systemwide**Modeler**

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Overview

- **Project Scope and Background**

- **Model**

- **User Interaction with *systemwide*Modeler**

- **Resources**

NOTE: All acronyms are defined in a Glossary at the end of this briefing.

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Project Scope and Background

CAASD System-wide Modeling

- **CAASD system-wide analyses performed in support of decision-making activities**
  - **Benefits assessment**
  - **Alternatives analysis, e.g., Operational Evolution Plan**
  - **Problem prediction, e.g., Future Airport Capacity Task**
- **Objectives are to answer questions and provide insight about**
  - **Impacts on**
    - **Traffic loads (airport, arrival/departure queues), sectors, airways**
    - **Delays**
    - **Controller workload**
    - **Fuel burn**
  - **Due to changes in**
    - **Demand (commercial schedules, general aviation activity)**
    - **Capacities (airports, en route sectors)**
    - **Procedures and operational strategies (TFM initiatives)**

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*systemwide*Modeler Project

- *systemwide*Modeler is latest CAASD NAS-wide simulation capability
  - Predecessors: NASPAC, DPAT, MLM
  - Overall model designed and implemented in 2006
    - Component models (e.g., airport, sector) have longer histories
  - Implemented in Wolverine Software's SLX™ simulation language
- Performance depends on scenario
  - Typical run simulating the NAS for a day (about 60,000 flights) takes 10 − 20 minutes and use 0.5 gigabytes peak memory
- Validation of impedance mechanisms is underway
  - Some confidence because *systemwide*Modeler can be configured to mimic predecessors

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Model

Environment

- **Airports**
  - **Location**
  - **Configurations (scheduled)**
  - **Coordination fixes**

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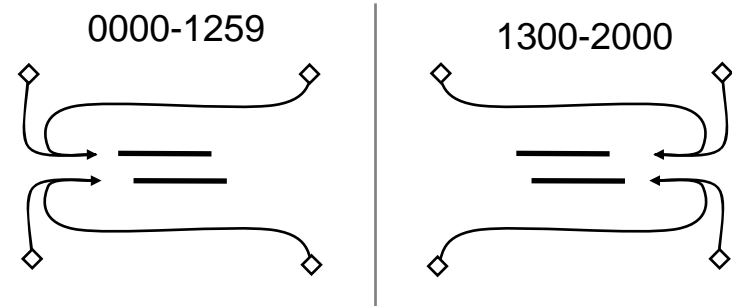
- **Airspace**
  - **Irreducible**
    - **For example, Fixed Posting Areas**
  - **Aggregations of irreducible airspace**
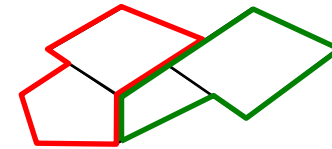
- **Control entities**
  - **En route sectors**
    - **Airspace assignments (scheduled)**
  - **Terminal Radar Approach Control (TRACON)**
    - **Airspace and airport assignments**

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Flights and Associated Objects

- **Flight is a mission flown by an airframe**
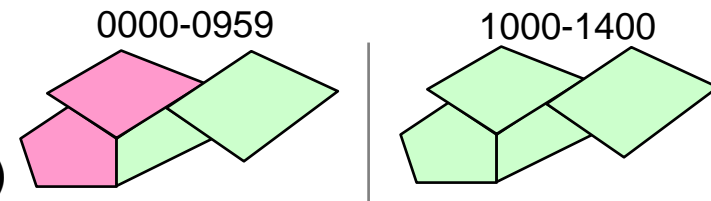- **Associated objects**
  - **Airframe**
    - **With associated equipment, propulsion, and equipage**
  - **Operator**
    - **May be endowed with *policies* that govern**
      - **Compliance with restrictions/advisories**
      - **Re-planning/cancellation decisions**
    - **Distinguishes different carriers, general aviation, military, etc.**
  - **Plan**
    - **Trajectory**
    - **Transits (of airspace)**
    - **Departure and arrival coordination fixes**
  - **Constraints**

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Flight Execution and Planning

- **Flight Execution**
  - **Simple progression through a *current plan***
    - **Trajectory points with impeded times**

- **Flight Planning**
  - **Manages current plan**
    - **To respect constraints**
    - **To react to delay**
  - **Currently, *systemwide*Modeler makes temporal modifications to plan**
    - **Rule-based delay response to constraints**
  - **Future versions**
    - **Rule-based route and altitude response**
    - **Rule-based accept delay/cancel response**
    - **Generation, testing, and selection of candidate plans**

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Temporal Constraints

No Overlap

c_0 c_1

time

t_0 t_1

response
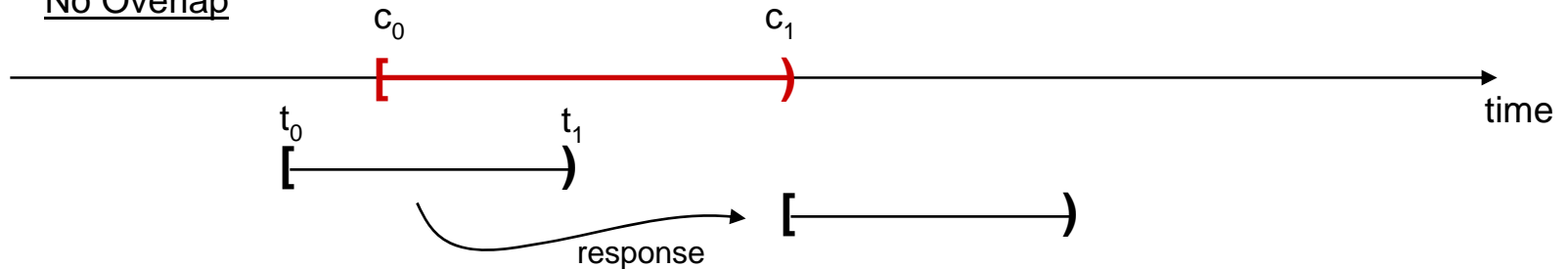
Used to disallow simultaneous occupancy or simply to delay flight

Special Cases

- $c_0 = 0$ causes delay until time c_1
- $t_0 = t_1$ causes delay of single point

Maximum Duration

t_0 t_1

response
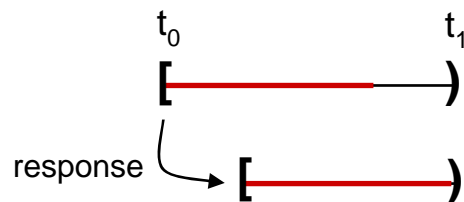
Used to limit delay absorption

Minimum Duration

t_0 t_1

response
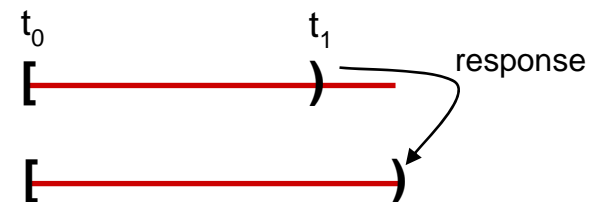
Used to enforce physical limits

In addition, when a flight's trajectory point is delayed all downstream trajectory segments revert to unimpeded durations before again being subject to constraint satisfaction. So flights can "close gaps" and avoid respecting expired constraints

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Resources

- **A *resource* is an entity interested in certain flights**
  - **Stays informed about those flights**
  - **May issue constraints (only influence on flight execution and planning)**
  - **Reports certain events and prevailing conditions**
- **Satisfies particular interface**
  - **Registration**
  - **Detection of flight use**
  - **Receipt of trajectory point passage notification**
  - **Receipt of plan change notification**
- **Resources implemented so far**
  - **Multi-Point Airport Capacity model (airports)**
  - **IAC Sector, TSSIM (en route sectors)**
  - **Terminal, TRACON (terminal areas)**
  - **Corridor**
  - **In-Trail Restriction** } new terminal area modeling concept combines these
  - **GDP**
  - **Airframe**
- **User "summons" only resources of interest**

Services for Resources

- **Significant portion of resource code is shared**
- **Liaisons**
  - **Monitor flights**
  - **Notify resources of trajectory point passage and plan changes**
- **Filters**
  - **Common syntax to define filters on flights and trajectory points**
  - **Shared parsing and selection functionality**
- **Condition managers**
  - **Resource**
    - **Determines which flights use it**
    - **Passes on notifications of passage and plan changes**
  - **Manager (on behalf of resource)**
    - **Monitors condition**
    - **Issues constraints**
  - **Examples**
    - **IAC management**
      - **Limits occupancy**
      - **Cycle detection and mitigation**
    - **MAD management**
      - **Limits expected delay absorption**

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Typical Flight-Resource Interaction

Activation   Incorporation   planning horizon   Entry   Exit

Flight
- *Execution* — Trajectory point passage ...
- *Planning* — Receive constraints and re-plan as necessary ...

Liaison
- Monitor plan for changes / Monitor execution for passage
- Notify resource of plan changes / passage

Resource
- Determine if flight uses resource
- Possibly issue constraint(s)
- If so, register interest in three points
  - Entry – planning horizon
  - Entry
  - Exit
- Maintain awareness of flight plans / condition
- Re-issue constraint(s) as needed

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User Interaction with
*systemwide*Modeler

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Pre-Processing

- **Background input and flight input generated with custom tool (GRASP Report Generator)**
- **Taps existing CAASD tools and data repositories**
  - **CRCT trajectory model**
  - **GRASP airspace transit detection**
  - **Background data sources**
    - **ACES**
    - **NFDC**
    - **Jeppesen**
  - **Flight input data sources**
    - **OAG and ETMS for schedules and routes**
    - **CRCT altitude restrictions database**
    - **RUC for winds**
  - **Resource data sources**
    - **IAC Sectors: MAP values and ETMS CZ messages**
    - **Airport: Airport capacity benchmarks**
    - **Corridors: ETMS analysis underway**
    - **GDPs**
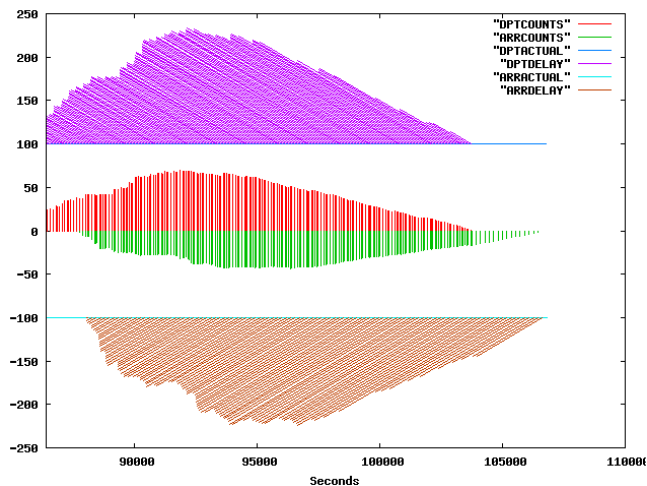   - **In-trail restrictions**

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Event Reporting

- **Simulation engine records very few statistics**
  - **Analysis of run is left to user**
- **Substantive output is event reports**
  - **Written to user-specified files; database amenable**
  - **User may specify which events for which entities are reported**
- **Flight events**
  - **Trajectory point passage**
    - **Including airspace boundary crossings and airport events**
- **Resource events**
  - **Incorporation, entry, exit**
  - **Most reports include flight identification and prevailing conditions**
- **Constraint events**
  - **Constraint type, constrained flight, issuing entity**

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Post-Processing

- **Project-specific needs drive most post-processing**
- **However, repository of broadly applicable tools is growing**
  - **Simple profilers**
    - **Sector counts and workload profiles**
    - **Airport loads and delay**
  - **Limited animation**
    - **Wolverine Proof™ animation software**

Resources

Multi-Point Airport Capacity (MPAC) Resource

Departures

designated "waiting"

pegged to preceding flight

occupancy duration computed

blocks airport to like operation

Arrivals

hourly arrivals

Pareto frontier (from benchmark capacities)

arrival occupancy duration: *1/a*
departure occupancy duration: *1/d*

a

A

(waiting arrivals)

D

(waiting departures)

d

hourly departures

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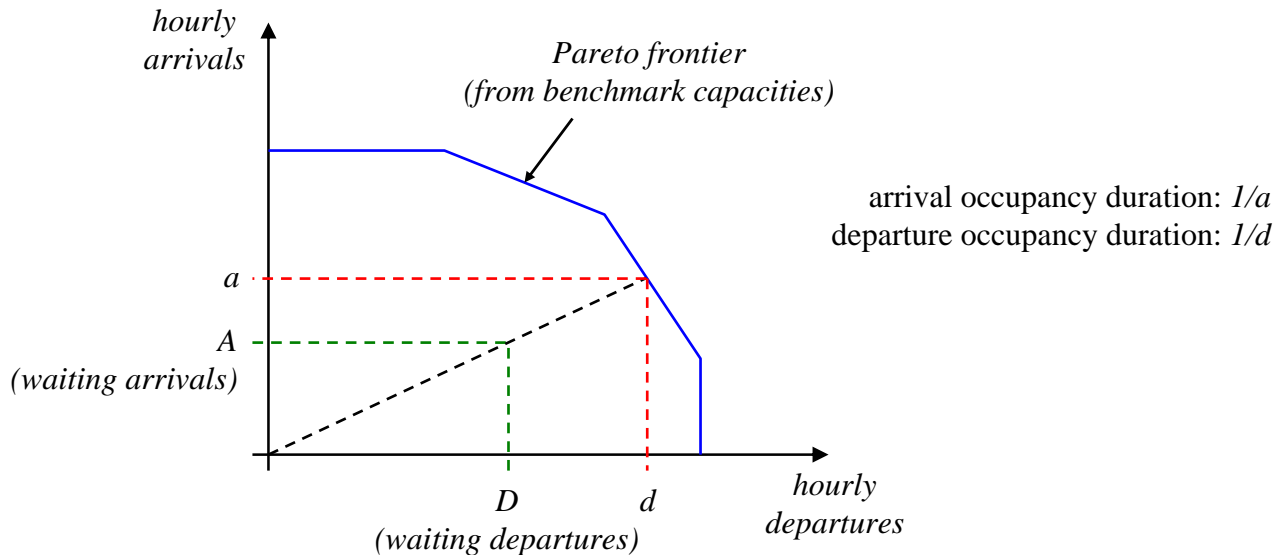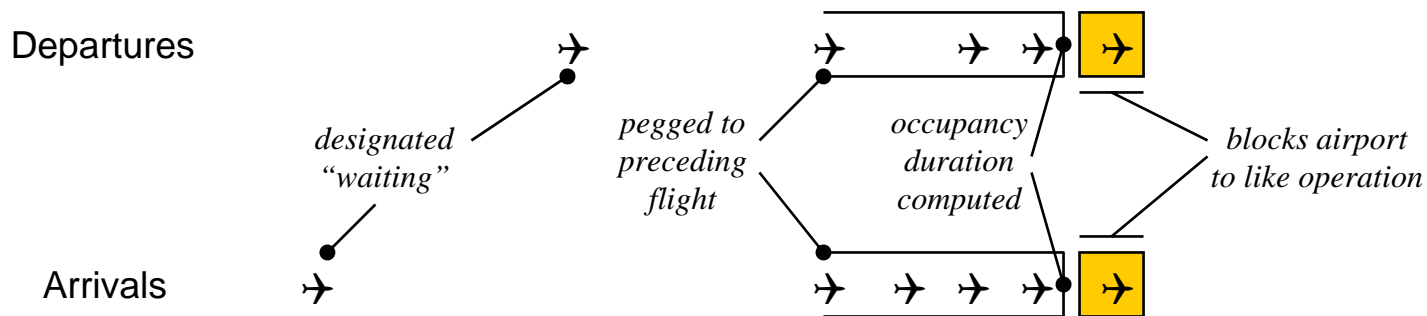
Instantaneous Aircraft Count (IAC) Sector Resource

Sector capacities are 3

Sector A aware of 7 flights, so this flight will wait for exit of flight 6, 7, or 8

Sector B aware of just 2 flights, so this flight need not peg
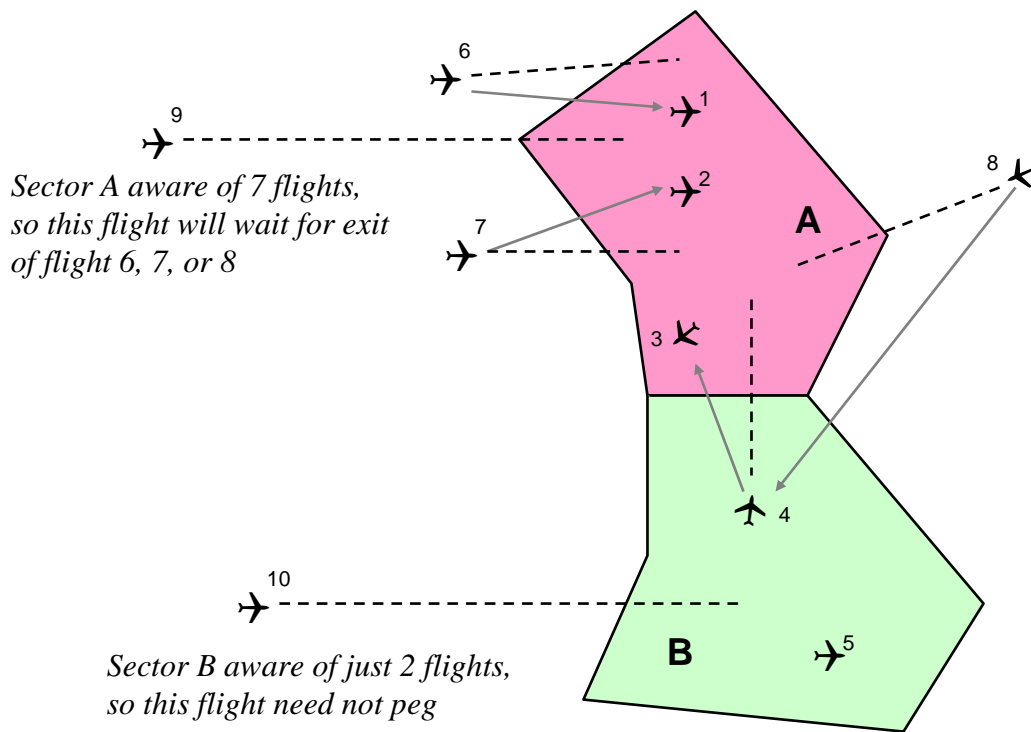
- **Sector capacities may change on schedule**
  - **One analysis is using dynamic capacities to model effects of convective weather**
- **Airspace assigned to sectors may change on schedule**

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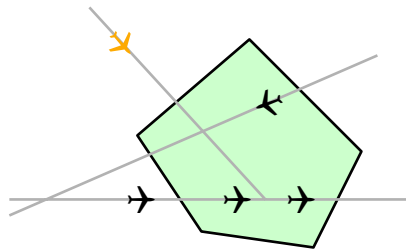# Traffic-Sensitive Sector Impedance Model (TSSIM)

flight workload

Entry　　　*Exit*　　*t*

sector workload

threshold

t

delayed entry

Entry　*change notification*　*Exit*　*t*

As flight approaches sector, its nature and activity in the sector is evaluated

- Commercial flight? GA? Military? Equipage?
- Previous/next sectors?
- Transitioning altitude?
- Requires spacing for arrival airport?
- Involved in aircraft-aircraft conflict?
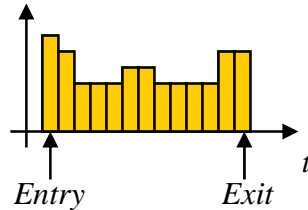
Modeled workload distributed over transit of flight

- Handoff and coordination tasks
- Monitoring and spacing
- Conflict detection and resolution
- Delay absorption
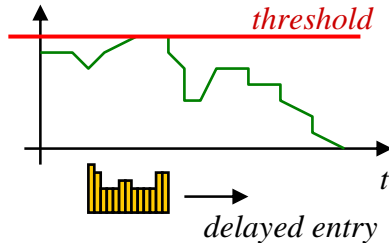
Flight's entry delayed until addition of modeled workload to sector's anticipated workload acceptable

- 15-minute moving sum of workload is governed

When resource informed of changes to plan, it updates workload as appropriate

- For example, delayed exit causes additional work

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Corridor Resource

This airport has departure fixes defined.
The flight happens to have one in route string

Legend:
- 🟢 Departure airport
- 🔴 Arrival airport
- 🟢 Departure fixes
- 🔴 Arrival fixes
- 🔴 TRACON boundary crossing
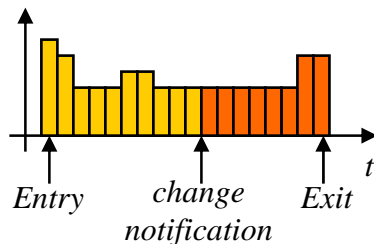- 🔵 En route fix

Flight has two en route fixes in route string that define a corridor

This airport has arrival fixes defined.
The flight has none in route string so corridor associated with fix nearest to TRACON boundary crossing is used

- **Use of corridor defined by use of end points**
  - **Named fixes or airports**
  - **TRACON boundary crossing (for TRACON corridors)**
- **Corridor issues IAC constraint and MAD constraint**
- **In practice, TRACON corridors scheduled in concert with airport configurations**
  - **So TRACON impedance sensitive to coordination fix, airport configuration, equipment type, and filters on flight**

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In-Trail Restriction Resource

- **Models minutes- or miles-in-trail restrictions**
  - **Over fixes**
  - **Over sector boundary crossings**
- **Uses filters to restrict attention to particular flights**
  - **For example, given destination, jets only, altitude range**
- **Effective for specified time interval**
- **Compliance may be specified**
- **Model**
  - **Occupancy of resource starts at entry point**
  - **Duration is specified minutes or based on specified miles and speed**
  - **Instantaneous occupancy limited to one**
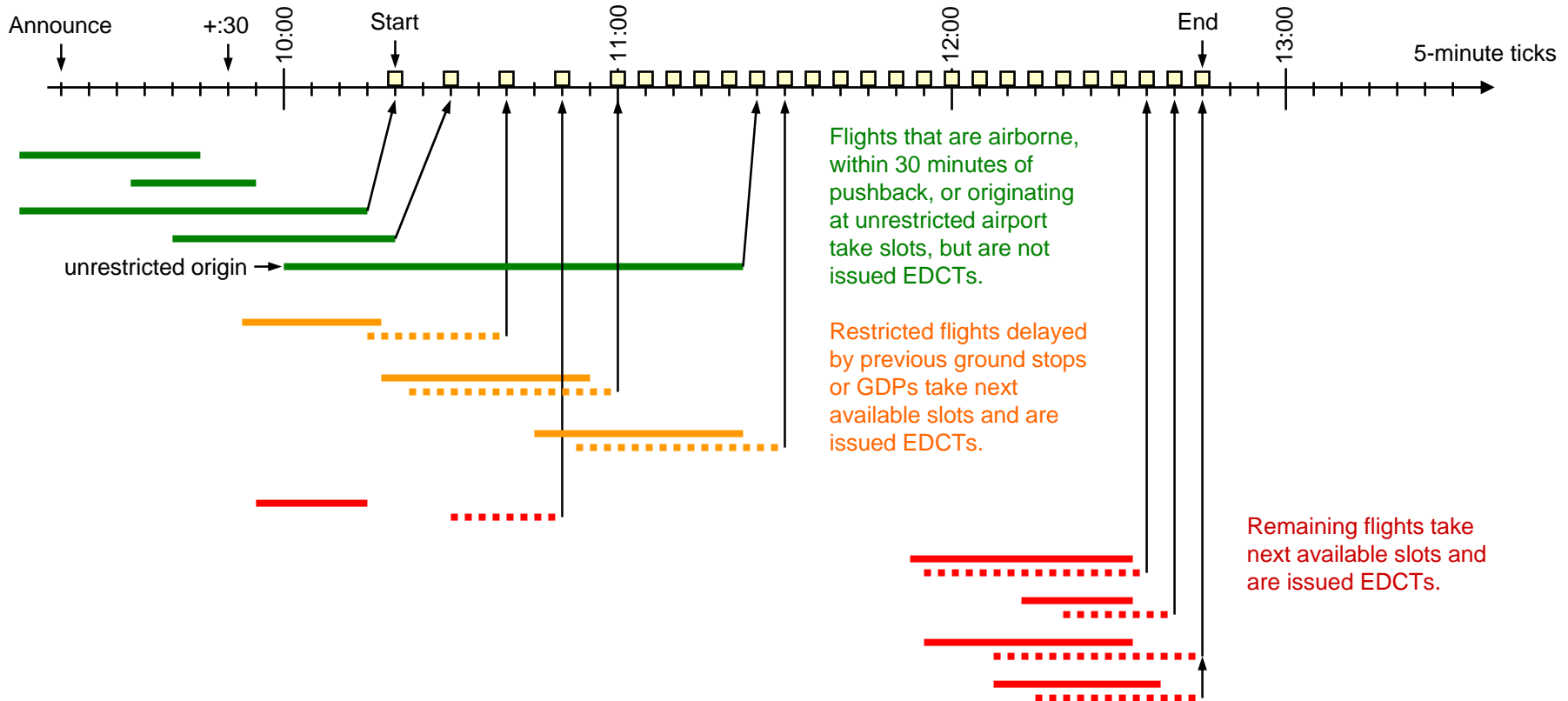
Ground Delay Program Resource

- **EDCTs issued to flights bound for target destination from specified origins to achieve specified arrival rate by hour**
- **Model**
  - **When simulation reaches GDP announcement**
    - **Arrival slots determined for each hour that GDP effective**
      - **Evenly distributed over hour**
    - **Available slots assigned to flights, first by following categories, then by scheduled arrival time**
      - **Airborne flights, flights within 30 minutes of scheduled pushback, flights not departing restricted origin**
      - **Restricted flights subject to previous ground stops or GDPs**
      - **Other restricted flights**
    - **EDCTs issued to second and third groups consistent with slot assigned (and planned trajectory)**
      - **If no slot assigned, EDCT consistent with arrival at GDP end time**
      - **Flights respect EDCTs with probability consistent with compliance rate**
  - **When simulation reaches GDP cancellation (if any)**
    - **Delayed flights free to depart**

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Ground Delay Program Example

Announced at 9:20
Start at 10:20, End at 12:45
Rate is 6 for 10:00-11:00
Rate is 12 for 11:00-13:00

Slots evenly distributed over clock hours consistent with target rates

Announce   +:30   10:00   Start   11:00   12:00   End   13:00   5-minute ticks

Flights that are airborne, within 30 minutes of pushback, or originating at unrestricted airport take slots, but are not issued EDCTs.

unrestricted origin →

Restricted flights delayed by previous ground stops or GDPs take next available slots and are issued EDCTs.

Remaining flights take next available slots and are issued EDCTs.

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Airframe Resource

- **Simple resource whose instantaneous occupancy is limited to one**

- **Unavailable starting at end of flight (AT GATE) for some duration (turnaround time)**
  - **Function of airport and equipment type**

- **Flights using same airframe resource are "linked"**
  - **To model propagation of delay**

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Glossary

ACES	**Adaptation Controlled Environment System**
CAASD	**The MITRE Corporation's Center for Advanced Aviation System Development**
CRCT	**Collaborative Routing and Coordination Tool**
CZ	**ETMS sectorization message indicator**
DPAT	**Detailed Policy Assessment Tool**
EDCT	**Estimated Departure Control Time**
ETMS	**Enhanced Traffic Management System**
GA	**General Aviation**
GDP	**Ground Delay Program**
GRASP	**GRAIL Airspace Toolkit**
IAC	**Instantaneous Aircraft Count**
MAD	**Maximum Absorbable Delay**
MAP	**Monitor Alert Parameter**
MLM	**Mid-Level Model**
MPAC	**Multi-Point Airport Capacity**
NAS	**National Airspace System**
NASPAC	**NAS Performance Analysis Capability**
NFDC	**National Flight Data Center**
OAG	**Official Airline Guide**
RUC	**Rapid Update Cycle**
TFM	**Traffic Flow Management**
TRACON	**Terminal Radar Approach Control**
TSSIM	**Traffic-Sensitive Sector Impedance Model**

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