



The European Organisation for Civil Aviation Equipment
L'Organisation Européenne pour l'Équipement de l'Aviation Civile

MINIMUM AVIATION SYSTEM PERFORMANCE STANDARD FOR REMOTE TOWER OPTICAL SYSTEMS

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9-23 rue Paul Lafargue
93200 Saint-Denis, France
Web Site: www.eurocae.net

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Documents
Document Sharing Hub
Tel: +33 1 49 48 19 63
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FOREWORD

1. This document was prepared by EUROCAE Working Group 100 "Remote & Virtual Tower (RVT)" and was approved by the Council of EUROCAE on 30 October 2018.
2. EUROCAE is an international non-profit making organisation in Europe. Membership is open to manufacturers and operators of equipment for aeronautics, trade associations, national civil aviation administrations, and, under certain conditions, non-European organisations. Its work programme is principally directed to the preparation of performance specifications and guidance documents for civil aviation equipment, for adoption and use at European and world-wide levels.
3. The findings of EUROCAE are resolved after discussion amongst Members of EUROCAE.
4. This document supersedes ED-240 Minimum Aviation System Performance Specification for Remote Tower Optical Systems (September 2016).
The document has been updated to include Performance Standards with respect to Visual Tracking and PTZ Object Following.
As compared with the previous version, the main changes are:
 - Visual Tracking Performance Specification
 - PTZ Object Following Performance Specification
5. EUROCAE performance standards and other documents are recommendations only. EUROCAE is not an official body of the European Governments. Its recommendations are valid as statements of official policy only when adopted by a government or conference of governments.
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EUROCAE
9-23 rue Paul Lafargue
93200 Saint-Denis
France

Telephone: +33 1 49 46 19 65
Email: eurocae@eurocae.net
Website: www.eurocae.net

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CHAPTER 1

GENERAL

1.1 INTRODUCTION

Remote Towers enable a greater capability and flexibility in the provision of Aerodrome Air Traffic Services (ATS) and Apron control than conventional towers. This innovative technology enables air navigation service providers (ANSPs) and airport operators to overcome many of the social, economic and service delivery issues that exist with conventional towers, while the additional features unique to the technology can enhance operator situational awareness, improve safety, and allow delivery of service in conditions or times that would not be possible from a conventional facility or be utilised to provide additional capabilities within a conventional tower or contingency facility.

The primary change in the transition from a conventional tower to a Remote Tower relates to how visual observation is carried out. In a conventional tower, the operator performs visual observation of the aerodrome and its vicinity by directly looking out of the window. At a Remote Tower, a *Remote Tower Optical System*, comprised of optical sensors (video cameras) at the aerodrome and a *Visual Presentation* to the operator, are provided. An *Optical Sensor Presentation* is a type of Visual Presentation that displays video images from cameras, which could come from visible spectrum sensors as well as beyond visible spectrum sensors, e.g., infrared, allowing the operator even to “see in the dark”.

The technology can be applied in many ways, including a replication of an existing tower operation but located at an alternative site, allowing location-independent provision of ATS and/or apron management. The implementation could be a single mast with cameras at the aerodrome that provides the operator with the required aerodrome view in the form of a panoramic display. Another possibility would be to have multiple cameras at different locations around the aerodrome providing specific views of the areas of responsibility to each operator tailored to their individual tasks, removing the constraint of having to share a single view, or a combination of both. ATS and/or apron management may be provided to several airports from a single Remote Tower Centre to achieve further benefits via consolidation, and to enable added resilience via switchable service provisioning from one Remote Tower Centre to another. Other applications might utilise elements of the technology within existing conventional towers, to take advantage of its capabilities or to remove the need to construct multiple towers to cover a large airport. The delivery of services to more than one airport from a single Remote Tower Module (RTM), either simultaneously or sequentially, is another potential possibility. The need for a physical tower that requires clear lines-of-sight to the runway and manoeuvring area can now instead be met by a RTM situated anywhere.

The technology allows additional features and capabilities that cannot be achieved when using normal OTW view such as an Augmented Visual Presentation comprised of overlays of visual cues, automatic object tracking, and other supplementary information for the operator. This augmentation can be supported by data fusion with non-optical surveillance sensors resulting in enhanced surveillance.

To facilitate the harmonisation and deployment of Remote Tower technology, the International Civil Aviation Organization (ICAO) has recommended the development of provisions for remotely-operated aerodrome ATS, including updating requirements for surveillance and communications and providing requirements for sensors and display technologies to replace visual observation [1][2]. In the EU context, EASA initiated a rulemaking task (EASA RMT.0624 “Technical and operational requirements for remote tower operations”) to develop an appropriate and proportionate regulatory framework including necessary guidelines for “remote aerodrome ATS” [4][5][6].

1.2

SCOPE AND STRUCTURE OF THIS DOCUMENTSCOPE OF THIS DOCUMENT

This document comprises a MASPS for Remote Tower Optical Systems and is applicable to:

(1) Optical System

This MASPS specifies the end-to-end performance of the Remote Tower Optical System comprising the whole chain from the optical sensor(s) to the optical sensor presentation. It is applicable to all optical sensor configurations that could be used to implement remotely-operated ATS and/or apron management for an aerodrome. The specific configuration of the optical system will be a matter for individual implementations.

(2) Visual Tracking

The Optical Sensor Presentation can optionally be augmented by Visual Tracking information to increase the situational awareness of the operator. This MASPS specifies the end-to-end performance of such a Visual Tracking function comprising the whole chain from the optical sensor(s) to the Optical Sensor Presentation, which then becomes an *Augmented Optical Sensor Presentation*.

(3) PTZ Object Following

The optical sensor presentation can optionally be augmented with an automatic PTZ object following function. This MASPS specifies the end-to-end performance of such a PTZ Object Following function comprising the whole chain from the optical sensor(s) to the Optical Sensor Presentation.

STRUCTURE OF THIS DOCUMENT

As outlined above, the scope of this document comprises:

(1) Optical System

(2) Visual Tracking

(3) PTZ Object Following

The corresponding performance requirements sections are:

CHAPTER 3 SYSTEM PERFORMANCE REQUIREMENTS

3.1 General System Performance Considerations

3.2 Optical System Performance

3.3 Visual Tracking Performance

3.4 PTZ Object Following Performance

The corresponding performance verification requirements sections are:

CHAPTER 5 PERFORMANCE VERIFICATION

5.1 General Considerations

5.2 Optical System Performance

5.3 Visual Tracking Performance

5.4 PTZ Object Following Performance

GENERAL REMARKS

This MASPS was produced with knowledge of existing and proven installations and the latest results from research projects such as SESAR [7][8][9][10][11][12][13][14][15][16][17][18][19][20][21][22][23][24][25] as well as the operational considerations outlined in APPENDIX 3: DRRP EXAMPLE VALIDATION. Adherence to this specification is intended to enable the implementation of a Remote Tower Optical System for an aerodrome. It is intended to be used by equipment designers, regulators, manufacturers, installers, service providers and operators.

The development of Remote Tower technologies and systems is an evolutionary process. As such, this MASPS for Remote Tower Optical Systems may be extended in future with additional specifications pertaining to the optical system or with a broadened scope to include additional systems. MASPS may also drive the development of subsequent MOPS by providing a clear allocation of system performances between its various individual components.

Compliance with this MASPS is recommended as one means of assuring that a Remote Tower optical system and each of its component subsystems will perform its intended function(s) satisfactorily.

NOTE: *Security (information security and physical security) as well as system maintenance is outside the scope of this document.*

1.3 TYPES OF REQUIREMENTS IN THIS DOCUMENT

In the scope of this document there are different types of requirements. For a complete list of requirements and their respective type, please see APPENDIX 1 REQUIREMENTS.

1.4 OPERATIONAL CONTEXT

The operational scope is in accordance with EASA guidance material [4] and [5] and the regulatory and operational requirements used in the final SESAR OSED [11]. The EASA guidance material mainly refers to the provision of ATS from a RTM to one aerodrome at a time, referred to as *Single Mode Operation*, however EASA has with NPA 2017-21 [6] proposed expanded regulatory material to encompass also more complex mode of operations, e.g., *Multiple Mode of Operation*.

This MASPS provides performance specifications for the optical sensor presentation, and its application is not limited to single mode. This document envisions the provision of an optical sensor presentation of traffic and other information that could be used for a range of applications including, but not limited to, service provision:

- to one aerodrome at a time from a single RTM (single mode operation)
- to multiple aerodromes simultaneously from a single RTM (multiple mode operation)
- for temporary periods, such as during planned or unplanned contingency situations, or to increase ATS capacity for specific events
- to distant or obscured aerodrome areas from a conventional tower - this would be equal to constructing additional conventional towers
- to specific areas of the aerodrome used for targeted control functions, such as apron control

When defining an optical sensor presentation, the performance requirements are influenced by the operational context and its related operational needs comprising, amongst others, the following factors:

- Traffic density
- Air traffic characteristics
- Physical topography of the aerodrome
- Airspace characteristics
- Airport layout (e.g., runways)
- Aerodrome infrastructure
- Operator roles and local procedures

1.5 DEFINITION OF TERMS

NOTE: *Some terms provided below are taken from ICAO documents, EASA documents or SESAR Documents [3][5][6][11].*

1.5.1 Fundamental Terms

Air Traffic Services

A generic term meaning variously, flight information service, alerting service, air traffic advisory service, or air traffic control service (area control service, approach control service or aerodrome control service) [3].

Operator

Throughout this document, the term “operator” is used to refer to the officer providing ATS in the role of ATCO or AFISO, or apron controller.

Service Provider

Throughout this document, the term “service provider” is used to refer to the organisation providing ATS and/or apron management through operators.

Remote Tower Module (RTM)

A module from which Remote ATS and/or apron management can be provided. An RTM includes one or more controller working positions (CWPs), including necessary ATS and/or apron management systems such as communications, aerodrome lighting control etc., and visual presentation displays, as required.

Remote Tower Centre (RTC)

A facility housing one or more RTMs [6].

Out-The-Window (OTW) view

The view from a conventional aerodrome tower’s visual control room.

Remote Tower Optical System

A visual surveillance system for the provision of aerodrome ATS and/or apron management that relays video images from optical sensors at the aerodrome, which could be visible spectrum as well as optical sensors beyond the visible spectrum (e.g., infrared), and presents them to the operator via an optical sensor presentation.

1.5.2

Detection and Recognition Terms

Target

Target of interest in the real world.

Object

Target of interest displayed on the optical sensor presentation.

Johnson’s Criteria Detection

Something in an image that raises an observer’s attention.

Johnson’s Criteria Military example: “There is something!” [26]

Visual Detection in ATS based on Johnson’s Criteria Detection

Johnson’s detection criteria applied to images of objects relevant to the provision of ATS displayed in a visual presentation.

Same as for Johnson’s criteria detection: “There is something!”

Johnson’s Criteria Recognition

Classes of objects can be differentiated.

Johnson’s criteria military example: Tank/Armoured Personnel Carrier/Lorry [26]

Visual Recognition in ATS based on Johnson’s criteria recognition

Attributes of an object relevant to ATS provision that may be perceived based on Johnson’s criteria recognition applied to its display in a visual presentation. Such attributes include the following:

- Class / category / type of aircraft: to be determined based on, for example, one or more of the following:
 - Aircraft size & fuselage configuration

- Engine configuration (e.g., wing-mounted or tail-mounted, number and type of engines)
- Wing configuration (e.g., wing mounted below or on top of the fuselage)
- Stabilizer configuration
- Landing gear configuration
- Aircraft painting or markings
- Vehicle type / class: e.g., fire truck / car / fuel truck / baggage trailer
- Personnel and obstructions: e.g., person / wildlife / FOD

NOTE: *In the context of this MASPS, the Johnson Criteria “Identification” is not considered.*

1.5.3

Presentation Terms

Visual Presentation

A visual display that shows real-time video images from the areas of responsibility of the Remote Tower ATS and/or apron management unit.

Visual Presentation comprises the following types of presentation:

- (a) Optical Sensor Presentation
- (b) Virtual Presentation
- (c) Augmented Optical Sensor Presentation

(a) Optical Sensor Presentation

Display of images from optical sensors (visible spectrum, thermal, IR, NIR, SWIR ...).

NOTE: *Implementations of the optical sensor presentation at the time of writing of this MASPS typically comprise a wide-angle display ((1) Panorama) that presents a wide field-of-view image derived from one or more fixed-view optical sensors, and a (2) PTZ view.*

(a) (1) Panorama

The term “panorama” is used in this MASPS to refer to a wide-angle display typically used to show images from fixed-view optical sensors. However, use of this term does not preclude other implementations of the optical sensor presentation.

(a) (2) PTZ

An imaging sensor or sensors with a pan/tilt pointing capability and a narrow, possibly variable, angle of view. The PTZ sensor and view emulate the function of binoculars in a conventional tower, and could also be used to assist, e.g., light gun operation.

(b) Virtual Presentation

A computer-generated synthetic visual representation of the aerodrome operational environment generated using target information derived from surveillance systems (e.g., multilateration, ADS-B, approach radar), static environment information (e.g., aerodrome layout, GIS data) and other sensor information (e.g., meteorological data). The virtual presentation may contain two-dimensional, three-dimensional, pictorial, symbolic or textual representations.

NOTE: *This definition includes two-dimensional plan-position indicator type displays as well as three-dimensional virtual environments.*

(c) Augmented Optical Sensor Presentation

A mixture of virtual presentation and optical sensor presentation, whereby information associated with real-world target is presented as 2D/3D graphical elements, image data, symbols or text overlaid onto the optical sensor presentation, either conformably or close to their optical images. Examples include runway/taxiway boundaries and stop bars, object indicators and labels.

1.5.4 Visual Tracking Terms

Visual Tracking

The function determining whether a target is interpreted as an object-to-be-augmented only by image processing of the video from optical sensors.

Object Augmentation

The augmentation of the display of objects-to-be-augmented (objects moving or recently moving) on the optical sensor presentation by using information obtained.

NOTE: *Augmentations of permanent objects such as buildings, taxiways, glidepaths, etc. are not in the scope of this MASPS.*

Box-and-Follow

See [Object Augmentation]

NOTE: *The term [BOX-AND-FOLLOW] is used in this document synonymously for the more formal term [OBJECT AUGMENTATION], as it appears to be commonly used in practice.*

Object Indicator

A graphical cue or symbol associated with an object which is displayed on the optical sensor presentation by the Object Augmentation process. The Object Indicator can take one or more forms such as, but not limited to:

- a geometric shape that encloses the pixels belonging to the object as recognized by the Visual Tracking functionality (see also 3.3.7)
- a symbol near the object
- an arrow pointing to the object

Sensor Coverage Volume

A three-dimensional space which is “covered” by the optical sensor.

Object Augmentation Classification Scheme

Visual tracking must differentiate between objects that are of interest to the operator and those that are not to avoid excessive display clutter or system processing workload. Objects are therefore divided into two classes:

- Object-to-be-augmented
An aircraft, vehicle, person, animal, obstacle or any other object, either moving or temporarily stationary, either on ground or in the air, which is considered to be of interest by the operator.
- Object-not-to-be-augmented
An aircraft, vehicle, person, animal, obstacle, or any other object either moving or temporarily stationary, either on ground or in the air, which is not considered to be of interest by the operator.

Ideally, only objects-to-be-augmented should be augmented. Although close to 100% success rate can be obtained using image processing if objects are specially marked and the environment is carefully controlled, this is infeasible with normal objects in real-world conditions. The following two terms are used to describe the cases where this does not occur:

- Missed Box-and-Follow
An object-to-be-augmented is not augmented.
- Unwanted Box-and-Follow
An object-not-to-be-augmented is augmented.

The following TABLE 1 depicts the object augmentation classification scheme.

TABLE 1: OBJECT AUGMENTATION CLASSIFICATION SCHEME

	Object Indicator present	Object Indicator not present
Object-to-be-augmented	Wanted Box-and-Follow (correct hit)	Missed Box-and-Follow (missed)
Object-not-to-be-augmented	Unwanted Box-and-Follow (false)	Correct Rejection

1.5.5**PTZ Object Following Terms**PTZ Object Following

Automatic control of the PTZ to persistently display an object-to-be-followed; that is, the PTZ's line-of-sight automatically follows an object-to-be-followed as it moves.

Object Following Classification Scheme

PTZ Object Following must differentiate between objects that are of interest to the operator and those that are not. Objects are therefore divided into two classes:

- Object-to-be-followed
An aircraft, vehicle, person, animal, obstacle or any other object, either moving or temporarily stationary, either on ground or in the air, which is considered to be of interest by the operator.
- Object-not-to-be-followed
An aircraft, vehicle, person, animal, obstacle, or any other object either moving or temporarily stationary, either on ground or in the air, which is not considered to be of interest by the operator.

1.6**ABBREVIATIONS****TABLE 2: ABBREVIATIONS**

AFISO	Aerodrome Flight Information Service Officer
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
ATS	Air Traffic Services
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.
EASA	European Aviation Safety Agency
EUROCAE	European Organisation for Civil Aviation Equipment
FOD	Foreign Object Debris
FTA	Fault Tree Analysis
HMI	Human Machine Interface
ICAO	International Civil Aviation Organisation
MASPS	Minimum Aviation System Performance Specification
MOPS	Minimum Operational Performance Specification
PTZ	Pan Tilt Zoom
RC	Recommendation
REQ	Requirement
SESAR	Single European Sky ATM Research
VGA	Video Graphics Array

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CHAPTER 2

SYSTEM DESCRIPTION

2.1

INTRODUCTION

When analysing the requirements of a Remote Tower Optical System, it is necessary to decompose the system into its conceptual building blocks, independent of the technical realisation. For this MASPS, only digital video systems are considered.

A Remote Tower Optical System is composed of the following building blocks:

- Optical Sensors: capture images and output a video stream
- Encoder/Processing: applies processing (possibly including compression) to the video stream
- Network: transmits the video and other signals such as operator control commands
- Decoder/Processing: applies other processing (possibly including decompression) to the video stream, e.g., processing of optional Visual Tracking or PTZ Object Following processes
- Optical Sensor Presentation: displays the video stream to the operator, optionally incl. augmented presentations
- PTZ Function: An imaging sensor or sensors with a pan/tilt pointing capability and narrow (i.e., magnified), possibly variable, field-of-view (emulates binoculars)
- Control HMI: interface for remotely operating sensors and other devices at the aerodrome
- Time Source: time reference for synchronisation of components

FIGURE 1 illustrates these basic building blocks of a Remote Tower Optical System.

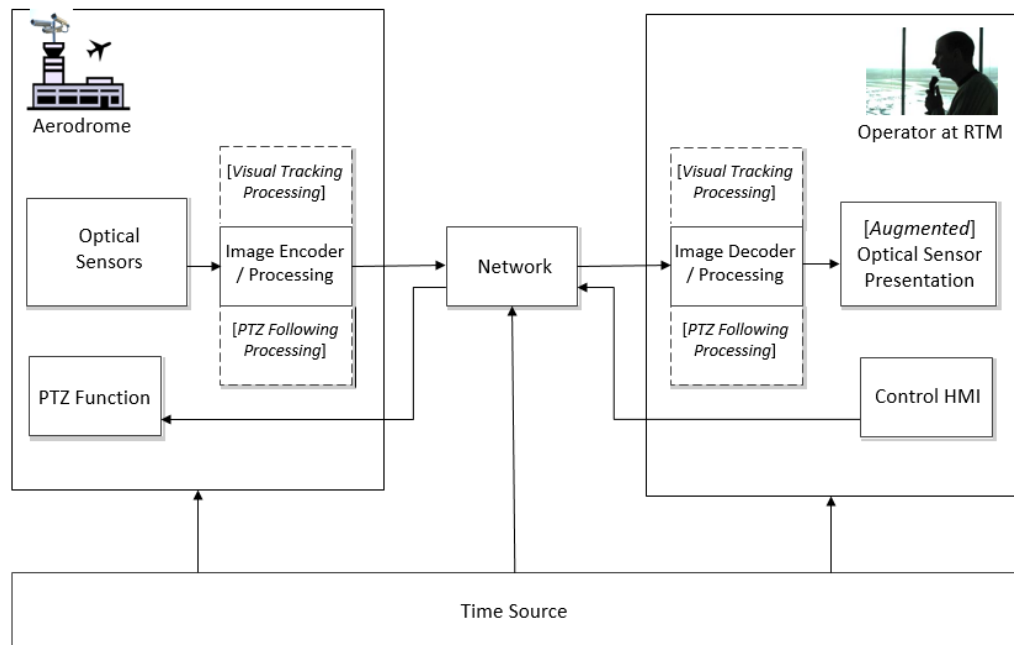


FIGURE 1: REMOTE TOWER OPTICAL SYSTEM CONCEPTUAL BUILDING BLOCKS

In a concrete implementation, one or more of these conceptual building blocks might be integrated into a single physical element.

The following subsections outline each building block in more detail.

2.2 OPTICAL SENSORS

The optical sensors at the aerodrome capture real-world images. Images are transmitted as a stream of video data to the next stage.

There are several types of optical sensors and sensor configurations; for example, single or multiple, fixed or rotating, planar, array or line-scan, within or outside visual spectrum optical sensors.

The implementation of the optical sensors drives the quality, update rate, resolution, colour depth and field-of-view of the video stream created by the optical sensors.

2.3 ENCODER / PROCESSING

The native video streams from the optical sensors require a transmission bandwidth that often exceeds the capacity of current typical telecommunication networks. Therefore, a compression mechanism is likely to be necessary to enable the video stream to be transmitted within the available bandwidth.

Additional processing may be carried out at this stage for example to enhance the video quality, add (meta-) information, remove operationally irrelevant parts of the video or Visual Tracking processing for object augmentations.

2.4 NETWORK

The video stream is transmitted over a network from the aerodrome to the RTM.

The network also transmits control and status signals to allow the remote operator to operate the optical sensors at the aerodrome.

The network must maintain the integrity of the video stream. The quality of the network affects delay, jitter and packet drop that in turn affect the images shown by the optical sensor presentation.

NOTE: *The network may be dedicated to the Remote Tower Optical System or may be shared with other communications. If the network is shared, quality of service and prioritisation mechanisms may be required to ensure that the Remote Tower Optical System performance requirements are met.*

2.5 DECODER / PROCESSING

At the RTM, the video stream is prepared for presentation (and potentially decompressed).

Additional processing may be carried out at this stage. For example, to enhance the video quality, add (meta-) information, remove operationally irrelevant parts of the video.

2.6 OPTICAL SENSOR PRESENTATION

Imagery from the optical sensors is displayed to the operator on one or more display devices.

Optionally, images may be augmented with, e.g., Visual Tracking or PTZ Object Following indicators, which results in an Augmented Optical Sensor Presentation.

2.7 PTZ FUNCTION

The PTZ function fulfils the function of the binoculars in conventional towers; that is, it allows the operator a close-up view of a specific location or object.

The PTZ movement speed has a direct influence on the time needed to change the view from one location or object to another. It is manually operated but optionally supported by an automatic PTZ Object Following function.

2.8 CONTROL HMI

The Control HMI allows the operator to control the components and functionalities of the Remote Tower Optical System. As a minimum, it provides the operator with a method to control the PTZ function. This could range from direct manual control of the

camera's orientation to automated control (e.g., presets that move the camera directly to predefined locations, object following).

2.9 TIME SOURCE

Mechanisms for checks of delay and image freshness require that components of the Remote Tower Optical System be synchronised to a master time source.

Accurate time synchronisation over the whole processing chain allows checks for the freshness and synchronisation of the images by comparing timestamps in the video stream.

2.10 VISUAL TRACKING (OPTIONAL)

A system function whereby groups of image pixels are associated with real world objects by image processing ("visually"). The system attempts to maintain the association between each object and its pixels between successive video frames ("tracking"), even in cases where for example the object moves, its background changes or the object is temporarily obstructed by another object. The output of the Visual Tracking function is used by the "Box-and-Follow" functionality to indicate objects to the operator.

2.11 PTZ OBJECT FOLLOWING (OPTIONAL)

A function whereby an object-to-be-followed is designated (e.g., by the operator using the Control HMI) and the pan and tilt axes of the PTZ are then controlled automatically to keep the PTZ pointing at the object, following its movements. That is, the PTZ automatically "follows" the designated object so that it remains centred (ideally) on the operator's PTZ display.

NOTE: *This function could also be implemented digitally without physically moving the sensor.*

CHAPTER 3

SYSTEM PERFORMANCE REQUIREMENTS

3.1 GENERAL SYSTEM PERFORMANCE CONSIDERATION

3.1.1 Minimum Quality of the Visual Presentation

The human visual sensing system is very sophisticated. Although replicating the operator's "out of the window" visual performance in terms of, e.g., angular resolution at the remote operator's visual presentation is theoretically feasible from a technical perspective, it is not necessarily appropriate and indeed may involve a trade-off with another aspect like, e.g., frame rate. Rather, the visual presentation must satisfy minimum operational requirements to allow the operator to provide an ATS and/or apron management safely and efficiently, but this does not necessarily require a technical system performance that matches some or all aspects of the human visual sensing system. Indeed, some system elements, such as augmentations of the visual presentation and low-light sensors, may enhance the operator's situation awareness beyond that which is achievable using just the naked eye.

The operator's impression of the visual presentation's quality results from a combination of many factors (e.g., display resolution, sensor resolution, field of view, contrast, video update rate, colour depth, video compression, bandwidth, network latency, jitter, noise, packet loss, codec, image uniformity, size of the display, distance of the display from operator, visual angle of targets by size and distance from camera). Network performance limitations and related costs will typically mean that a trade-off between these factors is required. The adequacy of the visual presentation to support the operator to achieve the required operational performance will also be dependent on the type of service provision and the environment. Furthermore, the implementation of the visual presentation must address human factors issues. In particular, video compression, video update rate, image resolution, jitter and size and location must be proven against human factor requirements.

Ultimately, even if a system meets the minimum aviation system performance specifications for individual parameters identified in this MASPS document, the quality of the visual presentation must be validated in the operational environment to ensure that it meets the human factors requirements, operational requirements and existing rules and regulations of the service provision. Changes to the functional system must be proven via a safety & human performance assessment.

3.1.2 Environmental Considerations

Environmental conditions (such as wildlife, precipitation, temperature extremes, etc.) may have an adverse effect on the system performance. Depending on the local environment, care must be taken to ensure that measures are put in place to protect the system against such conditions.

3.1.3 Operational Aspect

System performance requirements as detailed in this document are driven by factors such as:

- Local traffic amount and traffic mix
- Operational service levels
- Complexity, layout and physical size of the aerodrome
- Local procedures and regulations
- Local traffic patterns
- Position of the optical sensor(s)