Whitepaper: Introduction to remote virtual tower

Virtually all modern controlled airports are equipped with a staffed tower to provide air traffic services to operate and maintain arrival, departure and ground movement for commercial and non-commercial aircraft. However, increasing pressure to reduce costs and modernise service is compelling air navigation service providers (ANSPs) to rethink the status quo and to explore new concepts for air traffic management (ATM), such as remote virtual tower (RVT). Remote virtual towers can locate ATM services for multiple airports at one central location, thus creating several possibilities for synergy and savings.

This document will help air navigation service providers understand the remote virtual tower concept, including:

- A description of remote virtual tower
- The advantages and potential savings of remote virtual tower
- How to transition to remote virtual tower.

FREQUENTIS DFS AEROSENSE

Table of contents

1 The remote virtual tower concept

Air transportation has spread throughout the world, and flight traffic as well as passenger numbers are continuously increasing. Air transport has grown to include many smaller towns and remote locations, providing these locations with an indispensable traffic link and connection to major airports.

As the use of flying has grown, there is an increasing pressure on air navigation service providers ANSPs to reduce the operating costs of air traffic management ATM, especially for medium size and small airports. ATM services constitutes a fixed cost, which is hard to cover by relatively small air traffic. A fully equipped and operational tower at a small airport servicing only a handful of take-offs and landings per day can be an economic burden, which may overstretch the financial capabilities of low-traffic airports.

Remote virtual tower RVT is a possible solution for such airports to improve their profitability, offer longer opening hours, or prevent from being closed down. In addition, RVT also introduces a level of flexibility that allows service levels to be enhanced.

The goal of a RVT is to give airports remote control capabilities and introduce video-based control for ATM services in safety-critical environments. RVT replaces the visual view of flight craft movement and the terminal area of an airport, and enables ANSPs to provide air traffic services from a remote location with virtually the same visibility as a local tower.

RVT replaces the onsite view of the airport control tower with a visualisation system located at a remote site by using high resolution visual / infrared (IR) cameras, optimised for wide-range coverage by providing a video presentation that uses object detection and alerting functions together with information enhancement.

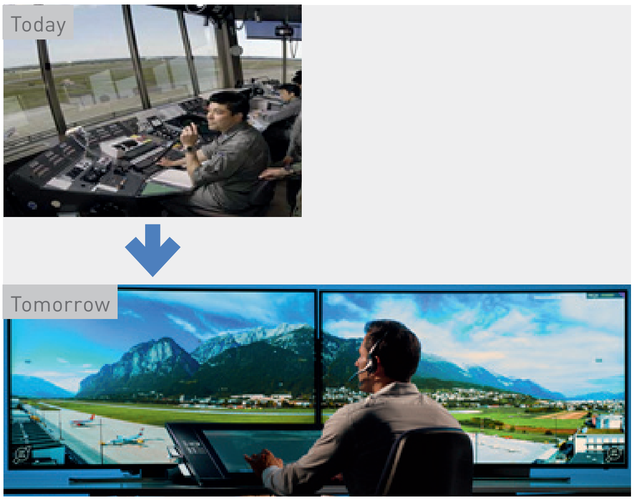

Figure 1: Todays and tomorrows layout of a controller working position

Operating a tower remotely opens a wide range of synergies, since it allows co-location of several towers to one remote tower centre (RTC), where several airports are controlled centrally by the same staff – providing better utilisation of resources.

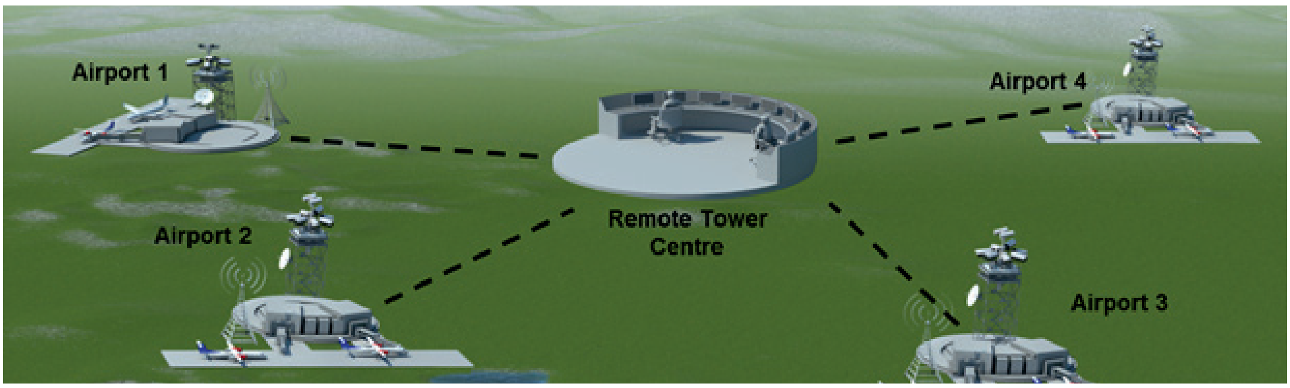

Figure 2: General topology of a remote virtual tower solution

1.1 Definition of remote virtual tower

The Single European Sky ATM Research (SESAR) defines remote virtual tower as follows.

A remote virtual tower is where air traffic services (ATS) are remotely provided through direct visual capture and visual reproduction (e.g. with cameras). The ATS are provided using a remote tower module (RTM), which includes operator workstation(s), ATM systems and display solutions.

A remote tower module is the term for the complete module, including both the controller working positions (CWPs) and the visual reproduction display screens.

A remote tower centre is a building where ATS are located to serve one or more airports. It usually includes several RTMs.

1.2 Usage scenarios for a remote virtual tower

The Single European Sky ATM Research programme has defined three different operational types of remote virtual tower:

- Single remote virtual tower
- Multiple remote virtual tower
- Contingency remote virtual tower.

Single: The single remote virtual tower configuration contains a RVT module and CWP dedicated to a single remote airport. The configuration is used to provide ATS to a dedicated airport and not switched between airports.

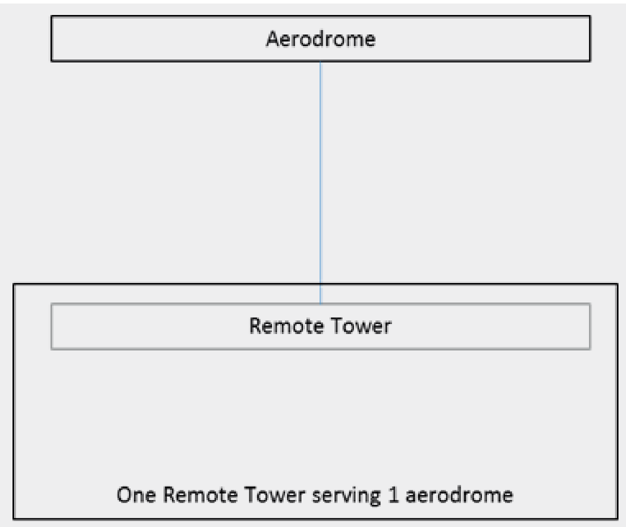

Figure 3: Topology of a single configuration

Multiple / sequential configuration: This configuration supports multiple airports controlled from a single remote tower module and CWP. In the sequential configuration, the module and CWP are connected to two or more airports, but only one airport at time. The module and CWP can be switched from one airport to the next.

The typical case where the sequential configuration applies is where multiple airports are managed on a common schedule and the airports are opened and closed in a sequential manner based on scheduled activity.

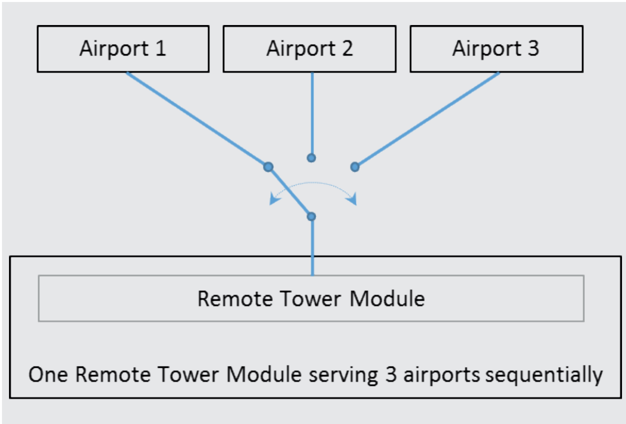

Figure 4: Topology of a multiple sequential configuration

Multiple / simultaneous configuration: This configuration also supports multiple airports controlled from a single remote tower module and CWP. In the simultaneous configuration, the module and CWP enable ATS to operate for two or more airports at the same time.

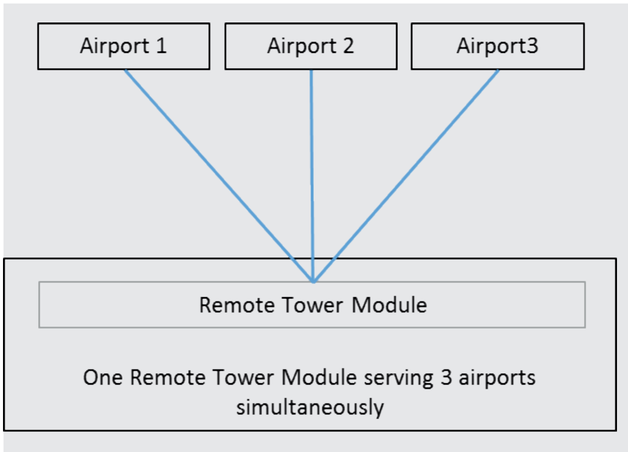

Figure 5: Topology of a multiple simultaneous configuration

Contingency: The contingency configuration is when a module and CWP are used as a redundancy for an ordinary tower.

Among the three configurations — single, sequential, and simultaneous — there are many different varieties of remote virtual tower implementation. For example, a shared remote virtual tower is a configuration where traditional controls are used for an airport for normal traffic hours, and the centralised RVT takes over.

1.3 Benefits of using a remote virtual tower

1.3.1 Cost saving aspects

The major revenue sources of airports are landing fees and passenger fees. These two correlate a roughly linear relation with air traffic. No flights and no passengers mean no revenues; many flights – many passengers – mean good revenues.

ATS have to be in place even if there is only a handful of air movements. For low traffic airports, the fixed costs for providing ATS are independent of the number of flights and passengers. For high traffic airports, the variable costs for providing ATS grow slowly, as more air traffic control officers (ATCOs) and more work places are needed. However, this growth is not proportional to the growth of revenues due to more flights and passengers.

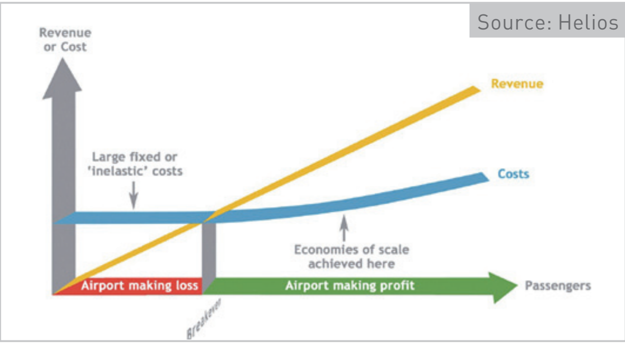

Figure 6: Economic aspects of remote virtual tower

The costs for providing ATS at an airport include:

- Fixed ATM costs — independent of the traffic flow
- Full ATM staffing at each tower
- Investments in tower building, refurbishment and facility management
- Maintenance costs
- Site-specific training.

If there is little air traffic, and landing fees and passenger fees do not cover the costs for providing ATS, airports will not reach the break-even point.

The International Civil Aviation Organization (ICAO) clearly defines the requirements for ATS in its Procedures for Air Navigation Services. Reducing the level of service below the ICAO minimum level is not an option. The cost saving potential on the service level side is therefore limited.

However, in order to provide ATS in compliance with international regulations, it is not necessarily required to have ATCOs placed on-site at airports. As long as the ICAO-mandated service level is kept, the out-of-the-window view can be substituted by a video-based view. Thus, ATCOs can be located remotely from an airport.

Even if a single airport is handled by a single remote virtual tower, there is some savings potential. The single configuration enables operators to work remotely, optimising shift changes and the number of supervisor positions.

However, co-locating multiple RVTs into one remote tower centre (RTC) can maximise savings by allowing the sharing of resources, since more than one airport can be handled by one controller in time shift mode.

Employing the synergies of hosting and co-using several RVTs in one RTC opens many possibilities, chiefly in the areas of facility, operations and resources:

Facility: For airports which already have a tower, after migration to remote virtual tower, facilities in an existing tower can also be re-used by other departments of the airport, e.g. as offices. This may save on costs (e.g. constructing new office building).

Operations: Instead of full-fledged towers, only masts with cameras and sensors need to be operated and maintained. Due to centralisation, there will be substantial savings in areas such as:

- Centralised data centre and IT
- Centralised operations centre

- Remote administration and monitoring
- Remote IT support.

Resources: Instead of resources at each airport, which may be under-utilised due to little air traffic, centralised resources can handle several airports and can employ a steady workload. Examples include:

Combining resource for multiple airports (time shifting): A controller can use time between scheduled traffic at one airport for other tasks, such as handling services for another airport, training or preparation work.

Combining activities from several airports: At small airports, there are still two controllers to manage traffic and provide support functions. With RVT, functions such as clearance delivery or flight information tasks of multiple airports can be assigned to one person. As a result, one controller could focus on tactical operation and service air movement and ground movement in a combined way.

Optimising night shifts: During night shifts with low traffic, one controller can monitor three airports, resulting in a saving of two ATCOs, or 66% per night shift.

Combining supervisor activities: A tower is normally equipped with at least one ATCO for air movement, one ATCO for ground movement and one supervisor. In an RTC environment, one supervisor can handle three airports, resulting in a saving of two supervisors or 66% per shift.

1.3.2 Service in remote areas

Remote virtual tower technology can control airport traffic from remote locations. This allows remote tower centres to be placed in populated or attractive places (e.g. larger cities, emerging regions). It is easier to find skilled and educated people in such areas, simplifying staffing and recruiting. This also provides a long-term perspective for people in their jobs and high flexibility of resources.

1.3.3 Security critical areas

Another factor for deploying remote virtual tower technology is security. A control tower at an airport is an obvious target and could be subject to bombing or other attack. The remote virtual tower approach keeps personnel at a safe, secure and protected location.

Additional technology (e.g. infrared-based night vision cameras, video-based object detection) can be used as an enhancement for the remote virtual tower for infrastructure protection and monitoring.

2 Components of a remote virtual tower

To fulfil the task of ATM, an Airport Traffic Control Tower of a conventional airport must have:

- Out-of-The-Window (OTW) view and binoculars
- Light guns
- Meteorological information
- Navigation aids status information
- Airfield Lighting control
- Air/ground and ground/ground voice communication
- Recording systems
- Flight data handling.

2.1 Basic profile

In a remote virtual tower installation, cameras replace the OTW — the view of the airport is presented to the ATCO electronically. This makes it possible for the ATCO to be located at a remote virtual tower, far away from the airport.

A typical remote virtual tower installation consists of:

- Equipment at the local airport
- Working positions at the remote virtual tower Centre
- A transmission network in between.

External interfaces are situated at the local airport or at the RTC. Depending on the implementation, some of these interfaces and the systems/sensors might be included in the remote virtual tower solution. In other cases, such sensors might already exist and need to be integrated into the remote virtual tower system, e.g. meteorological sensors, navigational aids, VHF radios.

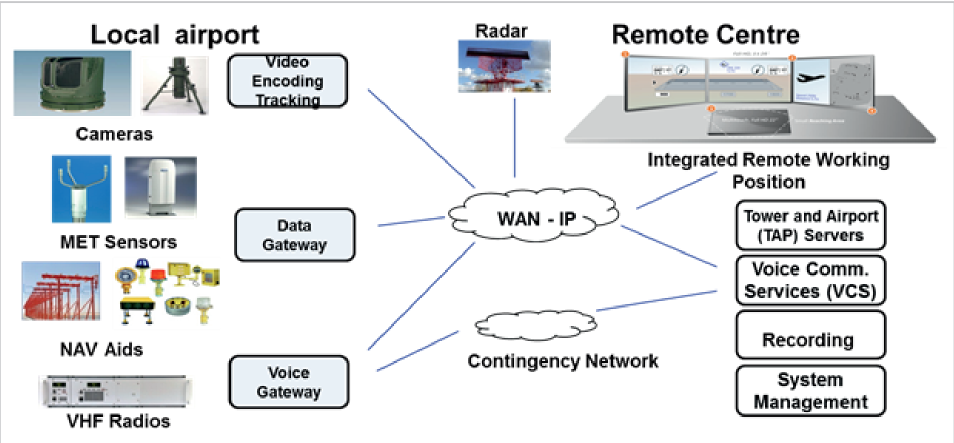

Figure 7: Components of a remote virtual tower Solution

The heart of a remote virtual tower solution is cameras placed at the host airport.

The cameras are mounted to capture a 180° or 360° view and they can be mounted at optimal locations at the airport, since they only need a mast and not a complete tower building. They can be distributed all over the airport to avoid any shadowed areas.

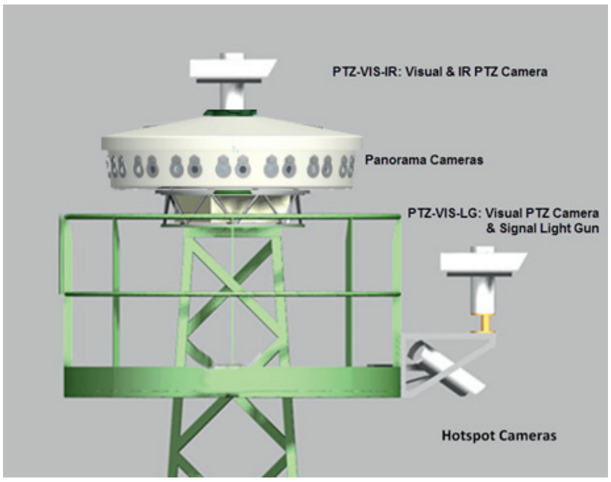

Figure 8: Cameras at the local airport

For relaying data and voice to a remote virtual tower, data and voice gateways are added at the local airport and integrated into the existing infrastructure. These network elements serve as gateways to connect the local airport and the remote virtual tower via a wide area network (WAN).

The network between the local airport and the remote virtual tower is key to the remote virtual tower implementation. It needs to have high availability and redundancy, and provide a very high QoS (high throughput, low latency, low bit error rate) to carry the video streams from the cameras to the working position. Figures for the required QoS are given later in this paper.

Figure 9: CWP in a remote virtual tower

At a remote virtual tower, the main component is the controller working position (CWP). The CWP needs to be designed with human factor guidelines in mind, and it features:

- A compact working position design
- High-resolution display technology
- Combined control panel (flight strips, camera control, control functions for AFL, ATIS).

Typically, a remote tower centre will include several CWPs, depending on the size, traffic volume and number of connected airports. A data centre serves the CWPs, and connects the remote virtual tower to the WAN, providing the necessary IT infrastructure to handle voice and data traffic from different airports.

Figure 10: A remote tower centre consists of several CWPs and a desk for a supervisor

2.2 Enhanced profile

Remote virtual tower can augment the traditional field views of the tower staff. Situation awareness tools enhance the operator's profile, reducing workload and increasing safety. Enhanced functions include:

- View enhancement (based on infrared cameras)
- Automatic detection of objects (video based)
- Augmentation support info in the video display
- Automated binocular tracking function
- Video based safety net and alerting function
- Integration and overlay of surveillance data
- Virtual airport view.

An example (below left) shows a traditional view of poor visibility, and (right) the same view enhanced by an infrared view.

Figure 11: Left is a traditional view at poor visibility; at right is same scene, but enhanced by an infrared view

With the help of a digital terrain model (DTM) and geographic information system (GIS), a 3D virtual airport view van be generated, which can be overlaid with planned and real data from the aircraft, allowing the ATCO to have a virtual overview of the airport and the air traffic, as shown in the picture to the right.

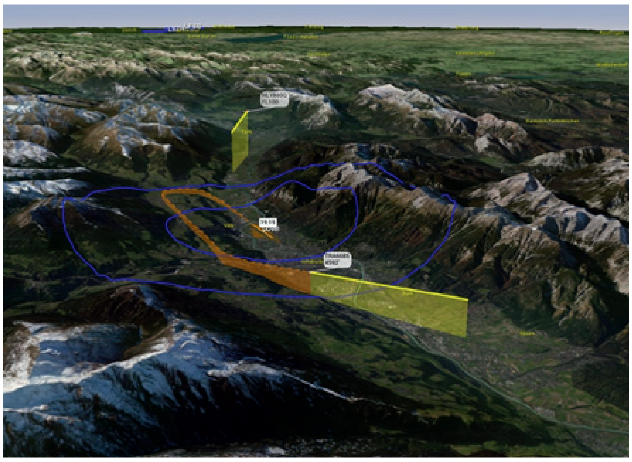

Figure 12: Virtual airport view

3 Transition to remote virtual tower

Remote virtual tower is a custom solution that the ANSP purchases, implements and runs. The introduction and transition to remote virtual tower affects many different operational areas of an ANSP. Each transition plan needs to be tailored to the specific situation and landscape of the ANSP.

Since remote virtual tower has the potential to significantly change ATM as performed today, thorough planning is important to consider:

- Analysis of the airport landscape and its suitability for RVT
- Definition of location and facilities for the remote tower centre
- Preparation of regulatory approval for remote virtual tower
- Examination of changes in existing processes and operational rules
- Exploration of the impact on existing staff
- Involvement of workers councils and unions
- Verification of the capabilities and QoS of the transmission network
- Planning for training and transition processes for introduction of remote virtual tower
- Examination of cost structure and profitability analysis.

One of the early steps is to find and select reasonable trial sites for an installation. One setup might be a small airport, with the remote virtual tower located on the tower of a nearby medium-sized airport. Other setups are possible, of course, depending on the goals and scope of the trial.

A trial installation can help the ANSP perform tests and validation steps, such as:

- Validating the goals and feasibility of implementing remote virtual tower
- Involvement of ATCOs and building confidence and acceptance for such solutions
- Verification of the business case before a large rollout
- Verification of the technical infrastructure (network capabilities)
- Involvement of regulators
- Harmonisation of ATM operations between airports (if the trial involves several airports)
- Use of a system for controller training
- Optimisation of the system maintenance concept
- Addressing and mitigating risk of operation in early phases of the project.

Regarding operational matters, a trial installation can:

- Validate the feasibility of common operating methods
- Validate optimisations of the service schedule
- Validate technical feasibility by means of continuity/reliability of the end-to-end system
- Validate increased safety.

Frequentis DFS Aerosense has already gained a significant amount of experience by conducting trials in several countries and with several ANSPs. Being a lead contributor to SESAR, with experiences based on best practices from other trial installations, Frequentis can help an ANSP jump-start a pilot project with workshops and consulting (performed directly by Frequentis or through a third-party), resulting in top-line estimates, scope, responsibilities, costs and timelines for a pilot as well as a roll-out. The Frequentis solution enables the ANSPs to execute their common tasks as usual while supporting standardised operating methods and procedures.

In addition, Frequentis DFS Aerosense can provide support in such areas as:

- Network and transmission technologies
- Human factors and working position design
- Safety management
- Training and simulation (addressed via partners)
- Integration of legacy systems
- Optical expertise (camera coverage, detection ranges, etc.).

4 Pilot implementation management plan

A detailed preliminary plan is critical to success. The Frequentis solution covers initial needs for a trial configuration conforming to the most common workflow scenarios and includes options for integration.

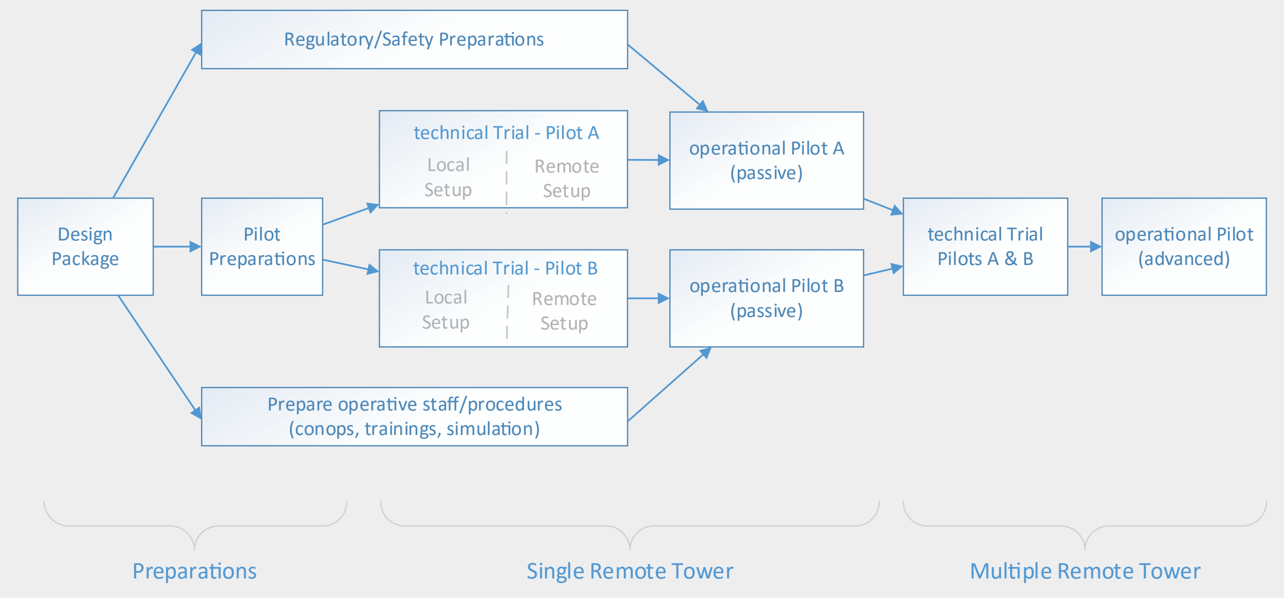

Figure 13: Work packages of a RVT project

4.1 Planning and organisation

An ANSP typically conducts project planning with consulting support or in cooperation with Frequentis. Frequentis can supply detailed information and specifications for a trial setup and supports the ANSP in validation of requirements and the authorisation process. The work package includes the evaluation of requirements and an analysis of feasibility (technical, operational and safety) as well as the definition of validation aims and measures. Common project management tasks, like the creation of a project timeline and risk management, are included. The result of these actions is a concerted "design package." Internal stakeholders should be involved in the design phase, since the transition will have a significant impact on the existing operational processes.

Reviewing possible use cases (→ chapter "use cases") of the stages/steps of the pilot project/ implementation will lead to a productive solution, allowing the involved ATCOs to test a setup under real conditions. A plan should break down the transition into work packages, as shown on figure 13.

Frequentis consultants will help design a trial project, including technical and operational features, configuration, on-site infrastructure, safety issues, a WBS and timetable, as well as acceptance criteria. The trial preparation package includes the technical and organisational on-site preparations for each of the trial airports.

There should be a focus on integrating new or changed operational workflows and training the responsible staff. It is also important to start the task of discussing safety topics with regulators in parallel with the other preparations.

Depending of the existing network infrastructure, pilot trials may be split up into local and remote technical validation tests. The number of pilot setups are planned with respect to the requested test scenarios (e.g., at least two trial airports are needed in order to carry out the multiple remote virtual tower tests). The first implementation and test could be carried out locally, enabling a more rapid approach of testing of the core system, without the need of a WAN connection. In a second phase of the first technical trial, the same tests can be done from a Remote tower centre, now testing the functionality of the WAN network implicitly. These trials are targeted on testing functionality, system integration and system stability and performance. After succeeding, the operational pilot may start with the testing of the real workflows in "passive mode," separately for each site in a single mode.

The next step is implementing and testing the technical integration of multiple remote virtual tower airports, which will enable controllers to operate multiple remote airports in sequential and parallel ("advanced") mode.

Note: It is important to emphasise allowing enough lead-time for staff training and safety regulations.

4.2 Site infrastructure

During the design phase, an evaluation takes place in order to analyse on-site changes from the technical and operational viewpoint. Frequentis is able to simplify these tasks by providing existing vendor concepts, to be compared and evaluated for deviations. Most site-specific requirements are identified in the fields of technical integration like interfaces, space and power needs, cooling, and security demands. Other location-dependent tasks, such as involvement and commissioning of (internal and external) service providers (facility management, IT operations, network, physical and data security, technical maintenance) are also important. Implementation of monitoring is also vital, and represents an essential part of the operating processes (e.g. incident management), as well as the validation of the reliability of system components or the system in its entirety (end-to-end).

4.2.1 Remote tower centre Infrastructure

The centre site includes the ATCOs and RTMs. Ideally, it also houses the (primary) data centre infrastructure, to process and record the streaming and control data. The data centre infrastructure consists of one to three standard IT-server-racks, depending on the number of remote controlled airports. In redundant setups (for advanced steps of the pilot schedule), a secondary, geo-redundant data centre is recommended. The location of the data centre depends on considerations like network performance. Pilot preparation topics are documented within the design document and should be agreed between the ANSP and the vendor. For a baseline, two remote tower modules (RTM) are required. One supervisor working position (SWP) is optional and depends on ANSP requirements. Workstations are operational in the main operations room at the remote tower centre (RTC). The Data centre for the remote virtual tower system is placed near the remote tower centre, with a fibre data connection between the data centre and the remote tower centre.

Summary of technical high-level requirements:

Technical property	Required value
Power needs – RTM	1 KW / 230VAC dual feeds with UPS
Power needs – data centre (total)	10-15 KW / 230VAC dual feeds with UPS
Rack space	1-3 standard 19-inch IT-Cabinet (42HE)
Floor space per RTM	7m²

Infrastructure work packages for the pilot include:

- Placing/installing the consoles
- Placing/installing servers and systems
- IT Infrastructure (power, cooling, LAN Network/ cabling)
- System management integration
- WAN/MAN network integration
- Additional/optional accessories or services – provided by third party suppliers/providers
- Physical and data security.

In preparation for the trial, some infrastructure requirements, such as the degree of redundancy, are dependent on specific validation aims, test cases and the progress of the pilot phase. Therefore, the technical design of the centre site may vary from case to case and depends on:

- The number of work places/RTMs
- Specific security requirements (physical + data security)
- Redundancy/fault tolerance requirements (including power, cooling, network, other HW/Services)
- Specific network requirements (dependent from services).

Some other important aspects are the integration of the altered operational and technical procedures by means of a change management.

4.2.2 Airport site infrastructure

The target airport is equipped with a camera tower, including meteorological sensors and camera servers and radio, sensor and control interfaces. In certain cases, radar equipment may also be integrated.

Summary of technical high-level requirements:

Technical property	Required value
Power needs – Equipment	10 KW / 230 VAC dual feeds with UPS
Space – encoders	Standard 19-inch IT-Cabinet (42HE)
Requirements of mast	The height of the mast is adapted to airport's specific requirements, considering obstacle restrictions and optimal viewing locations (free line of sight needed for all relevant areas). Frequentis may do a site survey and a 360° panorama picture of the selected camera location by using a UAV drone (optional).
Stability and robustness of the property must be below 0.1° for each mast.	
Weight of the Camera-Equipment	200 kg

Infrastructure work packages for the pilot configuration:

- Space and preparation for technical room/container
- Cameras and sensor positioning
- Building Mast / use existing buildings for camera mount
- WAN/MAN network integration
- IT infrastructure (power, cooling, LAN network/cabling)
- Interface integration (sensors, radar, radio etc.)
- Physical and data security (security assessment and security management plan).

4.2.3 Transport, mounting and installation of equipment

The ANSP is in charge of processing the importation and customs duty for the required equipment, shipped by Frequentis. The ANSP allocates a responsible contact person, who can execute technical changes within the airport and coordinate the stakeholders responsible for mounting and installation. In the course of the pilot planning, Frequentis provides the customer a checklist to clarify tasks and responsibilities.

4.2.4 Sourcing of parts and equipment in the country

The Frequentis solution is based typically on standard HW/SW product solutions, and the sourcing of these parts and licences is flexible from Frequentis' point of view, depending on the ANSP's preferences and availability and the maintenance and support services for equipment.

4.3 Network infrastructure provision

The network connection between the target airport and the RTC may have some challenging requirements. The amount of bandwidth required to send video and audio data from a remote airport to a centre is much higher than regular ATM-related applications such as VHF, radar, and others. The network solution has to ensure that low-bandwidth but highly safety-critical traffic is not adversely affected by these large amounts of video feeds. An end-to-end network design has to consider video and voice requirements carefully in terms of bandwidth requirements, end-to-end performance, and QoS priorities.

4.3.1 Network performance requirements

Factors that critically affect the remote virtual tower applications' functionality are bandwidth and latency. Also, the error rates and jitter values may play a role if they are deviating strongly from common values. There are several aspects to bandwidth and its efficiency. The first step is proper bandwidth calculation. The overall bandwidth required in a multi-application network depends on the amount of stations in the network and the traffic that will either be sent or received. The biggest influence on bandwidth calculation is the panorama stream. The variation of the bandwidth for the panorama stream is based on different parameter options such as the number of cameras, compression quality, frame rate and resolution. To assess the required bandwidth, the following table shows some typical bandwidth and latency requirements and lists two different option for the panorama stream:

Traffic	Latency [ms] RVT to DC	Latency [ms] DC to RTC	Bandwidth [Mbps]
Variant A panorama stream High resolution (14 HD cameras)	< 100	< 10	50 Mbps
Variant B panorama stream Low res (combined with IR)	< 100	< 10	15 – 20 Mbps
PTZ camera	< 100	< 10	6 Mbps
Voice stream	< 100	< 10	1 Mbps
Control & information data	< 100	< 10	1 Mbps

The bandwidth variants stated above represent two guiding values for exemplary setup composition, which may be customised for specific customer needs. Frequentis provides a smart bandwidth optimisation tool, which is capable of sharing bandwidth between airports and reserving bandwidth on demand. A smart scheduling tool supports an end-to-end workflow for operating remote tower centres and allows ANSPs to set up connections between the remote virtual tower and the remote tower centre only when a movement – landing, taxiing, or take-off – at an airport is actually happening. After the movement is finished, the remote virtual tower service can be switched to a lower, more cost-efficient service level.

4.3.2 Network reliability

A critical aspect of changing to a RVT operation is the reliability of the network. In this context, not only availability of a single connection is important, but also backup systems like link redundancy (two entirely independent links). An end-to-end design needs to consider also the operational back-up scenarios for the back-up networks and back-up remote tower centre.

It is important to have adequate support contracts and maintenance agreements with providers and suppliers in order to enable a quick recovery in case of errors/faults.

Cooperation with network providers

The limited amount of services classes in telecommunication networks make it important to design ATM-grade networks specifically to ANSP needs, which are different from the regular enterprise customer of telecommunication service providers. This fact mitigates in favour of a tight cooperation with the network provider(s). The provider should offer QoS management and the possibility of an SLA at a certain point in the pilot phase, including availability monitoring and reporting. It is advisable to consider appropriate lead times for establishing network connections, and to allow the provider to optimise its network, allowing for a possible change of the provider, a change of the link technology, or even construction changes.

Frequentis can provide consultancy service for the end-to-end network solution and can take over the network design, if needed by the customer.

4.4 Validation procedure definition

A validation strategy should encompass the needs of different stakeholders and provide the expected benefits of a RVT solution, as well as to prove the "fitness for purpose" in terms of stakeholder expectations, performance expectations and project requirements (particularly safety requirements). The purpose of the validation process is to validate business objectives, the soundness of the operational concept and the system, whose performance is rated against several key performance indicators. The t ask of conducting validations is owned by the ANSP, but Frequentis can consult on these working steps, since Frequentis, in cooperation with other SESAR members, has already collected a comprehensive set of best practices and can provide pertinent experts in these fields:

- Feasibility
- Acceptability
- Human performance
- Cost
- Level of service/capacity
- Safety and availability
- Interoperability and integration
- Regulatory conformance.

Frequentis is leading the design of future integrated controller working positions (ICWP) and may therefore offer profound knowledge in validating the human performance targets. Frequentis also understands safety another critical validation target area for implementing RVT, underpinned by many success stories.

Treading the path of validation for RVT includes the following steps:

Regulator involvement starts by identifying the responsible regulators (e.g. National Safety Authority) and the effective regulations for a specific trial airport, as well as compliance with technical standards (EUROCAE). EUROCAE working group 100 is currently defining a MASPS (Minimum Aviation System Performance Specification[1]) for the remote virtual tower solution under the lead of Frequentis. Frequentis is identifying the sources for related safety regulations and may facilitate the process of validating them. Inputs that influence validating regulatory conformance are a combination of traditional airport regulations, like ICAO Doc4444 and national CAA requirements, as well as SESAR Validation Reports, specific airport safety requirements from the ANSP, and system performance specifications like the EUROCAE WG-100 MASP.

Stakeholders interested in defining validation measures:

- ANSP ATM/AFIS staff
- Users – airlines, airports, general aviation
- Regulators – CAA.

By defining validation and demonstration exit criteria, collected requirements should be transformed to concrete, measureable KPIs. After the exit criteria are agreed upon by the stakeholders, the project team may create a programme plan for the ANSP with the objective of implementing conformance to requirements. The assessment of exit criteria can then prove the pilot phase was tested successfully and all previously-defined validation targets have been fulfilled. In the end, the lessons learned enable continuous improvement and may improve the implementation concept for later rollouts.

Figure 14: Validation flow

[1] MASPS describes and specifies the operational and/or functional requirements of a complete end-to-end system, which may include airborne, on-ground and space segments. It should provide a high-level architecture describing the individual components, and should allocate between those components the performance, safety and interoperability requirements.

5 Rules and regulations

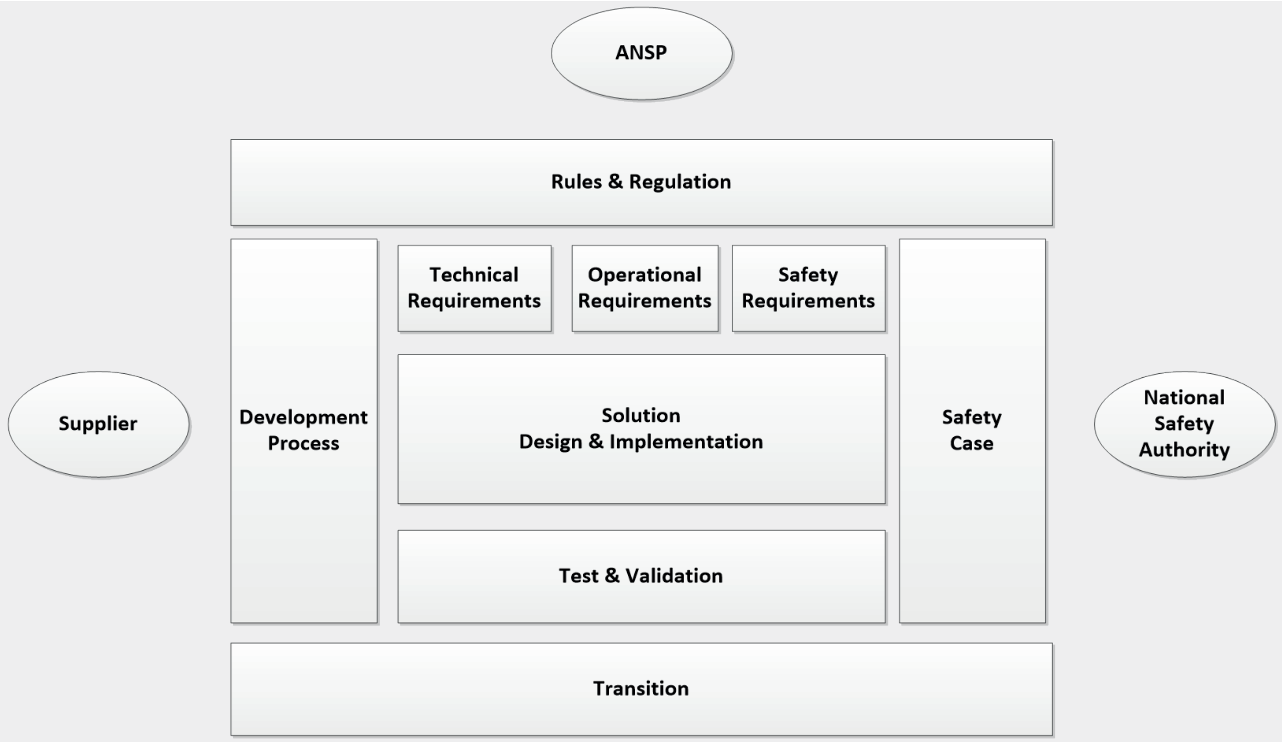

Figure 15: Regulatory environment of remote virtual tower

Implementing a new concept in ATM requires an assessment of existing rules and regulations regarding its impact related to safety and other operational factors, and an approval by the National Safety Authority (NSA). NSA would typically rely on existing standards and regulations for such solutions and would request a safety assessment and operational references and experiences in a similar context.

Major issues that need to be addressed in the realm of safety are:

- What is the impact of degraded modes in case of equipment failure?
- What is the impact of relying more on the data network?
- Is it easier to compromise security in RVT?
- How to manage alerting?
- Will a contingency RTC be needed?

In the SESAR program, an analysis of existing international standards was performed to define the impact of a remote virtual tower concept and derive requirements and guidelines. The main issues addressed in existing standards are related to controller tasks based on a visual view.

Currently there are no specific regulations dealing with video-based control in the context of remote ATM. An initiative in ICAO was recently started, in which the concept of remote provision of ATS was highlighted by several countries at the 12th ICAO Air Navigation Conference (ANC), working paper #42. This will likely start the process of validating the need for international rule changes or new ICAO recommendations with regard to remote virtual towers for one or several airports.

In parallel, activities were launched in the European Organisation for Civil Aviation Equipment (EUROCAE) to form a working group to standardise and harmonise requirements for remote virtual tower solutions.

As international rule changes are subject to long lead times, new concepts are often endorsed at first by the NSA following standard safety assessment requirements.

To comply with existing rules and regulations, it is important to note that a new system replacing the visual view provides similar capabilities to the operator to enable fulfilment of tasks in a safe and efficient way. Performance requirements related to viewing capabilities, and dedicated reliability requirements, leading to a system design with redundancy on several layers and dedicated safety related functional requirements to ensure safe operations, might possibly also cause adaptations of the existing rules. The whole implementation process from specification, design, test and validation, transition and training needs to be driven by the ANSP in close cooperation with the solution supplier and aligned with the NSA.

6 Abbreviations

AFIS	Aerodrome flight information service officer
AFL	Above field level
AIM	Aeronautical information Management
ANC	Air navigation conference
ANSP	Air navigation service provider
APP	Approach control service
ATCO	Air traffic control officer
ATM	Air traffic management
ATS	Air traffic services
BTU	British thermal units
CAA	Civil aviation authority
Conops	Concept of Operations
CWP	Controller working position
DC	Data centre
DTM	Digital terrain model
EUROCAE	European Organisation for Civil Aviation Equipment
GIS	Geographic information system
GRD	Ground control service
HMI	Human machine interface
ICAO	International civil aviation organisation
ICWP	Integrated controller working positions
KPI	Key performance indicator
LAN	Local area network
MAN	Metropolitan area network
MASPS	Minimum aviation system performance specification
MOPS	Minimum operational performance specification
NSA	National safety authority
OTW	Out-of-the-window
PTZ	Pan-tilt-zoom
QoS	Quality of service
RVT	Remote virtual tower
RTC	Remote tower centre
RTM	Remote tower module
SESAR	Single European Sky ATM Research
TAP	Tower and airport services
TWR	Tower control service
UPS	Uninterruptable power supply
VCS	Voice communication system
VPN	Virtual private network
WAN	Wide area network
WBS	Work breakdown structure

7 References

[1] Remote and Virtual Tower Technical Specifications, SESAR 2014

[2] OSED for Remote Provision of ATS to Aerodromes, including Functional Specification, SESAR 2014

[3] Procedures for Air Navigation Services - Air Traffic Management,
ICAO Doc 4444ATM/501

[4] Working paper #42, 12th ICAO Air Navigation Conference (ANC) 2012

8 Appendix A: Comparision between regular towers and remote virtual towers

The following illustrations refer to a comparison between regular towers and remote virtual towers.

8.1 Standardisation and ongoing activities

Category	Regular tower	Remote virtual tower (RVT)
Worldwide standards and regulations	e.g. ICAO 4444 and local regulations in each country and region	Currently the main reference standard is ICAO 4444
Ongoing and planned standardisation activities		• SESAR – Remote Virtual Tower Projects Work Package 6 & 12, • EUROCAE Working Group 100 • ICAO ASBU module B1-81
Safety	Existing safety cases	Adaptation of safety case required
Regulator	Approved by regulator	Additional effort for approval from regulator to be foreseen

8.2 Tower operations

Category	Regular tower	Remote virtual tower (RVT)
Controllers location	Controllers are situated at tower	Controllers are situated at remote tower centre (RTC)
Staffing	Full staffing for one tower in 24/7 operations	Staffing of RVT centres to foresee unexpected flights (e.g. VFR or emergencies) in order to avoid controllers working beyond capacity
Controller assignments	Fix assignment (rating) of controllers to a dedicated airport	Flexible assignment of controllers to different airports connected to the RTC
Controller ratings	No multiple tower operations and only few Air Traffic Managers hold ratings for more than one tower	Multiple RVT ops requires multiple ratings for each ATCO and careful staffing schedules to gain benefits stated above
Supervisor roles	Dedicated supervisor per tower (if required)	Supervisor can be shared between different towers
System monitoring	Local engineer for system monitoring	Remote monitoring of multiple airports possible
Facility management	Local tower facilities management required (for OPS room, staff room, offices…)	Only one facility management for remote tower centre required
Cross ANSP operations	Currently no cross-ANSP tower operations implemented	The technology of RVT will afford ANSPs the ability to offer RVT operations across state borders
Contingency operations	Single tower operations at one airport	Single remote virtual tower operations plus possible contingency operations (for main airport but also for other airports)
Trainings	Existing training procedures	Dedicated training required – adaptation of simulator required

8.3 Procedures

Category	Regular tower	Remote virtual tower (RVT)
Standard View	Human eyes, out of the window view	360° Panorama Visualisation
Visual constraints	Some constraints at some airports due to the single operational viewpoint from a central, high up perspective, and subject to prevailing viewing conditions at the time (e.g. clear, foggy)	With the use of reproduced out of the window views, these limitations can be eliminated. In all cases, the visual reproduction shall enable visual surveillance of the airport surface and surrounding area. Flexible selection of camera location (mast).
Magnification	Magnification via binoculars possible to focus one "target" only	Automatic multi target tracking possible by means of pan-tilt -zoom (PTZ) camera and sensor technology
Nightview	Limitations caused by human eyes	Visualisation enhancement via infrared technology
Static object identification	Static object to be observed by ATCOs using out of the window (OTW) and/or binocular	Static object identification by ATCOs either via panorama camera view at high resolution or PTZ cameras including alert function for panorama view
Traffic separation	Traffic separation based on visual observation	Displays to provide enhanced overlays including zoom cameras
Aircraft manoeuvers identification	Identification of safety related manoeuvers (e.g. decline, landing lights, gear down) by means of OTW, radar and/or binocular	Identification of safety related manoeuvers (e.g. decline, landing lights, gear down) by means of high resolution panorama camera view, radar and PTZ cameras (with more focus on PTZ)
Runway incursion	Runway incursion detection only possible by means of costly technology upgrades and/or visual checks	Enhanced safety by integrated (optical) safety net or intrusion detection based on overlay technology
Sound observation	ATCOs human ears	Airport sound microphones

8.4 Infrastructure

Category	Regular tower	Remote virtual tower (RVT)
Standardisation	Individual local towers	With the removal or decommissioning of individual local towers, disparate systems and procedures can be standardised to a greater level in a shared uniform facility.
Maintenance	Each airport has its unique tower building and infrastructure with dedicated maintenance needs	Local installation consisting of systems/sensors will be maintained by central maintenance teams. The remote facility will also require maintenance, but simpler building using common systems and components will lead to a reduction in overall maintenance costs.
Future airport expansions	Runway / airport extension might lead to the need of a new and/or additional tower building	Future extensions can be covered by additional sensors and cameras without the need of further infrastructure (civil works)
Controller console	Individual tower controller suite for each tower Typically not harmonised working positions between different towers	Same integrated working position concept for each airport; plus: • Camera and display technologies that create a uniform visual view • Possible add-on: Radar and Multilateration surveillance technologies • HMI with graphical overlay such as tracking information, weather data, visual range values and ground light status etc. to provide enhanced safety
Data integration	Standard tower controller interfaces with separate information displays	Augmentation of weather information and surveillance data
Cyber security	Standard cyber security mechanism in operation	ANSPs and aircraft operators will establish a reporting system for cyber-related occurrences, and cyber security shall become an essential part of their security management system.
Contingency operations	Contingency processes are based on manned tower operations with different fall back levels	Adequate contingency procedures in case of hardware malfunctions (e.g. camera, controller working positions) and system downgrades in place
Radio backup	Local backup radio available	Backup radio via remote connection (contingency line)
Radio ultime secours	Standard fall back scenarios in case of full or partial failures apply (e.g. use of light gun in case of A/G comms failures)	RVT provides specially designed light guns, remotely controlled and mounted at PTZ Camera

8.5 Controllers view – regular ATC tower

Figure 16: Regular ATC tower

8.6 Controllers view – remote virtual tower

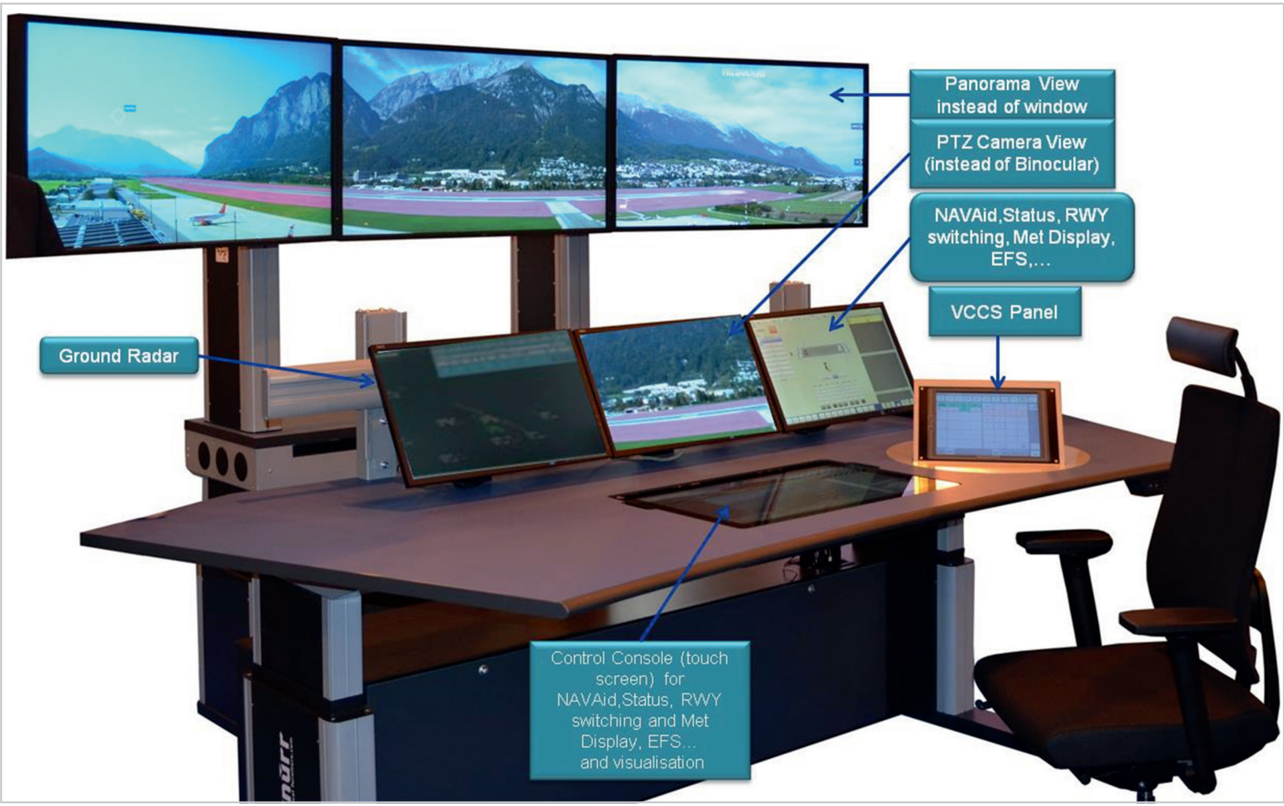

Figure 17: Remote virtual tower

FREQUENTIS DFS
AEROSENSE

FREQUENTIS DFS AEROSENSE GmbH
Innovationsstraße 1
1100 Vienna, Austria
Tel: +43-1-811 50-0
www.aerosense.solutions