Analyzing the Benefits of Distributed Air/Ground Traffic Management Concepts

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Technology Assessment

Briefing Outline

- Project top view
- DAG-TM concepts
- Modeling approach
- Key analytical components

What is DAG-TM?

- NASA Research Project
- Gate-to-gate NAS operations in which flight deck crews, air traffic service providers, and aeronautical operational control facilities use distributed decision-making. Of the 15 DAG-TM concept elements, 3 are currently being developed:
- En Route Free Maneuvering for Separation and TFM Conformance
- En Route Trajectory Negotiation for Separation and TFM Conformance
- Terminal Arrival: Self-Spacing Merging and In Trail

En Route Free Maneuvering

- En Route Free Maneuvering for
  - User-preferred Separation Assurance
  - Local Traffic Flow Management (TFM) Conformance
- Enables autonomous aircraft to maneuver freely while maintaining separation assurance from hazards (traffic and area)
- Plus conform to any local TFM constraints.
- Assumes
  - air-to-ground data communications
  - airborne decision support tool (DST) to support airborne self-separation, self-optimization and TFM constraint meeting.

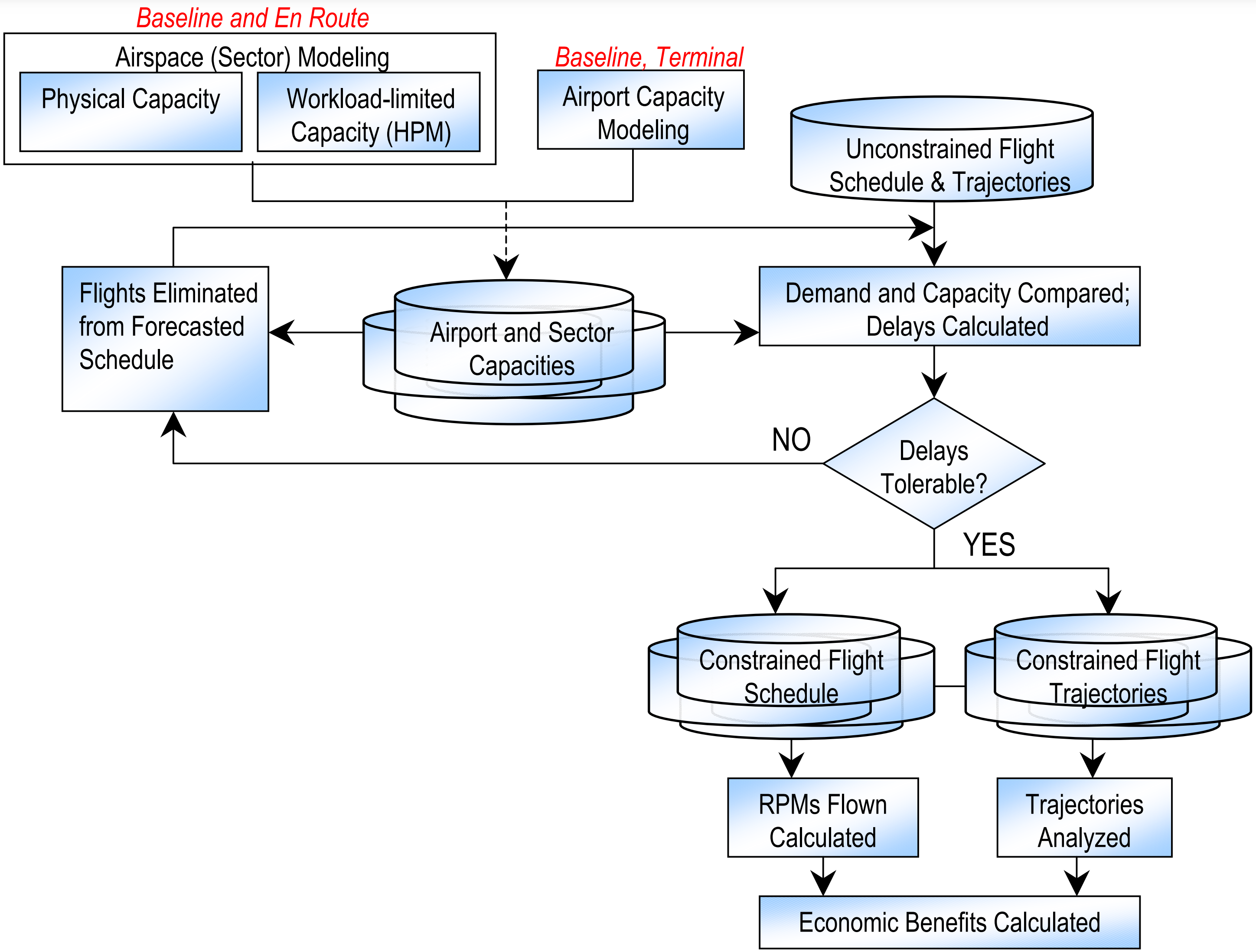
En Route Trajectory Negotiation

- En Route Trajectory Negotiation for
  - User-preferred Separation Assurance
  - Local TFM Conformance.
- Permits automated negotiation of user-preferred trajectory changes for separation assurance and meeting of TFM constraints
- Common information is automatically shared between the users and the ATSP.
- Integrates air and ground-based DST capabilities through data link to reduce ATSP workload and facilitate user preferred trajectories in the presence of traffic and TFM constraints

Terminal Arrival: Self-Spacing for Merging and In-Trail Separation

- Equipped aircraft merge into an arrival stream and maintain in-trail separation with a *specified lead aircraft*
- Requires the provision of traffic and intent data through a Cockpit Display of Traffic Information
- IMC as if VMC separations
- Airborne DSTs will be required to assist the flight crew in performing merging and spacing

Methodology Overview



Key Analytical Components

- Determination of future capacity baseline and deltas
- Human performance modeling
- Forecast flight schedule
- Airport capacity analysis
- Flight elimination algorithm
- Economic benefits valuation
- Life-cycle cost analysis

Forecasting Future Capacity Baseline

- Start by generating an "unconstrained" future flight schedule: O & D, arrival and departure times, aircraft type, and 4-D trajectory.
- "Unconstrained" means that this schedule only reflects demand, without consideration of capacity limitations
- Then generate "constrained" schedule. Airport capacities based on runways, configuration, and weather. Airspace capacities based on physical capacity needed to resolve conflicts and controller workload limit.
- Impose delay tolerances and eliminate flights from schedule to resolve capacity/demand imbalance.

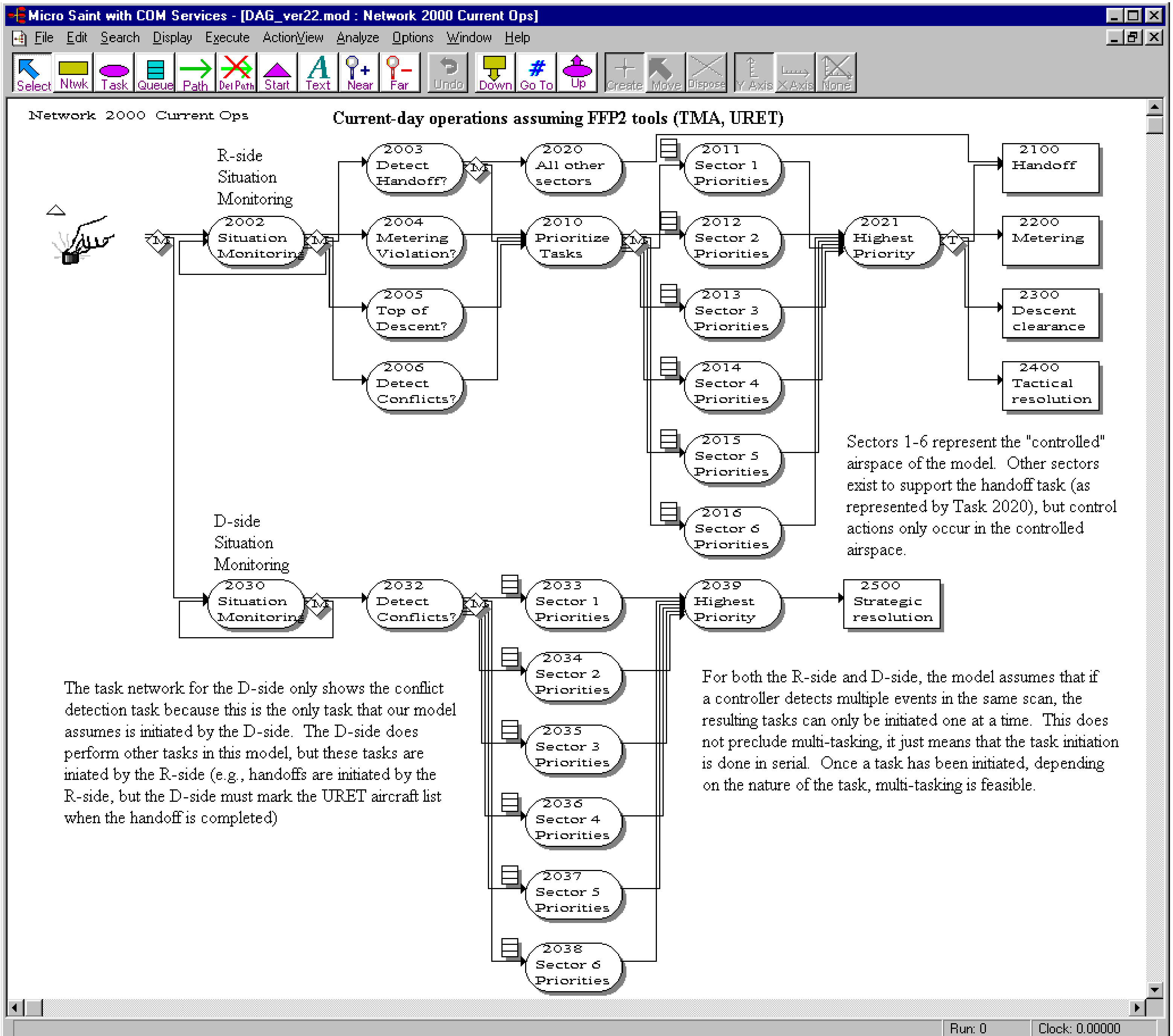
Forecasting Future Deltas

- High fidelity sector-level simulation that reflects factors for the baseline.
- Modeling factors include the route structure, separation buffers, look-ahead times, missed and false alert rates, and imposition of metering.
- Simulation incrementally adds airplanes until average delays increase dramatically due to the conflict detection and resolution process or until throughput plateaus. This defines the maximum number of aircraft that can occupy the given sector while ensuring separation with adequate buffers.

Human Performance Modeling

One of the goals of ER concepts is to offload and/or improve controller performance so that more aircraft can be accommodated in a sector at any one time, increasing sector throughput.

1. **Human performance model for the baseline is executed with sector loading values (aircraft count) that correspond to current day Monitor Alert Parameter values to establish a benchmark acceptable level of workload.**
2. **Add in ER concept. Models are executed with the same sector loading values as in Step 1. It is expected that the predicted workload will be reduced compared to the benchmark.**
3. **With ER concepts, the models are re-executed with incrementally larger values of sector loading until the workload predictions reach the same acceptable level of workload that corresponds to the benchmark.**
4. **Sector throughput improvement is measured as a percentage improvement to current sector capacities.**


Micro Saint with COM Services - [DAG_ver22.mod : Network 2000 Current Ops]
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Network 2000 Current Ops
Current-day operations assuming FFP2 tools (TMA, URET)
R-side Situation Monitoring
2002 Situation Monitoring
2003 Detect Handoff?
2004 Metering Violation?
2005 Top of Descent?
2006 Detect Conflicts?
2020 All other sectors
2010 Prioritize Tasks
2011 Sector 1 Priorities
2012 Sector 2 Priorities
2013 Sector 3 Priorities
2014 Sector 4 Priorities
2015 Sector 5 Priorities
2016 Sector 6 Priorities
2021 Highest Priority
2100 Handoff
2200 Metering
2300 Descent clearance
2400 Tactical resolution
Sectors 1-6 represent the "controlled" airspace of the model. Other sectors exist to support the handoff task (as represented by Task 2020), but control actions only occur in the controlled airspace.
D-side Situation Monitoring
2030 Situation Monitoring
2032 Detect Conflicts?
2033 Sector 1 Priorities
2034 Sector 2 Priorities
2035 Sector 3 Priorities
2036 Sector 4 Priorities
2037 Sector 5 Priorities
2038 Sector 6 Priorities
2039 Highest Priority
2500 Strategic resolution
The task network for the D-side only shows the conflict detection task because this is the only task that our model assumes is initiated by the D-side. The D-side does perform other tasks in this model, but these tasks are iniated by the R-side (e.g., handoffs are initiated by the R-side, but the D-side must mark the URET aircraft list when the handoff is completed)
For both the R-side and D-side, the model assumes that if a controller detects multiple events in the same scan, the resulting tasks can only be initiated one at a time. This does not preclude multi-tasking, it just means that the task initiation is done in serial. Once a task has been initiated, depending on the nature of the task, multi-tasking is feasible.
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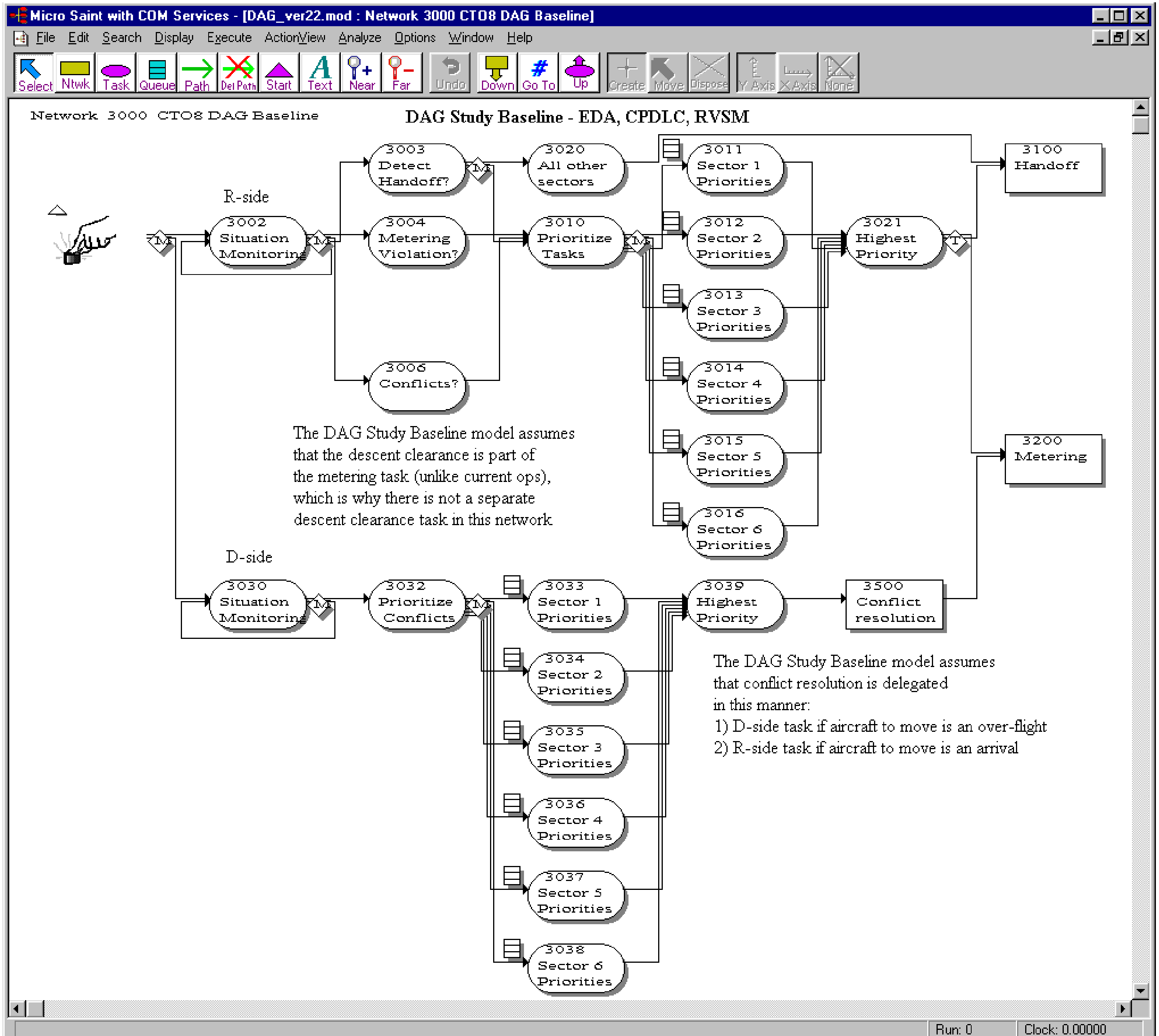
Micro Saint with COM Services - [DAG_ver22.mod : Network 3000 CTO8 DAG Baseline]
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Network 3000 CTO8 DAG Baseline
DAG Study Baseline - EDA, CPDLC, RVSM
R-side
3002 Situation Monitoring
3003 Detect Handoff?
3004 Metering Violation?
3006 Conflicts?
3020 All other sectors
3010 Prioritize Tasks
3011 Sector 1 Priorities
3012 Sector 2 Priorities
3013 Sector 3 Priorities
3014 Sector 4 Priorities
3015 Sector 5 Priorities
3016 Sector 6 Priorities
3021 Highest Priority
3100 Handoff
3200 Metering
The DAG Study Baseline model assumes
that the descent clearance is part of
the metering task (unlike current ops),
which is why there is not a separate
descent clearance task in this network
D-side
3030 Situation Monitoring
3032 Prioritize Conflicts
3033 Sector 1 Priorities
3034 Sector 2 Priorities
3035 Sector 3 Priorities
3036 Sector 4 Priorities
3037 Sector 5 Priorities
3038 Sector 6 Priorities
3039 Highest Priority
3500 Conflict resolution
The DAG Study Baseline model assumes
that conflict resolution is delegated
in this manner:
1) D-side task if aircraft to move is an over-flight
2) R-side task if aircraft to move is an arrival
Run: 0
Clock: 0.00000

Throughput Analysis Assumptions

- Any excessive delay must be dealt with in the planning stage
  - Some flights demanded in the unconstrained schedule would not be realized (removed from the future schedule) to satisfy the NAS constraints
  - A sample traffic in a good weather day is considered
- Benefit is measured by the difference of traffic under DAG-TM and the baseline

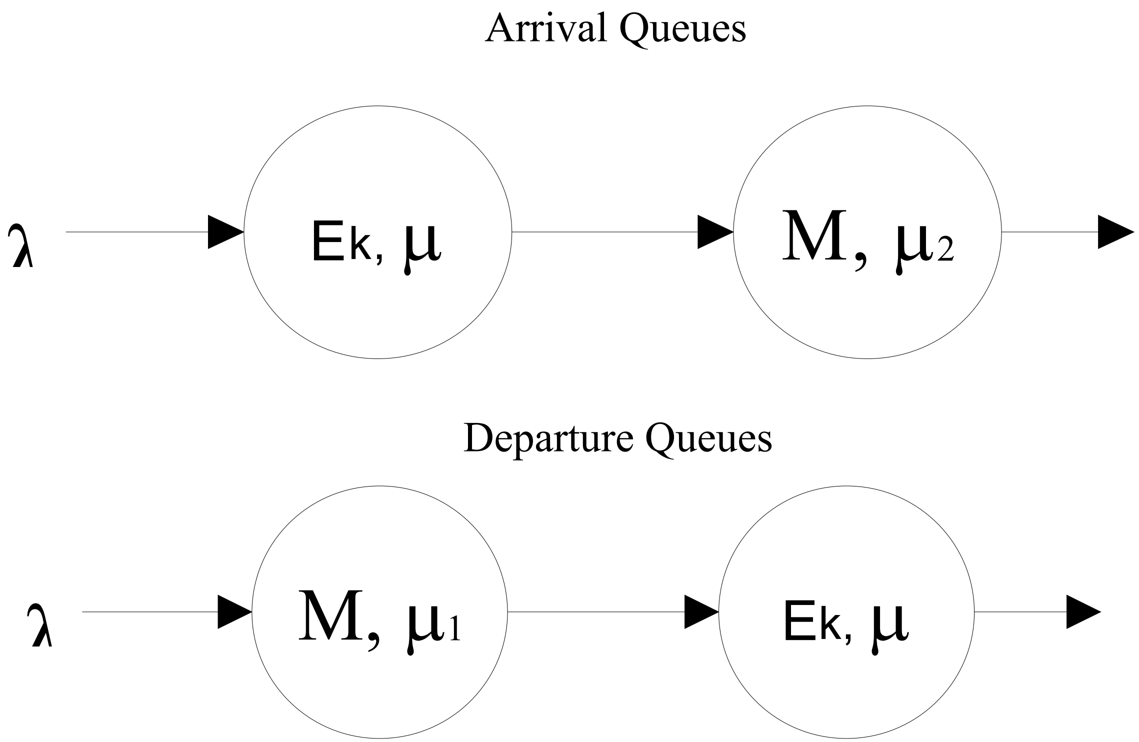
Key Assumptions of Commercial Flight Schedule Forecast

- Industry-wide, long-term model
- Traffic growth between two cities must be proportional to the traffic growth at both cities, respectively
- If unconstrained,
  - it satisfies the forecasts at higher aggregate levels, such as FAA's TAF and ICAO's FESG.
  - the carrier operation practice will continue
    - The current schedule is the best to meet the air traffic demand.
    - The passenger time-of-day demand pattern will be unchanged in the future
- If constrained,
  - the traffic has to be reduced from the unconstrained
  - the schedule will be kept as close to the unconstrained as possible
- All commercial flights connected to any U.S. airports are considered

Imposing NAS Constraints in LMINET

- Airport constraints are implemented via delay tolerance
  - A function of demand and capacity
  - Implemented for large 102 airports in U.S.
- Sector capacities are implemented with the Monitor Alert Parameter (MAP)
  - The maximum number of aircraft simultaneously in a sector within 15-minute window
  - Current FAA practice

LMINET Airport Delay Model



Queuing network model

Demand updated every 15 minutes

System states updated dynamically

Flight Elimination Algorithm

- **Objective: Eliminate flights to satisfy the capacity constraints while preserving as much traffic as possible**
  - **An industry-wide model**
  - **An optimization problem that must be dealt with holistically**
    - **Solution is by a heuristic for the integer programming problem based on the elimination score of each flight: Sum of # of eliminations required at each NAS service node in LMINET divided by a flight traffic measure.**
  - **Traffic measure is in terms of operations or available set miles (ASM)**
    - **The traffic measure used has a significant effect on the results of the analysis.**

Choosing a Traffic Measure to Maximize

Maximizing Operations

- NAS will continue to be operated as it is today; i.e., "equal opportunity, first come first served"
- All flights treated equally. Doesn't matter how many passengers are carried, whether commercial or GA. What matters is the NAS resources used (long flights traversing many sectors penalized)

Maximizing ASMs

- NAS will try to optimize in the future as congestion increases. How? By the actions of dominant airlines (self regulation) and/or by policy decisions (government regulation).
- GA flights severely impacted since they contribute many fewer ASMs (small planes flying short routes, predominantly).
- More rational objective from a pure economic perspective

Project Detail

- NASA Ames AATT Project
- Dan Kozarsky, Task Requestor
- Teammates: CSC, CSSI, and Micro Analysis and Design

CSC LMI CSSI, Inc. Micro Analysis & Design