European Aviation Safety Agency

Guidance Material

on the implementation

of the remote tower concept

for single mode of operation

Issue 1

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GUIDANCE MATERIAL ON THE IMPLEMENTATION OF THE REMOTE TOWER CONCEPT FOR SINGLE MODE OF OPERATION

This Decision introduces Guidance Material on the implementation of the remote tower concept for single mode of operation, which is within the scope of the current regulatory framework.

1. Definitions

For the purpose of this document, and in order to enhance its understanding, the following definitions shall apply:

1. 'Aerodrome conventional tower' means a facility located at an aerodrome from which ATS can be provided to aerodrome traffic mainly through direct visual observation of the area of responsibility of the ATS unit.
2. 'Aerodrome remote tower' means a facility from which ATS can be provided to aerodrome traffic through real-time visual presentation of the elements contained in its area of responsibility (manoeuvring area and vicinity of the aerodrome) together with other elements that support the operation.
3. 'Aviation undertaking' means an entity, person or organisation, other than an air navigation service provider, that is affected by or affects a service delivered by a service provider.
4. 'Direct visual observation' means observation through direct eyesight of objects situated within the line of sight of the observer, possibly enhanced by external elements (e.g. binoculars).
5. 'Movement' means the operation of an aircraft for take-off or landing.
6. 'Operational context' means the operational characteristics that define the situation where the remote tower concept is to be implemented.
7. 'Remote tower centre' means the facility composed of one or more remote tower modules from which ATS can be provided to several aerodromes.
8. 'Remote tower module' means the workstation of an ATCO/FISO from which remote aerodrome ATS can be provided. It includes both the Controller Working Positions (CWPs) (including the necessary ATS systems) and the visual presentation display screens.
9. 'Single mode of operation' means the provision of ATS from a Remote Tower Module (RTM) for only one aerodrome at a time.
10. 'Out-the-window view' means a view of the areas of responsibility of the ATS unit from a conventional tower.
11. 'Visual presentation' means:
    - a view equivalent, in terms of visual coverage, to the one available at the corresponding conventional tower; or
    - in the absence of a conventional tower, or when other locations are deemed more beneficial, it means an unobstructed view of all the areas of responsibility of the ATS unit.

2. Safety assessment of the changes to the functional system

2.1. Identification of the change

The solutions which are available for the aerodrome remote tower (hereinafter referred to as 'remote tower') system are not based on a unique system configuration but on a set of basic functionalities which can be enhanced with additional functions with the aim to improve the situational awareness and conflict detection capabilities of the Air Traffic Controller (ATCO) or

the Flight Information Service Officer (FISO). This would require ATS providers to conduct an initial analysis of the set of functionalities which would be required for the particular change.

The remote tower functionalities can be classified in two categories:

— **Basic equipage:** This category represents the minimum equipage of technical enablers which are necessary for the operation of the remote tower at a single aerodrome. The following technical enablers are either new or modified[2] in some way to be adapted to the remote provision of ATS:

- visual presentation,
- binocular functionality,
- voice/data communication,
- visual communication,
- management of assets (aerodrome lights, alarm management, status of navigation aids, meteorological data, etc.).

Aerodrome sound reproduction should also be available if the outcomes of the safety assessment and the human performance assessment require so.

— **Enhanced equipage:** In addition to the functionalities included in the basic equipage, enhanced equipage includes some additional options intended to further improve the situational awareness and conflict detection capabilities of the ATCO/FISO. They may include but are not limited to:

- Use of infrared cameras.
- Dedicated means to facilitate the detection, recognition, identification (e.g. based on surveillance data or on flight plan correlation) and tracking (e.g. labels directly in the visual presentation) of aircraft[3].
- Dedicated means to facilitate the detection and tracking (e.g. labels directly in the visual presentation) of vehicles on the manoeuvring area.
- Dedicated means to facilitate the detection and tracking of obstructions/objects on the manoeuvring area (e.g. personnel or animals).
- Functionalities to assist the judging of the aircraft's position or altitude (depth of vision for the ATCO/FISO).
- Presentation to the ATCO/FISO of additional overlaid information (visual overlays). The type of overlaid information may include (some of the elements are the result of other advanced visualisation features):
    - information associated with a specific element or target in the visual field, aiding or facilitating detection, recognition, identification and ranging;
    - information indicating or highlighting specific parts of the aerodrome (such as runways, taxiways) in order to enhance the ATCO's/FISO's situational awareness, specifically in reduced light, low-visibility conditions and night;
    - information related to the general area of interest or area of responsibility in order to assist the ATCO/FISO and minimise 'head down' time;

[2] They may be complemented with other functionalities (e.g. electronic flight strips), but they are not included in the list as far as they are not strictly necessary for the remote tower concept and they could also be available in a conventional tower.

[3] These functionalities should be thoroughly analysed from a human factors perspective to avoid any possible risks that may arise as a result of their implementation.

- information to assist the ATCO/FISO (e.g. as regards current wind and RVR values, and status of aerodrome systems such as runway and approach lighting).

The analyses and validation exercises conducted in the frame of the SESAR project have shown that for certain operational contexts (see Section 2.3.) the functionalities presented in the **basic equipage may be sufficient** to provide the same level of safety as in the current operations at an aerodrome conventional tower (hereinafter referred to as 'conventional tower'), when available, subject to the confirmation by the corresponding safety assessment of the local implementation.

Nevertheless, in case that the operational context of the target aerodrome exceeds that referred to above or when enhanced functionality is considered, the ATS provider should evaluate the possibility of complementing the basic equipage with additional functionalities (enhanced) in order to ensure an appropriate level of mitigation of the operational risks. In this case, the ATS provider should conduct an in-depth evaluation of the selected enhanced functionalities, including the necessary validation activities and human performance assessment, as part of the corresponding safety assessment of the local implementation.

2.2. Safety assessment methodology

The remote tower concept, as a change to the functional system, does not require any specific safety assessment methodology. The available procedures, which are part of the SMS and their compliance with Commission Implementing Regulation (EU) No 1035/2011 has been demonstrated, may be used for the safety assessment. Nevertheless, the particularities of the remote tower concept, as technological change, may require the need to take into account some specific considerations in the application of such approved procedures. The objective of the developed GM is to provide ATS providers and competent authorities with such considerations. In order to facilitate the approval process, Appendix 1 summarises (in a non-exhaustive list which is to be considered as reference only) the overall elements deemed necessary for the implementation of the remote tower concept.

The present GM takes into account the main elements of the safety work performed in the frame of the SESAR project and how this available experience can be incorporated by the ATS providers into their respective safety assessment processes for the introduction into service of the remote tower concept. The identified elements are those which, based on the SESAR safety work, some particular emphasis may be required to be put on in relation to the remote tower aspects. They are considered to be generally applicable although they should be completed as necessary by the ATS providers by taking into account local implementation aspects or particularities of the selected solution. Also, this GM should be used as complementary information to the existing safety-related information (e.g. hazards baseline, existing mitigations) available to ATS providers for the introduction of changes affecting ATS.

2.2.1. Scope, boundaries, interfaces and operational environment characterisation

The environment for the remote provision of ATS is extended compared with the conventional tower so far as it is necessary also to consider that the remote facility's as well as the aerodrome's operating environment is significantly changed.

These aspects should be taken into account when determining the properties of the operational environment as well as the scope, boundaries and interfaces of the technical systems. The technical systems shall be located at two different places, at the aerodrome and at the RTC, interacting with each other but also with external entities at both sides. The way in which the technical systems will interact may be different from that of the conventional tower, something that may introduce some new situations which would require some consideration during the safety analysis. Then, the operational characteristics, roles and responsibilities as well as the

technical characteristics may be different for each environment, so a separate characterisation should be done for each of the environments, i.e. for aerodromes and RTCs.

The aerodrome's operational context may be characterised in terms of (see Section 2.3.):

— type of ATS;

— airspace-related aspects (e.g. airspace classification, CTR, Aerodrome Traffic Zone (ATZ), Terminal Control Area (TMA), type of flight procedures);

— aerodrome layout complexity (e.g. number of Runways (RWYs), number of Taxiways (TWYs) and runway entrances, parallel or crossing runways, number and location of aprons);

— traffic characteristics (e.g. number of movements per day, number of simultaneous movements, type of traffic, aircraft fleet mix);

— environmental conditions at the aerodrome.

The aerodrome's technical environment may be characterised through the description of the existing communication, navigation and surveillance systems available at the aerodrome plus the available safety nets. They do not necessarily change as a result of providing ATS remotely. This technical characterisation does not include the installation of the remote tower equipment at the aerodrome. Those features of the technical characterisation of the conventional tower which are affected by the change and the remote tower equipment itself should be considered as part of the safety assessment.

The RTC's operational and technical environment should include the detailed description, as necessary for the safety assessment, of the technical infrastructure of the RTC and RTMs plus the way in which they will be operated, and also the changes at the aerodrome site.

2.2.2. Interdependencies and assumptions

The introduction into service of the remote tower concept is a change to the functional system that may impact on one or several aviation undertakings, as it may introduce changes to the way in which they receive the ATS or the operational context in which these services are provided to them, or to the way in which the aviation undertakings are operating. The aviation undertakings potentially affected by the introduction into service of the remote tower concept would include, at least, the aerodrome operator and the aircraft operators.

Also, the change may also affect other service providers (e.g. Communication Navigation Surveillance (CNS) providers, adjacent ATS providers) other than the ATS provider proposing the change.

These interdependencies with other service providers and with aviation undertakings should be taken into account by the ATS provider when conducting the safety assessment. In particular, the ATS provider should determine:

— the dependencies with each other and, where feasible, with the affected aviation undertakings; and

— the assumptions and risk mitigations that relate to more than one service provider or aviation undertaking.

As regards aviation undertakings (e.g. aerodrome operator, aircraft operators), the ATS provider should seek their participation in the safety assessment process when assumptions and risk mitigations are shared with those aviation undertakings concerned.

Nevertheless, for the aerodrome operator, it is strongly recommended that this involvement be extended towards a coordinated assessment to ensure consistency between their respective safety assessments. These coordinated means should allow as much as possible:

— joint identification of the scope of their responsibilities with regard to the particular implementation, and in particular their safety responsibilities;

— joint identification of the interdependencies;

— joint identification of the hazards/effects associated with the change in the common context;

— common understanding of the consequences in the shared operational context and chains of causes/consequences;

— agreement on the change assumptions that affect each party and those assumptions that jointly relate to them;

— mutual agreement on the risk mitigation measures each party is supposed to implement and those risk mitigations measures that require joint implementation.

In case where a particular implementation is found to have interdependencies with other Air Navigation Service Providers (ANSPs), these ANSPs should be involved in the safety assessment of the ATS provider and the necessary coordination means should also be established with the aim of having agreed and aligned assumptions and mitigations in their respective safety assessments.

2.2.3. Safety criteria

Keeping in mind that the main driver of the implementation of the remote tower concept is cost-efficiency, the safety criteria to be applied should ensure that the level of safety after the introduction into service of the remote tower concept is at least not reduced compared to current conventional tower operations.

Then, the aim of the safety assessment shall be to demonstrate that ATS provided remotely for one aerodrome is as safe as ATS provided currently locally in equivalent conditions of traffic (in terms of capacity and movements) and operational environment than in current operations. In case there is a change to these traffic-related parameters, compared to current operations, the safety criteria should be reviewed and adapted to the new situation.

The ATS provider may establish the safety criteria taking into account the accidents/incidents that may be induced from the tower operation (either remotely or locally) as, for example, mid-air collision in TMA, controlled flight into terrain, wake-vortex-induced accident, taxiway collision and/or runway incursion.

2.2.4. Identification of hazards and failure conditions

The SESAR project has identified several general operational hazards in relation to the provision of ATS. They may not be strictly related to the remote provision of ATS, but also to the provision of ATS from a conventional tower. Nevertheless, the introduction into service of a remote tower system at a particular aerodrome may affect the causes or the probability of occurrence of any of those hazards. Then, they should be considered as an initial list for the ATS providers and adapted appropriately taking into account their respective safety baseline for ATS in the target local aerodrome. They are presented in **Table 2** (Appendix 2) for ATC provision, and in **Table 3** (Appendix 3) for AFIS provision, including a short description and operational effects.

In addition to these operational hazards, the ATS provider should identify those hazards at functional level corresponding to the main functionalities identified in the remote tower system (see Section 2.5.). These functional hazards may be integrated in the operational hazards. Due to the nature of the system and its operation, at least the following failure modes should be considered (for each of the functions):

— total loss of the function;

— partial loss of the function;

— erroneous/corrupted data (not credible error/corruption);

— delayed data;

Based on these failure conditions, the ATS provider should identify additional hazards at functional level. They shall be called 'functional hazards'.

2.2.5. Assessment of the hazards' effects

For the operational and functional hazards resulting from the hazard identification activity, the ATS provider should conduct an assessment of the hazards' effects and the classification of their severity, taking into account the particularities of the operational environment (e.g. airspace, aerodrome characteristics). The assessment should be conducted under both normal and abnormal conditions. The Functional Hazards Assessment (FHA) should take into account the severity of the operational effects stemming from the identified functional hazards.

The ATS provider may define some representative use cases to cover the normal operations and potential abnormal conditions that the ATCOs/FISOs may face when operating the remote tower. This may be based on existing normal operations and abnormal conditions already identified as part of the operation of the conventional tower. The objective would be to identify those conditions which might be more significantly affected by the particular aspects of the remote tower operation (e.g. visual presentation).

Examples of such use cases (nominal conditions) are the following:

— arriving/departing aircraft handled by remotely provided ATS;

— arriving/departing aircraft when an animal is on the manoeuvring area;

— VFR flight in the traffic circuit is conflicting with an arriving/departing IFR flight;

— management of Special VFR flights;

— management of flights during reduced light (e.g. twilight) and at night conditions;

— low-visibility procedures;

— transition of ATS provision from conventional TWR to remote TWR;

— other operations (e.g. helicopter autorotations, practising forced landing, etc.);

— control of vehicles and personnel on the manoeuvring area.

Additionally, some abnormal conditions may be identified. Some examples of abnormal conditions might be the following:

— unexpected/unplanned flight in airspace;

— aircraft with urgency or emergency;

— arriving aircraft with landing gear not down;

— crash at the aerodrome or in its vicinity;

— fire at the aerodrome;

— (unplanned) closure of ATS at the aerodrome;

— ATCO/FISO overload;

— abnormal weather (for example, low atmospheric pressure, strong winds).

The ATS provider should take into account the potential lack of independence among the identified functional hazards due to the possible use of shared resources among several functions of the remote tower system. Then, a Common Mode Analysis (CMA) should be conducted to get evidence that, based on existing design, the failures, failure modes or hazards assumed to be independent, are truly independent. The effects of design, manufacturing,

maintenance errors (e.g. hardware, software, network) and failures of system components or used resources which impact on their independence should be analysed.

2.2.6. Determination of the safety objectives and safety requirements

As in previous phases, the determination of the safety objectives and safety requirements should follow the SMS processes whose compliance with Commission Implementing Regulation (EU) No 1035/2011 should be demonstrated, and which are accepted by the competent authority. The identification of specific safety objectives and safety requirements should be driven by the dedicated Risk Classification Scheme(s) (RCS(s)) which is (are) part of the SMS.

The ATS provider should pay special attention to some particular aspects that, based on the SESAR project, would require the definition of specific safety objectives and/or safety requirements in order to ensure that the level of safety is the same as in the current conventional tower operations (as defined through the safety criteria). The following list of aspects could serve as an example:

— loss or degradation of the visualisation of the manoeuvring area and of the vicinity of the aerodrome;

— failure or degradation of the ground–ground communication (e.g. with relevant and/or adjacent ATS units, or with personnel/vehicles operating at the aerodrome);

— failure or degradation of the air–ground communication;

— loss or malfunction of the ATCO's/FISO's controlling/operating capability of the visual and non-visual navigation aids.

Additionally, the introduction into service of the remote tower concept would also imply some changes to other areas which are not strictly related to the visual presentation but may also be impacted. For example, in case that the surveillance data is used by the ATCO/FISO in a certain tower, it would be necessary to ensure that the introduction into service of the remote tower concept does not have a negative impact on the quality (e.g. loss of data, delays) of such data in order to be consistent with the current conventional tower operations. This may occur due to the need to reroute the data available at the conventional tower to the remote one.

The need for such analysis will depend on the particular configuration and associated operating procedures of each conventional tower. Nevertheless, the safety assessment activities should evaluate whether some safety requirements (mitigation measures) are necessary in order to ensure that such information (e.g. surveillance data in the previous example) is provided in a similar manner, in terms of integrity and availability, as in the current operations. This may include (depending on the local tower set-up):

— information on arriving and departing procedures;

— information on active/non-active elements (glider sectors, closed taxiways, restricted areas, etc.) in the area of responsibility;

— flight plan information related to the relevant traffic;

— surveillance data;

— availability of meteorological information (as per ICAO PANS-ATM, Chapter 6.6 and Chapter 4.10).

Furthermore, the safety assessment may identify some additional safety requirements in order to ensure that the ATCO/FISO can apply the relevant current procedures (e.g. coordination and transfer of traffic, management of missed approaches, etc.).

The Software Assurance Level (SWAL) allocation process will identify the required SWAL for the different software components, which are part of the remote tower system. The ATS providers shall apply the SWAL allocation process identified in the respective Software Safety Assurance

System (SSAS), which shall comply with Commission Regulation (EC) No 482/2008[4], in the frame of the safety assessment activities.

2.2.7. Human performance assessment

The introduction into service of the remote tower concept has direct implications on human factors as it may influence the capability of the ATCO/FISO to accomplish their allocated tasks and to meet their job requirements.

The concept envisages the introduction of new standards in the technology associated to image presentation, which encompasses several aspects. The ATS provider should assess the potential impact of this new technology in the workplace situation where it will be applied, taking into account the working environment and the ergonomic infrastructure.

In addition to technological aspects, the assessment of other human performance aspects (such as workload, fatigue and boredom, situational awareness and perception) will be required through simulations and active shadow mode[5] operations to ensure that human performance is not negatively impacted.

A list of elements and examples is available in **Appendix 4**.

2.3. Operational context

The remote tower concept is, in principle, envisaged to be implemented at aerodromes of all sizes and conditions. Therefore, it seems reasonable to define those elements that would make an aerodrome suitable for the remote provision of ATS while maintaining at least the same level of safety as if the service was provided from a conventional tower. The idea is that these elements should be part of the safety assessment to be conducted prior to the introduction into service of the remote tower concept at an aerodrome, so that the particular conditions of that given aerodrome are taken into consideration.

On the other hand, the remote tower concept is based on the fact that the ATCO/FISO will have no direct visual observation of their area of responsibility. Therefore, one of the primary objectives of the concept is to introduce a new way to provide visual observation of the area of responsibility of the ATCO/FISO (manoeuvring area and the vicinity of the aerodrome) that fulfils the existing ICAO provisions. The new features, therefore, relate primarily to visual observation. Due to the nature and characteristics of the new visual observation means, and provided that any visual presentation of the scenario will never be equal to direct visual observation, there is the risk that the new visual presentation could have a negative impact on safety, for which mitigation measures will be needed. As regards the differentiation between ATC provision and AFIS provision with respect to visual presentation, there have not been identified any significant differences that may affect the implementation of the remote tower concept at a certain aerodrome. However, as far as the other aspects are concerned, specific characteristics for each of the cases should be taken also into consideration in the safety assessment.

Appendix 4 summarises all those characteristics related to human performance that could have an impact on the operational context of remote provision of ATS, and that should be taken into consideration when conducting the safety assessment. It also includes the reference operational characteristics considered in the analyses and validation exercises conducted in the frame of the SESAR project and for which it has been confirmed that the basic equipage (as defined in Section 2.1.) may be sufficient to provide for the same level of safety as in the current operations

[4] Commission Regulation (EC) No 482/2008 of 30 May 2008 establishing a software safety assurance system to be implemented by air navigation service providers and amending Annex II to Regulation (EC) No 2096/2005 (OJ L 141, 31.5.2008, p. 5).

[5] Active shadow mode is referred to the situation where, in the context of a validation exercise where shadow mode is being conducted, the ATCO(s)/FISO(s) actually providing the ATS are doing so from the remote location.

(conventional tower), subject to the confirmation by the corresponding safety assessment of the local implementation.

2.3.1. Traffic density

The results of the validation exercises available so far show that the single mode of operation for the remote provision of ATS may be applied to **low-density aerodromes** (where low density is defined as being mostly a single movement, rarely exceeding two simultaneous movements). Therefore, based on the validation exercises and the associated safety assessments conducted, this GM can only confirm the sufficiency of the basic equipage in low-density aerodromes subject to the confirmation by the corresponding safety assessment of the local implementation.

For aerodromes where traffic density exceeds the above-mentioned characteristics, the ATS provider should follow the guidelines stated in Section 2.1.

2.3.2. Air traffic characteristics

The type and characteristics of air traffic operating at an aerodrome with remote provision of ATS is an important aspect to focus on, especially when VFR and IFR traffic is combined. Characteristics such as mix of aircraft or equipment are deemed to be important, and should be considered when conducting the safety assessment.

2.3.3. Characteristics of the aerodrome's layout

According to the validation activities and safety assessments conducted, the airfield layout (comprising runways, taxiways and aprons) for which the remote operation is going to be conducted must be taken into consideration when implementing the remote tower concept.

Considering the assumptions which the validation exercises (and their results) have been based upon, certain airfield characteristics (typically one runway, one to three runway entrances per runway, one to four aprons) are considered validated for the implementation of the concept, based on a basic equipage.

In any case, the objective is not to prevent the implementation of the concept in different scenarios. For each of the cases, a safety assessment should be conducted by the ATS provider, so the objective is to stress the need to consider these aerodrome characteristics when establishing the necessary functionalities of the system.

2.3.4. Airspace characteristics

According to the validation activities and safety assessments conducted, the airspace characteristics must be taken into consideration when implementing the remote tower concept. The SESAR project considered a target aerodrome with an associated airspace classified as C or less restrictive. However, the intention is not to prevent the implementation of the remote tower concept for class A and B airspace (according to Commission Implementing Regulation (EU) No 923/2012), provided that the results of the safety assessment allow so.

2.3.5. Aerodrome infrastructure and surroundings (physical orography)

Provided that each aerodrome is unique and has its own characteristics regarding orography (natural obstacles) and surroundings, it is considered important to take into account the specific aspects that may affect the implementation of the concept.

2.3.6. Environmental characteristics

Environmental factors are another critical aspect to be considered when assessing the impact that the implementation of the concept may have on the aerodrome operations and/or ATS provision.

Therefore, at least the following environmental conditions should be taken into consideration for the development of the safety assessment:

— Low-visibility conditions: both for operations (low-visibility procedures) and for the impact on the visual presentation system (e.g. need for enhanced equipage, such as infrared cameras).

— Snow: both for operations and for the impact on the visual presentation system (e.g. image filters).

— Winds: both for operations and for the impact on the visual presentation system (e.g. cameras siting/installation aspects).

— Icing: both for operations and for the impact on the visual presentation system (e.g. need to monitor de-icing operations).

— Meteorological phenomena (rain, hail, etc.).

— Birds and other animals.

2.4. Operator's roles and performance

2.4.1. Roles

The ATS provider should identify the particular configuration of the remote tower/RTC and operating methods applied taking into consideration the particular needs of the aerodrome(s) which comply with Commission Implementing Regulation (EU) No 1035/2011. Nevertheless, the ATCO's/FISO's main responsibilities regarding the remote provision of ATS should remain the same as when the service is provided from a conventional tower.

2.4.2. Training and competence requirements

Together with the ATCO training and competence requirements identified in Chapter **Error! Reference source not found.** of the NPA, personnel involved in the maintenance of facilities, installations and equipment enabling and supporting the remote provision of ATS at an aerodrome should be adequately trained, qualified and competent to perform their duties in accordance with the requirements laid down in Commission Implementing Regulation (EU) No 1035/2011 and in Commission Regulation (EU) No 139/2014[6], as appropriate.

2.5. System/equipment aspects

This Section addresses the system/equipment aspects, focussing mainly on the description of the remote tower system's high-level functions. Both the description of the functions and the identified objectives should be considered by the ATS providers and manufacturers as one of the inputs on which the technical specifications of the remote tower system and its constituents should be based.

This should be understood as a minimum list whose level of detail should be further expanded by the ongoing work of the EUROCAE WG-100.

The high-level functional description is focussed on the basic equipage, as defined in Section 2.1. Functionalities associated with the enhanced equipage (e.g. infrared, overlay) are not covered.

Additional considerations have been included to cover some installation aspects (e.g. siting aspects, ergonomics), plus specific considerations about how to organise the

[6] Commission Regulation (EU) No 139/2014 of 12 February 2014 laying down requirements and administrative procedures related to aerodromes pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council (OJ L 44, 14.2.2014, p. 1).

system's/equipment's specifications. Finally, a dedicated section on information and cyber security has been included to address the assessment of the potential impact on safety stemming from security threats.

2.5.1. RTM/RTC concept

An RTM will enable ATCOs/FISOs to maintain view of the aerodrome, including the manoeuvring area and surfaces, and may be located at the aerodrome site or at a location remote from the aerodrome.

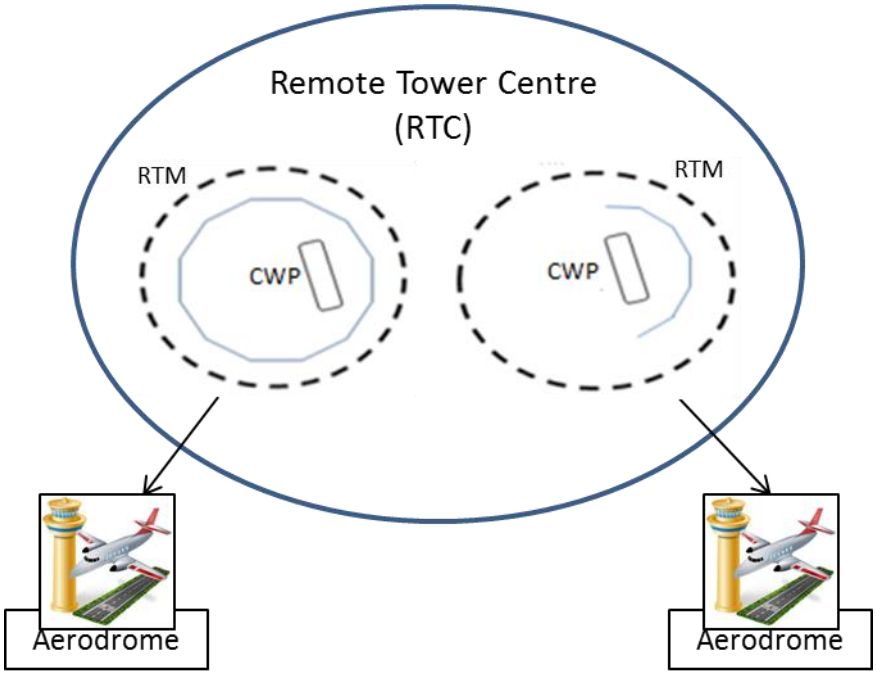
The ATS provider may decide that the remote provision of ATS from an RTM would be from a centralised facility known as **RTC**. RTC (see Figure 1) can house one or more RTMs where ATS may be provided remotely to one or several aerodromes[7].

An RTC can be set up as shown in Figure 1, with multiple RTMs and maybe one or more supervisor positions (depending on the size and requirements of the RTC). In a single-mode-of-operation scenario, the ATCO/FISO in an RTM operates **only one aerodrome.** Nevertheless, the ATS provider may decide to change the allocation between RTM and aerodrome in order to improve the efficiency of the resources or to respond to specific contingency situations. The ability to swap RTMs will depend on many factors, such as ATCO licensing (see Chapter 4).

The ATS provider's decision on the number of available RTMs in an RTC will depend on the number of aerodromes connected to the RTC. Nevertheless, additional/spare RTMs may also be included based on contingency requirements.

If the RTC is composed of several RTMs, the ATS provider should ensure that the ATCO/FISO uses similar operating methods and procedures for all the aerodromes connected to an RTM/RTC, and that all RTMs in an RTC should be standardised in terms of Human–Machine Interface (HMI) and equipment (in order to contribute to the overall improvement of uniformity of ATM services).

The ATCO/FISO should verify the status of an aerodrome and its related systems before assuming responsibility for providing ATS remotely to the aerodrome.



[7] Despite this wider applicability of the remote tower concept, the developed material is aimed at covering only single mode of operations where ATS is provided from a Remote Tower Module (RTM) for only one aerodrome at a time.

Figure 1: High-level overview of the provision of remote tower ATS

2.5.2. Human–computer interaction functions

Visual presentation

Visual presentation is the core of the remote provision of ATS and replaces the OTW view. It should provide a presentation which will enable the ATCO/FISO to maintain continuous watch on all flight operations at and in the vicinity of an aerodrome as well as on vehicles and personnel on the manoeuvring area.

Visual presentation may have several forms and might be the result of many technical solutions. However, as mentioned above, for the purpose of this material, it is assumed that visual presentation is only based on a **visible spectrum, camera-based solution** (where cameras capture the image at the aerodrome and the image is relayed to the ATCO's/AFISO's screens).

In such a camera-based solution, this overall function may be split into the following sub-functions:

— **Video-stream management** responsible for the processing of video data from several local cameras and transferring this data to the RTC. It can include bandwidth management and compression, monitoring of delay times, frame rate, and access control.

— **Camera control** providing access to the control functions of the cameras (conventional and binocular functionality), including the necessary authentication means and control function related to the camera setting and image adjustment/optimisation.

— **Video-data fusion** combining different inputs from sensors (when available) and generating an aggregated system track for a dedicated object.

The visual presentation function may include other functionalities (e.g. visual tracking for automatic object tracking). Nevertheless, they are outside the scope of this material.

As part of the visual presentation, one of the most critical parameters for the ATCO's/FISO's ability to perform the assigned ATS tasks is the time delay between image/data capture and presentation to the ATCO/FISO on the visual presentation (screens). This is also called **end-to-end delay.** The maximum allowable end-to-end delay should be determined by the safety assessment taking into account the operational context but, in any case, it should not be longer than **1 second,** as this value is considered, from a safety perspective, to be the maximum delay allowed for very low-density aerodromes (which are representative of the simplest operational contexts). Longer delays may affect the ATCO's/FISO's situational awareness (compared with the reality) with a potential safety impact. Then, the ATS provider should demonstrate that the end-to-end delay does not exceed the established maximum end-to-end delay value. Additionally, the remote tower system should include a monitor of such delays and the corresponding alerts should be presented to the ATCO/FISO in case the maximum delay value is exceeded.

The fidelity of the visual presentation presented to the ATCO/FISO also depends on the frame rate, defined as the number of times per second the visual presentation is updated. The frame rate defines the capability of the ATCO/FISO to visualise and monitor moving objects (e.g. aircraft, vehicles). The minimum allowable frame rate should be determined by the safety assessment taking into account the operational context in order to ensure adequate tracking of moving objects by the ATCO/FISO. The required frame rate will drive the frequencies at which the different equipment in the image processing chain should work as well as the amount of visual information to be sent from the equipment located at the aerodrome to the RTM/RTC.

In combination with these performances, the remote tower system should include a monitor of the 'frozen' image (i.e. image not refreshed) and the corresponding alerts should be presented to the ATCO/FISO in such cases.

In addition to the aforementioned, there are also other parameters which may affect the quality of the visual presentation (image/data) presented to the ATCO/FISO, impacting potentially on the ability to safely provide ATS. The quality of the visual presentation can be defined as the combination of the image quality factors and image similarity to human eye vision.

Image quality factors (e.g. sharpness, contrast) are driving the granularity and fidelity in which the reality captured by the camera is presented in the visual presentation. These quality parameters should be part of the remote tower system specification. However, there is no general consensus about the objectives to be met by the remote tower system regarding image sharpness.

These parameters may be defined in the remote tower specification as performance objectives indicating the ATCO's/FISO's capability to perform specific actions (e.g. detection, recognition) of targets (e.g. aircraft, vehicles, personnel) on certain parts of the aerodrome (e.g. distance or specific points) and under specific environmental conditions (e.g. daylight, reduced light conditions). Specific analyses should be conducted by the ATS providers in order to establish such technical (performance) requirements.

These specific analyses may include:

— identification of several reference locations at the aerodrome, its vicinity, and traffic circuit;

— definition of the expected action(s) from the ATCO/FISO on each of those points (e.g. detection/tracking of a vehicle, recognition of an aircraft);

— identification of the conditions under which the ATCO/FISO may perform each of the actions (e.g. for the same point, a different action may be expected from the ATCO/FISO depending on the visibility conditions);

— establishment of the performance requirements for the visual presentation (image quality) taking into account each of the expected action(s), the environmental conditions, and the locations at the aerodrome.

As a result of this analysis, the image quality factors are presented in terms of expected ATCO/FISO performance in certain visibility conditions. These requirements might be complemented with additional requirements regarding different visibility conditions (dark and low visibility) or with the detection capabilities of smaller objects but at shorter distances (e.g. vehicles on the manoeuvring area), if found relevant. These requirements should be subject to the corresponding validation activities, including a human factors analysis with confirmation that the image quality allows the ATCO/FISO to maintain the ability to safely provide ATS.

The similarity of the presented image to the human eye vision, avoiding irregularities or other disruptive effects which may lead to human performance issues (e.g. fatigue) and may also jeopardise the situational awareness of the ATCO/FISO, is another factor. In this sense, the remote tower technical system should include (as applicable, depending on the selected technical solution) the means to:

— provide in the visual presentation a non-flickering impression to the human eye;

— provide a visual presentation with smooth and regular impression of moving objects to the human eye;

— avoid any unwanted, unnecessary discontinuities or non-uniformities in terms of presented scale, orientation and field of view of the area under observation by the ATCO/FISO;

— indicate in the visual presentation any existing discontinuities or non-uniformities in terms of presented scale, orientation and field of view of the area under observation by the ATCO/FISO, so as not to cause any misleading impressions regarding the spatial geometry of the area of responsibility.

Furthermore, visual presentation might be degraded due to the environmental conditions at the aerodrome where the services are provided, either due to meteorological conditions, lighting conditions or other effects (e.g. animal interference on cameras). In order to avoid the potential effects on the ATCO's/AFISO's ability, the remote tower technical system should include (as applicable, depending on the selected technical solution) the means to reduce the negative impact on the visual presentation caused by animals (e.g. insects, birds), variable light conditions across the field of view of the camera, counter-light effects or precipitation (e.g. rain, snow) which can block the camera.

The set-up of the visual presentation screens in terms of number of screens, image compression, layout orientation, area covered/included in the panoramic view, viewing angle, etc., should be tailored and assessed for each environment from where ATS is planned to be provided remotely so that all the critical areas (e.g. climbing and landing areas) are fully captured on the visual presentation screens and 'hotspots' (e.g. holding positions, TWY entrance/exits) are clearly visible in the screen layouts (e.g. far-from-screen edges).

Binocular functionality

Binocular functionality is intended to replace the manually operated binocular which is currently used in conventional towers, as stated in the ICAO Doc 9426 provisions on specific requirements for an aerodrome control tower.

This functionality is additional to the overall visual presentation in that the ATCO/FISO may be facilitated whenever necessary to look at certain items of interest more closely (e.g. engine on fire, landing gear extended, RWY condition/objects on RWY, etc.). For this purpose, this binocular functionality should provide the ATCO/FISO with the option to angle the view and zoom in on objects as required.

Binocular functionality should be as simple, quick and easy to use as manually operated binoculars are (in a conventional tower), and should include a **moveable zoom feature** with a visual indication of the direction of bore sight, and should be able to follow aircraft moving in the area of the ATCO's/AFICO's responsibility.

The visual presentation provided by the binocular functionality should fulfil the same performance requirements (e.g. end-to-end delay, refresh rate) as the overall visualisation functions do. Regarding image quality, the binocular functionality should be of sufficient quality (image sharpness, magnification, contrast) to support the related ATCO/FISO tasks.

Moreover, certain aerodrome 'hotspots' may be configured (automatic functions including zoom, pan-and-tilt, and focus) enabling the ATCO/FISO to quickly jump to frequently recurring areas of interest (e.g. waypoints, thresholds, RWY sweep, etc.) utilising predefined positions and automatic scans set for the binocular functionality.

On the other hand, binocular functionality may also include, as part of the enhanced functionalities, automatic tracking of moving aircraft, vehicles or obstructions (e.g. personnel or large animals). It would increase the ATCO's/FISO's ability to spot and follow relevant objects. This feature of the binocular functionality would be especially useful during non-nominal or distress situations where quick reaction is required. It could provide close-up images of the relevant objects (on a binocular function screen) or highlight the relevant objects in the overall context (visual presentation screen). The ATS provider should conduct an in-depth evaluation of this additional functionality, including the necessary validation activities and human performance assessment, as part of the corresponding safety assessment of the local implementation.

Sound reproduction

This function refers to the capture and reproduction of the aerodrome's background sounds at the CWP. It is aimed at further improving the ATCO's/AFISO's situational awareness by combining visual presentation and surrounding noise.

Today's practices at conventional towers allow the ATS provider to minimise or even suppress environmental sound, following a conclusion from a human factors analysis. Taking this into consideration, for the case this function is implemented for actual outdoor sound reproduction, the volume should be adjustable and it should be possible to be turned off by the ATCO/FISO.

In any case, this functionality should be subject to a human performance assessment.

Voice/data communication

It includes air–ground and ground–ground voice communications between the ATCO and the other actors involved in the provision of ATS:

— **Air–ground voice/data communications:** It corresponds to voice/data communication between ATCOs and aircraft flight crew. This supports the aeronautical mobile service as defined in Chapter 1 of ICAO Doc 4444 and in Chapter 6.1 of ICAO Annex 11.

Note: If a separate ground controller position is introduced, a separate communication channel for the control of traffic operating on the manoeuvring area would be needed.

— **Ground–ground voice/data communications** covering:

- Voice/data communication between ATCO/FISO and other relevant and/or adjacent ATS units. This supports the Aeronautical Fixed Service (AFS) as defined in Chapter 1 of ICAO Doc 4444. The ATCO/FISO shall use AFS (ground–ground communications) in accordance with Chapter 6.2 of ICAO Annex 11.
- Voice communication (VHF) between ATCO/FISO and vehicle drivers on the aerodrome's surface. The ATCO/FISO shall use surface movement control service (communications for the control of vehicles other than aircraft on the manoeuvring areas at controlled aerodromes) for the aerodrome(s) under control, in accordance with Chapter 6.3 of ICAO Annex 11.
- Voice/data communication between ATCO/FISO and aerodrome personnel.

The remote tower infrastructure should allow the ATCO/FISO to establish such voice/data communication links as in the conventional tower. The remote tower system should alert the ATCO/FISO in case of failure of the air–ground and ground–ground voice/data communication links.

Furthermore, regarding air–ground communications, they are typically established through the local radio at the aerodrome. In the remote-tower-operation scenario, the RTC might need a dedicated connection (e.g. through WAN) to the local radio at the aerodrome in order to have access to the air–ground communication link with the flight crew. Dedicated infrastructure would be necessary for that. This remote command of the aerodrome radio might be subject to delays due to communication link latency from the RTC to the local radio. The maximum allowable delay should be determined by the safety assessment taking into account the operational context in order to ensure timely communication between flight crew and controller. Additionally, the safety assessment should consider the relative timing between this communication and the visual presentation to the ATCO/FISO (driven by the end-to-end delay) in order to ensure the necessary level of coherence between the image and voice communications available at the ATCO/FISO.

Also, especially for a backup or emergency radio system, a dedicated and independent backup connection between the aerodrome and the RTM or RTC will be required. Standard fallback

solutions, such as handheld radios used directly in the conventional tower, may not be applied to the remote tower scenario due to coverage limitations.

Visual communication

The remote tower infrastructure should allow the ATCO/FISO to have equivalent visual communication means with the aircraft as in the conventional tower implementation in order to ensure that:

— the ATCO/FISO can communicate via a signalling lamp with the respective aircraft in accordance with Section 5.1.3 of ICAO Annex 14;

— the ATCO/FISO can clearly observe visual communication from aircraft that are within the ATCO's/FISO's visual range, i.e.:

- aircraft flashing or showing landing lights in reduced light conditions;
- aircraft repeatedly changing its bank angle ('rocking wings') in daylight;

— the ATCO/FISO can clearly observe visual communication from aircraft that are within their field of view on the aerodrome's manoeuvring area, i.e.:

- moving ailerons (or rudder) in daylight;
- flashing or showing landing lights in reduced light conditions or at night.

The above-mentioned last two capabilities can be used as part of the identification of the required image quality to be presented to the ATCO/FISO. These criteria may also be used complementary to other quality requirements.

In order to ensure that the ATCO/FISO can communicate via the signalling lamp, it would be required to have the remote command capabilities of the signalling lamp from the remote tower. This remote operation may require the use of the data network (e.g. WAN). The remote tower system should have the means to ensure that the remote command of the signalling lamp is effectively performed and the means for the ATCO/FISO to detect any potential failure in its commanding.

2.5.3. Voice and data recording

The voice and data recording function is intended to satisfy the recording requirements specified in Chapter 6 of ICAO Annex 11 which cover any voice communication (either ground–ground or air–ground), any data link communication, and any automatic transfer of data to and/or from ATS computers. For the particular case of the remote tower, in comparison with a conventional tower, the recording functionality should also include the visual presentation data and the actual ambient sound from the aerodrome (when available), as this information is transferred automatically among the computers. This function will also provide data for the analysis of events in which a particular behaviour of the visual presentation may have contributed to them.

The implementation of the voice and data recording functions should ensure 'non-interference' (no degradation or loss, etc.) with the visual presentation.

2.5.4. Management of assets

Aerodrome lighting system management

This function should enable the remote tower to control the aerodrome's lighting system and to monitor in real time that it is constantly able to support the operational needs in order to assure the conduct of all the aerodrome operations in an appropriate way under all conditions (e.g. Commercial Air Transport (CAT) I, CAT II, CAT III). It should allow the ATCO/FISO to:

— remotely operate the signalling lamp located in the aerodrome premises;

— remotely monitor the status and operate the aeronautical ground lighting system which is located on the aerodrome's manoeuvring area;

— remotely monitor the status and operate the runway and aeronautical ground lighting system (visual navigation aids) located at the aerodrome.

The implementation of this function should provide the means to ensure that this remote operation is effectively performed.

The remote operation of the signalling lamp might be subject to delays due to communication latency from the RTC to the aerodrome infrastructure. The maximum allowable delay should be determined by the safety assessment taking into account the operational context in order to ensure the ATCO's/AFISO's ability to act timely.

Alarm management

At any moment, the ATCO/FISO shall maintain the ability to monitor and trigger accident, incident and distress alarms as applicable to the aerodrome. The remote tower system should allow for such possibility, which may introduce additional requirements on the visualisation part but also on the need to remotely manage the corresponding alarms at the aerodrome.

Additionally, the remote tower system should ensure that relevant aerodrome service/personnel can contact the ATCO/FISO in order to inform them about any situation or condition at the aerodrome that might affect the safe provision of ATS.

Management of navigation aids

According to Section 7.3 of ICAO Annex 11, the ATS units shall be kept informed of the current operational status of radio navigation services and visual aids essential for take-off, departure, approach and landing procedures within their area of responsibility and of those radio navigation services and visual aids essential for surface movement. In the remote tower system, the information about the status of these radio navigation and visual aids should be collected and presented to the ATCO/FISO. The remote tower should ensure that the integrity of this information is preserved throughout this process.

According to ICAO Doc 4444, the ATCO/FISO shall select the runway in use for which it could be necessary to have the capability to select the navigation aids (e.g. Instrument Landing System (ILS)) associated to the operation. This remote management may require the use of the data network (e.g. WAN). The remote tower system should offer the means to ensure that the remote management of the navigation aids is effectively performed, and the means for the ATCO/FISO to detect any potential failure in its management.

2.5.5. RTC–aerodrome communication aspects

The RTC concept relies on communications as a critical enabler. Visual presentation, air–ground and ground–ground voice communication, as well as manoeuvring of equipment on the aerodrome rely on the RTC–aerodrome communication link. This has the impact that conventional contingency mechanisms will no longer be directly applicable and they will have to be adapted to work remotely.

It is therefore essential that the ANSP take the communication aspect into account when designing the technical architecture, including the identification of redundancy needs. When the ANSP relies on third-party providers (e.g. network or telecom service providers), it should ensure that the appropriate safety requirements are incorporated into the Service Level Agreements (SLAs) with such third-party providers, and that the quality assurance processes can verify that such services are provided in accordance with the applicable requirements, standards and procedures.

2.5.6. Technical supervision

This function would be aimed at monitoring the services provided by the system and at providing the capability for starting, stopping or restarting the system or part of it. The person responsible for the technical supervision may be in charge of the following tasks:

— presentation of the system's technical status: monitors system availability by acquiring, synthesising and displaying the technical and functional status of all the system's hardware/software resources;

— provision of failure detection and analysis assistance: generates alarm or warning upon failure detection;

— provision of support for the analysis of supervision data (enables queries on the history of events);

— provision of supervision commands and actions: accepts supervision commands/actions (e.g. (re)start/stop/standby/reset/switchover) from eligible operators and gives the capability to perform maintenance activities.

In the remote tower context, the person responsible for the technical supervision should be responsible for the equipment installed either at the aerodrome (e.g. cameras, sensors, compression servers, network switches), or at the RTC (e.g. decompression servers, video screens), or at any other location. This may be deployed in a distributed environment but the information should be presented in a way that both the ATCO/FISO and the person responsible for the supervision (or other assigned person) are able to monitor the overall technical status and detect any technical failure mode/degraded mode that could impact on the remote tower operation.

2.5.7. Other ATS systems

The remote tower system may be combined with other ATS systems used in the conventional towers like the electronic system for the presentation and update of flight plan and control data (electronic strips) or the monitoring of the technical status of the systems. For these cases, the installation of such systems will be subject to the same provisions as conventional towers are, subject to the corresponding safety assessment and, hence, no specific provisions are found to be necessary.

2.6. Siting aspects

The remote tower system (e.g. camera's field-of-view, visualisation coverage) and its installation (e.g. number and location of cameras) should ensure that the ATCO/FISO have access to a visual presentation of the flight operations on and in the vicinity of the aerodrome as well as of vehicles, obstacles and personnel on the manoeuvring area. Chapter 1 of ICAO Doc 4444 states that 'an aircraft is in the vicinity of an aerodrome when it is entering or leaving an aerodrome traffic circuit'. The visual presentation of some other aerodrome elements (e.g. windsock) may be necessary.

The cameras used for the remote provision of ATS may also be used to satisfy some of the visualisation requirements at the aerodrome (see Section 3.) regarding the aerodrome's manoeuvring area, including any remote de-icing/anti-icing facilities. Nevertheless, dedicated cameras may also be installed to meet these needs and the information should be presented at the CWP, as it is currently done in conventional towers.

The final determination of the number of cameras to be used and the locations at which the cameras are to be installed may also be influenced by other parameters, such as:

— dimensions of the aerodrome;

— design characteristics and complexity of the aerodrome's layout;

— location of the communication, navigation and surveillance equipment (both existing and planned) to prevent any potential interference;

— types of operations that take place at the aerodrome;

— prevailing weather phenomena;

— functionalities and capabilities of the cameras employed;

— existing constructions (e.g. terminal buildings);

— existing control tower;

— desired line of sight angle of incidence;

— avoidance of creation of new obstacles;

— direct or indirect sun glare;

— night-time lighting glare;

— external light sources.

A dedicated, comprehensive and coordinated assessment should be conducted by the ATS provider and the aerodrome operator in order to demonstrate that the number, location and characteristics of the cameras fulfil all the objectives for each individual case.

2.7. RTM ergonomics

As a basis, the ATCO/FISO will be provided with an RTM enabling the provision of ATS from a remote location. Hence, the ATS provider should ensure that all the systems and tools required for the ATCO/FISO to perform their required tasks are available at the CWP. Despite the introduction of new technical systems, the underlying principles and the ATS systems should remain familiar to the ATCO/FISO and in line with those used in current operations such as, for example:

— flight progress strips (electronic or paper);

— radio-telephony and/or data link communications (ground and air);

— functionality for monitoring and/or controlling aerodrome lights, signalling lamps, navigation aids, alarms and other aerodrome systems.

On the other hand, the working environment may have a negative impact on the ATCO's/FISO's observation capabilities of the visual presentation. In addition to the working environment and ergonomics for the CWP in a conventional tower, a dedicated analysis of the working environment and ergonomics should be conducted by the ATS provider in order to ensure that the observation capabilities of the ATCO/FISO are acceptable in order for them to safely provide ATS. As a minimum, the assessment should include the lighting conditions at the RTM as a function of, among others, the presentation solution (e.g. use of video screen or projector), the availability of several RTMs in an RTC, or the possibility of having individual lighting conditions for each RTM (depending on the conditions at the remote aerodrome).

2.8. Information and cyber security

The distributed architecture of the remote tower infrastructure and the use of shared resources (e.g. WAN) make it more vulnerable to potential security threats to computer systems or the data exchanged compared to the conventional tower's infrastructure. Among all the data exchanged, the visual presentation data is perceived to be the most sensitive due to the potential safety impact. Nevertheless, high risks may be posed due to unavailability of such data (denial of service) rather than the unauthorised modification (data tampering) due to the different monitoring means available and the capability of the ATCO/FISO to detect inconsistent or corrupted visualisation data. However, other types of data (e.g. status of the navigation aids)

may also be the subject of security vulnerabilities (e.g. unauthorised modification), with limited ATCO/FISO capability to detect potential integrity problems in the information presented at the RTM.

Additional possible impacts may be due to loss of communication with the remote aerodrome (e.g. local radio, signalling lamp) which would impact on the ATCO's/AFISO's capability to communicate with the flight crew or to command the systems at the aerodrome.

Consequently, the introduction of the remote tower concept may affect the security risk assessment and these security vulnerabilities may have an impact on safety. For this reason, these security vulnerabilities may add new causes to the existing safety hazards (e.g. possible corruption of navigation aids information, loss of visual presentation data) or may add new hazards (e.g. complete loss of the provision of ATS). Based on these considerations, the ATS provider should conduct a dedicated security risk analysis and take the necessary measures to protect its systems and constituents against information and cyber security threats.

In this context, security threat is defined as any circumstance or event with the potential to adversely impact on the operation, systems and/or constituents due to human action (accidental, casual, or intentionally or unintentionally mistaken) resulting from unauthorised access, use, disclosure, denial, disruption, modification, or destruction of information and/or information system interfaces. Note that this may also include malware and the effects of external systems on dependent systems.

2.9. Remote tower system constituents

In relation to the demonstration of compliance with respect to the interoperability Regulation[8], the split of the technical system into constituents falls under the responsibility of the ATM/ANS service provider, in agreement with the respective competent authority. The split may depend on several factors, such as the availability of Community Specifications (CSs) for certain parts of the system and even how the contractual arrangements between the service provider and the constituent manufacturers are established.

Based on the considerations above, some recommendations are put forward on how the remote tower system may be split into constituents and it is up to the ATS provider, in agreement with the respective competent authority, to decide about the split. It is noted that the term 'remote tower system' only refers to the parts of an RTM that are specific to the remote provision of ATS.

On the one hand, from the analysis of the high-level functionalities presented in Section 2.5., it can be concluded that the remote tower system constituents may be grouped as follows:

— visual-presentation-related functionalities (e.g. visual presentation itself, binocular functionality, visual communication);

— voice/data-communication-related functionalities (e.g. air–ground communication);

— manoeuvring- and monitoring-related functionalities (e.g. management of assets, technical supervision).

The aforementioned functional grouping has been selected as the basis for the proposed split, identifying a constituent as responsible for the implementation of each of these categories. Nevertheless, these recommendations are based on two main assumptions:

— that the system (physical) architecture ensures independence from each of the constituents;

— and that the interface specification among them is based on existing standards.

[8] Regulation (EC) No 552/2004 of the European Parliament and of the Council of 10 March 2004 on the interoperability of the European Air Traffic Management network (the interoperability Regulation) (OJ L 96, 31.3.2004, p. 26).

For a particular technical solution, the validity of these assumptions should be assessed by the ATS provider.

On the other hand, it is important to analyse the ATM/ANS service for which a constituent should be considered. This might also affect the possible split of the system into constituents. The main question would be whether the visual presentation part should be considered as a single constituent in the ATS domain or as a combination of ATS constituents and CNS (surveillance) constituents (e.g. cameras) or, in other words, if the visualisation means (cameras) can be considered as surveillance equipment. With regard to that, the definition of 'ATS surveillance system' of ICAO Doc 4444 is recalled:

'ATS surveillance system. A generic term meaning variously, ADS-B, PSR, SSR or any comparable ground-based system that enables the identification of aircraft.

Note.— A comparable ground-based system is one that has been demonstrated, by comparative assessment or other methodology, to have a level of safety and performance equal to or better than monopulse SSR.'

The image captured by the cameras is used for the identification of aircraft by the ATCO/FISO, but is also used for other purposes (e.g. vehicles and personnel, events at the aerodrome) upon which the safety of the ATS provision also relies.

Furthermore, the consideration of the cameras as a separate (surveillance) constituent may require that the communication between these devices and the rest of the remote tower system (e.g. compressor servers) is performed according to well-identified and publicly available standards, as it is the case for other surveillance means. This may not be feasible insofar as there could be a dependence on the particular technical solution.

Following this analysis, it has been concluded that the ground infrastructure for capturing images at the aerodrome and in its vicinity should be considered as ATS constituent (or part of it).

The following table summarises the results of both analyses that constitute the recommended way of organising the allocation of the system's constituents.

Table 1: Remote tower system constituents

Constituent	Allocated functions (Basic equipage, Section 2.5.2.)	ATM/ANS service
Visual presentation	Visual presentation Binocular functionality Visual communication	ATS
Voice/data communication	Sound reproduction (optional) Voice/data communication	CNS
Manoeuvring and monitoring	Voice and data recording Management of aerodrome lights Management of alarms Management of navigation Technical supervision	ATS

The following is noted:

— Ongoing EUROCAE WG-100 work is aiming to produce a Minimum Aviation System Performance Specification (MASPS) for the visual presentation function.

— The denominations of the constituents are included for illustrative purposes only.

— The ATS provider may split further these constituents (e.g. splitting between equipment at the aerodrome and at the RTC), which would require the definition of the interface specifications (standards) among the identified new constituents.

— The ATS provider may consider the possibility to include additional constituents or additional functionalities to the identified ones.

— The ATS provider may consider to add other functions to the identified constituents provided that they are consistent with the ATM/ANS service (ATS or CNS) provided.

— The ATS provider may consider to merge visual presentation with manoeuvring and monitoring, as they belong to the same domain.

2.10. Abnormal situations and contingency procedures

Contingency procedures must be adapted to the specific local conditions, taking into consideration elements such as:

— the use of emergency flares or signal lights, and signal light gun use procedure;

— alerting in case of failure conditions;

— impact on the service provision in case of major failure;

— the management of existing traffic in the scenario of complete failure at the time when the failure occurs.

In case ATS provision is affected by the degradation of the system or during an abnormal situation, the system should be able to fulfil the following requirements:

— Remote provision of ATS shall be terminated in case of inadequate capability of the remote tower system elements to provide the service.

— Airspace users, relevant and adjacent ATS units, and respective aerodrome services units shall be notified without undue delay when ATS cannot be provided anymore (unplanned termination of the ATS provision due to system failures). For these cases, the remote provision of ATS shall appropriately (safely) be terminated.

— The remote tower shall enable, as in current operations, the detection of unexpected flights in the area of responsibility where ATS is being provided.

— The remote tower shall enable the detection of emergency situations on the aircraft (landing gear problems, fire on tyres or in the aircraft, tail strike, etc.).

— The remote tower shall enable the initiation of emergency procedures and shall follow emergency situations for aircraft.

— The remote tower shall enable the detection and management of a crash situation at the aerodrome or in its vicinity.

— The remote tower shall enable the detection and management of potential abnormal situations (abnormal weather, fire on terminal or aerodrome building, overload on the apron, etc.) at the aerodrome that could affect or even force the termination (unplanned terminations) of the provision of ATS.

The following items represent examples of situations that may result in an abnormal situation for which contingency procedures should be applied.

— Events related to visual presentation, including:

- unreliable visual presentation, e.g. 'blank screen', frozen presentation, or end-to-end delay above the maximum value allowed;
- degraded mode, e.g. partial loss of visual presentation/image degraded or loss/degradation of zooming/binocular functionality.

— Events related to other system aspects, including:

- loss/degradation of audio/ambient sound (if available);
- loss/degradation of mobile communication;
- loss/degradation of other systems (aerodrome operating lights, signal lights, etc.).

2.11. Transition plan

As part of the introduction into service of the remote tower concept, the ATS provider should establish a transition plan in the way that ATS is migrated from the conventional tower, when there is one, to the remote tower, in coordination with the aerodrome operator. This transition plan should define the different phases to be followed (and the associated transition criteria), allowing in any case for the fallback procedure to the ATS provided from the conventional tower in case of unexpected events or problems. Then, the capability of providing ATS from the conventional tower should be maintained during all the transition process plus an additional period (to be defined by the ATS provider) for contingency reasons. The transition plan should be documented as it should be subject to a safety assessment.

When the transition is performed from a conventional tower to a remote tower[9], the transition plan may consider the following states:

[9] When the transition is performed at an aerodrome where no conventional tower exists (and therefore no associated ATS is provided), the transition plan should be adapted appropriately and may be considered as deployment plan implementing a new ATS, taking into consideration the different elements contained in this GM and the specific conditions of the target aerodrome.

— Local control: While in this state, ATS will be provided locally to the particular aerodrome.

— Transferring control: In this state, ATS will still be provided locally, but the necessary data will also be rerouted to the remote location for shadow mode operations/transfer-of-control initiation.

— Remote control: In this state, the responsibility for providing ATS will lie with the remote site personnel.

The transition between states may be performed through a handover process between the conventional tower and the remote facility. This handover process should only start once the remote facility is ready to assume responsibility for the service. The handover protocol may be split as follows:

— While maintaining the provision of ATS from the conventional tower (local control state), the remote officer shall call the local facility in order to declare their ability to assume responsibility for ATS.

— Acknowledgement of this request by the local facility will trigger the transition to the 'transferring control' state.

— When all the necessary information is transferred and when all the required technical operations are completed in order to allow the remote system to work properly, the remote officer's acceptance of the responsibility will trigger the transition to the 'remote control' state. The conventional tower office will then inform all the other actors involved (i.e. local emergency personnel, aerodrome services, adjacent and relevant ATS units, etc.) of the successful completion of transfer of responsibility.

The remote tower functional system should be designed in such a way that these states (or equivalent ones) and the associated transitions are feasible. Additionally, the possibility to return to the 'local control' state from the 'remote control' state should be maintained throughout the transition process, and should be also maintained for some time after the successful transition for contingency reasons.

Airspace users, relevant ATS units (e.g. those in charge of adjacent sectors), and respective aerodrome units should be notified without undue delay when ATS is provided from the remote tower (planned and/or exceptional provision of ATS), or when ATS from the remote tower is planned to be terminated (as per planned schedules). This notification process should be applied through the Aeronautical Information Publication (AIP) (e.g. Notice to Airmen (NOTAM)).

Moreover, when the transition is completed, the following requirements should be met:

— ATCO/FISO (or the responsible person designated by the ANSP) providing ATS from a remote tower should apply the relevant remote tower position start-up procedure before providing ATS from that remote position. This start-up procedure shall include the confirmation of the remote tower's capability to provide the service. This procedure should cover at least the following elements:

  - MET information;
  - ground–ground (with other ATS units), air–ground, and ground–ground (with aerodrome services and personnel) communication system;
  - visualisation system;
  - visual and non-visual navigation aids.

— Personnel at the aerodrome shall be informed by the ATCO/FISO (or by the responsible person designated by the ANSP) when the remote provision of ATS is to be initiated and terminated.

— Prior to a planned termination, ATCO/FISO shall ensure that ATS can be appropriately (safely) terminated.

— Prior to an unplanned termination, ATCO/FISO shall ensure that ATS is appropriately (safely) terminated.

— ATCO/FISO shall inform all traffic under their responsibility in case the provision of ATS is unplanned terminated.

3. Aerodrome-related aspects

It is important to ensure coordination between the competent authority, the ATS provider and the aerodrome operator throughout the implementation and approval process of the remote tower concept. The following aspects should be taken into consideration to meet this objective.

3.1. Certification and approval

3.1.1. Documentation to be provided by the aerodrome applicant at the initial aerodrome certification

The documentation for the initial certification of the aerodrome should also include information regarding the provision of ANS at the aerodrome, including:

— the type of ATS provided (ATC services or AFIS); and

— the way ATS is provided:

- locally (ATS unit established at the aerodrome), or
- remotely (ATS unit not established at the aerodrome).

If ATS is not provided locally, the submitted documentation (apart from the necessary arrangements between the aerodrome operator and the ATS provider) should clearly identify:

— the location of the remote ATS unit;

— the tasks that will be needed to be carried out locally at the aerodrome in order to enable and support the remote provision of ATS; and

— the organisation that will carry out these tasks locally.

The submitted drawings showing the design of the aerodrome should contain information regarding:

— the kind of facilities, installations and equipment to be established at the aerodrome or in its vicinity (e.g. cameras, sensors, etc.) to enable and support the remote provision of ATS; and

— their location.

Information concerning the planned overall height of the above-mentioned facilities, installations and equipment should also be provided.

Moreover, information should be provided regarding the technical solutions employed for:

— the operation/control/monitoring of the aerodrome's lighting systems and their individual elements, as appropriate;

— the communication systems between the remote ATS unit and the relevant aerodrome units (e.g. RFFS station, apron management services unit), or vehicles operating on the manoeuvring or movement area (if apron management services are also provided by the remote ATS unit);

— the operation of the alerting system for RFFS purposes;

— the operation of the signalling lamp;

— the provision of light and pyrotechnic signals to aerodrome traffic as provided for in Commission Implementing Regulation (EU) No 923/2012 (SERA.3301, Appendix 1); and

— any other aerodrome equipment/system which would have to be used by the ATS personnel, should ATS be provided locally.

3.1.2. Aerodrome manual

In case of remote provision of ATS, the aerodrome manual should additionally contain relevant information including but not limited to:

— the provision of relevant information to the Aeronautical Information Service (AIS) for publication in the AIP (see Section 5);

— procedures for the transition of ATS provided locally to ATS provided remotely, and vice versa, if applicable;

— procedures for initiating a NOTAM declaring the aerodrome closed in the event of failure of facilities, installations and equipment enabling and supporting the remote provision of ATS;

— procedures for the day-to-day coordination between the aerodrome operator and the ATS provider, as appropriate;

— procedures for the participation of ATS personnel in the aerodrome's safety committees, including the Local Runway Safety Team, and the implementation of the local safety programmes, including joint training and aerodrome familiarisation with other relevant personnel;

— the maps and charts of the aerodrome showing the location of facilities, installations and equipment enabling and supporting the remote provision of ATS, within and outside the aerodrome's boundaries;

— the operating, maintenance (including emergency maintenance), and repair instructions, servicing information, troubleshooting and inspection procedures of facilities, installations and equipment enabling and supporting the remote provision of ATS;

— the procedures for meteorological observation and provision;

— the procedures for the protection of facilities, installations and equipment enabling and supporting the remote provision of ATS, control of activities, and ground maintenance in the vicinity of these installations; procedures for safeguarding such facilities, installations and equipment against acts of unlawful interference; and

— the procedures for the use of light and pyrotechnic signals to aerodrome traffic.

3.2. Operational aspects

3.2.1. Coordination between the aerodrome operator and the ATS provider in the event of system failure

In the event of failure of any of the facilities, installations and equipment enabling and supporting the remote provision of ATS, the aerodrome operator should coordinate with the ATS unit and, if necessary, initiate the issue of a NOTAM declaring the aerodrome closed.

3.2.2. Aerodrome operator — Aerodrome safeguarding

In case of remote provision of ATS, the aerodrome operator should ensure that:

— the risk of sources of non-visible radiation, or the presence of moving (or fixed) objects which may interfere with, or adversely affect, the performance of applicable facilities,

installations and equipment enabling and supporting the remote provision of ATS is assessed and mitigated; and

— appropriate security procedures are established and implemented for the protection of such facilities, installations and equipment.

3.2.3. Maintenance of the remote tower system facilities

Where ATS is provided remotely, the maintenance programme of the remote tower systems at the aerodrome should also address the maintenance needs of the facilities, installations and equipment, including electrical systems, which enable and support the remote provision of ATS.

A preventive maintenance programme should be established and implemented to cover the facilities, installations and equipment enabling and supporting the remote provision of ATS. Such a programme should contain information related to scheduled maintenance work in order to prevent a failure or degradation of such facilities, installations and equipment.

The preventive maintenance programme should contain all the necessary information for its timely and correct implementation including but not limited to:

— the type of inspections/checks to be carried out (e.g. visual inspection, cleaning of equipment, equipment stability/alignment, calibration, etc.) for each facility, installation and equipment, taking also into account factors such as their location and meteorological phenomena;

— the frequency of inspections/checks for each facility, installation and equipment;

— the tools and equipment required for each type of inspection/check; and

— the periodic replacement of parts of equipment that may be required, while the preventive maintenance programme should be based on the maintenance instructions of the manufacturer of the respective facility, installation and equipment, as appropriate.

Arrangements should be in place to ensure that timely corrective maintenance action is taken to ensure safety and regularity of services. Such arrangements should cover the cases of maintenance needs that are:

— identified either during preventive maintenance activities; or

— raised at any other time (e.g. due to equipment malfunction or failure).

Such arrangements should also specify the maintenance responsibilities of the involved organisations.

3.2.4. Remote provision of ATS — Management of the change — Aerodrome operator

At aerodromes where ATS is provided by an ATS unit which is established at the aerodrome and the introduction of remote provision of ATS is planned, due care and time should be taken for the adequate preparation of the transition plan before the change is introduced.

Due to the significance of the change, a competent authority approval may be required. Therefore, the aerodrome operator should communicate its intentions and plan to the competent authority in due time before the planned introduction of the new operating concept in order to avoid unnecessary delays.

As part of the aerodrome operator’s processes and procedures for managing safety, including changes, a safety assessment should be submitted by the aerodrome operator to its competent authority prior to the introduction of the change. This assessment should be properly coordinated with the ATS provider, but also with other interfacing organisations that may be affected by the change.

Although each aerodrome's unique characteristics (based on its complexity, types of operations, organisational arrangements, etc.) may have an effect on both the content and the outcome of the safety assessment, it is expected that this process should include the following areas:

— Tasks that are currently performed by the ATS provider and which may need to be performed by the aerodrome operator. This may include:

- Tasks that fall under the responsibility of the aerodrome operator but had been performed by the ATS provider based on existing local arrangements (e.g. runway surface condition assessment or apron management service), and which will need to be performed by the aerodrome operator; and
- Tasks which fall under the responsibility of the ATS provider and which are planned to be performed by the aerodrome operator, based on similar arrangements. Such tasks may include but are not limited to:
    - maintenance of facilities, installations and equipment necessary for the remote provision of ATS;
    - meteorological observations;
    - provision of pyrotechnic signals to aerodrome traffic;
    - other.
- Tasks which were, and will continue to be, performed by the aerodrome operator, but which may be affected by the introduction of the change in that they may need to be enhanced in order to cover additional areas. Such tasks may include but are not limited to:
    - regular inspections conducted by the aerodrome operator;
    - safeguarding and protection of facilities, installations and equipment necessary for the remote provision of ATS (e.g. obstacles, interference from various sources, etc.);
    - security procedures for the protection of facilities, installations and equipment necessary for the remote provision of ATS;
    - other.

— Need for review of the necessary documentation, including the aerodrome manual, in order to identify any need for updates of or changes to the relevant procedures or the roles allocated to the ATS or aerodrome personnel. This may include but is not limited to:

- maps and charts;
- aerodrome maintenance programme and related procedures;
- establishment of new procedures to cover new or amended areas of responsibility;
- roles of different organisations in the aerodrome emergency plan;
- (A)-SMGCS appropriateness and effectiveness;
- ATS provider participation in local working procedures (e.g. aerodrome safety committees, including the Local Runway Safety Teams, crisis management, etc.);
- provision of relevant information to the AIS;
- other.

— Need for review, update and timely implementation of the training requirements for aerodrome personnel, as a result of task reassignment/enhancement, but also amendment of the aerodrome procedures.

— Technical solutions employed:

- remotely for the implementation of the remote provision of ATS, such as:
  - operation/control of the aerodrome's lighting systems and their individual elements, as appropriate;
  - communication systems between the remote ATS unit and the relevant aerodrome units (e.g. RFFS station, apron management services unit) or vehicles operating on the manoeuvring or movement area (if apron management services are also provided by the remote ATS unit);
  - operation of the alerting system for RFFS purposes;
  - other.
- at the aerodrome in order to support the implementation of the remote provision of ATS, such as:
  - provision of power supply to the facilities, installations and equipment for providing and supporting ATS remotely;
  - location/installation of cameras;
  - other.

3.2.5. Power supply at aerodromes

Electrical power supply systems for the remote provision of ATS

— Cameras and related facilities located at an aerodrome for enabling and supporting the remote provision of ATS should be provided with adequate primary power supply.

— Cameras and related facilities located at an aerodrome for enabling and supporting the remote provision of ATS should be provided with a secondary power supply capable of supplying power when there is a failure of the primary power supply. Electric power supply connections to such cameras and related facilities should be so arranged that they are automatically connected to the secondary power supply when the primary power supply fails.

— The power supply for cameras and related facilities mentioned in the two indents above should be continuous/uninterrupted irrespective of the runway type.

Guidance Material — Electrical power supply systems for the remote provision of ATS

The type and number of related facilities, located at an aerodrome, that should be provided with secondary power supply (apart from the cameras themselves) is a function of the design of each individual system and the solution(s) adopted in each case.

In any case, all such facilities whose function is such that if failure of their primary power source would result in an interruption of the transmission of the visual presentation to the ATS unit should be identified and provided with a secondary power supply meeting the relevant continuity requirements.

The continuity requirement regarding power supply for cameras and related facilities is without prejudice to the applicable switchover times of other facilities located at the aerodrome (e.g. visual approach slope indicators, runway-threshold lights, runway-end lights, runway-edge lights, runway-touchdown-zone lights, stop-bars, etc.).

3.2.6. Cameras at aerodromes

At aerodromes where ATS is provided remotely, appropriately located cameras should be used to provide visual presentation of an unobstructed view of at least:

— the aerodrome's manoeuvring area, including any remote de-icing/anti-icing facilities; and

— the aerodrome's vicinity

to the ATS personnel.

At aerodromes where ATS is provided remotely and the respective ATS unit is also responsible for the provision of apron management services at the aerodrome, cameras should be so located as to provide visual presentation of an unobstructed view of the apron(s) under the responsibility of that ATS unit.

4. Possible impacts on airspace users

It is anticipated that it may be hard to distinguish small aircraft while manoeuvring (e.g. when turning, the angle of the aircraft to the camera may be such that the aircraft's dimensions could not/hardly be distinguished by the human eye). This also depends on the resolution capabilities of the visualisation equipment and the mode in which it is used. In principle, as recent implementation and validation activities have shown, the remote tower concept should not impact airspace users. In any case, the ATS provider should take some elements into consideration when conducting the safety assessment in order to propose mitigation measures, if needed. The ATS provider should evaluate the need to establish a TMZ within the ATZ and to propose it to the relevant competent authority when the result of the safety assessment establishes a risk for which the derived solution implies the use of surveillance equipment. Other possible impacts should also be analysed following the results of the safety assessment.

5. AIP

As a consequence of the implementation of the remote tower concept, the following additional elements have been identified as necessary to be published through the AIS:

— remote aerodrome ATC/AFIS provision; and

— location of signalling lamp (in case of communication failure).

6. Appendices

6.1. Appendix 1: Checklist for the approval of the implementation of the remote tower concept

Based on the content of NPA 2015-04, the following elements are listed (for reference purposes only) in order to summarise the aspects to be considered for the approval of the implementation of the remote tower concept.

— Transition plan developed by the ATS provider and the aerodrome operator.

— Implementation timeline agreed by the ATS provider, the aerodrome operator and the competent authority(ies).

— Siting assessment to meet view and visual presentation requirements.

— Working environment, human performance and ergonomics analysis.

— Aerodrome's documents affected by the certification process.

— Contingency coordination plan agreed between the ATS provider and the aerodrome operator.

— Review and documentation of roles and responsibilities assigned to the ATS provider and the aerodrome operator.

— Safety assessment which includes but is not limited to the following topics:

- documentation that the basic equipage requirements are met;
- assessment of the need for enhanced equipage functionalities based on traffic density, air traffic characteristics, aerodrome layout, airspace characteristics, aerodrome infrastructure and surroundings, and environmental characteristics;
- reassignment of tasks among the ATS provider and the aerodrome operator;
- impact on operational procedures;
- tasks requiring modification or enhancement;
- review and update of the training requirements for ATS provider's and aerodrome operator's personnel;
- analysis of the interdependencies with other service providers and aviation undertakings, and analysis of the necessary coordination processes and procedures;
- review and update of the aerodrome documentation;
- requirements for airspace users (e.g. equipment on board, etc.);
- functional hazards assessment and CMA;
- determination of safety requirements and mitigations;
- security risk analysis;
- AIP modification proposals.

6.2. Appendix 2: List of operational hazards for ATC services

Table 2 below lists the operational hazards and the operational effects for the ATC services, based on the results of the SESAR safety work, in the context of the SESAR project.

Table 2: List of operational hazards (SESAR safety assessment — ATC case)

ID	Description	Operational effects
OH-01	Remote ATC incorrectly coordinates with other ATSU with respect to inbound/outbound traffic.	A potential conflict can be induced Imminent infringement
OH-02	Remote ATC incorrectly manages the entry of a flight into traffic circuit.	A potential conflict can be induced Imminent infringement
OH-03	Remote ATC incorrectly manages arriving aircraft.	A potential conflict can be induced Imminent infringement
OH-04	Remote ATC incorrectly manages departing aircraft.	A potential conflict can be induced Imminent infringement
OH-05	Remote ATC fails to provide appropriate separation to traffic in the vicinity of the aerodrome.	Imminent infringement
OH-06	Remote ATC fails to provide appropriate separation to traffic with respect to restricted areas.	Tactical conflict
OH-07	Remote ATC incorrectly manages missed approach situation.	Imminent infringement
OH-08	Remote ATC does not detect in time conflicts/ potential collision between aircraft in the vicinity of the aerodrome.	Imminent collision
OH-09	Remote ATC does not detect in time restricted area infringements.	Tactical conflict
OH-10	Remote ATC fails to provide appropriate instruction to resolve a conflict between traffic in the vicinity of the aerodrome.	Imminent collision
OH-11	Remote ATC fails to provide appropriate instruction to resolve an airspace infringement.	Tactical conflict
OH-12	Remote ATC fails to provide appropriate information to departing aircraft for the start-up.	Tactical taxiway conflict generated
OH-13	Remote ATC fails to enable push-back/towing operations to appropriate aircraft.	Tactical taxiway conflict generated
OH-14	Remote ATC provides inadequate taxiing instruction to aircraft on the manoeuvring area.	Encounter with aircraft, vehicle or obstacle
OH-15	Remote ATC provides inadequate taxiing instruction to vehicle on the manoeuvring area.	Encounter with aircraft, vehicle or obstacle
OH-16	Remote ATC does not detect in time potential conflict on the manoeuvring area.	Imminent collision
OH-17	Remote ATC fails to provide appropriate instruction to resolve conflicts on the manoeuvring area.	Imminent collision

ID	Description	Operational effects
OH-18	Remote ATC fails to provide (appropriate) navigation support to aircraft and vehicle on the manoeuvring area.	Tactical taxiway conflict generated
OH-19	Remote ATC incorrectly manages runway entry for a departing aircraft (occupied runway).	Runway conflict
OH-20	Remote ATC incorrectly manages runway exit for a landing aircraft.	Runway conflict
OH-21	Remote ATC incorrectly manages runway crossing (occupied runway) for a vehicle or an aircraft.	Runway conflict
OH-22	Remote ATC fails to properly support departing and landing aircraft (with respect to visual aids).	Runway conflict
OH-23	Remote ATC incorrectly manages vehicle-related tasks on the runway.	Runway conflict
OH-24	Remote ATC incorrectly manages aircraft take-off (occupied runway).	Runway conflict
OH-25	Remote ATC incorrectly manages aircraft landing (occupied runway).	Runway conflict
OH-26	Remote ATC fails to detect in time runway incursions (aircraft or vehicles).	Runway penetration
OH-27	Remote ATC fails to provide appropriate instruction to resolve runway incursion and prevent potential collision on the runway.	Runway penetration
OH-28	Remote ATC fails to detect in time a flight towards terrain in the vicinity of the aerodrome.	Imminent Controlled Flight Into Terrain (CFIT)
OH-29	Remote ATC fails to provide appropriate support to pilot on a CFIT situation.	Imminent CFIT
OH-30	Remote ATC fails to establish sufficient wake-turbulence spacing between aircraft.	Turbulence in front of the aircraft at a distance less than the separation minima
OH-31	Remote ATC fails to properly support landing/ take-off operations with respect to weather conditions.	Potentially to a landing accident
OH-32	Remote ATC fails to properly support landing/ take-off operations with respect to runway conditions and potential foreign objective debris.	Potentially to a landing accident
OH-33	Remote ATC fails to properly support departing and arriving aircraft on the runway with respect to non-visual aids.	Potentially to a landing accident
OH-34	Remote ATC fails to detect in time an intrusion inside landing-air protection area.	Potentially to a landing accident

6.3. Appendix 3: List of operational hazards for AFIS services

Table 3 below lists the operational hazards that may be considered by the ATS provider for the AFIS. The SESAR safety works has focussed on the ATC case applied assuming that the most constraining results specifying the remote tower concept would be derived from ATC services. Then, this list should be considered as an initial list by the ATS provider to be further developed as necessary.

Table 3: Initial list of operational hazards (SESAR safety assessment — AFIS case)

ID	Description
OH-AFIS-01	Remote AFIS fails to properly select runway-in-use.
OH-AFIS-02	Remote AFIS fails to identify potential 'conflicts' in the vicinity of the airport.
OH-AFIS-03	Remote AFIS fails to provide appropriate traffic information (including local traffic) to relevant traffic: — direction of flight or traffic concerned, — type of wake-turbulence category, — level of traffic and potential changes, — relative bearing (12-h clock indication), — other relevant information.
OH-AFIS-04	Remote AFIS fails to provide appropriate information concerning the availability of the runway for departing/arriving traffic.
OH-AFIS-05	Remote AFIS fails to provide appropriate traffic position information on the manoeuvring area.
OH-AFIS-06	Remote AFIS fails to provide appropriate wake-turbulence- and jet-blast-related information.
OH-AFIS-07	Remote AFIS fails to provide appropriate essential information on airport conditions (surface conditions, maintenance works, obstacles, birds, lighting system failure, etc.) to departing and arriving traffic: — conditions on the manoeuvring area, — conditions on the parking area.
OH-AFIS-08	Remote AFIS fails to provide appropriate start-up instructions to departing traffic.
OH-AFIS-09	Remote AFIS fails to provide appropriate meteorological information to departing and arriving traffic.
OH-AFIS-10	Remote AFIS fails to manoeuvre the visual signals to indicate to traffic that aerodrome is not safe.
OH-AFIS-11	Remote AFIS incorrectly coordinates with ATC for arriving traffic.
OH-AFIS-12	Remote AFIS incorrectly coordinates with ATC for departing traffic.
OH-AFIS-13	Remote AFIS fails to provide appropriate information on local traffic to assist taxiing operations.
OH-AFIS-14	Remote AFIS incorrectly provides authorisation to persons/vehicles to enter into the manoeuvring area.

ID	Description
OH-AFIS-15	Remote AFIS fails to provide light signals to ground vehicles and personnel on the manoeuvring area (when adequate or in case of radio communication failure).
OH-AFIS-16	Remote AFIS fails to provide appropriate relevant information on local traffic and aerodrome conditions to assist the flight crew in deciding when to take off.
OH-AFIS-17	Remote AFIS fails to provide appropriate relevant information on local traffic and aerodrome conditions to assist the flight crew in deciding whether to land or go around.
OH-AFIS-18	Remote AFIS fails to detect a runway incursion or the existence of any obstruction (including animals) on or in close proximity to the take-off/landing area.
OH-AFIS-19	Remote AFIS fails to operate aeronautical ground lights: — manoeuvring lighting, — taxiway area lighting.
OH-AFIS-20	Remote AFIS fails to monitor visual aids status.

6.4. Appendix 4: Human performance aspects

Technology aspects

— Image quality factors (e.g. contrast, brightness, sharpness, etc.);

— Screen layout;

— Resolution;

— Field of view;

— Colours;

— Dynamic range;

— Automation of camera movements;

— Avoidance of blind areas;

— Reliability of the visual presentation;

— Availability of the visual presentation;

— Integrity of the visual presentation;

— Accuracy of the visual presentation;

— Time delays between image capture and visual presentation;

— Appearance of image freezing issues;

— Capability of the visual presentation to provide smooth and regular impression of moving objects to the human eye eventually in both 2D and 3D presentation;

— Quality of the visual presentation to allow the ATCO/FISO to discriminate distance between objects;

— Procedures in case of image integrity failure.

Elements of the human performance assessment

The following elements (but not limited to) should be taken into consideration as a consequence of the replacement of direct visual observation with visual presentation:

— ATCO/FISO situational awareness;

— ATCO/FISO perception;

— ATCO/FISO capacity to detect all aircraft;

— Maintenance of continuous watch through visual contact on the elements contained in its area of responsibility (airfield manoeuvring area and vicinity of the aerodrome);

— Effect of time delays on visual presentation in all situations, with special attention to the case of emergency situations (e.g. runway incursions);

— Potential confusion over the different views that an ATCO/FISO could suffer from having images originated from different cameras with different locations and angles of view on the manoeuvring area (e.g. positioning cameras on both sides of a runway);

— Differences in brightness between ground and sky in the screen views;

— Partial obstruction of visual detection during sunrise or sunset;

— Contrast of screens with the background;

— Colour balance with different daylight configurations;

— Screens arrangement (e.g. 6 or 9 screens, 240 or 360 degrees);

— Capability of the cameras to capture and transmit blinking beacon images in all circumstances;

— Specific local conditions affecting the visibility (e.g. deficiencies in image capture due to seawater splash);

— Availability of aerodrome ambient sound and acoustic characteristics of the control room;

— Camera angles and screen orientation in relation to aerodrome layouts and in relation to the different legs of the VFR circuit;

— Integrated flight data label information (if available), both with static information and with dynamic information, and measures to prevent the label from shadowing visual information;

— Visual object tracking functionality (if available), either automatically (rotation, tilt to the desired elevation angle and focus at the indicated distance) or through a manual pan-and-tilt/zoom function.

Other human-performance-related aspects

Apart from the above-mentioned elements, some other aspects not strictly related to the replacement of direct visual observation need to be considered in the safety assessment. The following aspects should be used as an example:

— Local procedures to manage movement of vehicles and persons on the manoeuvring area;

— Local procedures on the coordination of remote tower and approach control (APP) services, whether merged or not in the same dependency;

— Local procedures for operations during low-cloud situations, limited visibility or similar;

— Specific training elements related to local aerodrome characteristics;

— Potential impact on VFR flights compared to the equivalent in a conventional TWR environment.

— Effect of the types of airspace surrounding the aerodrome concerned (e.g. class C and D) on issuing take-off clearances;

— Effect on the visual observation of size, equipment, flight patterns and behaviour of VFR;

— Specific local requirements needed for safety reasons, such as:

  - additional separations,
  - ground equipment (e.g. radar),
  - on-board equipment (e.g. transponder, ADS-B),
  - specific camera configuration (e.g. two layers of cameras for ground and one layer for sky to minimise contrast),
  - specific additional camera equipment (e.g. adaptable housing to mitigate sunshine effects),
  - specific screen requirements (e.g. automatic adjustable contrast to mitigate daylight variations),
  - specific ancillary equipment (e.g. automatic cleaning system for the windows protecting the cameras to avoid snowflakes affecting image capturing).

6.5. Appendix 5: List of acronyms

AFIS	Aerodrome Flight Information Service
AFS	Aeronautical Fixed Service
AGLS	Aeronautical Ground Lighting System
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service
AMC	Acceptable Means of Compliance
ANS	Air Navigation Service
ANSP	Air Navigation Service Provider
APP	Approach Control
ATCO	Air Traffic Controller Officer
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Service
ATZ	Aerodrome Traffic Zone
AVF	Advance Visual Features
CA	Competent Authority
CAT	Commercial Air Transport
CFIT	Controlled Flight Into Terrain
CNS	Communication Navigation Surveillance
CMA	Common Mode Analysis
CPDLC	Controller Pilot Data Link Communications
CS	Community Specifications
CTR	Aerodrome Control Zone
CWP	Controller Working Position
DOC	Declaration Of Conformity
DSU	Declaration of Suitability of Use
FHA	Functional Hazards Assessment
FIS	Flight Information Service
FISO	Flight Information Service Officer
GM	Guidance Material
HF	Human Factors
HMI	Human–Machine Interface
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
MASPS	Minimum Aviation System Performance Standards
MET	Meteorological
MOPS	Minimum Operational Performance Standards
NOTAM	Notice to Airmen
NPA	Notice of Proposed Amendment
OTW	Out-The-Window
RATS	Remote Aerodrome Traffic Service
RCS	Risk Classification Scheme

RFFS	Rescue and Firefighting Services
RMZ	Radio Mandatory Zone
RTC	Remote Tower Centre
RTM	Remote Tower Module
RTO	Remote Tower Operation
RWY	Runway
SSAS	Software Safety Assurance System
SWAL	Software Assurance Level
SESAR	Single European Sky ATM Research
SLA	Service Level Agreement
SMS	Safety Management System
TMA	Terminal Control Area
TMZ	Transponder Mandatory Zone
TWR	Tower
TWY	Taxiway
VFR	Visual Flight Rules
VHF	Very High Frequency
WAN	Wide Area Network