

EVALUATION PLAN FOR SYSTEM-WIDE BENEFITS OF AN AIRPORT SURFACE-OPERATION AUTOMATION CONCEPT

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Abstract

The predicted growth in air travel requires capacity enhancement in the National Airspace System (NAS), and congestion at key airports has been recognized as one of the most prominent problem areas. With flights operating at limits dictated by operational requirements associated with current airport configurations, airport expansion plans involving addition of new runways and taxiways are in place to increase the airports' capacities. However, the expansion projects necessarily increase the complexity of the airport configurations, which tends to penalize the efficiency of the system, partially offsetting the capacity-related benefits of the investments. The Surface Operation Automation Research (SOAR) concept has been proposed as a collaborative concept to provide automation for surface-traffic management (STM) and the flight deck to enhance the operational efficiency in complex airport environments, thus softening the unintended penalties associated with airport expansions. STM automation is based on the Ground-Operation Situation Awareness and Flow Efficiency (GO-SAFE) concept previously reported to ease runway access conflicts, especially in situations where active-runway crossings constitute a significant taxi delay problem. To help achieve the potential GO-SAFE benefits, the Flight-Deck Automation for Reliable Ground Operation (FARGO) concept has been proposed to provide the necessary flight-deck automation for enabling precision taxi control to comply with GO-SAFE advisories. Development and evaluation of the SOAR concept is being pursued in a 5-year program. A previous publication has documented an initial evaluation of the concept based on computer simulations of surface operations at a single hub airport. Expanding on this previous evaluation, this paper describes a NAS-wide evaluation effort to assess the system-wide benefits of the SOAR concept.

Introduction

The problem of air traffic growth unmatched by commensurate growth in capacity has been witnessed with the peak summer flight delays prior to the September 11, 2001 terrorist attack. The flight-delay problem has been well documented and recognized by all concerned parties including the Federal Aviation Administration (FAA) and NASA, and the slow down in air travel since the 2001 attack is recognized by all to be a temporary effect. FAA recognizes the capacity problem, and in the National Airspace System (NAS) Operational Evolution Plan (OEP) [1] specifically identifies congestion at key airports as one of the domains where the problem is most prominent.

The air traffic in the NAS operates in three commonly referred-to domains: en route, terminal, and surface. The routes taken by the air traffic from the surface through the terminal airspace to the en route airspace expand out resembling a tree structure branching off from the base upwards to its branches. Whereas taxi operations on the surface are confined to the planar surface along predefined runways and taxiways, air traffic in en route airspace enjoys additional degrees of freedom in terms of variable flight levels and the option to deviate from predefined air routes. As a result, the airspace provides more spatial flexibility as it transitions up the domains, permitting ideas such as free flight in the en route space to benefit the air transportation community. In the reverse direction, the airspace is increasingly more constrained spatially, and the traffic needs to be more orderly as it operates on the surface to address the funnel effect.

In particular, major airlines practicing hub-and-spoke operations for cost savings were determined to be suffering from major delays at the hub airports [1]. In view of landing and departure rate limits imposed by separation requirements, construction of new runways is ultimately inevitable to achieve capacity gain. In addition to

the cost of construction, the increase in surface traffic complexity resulting from the airport expansion will incur other indirect costs or penalties that should be taken into consideration. The Surface Operation Automation Research (SOAR) concept [2], [3] has been proposed to provide automation tools for coordinating efficient surface traffic movement. Development and evaluation of the SOAR concept is currently being supported by the NASA Virtual Airspace Modeling and Simulation (VAMS) Project. An overall evaluation plan of the SOAR concept is provided in [4]. The plan includes an initial evaluation in 2003 using computer simulations for taxi operations and surface traffic management (STM) automation [5] at a single hub airport, and results from the evaluation have been reported in a recent publication [6]. Following this initial evaluation, the overall evaluation plan includes a system-wide assessment effort in 2004 to study the SOAR impact on the whole NAS. This paper represents a progress update of the SOAR project with the presentation of the system-wide evaluation plan. For the sake of completeness, the next two sections include an overview of the SOAR concept and a brief review of the single-airport simulation evaluation results. These are followed by discussions of the anticipated system-wide benefits of the SOAR concept, the simulation program intended for the evaluation effort, and the activities being planned to complete the system-wide evaluation. Reporting on the work in progress, this paper does not include any system-wide evaluation results, which will be the subject of future reports.

Overview of SOAR Concept

The SOAR concept introduces advanced automation to the two main environments responsible for surface operation: (i) STM or the ground control environment, and (ii) the flight deck. This collaborative automation concept will provide maximal performance when these two environments can be tightly integrated in a Centralized Decision-Making, Distributed Control (CDDC) paradigm, as illustrated by the block diagram in Figure 1 describing the roles of the automation components.

The ground-control automation system will provide the centralized decision-making

functionality for STM. It will base its decision on the surveillance data, flight plans and Airline Operational Control (AOC) requirements, to generate time-based taxi routes for optimum traffic efficiency. Advanced digital data link will enable the issuance of complex taxi clearances for the flights to taxi according to the desired time-controlled taxi routes and monitoring the vehicles' compliance. The SOAR ATM automation component is based on the *Ground-Operation Situation Awareness and Flow Efficiency (GO-SAFE)* concept described in [5].

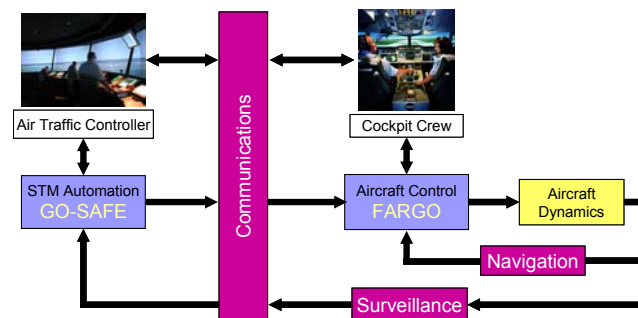


Figure 1. High-Level Block Diagram of SOAR Collaborative Automation Concept

The flight-deck automation systems in the aircraft participating in the surface operation will collectively provide the distributed control of the overall traffic system in a collaborative manner. Advanced automation and navigation technologies will enable the pilots with auto-taxi capabilities or automation aids for performing precision taxi to achieve the time-controlled taxi routes issued as clearances by the GO-SAFE system. New operation procedures will need to be defined for carrying out data-linked clearances, and for automatic loading of the clearances into the flight decks' flight management systems (FMS). A previous effort has demonstrated with computer simulations that advanced nonlinear control methods can enable the aircraft to track very precisely defined time-controlled taxi routes [7], even in the highly dynamic environment of performing active-runway crossing immediately after the aircraft has landed on an adjacent runway. The *Flight-deck Automation for Reliable Ground Operation (FARGO)* system envisioned in SOAR represents further development of this idea to achieve the flight-deck automation component of the concept.

Integrated operation of the GO-SAFE and FARGO automation systems allow air traffic control (ATC) and the pilots to achieve the benefits envisioned by the SOAR concept. In summary, GO-SAFE performs traffic planning to simultaneously enhance arrival/departure efficiency and surface traffic efficiency. This is a key factor of the SOAR concept, related to its ability to deliver close to peak traffic rates without substantial taxi delay. Execution of the plan is enabled by accurate surveillance, data link for issuing clearances with detailed route information, and precision taxi performance delivered by the FARGO system enabled by accurate navigation. The traffic planning will also take advantage of high-quality traffic prediction data coming from other systems, such as the Center-TRACON Automation System (CTAS) [8] with its various tools [9]–[13], and the Surface Management System (SMS) [14], [15]. The GO-SAFE and FARGO user interfaces with the underlying automation enable human operators to deliver efficient operations otherwise unattainable with current systems; hence they allow the operators to achieve higher performance within acceptable workload. These user interfaces with accurate surveillance data also enhance safety by improving the situation awareness of the operators. They help to reduce confusion between different flights on the surface, and they also provide timely alert in the case of impending conflicts.

Findings from Single-Airport Evaluation

In 2003, the SOAR concept was evaluated using a simulation of the airport traffic at a single airport. The airport modeled in the simulation was Dallas/Fort Worth International Airport (DFW), and the evaluation compared the performance of the SOAR systems with that from current operational practices. A recent paper [6] has reported on the results from the evaluation, and this section includes a brief review of these results.

Performance Factors and Metrics

The main performance factor for any capacity-increasing concept is inevitably capacity. Reference [6] discusses why a reasonable metric for quantifying the capacity of the airport should be the

maximum achievable throughputs of the arrival and departure traffics. It points out that, in the process of maximizing arrival and departure throughputs, additional taxi delays might be incurred and such delays would contribute to system travel delays. Hence, the notion of airport capacity should be studied as a combination of two sub-domains: capacity at the airport “periphery,” and capacity within the airport “surface.” Specifically, the airport surface capacity addresses how well the network of runways and taxiways can absorb the air traffic in and out of the airport, without creating a bottleneck between the runways and the terminal gates.

Airport Periphery Capacity in Terms of Arrival and Departure Throughputs

For a given airport layout, the airport periphery capacity is constrained by an upper bound that depends on two primary factors: the number of runways, and the maximum traffic rate per runway. The maximum traffic rate per runway in turn depends on many factors, such as operational requirements on arrival/departure traffic mix, and aircraft separation due to wake vortex and other concerns. The integral product of the number of runways with the maximum traffic rate per runway under ideal situations constitutes an upper bound on the total traffic throughput of the airport. This upper bound can be considered the “ideal” capacity, which can be modeled in terms of Pareto frontiers [16]–[18]. The Pareto frontier models capacity as a tradeoff between arrival and departure rates. It does not account for any capacity loss due to surface operation or other factors.

In practice, the achievable capacity at the airport may be substantially lower than the ideal capacity due to inefficiency, much of which is caused by interference among the traffic. The increase in airport configuration complexity resulting from the airport expansion exacerbates the inefficiency. A notable example is the increased number of active-runway crossings resulting from increased traffic and airport expansion. To bring the achievable capacity close to the ideal capacity, ATC operation can minimize the impact of active-runway crossings on takeoff and landing operations by minimizing the total time taken up by runway-crossing activities. This can be achieved by queuing up the flights that require crossing and

clearing them to cross as a batch. The side effect is inevitably the increase in taxi delay when the flights have to line up and wait for a large enough group to form before crossing. This represents a tradeoff between the two efficiency factors:

- Reduction in achievable periphery throughput, a penalty on arrival/departure efficiency
- Increase in taxi delay, a penalty on surface traffic efficiency

This tradeoff suggests that airport runway throughputs constitute a good metric to assess airport periphery capacity, and taxi delay is a good metric to assess airport surface capacity.

The FAA Office of Aviation Policy and Plans has created the Aviation System Performance Metrics (ASPM) [19] to provide metrics of individual flights according to the phases of their flight. ASPM integrates data from two primary sources: the Enhanced Traffic Management System (ETMS) and Out, Off, On and In (OOOI) data from Aeronautical Radio, Inc. (ARINC). For the surface domain, in particular, ASPM includes metrics for both airport throughput and taxi efficiency determination. The ASPM data should provide a good reference for the airport periphery throughputs. Table 1 contains the optimum and

reduced rates for our target airport, DFW.

The layout of DFW is shown in Figure 2. The evaluation reported in [6] was based on the south-flow configuration, in which four runways (17L, 17C, 18R, and 13 R) are for the arrival traffic and the remaining three (13L, 17R, and 18L) are for departure. Referencing the optimum arrival and departure rates in Table 1, it can be concluded that roughly each runway allows up to 40 operations per hour, irrespective of whether the runway is for arrival or departure. This optimum rate is consistent with average aircraft separation of approximately 1.5 min between landing or takeoff operations.

Table 1. Optimum and Reduced Rates for DFW Provided by ASPM

	Hourly Rates			15-min Rates		
	Dep	Arr	Tot	Dep	Arr	Tot
Optimum	120	150	270	30	38	68
Reduced	90	95	185	23	24	46

Airport Surface Capacity in Terms of Taxi Delay and Efficiency

The notion of airport surface capacity should address how well the network of runways and taxiways can absorb the air traffic in and out of the

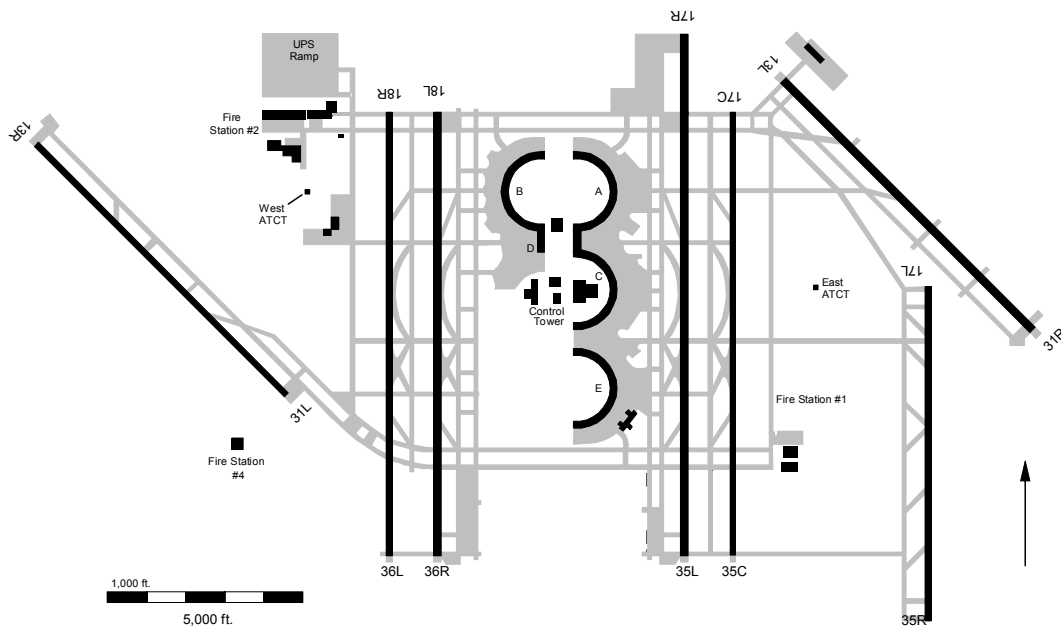


Figure 2. Current DFW Layout with 7 Runways

airport. From an operational point of view, surface traffic performance is strongly reflected in taxi delay, which thus constitutes the most meaningful metric for assessing the performance [20].

The “taxi-out” and “taxi-in” metrics in ASPM are defined as the difference in actual taxi time and unimpeded taxi time for taxi-out and taxi-in operations, respectively. Unimpeded taxi times in ASPM are estimated from available data, but they require additional processing from real traffic data because totally unimpeded operation is not available in real life for all possible taxi routes. Since the SOAR evaluation is based on computer simulations, the taxi time and unimpeded taxi time for each flight can be determined by simply running the simulation under the appropriate conditions.

Under the assumption that one would not taxi faster than under nominal situations, the taxi delay is always non-negative:

$$\begin{aligned} \text{Taxi Delay} \\ &= \text{Actual Taxi Time} - \text{Unimpeded Taxi Time} \\ &\geq 0 \end{aligned}$$

The taxi delay metric is also related to surface traffic efficiency. One can use the taxi time and unimpeded taxi time to define taxi efficiency metrics, which are described in [6].

Evaluation Experiment Design

The main objective of the initial evaluation was to assess the potential benefits of the SOAR concept relative to current surface operations without the automation systems. The use of automation systems in the SOAR concept is expected to require changes in operational procedures and rules, and the human performance is also expected to be affected by the automation. In order to capture these causal differences in the evaluation, the roles and responsibilities of the human operators and the automation systems were examined. The findings led to the adaptation of the ground-operation simulation (GO-Sim) software [5] to two separate simulations: one for evaluating the SOAR concept, and one for simulating current operations, as illustrated in Figure 3. For the SOAR concept, GO-Sim was modified so that the taxi control for the individual flights would simulate FARGO operations that could precisely track the

GO-SAFE time-based clearances. For current operations, software logic was introduced to simulate the ATC function of issuing clearances without GO-SAFE timing information, and the flight control function was modified to simulate taxi without any time-based taxi control objective.

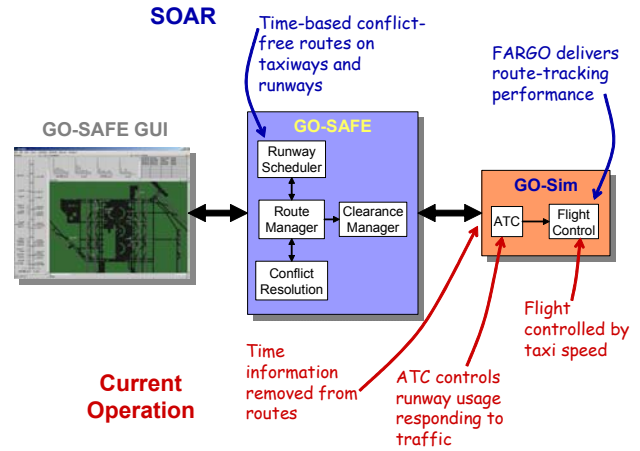


Figure 3. Adaptation of Computer Simulations for Evaluating SOAR Concept Compared to Current Operations

The traffic demand sets were specified for the evaluation, including a future demand data set developed from a transportation demand and economic analysis forecast for the year 2022 [21]:

- A data set representing operations at 250 domestic airports with 30,237 operations extracted from ETMS data for May 17, 2002
- A filtered data set corresponding to domestic commercial passenger flights at 98 major US airports with 16,468 operations
- A future demand data set developed from a transportation demand and economic analysis forecast for the year 2022, for the 98 major US airports containing 33,167 flights

These data sets were filtered to extract the flight records for all flights having DFW as either the origin or destination airport.

Evaluation Results

Although the evaluation involved the three demand data sets discussed above, only the results from two demand sets are included here for the sake of brevity. In particular, the 250-airport data set is

considered a good representation of the current demand, as illustrated by its similarity with the ASPM data, and the future demand data set represents the increased demand anticipated for the future.

Airport Periphery Throughputs

Figure 4 compares the total throughputs between the current operations and the SOAR concept using the 250-airport demand data set. It can be seen that the SOAR concept is delivering higher peak throughputs, and it is able to deliver the throughputs earlier to allow it more time to absorb more traffic later on.

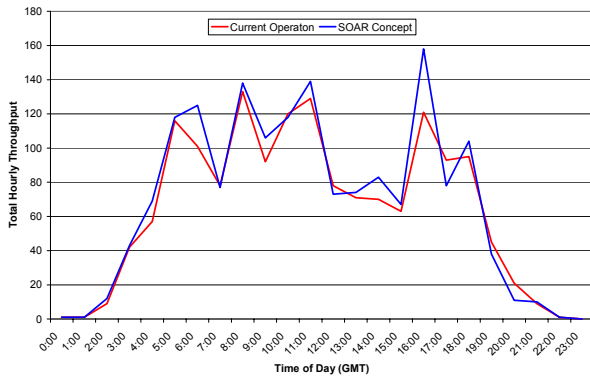


Figure 4. Comparison of Hourly Throughputs between Current Operation and SOAR Concept at DFW from 250-Airport Demand Set

Figure 5 compares the total throughputs between the current operations and the SOAR concept for the future demand data set. It can be seen here that the throughput improvement due to the SOAR concept is more pronounced.

Taxi Delay Results

Figure 6 compares the average taxi delays between the two operational approaches with the 250-airport demand set and the SOAR concept is demonstrating an obvious advantage. The benefit of the SOAR concept is, however, more valuable than what is shown by the relative shape of the plots because it is the absolute difference in the time delays that characterizes the amount of time and resources saved.

Figure 7 compares the average taxi delays between the current operations and the SOAR concept for the really demanding traffic from the future demand data set. Here the benefit of the

SOAR concept in saving taxi time is even more pronounced.

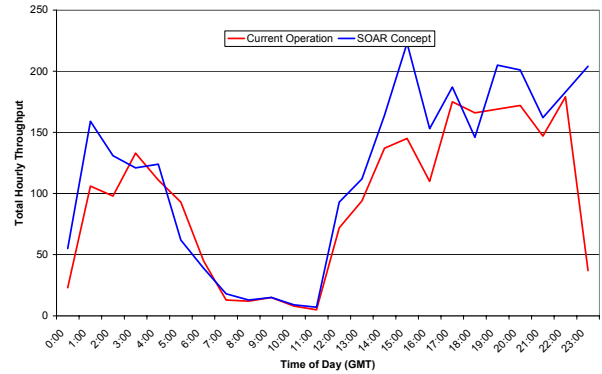


Figure 5. Comparison of Hourly Throughputs between Current Operation and SOAR Concept at DFW from Future Demand Set

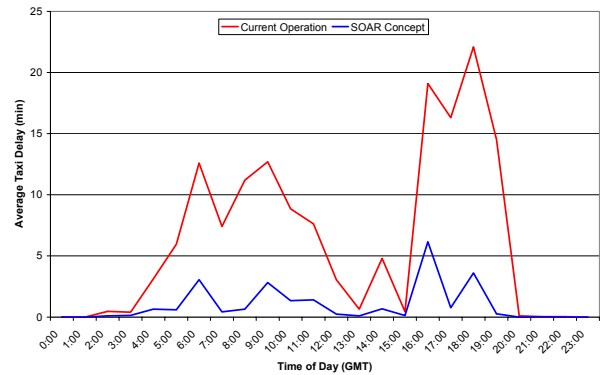


Figure 6. Comparison of Average Taxi Delays between Current Operation and SOAR Concept at DFW from 250-Airport Demand Set

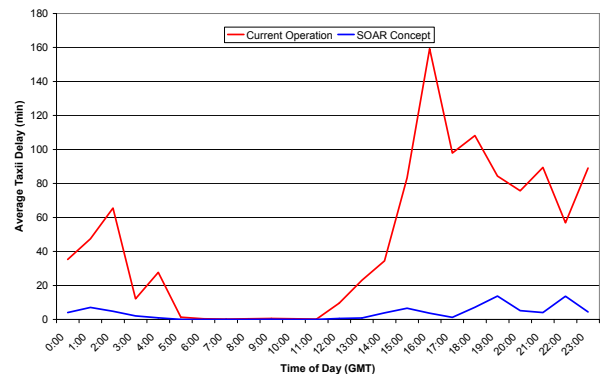


Figure 7. Comparison of Average Taxi Delays between Current Operation and SOAR Concept at DFW from Future Demand Set

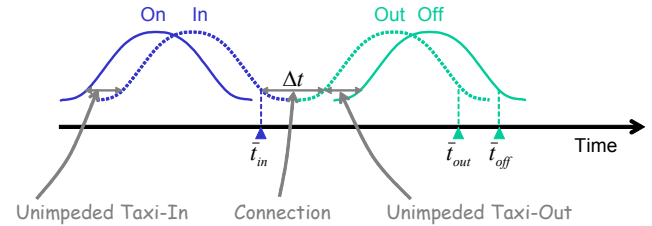
Anticipated System-Wide Benefits

For a single airport, the periphery throughputs and taxi delays are appropriate metrics for assessing the capacity of the airport in terms of its ability to handle the traffic demand. When extending these metrics to study the system-wide impact of the SOAR concept, these metrics all become performance factors affecting the system-wide traffic delay, which may be measured daily or over other periods of interest.

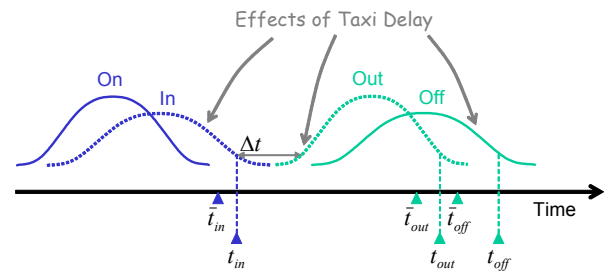
In addition to the direct contribution of taxi delays towards the system-wide traffic delay, the periphery throughputs and taxi delays also bring about secondary effects by rippling through the system as a result of flight connections. The SOAR concept is most relevant for hub-and-spoke operations, due to its potential to maintain surface traffic efficiency under heavy traffic. To illustrate how heavy traffic affects hub operations, we refer to Figure 8 to examine how the effect of taxi delays caused by the heavy traffic would propagate through the system. Figure 8 illustrates the density of arrival and departure traffic using the Out, Off, On and In (OOOI) convention. Part (a) of the figure shows the traffic densities under ideal situations with a bank of arrival flights followed by connections involving passenger and baggage transfers, and then by the departure of a similar bank. The traffic densities for arrival and departure are shown as the On and Off curves, respectively. With nominal taxi times, traffic densities corresponding to arrival at the gate and pushback are shown by the In and Out curves, respectively. The figure also indicates the taxi-in and taxi-out times, as well as the amount of time Δt required for the passengers to make the connections. The variables \bar{t}_{in} , \bar{t}_{out} and \bar{t}_{off} correspond to the end of the time windows for the gate arrival, gate departure, and final departure of the bank of flights, respectively.

If the heavy traffic from the hub operations causes excessive taxi delays, then the In curve for the taxi-in traffic would be spread out as shown in Figure 8(b). The same will happen to the Off curve for the departure bank. The taxi-in delays cause the end of the In curve to be shifted to t_{in} . When the arrival flights are delayed for taxiing to the terminal, the passengers will not have enough time

to move to the connection flights before they push back. Figure 8(b) shows the consequence of delaying the pushback operations to accommodate the connections, leading to a further delay in the departures defined by the Out and Off curves, with the end of the time windows moved to t_{out} and t_{off} , respectively.



(a) Ideal Hub Connections



(b) Effect of Taxi Delays with Delayed Pushback

Figure 8. Effect of Taxi Delays on Hub Operations

The discussion thus far has been concerned with the effects due to taxi delays alone. When reductions in throughputs are also taken into consideration, the On curve will also spread out and the Off Curve will spread out further.

All of these effects tend to push back the final departure time t_{off} of the connection flights in the departure bank. This will result in arrival delays of these flights at their destination airports. Arrival delays in hub-and-spoke operations further complicate the arrival bank of traffic, leading to more delay problems at those airports. As these delays propagate through the airports through the day, they result in a ripple effect that proliferates through the system [22]. The cumulative effect is what a system-wide evaluation should focus on. The following metrics are useful for quantifying these delay factors for each flight.

- *Gate Departure Delay* — This is the difference between the actual gate departure time and the originally scheduled gate departure time.
- *Surface Departure Delay* — This is the same as the *Taxi-Out Delay*, which is the difference between the actual taxi-out time and the unimpeded taxi-out time.
- *Airborne Delay* — This is the difference between the actual flight time from takeoff to landing and the originally scheduled flight time.
- *Surface Arrival Delay* — This is the same as the *Taxi-In Delay*, which is the difference between the actual taxi-in time and the unimpeded taxi-in time.
- *Block Delay* — This is the difference between the actual gate-to-gate travel time and the originally scheduled gate-to-gate travel time.
- *Total Delay* — This is the difference between the actual gate arrival time and the originally scheduled gate arrival time.

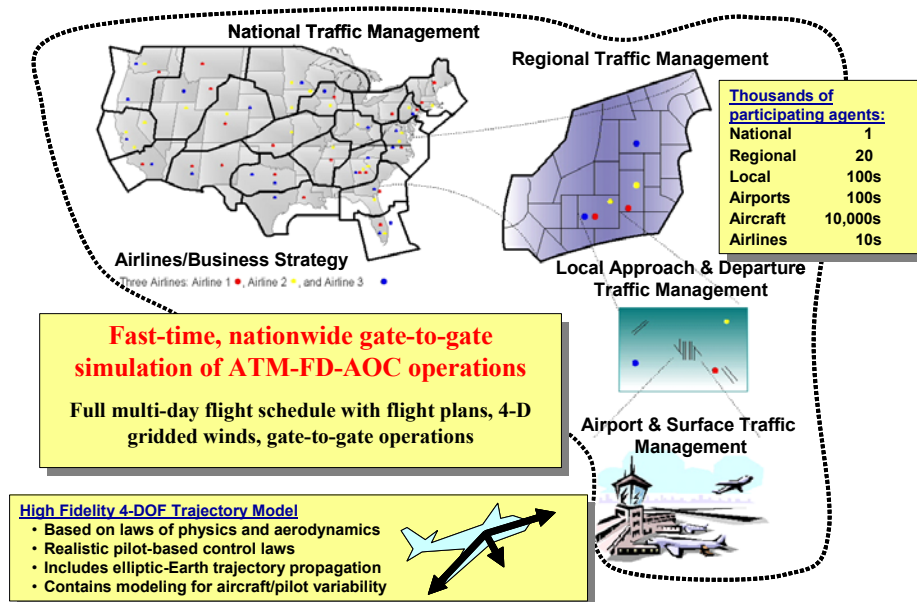
Metrics other than these delay quantities can be derived from them, and they include fuel savings, passenger time savings, crew costs, etc., which can be accumulated in computing annual cost savings.

NAS-Wide Evaluation Tool

The system-wide evaluation being planned for the SOAR concept will be carried out using the Airspace Concepts Evaluation System (ACES) [23]–[25]. As one of the major products being developed under NASA’s VAMS Project, ACES provides a fast-time simulation and modeling capability for design and trade-off studies of system-level concepts within the NAS. The system is designed to be a flexible NAS simulation and modeling environment that can assess the impact of new NAS tools, concepts, and architectures, including those that represent a significant departure from the existing NAS operational paradigm such as the SOAR concept. Figure 9 contains a graphical depiction of the high-level capabilities of ACES provided by Seagull Technology, the technical lead in the development of ACES.

ACES utilizes the High-Level Architecture (HLA) developed by the Department of Defense and an agent-based modeling paradigm to create the large scale, distributed simulation framework necessary to support NAS-wide simulations. HLA facilitates integration and interaction of independently developed simulations, and agent-based modeling further eases integration and

efficient runtime execution of the simulation components. The current ACES system [24] models the Air Traffic Control System Command Center (ATCSCC) as well as the Air Traffic Management (ATM) components of ATC and Traffic Flow Management (TFM) operations, respectively for the en route Air Route Traffic Control Center (ARTCC), Terminal Radar Approach Control (TRACON), and Airport Traffic Control Tower (ATCT). These models are implemented as agents, as are individual flights. The models account for airspace and airport designs and procedures, including airport visual flight rules (VFR) and instrument



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Figure 9. Implementation of ACES for NAS-Wide Evaluation

flight rules (IFR).

Since the SOAR concept is specific to the surface domain, its evaluation with ACES should focus on the models around the airports. These include ATC and TFM functions at the ATCT. Whereas modeling of aircraft operations and airport runway configurations are lacking in details for representing actual operations specific to current operations or the SOAR concept, the current ACES implementation purportedly has some level of modeling for the effects of heavy traffic on taxi delays. The issue of ripple effect for hub connections in principle would depend on AOC practices, but these rules are not implemented in much detail in the ACES AOC model. With these limitations in mind, the evaluation of the SOAR concept with ACES will attempt to make the best use of the model flexibility in ACES to determine how operations under the SOAR concept can be distinguished from those under current operations. This will involve identifying the appropriate input variables of the simulation model to adjust in order to represent the two operational concepts. If necessary, modification of the ACES software agents that model the pertinent elements will be considered.

Evaluation Plan

To properly evaluate the effect of flight connections, the scenario has to accurately model the connection operations. This will require some modeling of the passenger connection requirements. It has been suggested that tail-number tracking is required for modeling flight connections for evaluating hub turn-around, and recommendations have been made to include this modeling capability in future versions of ACES. It is obvious that tail-number tracking alone is not enough to model the connections, and additional understanding of how airlines operate will be required to accurately model the connection effects. These effects will in turn affect NAS-wide operations as the delayed departure of one bank of flights will delay the operations through the system at least through the end of the day.

It is unreasonable to expect that ACES can implement all the necessary formulations for detailed analyses of airline operations on airport connections, and such capabilities certainly are only

scantly developed in the version of ACES currently planned for the system-wide evaluation of the SOAR concept. Consequently, the evaluation plan will involve more than simply straightforward simulation runs. Figure 10 lays out a plan for the evaluation effort. The top part of the figure contains the steps for calibrating the ACES simulation and adjusting its parameters to make the simulation consistent with the GO-Sim simulation results, and the bottom part describes how the parameter adjustments will be extended to the other major airports to create a NAS-wide model suitable for evaluation of the SOAR concept. The following steps are in accordance with those identified in Figure 10:

1. To help calibrate the ACES simulation with the GO-Sim results, the first step is to extract the DFW-specific traffic data from the system-wide demand data sets.
2. The extract data sets form the input for GO-Sim and ACES runs. Both the GO-Sim and ACES simulations are executed with parameters and modeling to represent the SOAR concept and current operational practices. Simulation input variables fall into two main categories:
(i) model parameters such as airport capacity, nominal taxi times, taxi delay modeling data, and
(ii) run-time variables such as traffic demand and weather variation through the day. Only the model parameters will be considered for adjustment for representing SOAR and current operations.
3. The output data from the GO-Sim and ACES runs are processed to extract the relevant throughput and taxi delay information. The information is compared between the GO-Sim and ACES cases, and significant discrepancies are identified to determine how the airport parameters of DFW should be adjusted to reduce the discrepancies. Step 2 and 3 will be repeated with new ACES runs using the updated parameters until the analysis results are consistent with the GO-Sim results.
4. Since the SOAR concept is expected to have the biggest impact on hub operations, only major hub airports in the NAS will be considered for modeling the difference between the SOAR concept and current operational practices. Currently a total of 24 airports have

been identified for the six major U.S. hub-and-spoke airlines: United Airlines, American Airlines, Delta Air Lines, US Airways, Northwest Airlines, and Continental Airlines.

5. The GO-SAFE/GO-Sim simulation has been implemented only for DFW. It is beyond the resources available to adjust the parameters individually for the other airports using GO-Sim runs. Therefore the parameters obtained from the throughput and taxi performance at DFW will be “extrapolated” to all the identified hub airports. This will take into account the airport layout and configurations, and will involve some guess work. Archival data from such sources as ASPM will help to justify the deduced quantities to some extent. Since most the airports have less complicated layouts than DFW, the “extrapolation” process is expected to give rational results.
6. With the parameters for all the relevant airports adjusted, the ACES simulation can be used to run all the test data intended for the assessment
7. Post-processing of the raw data from the ACES runs will be performed to determine the impact of the SOAR concept according to system-wide delay metrics and other related cost/benefit metrics. The results can also be annualized by combining results from simulations using

demand data sets and weather conditions for representative days.

Although Step 3 has mentioned only the adjustment of the input parameters for calibrating the airport model, where this approach is inadequate for obtaining the desirable effects, development of special model software within ACES’ agent framework will be explored. An example is the introduction of logic to the AOC agents to allow it to handle dynamic adjustment of connection flights.

Concluding Remarks

The NASA Virtual Airspace Modeling and Simulation (VAMS) Project is developing capacity-increasing concepts to address the anticipated increase in air traffic demands in the National Airspace System (NAS). Among these various concepts, the one being pursued by the Surface Operation Automation Research (SOAR) effort focuses on the airport congestion problem with a solution involving collaborative automation systems between the control tower and the flight deck to deliver efficient and safe operations.

An initial evaluation of the SOAR concept was performed with computer simulations of surface operations at a single airport modeled after Dallas/Fort Worth International Airport (DFW), and the results were reported in a previous paper. A

second evaluation has been planned to evaluate the effect of the SOAR concept on the whole NAS. This evaluation will be based on a computer simulation — the Airspace Concepts Evaluation System (ACES) — which is being developed under the VAMS Project for simulating the NAS air traffic over the continental US. This paper describes the plan for the evaluation effort, and the analysis results are expected to be available later in the year.

Although ACES is a highly sophisticated simulation package that

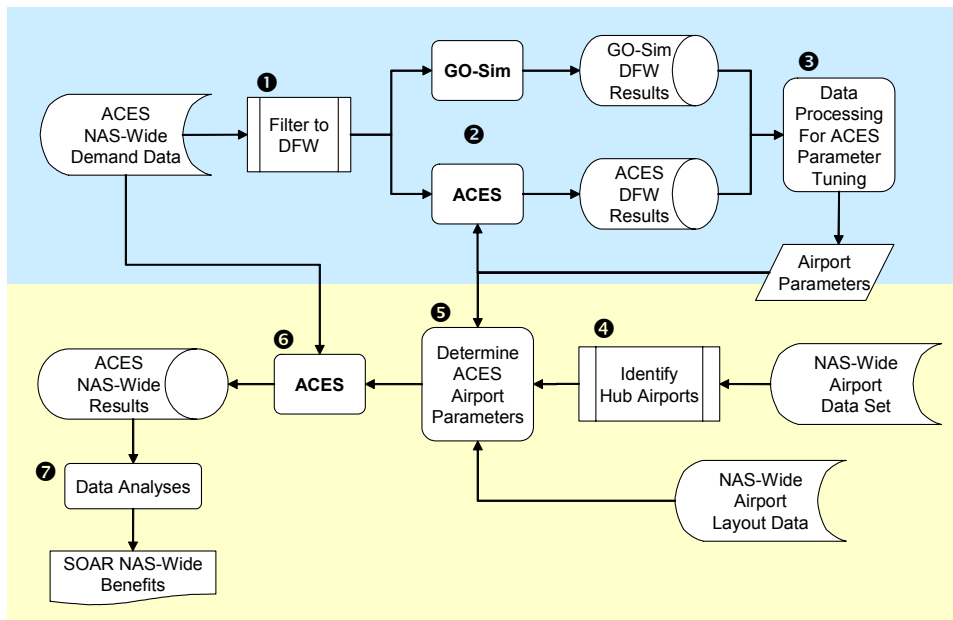


Figure 10. Plan for Evaluating System-Wide Benefits of SOAR

takes advantage of High-Level Architecture (HLA) and agent software to model and simulate the relevant systems comprising the NAS, it would still be unreasonable to expect a simulation package with such broad scope to include detailed models of every system. In the case of SOAR evaluation, the airport model components, including the tower control, airport configurations, aircraft taxi operations, etc., cannot be as detailed as those modeled in the ground-operation simulation used in the aforementioned DFW simulation. Evaluation of the NAS-wide benefit of the SOAR concept with ACES simply has to make the best use of the ACES modeling capabilities to approximate the performance of the concept in order to compare it with the performance according to current day operations. To this end, the evaluation plan includes calibration steps to make the ACES models match the results from the DFW evaluation, and additional steps are required to generalize the model to other major hub airports.

The ACES metrics may be able to provide a certain amount of human performance assessment through relationships with traffic load or other pertinent factors. Nevertheless, important human-related performance factors such as workload, safety, adequacy of the user interface, etc., will require human-in-the-loop evaluations in the intended environment or in realistic simulators. The use of the FutureFlight Central tower simulator, and cockpit simulators in the Crew Vehicle Systems Research Facility, both world-class facilities at NASA Ames Research Center, is recommended for integrated human-in-the-loop evaluation of the SOAR automation systems.

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