Abstract
Surface Traffic Limitations Enhancement (STLE) is a NASA-developed advanced modeling capability for simulating airport surface aircraft movement. STLE augments NASA’s Advanced Concept Evaluations System (ACES), which is a fast-time computer simulation of nationwide airport and airspace traffic operations. STLE expands ACES software logic and data inputs and outputs to simulate individual aircraft surface trajectories through an airport’s terminal gate/ramp, taxiway and runway system. STLE models surface operations using a link-node modeling structure. The modeling simulates aircraft motion dynamics, tracks the movement of each flight, assesses the traffic situation, determines route assignment, detects and resolves potential conflicts, considers node required/planned crossing time constraints, and evaluates traffic throughput and delay. Inputs include specification of link and node graph components, gate and runway configurations, operating rules and procedures, and traffic and airport operating conditions schedules, typically for a 24-hour study period. Output statistics describe transit time and delay by flight and traffic loading as well as queues and transit times by link and node.

Node transit control governs actual movement of each aircraft from a link into a node and movement from a node into a link, which determines delay propagation through the surface network. STLE distinguishes sequencing nodes (e.g., taxiway intersections) and complex nodes (e.g., gate, gate group) functions. Link transit control supports this nodal network analysis process by managing traffic movement along each link to deliver aircraft to a node. STLE provides a system of working pluggable modules that represent current operations. These pluggable modules are the foundation for subsequent replacement and supplemental models.

Introduction
This paper describes work to enhance the existing Surface Traffic Limitations function of the NASA Advanced Concept Evaluations System (ACES) Build 4.6 to support more detailed analysis of future concepts for airport surface operations. This ACES-based Surface Traffic Limitations Enhancement (STLE) computerized simulation function is a platform for evaluating current and alternative future Air Traffic Management (ATM) concepts of operation, such as those being considered by NASA’s NextGen Airspace and Airport projects.

This initial STLE design provides a system of working pluggable modules that are the foundation for subsequent plug-in models. This foundational modeling is designed to represent current NAS operations, but amenable to modular substitution and expansion. The foundational models serve as placeholders for replacement routines or the basis for supplemental routines describing future advanced applications.

Advanced Concept Evaluations System
ACES [1-4] is a distributed, non-real time, discrete-event computer simulation of local, regional and nationwide air traffic operations in the U.S. National Airspace System (NAS). ACES models individual aircraft flights from terminal gate departure to arrival, simulating flight movement through taxi-out, runway takeoff, climb, cruise, descent, runway landing, taxi-in and gate arrival. ACES applies four-degree of freedom (4-DOF) aircraft dynamics modeling to generate four dimension (4D) en route flight trajectories. ACES agent-based modeling, simulates traffic constraints and resolutions imposed by airport, terminal and en route air traffic control (ATC) and traffic flow management (TFM) operations. ACES models
operations at all en route centers and sectors and thousands of airports and associated terminals. This system provides a flexible NAS simulation and modeling environment to assess the impact of new NAS tools, concepts, and architectures, including those that represent a significant departure from the existing NAS operational paradigm. ACES processes a NAS-wide flight schedule that represents current or future NAS traffic loading. ACES evaluates airspace, airport and airport network delay.

The existing ACES Airport ATC agent (i.e., without STLE) performs basic modeling of runway, taxiway and gate operations. Existing runway modeling applies aircraft spacing rules to assign takeoffs and landings but uses nominal transit times to model non-runway surface operations. STLE introduces new modeling components that significantly change the ACES Airport ATC modeling structure to enhance surface movement modeling.

**STLE Overview**

NASA’s STLE expands ACES software logic and data inputs and outputs to simulate individual aircraft operations on the airport surface. STLE models surface traffic movement through the gate/ramp-taxiway-runway network using a link-node modeling structure. STLE is a discrete-time modeler using stimulant events (e.g., link and node entry requests) to trigger traffic assessment functions. STLE components track the movement of each flight, assess the traffic situation, make route assignment and conflict detection and resolution decisions, and issue routing and movement commands.

The modeling applies nodal network analysis to (1) develop and assess route and runway assignments, surface trajectories, required node crossing times, and aircraft in-trail and crossing spacing requirements, (2) manage and generate aircraft motion and (3) evaluate traffic throughput and delay. Inputs include specification of link and node graph components, gate and runway configurations and utilization procedures, traffic schedule and airport operating conditions schedule, typically for a 24-hour study period. Output statistics describe transit time and delay by flight and traffic loading, queues, transit times by link and node.

The STLE link and node graph is a specific representation of an individual airport, and requires user-input to define each link and node. The user determines and defines surface operational domains (STLE default: Gate-Ramp, Taxiway and Runway System domains). The airport link-node graph illustrated in Figure 1 encompasses a gate and ramp area, a runway system with crossing taxiways, and a taxiway network.

![Figure 1. User-Defined Link-Node Graph.](image)

STLE integrates new code with existing ACES logic, with appropriate restructuring of modeling entities and data exchange processes. This integrated software consists of replaceable and extensible (i.e., plug-and-play) models that support simulation of current and future operations. These models (i.e., algorithms with associated data input and output processes) are user-selectable and replaceable under the general plug-and-play concept. A model being implemented for a simulation run may be selected from a set of default alternative models (where provided), any of which may be replaced prior to a simulation run, or the set may be expanded. The user also has the option to introduce new models.

The STLE plug-in architecture conforms to the notional modeling structure illustrated in Figure 2. The Route Planning component is a mechanism to
implement plug-in routines that determine surface route assignment with or without Required Time of Arrivals (RTAs). These route assignment routines emulate current controller decision-making or future ATC or flight deck Decision Support Tool applications (e.g., automation to generate route advisories based on shortest or least-time path selection, network delay optimization, or congestion or conflict avoidance advisory generators).

**Figure 2. Notional STLE Modeling.**

The Trajectory Monitoring component is a mechanism to implement plug-in routines that track aircraft surface trajectory movement and apply transit control intervention to provide conformance with operating rules and procedures. In this initial STLE architecture, Trajectory Monitoring functions implement Flight Movement routines to emulate aircraft transit through the link-node network. A surface flight object moves through the link-node network according to a route assignment subject to aircraft motion and trajectory intervention modeling.

**Network Structure**

STLE link, node and surface flight object modeling defines the graph structure and operating characteristics. Links and nodes maintain graph-specific data, and surface flight objects maintain aircraft-specific data.

**Link and Node System**

STLE’s set of link and node objects is a graphical abstraction of the surface system, where surface modeling accuracy is dependent on the level of detail provided by the ACES user input data. The link and node network graph defines the physical location and geometry of surface taxiway and runway segments, intersections and service facilities such as terminal gates, parking areas, deicing stations and so forth. These objects have parameters describing physical location (e.g., latitude and longitude), dimension (e.g., taxiway length, intersection radius), speed limit and other attributes.

A link in the foundational STLE link-node graph is a line (or edge) connecting two nodes. A node (or vertex) is located at the end point of one or more links. One or more links can connect two nodes. A link can contain numerous aircraft at any time.

Foundational STLE implements a “singular” link and “sequencing” and “complex” node objects (see Figure 3). A singular link is a one-lane, bidirectional link, but is usable only in a single direction at an instant. The modeling imposes unidirectional use based on routing assignments and traffic state. Foundational STLE supports linear (straight line) and curvilinear link constructions.

**Figure 3. Link and Node Types.**

STLE user-based graph construction parametrically specifies each link’s structural and operational attributes. These attributes include the identity of a link and each of its two end nodes, the domain in which the link resides, its function, type, directionality, shape, capacity (maximum number of aircraft at an instant) and speed limit.

Foundational STLE implements “sequencing” and “complex” nodes. A sequencing node represents a position on the surface space traversed by aircraft, typically an intersection. Sequencing nodes are imbedded in the link-node graph and account for the majority of nodes in a network graph. A sequencing node has dimension and can contain at most one aircraft, and an aircraft transits
the sequencing node in finite time. The default sequencing node is a circle having a 50 foot radius.

A complex node represents a facility located on the surface space that can contain multiple aircraft simultaneously. A complex node may be used to represent a single gate, a set of multiple gates or an entire terminal complex, as well as special purpose areas such as parking, deicing or holding areas (as alternatives to use of multiple link representation).

**Surface Domains**

The user defines the operational domain in which a link is located by specifying the link domain attribute. Foundational STLE defines the following default domains:

- **Gate-Ramp** domain represents airline/aircraft-operator gate/ramp/apron traffic management scope of operation
- **Taxiway** domain represents ATC Tower Ground Control scope of operation
- **Runway** domain represents ATC Tower Local Control scope of operation

STLE supports unlimited domains per ACES user specification. Here, multiple gate-ramp domains would represent different airlines, aircraft operators, or terminal gate zones. Multiple taxiway or runway system domains would represent local operations in which geographically separate surface areas of an airport are under the jurisdiction of different ground or local controllers.

**Flight Object**

The STLE surface flight object retains and provides data describing the physical state and intent of an aircraft on the airport surface. The surface flight object at any simulation instant is associated with a specific link or node (i.e., a surface flight object effectively is in either a link or a node). STLE moves a surface flight object from node-to-link or link-to-node. The surface flight object’s data describe currently assigned route, next link and node identifications, operating attributes (e.g., flight identity, inbound or outbound status, next link and node identifications, aircraft type, size, speed range), flight data (e.g., aircraft type, registration number). The surface flight object receives and retains motion descriptors (e.g., link or node exit time constraint) and provides aircraft attribute information to other entities.

**Route Planning**

As part of Route Planning (per Figure 2 above), STLE processes link-node network structure data, evaluates aircraft state and intent data, and determines routing assignments. STLE pluggable models generate a surface route and clearance limit assignments for each aircraft. Each surface route is defined by a start node and series of links and nodes. STLE allows specification of required entry or exit time at nodes and links using user-provided plug-in models. A clearance limit specifies the extent (e.g., next node or domain boundary node) along an assigned route to which a flight is allowed to proceed. STLE simulates the movement of a flight along the assigned route to the clearance limit node, at which point STLE regenerates a clearance limit.

STLE Route Planning starts an outbound route at the terminal departure gate node and starts an inbound arrival flight route at the landing runway exit node (see Figure 4).

**Figure 4. Route Planning.**

STLE allows route planning across and within domains. The user has options to plug-in various route planning and associated models, including those to provide advanced capabilities such as:

- Gate assignment optimization
- Ramp route optimization
- Surface route optimization
- Runway selection optimization
- Runway traffic sequence optimization
- Runway configuration optimization

The STLE Route Planning architecture supports identification of any remaining link-node path to a specified destination node starting from any node. Foundational STLE assigns a surface route segment to conform to specified start and end points for a departure or arrival flight. These route limits are defined by identifying an appropriate pair of points, each of which may be anywhere in the network (e.g., a gate node and a node on the ramp/taxiway boundary defines the start and end points of a ramp route segment; another node pair may define a route segment crossing a domain boundary).

Foundational STLE default Route Planning assigns a full surface route between gate and runway entry or exit to each flight. The default start and end points are the terminal departure or arrival gate node and the runway entry or exit node, depending on departure or arrival flight. Foundational STLE default Route Planning modeling provides for:

- Gate Assignment
- Runway Assignment
- Surface Route Assignment
- Surface Clearance Limit Assignment

**Gate Assignment**

Foundational STLE enables rule-based modeling of gate assignments by the user. STLE provides a pluggable placeholder to insert rules by which a gate is assigned to each flight according to local configurations and procedures. Typically gate assignment depends on aircraft operator and type and gate capability and availability.

**Runway Assignment**

Foundation STLE implements existing ACES Runway Assignment modeling [2] without modification. In this pluggable STLE model, rules are user-defined for each airport/terminal area per local procedures. Given terminal boundary fix (per flight plan), aircraft jet (J), turboprop (T) or piston(P) engine type and runway use configuration (per airport operating condition), the takeoff or landing runway is assigned based on user-defined: runway-to-departure fix association for takeoff flights; arrival fix-to-runway association for landing flights; and runway-aircraft engine type (J/T/P) association for takeoff and landing flights.

Figure 5 illustrates the dependence of runway assignment on fix and engine type.

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<table>
<thead>
<tr>
<th>T/P</th>
<th>Arrival Fix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Departure Fix</td>
</tr>
</tbody>
</table>
```

**Surface Route Assignment**

The foundational STLE Surface Route Assignment model assigns a predefined surface route to each departure or arrival flight. A set of prescribed routes is defined by user input. This pluggable model examines gate and runway assignments and the prescribed routes to select a surface route to assign to a flight. The selection is determined by matching a flight’s origin and destination gate and runway assignment with those of a user pre-specified route. Outbound prescribed paths are defined between each terminal departure gate node and runway entry node. Inbound prescribed paths are defined between each potential runway exit node and each terminal departure gate node (see Figure 4 above).

**Surface Clearance Limit Assignment**

STLE allows identification of any node or link as the clearance limit from any other node or link, each on the assigned route. Foundational STLE currently provides three user-selectable Surface Clearance Limit Assignment pluggable models:

- Default Mode: Set the clearance limit to next link or node (i.e., the clearance limit steps along
the sequence of links and nodes of an assigned route).

• Set the clearance limit to the end of the current/next domain (i.e., the node on the domain boundary).

• Set the clearance limit to end node of the full route assignment.

STLE issues a new clearance limit when a flight reaches a current clearance limit, allowing the aircraft to proceed subject to other constraints. The intent is to provide an intervention point at which a future plug-in model may assess alternative assignment (e.g., optimization) strategies.

Trajectory Monitoring

As part of Trajectory Monitoring (per Figure 2 above), STLE modeling functions determine actual surface movement. This function moves aircraft along assigned routes according to speed rules, assesses traffic situation data, and intervenes to provide conformance with operating procedures. Foundational STLE implements the following surface movement management models:

• Link Transit Control
• Sequencing Node Transit Control
• Complex Node Transit Control
• Runway (System) Transit Control

These pluggable models govern aircraft motion along each link and through each node and define link and node entry and exit times. STLE transit control models do not trace time-distance trajectories through links and nodes, but instead determine exit times based on entry time, transit time and delay. The models assess spacing, capacity and required times of arrivals constraints, and assign delay to satisfy constraints. Actual flight movement includes response time (default: five seconds), and additional time allowance for pilot and controller interaction.

STLE transit control incorporates required time specification in determining link-node movement times by not allowing an aircraft to exit a link and enter or exit a node earlier than the corresponding RTA. However, Foundational STLE does not have logic to calculate RTAs since they are not part of current operations. Foundational STLE does provide entry and exit RTA parameters as placeholders for specification by future plug-in models. Such plug-in models likely would include a look-ahead capability to predict flight trajectories, predict congestion, and determine resolution actions. Foundational STLE assigns a default value to each link and node RTA parameter that has no effect on actual times and delay.

The link and node transit control models manage non-runway surface taxi and gate occupancy operations. Node Transit Control modeling distinguishes sequencing node and complex node applications. Runway Transit Control models manage takeoff, landing and taxi crossings of active runways. The models are described below.

Link Transit Control

Foundational STLE pluggable Link Transit Control analyzes an aircraft’s traversal of a non-runway link in response to the event of the aircraft’s actual entry into the link. At the simulation instant of an actual link entry by a flight (i.e., an actual exit time from the adjoining upstream node), Link Transit Control modeling determines this aircraft’s link transit taxi characteristics and constraints and estimates the earliest-possible link exit time (i.e., calculates this flight’s earliest exit time based on restrictions). This exit time defines the requested entry time to the adjoining downstream node.

Foundational STLE Link Transit Control modeling function processes aircraft through the link on a first-entry, first exit basis (i.e., aircraft exit sequence is the same as the link entry sequence) which maintains required spacing between successive aircraft without allowing overtakes. With reference to the Figure 6 illustrative example, the general algorithmic process is as follows.

1. At actual link entry, calculate un-delayed link transit time.
2. Determine un-delayed exit time.
3. Obtain link exit RTA if provided.
4. Determine operationally-constrained exit time (i.e., resolve spacing and overtake constraints relative to a preceding aircraft queued on this link).
5. Estimate earliest-possible exit time (i.e., un-delayed exit time, exit RTA or constrained exit time, whichever is latest).

*Link earliest exit time is based on:*
- Link actual entry time
- Taxi speed per aircraft type
- Required link exit time (RTA)
- No overtake assumption
- Minimum headway
- Aircraft length

Figure 6. Link Transit Control.

Foundational STLE Link Transit Control implements a simplified aircraft speed model. This model assigns constant link speed where aircraft speed is set equal to the user-defined link speed limit for non-runway links regardless of aircraft type and surface and visibility conditions.

Spacing is applied based on a minimum time headway required between the nose of an aircraft and the nose of its preceding aircraft. Foundational STLE assigns 3-second surface traffic inter-aircraft minimum time spacing default value.

Actual link exit time is determined by the Node Transit Control model of the outbound node.

**Sequencing Node Transit Control**

Foundational STLE pluggable Node Transit Control analyzes an aircraft’s entry into, traversal of and exit from a non-runway sequencing node in response to the event of the aircraft’s requested entry into the node. At the simulation instant of a requested node entry by an aircraft (i.e., an assigned exit time from a link inbound to the node), Node Transit Control modeling determines this aircraft’s node transit taxi characteristics and constraints and initiates the process of assessing node transit. Node transit may be denied upon initial request due to constraints and restrictions, imposing delay, but the end product of the Node Transit Control process is the calculation of this aircraft’s node actual entry and exit times. The node actual exit time defines the actual exit time from an adjoining inbound link; the node actual exit time defines the actual entry time into an adjoining outbound link.

Sequence Node Transit Control assesses node occupancy blockage, aircraft spacing requirements and outbound link-entry traffic state (see Figure 7). The transit control logic determines an aircraft’s node exit time that satisfies minimum spacing with the preceding node occupant and satisfies outbound link space availability and aircraft capacity, provided the flight’s outbound link does not contain opposite-direction aircraft (inbound to this node) and the node is not subject to gridlock (i.e., all connecting links have inbound aircraft). Node exit is not allowed until opposite direction traffic exits its outbound link through this node. Foundational STLE does not resolve gridlock.

*Node actual entry time is based on:*
- Node requested entry time
- Required node entry time (RTA)
- Node blockage state
- Outbound link space-available state
- Outbound link capacity

Figure 7. Sequencing Node Transit Control.

The general algorithmic process is as follows.

1. At node entry request, calculate un-delayed node transit time.
2. Determine requested node exit time using un-delayed node transit time.
3. Obtain node entry and exit RTAs if provided.
4. Determine operationally-constrained exit time; i.e., resolve spacing constraints relative to: (a) the preceding occupant of the node; (b) available space on outbound link and (c) available capacity (i.e., user-defined aircraft count limit) on outbound link.
5. Suspend node entry (i.e., delay/queue the aircraft on the inbound link) if: the node is blocked; space availability on the outbound link is insufficient to accommodate this
aircraft; or the outbound link is occupied by opposite-direction traffic.

Otherwise,

6. Assign node actual exit time (i.e., requested exit time, exit RTA or constrained exit time, whichever is latest) and corresponding actual entry time, both adjusted for response time delay.

In the case of delay upon initial entry request, the aircraft is held in the inbound link until a subsequent event stimulates reevaluation of the entry request. The stimulant events are node exit by another aircraft and outbound link exit by another aircraft. These events open the node or the outbound link for entry by the next candidate for node entry. A candidate is queued and ready for node entry on an inbound link, and would be at the head of its queue if multiple aircraft are delayed on this link. Candidates are prioritized in time order of node requested entry time. In the case on multiple candidates, each on a different inbound link, the Node Transit Control logic progressively examines candidates in order of earliest requested entry priority until one (if any) qualifies for entry in response to the current stimulant event.

Sequencing node logic does not allow an aircraft to be held in the node. An aircraft transits the node at its assigned speed without delay once it enters. Foundational Sequencing Node Transit Control implements a simplified aircraft speed model. This model assigns constant speed through a node where aircraft speed is set equal to the speed assigned to that aircraft on the inbound link to this node.

Transit control modeling calculates the space available on a link based on the link length, number of link occupants, aircraft length (default: 140 feet) and the minimum distance spacing requirement. This spacing headway is derived from the minimum time headway and aircraft speed. As a special exception to available space constraint, at most one aircraft is allowed to enter a link if the link is too short to satisfy the aircraft length criteria.

**Complex Node Transit Control**

The above description of transit control for a sequencing node applies to complex nodes, subject to certain differences. Unlike sequencing nodes, complex nodes can have multiple occupants, and an occupant can absorb delay in the complex node. Complex node modeling uses user-adjustable input parameters defining aircraft occupancy count capacity and minimum occupancy time.

Complex Node Transit Control modeling determines node actual entry times without direct consideration of node exit constraints. The pluggable modeling decouples complex node entry decisions from complex node exit decisions. An aircraft is allowed to enter a complex node if node capacity is not exceeded. Node actual entry time is earliest-possible entry time plus response time. Downstream link constraints are not relevant to determination of actual entry time. An aircraft after entry may experience exit delay due to outbound link constraints. This delay has no effect on its previous actual entry time.

**Surface Delay Propagation**

Link and node transit control models interact, with Node Transit Control serving as the primary authority determining traffic movement in and out of links and nodes. Node entry constraints cause delay to aircraft, which is taken on links inbound to nodes. Node entry constraints cause delay to aircraft, which is taken on links inbound to nodes. Continual delay during traffic congestion leads to link saturation, which constrains upstream node exits, which in turn constrain node entries resulting in delay absorption on other upstream links. This effect is illustrated in the Figure 8 where delay generated at a node propagates through the surface link-node network.

![Surface Network Delay Propagation](image-url)
**Runway Transit Control**

STLE Runway Transit Control integrates takeoff, landing and taxi crossings of active runways into the overall surface movement management process.

Foundational Runway Transit Control implements the existing ACES Runway Modeling [2] in conjunction with link and node transit control. ACES Runway Modeling applies user-defined descriptors of runway configurations and matrices of aircraft minimum separation time requirements to determine actual landing and takeoff times. The modeling provides proper spacing between successive runway operations, and is responsive to user-scheduled runway configuration changes. Foundational STLE augments the ACES Runway Modeling feature by adding pluggable capabilities to determine runway link and node occupancy based on aircraft speed, applying runway node transit control to takeoff, landing and taxi crossing aircraft, applying RTAs to runway operations if provided, and implementing a Runway Blockage function.

Runway Blockage examines network link and node occupancy states to prevent actual use of a runway by more than one aircraft at an instant. This capability precludes runway entry if a runway or its interacting runways are occupied by a takeoff, landing or taxiing aircraft regardless of spacing matrix requirements. Runway Blockage overrides the minimum separation time matrix if warranted.

Foundational Runway Transit Control moves takeoff or landing aircraft continuously along a runway until exit without delay (i.e., runway operations are uninterrupted). STLE applies specially-derived runway speed models (see Figure 9) to calculate link and node entry and exit times.

Foundational STLE applies these speed-distance-time formulations to determine runway occupancy and occupancy time for takeoff and landing operations. STLE models takeoff runway occupancy starting at the aircraft’s runway entry node and ending at the runway end threshold node. For landing operations, STLE modeling identifies candidate runway exit points. Exit points are runway nodes that connect to standard-speed or high-speed runway exit links.

**Figure 9. Takeoff and Landing Speed Models,**

With reference to Figure 10, STLE Runway Modeling calculates landing speed at each successive post-touchdown node to determine if the speed satisfies the exit speed limit the node’s exit link. The aircraft exits this node if the exit link can accept the aircraft based on space availability, occupancy versus capacity and opposite direction traffic state. If not acceptable, the runway transit modeling process is repeated at the next runway node and subsequent nodes if necessary. Should the aircraft reach the runway end node and not be allowed to exit due to surface traffic congestion, the aircraft is held in this end node. A hold in the runway end node blocks the runway, preventing landings on the runway, propagating delay to inbound aircraft in TRACON airspace.

**Figure 10. Landing Runway Exit.**

Runway Transit Control for an aircraft taxiing across a runway node is similar to that of a sequencing node. Assessment is invoked at the instant of the node entry request, and, if initially denied, is re-invoked at the event instant of any subsequent exits from this node. Hence, runway nodes progressively become candidates for taxi crossing as a takeoff or landing moves along the runway. Also, a runway node becomes a candidate
for taxi crossing when a preceding taxiing aircraft exits the node.

Runway node taxi crossing actual assignment conforms to node requested exit time, RTA, node blockage due to current or previous occupant, and outbound link space availability, capacity and opposite-direction traffic constraints (see Figure 11). In addition, the modeling prevents runway taxi crossing if the crossing operation does not fit within the time spacing available between the previous and assigned next runway takeoff or landing operation. The taxi crossing is delayed at least until the next opportunity based on subsequent runway events.

Figure 11. Taxi Crossing of Active Runway

Newark Airport STLE Test Site

As part of the foundational model development, Newark Liberty International Airport (KEWR), Newark, NJ, is used as a reference to assist designing, implementing and testing STLE modeling logic and data structures. KEWR has a suitably comprehensive operation with sufficient operational complexity and scope to support STLE development. KEWR has closely-spaced parallel runway and crossing runway, alternative runway configurations for different airport operating conditions, an extensive surface network of gates, ramps and taxiways, and high-density traffic loading including commercial passenger and freight and general aviation operations.

Figure 12 is an airport surface diagram of KEWR in a Northeast (NE) runway system configuration, superimposed with the assumed predefined static arrival (red) and departure (blue) taxi routes. The predefined taxi routes are constructed to avoid any two aircraft pointing head-to-head at any intersection. These routes are defined for STLE development and test purpose and do not necessarily adhere to actual local operations.

ACES with STLE is applied using the flight schedule for 19-February-2004 for the purpose of comparing results with FAA Aviation System Performance Metrics (ASPM). ASPM data represent actual operations, and show KEWR to be in the Northeast configuration the entire day with arrivals on runway 4R and departures on 4L.

Figure 13 comparisons of takeoff and landing counts by 15 minutes show STLE to be in general agreement with ASPM with respect to peaking pattern, while agreement between magnitude values varies. Comparisons of taxi times and delay statistics found similar results. Exact matching is not expected in part because metrics are computed differently by STLE and ASPM, and the STLE predefined static routes are not the exact actual taxi routes used at KEWR. Planned further development work provides for comprehensive comparative analysis of modeling results and actual data.
Concluding Remarks: Further Work

NASA is developing STLE as a platform for evaluating future concepts of operations, not simply as a surface traffic simulation tool. As such, STLE is a preliminary candidate for ACES upgrade, and is undergoing further development to enhance modeling scope, fidelity, and applicability. Efforts are underway to integrate STLE-type surface modeling with advance terminal airspace modeling, including 4D aircraft trajectory modeling. This work is expected to supersede STLE with an ACES Terminal Model Enhancement (TME) modeling function. TME incorporates STLE and expands airport and terminal airspace ATC and TFM agent modeling capabilities in ACES, including upgrades to route planning, aircraft movement and transit control algorithms. Work to redesign the integrated terminal surface-airspace software architecture focuses on facilitating general pluggability over a broad range of modeling functions. Plans include validation of modeling logic and statistical results.

References


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