INTERNATONAL CIVIL AVIATION ORGANIZATION
ASIA AND PACIFIC OFFICE

Multilateration (MLAT)
Concept of use

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List of Acronyms

ADS-B	automatic dependent surveillance — broadcast
ADS-C	automatic dependent surveillance — contract (also known as
	ADS or ADS-A)
ADSP	ADS Panel (of ICAO)
AIGD	ADS-B Implementation and Operations Guidance Document
	Trade name for Rannoch Multilateration
AIRSCENE	aeronautical information services
AIS	Asia-Pacific Air Navigation Planning and Implementation
APANPIRG	Regional Group
	area proximity warning
APW	airborne separation assistance system
ASAS	airport surface detection equipment
ASDE	airspace management
ASM	air traffic control
ATC	air traffic flow management
ATFM	air traffic management
ATM	Air Traffic Management Operational Concept Panel
ATMCP	controller access parameters
CAP	cockpit display of traffic information
CDTI	communications, navigation and surveillance
CNS	controller-pilot data link communications
CPDLC	data link initiation capability
DLIC	emergency locator transmitter
ELT	estimated time of arrival
ETA	future air navigation systems
FANS	flow and capacity management
F&CM	flight information service — broadcast
FIS-B	flight management system
FMS	global navigation satellite system
GNSS	ground proximity warning
GPW	high frequency
HF	human-machine interface
HMI	initial approach fix
IAF	International Civil Aviation Organization
ICAO	instrument flight rules
IFR	Multistatic Dependent Surveillance: Sensis trade name for
MDS	multilateration
	Multilateration
MLAT	minimum safe altitude warning
MSAW	medium term conflict detection
MTCD	ICAO's Operational Data Link Panel
OPLINKP	primary surveillance radar
PSR	regular passenger transport
RPT	search and rescue
SAR	Standards and Recommended Practices
SARPs	ICAO's separation and airspace safety panel
SASP	surface movement control
SMC	secondary surveillance radar
SSR	short term conflict alert
STCA	Traffic alert and collision avoidance system
TCAS	traffic information service — broadcast

TIS-B	visual flight rules
VFR	visual meteorological conditions
VMC	Wide Area Multilateration
WAM	

Foreword

1.1. This document presents the Multilateration Surveillance (MLAT) concept of use and therefore provides a description of MLAT systems and their detailed role as an application enabling important changes to the future communications, navigation, and surveillance/air traffic management (CNS/ATM) system.

1.2. The description of the role of MLAT takes into account the heterogeneous and evolving situation with respect to the available ground infrastructure, aircraft capabilities, airspace regimes, the coincidence with Automatic Dependent Surveillance – Broadcast (ADS-B) systems, and interface with legacy surveillance systems.

1.3. Wide Area Multilateration (WAM) implementations are an opportunity to provide useful ATC surveillance where it is required and concurrently introduce ADS-B for partial use. This forms a graduated transition from the current global environments to a future ADS-B based system.

1.4. The MLAT concept of use is described to show potential use in the wide area and airport surface operations, and that it is able to be considered both as an independent system and as complementary to other enablers such as secondary surveillance radar (SSR), SSR Mode S, ADS-B or ADS-C.

1.5 The impacts on operational and organizational levels arising from the introduction of MLAT systems is noted for consideration.

Glossary of Terms

In this document:

ADS-B IN means the reception of ADS-B position reports by an aircraft.

ADS-B OUT means the transmission of ADS-B position reports.

Surveillance System means an airborne or ground system used for monitoring the positions of aircraft and other objects for the purpose of air traffic management.

Chapter 1. Introduction

1.1. Purpose and scope

1.1.1. The purpose of this document is to develop a concept of use for MLAT. This technology is being developed, tested and is also used operationally in several areas of the world. However, international standards to incorporate MLAT into the future global CNS/ATM system have not yet been completely developed. This document is a step in this ICAO process.

1.1.2 The work to develop SARPs and guidance material for ADS-B was based upon a concept of use for the technology, as agreed by the 11^{th} Air Navigation Conference in 2003. Since that time a major conceptual change has occurred with the term “radar” now being replaced in many ICAO documents with the term “ATS Surveillance System” and an associated performance-based definition; a recognition that ADS-B and other technologies can provide ‘radar-like’ services.

1.1.3 APANPIRG has chosen to follow a similar procedure to that successfully used for ADS-B; to develop a Concept of Use so observers and participants have a common understanding, and then to update the ADS-B Implementation and Operational Guidelines Document (AIGD) to include MLAT. The scope of this document is restricted to the concept of use portion of the task. It does not contain specific operational requirements, although its contents will lead naturally to the development of operational practices for MLAT.

1.2. Background

1.2.1. In the early 1990’s, ICAO approved the concept of the Future Air Navigation System (FANS) based on satellite and datalink technology, which later became known as CNS/ATM. It was recognised that the traditional ATC surveillance system has limitations that constrained its capabilities in the existing and future ATM environment.

The limitations identified include the following:

- *limited or no conventional surveillance* - including non-equipped continental areas, low altitudes, non-continental areas, surface movements, silence cones, blind areas, antenna screening, etc. In some cases (e.g. oceanic areas), this will result in the need for procedural control, using voice position reports;

- *electro-mechanical rotation of the classical radar antennas*, not only with high power demand and RF output, but also inefficient scanning periods and limited ability to adapt the reporting rate to suit ATC needs.
(Note: E-SCAN antennas may offer an alternative in this case);

- *radar garbling, fruit and splitting*;

- *unavailability of aircraft derived data*, beyond the Mode A/C identification and altitude data;

- *non-homogeneous operation*, caused by the current existence of a diversity of systems with different performance and capabilities;

- increasingly some regions have a *shortage of Mode A codes* (a maximum of 4096 available) requiring frequent changes of code during the flight or duplicate use which can create identification ambiguities;

- *lack of capability to fully support future airborne situation awareness* applications, because the corresponding surveillance data are not available to the aircrew; and

- *lack of capability to fully support airport surface surveillance* applications.

1.2.2. Due to constraints like these and to a large extent driven by cost, the necessary levels of capacity, flexibility and efficiency required to meet the future predicted air traffic growth, will not be met by the traditional surveillance systems alone. Various surveillance technologies have been developed to address these limitations. These include Mode S secondary surveillance radar (SSR) with enhanced services, ADS-contract (ADS-C), ADS-broadcast (ADS-B), and Multilateration (MLAT).

1.3. Concept overview

1.3.1. ICAO Global ATM Operational Concept (Doc 9854) describes the services that will be required to operate the global air traffic system up to and beyond 2025. The operational concept addresses what is needed to increase user flexibility and maximize operating efficiencies in order to increase system capacity and improve safety levels in the future air traffic management system. The extensive work which has taken place or is currently underway has convinced ICAO that ADS-B functionality has the potential to be one of the key elements necessary in achieving these operational concept goals.

1.3.2. Early implementations of ADS-B have been supported by the developed ICAO standards for airborne equipment and for ATC separation. Where ADS-B OUT performance is readily achievable for the majority of aircraft, the benefits of this surveillance are quickly achieved. MLAT is a related alternative technology that will suit many States' surveillance needs for the medium term. The receipt and processing of ADS-B as part of an MLAT system encourages progressive installation of ADS-B avionics and thereby increases the benefits achievable with ADS-B.

1.3.3. The ADS-B Concept of Use document describes the role of ADS-B as one of the enablers of this future global CNS/ATM system. This MLAT Concept of Use is supplementary to that document, indicating the place of Multilateration usage.

1.3.4. The description of MLAT in this context is addressed in Chapter 2. It includes functionality, the role of MLAT and ADS-B in ATM, operational improvements, and typical applications. The applications can support all phases of flight gate-to-gate.
Chapter 4 addresses important issues for consideration, and Chapter 5 addresses implementation considerations for States.

1.3.5. During the development of the MLAT concept of use, considerations were made for other co-existing enablers (*inter-alia* ADS-B, ADS-C, TIS-B and CPDLC) in order to identify their complementary roles in the various operational scenarios.

1.3.6. The overall objective is to develop a common understanding of terms, definitions and possible uses of MLAT in the future environment. A secondary objective is to do this early enough in the various stages of development to assist efforts to influence and facilitate that development.

Chapter 2. Concept for Surveillance Using Multilateration

2.1. General

2.1.1 Surveillance is used in civil aviation for many purposes, including ATM, weather reporting, terrain avoidance, and search and rescue. A variety of technologies are used to provide surveillance data for ATM, but for full independence (of the targets under surveillance - which may include aircraft, vehicles and a variety of other “traffic”) the techniques available are visual acquisition, primary surveillance radar (PSR), and millimetric PSR (for debris, animals, birds).

2.1.2 All other techniques, including MLAT, SSR, ADS-C, ADS-B, CPDLC and voice position reporting, require varying degrees of cooperation from the target and the carriage of serviceable equipment to facilitate the exchange of data. For example, both voice and CPDLC position reporting mandate the use of specific communication equipment and are “dependent” on the 4-D navigation data determined by the avionics.

2.1.3 Multilateration is a co-operative system also, but one which can utilise data received from an aircraft that may be transmitted in response to different technologies. The minimum level of avionics to enable Multilateration with interrogation is a Mode A/C transponder. SSR Mode S or ADS-B avionics will enhance the performance of the system and may remove the need for interrogation.

2.1.4 While ADS-B transmissions contain the position data and may be received directly by other aircraft, MLAT surveillance data is processed by the ground system and typically provided only to an ATS facility, although rebroadcast to ADS-B equipped aircraft within a TIS-B service volume is potentially possible.

2.2. MLAT functionality

2.2.1 MLAT is a surveillance application that accurately establishes the position of transmissions, matches any identity data (octal code, aircraft address or flight identification) that is part of the transmission and sends it to the ATM system

2.2.2 Like SSR, MLAT is considered to be a co-operative surveillance technique, combining a dependence on target-derived data for identification and altitude with ground based calculation of position. MLAT can achieve a higher update rate than a typical rotating radar, determined by the intervals between aircraft transmissions (responses).

2.2.3 An MLAT system consists of the following components:

- A transmitting subsystem that includes interrogation message generation and transmission function;

- An optional Intelligent Interrogation process that determines whether an MLAT interrogation is required (in an area being interrogated by TCAS and SSR systems)

- A receiving antenna array subsystem that receives the transmissions from the target and timestamps receipt at each antenna; and

- A central processor that calculates and outputs the MLAT (and ADS-B) tracks.

Note - Having an interrogation transmitter ensures regularity of responses from the target aircraft/vehicle. The target aircraft/vehicle/obstacle must have a subsystem that will respond to an interrogation OR is automatically generating a transmission on the 1090MHz frequency.

2.2.4. The fitment of transponders in target aircraft or vehicles is essential for SSR Mode A/C/S radar, Multilateration, and ADS-B systems. The types can be summarised as follows:

2.2.4.1. Mode A/C Transponder - needs interrogation from radar, a multilat System, or TCAS. Special processing is used to manage matching of individual replies when received at multiple ground stations.

2.2.4.2. Mode S transponder - transmits DF11 download format automatically without radar interrogation and allows unique matching of messages received at all ground stations. Mode S provides error free mode C data.

2.2.4.3. ADS-B transmitter - transmits DF17/18 download formats automatically without radar interrogation and allows unique matching of messages received at all ground stations. Mode S provides error free mode C data

2.2.5. The airborne sources of the position, navigation or intent data in ADS-B and Mode S transmissions are not considered to be part of the MLAT system. Mode A/C transponder standards are the minimum applicable for MLAT surveillance.

2.3 The role of MLAT in Air Traffic Management (ATM)

2.3.1 ATM is described in the ICAO Global ATM operational Concept (Doc 9854) as the dynamic, integrated management of air traffic and airspace in a safe, economical and efficient manner through the provision of facilities and seamless services in collaboration with all parties. The operational concept also describes a system that provides ATM through the collaborative integration of humans, information, technology, facilities and services, supported by air, ground and/or space-based communications, navigation and surveillance.

2.3.2 This operational concept identifies seven interdependent components of the future ATM system. They comprise:

a) airspace organization and management;
b) aerodrome operations;
c) demand and capacity balancing;
d) traffic synchronization;
e) conflict management;
f) airspace user operations; and
g) ATM service delivery management.

2.3.3 Inherent to this concept are the characteristics of scalability and adaptability, according to the specific needs and operational environment of each State and region. MLAT shares these characteristics in that specific applications of the technology may be implemented according to need.

2.3.4 MLAT is an enabling technology that will enhance the provision of ATM in a variety of applications, from “radar-like” air traffic control purposes to enhanced situational awareness of surface movements. MLAT offers most advantages in situations where other surveillance systems (eg radar) are not available. It can also be combined with other surveillance systems, such as radar and ADS-B, to improve the total surveillance picture.

2.3.5 MLAT applications will have a direct effect upon aerodrome operations, traffic synchronization, airspace user operations, and conflict management. These effects will then influence the nature of airspace organization and management, demand and capacity balancing, and ATM service delivery management.

2.4. ATM improvements and benefits

2.4.1. MLAT applications, particularly when combined with ADS-B, are expected to provide important operational improvements by addressing some of the limitations of the traditional radar surveillance system, optimize the controller workload and provide benefits in the areas of safety, capacity, efficiency and environmental impact, thus contributing to the overall CNS/ATM objectives. These benefits include the following:

a) low cost extension of the surveillance coverage for low altitudes (below existing radar coverage) and areas where no radar coverage currently exists, leading to more efficient use of airspace;

b) enabling airports to obtain surface and local surveillance including general aviation and military operations;

c) use of aircraft-derived data in a variety of systems e.g. ground-based conflict alert, minimum safe altitude warning, danger area proximity warning, automated support tools, surveillance data processing and distribution.

d) increasing airport safety and capacity, especially under low visibility conditions, by providing airport surface surveillance and, at the same time, protecting against runway incursions by aircraft and vehicles.

e) changes to airspace sectorization and route structure resulting from improvedsurveillance should provide more efficient routing;

f) reduced infrastructure costs in airspace in which MLAT coverage is provided. It may be possible to decommission some radar equipment. Where multiple surveillance coverage is presently required, optimization of the surveillance infrastructure should be achieved by the implementation of the most efficient mix of radar sensors, MLAT and ADS-B; and

g) cost savings achieved from the implementation of an MLAT and ADS-B based surveillance system rather than the life cycle expenses associated with installing, maintaining, and extending existing radar-based surveillance systems.

2.4.2. Valid reasons exist for a State having some SSR and PSR or other technologies for civil air traffic surveillance coverage. For example, Mode S enhanced surveillance, ADS-C and other systems can also be used to deliver some of the above benefits.

2.5. MLAT applications

2.5.1 Overview

In an effort to provide the operational improvements identified above, a number of applications are already developed and being operated.

2.5.2. MLAT ATM Applications

Broadly speaking, the air traffic control application of MLAT fall under the following headings:

- Airport surface surveillance applications for ground and aerodrome control
- Area and Approach surveillance in airspace with radar coverage;
- Area and Approach surveillance in airspace without radar coverage;

- ATM system technical improvements including sampling of RVSM performance and sampling ADS-B performance.

2.5.3. MLAT Specific Use Applications

- Airport surface surveillance; and aircraft derived data for ground-based ATM tools.
- Situational awareness
- Airport Low Visibility Operations (e.g. CATIIIB)
- Parallel Runway Approach Monitoring
- Other applications Ramp control/gate management
- Noise monitoring data provision
- Airport usage data (for Billing)
- Airways usage data (for Billing)
- Flight following (for AOC, flying schools)
- Enhanced ATS situational awareness (tagging obstacles, restricted areas)
- Enhanced overall flight data for improved SAR activity

2.5.4. Ground-based surveillance applications

4.5.4.1 This application provides a source of airport surveillance information for safer and more efficient ground movement management at airports. Relevant airport ground vehicles need to also be equipped and displayed, together with aircraft, on a situation display.

4.5.4.2 MLAT supports ground conflict detection by providing frequent updates of aircraft and vehicle positions, enabling the monitoring of aircraft and vehicles to protect against runway incursions, and to monitor taxiing operations in low visibility operations such as CATIIIB minima conditions. It is an essential part of some A-SMGCS systems.

2.5.5. Other uses

2.5.5.1 ATC surveillance for airspace where there is no radar coverage, or where radar coverage exists, as a backup and possible replacement for SSR.

2.5.5.2 The higher update rate available with MLAT reports, in combination with other capabilities, may enhance surveillance services and allow the application of reduced separation standards. ICAO's Separation and Airspace Safety Panel (SASP) is currently examining the introduction of MLAT separation standards, and at least one State already provides ATC separation services with MLAT.

2.5.5.3. This application can support ATC surveillance currently provided by radar, in Terminal or wider airspace. An example is the case of surveillance in areas where single radar coverage is provided. Where SSR is used, MLAT can provide a backup system and supplement radar position updates through additional position reports. Where PSR is used MLAT can provide additional data, such as aircraft identification.

2.5.5.4. ATC surveillance in airspace without radar coverage. This application will provide ATC surveillance in non-radar areas, (e.g. remote approach control areas). While ADS-B alone could provide surveillance coverage from "gate-to-gate", MLAT will be able to ensure the surveillance of aircraft equipped only with SSR transponders in those areas closer to the airport where traffic levels justify ATC surveillance, but radar is not feasible or affordable.

2.5.5.5. Other MLAT applications being considered or used to varying degrees include:

- monitoring of aircraft to ensure that flight trajectories comply with noise sensitive environments (e.g. curfew);
- facilitating the collection of data for the issuing of aviation charges in remote areas where this may be applicable;
- enabling the display of temporary obstacles — e.g. a construction crane equipped with a transponder or ADS-B emitter;
- validation of ADS-B transponder performances; and
- Search and rescue (SAR) and emergency response.

Chapter 3. Operational Deployments

3.1 Description of MLAT potential benefits

3.1.1 The operational environments in which MLAT will be used may include any of the following characteristics:

- varying infrastructure capabilities, ranging from the lack of any surveillance means up to the co-existence of ADS-B and MLAT with different types of conventional data sources such as primary and secondary surveillance radars. Some MLAT vendors can deliver a pseudo rotational 'radar like' ASTERIX Cat 1 / 48 output to minimise the initial setup adaptation required. It is expected that a variety of other technologies such as ADS-C and CPDLC will play a complementary role in the provision of ATC service;
- mixed aircraft equipage levels, at least in the transition period;
- varying airspace types (e.g. different traffic density levels);
- varying flight phases, e.g. airport surface, TMA, en-route, non-continental, continental; and
- varying types of application/services in different environments.

3.1.2. MLAT can detect ADS-B reports generated and also manipulate report rates by the transmission rate of interrogations, and in processing to output at a rate that suits the communications network and ATM system.

3.1.3. Compared to radar sensors, an MLAT system for an aerodrome surface application or for a local area around an aerodrome is less than half the cost. A Dual ADS-B location with power and communications is about half to two-thirds the cost of a full MLAT system, excluding the cost of transponder upgrades.
Other than cost, another important advantage of both ADS-B and MLAT are the degrees of redundancy which a single radar does not have.
An MLAT system configuration can allow staged degradation before the system would become unusable.

3.2 Users of MLAT

The users of MLAT will primarily be in ATC roles, from gate to gate. Here are some examples:

3.2.2 ATC Ground

Ground Tower and Surface Movement controllers will use MLAT for surface surveillance of aircraft and vehicles on the apron and or manoeuvring area. This is most desirable when the airport layout is complex (assessed by the configuration of buildings, the number of runways and taxiways) and where airports are capable of conducting operations out of visual range of the air traffic controller responsible (CAT II and III ILS operations and vertically-guided GNS approaches to similar minima are likely to fall in this category).

3.2.3 ATC Aerodrome

Aerodrome controllers will utilise the surveillance to assist with runway utilisation, and confirm that traffic is following instructions to and from the runway. Final approach monitoring using the high update available from an MLAT system providing more precision to discern whether an aircraft is lining up to land on the wrong runway, and to automate the alerting of such a situation. For departing flights in an environment where Tower initiated departures applies, the high update rate will provide a smoother and instantaneous turn of a lead aircraft as observed on the display so minimising waiting time for a following departure.

3.2.4 ATC Approach

MLAT for approach control will be useful in ATM system software to smooth the turns of displayed tracks, and can be used for Terminal area ATC surveillance in place of SSR or as a backup to SSR.

3.2.5 ATC Area control

Wide Area Multilateration (WAM) can extend beyond the Terminal area, depending on the configuration of the sensors. In this respect MLAT can provide a backup for SSR for a specific area, as a fill in to a specific airspace where surveillance is required and aircraft equipped only with Mode A/C transponders are common, in both cases the benefit of ADS-B data being received from each single site greatly improve the coverage for suitably equipped aircraft.

Chapter 4. Issues

4.1 Issues to consider

There are many issues associated with the introduction of MLAT to the air traffic management operational concept. The following are technical and operational issues to consider during development and implementation of MLAT. This list is not exhaustive, but serves as a guide for States considering MLAT systems for their surveillance needs.

4.2 Technical issues

4.2.1 Technical standards

4.2.1.1 As 1090MHz Extended Squitter (also known as 1090ES or Mode S data link) ADS-B and MLAT technology matures, the technical standards for the airborne as well as the ground systems are being refined. This leads to the need to potentially upgrade these systems to meet new national and international requirements. Efforts are underway within ICAO to ensure global interoperability.

4.2.1.2. Multiple Sites each require power and data communication paths. Site access, land rental or ownership, and technical maintenance capability to add multiple sites are issues to consider.

4.2.1.3 VHF coverage of the airspace may be coincident with a MLAT interrogation site to ensure best coverage. As with ADS-B the preferred situation is for the responsible controller to have reliable radio access to any flights within the controlled airspace.

4.2.2 Aircraft installation

Various types of aircraft have different installation certification and integration requirements. Consequently there are differences in costs. Antenna placement in relation to ground system sensors is a similar consideration as for SSR. Where ADS-B data received by the MLAT system is to be used alone, the issues regarding transponders and the GNSS systems must be considered. Specifically issues such as the navigation system integration to ADS-B or Mode S, compatibility with various link technologies, and cockpit controls and displays issues all have to be considered. Certification will also vary with intended function (e.g. ATC surveillance services, TIS-B situational awareness) as well as aircraft type (e.g. single engine aircraft versus heavy jet aircraft).

4.2.3 Remote ground stations

Installation, certification, and maintenance monitoring of remote MLAT ground stations to meet intended level of service raise their own issues. These include leasing agreements, power requirements, communication to a central facility (e.g. air traffic control centre), installation remote control features, accessibility and security. Remote switching and monitoring is an important consideration.

4.2.4 Automation system adaptation

Ground-based air traffic control system adaptation to facilitate the acquisition, processing and distribution of MLAT data is a significant issue. The automation's capacity for handling the data (e.g. processing power available, local area network, data storage capacity), maintenance monitoring, correlation between various surveillance sources and integration into existing safety functions (e.g. conflict alert, minimum safe altitude warning) are a few areas to consider. Employing a Service Provider to deliver the system outputs is another option.

4.2.5 Technical Maintenance

For a new surveillance area, increased provision of Technical Maintenance support is likely to be required given the multiple remote sites inherent with MLAT configurations, and similarly maintenance for power supply and network communications personnel.

4.2.6 Security

4.2.6.1 The flexibility and versatility of the proposed MLAT systems will allow for many safety and capacity enhancing applications in the short and long term. As applications approach maturity and their requirements become more complex, they also become more sensitive to some outside interference, a risk not dissimilar to current systems using SSR Mode A/C.

4.2.6.2 1090MHz interference sources can be malicious or accidental and can occur intermittently or for an extended period. The interference can be a localized source causing for example a “co-channel interference” problem up to a military denial of airspace operation involving active jamming. The sources, causes, and effects of an interference event can be broadly categorized into several groups. There are practical limits that must be recognized due to technological, political, and fiscal reasons. Not all solutions will be technical - that is, come from a box. Some of the solutions may be procedural, legal, technical or a combination of all. In short, States will need to consider the likelihood and severity of interference by conducting appropriate hazard and safety assessments as a means of developing mitigation strategies.

4.2.7 Performance of the data link

4.2.7.1 Bandwidth and performance of the 1090 MHz data link is dependant upon the complexity of the scenarios that are envisaged and could be a significant issue in high density areas.

4.2.7.2 For example, the level of equipage (i.e. which airport vehicles and/or obstacles are fitted with transponders or ADS-B emitters), the number of aircraft involved and possible use of TIS-B to rebroadcast data from another surveillance source will need to be considered.

4.3 Operational issues

4.3.1 Human factors issues

4.3.1.1 The human factors considerations associated with surveillance systems are dependent not on the technology, but on the specific applications. That is, the issues are dependent upon the answers to questions, such as:

- what is the information to be displayed (e.g. aircraft position data or derived aircraft intent)?
- how are the input systems different and what is the appropriate way to show differences that may be important to operators?
- who (e.g. tower, ACC, airline operations) is the user of this information? Displays will need to be developed and evaluated for different applications;
- how will the information be used? The information and the way in which it is displayed must be capable of supporting the decisions that the users will make based on the MLAT information.

4.3.1.2 While the specific issues will depend on the specific applications, there are general issues that should be anticipated. These include:

- *effective integration of MLAT information into the situation display*. The position determined by MLAT can be different to the position reported by radar or other systems. When more than one input type is received, these positions will need to be reconciled so that only one position (preferably the most accurate position possible) is displayed for a single aircraft. This can be achieved by the use of a multi sensor (e.g. MLAT, ADS-B, SMR, ASR) data processor. Controllers need to know which aircraft are being tracked by which system when the type of surveillance affects how they control that aircraft, or the quality of the reported position, so that appropriate separation standards can be applied. Depending on the application and the limit of MLAT coverage, controllers may also need to know other capabilities of the displayed aircraft, such as RNP, ADS-B and CDTI. All of this adds information to be integrated into the present displays;

- *limitations of the technology*. Users will need to fully understand the limitations of the information presented and be informed of any known degradations or failures.

- *degree to which the displayed information supports the application*. The degree to which the MLAT information supports spacing and separation tasks and the degree to which flight crews and controllers are expected to successfully accomplish and integrate these tasks is being assessed in different ICAO forums. How the information is displayed is as important as the integrity of the information in supporting the user's confidence in the system. A concept under active development is to provide improvements to HFOM, for example elevating an GPS derived ADS-B position FOM that is marginal for use - by supporting MLAT FOM; and

- *effects on workload*. The effects of the additional information, and the procedures associated with specific applications, on the workload of the user need to be assessed. The information needs to be integrated so that it is unambiguous, immediately useful, and does not interfere with other critical information.

4.3.2 Procedures development, separation standards, airspace design, and training issues

In support of new operations, appropriate procedures, separation standards, airspace design, and training are being developed to effectively utilize MLAT and its applications. Controllers, pilots, and maintenance technicians, as well as others who may use MLAT or be impacted by the procedures need proper training on coverage issues, normal and failure mode operations. In addition, airspace design (e.g. size of ATC sectors) will need to be considered for the types of services provided.

4.3.3 Fleet equipage

With the availability of various ADS-B and SSR technologies and the cost of equipping or re-equipping aircraft with new avionics, it is unlikely that aircraft will have homogeneous equipment. The introduction of MLAT allows the system to have full surveillance of all transponder equipped aircraft without the hurdle of making the carriage of ADS-B transponders mandatory for a State or large airspace area.

It should be remembered that in some MLAT systems, ADS-B is an integral part, so aircraft operators should be encouraged to install ADS-B OUT capability which will benefit the whole airspace system in time, and which can benefit the operator and ATS system directly through improved coverage in areas beyond the MLAT high performance area.

The design configuration of the MLAT system may have only some or no MLAT receivers detecting ADS-B. In the cockpit, the traffic information service — broadcast (TIS-B), may evolve to be of particular importance, ensuring consistency on both air and ground traffic situation displays.

4.3.4 Transition issues

One of the main issues with regard to the impact from the transition towards an ADS-B-based surveillance system is that MLAT extends out the time when full capability of ADS-B is needed. In the foreseeable future, the systems have to be capable of coping with a heterogeneous set of aircraft capabilities, types of surveillance sensors, local system sophistication etc. and should be capable of providing the required quality of service both on the ground and on board the aircraft. This quality of service should be at least equal to that of the current system in place. MLAT is often seen as a 'transitional technology' that caters for legacy aircraft while also being capable of processing ADS-B transmissions.

4.3.5 Institutional

There are common types of institutional issues regardless of the State implementing MLAT. These include such things as legal issues (e.g. separation standards), radio spectrum allocation/management, and certification issues. Each State will have to resolve these, but global harmonization needs to be considered for consistency.

4.3.6 Environmental issues

4.3.6.1 With any new system, environmental issues need to be considered to include noise abatement, airspace constraints, and remote ground system installations.

4.3.6.2 The ADS-B processing capability of MLAT systems enables new or improved applications which are expected to contribute significantly to these savings by providing more direct or efficient routings, and easier access to the optimum altitudes and airspeeds.

Chapter 5. Implementation

5.1 Planning

There is a range of activity that needs to take place to bring an application from initial concept to operational use. This section documents these activity areas under the topics of collaborative planning and decision making, system compatibility and integration, while the second section of this chapter provides a checklist to assist States with the management of MLAT implementation activities.

5.1.2 Implementation team to ensure international coordination

5.1.2.1 From the ICAO perspective, when a State decides to implement a new technology it benefits the wider ATM community if they consult and advise the wider ATM community of plans and implementation issues encountered. Moreover, the implementation should also be coordinated between States and Regions as appropriate, in order to achieve maximum benefits for airspace users and service providers.

5.1.2.2 An effective means of coordinating the various demands of the affected organizations is to establish an implementation team. Team composition may vary by State or Region, but the core group responsible for MLAT implementation planning should include members with operational expertise in aviation disciplines, with access to other specialists as may be required. Where both MLAT and ADS-B services are being introduced at the same time, or being considered, a single team should seek a harmonised approach for both systems.

5.1.2.3 Ideally, such a team should comprise representatives from the ATS providers, regulators and airspace users, as well as other stakeholders likely to be influenced by the introduction of MLAT and ADS-B, including manufacturers and military authorities. All identified stakeholders should participate as early as possible in this process so that demands are identified prior to the making of schedules or contracts.

5.1.2.4 The role of the implementation team is to consult widely with stakeholders, identify operational needs, resolve conflicting demands and make recommendations to the various stakeholders managing the implementation. To this end, the implementation team should have high-level access to the decision-makers.

5.1.3 System compatibility

5.1.3.1 ADS-B has potential use in almost all environments and operations and is likely to become a mainstay of the future ATM system. MLAT is able to fill in the gaps for areas where surveillance is needed, but where targets / aircraft have only Mode A/C or Mode S short squitter transponders. Engineering and operational trials of both systems have been conducted and operational implementations have occurred, and ADS-B now has a comprehensive set of internationally accepted standards. Generally first applications are in niche areas where radar surveillance is not available or possible. ICAO Regional cooperation and alignment are important.

5.1.3.2 Given the international nature of aviation, special efforts should be taken to ensure harmonization though compliance with ICAO Standards and Recommended Practices (SARPs). The choice of actual technologies to implement MLAT (and ADS-B) should consider not only the required performance of individual components, but also their compatibility with other CNS systems.

5.1.3.3 The future concept of ATM encompasses the advantages of interoperable and seamless transition across flight information region (FIR) boundaries and MLAT/ADS-B implementation teams should include simulations, trials and cost/benefit analysis to support these objectives.

5.1.4 Integration

5.1.4.1 MLAT implementation plans will include the development of both business and safety cases. The adoption of any new CNS system has major implications for service providers, regulators and airspace users and special planning should be considered for the integration into the existing and foreseen CNS/ATM systems. The following briefly discusses each element.

5.1.4.2 The communication system is an essential element within CNS. An air traffic controller can now monitor an aircraft using MLAT and ADS-B in non-radar areas where previously only voice position reports were available. However, a communication system that will support the new services resulting from the improved surveillance will be necessary.

5.1.4.3 Where MLAT is being introduced to perform A-SMGCS or PRM functions, consideration must be given to the supporting navigational systems such as ILS, GLS, airport lighting, taxiway markings, etc

5.1.4.4 MLAT and ADS-B may be used to supplement existing surveillance systems or as the principal source of surveillance data. Ideally, surveillance systems will incorporate all available data to provide a coherent picture that improves both the amount and utility of surveillance data to the user. The choice of the optimal mix of data sources will be defined on the basis of operational demands, available technology, safety and cost-benefit considerations.

5.1.4.4.2 MLAT is dependent on the aircraft having at least a Mode A/C transponder. It can receive identity through correlation of a code with the flight plan, or the flight identification transmitted by ADS-B or Mode S transponder

5.2. Implementation checklist

5.2.1 The purpose of this implementation checklist is to document the range of activities that need to take place to bring an MLAT application from an initial concept to operational use. This checklist may form the basis of the terms of reference for an MLAT implementation team, although some activities may be specific to individual stakeholders. *Note - When completed, the MLAT/ADS-B Implementation and Operations Guidance Document will be more prescriptive of these headings.*

5.2.2 The activities are listed in an approximate sequential order. However, each activity does not have to be completed prior to starting the next activity. In many cases, a parallel and iterative process should be used to feed data and experience from one activity to another. It should be noted that not all activities will be required for all applications.

5.2.3 Concept phase

construct operational concept for the airport or airspace:

- define the purpose of MLAT and ADS-B;
- operational environment;
- ATM functionality that will be affected
- ATM system modifications necessary (and cost estimates)
- infrastructure;
- identify benefits:
- safety enhancements;
- efficiency;
- capacity;
- environmental;
- physical and electronic (remote control) access; and
- other metrics (e.g. predictability, flexibility, usefulness);
- identify constraints:
- pair-wise equipage; need for exclusive airspace;
- required coverage
- required configuration /ground infrastructure;
- RF spectrum;
- define airspace area within which MLAT accuracy is acceptable
- integration with existing technology; and

- technology reliability / availability (system, communications, power);
- contingency systems / procedures
- prepare business case:
- cost benefit analysis; and
- demand and justification.

5.2.4 Design phase

identify operational requirements:

- security;
- systems interoperability;
- identify human factors issues:
- human-machine interfaces;
- training development, delivery and license validation;
- workload demands;
- role of automation vs. role of human;
- crew coordination/pilot decision-making interactions; and
- ATM collaborative decision-making;
- identify technical requirements:
- site selection
- standards development;
- data required;
- functional processing;
- functional performance; and
- required certification levels;
- equipment development, test, and evaluation:
- prototype systems built to existing or draft standards/specifications;
- methodology required by the ANSP safety management system
- developmental bench and flight tests if sufficient data not already provided;
- select technology;
- develop procedures:
- pilot and controller actions and responsibilities;
- phraseologies;
- separation/spacing criteria and requirements;
- controller's responsibility to maintain a monitoring function, if appropriate;
- identify any controller issues for operations at the transition between types of surveillance.
- contingency procedures; and
- emergency procedures;
- prepare design phase safety case:
- safety rationale;
- safety budget and allocation; and
- functional hazard assessment.

5.2.5 Implementation phase

prepare implementation phase safety case;

- Obtain acceptance as necessary of safety case
- Include any safety mitigation that is required into system design or procedures.

Prepare the sites:

- communication, power and physical preparation for remote and central equipment sites;

- *conduct operational test and evaluation:*flight deck and ATC validation simulations; and
- flight tests and operational trials;
- obtain systems certification:
- aircraft equipment performance checks; and
- ground system deployment and checking;
- obtain regulatory approvals: flight operations; and air traffic;
- implementation transition:
- continue data collection and analysis;
- continue feedback into standards development processes; and
- performance monitoring to ensure agreed performance is maintained.

5.2.5.1 Once the implementation phase is complete, the ongoing maintenance and upgrading of both MLAT and ADS-B operations and infrastructure should continue to be monitored, measured and reported on – both internally and externally, through the appropriate forums.