CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

Probabilistic Congestion Management

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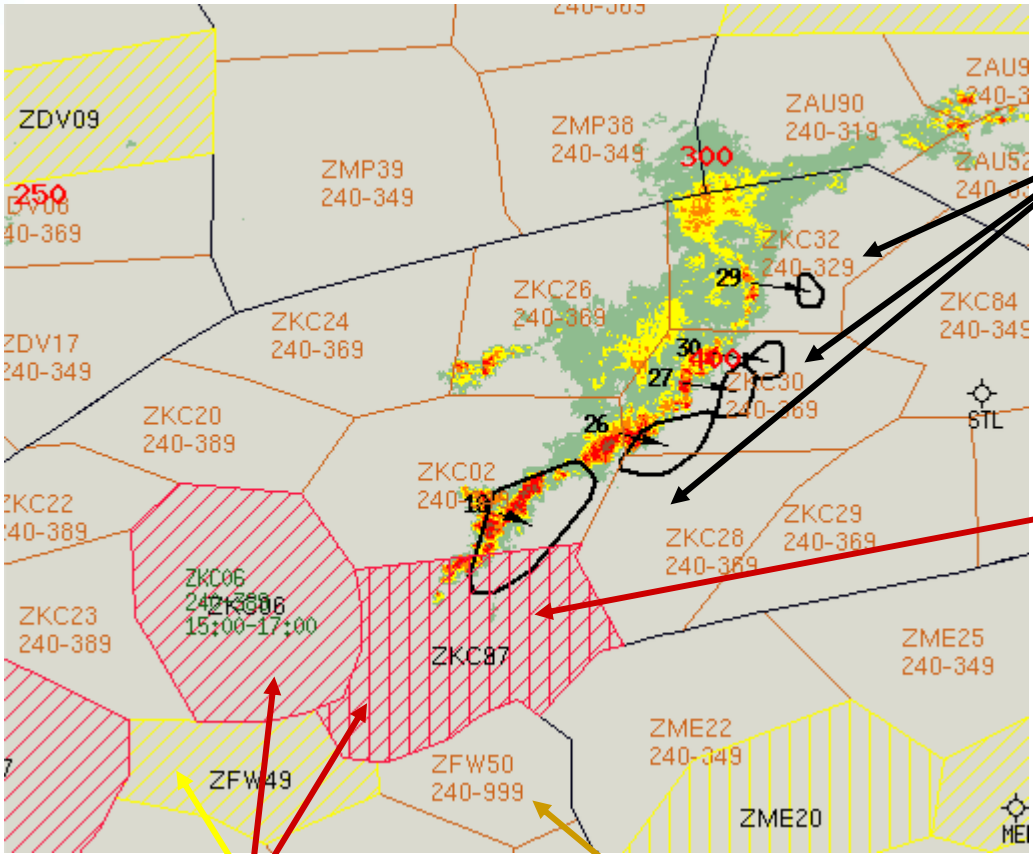
En Route Congestion



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?

Congestion Alerts

Air traffic control sector

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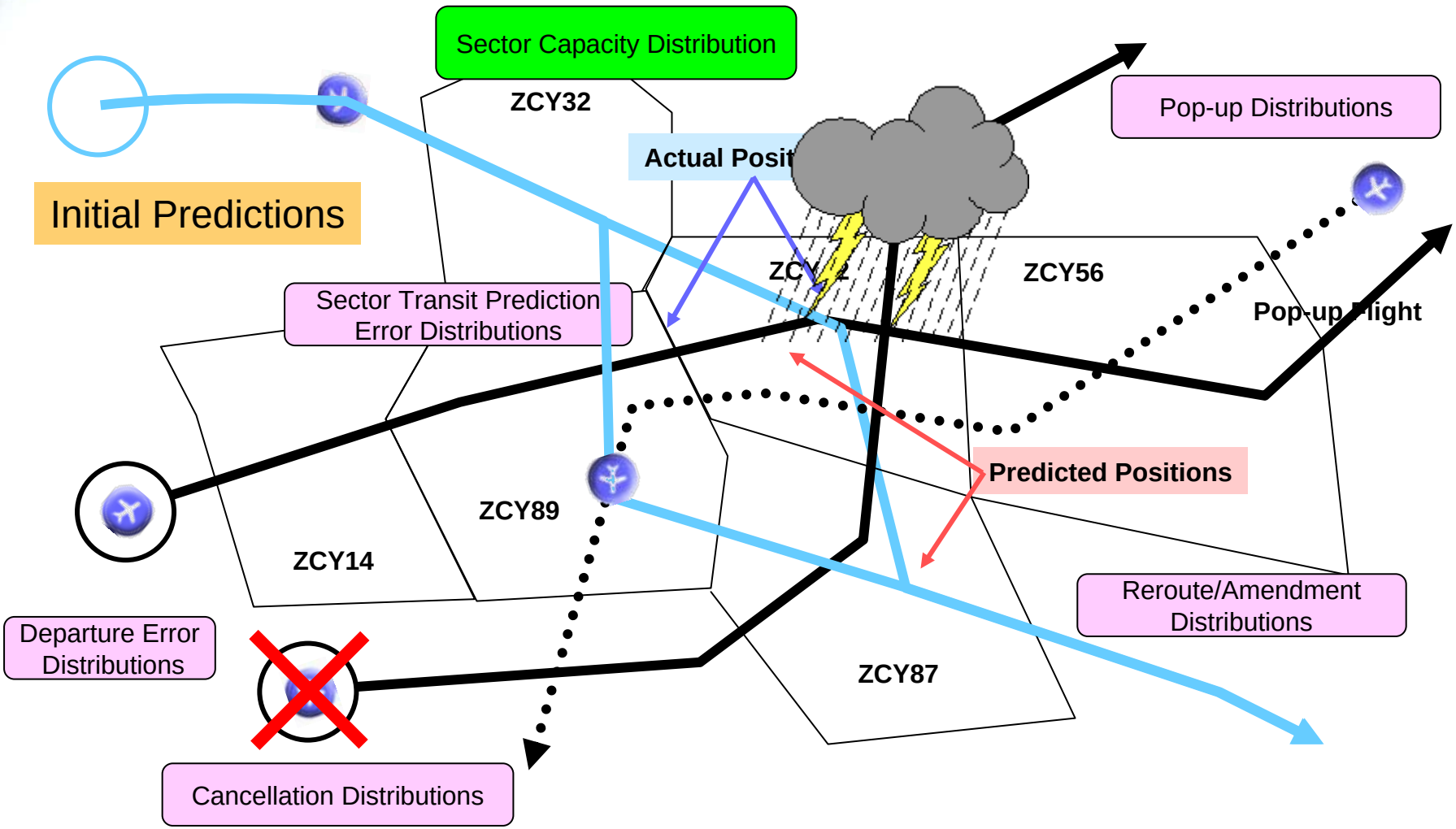
Predicting Sector Congestion: Sources of Uncertainty



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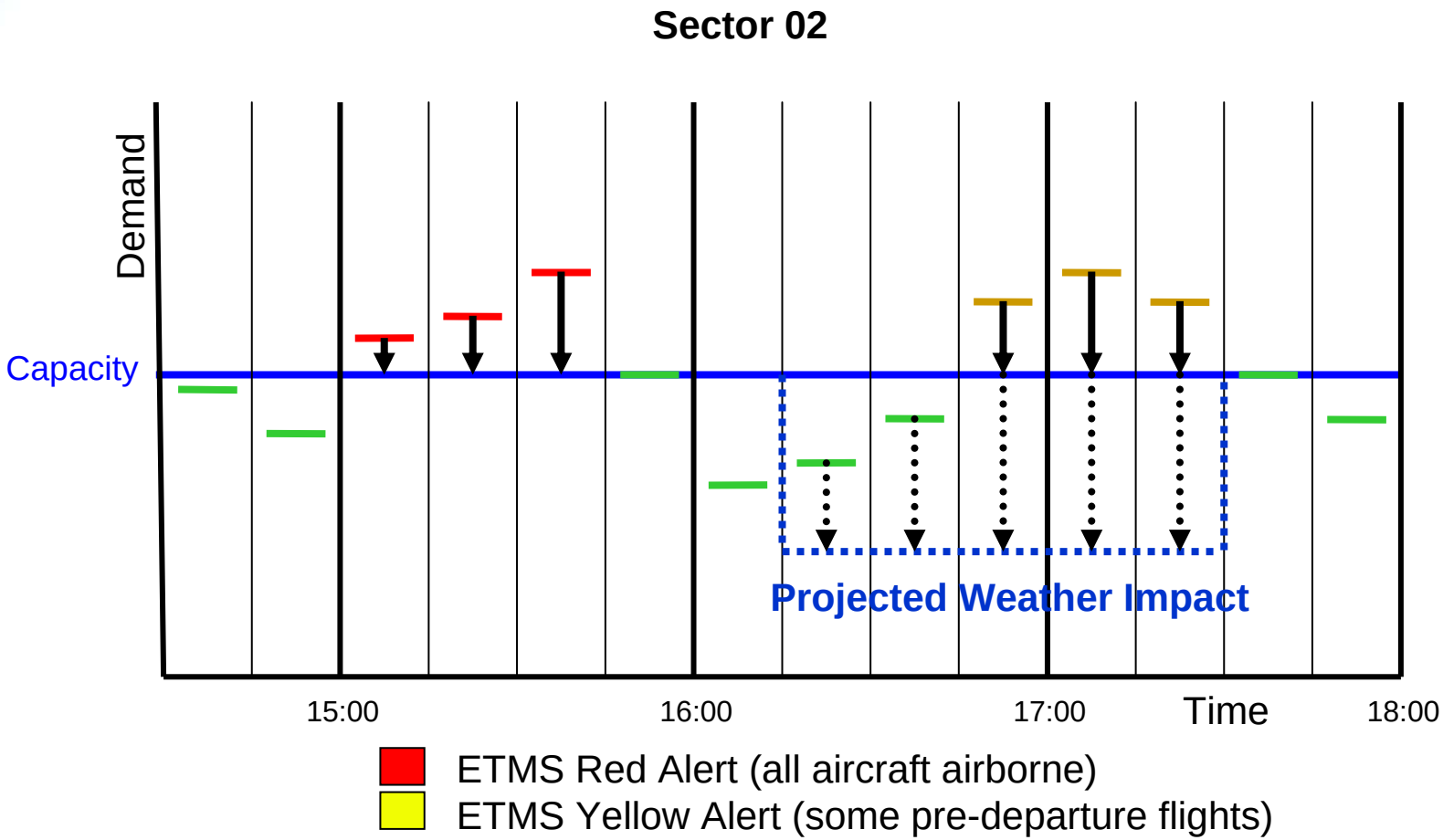
En Route TFM Today: Deterministic Congestion Management



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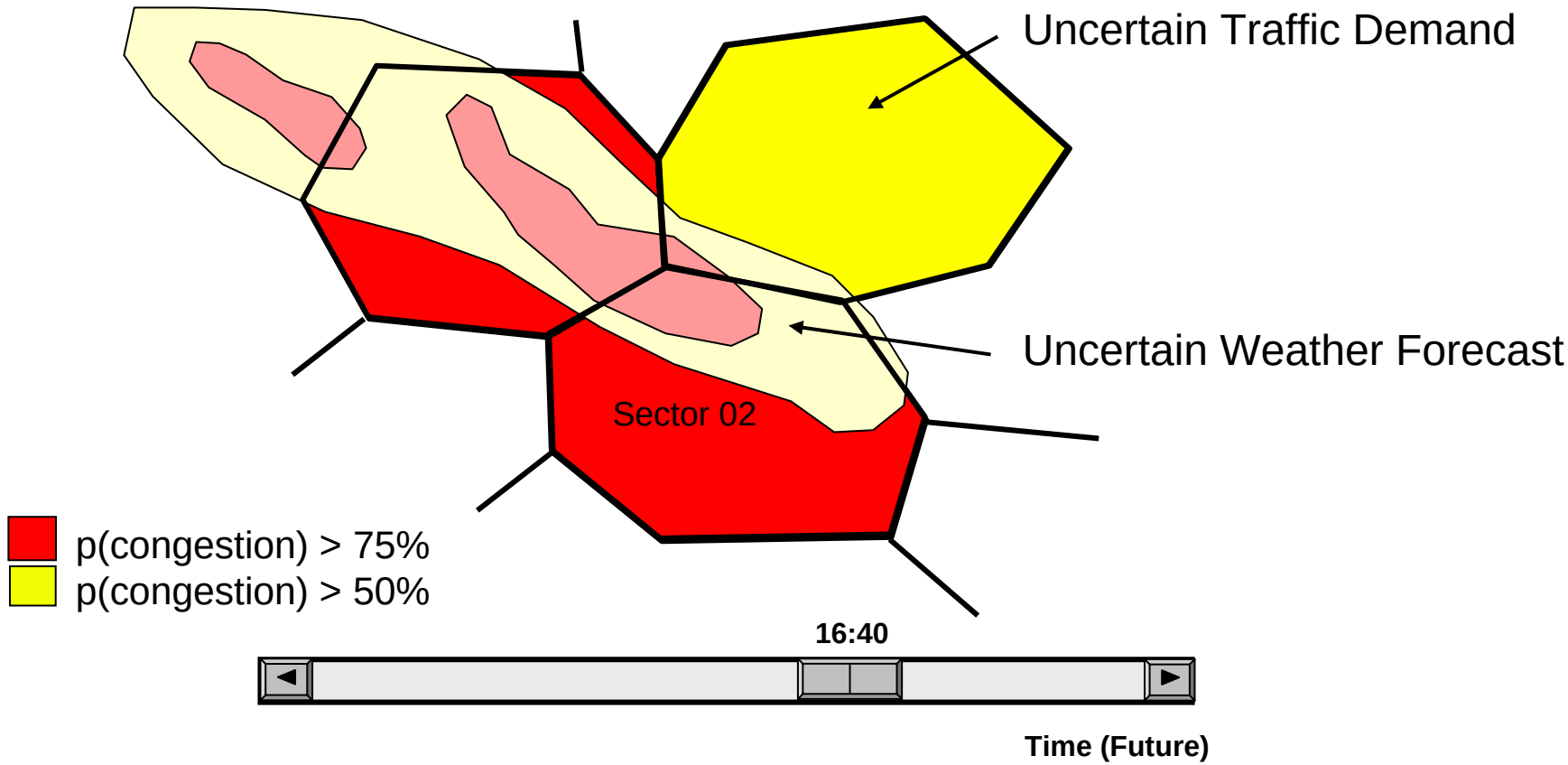
Future Sector Congestion Plan View



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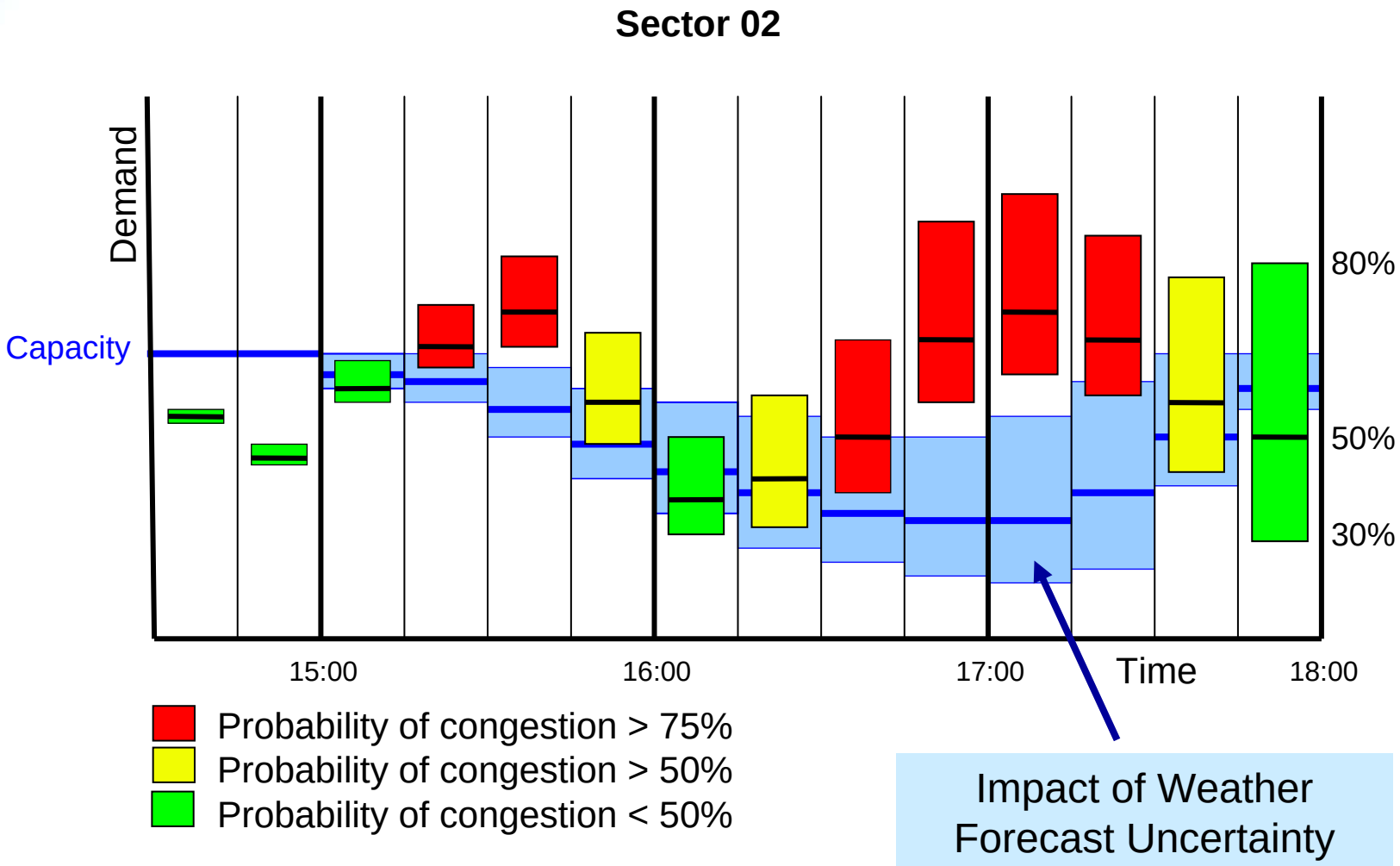
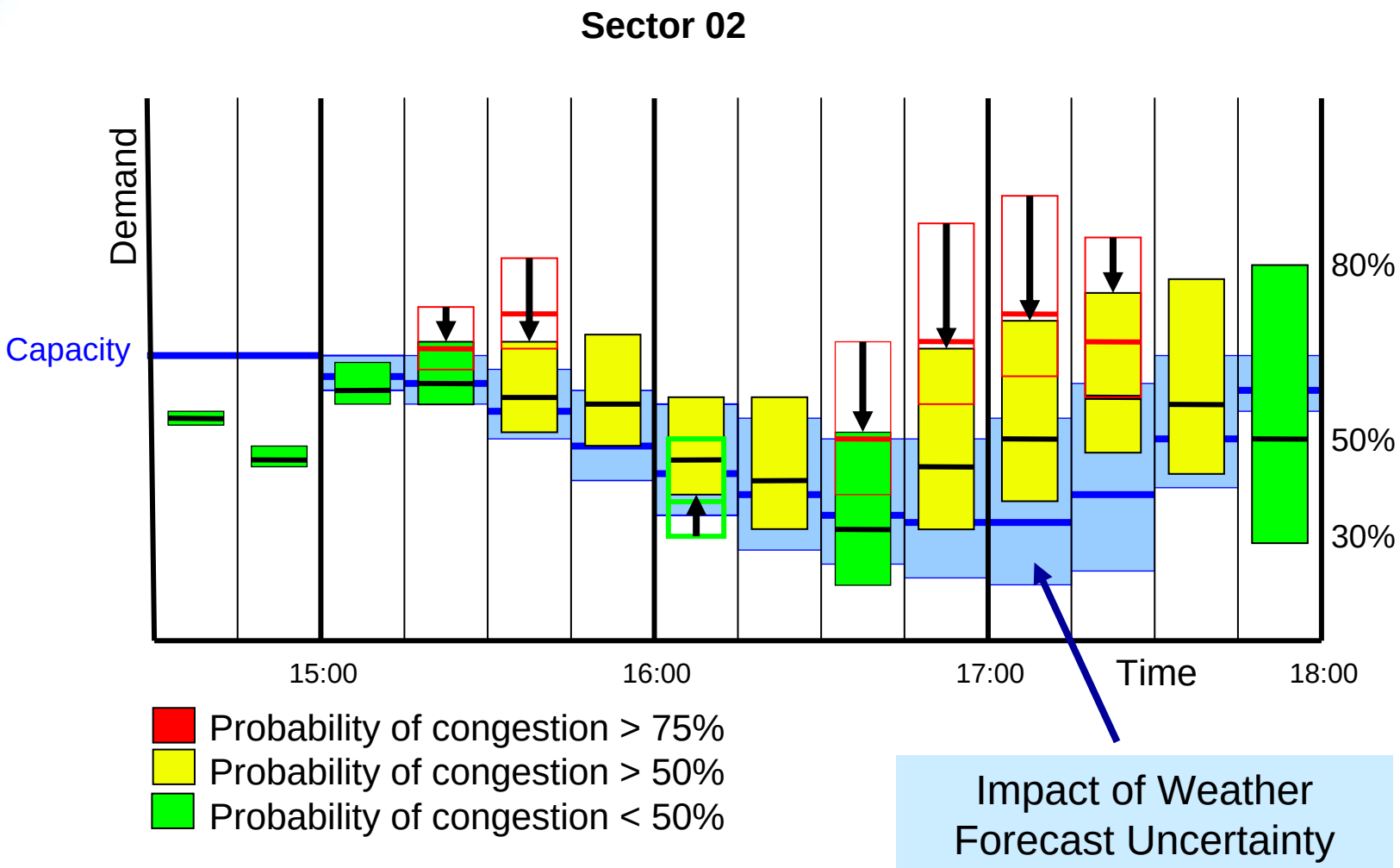
Probabilistic Future Sector Demand and Capacity Graph



Managing Congestion to an Acceptable Level of Risk (Probability)

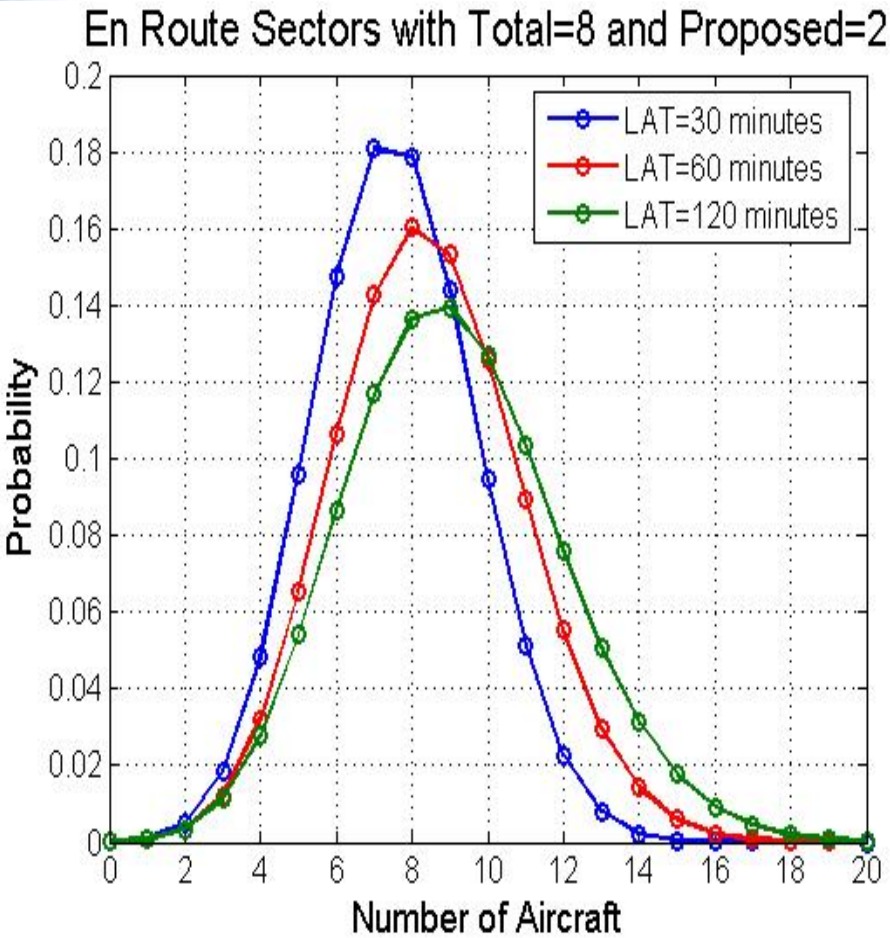


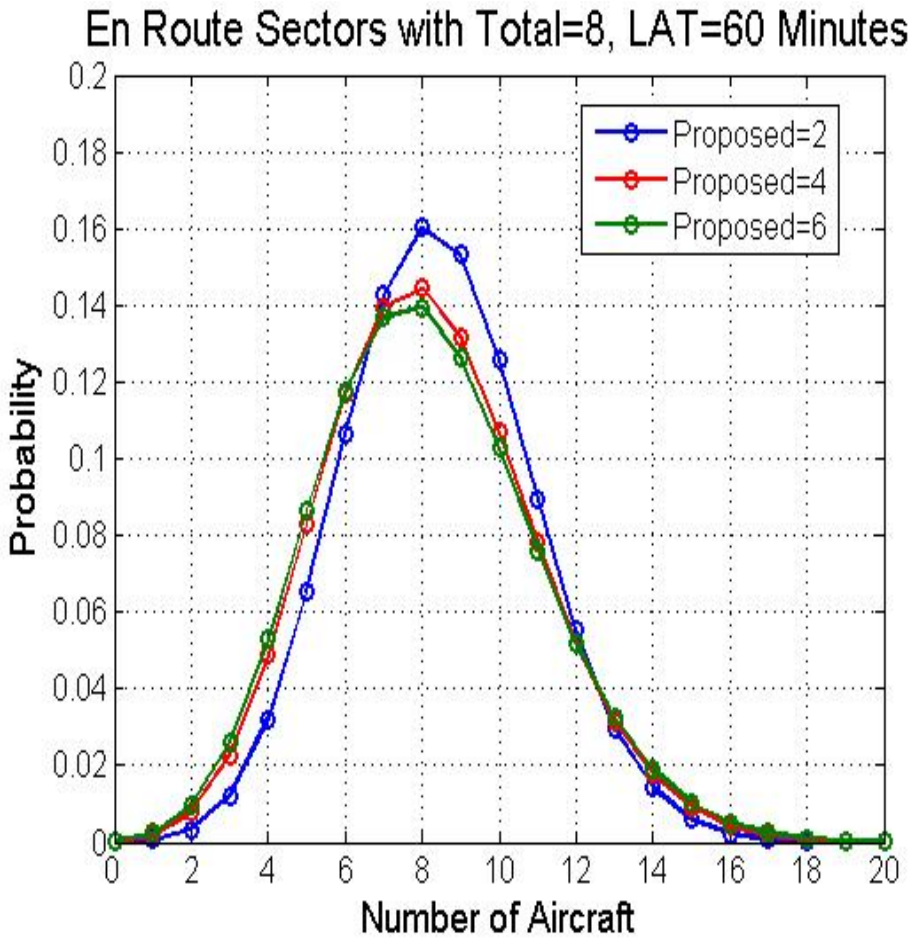
Forecasting Demand Uncertainty: Aggregate Model

- First approach: model variability in peak demand predictions
  - Based on empirical measurements under low traffic conditions
    - 6 months of observed predicted and actual peak counts
  - Statistical modeling based on critical factors:
    - Primary sector traffic type (departure, arrival, en route, mixed)
    - Baseline number of flights predicted (Total)
    - Number of those flights still on the ground (Proposed)
    - Look-Ahead Time (LAT)

- Model is composed of closed-form distributions with variable parameters (mean, standard deviation)
  - See paper for complete model details

Aggregate Demand Model Example





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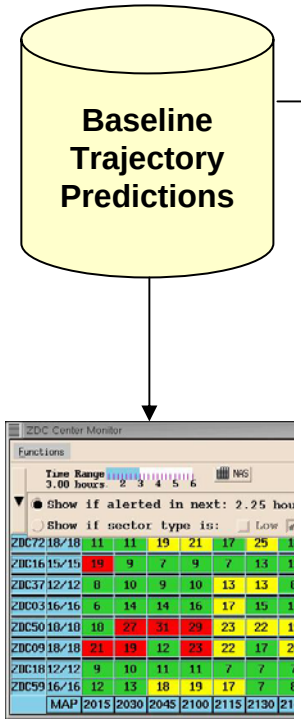
Applications and Limitations

- **Applications**
  - **Improved congestion displays, with prediction bias removed and better classification of alerts**
  - **Testing of automated congestion resolution algorithms – model is very fast to compute**
  - **Can be readily adjusted to reflect changing traffic characteristics**
- **Limitations**
  - **Not aircraft-specific**
  - **Not sector-specific**

- **A more detailed model is being developed.**

Monte-Carlo Simulation Model



Deterministic Sector Demand Predictions

Baseline Trajectory Predictions

One Monte-Carlo Simulation Trial:

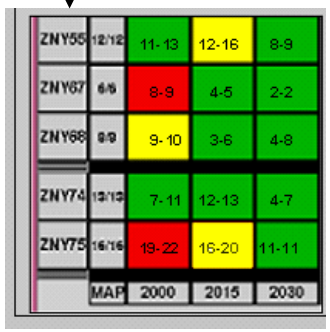
- Remove "no-shows"
- Apply unanticipated routing and altitude changes
- Apply departure prediction errors
- Apply sector transit prediction errors
- Add "pop-ups"

New set of predicted trajectories, with uncertainties applied

"N" simulation trials…

Calculate Statistics

Probabilistic Sector Demand Predictions



Probabilistic Displays, Decision Analysis, Real-Time DS Automation, …

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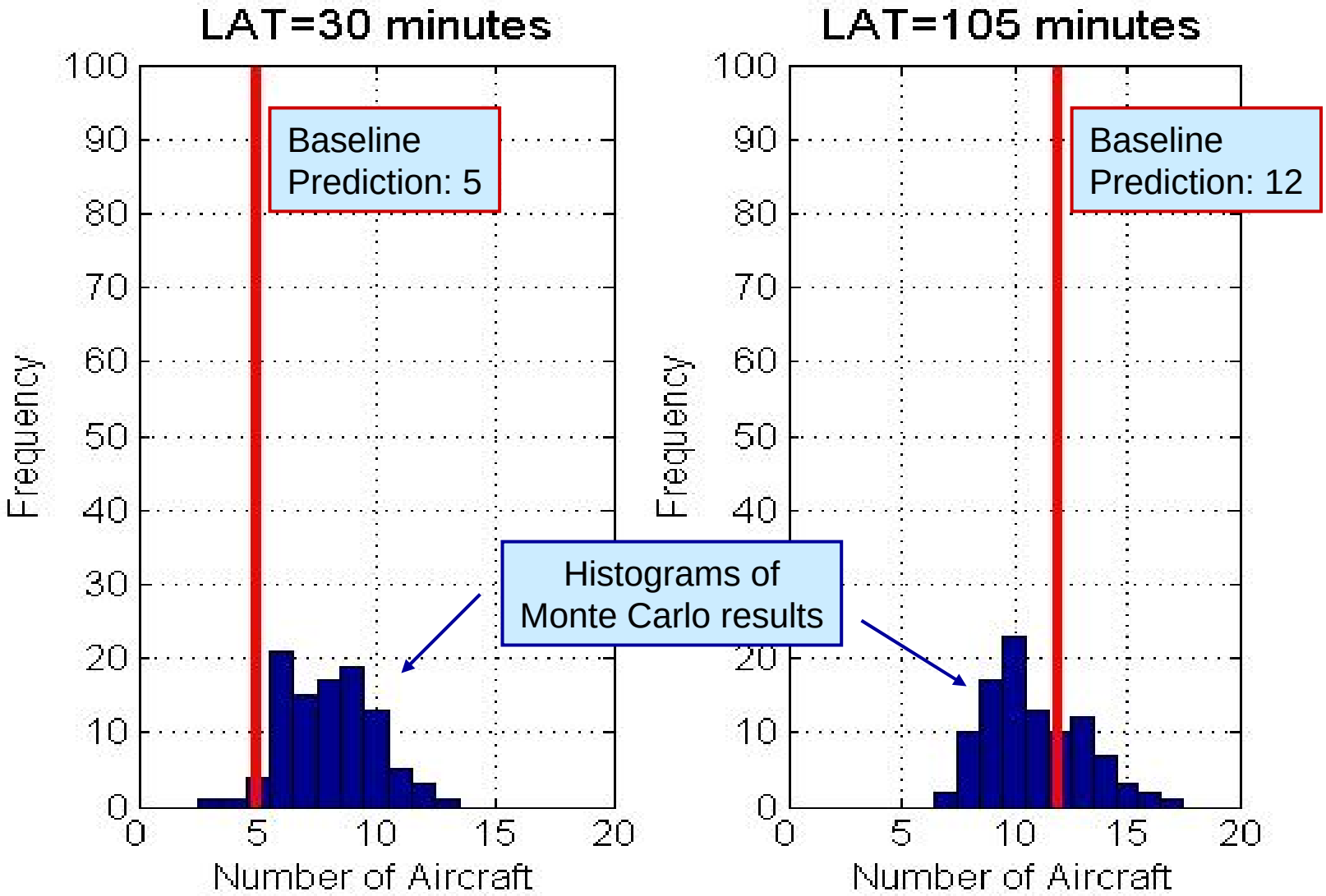
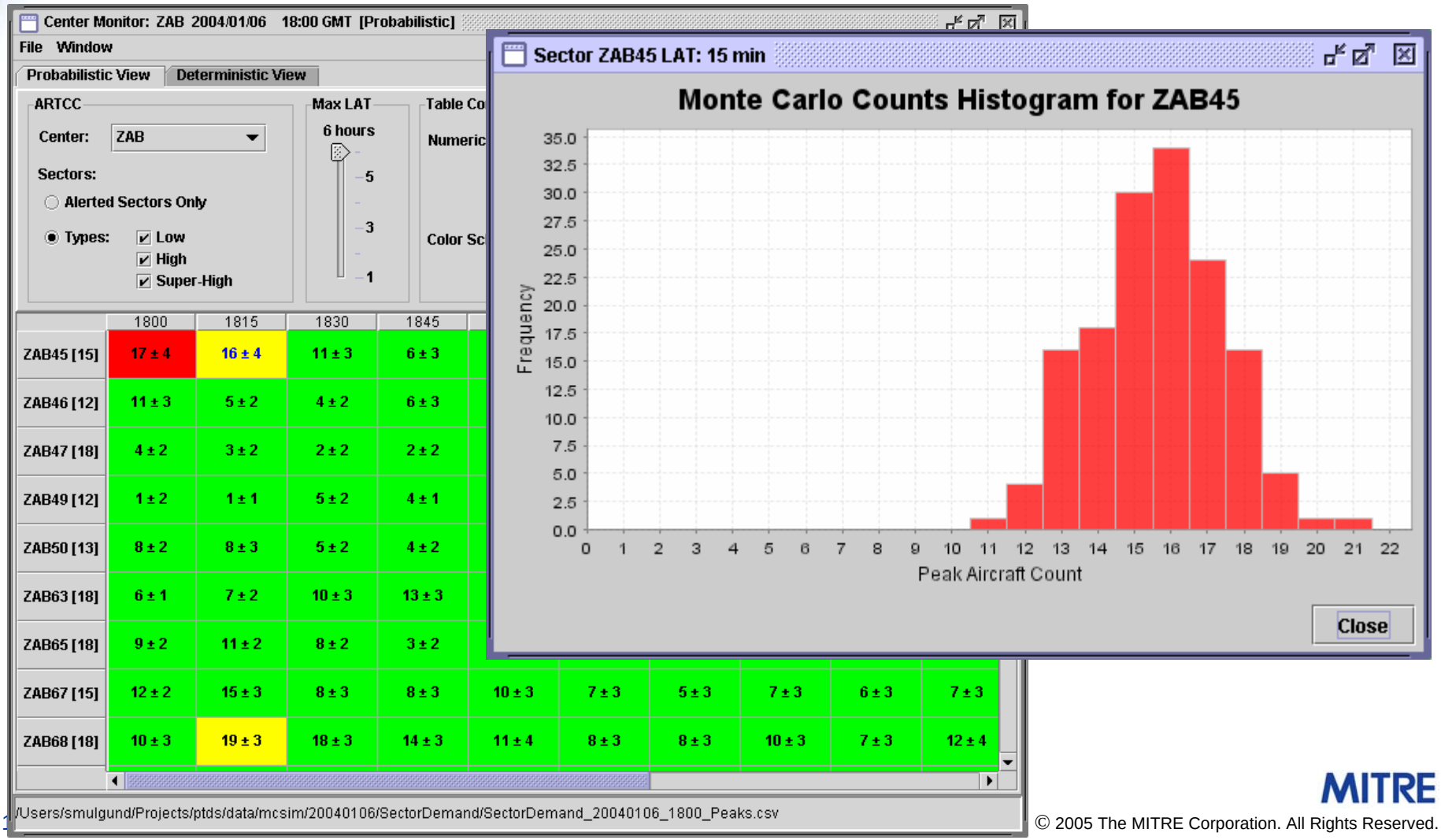
Example Results: En Route Sector - Two Prediction Horizons

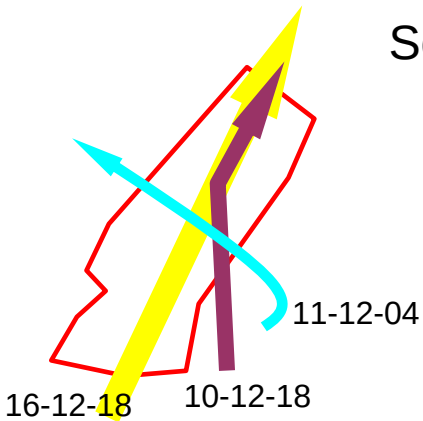


Displaying Traffic Demand Uncertainty



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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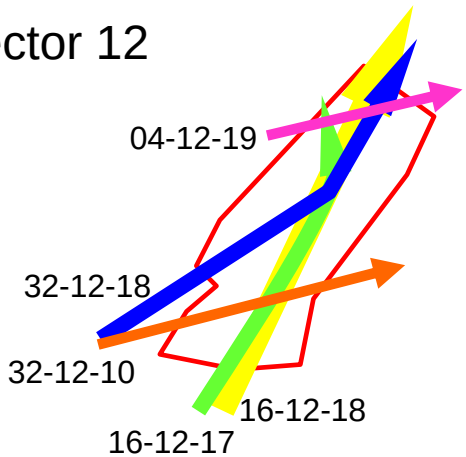
Sector 12



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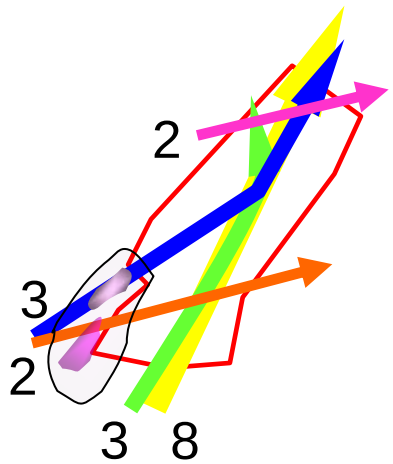

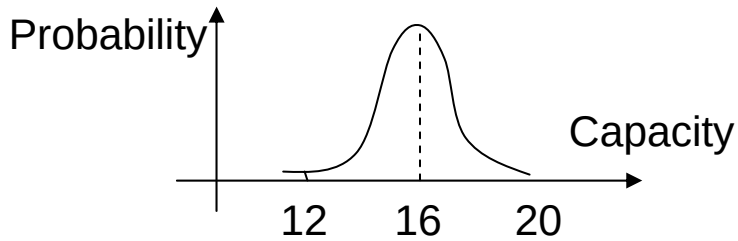

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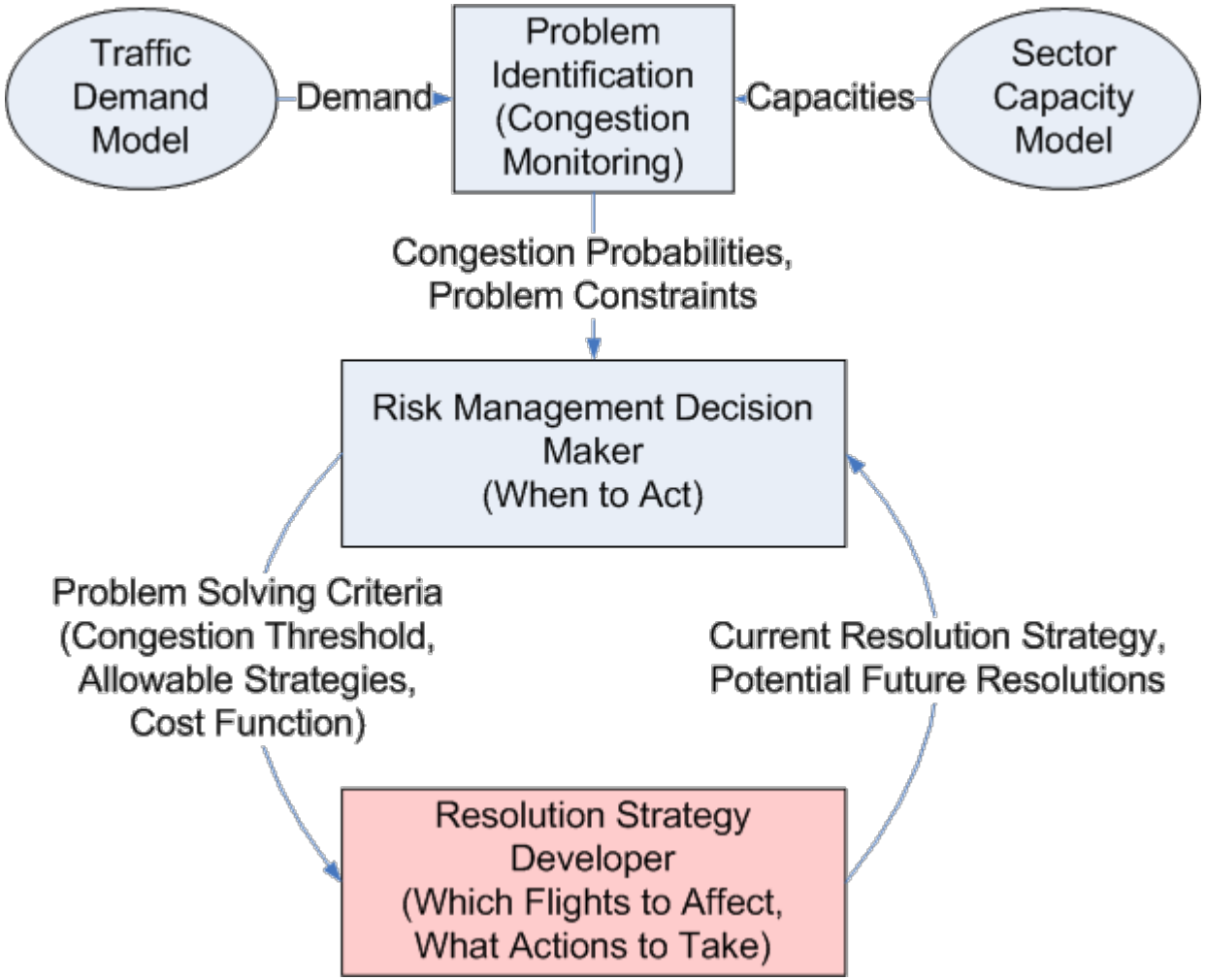
Applying Probabilistic Forecasts: Risk Management Decision Loop



Conclusion

- **En route congestion management in the U.S. today is highly manual and very conservative, due to uncertainty.**
  - **This is a major roadblock to anticipated air traffic demand growth.**
- **The concept proposed here can address this need**
  - **Uncertainty is explicitly used**
  - **Targeted, incremental solutions are recommended**

- **Much work remains!**
  - **Initial resolution algorithms have been prototyped, based on initial demand uncertainty model**
  - **Sector capacity prediction model is not yet complete**
  - **NAS user collaboration modes are still being explored**
  - **Major human factors issues must be addressed**