Surface Operation Automation Research
— SOAR —

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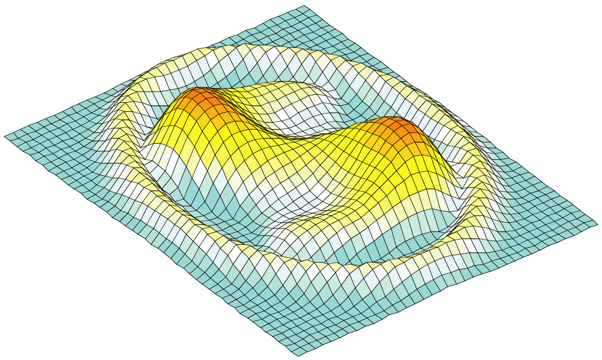
Virtual Airspace Modeling and Simulation (VAMS)
Air Transportation System Capacity-Increasing Research
Technical Interchange Meeting
May 21–23, 2002



Outline

- Background
- SOAR Concept
- Ground-Control Automation
- Flight-Deck Automation
- Operational Integration of Automation Systems
- Remarks on Evaluation Metrics

Background

“Free Flight” Concept Applied to Surface Operation

Critical Factors Affecting Capacity

- **Two factors of capacity**

  Capacity = Space × Density

  - **Space enhancement: increase in runways and taxiways**
  - **Density enhancement: reduction in separation**
- **NAS OEP Solutions**

  Near-term (2001)

  - **New runways at Detroit and Phoenix**

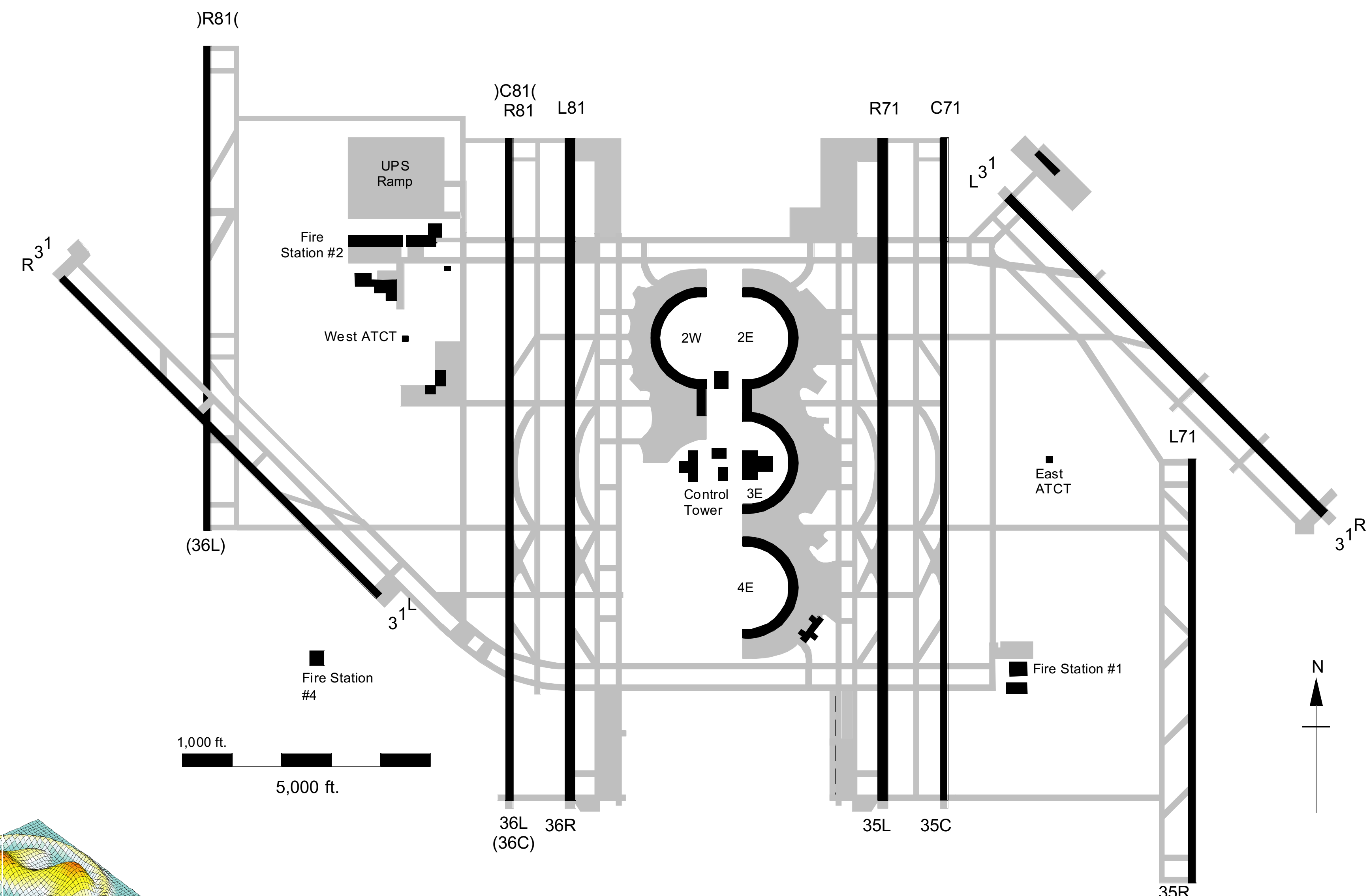
  Mid-term (2002–2004)

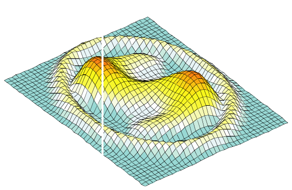
  - **New runways or extensions at six of the top 31 airports: Houston, Minneapolis, Miami, Orlando, Charlotte, Denver**

  Far-term (2005–2010)

  - **New runways at another six of the top 31 airports: Atlanta, Cincinnati, Dallas Ft. Worth, Dulles, St. Louis, and Seattle**
- **Increasing number of runways may be necessary, but often not sufficient**

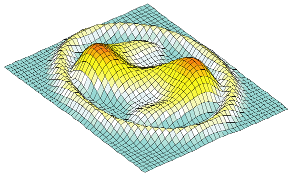
Airport Expansion Example — DFW





Difficulties Associated with Airport Expansion

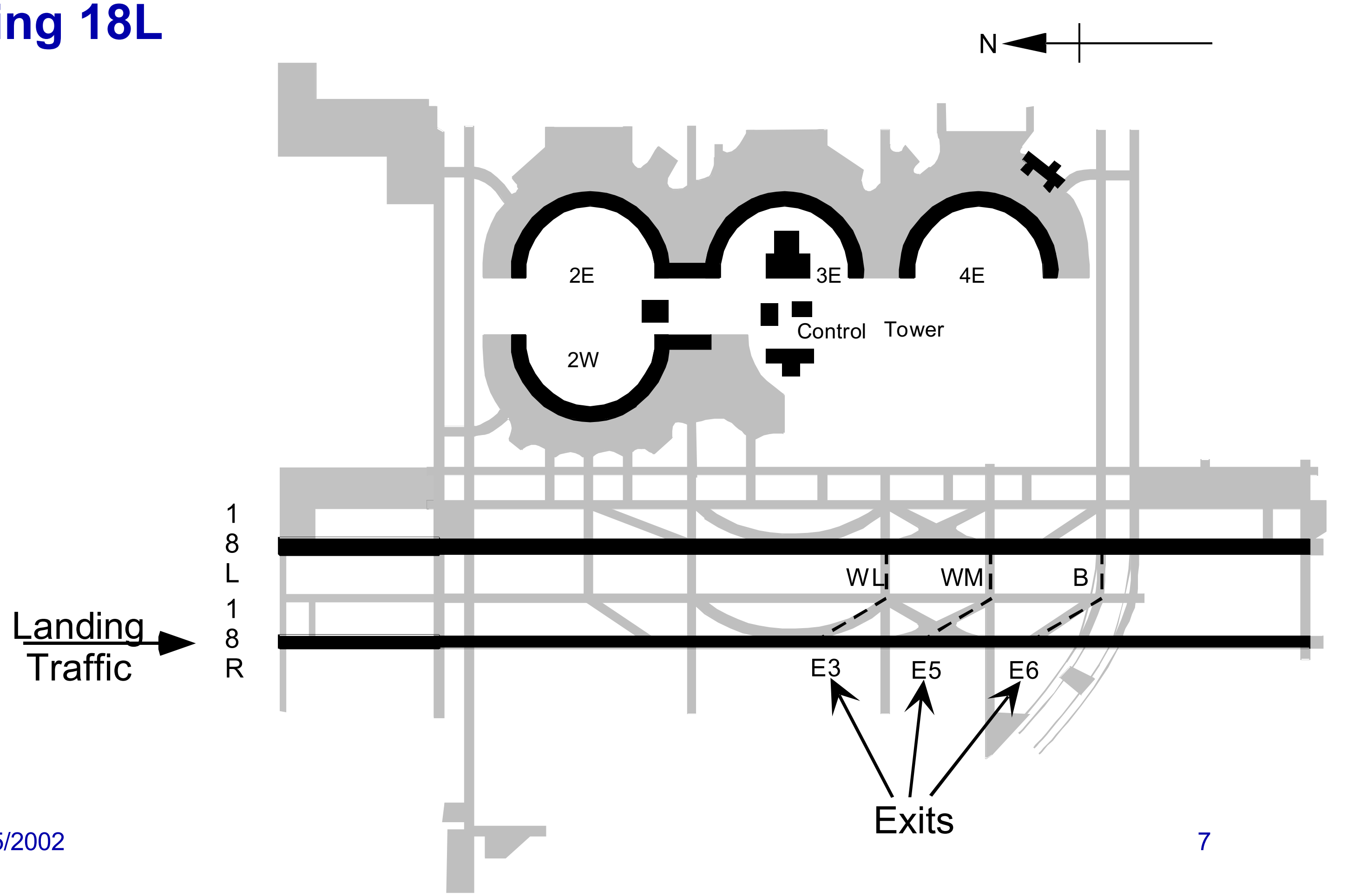
- Resulting increase in surface traffic complexity may experience diminishing returns
- Inside runways block traffic between outer runways and ramp area
- Increased throughput on outer runways increases need for runway crossing
- Increased throughput on inner runways reduced opportunity for runway crossing
- Controllers have to contend with
  - More flights
  - More intersections
  - More runway crossings
  - Less opportunity for runway crossing



Example of Taxi Delay at DFW

Arrivals on 18R

- **exit at E3, E5, and E6**
- **often have to queue up on WL, WM, and B, three deep, prior to crossing 18L**



NAS OEP Solutions for Enhancing Efficiency

- **Mid-term (2002–2004)**
  - **More efficient use of parallel and crossing runways (as well as more arrival runways in general) increases airport arrival/departure capacity**
  - **Coordinated management of surface movement at a larger number of airports increases efficiency of movement on airport surface in all weather**
  - **Improved runway configuration coordination between facilities and carriers reduces flow disruptions in the transition**
- **Far-term (2005–2010)**
  - **Surface navigation using cockpit display to augment visual data and provide common situational awareness improves robustness and efficiency**
  - **Enhanced surface management coordination increases efficiency of movement on airport surface in all weather**
  - **Improved runway configuration coordination between facilities and carriers across adjacent airports reduces flow disruptions in the transition**

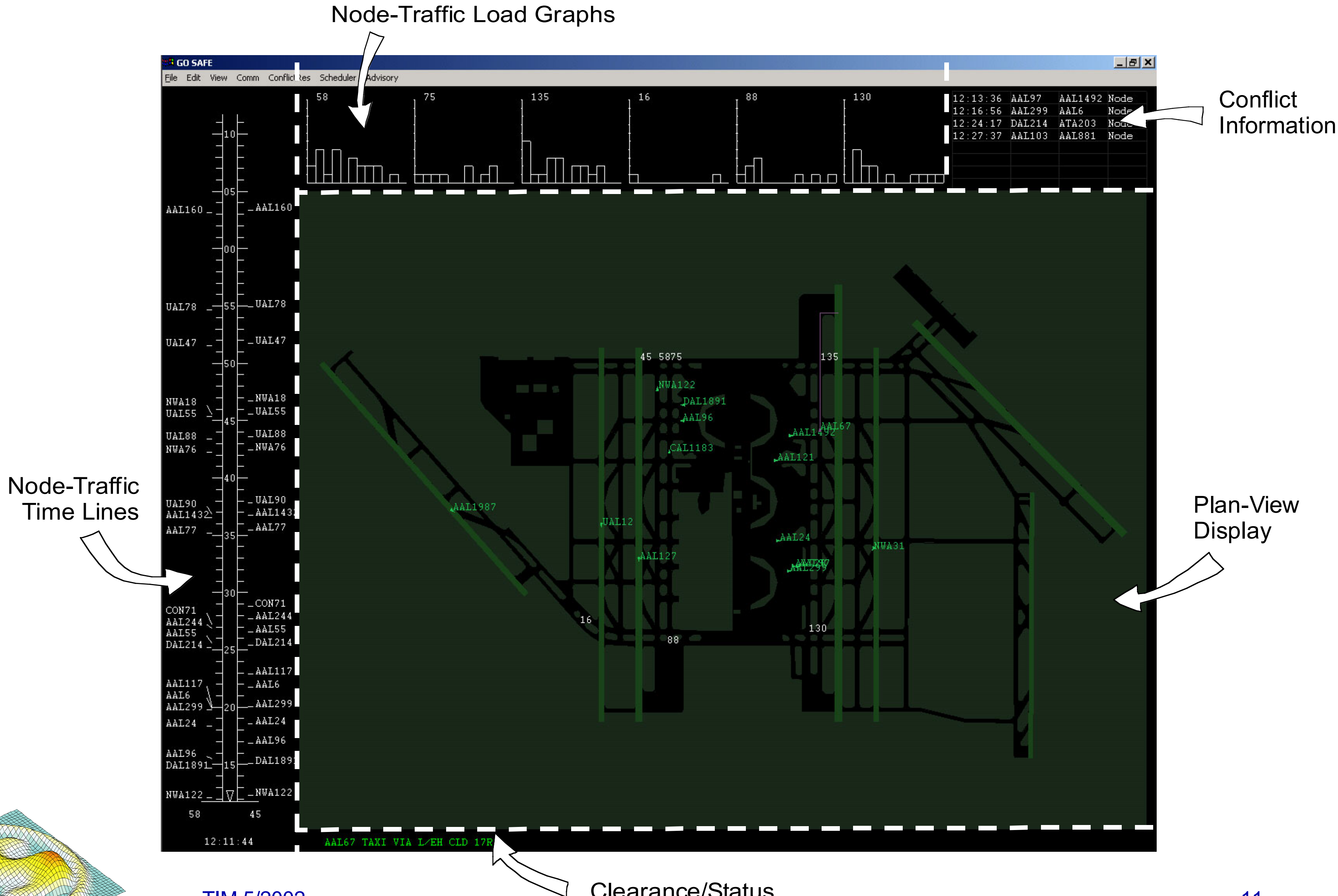
SOAR Concept

- Advanced automation in Centralized Decision-making, Distributed Control (CDDC) paradigm
- Centralized Decision-Making: Automation for Ground Control
  - Bases decisions on surveillance data, flight plans, and AOC requirements
  - Generates time-based taxi routes for optimum traffic efficiency
  - Existing prototype system: Ground-Operation Situation Awareness and Flow Efficiency (GO-SAFE)
- Distributed Control: Automation for Flight Deck
  - Executes time-controlled taxi routes
  - Provides auto-taxi capabilities or automation aids for pilots
  - Automation concept: Flight-deck Automation for Reliable Ground Operation (FARGO)
- Integrated operation of both systems

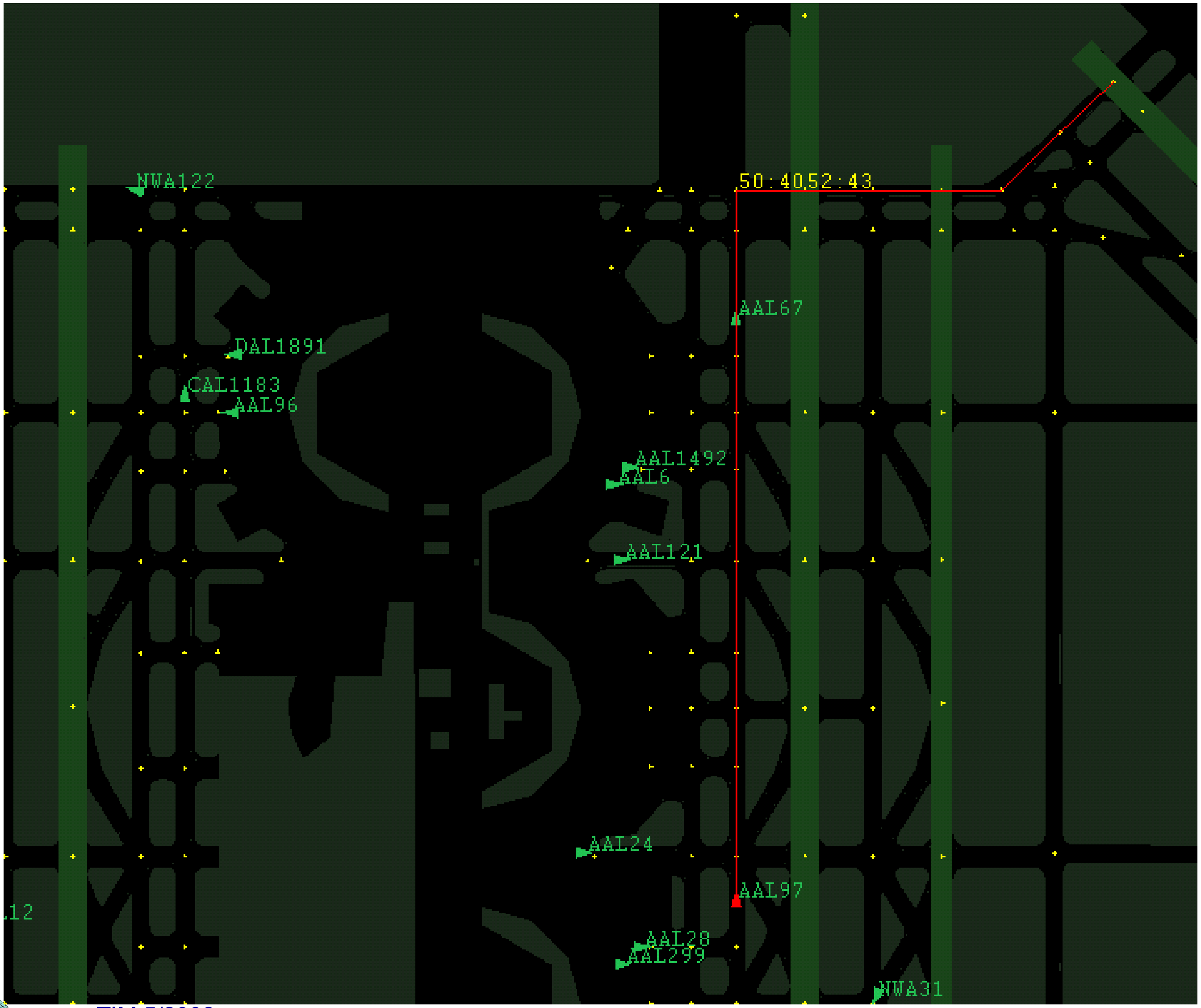
Desired Functions for Ground-Control Automation

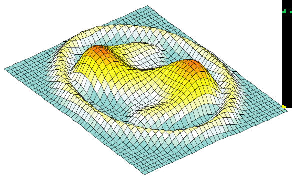
- **User interface, including situational display for monitoring surface traffic, and alert of impending problems**
- **Taxi-route generation and editing**
- **Conflict detection and resolution**
- **Decision support tool for planning and adjusting taxi routes for delivering efficient and safe traffic**
- **Clearance manager for generating and processing advisories and clearances, and for monitoring the resulting progress**
- **Information exchange with relevant systems in the NAS infrastructure and other automation systems**

Overview of GO-SAFE GUI



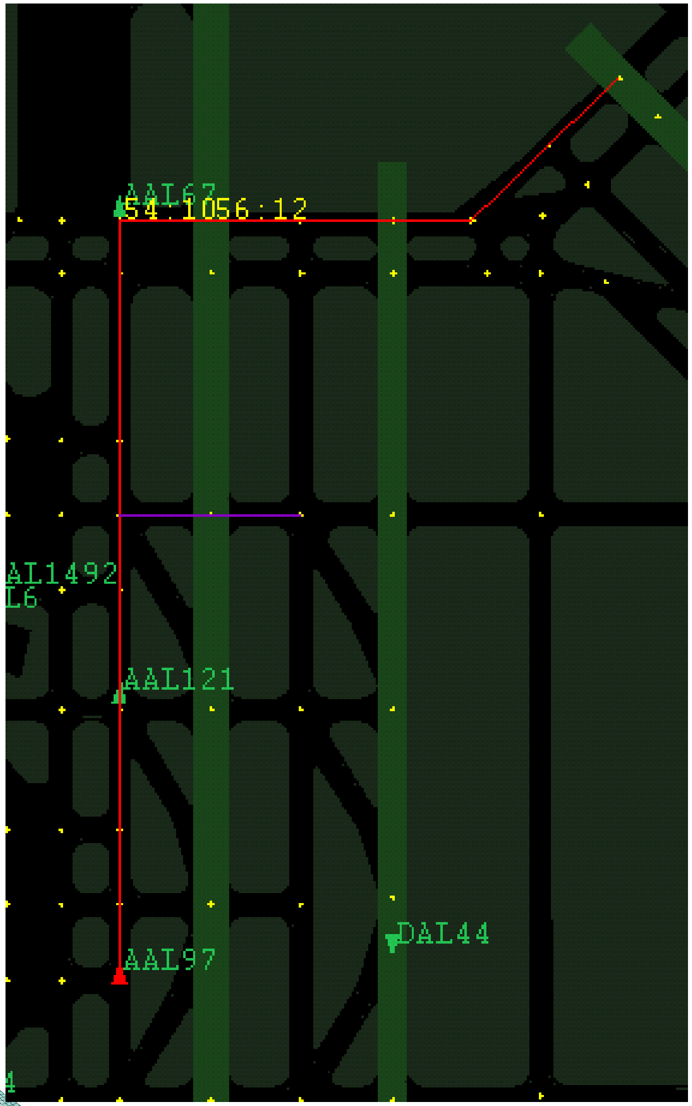
Example of Route Editing by Changing Destination





Route Resulting from Dragging Destination Node

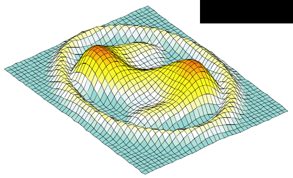
Example of Spatial Editing of Taxi Route



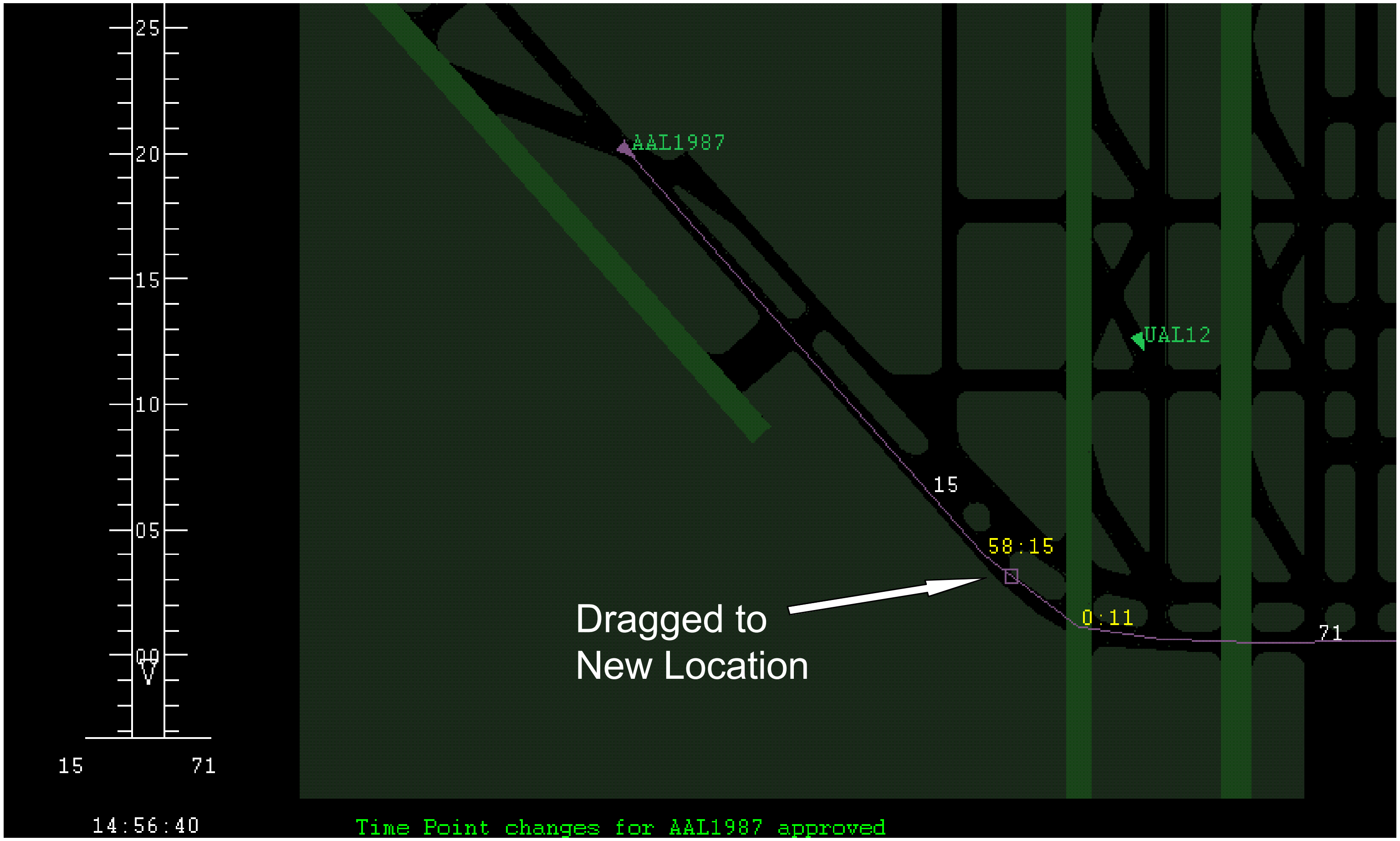
Example of Temporal Adjustment of Taxi Route

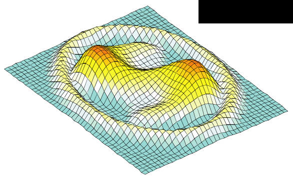
Time Marker

Predicted Location



Dragging Predicted Location to New Location





Conflict Detection and Resolution

- **Requirements for conflicts on airport surface not as serious as for IFR flights: in current operations, cockpit crew responsible for separation while taxiing**
- **Three general types of conflicts:**
  - **Node/intersection crossing**
  - **Overtaking**
  - **Head-on**
- **Node-crossing and overtaking conflicts appear only in GO-SAFE internal route computations, but are automatically resolved by crews in current operations.**
- **Head-on conflicts may lead to dead lock.**
- **Auto-taxi or high-workload taxi will require conflict-free clearances.**

Decision Support System

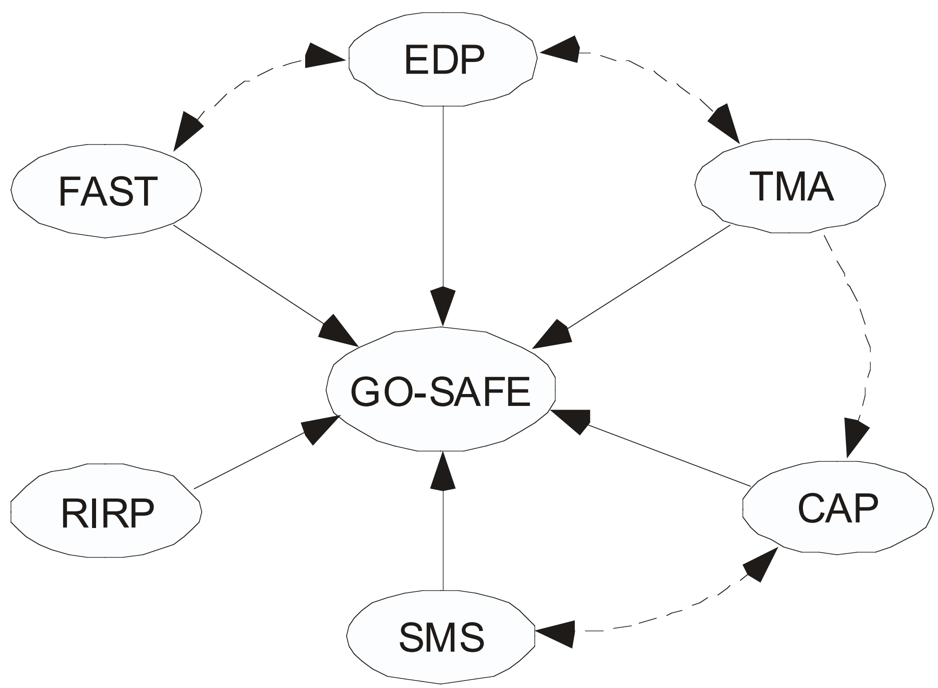
- Core component for achieving efficient surface operations
- Schedule Manager
  - Calculates runway usage schedules for landing, takeoff and crossing traffic
  - Enables efficient active-runway crossing
  - Landing traffic has priority
  - Allows simultaneous runway occupancy under special conditions
- Challenge: Other decision-support functions to optimize efficiency of traffic over whole surface traffic

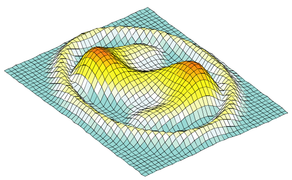
Clearance Manager

- **Manages and issues advisories/clearances**
- **Encodes clearances according to route definition, including crossing time restrictions**
- **Monitors clearances and flight clearance status:**
  - **clearance ready**
  - **acknowledgment pending**
  - **acknowledged**
  - **rejected**
- **Challenge: Requires research in proper user interface**

Information Exchange

- Communications with flights
- Flight data from Host Computer, AOC, etc.
- Surveillance data from ADS-B, ASDE, AMASS, ATIDS, ARTS, etc.
- Information exchange with other tools





Desired Functions for Flight-Deck Automation

- **Auto-taxi function for precisely controlling the aircraft taxi to accomplish the taxi clearance with tight control margins**
- **Pilot interface to allow the pilots to perform precision-taxi**
  - **Far-term: fully automatic taxi**
  - **Near-term: control signals generated by the auto-taxi function to direct manual control**
- **Previous research established potential of high-precision aircraft taxi control for improving traffic efficiency:**
  - **High-precision taxi operations are achievable with advanced guidance and control.**
  - **Potential benefits of automation can be sustained under manual control with effective pilot interfaces.**

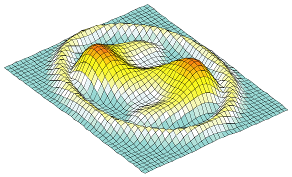
V. H. L. Cheng, V. Sharma, and D. C. Foyle, "A Study of Aircraft Taxi Performance for Enhancing Airport Surface Traffic Control," *IEEE Transactions on Intelligent Transportation Systems*, Vol. 2, No. 2, pp. 39–54, June 2001.

Pilot Interface Considerations

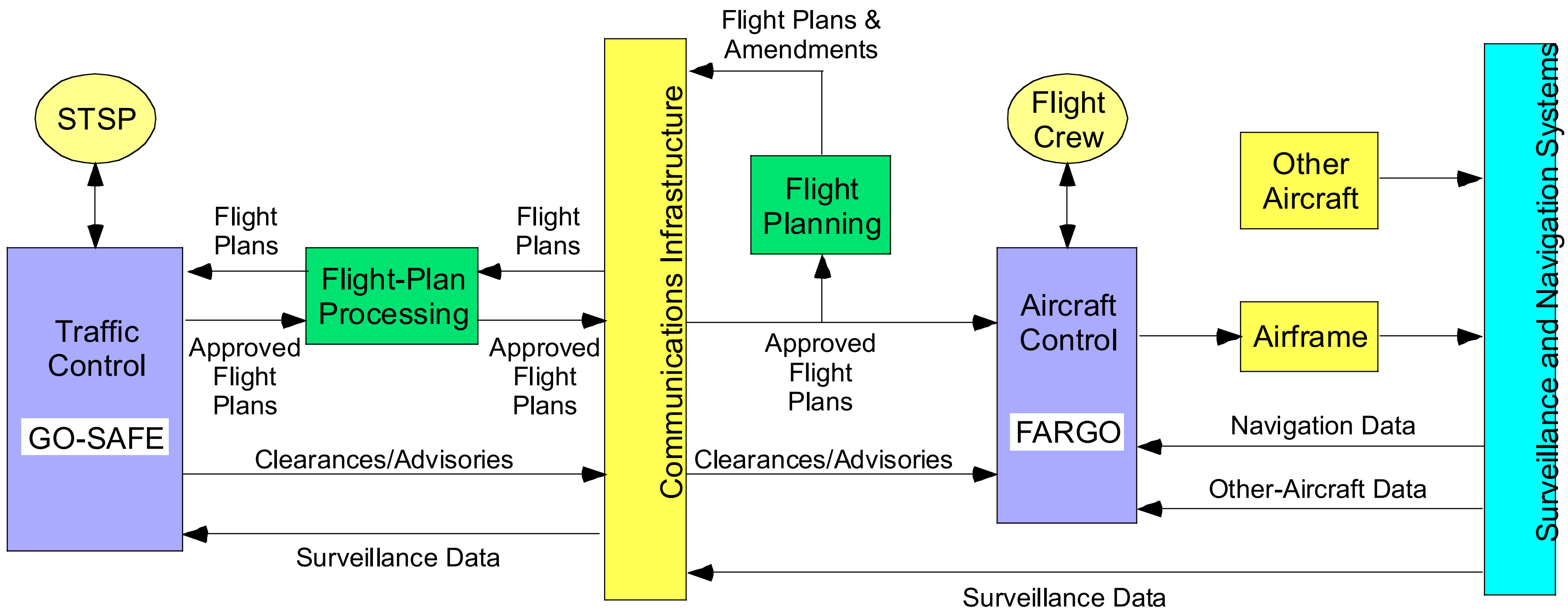
- **Landing, roll out, and turn off require deceleration followed by continuous taxi**
- **Traditional flight director concept**
  - **Speed bug unsuitable for deceleration control during roll out**
- **Other options**
  - **Braking cue + Throttle/Speed cue**
  - **RTA at key locations, e.g. holding lines**
- **Issues**
  - **Mode awareness problems: switching from deceleration to constant-speed taxi**
  - **Discrete adjustments of brakes and throttle**
- **Challenge: Future research particularly important for developing automation-assisted system for manual control**

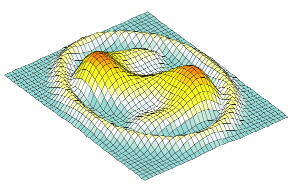
Operational Integration of Automation Systems

- Complex taxi routes with time constraints necessitate data-link clearances.
- Challenges:
  - Controllers cannot expect immediate acknowledgement.
  - Cockpit crew may be distracted from flight control
    - Reading clearances
    - Understanding details
    - Responding via console input
  - Near-term application of the technologies required different approaches.
- Route information can be more easily entered into FMS.



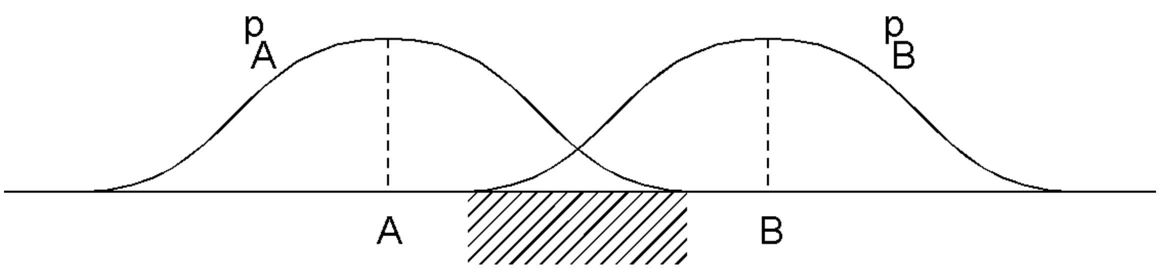
SOAR Top-Level Model Relative to GFI Model



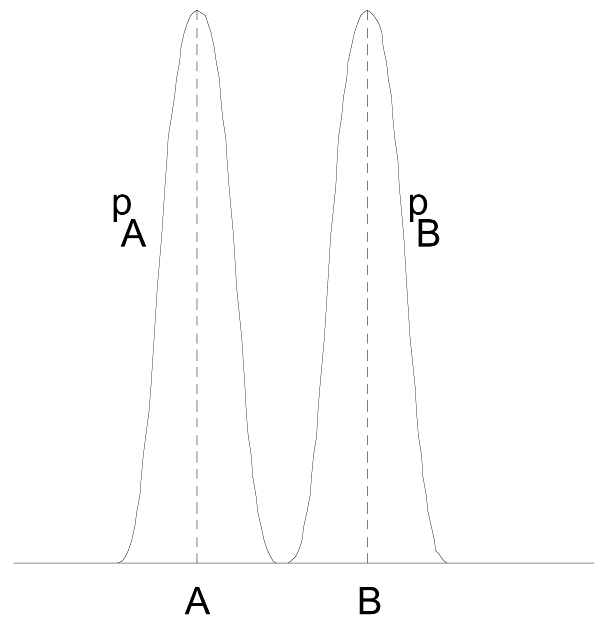


Remarks on Evaluation Metrics

- **Capacity: Number of flights serviced in given time period**
- **Efficiency: Taxi time, delay**
- **Workload: Controller, Cockpit Crew**
- **Safety: Probability of incidents, not necessarily based on overly conservative separation requirements**



Imprecise control with large mean separation



Precise control with small mean separation

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