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

MINIMUM AVIATION SYSTEM PERFORMANCE STANDARD FOR REMOTE TOWER OPTICAL SYSTEMS

ED-240A

October 2018

Supersedes ED-240

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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.
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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
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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 DOCUMENT

SCOPE 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

<u>Air Traffic Services</u>

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

<u>Visual Presentation</u>

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) <u>Optical Sensor Presentation</u>

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.*

<u>(a) (1) Panorama</u>

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.

<u>(a) (2) PTZ</u>

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) <u>Virtual Presentation</u>

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) <u>Augmented Optical Sensor Presentation</u>

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

1.7 REFERENCES

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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.

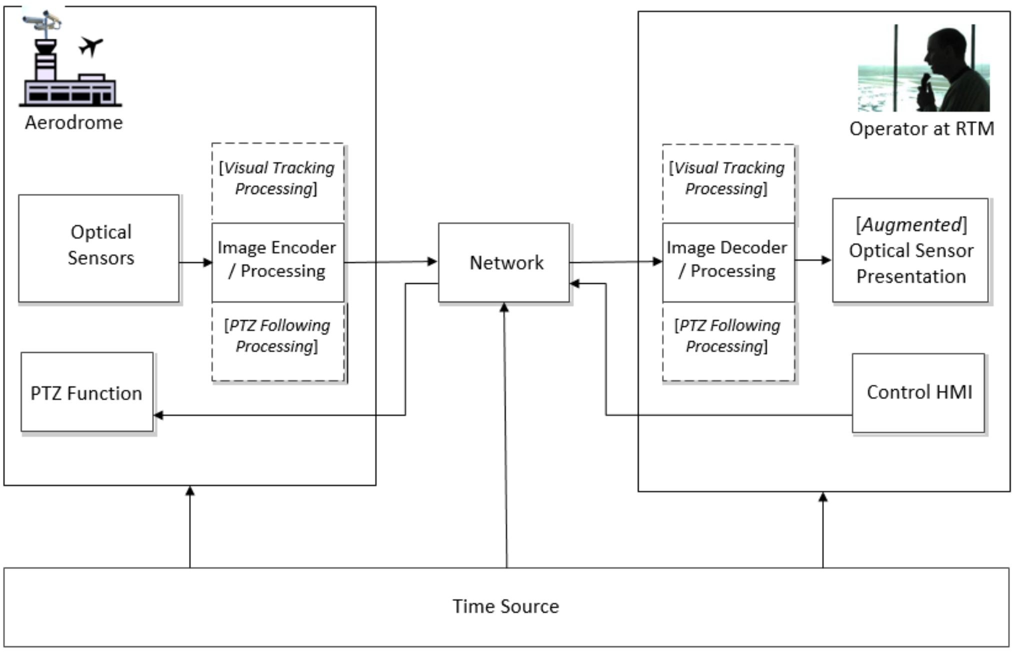


FIGURE 1: REMOTE TOWER OPTICAL SYSTEM CONCEPTUAL BUILDING BLOCKS

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)

3.1.4 Technical Aspect

To give maximum flexibility to implementers, the system performance described in this MASPS is defined in a way that is not specific to any technology or implementation method.

3.1.5 Reference Condition: Lighting and Visibility

Within this MASPS, lighting and visibility conditions always refer to daylight clear visibility conditions and comprise the following reference parameter values [27]:

1. Illumination of at least 10,000 lx
2. Visibility of at least 20 km
3. Colour temperature of the sky of approximately 25,000 K.

NOTE: *Environmental factors (such as the presence of natural or artificial light at night) may significantly impact the system performance. In this document no requirements have been defined for conditions deviating from the standard reference above. System performance against operational requirements should be validated under the standard reference condition above.*

NOTE: *A variety of atmospheric conditions are conceivable but not all can be practically tested. Therefore, reference conditions are proposed by this MASPS to harmonise test conditions. These specific reference conditions were chosen to provide the least challenging atmospheric conditions a system under evaluation needs to fulfil. If the system fails under reference conditions, it will most probably fail as well in other atmospheric conditions. If verification under this reference conditions succeeds, the requirements in this MASPS can be considered as verified.*

3.2 OPTICAL SYSTEM PERFORMANCE

3.2.1 Detection and Recognition Range Performance (DRRP)

[REQ 01] The DRRP requirements table shall be created by the operator/service provider to specify their aerodrome-specific operational needs in terms of what must be detected and / or recognized and within which range.

When defining DRRP requirements, guidance can be obtained by considering existing SESAR OSED Requirements [11], EASA guidance material [4][5][6] or APPENDIX 3 DRRP EXAMPLE VALIDATION.

DRRP requirements always refer to the lighting and visibility reference condition in 3.1.5.

<u>Each DRRP requirement is determined by the following parameters:</u>

- Parameter 1: Area of Interest (where)
- Parameter 2: Target Properties (what)
- Parameter 3: Panorama or PTZ (how)
- Parameter 4: Detection or Recognition (quality)

Each parameter corresponds to a column in <u>TABLE 3</u>.

<u>Parameter 1: Area of Interest</u>

The operator/service provider specified operationally relevant areas to which the DRRP requirements are referred: e.g., final approach, traffic circuit, manoeuvring area, apron.

<u>Parameter 2: Target Properties</u>

The DRRP depends on the following properties of a target which needs to be detected or recognised:

- Size
- Form
- Contrast

NOTE: *Size shall be defined explicitly, form and contrast have a general influence on the performance.*

For example, the operational SESAR requirements in [11] for the final approach area of interest refer to an ATR72 as a 'medium' aircraft, the equivalent profile of which in a head-on approach was estimated as 7.0 x 7.0 meters. Further profile sizes for light aircraft, personnel, animals, vehicles, obstructions, and aircraft markings are referred to in TABLE 3.

Parameter 3: Panorama and PTZ

Detection and Recognition Range Performance shall be defined for Panorama and PTZ separately.

Parameter 4: Detection and Recognition

DRRP requirements in the context of this MASPS are related to the criterion of Detection (D) & Recognition (R) of targets ("What target has to be seen from an operational point of view?"), which is based on Johnson's criteria (for definition see Section 1.5.2)

This criterion addresses the perceptual thresholds at which an observer is able to discriminate a target in terms of:

1. Detection, usually "something can be seen"
2. Recognition, the type of object can be discerned, e.g., a fixed-wing aircraft versus a helicopter

NOTE: *The DRRP requirements do not refer to Johnson's criteria "identification" since "identification" in an ATS context is very different to its meaning stated in Johnson's criteria. Moreover, identification in the ATM context can hardly be performed with optical sensors only, unless you can read out the registration mark of an aircraft.*

Definition of Range Performance Value

The actual range performance value in the DRRP requirement concerns the distance from the optical sensor(s) (camera) to a target and defines the minimum range at which the target shall be detected or recognised.

The position at which the optical sensor(s) is sited is typically the result of an iterative decision process between the operator/service provider and the supplier, and must be considered when calculating the range performance value.

For instance, when the area of interest is the manoeuvring area, the DRRP range performance value is the farthest distance from the optical sensor to the edge of the manoeuvring area.

Similarly, if operators need to recognise a medium-sized aircraft on final approach at a distance of 4 nm from the landing runway threshold, the range performance value will be the range from the optical sensor position (camera) to the aircraft in that defined position.

FIGURE 2 illustrates how to calculate the range performance value. It is possible that the sensor coverage volume of an optical sensor at a specific site will only partially cover a specific area of interest, for example due to sheer distance or physical obstructions (distant perimeter taxiways, narrow piers in the apron area, etc.). In such cases, additional cameras or camera sites may be used to fully cover the area of interest.

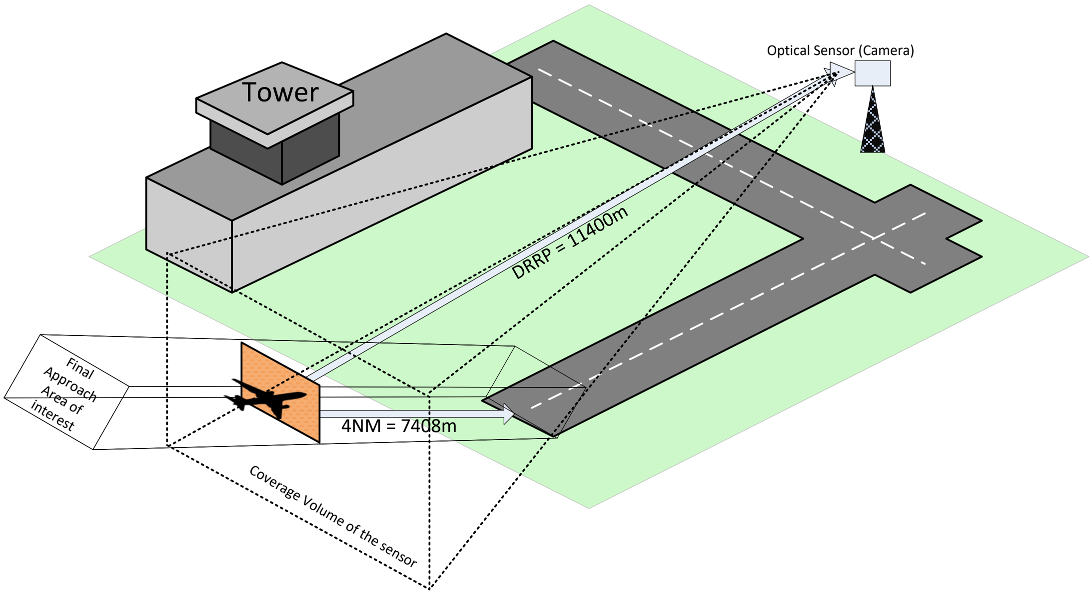


FIGURE 2: RANGE PERFORMANCE VALUE CALCULATION

How to generate DRRP requirements

1. The operator/service provider creates a DRRP requirement by specifying all parameters and determining the corresponding range performance values for “D” (detection) and “R” (recognition) for the “Panorama” and “PTZ” optical sensor presentations (filling out each cell of a row in the table), bearing in mind where the optical sensor(s) will be sited. Step 1 is repeated until all necessary operational requirements DRRP are transferred into the form of DRRP requirements.
2. Each identified DRRP requirement is tabulated as in the example matrix in TABLE 3.
3. After this process, the completed table contains the defined DRRP requirements set.

TABLE 3 provides an example template for generating aerodrome ATS and/or apron management specific DRRP requirements. All rows and specified values in the table must be seen as examples only. The parameters shall be defined according to the operators’ need. Further, the entire table can be expanded, shortened, and/or duplicated for different sensor sites. A final completed table represents the range performance of all targets that operators need to be able to detect and recognize in their operational areas of interest.

TABLE 3: EXAMPLE MATRIX FOR CREATING AERODROME SPECIFIC DRRP

				Range (m) for Detection (D) and Recognition (R)			
				Panorama		PTZ	
ID	**Area of Interest**	**Targets**	**Profile Size (m)**	**D**	**R**	**D**	**R**
[DRRP REQ 1]	Final Approach	Medium Aircraft	7.0 x 7.0 x 27,2				
[DRRP REQ 2]	Traffic Circuit	Light Aircraft	2.25 x 2.25 x 8.2				
[DRRP REQ 3]	Manoeuvring Area	Persons / Animals	1.8 x 0.5 x 0.5				
[DRRP REQ 4]	Manoeuvring Area	Vehicle	2.5 x 1.5 x 5.0				
[DRRP REQ 5]	Manoeuvring Area	Obstructions	0.3 x 0.3 x 0.3				
[DRRP REQ 6]	Apron	Light aircraft	2.25 x 2.25 x 8.2				
[DRRP REQ 7]	Apron	Obstructions	0.3 x 0.3 x 0.3				
[DRRP REQ 8]	Apron	Vehicle	2.5 x 1.5 x 5.0				
[DRRP REQ 9]	Apron	Persons / Animals	1.8 x 0.5 x 0.5				
[DRRP REQ #]	user specified						

NOTE: *To provide an example of performance measurements from an existing Remote Tower Optical System implementation at the time of writing, sample values from a MASPS conformance verification of a prototype Remote Tower implementation are provided in APPENDIX 3 DRRP EXAMPLE VALIDATION.*

3.2.2 Latency

Definition

Latency consists of the capture-to-display latency of the system plus the time interval between 2 frames.

[REQ 02] There shall be no greater than a 1 second time delay between the occurrence of an event in the real world and the presentation on the display.

NOTE: *The maximum latency of 1 second is related to existing ground surveillance sensor standards [29] and is considered as reasonable in a Remote Tower environment.*

3.2.3 Video Update Rate

[REQ 03] Technically, the video update rate shall be greater than 1 frame update per second due to the definition of [REQ 01].

[REQ 04] Operationally, for the optical sensor presentation the video update rate shall be adequate for the operator to achieve the required operational performance in the specific operational context.

NOTE: *At the time of writing of this MASPS, there were Remote Tower Systems that had gained regulatory approval for aerodrome ATS with 25 and 30 frames per second (fps).*

NOTE: *An empirical study published in 2018 [30] concludes that lower video update rates might also satisfy operational performance requirements.*

3.2.4 Video Failure Notification Time

Definition

The elapsed time between a failure affecting the operational usability of the video images presented to the operator and notification thereof to the operator.

[REQ 05] The video failure notification time shall not exceed 2 second.

3.2.5 PTZ Function Control Latency

[REQ 06] The PTZ function shall respond within 250 milliseconds of operator input.

3.2.6 PTZ Function Movement Speed

[REQ 07] PTZ Pan Speed: PTZ must be capable of reaching a continuous panning speed of at least 60 degrees per second.

[REQ 08] PTZ Tilt Speed: PTZ must be capable of reaching a continuous tilting speed of at least 60 degrees per second.

[REQ 09] PTZ Pan Positioning: The time between two pan positions which are 60 degrees apart from a resting state to a resting state shall be less than 2 seconds, not including PTZ function control latency.

[REQ 10] PTZ Tilt Positioning: The time between two tilt positions which are 60 degrees apart from a resting state to a resting state shall be less than 2 seconds, not including PTZ function control latency.

NOTE: *Zoom speed performance has not been considered as a minimum requirement due to the variability of different zoom levels and equipment. These system performance requirements can be satisfied with a fixed zoom (i.e., a fixed focal length sensor).*

3.2.7 Time Synchronisation

[REQ 11] The system shall be synchronised to an external time reference, such as a master UTC clock, to within 100 milliseconds.

NOTE: *This is to ensure that all date and time indications and calculations associated with the system are synchronised.*

3.2.8 Jitter

Definition

Jitter is the variation of the time period between two successive image frames and consists of a combination of video capture jitter and video update jitter.

NOTE: *See APPENDIX 5 JITTER for a more detailed description.*

[REQ 12] The system shall include a video jitter buffer to minimize the video update jitter. The buffering time shall be defined. If the jitter is larger than this buffering time, a notification shall be issued.

NOTE: *Technically, it is very hard to measure and set a specific Video Update Jitter value as a requirement. Therefore, no specific Video Update Jitter requirement is described here, but a buffering requirement is defined. This buffer rebalances the uniformity of the video frames.*

NOTE: *Defining a reasonable buffering time is dependent on overall system latency, network quality etc. Increasing the buffering time will add latency to the system.*

[REQ 13] The video jitter (video capture jitter and video update jitter) of the optical system shall be validated to confirm that the required operational performance is achieved in the specific operational context.

3.2.9 Packet Loss

Definition

The discarding of packets in the network, e.g., when the network device is overloaded.

[REQ 14] The Packet Loss of the optical system shall be continuously monitored. If a threshold is exceeded an indication shall be presented.

[REQ 15] For the optical system, the Packet Loss shall be measured and validated to enable the required operational performance in the specific operational context.

NOTE: *If a network packet is dropped during transmission of an image, only a part of the image will be affected as an image frame requires a large number of network packets due to its size. The visual effect of a lost packet on the image depends on various factors (encoding method, movement in the picture, contrast, error correction mechanisms, etc.) and therefore cannot be represented by a single numerical value. Retransmission of a lost packet is not feasible due to the introduced latency.*

3.3 VISUAL TRACKING PERFORMANCE

3.3.1 Visual Tracking Range Performance (VTRP)

[REQ 16] The VTRP requirements table shall be created by the operator/service provider to specify their aerodrome-specific operational needs in terms of which ‘object(s)’ must be augmented in which “area of interest”. Each VTRP requirement is based on a corresponding DRRP requirement.

NOTE: *An object-to-be-augmented must be captured by a minimum pixel set (a certain “size”) which is sufficiently large that the Visual Tracking Functionality can Box-and-Follow that object using image processing alone.*

<u>Each VTRP requirement is determined by the following parameters:</u>

- Parameter 1: Corresponding DRRP requirement
- Parameter 2: Scenario
- Parameter 3: Range of Visual Tracking Initiation
- Parameter 4: Probability of Continuous Object Indication Loss (PCOIL)

Each parameter corresponds to a column in <u>TABLE 4</u>.

<u>Parameter 1: Corresponding DRRP</u>

Each VTRP requirement is derived from a related DRRP “*Detection*” requirement, and the target from the DRRP requirement becomes an object-to-be-augmented.

NOTE: *Visual Tracking and the corresponding VTRP can be based on each optical sensor which provides a video stream. Typically, Visual Tracking is applied to objects displayed by the Panorama, but can also be applied to the PTZ.*

Each VTRP requirement corresponds to its related DRRP requirement in terms of what shall be seen and where; that is, what “targets” are to be visually tracked in which “area of interest”.

<u>Parameter 2: Scenario</u>

A textual description of the operational scenario in which targets are to be visually tracked.

<u>Parameter 3: Range of Visual Tracking Initiation</u>

The actual (maximum) range performance value concerning the distance from the optical sensor(s) to a target which shall be boxed-and-followed.

<u>Parameter 4: Probability of Continuous Object Indication Loss (PCOIL)</u>

Once Box-and-Follow has been initiated, the probability that the Visual Tracking Functionality maintains an Object Indication without losses that exceed an operationally acceptable duration.

NOTE: *It is assumed that a loss of object indication may be operationally acceptable and there might be different probabilities for different loss intervals.*

How to generate VTRP requirements

1. An operator/service provider starts creating a VTRP requirement by choosing or creating a DRRP requirement.
2. Based on that DRRP requirement scenario, the operator/service provider specifies a VTRP scenario.
3. Based on that DRRP “Detection” value and the scenario, the operator/service provider specifies the distance at which it shall be possible to initiate Visual Tracking of an object-to-be-augmented.
4. The operator/service provider specifies the minimum probability with which the object shall be augmented.
5. Step 1-4 are repeated until all necessary operational VTRPs are translated into VTRP requirements (see the example matrix in TABLE 4).
6. After this process, the completed table contains the defined VTRP requirements set.

TABLE 4 provides a template for generating aerodrome ATS and/or apron management specific VTRP requirements.

TABLE 4: EXAMPLE MATRIX FOR CREATING AERODROME SPECIFIC VTRP

ID	Corresponding DRRP	Scenario	Visual Tracking Range Value (m)	PCOIL
[VTRP REQ 1]	**[DRRP REQ 1]**	Light aircraft from Final to Touchdown	2000m	> 3 sec and < 5 sec track loss: 1 per 30 sec < 3 sec track loss:1 per 10 sec
[VTRP REQ 2]	**[DRRP REQ 2]**	Light aircraft on the runway	1000m	< 3 sec track loss:1 per 60 sec
[VTRP REQ #]	**[DRRP REQ #]**	Medium aircraft landing from 3NM on final to vacating the runway	3000m	> 3 sec and < 5 sec track loss: 1 per 30 sec < 3 sec track loss:1 per 10 sec
…	…	…	…	…

NOTE: *These numbers are example values only.*

NOTE: *There may be areas in which the initiation of Box-and-Follow is not wanted (e.g., car traffic on the road outside the aerodrome).*

3.3.2 Number of Unwanted Object Indications (NUOI)

Definition

The number of times objects-not-to-be-augmented are augmented on the optical sensor presentation (unwanted object indicators) over a defined period of time.

[REQ 17] The NUOI shall be assessed subjectively by the operator.

NOTE: *Since the characteristics of NUOIs are very complex in terms of size, location, duration, moving or stationary, a quantitative assessment and a referred minimum performance requirement cannot be objectively defined. Instead, the operator subjectively assesses whether the given NUOI performance is accepted. For this reason, the NUOI relates to the PCOIL in the VTRP, but is not an additional column (because it is not quantifiable).*

NOTE: *System settings and traffic scenarios used for verification must be the same as when verifying the POI parameter in the VTRP requirement.*

3.3.3 Object Indication Tracking Update Rate (OITUR)

Definition

The frequency at which the Visual Tracking Function generates object indications.

[REQ 18] The OITUR shall be $\geq$ 1 Hz.

NOTE: *Interpolation of object motion can be used to smooth the movement of the object indication. Object Indicators generated by interpolation of object motion cannot be counted towards the OITUR requirement.*

NOTE: *See also section 3.3.6.*

3.3.4 Position Renewal Time-Out Period (PRTOP)

Definition

The elapsed time after the last detected movement of the object after which the indicator shall be removed.

[REQ 19] The PRTOP shall be defined by the operator in seconds.

NOTE: *This could be a global system setting or per defined area.*

3.3.5 Object Augmentation Initiation Time (OAIT)

Definition

The maximum elapsed time between the detection of object motion and the object indication.

[REQ 20] The OAIT shall be subjectively assessed by the operator.

NOTE: *It is important that the optical sensor presentation displays an object augmentation quickly after an object has started moving.*

NOTE: *An exception to this requirement is if there is no significant change in the pixels representing an object but the object is expected to be moving (e.g., when an object starts moving directly towards or away from the sensor).*

3.3.6 Considerations on Synchronisation of Update Rates

To avoid the trailing box effect as depicted in FIGURE 4, the following update rates must be synchronised:

- Video Update Rate (3.2.3) (Video Processing Chain)
- OITUR (3.3.3) (Visual Tracking Processing Chain)

There may be different latencies between the Visual Tracking and Video Processing Chains. They require synchronisation so that the object's augmentation is displayed at the same location as the object.

FIGURE 3 below shows an example where the processing chains are "out of sync". The processing in the optical sensor tracking box takes in this example two frames causing the Box-and-Follow augmentation to lag two frames behind the actual tracked object.

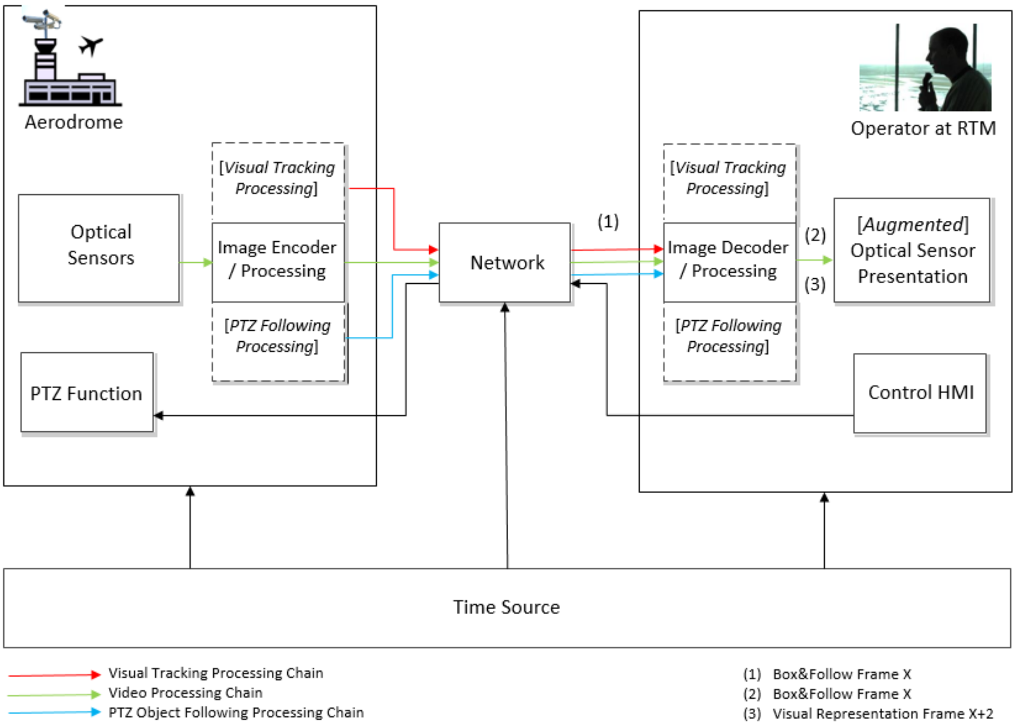


FIGURE 3: OBJECT AUGMENTATION AND OPTICAL PRESENTATION IS OUT OF SYNC

The resulting effect that the Object Indicator will trail the object-to-be-augmented is shown in FIGURE 4.

FIGURE 4: BOX-AND-FOLLOW WILL TRAIL THE AIRCRAFT IN AN OUT OF SYNC SITUATION

3.3.7 Considerations on Object Augmentation

OBJECT POSITION REFERENCE POINT (OPRP)

The OPRP is a point in image space which is computed as the geometric centre of the cluster of pixels associated with an object.

OBJECT POSITION CONTAINMENT FIGURE (OPCF)

The OPCF is a graphical indicator overlaid onto the sensor video image in the augmented optical sensor presentation that should partly or completely enclose the pixels of an object's image.

POSITION OF OPRP AND OPCF

FIGURE 5 shows the ideal positions of OPRP (RED DOT) and OPCF (BLUE CIRCLE) overlaid on a video image of an object, which may be optionally displayed on the optical sensor presentation.

FIGURE 5: OPRP (RED DOT) AND OPCF (CIRCLE)

Ideally, the OPRP is located at the centroid of an object's image on the augmented optical sensor presentation, and the OPCF should completely enclose the object. In practice this may not always be the case owing to the limitations of the system's ability to discriminate an object's pixels from the background. FIGURE 6 shows an example of an aircraft taking off at night. Only the bright lights have sufficient contrast to be discriminated from the background and appear to the system as a cluster of small objects rather than one continuous object. The computed OPRP is consequently "off centre" on the aircraft's video image and the OPCF does not completely enclose it.

FIGURE 6: INCORRECT OPRP AND OPCF CALCULATIONS DUE TO INSUFFICIENT CONTRAST

***NOTE**:* *There will be a site and system specific minimum size of the OPCF to allow the operator to better discriminate small objects against the background on the augmented optical sensor presentation.*

***NOTE**:* *The object indicator relates to the object containment figure in order to be displayed properly (e.g., not hiding / overlaying anything of the object).*

***NOTE**:* *The shape of the OPCF may be site and system specific (e.g., rectangular, circular or elliptical).*

***NOTE**:* *Considering the APPENDIX 4 OPERATIONAL CONSIDERATIONS: [OC 1-01], operators should be able to enable or disable Box-and-Follow functionality at individual CWPs or displays by a simple manual input.*

3.4 PTZ OBJECT FOLLOWING PERFORMANCE

<u>Considerations regarding the PTZ Object Following Function</u>

The ability of the system to initiate and automatically follow objects by the PTZ is affected by a number of factors which could lead to degraded performance or loss of objects:

- Whether PTZ Object Following Function is initiated manually by the operator or automatically by the system in response to various triggers or actions such as:
  - The operator "pointing" at the image of the target in the PTZ or the augmented box in the Panorama optical sensor presentation.
  - Automatically, optionally linked to the Visual Tracking function.
  - Automatically, optionally linked to external information (e.g., radar position data)
- The object's speed across the image (i.e., its line of sight rate), which may vary from standstill to maximum PTZ movement in any direction (2D – i.e., azimuth and pitch).
- Variation in the apparent shape of the object with its changing aspect angle as the object turns, gets closer, moves away, or a combination of these.
- Temporary visual obstruction of the object by obstacles such as masts, buildings, clouds and other stationary or moving objects.
- Variation in the contrast of the object against its background, due to the object's motion, changes in the background (e.g., moving clouds) or changes in lighting.
- Variation in the apparent size of the object's image on the sensor as the zoom function is applied or the object moves away from or closer to the camera.

3.4.1 Probability of PTZ Object Following Loss (POL)

- DRRP requirements describe which object(s) the operator shall be able to detect and recognize at a given distance. In other words, DRRP specify what is to be seen.

- VTRP requirements describe which object(s) must be augmented by the Visual Tracking Functionality in which area of interest. In other words, what has to be boxed-and-followed.
- POL requirements describe the probability with which the PTZ Object Following Functionality is following an object-to-be-followed moving a given path in an operational scenario.

[REQ 21] The POL requirements table shall be created by the operator/service provider to specify their aerodrome-specific operational requirements in terms of which object(s) in which scenario has to be followed by the PTZ Object Following Function with which maximum probability of object loss.

NOTE: *An object-to-be-followed must be captured by a minimum pixel set (a certain "size") which is sufficiently large that the PTZ Object Following Function is able to follow that object.*

NOTE: *The PTZ Object Following Function described here is based on the PTZ video stream.*

Each POL requirement is determined by the following parameters:

- Parameter 1: Scenario
- Parameter 2: Probability of Object Loss

Each parameter corresponds to a column in TABLE 5.

Parameter 1: Scenario

A textual description of an operational PTZ Object Following scenario.

Parameter 2: Probability of PTZ Object Following Object Loss (POL)

The probability of PTZ Object Following Loss is the maximum probability that an initiated PTZ Object Following undesirably stops following an object-to-be-followed.

NOTE*:* *The performance considerations in Section 3.4 have to be fulfilled.*

How to generate POL requirements

1. An operator/service provider creates a POL requirement by describing the PTZ Object Following operational scenario and determining the POL.
2. Step 1 is repeated until all necessary operational POL are transferred into the form of POL requirements.
3. Each identified POL requirement is tabulated in the example matrix in TABLE 5
4. After this process, the completed table contains the defined POL requirements set and is verified by the test procedure outlined in Section 5.4.1.

TABLE 5 provides a template for generating aerodrome ATS and/or apron management specific POL requirements. All rows and specified scenarios and probability of PTZ Object Following Losses in the table must be considered as examples only. The values shall be defined according to the operators' need. Further, the entire table can be expanded or shortened, and may also be duplicated for PTZ cameras. The final completed table represents POL performance of all targets that operators need to be able to follow with the PTZ Object Following Function in their operational areas of interest.

TABLE 5: EXAMPLE MATRIX FOR CREATING SCENARIO SPECIFIC POL

ID	Scenario	POL
[POL REQ 1]	Maintenance car inspecting the runway from holding point till vacating the runway	#%
[POL REQ 2]	Medium aircraft landing from 3NM on final to vacating the runway	#%
[POL REQ 3]	Light aircraft performing a traffic circuit from base to base	#%
[POL REQ #]	Airport staff moving within the runway protection area	#%
…	…	…

***NOTE*:** *With purely optically-based tracking, the PTZ Object Following function "follows" an object based on its apparent speed and direction of travel. If the object-to-be-followed passes close to, in front of or behind another object with similar apparent motion, there may be cases in which the PTZ Object Following function can fail to correctly discriminate the two objects, which may cause it to stop following or even worse, to start following the other object.*

CHAPTER 4

INTEROPERABILITY REQUIREMENTS

NOTE: *The interoperability requirements as outlined in the following chapter are applying to the optical system. The optional Visual Tracking and PTZ Object Following functionality need no interoperability requirements.*

For every Remote Tower System, operational use requires that certain functions are available when needed; that the functions are fully functional and, if not, that the operator is made aware of the nature of any failure so that appropriate action may be taken. These issues should be addressed in the dependability and interoperability requirements of the overall system.

Design specifications must be produced to ensure that the performance of the installed system meets its dependability and interoperability requirements when in operational service. It should be noted that procedures, external systems and other methods could be used to meet the requirements.

Typically, dependability and interoperability requirements include:

- System Integrity
- System Availability and Continuity of Service
- Synchronisation

4.1 SYSTEM INTEGRITY

The Remote Tower System is used to provide information which is directly used for the delivery of aerodrome ATS and/or apron management and as such, it is essential that the information presented has integrity consistent with its operational use.

Care must be taken to define the performance of the system in various states of reduced redundancy or degraded capability (i.e., loss of a single optical sensor). Mechanisms must be in place to inform the operator of any reduction in performance that may affect ATS and/or apron management.

As a minimum, system designers should ensure that the Remote Tower Optical System includes performance and integrity monitoring.

It is also necessary to ensure that any contributing data sources which could affect the identification of objects presented to the operator, such as aerodrome databases or flight plan information systems, have adequate integrity. In general, designs should ensure that key information, such as is displayed by the optical sensor presentation, is sourced entirely from system elements designed specifically for high operational integrity in real time. It is therefore essential that the Remote Tower Optical System monitor the health of any data source that contributes to the optical sensor presentation, and take appropriate action if a data source is disabled or degraded. The Remote Tower Optical System should:

- Include the status of all sub-systems and data sources in the Remote Tower Optical System fault logic and determine if the failure of any sub-system impacts the overall system health.
- Discontinue usage of data from a failed sub-system.
- Display the overall Remote Tower Optical System status and sub-system statuses on the operator HMI when necessary.
- Clearly inform the operator if “safety net” functions are disabled or degraded, either through de-selection or through system failure.
- Clearly inform operational and / or technical supervisors regarding the operational and technical status, respectively.

4.1.1 Integrity Monitor Response Time (IMRT)

Definition

The time between the failure or degradation of a part of the system (e.g., mechanical failure of the PTZ, no time synchronisation) and appropriate action by the system (including alerting the operator).

[REQ 19] The IMRT shall be ≤ 10 seconds.

NOTE: *The IMRT is applicable from the time of detecting the failure to alerting, and from the time of rectification of the failure to the time for the alert status returning to normal.*

NOTE: *The IMRT requirement does not apply to the video stream, because this is considered more critical and is described in Section 3.2.4.*

4.2 SYSTEM AVAILABILITY AND CONTINUITY OF SERVICE

System availability and continuity of service encompass the reliability and maintainability of a system. For a Remote Tower Optical System, which is used operationally in a continuous manner rather than for a series of discrete operations, availability and continuity of service are similar concepts except that availability includes scheduled outages of the system.

Two types of system availability can be expressed:

- Inherent Availability
- Operational Availability

Inherent availability is generally derived from analysis of an engineering design and is based on quantities under control of the designer.

The overall operational availability, considering other causes of unavailability such as logistics delay and preventive maintenance, is not a design matter.

Operators of a system may need to consider both types of availability; however, only the inherent availability is considered for specifying Remote Tower Optical System availability in this MASPS.

Inherent availability is defined as the probability that an item will operate satisfactorily at a given point in time when used under stated conditions in an ideal support environment. It excludes logistics time, waiting or administrative downtime, and preventive maintenance downtime. It includes corrective maintenance downtime.

Inherent availability is calculated as mean time between critical failures (MTBCF) divided by mean time between critical failures plus the mean time to repair / restore service (MTTR):

Inherent availability = (MTBCF / (MTBCF + MTTR)) × 100%

Assumptions:

- MTTR is based on time to repair assuming all required personnel, tools, spares and procedures are available on site and personnel are suitably trained and competent.
- Periods of planned maintenance are discounted from the availability figures.

As the Remote Tower Optical System is built up of several components, availability should be computed based on the MTBCF and MTTR of the components.

NOTE: *Different degradation levels of the system need to be considered, such as loss of single/multiple optical sensors, loss of optical sensor presentation devices, reduced redundancy in the system, etc. The modes of degradation are highly dependent on the ATS* and/or apron management *provided and the system's architecture.*

4.2.1 Mean Time Between Critical Failures (MTBCF)

Definition

The total operating time between critical failures. For Remote Tower Optical Systems, a critical failure is the loss of one or more critical functional parts.

[RC 01] The MTBCF should be ≥ 20,000 hours.

NOTE: *For Optical Remote Tower Systems, a compulsory minimum MTBCF requirement is not an appropriate technical specification for this MASPS due to the complexity of the system's operational application and operational environment.*

*The value of the MTBCF minimum requirement must be defined by the operator/*service provider *as part of its safety hazard analysis. The safety analysis must consider the intended type and level of service that will be provided using the system (e.g., air traffic control services, airport advisory services, or apron control).*

Therefore, this document provides a recommended value, not a minimum system performance requirement. This recommended value considered the MTBCF of ≥ 10,000 hours defined in the MASPS for A-SMGCS ED-87C [29].

4.2.2 Mean Time to Repair (MTTR)

Definition

The sum of the time to locate and repair each fault to the number of failures.

[RC 02] The MTTR should be ≤ 2 hours.

NOTE: *The times used to calculate the MTTR should include failure recognition time, troubleshooting time, access to and replacement of defective module, restart/reboot actions, and repair verification time.*

NOTE: *MTTR does not include the logistic down time, only the actual time used to diagnose the fault and make the repair.*

NOTE: *For Optical Remote Tower Systems, a compulsory minimum MTTR requirement is not an appropriate technical specification for this MASPS due to the complexity of the system's operational application and operational environment.*

*The value of the MTTR minimum requirement must be defined by the operator/*service provider *as part of its safety hazard analysis. The safety analysis must consider the intended type and level of service that will be provided using the system (e.g., air traffic control services, airport advisory services, or apron control.)*

This document therefore provides a recommended value, not a minimum system performance requirement. This recommended value considered the MTTR of ≤ 1 hour defined in the MASPS for A-SMGCS ED-87C [29].

CHAPTER 5

PERFORMANCE VERIFICATION

5.1 GENERAL CONSIDERATIONS

Reference Tests

The tests described in this chapter are reference tests. Alternative tests may be used as long as they are equivalent to the reference tests.

Test Description

All tests described in this section are reference tests to demonstrate conformance to this MASPS. Clocks used in these test procedures shall be accurate to within 100 milliseconds.

Test Description Format

- Parameter name as part of the headline
- Reference to definition and requirement number
- Test approach: general test considerations
- Test procedure: description of test method, including analysis of test data.

General Test Procedure

1. Record the time and date of testing, and identify the participants and their roles in the testing.
2. Record the type of testing being performed and the procedure that is being used for testing.
3. Record the identity (type no., serial no.) of each item of equipment to be tested and its configuration.
4. Verify the environmental conditions by defining several well-defined reference points to be detected by the optical system.
5. Ensure that inputs to the equipment under test are known and controlled in accordance with the requirements.
6. Record the results and ensure that correct results are obtained in accordance with the requirements.
7. Ensure to a reasonable degree that incorrect input data are detected and expected results are observed.

General Operator's Acceptance

For some parameters, the operator's acceptance is to be assessed to validate the parameter from an operational perspective. If applicable, perform the following steps:

1. Specify a representative sample size (number of operators).

NOTE: *Since the intended population of operators concerned with the system under test is naturally small, it should be attempted to collect data from the whole population as every reduction in sample size will further increase any bias problem.*

2. Record the visual presentation for a statistically significant length of time containing a traffic scenario that is representative of a typical working day in standard lighting and visibility conditions (see Section 3.1.5).
3. Replay the reference recording in real time and assess the operators' acceptance with respect to the phenomenological performance of the parameter under test.
4. Collate all data and analyse it using a non-parametric test statistics, e.g., a binominal test, to conclude on the operator's acceptance of the parameter under test.

5.2 OPTICAL SYSTEM PERFORMANCE

5.2.1 Detection and Recognition Range Performance

Definition

See Section 3.2.1 Detection and Recognition Range Performance (DRRP)

Requirements

See Section 3.2.1 Detection and Recognition Range Performance (DRRP)

[REQ 01]

Take the requirements generated by the approach described in section 3.2.1.

Test Approach: Operator Acceptance

NOTE: *Also see APPENDIX 3 DRRP EXAMPLE VALIDATION*

Test Procedure: Operator Acceptance

1. As targets, use regular traffic or specific test objects corresponding to the targets from Section 3.2.1 Detection and Recognition Range Performance (DRRP).
2. Two observers with appropriate visual performance (e.g., valid medical requirement ICAO CLASS 3), with their eyes at a distance to the visual presentation equivalent to the designed viewing distance in its RTM, decide when an object of concern is detected and/or recognised.
3. Record the panorama video and PTZ video during the test period with defined time stamps. Optionally, record correlating radio communication.
4. Determine the time stamp when an object of concern is detected and/or recognised in agreement to both observers.
5. Use the time stamp to determine the object coordinates provided by an appropriate reference means (e.g., wide area multilateration or onboard navigation means). For ground-based targets, an airport map may be sufficient to refer to the actual target position. See also 5.1 General Test Procedure (4).
6. Calculate the distance from the real target position to the position of the camera system based on the defined reference means.
7. The calculated data must conform to the requirements of Section 3.2.1 Detection and Recognition Range Performance (DRRP).

5.2.2 Latency

Definition

See Section 3.2.2 Latency

Requirements

See Section 3.2.2 Latency

[REQ 02]

Test Approach: Technical

1. Test shall be carried out on the complete Remote Tower Optical System including all network equipment.
2. All aspects of capture, encoding, decoding, processing, transmission and display are tested.
3. Measurement will be performed by calculating the time difference between two time displays, which will show the duration of time that it takes for video to be captured, processed, transmitted and displayed by the system.

Test Procedure: Technical

Testing should be carried out with a fully functional system.

For each optical sensor in turn:

1. Verify that both time displays are synchronized to a common time reference and ensure that the synchronisation difference is lower than the measurable time increments.
2. Place a time display in front of the optical sensor within its field-of-view.
3. Place another time display at or near the RTM.

4. Take a statistically significant number of pictures of the two time displays: that is, pictures that show the image of the optical sensor's time display as displayed by the RTM, and the time display at the RTM.
5. Calculate the average time difference between the two time stamps displayed and add the time interval between 2 frames.
6. Ensure that end-to-end delay does not exceed the values specified in Section 3.2.2 Latency.

5.2.3 Video Update Rate

Definition

See Section 3.2.3 Video Update Rate

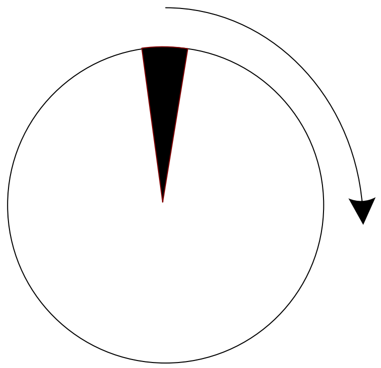
Requirement

See Section 3.2.3 Video Update Rate

[REQ 03]

Test Approach: Technical

1. Create a round white disk with a black sector in it as shown below.



2. Test shall inspect images recorded at the optical sensor presentation.

Test Procedure: Technical

Testing should be carried out with a fully functional system.

Set up the system in fully functional mode.

For each optical sensor in turn:

1. Place the disk within the optical sensor's field of view.
2. Rotate the disk at a constant speed of exactly 1 rotation per second.
3. Record the displayed frames (e.g., by "screen capture") as shown to the operator for at least one second.
4. Verify frame by frame that the number of different positions of the sector per second is equal to the required frame rate.

Requirement

See Section 3.2.3 Video Update Rate

[REQ 04]

Test Approach: Operator Acceptance

Subjective assessment of the operator's acceptance to validate the parameter's value.

Test Procedure: Operator Acceptance

Please refer to section 5.1 General Operator Acceptance.

5.2.4 Video Failure Notification Time

Definition

See Section 3.2.4 Video Failure Notification Time

Requirement

See Section 3.2.4 Video Failure Notification Time

[REQ 05]

Test Approach: Technical

Measurement is performed by calculating the time difference between two time displays, which will show the duration of time that it takes for a failure to be detected by the system and notified to the operator.

Test Procedure: Technical

Testing should be carried out with a fully functional system.

Set up the system in fully functional mode.

Execute test for each of the following events: failure of network connectivity, power failure of components, failure of other cables apart from network (such as video connection).

1. Verify that both time displays are synchronized to a common time reference and ensure that the synchronisation difference is lower than the measurable time increments.
2. Place a time-display in front of the optical sensor within its field of view.
3. Place another time-display at or near the optical sensor presentation at the RTC.
4. Start recording (e.g., by “screen capture”) having both time displays visible in one recording.
5. Induce the failure.
6. Wait until the operator is notified.
7. Perform a frame-by-frame analysis of the recording for the last time displayed from the time display in front of the optical sensor.
8. Verify that the time difference between the time above and the local time displayed at the optical sensor presentation is below the required value.

5.2.5 PTZ Function Control Latency

Definition

See Section 3.2.5 PTZ Function Control Latency

Requirement

See Section 3.2.5 PTZ Function Control Latency

[REQ 06]

Test Approach: Technical

1. The execution of the test will be recorded using a video camera. Video recording from the camera will be analysed to ensure the system reacts within performance requirements.
2. Equipment shall be co-located on a test bench to ensure the camera movement can be recorded by the camera.
3. A preset button is used to simplify the measurement of the time at which the operator executes a control command.

Test Procedure: Technical

Testing should be carried out with a fully functional system.

Set up the system in fully functional mode.

Execute test for each of the following events: pan command, tilt command.

1. Verify that both time displays are synchronized to a common time reference and ensure that the synchronisation difference is lower than the measurable time increments.
2. Place a time display in front of the PTZ optical sensor within its field of view.
3. Place the other time display at or near the optical sensor presentation at the RTC.
4. Start recording (e.g., by “screen capture”) having both time displays and also the command input visible in one recording.
5. Operator initiates a command.

6. Perform a frame-by-frame analysis of the recording to detect the first movement of the PTZ camera from the optical sensor presentation and record the time displayed from the time display in front of the optical sensor.
7. Verify that the time difference between the time above and the local time at the command at the control HMI was below the required value.

5.2.6 PTZ Function Movement Speed

Definition

See Section 3.2.6 PTZ Function Movement Speed

Requirements

See Section 3.2.6 PTZ Function Movement Speed

[REQ 07] PTZ Pan Speed

[REQ 08] PTZ Tilt Speed

[REQ 09] PTZ Pan Positioning

[REQ 10] PTZ Tilt Positioning

Test Approach: Technical

1. The execution of the test will be recorded using the PTZ video. Video recording from the PTZ function will be analysed to ensure the system reacts within performance requirements.
2. A preset function for pan/tilt is used to simplify the measurement of the time at which the operator executes a control command.

Test Procedure: Technical

Testing should be carried out with a fully functional system.

Set up the system in fully functional mode.

1. Mark two pan positions.
2. Speed up the pan function to maximum speed and measure the time it takes from one to another pan position.
3. Verify that the maximum pan speed is higher than the required value.
4. Repeat steps 1 to 3 also for the tilt function.
5. Verify that the maximum tilt speed is higher than the required value.
6. Start recording the PTZ video stream.
7. Use a 0-degree Pan Preset and check for the correct position.
8. Use a 60-degree Pan Preset and check for the correct position.
9. Using a video analysis tool, inspect the time when the PTZ function started moving at the first position and when it stopped moving at the second position.
10. Verify that the interval is less than the required pan value.
11. Repeat steps 7 to 9 also for the tilt function.
12. Verify that the interval is less than the required tilt value.

5.2.7 TIME SYNCHRONISATION

Definition

See Section 3.2.7 Time Synchronisation

Requirement

See Section 3.2.7 Time Synchronisation

[REQ 11]

Test Approach: Technical

In most of the cases, time synchronisation uses facilities provided by an operating system service. In these cases, operating system tools can be used to monitor the synchronisation status.

Test Procedure: Technical

Use a test tool of the time synchronisation system to check for the difference between the local clock and the reference time.

For example, the NTQP (Network Time Query Protocol) tool used by NTP (Network Time Protocol) would display something like this (FIGURE 7):

```
> ntpq -p adam viewer01
server      remote          refid           st t when poll reach   delay   offset    jitter
==============================================================================
viewer01   *adam        192.168.222.49  2 u    27    64    377    0.297  -27.816  17.367
```

FIGURE 7: NTPQ OUTPUT EXAMPLE

The time offset in this example is 27.8 ms.

1. Verify that the system components are synchronised with the reference time.
2. Output and record the time differences of the components in the system.
3. Verify that the time differences are below the required value.

5.2.8 Jitter

Definition

See Section 3.2.8 Jitter

Requirement

See Section 3.2.8 Jitter

[REQ 12] Video Jitter Buffer

Test A3pproach: Technical

The purpose of this test is to verify that the system issues a notification when the defined buffering time is exceeded.

1. Test shall be carried out on the complete Remote Tower Optical System including all network equipment.
2. All aspects of capture, encoding, decoding, processing, transmission and display are tested.

Jitter is induced in the system by using a test tool. The test tool must be able to randomly delay frames in a configurable time range.

Test Procedure: Technical

Testing should be carried out with a fully functional system. Set up the system in fully functional mode.

For each Visual Presentation:

1. Configure the test tool to not induce jitter.
2. Measure the typical jitter buffer usage of the system for a longer period of time.
3. Increase the jitter contribution from the test tool until the jitter buffer is exhausted.
4. Verify that a notification is issued.
5. Decrease the jitter contribution from the test tool until the jitter buffer is no longer exhausted.
6. Verify that the notification is cleared.

Requirement

See Section 3.2.8 Jitter

[REQ 13] Video Jitter Threshold

Test Approach: Operator Acceptance

The purpose of this test is to verify that the video jitter (of different sources) in the system is operationally acceptable.

1. Test shall be carried out on the complete Remote Tower Optical System including all network equipment.
2. All aspects of capture, encoding, decoding, processing, transmission and display are tested.

3. The test should be carried out during a time period that contains traffic that is representative of a typical operational scenario with moving objects of interest.
4. Special emphasis should be given to moving objects as the effects of video jitter are seen only on them.

Test Procedure: Operator Acceptance

Please refer to section 5.1 General Operator Acceptance.

Requirement

See Section 3.2.8 Jitter

5.2.9 Packet Loss

Definition

See Section 3.2.9 Packet Loss

Requirement

See Section 3.2.9 Packet Loss

[REQ 14]

Test Approach: Technical

Test inspects the effects of packet loss to the visual representation.

The test will be performed using a network simulator capable of dropping packets in a stochastic way.

Test Procedure: Technical

Testing should be carried out with a fully functional system, set up the system in fully functional mode.

For each Visual Presentation:

1. Configure the network simulator for 0 drops (that is, no packet loss).
2. Record the value the system displays as the current packet drop.
3. Increase the packet drop in the network simulator until packet loss operator acceptance becomes unacceptable for the operational scenario.
4. Record the value the system monitoring shows for the current packet drop.
5. Configure the packet drop indication to notify if this packet drop level is exceeded.
6. Rerun steps 1-3 to verify that the indication of packet loss is displayed correctly.

Requirement

See Section 3.2.9 Packet Loss

[REQ 15]

Test Approach: Operator Acceptance

Subjective assessment of the operator’s acceptance to validate the parameter’s value.

Test Procedure: Operator Acceptance

Please refer to section 5.1 General Operator Acceptance.

5.3 VISUAL TRACKING PERFORMANCE

5.3.1 Visual Tracking Range Performance (VTRP)

Definition

See Section 3.3.1 Visual Tracking Range Performance (VTRP)

Requirements

See Section 3.3.1 Visual Tracking Range Performance (VTRP)

[REQ 16]

Take the requirements generated by the approach described in Section 3.3.1.

Test Approach: Technical

1. Take the VTRP requirements as generated in Section 3.3.1 Visual Tracking Range Performance (VTRP).
2. For each VTRP requirement apply the following test procedure.

3. The goal of this test procedure is to test the parameters (1) Visual Tracking Range Value and (2) PCOIL.

Test Procedure: Technical

1. Record the panorama video during the execution of the scenario with defined time stamps, or use a pre-recorded scenario as input to the tracker.
2. Use the time stamp to determine the object position provided by an appropriate reference means (e.g., wide area multilateration or onboard navigation means). For ground-based targets, an airport map may be sufficient to refer to the actual target position.
3. Determine the distance from the object position to the position of the camera system when the tracking starts. Distance must be equal to the Visual Tracking Range Value of the corresponding VTRP requirements.
4. Next, check that the object is box-and-followed all the time while the scenario is running. Record the times of any intervals during which tracking is interrupted.
5. If necessary, perform multiple runs for statistical significance. Count the overall time of the scenario(s) and calculate the non-tracked intervals. Compare with the defined values of the PCOIL.

5.3.2 Number of Unwanted Object Indications (NOUI)

Definition

See Section 3.3.2 Number of Unwanted Object Indications (NUOI)

Requirements

See Section 3.3.2 Number of Unwanted Object Indications (NUOI)

[REQ 17]

Test Approach: Operator Acceptance

Subjective assessment of the operator’s acceptance to validate the parameter’s value.

Test Procedure: Operator Acceptance

Please refer to section 5.1 General Operator Acceptance.

5.3.3 Object Indication Tracking Update Rate (OITUR)

Definition

See Section 3.3.3 Object Indication Tracking Update Rate (OITUR)

Requirements

See Section 3.3.3 Object Indication Tracking Update Rate (OITUR)

[REQ 18]

Test Approach: Technical

Performance recording.

Test Procedure: Technical

Record the number of processed images per second and compare the number to the requirement.

5.3.4 Position Renewal Time-Out Period (PRTOP)

Definition

See Section 3.3.4 Position Renewal Time-Out Period (PRTOP)

Requirements:

See Section 3.3.4 Position Renewal Time-Out Period (PRTOP):

[REQ 19]

Test Approach: Technical

1. As targets, use regular traffic or specific test objects corresponding to the targets from Section 3.2.1 Detection and Recognition Range Performance (DRRP).
2. The output of the augmented visual presentation shall be recorded.

3. The test should be carried out on the output of the visible light sensor and infrared light sensor (if applicable).

Test Procedure: Technical

1. For an object to be augmented, record the output of the augmented visual presentation until the object is no longer augmented.
2. Review the recording to determine the time stamp when the object being augmented is no longer moving.
3. Determine when the object being augmented is no longer augmented and determine the time stamp.
4. Calculate the difference between the two time stamps.
5. Verify the difference value against the required PRTOP.

5.3.5 Object Augmentation Initiation Time (OAIT)

Definition

See Section 3.3.5 Object Augmentation Initiation Time (OAIT)

Requirements

See Section 3.3.5 Object Augmentation Initiation Time (OAIT):

[REQ 20]

Test Approach: Technical

1. As targets, use regular traffic or specific test objects corresponding to the targets from Section 3.2.1 Detection and Recognition Range Performance (DRRP).
2. The output of the augmented visual presentation shall be recorded.
3. The test should be carried out on the output of the visible light sensor and infrared light sensor (if applicable).

Test Procedure: Technical

1. For a given object to be augmented, record the output of the visual presentation from when it first appears on screen and when object augmentation begins.
2. Review the recording to determine the time stamp when the object becomes an object-to-be-augmented.
3. Determine the time stamp when the object to be augmented is augmented.
4. Calculate the difference between the two values.
5. Verify the difference value against the required OAIT.

5.4 PTZ OBJECT FOLLOWING PERFORMANCE

5.4.1 Probability of PTZ Object Following Loss (POL)

Definition

See Section 3.4.1 Probability of PTZ Object Following Loss (POL)

Requirements

See Section 3.4.1 Probability of PTZ Object Following Loss (POL)

[REQ 21]

Take the requirements generated by the approach described in Section 3.4.1.

Test Approach: Technical

1. As objects, use regular traffic or specific test objects corresponding to the targets from Section 3.2.1 Detection and Recognition Range Performance (DRRP).
2. The PTZ Object Following video stream shall be recorded.
3. The test shall cover all modes of operation for the PTZ following function (including tracking, coasting etc.).

Test Procedure: Technical

1. For a given object-to-be-followed, record the output of the PTZ display from when the operator first begins following the object, until the operator no longer wishes to follow the object.

2. Review the recording and verify, on a frame by frame basis, that the object to be followed appears within each frame.
3. Note the number of frames that contain the object and the number that do not.
4. Calculate the POL according to the test.
5. Repeat the test until a reliable average can be determined.
6. Compare the result against the required POL.

5.5 SYSTEM DEPENDABILITY AND INTEROPERABILITY

Reliability (and the related concepts of maintainability and availability) should be duly considered during all system lifecycle phases (design, development, deployment, operation and maintenance).

To ensure that all reliability, maintainability and availability (RMA) requirements are met and the system will perform effectively in the intended operational environment, various verification techniques (e.g., analysis, test and inspection) can be used during the different life cycle phases of the system.

During the design phase, system reliability and maintainability aspects are analysed as an inherent part of the design process (e.g., design activities such as reliability prediction/modelling, risk assessments (FME(C)A, FTA etc.) and maintainability analysis). The results of these analyses (and the system design itself) are typically reviewed at several stages and demonstrated during formal reviews (e.g., preliminary and critical design reviews).

During the succeeding phases of development and deployment, reliability might in addition be verified by using inspection and test techniques. Testing may occur at several levels (e.g., component, circuit board, unit, assembly, subsystem, system), during several stages and by using different types of testing (e.g., life testing and accelerated life testing).

Reliability and maintainability requirements verification should also be included in the formal system acceptance testing cycles.

During operation and maintenance, reliability and maintainability should be monitored by keeping track of failures, and should be ensured by having a robust corrective action system in place.

Whatever the choice of verification techniques, the RMA processes and related activities should be agreed at an early stage between the system supplier and operator/service provider, and well documented in an RMA plan.

A non-exhaustive overview of verification techniques is given in TABLE 6 below:

TABLE 6: SYSTEM DEPENDABILITY AND INTEROPERABILITY VERIFICATION TECHNIQUES

Verification Technique	When	Description
Reliability prediction and modelling	Starting from (early) design	System block diagram assessment and availability simulation, using the system architecture, appropriate component failure and repair data etc. This modelling should be refined later in the system lifecycle based on (detailed) design and test data.
Risk analysis	Design	During the design phase, several risk assessment techniques (both qualitative and quantitative) might be used, such as: • Failure Mode and Effects (& Criticality) Analysis (FME(C)A); to identify potential single failures; to identify critical items and assess system redundancy. • Fault Tree Analysis (FTA): a systematic, top-down, penetration to significant failure mechanisms.
Maintainability analysis	Design	Assessment of the design with regard to ease of maintenance, in collaboration with human factors engineering experts. Other aspects to be looked at: fault detection/isolation coverage, logistics, repair times, etc.
Software Safety Assurance	Software Development	The software safety assurance shall conform to EUROCAE ED-153 [28] or similar.
Reliability testing	Development/ deployment	Several test techniques may be used, such as (laboratory) system life testing (under conditions expected during system life), to identify generic problems (e.g., with regard to design) or to validate estimates of lifespan, and (laboratory) accelerated system life testing (using specifically designed accelerated aging methods).
System acceptance testing	Development/ deployment	As part of system acceptance testing, it should be verified through appropriate demonstration or analyses that all RMA functional and performance requirements have been met. As part of the Site Acceptance Test cycle, a stability test may be included to assess system reliability over a well-defined period.

The dependability parameters, such as reliability, availability, and continuity of service, need to be tested and verified by gathering data on equipment failures, preferably from a large number of systems, over an extended period of time. Such testing will normally entail performing a statistical analysis based on many years of continuous operation. An acceptable method of estimating reliability and availability would be to conduct a reliability, maintainability, availability analysis based on component failure rate data.

5.5.1 Integrity Monitor Response Time (IMRT)

Definition

See section 4.1.1 Integrity Monitor Response Time (IMRT)

Requirement

See section 4.1.1 Integrity Monitor Response Time (IMRT)

[REQ 22]

Test Approach: Technical

This testing should be carried out by monitoring the system to ensure that appropriate action is taken in the event of:

- Failure or degradation of the system
- Recovery of the system after a failure

Test Procedure: Technical

Testing should be carried out with a fully functional system.

The test output will be the output of the optical sensors and the appropriate HMI for the visual display under test.

Set up the system in fully functional mode.

For each sensor system in turn:

1. Arrange for a situation corresponding to an optical sensor or test target failure and record the time of the event (t1).
2. Record the time (t2) at which the contribution from the failed optical sensor is excluded from the visual display output and that appropriate alerting is activated.
3. Arrange for the optical sensor failure to be removed and record the time of the event (t3).
4. Record the time (t4) at which the contribution from the optical sensor is restored to the visual display output and the alert status returns to normal.
5. Confirm that the time differences (t2–t1) and (t4–t3) are consistent with the required IMRT.
6. Repeat this test several times, each time creating a different type of failure, to validate the result.

5.5.2 Mean Time Between Critical Failures (MTBCF)

Definition

See Section 4.2.1 Mean Time Between Critical Failures (MTBCF)

Recommendation

See Section 4.2.1 Mean Time Between Critical Failures (MTBCF)

[RC 01]

Test Approach: Technical

As described in the definition of the parameter, the mean time between critical failures can only be determined after a sufficient time of operation (i.e., several months) of the system. Until such data are available, a theoretical calculation based on the MTBF values of individual components shall be performed.

Test Procedure: Technical

All occurrences of critical failures should be recorded and the time gaps between successive critical failures should be averaged.

5.5.3 Mean Time to Repair (MTTR)

Definition

See Section 4.2.2 Mean Time to Repair (MTTR)

Recommendation

See Section 4.2.2 Mean Time to Repair (MTTR)

[RC 02]

Test Approach: Technical

As described in the definition of the parameter, the mean time to repair can only be determined after a sufficient time of operation (i.e., several months) of the system.

Test Procedure: Technical

For all events of critical failures of the system the time the failure happened and the time the system can be given back to operation should be recorded. The resulting time difference will result in the time to repair. An average over all calculated times to repair will result in the mean time to repair.

APPENDIX 1

REQUIREMENTS

Section [REQ]	Name	Value
3.2.1 [REQ 01]	Detection and Recognition Range (DRRP)	*Operator Acceptance*
3.2.2 [REQ 02]	Latency	<= 1 s
3.2.3 [REQ 03]	Video Update Rate	> 1 fps
3.2.3 [REQ 04]	Video Update Rate	*Operator Acceptance*
3.2.4 [REQ 05]	Video Failure Notification Time	<= 2 s
3.2.5 [REQ 06]	PTZ Function Control Latency	<= 250 ms
3.2.6 [REQ 07]	PTZ Pan Speed	>= 60°/s
3.2.6 [REQ 08]	PTZ Tilt Speed	>= 60°/s
3.2.6 [REQ 09]	PTZ Pan Positioning	<= 2s
3.2.6 [REQ 10]	PTZ Tilt Positioning	<= 2s
3.2.7 [REQ 11]	Time Synchronisation	<= 100 ms
3.2.8 [REQ 12]	Video Jitter Buffer	*N/A*
3.2.8 [REQ 13]	Video Jitter Threshold	*Operator Acceptance*
3.2.9 [REQ 14]	Packet Loss Monitoring	*N/A*
3.2.9 [REQ 15]	Packet Loss Threshold	*Operator Acceptance*
3.3.1 [REQ 16]	Visual Tracking Range (VTRP)	*Operator specified*
3.3.2 [REQ 17]	Number of unwanted Object Indications (NUOI)	*Operator Acceptance*
3.3.3 [REQ 18]	Object Indication Tracking Update Rate (OITUR)	>= 1 Hz
3.3.4 [REQ 19]	Position Renewal Time-out Period (PRTOP)	*Operator specified*
3.3.5 [REQ 20]	Object Augmentation Initiation Time (OAIT)	*Operator specified*
3.4.1 [REQ 21]	Probability of PTZ Object Following Loss (POL)	*Operator specified*
4.1.1 [REQ 22]	Integrity Monitor Response Time (IMRT)	<= 10 s
4.2.1 [RC 01]	Mean Time Between Critical Failures (MTBCF)	>= 20 000 hrs
4.2.2 [RC 02]	Mean Time To Repair (MTTR)	<= 2 hrs

NOTE: *"Operator specified": The operator specifies and validates a minimum performance value.*

NOTE: *"Operator Acceptance": The operator validates a given value by accepting the value or not.*

NOTE: *"N/A": Due to the parameter's inherent complexity a stand-alone value cannot be extracted. However, the value can be measured, monitored and validated by an operator.*

APPENDIX 2

REQUIREMENT / TEST CORRESPONDENCE MATRIX

Section [REQ]	Test section	TECH	OPS	Name
3.2.1 [REQ 01]	5.2.1		YES	Detection and Recognition Range
3.2.2 [REQ 02]	5.2.2	YES		Latency
3.2.3 [REQ 03]	5.2.3	YES		Video Update Rate
3.2.3 [REQ 04]	5.2.3		YES	Video Update Rate
3.2.4 [REQ 05]	5.2.4	YES		Video Failure Notification Time
3.2.5 [REQ 06]	5.2.5	YES		PTZ Function Control Latency
3.2.6 [REQ 07]	5.2.6	YES		PTZ Pan Speed
3.2.6 [REQ 08]	5.2.6	YES		PTZ Tilt Speed
3.2.6 [REQ 09]	5.2.6	YES		PTZ Pan Positioning
3.2.6 [REQ 10]	5.2.6	YES		PTZ Tilt Positioning
3.2.7 [REQ 11]	5.2.7	YES		Time Synchronisation
3.2.8 [REQ 12]	5.2.8	YES		Video Jitter Buffer
3.2.8 [REQ 13]	5.2.8		YES	Video Jitter Threshold
3.2.9 [REQ 14]	5.2.9	YES		Packet Loss Monitoring
3.2.9 [REQ 15]	5.2.9		YES	Packet Loss Threshold
3.3.1 [REQ 16]	5.3.1	YES		Visual Tracking Range
3.3.2 [REQ 17]	5.3.2		YES	Number of unwanted Object Indications (NUOI)
3.3.3 [REQ 18]	5.3.3	YES		Object Indication Tracking Update Rate (OITUR)
3.3.4 [REQ 19]	5.3.4	YES		Position Renewal Time-out Period (PRTOP)
3.3.5 [REQ 20]	5.3.5	YES		Object Augmentation Initiation Time (OAIT)
3.4.1 [REQ 21]	5.4.1	YES		Probability of PTZ Object Following Loss (POL)
4.1.1 [REQ 22]	5.5.1	YES		Integrity Monitor Response Time (IMRT)
4.2.1 [RC 01]	5.5.2	YES		Mean Time Between Critical Failures (MTBCF)
4.2.2 [RC 02]	5.5.3	YES		Mean Time To Repair (MTTR)

NOTE: *Column “TECH” indicates that this parameter is verified by a technical test procedure.*

NOTE: *Column “OPS” indicates that this parameter is validated by an operational test procedure.*

APPENDIX 3

DRRP EXAMPLE VALIDATION

The following DRRP data was recorded at the DLR Remote Tower research platform installed at Braunschweig-Wolfsburg Aerodrome (Germany) in accordance to the recommended test procedures in section 5.2.

The system operates eight 1920x1080 HD cameras with 8mm lenses that result in a 360° x 66° field of view panorama (6 x 40° + 2 x 60° horizontal field of view) with 12 bits/pixel and a video update rate of 30 frames per second. The resolution with these settings is 2 arc minutes (about 0.3m/500m). The PTZ operates at VGA resolution and 25 frames per second, and a fixed 16x zoom factor was used.

FIGURE A3-1 shows the Panorama View from the camera position of Braunschweig-Wolfsburg airport.

FIGURE A3-1: PANORAMA VIEW FROM THE CAMERA POSITION OF BRAUNSCHWEIG-WOLFSBURG AIRPORT

FIGURE A3-2 shows the aerodrome chart of Braunschweig-Wolfsburg airport including the camera position, the Panorama View from the camera position, and the field of view.

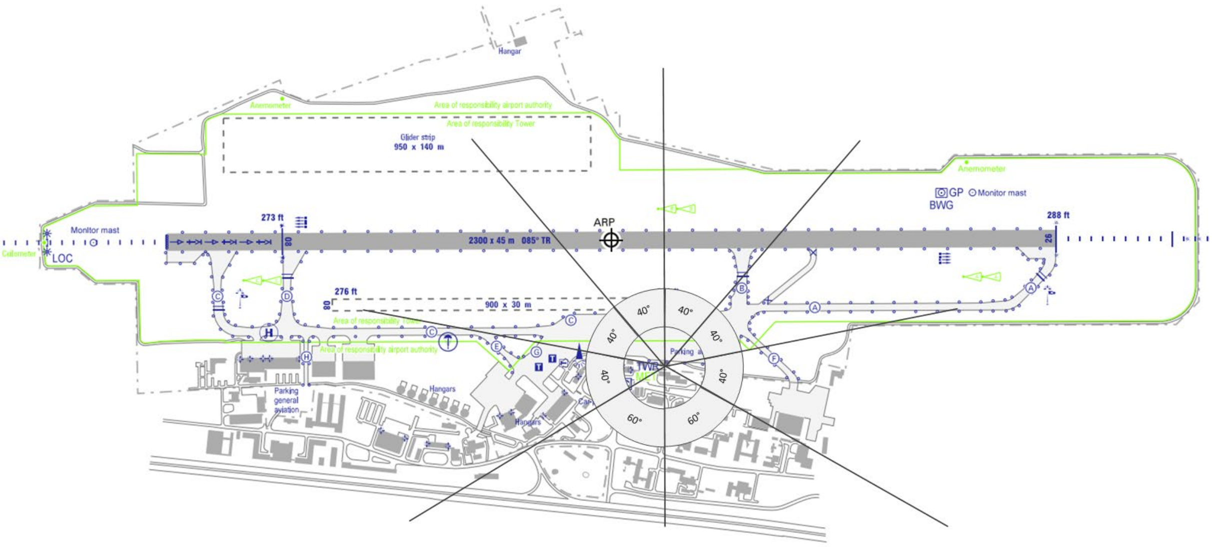


FIGURE A3-2: AERODROME CHART OF BRAUNSCHWEIG-WOLFSBURG AIRPORT INCLUDING THE CAMERA POSITION AND THE FIELD OF VIEW

TABLE 7 outlines the DRRP sample measurements from the DLR Remote Tower Research Platform installed at Braunschweig-Wolfsburg airport.

TABLE 7: DRRP SAMPLE MEASUREMENTS

				Range (m) for Detection (D) and Recognition (R)			
				Panorama		PTZ	
ID	**Control Zone Area**	**Targets**	**Example**	**D**	**R**	**D**	**R**
[DRRP REQ 1]	Final Approach	Medium Aircraft	Dornier 328-110	5700	2200	14300	6600
[DRRP REQ 2]	Manoeuvring Area	Light aircraft	Cessna 172	2400	1500	not measured	not measured
[DRRP REQ 3]	Manoeuvring Area	Personnel / animals	Person	500	300	>1500	1500
[DRRP REQ 4]	Manoeuvring Area	Vehicle	Pickup car	1500	900	>2000	>2000
[DRRP REQ 5]	Apron	Light aircraft	Cessna 172	2400	1500	not measured	not measured
[DRRP REQ 6]	Apron	Obstructions	Taxiway lighting lamp	400	not measured	1600	not measured
[DRRP REQ 7]	Apron	Vehicle	Pickup car	1500	900	>2000	>2000
[DRRP REQ 8]	Apron	Personnel / animals	Person	500	300	>1500	1500
[DRRP REQ 9]	Apron	A/c markings	1m² signpost	250		1000	

APPENDIX 4

OPERATIONAL CONSIDERATIONS

This appendix proposes a set of initial operational considerations (OC) which reflect lessons learnt from present operational experience. The considerations are provided only as guidance material.

These operational considerations fall into two categories and correspond to the indicated technical performance requirements sections:

(1) Object Augmentation / Box-and-Follow Operational Considerations

These operational considerations are corresponding to Section 3.3 Visual Tracking Performance

(2) PTZ Object Following Operational Considerations

These operational considerations are corresponding to Section 3.4 PTZ Object Following Performance

Future research and actual operational experience could identify additional OCs.

(1) Visual Tracking Operational Considerations

The Box-and-Follow functionality should detect moving objects of interest within the individually specified areas of interest and indicate them to the operator. Objects of interest must meet prescribed size criteria detailed in an operator-defined matrix. The purpose of displaying indicators is to highlight to the operator information on the optical sensor visual presentation. This information improves the operator’s situational awareness. Lighting and visibility conditions used for validation of the box-and-follow functionality are the same as those for optical presentation in this MASPS.

Box-and-Follow should produce indicators that are as correct as technically possible. Box-and-Follow should minimize unwanted indications, or indicators that cover operationally relevant information.

The Box-and-Follow functionality should support operator interaction, allowing the operator to make system adjustments that are appropriate for the current operational circumstances. This includes allowing the operator to decide if the provided indicators are of operational interest or unwanted and act accordingly to delete or suppress such indicators. It should also allow the operator to define areas where the functionality will not initiate and display indicators.

[OC 1-01] Box-and-Follow should allow the operator to “switch on and off” the functionality at individual CWPs by a simple manual input.

[OC 1-02] Box-and-Follow should, within the individually defined areas of interest, box-and-follow objects-to-be-augmented as defined in the VTRP (see Section 3.3.1 Visual Tracking Range Performance (VTRP).

[OC 1-03] Box-and-Follow should display an indicator for all objects of interest that meet the criteria described in [OC 1-02].

[OC 1-04] Box-and-Follow should provide a configurable timeout parameter which allows the system to drop an indicator from moving objects of interest that stop for more than the configured time. The Object Indicator should reappear when the object starts moving again.

NOTE: *This should be configurable for different areas of interest to improve the systems inability to distinguish between important and unimportant objects (which otherwise would be treated equally).*

[OC 1-05] Box-and-Follow should allow configuration of the visual characteristics of object indictors (e.g., size, transparency, or colour).

[OC 1-06] Box-and-Follow should allow the operator to define and create temporarily masked areas on the [augmented] optical sensor presentation within which object indicators are to be supressed.

[OC 1-07] Temporarily masked areas should be clearly indicated so the operator is aware when they are active.

[OC 1-08] Box-and-Follow should support the reduction of unwanted object indicators which may arise as a result of environmental conditions (e.g., seasonal changes, waves at a seaside, high and low contrast areas).

[OC 1-09] The Box-and-Follow functionality should Box-and-Follow objects-to-be-augmented with an operationally acceptable reliability (see TABLE 4).

NOTE: *This has been shown to be an important factor in building operator trust in the system.*

(2) PTZ Object Following Operational Considerations

[OC 2-01] The PTZ Object Following function should be able to follow objects of interest visible in the optical sensor presentation.

[OC 2-02] The PTZ Object Following function should be able to be initiated by different means (e.g., manual by interacting in the panorama or the PTZ view).

[OC 2-03] Each PTZ camera should have an independent follow capability and be capable of PTZ following simultaneously.

[OC 2-04] The PTZ Object Following function should have at least the same range performance as the Box-and-Follow range performance of the panoramic camera system.

[OC 2-05] The PTZ Object Following function should allow the operator to “switch on and off” the functionality at individual CWPs, and for individual PTZ cameras, by a simple manual input.

[OC 2-06] Once initiated, the PTZ Object Following function should maintain the same zoom setting as at the time of initiation.

[OC 2-07] The PTZ Object Following function should, while following an object, support (1) manual zoom in and out or (2) a fixed-zoom implementation.

[OC 2-08] The PTZ Object Following function should display an indication of which object(s) is/are being followed by which PTZ(s).

[OC 2-09] The PTZ Object Following indication should be continuously distinguishable against the background.

[OC 2-10] PTZ Object Following indication should be presented on the panorama and/or on a separate screen.

[OC 2-11] PTZ Object Following should be independent of the coverage of the panorama, i.e., be able to follow objects outside the panorama coverage.

[OC 2-12] The PTZ Object Following function should follow an operator identified object of interest at least 95% of the time by using a “coasting function” which allows automatically reactivation of a temporarily lost target, e.g., passing behind buildings, poles, or due to sharp cloud contrasts.

NOTE: *PTZ Coasting Function in this context is defined as maintaining PTZ movement by predicting the movement of a target that has been lost.*

[OC 2-13] The PTZ Object Following function should differentiate between objects being followed and other objects passing in front of or behind them with minimal indicator swapping.

[OC 2-14] The PTZ Object Following function should present a smooth and non-flickering image to the human eye.

[OC 2-15] When the operator locates an object-to-be-followed and initiates the PTZ Object Following function, the PTZ must find the object, initiate following and indicate this to the operator in a timely manner.

[OC 2-16] If PTZ Functionality stops following the moving object, this should be instantly indicated to the operator.

[OC 2-17] Reactivation of the PTZ Object Following function should be easy.

[OC 2-18] The movement of the PTZ line-of-sight should be steady with respect to the movement of the object.

[OC 2-19] The operation of PTZ Object Following shall be independent of the display of boxing-and-following.

APPENDIX 5

JITTER

Jitter is time non-uniformity of frames in the system. This can either be induced by a non-periodical capture by the sensor or by aperiodic delays in the processing chain to the display. The jitter from all process steps will on the display be a multiple of the display refresh interval. Jitter can have an impact on an operator's situational awareness, e.g., on the perception of speed.

Jitter in a Remote Tower Optical System is defined as a combination of:

(1) Video Capture Jitter

(2) Video Update Jitter

The rest of this appendix outlines details on (1) and (2).

01 Video Capture Jitter

Video Capture Jitter is the variation of the period between each successive pair of sampled images. Video Capture Jitter is present if the rate at which images are captured varies. In such a situation, objects that travel at a constant speed are sampled with variable displacement from frame to frame. FIGURE A5-1 shows the effect of Video Capture Jitter when capturing an aeroplane moving at constant speed. FIGURE A5-1 (a) shows how a moving aeroplane is depicted with no Video Capture Jitter, while (b) shows the effect of how a moving aeroplane is depicted when there is Video Capture Jitter (variation in capture rate). From (b) it is seen that the displacements of aeroplane between frames #1, #2 and #3 are different even though aeroplane is moving at a constant speed in the real world. FIGURE A5-2 shows how video is captured without any jitter, while FIGURE A5-3 shows how video capture jitter affects the video.

Video Capture Jitter appears to a viewer as jerky movement. A Video Capture Jitter requirement defines the maximum allowed deviation of frame-to-frame period for any two consecutive frames.

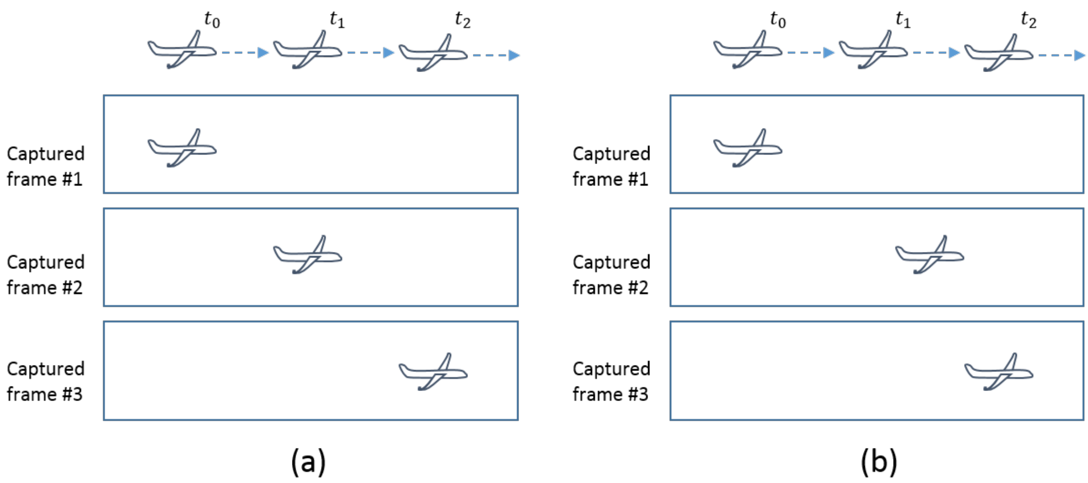


FIGURE A5-1: EFFECT OF VIDEO CAPTURE JITTER WHEN CAPTURING AN AEROPLANE MOVING AT CONSTANT SPEED

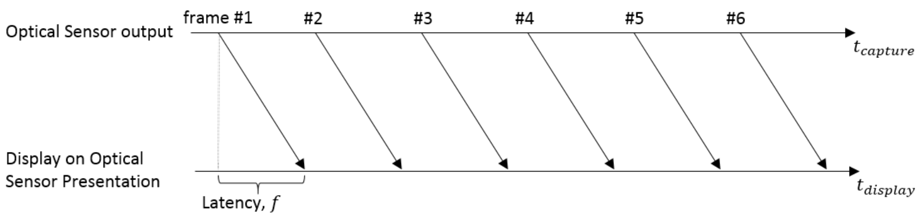


FIGURE A5-2: VIDEO SENT FROM OPTICAL SENSOR TO OPTICAL SENSOR PRESENTATION WITHOUT ANY JITTER

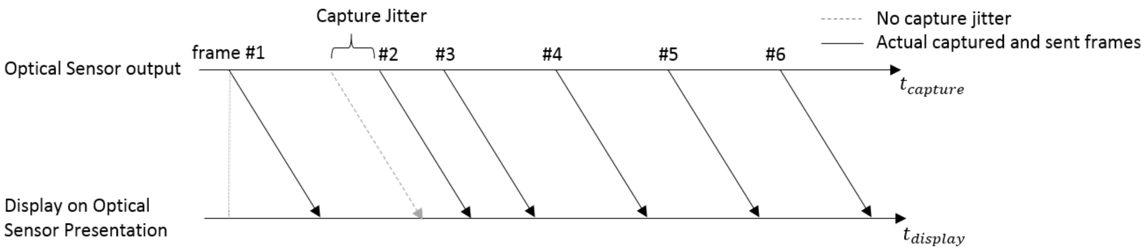


FIGURE A5-3: VIDEO CAPTURED BY OPTICAL SENSOR WITH VIDEO CAPTURE JITTER

The interframe interval i between two consecutive frames, $frame_N$ and $frame_{N-1}$, is given by the time of when the frames were captured $t_{capture}$

$$i(frame_N) = t_{capture}(frame_N) - t_{capture}(frame_{N-1})$$

Video Capture Jitter (VCJ) is calculated from interframe interval, i, and the frame rate as shown below:

$$VCJ(frame_N) = i(frame_N) - 1/framerate$$

<u>02 Video Update Jitter</u>

When Video Update Jitter is induced in the system, objects sampled with constant displacement will be displayed with variable time between each frame. Update Jitter comes from encoding, network (due to network jitter itself, but also due to different amount of data for a frame due to encoding), decoding and display software. Video Update Jitter is perceived as an object having variable speed; objects moving with constant speed will be perceived as accelerating or decelerating.

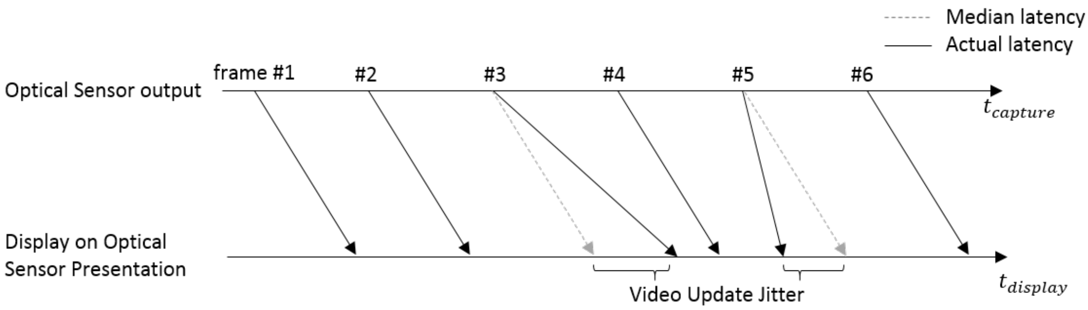


FIGURE A5-4: VIDEO SENT FROM OPTICAL SENSOR TO OPTICAL SENSOR PRESENTATION WITH UPDATE JITTER

Latency f for a frame $frame_N$ is given by the difference in time from when the image was captured, $t_{capture}$ to the time when it is displayed $t_{display}$, as shown in <u>FIGURE</u>

A5-4. Video Update Jitter is deviation in latency from median latency. Latency is mathematically expressed as:

$$f(frame_N) = t_{display}(frame_N) - t_{capture}(frame_N)$$

Video Update Jitter (VUJ) for any frame is expressed as:

$$VUJ(frame_N) = f(frame_N) - f_{median}$$

Where f_{median} median of the latency for all frames, which is the typical latency of the video.

NOTE: *Display monitors have typically 60 Hz refresh rate. With an optical sensor with frame rate less than 60 Hz, the display will show the same frame multiple times. This implies that the display may also contribute to Video Update Jitter. If display rate is not a multiple of the optical sensor frame rate, then the display will potentially contribute to* $\pm\frac{1}{display\ rate}$ *update jitter.*

APPENDIX 6

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