A via ACARS or ATN B1 via VDL2 (VHF) where the latter service does not yet contain ADS-C in practice.

ADS-C is conceptually capable of three types of message contracts:

1. A periodic contract (normal and emergency) in which certain information is requested to be sent at a specified rate;
2. An event contract in which certain information is requested at the occurrence of a specified event (or sequence of events);
3. A demand contract in which a one-time polling of the aircraft for specific information is requested.

It should be noted that in other ICAO documents (e.g. Annex 10) five contracts are mentioned. In this case the fourth contract is an emergency contract (described in the list above as a special case of the periodic contract) and the fifth contract is a forward contract (between two ADS ground components). Also a demand contract might be considered as a periodic contract with a reporting rate of zero. For ATN it is additionally required that the ground system supports the ADS emergency mode as defined in ICAO Doc 9705.

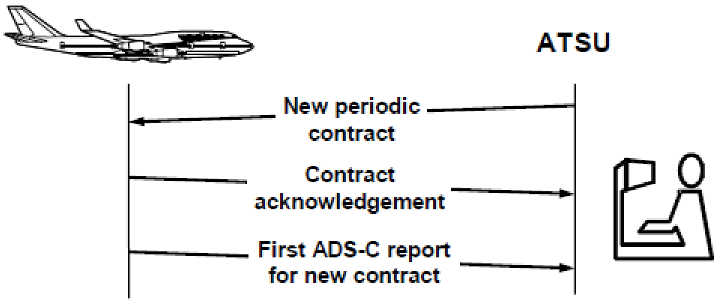

Figure 5-1: ADS-C Periodic Contract Sequence (Source: ICAO GOLD)

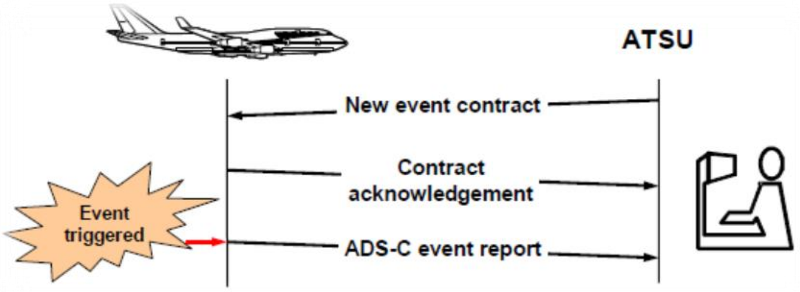

Figure 5-2: ADS-C Event Contract Sequence (Source: ICAO GOLD)

The figure above shows the difference between a periodic and event contract as depicted in the GOLD standard. Event contracts can be triggered by different types of events. The ones considered in the GOLD standard are:

- Waypoint Changes (due to waypoint sequencing or operational reason)
- Level Range Deviation (with an upper and lower limit)
- Lateral Deviation (from expected position in flight plan larger than threshold)
- Vertical Rate Change (rate of climb/descent exceeds threshold values)

Other events documented in ED 122 (Oceanic SPR) but not in use for applications and not mentioned in GOLD are:

- Airspeed Change
- Ground Speed Change
- Heading Change
- Extended Projected Profile Change
- Figure of Merit (FOM) Change
- Track Angle Change
- Level Change

As regards the data contained in ADS messages a difference between basic and on-request data is made. The Basic ADS Group that contains the aircraft latitude, longitude, altitude, time stamp and

FOM included in all ADS-C messages sent. The reporting rate or interval defines how often the Basic ADS Group is sent. Additional information is available and structured into On-request Groups. Each on-request group may have a unique modulus that indicates how often an on-request group would be included with the Basic ADS Group sent.

Depending on whether the PANS-ATM standard is considered, which builds on ATN, or the GOLD standard, which is more practical as it related to FANS 1/A, data groups might look a bit different. Table 5-3 shows the FANS 1/A definition from the ICAO GOLD. Next the data groups are described using illustrations from the GOLD standard.

Table 5-3 Definition of Basic and On-request Groups given in PANS-ATM

A	**Aircraft identification**	D	**Air vector** Heading Mach or IAS Rate of climb or descent	G	**Short term intent** Latitude at projected intent point Longitude at projected intent point Altitude at projected intent point Time of projection If an altitude, track or speed change is predicted to occur between the aircraft's current position and the projected intent point, additional information would be provided in an intermediate intent block as follows Distance from current point to change point Track from current point to change point Altitude at change point Predicted time at change point
B	**Basic ADS** Latitude Longitude Altitude Time Figure of Merit	E	**Projected profile** Next waypoint Estimated altitude at next waypoint Estimated time at next waypoint (next+1) waypoint Estimated altitude at (next+1) Estimated time at (nect+1) waypoint		
C	**Ground Vector** Track Ground speed Rate of climb or descent	F	**Meteorological information** Wind speed Wind direction Wind quality flag Temperature Turbulence (if available) Humidity (if available)	H	**Extended projected profile (in response to an interrogation from the ground system)** Next waypoint Estimated altitude at next waypoint Estimated time at next waypoint (next+1) waypoint Estimated altitude at (next+1) waypoint Estimated time at (next+1) waypoint (next+2) waypoint Estimated altitude at (next+2) waypoint Estimated time at (next+2) waypoint (repeated for up to (next+128) waypoints

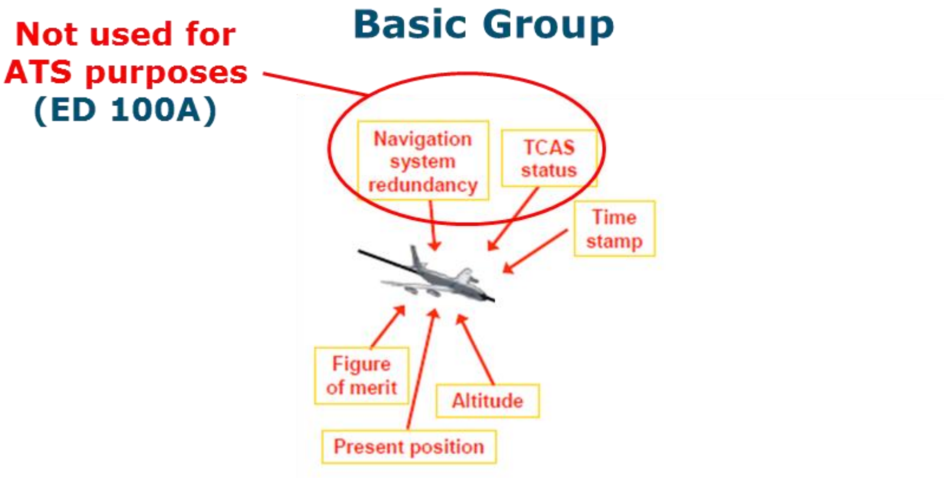

Figure 5-3: ADS-C Basic Group

As can be seen the Basic ADS Group (Figure 5-3) contains the present position. This position is given in longitude/latitude together with the altitude and a time stamp in seconds past the last hour. A figure of merit (FOM) provides the navigational accuracy of position data on a scale from 0 to 7, i.e. from complete loss of navigational capability to augmented GPS accuracy (less than 0.05 NM). The indicated TCAS status and the navigation system redundancy are not used for ATS purposes according to ED 100A.

Figure 5-4: ADS-C Flight Identification Group

The Flight Identification Group (Figure 5-4) contains the aircraft identification that must match the one in the filed flight plan.

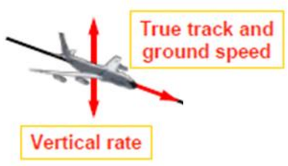

Figure 5-5: ADS-C Earth Reference Group

The Earth Reference Group (Figure 5-5) contains true track and ground speed as well as vertical rate (at the current position and time stamp).

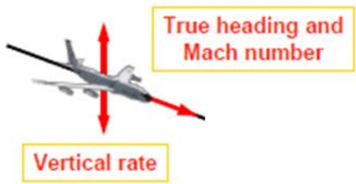

Figure 5-6: ADS-C Air Reference Group

The Air Reference Group (Figure 5-6) contains the true heading and Mach number as well as the vertical rate again (at the current position and time stamp).

Figure 5-7: ADS-C Airframe Identification Group

The Airframe Identification Group (Figure 5-7) contains the aircraft 24-bit code address.

Figure 5-8: ADS-C Meteorological Group

The Meteorological Group (Figure 5-8) contains the measured wind speed and direction as well as temperature (at the current position and time stamp).

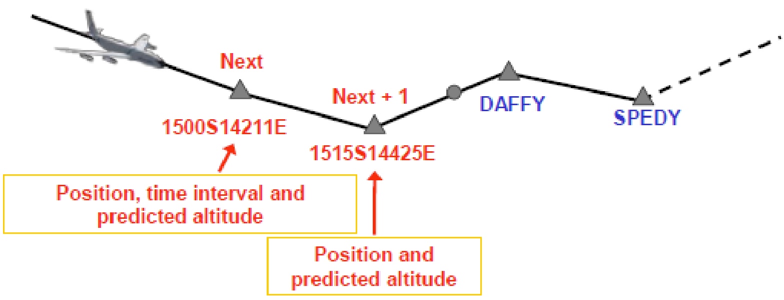

Figure 5-9: ADS-C Predicted Route Group

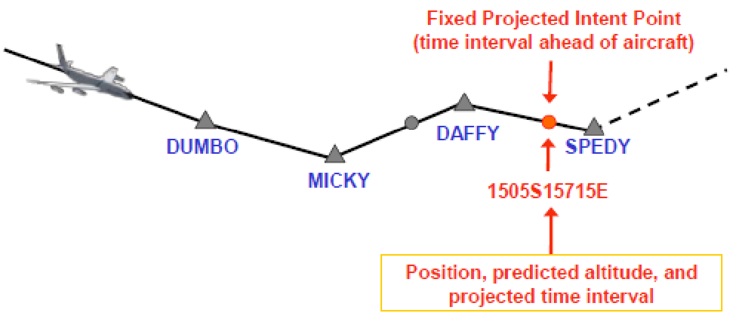

Figure 5-10: ADS-C Fixed Projected Intent Group

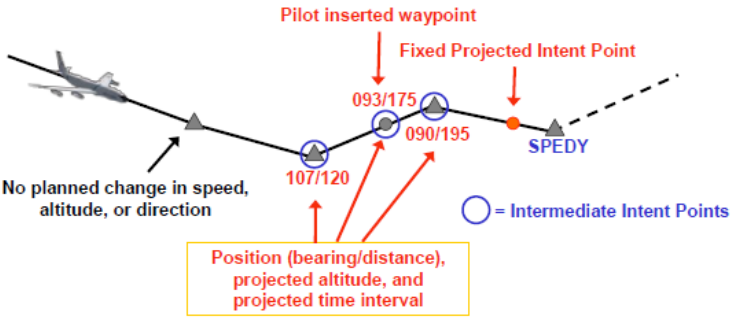

Figure 5-11: ADS-C Intermediate Projected Intent Group

The biggest difference between the ATN and FANS definition is the ATN defined Extended Projected Profile (EPP), which must be capable of sending intent information to the ground including the next 128 waypoints. Such an amount of data is not sent in the FANS groups in use today. They either have the Predicted Route Group (see Figure 5 10), which corresponds with the Projected Profile (PP), or the Fixed Projected Intent (FPI), a single intent point, not necessarily on a waypoint (see Figure 5 11) and the Intermediate Projected Intent Group (IPI) which consists of a Fixed Projected Intent Point and up to 10 positions in between the current point and the Fixed Projected Intent Point at which route changes happen, such as a change in altitude or speed (see Figure 5 12). The latter two would fall in the Short-term Intent Group as described for the ATN.

The only optional groups considered in ED 110 are the PP and the EPP. ED 110 also describes the Flight Plan Consistency (FLIPCY) service. The objective of this service is to automatically detect inconsistencies between the ATC used flight plan and the one activated in the aircraft system. It provides controllers and aircrew with automated support confirming that the route and terminal area portions of the airborne and ground flight plans are in conformance. FLIPCY is an Air Traffic Service based on the ADS application. The service description for FLIPCY assumes use of an ADS Demand Contract, but any of the ADS contract types discussed earlier may be used.
In oceanic and remote airspace there are two other ADS-C related services that are based on Position Reporting and Information Exchange Reporting (PR/IER). Route Conformance Monitoring is achieved by making use of PRs. Separation assurance uses ADS periodic and event reports with PR and IER.

Further, the ADS-C ground system capabilities that are described in GOLD and PANS-ATM standards concern the services in which ADS-C reports may further be used:

- In conflict detection and prediction ADS-C reports for establishing and monitoring of traditional time-based separation minima or distance-based separation standards.
- In flight plan updates. Estimates for downstream waypoints or other information of the flight plan, such as the Mach number from the Air Reference Group, may be updated in the ATSU.
- For updating meteorological information (wind forecasts).
- Waypoints may be flagged as passed.
- In conformance monitoring the basic and intent groups are compared to the flight plan. This will help to ensure route and level conformance (lateral and level deviation) and help generating (and clearing) alerts by monitoring vertical rate changes.
- The ADS-C position symbol may be updated and extrapolated for tracking purposes.
- Also the data may be used for generating (and clearing) ADS-C emergencies.

Abbreviations

ACARS	Aircraft Communications Addressing and Reporting System
ACC	Area Control Centre
ACL	ATC Clearances
ACM	ATC Communications Management
ADS-C	Automatic Dependent Surveillance-Contract
AMAN	Arrival Manager
AMC	ATC Microphone Check
ANSP	Air Navigation Service Provider
AOC	Aeronautical Operational Control
APP	Approach
ASA	Air Services Australia
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
COM	Communication
CPDLC	Controller-pilot data link communications
DAP	Downlink Airborne Parameters
DLIC	Data Link Initiation Capability
DOCS	Documents
EASA	The European Aviation Safety Agency (EASA)
EHS	Enhanced Surveillance
EPP	Extended Projected Profile
ETA	Expected time of Arrival
ETFMS	Enhanced Tactical Flow Management Systems
EUROCAE	The European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FIM	Flight Deck Interval Management
FIR	Flight Information Region
FLIPCY	Flight Plan Consistency
FMC	Flight Management Computer
FMS	Flight Management System
FOM	Figure Of Merit
FPI	Fixed Projected Intent

FPL	Flightplan
GOLD	ICAO Global Operational Data Link Document
IAF	Initial Approach Fix
ICAO	International Civi lAviation Organisation
iCAS	iTEC Center Automation System
IER	Information Exchange Reporting
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IPI	Intermediate Projectes Intent
IR	Implementing Rules
KDC	Knowledge and Development Centre Schiphol
KLM	Royal Dutch Airlines
KNMI	Dutch Meteorological Service Provider
LVNL	Air traffic Control the Netherlands
MCDU	Multipurpose Control&Display Unit
NAV	Navigational
NLR	National Aerospace Laboratory
NPA	Notices of Proposed Amandment
PANS	Procedures for Air Navigation Services
PP	Projected Profile
PR	Position Reporting
RNP	Required Navigation Performance
RTCA	Radio Technical Commission for Aeronauticals
SARA	Speed and Route Advisor
SARPS	Standards and Recommended Practices
SATCOM	Satellite Communication
SEE	Safety, Efficiency, Environmental
SESAR	Single European Sky ATM research
SID	Standard Instrument Departure
SPR	Safety and Performance Requirements
SUPP	Supplement
SUR	Surveillance
SWIM	System Wide Information Management
TMA	Terminal Approach Area
TP	Trajectory Prediction
TWR	Tower
VDL2	VHF data Link Mode 2
XMAN	Cross Border Arrival Manager

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Annex A ADS-C equipage at Schiphol airport over the day

A.1 Departures

Hour (UTC)	ADS-C in flightplan	No ADS-C in flight plan	Total flight plans	ADS-C %
0	40	56	96	42%
1	65	103	168	39%
2	19	374	393	5%
3	44	2119	2163	2%
4	14	3873	3887	0%
5	115	5819	5934	2%
6	586	6719	7305	8%
7	1095	10652	11747	9%
8	3460	9806	13266	26%
9	3407	8050	11457	30%
10	1976	8332	10308	19%
11	2656	7358	10014	27%
12	2248	7649	9897	23%
13	1789	6237	8026	22%
14	758	9979	10737	7%
15	1659	8260	9919	17%
16	841	5117	5958	14%
17	222	5064	5286	4%
18	871	10072	10943	8%
19	1692	11428	13120	13%
20	861	4438	5299	16%
21	327	890	1217	27%
22	61	402	463	13%
23	42	54	96	44%

A.2 Arrivals

Hour (UTC)	ADS-C in flightplan	No ADS-C in flight plan	Total flight plans	ADS-C %
0	163	1080	1243	13%
1	75	590	665	11%
2	479	362	841	57%
3	2195	489	2684	82%
4	3531	1288	4819	73%
5	3831	5200	9031	42%
6	2947	10192	13139	22%
7	2163	7223	9386	23%
8	1928	5697	7625	25%
9	1319	6416	7735	17%
10	1202	5455	6657	18%
11	703	7278	7981	9%
12	949	4546	5495	17%
13	1129	8303	9432	12%
14	506	5021	5527	9%
15	214	3310	3524	6%
16	581	5904	6485	9%
17	319	11057	11376	3%
18	132	7592	7724	2%
19	128	4079	4207	3%
20	41	2839	2880	1%
21	14	1264	1278	1%
22	9	621	630	1%
23	18	195	213	8%