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CANSO Guidance Material for Remote and Digital Towers

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Contents

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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 that implementations are uniform, safe and integrated without compromising service levels. This document supports this international effort.

What is a Digital Tower?

Definitions and Background

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

Digital tower technologies provide a view of the aerodrome and its vicinity, enabling operators to conduct visual surveillance using digital means rather than relying on the view provided from the visual control room 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 aerodrome ATS that can be provided when operating from a digital tower are the same as those defined in international standards and recommended practices and should be no different from the aerodrome ATS provided from a conventional aerodrome 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 aerodrome ATS based fully in accordance with ICAO documents 4444 and 9426 was approved into operation in Sweden in April 2015. Some remotely provided aerodrome flight information services have been provided in Japan, however, since 1974 [1].

The digital tower concept was initially developed for low density aerodromes hoping to achieve a more cost-efficient way of providing aerodrome 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, providing the opportunity to locate in an area where the potential to recruit and retain skilled staff is increased. For low density aerodromes 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 aerodrome ATS, including air traffic control, aerodrome flight information services and apron control services.

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

In addition to cost efficiencies [2], 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 aerodrome ATS 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 varied 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 need. The core operating modes discussed below are not mutually exclusive.

EASA has defined two operating modes [3]:

- 'Single mode of operation' means the provision of ATS from one remote tower/remote tower module for one aerodrome at a time
- 'Multiple mode of operation' means the provision of ATS from one remote tower/remote tower module for two or more aerodromes at the same time (i.e. simultaneously)

In addition, other notable applications exist as follows:

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

Currently there is not considered to be a significant difference in the technologies required to facilitate any of the core operating modes. The operational complexity (of the operating mode and of the operating environment) influences the technology and equipage requirements.

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

Single mode operations

Single mode operations refer to the provision of an aerodrome ATS to one airport from a digital tower. 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, where a conventional tower is not used.

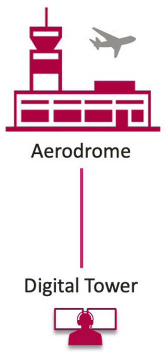


Figure 1: Illustration of 'Single Mode' Credit: Think Research

Multiple mode operations

Multiple mode operations involve the provision of aerodrome ATS to two or more aerodromes simultaneously from a digital tower. 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 aerodrome ATS to more than one aerodrome 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.

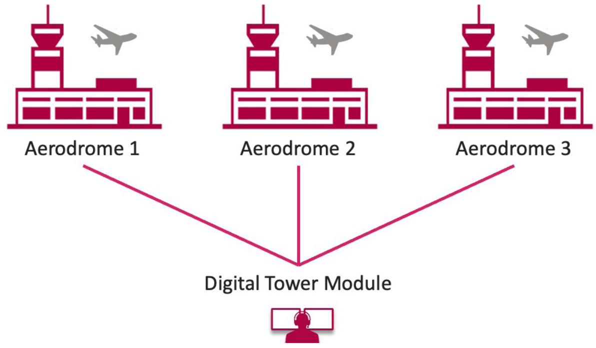


Figure 2: Illustration of 'Multiple Mode' Credit: Think Research

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

Contingency mode operations

Contingency mode operations refer to the provision of aerodrome ATS in cases where the permanent ATS facility is unusable, e.g. in non-nominal or business continuity events. 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 mode applications.

When implementing a contingency digital tower, the configuration (including any out-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 mode operations can be provided from a permanent digital tower facility or a temporary facility. Temporary facilities may not have the same certification requirements.

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 aerodrome expands, or may eliminate blind spots that can emerge with the growth of the aerodrome.

In addition, the inclusion of digital tower technologies can have other benefits both in digital and conventional towers. For example, infra-red 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 aerodrome ATS function to be better connected to other ATS and aerodrome functions, for example connections to airport operations centres or area control centres, and this, in turn, can enhance information sharing 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
- Aerodrome layout
- Airspace characteristics and classification
- Operator roles and local procedures, and
- Required performance

These aspects of the operational environment have an influence on the most suitable technical implementation, as would be the case when considering conventional tower operations.

The experiences have shown that of these, 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) flight plans, 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 [4].

In a conventional tower, operators have the freedom to move around the visual control room (VCR) to improve their view of the aerodrome and vicinity. In a digital tower environment, this is only possible if the correct equipment and configuration of cameras and surveillance sensors are provided.

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

For aerodromes 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 aerodromes with a higher traffic density or with a lot of additional traffic in the vicinity, for example, from neighbouring control zones (CTR) 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 its important that all vehicle movements can be seen when providing aerodrome 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

Aerodrome 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 density considerations when operating multiple mode

When operating using multiple mode, the total traffic density of all aerodromes being simultaneously provided with a service needs to be considered, including the interaction of traffic schedules. If the traffic schedules of aerodromes 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 aerodrome also need to be considered.

Specific mitigations to manage traffic and the workload or operators, when providing a simultaneous service to two or more aerodromes, 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 aerodrome 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 aerodrome ATS to two or more aerodromes 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

The nature of an aerodrome 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 physical infrastructure at the aerodrome 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 aerodrome 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.

Technology

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

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

Visual sensor presentation

High quality reliable visual presentation technology sits at the core of the digital tower concept. EUROCAE Ed-240A [5] defines a digital tower visual presentation as: "A visual display that shows the areas of responsibility of the digital tower ATS unit. Visual presentation comprises the following types of presentation:

- Optical Sensor Presentation;
- Virtual Presentation;
- Augmented Optical Sensor Presentation."

The EUROCAE Ed-240A focuses on optical sensor presentations.

Other technical enablers

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

- Binocular functionality
- Signalling lamp
- Aerodrome sound reproduction
- Communication devices to facilitate service provision
- Management of navigation aids, aeronautical ground lights and other aerodrome assets
- Meteorological information
- Other ATS functions and systems as required (and not necessarily affecting the provision of aerodrome ATS from a location remote from the aerodrome)
- Hot spot or gap filler cameras
- Other 'enhanced features' of a digital tower, including objective 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. infra-red 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 would need to accompany the introduction of any new features or tools. The maturity of some of these enhanced features is still only 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 aerodrome 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, will need to be considered.

Digital tower facilities need to consider the ratio of aerodromes to operators, the specific visual requirements of each operational role and the operational mode provided. All influence 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 compressed and displayed on a 180 degree or 220 degree lay out of display screens).

Specific examples of operational configurations are now discussed.

One operator, one CWP

Only one operational role needs to be considered when configuring the aerodrome 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 are to be used to provide ATS to an aerodrome, for example during off peaks 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. It is not a requirement, however if the 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 aerodromes

The visual presentation display will be required to show each aerodrome, with a variety of possible methods used to achieve this. Control tools used may be duplicated or integrated for use for all aerodromes. Operators will need to be able to clearly identify which aerodrome is being controlled by input devices and to which aerodrome 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 Visual Control Room (VCR).

Digital tower centres

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

Centralising aerodrome ATS for more than one airport provides the ability to use a central aerodrome ATS resource pool. However, licensing and certification will need to be considered and may limit how dynamic that resource pool can be.

Limitations may also include the level of standardisation possible within the central facility. If airports choose to use different technology, providers and equipment, then the ability to share such resources in a flexible way may be reduced. Such limitations do not necessarily reduce the benefit of co-locating aerodrome ATS.

The use of a digital tower facility/RTC allows the sharing of resources such as staff, buildings, equipment, providing cost efficiency benefits through this increased ability to share.

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 below. These are now discussed.

Figure 3: Key benefits of digital towers Credit: Think Research

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 expenditure, potential savings can be achieved.

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

Operational cost savings can also be realised by reducing maintenance on equipment and associated costs. This would be possible by combining equipment into one facility and by using the same or similar system set ups for many airports. This streamlining of the equipment used across many airport towers is in contrast to the use of different types of equipment in conventional towers.

There are significant capital expenditure savings to be yielded by installing a digital tower at a new airport, saving the need to build a physical tower. Significant expenditure will also be saved in additional costs such as maintenance, equipment servicing and the additional cost of accommodating staff.

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

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

Flexibility, level of service provision and availability

Digital towers enable a level of flexibility that is not currently achievable when operating from a more conventional tower.

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 aerodrome 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 aerodromes. 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. Airports are enabled to 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.

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.

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.

One consideration when erecting new structures on airfields is whether or not they obscure the tower's view. Given the complexity of many airports, and that the original tower would have been built without new structures in mind, 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 of critical importance. Providing a means to avoid the cessation or reduction of aerodrome ATS during adverse conditions (benefits passengers, ANSPs, airport operators, airlines and the entire network. Here are a few examples of how the digital towers can help to increase operational resilience.

Adverse meteorological and low visibility conditions often have a negative effect on traffic flow owing to the need to increase the spacing between aircraft, and aircraft often moving slower on the ground. In such conditions the use of digital tower technologies, including infra-red 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 aerodrome ATS facility may enable aerodrome 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, 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

Aerodrome 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 for continency can enable a high percentage of capacity to be maintained should the conventional tower become unserviceable. Currently operational digital towers used to provide aerodrome ATS contingency do not operate with restrictions on traffic levels that are different from the conventional tower operation.

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, valuable at times of crisis or when other restrictions on operational resources are in place, such as social distancing.

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, enabling more integration and automation, may be used to improve service delivery compared to current operations in some environments.

Safety

Implementations of 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 would enable enhanced aerodrome visibility and support controllers in detecting and resolving safety-critical situations. The ability to optimise the view that the controller has of the aerodrome 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.

Centralisation of services and information

To maximise the benefits of the concept, an ANSP may decide to co-locate digital towers at a centralised facility. Such a facility may appear similar to an Area Control Centre (ACC).

The following benefits may be enabled through operating from a central and shared facility:

- Improve cost management
- Staffing efficiencies
- Standardisation (if desired) both in terms operational procedures and training
- Social benefits
- Information and data sharing
- Increased collaboration and connectivity between stakeholders

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.

Stakeholder benefits

Digital towers are a concept with the potential to benefit a wide range of stakeholders. The various effects that a digital tower implementation may have is important to consider and keep those stakeholders informed of.

Air traffic controllers (ATCOs), aerodrome flight information service officers (AFISOs) and air traffic safety electronics personnel (ATSEPs) are one of the main stakeholder groups to initially 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.

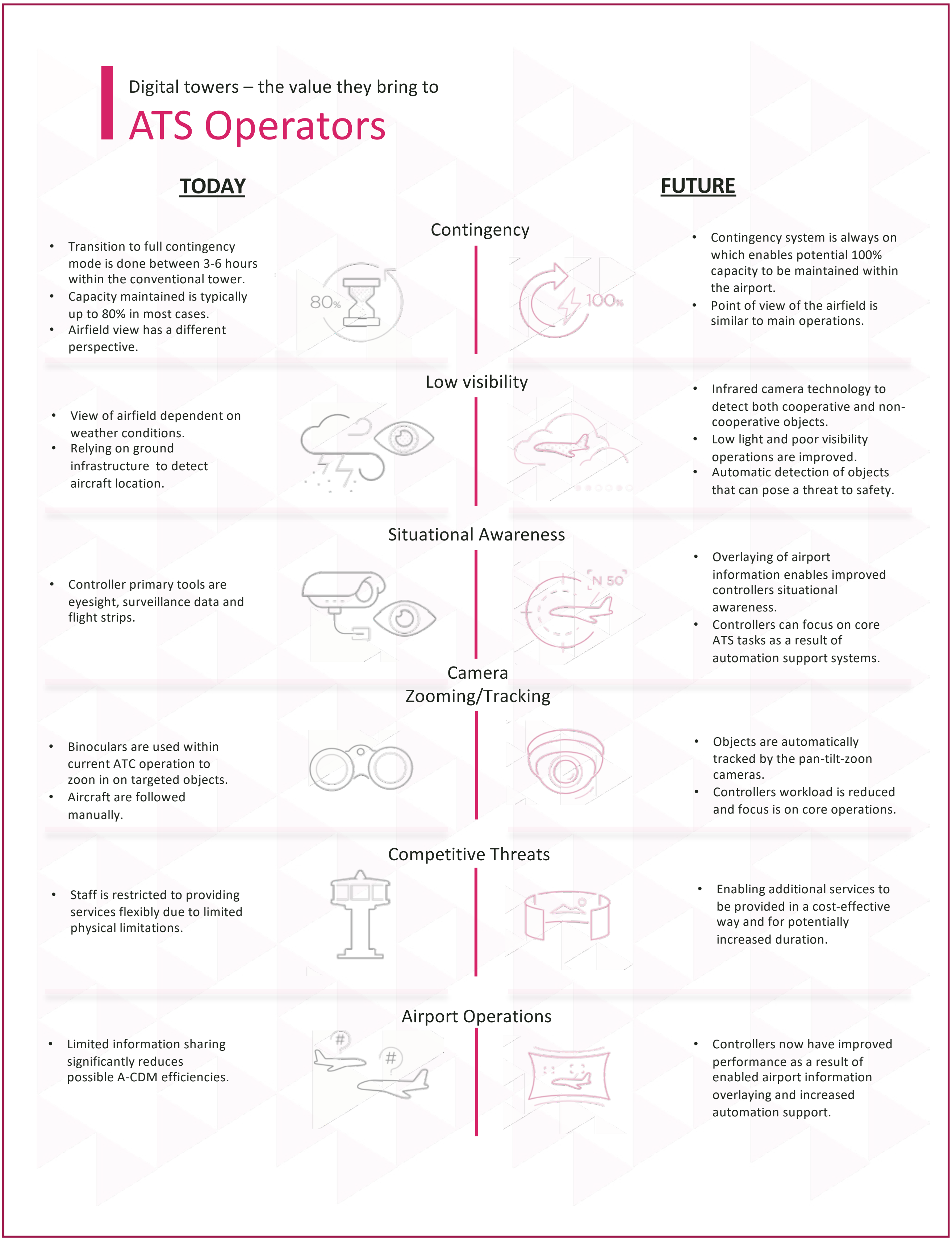


Figure 4: The potential value digital towers may bring to Ats – based on materials provided by Airways New Zealand *Credit: Think Research*

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

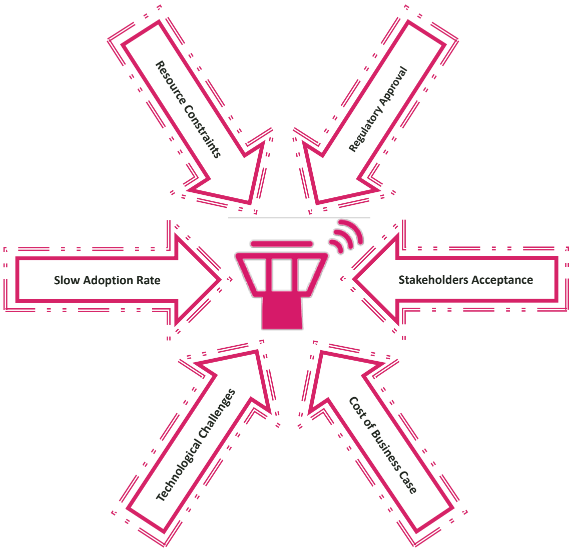


Figure 5: Key challenges faced by digital tower programmes   Credit: Think Research

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 wellbeing 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, and if ATCOs are reluctant to permanently relocate. It is 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 bespoke products that lack standardisation. 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 aerodrome 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 as there is no need for these to exist. The regulation. 2017/373 applies regardless of conventional or remote operations.

However, there is extensive regulatory guidance provided to support the application of Reg. 2017/373 in the remote ATS context in the form of the EASA remote aerodrome ATS GM Issue 2 (Feb 2019). [3]

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

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

Making a case which provides clear evidence to decision makers on whether or not to implement digital towers is more difficult than expected, considering the cost efficiencies the concept potentially delivers. One of the reasons the business case can be hard to define is that the cost of entry is still high, while the long-term return is significant and transformational. This is due to the lack of global up take seen 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 be presently available. 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 will relate to the time required, potential delay costs and the need for operator resource throughout.

Improvements to the standardisation of the approval process will come naturally. However, as the primary benefits of digital towers come from the solutions being bespoke to specific operations, it is likely that tailored assessments will always be required.

Infrastructural and technological limitations

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

Resource constraints

Pre-implementation activities require operational resources and ensuring this resource is available is often a challenge. The experiences of early adopters showed that there is benefit in ensuring that the 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.

Digital Towers: A View Through Cases 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)
- Existing airports that do not have a tower but where the provision of an aerodrome 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 aerodrome 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).

The case studies include the following operational modes:

- Single mode (LFV, SDATS, DFS, FAA)
- 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 One	**FAA Digital Towers**
Case Study Two	**LFV & Saab Digital Air Traffic Solutions (SDATS) Remote Tower Services**
Case Study Three	**HungaroControl Remote Tower Operations**
Case Study Four	**DFS Remote Tower Control**

Case Study:
FAA Digital Towers

Figure Case Study 1: Inside the Digital Tower Credit: FAA

The Federal Aviation Administration (FAA) is evaluating the viability of remote tower systems to support Class D Airport Traffic Control Tower (ATCT) operations. 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 tower systems. The FAA intends to develop an official list of certified remote tower systems that airports can choose from when equipping a new ATCT facility. Evaluations are in progress at Leesburg Executive Airport (KJYO) in Leesburg, Virginia using the Saab remote tower system and Northern Colorado Regional Airport (KFNL) in Fort Collins, Colorado using Searidge Technologies remote tower system.

Overview – Current status

- KJYO and KFNL are in different stages of evaluation and maturity. KJYO began first and is further along in the evaluation phases. It is also currently undergoing a verification and validation of active control of aircraft while KFNL has reached the passive phase of evaluations
- Initially the remote tower equipment at KJYO was installed in a temporary location on airport property. Daily RT operations, begun in June 2018, have now been suspended while the equipment is relocated to a permanent location off airport
- KFNL will begin passive evaluations in late 2020 to early 2021 to collect data while ATCT operations are run from an on-site Mobile Air Traffic Control Tower (MATCT)

Operational environment

Test site #1 – Leesburg Executive (KJYO)

- Runway 17/35 Dimensions: 5500ft x 100ft/1676m x 30m

Airport Operational Statistics (*Source: AirNav.com*)

Aircraft Type	Number based at KJYO
Single engine aircraft	167
Multi engine aircraft	22
Jet aircraft	11
Helicopters	6
Gliders airplanes	1
Total Aircraft based at KJYO	207
*Based on 12-month period ending 31 December 2017	

Aircraft Operations*	Avg. 292 ops/day
Local General Aviation	85%
Transient General Aviation	11%
Air Taxi	2%
Military	1%

Test site #2 – Northern Colorado Regional (KFNL)

- Runway 15/33 Dimensions: 8500ft x 100ft/2591m x 30m; and
- Runway 06/24 Dimensions: 2273ft x 40ft/693m x 12m

Airport Operational Statistics (*Source: AirNav.com*)

Aircraft Type	Number based at KFNL
Single engine aircraft	207
Multi engine aircraft	15
Jet aircraft	10
Helicopters	18
Gliders	1
Ultralights	1
Total Aircraft based at KFNL	**252**
*Based on 12-month period ending 31 December 2018	

Aircraft Operations*	Avg. 260 ops/day
Local General Aviation	37%
Transient General Aviation	59%
Air Taxi	4%
Military	<1%
Commercial	<1%

Business Drivers and Challenges

Drivers and business goals

The FAA's Federal Contract Tower (FCT) Program was established in 1982 to contract out the operation of certain low-activity towers. There are approximately 250 FCTs, 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 resumption of FCT application processing. Eligibility for acceptance into the FCT is determined by a congressionally mandated Benefit Cost Analysis (BCA) formula. The safety and efficiency benefits of providing air traffic services must exceed their cost. The cost of RT systems can significantly lower than construction of a new air traffic control tower (ATCT), possibly improving the overall cost to benefit ratio of potential airport candidates for the FCT program.

Challenges

The FAA is evaluating to prove that RT can be used by controllers to provide the same level of service as a Class D ATCT with no discernable difference identifiable by the user. The evaluations revealed several challenges including issues with human factors, system hardware faults, and variable operations in a Class D environment.

- A challenge of a RT is limited depth perception. While depth perception is different in an RT compared to an ATCT view, necessary perceptual cues are still present and allow for controllers to perceive depth perception. At KJYO, controllers are able to sequence and space with the use of site-specific standard operating procedures (SSOPs)
- Various system equipment failures leading to delays in evaluations and cessation of operations from the RT
- Cameras can be susceptible to vibration/deflection which affects alignment and presentation of the image on display

Technical Solutions

Solutions to some of these issues involve:

To improve depth perception and reduce distance from controller working position to the visual presentation, the video display screens were reconfigured to increase the curvature of the display. The reduction of distance from the controller to the video displays has been demonstrated to assist the controllers in initial detection and spatial orientation of targets in the air.

- FAA is developing reliability requirements such as mean time between critical failures (MTBCF)
- Backup and continual power requirements to be defined in future activities
- Vendor-driven technical solutions are being employed to ensure camera stabilisation

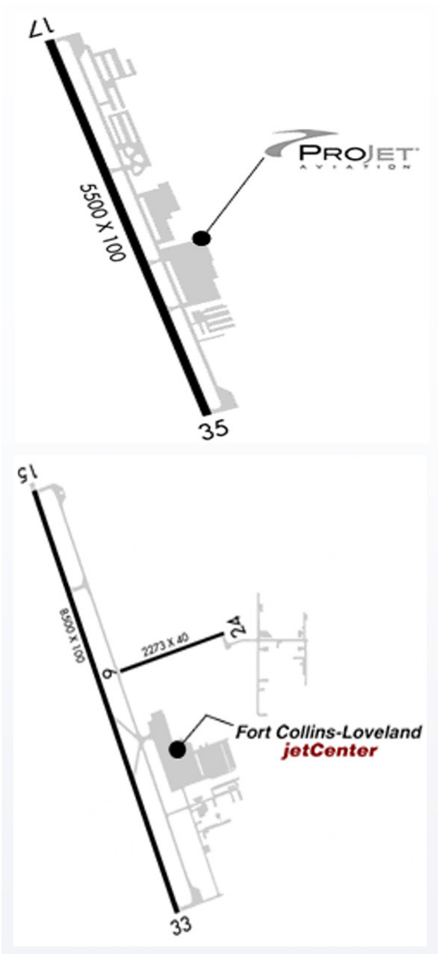


Figure Case Study 1: KJYO Airfield Design | Credit: FAA

Planning and Deployment

The FAA intends that RT operations be transparent to pilots, while providing an equivalent level of service of a traditional Class D ATCT. The goal of providing indistinguishable service requires a high standard of performance for both equipment and personnel. This goal creates multiple implementation questions for certification of systems and eventual incorporation of RT services into the National Airspace System (NAS).

Lessons Learnt

- Mounted camera systems are susceptible to weather phenomena and other sources of deflection
- SSOPs may be required to coincide with information presented on RT visual display to ensure the safe and efficient provision of required Class D airspace services

Next Steps

- KJYO RT equipment is being relocated to a permanent offsite location and will resume evaluation when installation is completed
- Future airports for the RT Pilot Program will be chosen based on the expansion of the applications of RT in Class D environments
- Current plan is to evaluate RTs at up to six separate locations in succession, building on knowledge gained from each previous test site
- The Department of Defense (DoD) has selected a RT system offered by Frequentis Corporation. Evaluations will be conducted at two separate locations. The FAA has asked to participate as an observer and for access to evaluation data results

Case Study:
LFV & Saab Digital Air Traffic Solutions (SDATS) Remote Tower Services

Figure Case Study 2: Inside the Digital Tower *Credit: SDATS*

The Swedish experience – two remote tower centres, eight airports, and five years of operational experience

LFV was the first ANSP in the world to provide aerodrome control services remotely in April 2015, from a RTC in Sundsvall, using a digital tower system provided by industry partner Saab. Currently four Swedish regional airports are provided with remote aerodrome ATS from that RTC.

LFV and Saab have now partnered to form a joint venture – Saab Digital Air Traffic Solutions (SDATS), an EU certified ATS provider. As of 1 January 2019 SDATS is the ATS provider for RTC Sundsvall.

Another RTC, 'RTC Stockholm', is being deployed in connection to the LFV ATCC at Stockholm-Arlanda airport. The initial plan is to provide remote aerodrome ATS to four Swedavia (state airport operator) airports from RTC Stockholm. The first airport to be connected to RTC Stockholm (Kiruna) is expected to become operational in 2021. LFV will be the ATS provider for RTC Stockholm.

Operational Environment (traffic figures based on 2018 annual data)

RTC Sundsvall airports:

- Örnsköldsvik (ESNO) – ~3.500 movements
- Sundsvall-Timrå (ESNN) – ~8.000 movements
- Linköping/Saab (ESLL) – ~11.500 movements
- Sälen/Scandinavian Mountains (ESKS) – In operation as of 22 Dec 2019

RTC Stockholm airports:

- Kiruna (ESNQ) – ~5.000 movements annually
- Åre Östersund (ESNZ) – ~10.500 movements
- Umeå (ESNU) – ~23.000 movements
- Malmö (ESMS) – ~50.000 movements
- All airports provided with:
  - Aerodrome control service
  - Approach control service
  - Meteorological observation service (METOBS)
- All airports are single runway airports without a parallel taxiway, except:
  - Åre Östersund (ESNZ) – single runway with parallel taxiway
  - Malmö (ESMS) – 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 (ESLL has military flight school), helicopters etc

Business Drivers and Challenges

Drivers and Business Goals

Capacity/Flexibility/Cost:

- Low use of ATC staff – with low traffic at these airports, the effective ATCO 'controlling' time is low
- Limited flexibility – hard to move ATCOs around due to distance, different operational procedures and different systems/HMI in all towers. Often takes weeks to be trained and transferred to another tower
- Expensive to keep small rural airports open, yet vital for the local business sectors and community.
- Airlines and Policymakers are pushing for reduced airport and ATS fees
- The provision of aerodrome ATS in Sweden is a competitive market which means that cost and level of service must remain competitive
- Many of the airports being considered for digital tower implementations in Sweden have an ageing infrastructure and equipment that will require replacing

Safety and Human Factors:

- When working at airports with low traffic volumes, ATCOs may be under-stimulated. ATCOs also often work in isolation which reduces the opportunities for experience and knowledge exchange
- Different/non-standardised operational procedures and equipment across airports
- Airport developments and runway extensions could bring limitations in visual views from the existing towers
- Poor or no systems to support ATCOs in existing conventional towers to detect runway incursions, airspace infringement, and drones, or to improve situational awareness during low visibility and darkness.

Challenges

Challenges have mostly related to the change management process and stakeholders' acceptance rather than technical or operational aspects.

- Long lead times for the regulatory operational approvals – around two years from application to operational approval for the first airports. This is likely to be related to the fact that there was little to no prior experience within the regulator nor within LFV and that there were no specific supporting regulatory materials or technical standards available for remote aerodrome ATS at the time of the first implementations
- The pilot and ATCO community have expressed concerns about the change from conventional to digital tower operations. LFV identifies that the provision of early information and involvement of all affected stakeholders in the change management process is crucial if an implementation is to be successful
- The level of technical integration, systems and components in the RTC means many different types of alarm, alert, and message are possible. A new modern integrated alarm

system needed to be developed to ensure that ATCOs only received operationally relevant and understandable information. Non-operationally relevant information is directed to technical supervisory positions and or maintenance organisations

More Insights

Video 1:
Common questions from air traffic controllers about digital towers

Video 2:
Five pieces of advice when going for a digital tower

Technical Solution

The strategy for realisation was to replicate the conventional tower as much as possible, in order to smooth the transition and to ensure fulfilment with existing rules and regulations (e.g. ICAO Doc 4444) for aerodrome ATS service owing to the lack of regulatory guideline material or technical specifications at the time.

Functions which could not be replicated were replaced with something similar at the controller working position, e.g. monitors instead of windows, pan-tilt-zoom (PTZ) cameras instead of binoculars. No additional functionality was provided as the philosophy was to keep the design of the first implementations simple and as close as possible to the conventional tower to minimise the level of change for stakeholders.

- 14 HD cameras providing a high resolution, 30 frames per second, 360° horizontal view of the aerodrome and its vicinity. A +/- 23° vertical view (45.7 ° total vertical opening angle from the bottom to the top of the screens) as in the ordinary tower
- Two PTZ cameras coupled with signalling lamp
- Gap filler cameras to provide visual coverage of hot spot areas and operational blind spots etc., subject to local conditions and operational needs
- Pressurised, heated, andcooled (depending on season) camera housing ensuring functionality in all weather conditions and protecting against animal and insect interference
- Microphones capturing and relaying the aerodrome sound to the remote operator, providing an improved sense of presence and situational awareness. Especially relevant for small airport environments
- All other systems and ATCO support tools as required (radio/interphone, radar/surveillence, airport nav/lighting manoeuvre etc.)
- A maximum end-to-end delay from sensor to display of less than a second
- Redundant network (separate and independent lines and routes) and power supply to ensure undisrupted service

Planning and deployment

The implementations set out to provide the same service as would be provided from a conventional tower but from a remote location using new technical tools. The aim was to provide operators with the ability to mentally transition from providing aerodrome ATS from the old environment to the new in a smooth way and adapt to this change over time, before introducing any more innovative technologies.

The implementation of a digital tower was treated as a safety-related change to a functional system according to Regulation (EU) 2017/373 'ATM/ANS Common Requirements':

- Technology and equipment: ANSP and ATCO operational demand is the driver and the system shall support existing rules and regulation
- Procedures: The system shall support the ATS service – no changes for pilots or stakeholders
- Operators are trained to perform the service according to the above and require only unit system training

To consider for the planning and deployment (lessons learnt):

- Bring in operators (ATCOs) early in the process so they can influence the industrial design and build trust in the system
- Close coordination with the aerodrome operator is important (multi-actor change)
- Bring in safety assessors and experts early in the process
- Bring the Regulator on-board early
- Early consultation with stakeholders, trades

unions and the like is a key factor for success

- Use a step-by-step implementation and add features in the future. Start basic and have an operational concept
- Change management is critical and may need to include a significant amount of engagement and time to ensure stakeholders come to understand and value the change

Lessons Learnt

- Working together creates synergies:
  - Operational and technical staff in the same building
  - Colleagues from other ATS units and towers – no more working alone
- 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).
- We can use most of our operational manuals (design decision 2010)
- Depth perception is not an issue and is a mental process that ATCOs learn in the new operational environment. Reduction in separation minima (visual separation) is still applied in accordance with ICAO Doc 4444
- Cameras may sometimes provide a lower performance compared with human eye based on conventional tower out the window view. However sometimes performance is improved. For example:
  - Objects will typically appear smaller than in real life – faraway small objects may sometimes be harder to detect depending on visibility and daylight conditions
  - Cameras present 'longer' days enabling the controller to see better during dusk and dawn. Controllers should be aware of this effect so that they appreciate that flight crews may not be able to see things that they do. Additionally visually positive effects have been seen in mist
  - When operating from a digital tower, it is possible to look straight into the sun and avoid glare 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
  - Presenting 360° in a ~225° U-shaped remote tower module opening, ATCOs adapted to the view provided easily. It even brings some benefits as the operator has the complete scenery 'in front of them' with. no need to turn around to look behind
- Visual overlays, infrared cameras, and the like can be introduced to provide ATCO decision making support. Such functionality is not seen as a requirement, but more of a 'nice to have' feature.
- MET observations can still be performed by ATCOs from the RTC
- Do not mix many different systems. Let the interaction be handled by one system for all system parts. Reduce workload by system integration
- A simulator and a Test and development System or remote tower module in the RTC will support operations and deployments by enabling:
  - ATCO training (e.g. recurrent, emergency, degraded modes, etc.)
  - Validation of new airports and ATS-units, operational modes (e.g. 'multiple'), etc
  - Verification and validation of new system releases

Future and Next Steps

"RTC 2.0"

New tools and features will be added to the remote tower functional system over time. This may include visual tracking and 'box and follow' and radar tracking and labels overlays, with the aim of increasing ATCOs' situational awareness and heads-up time. However the philosophy is that operational approvals will always be based on a basic set-up, and that service provision and capacity shall not be dependent on any such additional tools or features.

Multiple mode of operations

An implementation project to implement 'multiple mode of operations' with one ATCO serving two airports simultaneously is ongoing. Realistic real time simulations focusing on human performance, safety and procedures for degraded modes and emergency situations were performed for Sundsvall (ESNN) and Örnsköldsvik (ESNO) airports in 2019 with positive results. The next steps will be to further develop the safety case and to start live validations (following regulatory approval).

Simplified solutions for AFIS

LFV and SDATS are working together to develop a simplified, low-cost remote tower solution for AFIS applications.

Case Study: HungaroControl Remote Tower Operations

Figure Case Study 3: Inside the Digital Tower *Credit: HUNGAROCONTROL*

Facing the constraints and operational service impacts of ageing tower infrastructure, HungaroControl needed to find a cost-effective solution to safely and efficiently serve more than 115,000 movements at Budapest Liszt Ferenc International Airport (LHBP). In partnership with its integration and technology partners, Searidge Technologies for video system, and Indra Navia for Advanced Surface Movement Guidance and Control System (A-SMGCS), HungaroControl coupled advanced technology with a coordinated and people-focussed implementation program to successfully digitise tower operations. Since 2017, Budapest RTC has been fully operational as a contingency facility. The RTC has been used to provide ATS to more than 12,000 controlled movements over 2,500 operational hours.

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 program is to upgrade the RTC so that it can be used to permanently provide aerodrome 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 between the farthest thresholds is 6 km. There are two terminal buildings with individual aprons. Some 122,814 movements were registered in 2019 (mainly IFR) with 16,173,489 passengers. 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 ATCO, and one supervisor positions in the tower and these are also provided in the contingency RTC.

Business Drivers and Challenges

Drivers and business goals

Following more than 30 years of operational service, the conventional control tower at LHBP is facing the end of its planned lifecycle. 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 these options would require 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 around 12 months in implementation effort. All while building an enhanced capability to deliver resilient tower services.

Challenges

- Engagement with operational staff from concept-to-operation to build change consensus and technology acceptance
- Integration of a new technology – application of safety principles to drive safety by design and enforce system resilience
- Emphasis on human performance to unders-tand the impact of change on end-users, and identify the technology and process solutions to enhance safety and performance
- NSA certification process – new concept means limited industry-level experience and lack of supporting materials, extra effort is needed from ANSP and NSA sides
- Planning and implementation of the video system to maximize 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 and so on. 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 (expect 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. 22 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 requirements:

- 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 three additional PTZ cameras, which can turn, tilt and zoom independently (changing focal length and sharpness). Each PTZ camera includes a thermal sensor, 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 LCD screens installed at the CWPs (one to display the image of fix 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 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 the situational awareness especially in case of reduced visibility conditions or at night.

Planning and Deployment

The RTC implementation is a long-term program for HungaroControl, containing different stages, to improve and add functionality. The first stage was the SESAR Very Large Demonstration in 2016. Following this, 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 and human factor assessments have been conducted, taking into account already existing studies and operational experiences. These assessments start in the definition phase of the project and help 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. A well-planned validation process (passive and active shadow mode) is key to evaluating the new functionalities, the new environment and to justify the requirements. Cyber security aspects were also taken into consideration, in line with existing standards.

The National Supervisory Authority (NSA) has been involved in the projects from the beginning, and helped to develop a clear understanding of 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 documentation.

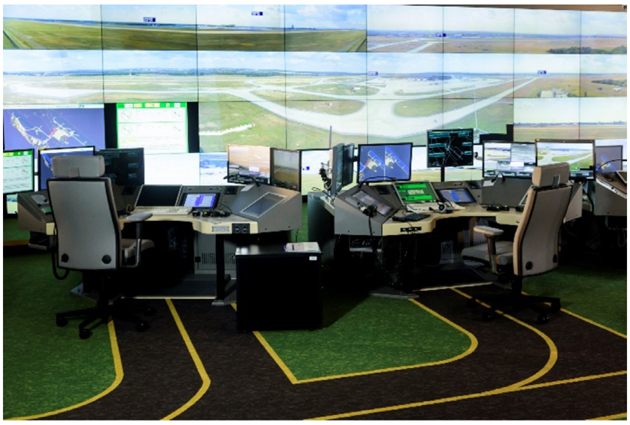


Figure Case Study 3: Inside the digital tower showing working positions
Credit: HUNGAROCONTROL

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.

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 also visual representation planning. Provision of a platform that delivers enhanced visual capabilities not possible from a conventional tower should also be considered. Building on an out-of-the-window view concept, additional camera sensors were installed to create auxiliary view¬points that augment the visual range of operators and unlock previous blind spots.

The RTC room is supplied with increased capacity air conditioning and 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. As the RTC room is located in the ANSP building detailed implementation plans were made.

A special group of air traffic controllers (called 'Tiger team') was involved from the beginning of RTC planning, and participated in SESAR Very Large Scale Demonstration, to shape the RTC according to ATCOs' 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 have participated in validation sessions, and everyone had the opportunity to provide feedback.

All ATCOs gained a license extension to be able to control traffic from the RTC. Currently, every ATCO must work from the RTC for a dedicated time each year to maintain competence. The current requirement is at least 20 hours per year.

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 take over control from the conventional tower (either in case of normal transition for training purposes, or in a contingency situation), and also to give it back.

Lessons Learnt

The following lessons learnt are based on more than 800 hours of real operational experience in the Budapest operational environment.

- 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
- All members of the TWR ATCO staff are capable of controlling from an RTC environment, regardless of their background and experience
- RTC is suitable for an airport with two runways, and in case of LVP/VMC operations
- Difficulties can occur with the night setup, owing to differences in light levels throughout the aerodrome at night. For example, apron areas may be very well lit, while other areas are very dark, and balancing this can be challenging. As such the night operation should be validated and optimised
- In case of a contingency RTC, regular training is required to maintain ATCO competency
- To support RTC operations, new skills are necessary for the technical staff. One example is staff will be required to maintain cameras, sometimes located at height. This may require technical training and new protective equipment etc. For these, staff training is important and additional staff may be required
- The representation of additional information on the video surveillance systems, such as overlay labels, was found to be a useful and beneficial for controller human performance and efficiency

Future and Next Steps

In the future, HungaroControl intends to expand its digital tower capability further. The TWR system used today has all the features to provide ATC services safely to LHBP, but the lack of system integration increases complexity and is a significant constraint for future capacity growth. A large-scale system upgrade, aiming for system integration and modularity, is planned for 2023. As part of this upgrade program, the visualisation will be further improved both in terms of hardware and software. CWPs will be re-designed to provide a simple, intuitive and comfortable environment for ATCOs in order to minimize 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.

More Insights

Video 1:
Remote Tower Operations in Hungary

Case Study: DFS Remote Tower Control

450 km distance | international airport | > 15k movements

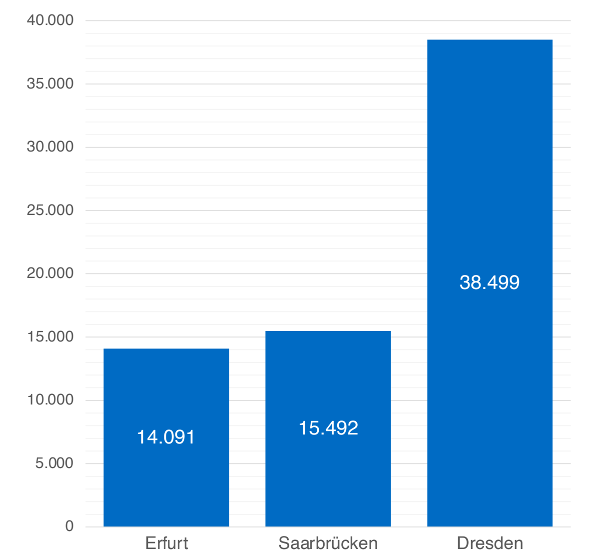
Highly sophisticated remote tower project went live in Germany in 2018.

Since 4 December 2018, aerodrome ATS at Saarbrücken airport have been provided successfully by DFS from its Remote Tower Centre in Leipzig, over 450 km away. DFS and the Austrian ATM technology provider Frequentis mutually developed the solution. The close cooperation continues in the form of their joint-venture FREQUENTIS DFS AEROSENSE, which provides customized digital tower solutions worldwide.

Overview – current status

DFS Deutsche Flugsicherung has developed an advanced remote tower solution for the three international airports Saarbrücken, Erfurt and Dresden, together with the Austrian high-tech company Frequentis. In December 2018, the remote tower solution went into regular operations for Saarbrücken International Airport, which has 15,000 flight movements per year. The other two airports will be phased into the Remote Tower Control Centre in Leipzig step by step.

Traffic figures (2018)



Business Drivers and Challenges

Drivers and business goals

Operational advantages:

- Harmonising the ATM technology
- Ensuring safety and capacity in increasingly complex air traffic control environment
- Job enrichment for ATCO
- Location-independency
- Up to 18% savings on OPEX

Commercial factors:

- Infrastructure and synergy effects
- Improved staffing efficiencies in operations and engineering
- Up to 80% savings on CAPEX
  (Result of a DFS and Frequentis study 2018)

DFS chose to start RTC at Saarbrücken airport as otherwise DFS would have had to construct a new control tower. Additionally the number of flight movements at Saarbrücken airport was at a level considered to be manageable considering this was proposed as the first implementation of remote tower services in Germany. Lastly, Saarbrücken airport is the furthest from the center in Leipzig. If the infrastructure is set up for this distance, the other distances should not be a problem.

Challenges

Challenges included finding a system for the out-of-the-window view that met our requirements in terms of performance, flexibility, quality and safety. The main challenge, however, was a new working environment. Even though the feasibility of the RTC project had already been demonstrated in 2012, DFS still had to deal with the change process.

Technical Solution

The remote tower technology, developed together with Frequentis, reproduces an advanced out-of-the-window view; instead of looking through the tower windows, the controller looks at a panoramic view on five screens.

The controller working position

The controller working position in the DFS Remote Tower Centre has been developed together with the ATCOs, according to the operational needs.

Its size and arrangement fits perfectly to the controllers ergonomical needs. It minimises head movement and head-down times.

The technology

A combination of video and infrared cameras deliver a permanent 360° view of the airport. Automatic object recognition and tracking in the panorama display supports the situational awareness. The system provides additional optical information, which is, in some situations (e.g. at night), better than the conventional out-of-the-window view.

Technical highlights:

- Scaleable 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
- Camera automatic cleaning system.
- Redundant local and wide area networks for data transmission

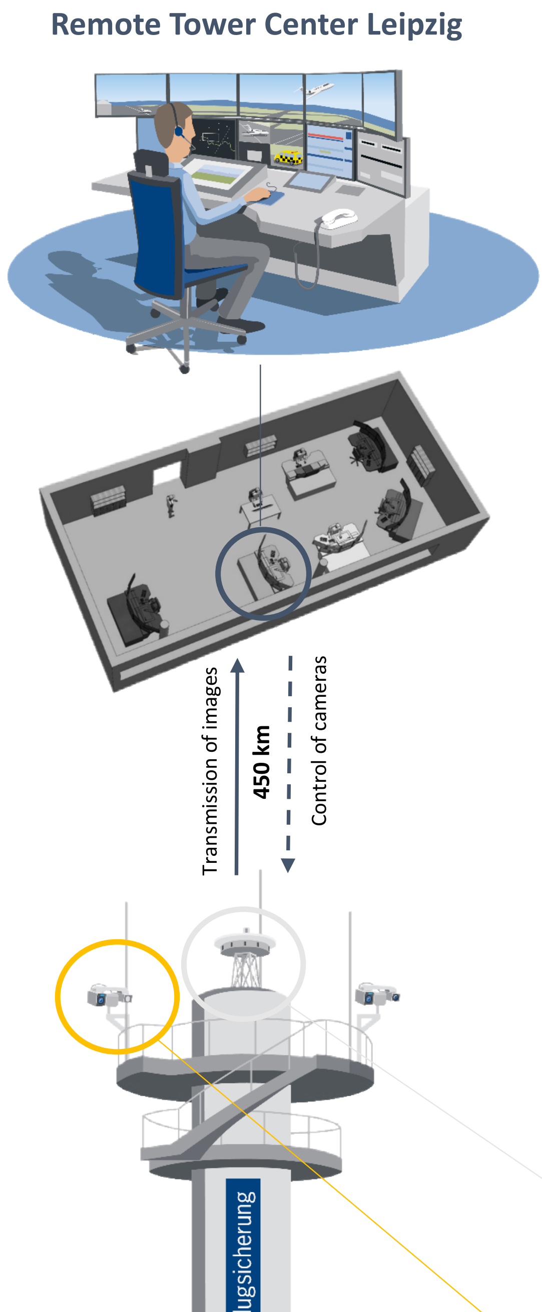


Figure Case Study 4: DFS Remote Towers *Credit: DFS*

Planning & 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 andservice quality for airspace users. The system had to deliver a safety level at least equivalent to conventional aerodrome control services. It had to comply with ICAO and EUROCAE as well as with 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 aerodrome's individual needs. In Germany, the best solution was to establish a Remote Tower Control Centre in Leipzig, from where the international airports of Saarbrücken, Erfurt and Dresden will be controlled. One tower controller (AIR + GND combined) in the RTC Centre in Leipzig will provide single tower control services for one airport at a time (single mode). However, they will be cross-trained to provide remote tower services for the other airports as well. There will 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 set up 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 Remote Tower Control Centre went into operation in December 2018 with aerodrome control services for Saarbrücken International Airport.

Figure Case Study 4: Development Status 2016 *Credit: DFS*

Figure Case Study 4: Controller Working Position in Leipzig Centre *Credit: DFS*

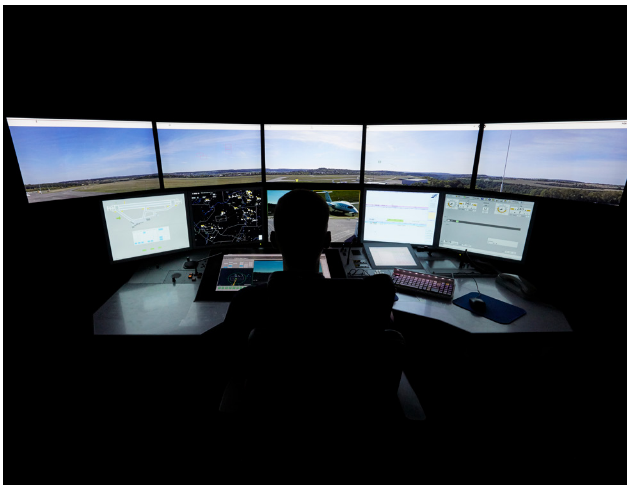


Figure Case Study 4: Panorama of the Original, Operational Cwp Scn<->Lej. Here with the Full HD day view *Credit: DFS*

Lessons Learned

- The early involvement of ATCO and ATSEP was very important and contributed to the success of the first commissioning (Saarbrücken airport from RTC Leipzig)
- 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 is very helpful. It gives you more details during darkness"
- The safety concept developed with ATCO and ATSEP works and has proven itself
- The project is constantly developing the system further with ATCOs to steadily improve the situational awareness

Figure Case Study 4: RTC Leipzig and Connect Airports *Credit: DFS*

Future and Next Steps

Following the experience of a successful implementation and operations of the remote tower system in Saarbrücken, DFS is already doing its next steps to setup remote tower services for Erfurt and Dresden airports from the Remote Tower Control Centre in Leipzig. Erfurt airport has a similar number of flights to Saarbrücken airport, while Dresden airport has significantly more traffic, approximately 38,000 annual aircraft movements. Erfurt Airport is planned to be connected with Leipzig in 2021. For Dresden Airport the system with a new sensor concept is expected to be installed in 2020. Once the three airports are controlled from one location, it is forecasted that cost benefits will increase significantly.

The successful joint venture Frequentis DFS Aerosense, that has been set up in 2018 between the DFS subsidiary, DFS Aviation Services and Frequentis, delivers tailored turnkey solutions for all use cases for international customers. More information: www.aerosense.solutions

More Insights

Video 1:
Remote Tower Operations in Germany, explanation

Video 2:
Remote Tower – One year of operation in Germany

When to Implement Digital Towers?

Events Initiating the Move to Digital Towers

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

The initiation events are often decision points for assessing cost benefit, where the option to implement a digital tower solution is assessed against other options. These can include, for example, when a conventional tower requires refurbishment, a new conventional tower building is also an option. Or when 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. Similarly, if an airport faces financial pressures, then many options will exist to improve income streams or reduce costs.

The implementation strategy that an ANSP then specifies will be influenced by what has initiated the programme. For example this 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.

Figure 6: Examples of reasons to initate a digital tower implementation
Credit: Think Research

How do I get started with Digital Tower?

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 aerodrome 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

Regulatory and Standardisation Outlook

The following regulatory outlook is current to Spring 2020.

International Civil Aviation Organization – 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 aerodrome 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 aerodrome 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 aerodrome 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 aerodrome ATS.

European Union Aviation Safety Agency – EASA

EASA established rulemaking task RMT.0624 ('Technical requirements for the provision of remote aerodrome air traffic services') in 2014, to develop a regulatory framework and guidance for remote tower operations/remote aerodrome 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 aerodromes', 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 aerodrome 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 as well as 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 larger or full concept of remote aerodrome ATS (not limited to 'single mode' and 'low density aerodromes') addressing also more complex operational contexts and applications, such as:

- The simultaneous provision of ATS to more than one aerodrome (multiple mode of operation)
- The provision of ATS to larger aerodromes
- 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 aerodrome ATS

A third phase of RMT.0624 commenced in 2020, with the aim to keep the EASA regulatory material up do date with the continued evolution of the remote tower concept and any future technological and operational developments and to maintain alignment of the material with the developments of the general EU ATM/ANS regulatory framework. The aim is also to further evolve the existing material concerning some specific aspects where deemed beneficial, such as; cyber security, third-party communication, human factors and performance related to the new technology. Any potential new updated EASA material is expected to be published by Q4 2023 (with a public consultation via a Notice of Proposed Amendment (NPA) expected in Q4 2022) [6].

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 aerodrome ATS. This first version did not consider any augmentation functions or sensors other than cameras.

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

Continued work is ongoing within WG-100 with a further revision/extension – ED-240B, which will also include performance requirements related to the incorporation of information from non-optical surveillance systems/sensors, anticipated for publication by late 2020.

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

Approval 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 [7] sets out 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 have largely relied on shadow mode and real time simulation techniques to provide validation evidences.

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
- 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 aerodrome 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 high cost and so it is recommended that sufficient time is put into setting out a validation strategy, defining specific validation aims and ensuring the correct operational resource is used during the validation.

Safety assurance

The Implementation of remote aerodrome 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) [TBC].

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.

European guidance material states that 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 the existing elements of the functional system affected by the change, and the new elements. Interfaces and dependencies of the system, and the environments to which remote or digital aerodrome ATS are to be implemented should be also assessed. 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 level corresponding to the main functionality identified in the digital tower. Guidance stipulates this should include, but not be limited to, partial or total loss of the function, erroneous, corrupted, and delayed data.

An analysis of the specific impacts and effects of identified hazards should also be included within the safety assessment. These should ensure that the effects in the specific operational environment are understood and the hazards 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 to EASA ED Decision 2019/004/R.

Human factors

When implementing a digital tower, a human performance assessment is recommended, as the concept has a direct influence on the capability of the 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 to assess the nature and the impact of a change on operators. Constructs that can be measured with this range of technique varies from:

Human Factors Measures	
Mental Workload	The amount of workload (effort) that someone must deliver to get a certain task done.
Stress	A psychological experience of distress and anxiety.
Fatigue	Being tired or feeling fatigued due to task load in relation to the amount of rest that one has experienced.
Attention	Attention, and the opposite distraction, are the base for situational awareness.
Situational Awareness	Being aware of everything that is relevant for task execution, and being able to understand how a situation will develop soon.
Operator Acceptance and Trust	Confidence and acceptance of operators in a new system or operation.
HMI Design	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.
Attitude Towards a Change	It is of utmost importance that operators (ATCOs) support a change that is planned to ensure a smooth introduction of this change. Change in this context can vary from new hard – or software, new operating procedures, to anything that is different and influences how an operator executes his or her work.
Efficiency	The efficiency of an operator basically comes down to the amount of work that he or she can process in a certain amount of time and with a certain amount of means. Aspects of this phenomenon relate clearly to human factors.
Human Error	The amount of errors that a person will make, or the likelihood that a person will make errors 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. 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) – measuring 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) – measuring changes in sweat gland activity as a result of emotional arousal, and therefore also relate to stress, mental workload and situational awareness
- Eye tracking – comprises a number of variables that all can be measured with an eye tracker. Attention, distraction, fatigue visual or mental workload can all be measured
- ElectroEncephaloGraphy (EEG) – Brainwaves as indication of attention, fatigue, being concentrated

Subjective

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

Performance

- Output of computer systems in the tower or from a simulator may be used to quantify the performance of operators. A great deal of variables may be used to indicate the amount of traffic, the number of additional tasks, the errors or reaction time of the operator, may be available to express the operator’s actions and performance in numbers

The HF domain comprises a broad range of areas which can be found in Annex I 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)

Further detail on the Human Factors elements to be considered can be found in Chapter 6.2 of the source document [3].

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, the data that is presented to operators while they are providing aerodrome 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 as well as at the data that is presented to operators while they are providing aerodrome ATS. 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 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'

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

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

Such audio information may be provided in some digital tower facilities. Where provided, recording of such audio data should be considered. EASA GM [3] recommends the inclusion of ad. sound in the data recording. Such audio information may be of greater importance to operators when providing aerodrome ATS to smaller/lower density airfields. Where operators may use audio cues to aid situational awareness.

Licensing and training of operators

Operators providing an aerodrome ATS from a digital tower will be required to hold adequate licensing and ratings for the aerodromes they are providing a service to, as such resource and rostering will need to take this into account.

For some implementations, supervisory roles may be required. The roles and responsibilities of a digital tower centre supervisor would overlap with that of a supervisor in a conventional tower with the addition of responsibilities linked to the need to coordinate many different aerodromes 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 the remote aerodrome 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 aerodrome ATS from a remote tower: "to acquire knowledge of the concept of remote aerodrome ATS and of the characteristics of the operating environment, to appreciate the necessity to consider the specific human factors influence on the remote aerodrome air traffic services, as well as to recognise specific abnormal situations and to manage their impact". Specific training topics are outlined within the regulation.

EASA GM (Issue 2, Feb 2019) chapter 10 furthers that the guidance provided by regulation (EU) 2015/340 should also apply to AFISOs providing aerodrome 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 more flexibly, and to unify maintenance and support capabilities. The nature of any interactions between the solutions for each aerodrome – 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 aerodrome – which may have specific requirements, for example, the technical solutions provided need to be more tailored. In such circumstances, when standardised solutions are not desired or required benefits may still be gleaned from providing ATS from a single shared digital tower facility/RTC.

Many different concept applications could be applied within one digital tower facility/RTC.

Aerodromes with higher traffic densities and increased complexity are less likely to be provided with a digital tower solution which can be standardised for any aerodrome. However, such aerodromes may provide improved financial stability to support providing such a tailored and dedicate digital tower solution.

Centralising multiple aerodromes into one digital tower facility, where RTMs and resources can be shared may provide an improved business case for implementing a digital tower solution at lower density aerodromes that may not be as financially able to support a dedicated digital tower solution alone.

Locating a digital tower facility

On airport site

One consideration for the location of a digital tower is on the site of an aerodrome. Depending on the mode of operation being applied within the digital tower, the aerodrome where the facility is located may also be provided with digital tower aerodrome ATS. Alternatively, a large airport may host a digital tower which is used to provide aerodrome 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 resource (controllers and support staff)
- Ease security issues that may surround an off-site facility
- Ease in change management, improving the acceptance of the change 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

Given that there is no physical restriction in terms of the location of a digital tower it does not have to be located at an airport. Locating a digital tower facility outside of an aerodrome 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 change of ownership of ANSP or 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 feasibly 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 aerodrome ATS by a variety of different ANSPs, and this would impact on the ability to share resources and may add a layer of complexity to operations.

The owner of the digital tower facility will also have an influence on its location; primarily if the facility is collocated on an aerodrome site or not.

Cyber security

From a cyber security perspective, it is necessary to consider additional threats related to 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* 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 and in particular 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 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.

Aerodrome equipment maintenance

The visual sensors based at the aerodrome (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.

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

Operating in extreme high or low temperatures will 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 aerodrome ATS.

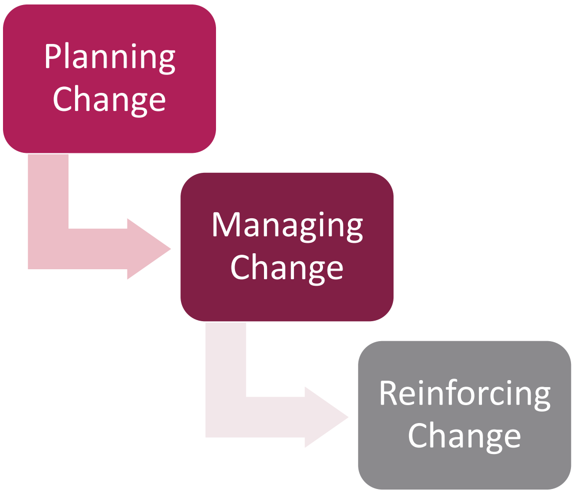


Figure 7: High-Level Change Management Steps *Credit: Think Research*

EASA GMs [3] introduce key change management considerations and recommendations for aerodrome operators.

A transition plan outlines how the operation will make the switch from the current operation to the digital tower operation. Such a plan is of added value if it covers the period of pre-implementation activities such as training and validation, and transition into live operations.

The transition plan can be integrated with change management plans to ensure that 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 aerodromes

Larger aerodromes may require more complex digital tower solutions to fulfil user requirements. Integration with additional sensors, such as advanced surface movement guidance and control system (A-SMGCS) and collaborative decision making (CDM) systems. Additionally, owing to physically larger areas, additional and specifically placed cameras (e.g. for hotspots) may be required. Larger aerodromes 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, as an example, individual RTMs supported with a common 'video wall'. Such a solution would provide common situational awareness while allowing individual operators the opportunity to customer their operational view to suit their needs.

When working in an environment with lots of different working positions and operators, it may be necessary to duplicate some of the technologies, e.g. binocular functionality, to ensure operators can independently operate these support tools when required. Specific working methods should be developed for the control and operator of support tools in a digital tower which must be 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 business case for implementing.

What is next for Digital Towers?

Future Technology concepts

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

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 aerodrome ATS service provision, the airport operations and the wider ATM network
- Enhance performance in a specific area e.g. safety management
- Provide advanced conflict detection and forecasting and visualising so that it supports operators in responding
- Visualise information in novel ways e.g. augmented vision (trajectory based i.e. approached paths)
- Provide more integration of the digital tower with other ATS systems through one human machine interface

Such advanced technology is thought to be of greater importance when operating in certain, often more complex, operational environments. Such technologies may also be included if ANSPs are targeting specific performance improvements.

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

This next phase of the digital tower concept looks to enhance aerodrome 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 services), with other functions of the airport and with other airports.

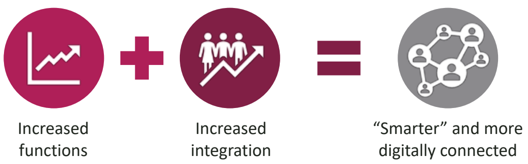


Figure 8: Illustration of the Components of Digitalisation *Credit: Think Research*

Opportunities

Large scale digital tower centre

Digital tower centres providing aerodrome ATS together with other ATS (approach and Area services) may be seen more in the future. Such large-scale operations enable a range of performance and efficiency benefits, including: flexible staff allocation, increased availability of aerodrome 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, and increased need to coordinate and new dependencies between previously independent operations.

ATM and UTM integration

Digital tower technologies may be used to help to accommodate a growing unmanned aircraft system (UAS) presence. Here, digital tower technologies may help to improve safety, which in turn may help this form of traffic to integrate with more traditional forms of air transport. Digital safety nets and object tracking technologies may help to enhance airspace safety. Information on UAS presence may be instantly provided to operators, increasing their situational awareness and help to mitigate against the need to close or restrict traffic to maintain safe operations when there is a detected UAS presence.

Sources

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[9] *ICAO Working Paper, AN 7/63.1.1-17/23, Proposals for the amendment of Annex 10, Volume II relating to pronunciation of numbers and PANS-ATM (Doc 4444) relating to remote ATS and ATM procedures*, 6 March 2017

[10] *Think Research, Think Digital ATS (D-ATS) White Paper*, 2016

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 European Union Aviation Safety Agency (EASA) is below. This term focuses on facilities where the: "Air traffic services (ATS) is provided principally through indirect observation of the aerodrome 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 aerodrome air traffic services (ATS) is provided principally through indirect observation of the aerodrome 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 aerodrome from which aerodrome ATS is provided principally through direct out-of-the-window observation of the aerodrome and its vicinity.

Acronyms

ACC	Area Control Centre
AFIS	Aerodrome Flight Information Service
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
A-SMGCS	Advanced Surface Movement Guidance and Control System
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATCO	Air Traffic Control Officer, Air Traffic Controller
ATM	Air Traffic Management
ATMOPSP	Air Traffic Management Operations Panel
ATS	Air Traffic Services
ATSEP	Air Traffic Safety Electronics Personnel
CANSO	Civil Air Navigation Services Organisation
CDM	Collaborative Decision-Making
CERT	Computer Emergency Response Team
CNS	Communication, Navigation & Surveillance
COTS	Commercial Off-The-Shelf (Software)
CTR	Control Zone
CWP	Controller Working Position
DFS	Deutsche Flugsicherung GMBH
EASA	European Aviation Safety Agency
ECG	Electrocardiogram
EEG	Electroencephalogram
E-OCVM	European Operational Concept Validation Methodology
EUROCAE	European Organisation For Civil Aviation Equipment
EUROCONTROL	European Organisation For The Safety Of Air Navigation
FAA	Federal Aviation Administration
FOD	Foreign Object Debris
FPS	Flight Progress Strip
GM	Guidance Material
GSR	Galvanic Skin Response
HMI	Human-Machine Interface
ICAO	International Civil Aviation Organization
LFV	Luftfartsverket (SE) (CAA of Sweden)
LVP	LOW VISIBILITY PROCEDURES

MASPS	Minimum Aviation System Performance Standards
MTBCF	Mean Time Between Critical Failures
NPA	Notice of Proposed Amendments (Avis De Proposition De Modification)
OSED	Operational Service And Environment Definition
PANS-ATM	Procedures for Air Navigation Services – Air Traffic Management (ICAO DOC 4444)
PPR	Prior Permission Required
RADAR	Radio Detecting and Ranging
RMT	Reference Mission Trajectory
RTC	Remote Tower Centre
RTM	Remote Tower Module
SDATS	SAAB Digitial Air Traffic Services
SDT	Smart Digital Tower
SESAR	Single European Sky ATM Research (Programme)
SJU	Sesar Joint Undertaking
TBC	To Be Completed
TMZ	Transponder Mandatory Zone
UAS	Unmanned Aircraft System
UTM	Unmanned Aircraft System Traffic Management
VCR	Visual Control Room
VFR	Visual Flight Rules
WG	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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