CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

Incremental, Probabilistic Decision Making for En Route Traffic Management

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7th USA/Europe ATM R&D Seminar

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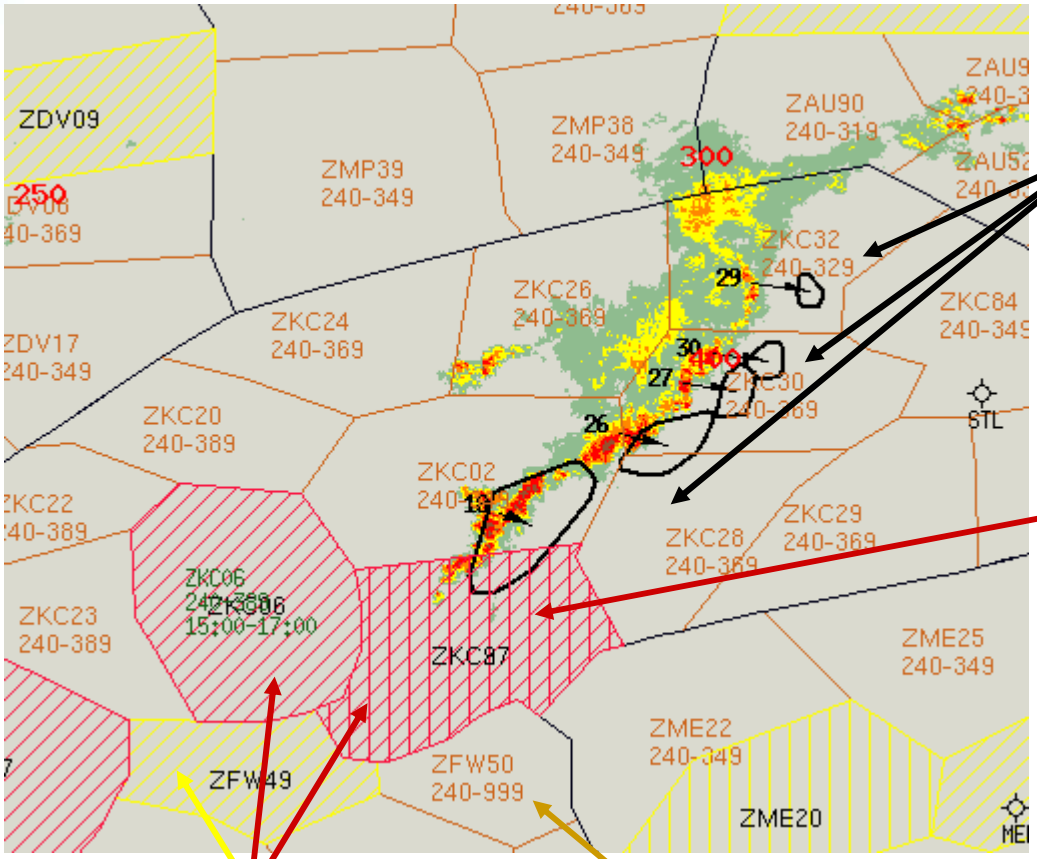
En Route Airspace Congestion



Uncertain weather forecasts indicate current and future loss of airspace capacity…

Uncertain traffic forecasts provide airspace demand…

If demand exceeds capacity, delays will occur and safety may be compromised.

Given the uncertainty:
When should air traffic be restricted?
Which flights should be affected?
How can NAS operators participate?

Congestion Alerts

Air traffic control sector

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The Strategic Planning Team: Developing the Strategic Plan of Operations

Telcons: Every 2 Hours

Status Info:
Weather Forecasts
Traffic Predictions
NAS Status
Special Ops…

SPO

Plan Execution:
Advisories

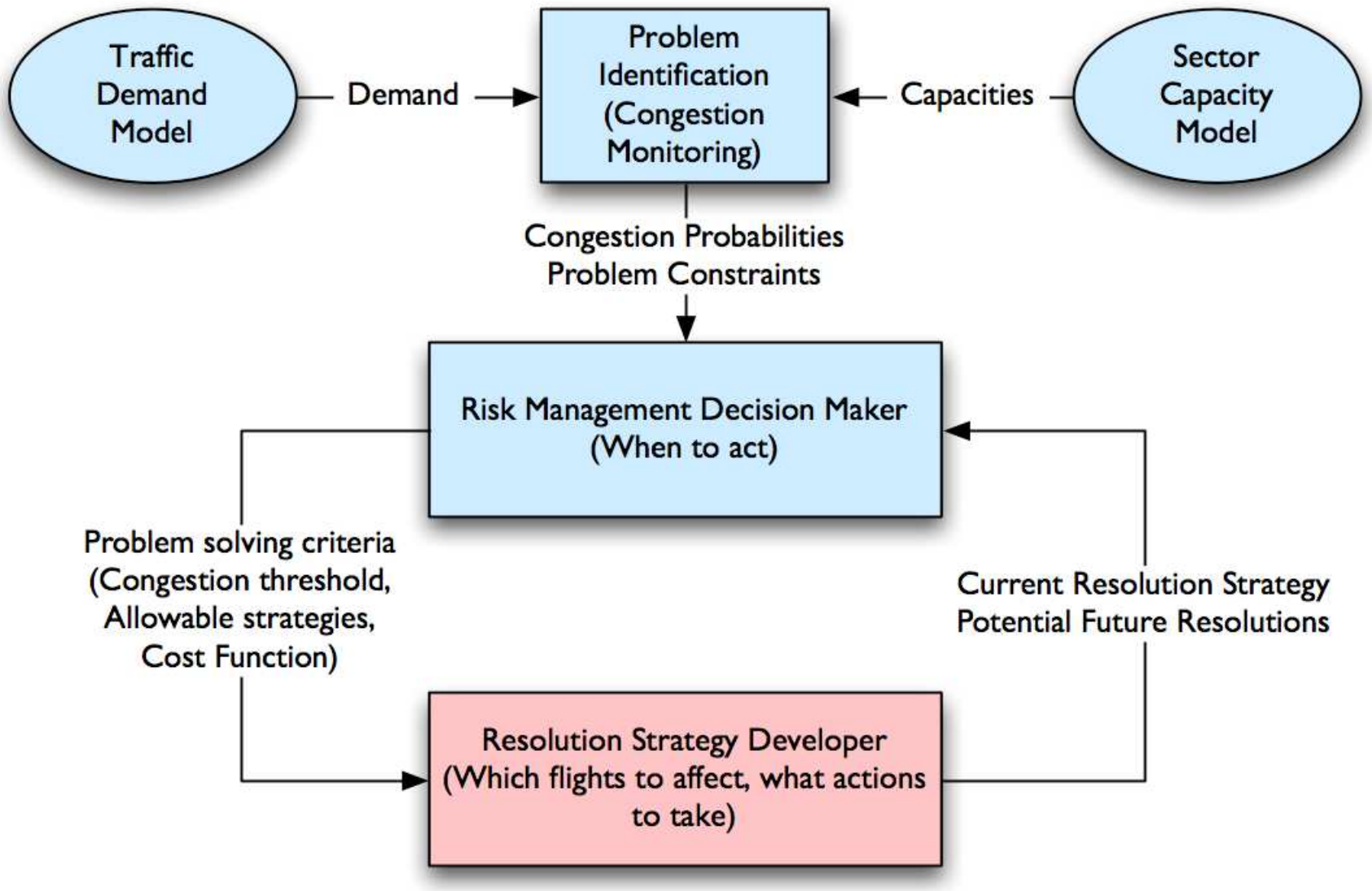
Flow Actions:
Reroutes
Airspace/Ground Delay Programs
Miles-in-Trail (MIT) Restrictions
Ground Stops

Assess,
Reevaluate

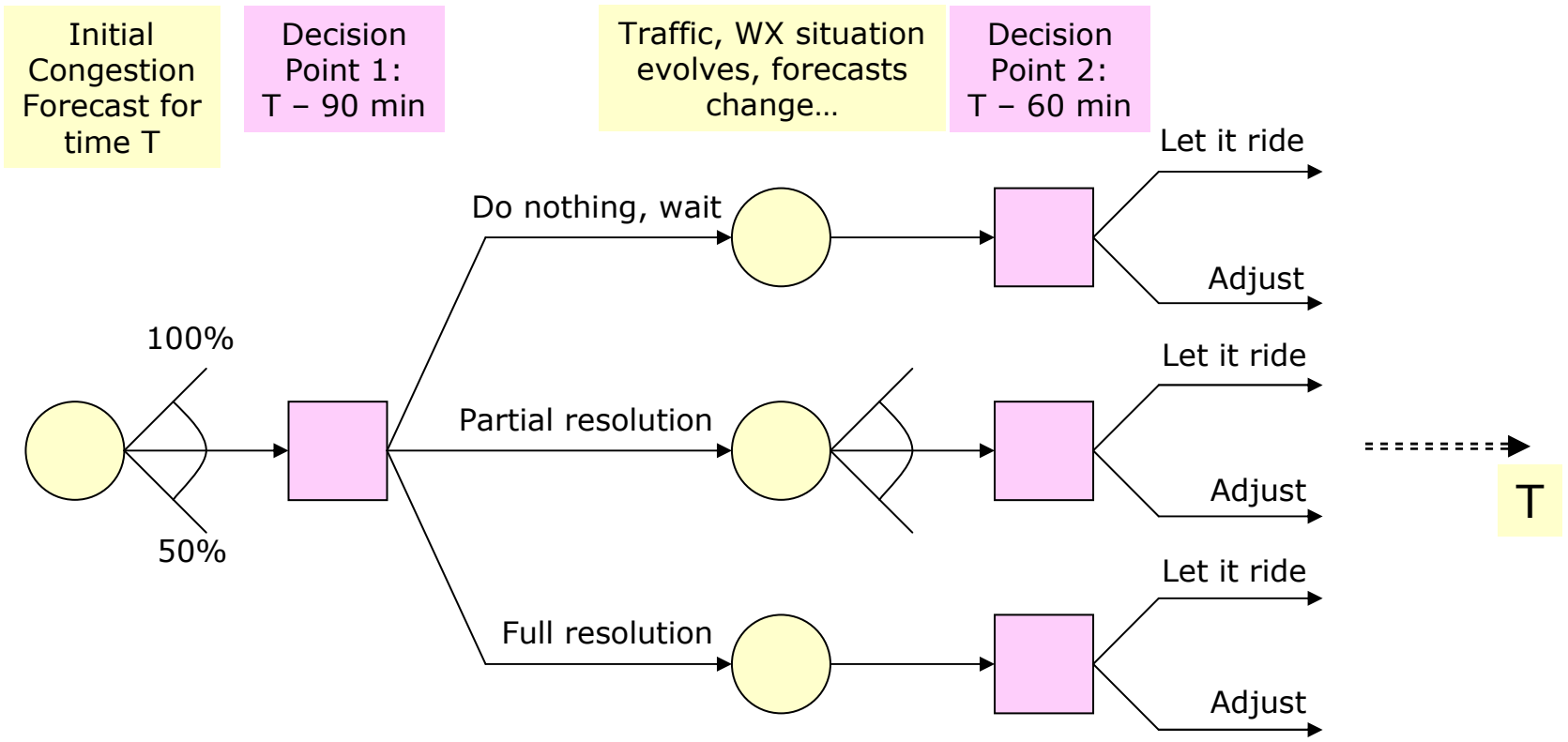
SPT participants:
Command Center specialists
Airline strategic planners
NAS field facilities (TMUs)
Weather forecasters
Military
International facilities
General aviation

Limited analytical information
No impact assessment tools
Mostly verbal/manual implementation

Risk Management Decision Loop

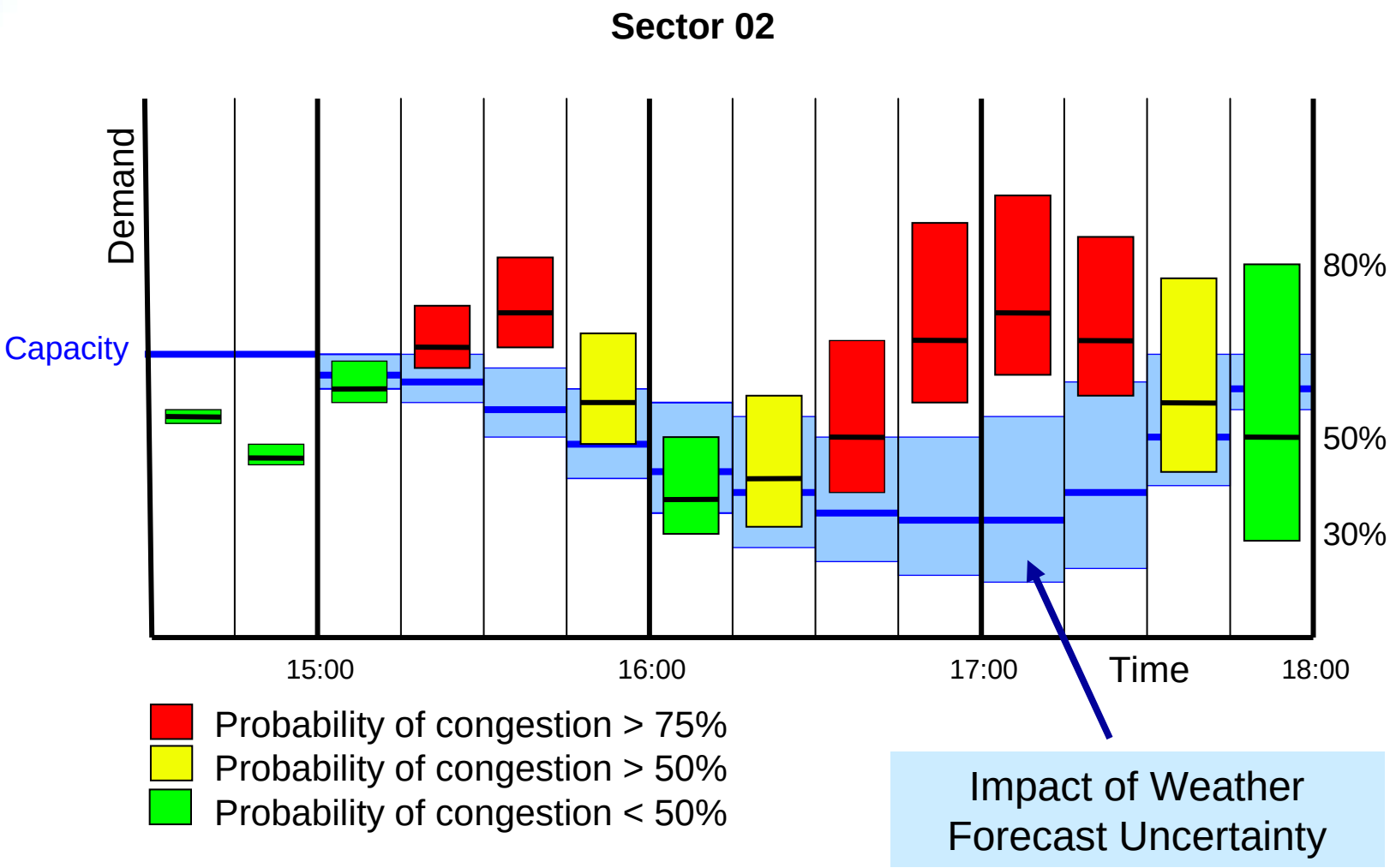


Congestion Resolution Decision Tree

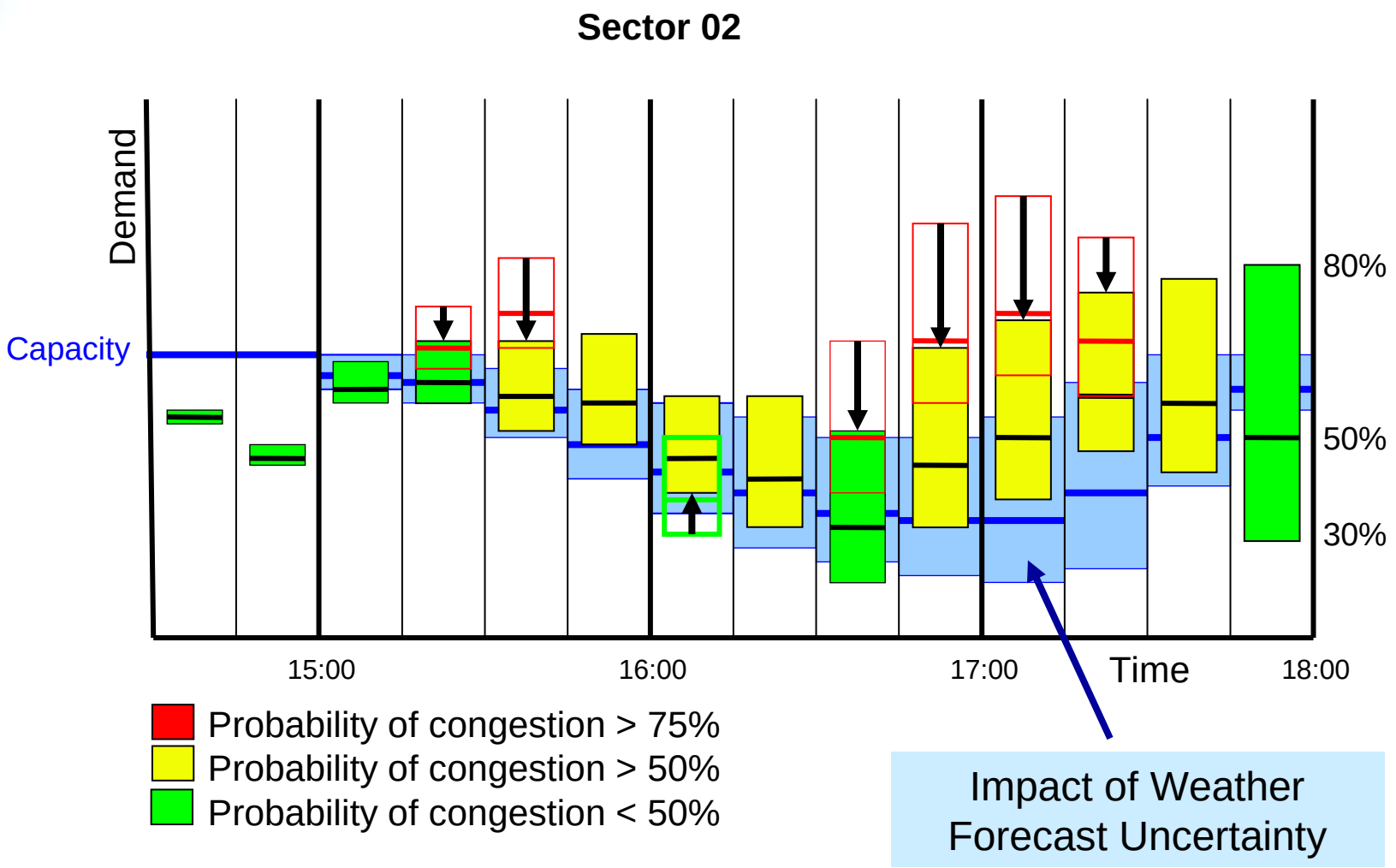


Of the possible decision paths, which one reaches the congestion management goal with the least operational impact?

Probabilistic Future Sector Demand and Capacity Graph



Managing Congestion to a Target Level of Risk (Probability)



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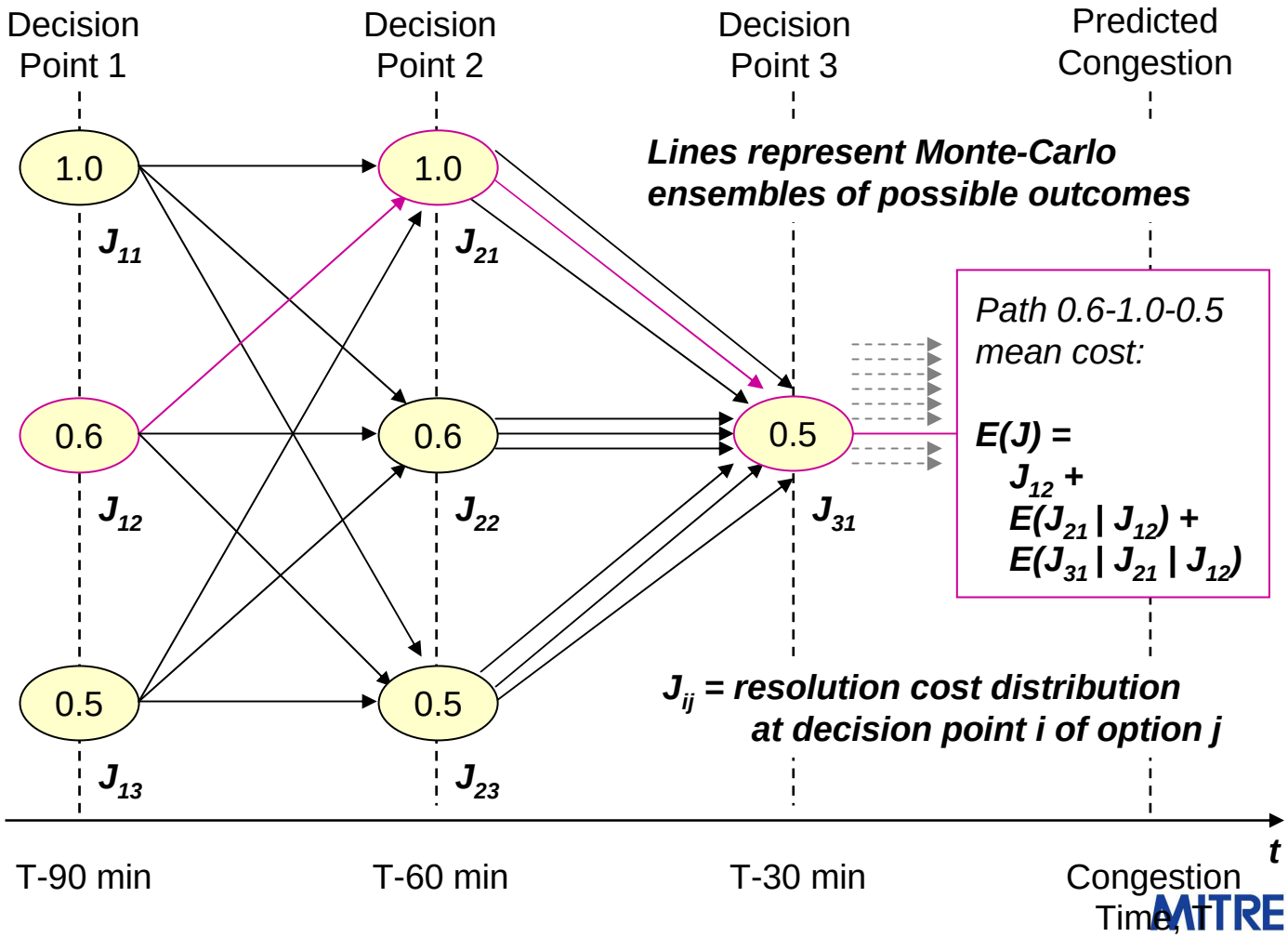
Discrete Sequential Decision Tree with Congestion Probability Goals

Start:

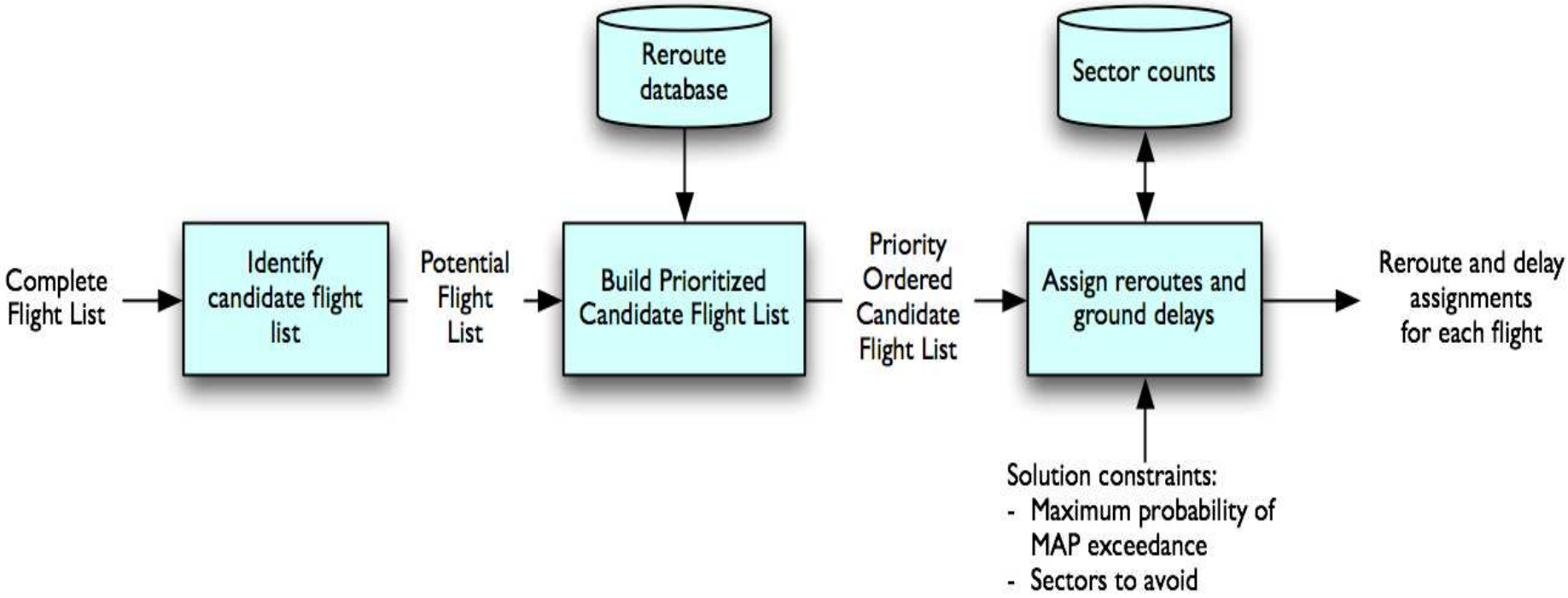
Set of predicted trajectories and corresponding congestion probabilities

Start:

Set of predicted trajectories, **predicted weather**, **weather-impacted capacity**, and congestion probabilities



Resolution Algorithm



- Fast to compute, but does not find the optimal solution in complex situations (one pass only)

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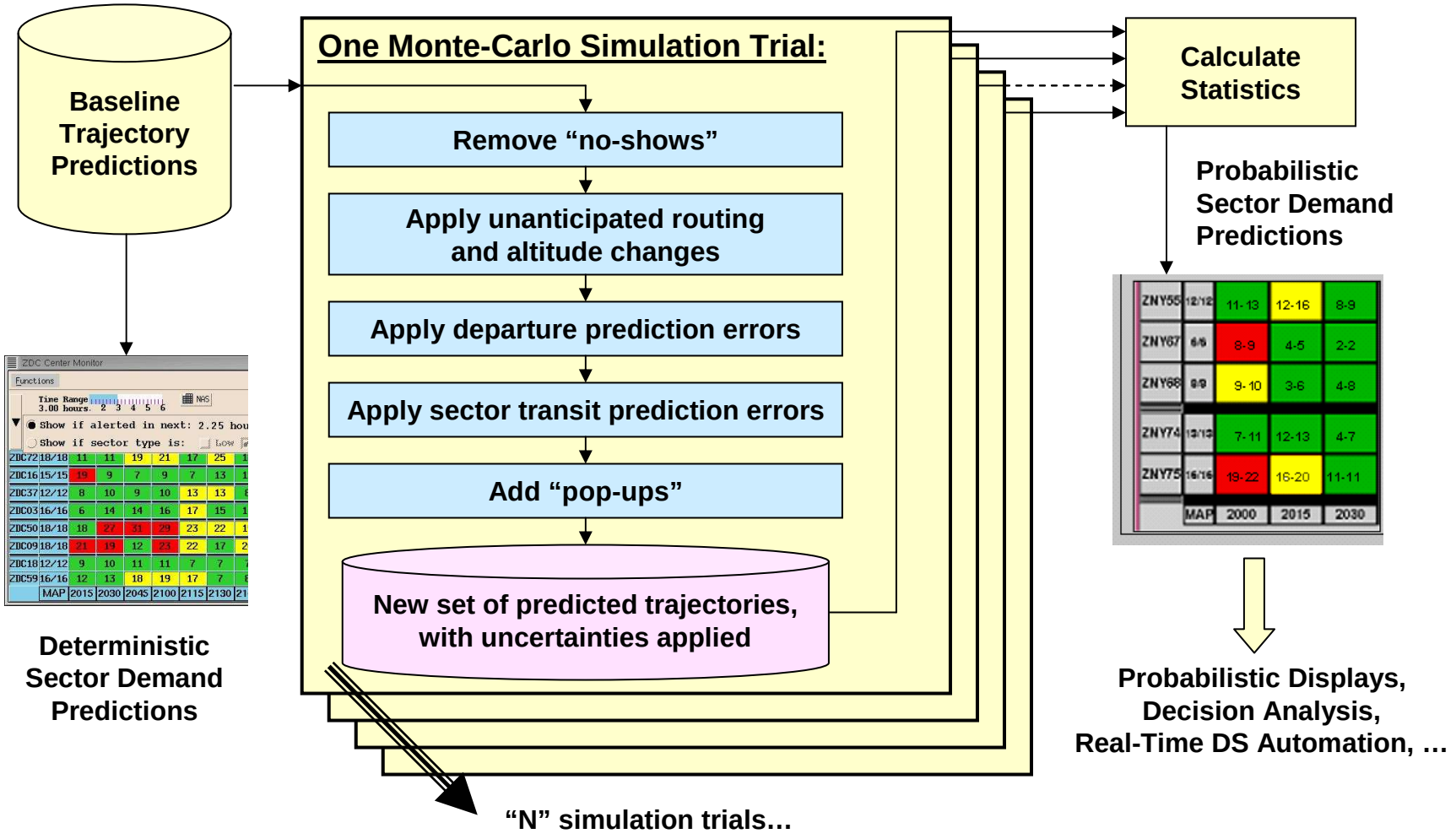
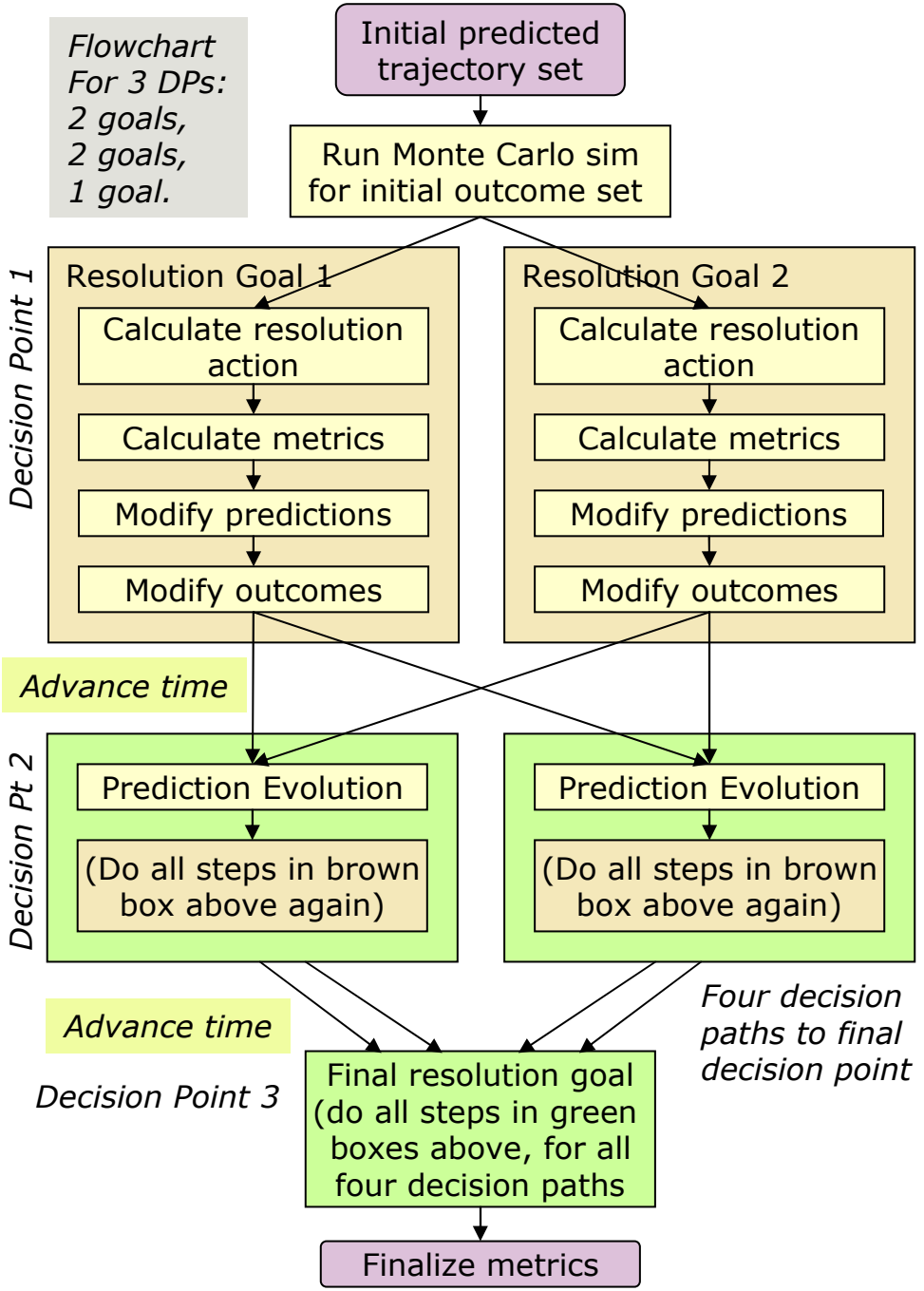
Monte-Carlo Simulation Process

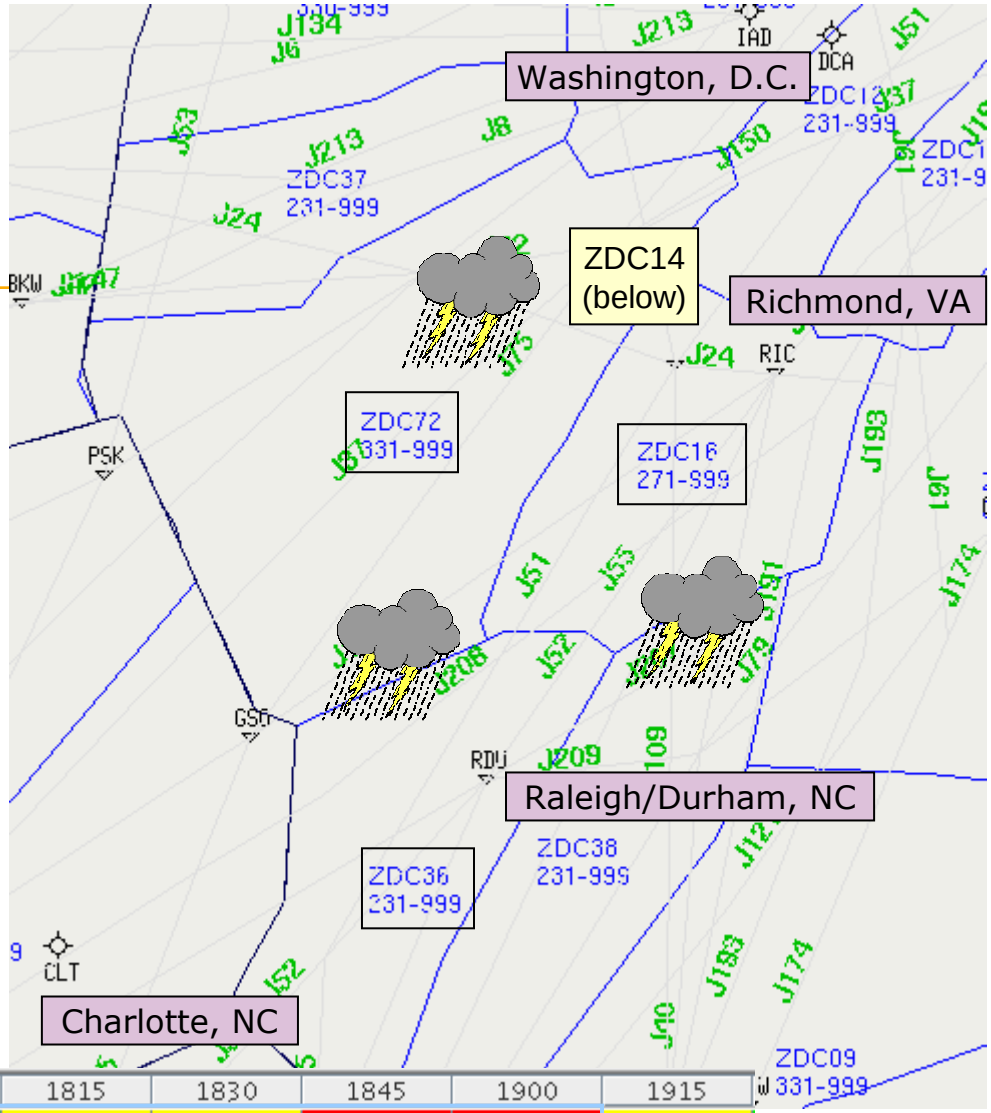


How it Works
(see paper for details)



Congestion Scenario Example

- 4 Sectors in the Congestion Resolution Area (CRA)
- 38 Sectors in the Congestion Management Area (CMA)
- ~1500 flights (200 in CRA)
- Weather reduces MAP by 5 in the CRA sectors
- Stochastic traffic, deterministic capacity



	1700	1715	1730	1745	1800	1815	1830	1845	1900	1915
ZDC14 [14]	8	11	8	6	6	9	11	13	12	11
ZDC16 [15]	6	6	6	9	8	10	11	11	5	5
ZDC36 [16]	5	9	7	13	8	12	14	9	6	7
ZDC72 [18]	15	17	11	7	14	14	17	18	13	13

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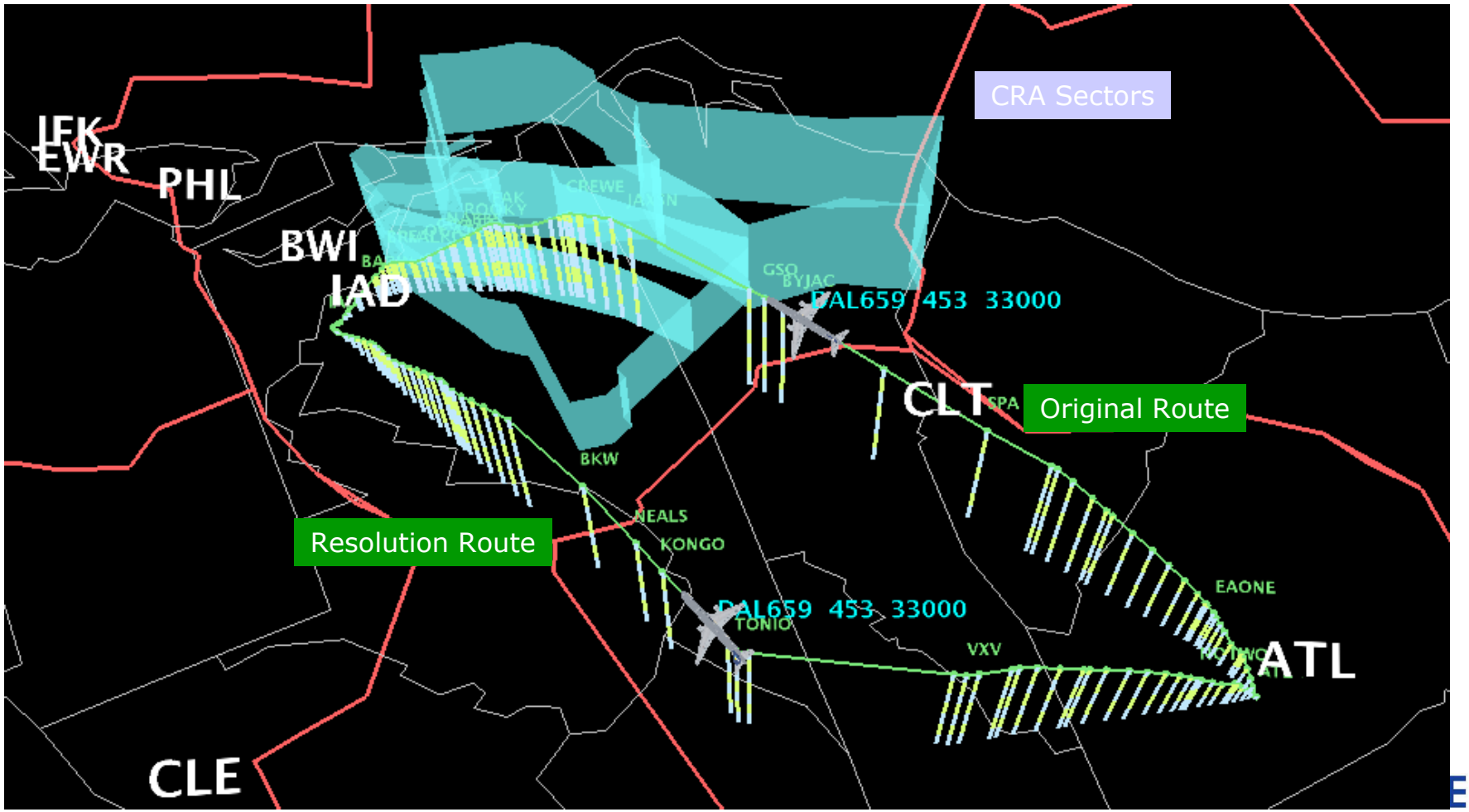
Reroute Example: Avoiding Congested Sectors Without Arrival Delay



Results

Decision Path	Mean No. of Flights Affected	Mean Total Positive Delay (min)	Mean TPD per Flight
1.0-1.0-0.5	29.5	271	9.2
1.0-0.6-0.5	53.6	400	7.5
1.0-0.5-0.5	71.1	557	7.9
0.6-1.0-0.5	48	318	6.6
0.6-0.6-0.5	58.6	392	6.7
0.6-0.5-0.5	71.1	489	6.9
0.5-1.0-0.5	83.6	643	7.7
0.5-0.6-0.5	87.5	678	7.7
0.5-0.5-0.5	93.3	752	8.1

Did not solve congestion

Best successful result

Micromanagement is bad

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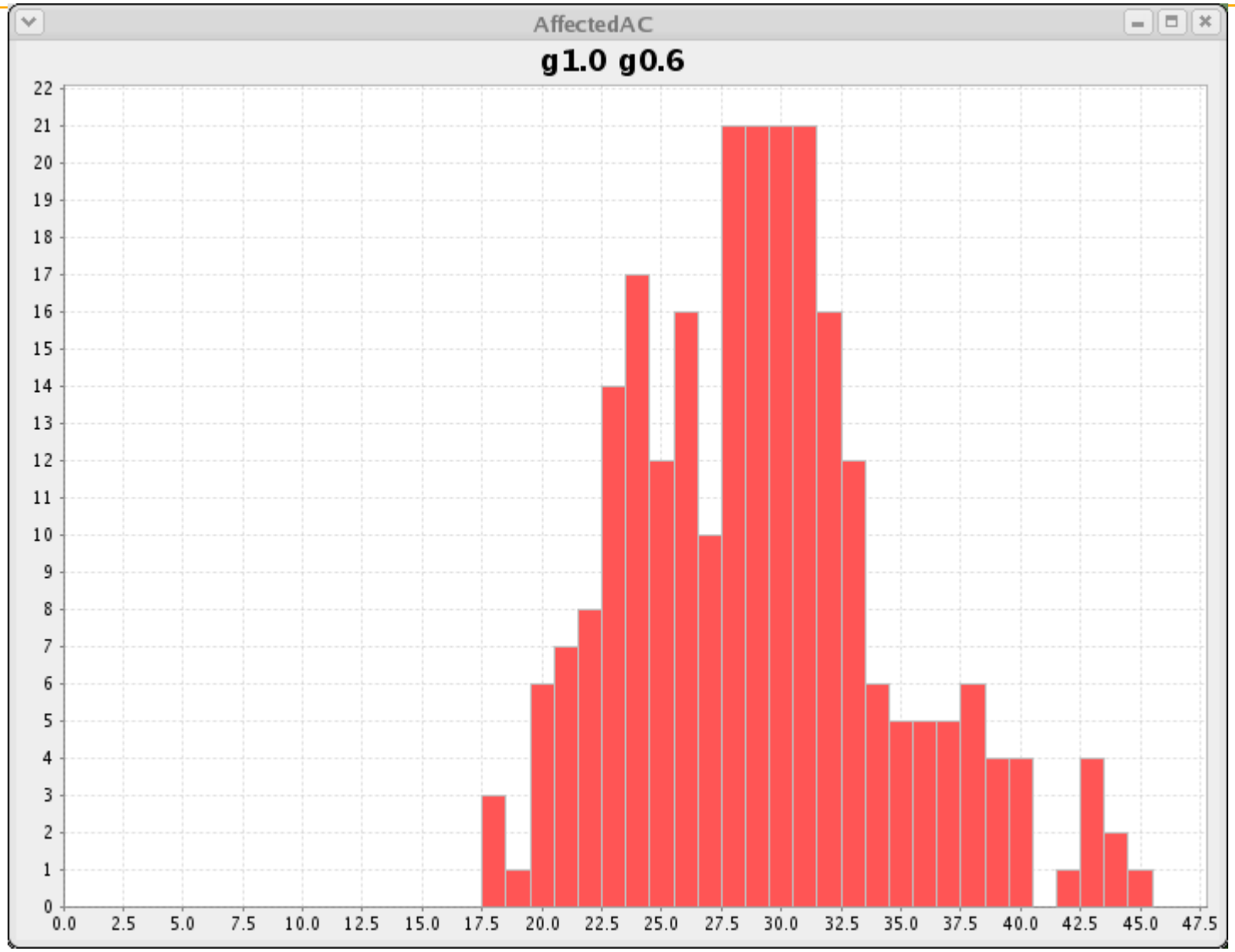
Variability is Large (1)



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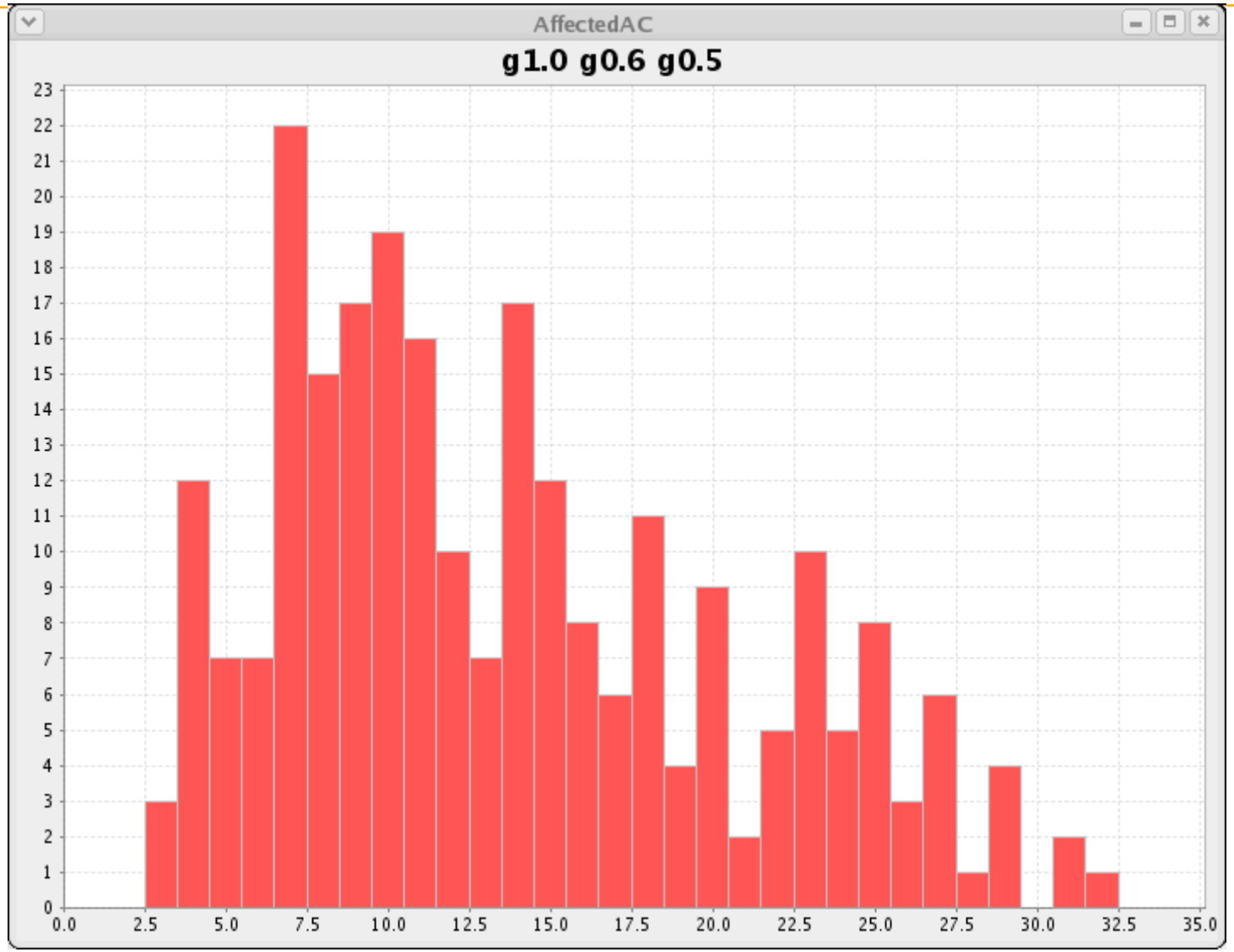
Variability is Large (2)



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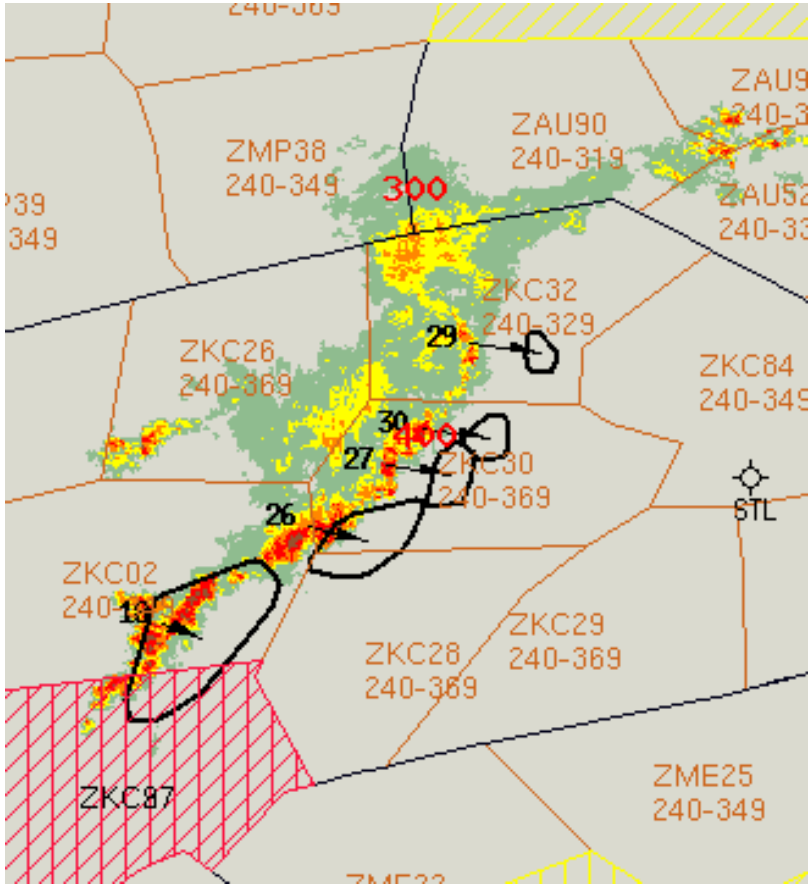
Next Steps

- What is the right goal?
  - Play for best expected value, or hedge against risk of “very bad” outcomes, or reduce uncertainty, or…?
- Explicitly consider probabilistic capacity
  - Platform for evaluating probabilistic weather forecast products
  - Apply new capacity approaches (see Lixia Song’s ATM 2007 paper)
- Run a matrix of scenarios & decision trees:
  - Derive trends, decision heuristics for near-term systems
- Adapt to benefits analysis scenarios
  - Benefits of incremental vs. one-time decision-making
- Relationship to longer-term (2-6 hour) planning activities
- Further develop collaboration mechanisms for NAS users

Modeling Weather (1)



- **Initial model: capacity based on VIL level 3+ coverage (PACER)**
- **Parameterize variations in weather evolution:**
  - **Intensity/Growth/Decay**
  - **Timing (speed)**
- **Apply simple uncertainty models to parameters**
  - **Function of LAT**
- **In this way, can model both initial uncertainty and forecast improvement as congestion time nears**

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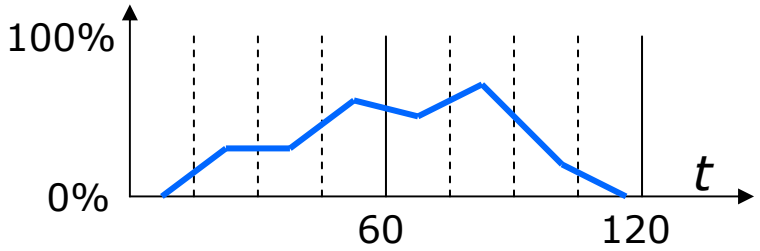
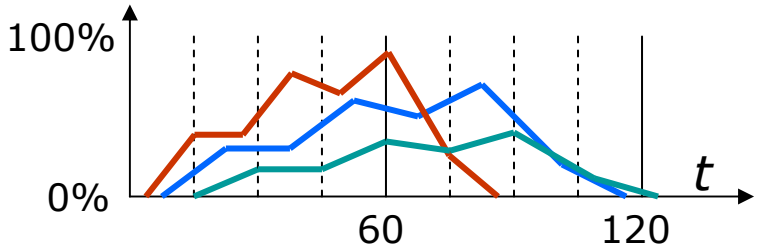
Modeling Weather (2)

- **Take actual VIL 3+ coverage as the "prediction"**
  - **For each sector:**



- **Model speed & growth/decay multipliers as triangular-distributed variables**
  - **Shift, dilate, and scale the baseline coverage**



- **Use distributions to calculate initial Monte Carlo weather outcomes <u>and</u> to update predictions**

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Conclusion

- **Developed a new method for sequential ATM decision making in the presence of empirically-modeled uncertainties**
  - **Currently an off-line simulation process, can be used to evaluate forecast products, do cost/benefit analyses, and develop decision-making heuristics**
  - **Potentially adaptable to real-time applications**
- **Monte Carlo simulation technique allows evaluation of the ensemble of potential outcomes**
  - **Not limited to data-mining of actual events**
- **Incremental resolution approach is consistent with advanced ATM concepts**
  - **Trajectory-based traffic management**
  - **“Traffic management by exception”**

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More Stuff

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Background: En Route Traffic Flow Management (TFM) in the U.S.

- **Primary mission is to balance demand for air traffic services with available system capacity**
  - **Ensure efficient use of the National Airspace System (NAS)**
  - **Allocate air traffic flows to capacity-constrained NAS resources (airports, coordination fixes, ATC sectors)**

- **Support safety by maintaining traffic flows at levels that can be safely managed by air traffic controllers**
  - **Manage traffic demand to acceptable levels**
  - **Act on sector and airport loading issues**
- **Support customers by providing maximum access to NAS resources**

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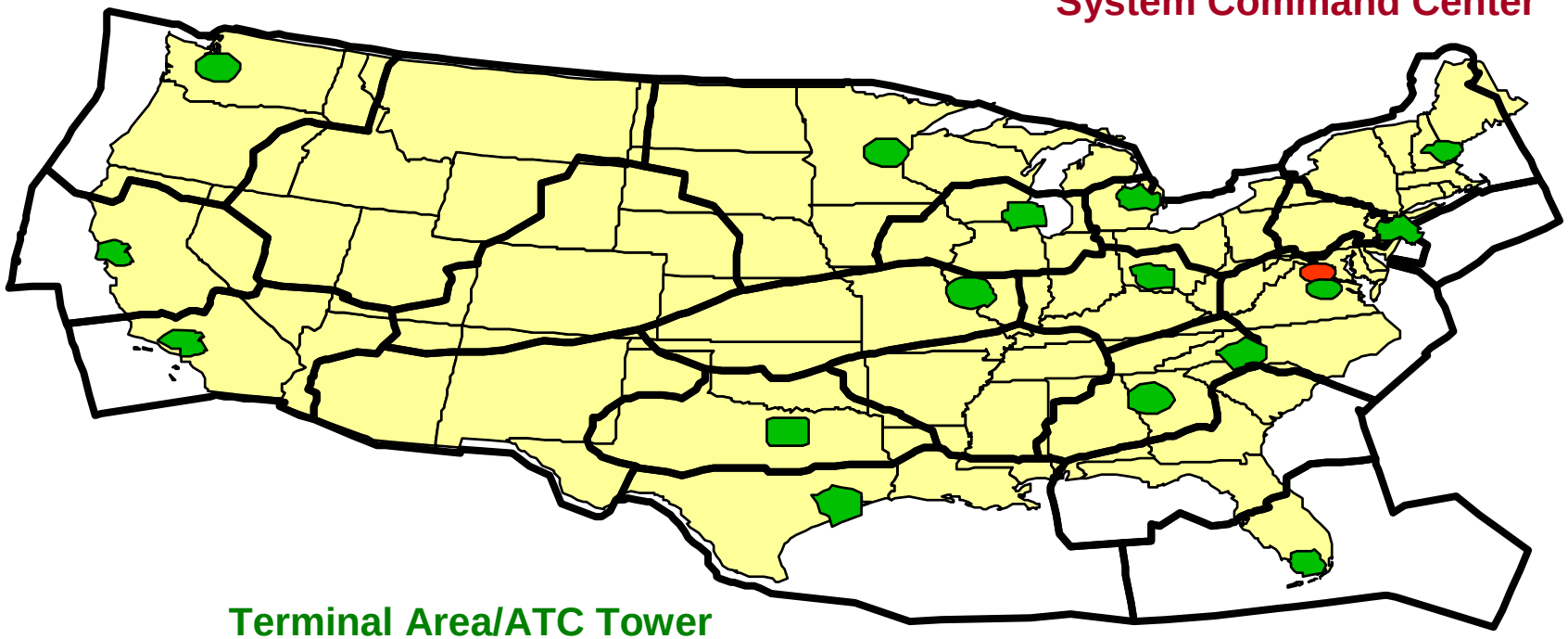
Traffic Management Facilities

Air Route Traffic Control Centers:
Traffic Management Units (TMUs)

Air Traffic Control System Command Center



Terminal Area/ATC Tower TMUs

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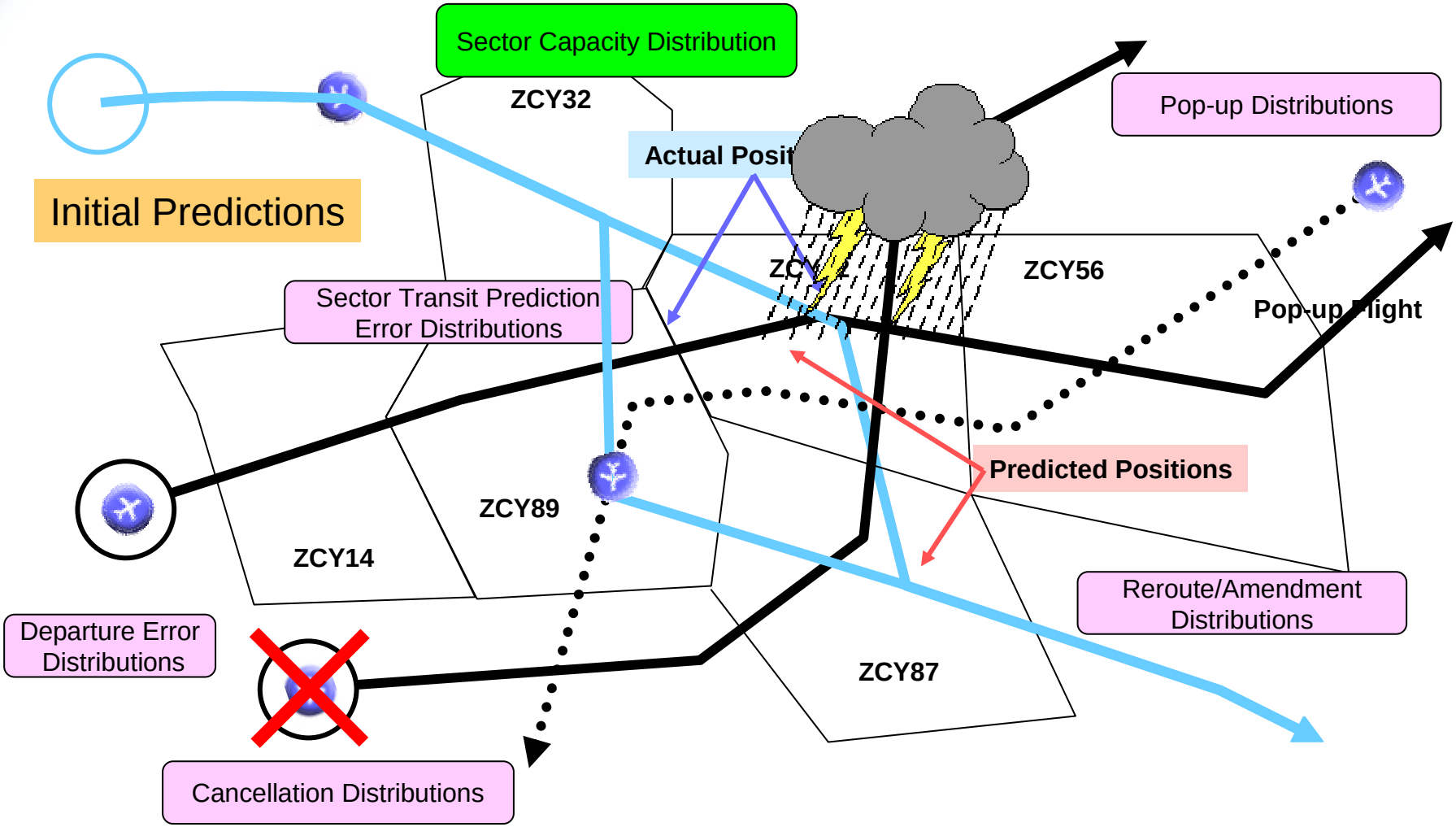
Predicting Sector Congestion: Sources of Uncertainty



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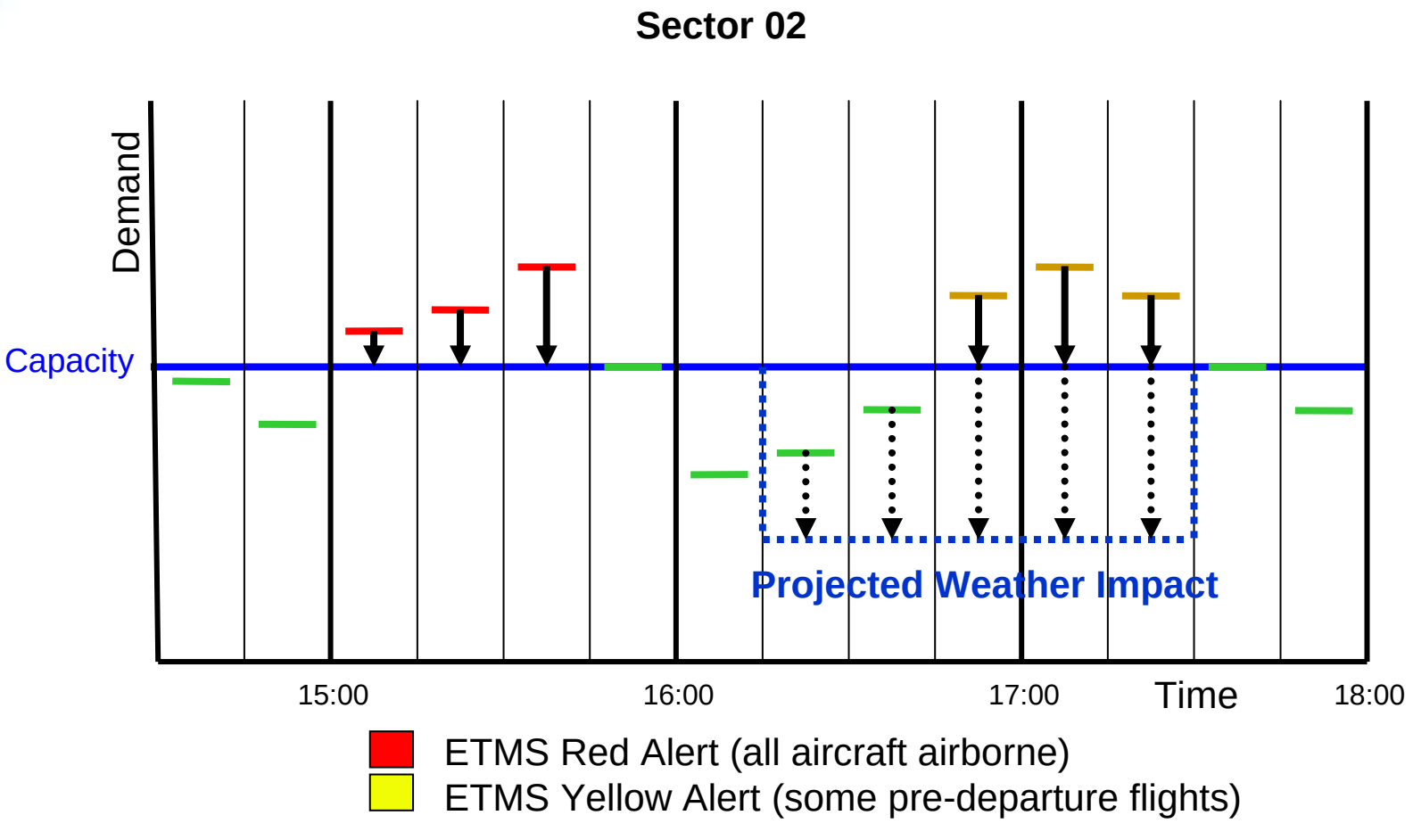
En Route TFM Today: Deterministic Congestion Management



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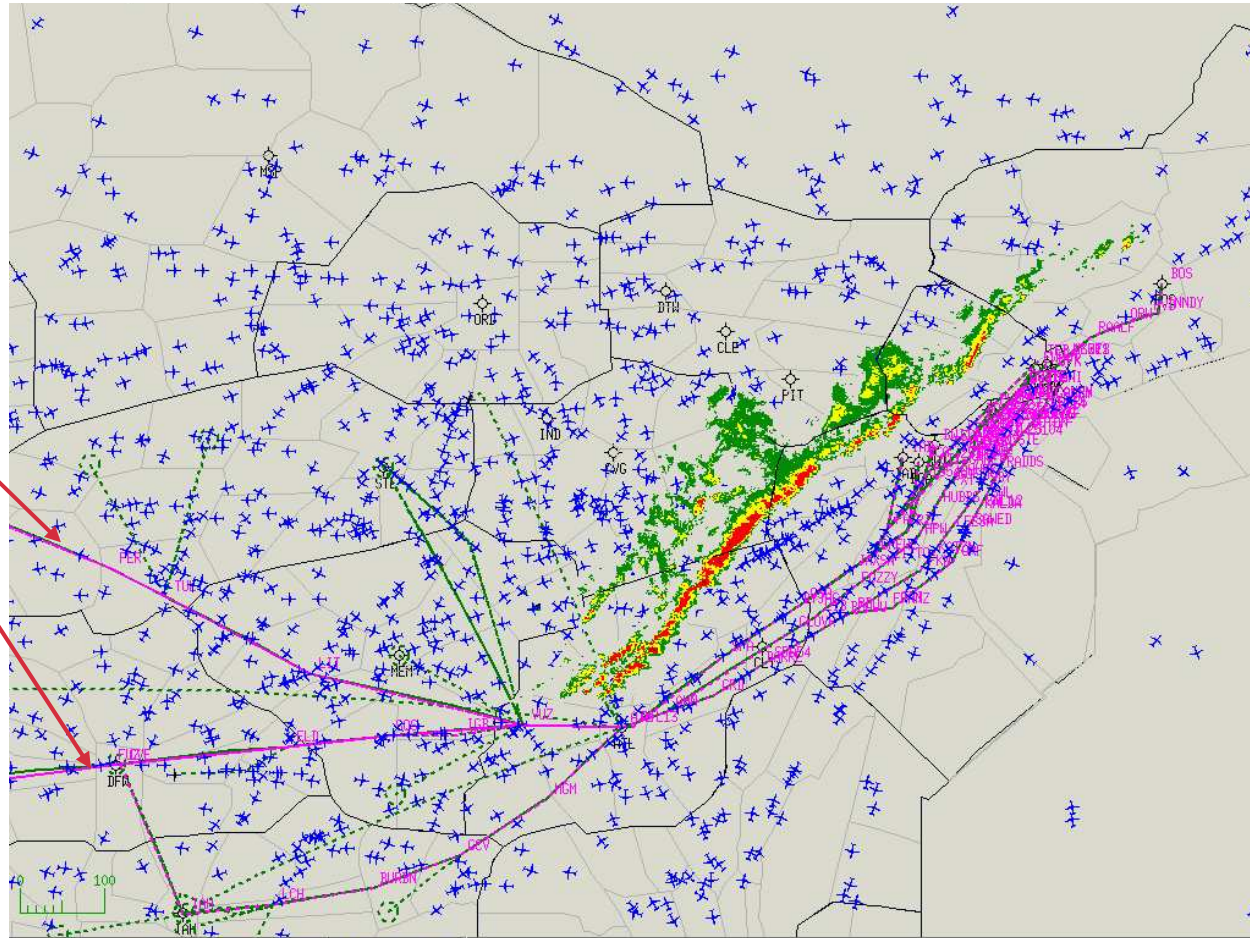
Today: Large-Scale Resolution Actions ("National Playbook")

Pre-defined routes of VUZ (Vulcan) Play



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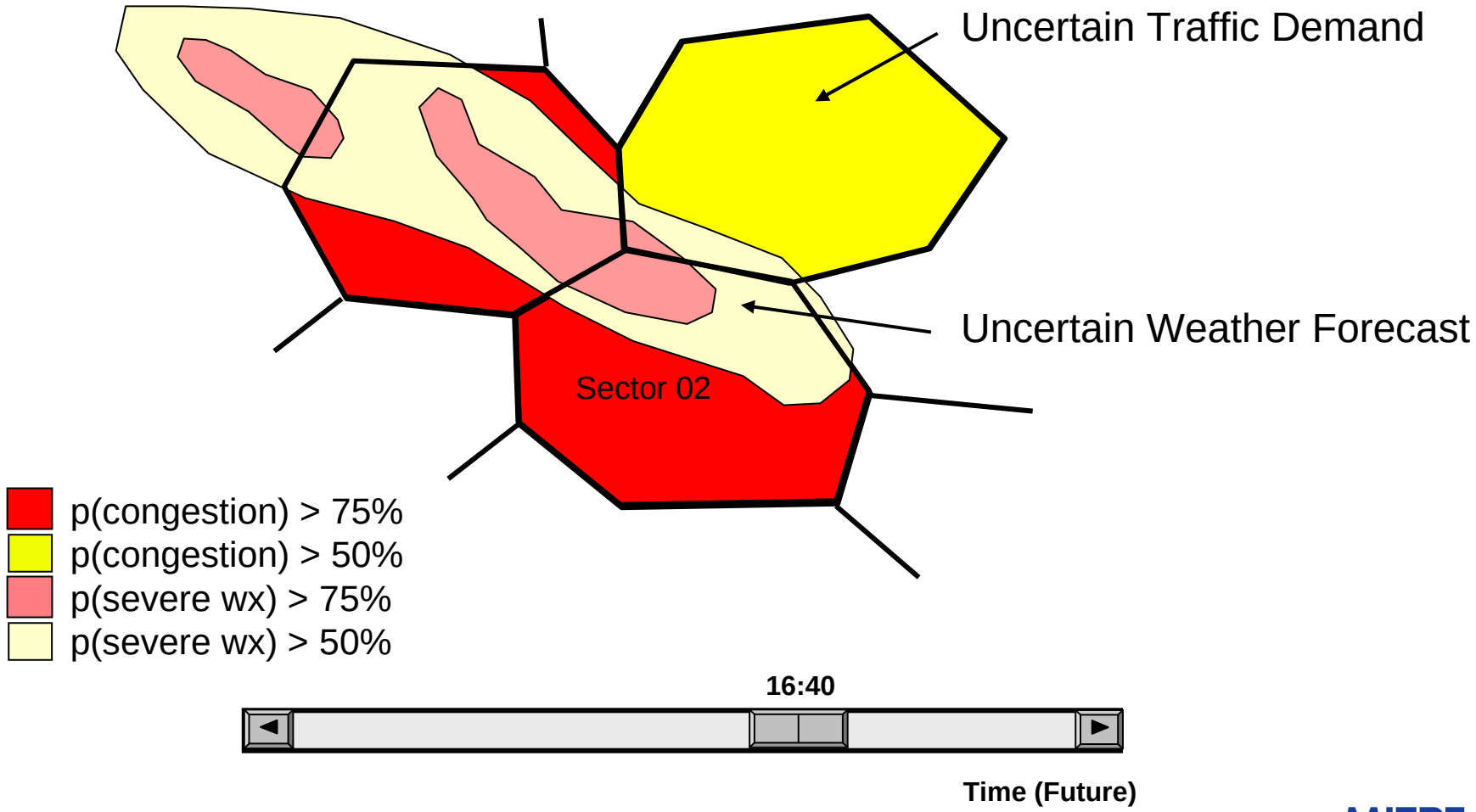
Future Sector Congestion Plan View



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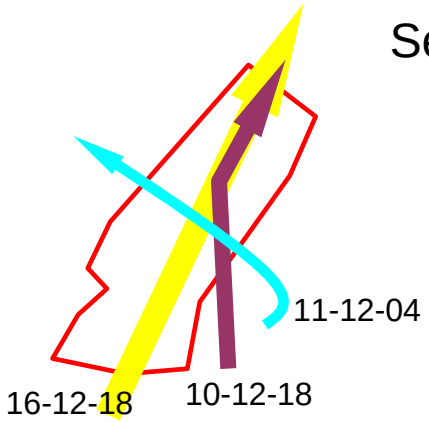
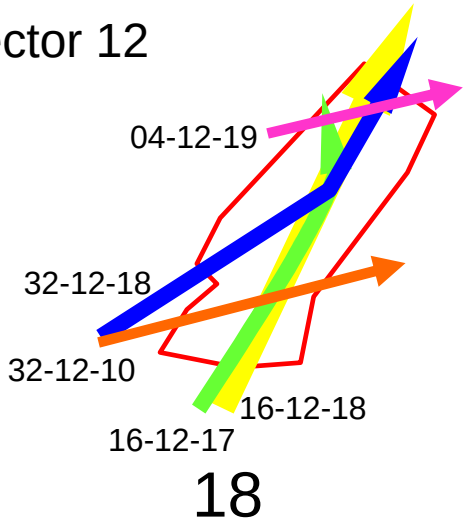
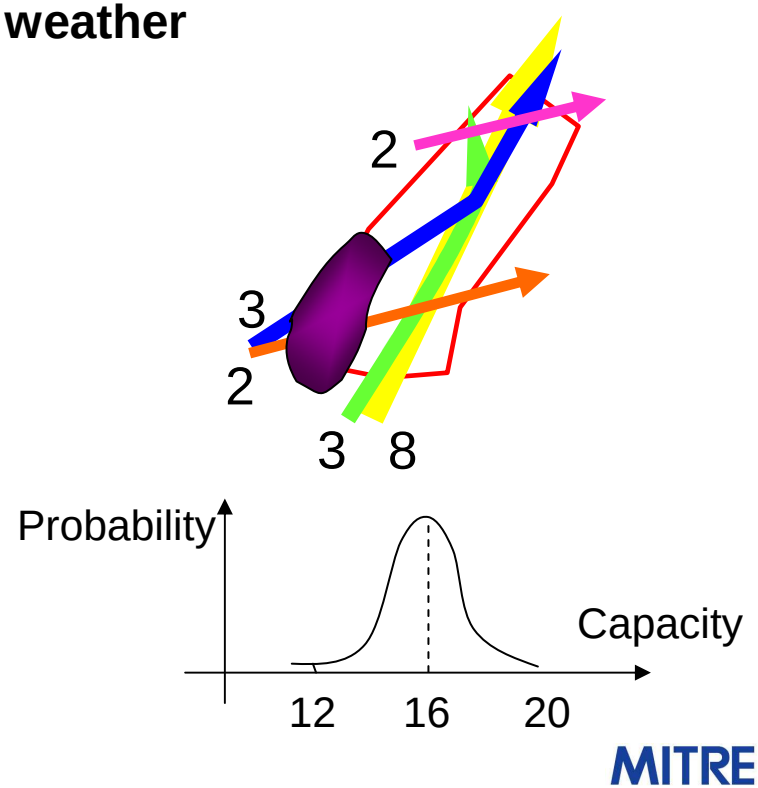
Sector Capacity is Complex and Uncertain

- **Need a better way to measure and predict capacity to support congestion management when considering uncertainty.**
  - **measure *flows* rather than *aircraft* considering the time frame and uncertainty involved in TFM**
  - **capture the impact of convective weather**







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