# Synthesis of Remote Air Traffic Control System and Air Traffic Controllers' Perceptions

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**Airports face financial constraints in the use of services of air traffic control (ATC) towers. The remote air traffic control system (RATCS) is anticipated to be an economical and safe alternative to a control tower. RATCS is a concept intended to supply ATC to an airport by providing communication, navigation, and surveillance from a remote location. This study aims to gain insights about RATCS by conducting a review of existing studies, airport visits, discussions with RATCS technology providers, RATCS demonstration visits, and questionnaire surveys and interviews of controllers. A major inference from nontowered airport visits is that the introduction of RATCS will present many challenges such as pilot readiness to be supervised by RATCS, differences in local conditions, and significant limitations in available infrastructure. The knowledge gained through airport–demonstration visits and meetings with RATCS providers assisted in designing a questionnaire survey and interview. The number of surveys and interviews was limited; hence, conducting a comprehensive quantitative evaluation from responses was difficult. Nevertheless, controllers who participated in the study developed a consensus. The survey outcomes showed that controllers had concerns about RATCS functionality for communication or coordination between controllers and for ATC in high traffic conditions. The controllers provided favorable responses toward new features of RATCS, such as infrared cameras, high-definition monitors, target tracking functionality, and runway overlays. Potential advantages of RATCS anticipated by some controllers include systems with replay capabilities, situational awareness capabilities in low-visibility conditions, and surveillance capabilities of ground operations.**

Air traffic control (ATC) in the United States has grown immensely from the "flying circus" of Archie W. League in 1929 to today's workforce of around 15,000 air traffic controllers who guide more than 87,000 flights every day at more than 500 locations (*1, 2*). A review of ATC in the United States points toward rapid progress of technologies, from simple flags to the sophisticated tools of the FAA's Next Generation (NextGen) program (*3*). One of the only constants through the years has been the purposes of ATC: preventing collisions between aircraft operating in the system and providing a safe, orderly, and expeditious flow of traffic. Nevertheless, pivotal concerns related to different aspects of tower control remain, including human–computer interaction, situational awareness (SA), cost of airport control towers, the airport safety management system, and capacity variations (*4*).

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## MOTIVATION

Control towers are very important for maintaining safety at an airport. This importance can be highlighted by a study conducted by the Aviation Safety Reporting System for nontowered airports, in which 51 pilots were interviewed between September 2000 and August 2001 (*5*). The results indicate that 35% of incidents lacked alerts to the conflict and that 40% of the incidents included the presence of a topographical obstruction to the pilots' line of sight. Lack of SA was the factor most frequently identified by pilots as contributing to a runway incursion event. Interviewees suggested that new technologies could help alleviate problems that pilots commonly experienced at nontowered airports.

In March 2013, the FAA announced that it would close 149 ATC towers at small airports as a budget reduction measure under the sequestration cuts in the Budget Control Act of 2011 (*6*); the Reducing Flight Delays Act of 2013 helped FAA to keep the towers open. An important takeaway from this legislation is that airports, especially the smaller airports, face major financial constraints to build and maintain control towers.

ATC at airports plays an important role in the NAS, but financial constraints limit the introduction and sustainment of ATC in airport operations. The construction of a single control tower under a federal contract may take 3 to 5 years, with development and construction costs of approximately $4.2 million, average annual operations and maintenance costs of $185,000, and several hundred thousand dollars for annual controller compensation (*4*). These costs are exceptionally steep for airports, especially smaller airports that must depend on federal tower programs or other resources to support the services of a control tower. New and innovative technologies can provide alternative solutions to this problem. The concept of a remote air traffic control system (RATCS) has been documented as one solution and is being developed in many countries. Preliminary studies show that an RATCS can provide substantial economic benefits compared with traditional ATC operations (*7*). It also is expected to be one of the earliest implementations of the NextGen air traffic management concept of managing airspace. As a new concept, the RATCS faces technical and nontechnical challenges in successful implementation at airports. The objectives of this study are to review the different aspects of RATCS compared with a traditional control tower and to understand air traffic controllers' perceptions toward the RATCS. To gain insight about the RATCS, a comprehensive review of related projects and studies was conducted. In addition to use of the review, insight was gained through airport site visits, discussions with RATCS technology providers, RATCS demonstration visits, and questionnaire surveys and interviews of air traffic controllers. The following sections describe the research approach as well as the outcomes from each step of the study.

## CONCEPT OF RATCS

RATCS is a concept intended to deliver ATC services for an airport by providing communication, navigation, and surveillance from a remote location. Under RATCS, air traffic controllers are relocated to a remote facility from which they provide ATC for an airport or multiple airports. RATCS providers claim that RATCS anticipates providing improved service capabilities, reduced costs, and improved safety at airports by using new technologies without seeking significant changes to regulations and services levels that ATC provides to airspace users (*8*). The providers also claim that the remote facility has sufficient communication, navigation, and surveillance equipment to satisfy normal Class D airspace requirements. Furthermore, it will provide additional equipment, with the first assembly of equipment at the airport and the second assembly at the remote facility.

### Assembly of Equipment at Airport

The purpose of the additional equipment at the airport site is to capture live-feed video of the airspace at and around the airport. As Figure 1 shows, this equipment includes

- High-definition (HD) cameras covering up to 360°,
- Pan–tilt–zoom (PTZ) cameras,
- Microphones,
- Signal light gun,
- Meteorological sensors, and
- A remote-control monitoring system.

This equipment is used to relay the live-feed video to the remote facility. (This list is not exhaustive and is a representative model of RATCS equipment.)

### Assembly of Equipment at Remote Facility

The purpose of the additional equipment at the remote facility is to project live-feed video of the airspace at and around the airport on HD monitors. The equipment includes

- HD monitors;
- Airfield stereophonic sound;
- PTZ camera view;
- Controls for signal light gun;
- Runway overlay and weather system;
- Flight data processing system;
- Radar data processing and display system integrated with target tracking functionality view;
- Image enhancement features, such as visual-gap fillers, filters, and infrared cameras; and
- Distress alarms.

Figure 2 illustrates some of these features. This equipment list is not exhaustive and is a representative model of RATCS equipment.

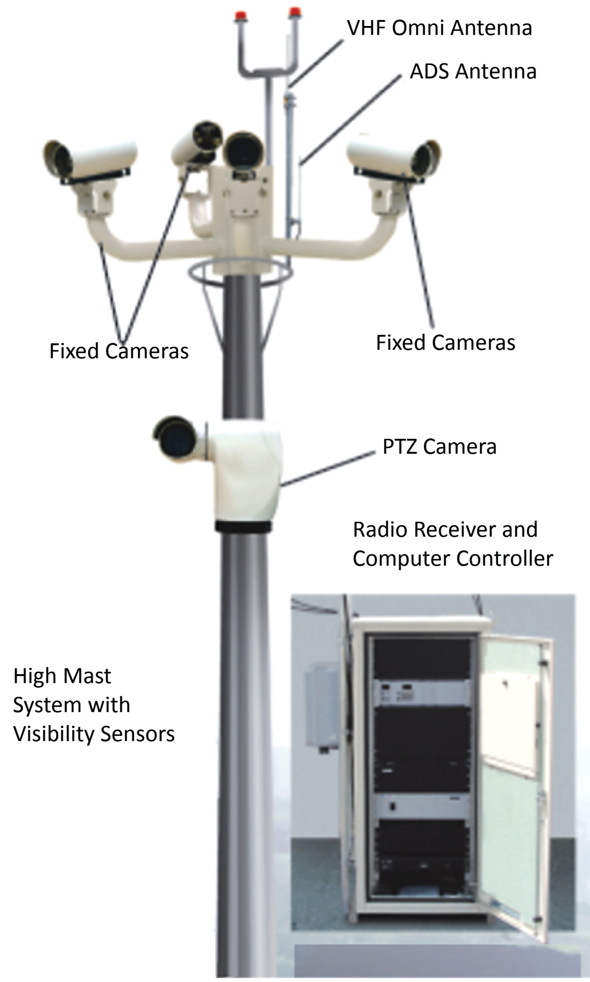


FIGURE 1 Assembly of equipment at airport.

### Integration of the Two Assemblies of Equipment

Figure 3 is a flowchart showing the integration of the two assemblies of equipment to form the RATCS system. Potential applications of RATCS include

- Replacing outdated tower facilities,
- Providing tower services at new airports,
- Merging two or more existing ATC sites into one,
- Providing contingency backup in case of emergency shutdown of the airport control tower,
- Providing training to trainee controllers, and
- Conducting record-and-replay tasks for investigative purposes.

## REVIEW OF STUDIES AND PROJECTS OF TYPES OF REMOTE AIR TRAFFIC SERVICES

### U.S. Projects or Studies

The NextGen Air Transportation System proposed a concept of a staffed NextGen tower to address airport capacity problems during nighttime or low-visibility operations by introducing a facility

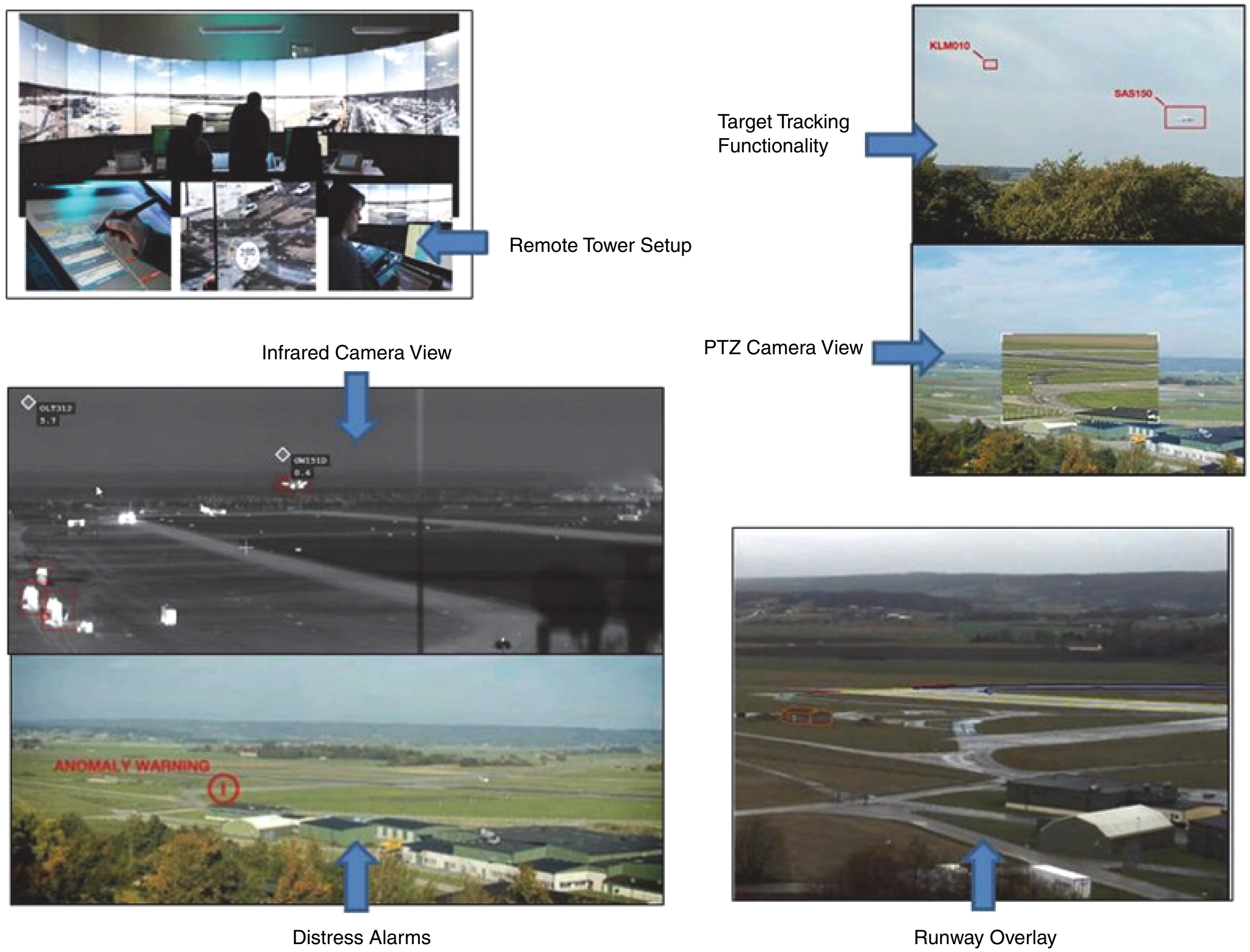


FIGURE 2 Assembly of equipment at remote facility.

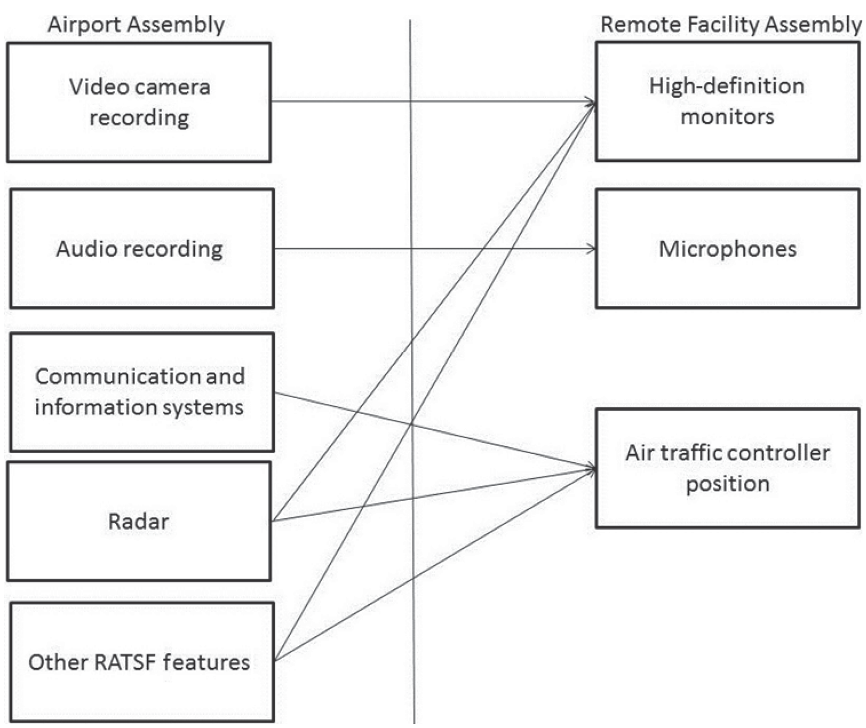


FIGURE 3 Flowchart of RATCS system.

from which controllers provide ATC to airports with assistance from an integrated tower information display that presents weather and surveillance data and a suite of decision support tools that uses data obtained from aircraft (*9*). The concept assumes that pilots and ATC will share all information in a netcentric environment and share responsibility equally in decisions. Test results of a human-in-the-loop (HITL) simulation experiment conducted to explore the concept of the staffed NextGen tower showed encouraging improvements in controller communication task–load and departure rates with no differences in workload, effort, safety, and SA (*10*). On the basis of a camera and human–machine interface assessment study, controllers consider visual surveillance through a cab window to be an indispensable element of achieving full SA (*11*). Critical issues encountered in the basic concept of the staffed NextGen tower include operational safety, handling of emergencies, and surveillance without aircraft-derived data and a human–machine interface.

Other projects being conducted for remote ATC are blended airspace (BA) and enhanced air traffic advisory services (at Leesburg Executive Airport in Virginia) (*12*). BA proposes to use a secondary surveillance capability such as wide-area multilateration as a substitute for normal radar surveillance for operations at Colorado mountain airports and to relay the surveillance data from the terminal area to a remote facility. The controllers (at the remote facility) rely primarily on electronic presentation of aircraft and vehicle locations on a display screen and pilot reports rather than an out-of-window view. The FAA conducted full-scale HITL simulation tests with Mitre Corporation's Center for Advanced Aviation System Development for initial user evaluation and demonstration in 2014, and the results of the tests are being evaluated. Mitre also developed an operational concept for providing selected tower services to nontowered airports to increase their capacity for instrument flight rules (*13*). Recommendations include changing airspace designation to Class D and assigning a given airport a unique frequency for ATC communications that covers both the airport and airspace immediately surrounding the airport. This concept requires bringing visual flight rules traffic under ATC. NASA has also examined remote ATC by studying several alternatives for improving runway safety at Los Angeles International Airport (LAX) under a program titled future flight central (*14*).

A comprehensive review of empirical research examining remote tower services for nontowered airports indicated that the concept has been proposed, studied, and under experimentation since the 1970s (*15*). Some concepts such as an automated pilot advisory system, automated terminal service, a smart airport automation system, and automated airport control volume have not been successful for a variety of reasons. However, concepts such as the Alaska capstone, the small aircraft transportation system, and wide-area multilateration surveillance have been successfully implemented or tested. With more technology available today, some of the earlier concepts for implementation as remote services to airports are worth revisiting.

## European Projects or Studies

Single European Sky ATM (Air Traffic Management) Research proposed remote ATC as a solution for small rural airports and validated it with three exercises in shadow mode for a single airport facility. Trials were conducted on the Angelholm–Helsingborg (Sweden) Aerodrome and the Værøy (Norway) Heliport with remote tower centers based at Malmö, Sweden, and Bodø, Norway, respectively. The assessment results indicated that, overall, the systems improved participant performance, but the concept was expected to have a strong impact on the current regulatory and standardization framework for the provision of ATC services (*16–18*). The introduction of new standards for the technologies associated with synthetic vision displays and image presentation, contingency procedures, and local procedures are other aspects highlighted in the Single European Sky ATM Research studies. Their human performance assessment indicated the need for training and gaining familiarity with the concept and the surrounding airspace as important aspects for increasing controller perception of safety.

The concept of an advanced remote tower was developed by Eurocontrol for airports with fewer than 25 movements at the mean busy hour with a mix of visual flight rules and instrument flight rules traffic (*19, 20*). An analysis conducted in 2006 concluded that the technology could provide required image–video resolution for visual detection but not for recognition (*21*). Technological advances since then are expected to change the adequacy of accessible image–video resolution to visual recognition. The German Aerospace Center funded three projects from 2005 to 2012 that focused on remote air traffic services for single and multiple airports (*22*). The remote towers project, sponsored by the Irish Aviation Authority in 2014, involved the provision of air movement control and surface movement control, including alerting services for Cork and Shannon (Ireland) airports from a remote tower center at the Dublin (Ireland) Air Traffic Services Unit. The Irish Aviation Authority is currently in the planning phase and will begin with demonstration trials. The UK's National Air Traffic Services currently has a virtual contingency facility as a remote backup for Heathrow Airport and is expected to maintain operations at 70% of capacity.

## Important Projects by Other RATCS Providers

Major RATCS providers are Saab Sensis, LFV, Searidge, Avinor, Harris, and Frequentis. Saab Sensis and LFV have been pioneers in building the concept of remote tower operations and are the first providers of a fully operational RATCS facility at Ornskoldsvik Airport in Sweden. This full operation was achieved after more than 10 years of concept validation and development. In 2014, Saab Sensis announced that it would implement operational tests for a similar model at Leesburg Airport (*23*). Searidge provides an ATC-grade video system and tracking capabilities by using an IntelliDAR system and has been selected by many airports around the world for its technologies (*24*). Its major endeavors in remote air traffic services include the remote runway surveillance system at Amsterdam (Netherlands) Schiphol Airport, remote monitoring capabilities at Dubai (United Arab Emirates) Airport, and virtual ramp remote control at Fort Lauderdale (Florida) Airport. Avinor installed a Saab remote tower at the Værøy Heliport and conducted 2 months of live testing at the start of 2013 with technologies such as runway incursion alarm, a new integrated controller working position, electronic flight strips, and online data communications. It also will introduce remote control tower services for up to 15 airports from one tower center in Bodo (*25*). Frequentis launched its own remote tower solution called smartVISION in partnership with Rheinmetall Defense and provides all-weather, all-day thermal infrared imagery.

### Contribution of This Study to Existing Studies and Projects

Although RATCS has been conceptualized in the United States, it has been implemented only for specific or partial air traffic services, such as Fort Lauderdale Airport. Similarly, European studies indicate that RATCS is in the testing phase at most locations. This study attempts to understand the RATCS concept by

- Gaining knowledge about the technologies involved,
- Understanding functioning of airports and ATC, and
- Gaining the perspective of the primary users of this concept: air traffic controllers.

The opinions, concerns, and recommendations of controllers from this study are expected to assist in identification of major issues and to assess the benefits and challenges of this concept. This paper summarizes the information gained through various efforts and highlights important conclusions.

## METHODOLOGY

RATCS is a concept that faces technical and nontechnical challenges for its successful implementation. It will affect technology providers, air traffic controllers, pilots, and airports. Hence, this study attempted to gain the perspectives of all of them. The study included the following four endeavors:

- Airport visits to understand the operations of airports with and without an ATC tower,
- Visits to RATCS demonstrations to gain direct experience on the functioning of the concept,
- Meetings and discussions with RATCS providers or RATCS concept developers to understand their perspectives, and
- Questionnaire surveys and interviews of air traffic controllers to understand their perceptions, opinions, and concerns about this concept.

Figure 4 illustrates these undertakings in the form of a simple flowchart.

### Airport Visits

Visits to a towered airport (Lakeland Linder Regional Airport) and a nontowered airport (Clearwater Airpark) in the Tampa Bay region of Florida were conducted. The choice of airports was based on quick and easy access. The differences in operations at towered and nontowered airports are well documented and well studied; their differences from the viewpoint of introducing RATCS were observed during the visits and are summarized in Table 1.

The major differences at towered and nontowered airports are airspace designation differences and the ATC rules associated with them. The important inference derived from Table 1 is that towered and nontowered airports have differing functioning styles and exhibit different forms of operational culture. An additional inference from the nontowered airport visit was that the introduction of RATCS will present a variety of challenges, such as general aviation pilots' unwillingness to be under the supervision of ATC through RATCS, differences in local conditions, and significant limitations in available infrastructure at airports.

### Demonstrations of RATCS and Meetings with RATCS Providers

Major RATCS providers are Saab Sensis, Searidge, LFV, Harris, Avinor, and Frequentis. The primary responsibilities of RATCS providers are to develop the concept from the technical and regulatory points of view. To understand their perspectives, a thorough review of their published studies was conducted, as summarized in the earlier section on important RATCS projects. To gain a better understanding of the concepts, the authors visited a Saab Sensis demonstration facility, teleconferenced with experts of Searidge technologies and of the BA program, and observed trials of BA HITL simulations.

#### *Visit to Saab Sensis Demonstration Facility in Washington, D.C.*

Saab Sensis has developed an RATCS package that can benefit airports to continue providing ATC. Their model includes the

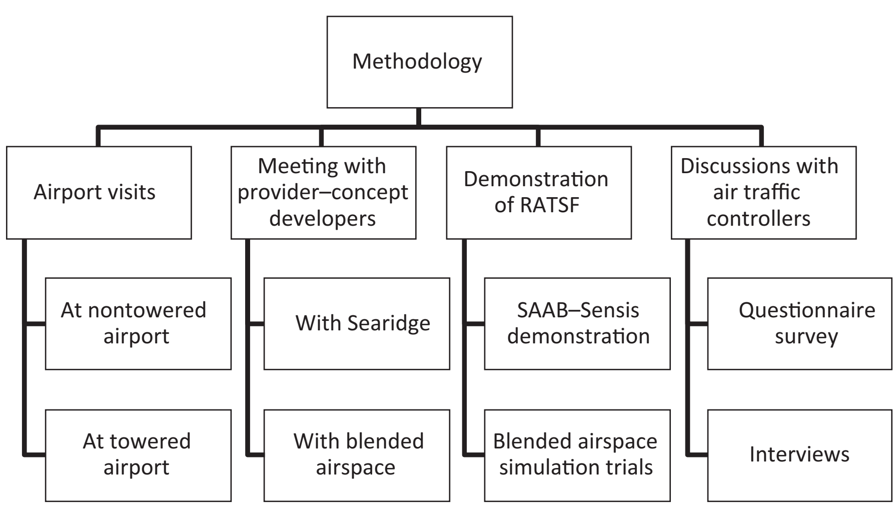


FIGURE 4 Flowchart of methodology.

TABLE 1 Existing Differences at Towered and Nontowered Airports with Perspective of RATCS

| Aspect | Towered Airport | Nontowered Airport |
|---|---|---|
| Existing type of traffic | Serve military, general aviation, and commercial air traffic | Serves general aviation air traffic |
| Nighttime operations | Higher occurrence of nighttime operations | Less occurrence of nighttime operations |
| Existing ground surveillance | Some provided by ATC | No ground surveillance |
| Responsibility of distance separation | ATCs and pilots both share responsibility | Pilots maintain distance separation between aircraft by pilot communication and visual observation |
| Sequencing rule | First-come, first-served rule or priority-based landing–takeoff | Only first-come, first-served rule; pilots communicate with each other to decide who arrives first |

out-the-window view being replaced by HD monitors and several additional features that are expected to improve surveillance capabilities for air traffic controllers. The demonstration visit familiarized the researchers with the different technologies of the Saab Sensis concept of operations. Highlights are as follows:

- Temporal latency. Real-time data have an end-to-end delay of less than 1 s for long distances.
- Safety. The potential for enhanced safety is high because of features such as tracking of aircraft with radar information, with the tracks visually designated on monitors; tracking of wildlife; use of infrared cameras for nighttime operations; and filters and enhancement features to improve visibility at night or in foggy conditions.
- Cost. Cost is expected to be a fraction of that of building a tower, but maintenance costs are unknown. A significant cost for installation and operations may be fiber optics cabling necessary for communication.
- Training. Controllers must be trained for multiple airport ratings if they are expected to work for different airports.
- Redundancy. PTZ cameras are considered as contingency plans if a camera stops working, but the quality of PTZ cameras needs to be studied extensively.
- Human factors. Tracking of objects such as birds and cars (outside the airport) can prove to be a distraction.
- Airport geometry. The demonstration observed was for a single runway; many challenges are expected for multiple runways.

### *Teleconference with Searidge*

Searidge conducted a remote tower demonstration with Nav Canada at Ottawa (Ontario) International Airport. In its concept of operation, replacement for the out-the-window view is done by stitching together different video views to create a panoramic view. According to a Searidge representative, an important benefit of a remote facility is using staff from a common remote center for nighttime operations at multiple small airports that have generally low traffic at night. The functionality of PTZ cameras differs from the Saab Sensis model in that the PTZ camera can be calibrated to zoom in to exact locations where needed by using radar data. Its advanced camera technology, IntelliDAR, is expected to act as a substitute for radar and can provide target tracking functionality for different objects. IntelliDAR provides a noncooperative surveillance system that does not require transponders in the aircraft for tracking capabilities. The range of IntelliDAR video sensors is approximately 1 mi. These sensors are placed strategically at different locations and the video feed from different sensors is stitched together through their processing methods to provide three-dimensional model tracking.

### *Teleconference with BA Personnel and Observation of BA Simulation Trials*

A formal teleconference with experts on the concept of BA was conducted to gain further understanding of its concept of operations. The meeting highlighted that BA encompassed airborne and ground surveillance aspects. To test the feasibility of BA, Mitre conducted 2-day experimental tests in March 2014 at its simulation labs with air traffic controllers and shadow pilots. These tests were followed by HITL simulation tests in July 2014, which the authors observed. Analysis of the tests determined that recruiting of air traffic controllers participating in the BA HITL trials for a survey to understand their opinions about remote ATC would be immensely useful for this study. Hence, this meeting was followed by a visit to the HITL tests at the Mitre facility in Virginia. The tests involved a small group of air traffic controllers conducting ATC operations under different safety-related scenarios, which were simulated with pilot volunteers to incorporate the communication aspect with prototype equipment set up for the potential BA system. The results of the tests were internally reviewed by Mitre, the National Air Traffic Controllers Association (NATCA), and FAA.

## Questionnaire Survey and Interviews with Air Traffic Controllers

In February and March 2015, questionnaire surveys and interviews were conducted with air traffic controllers to help identify their perceptions, opinions, and suggestions for the feasibility and implementation of RATCS. The primary objective was to determine what air traffic controllers believe can be the potential (positive and negative) issues and impacts in the introduction of RATCS. Figure 5 illustrates the major aspects of RATCS included in the questionnaire surveys and interviews.

### *Questionnaire Survey*

Participants were recruited with the support of NATCA. Ongoing discussions with NATCA determined that the questionnaire survey would be distributed to air traffic controllers who had exposure to the concept of RATCS or had participated in the BA HITL trials. This decision reduced the potential list of participants to fewer than 20, among whom six submitted responses to the questionnaire survey. To address privacy concerns, the surveys were sent to the participants through NATCA. The participants received the questionnaire surveys in the form of a Microsoft Word file and were asked to complete their surveys by typing or handwriting their responses. The questionnaire survey began with occupational questions about the

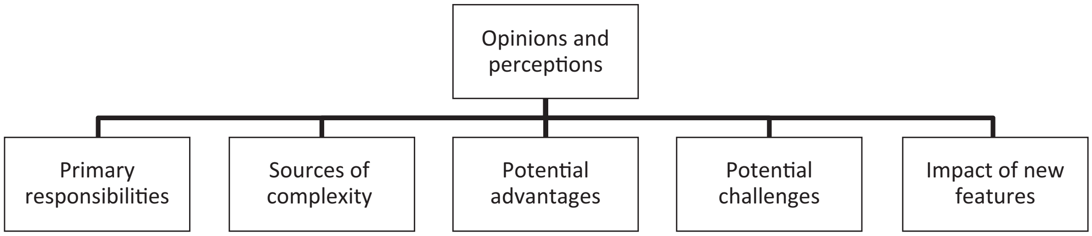


**FIGURE 5 Major aspects included in questionnaire survey and interviews.**

participants, including their familiarity with the concept of RATCS and their levels of experience as an air traffic controller and as a pilot. These questions were followed by a section that included an explanation of the RATCS concept (as explained in earlier) and other supplementary details in the form of text, images, and video. After the explanation of RATCS, questions related to the five major aspects highlighted in Figure 5 were asked. Supplementary questions about the concept of BA were added for participants who had exposure to the HITL trials. Most questions were objective (Likert scale and categorical) and included an option to provide comments. The survey was designed not to exceed 20 min.

### *Interviews*

Participants were recruited through direct communication with several employed and retired air traffic controllers in the Tampa Bay region. To recruit participants for the interviews, an introductory e-mail (with a description of both the interview guidelines and the purpose of the study and a consent form) was sent to all potential participants. The target list of eight participants resulted in two air traffic controllers participating in the interviews. Interview questions were similar to those in the questionnaire but with stronger emphasis on acquiring qualitative comments from the participants. No questions about BA were included, as the interview participants had not participated in the HITL trials. Several days before the interview the participants were provided with a set of briefing documents that explained the concept of RATCS and provided other supplementary details, which they were asked to use in preparation for the interview. The participants were requested to complete a recruitment survey form that included the same set of occupational questions that were asked in the questionnaire survey. A moderator facilitated the interviews by asking questions from the predesigned interview guide because having the moderator conduct the interviews without any preconceived notions was important for gaining useful information. The interview guide included a comprehensive list of questions, with follow-up questions to assist in gaining more detailed responses. An observer passively took notes of participant responses. The interviews were recorded to report the responses accurately. The guide was designed to complete the interview within 60 min.

### *Major Aspects Included in Questionnaire Survey and Interviews*

The participants were asked to express their opinions on the following five major aspects:

1. Responsibilities. According to FAA Document JO 7110.65V, an air traffic controller has five primary responsibilities: ensuring sufficient runway or airspace separation between two aircraft, providing arrival and departure clearances, sequencing arriving and departing aircraft, relaying clearances for instrument flight rules, and selecting runways for arrivals and departures (*26*).
2. Sources of complexity. Sources of complexity were identified from an existing study and included runway or taxiway restrictions, active runway crossings, runway or taxiway configuration, nonvisibility areas, airspace configuration, terrain or obstructions, high traffic volume, mixed air traffic, inclement weather, and unfamiliarity of pilots (*27*).
3. Potential advantages. Operations by RATCS could have potential advantages over operations by the control tower, including reduced approach or departure delays, improved SA in low-visibility conditions, a centralized service for controlling multiple remote airports, safer approach–departure operations, replay capabilities, more flexibility, higher ground surveillance capabilities, and higher visual aid to avoid wildlife-related accidents and incidents.
4. Potential challenges. Several potential challenges to performing ATC with the RATCS concept could arise, including reduced sensory information, lack of awareness of local airspace conditions, becoming overly reliant on remote conformance alerts, physiological impacts, workload changes, specific training and certification requirements, and maintaining existing efficiency.
5. Impact of new features. Participants were asked their opinions of different RATCS features, such as HD monitors, tracking capabilities integrated with radar, record and replay systems, image enhancement features, PTZ camera, and airfield stereo sound.

## Outcomes of Questionnaire Surveys and Interviews

Participant responses in interviews and questionnaire surveys are summarized below.

### *Questionnaire Survey Responses*

**Occupational Questions** Responses to occupational questions by the six participants indicated that three had worked for more than 25 years and three had worked for less than 10 years as an air traffic controller. One participant who had less than 10 years' experience had worked in an ATC tower without radar. Three participants had experience as pilots. Because of the lack of a significant number of responses, the occupational information was not used to conduct any further analysis of questionnaire surveys.

**Responsibilities** Participants were asked, "In your opinion, do you think RATCS will be beneficial or challenging to fulfill the responsibilities?" The participants believed that an RATCS environment

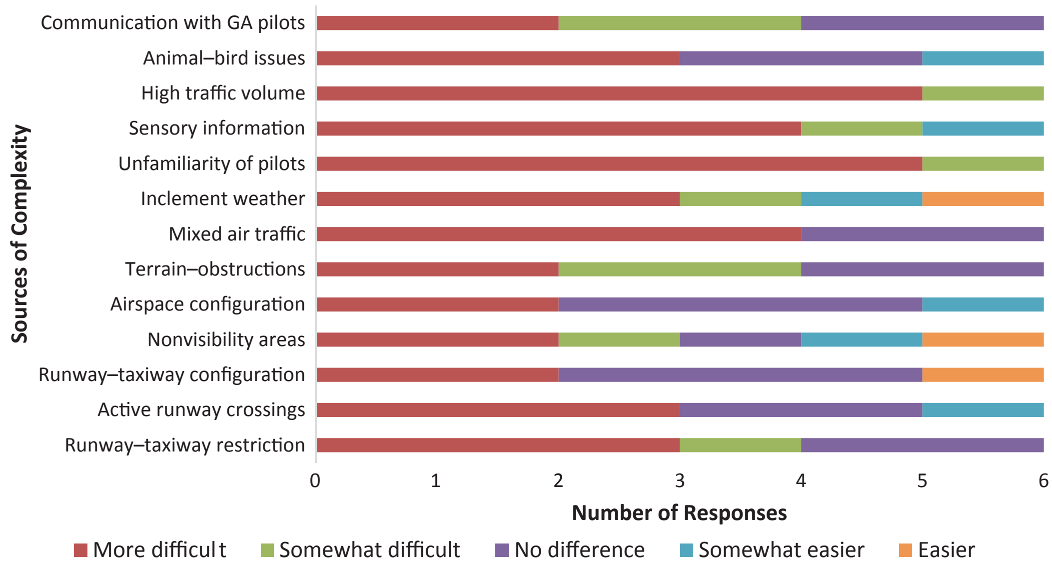


FIGURE 6 Likert scale ratings of responses regarding sources of complexity.

would prove to be challenging in fulfilling the responsibilities of ensuring sufficient runway or airspace separation between two aircraft, providing arrival and departure clearances, and sequencing of arriving and departing aircrafts. The remaining two responsibilities—relaying instrument flight rules clearances and selecting runways for arrival and departures—had the potential to benefit from RATCS features.

**Sources of Complexity** Participants were asked, "In what ways do you feel that working with different sources of complexity from a remote facility would be easier or harder compared to working in a control tower?" Figure 6 illustrates the results for this question and indicates that a majority perceived that ATC complexity would be "somewhat difficult" with RATCS compared with that of a control tower. However, a small number believed that complexity of ATC because of inclement weather, nonvisibility areas, and runway–taxiway configuration would be somewhat easier with RATCS than with a control tower.

**Potential Advantages** Participants were asked, "Do you think there are any advantages of RATCS operations over towered airport operations?" Figure 7 illustrates the results for this question. Some controllers anticipated that a safety management system with replay capabilities, SA capabilities in low-visibility conditions, and surveillance capabilities on ground operations would be potential advantages of RATCS. Respondents had neutral opinions on the potential of higher visual aids for wildlife-related incidents. The controllers somewhat disagreed that the RATCS environment would provide any of the remaining listed potential advantages over a control tower environment.

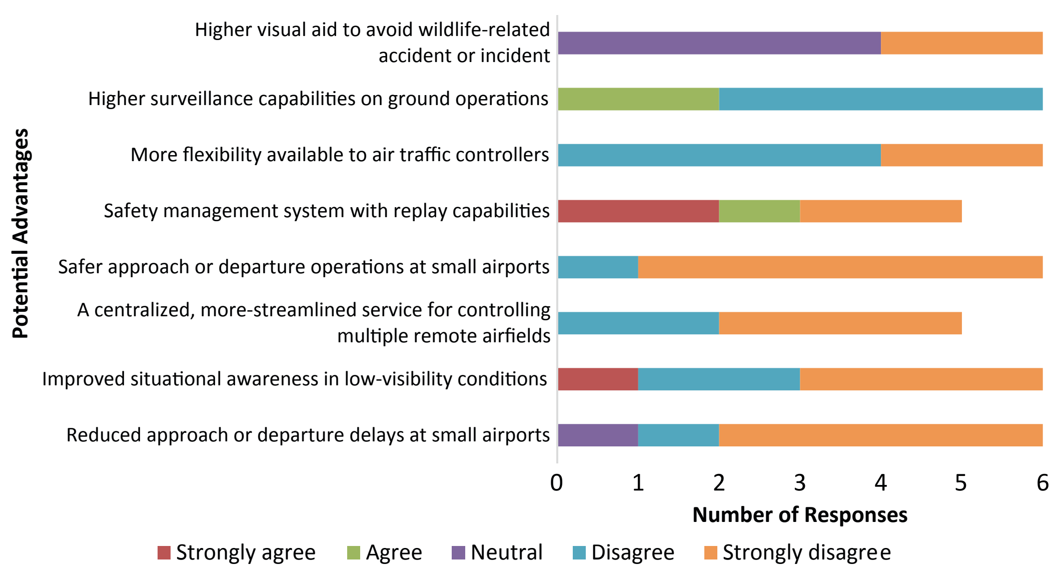


FIGURE 7 Likert scale ratings of responses regarding potential advantages.

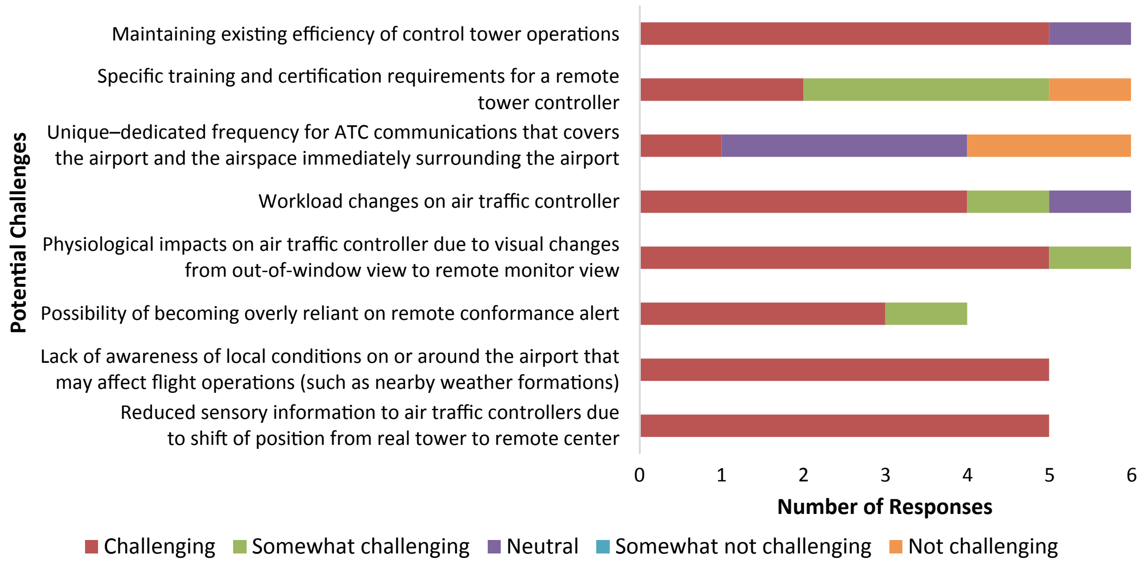


**FIGURE 8** Likert scale ratings of responses regarding potential challenges.

**Potential Challenges** Participants were asked, "Do you think there are any challenges of RATCS operations?" Figure 8 illustrates the results for this question. They agreed that all were serious challenges, with the exception of the provision of unique or dedicated frequency for ATC communications that would cover airport and airspace immediately surrounding the airport.

**Impact of New Features** Participants were asked, "Is there any feature that you believe will have a significant impact, either positive or negative?" Figure 9 illustrates the results for this question. Opinions on the use of HD monitors as a substitute for out-the-window view in daytime or nighttime and a PTZ camera as a substitute for binoculars were evenly split, with half expecting it to have a positive impact and half expecting it to have a negative impact. The following features were expected to have positive impact: tracking capabilities integrated with radar and their visual depiction on monitors, image enhancement using features such as filters to improve visibility in conditions such as glare or fog, and infrared cameras for low-visibility conditions in nighttime operations.

**Results of Supplementary Questions Related to BA** Four of the six respondents indicated that they had participated in BA HITL trials. They were asked their opinions on the following questions:

- Is information provided by a BA system in airborne and surface surveillance displays sufficient for safe and efficient operations?
- Do you think remote conditions will differ from real tower conditions?

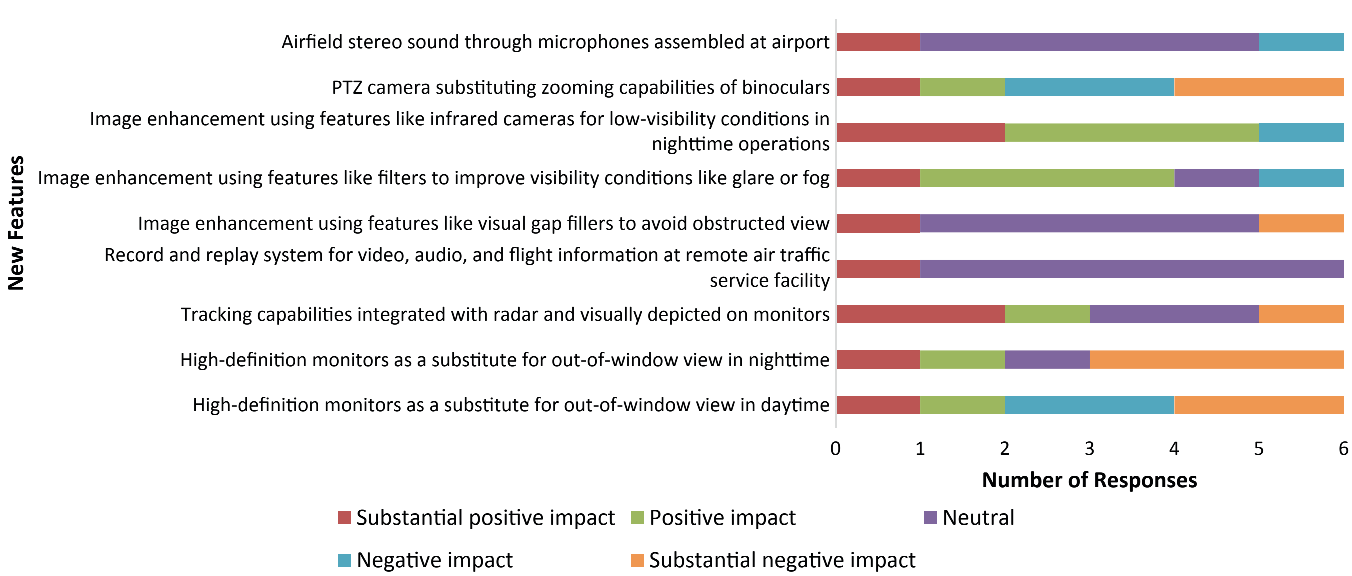


**FIGURE 9** Likert scale ratings of responses regarding new features.

Respondents did not believe that both airborne and surface surveillance displays from a BA system would be sufficient for safe and efficient operations and that remote conditions do not differ from control tower conditions. In their opinions, for safe operations, the BA concept could be improved with the introduction of cameras for an out-the-window view. From their experiences with BA simulations, they commented that, without the tools provided in BA simulations, safe airborne operations might be possible with only pilot reports and secondary surveillance but only with delays to aircraft. One controller stated, "I personally could never consider surface operations for a 'controlled airport' safe without visual references to the surface (cameras, etc.) due to wildlife, rogue vehicles, pedestrians, etc." The controllers saw value in the introduction of concepts of RATCS, as they would aid in detecting abnormal situations.

### *Interview Responses*

This section summarizes the responses of the participating controllers to interview questions.

**Occupational Questions** Responses to occupational questions of the two interview participants indicated that they had experience of more than 25 years in ATC, and one had experience as a pilot. Because of a lack of significant responses, the occupational information was not used to conduct any further analysis of interviews.

**Responsibilities** Participants were asked, "In your opinion, do you think RATCS will be beneficial or challenging to fulfill the responsibilities?" The opinions of participating controllers are summarized below:

1. To ensure sufficient runway or airspace separation between two aircraft in an RATCS environment, HD monitors with live feeds of 360° views are needed, but concerns were voiced about contingency plans in case of live-feed failure.
2. In an RATCS environment, providing arrival and departure clearance or conducting sequencing of arriving and departing aircraft would be challenging, especially with an increase in traffic.
3. Radar surveillance will be a necessary component to complement visual surveillance and pilot reports.
4. Selecting runways will be challenging at a large facility with multiple runways, multiple airport–airspace configurations, and communication between multiple controllers.

**Sources of Complexity** Participants were asked, "In what ways do you feel that working with different sources of complexity from a remote facility would be easier or harder compared to working in a control tower?" The opinions of participating controllers are summarized below:

1. Tackling the complexity in ATC created by runway and taxiway restrictions should be easy with the help of technologies like airport surface detection equipment for ground movements and runway overlay features provided in an RATCS environment.
2. An increase in the level of complexity with active runway crossings may occur because of the coordination issues between multiple controllers in an RATCS environment.
3. Complexity attributable to nonvisibility areas will be improved with RATCS enhancement features. One participant stated, "I have wished we had something like that many times to look around the corner that I cannot see because of the blind spot."
4. To tackle mixed air traffic flow, a radarscope is obligatory, as it aids in judging the speeds of aircraft. The controllers currently use remote sensory equipment such as radar or pilot reports during inclement weather.
5. RATCS enhancement features, if they work as promised, will aid in reducing complexity during inclement weather.
6. Pilot unfamiliarity will remain a major complexity in an RATCS environment and in a control tower environment.
7. Complexity of ATC operations during high traffic volume will worsen with the introduction of RATCS, as it warrants changes in local procedures that are not limited to strictly dedicated runways and to prohibition of aircraft crossing the runways. These changes in local procedures will have a negative impact on operational efficiency.
8. Identifying animals or birds is a common concern for air traffic controllers, but HD monitor views will help to diminish this problem.
9. Concerns were noted about increases in physiological fatigue associated with looking at screens and video feeds through PTZ cameras for long periods.

The controllers believed that the introduction of RATCS will not alter the level of complexity of ATC compared with control towers because of remaining sources of complexity: communication with general aviation pilots, sensory information, terrain and obstructions, airspace configuration, and runway–taxiway configurations.

**Potential Advantages** Participants were asked, "Do you think there are any advantages of RATCS operations over towered airport operations?" The opinions of participating controllers are summarized below:

1. The Saab Sensis visually based RATCS will potentially provide no improvements in reducing the approach or departure delays at small airports.
2. The Saab Sensis has the potential to improve SA in low-visibility conditions.
3. The concept of a centralized, more streamlined service for controlling multiple airports is feasible in low-traffic conditions and may help to reduce staffing, but with an increase in traffic volume such a service will become difficult, as air traffic controllers are not used to mixing air traffic operations of multiple airports and may cause human error. ATC at multiple airports will require unique training, unique certification, and unique experiences for multiple facilities.
4. Knowing whether RATCS can lead to safer approach or departure operations at airports is difficult.
5. The provision of safety management with replay capabilities by RATCS will be a better safety management system follow-up for forensic analysis by accident investigators and organizations such as the National Transportation Safety Board.
6. More technology provides the potential to increase flexibility in operations, but flexibility will be reduced with coordination issues with other controllers.
7. One participant stated, "I think the technology available today is enough, but they don't provide it at all airports, so if these technologies are provided remotely as a bundle, then it's going to be an improvement in surveillance."

**Potential Challenges** Participants were asked, “Do you think there are any challenges of RATCS operations?” The opinions of participating controllers are summarized below:

1. The knowledge of local airspace is obligatory for attaining a certification for a control tower as well as for RATCS.
2. Remote conformance alerts are probably going to be an advantage, whereas physiological impacts caused by visual changes from an out-the-window view to remote-monitor view are easily adaptable.
3. A rapid increase in workload is a big concern, and accomplishing such an increase remotely might be more difficult.
4. Air traffic controller perceptions about the challenge of maintaining the existing efficiency of control tower operations can be best explained by the following quotation: “Controllers have a tendency to push, and they are more concerned to do their job. They won’t sit back! Once you learn the system, they should be good, once you get used to equipment and see that is reliable.”

**Impact of New Features** Participants were asked, “Is there any feature that you believe will have a significant impact, either positive or negative?” The opinions of participating controllers are summarized below:

1. HD monitors will work well as a substitute for out-the-window views during daytime.
2. In contrast, HD monitors with an infrared camera feature will be useful to substitute for out-the-window views during nighttime operations.
3. The tracking capabilities integrated with radar and their visual depiction of aircraft and other objects tracked on monitors will be useful because they add to safety and help to identify aircraft and other objects faster and quicker.
4. The image enhancement features such as visual gap fillers to avoid obstructed views will be a big advantage because they give more information. One participant stated, “The more information, the better.”
5. A PTZ camera as a substitute for binoculars is a good feature, but concerns about distance perception were noted, and two or more PTZ camera views might be needed to provide a complete view.
6. Airfield stereo sound through microphones is unnecessary and may cause distraction or interfere with communications with fixed-based operators.

### Comparison of Results Between Mitre HITL Tests and This Study on BA System

Table 2 shows a comparison of the results of the Mitre HITL tests for the BA program and the current surveys and interviews.

## CONCLUSION

### Summary of Outcomes

Studies and projects of remote air traffic services being undertaken in different parts of the world were reviewed in this study. The concept of remote air traffic services, although it has many challenges, is gaining increasing acceptance, especially in Europe. In the United States, different concepts of remote air traffic services currently are being tested. This study aimed to gain insight about RATCS by conducting airport site visits, discussions with RATCS providers, RATCS demonstration visits, and questionnaire surveys and interviews of air traffic controllers.

The salient outcomes of the airport and demonstration visits and discussions with RATCS providers are as follows:

- The visit to a nontowered airport indicated an important challenge for RATCS: the perception of the pilot community using visual flight rules to accept any form of air traffic control.
- Small airports have lower traffic volumes and less complex runway layouts. Hence, they have immense potential to be pioneer airports in remote air traffic control.
- RATCS providers have sufficient technology but should consider the impacts of their concept of remote services on regulations, air traffic control rules, and local procedures in their studies and tests.
- Cost is a major factor in any new technology, and operations and maintenance costs of RATCS such as fiber and filter costs are a major concern.

The study surveys and interviews were designed to gain opinions, perceptions, and suggestions from controllers about different aspects of RATCS. Some themes recurred in the responses across all questions in interviews and surveys, as follows:

- Communication and coordination among controllers is perceived to be a difficult challenge to be tackled by using RATCS.

**TABLE 2 Differences in Results Between Mitre HITL Tests and Current Study Results**

| Major Result | Mitre HITL | Current Study |
|---|---|---|
| Participating controllers | 6 | 8 |
| Tests | 3 training scenarios, 12 test scenarios for BA concept | No tests |
| Impact of traffic on efficiency | Higher traffic decreased average percentage of completed operations in scenarios | Higher traffic expected to cause decrease in efficiency per survey–interview results |
| Radio communication | Number of radio communications increased with higher traffic and higher complexity | Communication identified by survey–interview participants as major hindrance |
| Situational awareness | Situational awareness ratings more or less the same in high or low traffic | SA expected to be negatively impacted in RATCS environment |
| Airborne surveillance display | Concept had more acceptance for safety than for efficiency | In questionnaire survey, participants indicated concerns for safety and efficiency with BA concept |
| Surface surveillance display | Showed limited value for aircraft operating without transponders; camera display was recommended | Camera display recommended to improve BA concept |

Further evaluation of this perception is needed, as RATCS is expected to provide similar controller positions as a control tower environment.

- Participants had concerns about how controllers can continue with ATC functions in a remote environment under conditions of significantly higher traffic volume.
- Controlling multiple airports is perceived to be one of the biggest challenges by the participating controllers.
- Recommendations of the participants included increasing the number of PTZ cameras, making radar surveillance obligatory, and adding automated conformance alerts.
- Participants who attended the BA HITL trials believed that the out-the-window view or an alternative version of it would be a helpful surveillance aid for remote air traffic control. They also recommended having radar surveillance to complement the RATCS concept.
- Some controllers anticipate a safety management system with replay capabilities, SA capabilities in low-visibility conditions, and surveillance capabilities on ground operations to be potential advantages of RATCS over a control tower.

### Limitations of Study and Scope of Future Work

This study used questionnaire surveys, interviews, airport visits, demonstration visits, and meetings with RATCS providers. The study had an important limitation: the small number of surveys and interviews. Hence, conducting a comprehensive quantitative evaluation from the responses proved difficult; however, the qualitative comments add value to the existing literature. Considerable potential exists to improve this study by conducting more questionnaire surveys and interviews of controllers from different parts of the country. Air traffic controller perceptions and opinions are expected to change with their experience levels, airport local conditions, and other factors. A larger sample size of responses would aid in conducting a multivariate analysis and adding value by studying controller perceptions about RATCS.

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