

# GUIDANCE MATERIAL FOR REMOTE AND DIGITAL TOWERS

Edition 2

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SKIES**

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# ACKNOWLEDGEMENTS

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# EXECUTIVE SUMMARY

This document provides air navigation service providers (ANSPs) with an introduction to the remote and digital tower concept and informs any decision-making processes before or during the inception of an implementation programme.

It provides an overview of the concepts and technologies involved, and what drivers, challenges and pressures can influence operations. The information considers real operational experiences and lessons learned by early adopters of the remote and digital towers, based on current technologies. Case studies are provided for a range of current implementations, to contribute to the sharing of information between ANSPs.

This document answers some specific questions that ANSPs may pose when considering a digital tower implementation including:

- What is a digital tower?
- Why implement a digital tower?
- When to implement a digital tower?
- How to get started with digital towers?
- What is next for digital towers?

To facilitate the harmonisation and deployment of remote and digital tower technology, the International Civil Aviation Organization (ICAO) recommended the development of common standards. These ensure implementations are uniform, safe, and integrated without compromising service levels. This document supports this international effort.

# SUMMARY OF UPDATES

The CANSO SDT FA identified the need to update the existing issue (1) of the CANSO Guidance Material for Remote and Digital Towers to ensure the content reflects the concept evolution, technology advances, and state of implementations.

The following **updates** to the existing content have been introduced:

- *Section “Why Implement Digital Towers?”, sub-section “Benefits” – Centralisation of services and information:* This section has been updated to include further details and considerations about centralisation of digital tower implementations within a common environment (remote/digital tower centre).
- *Section “Digital Towers: A View Through Case Studies”:*
  - *FAA Towers Case Study:* Updated to reflect current state of the implementation based on progress and achievements, and revised future plans.
  - *LFV and SAAB Remote Tower Services Case Study:* Updated to reflect current state of the implementation based on progress and achievements, and revised future plans.
  - *HungaroControl Digital Tower Case Study:* Updated to reflect current state of the implementation based on progress and achievements, and revised future plans.
  - *DFS Remote Tower Centre Case Study:* Updated to reflect current state of the implementation based on progress and achievements and revised future plans.
- *Section “How Do I Get Started with Digital Towers?”, sub-section “Regulatory and Standardisation Outlook”:* This section has been updated to incorporate any changes and on-going activities within standardisation bodies and working groups with regards to the development of digital tower regulations and guidance documents worldwide.
- Editorial update to the text and document structure to improve clarity, flow and consistency across the document.

The following **new inputs** to the existing content have been introduced:

- *Section “Why Implement Digital Towers?”, sub-section “Challenges” – Digital Tower Centre Interdependencies:* This new sub-section focuses on introducing considerations regarding the interdependencies between airports consolidated in a digital tower centre. Furthermore, within the sub-section are additional considerations regarding multiple mode operations based on experiences and lessons learned from past and on-going validation trials across the industry.
- *Section “Digital Towers: A View Through Case Studies”:*
  - *Avinor Remote Tower Programme:* New use case has been introduced that discusses the operational concept, technology, deployment activities, lessons learned, and future plans of the Avinor Remote Tower Centre housing 15 remoted airports.
- *Section “How Do I Get Started with Digital Towers?”, sub-section “Lifecycle Management”:* This new sub-section discusses the lifecycle of digital tower implementations by breaking down the lifecycle stages and providing considerations to support the understanding of users.
- *Section “What is Next for Digital Towers?”:*
  - *Advanced Concept Applications:* This new section on introducing emerging use cases for implementing digital tower technology in conventional tower operations.
  - *Drone Management and Detection:* This new section introduces the opportunity for digital towers to support the management and detection of drone operations around airports.



# WHAT IS A DIGITAL TOWER?

## DEFINITIONS AND BACKGROUND

The digital tower concept is one which enables the provision of airport air traffic services (ATS) from any location.

Digital tower technologies provide a view of the airport and its vicinity, enabling operators to conduct visual surveillance using digital means rather than relying on the view provided from the visual control room (VCR) using the naked eye and binoculars.

This surveillance is typically captured using digital camera technology and other sensors. Images are transmitted over a digital network and relayed to the operator on screens.

The airport ATS that can be provided when operating from a digital tower are the same as those defined in international standards and recommended practices (SARPs) and should be no different from the airport ATS provided from a conventional airport control tower.

## CONCEPT HISTORY

Development towards the digital tower concept in its current form started in the early 2000s and was further developed in international research programmes such as Single European Sky ATM Research (SESAR).

The first digital tower implementation providing airport ATS fully in accordance with ICAO documents 4444 and 9426 was approved into operation in Sweden in April 2015. However, some remotely provided airport flight information services have been provided in Japan since 1974<sup>1</sup>.

The digital tower concept was initially developed for low density airports hoping to achieve a more cost-efficient way of providing airport ATS by centralising resources and providing ATS more flexibly.

When implementing a digital tower, the location of the service provision is made independent of the airport location and as such, a location can be selected that will provide the most efficient use of resources. For example, a digital tower can be located in an area where the potential to recruit and retain skilled staff is increased. For low density airports the ability to provide ATS remotely was a key enabler – as such, the concept is commonly referred to as the remote provision of ATS or ‘remote tower’.

## CURRENT UNDERSTANDING

The full scope of digital tower operations encompasses a range of operating modes. These are heavily driven by the technologies used and offer a high degree of flexibility in terms of how each may be applied.

The concept and its technologies may be applied to all forms of airport ATS, including air traffic control, airport flight information services (AFIS) and apron control services.

The concept and its technologies are applicable to airport operations of all sizes.

In addition to cost efficiencies<sup>1</sup>, digital towers and the associated technologies can be implemented to bring about a range of societal and economic benefits for a variety of stakeholders. The use of cameras, screens and sensors enables various other technologies to be applied in the provision of airport ATS which were not previously possible. These innovative technologies may enable enhancements in overall service delivery and other aspects including safety, human performance, and capacity.

## OPERATING MODES

The digital tower concept encompasses a range of operating modes and applications applied using various technologies. The core operational modes, currently considered in operations and research and development, are discussed below. Variants of each operating mode exist, and each should be adapted accordingly to suit operational needs. The core operating modes discussed below are not mutually exclusive.

EASA has defined two operating modes<sup>3</sup>:

- “Single operating mode” refers to the provision of ATS to one airport from a digital tower facility
- “Multiple operating mode” refers to the provision of ATS to two or more airports simultaneously from a digital tower centre. airport

In addition, other notable applications exist as follows:

- The provision of remote airport ATS to an airport during contingency situations (Contingency mode) (a form of Single mode but with a specific use case).
- Operations within a conventional tower, for example, where additional technologies are implemented to enhance the existing operation.

Currently there is not considered to be a significant difference in the digital tower camera technology required to facilitate any of the core operating modes. The complexity of the operating environment is the key influencing factor to determine what digital tower technology is required. However, more emphasis on the Human-Machine Interface (HMI) and integration on the user side is required to support Multiple Operating Mode.

Further information on all the above operating modes is provided in the sections below.

## SINGLE OPERATING MODE

As defined in previous Single operating mode refers to the provision of an airport ATS to one airport from a digital tower (Figure 1). Services provided will include all forms of ATS and rely on a suitable operational team of one or more operators as required to maintain safe operations. This mode commonly refers to the full-time provision of ATS from a permanent digital tower facility located at or remotely from the airport or consolidated with other digital tower facilities into a centre.

## MULTIPLE OPERATING MODE

As earlier defined, Multiple operating mode refers to the provision of airport ATS to two or more airports simultaneously from a digital tower facility (Figure 2). As such, this reflects a significant change to current conventional operating methods.

Resourcing scenarios can be more complex, yet when any individual operator is providing airport ATS to more than one airport at the same time, they are operating under multiple mode. This will require some technical enablers to be duplicated and others to be integrated and combined to assist the operator.

The target environment for multiple mode will largely depend on the ability of the controller to provide airport ATS while maintaining acceptable levels of situational awareness and workload. Consideration will need to be given to traffic density, complexity, traffic schedules, and airfield layout of the airports to be provided with ATS simultaneously from the same digital tower working position.

## CONTINGENCY OPERATING MODE

Contingency operating mode refers to the provision of airport ATS in cases where the permanent ATS facility is unusable. As such, the technical solution is not proposed as a permanent replacement to the conventional tower, which will still be the primary facility for ATS provision.

Generally, there is no indication that the configuration or minimum requirements for a contingency digital tower would differ compared to single operating mode.

When implementing a contingency digital tower, the configuration (including any out-of-the-window view that is provided) may need to be more carefully considered alongside that of the conventional tower, which will still be in operation.

Contingency operating mode can be provided from a permanent digital tower facility or a temporary facility. Temporary facilities may not have the same certification requirements.

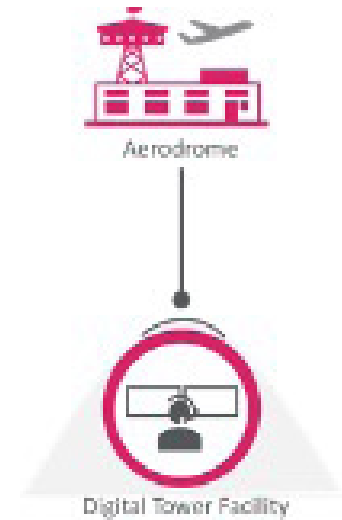


Figure 1 – Illustration of Single Operating Mode  
Credit: Think Research

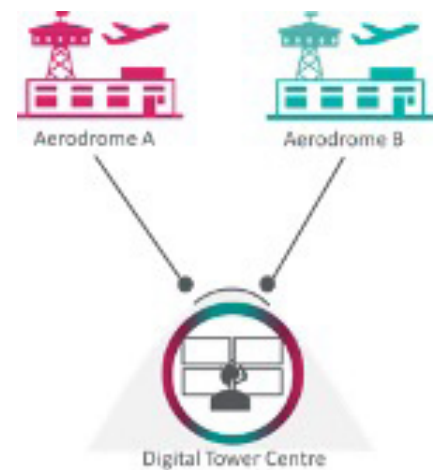


Figure 2 – Illustration of Multiple Operating Mode  
Credit: Think Research



## OPERATIONS WITHIN A CONVENTIONAL TOWER

Digital tower technologies can be installed in a conventional tower to support the operation in some manner. Technologies to enhance visual observation, for example, could include blind spot coverage, hot spot coverage or coverage of other areas of interest. The provision of cameras to provide such coverage may preclude the need to build additional conventional tower buildings as an airport expands or may eliminate blind spots that can emerge with the growth of the airport.

In addition, the inclusion of digital tower technologies can have other benefits both in digital and conventional towers. For example, thermal cameras providing benefits to low visibility or night operations.

The use of digital tower technologies within a conventional tower can enable previously unavailable, innovative ways to display information to operators. They can also enable the airport ATS function to be better connected to other ATS and airport functions, for example connections to airport operations centres or area control centres, and this, in turn, can enhance information sharing and facilitate a range of performance benefits.

## OPERATING ENVIRONMENT

The digital tower operating environment is one of the most important considerations when identifying a suitable mode of operations and technical configuration.

Factors to consider include:

- Air traffic density
- Air traffic characteristics
- Airport layout
- Airspace characteristics and classification
- Operator roles and local procedures
- Required performance
- Availability of contingency facility
- Diversion airport
- Weather observation service

These aspects of the operational environment influence the most suitable technical implementation, when considering conventional tower operations.

Experiences have shown that of the aforementioned considerations, traffic and airport characteristics are primary factors influencing the feasibility of a digital tower operation. How these factors have a specific influence on a digital tower operation and some of the key considerations are now discussed.

## TRAFFIC AND AIRSPACE CHARACTERISTICS

When providing ATS from a conventional tower, operators often find that aircraft operating on visual flight rules (VFR) and performing complex or unpredictable manoeuvres, can be demanding on workload and need additional, visual, attention. Such aircraft are also often physically smaller and thus harder to detect. This is no different in a digital tower environment<sup>4</sup>.

In a conventional tower, operators have the freedom to move around the VCR to improve their view of the airport and vicinity. In a digital tower environment, this is only possible if the correct equipment and configuration of cameras are provided.

The placement of cameras at an airport site and the inclusion of pivoting cameras is an important consideration. This is especially true at airports with a high degree of unscheduled VFR traffic and serving smaller aircraft types. In such environments, the inclusion of airport sound may also be beneficial to increase the operator's awareness of the location of aircraft.

For airports with a large traffic circuit, the extent of visual coverage will need to be considered.

There may be a need to provide additional cameras, those that can zoom, and visual target tracking technology. This particularly applies to airports with a higher traffic density or with a lot of additional traffic in the vicinity, for example, from neighbouring control zones or frequent overflights.

Enhanced technologies, such as visual or radar tracking with overlaid displays on the visual presentation, may provide additional support to operators working with complex traffic or providing a service to airports simultaneously.

Vehicle movements also need to be considered, and it's important that all vehicle movements can be seen when providing airport ATS from a digital tower. This may require sensors capable of detecting smaller objects and/or additional cameras positioned on the ground movement areas.

## **TRAFFIC DENSITY**

Airport ATS is sensitive to traffic loading and scheduling because of the need to manage the workload of operators and the ability of the infrastructure to facilitate the traffic.

Digital tower operations are just as sensitive to traffic peaks, with heightened sensitivity when operating in specific modes.

### ***TRAFFIC CONSIDERATIONS FOR MULTIPLE OPERATIONS***

When operating using multiple mode, the total traffic density of all airports being simultaneously provided with a service needs to be considered, including the interaction of traffic schedules. If the traffic schedules of airports to be paired together is not complimentary (e.g., traffic peaks at the same time causing erratic or irregular workload peaks, or little or no control over schedules), this may require more complex staffing to ensure the performance of operators is not reduced. ANSPs need to conduct thorough human performance assessments and should ensure the traffic interactions of all airports have been assessed. The traffic characteristics of each airport also need to be considered.

Specific mitigations to manage traffic and the workload of operators, when providing a simultaneous service to two or more airports, may need to be considered. This could include:

- The use of traffic coordination, scheduling or Prior Permission Required (PPR) procedures. Such measures can assist in the management of traffic peaks
- Where surveillance is present, imposing active traffic management, including Transponder Mandatory Zones (TMZ) to facilitate the enhanced classification of traffic

The above mitigations are likely to provide high level estimates of predicted activity at an airport in the timeframe of days or weeks, where any anticipated traffic peaks can be properly resourced. It is acknowledged that this level of control of the traffic is not feasible for some VFR airports.

The precise influence of traffic density when providing airport ATS to two or more airports simultaneously is subject to ongoing research and investigation. In all cases the required mitigations, if any, will depend on the specific use cases considered.

## **AIRPORT CHARACTERISTICS AND MAST LOCATION**

The nature of an airport in terms of layout, surroundings and physical features will influence the visual and operational requirements imposed on a digital tower solution. This will also influence the placement of the mast infrastructure at the airport site. Camera placement needs to be considered in terms of proximity to key features such as, among others, runways, runway thresholds, aiming points, final approach, runway intersections, runway protection surfaces, and taxiway intersections. Such cameras will provide an operationally accurate view of the airport and vicinity to operators.

The traffic density and traffic complexity of an airport will also have an influence on the requirements for a digital tower implementation.

High intensity and complex operations will often have a greater need for the support tools and may require more integrated ATS functions. This is not necessarily specific to digital towers and the

increased technical complexity associated with the control tower of a complex, high intensity airport operation, would be expected to be similar in a digital or conventional tower.

## WEATHER OBSERVATIONS

Weather observation and provision of weather reports are crucial for the safety and planning activities of operators.

Digital tower technology has been approved and can be used for the provision of weather observation services.

This is, to date, case specific and depends on specific MET requirements each ANSP needs to meet.

## TECHNOLOGY

Digital tower concepts are enabled by technology. The technical specification and configuration of each implementation needs to be tailored to the specific operating environment. The core of these technologies is summarised in this section.

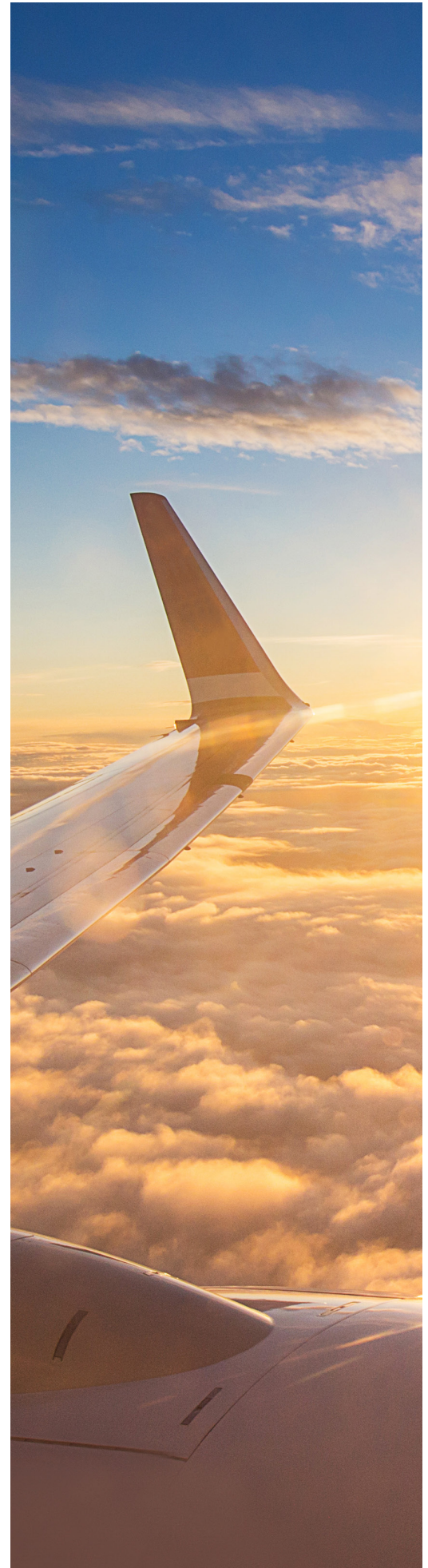
EASA guidance<sup>3</sup> and EUROCAE Minimum Aviation System Performance Specifications<sup>5</sup> should be referred to for details of digital tower technical enablers and technical system specifications.

## VISUAL SENSOR PRESENTATION

High quality and reliable visual presentation technology sits at the core of the digital tower concept. EUROCAE ED-240A Change 1<sup>5</sup> defines a digital tower visual presentation as: “A visual display that shows real-time video images from the areas of responsibility of the ATS and/or apron management unit.

*Visual Presentation comprises the following types of presentation:*

- *Optical Sensor Presentation (OSP)*
- *Augmented Optical Sensor Presentation (Augmented OSP)*
- *Virtual Presentation.”*



## OTHER TECHNICAL ENABLERS

EASA guidance material<sup>3</sup> states that the following technical enablers, which may feature in a digital tower, may require additional consideration regarding the transmission of data between the airport and the site of the digital tower facility. These include:

- Magnification functionality
- Signalling lamp
- Airport sound reproduction
- Communication devices to facilitate service provision
- Management of navigation aids, aeronautical ground lights and other airport assets
- Meteorological information
- Other ATS functions and systems as required (and not necessarily affecting the provision of airport ATS from a location remote from the airport)
- Hot spot or gap filler cameras
- Other 'enhanced features' of a digital tower, including object detection and following capabilities, Foreign Object Debris (FOD) detection support
- Visual information displayed onto the visual presentation

## ENHANCEMENTS

The inclusion of a visual presentation within a digital tower enables the use of novel and enhanced technical features and operational tool support. Such features may improve the situational awareness and conflict detection capabilities of the operator. Equipping the digital tower with enhanced features may facilitate an increase in capacity and level of service provision in some environments. Such enhanced technical features may include:

- Visual overlays of information
- Use of multiple optical sensors e.g., thermal cameras, additional cameras to cover areas of operational significance or blind spots
- Ability of cameras to lock on and follow targets in the visual presentation (visual tracking)
- Enhanced visual observations via software processing, e.g., software filters
- Radar surveillance data may be overlaid or augmented onto the visual presentation display to provide additional situational awareness. This can include radar track data, meteorological information, or aeronautical messages. If target tracking technology is provided then this may rely on radar or camera data, or a combination of both

The above enhancements to the visual presentation may bring about improvements in a range of conditions, e.g., in low visibility operations or a general performance increase by increasing automated functions and reducing operator workload.

A safety and human performance assessment needs to accompany the introduction of any new features or tools. Some of these enhanced features are still in the initial development phases and, as such, the feasibility for use in ATS provision, level of benefit provided, and the underlying technical requirements are still unspecified.

## **OPERATIONAL CONFIGURATIONS AND WORKING POSITIONS**

The configuration of a digital tower facility will influence the working methods established.

When providing airport ATS from a digital tower, operators are no longer constrained by the traditional out-of-the-window view which provides a fixed view that operators access by moving their bodies and using binoculars. However, conversely, the visual presentation screens used within digital towers are not as easily shared between individual operators. Additionally, many individual visual presentations may be provided in a digital tower. The use of these screens, including ensuring a common situational awareness between many operators, and procedures for the control of specific visual tools and cameras, need to be considered.

Digital tower facilities need to consider the ratio of airports to operators, the specific visual requirements of each operational role and the operational mode provided. All of these factors have an influence on the configuration of the Controller Working Position (CWP).

The CWP in a digital tower will include a visual sensor presentation (of some kind – see the section on visual sensor presentations above). The complete configuration is sometimes referred to as a Remote Tower Module (RTM).

The configuration of the CWP will influence how the visual presentation is presented to the operator. Many of the current operations include a pseudo-panoramic view of the airport – a 360-degree panoramic view mapped and displayed on 180 degrees or 220 degrees lay out of display screens. The field of view depends on the operator position with respect to the displays and their individual operator's field of view.

Specific examples of operational configurations are now discussed.

### ***ONE OPERATOR, ONE CWP***

Only one operational role needs to be considered when configuring the airport view and prescribing procedures for the use of control tools, input devices or other features.

### ***MORE THAN ONE OPERATOR, ONE DIGITAL TOWER FACILITY***

When two or more operators are working from a single working position, some tools and data sources may need to be replicated for each operator. Additional procedures may also be required to clarify how the visual presentation and control tools are shared. Commonly, digital towers include a single, large visual presentation display where operators share a common view to provide a shared situational awareness. It can also be beneficial to provide a tailored visual presentation for each operator. When multiple operators are within one facility the control of any pan, tilt or zooming cameras (mirroring binoculars) or other standalone visual functions will either need to be duplicated or have specific procedures to govern which operators have authority over specific visual equipment.

### ***DIGITAL AND CONVENTIONAL TOWER FACILITIES***

If the conventional tower and digital tower will be used to provide ATS to an airport, (e.g., during off-peak hours) to provide overflow positions during peak hours or as a contingency facility, then the configuration of the conventional tower CWPs may influence the configuration of the digital tower CWPs. If two CWP environments are made similar, then this may assist in the maintenance of working procedures across both facilities and aid human factors and change management.

## ***MULTIPLE AIRPORTS***

The visual presentation display will be required to show each airport, with a variety of possible methods used to achieve this. Control tools used may be duplicated or integrated for use for all airports. Operators will need to be able to clearly identify which airport is being controlled by input devices and to which airport any data outputs (Flight Progress Strip [FPS], radar, communications) relate to.

## ***OPERATIONS WITHIN A CONVENTIONAL TOWER***

If digital tower technologies are integrated for use in a conventional tower, the CWP will be tailored to suit that operation. This is likely to include a high degree of integration to reduce the complexity of working methods and the number of display and input control devices. In such environments, digital tower visual sensor presentations and Human Machine Interface (HMI) displays may be used to control various functions, reducing the overall complexity of the VCR.

## ***DIGITAL TOWER CENTRES***

To maximise the benefits of the concept, an ATS provider may decide to co-locate digital towers for different airports in one facility. Such a facility is commonly called a remote tower centre (RTC) and is like an Area Control Centre (ACC).

The use of a digital tower facility/RTC allows the sharing of resources such as staff, buildings, and equipment, providing cost efficiency benefits through this increased ability to share. Centralising airport ATS for more than one airport and standardising the type of equipment and HMI within a RTC provide the ability to use a central airport ATS resource pool and the use of a common HMI. This will also ease the training effort, allow operators to support multiple endorsements, lower the maintenance costs, and increase flexibility.

However, licensing and certification will need to be considered which could limit how dynamic that resource pool can be. Further limitations may also include the level of standardisation possible within a central facility if different technology, providers, and equipment are used. In such cases the ability to share such resources in a flexible way may be reduced, although the benefit of co-locating airport ATS remains.

# WHY IMPLEMENT A DIGITAL TOWER?

The decision to implement a digital tower will be based on a balance of business decisions which consider costs and benefits, risks, and rewards. Based on the experiences of early adopters using a variety of digital tower technologies and operational applications, the key benefits, challenges, and considerations are discussed here.

## BENEFITS

Digital towers and the associated technologies can be implemented to bring about a range of social and economic benefits for a variety of stakeholders. Benefits depend on the specific modes of operation and the implementation environment.

Key benefits enabled by digital tower concepts are shown in Figure 3. These are now discussed.

### COST EFFICIENCY

The indicators used to measure the benefit of a digital tower concept largely relate to efficiency. This includes both direct cost efficiency measures, and more qualitative measures like improved flexibility or availability.

Digital tower operations enable the provision of ATS from a facility and within a region that will provide the most efficient use of resources.

By managing staff more efficiently, and maximising the efficiency of future operational expenditures, potential savings can be achieved.

If operational modes enable resources to be shared between co-located airports within a digital tower centre, then further resource savings may be possible.

While digital towers introduce new equipment, operational cost savings can be realised by standardising the on-going maintenance process and co-locating the maintenance activities. This is possible by combining equipment into one facility and by using the same or similar system set ups for many airports.

There are significant capital expenditure savings to be gained by installing a digital tower at a new airport, including the savings associated with not building a physical tower. Significant money will also be saved in additional costs such as maintenance, equipment servicing and the additional cost of accommodating staff.

Centralising airport ATS is the primary way a digital tower implementation will provide cost benefits.

Implementing a digital tower provides a cost-efficient way to provide ATS to airports which do not currently have a control tower and are not provided with airport ATS.

### FLEXIBILITY, LEVEL OF SERVICE PROVISION AND AVAILABILITY

Digital towers enable a level of flexibility not currently achievable when operating from a more conventional tower. Decoupling the location of ATS provision from the airport has benefits to the ATS operators. This is especially true for airports located in areas with harsh climates or those with few or no amenities.



Figure 3 – Key Benefits of Digital Towers  
Credit: Think Research

## **FLEXIBILITY IN WHEN AN ATS IS PROVIDED (USER-FOCUSED SERVICE PROVISION)**

Operations from a digital tower provide the opportunity for ATS to be provided to an airport in a more flexible, traffic-oriented manner. The ability to adapt operational resources to suit demand is made easier if services are provided from a digital tower where resource may be shared between many airports. This makes it possible to provide a capacity-on-demand service to meet the needs of airspace users and the wider operation.

Small and regional airports with low traffic volumes often generate costs from permanent staffing and low staff utilisation. By using digital towers however, airports can ensure that staff are matched accordingly to traffic volumes without generating additional costs for low/no utilisation. This may require that the digital tower be in a central facility with other digital towers, thus providing the ability to share a resource pool.

ATS can also be more easily provided in hostile or other extreme environments where it would not be safe, easy, or possible to place controllers.

## **FLEXIBILITY OF WHERE AN ATS CAN BE PROVIDED TO OR FROM (REMOVING PHYSICAL RESTRICTIONS)**

Additionally, the physical construction of a digital tower is more flexible when compared to the constraints of constructing a conventional tower.

Several temporary airfields exist where air traffic services must be provided for a finite period, including mining or military operations. By moving the provision of this service to a centralised location, and pooling resources, cost is reduced and a flexible ATS can be provided as required.

Digital towers also provide more flexibility in the long-term when considering unpredictable or hard to foresee developments such as airport construction. New structures on airfields often obscure the view an operator has from a conventional tower. In such circumstances, the ability to simply raise the height of the digital tower platform, tilt the cameras or move the cameras altogether, represents a significantly more flexible option.

## **IMPROVED OPERATIONAL RESILIENCE**

The resilience of an airport operation is critically important. Operational resilience means having a way to avoid the cessation or reduction of airport ATS during adverse conditions which benefits passengers, ANSPs, airport operators, airlines, and the entire network.

Adverse meteorological and low visibility conditions often have a negative effect on traffic flow owing to the need to increase the spacing between aircraft. In such conditions, the use of digital tower technologies, including thermal cameras, additional cameras at operationally significant locations, and the integration of surveillance tracking to improve the visibility of the runways and manoeuvring area, may support operators and improve operational resilience. It is predicted that the use of such technologies could also lead to improvements in traffic flow and capacity. Currently, the use of digital tower technologies to change Low Visibility Procedures (LVP) minima or reduce separation is as yet untested, although evaluations are ongoing.



## IMPROVED CONTINGENCY AND CRISIS MANAGEMENT

The provision of a contingency airport ATS facility may enable airport ATS to continue in certain circumstances, including:

- The temporary planned or unplanned closure of the primary ATS facility (tower) due to system upgrades, technical failures, tower refurbishment, facility issues, or major building work
- An unplanned evacuation of the primary ATS facility (tower) such as fire or security alerts
- The provision of a service in hostile or dangerous environments
- Certain adverse meteorological and visibility conditions
- To help in crisis management

Airport ATS contingency is primarily provided through the provision of a backup facility. Digital tower technologies provide one means of providing this contingency to an airport.

The provision of digital tower solutions during a contingency can enable a high percentage of capacity to be maintained should the conventional tower become unserviceable. Currently, operational digital towers providing airport ATS contingency functions operate with the same traffic levels as in conventional towers.

The provision of a contingency digital tower facility can also provide additional resilience during times of crisis. The ability to run two parallel tower facilities (the conventional tower and the contingency digital tower) can help to provide additional flexibility to ANSPs. This has proven valuable during times of crisis or when other restrictions on operational resources are in place, such as to enable social distancing requirements during a pandemic.

## ENHANCED SERVICE DELIVERY AND PERFORMANCE

Digital towers enable the introduction of enhanced tool sets, including new and evolving technologies, such as enhanced radar overlays, improved interoperability with other agencies and airports, and improved data availability and visualisation. Such enhancements, enable more integration and automation, and may be used to improve service delivery in some environments.

## SAFETY

Implementing digital towers should not reduce the safety of the service being provided compared to conventional operations. This is a basic requirement of any change to ATS procedures or equipment.

Improvements to safety may be possible and are likely to be linked to the deployment of enhanced controller support tools. Such tools can enhance airport visibility and support controllers in detecting and resolving safety-critical situations. The ability to optimise the controller's view of the airport and its vicinity may also have operational safety benefits, including the removal of blind spots and improvements in the detection of runway incursion events. The inclusion of other enhanced features such as data information overlays and surveillance tracking can also have controller performance benefits in reducing workload and improving situational awareness.

The airport view displayed on the digital tower visual presentation can be recorded and stored for use in post-accident or near-incident analysis. This enhances the understanding of safety events and enables a faster response.

## CENTRALISATION OF SERVICES AND INFORMATION

Many countries have several remote, small or medium sized airports that are good candidates for consolidation into a centralised Remote Tower Centre (RTC) operation. The co-location of airports into a centralised facility is done by ANSPs to maximise the benefits of the concept. A RTC may appear similar to an ACC.

There are several benefits related to the establishment of a RTC, but also areas where careful consideration must be taken. It also provides the possibility of introducing the concept of multiple operations which is described below.

Smaller airports with legacy physical towers, whether it may be ATC or AFIS normally provide a single-person operation. Even with little traffic spread out through the day there is a single person staffing the tower.

Moving to a RTC will enhance the operation and the work situation for the ATCOs and AFISOs (the Operators).

- Social benefits: The Operators will be part of a work environment with colleagues present in the centre which will lead to a higher job satisfaction
- They will get immediate assistance in case of an incident or accident
- Improved cost management
- Staff efficiencies: It opens the possibility for endorsement to several airports that makes their work environment more interesting and the utilisation of the resources within the RTC more effective, especially with the introduction of multiple operations
- By working in a busier environment each Operator gains a better experience in his or her job performance, resulting in increased competence and know-how.
- Operational and technological standardisation: The RTC can provide a dynamic use of the resources so all RTMs may be similarly equipped and can be used with any airport. With this set-up, they will also be backup for each other and increase the availability of redundancy provision. It also opens the possibility to allow two RTMs to work with the same airport, either during handover or as a relief, e.g., by adding a ground or clearance delivery position.

Even without operating from a central facility, a digital tower is an enabler of improved data sharing. The ability to send and receive data to and from a digital tower provides a connection between the tower service and other services and functions such as airport operations centres, rescue services, approach services, enroute service or air traffic network management.

This exchange of digital information may help to improve knowledge and information sharing. In addition, operators and ANSPs may be able to present information in more innovative ways by using the visual presentation. Furthermore, data exchange increases collaboration and connectivity between stakeholders.

## STAKEHOLDER BENEFITS

ATCO, AFISO and air traffic safety electronics personnel (ATSEPs) are some of the main stakeholder groups to consider. Others include airlines, airport operators, airspace users, military, local communities, and the wider ATM network. Benefits to operators are illustrated in Figure 4, which is also an example of stakeholder engagement material.

# Digital towers – the value they bring to ATS Operators

## TODAY

- Transition to full contingency mode is done between 3-6 hours within conventional towers.
- Capacity maintained is typically up to 80%.
- Airfield view has a different perspective.



### Contingency



## FUTURE

- Contingency system transition is almost instantaneous.
- Capacity maintained can be up to 100%.
- Point-of-view of the airfield is similar to standard operations.

- View of airfield dependent on weather conditions.
- Relying on ground infrastructure to detect aircraft location.



### Low visibility



- Infrared camera technology to detect both cooperative and non-cooperative objects.
- Low light and poor visibility operations are improved.
- Automatic detection of objects that can pose a threat to safety.

- Controller primary tools are eyesight, surveillance data and flight strips.



### Situational Awareness



- Overlaying of airport information enables improved controller's situational awareness.
- Controllers can focus on core ATS tasks as a result of automation support systems.

- Binoculars are used within current ATC operation to zoom in on targeted objects.
- Aircraft are followed manually.



### Camera Zooming/Tracking



- Objects are automatically tracked by the pan-tilt-zoom cameras.
- Controllers workload is reduced and focus is on core operations.

- Staff is restricted to providing services in a flexible manner due to limited physical limitations.



### Competitive Threats



- Enabling additional services to be provided in a cost-effective way and for potentially increased duration.

- Multiple individual non-integrated information sources and tools used by controllers today.



### Airport Operations



- Integration of data which optimises the provision of ATS and has a direct impact on airport operations

Figure 4 – Mapping of Stakeholder Benefits

Credit: Think Research

## CHALLENGES

The challenges faced by digital tower programmes are specific to the operation and organisation. Some of the common types of challenges identified from the lessons of early adopters are discussed here and shown in Figure 5.

### STAKEHOLDER ACCEPTANCE

One of the main challenges for digital tower programmes is stakeholder acceptance. The environment of a digital tower is different from a conventional tower not only in terms of its configuration, tools, and systems but also in terms of workplace aesthetics and other aspects that may influence operator well-being and job satisfaction.

Operators may not initially be supportive of a transition to a digital tower if the proposed facility is not near to the airport, if the working environment, working position, and other tools represent a significant change or if ATCOs are reluctant to permanently relocate. It is therefore important for ANSPs to spend time assessing human impact and managing change.

The move to a digital tower can have a strong social impact. A well-known driver for implementation is cost efficiencies, and as such, stakeholders can often associate the concept with future reductions in the workforce and changes to roles and responsibilities.

Irrespective of the proposed implementation and related resource plan, the ANSP will need to ensure early and clear engagement with operators regarding the change if they wish to improve stakeholder acceptance. Early adopters of digital towers have used various mechanisms to improve stakeholder acceptance, including:

- Attempting to maximise similarity in controller working position configuration
- Attempting to reduce change to roles and responsibilities
- Communicating key implementation decisions clearly and quickly
- Ensuring the operational acceptance of users is considered via validation exercises, familiarisation events etc., and that feedback is proactively considered.

Further information relating to change management is provided later in this document.

### REGULATORY APPROVAL

Digital towers are customised products for which limited standards are available – currently only ED-240A Change 1. The uniqueness of each solution presents a regulatory challenge.

Manufacturers and ANSPs need to ensure compliance with existing regulatory requirements without following specific technical and service specifications for the application of remote and digital airport ATS. Instead, as with any change to an ATM system or procedure, validation and safety assessments are the primary means of assessing fitness for purpose and gaining regulatory approval. There are clear and fixed requirements in the European Union under EASA on, for example, safety assessment of changes to an ATS 'functional system' through Regulation (EU) 2017/373. However, there are no specific requirements or methods related to digital towers since there is no need for these to exist. Regulation 2017/373 applies regardless of conventional or remote operations. In addition, the current speed at which the regulatory framework is changed may also be taken into consideration during

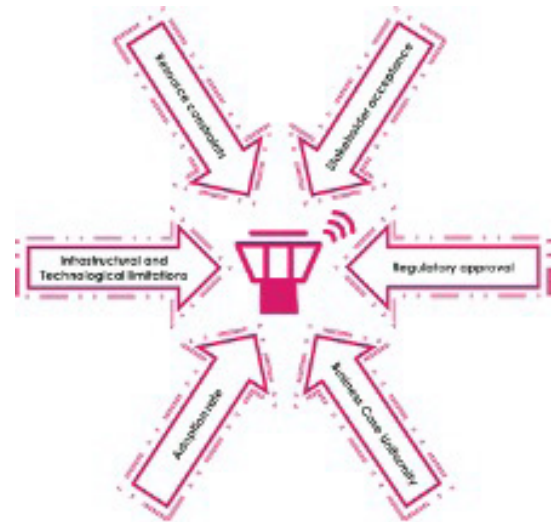


Figure 5 – Key Challenges Faced by Digital Towers  
Credit: Think Research

an approval process. Enough flexibility should be given to include regulatory framework updates within contracts between ANSPs and suppliers, this includes changes to those processes applied.

However, there is extensive regulatory guidance provided to support the application of Regulation 2017/373 in the remote ATS context in the form of the EASA remote airport ATS GM Issue 2 (Feb 2019)<sup>3</sup>.

This has created an environment of standalone case studies that have demonstrated compliance and satisfied national regulators in different ways.

During set-up phase of a project, a regulatory framework run-through is an example of how stakeholders can clarify challenges in regard to how regulations should be interpreted.

Regulators are working to provide updates to regulations and produced guidance materials to increase interoperability and harmonisation. A regulatory outlook is provided later in this document.

## **BUSINESS CASE, UNIFORMITY AND ADOPTION RATE**

Despite the cost-efficiencies offered by transitioning to a digital tower environment, making a case which provides clear evidence to decision makers on whether to implement digital towers is still more difficult than expected. One reason the business case can be hard to define is because the cost of entry is still high, even though the long-term return is significant and transformational. This is due to the slow global adoption rate to-date and a lack of standardisation and uniformity in the associated technologies.

Currently, digital towers require customised systems based on ANSP requirements. This customisation can increase costs. Although many of the component technologies applied within a digital tower are commercial-off-the-shelf (COTS) products, when combined for use in the provision of ATS, cost and complexity increase. There is also a need to invest in infrastructure which may not previously exist at the desired site. This includes the local and wide area networks, cyber security, and the provision of sufficient redundancy systems.

A lack of standards and prescriptive specifications means that validation, concept development, safety and human performance activities are required to ensure the deployed digital tower is fit for purpose. The maturity of the solution, at each stage, will be determined by stakeholders (national regulation, ANSP and operator's acceptance). The process to mature the



digital tower concept for a specific implementation can be costly and complex. This cost includes the need for involving operators throughout the implementation process and is also dependent on the duration of the overall project and its vulnerability to potential delays.

Improvements to the standardisation of the approval process will come naturally. However, since the primary benefits of digital towers come from solutions to problems that are unique to each specific operation, it is likely that tailored assessments will always be required.

## **INFRASTRUCTURAL AND TECHNOLOGICAL LIMITATIONS**

Technical limitations are apparent in some implementations. The custom nature of implementations means such limitations are best discussed within each specific case study.

## **RESOURCE CONSTRAINTS**

Pre-implementation activities require operational resources and ensuring these resources are available is often a challenge. The experiences of early adopters showed there are benefits to ensuring operational resources used to validate digital tower concepts have the correct ratings and a level of experience that enables them to be representative of the wider operator population.

Early adopters have also tended to enlist a 'core team' to support in the early activities when the concept is less mature. This is thought to improve acceptance. The core team can help to ensure that early development issues are resolved. Time can be invested into working with the core team to understand feedback and work proactively with the manufacturers to make updates to technology builds. The use of a core team may also improve the acceptance of the wider operator population as the rationale for the specific configuration of technologies can be discussed operator-to-operator, without the solution being seen to come from a purely business, engineering, or managerial level.

## **REMOTE TOWER CENTRE INTERDEPENDENCIES**

When bringing the service to multiple airports into the same centre, there are several considerations to keep in mind. In general, the ANSP should consider the impact of losing the service from the RTC for a shorter or longer period.

The RTC will handle multiple airports, and the impact of any occurrence that might render the RTC out of service needs to be investigated e.g., a fire, a power outage, sabotage, etc. A separate analysis must be made to determine the impact on such events. This may result in the need for a contingency RTC located away from the main RTC. The contingency RTC could also be used for training and simulation activities.

The RTC can be located quite a distance from the airports, and the network between the RTC and the airports need to be considered carefully. Aspects such as bandwidth, latency and redundancy are often issues that may be difficult.

Depending on the number of airports and RTMs in the RTC, the introduction of a supervisor role should be assessed. The Supervisor role in a remote tower centre is a new role. While the responsibilities of the RTC supervisor are yet to be fully defined, on-going trials and validations suggest the role will provide tactical and strategic support such as airports allocation to RTMs, consolidation / deconsolidation of airports, and resource planning.

## **MULTIPLE AIRPORT OPERATIONS IN REMOTE TOWER CENTRES**

When operating from an RTC which allows for the dynamic allocation of airport to RTMs, there will be periods with low traffic load on each airport. It may be feasible to assign multiple airports to the same Operator while still maintaining the required safety and workload levels. Operational validations within the context of SESAR have shown that the concept is reaching an acceptable maturity level.

When defining an operational concept for multiple operations, the ANSP needs to consider carefully which airports are suitable to be clustered and operated together. For example, combining airports with the same runway designator may cause confusion when operating these airports together.

Before implementing a multiple airport RTC operation, all areas of potential confusion on the operator and pilot side also need to be analysed. This includes the design of the HMI and related functionalities, and an analysis of how the system behaves when adding and removing airports from the RTM. It should be possible to do this while maintaining operations on the other airports allocated to the respective RTM.

The assistance of a supervisor becomes more important in a multiple operations scenario. The supervisor should have tools to predict traffic load for the various airports, as well as other factors that may affect operators' workload, e.g., weather changes. By using a "what-if" tool, the supervisor will be able to analyse the effect different airport combinations on the workload. This will allow the supervisor to assess when and how airports should be added to or removed from a RTM.

Voice communication procedures should be carefully planned for multiple operations. Early use cases have demonstrated that it is important for an operator to include the airport name when giving critical clearances. It is also recommended that tower frequencies of the clustered airports are coupled in the Voice Communication System (VCS) to avoid making the operator switch between the airports. This also helps avoid simultaneous transmissions between the airports.

ANSPs are showing an increasing interest in the multiple operations concept, and we will undoubtedly see the concept in operation soon.

# WHEN TO IMPLEMENT DIGITAL TOWERS?

## EVENTS INITIATING THE MOVE TO DIGITAL TOWERS

Various events can lead an ANSP to start a digital tower programme, and some of these initiation events are in Figure 6.

The initiation events are often decision points for assessing costs and benefits, where the option to implement a digital tower solution is assessed against other options. These can include, for example, when an airport expansion could introduce a blind spot from the tower, one option would be to adapt the expansion plans to remove or reduce those blind spots.

The implementation strategy that an ANSP then uses will be influenced by what has initiated the programme. For example, the project drivers will influence the location of the digital tower facility, the operational modes used for each airport, the level of benefits that may be achievable, and which technologies may be required.

# HOW DO I GET STARTED WITH DIGITAL TOWERS?

Getting started with a digital tower programme can be daunting in an environment where there is no firm framework for implementation and a constant spotlight on the concept. Here we'll discuss some important aspects to understand and consider before getting started. These include:

- An outlook on the status of regulatory consultations and updates to standards pertaining to remote or digital airport ATS. A focus is given to Europe as EASA has one of the most mature outlooks owing to European research and development and implementation activities.
- Aspects to consider when seeking operational approval are briefly outlined, including, safety assurance, human factors, validation, recording of data, licensing, and training.
- Other business aspects that are important to consider are also discussed, including facilities to locate a digital tower, security, ownership, change management and transition.



Figure 6 – Example of Reasons to Initiate Digital Tower implementation

Credit: Think Research



## REGULATORY AND STANDARDISATION OUTLOOK

The following regulatory outlook is current to Spring 2023.

### INTERNATIONAL CIVIL AVIATION ORGANISATION – ICAO

The ICAO Air Traffic Management Operations Panel (ATMOPSP) developed proposed amendments to Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc. 4444) to facilitate the provision of remote airport control service and the envisaged supporting technology. This amendment was introduced in ICAO PANS-ATM Doc. 4444 by Amendment 8, in force since 8 November 2018, thereby fully enabling remote airport ATS in the ICAO context.

The amendments include:

- A new definition for ‘visual surveillance system’
- A new chapter 7.1.1.2.1; stating that visual observation can be achieved through direct out-of-the-window observation or through indirect observation using a visual surveillance system
- A new ‘Note’ to the chapter, referring to the EASA Guidance Material (see below), to provide guidance on the subject at global level

Following this, based on several requests from States as well as umbrella and representative organisations, the ICAO ATMOPSP reinitiated its Remote ATS Sub-group in mid-2019, for the development of ICAO specific guidelines, potentially in the form of a dedicated ICAO Manual on remote airport ATS. The guidelines will be aligned with the EASA material and will then replace the current existing reference in *ICAO Doc. 4444* to the *EASA Guidance Material*.

In parallel to this activity, ICAO, through its ATS Planning Manual Sub-Group, is working on a long-sought update of the ATS Planning Manual (Doc. 9426), which is planned to also include a dedicated chapter on remote airport ATS.

### EUROPEAN UNION AVIATION SAFETY AGENCY – EASA

EASA established rulemaking task RMT.0624 (‘Technical requirements for the provision of remote airport air traffic services’) in 2014, to develop a regulatory framework and guidance for remote tower operations/remote airport ATS.

Following the first phase of RMT.0624, EASA published ‘Guidance Material on the implementation of the remote tower concept for single mode of operation’ – Issue 1 (EASA ED Decision 2015/014/R), focusing primarily on operations for ‘low density airports’, as well as ‘Requirements on Air Traffic Controller licensing regarding remote tower operations’ (EASA ED Decision 2015/015/R), in July 2015.

Following a second phase of RMT.0624, EASA issued ‘Guidance Material on remote airport air traffic services’ – Issue 2 and Acceptable Means of Compliance and Guidance Materials (AMC & GM) to Part ATCO’ — Issue 1, Amendment 2 (EASA ED Decision 2019/004/R), in February 2019, replacing the previously published 2015 EASA guidance. This updated guidance took into consideration the continued evolution of the concept and the latest experiences gained from R&D activities (e.g., all the SESAR 1 validation activities and solutions) and initial implementations throughout the EU and US. It was also extended in scope to cover the full concept of remote airport ATS (not limited to ‘single mode’ and ‘low density airports’) addressing also more complex operational contexts and applications, such as:

- The simultaneous provision of ATS to more than one airport (multiple mode of operation)
- The provision of ATS to larger airports
- The use of a remote tower as a backup facility for conventional towers
- Operations supported by new technical enablers which have traditionally not been available for airport ATS

A third phase of RMT.0624 commenced in 2020. This phase was driven by multiple goals including, maintaining the currency of the EASA regulatory material with the continued evolution of the remote tower concept and any future technological and operational developments; maintaining alignment of the material with the developments of the general EU ATM/ANS regulatory framework; and to evolve the existing material concerning some specific aspects, such as; cyber security, third-party communication, human factors and performance related to the new technology. EASA released a Notice of Proposed Amendment (NPA) for public consultation prior to publishing the updated material expected in 2023.

## EUROPEAN ORGANISATION FOR CIVIL AVIATION EQUIPMENT – EUROCAE

EUROCAE Working Group 100 (WG-100), dealing with “remote and virtual towers”, published the initial version of ED-240, ‘Minimum Aviation System Performance Specification for Remote Tower Optical Systems’, in September 2016, specifying the end-to-end performance for an optical (camera) system used for airport ATS. This first version did not consider any augmentation functions or sensors other than cameras.

A second version – ED-240A – was published in October 2018 which included performance requirements related to visual tracking augmentation/functionality.

A third version – ED-240A Change 1 – was published in September 2021 which included an update with respect to the optional integration of Non-Optical Sensors.

A fourth version – ED-240B – will include performance requirements related to the incorporation of information from non-optical surveillance systems/sensors. The document is currently undergoing public consultation and is expected to be published in the second half of 2023.

The requirements set forth by ED-240A Ch.1/ED-240B are applicable regardless of Single or Multiple mode of operation.

## APPROVAL AND ACCEPTANCE ASPECTS

### VALIDATION

Validation is the iterative process by which the fitness-for-purpose of a new system or operational concept being developed is established and as such, meets the needs of the user.

The European Operational Concept Validation Methodology (E-OCVM) established the framework that provides a common structure for what is required to perform validation.

The E-OCVM also describes a series of cases that can be produced to document evidence, for a digital tower concept this will likely include the following standard cases:

- Human performance
- Safety
- Business
- Environmental (may not be required, depending on specific operations)

Validation activities and their outputs should be structured to provide evidence for these cases.

To date, the validation of digital tower concepts has largely relied on shadow mode and real time simulation techniques to provide validation evidence.

Shadow mode validation is a technique which involves the provision of live operational data. This data is shown on the digital tower systems in parallel to the current operational systems.

- In passive shadow mode, operators have no interaction with the live data and the digital tower systems are non-interfering with the real-life operations
- In active shadow mode, the digital tower system and current systems are run in parallel, enabling operational users to contribute to live operations more actively
- In advanced, or 'hot' shadow mode, the digital tower is used to actively provide airport ATS with the current operational systems running in parallel as a fallback

In addition to shadow mode techniques, real time simulations have been used to validate digital tower concepts that are at earlier concept maturity stages. Such validation techniques use synthetic visual presentations. This may limit the ability for operators to assess the capability of any digital tower visual sensor presentations to meet their operational requirements. This technique can however aid in the development of technical enablers, CWP layouts, operating procedures and to provide an initial assessment of feasibility and operating methods.

Both live trials and real time simulation validation methods can be expensive so it is recommended that sufficient time is put into setting out a validation strategy, defining specific validation aims and ensuring the correct operational resources are used.

## SAFETY ASSURANCE

The implementation of remote airport ATS is a change to the functional system and, as such, it does not require any specific safety assessment methodology. The applicable safety assessment requirements are laid down in Regulation (EU) 2017/373 (which replaced the previously applicable Regulations (EU) 1034/2011 (oversight) and 1035/2011 (service provision) as of 2 January 2020).

The overall purpose of the safety work is to provide assurance to, firstly the ANSP, and secondly the competent authority, that the use of a digital towers will be acceptably safe in ATM operations. The assurance is documented and presented in the form of a Safety Case. The documented assurance should include an adequate and credible argument regarding the safety of the intended implementation and the evidence to support it.

It should also be stressed that under the current form of the approval process, providing ATS is a service that relies on others such as, CNS-services and services from the airport operator. In this regard, this reliance on other services should be considered within the functional change and also what the exact boundaries of a change may be.

European guidance material states the remote tower concept for the implementation of single mode operations does not require any specific safety assessment methodology. All ANSPs shall use their own safety assessment methodologies as accepted by the corresponding competent authority.

The safety assessment should cover both the new and existing elements of the functional system affected by the change. The assessment should also review interfaces and dependencies of the system, and the environments to which remote or digital airport ATS are to be implemented. Risks should be assessed in line with the ANSPs own safety management systems and lowered to a level deemed to be as low as reasonably practicable.

Hazard analysis should include the identification of any changes in the probability of occurrence of any operational hazards and identify those hazards at functional levels corresponding to the main functionality identified in the digital tower. Guidance stipulates a hazard analysis should include, but not be limited to, partial or total loss of any function, and the possibility of erroneous, corrupted, or delayed data.

An analysis of the specific impacts and effects of identified hazards should also be included within the safety assessment. These should ensure the effects in the specific operational environment are understood and the hazards are classified by severity. The assessment should be conducted under both normal and abnormal conditions.

Safety criteria and safety requirements shall be defined stipulating the requirements to ensure that the level of safety is the same as in current conventional towers. A list of operational hazards for safety assessment can be found in Annex I (one) to EASA ED Decision 2019/004/R.

## HUMAN FACTORS

When implementing a digital tower, a human performance assessment is recommended since the concept has a direct influence on the capability of operators to accomplish their tasks. Identifying and managing any human factors (HF) implications is important in ensuring a safe transition and may help to increase the likelihood of stakeholder acceptance.

HF assessments are developed to help assess the nature and the impact of a change on operators. Constructs that can be measured with this technique include:

HUMAN FACTORS MEASURES	
<b>Mental Workload</b>	The amount of work (effort) that someone must deliver to get a certain task done.
<b>Stress</b>	A psychological experience of distress and anxiety.
<b>Fatigue</b>	Being chronically tired due to task load in relation to the amount of rest that one has experienced.
<b>Attention</b>	Focus, and the opposite distraction, are the base for situational awareness
<b>Situational Awareness</b>	Being aware of everything that is relevant for task execution and being able to understand how a situation will develop.
<b>Operator Acceptance and Trust</b>	Confidence and belief of operators in a new system or operation.
<b>HMI Design</b>	The Human Machine Interface, or the hardware panels, displays, lines of sight, the software, procedures, etc. are ideally designed in such a way that they are adjusted to human standards and capabilities.
<b>Attitude Towards a Change</b>	It is of utmost importance that operators support a planned change to ensure a smooth introduction of this change. Change in this context can vary from new hardware (or software), new operating procedures, to anything different that influences how an operator executes his or her work.
<b>Efficiency</b>	The amount of work they can process in a certain amount of time and with a certain number of tools. Aspects of this phenomenon relate clearly to human factors.
<b>Human Error</b>	The number of mistakes that a person will make, or the likelihood that a person will make mistakes is something that can be assessed. When combined with the severity of the error this information can be relevant for safety assessments.

Table 1 – Relevant HF constructs

Several HF measurement techniques exist but they are often split into three main categories: bio-behavioural, subjective and performance measures. Each of those may contribute a new perspective. Ideally, a mixture of measurement techniques should be applied to fully understand all HF aspects of a certain change.

### **BIO-BEHAVIOURAL**

- **ElectroCardioGraphy (ECG)**

Can measure heart rate and variability of heart rate as an indicator of mental workload or stress. Modern wearables make it easier to measure ECG in a non-intrusive manner

- **Galvanic Skin Response (GSR)**

Can measure changes in sweat gland activity as a result of emotional arousal which is also related to stress, mental workload and situational awareness

- **Eye tracking**

Can measure several variables including attention, distraction, fatigue, and visual or mental workload

- **ElectroEncephaloGraphy (EEG)**

Can measure brainwaves as an indication of attention, fatigue, or concentration

### **SUBJECTIVE**

Questionnaires, rating scales and interviews are all instruments that can measure how operators subjectively perceive a situation. Note that validated scales often give more opportunities to compare between situations when formulating questionnaires and structuring interviews, numerous methods and approaches exist which are not all described in this section.

### **PERFORMANCE**

There are multiple ways to quantitatively assess an operator's actions and performance. For example, computer system outputs from inside the tower or from a training simulator can be used. Different variables may also be used to measure the amount of traffic, the number of tasks an operator is trying to accomplish, operational errors or the operators reaction time.

The HF domain comprises a broad range of areas which can be found in Annex I (one) to EASA ED Decision 2019/004/R recommended for consideration and assessments when implementing a digital tower:

- Human-Machine Integration and system
- Working environment
- Procedures and working methods
- Organisation and human-human interaction
- Transition factors (competencies, training, acceptance of the new working environment)

Additional details on the Human Factors elements to be considered can be found in Chapter 6.2 of the source document<sup>3</sup>. Assessing the performance of increased technological complexity is important and requires consideration of different HF aspects including technical and technological elements, human factor elements and procedural elements.

## DATA CAPTURE AND RECORDING

For the purposes of accident investigation, data presented to operators while they are providing airport ATS from the digital tower facility should be automatically recorded and retained. It may also be required to record data at the source or sensor. The following ICAO provisions should be referred to regarding the recording and retention of ATS data:

- ICAO should be referred to for voice and data recording requirements, specifically ICAO Annex 11, Chapter 6 which specifies recording requirements for aeronautical mobile service, aeronautical fixed service, surface movement control service and aeronautical radio navigation service
- ICAO Doc. 4444, Chapter 7.1.1.2.1 clarifies that, 'For the purposes of automatic recording of visual surveillance system data, Annex 11, 6.4.1 applies.

To ensure all the visual data presented is recorded, consideration should be given to the various visual components including, separate visual displays and tools such as binocular functions. EASA GMs section 5.6 can be referred to for further details.

Currently ICAO does not stipulate the recording and retention of background airport sounds provided to operators.

Such audio information may be provided in some digital tower facilities. Where provided, recording of audio data should be considered. EASA GM<sup>3</sup> recommends the inclusion of airport sound in the data recording. Audio information may be of greater importance to operators when providing airport ATS to smaller/lower density airfields as the operators may use audio cues to aid situational awareness.

## LICENSING AND TRAINING OF OPERATORS

Operators providing an airport ATS from a digital tower will be required to hold adequate licenses and ratings/endorsements for the airports they are providing a service to.

For some implementations, supervisory roles may be required. The roles and responsibilities of a RTC supervisor overlap with those of a supervisor in a conventional tower with the addition of responsibilities resulting from the need to coordinate many different airports and provide an oversight role.

Refer to regulation (EU) 2015/340 (and specially Annex II to ED Decision 2019/004/R) for the AMC and GM which are relevant for remote airport ATS.

Training requirements for ATCOs are stipulated within regulation (EU) 2015/340 with further guidance outlined in EASA GM (Issue 2, Feb 2019), Chapter 10.

Regulation (EU) 2015/340 GM3 ATCO.D.060(C) states that training should enable ATCOs providing airport ATS from a remote tower, "to acquire knowledge of the concept of remote airport ATS and of the characteristics of the operating environment, to appreciate the necessity to consider the specific human factors influence on the remote airport air traffic services, as well as to recognise specific abnormal situations and to manage their impact". Specific training topics are outlined within the regulation.

Additionally, EASA GM (Issue 2, Feb 2019), Chapter 10 states that the guidance provided by regulation (EU) 2015/340 should also apply to AFISOs providing airport ATS from a remote tower, although currently the regulation is only applicable to ATCOs.

ANSPs are also advised to consider the qualifications and training of ATSEPs involved in digital tower operations.

## BUSINESS ASPECTS

### DIGITAL TOWER FACILITIES

A key consideration for a digital tower facility or RTC is the configuration and technical equipage of that facility or tower. The requirements for the CWP, technical support tools, layouts, number of operators and other factors should be assessed on a case-by-case basis.

If a digital tower facility or RTC is used to house more than one digital tower, ANSPs may wish to consider the level of commonality or standardisation between the solutions.

For a large-scale digital tower or RTC, fully harmonised facilities would provide efficiencies. This would include a fully harmonised CWP or module (RTM), facilitating integrated training, the ability for operators to hold multiple endorsements, and hence to be rostered/scheduled more flexibly, and to unify maintenance and support capabilities. The nature of any interactions between the solutions for each airport – in terms of using the same resource pool and sharing other infrastructure – will also need to be considered.

Sharing such resources can provide economic benefits and enhance the flexibility of the relevant operations. The standardisation of digital towers within a single facility would maximise these benefits. However, standardisation of the digital tower solutions may not be desired or may be difficult to achieve owing to differences with each airport – which may each have specific requirements. For example, when technical solutions provided need to be customised. However, when standardised solutions are not desired or required, benefits may still be gleaned from providing ATS from a single shared digital tower facility or RTC because many different concept applications can be applied within one digital tower facility or RTC.

Airports with complex and/or higher density traffic are less likely to be provided with a standardised digital tower solution. However, such airports may still benefit from improved financial stability after receiving such a tailored and dedicate digital tower solution.

Centralising multiple airports into one digital tower facility (like an RTC), where RTMs and resources can be shared may provide an improved business case for implementing a digital tower solution. This is especially true for lower density airports that may not be able to financially support their own, dedicated Digital Tower solution.

### LOCATING A DIGITAL TOWER FACILITY

#### ***ON AIRPORT SITE***

One possible location of a digital tower is on the site of an airport. Depending on the mode of operation being applied within the digital tower, the airport where the facility is located may also be provided with digital tower airport ATS. Alternatively, a large airport may host a digital tower which is used to provide airport ATS for other, smaller airports in the vicinity. Locating the digital tower or RTC at the airport can offer several operational advantages.

The benefits of locating a digital tower on an airport site include:

- To provide proximity to existing resources (controllers and support staff)
- Mitigate security issues that may surround an offsite facility
- Mitigate resistance to change, by improving acceptance by controllers and support staff
- Ease planning permissions and approvals if the facility is provided on land that is already owned by stakeholders

## **OFF AIRPORT SITE**

One of the major potential benefits of using a digital tower solution is that the ANSP or airport operator is free to locate the new facility anywhere they choose, including at sites that are physically removed from an existing airport. Locating a digital tower facility outside of an airport may:

- Bring about unique physical security considerations
- Make relocating staff initially more problematic, yet in the long-term provide benefits as new staff may be more easily sourced when trying to staff airports based in remote communities
- Remove complications regarding the long-term future of the digital tower facility that could result from divisions or ownership changes within an ANSP or the airport operator

## **DIGITAL TOWER OWNERSHIP**

The business case and nature of a digital tower facility may be influenced by its ownership e.g., an airport operator, ANSP or local authority (such a state, local principality or similar).

If an airport group owns a digital tower facility, then the number of airports within that group needs to be considered. If only one airport is owned then the full benefits of sharing a centralised facility may be lost, unless outside airports are brought in. If several airports are owned, then the operational feasibility of applying digital tower concepts to each individual airport and the group need to be considered as this may influence the modes of operation that are feasible and as such, influence the technical solution.

The type of owner will also influence the nature of the airports connected. For example, a supplier or ANSP owned digital tower facility may be able to connect to airports covering a larger geographic region, and this may influence the ability to centralise resources. An airport owned digital tower facility may include airports which are provided with airport ATS by a variety of different ANSPs, and this would impact the ability to share resources and may add a layer of operational complexity.

The owner of the digital tower facility will also influence its location; primarily if the facility is collocated at an airport.

## **CYBER SECURITY**

From a cyber security perspective, it is necessary to consider additional threats related to the introduction of a ground-ground network between the sensors and ATS equipment. This includes potential threats to the sensors, to the ATS equipment and the network itself – which could include reduced performance due to a large-scale Denial of Service (DoS) attack on an organisation sharing the network.

The following should be referred to for information and guidance on cyber security in relation to the provision of an air traffic service:

- CANSO Cyber Security and Risk Assessment Guide from June 2014
- EASA remote tower guidance material · ICAO doc. 9985, ATM Security Manual, 1st Ed. (Restricted)
- ICAO doc. 8973, Aviation Security Manual, 8th Ed. (Restricted)
- ICAO Aviation Cybersecurity Strategy, October 2019
- European Strategic Coordination Platform Strategy for Cybersecurity in Aviation, September 2019
- Process Standard for ATM/CNS ground system security aspects for certification/declaration, ED-205, March 2019
- ISO27000 family of standards

Regulatory requirements for aviation cyber security are still catching up with new digital technologies including digital towers. Strategies for aviation cyber security have been published



by international and European bodies [ICAO Aviation Cybersecurity Strategy, October 2019 and European Strategic Coordination Platform Strategy for Cybersecurity in Aviation, September 2019]. These make clear that a coordinated national response is required, including requirements for protection of critical national infrastructure, which may include a coordinating body or computer emergency response team (CERT). For example, in Europe, EUROCONTROL has established EATM-CERT to help protect the European ATM network.

A basic framework for approval of ground systems from a cyber security perspective has been established in Europe as EUROCAE ED-205 [Process Standard for ATM/CNS ground system security aspects for certification/declaration, ED-205, March 2019] which draws heavily on the ICAO material and the ISO27000 family of standards.

## **PHYSICAL SECURITY**

Aviation Security requirements are defined by ICAO Annex 17 (Security) and the associated guidance provided in Aviation Security Manual (Doc. 8973 – Restricted). From a physical security perspective, the existing requirements apply to both the physical location that ATS is provided from and the sensor sites. No additional requirements are anticipated.

## **AIRPORT EQUIPMENT MAINTENANCE**

Maintenance of the airport's on-site infrastructure needs to be considered and a maintenance schedule or on-site technical support may be required.

The visual sensors based at the airport (i.e., camera sensors) will always need to provide a clear visual image and this may require self-cleaning mechanisms. Rotating lenses, lens wipers and compressed air can provide solutions to removing residue and other obstructions like sand.

Operating in extreme high or low temperatures will also need to be considered when procuring digital tower systems for some environments.

## PEOPLE CHANGE MANAGEMENT

Change management is an open-ended process of managing the people-side of a change with the use of processes, tools, and techniques. Change management is an organisation, or case-specific process that incorporates the planning, management, and reinforcement of change. Good change management is critical for the successful adaptation by stakeholders to the change which accompanies the move to a remote or digital airport ATS.

EASA GMS<sup>3</sup> introduce key change management considerations and recommendations for airport operators.

A transition plan outlines how the operation will make the switch from the current operation to the digital tower. It will have added value if it covers the time-period from pre-implementation (activities such as training and validation), through the transition into live operations.

The transition plan can be integrated with change management plans to ensure the plan is clearly communicated to controllers and other affected stakeholders.

The following key stakeholders are important to consider in terms of the effect to them:

- Airports
- Airlines
- Military
- Technical support staff and engineers
- Operational support staff
- Airspace users and general aviation
- Local communities
- The wider network

## CONSIDERATIONS FOR LARGE, COMPLEX AIRPORTS

Larger airports may require more complex digital tower solutions to fulfil user requirements because integration with additional sensors, such as advanced surface movement guidance and control system (A-SMGCS) and collaborative decision making (CDM) systems may be necessary. Additionally, owing to physically larger areas, additional and specifically placed cameras (e.g., for hotspots) may be required. Larger airports with multiple runways may also wish to consider more innovative visual presentation layouts to better accommodate the different operational roles and responsibilities. This may include many solutions, for example, individual RTMs supported with a common 'video wall'. Such a solution would provide common situational awareness while allowing individual operators the opportunity to customise their operational view to suit their needs.

When working in an environment with many different working positions and operators, it may be necessary to duplicate some of the technologies (e.g., magnification functionality), to ensure operators can independently operate these support tools when required. Specific working methods should be developed for the control and operation of support tools in a digital tower when shared between operators.

### OTHER CONSIDERATIONS

Depending on the precise technical configuration of the digital tower solution, the move to using screens and digital information provides the opportunity to train, validate and simulate using the same working position as used to provide live operations. This may improve the flexibility of training schedules and make it easier to validate concept or technology changes. The flexible use of digital tower solutions for other purposes may improve the implementation business case.



Figure 7 – High-level change management steps  
Credit: Think Research

## LIFECYCLE MANAGEMENT

Since digital tower projects are complex change projects, an active life cycle management process is necessary starting in the pre-tender-phase of a project.

### EVALUATING NEEDS AND DEFINING REQUIREMENTS

All necessary stakeholders should be involved in the process of evaluating needs and defining system requirements from an early stage. This is important to generate early buy-in of all stakeholders, especially the air traffic controllers. Since it is very hard to define the exact requirements for an entirely new system, the technical requirements should not be too detailed. Instead, more operational requirements should be defined, explaining what the users want to do operationally with the system. If done in this manner, suppliers will have more freedom and can explain how the requirement is fulfilled with their system when responding to the tender.



Figure 8 – Lifecycle management steps  
Credit: Think Research

### INITIAL FEASIBILITY ANALYSIS

An initial feasibility study is a pre-requisite for a well-structured project. It is essential to identify what is needed, what is possible, and what potential showstoppers are from the very beginning of the project to mitigate the risk of failure. Different aspects and elements of a RTC project are analysed, evaluated, and considered such as the current mode of operation, airport layout, technical systems, and the later overall use case. Workshops with the end-users are typically executed in this phase. Prototyping tools can provide support at this stage and experienced consultants can be involved to ask the right questions and to support the analysis. In the end, the feasibility study is a document providing an overview that can help you determine if a remote or digital tower solution for a desired use case make sense and is feasible from an operational and technical point of view.

### DESIGN, IMPLEMENTATION, AND TESTING

In modern digital tower projects, the implementation is realised in iterative steps. This approach provides the following advantages compared to traditional water-fall approaches:

- A high level of end-user buy-in, by involving all stakeholders at an early stage
- Immediate feedback after each iteration
- Quicker implementation time
- Less project risks

The regulator should already be involved at the implementation stage, so they have a good understanding of how the final system should fulfil the operational requirements and needs.

## APPROVAL AND CERTIFICATION

If the regulator was involved from the beginning of the project, then the approval and certification phase can be rather short. A tracing/tracking tool can save a lot of time to prove that all operational requirements are fulfilled by the system and the concept of operations.

The supplier supports the ANSP with various documents to create the safety case and other documents for the regulatory approval.

## MAINTENANCE AND UPDATES

Most of every digital tower system consists of COTS hardware like processing servers and CWP workstations. PC hardware has a typical life cycle of 5 to 7 years. In addition, camera technologies evolve very quickly and every 3-5 years, a new generation of cameras is introduced. Typically, the new camera generation outperforms the previous one in detection and recognition performance, which is beneficial to the ATCOs.

Since these components typically work in an IT environment of the ANSP, they are vulnerable to cyber security attacks. To minimise the risk of an attack, the operating system, and other software components must be kept up-to-date. Also, the support period for COTS software components like the operating systems or different software libraries is limited to a few years. Critical vulnerabilities are not fixed after the end of support date. All these circumstances make it mandatory to regularly upgrade hardware and software.

Since a typical life cycle of a digital tower installation should cover 15+ years, the hardware must be replaced 2 to 3 times in this time span and the software even more often. Therefore, traditional life cycle concepts no longer work with digital tower concepts.

The evergreen life cycle concept is the solution to keep remote towers secure and therefore safe.

To keep software secure, operating systems and software components should be upgraded frequently. If a critical vulnerability is detected however, the software may need to be updated sooner to close the security gap. Therefore, a safety and security process should be applied which regularly evaluates the overall system for vulnerabilities. Based on the results of those evaluations, the ANSP can decide if immediate action (through a patch update) is required or if the issue can be fixed during the next upgrade cycle.

Considering the additional effort (testing, documentation, etc.), which comes with software upgrades and patches, the ANSP must think about a smart life cycle and maintenance concept to keep the system secure and safe, while keeping the costs under control.

If the maintenance concept is not well-planned by the ANSP, the additional costs on the ANSP side can easily exceed the system costs. Therefore, it is essential for the ANSP to select a digital tower supplier, which has a proper maintenance concept in place. Various tools, which are integrated into the digital tower system can dramatically reduce the maintenance costs for the ANSP.

Software architecture also plays an important role in keeping software secure and costs low. An open and modular software architecture enables you to safely integrate new features and future camera



Figure 9 – Traditional vs Evergreen lifecycle concept  
Credit: Frequentis

technologies. This secures the ANSPs investment and ensures the digital tower system can remain technically relevant over 15+ years.

Moreover, an open and modular software architecture allows suppliers to provide different feature sets to different customers. The different feature sets can be configured without changing the software source code. With this concept, the following important goals are achieved:

- Customer software does not branch or forks, which reduced costs to maintain such connections
- Basic software maintenance costs are split between all customers of the supplier
- Increased security and safety due to centralised software assurance and testing
- The life cycle costs for the ANSP over 15+ years is much higher than the initial investment costs for the remote tower system. A good life cycle management and maintenance concept can therefore have a significant impact on operating costs and on the total cost of ownership. The life cycle costs must be considered when developing the business case because they can make a difference between a positive or negative business case.

# DIGITAL TOWERS: A VIEW THROUGH CASE STUDIES

Case studies have been provided by ANSPs to showcase their individual digital tower implementations.

The case studies have been selected to emphasise the diversity in digital tower solutions and applications. They include a mix of operational environments, business drivers and technologies.

Broadly the case studies showcase the following scenarios:

- Airports with very low to medium traffic density. Digital towers provide a mechanism to provide the service from an alternate location, improving the viability of ATS provision (LFV, SDATS, DFS, Avinor, Indra)
- Existing airports that do not have a tower but where the provision of an airport control service is desired. A digital tower provides a cost-efficient option (FAA)
- An airport where the conventional tower is approaching its end-of-life. A digital tower provides a cost-efficient replacement and interim business continuity facility (HungaroControl)
- Newly built or established airports, where a conventional tower is not established, and instead ATS is provided through digital towers or remote airport ATS (SDATS)

Case studies also showcase the centralisation of digital tower services for airports of various sizes in one facility, referred to as a Remote Tower Centre (RTC) (LFV, SDATS, DFS, Avinor, Indra).

The case studies include the following operational modes:

- Single mode (LFV, SDATS, DFS, FAA, Avinor, Indra)
- Contingency mode (HungaroControl) proposed to ultimately transition from solely being a contingency facility to becoming a permanent replacement to the conventional tower and used in Single mode.

## CASE STUDY 1



## CASE STUDY 2



## CASE STUDY 3



## CASE STUDY 4



**DFS** Deutsche Flugsicherung

## CASE STUDY 5



# FAA DIGITAL TOWERS

## INTRODUCTION

The Federal Aviation Administration (FAA) is testing the viability of Remote/Digital Control Tower systems to support Class D airspace operations at airports which currently do not have an operating Air Traffic Control Tower (ATCT). The FAA has partnered with state and local governments and private vendors to provide funding and technical support to develop procedures, best practices, and guidelines for Remote/Digital Towers. The FAA intends to develop an official list of certified Remote/Digital Tower suppliers that airports can choose from when equipping a new ATC facility.

Leesburg Executive Airport (KJYO) in Leesburg, Virginia received the FAA Operational Visibility Decision in September 2021 which authorised the Saab remote tower system for continued use for the provision of ATC services. Northern Colorado Regional Airport (KFNL) in Fort Collins, Colorado using Searidge Technologies remote tower system began testing in early 2022.



Figure 10 – Inside the FAA KFNL Digital Tower – Credit: Searidge



Figure 11 – Inside the FAA KJYO Digital Tower – Credit: FAA

## OVERVIEW

### CURRENT STATUS

- Leesburg Executive (KJYO) and Northern Colorado Regional (KFNL) are in different stages of the implementation and evaluation. KJYO started first and is further along in the implementation process. However, new FAA Operational Visual Requirements (OVR 2.0) that were released in November 2022 requires both vendors to review their system design to ensure compliance with the new requirements.
- During extensive testing at KJYO, the Saab remote tower system satisfied the FAA requirement of 3 consecutive months of continuous operations without equipment failures or operational incidents, thereby demonstrating consistent, safe, and reliable performance.
- While Remote/Digital Tower operations were transferred to an on-site Mobile Air Traffic Control Tower (MATCT) in 2019, they were resumed in April 2021 from a permanent RTC located adjacent to the airport. FAA testing concluded shortly thereafter, in May 2021 and the FAA Operational Viability Decision was delivered in September that year. The MATCT was subsequently removed from KJYO.

KFNL began testing the multi-mast and multiple CWP Searidge system in March 2022 to collect data

while ATCT operations are run from an on-site MATCT. Upcoming evaluations will include active testing where the MATCT will act as the back-up for live operations performed in the remote tower. Searidge will seek FAA Operational Viability Decision (OVD) at the conclusion of those upcoming activities.

## OPERATIONAL ENVIRONMENT

### TEST SITE #1 – LEESBURG EXECUTIVE (KJYO)

Refer to Figure 12 for airfield design.

- Runway 17/35 dimensions:
  - 5500x100ft./1676x30m.
- Airport operational statistics
  - Aircraft based on the field: 220:
    - Single engine airplanes: 177;
    - Multi engine airplane: 25;
    - Jet airplanes: 12;
    - Helicopters: 6.
  - Aircraft operations: avg. 292/day:
    - 85% local general aviation;
    - 11% transient general aviation;
    - 2% air taxi;
    - 1% military.

\*Statistics based on 12-month period ending 31 December 2017.

### TEST SITE #2 – NORTHERN COLORADO REGIONAL (KFNL)

Refer to Figure 13 for airfield design.

- Runway 15/33 dimensions:
  - 8500x100ft./2591x30m.
- Runway 06/24 dimensions:
  - 2273x40ft./693x12m.
- Airport operational statistics
  - Aircraft based on the field: 240:
    - Single engine airplanes: 201;
    - Multi engine airplane: 16;
    - Jet airplanes: 9;
    - Helicopters: 12;
    - Gliders airplanes: 1;
    - Ultralights: 1.
  - Aircraft operations: avg. 260/day:
    - 59% transient general aviation;
    - 37% local general aviation;
    - 4% air taxi;
    - <1% military;
    - <1% commercial.

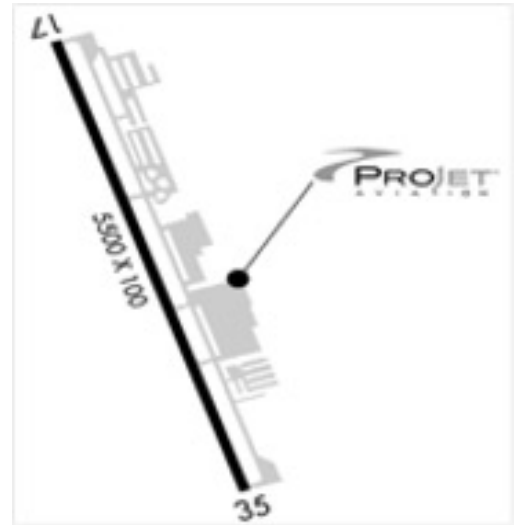


Figure 12 – KJYO Airfield Layout

Credit: FAA



Figure 13 – KFNL Airfield Layout

Credit: FAA



# BUSINESS DRIVERS AND CHALLENGES

## DRIVERS AND BUSINESS GOALS

The FAA's Contract Tower (FCT) Programme was established in 1982 to allow the agency to contract out the operation of certain low-activity towers. There are currently 256 contract towers, for which the FAA pays for air traffic control services on a contract basis. In 2008 the FAA suspended new additions to the FCT program due to budget constraints. The FAA Reauthorization Act of 2018 requires the FAA to resume processing of applications to the FCT programme. Eligibility for acceptance into the FCT is determined by a congressionally mandated Benefit Cost Analysis (BCA) formula. The safety and efficiency benefits of providing ATS must exceed its costs. The cost of Remote/Digital Tower systems may be significantly lower than construction of a new ATCT, possibly improving the overall cost to benefit ratio of potential airport candidates for the FCT program. Significant improvement in the cost-to-benefit ratio may allow for expansion of the FCT programme while reducing financial pressure on the overall budget.

## CHALLENGES

The FAA expects the Remote/Digital Tower to provide the same level of service as a traditional ATCT with no discernible difference identifiable by the user. The testing conducted at KJYO revealed several challenges that included: human factors, equipment capabilities and the provision of all required Class D services.

- **Challenge 1:** A major challenge of a Remote/Digital Tower is limited depth perception which complicates spacing and sequencing.
- **Challenge 2:** Opposite Direction Operations (ODO), required in Class D airspace by FAA policy (Joint Order 7210.3), are not permissible due to issues with depth perception and visual acquisition of aircraft.
- **Challenge 3:** Visual distortion of runway surface resulting from 360° view compressed to 196°.
- **Challenge 4:** Visual acquisition of aircraft limited to approximately 2-3 miles from camera position.
- **Challenge 5:** Challenges to visual acuity necessitated implementation of site-specific procedures that restrict provision of required Class D airspace services.
- **Challenge 6:** Determining the optimal candidate to work in the Remote/Digital Tower environment.
- **Challenge 7:** Airspace classification at KJYO location is Class G and was not changed to Class D. The operation was conducted while simulating Class D airspace. The FAA has deferred reclassifying the airspace as Class D until such time that the Saab remote tower system has achieved system design approval.
- **Challenge 8:** Anticipation of where aircraft are initially displayed on the screen based on pilot reported position and where they appear.
- **Challenge 9:** Power surge at KJYO caused 6-day cessation of operations.
- **Challenge 10:** KFNL cameras susceptible to high winds (in excess of 60 knots) resulting in camera mast vibration which temporarily affected the display.
- While testing at KJYO revealed challenges, more than a dozen FAA Safety Risk Management (SRM) assessments related to the phased evaluations concluded that all safety performance targets were met through all periods of operational use of the Saab remote tower system. The FAA concluded that the Saab system is operationally viable to provide the visual information needed for the provision of ATC services, and that ATCSs can provide the Class D airspace ATC services listed in FAA policy (Joint Order 7110.65) while using the system.

## TECHNICAL SOLUTION

Solutions to some of these issues involve:

- Training of best practices that were discovered through examination of collected data.
- Training to identify where aircraft can be expected to visually appear on the display based on their phase of flight.
- Candidates for employment must have recent, (within 5 years) relevant experience, i.e., VFR ATCT.
- The FAA installed and commissioned a Standard Terminal Automation Replacement System (STARS) at KJYO in 2022 as a Decision Support Tool to assist controllers in determining positions of aircraft for spacing and sequencing. STARS was also installed at KFNL.
- Searidge Technologies is adding a stability system to the masts to accommodate high wind conditions at KFNL.
- Since relocating the operations centre, Saab has deployed power surge protection and backup engine generators at the KJYO airport and at the off-airport RTC to protect the system from local power surges and outages.
- To improve the visual acquisition by controllers at KJYO, the 15 screens used to make the video display have been reconfigured to increase the curvature of the display from 196° to 223°. This change reduced the screen arrangement diameter from 6.0 meters (19.69 feet) to 5.1 meters (16.73 feet).
- To improve visual acquisition of aircraft by controllers, the workstation has been moved 0.2 meters (0.7 feet) closer to the display screen. Testing has proven this increases performance.

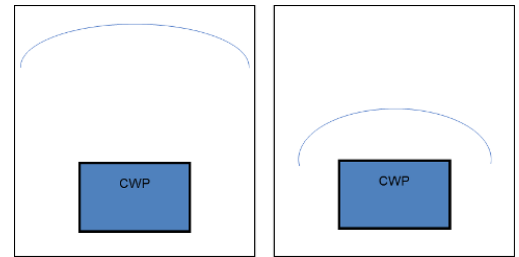


Figure 14 – FAA Digital Tower Module Original vs New Configuration

Credit: FAA

Figure 14 illustrates in top-down view the changes described by the last two bullet points.

## PLANNING AND DEPLOYMENT

The FAA intends for Remote/Digital Tower operations to be transparent to the pilot, while providing an equivalent level of service as would a traditional Class D ATCT. The goal of providing indistinguishable service requires a high standard of performance for both equipment and personnel. This requirement creates multiple challenges to certification of systems and eventual incorporation of Remote/Digital Tower services into the U.S. National Airspace System.

During the next testing phase at KJYO, the FAA required three consecutive months of continuous operations without equipment failures or operational incidents. Consistent, safe, and reliable performance had to be demonstrated before certification for operational use.

Remote/Digital towers are a potential cost-effective way to expand ATC services.

KJYO remote tower equipment is being relocated to a permanent off-site location and will resume testing when installation is complete.

Future airports used as test sites will be chosen based on various aspects. Each successive location will have different runway configurations.

The current plan is to test Remote/Digital Towers at six separate locations in linear order (one after another), building on knowledge gained from each previous test site.

The U.S. Department of Defence has selected a Remote/Digital Tower system offered by Frequentis. Testing will be conducted at separate locations. The FAA has requested to participate as an observer and for access to test data results.

## LESSONS LEARNT

- **Lesson 1:** Remote/Digital Tower systems may require additional surveillance equipment to provide Class D airspace ATC services
- **Lesson 2:** 196° display screen causes visual distortion of runway surface.
- **Lesson 3:** KFNL camera systems are susceptible to weather phenomena.
- **Lesson 4:** Limitations to depth perception prohibit use of Opposite Direction Operations and hinder the spacing and sequencing of aircraft.
- **Lesson 5:** Lack of surveillance, combined with challenges to visual acquisition of aircraft, resulted in the need to implement additional site-specific procedures which inhibit the provision of two services typically provided in Class D airspace: tower-applied visual separation and Line Up and Wait (LUAW).
- **Lesson 6:** All controllers had previous control tower experience; however the best performers were individuals with recent VFR tower experience.

## FUTURE AND NEXT STEPS

- Currently FAA does not intend to replace existing ATCTs with Remote/Digital Towers.
- Remote/Digital Towers are viewed as a potential cost-effective way to expand ATC services.
- The FAA has explicitly instructed all new vendors to submit digital tower systems for evaluation at their Technical Centre in Atlantic City, New Jersey. Beyond KJYO and KFNL, no other airports deployments will be considered until first being assessed at their Technical Centre in New Jersey.

# LFV & SAAB DIGITAL AIR TRAFFIC SOLUTIONS (SDATS) REMOTE TOWER SERVICES

## INTRODUCTION

On April 21st, 2015, LFV became the world's first remote airport control service. They receive this service airport from a Remote Tower Centre (RTC) in Sundsvall and use a remote tower system provided by industry partner, Saab. Currently four Swedish regional airports are connected to and provided with remote airport ATS from 'RTC Sundsvall', now serviced by SDATS. LFV has deployed their own RTC, RTC Stockholm, and the former partnership with Saab is now in a phase where the two entities are sole ATS-providers and subsequently no longer are interconnected.

'RTC Stockholm', has been deployed in connection to the LFV ATC centre at Stockholm-Arlanda airport, providing remote airport ATS to four Swedavia (state airport operator) airports: Kiruna, Are/Östersund, Umeå and Malmö. RTC Stockholm, at its end state, utilises 12 RTM's providing service to 24 airports by using multiple mode operations.



Figure 15 – Inside the LFV Digital Tower – Credit: LFV, SAAB

## OVERVIEW

### CURRENT STATUS

- RTC Sundsvall in operation since April 2015, providing remote airport ATS to four regional airports, with SDATS being the certified ATS provider as of 1st Jan 2019.
- RTC Stockholm in operation since June 2021, providing remote airport ATS to four Swedavia (state airport operator) airports: Kiruna, Åre/Östersund, Umeå and Malmö. During 2023, the last of the four airports, Malmö, will be connected to RTC Stockholm. LFV is the sole ATS provider for the airports.

### OPERATIONAL ENVIRONMENT

- **RTC Sundsvall airports:**
  - Örnsköldsvik (ESNO) – ~3.500 movements annually (based on 2018 traffic data);
  - Sundsvall-Timrå (ESNN) – ~8.000 movements annually (based on 2018 traffic data);
  - Linköping/Saab (ESLL) – ~11.500 movements annually (based on 2018 traffic data);
  - Sälen/Scandinavian Mountains (ESKS) – In operation as of 22nd Dec 2019
- **RTC Stockholm airports:**
  - Kiruna (ESNQ) – ~5.000 movements annually (based on 2018 traffic data);
  - Åre Östersund (ESNZ) – ~10.500 movements annually (based on 2018 traffic data);
  - Umeå (ESNU) – ~23.000 movements annually (based on 2018 traffic data);
  - Malmö (ESMS) – ~50.000 movements annually (based on 2018 traffic data).
- Airport Control Service and Approach Control Service (including Flight Information Service and Alerting Service) as well as Meteorological Observation Service (METOBS) provided for all airports.
- All airports are single runway airports without a parallel taxiway, except:
  - Åre Östersund (ESNZ); which is single runway with a parallel taxiway, and
  - Malmö (ESMS); which has one main runway with a parallel taxiway and one short runway for GA traffic.
- Airspace class C for all airports (CTR+TMA)
- Mixed traffic; IFR, VFR, scheduled, GA, military (ESSL has military test flight school), helicopter, etc.

# BUSINESS DRIVERS AND CHALLENGES

## DRIVERS AND BUSINESS GOALS

- **Driver 1:** Capacity/Flexibility/Cost
  - Low utilisation of ATC staff – low traffic on these airports, the effective ATCO “controlling” time is low.
  - Limited flexibility – hard to move ATCOs around due to distance and different operational procedures and different systems/HMI in all towers. Often takes weeks to be trained and “checked” in another tower.
  - Expensive to keep small rural airports opened, yet vital for the local businesses sector and community.
  - EU and the flying customers request for lowered airport and ATS fees.
  - Competitive markets – provision of airport ATS was opened for free market competition in Sweden some years ago.
  - Many airports have old infrastructure and there is a need to replace equipment as well as old towers.
- **Driver 2:** Safety
  - Risk for under stimulated ATCOs at small airports, often working in isolation (low experience exchange between colleagues in different ATS units).
  - Increased costs due to outdated equipment which requires new technology to be installed at the airports
  - A cluster of airports connected to a centre simplifies the process of creating structured and uniform methods for risk assessment, follow up of risk resources, management of changes in regulations, etc. which ensures quality assurance of ATC operations
  - Airport developments and runway extensions could bring limitations in visual view from the existing towers (was about to happen at one ATS unit).
  - Runway incursions, airspace infringement, drones, low visibility, and darkness – poor or non-existent system support in existing conventional towers.

## CHALLENGES

Challenges have been mostly related to the change management process and stakeholder acceptance rather than technical/operational aspects:

- **Challenge 1:** Maintaining the system development, ongoing deployments (3 of 4 airports are operational from the RTC and one more is in the process of transitioning), and regulatory changes within a single organisational area. Contractual agreements need to be made in a way allowing for quite rapid changes within regulatory framework.
- **Challenge 2:** The changes and opportunities in new technique in relation to current regulations makes it challenging in being proactive in the development of the services provided to the airport. The system should be designed in a way allowing for changes to be implemented in isolation, without affecting other parts of the system. The functional system is undergoing constant changes due to the speed of introducing new regulatory frameworks which requires a standardised and efficient change process to be adopted.
- **Challenge 3:** The pilot and ATCO community have, to some extent, expressed concerns about the change. Lesson learnt: early information and involvement of all affected stakeholders in the change management process is a key success factor!
- **Challenge 4:** Technical/operational: new modern integrated alarm system needed to be developed.

## TECHNICAL SOLUTION

The strategy for realisation was to replicate the conventional tower as much as possible, in order to smooth the transition and in order to ensure fulfilment with existing rules and regulations (e.g., ICAO Doc 4444) for airport ATS service (no EASA Guidance Material or EUROCAE specifications existed at the time of planning and first deployment). Functions which couldn't be replicated were replaced with something similar in the RTM/RTC, e.g., monitors instead of windows, pan-tilt-zoom (PTZ) cameras instead of binoculars. No extra functionality was added, the philosophy was to keep it simple (i.e., as close as possible to the conventional tower) and to design a concept and a system that supported the ATS-service (no changes for pilots and stakeholders).

- 14 High-definition cameras providing a high resolution, 30 frames per second, 360° horizontal view of the airport and its vicinity. +/- 23° vertical view (45,7 degrees total opening angle) as in the ordinary tower.
- 2 PTZ cameras (replacing traditional binoculars), coupled with signalling lamp.
- Gap filler cameras to cover for; hot spot areas, blind spots covered by e.g., buildings, far away observations, installed for some airports subject to local conditions and operational needs.
- Pressurised and heated/cooled (depending on season) camera housing ensuring functionality in all weather conditions and protecting against animal/insect interference.
- Microphones capturing and relaying the airport sound to the remote operator, providing an improved sense of presence and situational awareness.
- All other systems and ATCO support tools as needed (radio/interphone, radar/SUR (when available), airport nav/lighting manoeuvre etc.).
- Max end-to-end delay < 1 second.

Redundant network (separate and independent lines/routes) and power supply to ensure uninterrupted service.

## PLANNING AND DEPLOYMENT

A safety-related change to the functional system according to Regulation (EU) 2017/373 "ATM/ANS Common Requirements":

- Technology/equipment; ANSP/ATCO operational demand is the driver; the system shall support existing rules and regulation.
- Procedures: the system shall support the ATS service – no changes for pilots or stakeholders.
- Human Resources/elements are trained to perform the service according to above and need only unit system training.
- To consider for the planning and deployment (lessons learnt):
- Bring in ATCOs and Human Factor experts early in the process to work together through the implementation.
- Close coordination with the airport operator is important (multi-actor change).
- Bring in safety assessors/experts early on the process.
- Bring the Regulator on-board early.
- Early consultation with stakeholders, unions etc. is a key factor for success.
- Use a step-by-step implementation and add features in the future. Start simple and have an operational concept.



Figure 16 – SAAB Digital Tower Optical Solution  
Credit: SAAB

**“The biggest journey is not about the technology – it’s about change management.”**

– SDATS, 2019

## LESSONS LEARNT

- **Lesson 1:** Working together creates synergies
  - Operational and technical staff in the same building.
  - Colleagues from other ATS units/"towers" – no more "working alone".
- **Lesson 2:** ATCOs can more easily work at more airports thanks to the same CWP/HMI and thanks to standardised operational procedures (one combined operations manual for the complete RTC).
- **Lesson 3:** We can use most of our operational manuals (design decision 2010).
- **Lesson 4:** Depth perception is not an issue; it is a mental process that ATCO's learn in the new operational environment. Reduction of separation minima still used in accordance with ICAO Doc 4444.
- **Lesson 5:** Cameras sometimes provide a lower performance compared with human eye based on conventional tower out-of-the-window view, sometimes better performance. E.g.,
  - Objects will typically appear smaller than in real life, e.g., faraway small objects may be sometimes harder to detect depending on visibility and daylight conditions.
  - Cameras present "longer" days and visual positive effects in mist.
  - It is possible to look straight into the sun, thanks to mechanical "curtains" in front of cameras.
  - The key lesson here is:  
It is not important (nor is it possible) to exactly replicate the human eye performance, instead the key is to provide an image that sufficiently supports the ATS provision and the operational needs.
- **Lesson 6:** Presenting 360 degrees in a ~225 degrees U-shaped RTM opening, ATCOs adopted it easily. It even brings some benefits; the operator has the whole scenery "in front of them", i.e., no need to turn around to look behind.
- **Lesson 7:** Visual overlays, tracking (both visual and PTZ), infrared cameras, and surveillance information can be introduced to support ATCO's decision making. Those advanced features are typically "optional enhancements" rather than a core requirement in most cases.
- **Lesson 8:** MET observations can be adopted and is still performed by ATCOs from the RTC.
- **Lesson 9:** Do not mix a lot of different systems. Let the interaction be handled by one system for all system parts. Reduce workload by system integration.
- **Lesson 10:** A simulator and a Test and Development System/RTM in the RTC will support your operation/deployment:
  - ATCO training (e.g., recurrent, emergency, degraded modes, etc).
  - Validation of new airports/ATS-units, operational modes (e.g., 'multiple'), etc.
  - Verification/validation of new system releases



## FUTURE AND NEXT STEPS

- Next generation of RTC: Smaller RTM, new tools and features will be added to the remote tower functional system over time, such as visual tracking/'box and follow' and radar tracking/labels overlays, with the aim to increase ATCO situational awareness and heads-up time ("looking out the windows"). However, the philosophy is that operational approvals will always be based on a basic set-up, service provision/capacity shall not be dependent on any such additional tools/features.
- More focus on multiple mode of operation and supporting functions such as rostering and traffic load planning. An implementation project is ongoing with the aim to start providing 'multiple mode of operation' (1 ATCO/AFISO serving several airports) to two airports simultaneously. Realistic real time simulations, focusing on human performance, safety and procedures for degraded modes and emergency situations have been performed for Sundsvall (ESNN) and Örnsköldsvik (ESNO) airports during 2019 with positive results. Next steps will be to further develop the safety case and to start live validations (following regulatory approval). During 2022, LfV has continued their own simulations, building strong arguments for safe provision of ATS in multiple mode and are currently in the phase of further developing a safety case in relation to this new service.

# HUNGAROCONTROL DIGITAL TOWER

## INTRODUCTION

Facing the constraints and operational service impacts of ageing tower infrastructure, HungaroControl needed to find a cost-effective solution to safely and efficiently control the traffic of the medium-sized, Budapest Liszt Ferenc International Airport (LHBP). In partnership with its integration and technology partners, Searidge Technologies (for video system), and Indra Navia (for A-SMGCS), HungaroControl coupled advanced technology with a coordinated and people-focused implementation program to successfully digitise tower operations. Since 2016, Budapest RTC has been fully operational as a contingency facility. The RTC has been used to provide ATS to 20,000+ controlled movements over a period of 4,000 operational hours.



Figure 17 – Inside the HungaroControl Digital Tower – Credit: HungaroControl

## OVERVIEW

### CURRENT STATUS

After the SESAR Very Large-Scale Demonstration in 2016, the facility at LHBP was upgraded to a contingency RTC. While contingency situations are rare, the RTC is used frequently to provide ATS during normal live operations to enable air traffic controllers to maintain their competence. Based on the existing operational experience, the next step of the programme is to upgrade the RTC so it can be used to permanently provide airport ATS, replacing the conventional tower.

### OPERATIONAL ENVIRONMENT

Budapest Liszt Ferenc International Airport has two parallel and shifted runways, RWY 13R/31L (length: 3010 m) and RWY 13L/31R (length: 3707 m), the distance is 6 km between the farthest thresholds. There are two terminal buildings with individual aprons. 122,814 movements were registered in 2019 (mainly IFR) with a passenger number of 16,173,489. Runways are used mostly in segregated mode, but mixed operation is also possible. Budapest CTR is a class D airspace, primary and secondary radar surveillance are available both in the air, and on the ground (ATS system and A-SMGCS are available for the ATCOs). There are four ATCOs, and one supervisor positions in the tower.

## BUSINESS DRIVERS AND CHALLENGES

### DRIVERS AND BUSINESS GOALS

Following more than 30 years of operational service, the conventional control tower at LHBP faced the end of its useful life. After flood damage and technical outages caused significant service disruptions, it was crucial to find alternatives to maintain business continuity and assure service resilience. The two logical options were to refurbish the existing tower facility or to build a new tower to modern specifications.

Both options required a substantial capital outlay. Additionally, these options would also carry numerous transition risks that would undoubtedly lead to a lengthy delivery timeframe. By digitising tower services, HungaroControl avoided inordinate capital expenditures of approximately €5 million and saved approximately 12 months in implementation effort. All whilst building an enhanced capability to deliver resilient tower services.

### CHALLENGES

- **Challenge 1:** Engagement with operational staff from concept-to-operation to build change consensus and technology acceptance.
- **Challenge 2:** Integration of a new technology – application of safety principles to drive safety by design and enforce system resilience.
- **Challenge 3:** Emphasis on human performance to understand the impact of change on end-users and identify the technology and process solutions to enhance safety and performance.
- **Challenge 4:** National Supervisor Authority (NSA) certification process – new concept meant limited industry-level experience and lack of supporting materials in the 2010s, extra efforts were therefore necessary from ANSP and NSA sides.
- **Challenge 5:** Planning and implementation of the video system to maximise the benefits and offset the drawbacks of video surveillance.

## TECHNICAL SOLUTION

In the current tower building, it is possible to safely control airport traffic, even without direct visual contact, based on ATS system and A-SMGCS. This would apply during low visibility conditions due to fog, precipitation etc. During LVP operations capacity is limited and special procedures are put in place.

In the RTC the systems currently available in the conventional tower were duplicated, this was done to reduce the safety risk coming from the change of the operational environment. Although the systems (except the video surveillance system) are the same, the arrangement of the RTC room, and the CWPs are slightly different in the RTC compared to the conventional tower.

In the RTC room, the visualisation is provided through a distributed video surveillance system. Twenty-two fixed cameras are installed at several locations at the airport including on the conventional tower building itself, and other existing buildings.

The locations of the cameras were determined based on the following considerations:

- The cameras should provide adequate visual coverage of all parts of the movement area.
- Finals and all relevant parts of the CTR should be covered.
- Obstacle limitation surfaces should not be penetrated.
- The cameras should not interfere with existing surveillance and navigation equipment.

At certain locations, there are six additional PTZ cameras, which can turn, tilt and zoom independently (changing focal length and sharpness). Three PTZ cameras include thermal sensors, so they can function both as daytime and as thermal cameras. Each PTZ camera is capable of automatically following a moving target.

The overall visualisation of the airport is provided by a video wall, complemented with personal screens in the CWPs of individual controllers. The primary purpose of the video wall is to offer a shared visual reference to all controllers. The additional liquid-crystal display screens installed at the CWPs (one to display the image of fixed cameras, the other to display the image of PTZ cameras) provide more detailed information of the airport segment under the controllers' responsibility. Beyond showing the real time image, it is also possible to display various secondary pieces of information, such as meteorological data, surface border areas, and the integration of A-SMGCS, video system, surveillance and flight data. These features aim to enhance situational awareness, especially in case of reduced visibility conditions or at night.

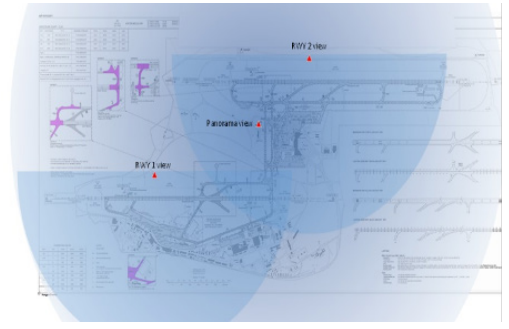


Figure 18 – Digital Tower camera placement at LHBP  
Credit: HungaroControl



Figure 19 – Budapest Airport Digital Tower Module  
Credit HungaroControl

## PLANNING AND DEPLOYMENT

The RTC implementation is a long-term programme for HungaroControl, containing different stages to improve and add functionality. The first stage was the SESAR Very Large-Scale Demonstration in 2016. Here the experiences of live demonstrations helped to reach the second stage, which was to establish a contingency capability, this was achieved in 2017.

At each stage, exhaustive safety assessments and human factor assessments were conducted, which considered existing studies and operational experiences. These assessments started in the definition phase of the project and helped to identify high-level safety and human factor requirements as soon as possible. The internal safety assessment methodology is followed for each project with the involvement of operational and technical experts and other relevant stakeholders (e.g., airport). A well-planned validation process (passive and active shadow mode) was key to evaluate the new functionalities, the new environment and justify the requirements. Cyber security aspects were also taken into consideration, which were in-line with existing standards.

The NSA was involved in the projects from the beginning, which helped to develop a clear understanding concerning the scope of the change and the implementation process. Specifically, early and ongoing engagement with the NSA helped the projects to:

- plan their supervisory task in advance
- clearly outline and clarify expectations concerning the project and/or documentation.

European guidance materials: EASA ED 2015/014/R, ED 2015/015/R and EUROCAE ED-240 were used to help define requirements and support planning and development. In case of later upgrades, ED 2019/004/R and EUROCAE ED-240A were also considered.

One of the key elements of a RTC is the video surveillance system. An analysis was conducted to list relevant visual surveillance requirements from operational, technical and safety perspectives, providing a basis for the definition of camera locations, camera type selection and visual representation planning. Provision of a platform that delivers enhanced visual capabilities not possible from a conventional tower were also considered. Building on an out-of-the-window view concept, additional camera sensors were installed to create auxiliary viewpoints that augmented the visual range of operators and unlocked previous blind spots.

The RTC room is supplied with increased capacity air conditioning, ventilation, cooling, and heating equipment. In addition, the electrical supply and IT networks were also extended to suit the RTC operation. Regarding the power supply, the operations room has the same redundancy level as the current tower. Since the RTC room is located in the ANSP building, detailed implementation plans were also made.

A special group of air traffic controllers (called “Tiger team”) was involved from the beginning of RTC planning, and participated in the SESAR Very Large-Scale Demonstration, to shape the RTC according to ATCO expectations. The group was a representative sample of the air traffic controller staff concerning age, sex, and experience. An ergonomic study was also conducted. In later stages, all staff participated in validation sessions, and everyone had the possibility to provide feedbacks.

All ATCOs gained a license extension to be able to control traffic from the RTC. Currently, every ATCO must work from the RTC a dedicated time each year to maintain competence.

To orchestrate this complex change, a transition plan was provided to support the implementation, taking into consideration operational, technical and safety aspects. As the RTC is a contingency facility, a special transition plan was defined to assume control from the conventional tower and then return it back to them (either in case of normal transition for training purposes, or in a contingency situation).

## LESSONS LEARNT

The following lessons learnt are based on more than 3,000 hours of real operational experience in the Budapest operational environment.

- **Lesson 1:** Based on feedback (and on the lack of feedback) airspace users cannot observe the difference between conventional tower and RTC operations, the service level is the same in the RTC environment.
- **Lesson 2:** All members of the TWR ATCO staff can control from a RTC environment, regardless of their background and experience.
- **Lesson 3:** RTC is suitable for an airport with two runways and those with LVP/VMC operations.
- **Lesson 4:** Optimal visual surveillance settings are different in special visual conditions (e.g., night, sunrise, sunset, low visibility), which requires several presentation modes.
- **Lesson 5:** In case of a contingency RTC, regular training is required to maintain ATCO competency.
- **Lesson 6:** To support RTC operations, new skills are necessary for the technical staff. Training is very important and additional staff might be needed.
- **Lesson 7:** Representation of additional information on the video surveillance system (e.g., labelling, wind rose) is useful and add value to the operations within an RTC, but the optimal amount should be carefully evaluated, and flexibility of these add-ons should be considered.
- **Lesson 8:** Appearance of the labels on the videowall (e.g., colour scheme) should be consistent with the A-SMGCS presentation.
- **Lesson 9:** The contingency RTC was used during the COVID-19 pandemic alternately with the conventional tower (day shift worked in the RTC facility, while night shift in the conventional tower) to physically separate the ATCO teams, hence increase resilience of the service.

## FUTURE AND NEXT STEPS

In partnership with Indra, HungaroControl intends to expand its Digital Tower capability. The TWR system used today has all the features to provide ATC services safely to LHBP, but the isolated heritage systems (e.g., ILS, AGL, RWY status, AFTN) are significant constraints on future capacity growth and state of the art functions. A large-scale system upgrade, aiming for system integration and modularity is ongoing. As part of this upgrade programme, the visualisation will be further improved both in terms of hardware and software. CWP's will be re-designed to provide a simple, intuitive, and comfortable environment for ATCOs to minimise the negative effects of visual information overload.

As part of the development roadmap, the TWR simulator will also be moved onto a Digital Tower platform to bring ATCO training closer to the actual work environment and to minimise transition risk.

Transition to fully remote tower operation with the new system is planned in 2024.

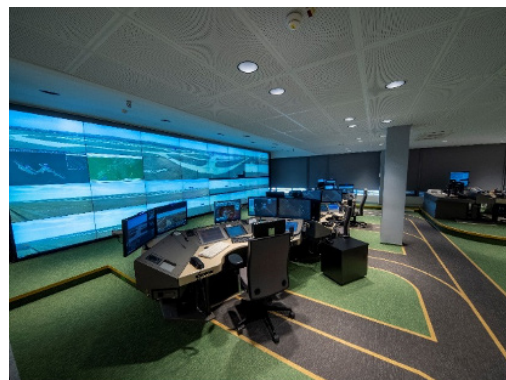


Figure 20 – Budapest Airport Digital Tower Video Wall  
Credit: HungaroControl

## CASE STUDY FOUR

### SAARBRÜCKEN AND ERFURT AIRPORTS

# DFS REMOTE TOWER CENTRE

## INTRODUCTION

RTC in Germany is operational at Saarbrücken and Erfurt international airports.

Since December 2018, airport services at Saarbrücken airport are provided by DFS from the RTC in Leipzig, more than 400 kilometres away. Using the experiences from the successful operations at Saarbrücken, in April 2022 DFS started remote airport services at Erfurt airport, about 120 kilometres away. DFS and the Austrian high-tech company Frequentis have mutually developed a particularly advanced solution.

## OVERVIEW

Before COVID-19, Saarbrücken Airport recorded more than 15,300 flight movements in 2018, of which just under 9,500 were under instrument flight rules (IFR) and around 5,900 under visual flight rules. Erfurt has a similar number of flights as Saarbrücken. In the future, DFS will use the new technology to control traffic at Dresden airport from Leipzig as well. Dresden, with some 36,000 aircraft movements, has significantly more traffic than Saarbrücken or Erfurt.

Traffic figures (2018) Traffic figures (2018)

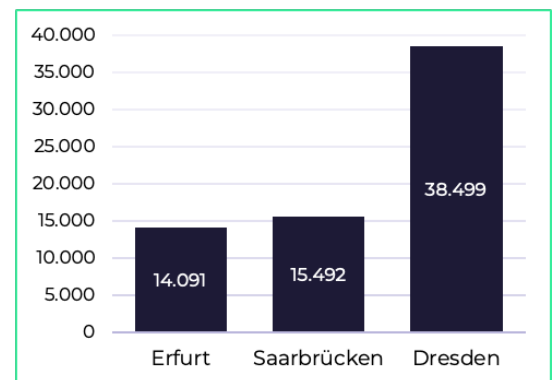


Figure 21 – Inside the DFS Remote Tower Centre – Credit: DFS

## BUSINESS DRIVERS AND CHALLENGES

DFS chose to start RTC at Saarbrücken for a couple reasons, 1) The manageable number of flight movements and, 2) To avoid constructing a new control tower. As a result, the costs for operating buildings and the associated infrastructure will now decline.

RTC increases efficiency and reduces costs – decisive factors in air traffic management. Our remote tower controllers will be cross-trained and authorised for the three designated airports. Maintenance and repair costs are reduced as systems are bundled at one location. Through this, we can reduce the number of staff and increase flexibility and efficiency.

For the controllers, the job will become more attractive, digital, and modern. RTC offers greater variety than today at similar medium-sized single-runway locations. Of course, there are challenges. One was to find a system for the visual presentation that met our performance, flexibility, quality, and safety requirements.

## CHALLENGES

The main challenge, however, was a new working environment. Even though the feasibility of the RTC project had already been demonstrated in 2012, we still had to deal with the change process.

Remote technology is a paradigm shift in ATC. It is the first step into the digital future.

## TECHNICAL SOLUTION

Our system is characterised by the fact that the working position in the RTC was developed according to the actual operational needs. The operational concept has not been changed, so our customers will not see any difference at RTC-operated airports.

The RTC controllers work with advanced ATS systems, developed by DFS, for situational awareness (radar), flight data processing, weather and information display and others.

The Frequentis system, which reproduces the out-of-the-window view, was completely new. Instead of looking through the tower window, the controller now looks at a panoramic view on five screens. Whereas in the tower, a controller would turn their head to get an overview, in RTC the controller pans the camera with a mouse in the desired direction. The controller can switch the image between normal (full HD) and infrared vision.

A combination of video and infrared cameras delivers a permanent, 360-degree view of the airport. The automatic object recognition and tracking in the panorama display supports situational awareness. The system provides additional optical information, which is superior to the conventional out-of-the-window view.

In addition, there are two pan-tilt-zoom cameras. The zoom function replaces the conventional binoculars. They provide 30x magnification in high density video and 24x magnification in infrared. The entire camera system is heated and equipped with an automatic cleaning system, so the cameras do not show condensation and are not affected by ice or dirt.

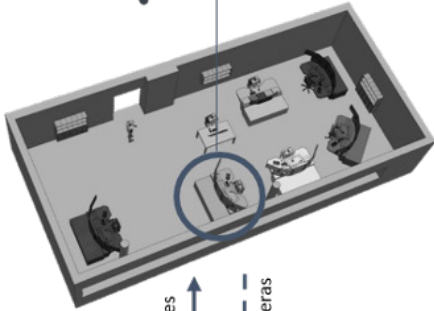
For data transmission, redundant local and wide area networks are used.

Saarbrücken and Erfurt traffic is handled by controllers in Leipzig through the RTC.



Figure 22 – DFS Remote Tower Module  
Credit DFS





Transmission of images  
450 km  
Control of cameras

## TECHNICAL HIGHLIGHTS:

- Scalable and scrollable 360° panorama
- Video (Full-HD) and Infrared – synchronised
- Stitched and harmonised, high dynamic range
- Flexible CWP design
- Two Pan-Tilt-Zoom (PTZ)-cameras for tracking (Video + IR)
- Mini ATM HMI to control the PTZ (PTZ-MAP)
- Picture recognition and surveillance-based tracking
- Object detection (Bounding)
- Multi-layer redundancy concept
- Augmented reality (overlay information)
- Remote Light Gun

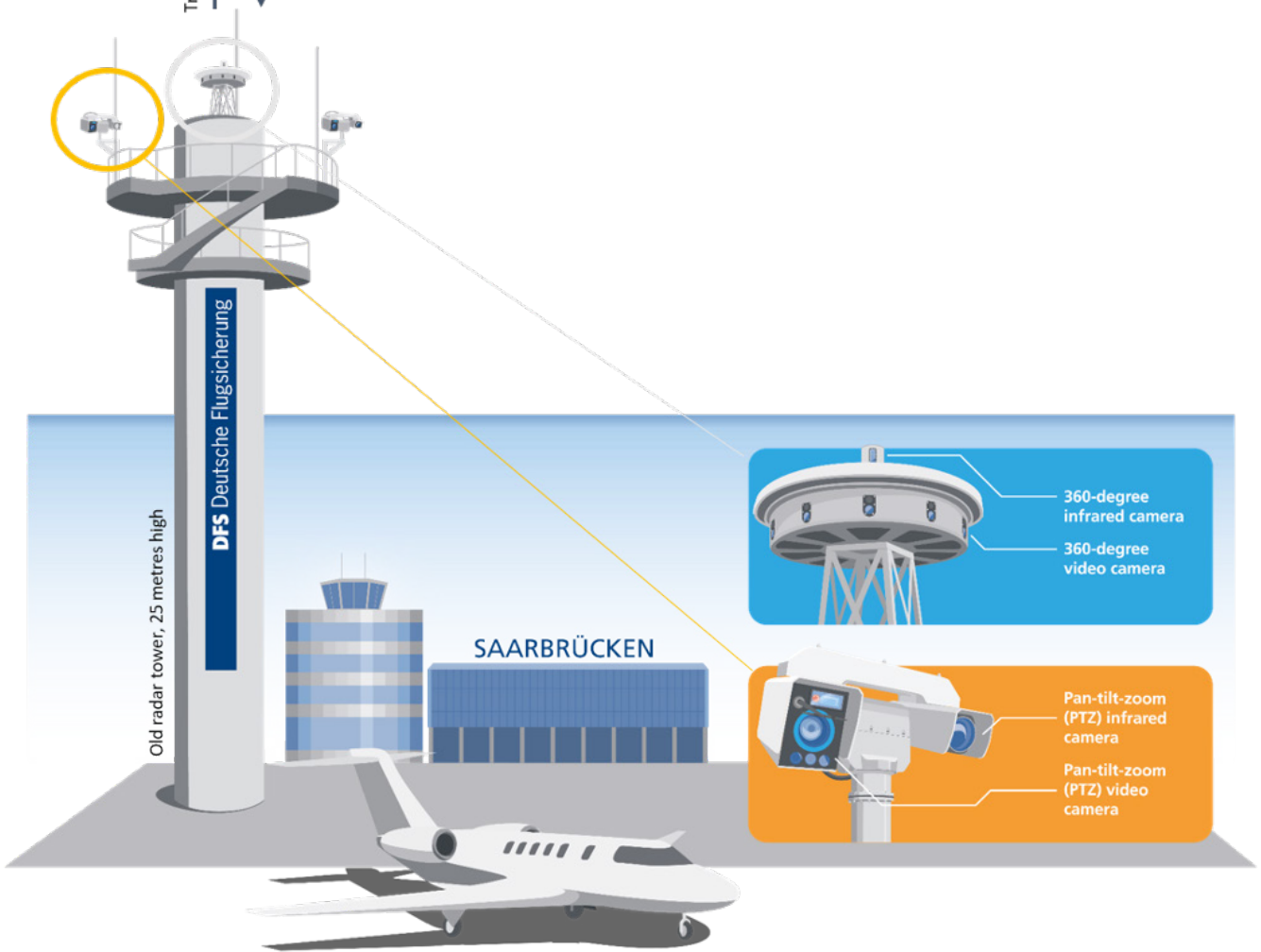


Figure 23 – Frequentis Digital Tower Solution for DFS  
Credit: Frequentis

# PLANNING AND DEPLOYMENT

## THE SITUATION

DFS operates 16 control towers at the designated international airports in Germany. Some of these airports have low to medium traffic volumes. Maintaining services at these airports requires a lot of personnel and is relatively cost-intensive. The main objectives of the remote tower project in Germany are to reduce the cost of tower operations by using new technologies and procedures and increase productivity – while maintaining safety and performance and service quality for airspace users. The system had to deliver a safety level at least equivalent to conventional airport control services. It had to comply with ICAO, EUROCAE, and Regulation (EC) No 549/2004 for the use of new systems and had to be approved by the national regulatory authority.

## THE SOLUTION

Creating a remote tower solution is more than a technical question. A good solution should consider each airport's individual needs. In Germany, the best solution was to establish a RTC in Leipzig, from where the international airports of Saarbrücken, Erfurt and Dresden would be controlled. One tower controller (AIR + GND combined) in the Leipzig RTC would provide single tower control services for one airport at a time (single mode). However, they would be cross-trained to provide remote tower services for the other airports as well. There would also be one common clearance delivery position for all airports in the end (multi-mode).

## THE DEVELOPMENT

An innovation such as RTC is based on years of research and development. DFS initially started investigating RTC in 2010. Together with the German Aerospace Centre (DLR), DFS established a research project and conducted a human factors study to analyse the influence of remote tower operations on ATCOs – the essential basis for successful remote tower operations. This study scrutinised the feasibility of the planned operations. In 2015, DFS started developing the RTC solution together with the Austrian high-tech company, Frequentis.

It took scores of analyses, studies, tests, operational and technological changes, and safety assessments to finalise the DFS approach. In 2017, the remote tower solution finally cleared its last hurdle. In a practice run, the system demonstrated that it met all requirements. Additional training and approval processes followed until the RTC went into operation in December 2018 with airport control services for Saarbrücken International Airport.



Figure 24 – Development status 2016  
Credit: DFS



Figure 25 – CWP in Leipzig RTC  
Credit: DFS

## LESSONS LEARNT

- **Lesson 1:** The early involvement of ATCO and ATSEP was very important and contributed to the success of the first commissioning (Saarbrücken airport from RTC Leipzig).
- **Lesson 2:** Advanced functions were very well appreciated and are now part of the daily work. Some comments from ATCOs:
  - “The zoom cameras have different zoom settings, something binoculars don't have”
  - “The infrared camera and infrared panorama are very helpful. They give you more details during darkness”
- **Lesson 3:** The safety concept developed with ATCO and ATSEP works and has proven itself.
- **Lesson 4:** The system is constantly evolving with ATCOs steadily improving the situational awareness.

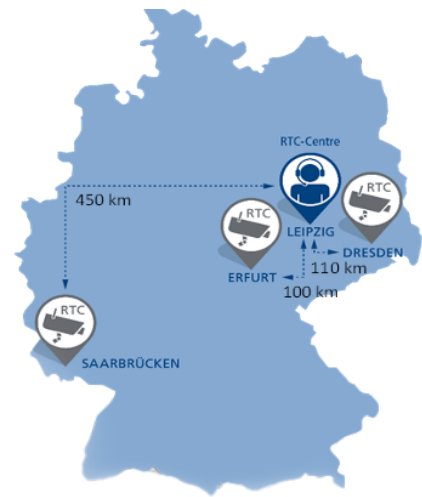


Figure 26 – DFS Remote Tower Solution Map  
Credit: DFS

## FUTURE AND NEXT STEPS

Following the experience of successful implementation and operations of RTC in Saarbrücken and Erfurt, DFS is planning to expand the use of RTC to Dresden, where implementation is currently foreseen in 2024. Three airports would then be controlled from one location, which should significantly increase the benefits.

A joint venture has been established between the DFS subsidiary, DFS Aviation Services, and Frequentis for the national and international marketing of the DFS remote tower system. The joint venture is called, “Frequentis DFS Aerosense” and they deliver tailored, turn-key solutions for all use cases.

## MORE INSIGHTS



[Remote Tower Operations in Germany, explanation](#)



[Remote Tower – One year of operations in Germany](#)

# AVINOR REMOTE TOWER PROGRAMME

## INTRODUCTION

The Avinor Remote Tower programme is a strategic initiative to implement remote Air Traffic Services at 15 airports throughout Norway. The airports are mostly smaller, local airports spread across a large geographical area.

### **DRIVERS' SUMMARY:**

- Reduction of capital expenditure by avoiding costly investments to replace ageing building infrastructure.
- Reduction of operational expenditure through more flexible rostering and multiple airport service provision.

### **SOLUTION SUMMARY:**

- A panoramic camera providing full 360-degree out-of-the-window view with additional support from Pan-Tilt and infrared cameras.
- Fully integrated Tower System (InNOVA) in the RTC with a standardised HMI for all airports.
- Mature solution for single airports and solution under development for multiple airport service provision.
- Development planned towards multiple operations.
- Kongsberg Defence and Aerospace delivering camera systems and system integration. Indra Navia delivering the integrated InNOVA Tower System and GAREX VCS.

### **EXPECTED GOALS / BENEFITS**

- Fully operational centre with 15 airports in 2023
- Multiple airport service provision
- More flexible service provision to airports
- More efficient rostering
- Improved job satisfaction
- An important step to further enhance digitalisation of airport Air Traffic Services



Figure 27 – Inside the Bodo Remote Tower Centre – Credit: Avinor, Indra

## OVERVIEW

### CURRENT STATUS

- The system has been in operational use since October 2019, when the Air Traffic Services to Røst airport were transferred to the RTC in Bodø. The implementation was gradually expanded to an additional seven airports. By September 2022, a total of eight airports are being served from the RTC.
- A new building hosts the Main RTC while a Contingency RTC is in the airport terminal building and serves as a training simulator and contingency facility.
- An upgraded software version of the Remote Tower System including a fully integrated InNOVA Tower System with Electronic Flight Strips (EFS) and surveillance data presentation went into operations on May 7, 2022.
- The InNOVA Tower System also provides the necessary interfaces to airport control and monitoring functions (NAV, AD-lights, power supply etc.), presentation of meteorological data, interface to AWOS and ATIS and system alarm panels.
- Future system development plans include deploying software to support the multiple airport service provision on the same integrated workstation.

### OPERATIONAL ENVIRONMENT

Airport(s) characteristics:

- Local and regional airports with single runways and runway lengths varying from 970 metres to 2,200 metres
- Scheduled IFR-traffic, ambulance flights (generally IFR-operations), SAR-operations with helicopter (mainly VFR) and some GA-traffic (mainly VFR).
- Avinor has further ambitions for digital tower technology and the safety case for the system is based on a traffic level that can serve larger airports.
- Airport Flight Information Service (AFIS) (14 airports) and Air Traffic Control Service (1 airport)
- AFIS-officers and Air Traffic Control Officers. All units are single person operated units with one working position. If traffic or events require, working positions can be duplicated by using an adjacent Remote Tower Module for support functions, e.g., coordination.

# BUSINESS DRIVERS AND CHALLENGES

## DRIVERS AND BUSINESS GOALS

- **Driver 1:** Reduce the cost of operations through more flexible rostering enabled by AFISOs and ATCOs having multiple airport endorsements.
- **Driver 2:** Reduce the cost of operations by enabling the provision of ATS to more than one airport from the same single manned working position.
- **Driver 3:** Reduce capital expenditure by investing in Remote Tower Technology rather than investing in new and more costly building structures and technical installations in traditional towers.
- **Driver 4:** Create a more varied and diverse working environment offering higher job satisfaction and more career opportunities to staff members (training and simulation, operational procedures, management roles).
- **Driver 5:** Enable flexibility and lower workload by having the same HMI on all user positions and a fully flexible allocation allowing any airport to be operated from any Remote Tower Module.

## CHALLENGES

- **Challenge 1:** Implementation of the fully integrated system proved to be more complex than anticipated so a step-wise implementation strategy was chosen as an initial alternative. The fully integrated system is now in operation.
- **Challenge 2:** The replacement of out-of-the-window view with cameras required specific training on system capabilities, limitations, and practical use.
- **Challenge 3:** Delays in programme deployment influenced change management processes resulting in increased costs.
- **Challenge 4:** Initially, the time required for the regulatory process was underestimated leading to a good dialogue to establish a robust plan for subsequent airport and software deployments.

## TECHNICAL SOLUTION

KONGSBERG and Indra delivered a full, turn-key solution for this project. There is a Main Remote Tower Centre (MRTC) equipped with 16 Remote Tower Modules (RTM) and a Contingency and Training RTC (CRTC) equipped with five RTMs.

15 airports will be connected to the MRTC and CRTC. Each airport has a rotating platform with two high resolution panorama cameras installed: A visual daylight camera and an infrared camera. At each airport, there is also a PTZ Platform with a VIS PTZ, an IR PTZ, a Signal Light Gun and a Laser Range Finder.

All airports are also fitted with ATIS and AWOS, and the system is connected to legacy airport equipment such as AGL, MET sensors, NAVAIDs, Crash Alarm, Generators, Airport equipment etc.

The Remote Tower Modules (RTM) are all dynamic and the operator may select any of the connected airports into any RTM. They have a uniform equipage, and the same style of HMI is used for all airports, regardless of the type of equipment installed at the airport.

The Heads-Down Display (HDD) in the RTM includes the Indra GAREX VCS and the Indra InNOVA Tower ATM system where all ATM tools, besides the VCS, are provided at a fully integrated touch screen. The HMI is the same for all airports, regardless of the type of legacy equipment installed.

This makes it easy for the operators to adapt to new airports and reduces the workload and need for training.

The Heads-Up Displays (HUD) consist of ten 65" ultra high-definition monitors providing a full, 360-degree panorama view with both visible and IR images available. Images from the PTZs are displayed as picture-in-picture.

The HUD provides graphical overlays as e.g., flight information (labels), MET information, RWY and TWY-outline, geographical outline, and Moving Target Indicators (MTIs).

The ATM system is closely integrated with the camera system. All control of the camera system is done from the ATM system.

The system also connects to a country-wide surveillance system and exchanges flight plan and AFTN information with central Avinor systems.

The operator has access to a country-wide surveillance image and relevant flight plans. The EFS work closely with the central Avinor ATM system where flight plan information is exchanged both ways. Flight Plans may also be made locally by the Remote Tower operator.

The HDD also provides access to ATIS and AWOS and enables the operators to do MET observation and issue new ATIS and METARs.

The GAREX VCS utilises VoIP technology to connect to the radio sites and external telephone connections.

A fully redundant network connects the two RTCs and all airports, utilising Avinor's dedicated backbone country-wide network.



Figure 28 – PTZ View on RTM  
Credit: Avinor, Indra



Figure 29 – Bodo RTC - Remote Tower Module (RTM)  
Credit: Avinor, Indra

## PLANNING AND DEPLOYMENT

### PLANNING AND REGULATORY ACTIVITIES

A full-time programme planner has the responsibility for the planning process and continuous follow-up of the programme plan. Similar dedicated roles have been established for the follow-up of risk and cost. The planning process has involved the airport operator, the regulatory authority, and staff organisations. Plans have been continuously updated and communicated according to the actual progress.

### REGULATORY ACTIVITIES

The regulatory dialogue was initiated at the very beginning of the programme. A subject matter expert from Avinor ANS was appointed specifically with responsibility for the regulatory dialogue. On the regulatory side, a specific individual was appointed specifically for the Remote Tower Programme. Regular meetings were held to clarify expectations and framework. This has all led to an open and constructive dialogue with the regulator and a collaborative planning of the regulatory process.

### HF AND CHANGE MANAGEMENT

Human Factors experts were assigned to examine every aspect of the programme. A similar approach was used for the safety and cyber security domains. The change management processes relate to staff relocations, training, operational and technical procedures. Transformation planning was therefore allocated to a specific transformation project.

### VALIDATION ACTIVITIES

An evaluation was made of the complete Remote Tower Module with the integrated display solution. Specific validation of the curving and distance to the screen wall in the RTM was also conducted to achieve the optimal balance between visual display quality and comfort of view and ergonomics. A specific camera inspection was carried out for each airport, ensuring that camera settings are adapted to ensure the best possible view while taking specific, local conditions into account. A Passive Shadow Mode period is conducted for each new airport. The validation continues with the Active Shadow Mode (ASM) phase to finalise operational validation. Normally a reversion to operation from the local tower is not made after the ASM period is commenced.

The programme contributed to three different SESAR validation exercises specifically oriented towards multiple airport service provision. These validations were an important platform to evaluate the concept, solution, operating methods, and the new role as RTC supervisor at different maturity levels.

### TRANSITION ACTIVITIES

For each airport transition, a specific transition plan was developed, and a transition organisation was established according to the Avinor ANS Change Management Procedure. The transition plan and the transition organisation ensured that all technical, operational, and administrative prerequisites were met to move from a pre-transition phase into the actual transition and then into the actual start of operations from the RTC. All transitions were followed by a post-transition period with defined follow-up tasks until the transition was formally completed.



## LESSONS LEARNT

- **Lesson 1:** The early and proactive dialogue with the regulator was an important enabler for a robust planning of the regulatory process. The appointment of specific points-of-contact from both the ANSP and regulator enabled an open and constructive exchange of information and expectations. This contributed to the creation of well-defined airport and software deployment plans.
- **Lesson 2:** The introduction of camera technology introduced specific training needs for operational staff to be aware of the performance characteristics of different technical components in the visual sensor system. User awareness of system capabilities and recommended usage helps to ensure a good situational awareness even under demanding meteorological conditions.
- **Lesson 3:** Local differences in existing airport placed systems (NAV, MET, power, AD lights) creates challenges in getting the system interface correctly set-up. Careful planning and testing of the airport interfaces will help mitigate the possibility of project delays.
- **Lesson 4:** If a remote tower programme involves relocation of staff, the mechanisms to handle the change should be established at the start of the programme. Continuous and open dialogue with trade unions will help smooth the relocation process and should include dialogue about the use of potential incentives that are adaptable to individual needs. It is also very important to handle each relocation as a unique case.

## FUTURE AND NEXT STEPS

The next step in the programme is to technically enable multiple airport service provision from a single workstation. The solution will enable the presentation of pictures from up to three airports on the screen-wall and display of relevant data and controls on the control display according to a common logic.

The subsequent step is to start the process for simulation and testing of multiple airport service provision and plan the regulatory approval process to enable the operational delivery across the 15 airports ultimately served from the RTC in Bodø.

Avinor has ambitions to expand the digital tower technology beyond the current 15 airports. There is currently no firm decision for a second phase of deployment, but the construction of two new airports in Northern Norway opens up interesting perspectives for the use of digital tower technology.



Figure 30 – Bodo RTC Facility  
Credit: Avinor, Indra



Figure 31 – Bodo RTC Operational Room  
Credit: Avinor, Indra

# WHAT IS NEXT FOR DIGITAL TOWERS?

## FUTURE TECHNOLOGY CONCEPTS

It is important that digital tower solutions are scalable for future technology.

### ADVANCED TECHNOLOGIES

Technology, and technology concepts that are still in development, but which have the potential to provide benefits to digital and conventional tower operations, are primarily concerned with the ability to:

- Integrate and share more useful data to aid the airport ATS provision, airport operations, and the wider ATM network
- Enhance performance in a specific area e.g., safety management
- Provide advanced conflict detection, forecasting, and visualising to support operators in responding to potential problems
- Visualise information in novel ways e.g., augmented vision (trajectory based i.e., approached paths)
- Provide better integration of the digital tower with other ATS systems through one human machine interface

These advanced technologies are more important when operating in certain, often more complex, operational environments. Such technologies may also be included if ANSPs are targeting specific performance improvements.

These technologies may enable a more automated, proactive, and connected operations i.e., smart tower concepts.

The next phase of the digital tower concept looks to enhance airport ATS and increase the integration between the tower and the rest of the air traffic management network. This may include increased information sharing and coordination with other ATS functions (approach and area control services), with other functions of the airport and with other airports.



Figure 32 – Components of digitalisation  
Credit: Think Research

### LARGE SCALE DIGITAL TOWER CENTRE

Digital tower centres providing airport ATS together with other ATS (approach and area control services) may be more frequent in the future. Such large-scale operations enable a range of performance and efficiency benefits, including flexible staff allocation, increased availability of airport ATS, new concepts of operations and improved business cases.

Challenges and differences will also arise from large-scale digital tower operations. These may include new roles (e.g., a cyber security manager), integrated training focused on tools and skills rather than specific sectors, increased coordination needs, and new dependencies between previously independent operations.

## ADVANCED APPLICATION CONCEPTS

The first publication of the CANSO Guidance Material for Remote and Digital Towers referred to single operating mode, multiple operating mode, contingency operating mode, and operations within a conventional tower. This section will focus on the growing demand from ANSPs and emerging use cases for implementing digital tower technology in conventional tower operations.

Operations within a conventional tower are also known as hybrid digital towers. Broadly, the operational concept involves implementing technology from remote/digital tower products into an existing tower operation, to provide benefits identified in a business case.

Identified benefits have included:

- Efficiency based on operating a Digital Tower-In-Tower. By controlling a small airport from an operational position in a conventional tower where similar efficiencies to those of a RTC are gained.
- Retention of capacity during an operational upgrade or contingency. Mitigating impacts of transitioning between facilities during an infrastructure upgrade.
- Enhancing the capacity of an existing ATC tower after an airfield expansion by introducing digital tower modules into a conventional tower. These modules can be operated as a fully digital control position or in a hybrid operation by utilising both visual out-of-the-window (OTW) and digital views.

To assist ANSPs with their identification of digital tower solutions to operational issues, several use cases are presented here.

### **DIGITAL TOWER-IN-TOWER**

Several of the benefits realised through the implementation of a RTC can also be applied to the introduction of a digital tower-in-tower. If an airport is identified as being suitable for remote operation, the digital tower system can be installed at the identified airport and an RTM installed in a conventional tower on a suitable operational position. The RTM can be operated using the single mode operation of remote tower.

Example:

- Live video is streamed across a secure wide area network (WAN) using an array of high definition fixed and PTZ cameras installed on site
- The images are stitched and presented seamlessly in real-time to an air traffic controller at an RTM in the conventional tower
- Change management and regulatory engagement are essential to ensure the RTM is safely integrated into the working environment in the conventional tower
- Enables the provision of airport control services at both airfields from a single existing tower site in single mode operation. Note: multiple mode operation could also be explored.

### **HYBRID DIGITAL TOWER**

As the name suggests, ANSPs have begun implementing “hybrid” operations in conventional towers. This entails the installation of digital tower system equipment at an airport, for use in the conventional tower and within the licensed operations at that facility. Two versions of this use case have been identified.

The first involves the implementation of a fully digital CWP into the existing tower. The CWP consists of video displays to provide the situational picture for a single air traffic controller, and the CWP should be designed to not block existing sight lines of other controllers operating in the conventional tower. The controller at the digital CWP could be providing control services to an additional runway or to an area of the airfield too distant from the existing tower to be observed fully out the windows.

#### Example #1:

- Live video is streamed across a secure local area network (LAN) using an array of high definition fixed and PTZ cameras installed on site
- The images are stitched and presented seamlessly in real-time to an air traffic controller at a fully digital CWP in the conventional tower
- Change management and regulatory engagement are essential to ensure the RTM is safely integrated into the working environment in the conventional tower
- Certification should be achieved using an RTM in a training facility, to ensure air traffic controllers are not relying on looking out the windows to provide a safe and efficient service.

The second use case is to install digital tower displays and user interfaces on existing conventional tower CWPs to enable the controller to provide the service using conventional, out-of-the-window views and views provided on digital displays. This can be useful when operating from a temporary or contingency control tower for extended periods of time, enabling higher capacity levels to be maintained during transition.

#### Example #2:

- Live video is streamed across a secure LAN using an array of high definition fixed and PTZ cameras installed on site
- The images are stitched and presented seamlessly in real-time to an air traffic controller at a normal CWP in the conventional tower
- Change management and regulatory engagement are essential to ensure the displays and user interface are safely integrated into the existing CWPs in the conventional tower
- Issues predating the implementation such as blind spots can be mitigated and views can be enhanced in low visibility

ANSPs are implementing hybrid digital operations in large international hub airports such as Changi, Hong Kong, and Paris – Orly as a first step towards digital airport operations. This is also an opportunity to familiarise operations and technical staff with digital tower technology and change management.

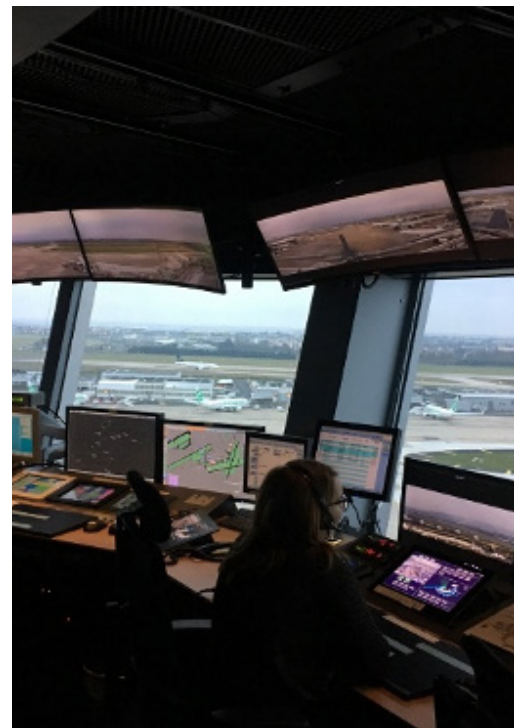


Figure 33 – Hybrid DT operations at Paris-Orly Intl. Airport  
Credit: Searidge

## ***DIGITAL TOWER AND DIGITAL APRON CONVERGENCE***

Since airports have been rebuilding from the effects of the pandemic, collaborative decision making between stakeholders has been increasing. A new application of this concept is to implement an airport-wide digital airport platform built upon the convergence of data from ATS and airport operations. It is then possible to deploy two systems, digital tower and digital apron, and implement CWP for both ATC and apron control in the form of a Digital Apron and Tower Management Systems (DATMS).

A DATMS comprises of a centralised open platform which enables cyber-secure systems – allowing easy integration of all Airport and key ATC systems deployed to the ANSP and Airport Authority. Key features could include:

- External interfaces interconnected, data sharing with secure eligibility
- Information portal between Airport Authority and ANSP
- A network of cameras covering the entire airport for ATC and apron control
- Ability to create future digital applications
- Artificial Intelligence (AI) applications
- Access to processed video to/from both systems (no duplication of processing)
- High level of redundancy
- High performance, secure, network

This new way of working enables convergence and accelerates movement away from the previous “silo” approach to data sharing.

Hybrid digital towers increase the range of applications available to ANSPs and provide a steppingstone to digital tower operations. There are opportunities to implement digital tower technology to augment existing conventional tower operations and share ATM data in innovative ways.

New applications using AI and machine learning can be incorporated through a digital tower platform and visualised in an operational context.

In the case of large international airports, hybrid operations provide a roadmap to full digital tower operations. Initial steps can be to enhance conventional operations or to implement a fully digital tower module in a traditional tower, providing early benefits and familiarising staff with the technology. A digital tower contingency system can be another step on the roadmap towards full capacity digital tower operations at the largest and busiest airports in the world.

## OPPORTUNITIES

### DRONES MANAGEMENT AND DETECTION

Drones bring more and more challenges for ANSPs. They multiply the number of aircraft in controlled airspace and often, uncooperative Unmanned Aircraft Systems (UAS) are an operational threat. This is especially true at airports regardless of whether they are managed via ATCOs using a remote and/or digital tower solution or from a conventional ATC tower.

#### ***UTM AND COOPERATIVE DRONES***

To integrate UAS into normal ATC operations the work environment of the ATCO should be prepared with all available technology needed to keep the overall workload low. Three sub-systems play an important role dealing with drones in an airport environment:

- Air situation display showing normal aircraft and drones at the same time
- Voice communication system to communicate with drone operators
- Electronic flight strips to give clearances to drone operators when necessary and to integrate drones into the normal ATC workflow

In addition to these sub-systems the possibility to augment the view of the ATCO on the panoramic view can enhance situational awareness, reduce the workload, and increase safety. ATCOs have a very difficult time trying to see very small drones in a normal tower environment. Augmented reality features of a digital tower system can make small UAS visible to the ATCO, even if they are too distant to be seen with the unaided human eye.

Through integration of all these systems the workload for the ATCO can be significantly reduced making it easier for them to control many aircraft and drones simultaneously.

### DRONE DETECTION AND UNCOOPERATIVE DRONES

A major threat for aircraft operations is caused by uncooperative drones, which violate the airspace of an airport. Therefore, many airports have invested in drone detection systems. Two major issues are related with drone detection systems:

- A drone detection system based on one technological solution often cannot detect drones in all areas and circumstances. Therefore, typically different technologies like drone radars, HF detection and other sensors are combined
- Drones can move very fast. The fused information of all drone detection systems must therefore be available for all stakeholders, including ATC, in real time to enable an efficient and quick defence of the threat.

A digital tower system can help to fuse the data of the different information systems and to bring detected drones to the attention of the air traffic controller. Augmented reality features of a digital tower system can create awareness directly in the field of view of an ATCO. This increases the situational awareness and increases the safety to a level which cannot be achieved in a conventional tower. Additionally, the ATCO can trigger counter measures directly from their working position.

Air traffic controllers benefit greatly from the advanced possibilities within a digital tower environment where it is currently possible for them to receive a fused view of information that includes normal aircraft and UAS directly in their field-of-view. In the future, the additional possibility that an ATCO could trigger an anti-UAS countermeasure directly from their CWP would also allow them to mitigate drone threats quickly and efficiently. With these considerations in mind, the level of situational awareness and safety in a digital tower control room could be even greater than in a conventional tower.

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# GLOSSARY OF TERMS

The definition/intended meaning of the following terms, used throughout this guidance material, are provided to assist readers. The term 'digital tower' is used generically for the concept and its technologies.

This term is intended to be interchangeable for the following terms applied by other organisations: remote tower, smart tower, remote and digital towers, and any other terms to refer to the concept and its technologies.

The definition of remote tower provided by the EASA is below. This term focuses on facilities where the: "ATS is provided principally through indirect observation of the airport and its vicinity." Within this guidance material we adhere to this definition but also expand to consider digital towers which may provide support within a conventional tower and may not provide the principal means of visual observation.

'Smart and digital tower' is a term only used to refer to the CANSO Smart and Digital Tower Task Force.

## **EASA definitions**

Remote tower means a geographically independent facility from which airport ATS is provided principally through indirect observation of the airport and its vicinity, by means of a visual surveillance system. It is to be seen as a generic term, equivalent in level to a conventional tower.

This can be compared in contrast with the definition for a 'conventional tower'; a facility located at an airport from which airport ATS is provided principally through direct OTW observation of the airport and its vicinity.



# ACRONYMS

ACRONYM	DEFINITION
<b>ACC</b>	Area Control Centre
<b>AD</b>	Airport
<b>AFIS</b>	Aeronautical Flight Information Service
<b>AFISO</b>	Airport Flight Information Service Officer
<b>AFTN</b>	Aeronautical Fixed Telecommunications Network
<b>AGL</b>	Airfield Ground Lightning
<b>AMC</b>	Acceptable Means of Compliance
<b>ANS</b>	Air Navigation Services
<b>ANSP</b>	Air Navigation Service Provider
<b>APP</b>	Approach
<b>ASM</b>	Active Shadow Mode
<b>A-SMGCS</b>	Advanced Surface Movement Guidance and Control System
<b>ATC</b>	Air Traffic Control
<b>ATCC</b>	Air Traffic Control Centre
<b>ATCO</b>	Air Traffic Control Officer
<b>ATM</b>	Air Traffic Management
<b>ATMOPSP</b>	Air Traffic Management Operations Panel
<b>ATS</b>	Air Traffic Services
<b>ATSEP</b>	Air Traffic Safety Electronics Personnel
<b>CAAS</b>	Civil Aviation Authority of Singapore
<b>CANSO</b>	Civil Air Navigation Services Organisation
<b>CDM</b>	Collaborative Decision Making
<b>CERT</b>	Computer Emergency Response Team
<b>CNS</b>	Communication, Navigation and Surveillance
<b>CONOPS</b>	Concept of Operations
<b>COTS</b>	Commercial Off-The-Shelf
<b>CTR</b>	Control Zone
<b>CWP</b>	Controller Working Position
<b>DATMS</b>	Digital Apron and Tower Management System
<b>DFS</b>	Deutsche Flugsicherung GMBH
<b>EASA</b>	European Aviation Safety Agency
<b>EC</b>	European Commission
<b>ECCG</b>	Electrocardiogram
<b>EEG</b>	Electroencephalogram
<b>EFS</b>	Electronic Flight Strips
<b>E-OCVM</b>	European Operational Concept Validation Methodology
<b>EUROCAE</b>	European Organisation For Civil Aviation Equipment
<b>EUROCONTROL</b>	European Organisation For The Safety Of Air Navigation
<b>FAA</b>	Federal Aviation Administration
<b>FCT</b>	FAA's Contract Tower
<b>FOD</b>	Foreign Object Debris
<b>FPS</b>	Flight Progress Strip
<b>GA</b>	General Aviation
<b>GM</b>	Guidance Material
<b>GND</b>	Ground
<b>GSR</b>	Galvanic Skin Response
<b>HD</b>	High Definition
<b>HDD</b>	Heads Down Display
<b>HF</b>	Human Factors
<b>HMI</b>	Human-Machine Interface

<b>HUD</b>	Heads Up Display
<b>ICAO</b>	International Civil Aviation Organisation
<b>IFR</b>	Instrument Flight Rules
<b>ILS</b>	Instrument Landing System
<b>IR</b>	Infra-red
<b>ISO</b>	International Organisation for Standardisation
<b>LAN</b>	Local Area Network
<b>LFV</b>	Luftfartsverket (SE) (CAA of Sweden)
<b>LUAW</b>	Line Up and Wait
<b>LVP</b>	Low Visibility Procedures
<b>MASPS</b>	Minimum Aviation System Performance Standards
<b>MATCT</b>	Mobile Air Traffic Control Tower
<b>MET</b>	Meteorological
<b>METOBS</b>	Meteorological Observation
<b>MTBCF</b>	Mean Time Between Critical Failures
<b>MTI</b>	Moving Target Indicators
<b>NAVAID</b>	Navigation Aids
<b>NLR</b>	Netherlands Aeronautical Centre
<b>NPA</b>	Notice of Proposed Amendments (Avis De Proposition De Modification)
<b>NSA</b>	National Supervisor Authority
<b>ODO</b>	Opposite Direction Operations
<b>OSC</b>	Operations Standing Committee
<b>OSED</b>	Operational Service and Environment Definition
<b>OSP</b>	Optical Sensor Presentation
<b>OTW</b>	Out-of-the-window
<b>PANS-ATM</b>	Procedures for Air Navigation Services – Air Traffic Management
<b>PC</b>	Personal Computer
<b>PPR</b>	Prior Permission Required
<b>PTZ</b>	Pan-tilt-zoom
<b>RADAR</b>	Radio Detecting and Ranging
<b>RMT</b>	Reference Mission Trajectory
<b>RTC</b>	Remote Tower Centre
<b>RTM</b>	Remote Tower Module
<b>RWY</b>	Runway
<b>SDATS</b>	SAAB Digital Air Traffic Services
<b>SDT</b>	Smart Digital Tower
<b>SESAR</b>	Single European Sky ATM Research Programme
<b>SJU</b>	SESAR Joint Undertaking
<b>STARS</b>	Standard Terminal Automation Replacement System
<b>TBC</b>	To Be Completed
<b>TF</b>	Task Force
<b>TMA</b>	Terminal Manoeuvring Area
<b>TMZ</b>	Transponder Mandatory Zone
<b>UAS</b>	Unmanned Aircraft System
<b>UTM</b>	Unmanned Aircraft System Traffic Management
<b>VCR</b>	Visual Control Room
<b>VCS</b>	Voice Communication System
<b>VFR</b>	Visual Flight Rules
<b>WAN</b>	Wide Area Network
<b>WG</b>	Working Group

The list above is a list of acronyms found in this publication only. Many more air traffic and remote and digital tower related acronyms exist and can be found in various publications.



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