RESULTS FROM THE INITIAL SURFACE MANAGEMENT SYSTEM FIELD TESTS

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Abstract

NASA Ames Research Center, in cooperation with the FAA and a Raytheon-led team, has completed initial field trials of the Surface Management System (SMS). This paper reports on the results of those initial field tests. SMS is a decision support tool (DST) that helps FAA controllers and air carriers collaboratively manage the movements of aircraft on the surface of busy airports, to improve capacity, efficiency, and flexibility, without degrading safety. SMS is an element of the FAA's Free Flight Phase 2 program. Initial SMS field tests were conducted in FedEx's ramp tower at Memphis International Airport (MEM) over two weeks in August and October, 2002, and in the Northwest Airlines MEM operations center during the October week. During the two weeks, FedEx ramp controllers and administrators used SMS while performing their normal jobs, and provided feedback to the researchers on the usefulness of the SMS information, the performance of the SMS algorithms, and the usability of the SMS interface. Results from the initial field tests are being used to refine SMS in preparation for shadow-mode testing with FAA controllers, scheduled for February, 2003 in the MEM ATC tower/Terminal Radar Approach Control (TRACON) facility. FedEx has continued to operationally evaluate SMS in its ramp tower following the October test and now considers the tool extremely valuable to its operations.

Introduction

Departure taxi delay is the largest of all aviation movement delays and results in the largest addition to direct operating cost [1]. Yet, surface automation has historically received significantly less attention than terminal and enroute automation. The delays that occur on the airport surface may result either from restrictions on the surface itself (e.g., airport surface congestion and runway capacity limitations) or from restrictions due to limited capacity of other downstream elements of the National Airspace System (NAS). In both cases, traffic management decisions to minimize the delays resulting from these constraints must be implemented on the surface. The Surface Management System provides information and decision support to maximize the efficiency of the airport surface.

Detailed information about the future departure demand at an airport is not currently available. SMS provides operational specialists at ATC facilities and air carriers with both near-term predictions (e.g., departure sequences, times, queues, and delays for runways or other resources) to support tactical control of surface operations and longer time-horizon, aggregate forecasts (i.e., total demand for a resource per interval of time) to support strategic surface planning. The resulting shared awareness of the current and future arrival and departure situation enables improved decision making and collaboration among those users. Note that this is a similar capability for departures as the predicted arrival demand and expected delay information provided by the Center-TRACON Automation System (CTAS) Traffic Management Advisor. Furthermore, SMS uses its ability to predict how future demand will play out on the surface to evaluate the effect of various traffic management decisions in advance of implementing them, to plan and advise surface operations.

Initial SMS field tests were conducted in FedEx's ramp tower at Memphis International Airport over two weeks in August and October, 2002. During the October test, SMS was also exercised in the Northwest Airlines MEM operations center. This paper focuses on the operational evaluation in the FedEx ramp tower. During the testing, FedEx ramp controllers and administrators used SMS while performing their normal jobs, and provided feedback to the researchers on the usefulness of the SMS information, the performance of the SMS algorithms, and the usability of the SMS interface.

One of the reasons for beginning the operational evaluation of SMS in the ramp tower environment was to reduce risk associated with subsequent demonstrations. The results from the initial field tests are being used to refine SMS in preparation for shadow-mode testing with FAA controllers, scheduled for February, 2003 in the MEM ATCT/TRACON facility. Shadow-mode testing uses real-time data sources but allows the user to exercise SMS in a non-operational environment, to verify that it is ready to be used operationally. In addition, how aircraft are controlled in the ramp, in particular when and in what order they are pushed back and taxied to the spots, has a substantial impact on the efficiency of the airport runways. Observations at MEM and other airports have suggested that when the ramp towers do a good job of delivering aircraft to the air traffic control tower (ATCT), the FAA controllers are able to use the runways very efficiently. However, the ATCT may not have sufficient controllability over the departure sequence and runway loading after aircraft reach the spot to construct an efficient departure schedule if the stream of traffic received by the tower has not been preconditioned. Therefore, efficient use of the runways often requires collaboration between the ramp tower and FAA tower.

The remainder of this section presents an overview of SMS. The following section describes what was done during the field tests. The field test results are subsequently presented in two parts – the human factors results and the results of analyzing SMS algorithmic performance. The paper finishes with a summary and plans for future work.

Overview of SMS

The Advanced Air Transportation Technologies (AATT) Project at NASA Ames Research Center is working with Raytheon and Metron Aviation, among others, to study automation for aiding airport surface traffic management. The FAA's Free Flight Program Office is supporting the development of SMS and will continue to work with the NASA team throughout the project to transfer the SMS technology to the FAA for possible deployment. This section introduces SMS; additional details may be found in references [2-3].

The Surface Management System is a decision support tool that provides information and advisories to help the FAA (both traffic managers and controllers) and air carriers collaboratively manage the airport surface. SMS has three fundamental capabilities: 1) the ability to predict the movement of aircraft on the airport surface and in the surrounding terminal area (i.e., what will happen assuming current traffic management initiatives), 2) the ability to use this prediction engine to plan surface operations (i.e., what would happen assuming various other traffic management initiatives), and 3) the ability to disseminate this information and provide appropriate advisories to a variety of users.

These fundamental capabilities allow SMS to provide information and advisories that are customized to the needs of each user. SMS supports a variety of users: the Local and Ground controllers and Traffic Management Coordinator (TMC) in the ATCT, the TMCs in the TRACON and Air Route Traffic Control Center (ARTCC), the ramp controllers and supervisor in ramp towers, and the dispatchers and ATC coordinator in Airline Operations Centers (AOCs). In addition, SMS supplies information to the Enhanced Traffic Management System (ETMS) which supports the ATC System Command Center (ATCSCC). To support this broad set of users, SMS could be deployed as three separate tools. First, SMS controller tool capabilities are designed to help the FAA Local and Ground controllers as well as ramp tower controllers manage individual aircraft. Second, SMS's traffic management functionalities support strategic planning by providing more aggregate information and are intended to be used by TMCs in the ATCT, TRACON, and ARTCC as well as by dispatchers in the AOCs and ramp tower supervisors. Third, the NAS information component of SMS, which provides data to increase the predictability of the NAS and, thereby, support traffic flow management (TFM) is useful to other applications used by the ATCSCC and to ATC coordinators in AOCs.

By creating shared awareness of the future surface situation, SMS allows the ATCT, TRACON, ARTCC, and air carriers to coordinate traffic management decisions. SMS-provided information is expected to be most helpful during irregular operations, when knowledge of daily schedules gained through experience cannot be used to predict the timing of future demand. SMS's planning tools attempt to increase airport throughput (i.e., peak capacity rate), increase the efficiency of surface operations (i.e., minimize the cost of unavoidable delays and their environmental impact), and improve user flexibility (i.e., minimize the impact of delays on air carrier business objectives), without increasing user workload. SMS continually updates its advisories to react to the current situation and controller actions and is collaborative between the ATCT and the air carriers.

To predict the near-term state of traffic on the surface, SMS uses real-time surface surveillance information that includes aircraft identity from ASDE-X, a next-generation surface surveillance system currently being developed by the FAA, and a surface trajectory synthesis algorithm that accurately predicts the movement of aircraft on the airport surface. To predict departure times further in advance (i.e., prior to aircraft pushback), SMS uses airline-provided information about when each aircraft will want to push back in conjunction with the trajectory synthesis algorithm.

SMS utilizes four types of displays to convey information and advisories: map displays, timelines, load graphs, and tables. A map display provides the location and direction of motion for each aircraft on a two-dimensional diagram of the airport surface and includes flight-specific information in data blocks. Timelines show when an aircraft is predicted to occupy a physical location (e.g., a runway threshold, spot, or parking gate) but do not show the current location of the aircraft. Load graphs display the aggregate amount of current and forecasted demand on an airport resource (e.g., a runway or departure fix). Flight and status tables provide flight-specific information (e.g., OUT and OFF times and departure runway) in a tabular format. The SMS displays and features (e.g., to search for and highlight an aircraft) are described in greater detail in reference [4].

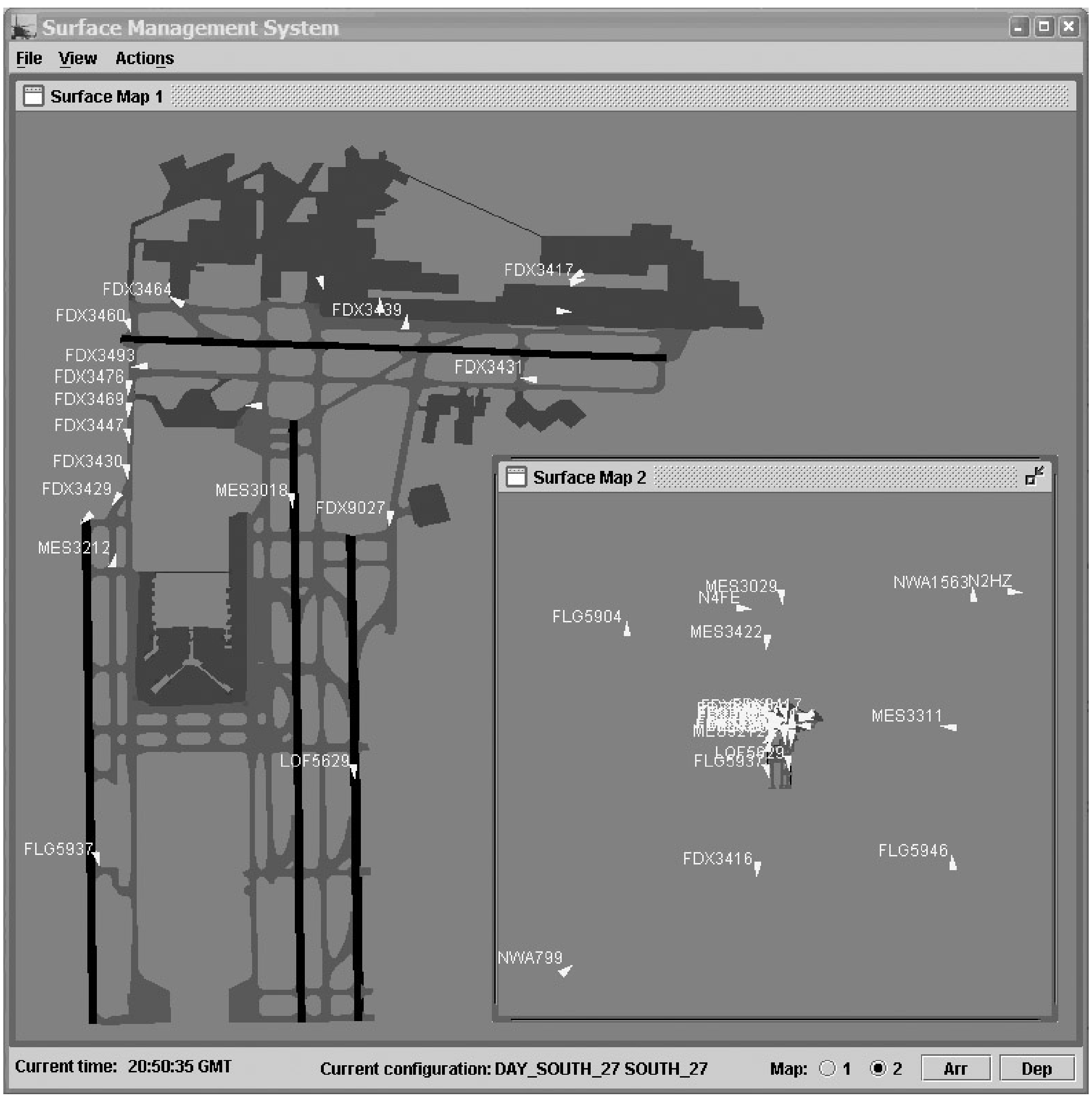

Figure 1. Example of the SMS Map Display.

Figure 1 shows the SMS map display, including an inset of part of the terminal area. Figure 2 is an example of an SMS timeline, showing all arrivals predicted over the next 20 minutes on the left side and all departures on the right side. Each aircraft is shown at the time it will land or takeoff; the predicted runway is shown in the data block. Figure 3 is an example of an SMS load graph. The picture shows the predicted departure demand for each of four departure gates (the color coding has been removed for publication); there is a significant eastbound push beginning 15 minutes from the present time.

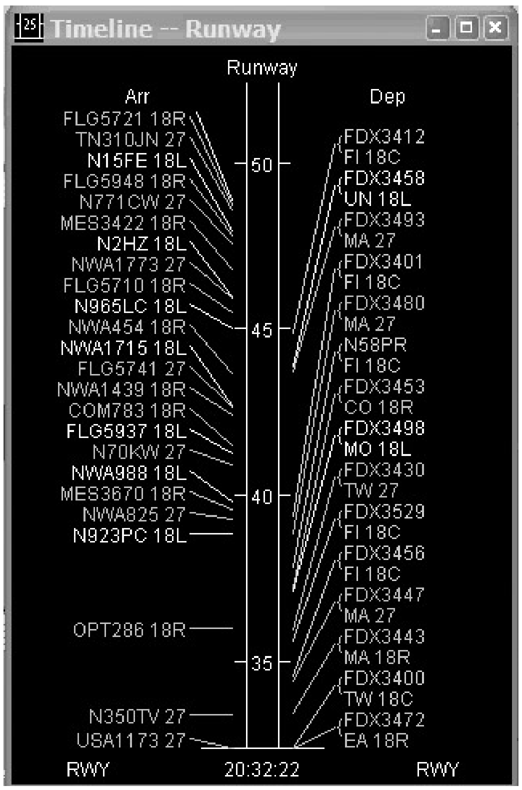

Figure 2. Example of an SMS Timeline.

Overview of Field Tests

The initial field tests were conducted in FedEx's ramp tower at Memphis International Airport. MEM is FedEx's largest hub and the largest cargo airport in the world. MEM also serves as a hub for Northwest Airlines. This section describes what was done in Memphis during the two weeks of operational evaluation. As seen in Figure 1, MEM has two main terminal/ramp complexes. The FedEx ramp is located north of runway 9/27; the passenger terminal is located between the parallel runways. Although passenger flights make up the majority of traffic during the day, FedEx operates a single daytime bank; about 130 aircraft depart between 3 and 5 PM after having arrived gradually throughout the day. Night operations are predominantly FedEx, with 150 aircraft arriving between 9 PM and 12:30 AM and departing between 2:30 and 4:30 AM, after the cargo has been sorted and reloaded.

SMS was tested during FedEx's night operations August 26 – 28 and October 17, and during the days of October 15 - 18. The results of the August demonstration were used to make refinements to SMS before the October demonstration. Normal daytime staffing in the FedEx ramp tower consists of one administrator and two ramp tower controllers (one responsible for the west side of the ramp and one responsible for the east side). At night, the ramp is divided into four regions (Northwest, Northeast, Southwest and Southeast) each with a ramp controller.

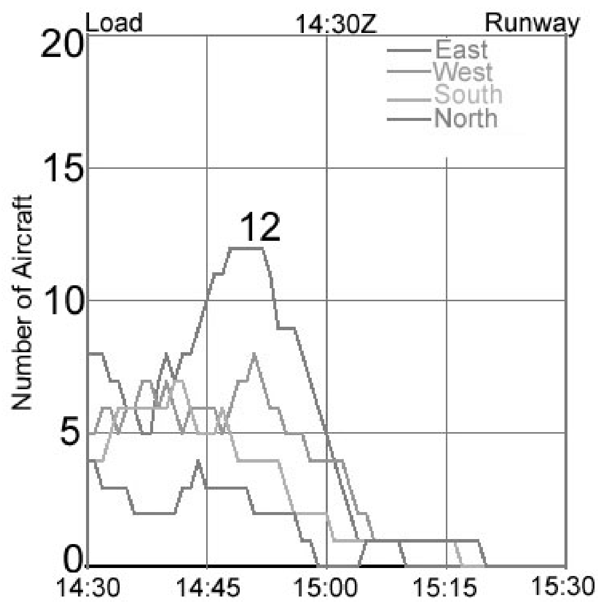

Figure 3. Example of an SMS Load Graph.

SMS was installed at the administrator's position and one ramp controller position (the East position during the day and the Southwest position at night). The administrator's job is to supervise the ramp controllers and coordinate their actions to achieve his/her strategic plan for the push. The primary administrator's task relevant to SMS is managing the flow of aircraft out of the ramp to load the runways evenly and control the queue lengths. To accomplish this, the administrator advises ramp controllers when to hold aircraft at their gates to increase or decrease the amount of traffic from each ramp area. To support this task, the SMS administrator's display, shown in Figure

4, provided information about the current and forecast runway utilization and delays.

The ramp controllers are responsible for the tactical movements of aircraft on the ramp, including approving aircraft pushbacks, selecting to which spot to taxi each aircraft, and monitoring the aircraft's movement from their gate to the spot, or vice versa. A "spot" is the location on an airport surface at which aircraft are transferred from ramp control to FAA tower control, or vice versa. The ramp controller's SMS display was designed to support the specific tasks of selecting which flight to push back next and maintaining traffic flow situational awareness.

Figure 4. SMS Displays at the FedEx Ramp Tower Administrator Position.

Eventually, SMS information will be provided to the NAS users digitally, allowing the NAS users to display the information or integrate it into company systems as desired. Therefore, the SMS project does not intend to design NAS user displays (FAA user displays will be designed). However, in order to determine the ramp tower users' information needs, initial SMS display designs were presented from which the users could evaluate the accuracy and usefulness of the SMS-provided data. This paper does not present detailed information about the displays designs. Instead, the paper focuses on the feedback which was received about the information content of the displays.

The SMS displays were provided to the ramp controller on a single monitor. Space limitations in the controller's work area prevented a full-size monitor from being located close enough to the ramp controller to easily see information on the SMS displays. Consequently, a laptop screen was used at the controller position. Despite the smaller screen size, the proximity of the screen allowed the ramp controller easy access to the SMS information.

During the arrival rush, SMS provided the ramp controllers current aircraft location (both on the airport surface and in the terminal area) via a map display, and predicted arrival sequence, ON and IN times, taxi delays to the controllers' spots and gates, and flight status via two timelines and a flight table. During the departure push, SMS provided aircraft location (primarily on the ramp) via a map display, predicted pushback time and sequence of aircraft leaving the ramp area via a timeline, and flight status via the timeline and a table.

SMS displays were presented to the administrator on two 17-inch LCD monitors. One monitor provided current aircraft locations via a map display. During arrivals, the second monitor provided predicted arrival sequence and ON times via a timeline, un-delayed arrival and departure demand via a load graph, and flight and runway status via tables. During departures the second monitor provided predicted OFF times and predicted queues at the runway via a timeline, predicted and current queue length, un-delayed arrival and departure demand, and predicted overall delay via three load graphs, and flight status, departure fix status, and runway status via tables.

Training on the use of SMS was held two weeks prior to the initial demonstration. At this time, human factors engineers observed ramp tower personnel performing their jobs to collect baseline data prior to SMS being available. FedEx ramp tower personnel currently use several different sources to get information about the current state of aircraft and airport resources: looking out the window, a commercially available filtered repeater of FAA radar surveillance showing aircraft locations in the terminal area, listening to ATCT Ground and Local radio frequencies, and an internally-developed automation tool called the Ramp Management Advisory System (RMAS). This combination of information sources provides a good view of the current state of the airport. However, a picture of the future situation on the airport surface is not currently available.

During the tests, human factors observers were stationed at the administrator position and the controller position to help the FedEx personnel use SMS, record observed usage and user comments, and administer questionnaires. Three different types of data was collected: SMS log files, human factors observations, and questionnaires. SMS log files record data such as the aircraft target positions at each point in time, user keyboard entries, SMS predictions, and the runways used by each aircraft. The human factors observations included what information was used by the administrator or controller, which displays were preferred, and what questions the users asked.

Questionnaires were administered after each of the arrival and departure pushes. These questionnaires focused on the usability, suitability, and acceptability of the SMS user interfaces. Usability refers to the ability of the user to readily obtain and use the information presented. Suitability refers to the appropriateness of the user interfaces to the task requirements and information needs. Acceptability reflects the user's trust in the information presented and his/her willingness to incorporate SMS into his/her task performance strategies. The questions consisted of ratings on a 7-point Likert scale, multiple choice, and open-ended questions. The questionnaires were designed to be specific to the arrival or departure push and were different for the administrator and the controller. All forms of data collection were confidential.

Experience from developing CTAS has shown that involving the eventual users throughout the development process significantly benefits the quality, operational applicability, and usefulness of the final product. Therefore, the FAA and NASA have formed an SMS user cadre, consisting of ATCT controllers, traffic managers, and air carrier representatives, to provide feedback on the SMS concept, performance, and interfaces, throughout development. In addition to the FedEx ramp tower staff who participated as subjects, additional FAA controllers and TMCs participated in the October demonstration as observers, providing feedback from the perspective of how SMS would be useful to their jobs.

Hardware Installation

To prepare for the field tests, two real-time, controller-in-the-loop simulations of SMS were conducted in the Future Flight Central (FFC) ATC tower simulator at NASA Ames Research Center. During the simulations, the Dallas-Fort Worth International Airport (DFW) was modeled. FAA controllers from DFW participated, using SMS to help control simulated traffic in FFC. Results from these simulations, discussed in references [5-6], were used to prepare SMS for testing in the FedEx ramp tower. In addition to DFW and MEM, SMS has been adapted for ATL and JFK as part of benefits and cost work, illustrating the portability of SMS to other airports. SMS field tests are being conducted in Memphis to take advantage of the FAA's SafeFlight 21 experience and infrastructure at the airport. MEM also exhibits surface and departure characteristics that are common to many airports. For example, MEM experiences significant departure queues and unbalanced departure runways during some departure pushes, and the airfield layout creates opportunities for surface congestion and runway crossing delays.

Figure 5 shows the system architecture for SMS in Memphis. SMS uses real-time location and identity information about aircraft on the airport surface, which it receives from the FAA SafeFlight 21's ASDE-X prototype. SMS also gets airborne surveillance information for the terminal airspace from the SafeFlight 21 system, which it uses along with ETMS data to predict landing times for the arrivals.

SMS receives flight plan information, surveillance information for arrivals outside the terminal area, and the air carrier's updated planned departure times for each flight from ETMS. To correctly model inter-departure times, SMS must know what downstream restrictions are in effect. ETMS also provides EDCTs for aircraft affected by ground holds. Non-interference testing of SMS, to demonstrate that SMS does not disrupt ETMS or any other NAS system, was conducted at the FAA's William J. Hughes Technical Center prior to installation of each version of the software. Testing also demonstrated that SMS properly removes sensitive information (e.g., flight IDs of military aircraft) from displays in the FedEx ramp tower. The current airport configuration, planned configuration changes, MIT restrictions, and APREQ times must be manually entered.

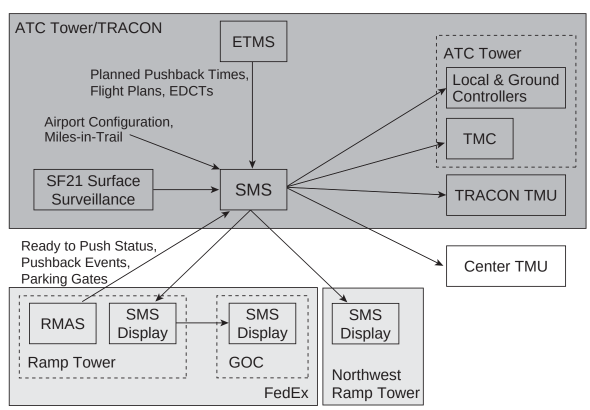

Figure 5. SMS Architecture at Memphis International Airport.

Initially, SMS information will be displayed on separate displays in the air carrier facilities. Eventually, the SMS information will be provided via a standard interface, so that the air carriers can integrate it into their automation systems. In Memphis, SMS is connected to FedEx's RMAS system to receive parking gate information. SMS needs to know at what gate each arrival will park to predict taxi-in times as well as surface conflicts between arrivals and departures. SMS also receives flight status information (i.e., ready to push and pushed back) from RMAS to compensate for flights that do not appear in the surface surveillance data. Eventually, the air carriers will provide this data through either ETMS or the standardized interface across which they receive SMS data. This approach avoids the need to interface separately to every air carrier's ramp tower automation system.

SMS displays will eventually present information and advisories to the Local and Ground controllers as well as the TMC in the ATCT, to the TMCs in the TRACON and ARTCC, and to FedEx and NWA's AOCs. In addition, SMS data will be provided to ETMS to improve traffic flow management products that use predictions of takeoff times. The human factors need to minimize the number of displays in front of ATCT controllers may motivate sharing of displays rather than installing dedicated SMS displays. Consequently, SMS's eventual deployment configuration may incorporate SMS data elements into the displays associated with other systems (e.g., ASDE-X or the STARS ATCT display). In addition, to improve maintainability, the SMS software algorithms could be hosted as part of some other automation system (e.g., ETMS). Integration of SMS with these other systems is beyond the technical scope of the current task and would limit the flexibility required during the research phase. The NASA team is working with the FAA to define the appropriate deployment architecture for SMS.

Field Test Results

The FedEx users provided feedback on the usefulness of the SMS information/functions, the performance of the algorithms, and the usability of the interface. In addition to soliciting qualitative user feedback, data was collected during the simulations to analyze the current performance of the SMS algorithms. These two sets of results are presented in the following two sub-sections.

Human Factors Results

During the first demonstration week, the users' interactions with SMS consisted primarily of comparing SMS information with information from other sources (e.g., RMAS, out-the-window) to develop confidence in the SMS information and become familiar with where to look in SMS to find particular information. The human factors observers facilitated this process by pointing out information on the SMS display to supplement the training that had been provided. After becoming comfortable with a new tool, users frequently use the tool to replace previous, less efficient information sources. Eventually, users (and organizations) see opportunities to change the way they do their jobs that were not possible previously but are now possible with the new technology

As their familiarity with SMS increased, the ramp controllers began using SMS-predicted ON and IN times during the arrival rushes. During the arrivals, one of their tasks is to enter ON and IN times into RMAS for flights that RMAS does not automatically receive the times. Previously, controllers would have to carefully watch each flight to see when it landed and reached its parking gate. For gates that can not be seen out the window, they would have to either estimate or use a camera system to watch the flight. With SMS, they could enter the times at their convenience either early (using SMS predictions) or later (using SMS's ability to recall stored times). Additionally, the controllers reported using the predicted arrival sequence from SMS to "keep ahead of radio calls." Previously, controllers would have to monitor the ATCT Local and Ground radio frequencies to hear which FedEx arrivals were coming in next.

Figure 6. FedEx Ramp Controller Using SMS During SMS Field Tests.

All users reported interest in the aircraft position information and the map display, both on the surface and in the terminal area. This information will become available from the FAA's ASDE-X system; SMS receives this information from a prototype of that system. According to the controllers, the most useful information during the arrival rush is the estimated gate arrival times and landing sequence. SMS-predicted arrival times were given a mean acceptability rating of 3.3 (σ = 0.6) on a 0 – 4 scale where 0 = completely unacceptable and 4 = completely acceptable. The mean acceptability of the predicted aircraft sequence was 2.7 (σ = 1.2). During the departure push, the controllers reported using the positional information to determine the departure queue lengths. Some controllers asked for aircraft to be identified by their ramp area in order to determine the number of aircraft pushing from each ramp.

According to the administrators, the most important SMS information during the arrival rush is accurate predicted ETAs and accurate landing sequence. They requested that the information be color-coded to show flight status (enroute, on final, taxiing, in the ramp). Both controllers and administrators used the predicted arrival runway to estimate taxi time, since this is how they have always estimated when the aircraft will reach the gate; they had not yet changed their work process by directly using SMS IN time predictions.

On departure, the administrators expressed an interest in having taxi times displayed for each aircraft to help them minimize the taxi times. The administrator also requested information about active aircraft versus scheduled aircraft to help them monitor how efficiently the rush was progressing. During the daytime departure push, the administrators asked for the information on the timelines to be filtered to only show FedEx flights instead of all flights on the airport surface. According to the administrators, the most useful information for the departure push was current and predicted runway queue lengths because this information helped them manage the runway queue lengths by helping them decide when to hold aircraft at the gate.

Observations and analysis of questionnaire responses indicate that SMS data is most useful to the ramp controllers during the arrival rush and the administrator during the departure push. However, this conclusion may be partly because the controllers are busier during the departures and, therefore, may not have had time to integrate SMS into the work process. Consequently, SMS may be seen as an additional task rather than something that makes their job easier and allows them to do their job better.

During the second week of the demonstration, the controllers used the predictions provided by SMS to monitor the inbound traffic in order to plan more efficiently for periods of higher and lower demand. They reported predicted ON times, aircraft location on the airport surface, parking gate or spot, predicted landing sequence, and flight status to be the most useful pieces of SMS information. During the departure push, the administrators used the SMS information to make decisions about holding aircraft at their gates to minimize taxi times and, consequently, fuel burn. The administrators reported that the most important pieces of SMS information during the departure push were: the number of aircraft taxiing to each runway, the number that were currently pushing, the current queue length at the runways, and notification of late inbound aircraft.

During an afternoon departure push, the administrator noticed from an SMS load graph that a late arrival was approximately 15 minutes from the airport. The administrator notified the appropriate controller, who had independently noticed this late aircraft on his SMS timeline. The aircraft was scheduled to arrive via spot 6, which SMS predicted would be blocked at that time by a departing aircraft that had already been cleared for pushback. In response to this SMS information, the controller was able to redirect the departing aircraft out a different spot and avoid a conflict on the ramp. Additional details about human factors results are available in reference [7].

Data Analysis Results

To guide the algorithmic development effort, a substantial amount of analysis of the algorithms performance has been conducted. However, as the SMS algorithms are improved in response to these analyses, the analyses quickly become out of date. The following is a selection of studies that show the performance of the SMS algorithms at the October, 2002 field test. The SMS prediction algorithms are discussed in references [8-9].

Figure 7 shows the distribution of the error in the time at which SMS expects flights to pushback. The error is measured as the time at which the RMAS pushback request message is received minus the SMS predicted OUT time (from ETMS). The plot shows that during the October test aircraft pushed back earlier than expected by ETMS. This is an inaccuracy in the data SMS uses as an input. To reduce this error, SMS would need the air carriers to update their expected pushback times more frequently.

Figure 8 shows the distribution of the error in SMS's prediction of taxi times. The plot is for both arrivals and departures; additional plots could be drawn to show only a subset of flights (e.g., departures from a certain ramp area to a certain runway), or a portion of the taxi (e.g., movement time between crossing a spot and joining a runway queue). The figure shows both the distribution of actual taxi times and SMS predicted taxi times.

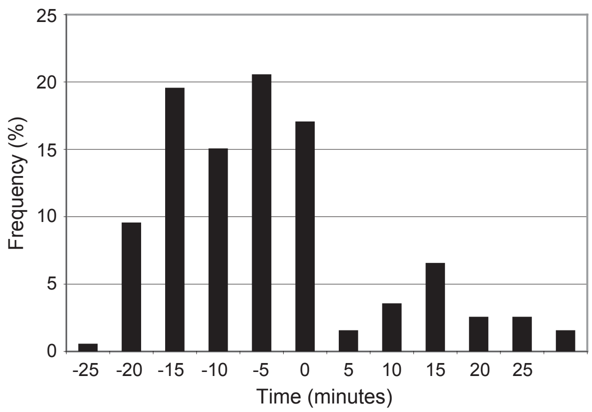

Figure 7. Pushback (OUT) Prediction Error.

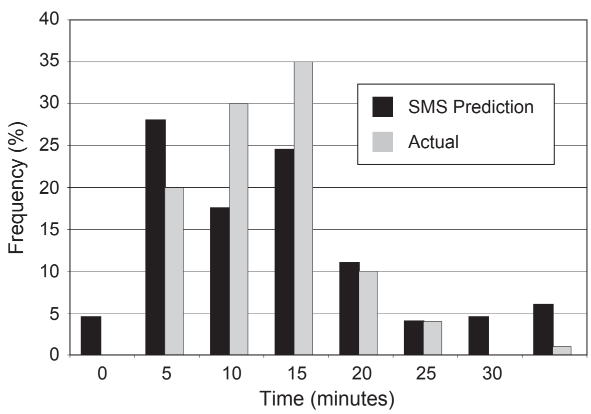

Figure 8. Taxi Time Prediction Error.

Figure 9 shows the average absolute SMS prediction errors for the OUT, OFF, ON, and IN events, measured 20 minutes prior to the actual event. Figure 10 compares the average signed error in the SMS and ETMS predictions of gate arrival (IN) time, as a function of time before reaching the parking gate. Surface surveillance is used to determine the actual IN time. The ETMS Scheduled IN time is constant. The SMS prediction converges to zero error almost 10 minutes before the aircraft reach their parking gates. The SMS prediction includes two components, a prediction of ON time and a prediction of taxi time that is conditioned on the aircraft landing at the predicted ON time. The October version of the SMS algorithms did not predict the arrival runway accurately and, therefore, ON time predictions were inaccurate. In addition, the October version of the software did not accurately model the delay required to taxi across an active runway. These issues, which are being addressed in the updated algorithms, were responsible for the variation in the estimated IN time more than 15 minutes before actual IN time.

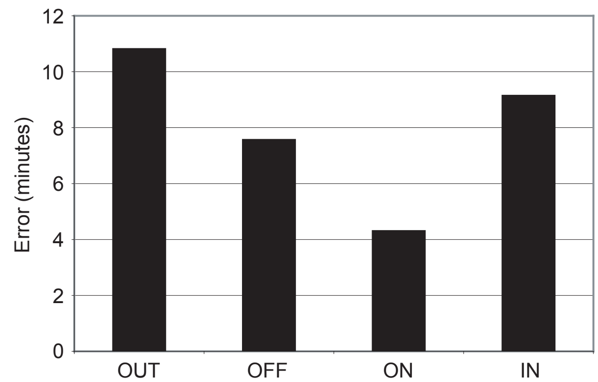

Figure 9. Average Prediction Errors 20 Minutes Prior to Actual Event.

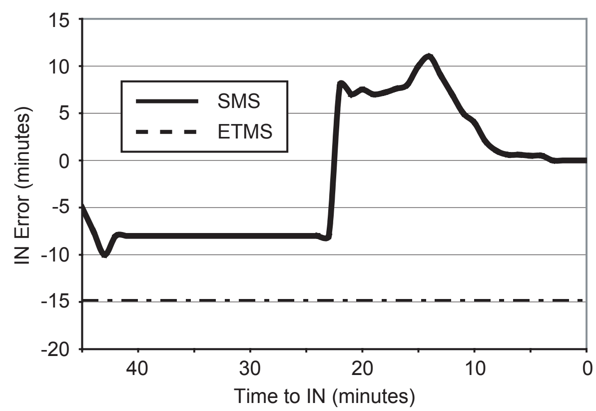

Figure 10. Gate Arrival (IN) Time Prediction Error.

Figure 11 compares the average absolute error in the SMS OFF time prediction (i.e., the magnitude of the difference between the SMS-predicted takeoff time and the actual takeoff time) as a function of the prediction horizon (i.e., the amount of time before the actual takeoff). The SMS error is significantly smaller than the ETMS error, and approaches zero as the prediction horizon decreases. Since ETMS has no information about what is happening on the airport surface, its error remains nearly constant until after the aircraft has taken off.

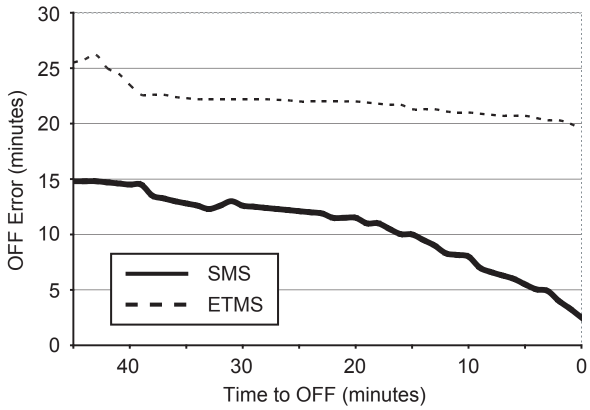

Figure 11. Takeoff (OFF) Time Prediction Error.

Summary

The two primary goals of this field test were to 1) evaluate the utility of SMS in the ramp tower environment and 2) evaluate the performance of SMS algorithms. This paper has discussed field test results for each of these goals. These results support the conclusion that the SMS prototype has matured substantially since the laboratory simulations and promises to provide significant benefits and, therefore, warrants continued research and development.

That following the October test, FedEx has continued to operationally evaluate SMS in its ramp tower on a daily basis and now considers the tool extremely beneficial to its operations, demonstrates the value of the SMS information in the ramp tower environment. In addition to aircraft location, the SMS information found to be most useful was arrival time and sequence predictions and the numbers of aircraft pushing back, taxiing, and currently queued for each runway. These results will contribute to the definition of the information requirements for air carrier users of SMS. However, due to the tremendous variability between airports, not every SMS capability will be useful at every airport. Therefore, not all ramp tower applications of SMS could be observed during this field test.

Although the human factors results show that the SMS information is currently of sufficient accuracy to be useful in the ramp tower environment, the analysis results show that there are opportunities for further improvement in the prediction accuracy. Substantial progress has already been made in preparation for upcoming testing with FAA users. These algorithmic improvements will be reported in future reports. Shadow-mode testing with FAA controllers is scheduled for February, 2003 in the MEM ATCT/ TRACON facility.

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