Friends and Partners in Aviation Weather

A Day In the life of the

Aviation System

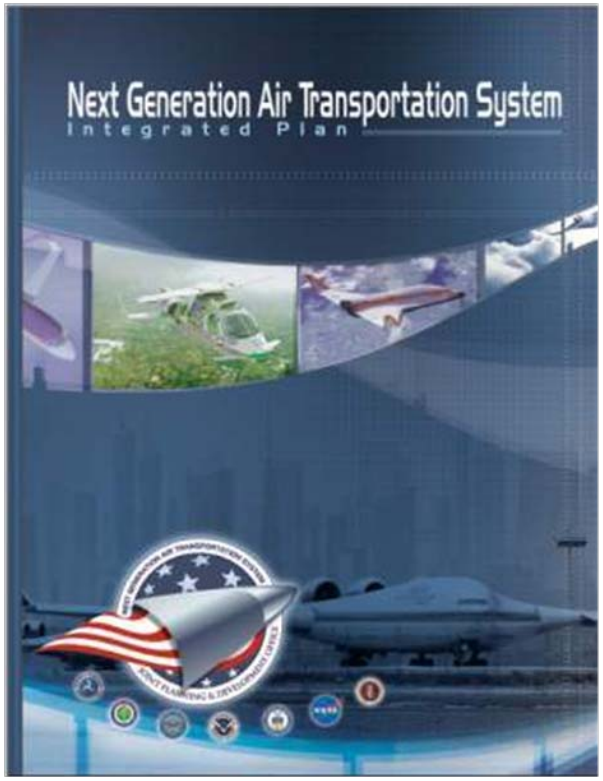
Under

NextGen

July 2008

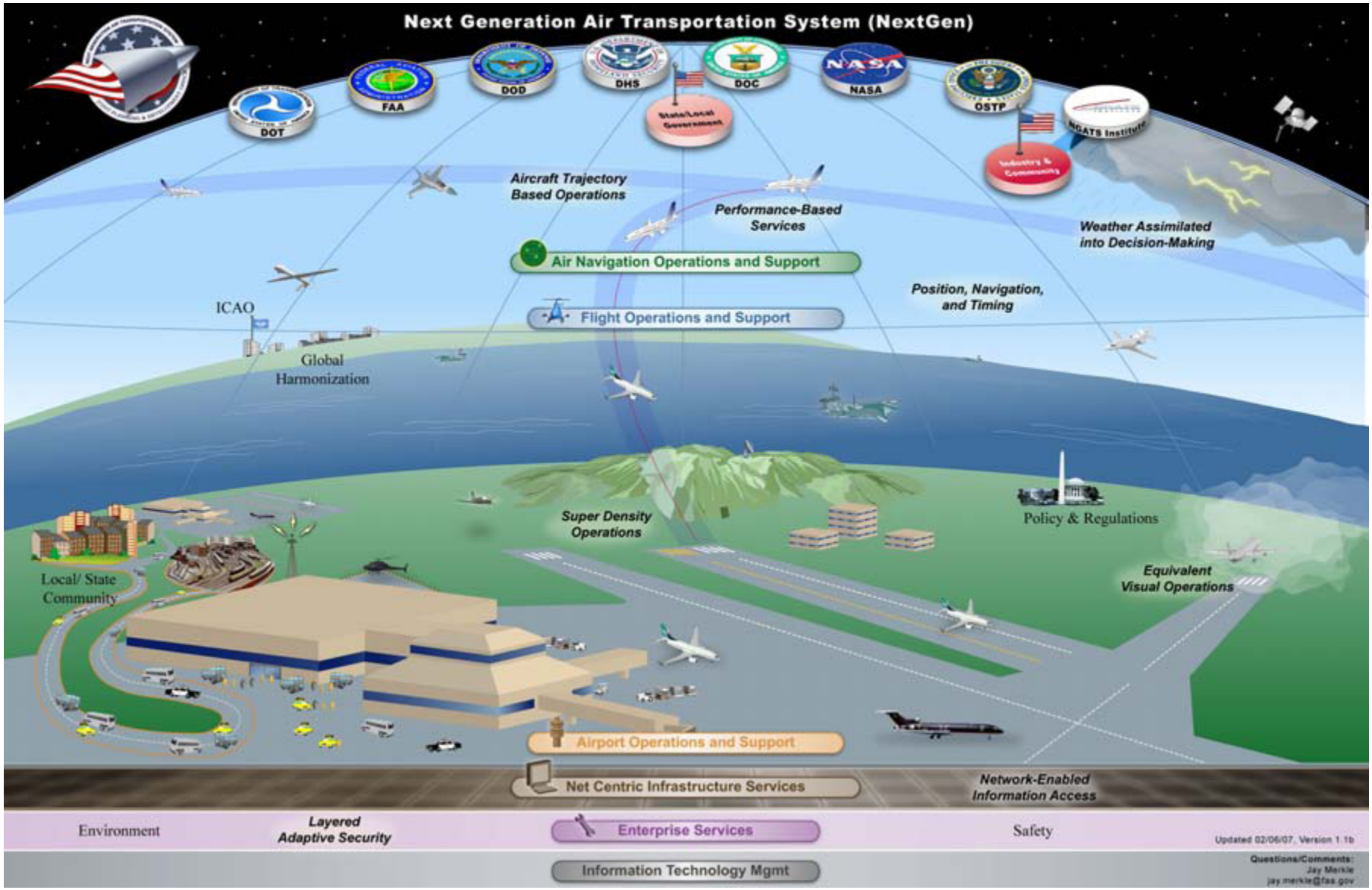
Bill Leber

The Next Generation Air Transportation System (NextGen) Plan Defines A System That Can Meet Demands For The 21st Century



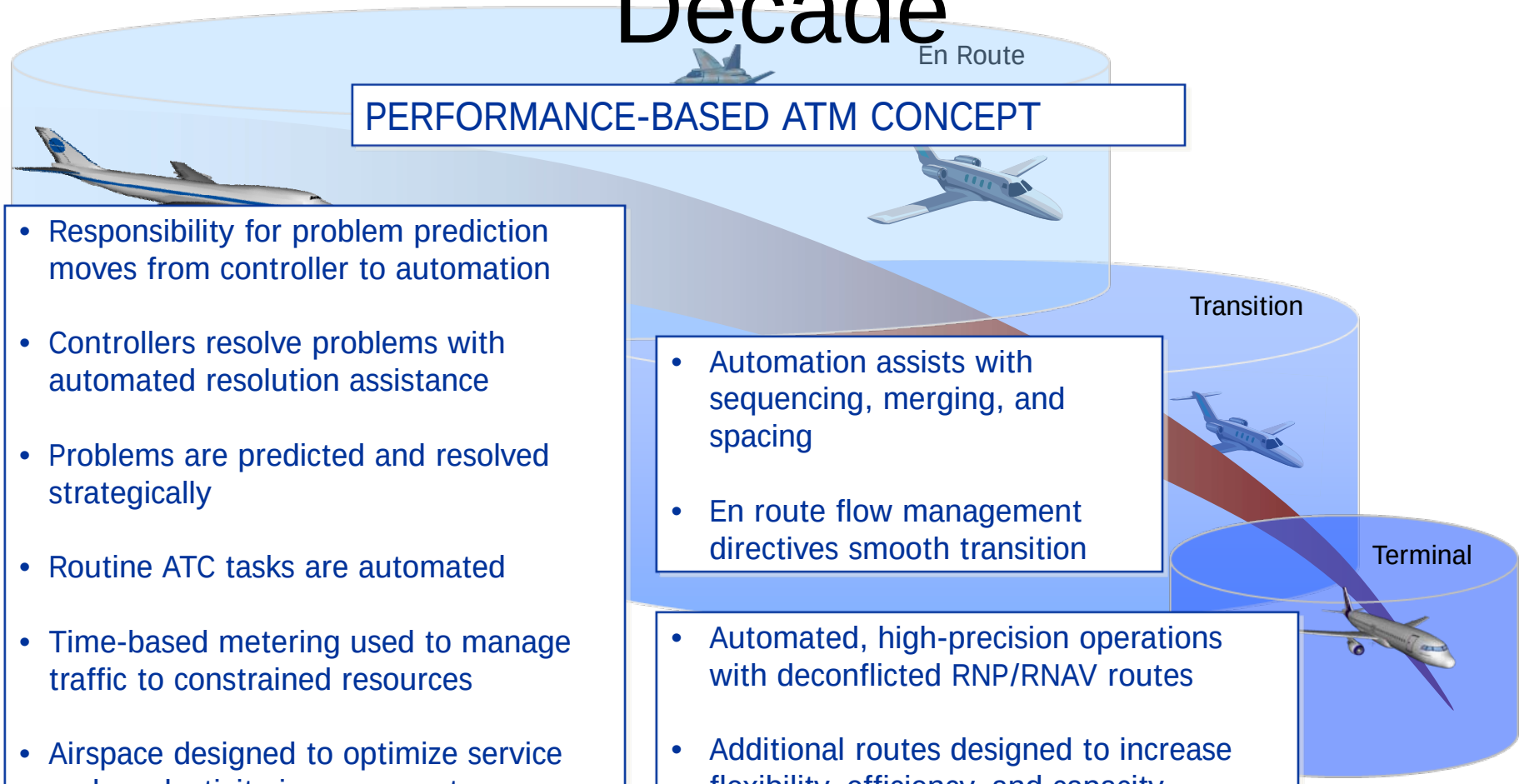
Capabilities

- **Trajectory-Based Operations**
- **Performance-Based Operations and Services**
- ***Precision Navigation***
- **Weather Integration**
- **Network-Centric Information Sharing**
- **Surveillance Services**
- **Equivalent Visual Operations**
- **Super Density Operations**
- **Layered, Adaptive Security**


Next Generation Air Transportation System (NextGen)
DOT
FAA
DOD
DHS
DOC
NASA
OSTP
State/Local Government
NGATS Institute
Industry & Community
Aircraft Trajectory Based Operations
Performance-Based Services
Weather Assimilated into Decision-Making
Air Navigation Operations and Support
Position, Navigation, and Timing
Flight Operations and Support
ICAO
Global Harmonization
Super Density Operations
Policy & Regulations
Local/ State Community
Equivalent Visual Operations
Airport Operations and Support
Net Centric Infrastructure Services
Network-Enabled Information Access
Environment
Layered Adaptive Security
Enterprise Services
Safety
Information Technology Mgmt
Updated 02/06/07, Version 1.1b
Questions/Comments:
Jay Merkle
jay.merkle@faa.gov

Responding to the Challenges

An Outlook for the Next Decade



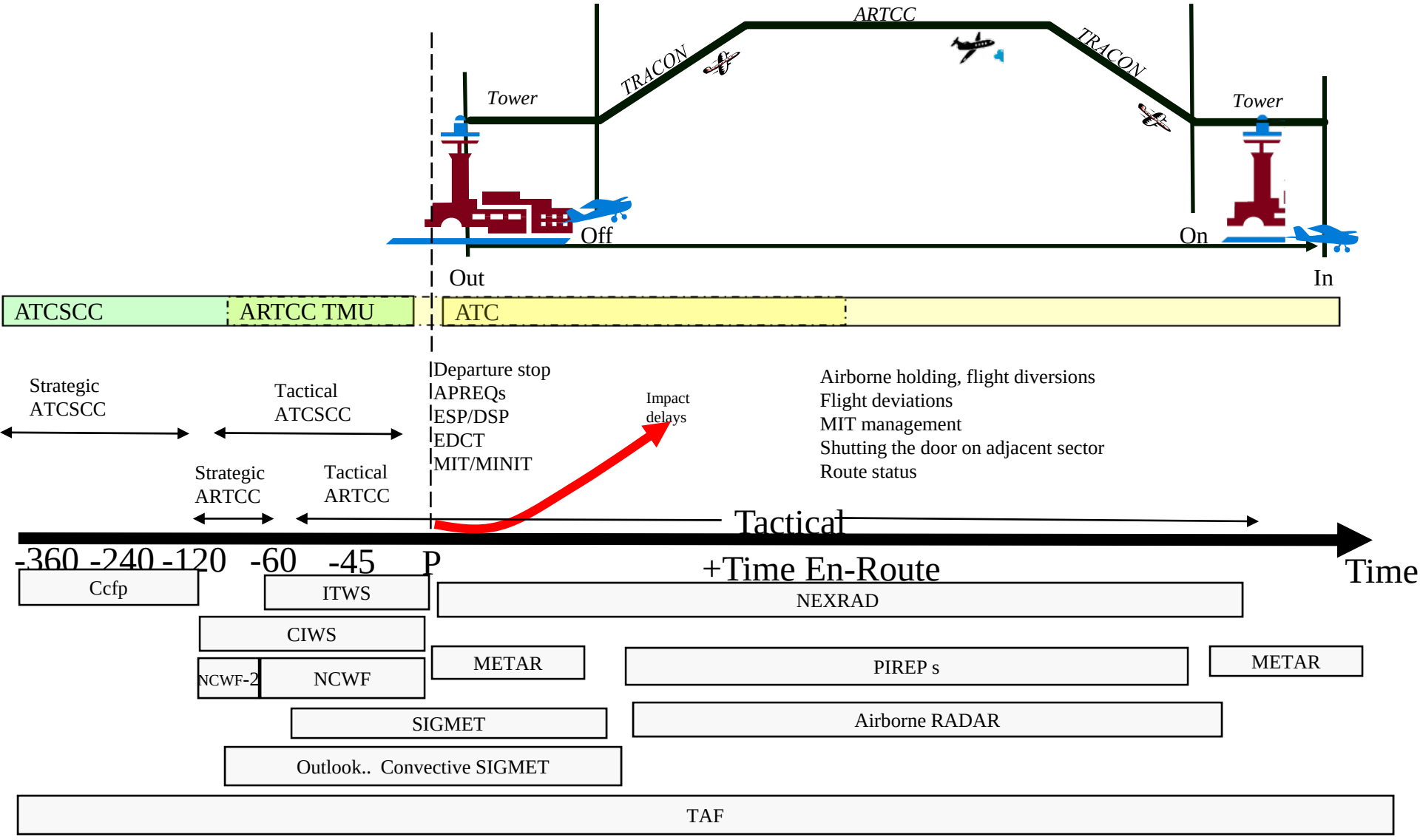
PERFORMANCE-BASED ATM CONCEPT

- Responsibility for problem prediction moves from controller to automation
- Controllers resolve problems with automated resolution assistance
- Problems are predicted and resolved strategically
- Routine ATC tasks are automated
- Time-based metering used to manage traffic to constrained resources
- Airspace designed to optimize service and productivity improvements

- Automation assists with sequencing, merging, and spacing
- En route flow management directives smooth transition

- Automated, high-precision operations with deconflicted RNP/RNAV routes
- Additional routes designed to increase flexibility, efficiency, and capacity

Decision-Making Time Horizons
Strategic vs Tactical



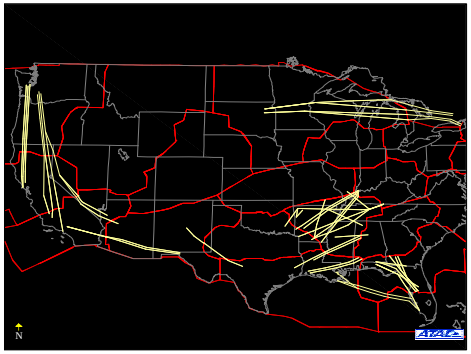
Airspace is the Foundation to the Future

Near-term ***2015-2020 NextGen Foundation Projects*** ***NextGen***

- **Effectively *APPLY* the solutions that we have available today**
- ***EXPEDITE* the most promising and cost-effective solutions of the future**

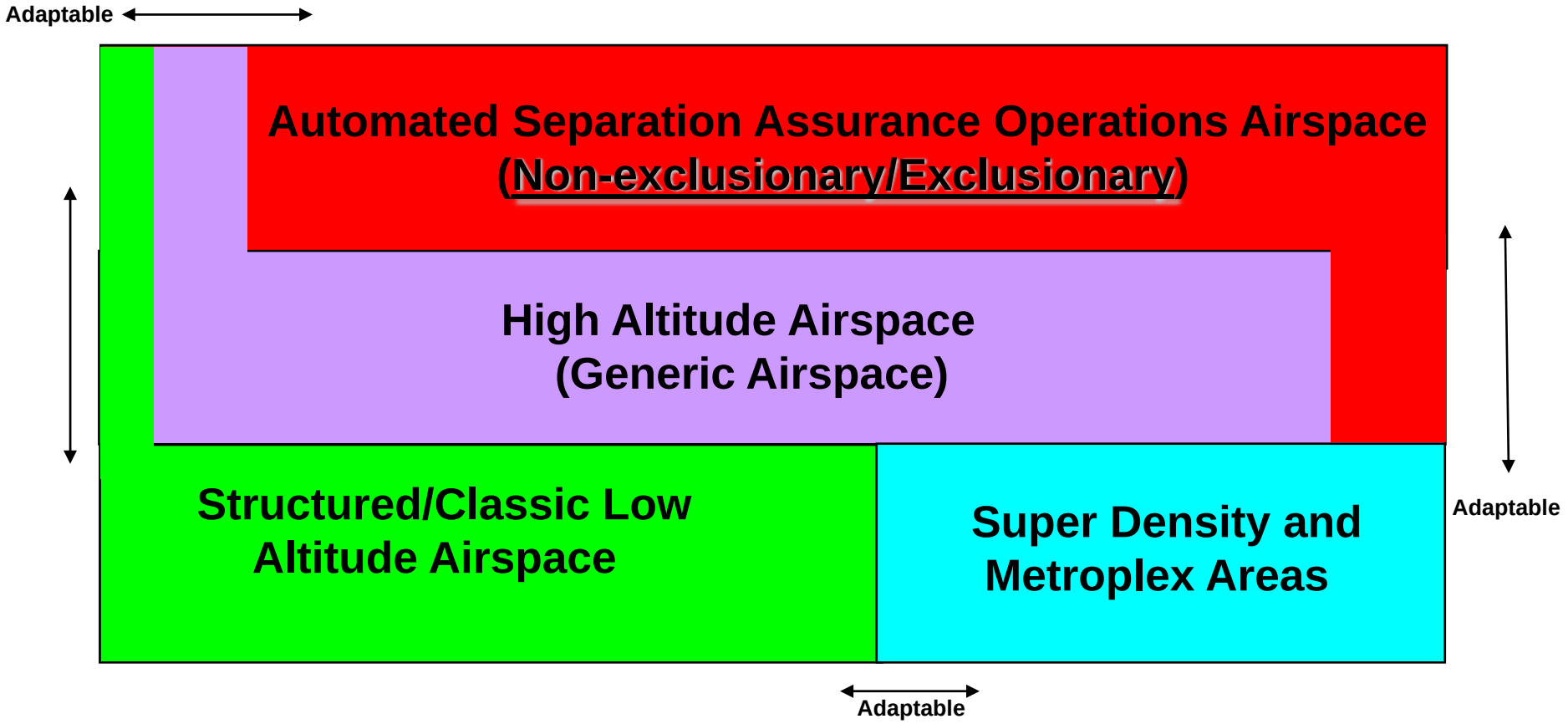
FILL THE OPERATIONAL GAP

- **Move from individual RNAV/RNP routes to large scale, networked implementation**
- **Airspace design balancing operational, resource, security needs**
- **Agile and adaptive airspace structure**
- **Align airspace to function instead of geography**



Airspace Configuration Concept

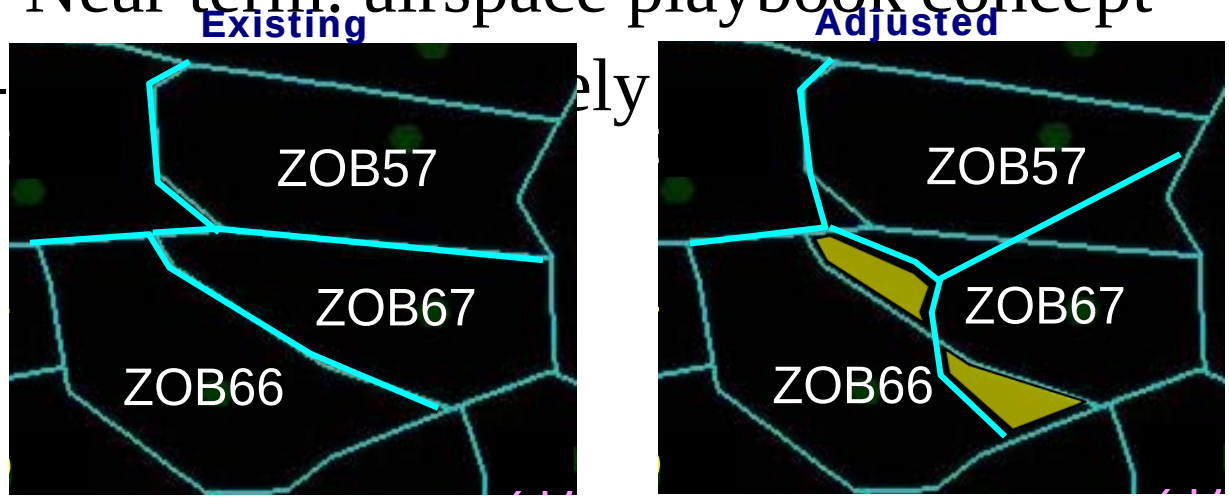
Provide flexibility where possible and structure where needed



Exact boundaries will depend on the equipped aircraft and traffic density

Adaptable Airspace

- En route congestion problem
- Structure and boundaries change based on traffic demand
  - Near term: airspace playbook concept
  - –ely

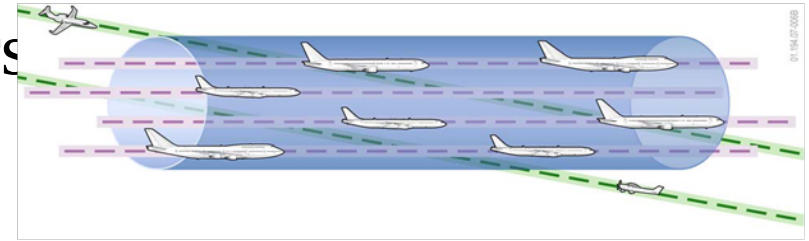


Research Issues

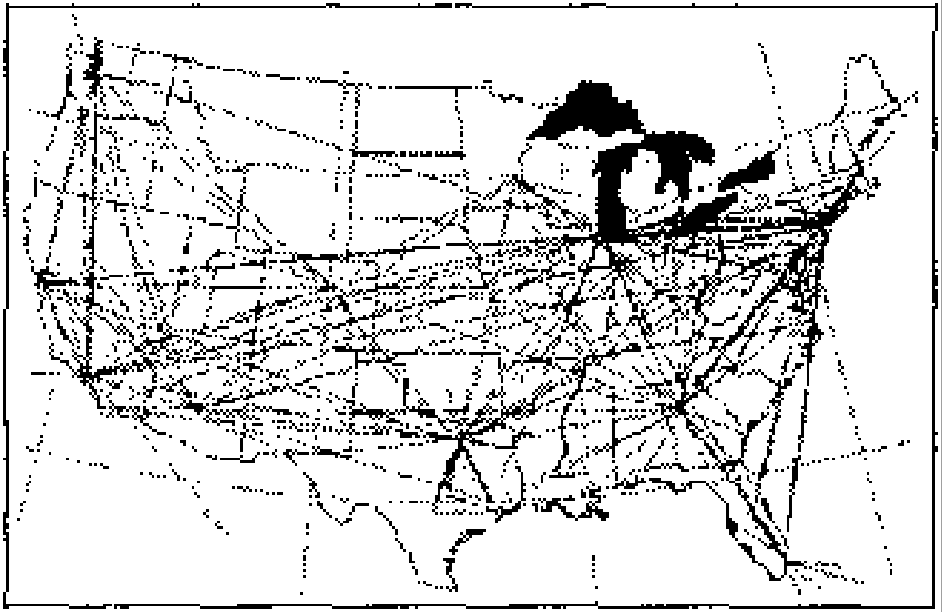
- When, how much, and where to change airspace?
- How much advance notice to provide to the operator?

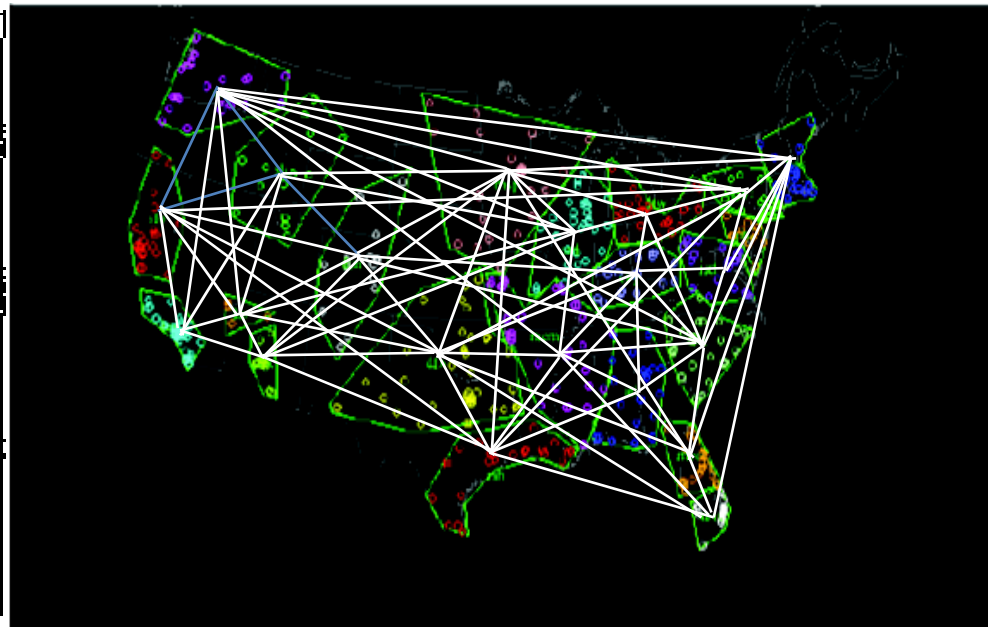
Restructured Airspace

- New airspace categories for advanced concepts
  - Automated separation operations (ground or airborne) airspace
  - Corridors-in-the-sky
  - Dynamic sectors
  - Larger airspace sectors



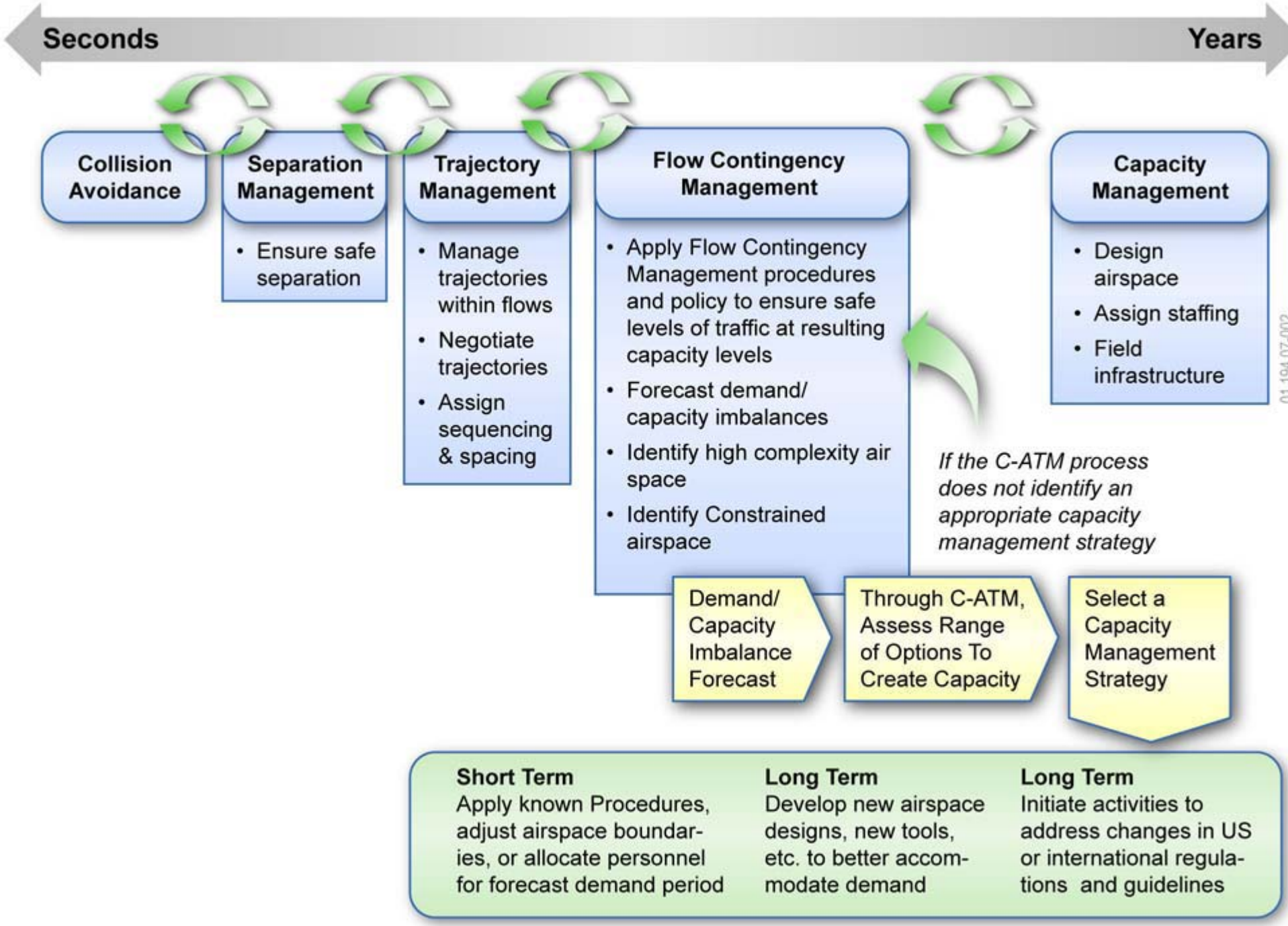
Corridors-in-the-Sky



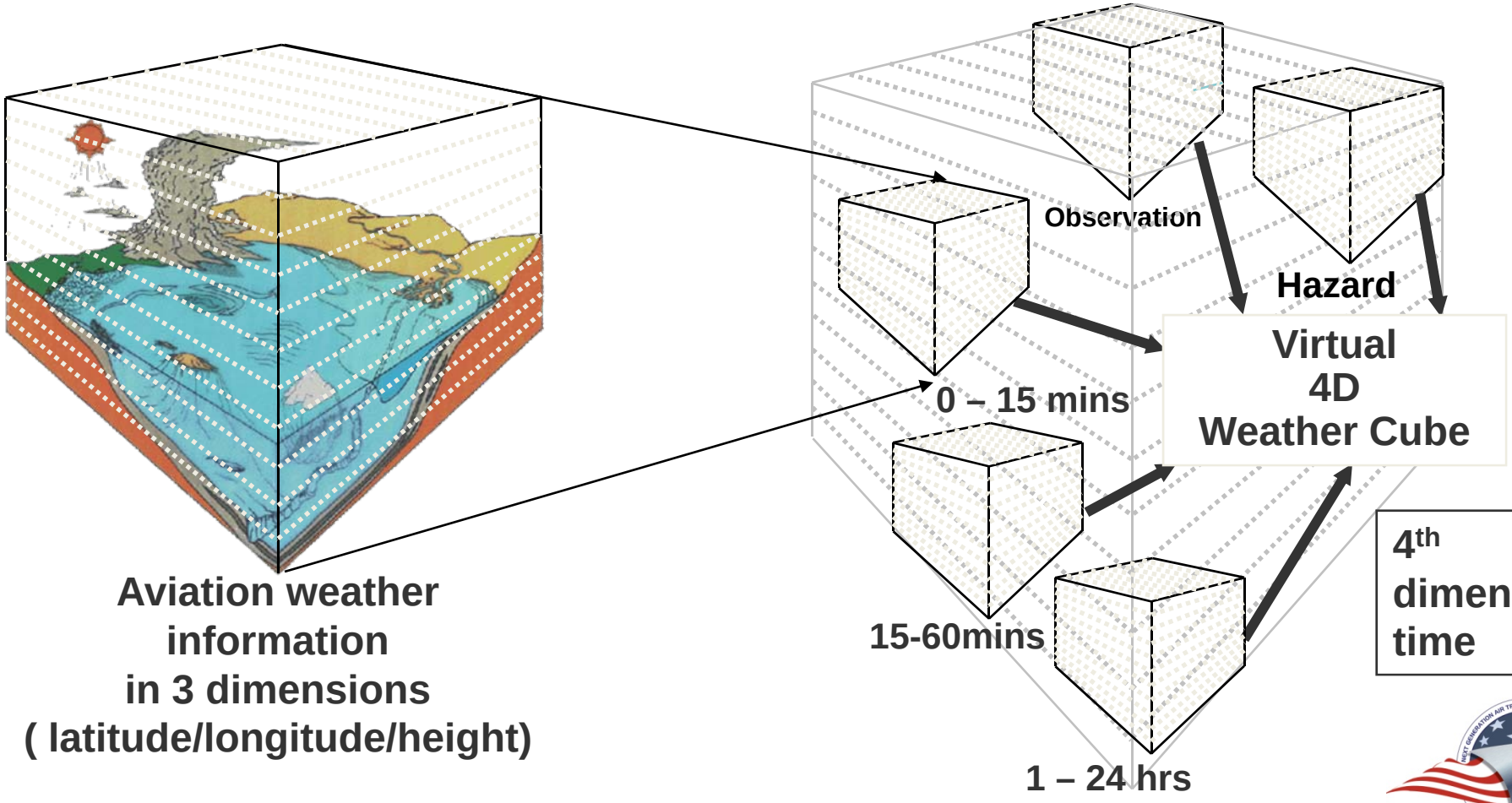


- **Design of tube networks that capture large amount of traffic and reduce extra flight distance needed**
- **Small number of corridors and high volume of traffic corridors**

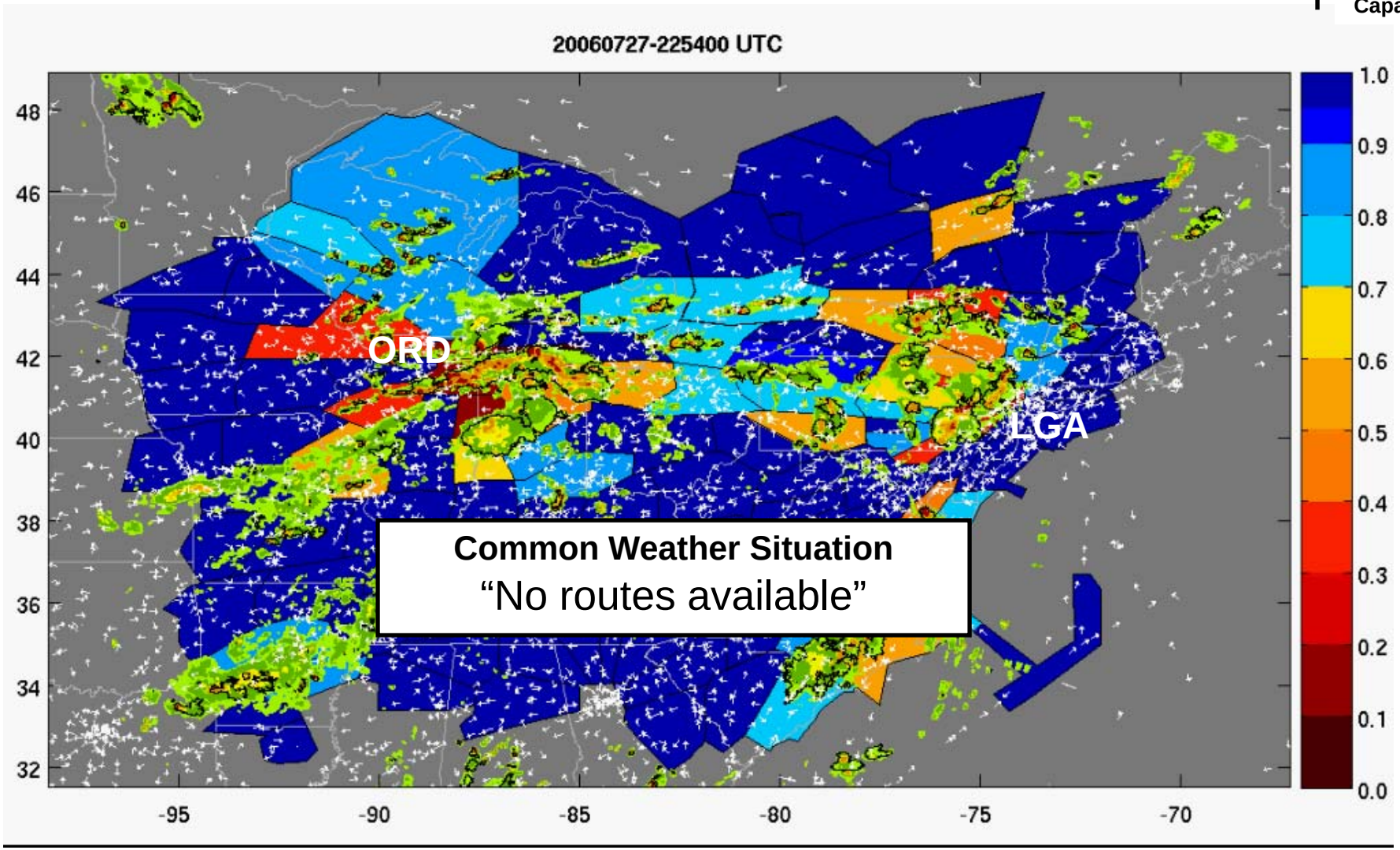
Scenario 1
Preplanning


Seconds
Years
Collision Avoidance
Separation Management
• Ensure safe separation
Trajectory Management
• Manage trajectories within flows
• Negotiate trajectories
• Assign sequencing & spacing
Flow Contingency Management
• Apply Flow Contingency Management procedures and policy to ensure safe levels of traffic at resulting capacity levels
• Forecast demand/ capacity imbalances
• Identify high complexity air space
• Identify Constrained airspace
Capacity Management
• Design airspace
• Assign staffing
• Field infrastructure
If the C-ATM process does not identify an appropriate capacity management strategy
Demand/ Capacity Imbalance Forecast
Through C-ATM, Assess Range of Options To Create Capacity
Select a Capacity Management Strategy
Short Term
Apply known Procedures, adjust airspace boundaries, or allocate personnel for forecast demand period
Long Term
Develop new airspace designs, new tools, etc. to better accommodate demand
Long Term
Initiate activities to address changes in US or international regulations and guidelines

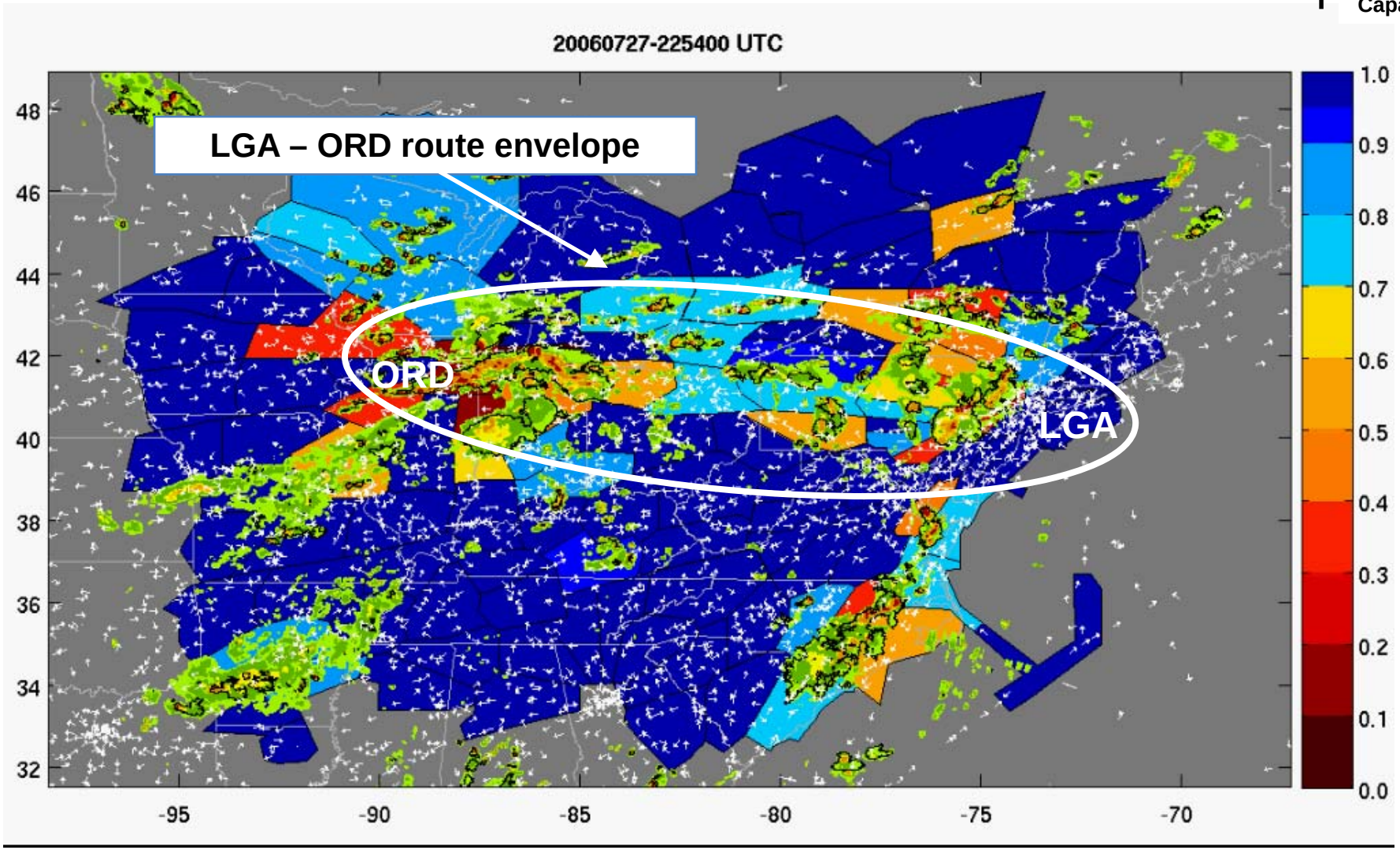
Virtual 4D Weather Cube



Flying LGA to ORD in Weather

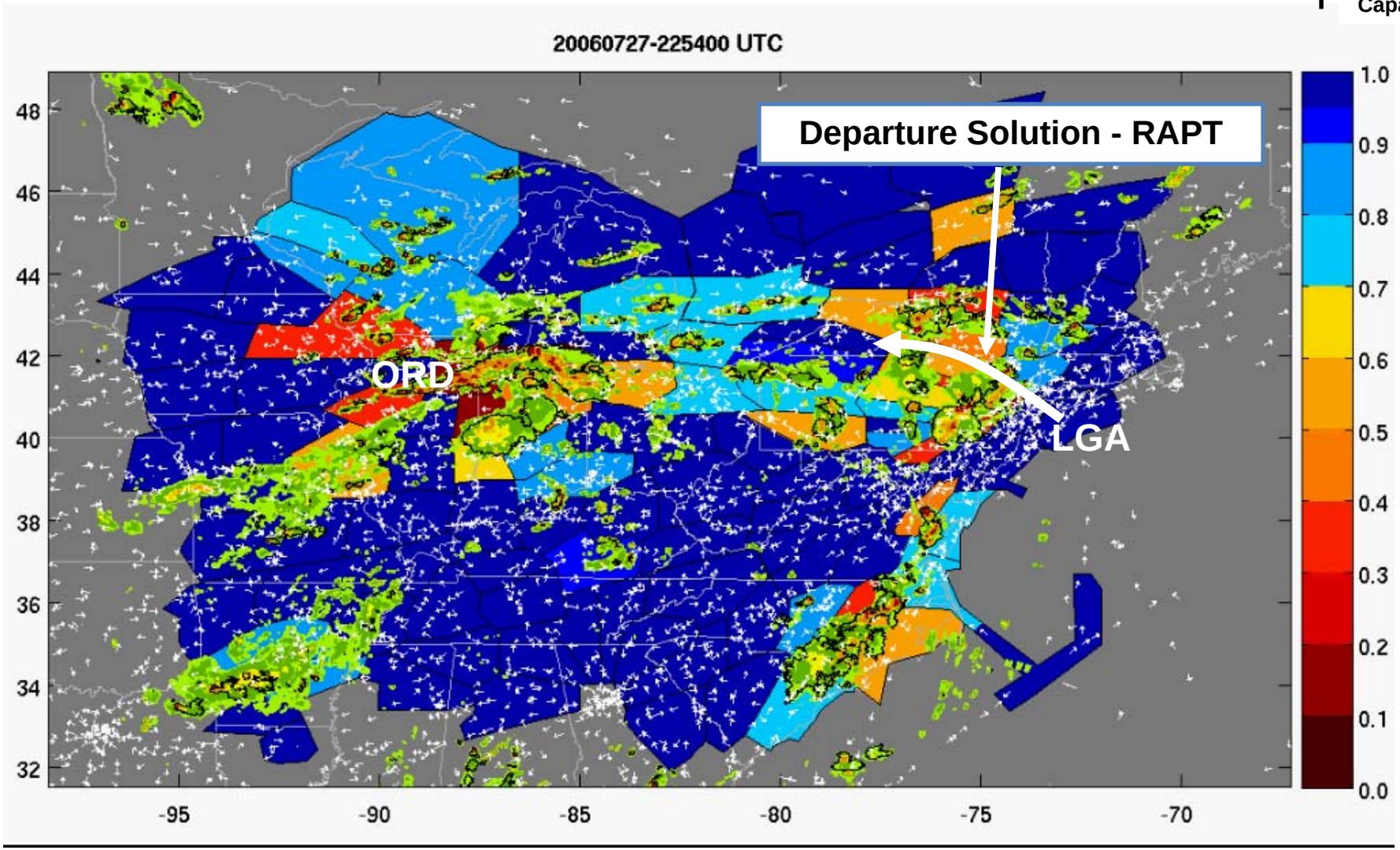


Adaptive ATM

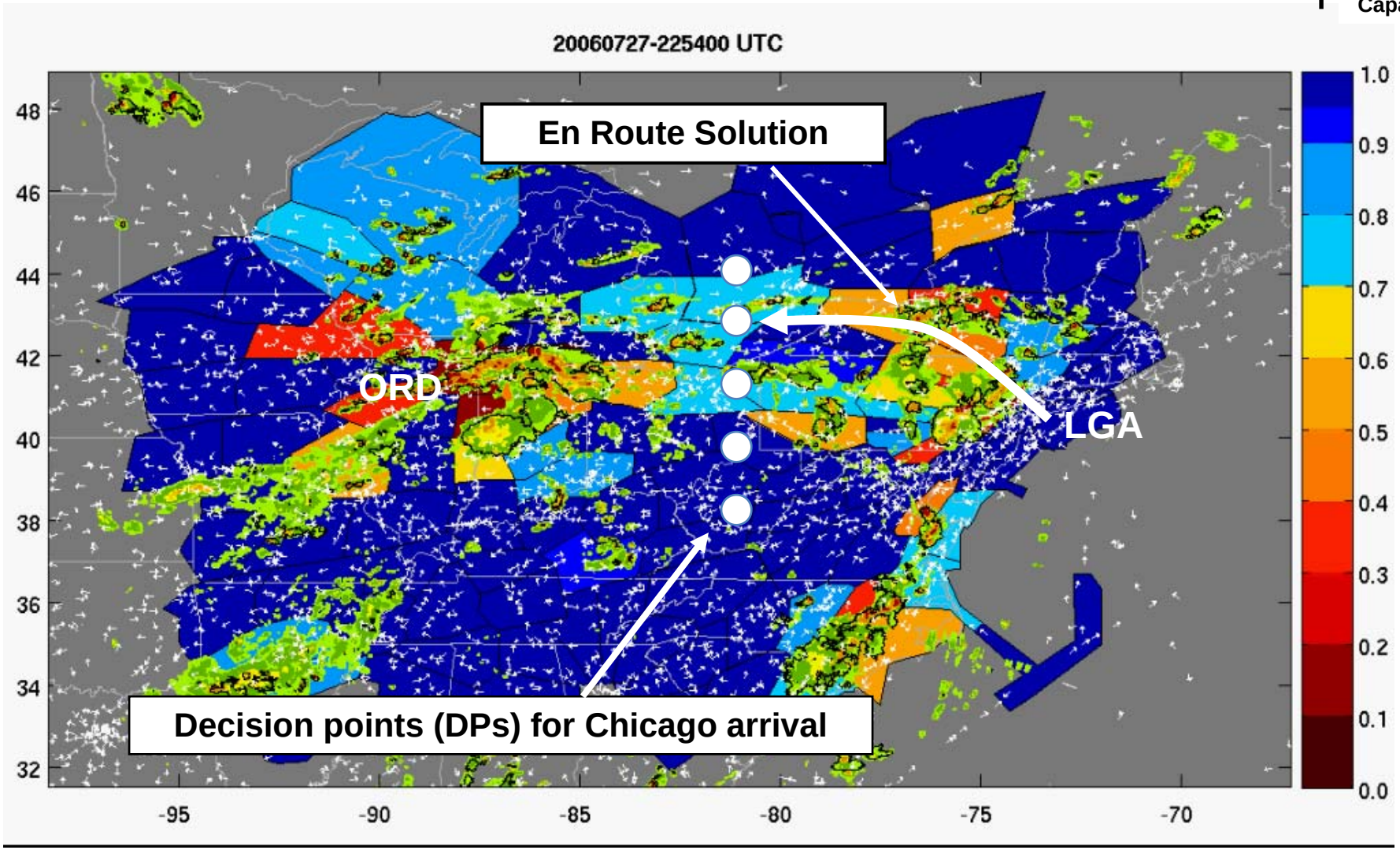


Incrementally define Route and Decision Points

Adaptive ATM

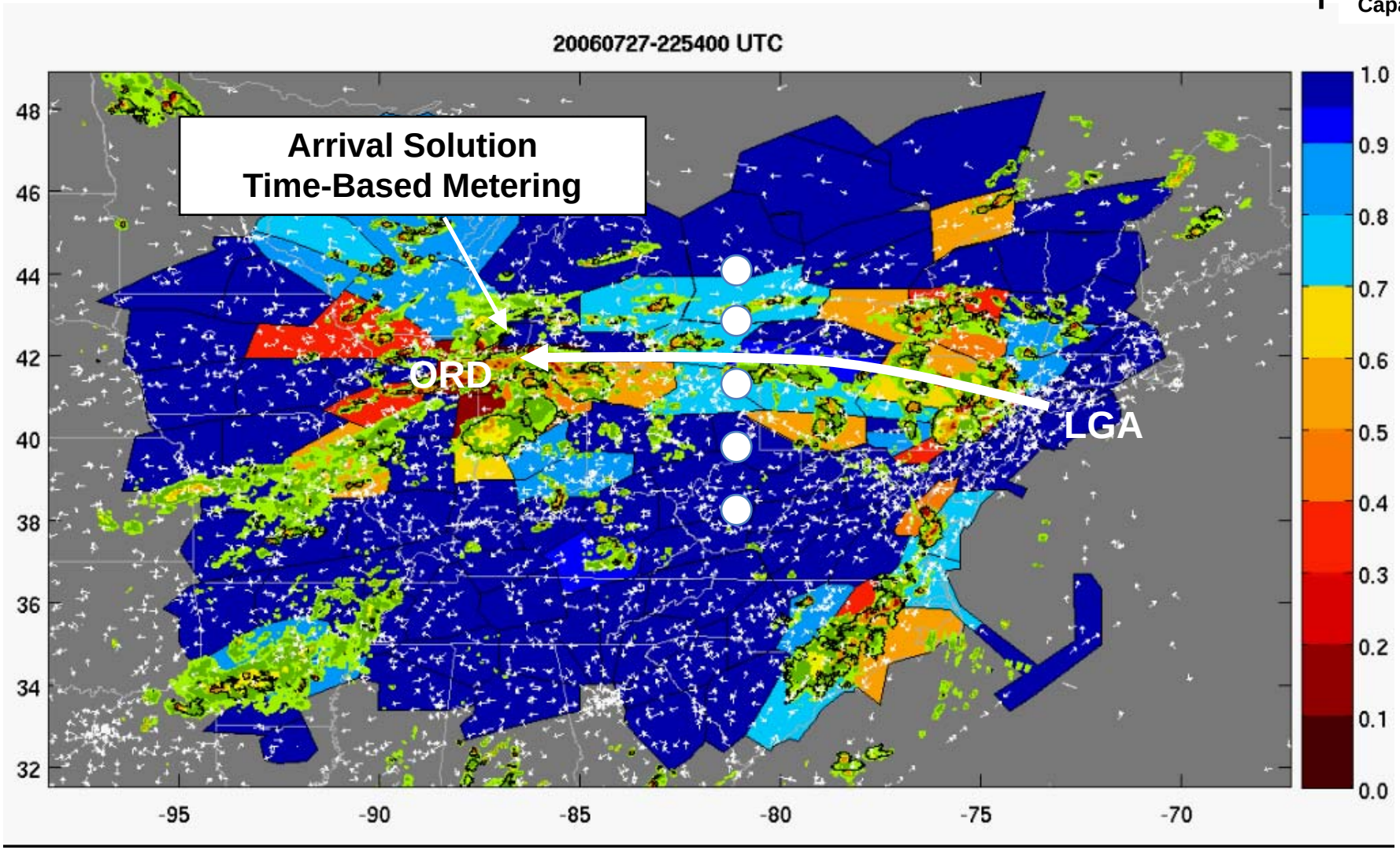


Adaptive ATM

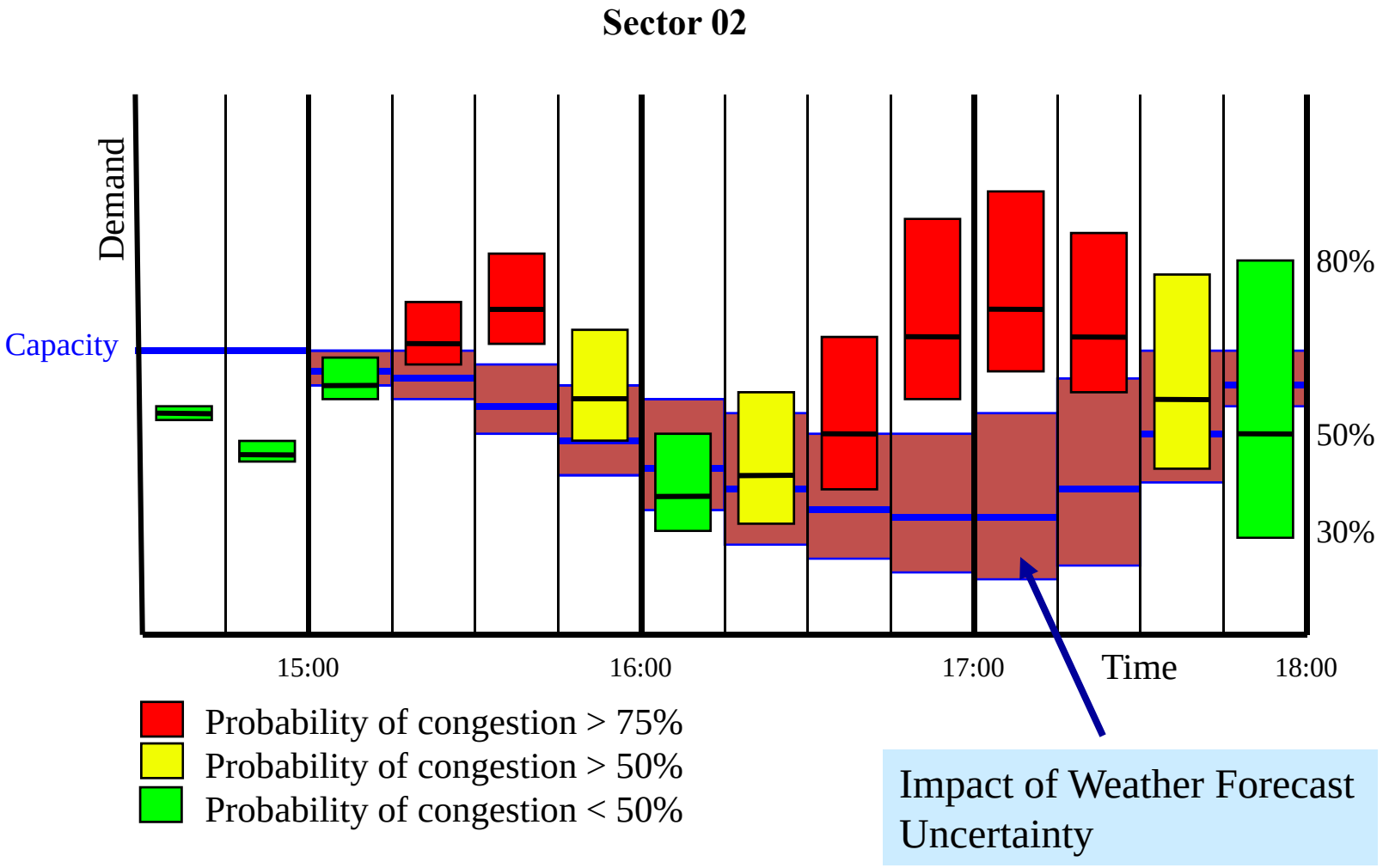


As the flight progresses, Uncertainty is reduced

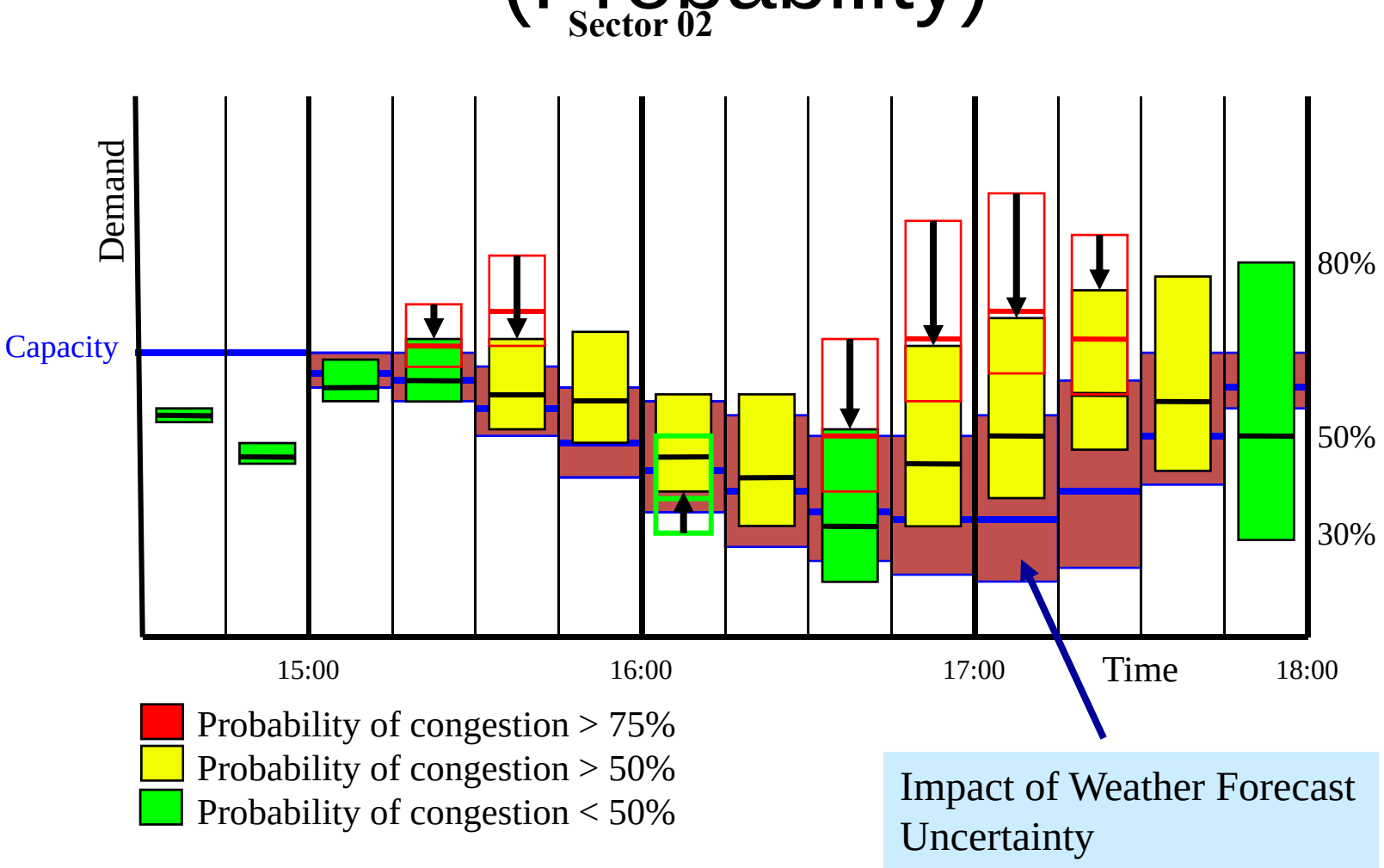
Adaptive ATM



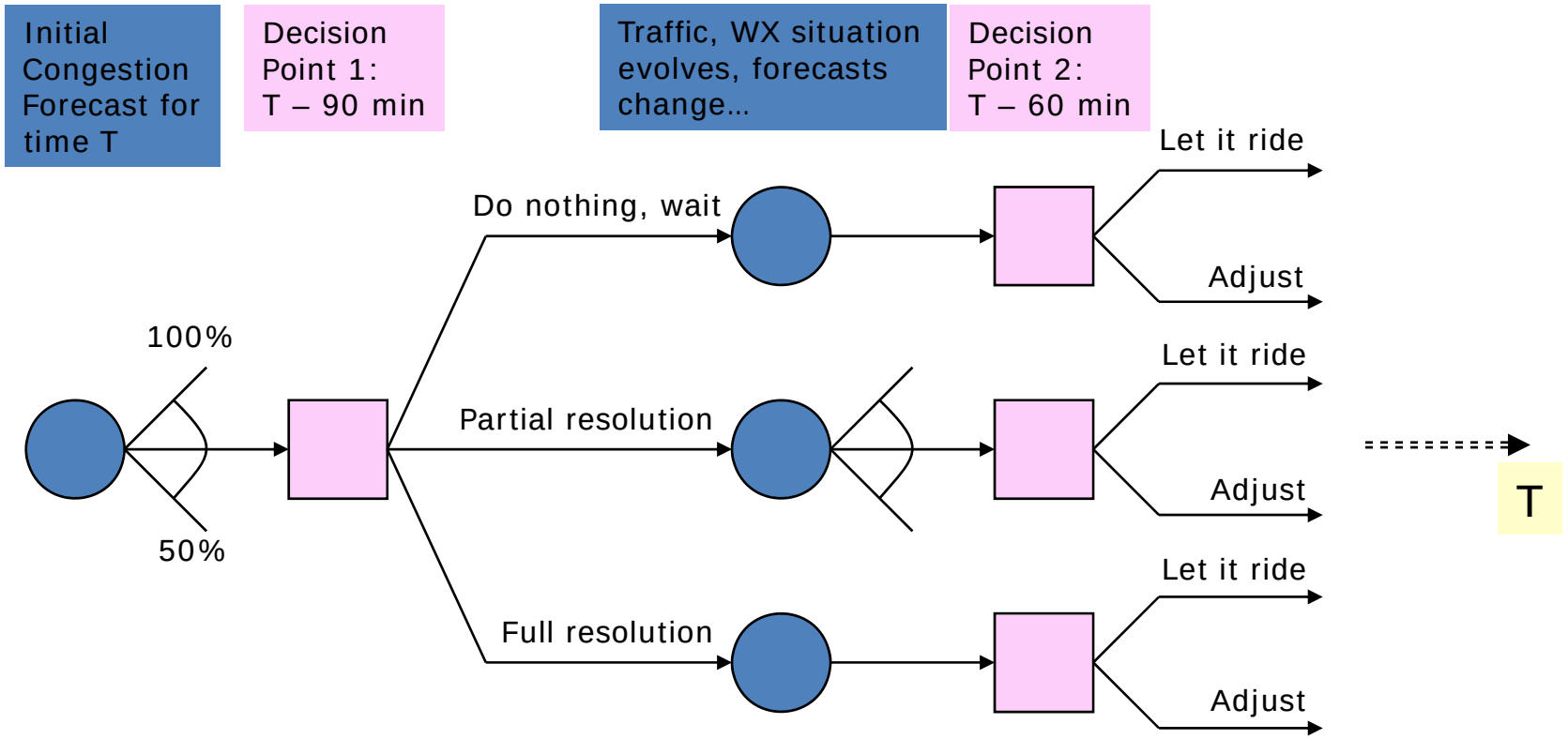
Probabilistic Future Sector Demand and Capacity Graph



Managing Congestion to an Acceptable Level of Risk (Probability)



Congestion Resolution Decision Tree

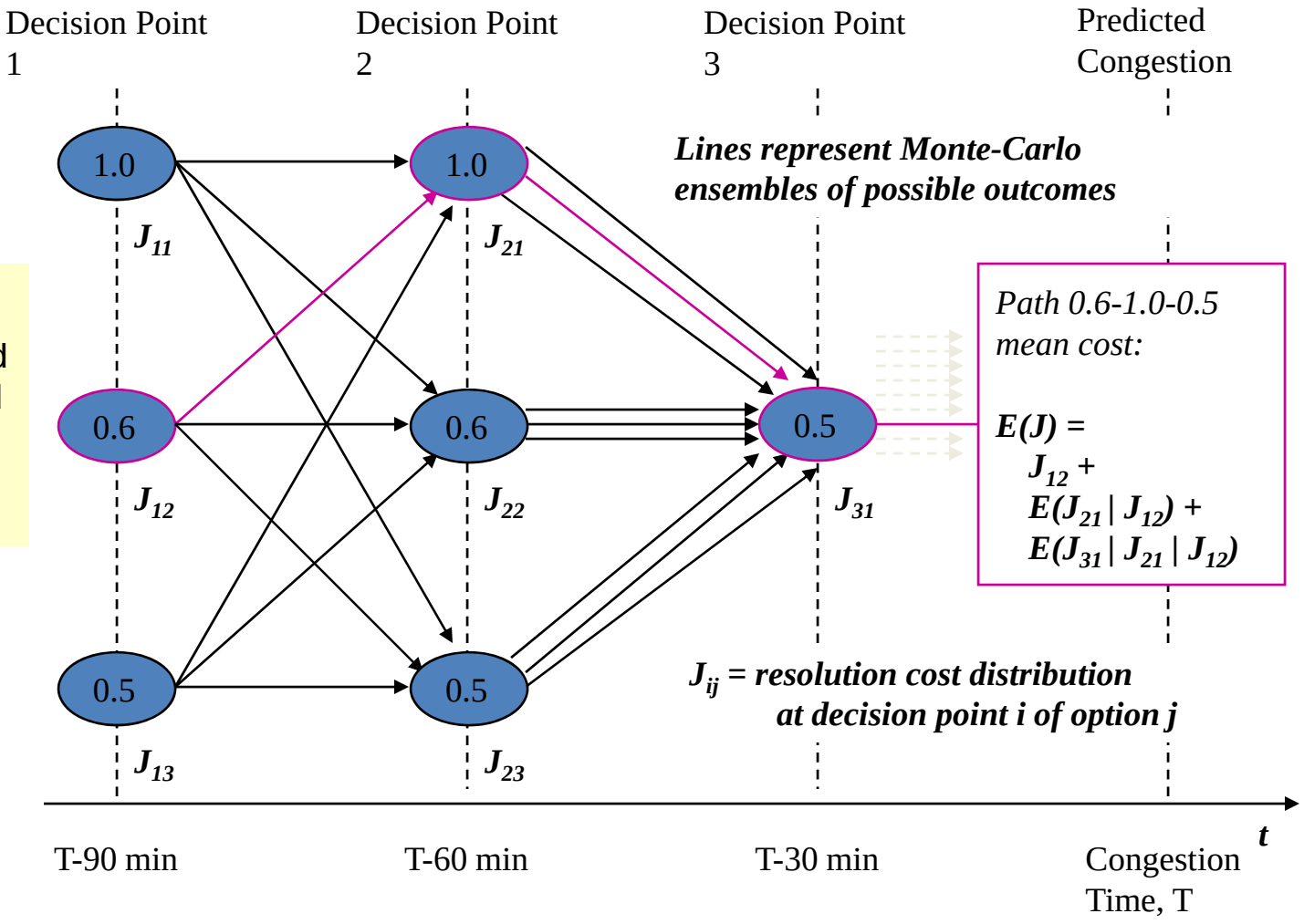


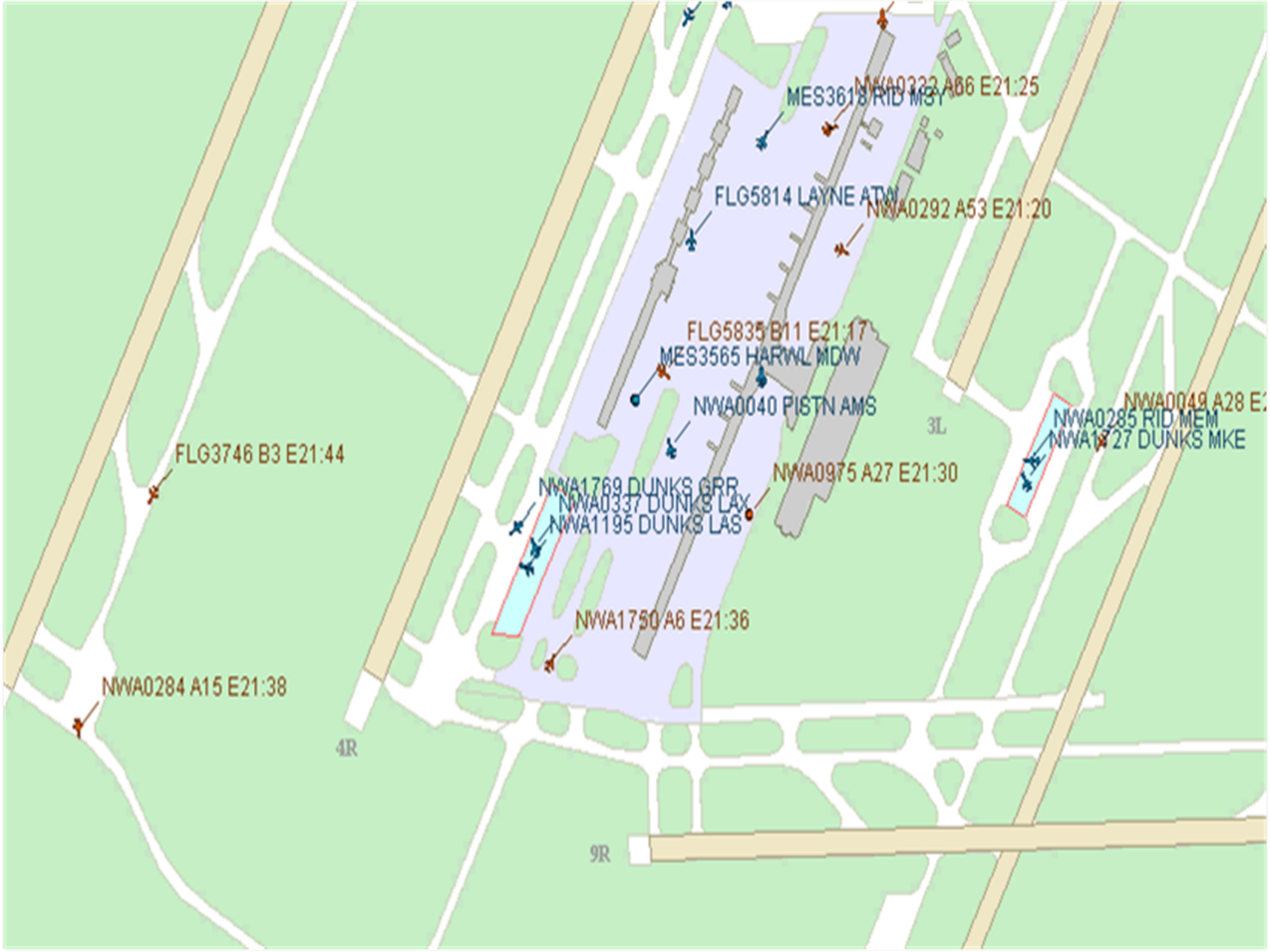
Of the possible decision paths, which one reaches the congestion management goal with the least operational impact?

Time-Optimal Decision Making Simulation

Start:

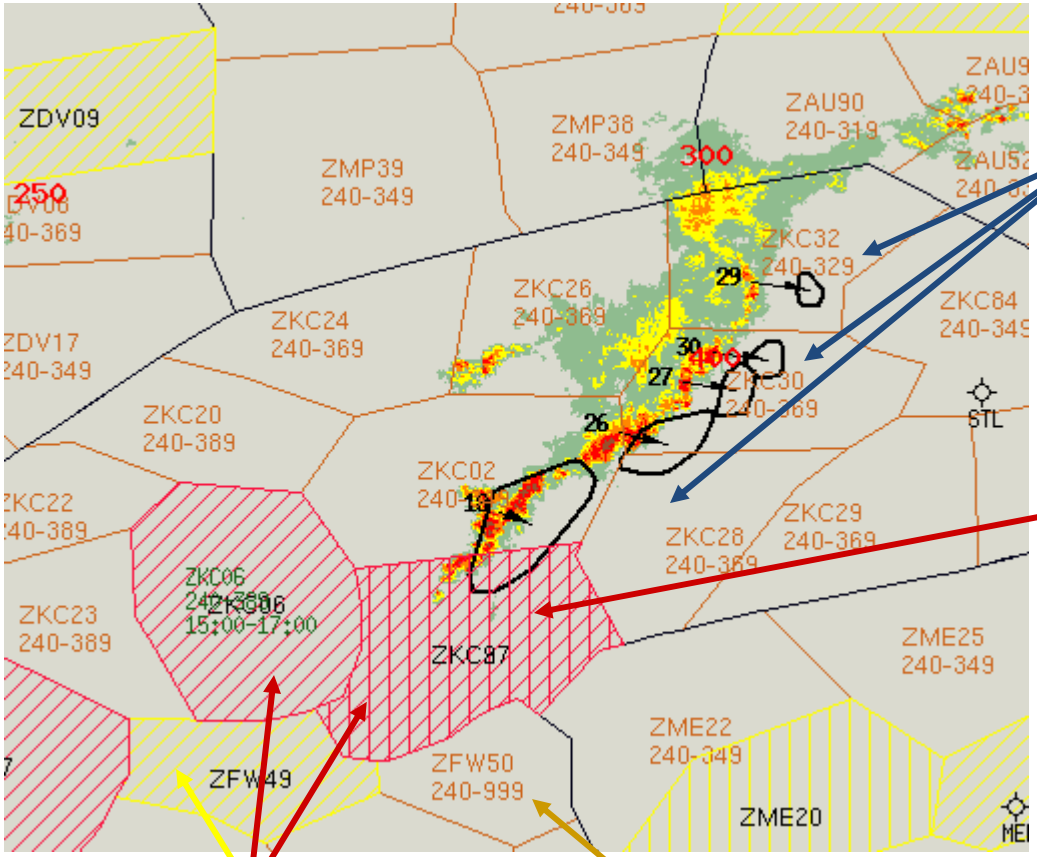
Set of predicted trajectories and corresponding congestion probabilities




NWA0333 A66 E21:25
MES3618 RID MSY
FLG5814 LAYNE ATW
NWA0292 A53 E21:20
FLG5835 B11 E21:17
MES3565 HARWL MDW
NWA0040 PISTN AMS
3L
NWA0049 A28 E
NWA0285 RID MEM
NWA1827 DUNKS MKE
FLG3746 B3 E21:44
NWA0975 A27 E21:30
NWA1769 DUNKS GRR
NWA0337 DUNKS LAX
NWA1195 DUNKS LAS
NWA1750 A6 E21:36
NWA0284 A15 E21:38
4R
9R

Scenario 2
Enroute

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.

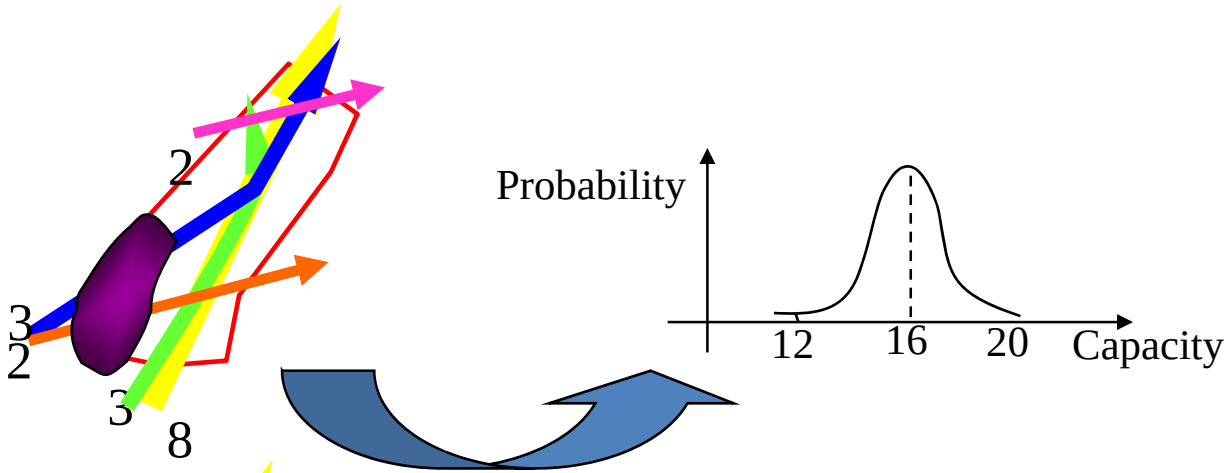
Given the uncertainty:
When should air traffic be restricted?
Which flights should be affected?
How do NAS operators participate?

Congestion Alerts

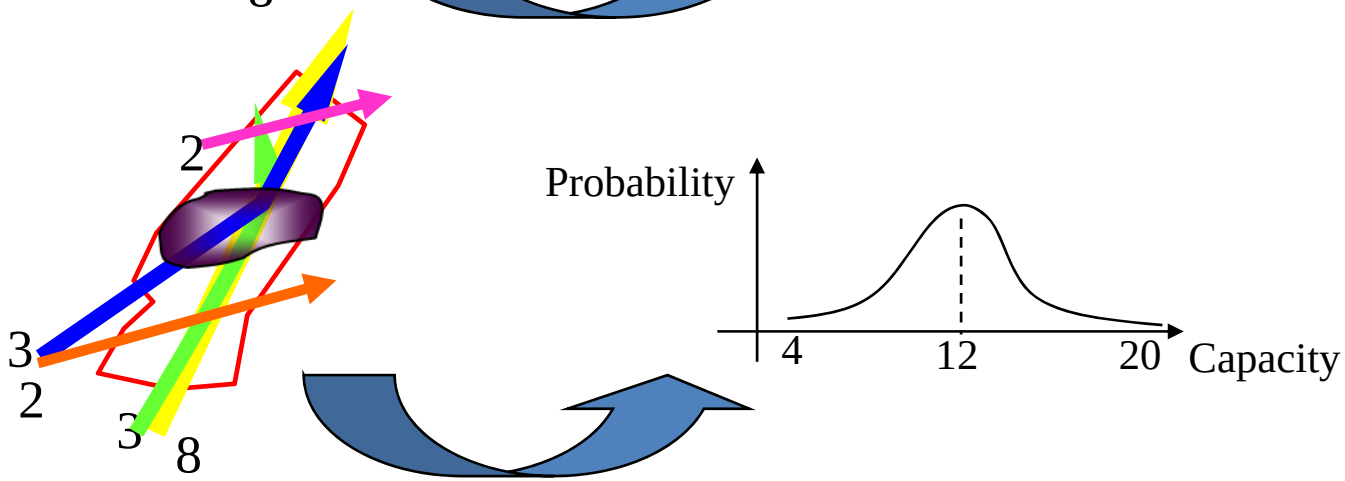
Air traffic control sector

Location of the Weather Matters --- Flow Impact

Case A

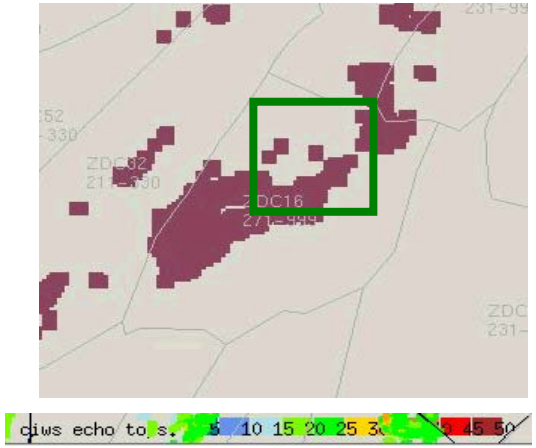


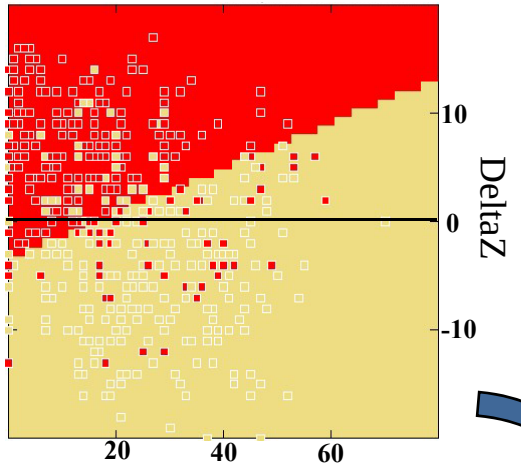
Case B



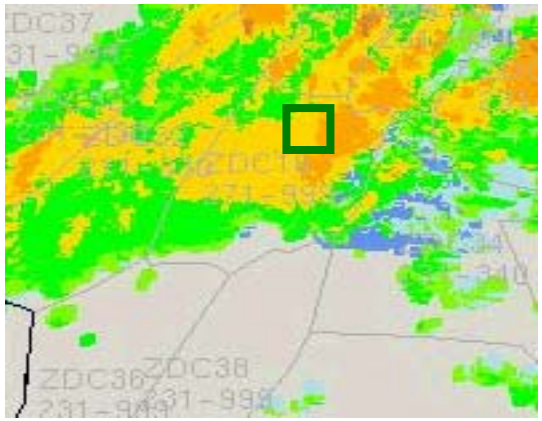
Lincoln Lab Pilot Behavior Analysis and the WAF Altitude Field

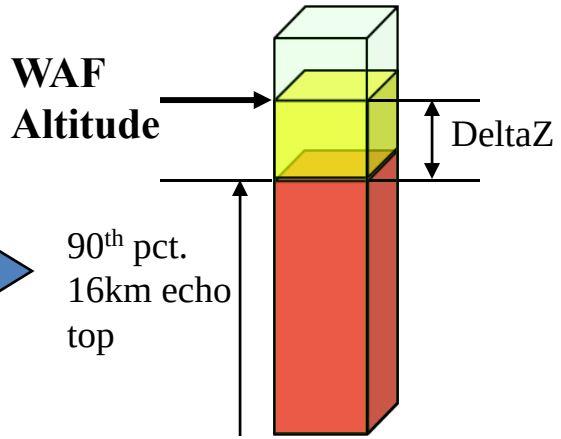
VIL coverage in 60X60 region





90th pct. Echo top in 16X16 region

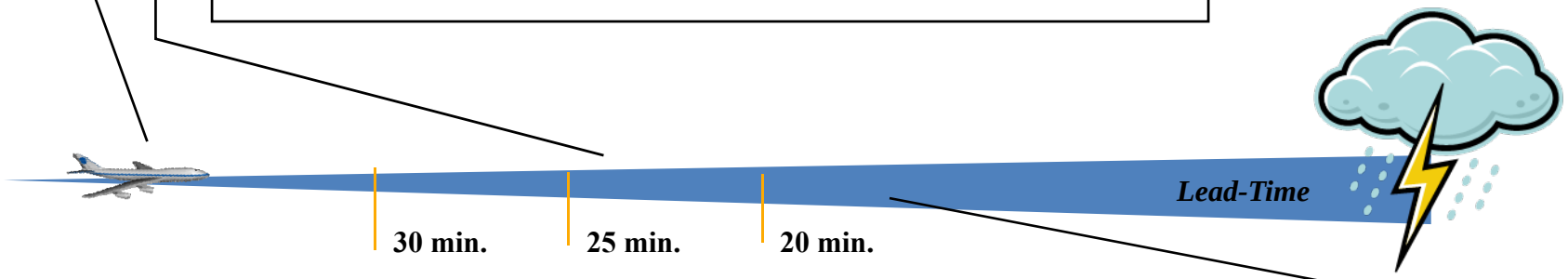




Developing Concept for Automated Tactical ATC Weather Avoidance

30 minutes and higher lead time before a flight intersects weather problems: TFM automation uses weather forecasts to predict congestion, and produces initiatives to reduce volume around weather. ATC implements initiatives and resolves any near-term conflicts with other aircraft and weather.

20 – 25 minutes lead time: ATC automation responds to proactive requests via data link for reroutes around weather.

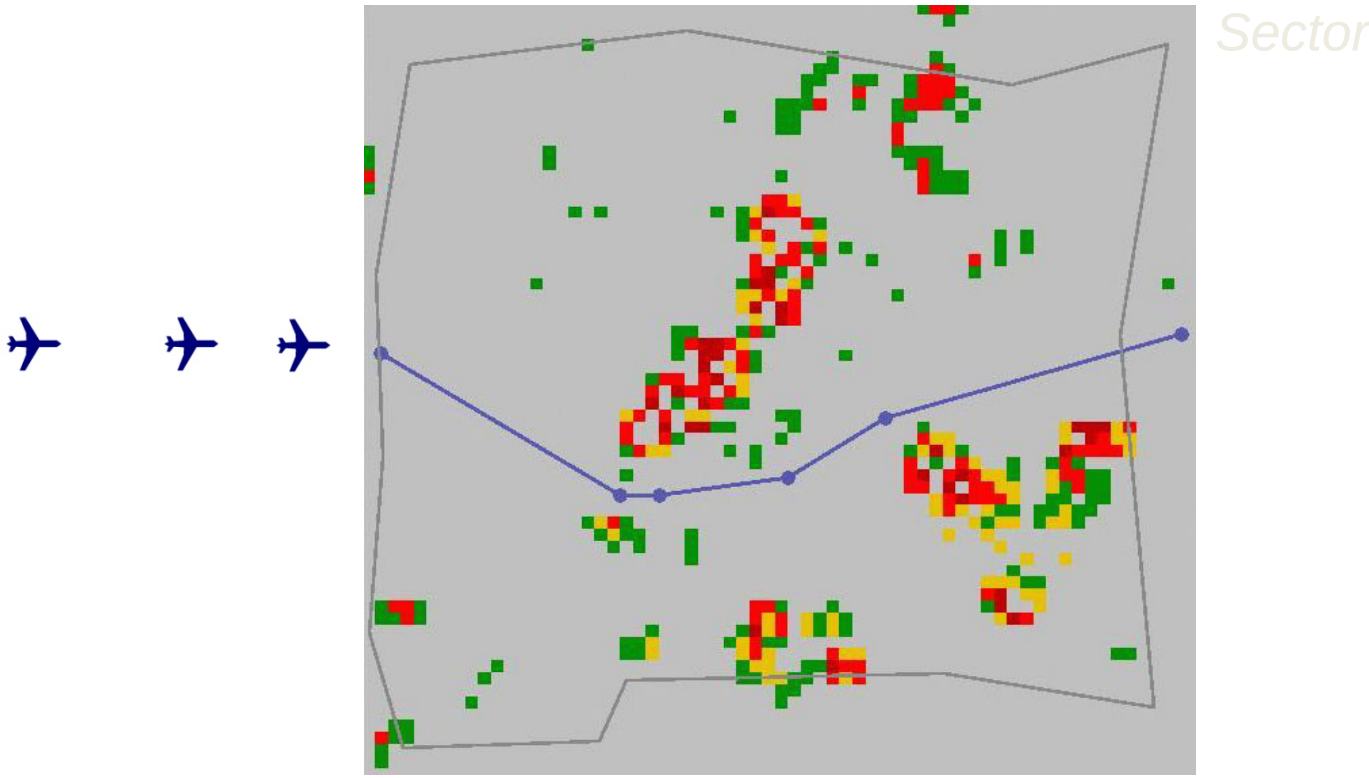


Up to 20 minutes lead time: ATC automation uses weather forecasts to predict aircraft to convective weather intersections and generates resolutions that avoid other aircraft and weather. Clearances are automatically distributed to data link equipped flights. Pilots have the option to request changes to the route, including requesting a route back through the weather.

Example of NASA Weather ATM Integration Research

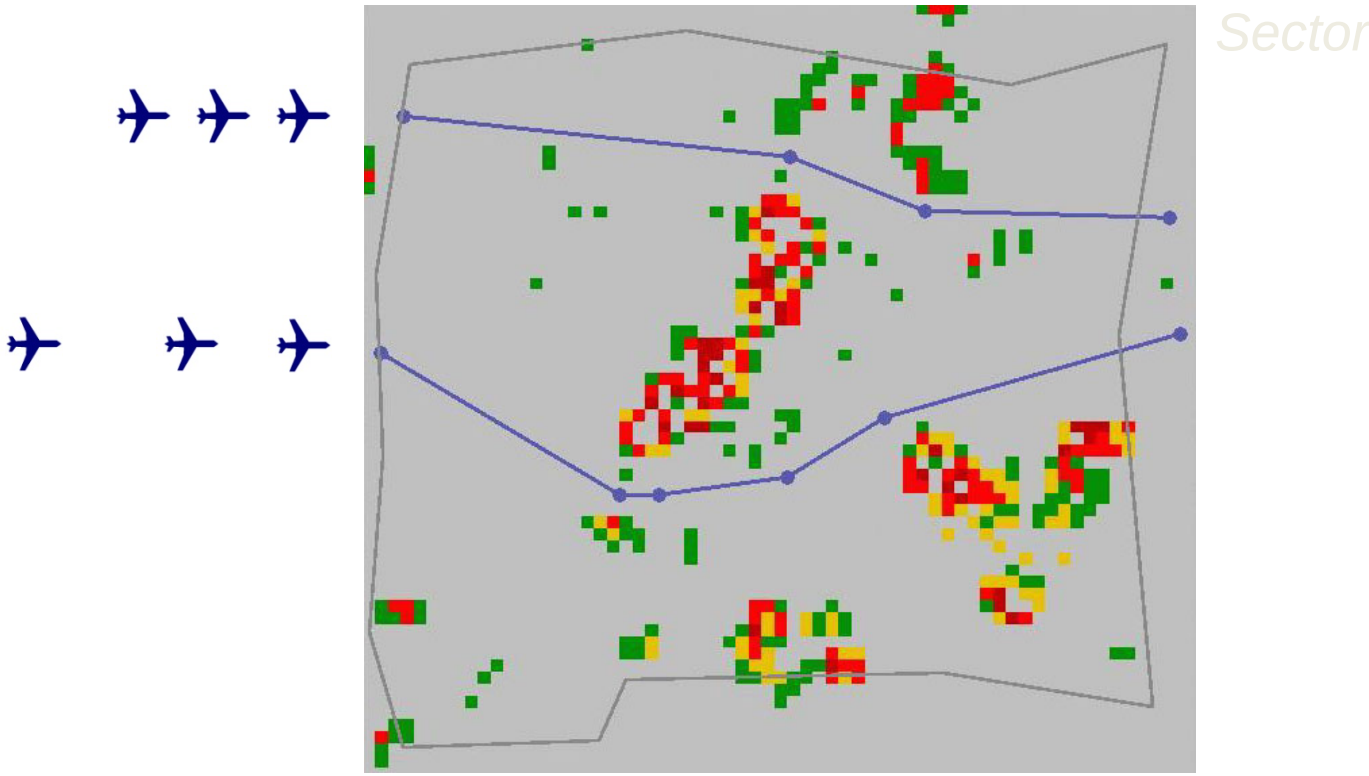
Movie loop shows one way to adjust
to enroute storms

Weather Avoidance Algorithms for En Route Aircraft



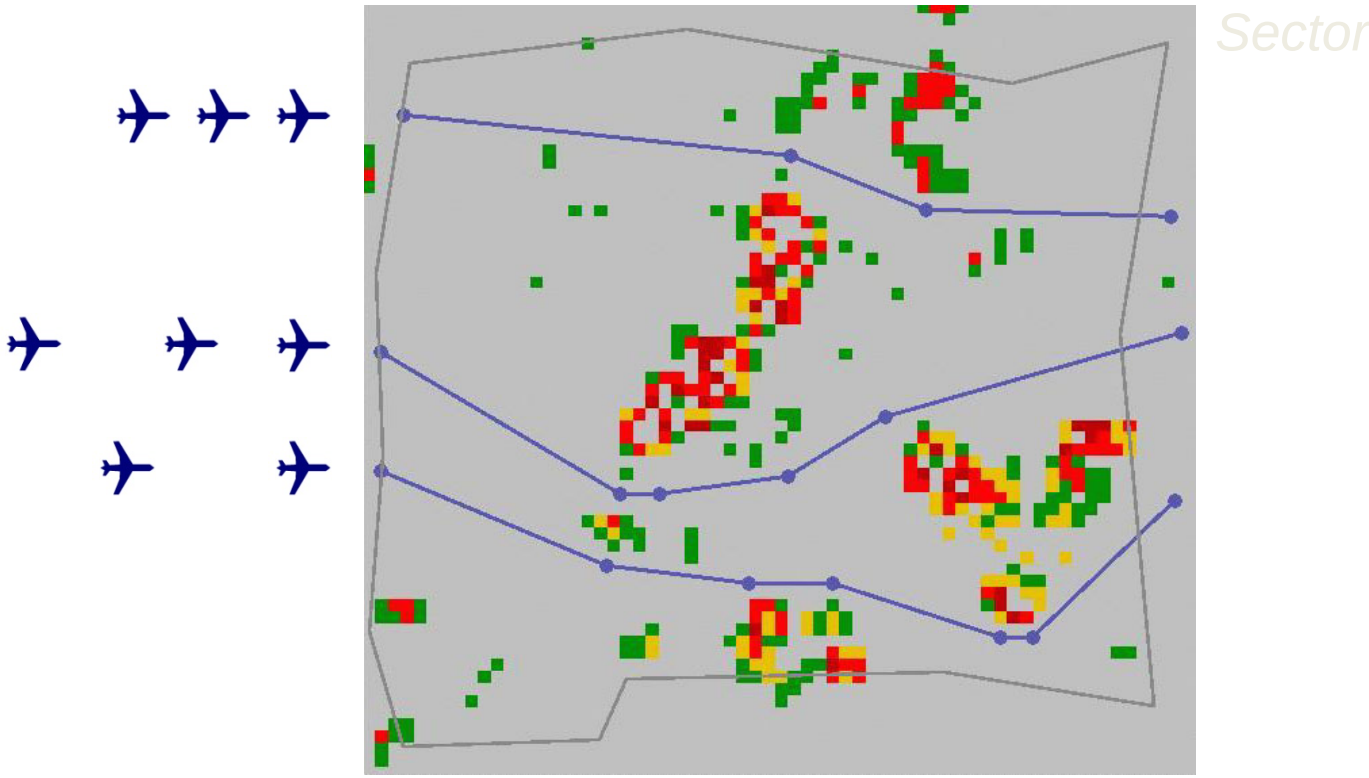
1 Flow

Weather Avoidance Algorithms for En Route Aircraft



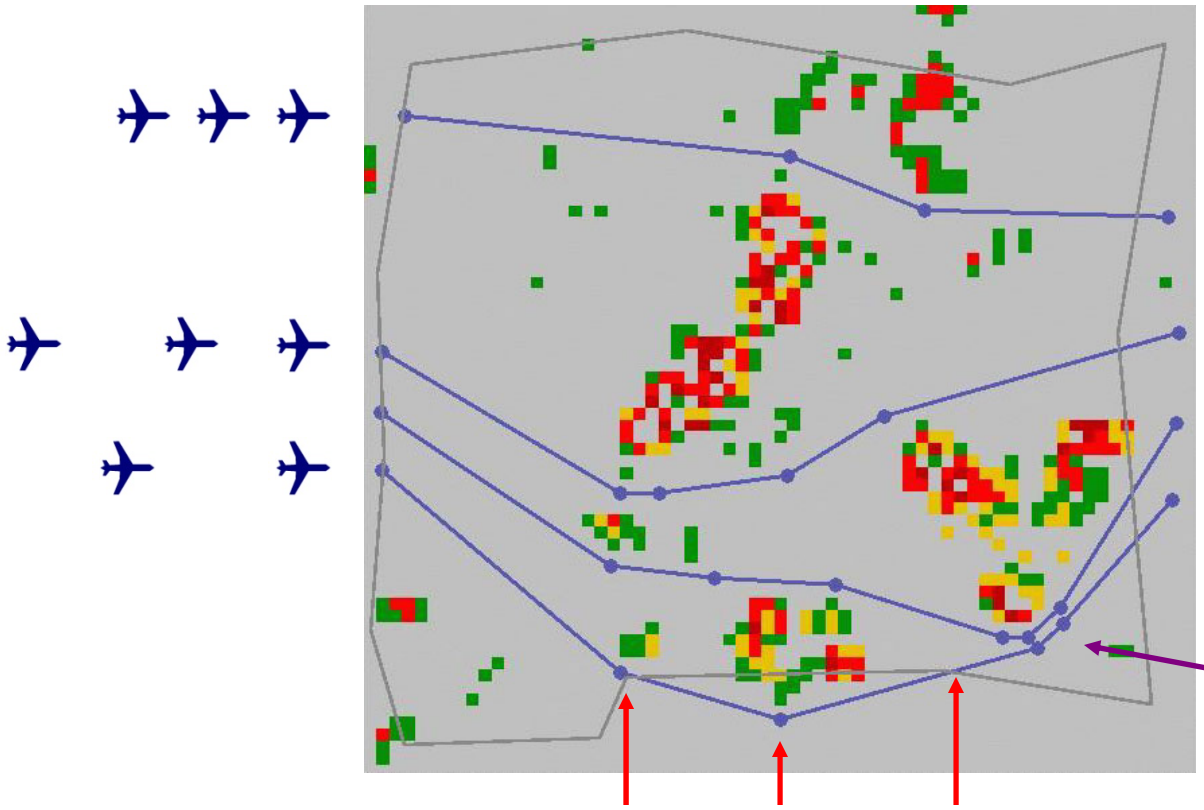
2 Flows

Weather Avoidance Algorithms for En Route Aircraft



3 Flows

Weather Avoidance Algorithms for En Route Aircraft

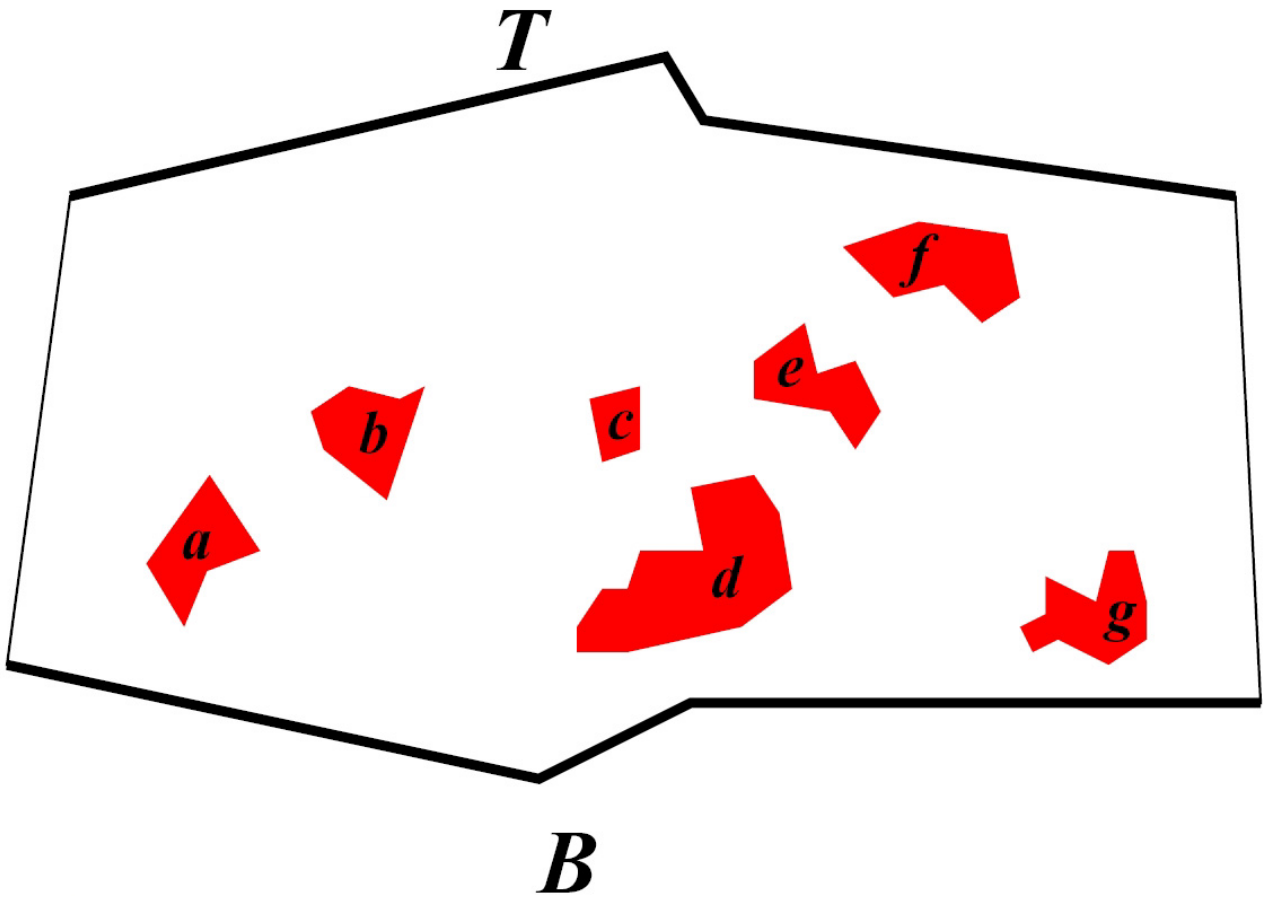


4 Flows

→ Are 3 Routes through the Sector a Maximum?

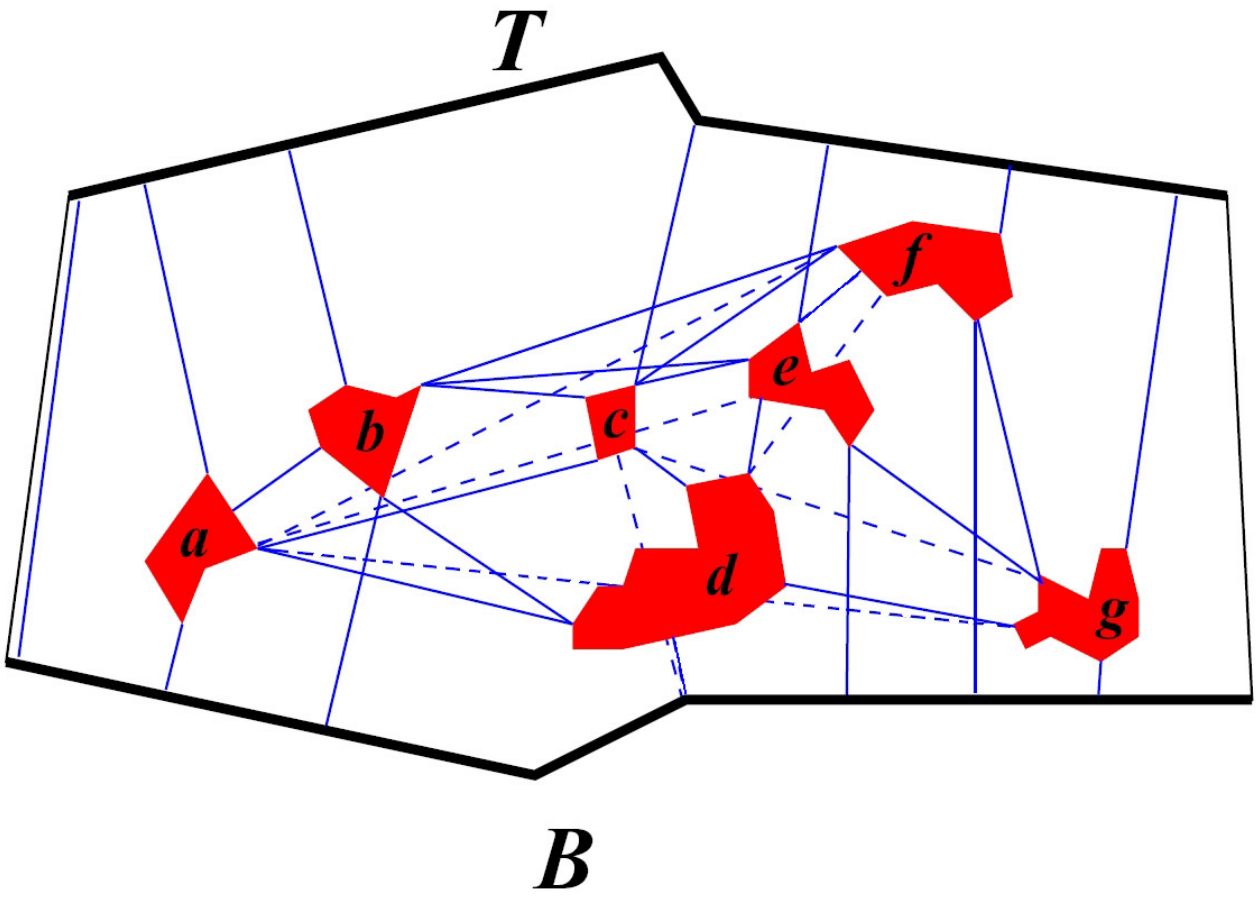
Algorithm: Mincut (Deterministic)

1. Airspace with Hazardous Weather Constraints

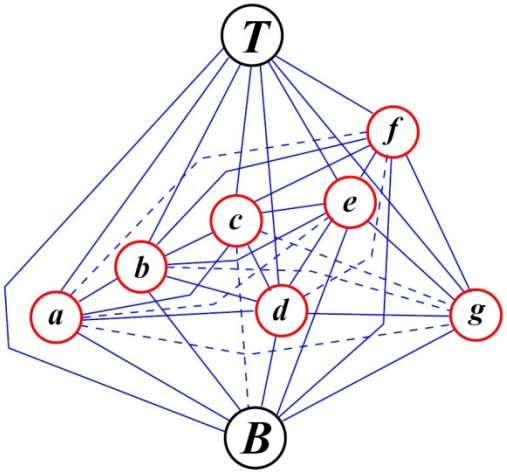


Algorithm: Mincut (Deterministic)

2. Define Critical Graph – connect closest points (B, T, a → g)

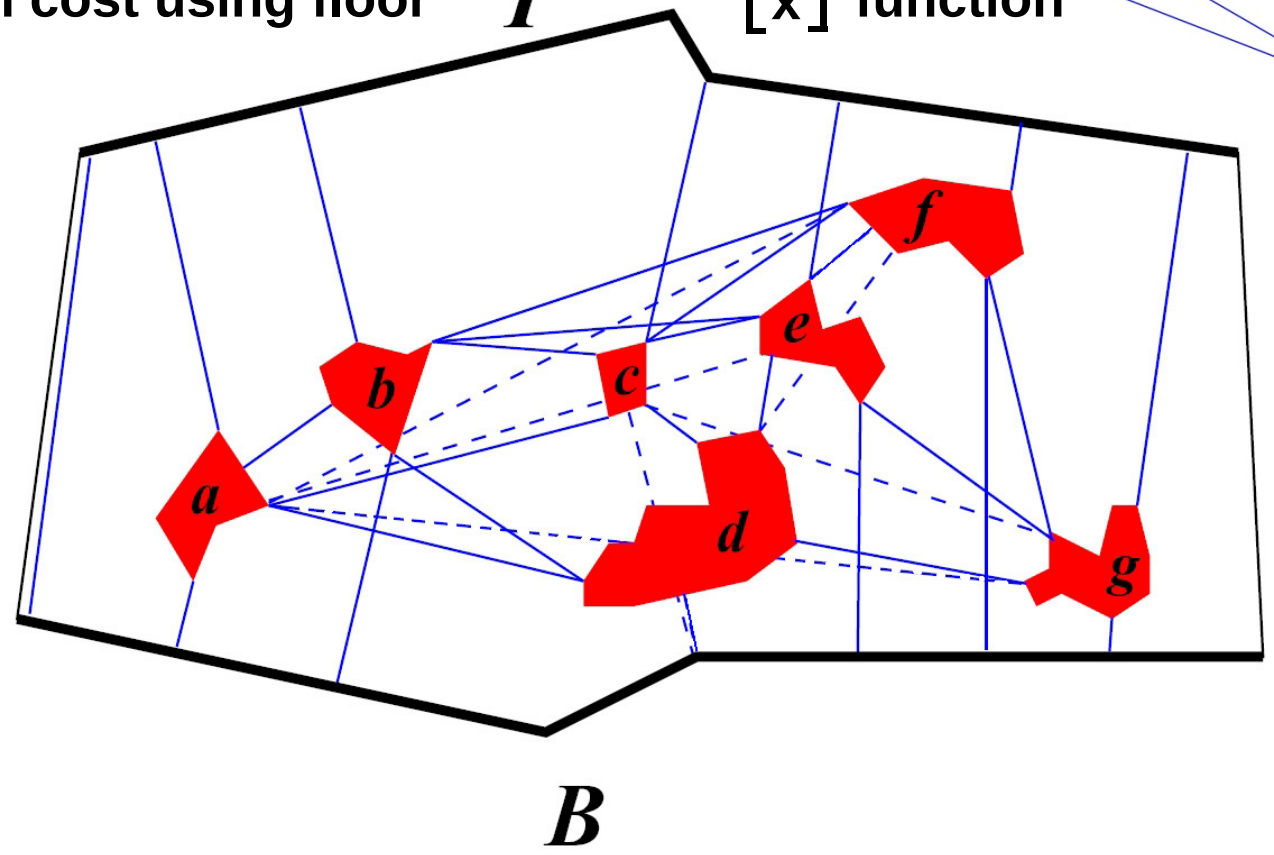


Algorithm: Mincut (Deterministic)



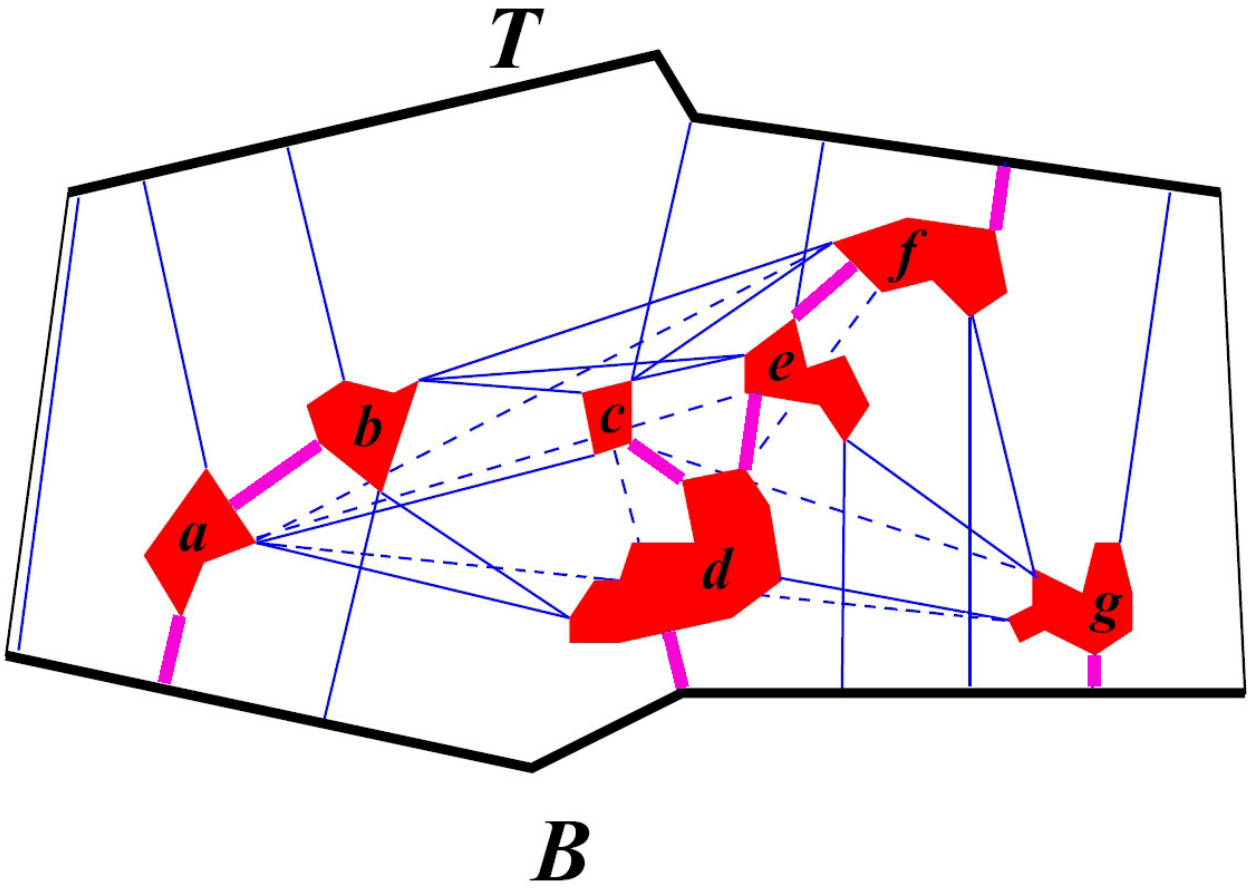
2. Define Critical Graph – connect closest points

Assign cost using floor $\lfloor x \rfloor$ function



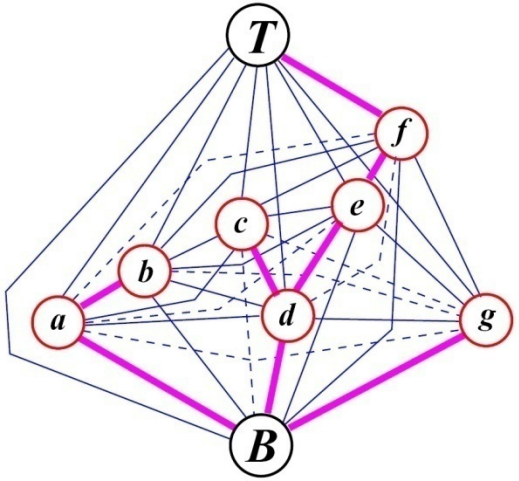
Algorithm: Mincut (Deterministic)

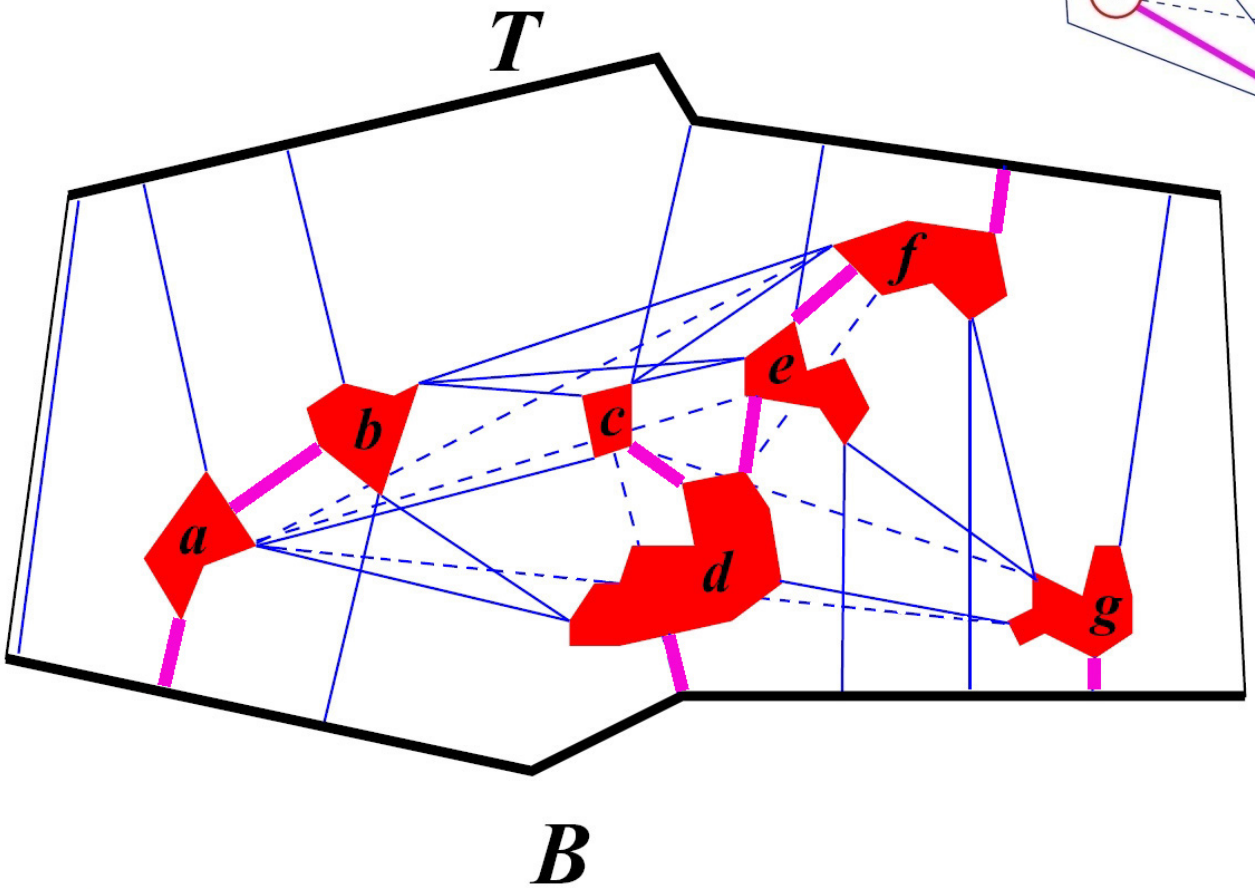
3. Search for Shortest Path Tree within Critical Graph



Algorithm: Mincut (Deterministic)

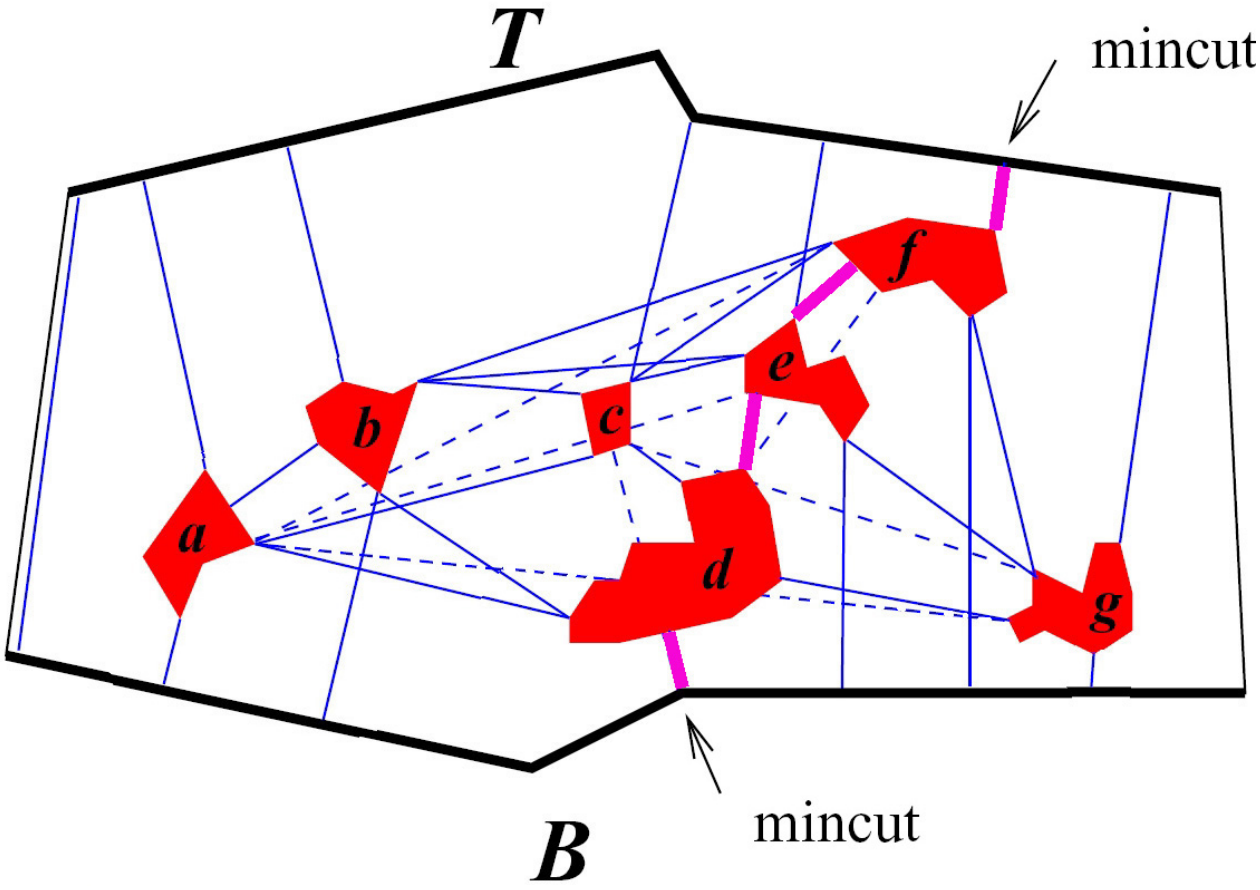
3. Search for Shortest Path Tree





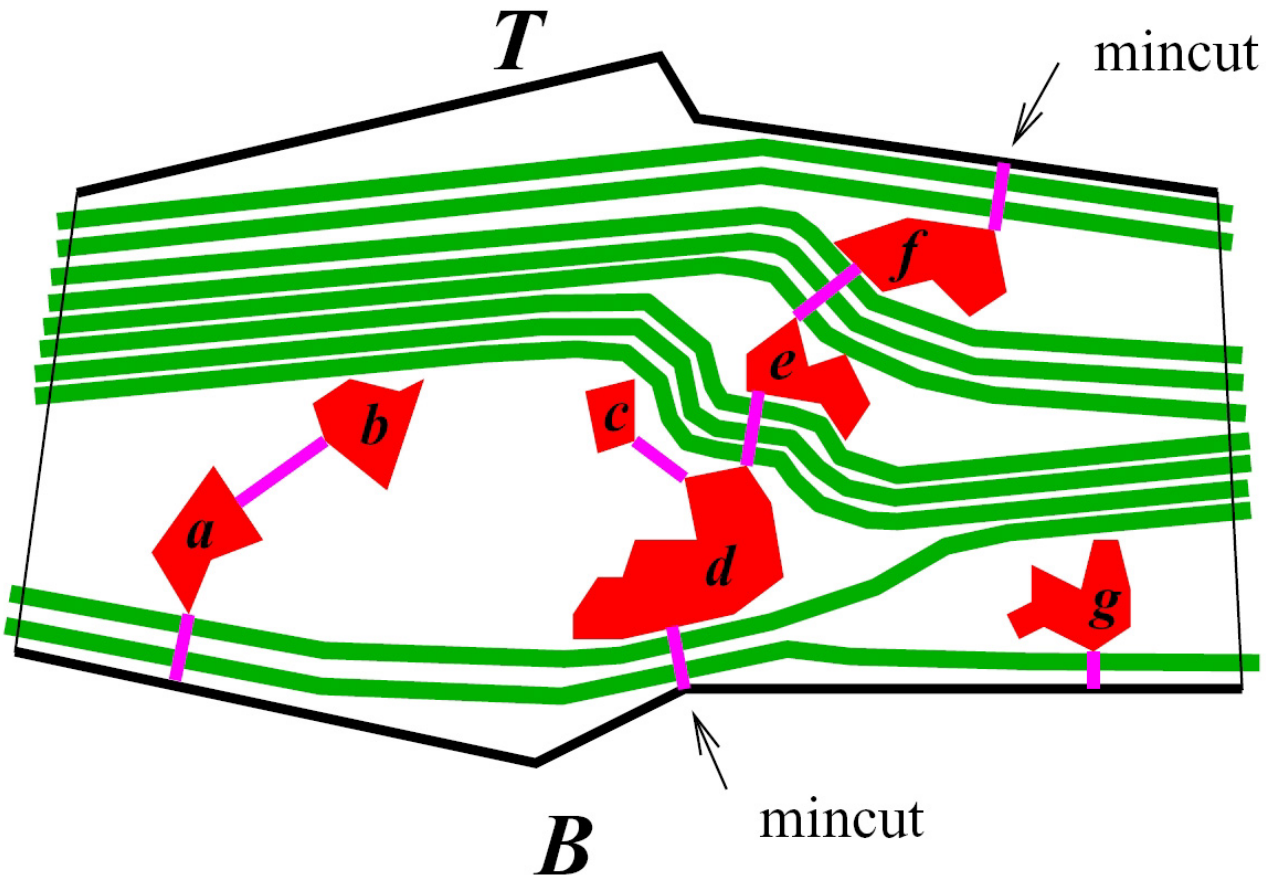
Algorithm: Mincut (Deterministic)

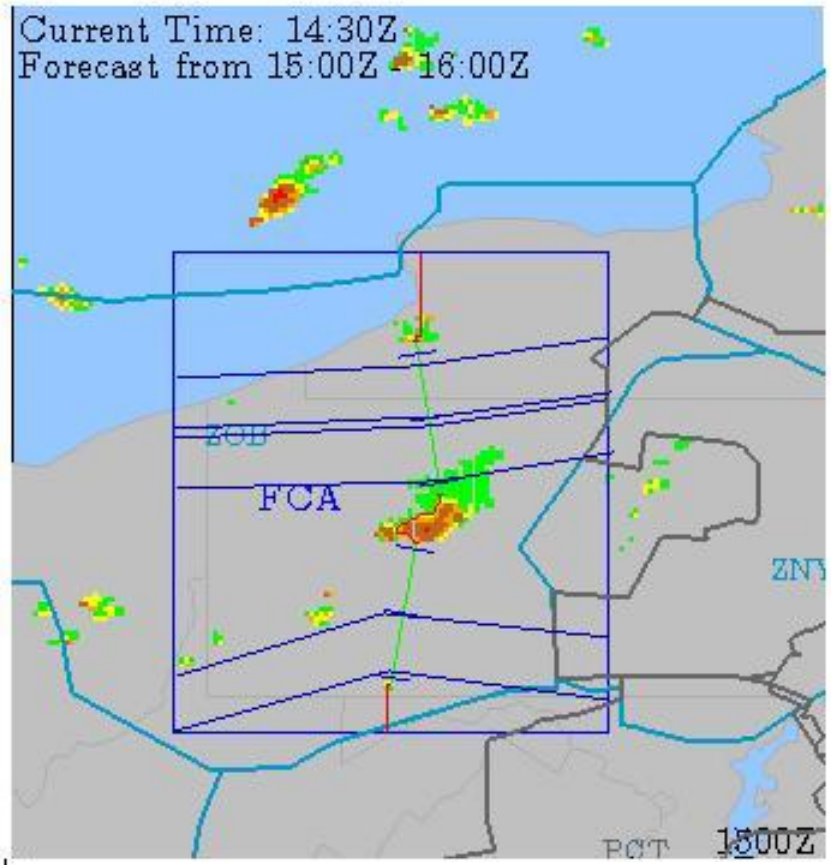
4. Shortest B-T Path in Shortest Path Tree defines the mincut

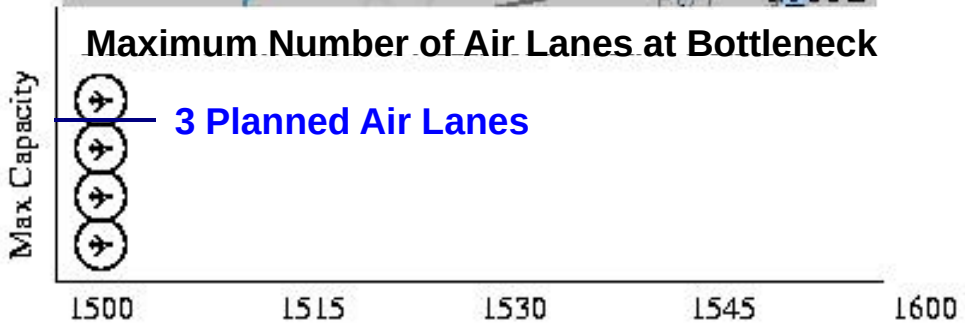


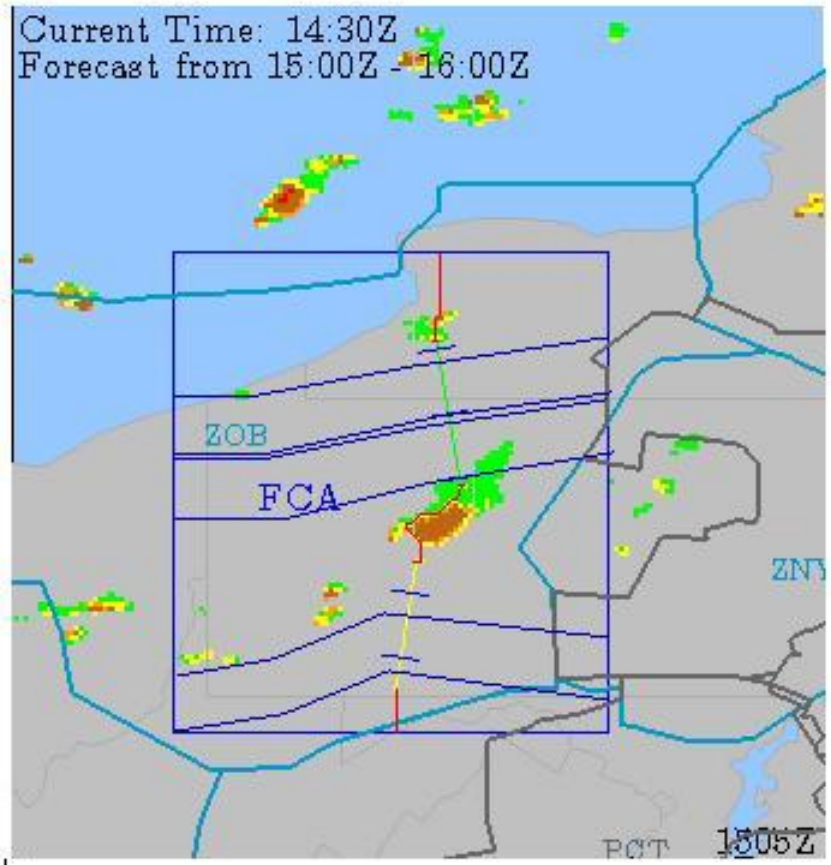
Algorithm: Mincut (Deterministic)

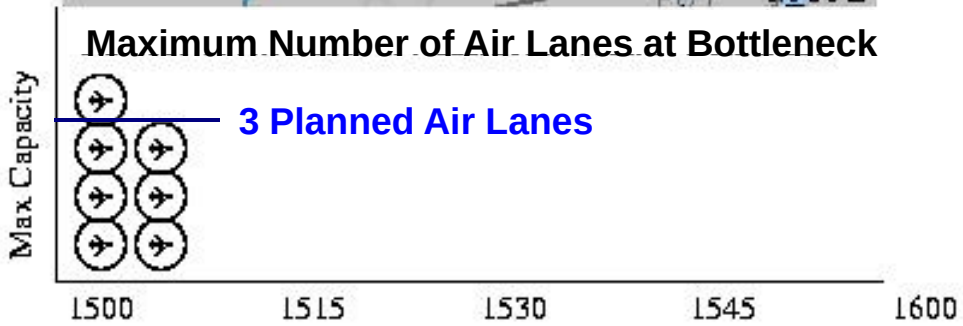
5. Find maximum number of air lanes through the mincut

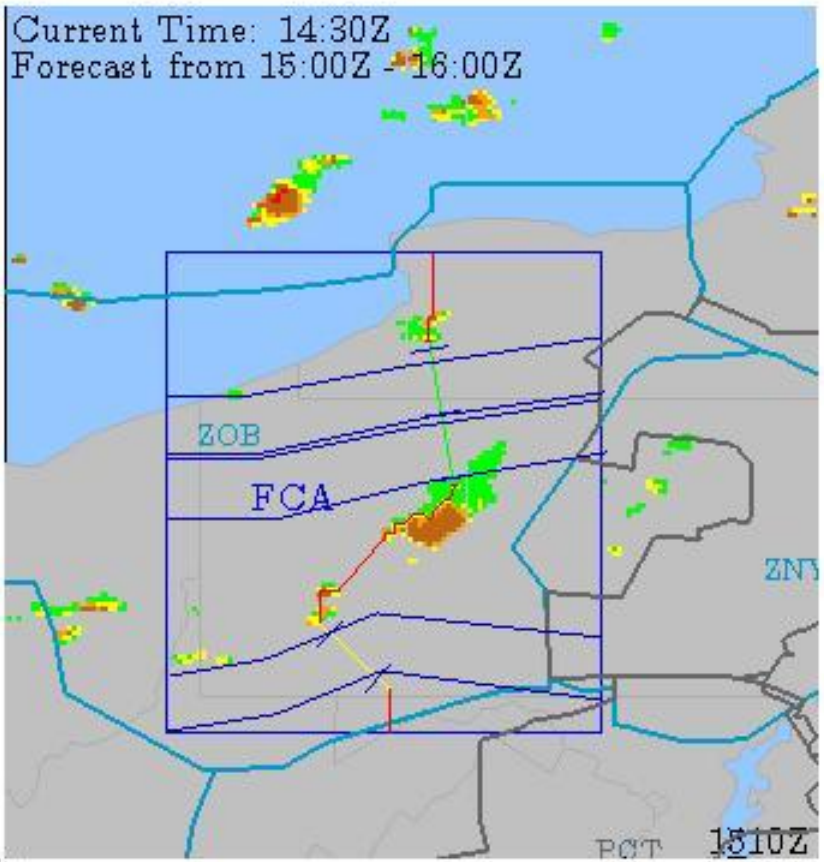



Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1500Z


Maximum Number of Air Lanes at Bottleneck
Max Capacity
3 Planned Air Lanes
1500
1515
1530
1545
1600


Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1505Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600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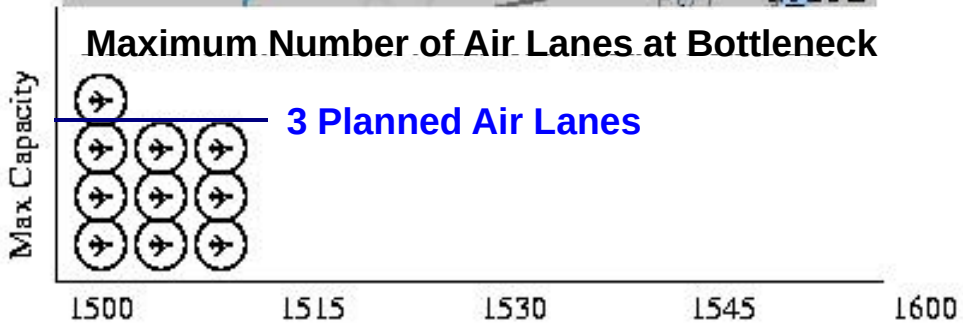
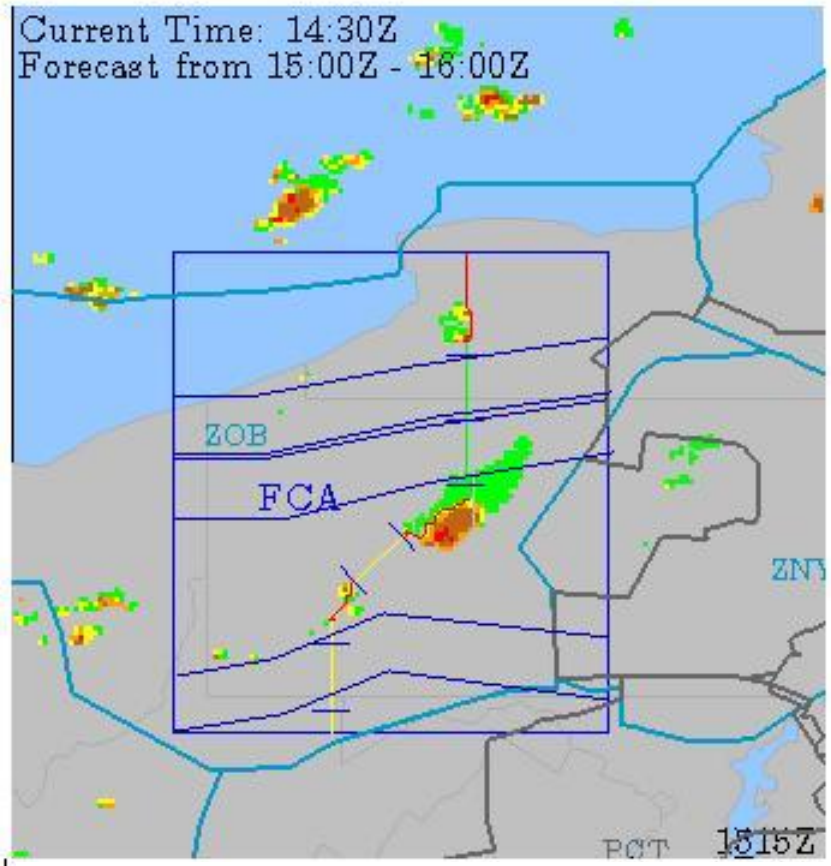
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1510Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600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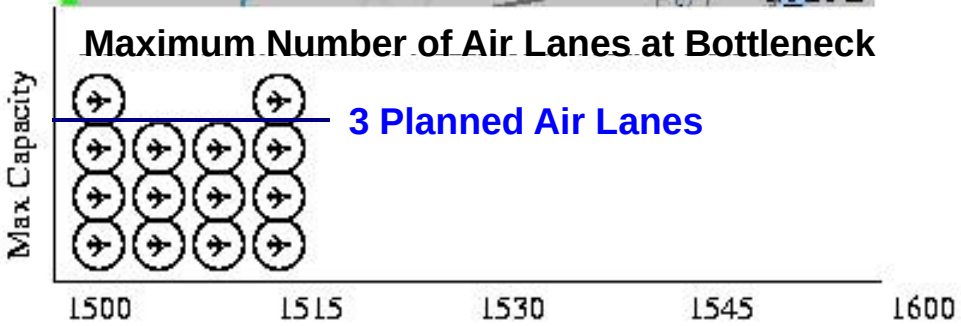
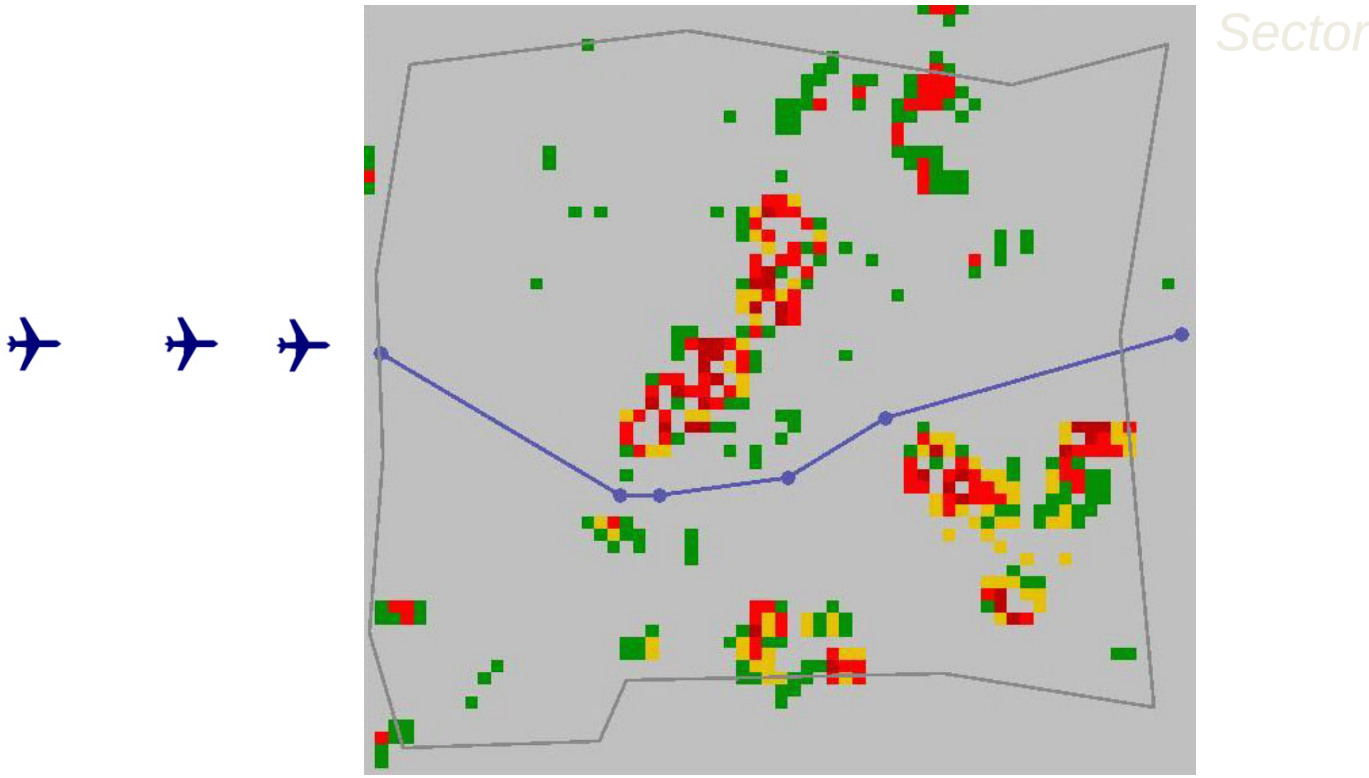
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1515Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600

Example of NASA Weather ATM Integration Research

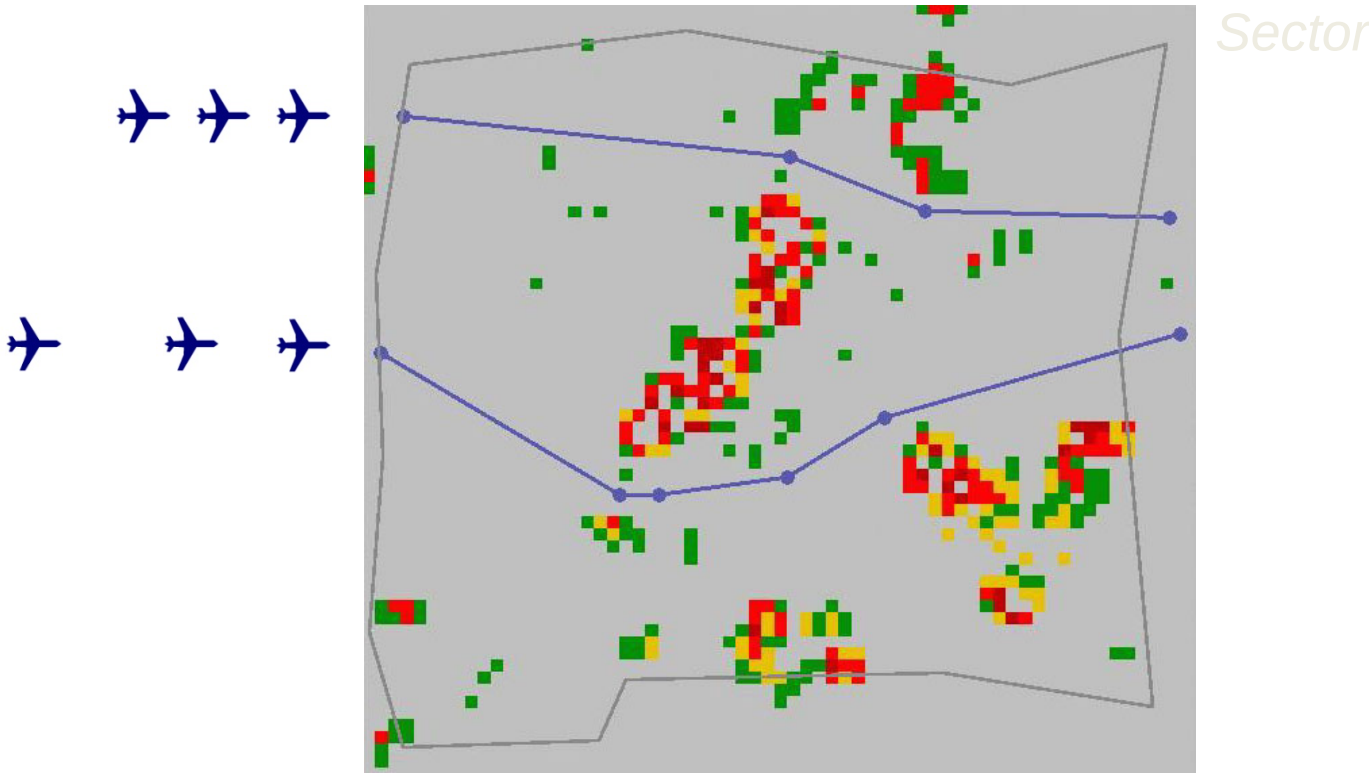
Movie loop shows one way to adjust
to enroute storms

Weather Avoidance Algorithms for En Route Aircraft



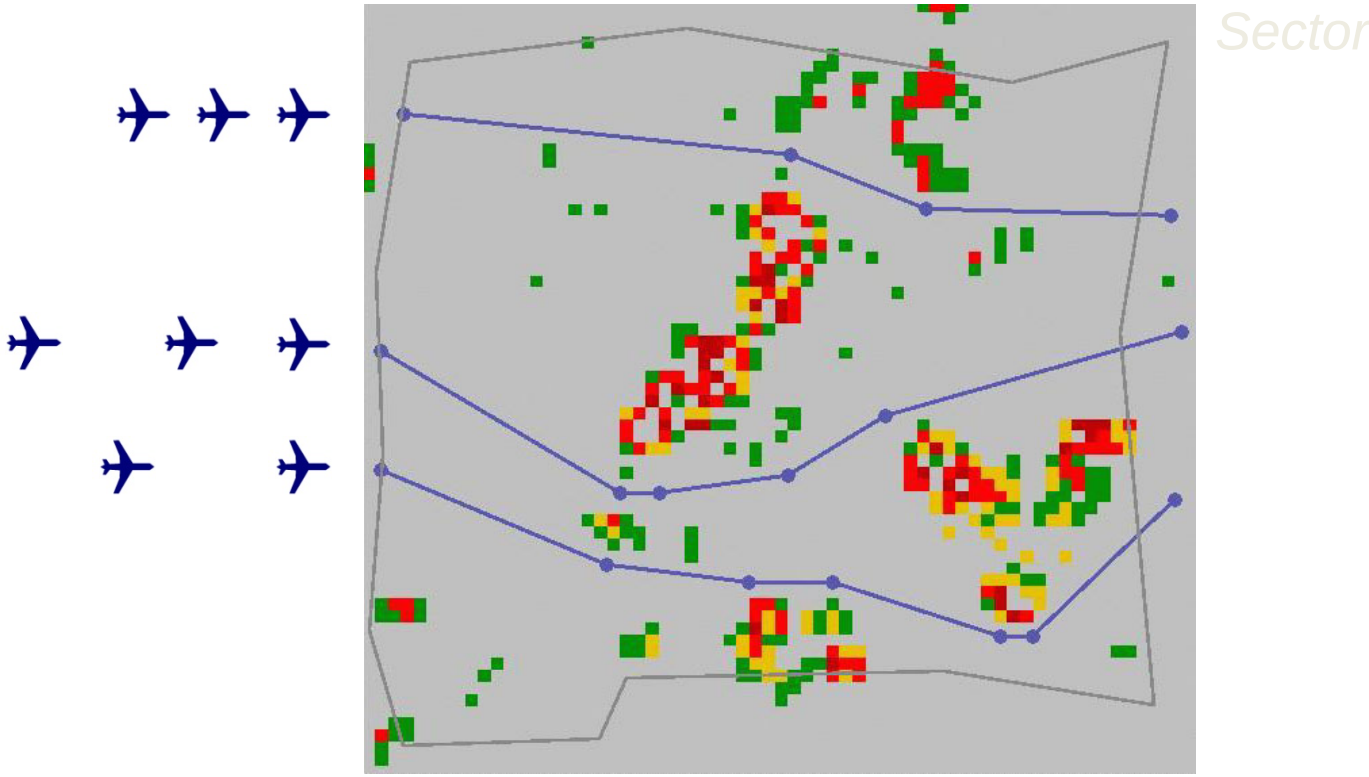
1 Flow

Weather Avoidance Algorithms for En Route Aircraft



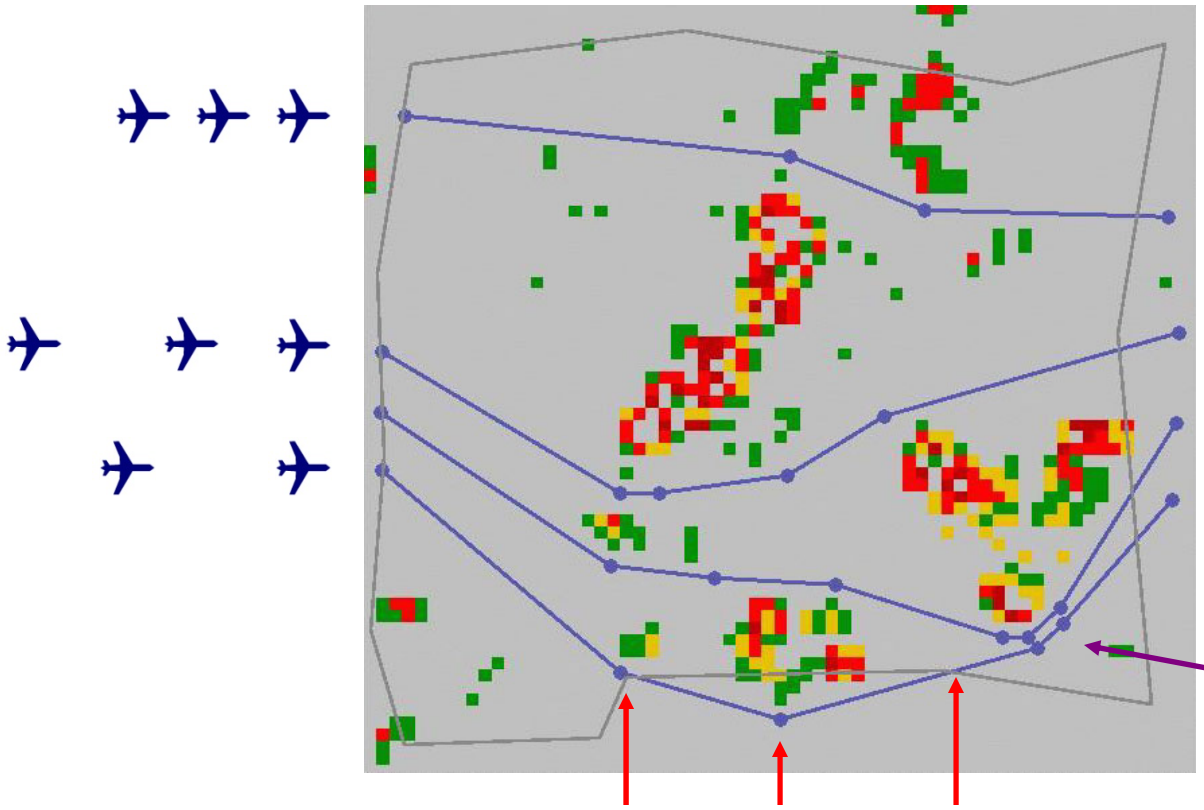
2 Flows

Weather Avoidance Algorithms for En Route Aircraft



3 Flows

Weather Avoidance Algorithms for En Route Aircraft

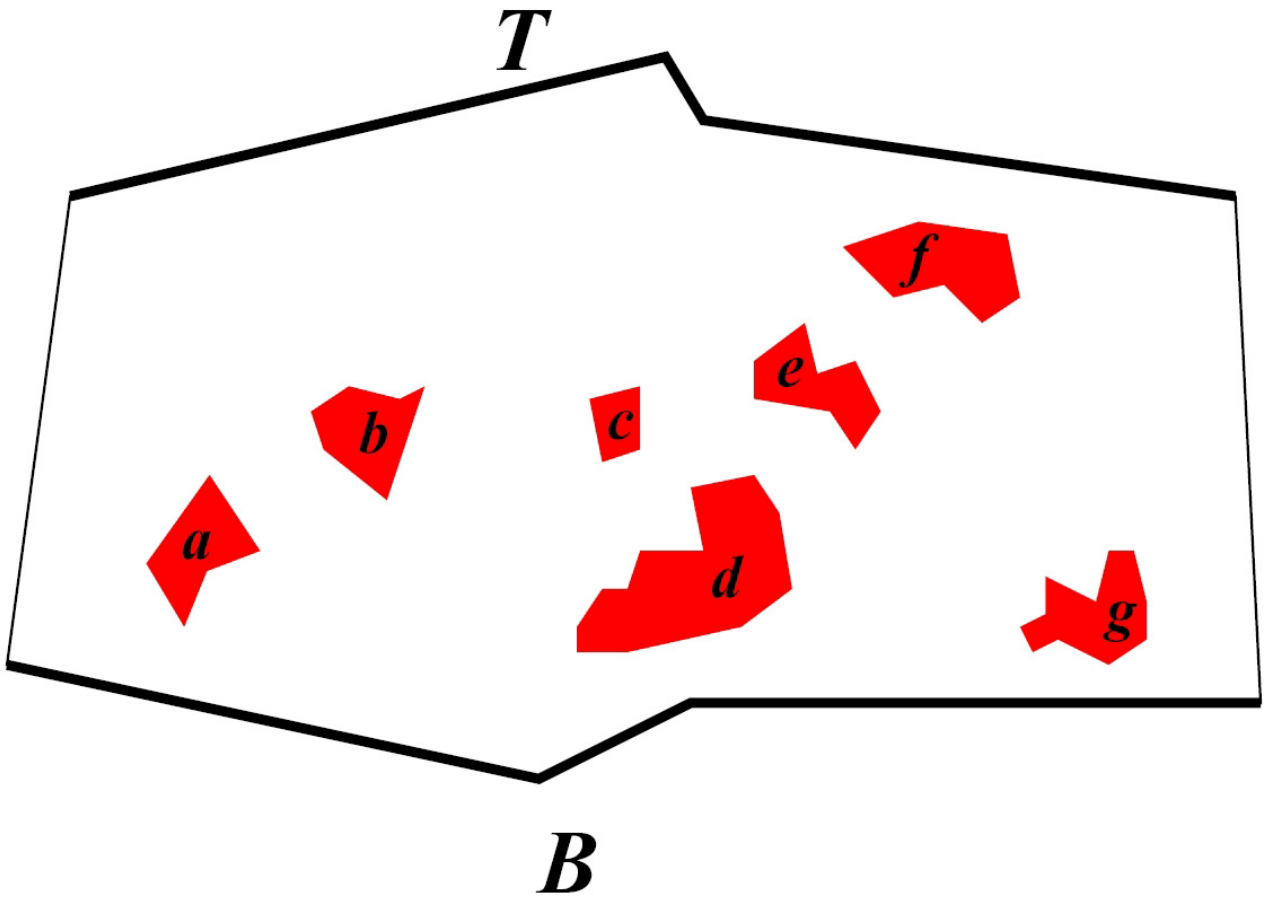


4 Flows

→ Are 3 Routes through the Sector a Maximum?

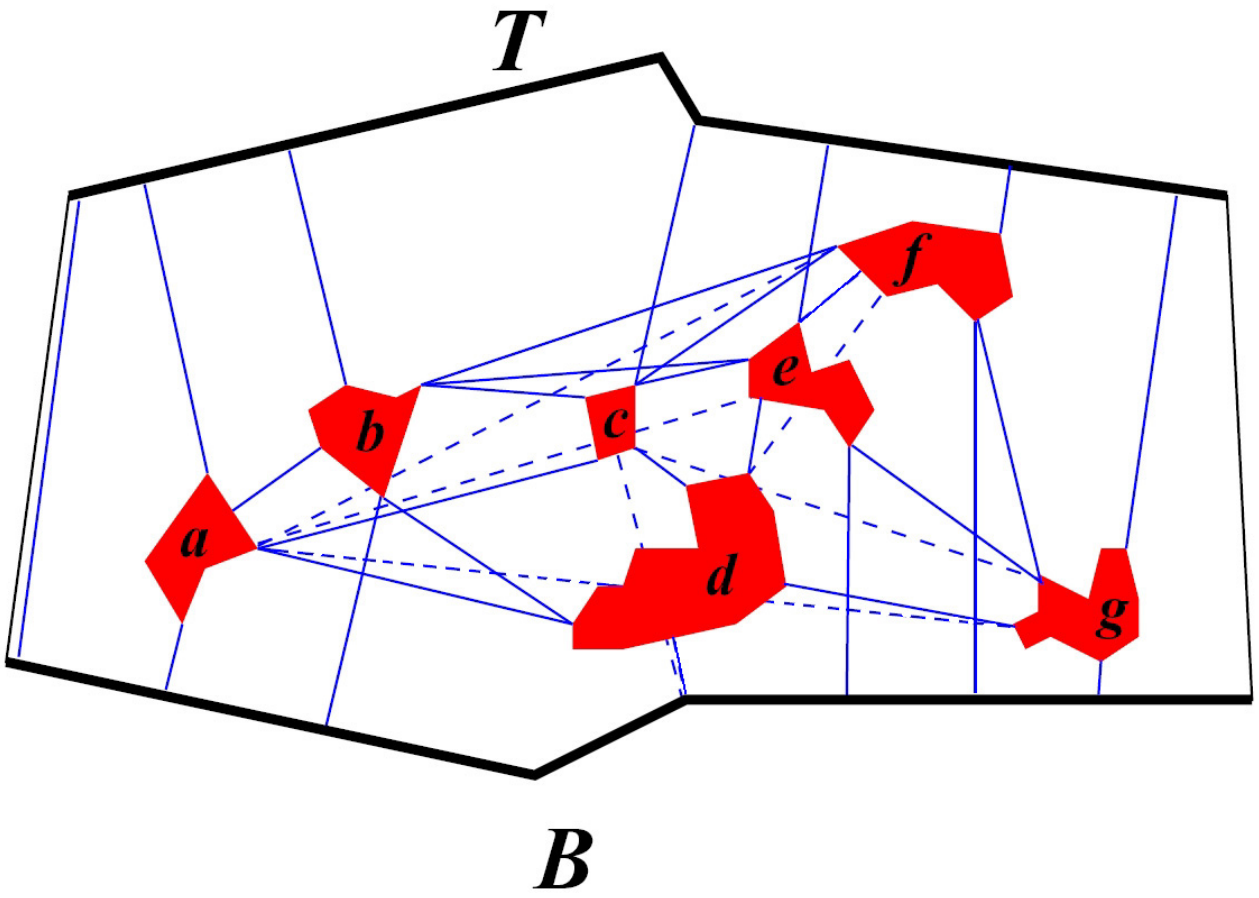
Algorithm: Mincut (Deterministic)

1. Airspace with Hazardous Weather Constraints

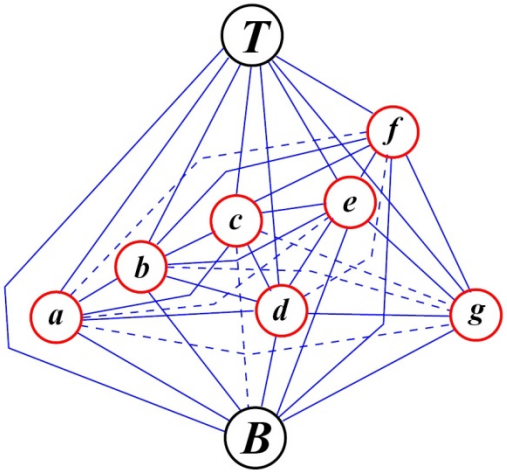


Algorithm: Mincut (Deterministic)

2. Define Critical Graph – connect closest points (B, T, a → g)

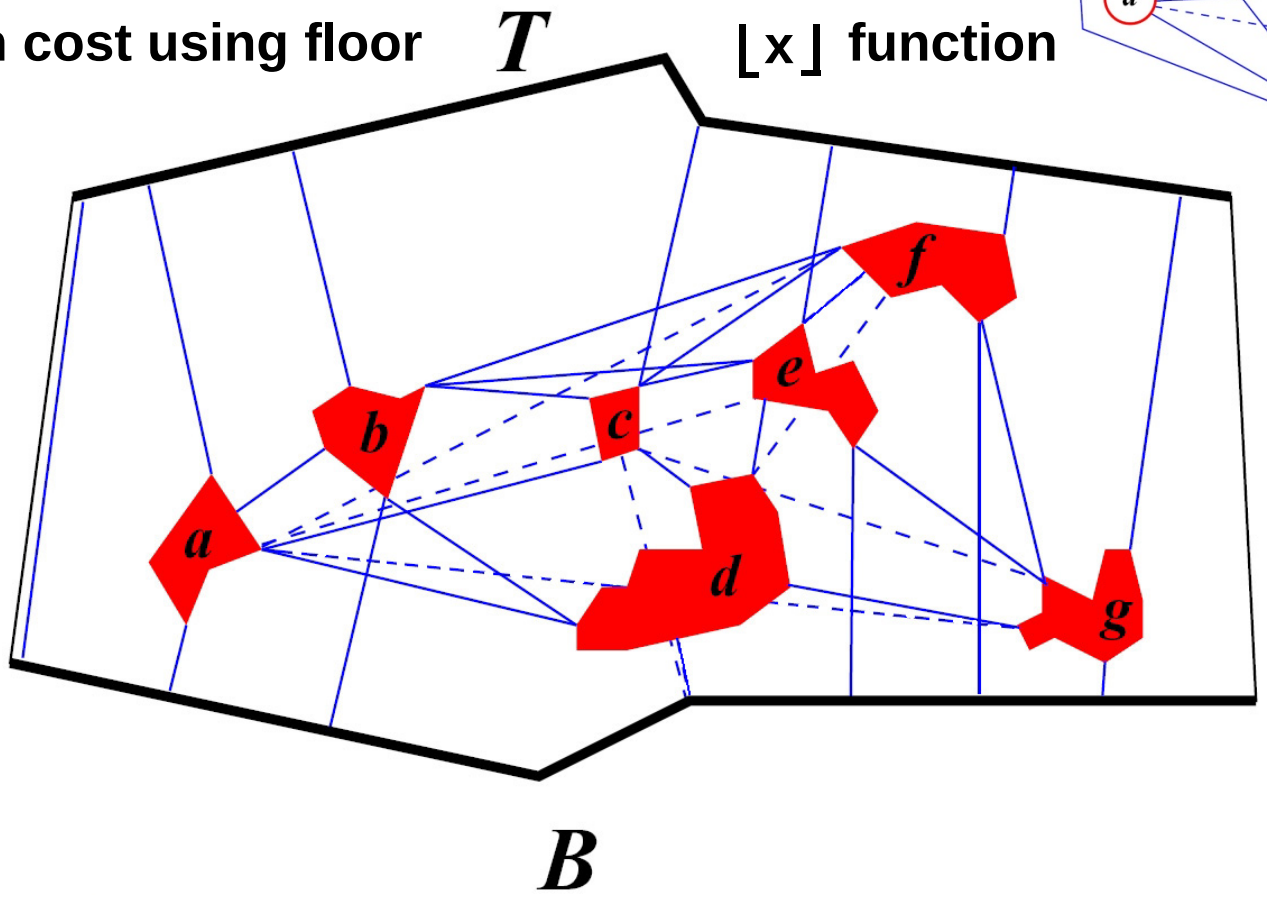


Algorithm: Mincut (Deterministic)



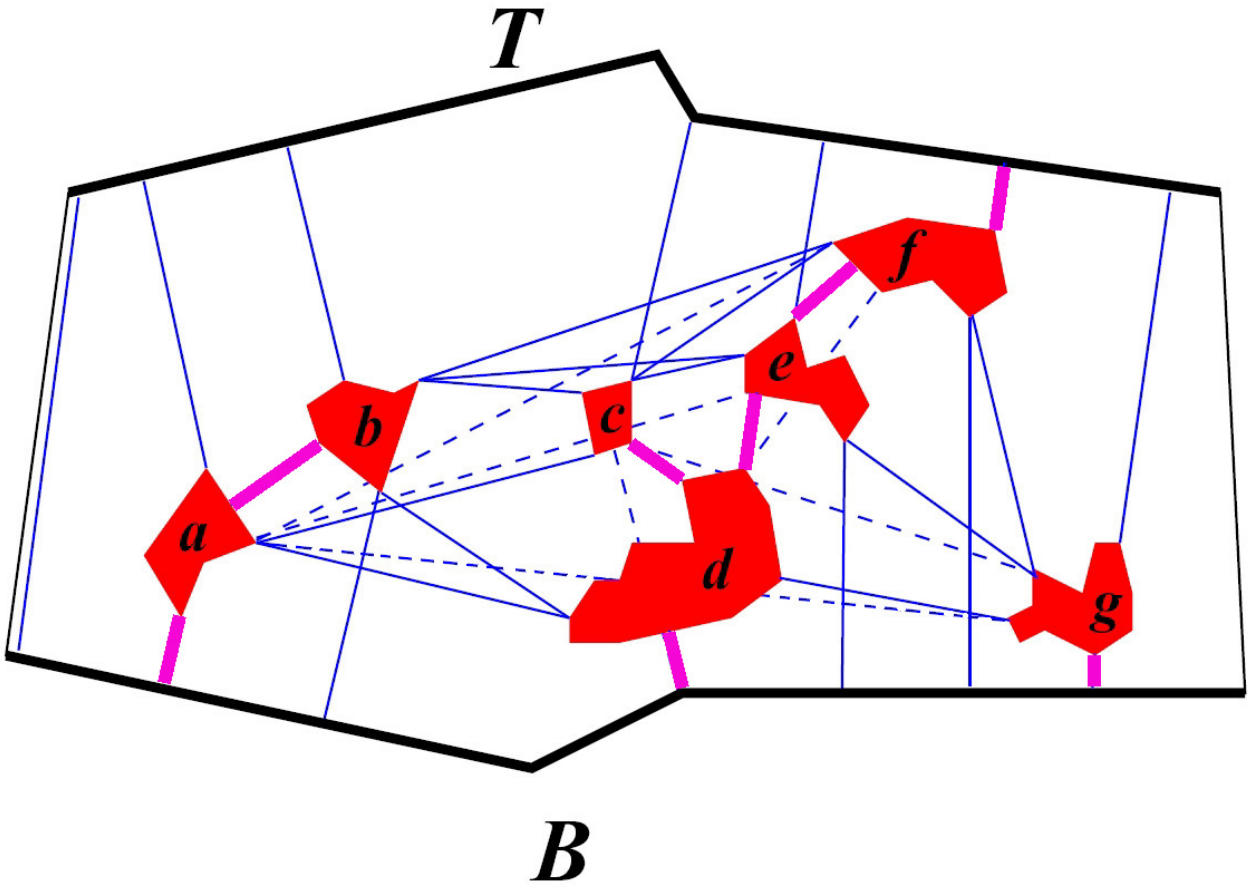
2. Define Critical Graph – connect closest points

Assign cost using floor $\lfloor x \rfloor$ function

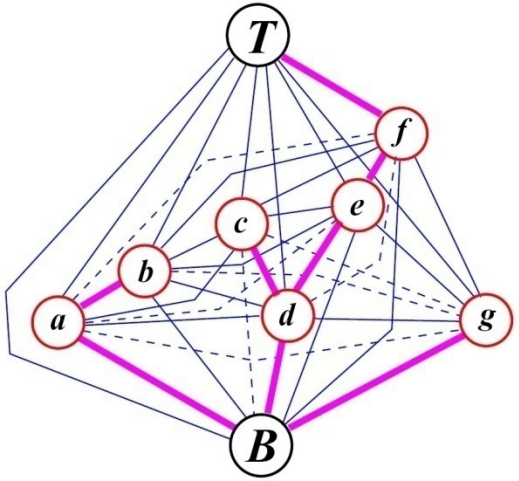


Algorithm: Mincut (Deterministic)

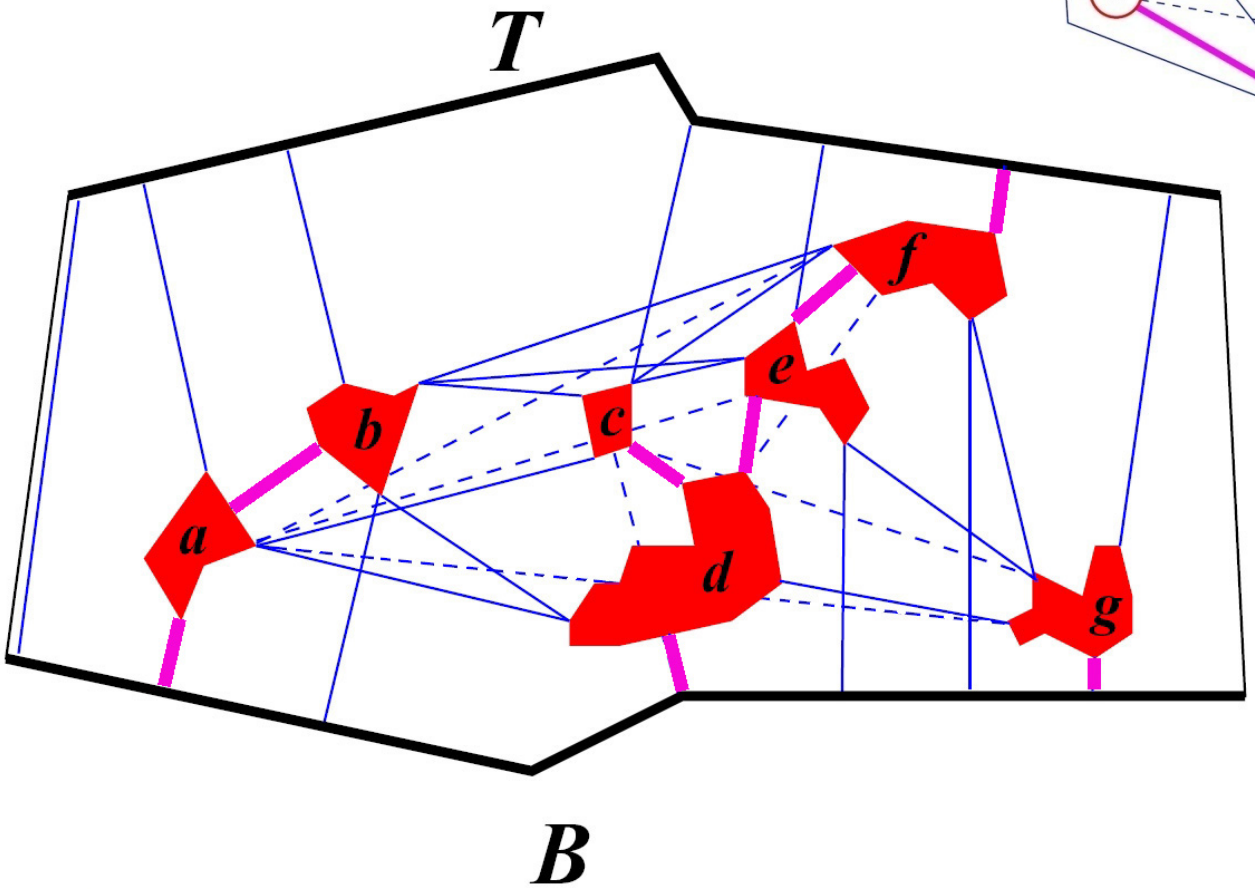
3. Search for Shortest Path Tree within Critical Graph



Algorithm: Mincut (Deterministic)

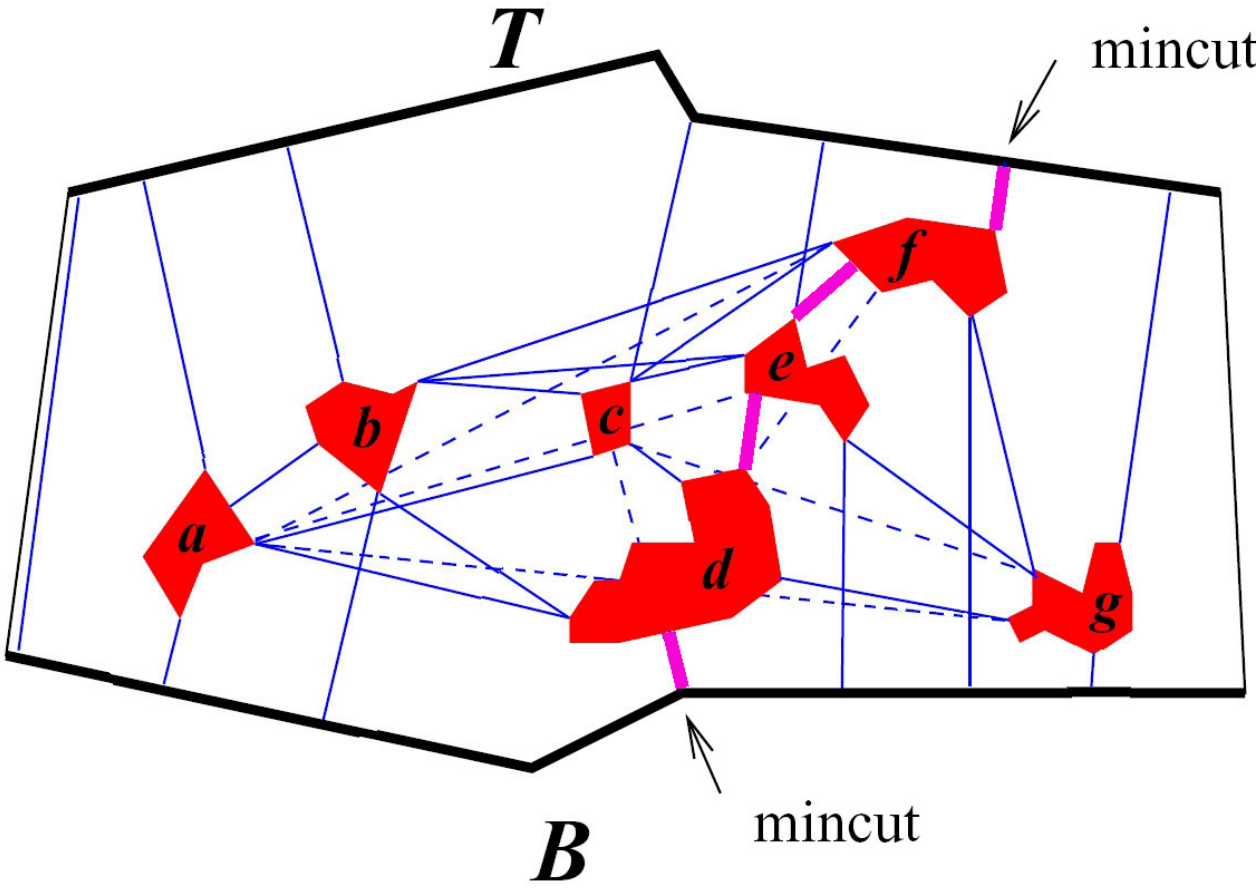


3. Search for Shortest Path Tree



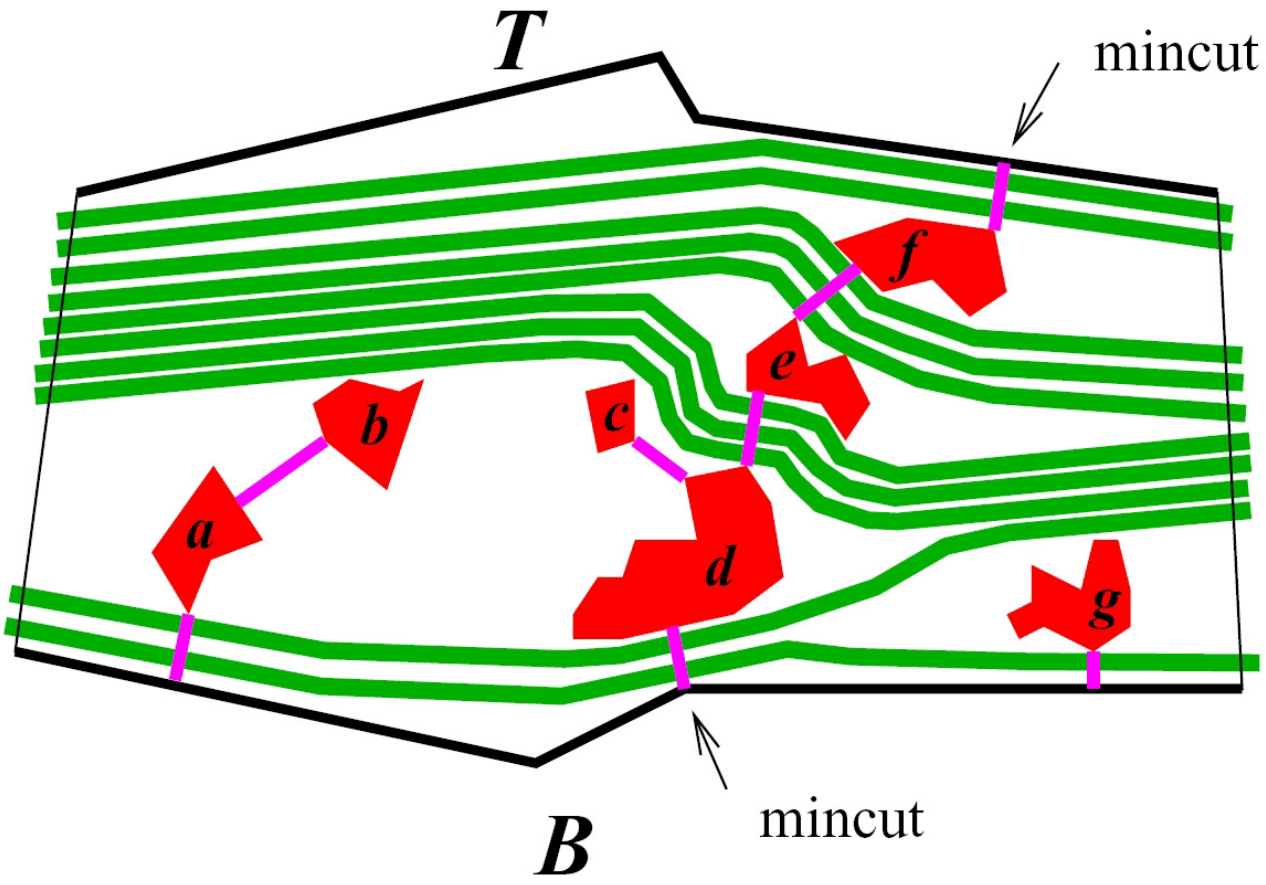
Algorithm: Mincut (Deterministic)

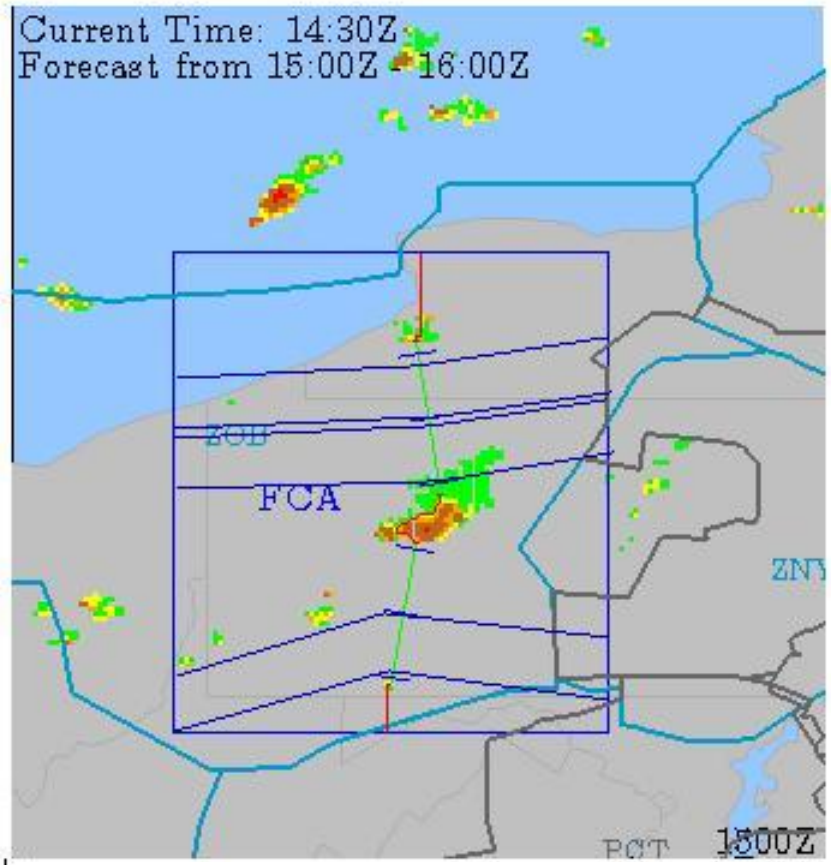
4. Shortest B-T Path in Shortest Path Tree defines the mincut



Algorithm: Mincut (Deterministic)

5. Find maximum number of air lanes through the mincut

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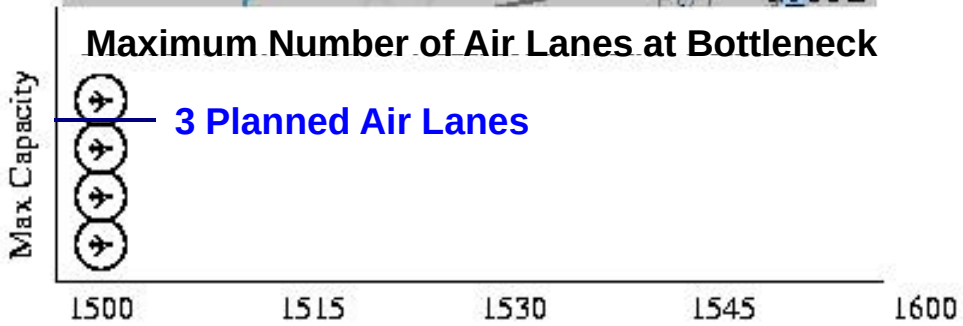
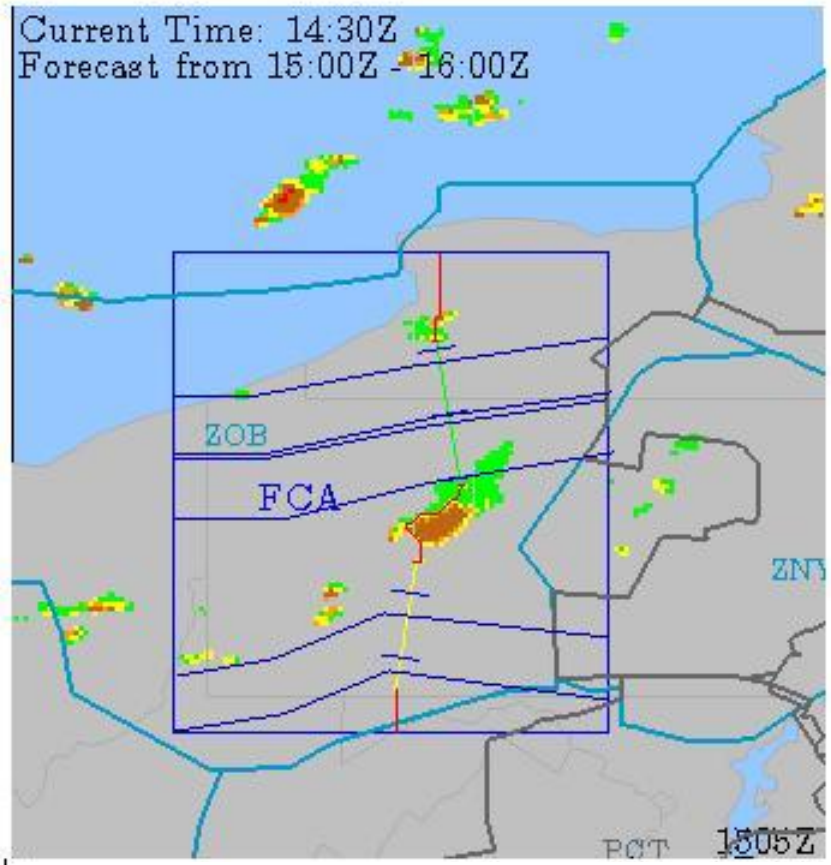
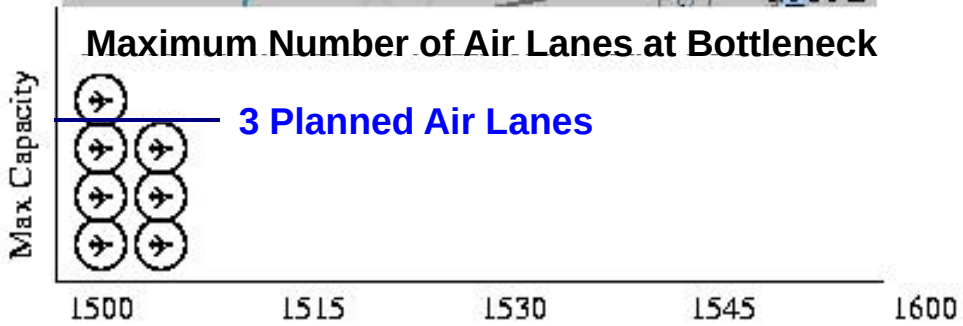
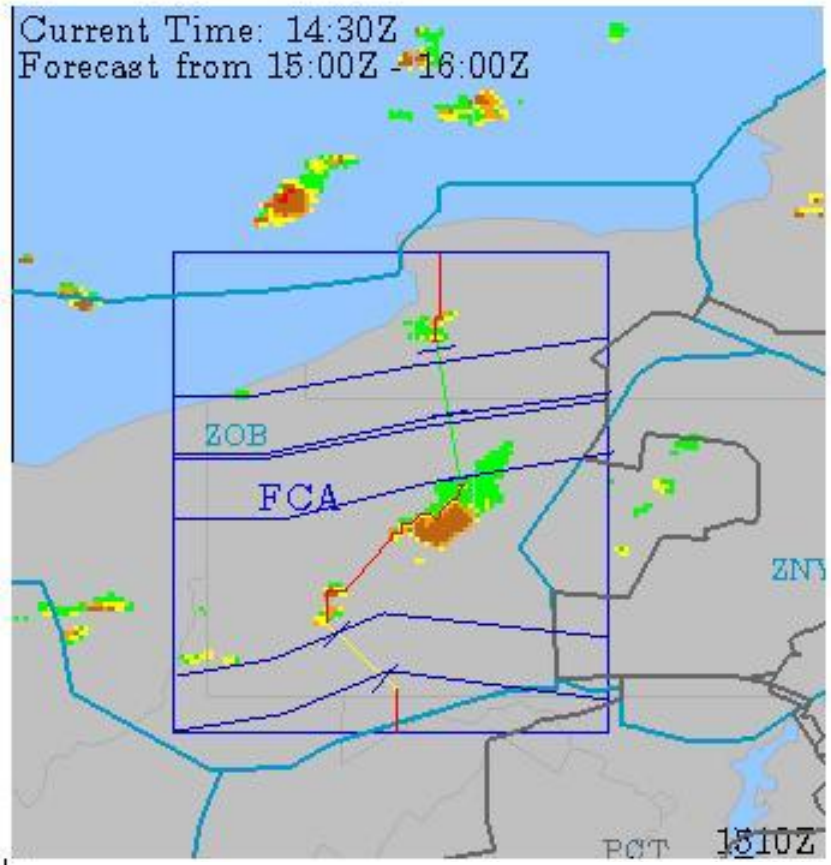
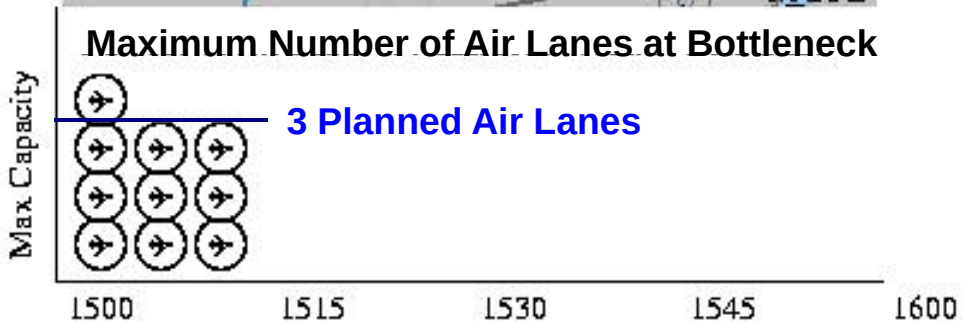
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1500Z

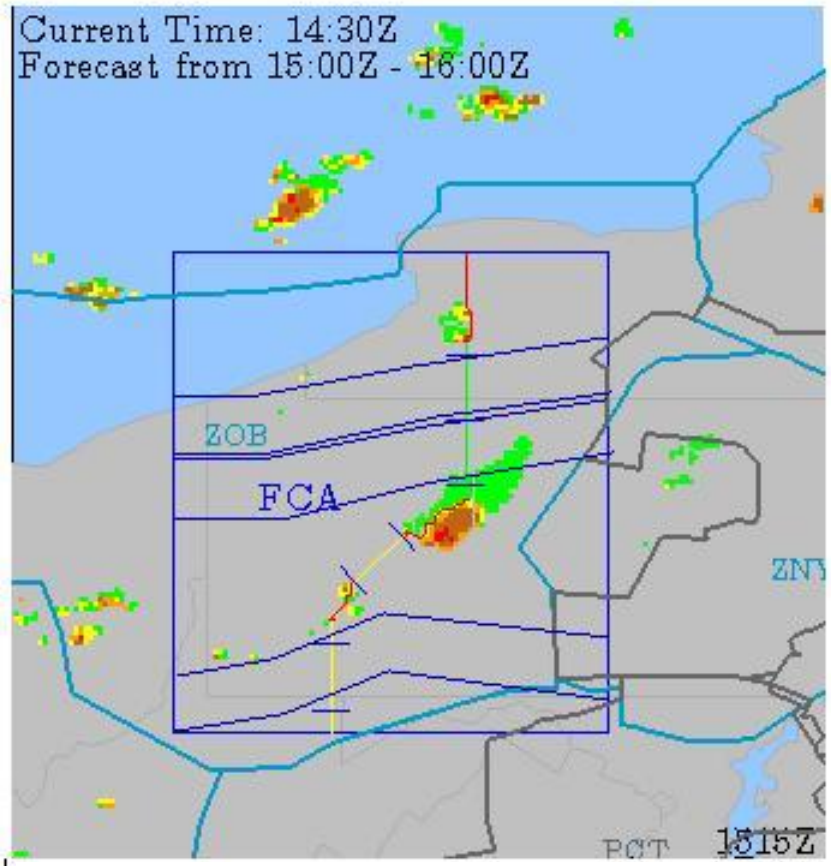

Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600

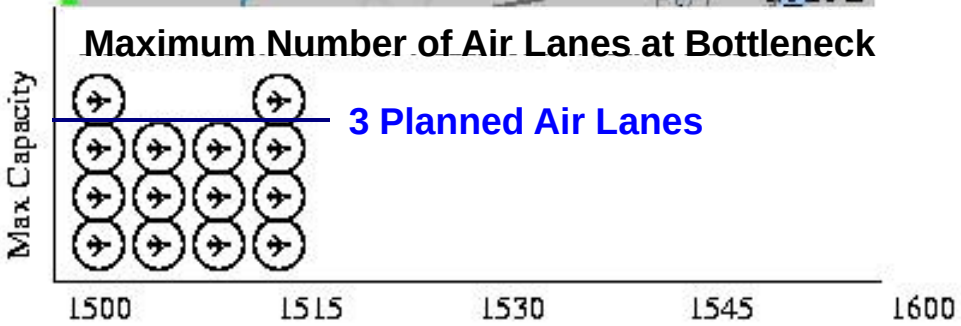

Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1505Z

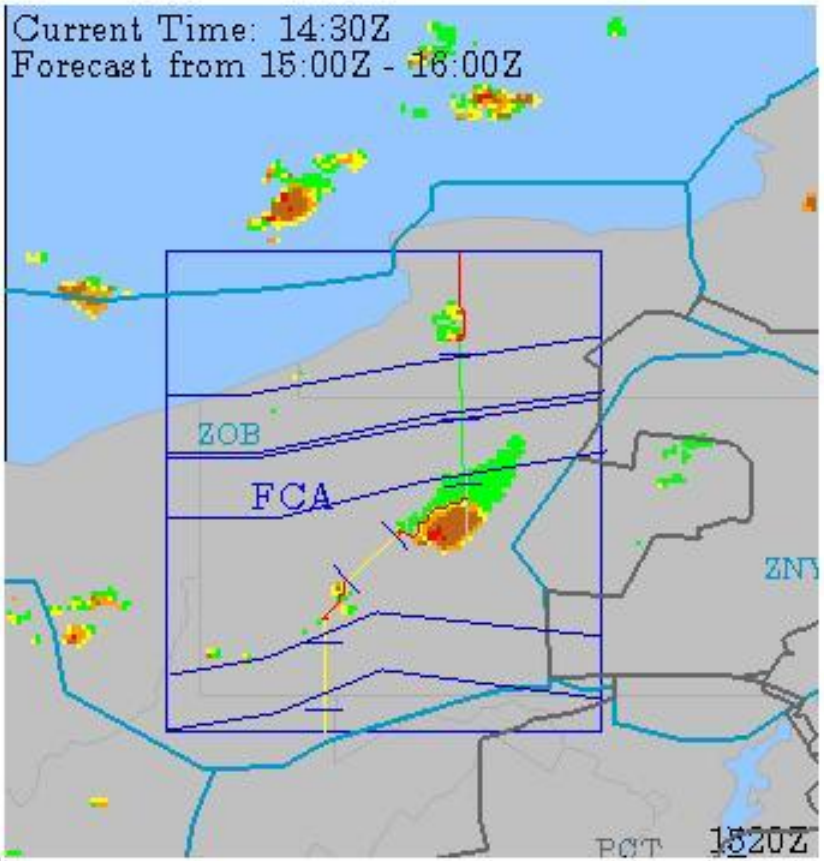

Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600


Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1510Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600


Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1515Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600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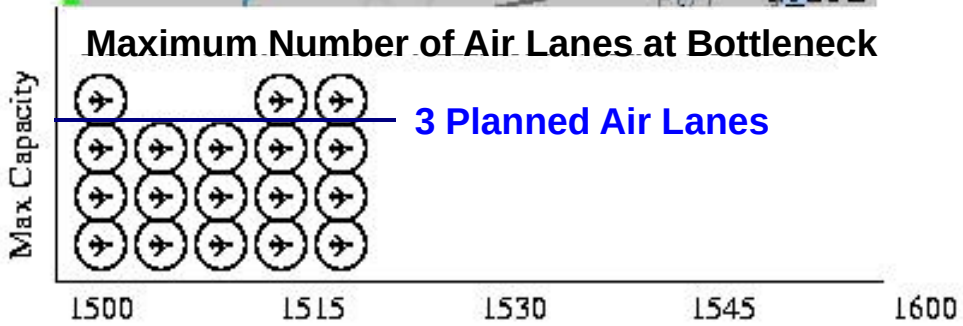
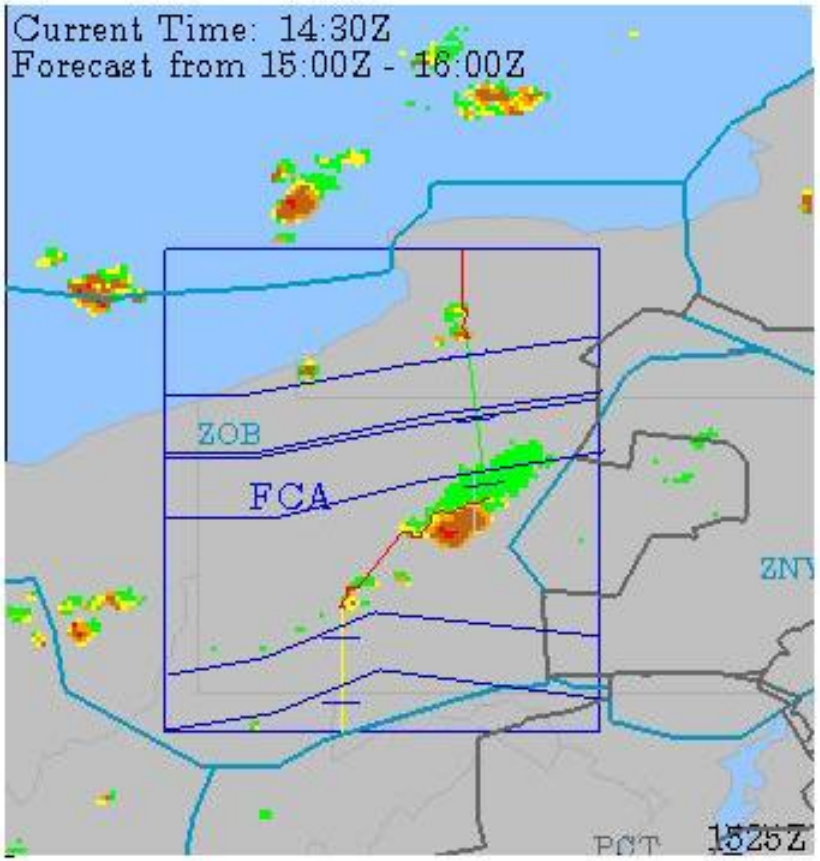
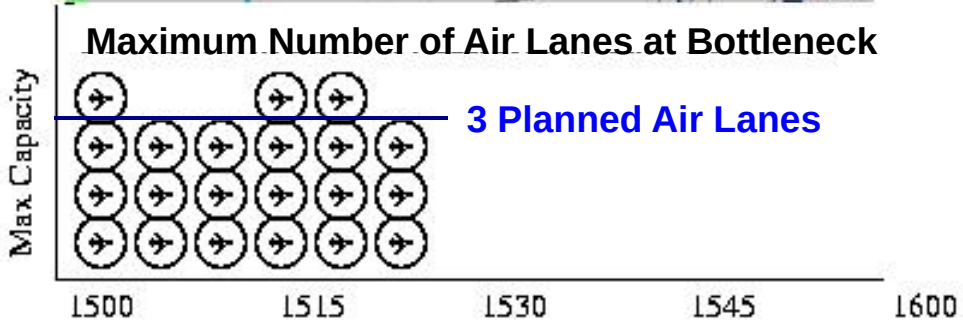
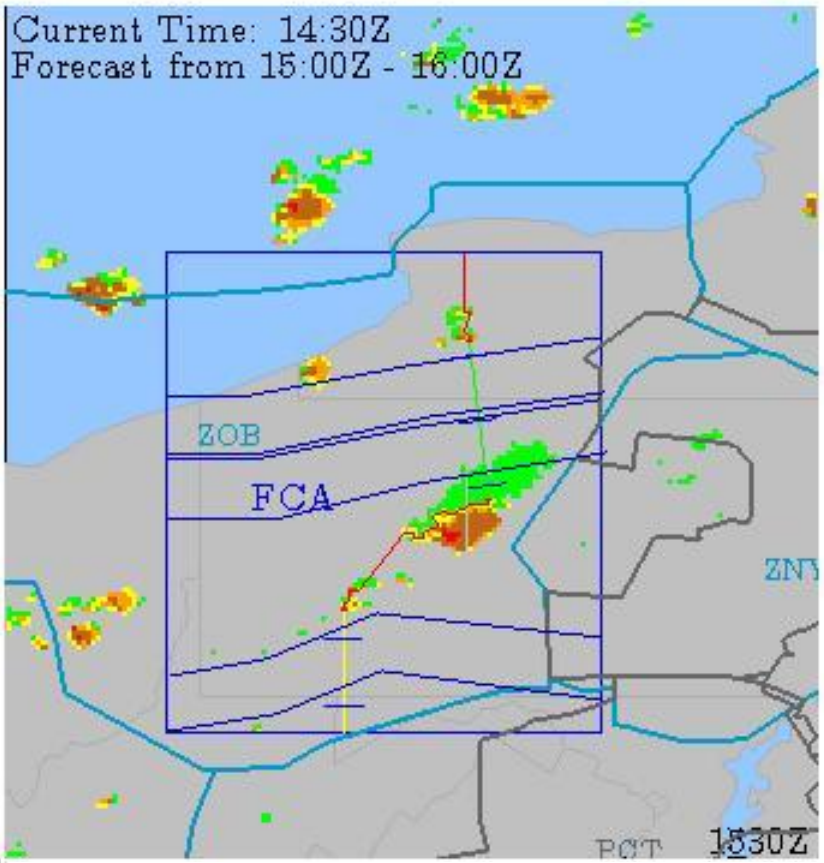
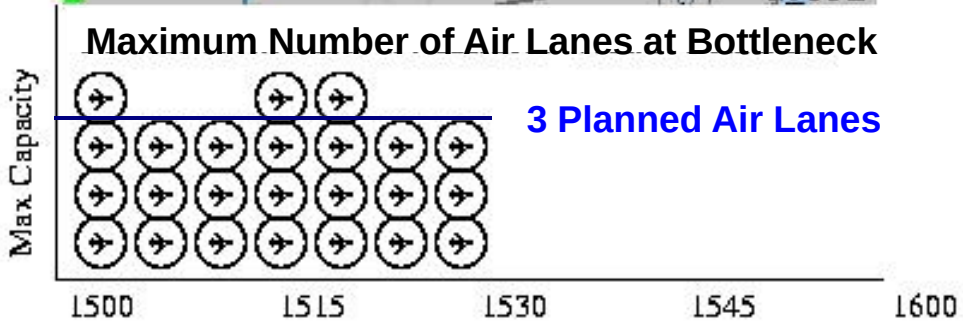
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1520Z

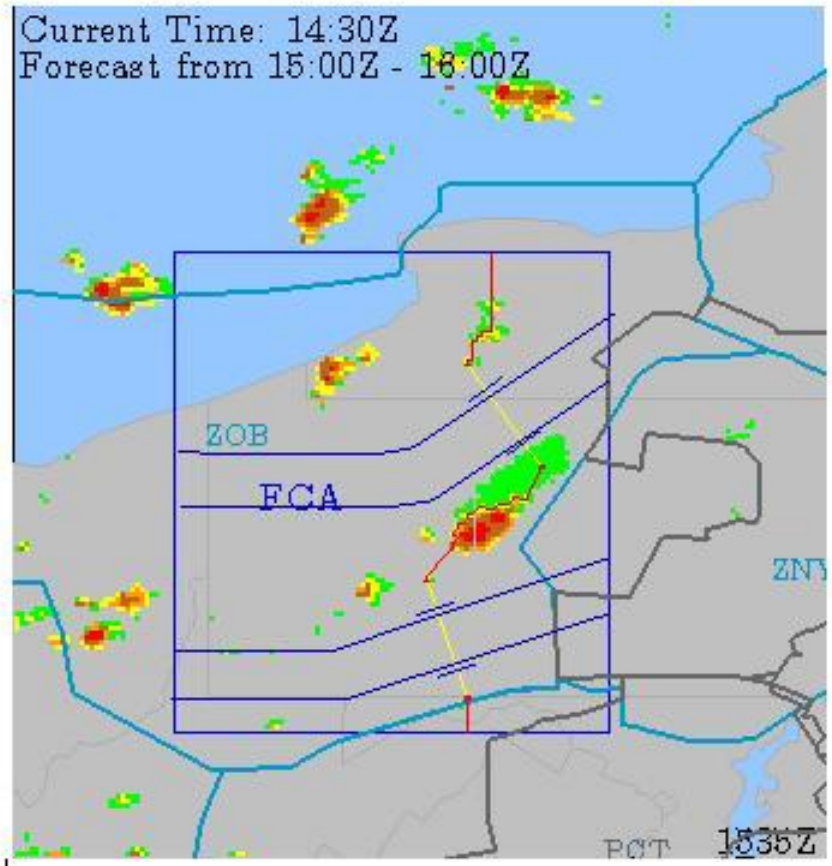

Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600


Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1525Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600


Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1530Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600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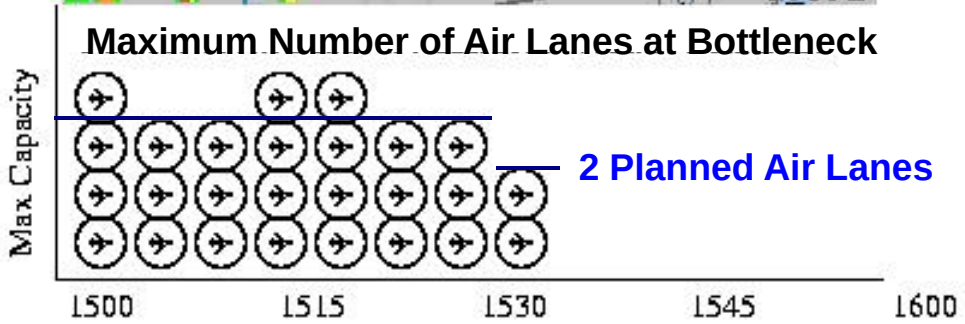
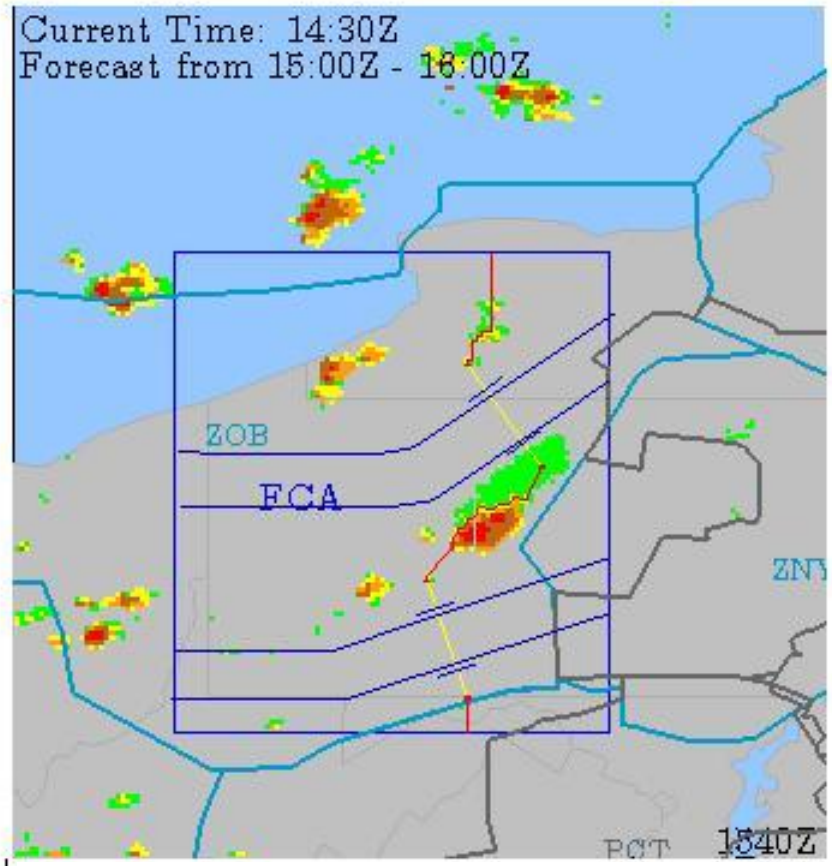
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1535Z


Maximum Number of Air Lanes at Bottleneck
2 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600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Forecast from 15:00Z - 16:00Z
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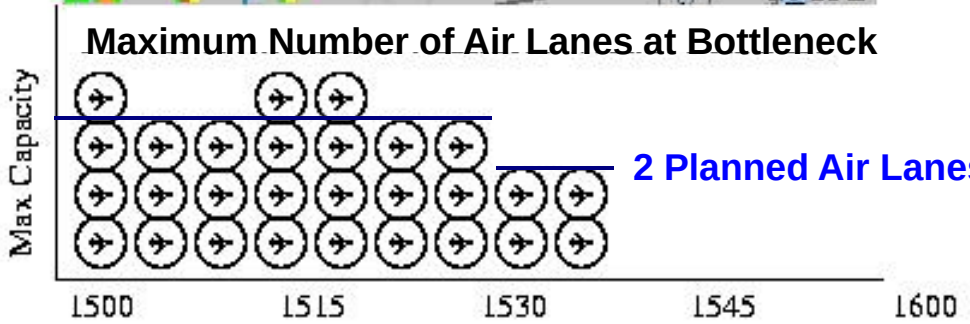
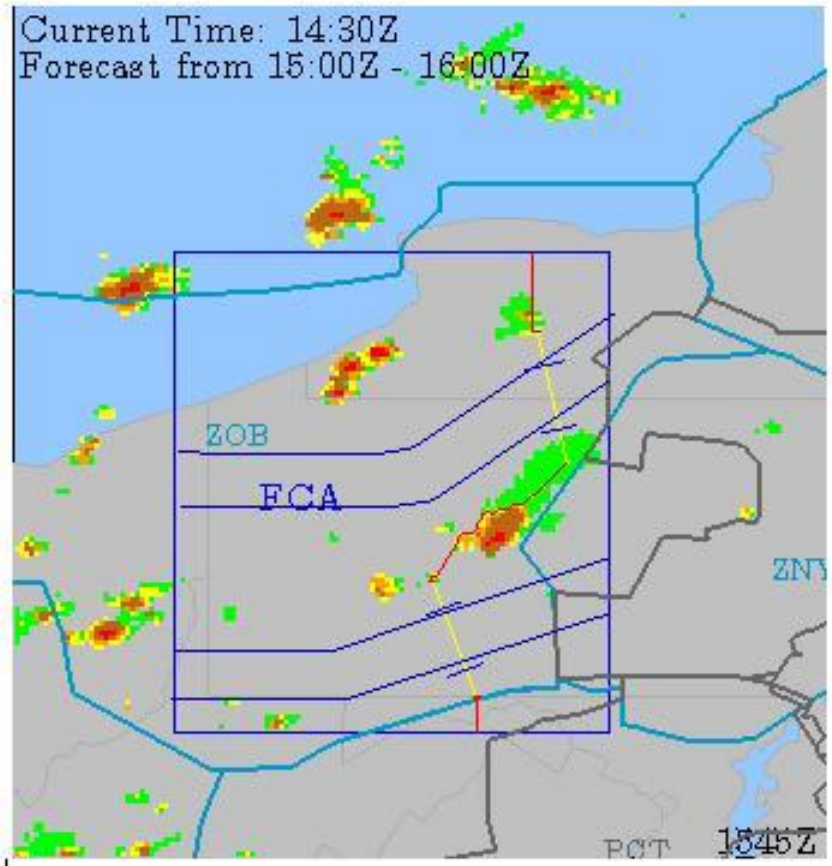
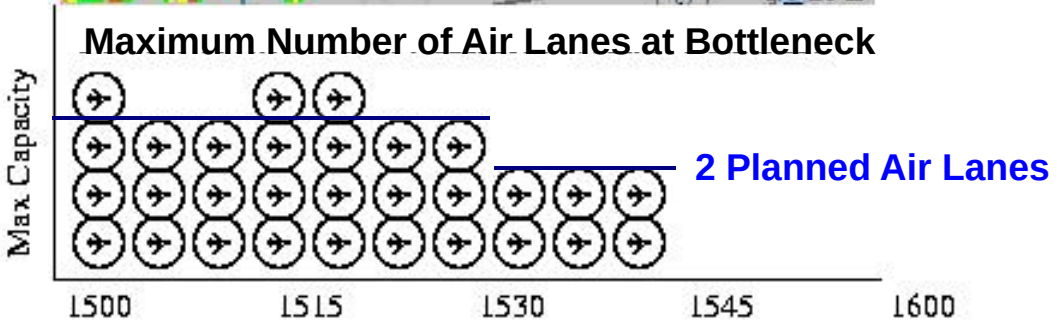
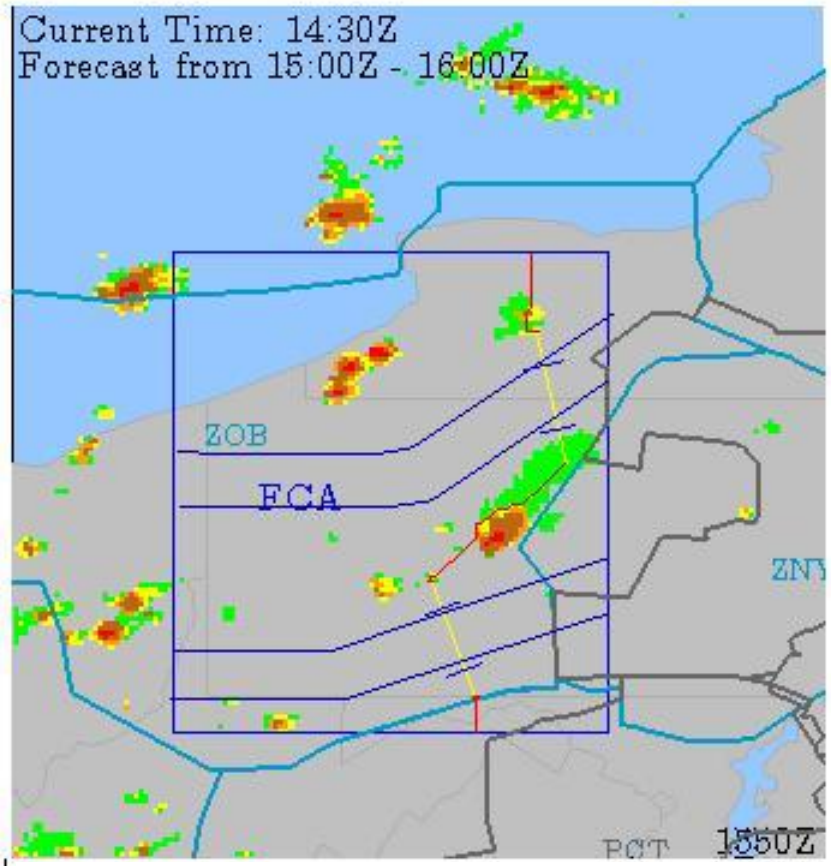
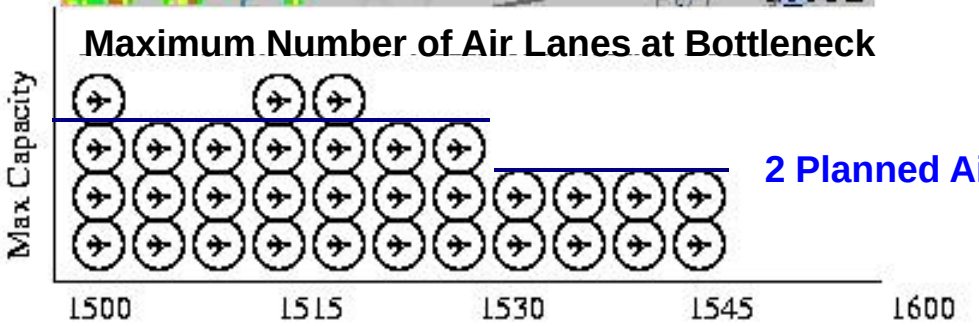
FCA
ZNY
PCT
1540Z

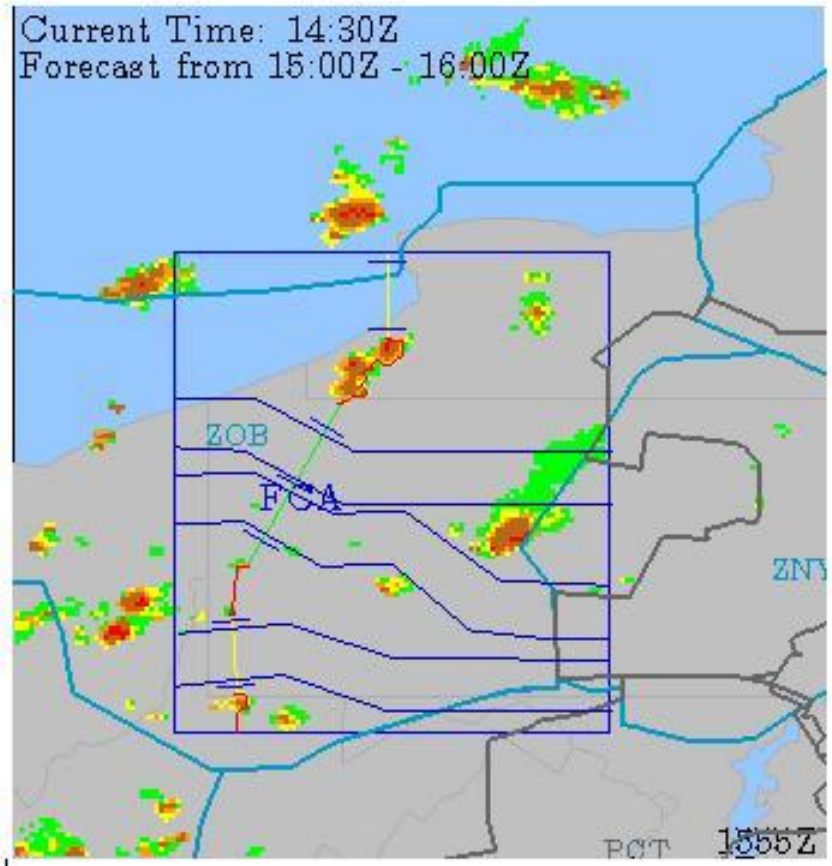

Maximum Number of Air Lanes at Bottleneck
2 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600

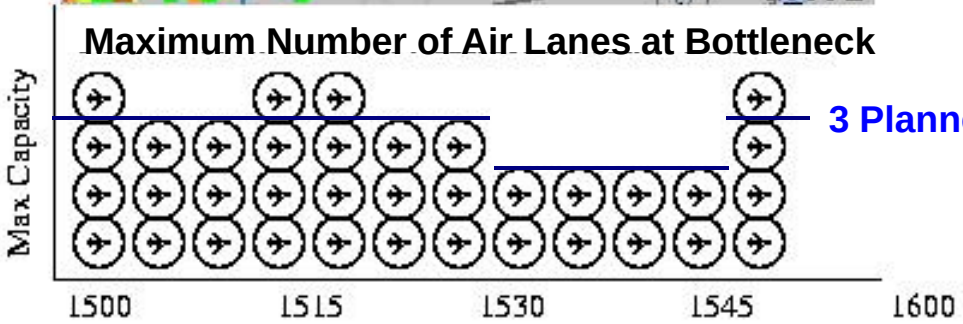

Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1545Z

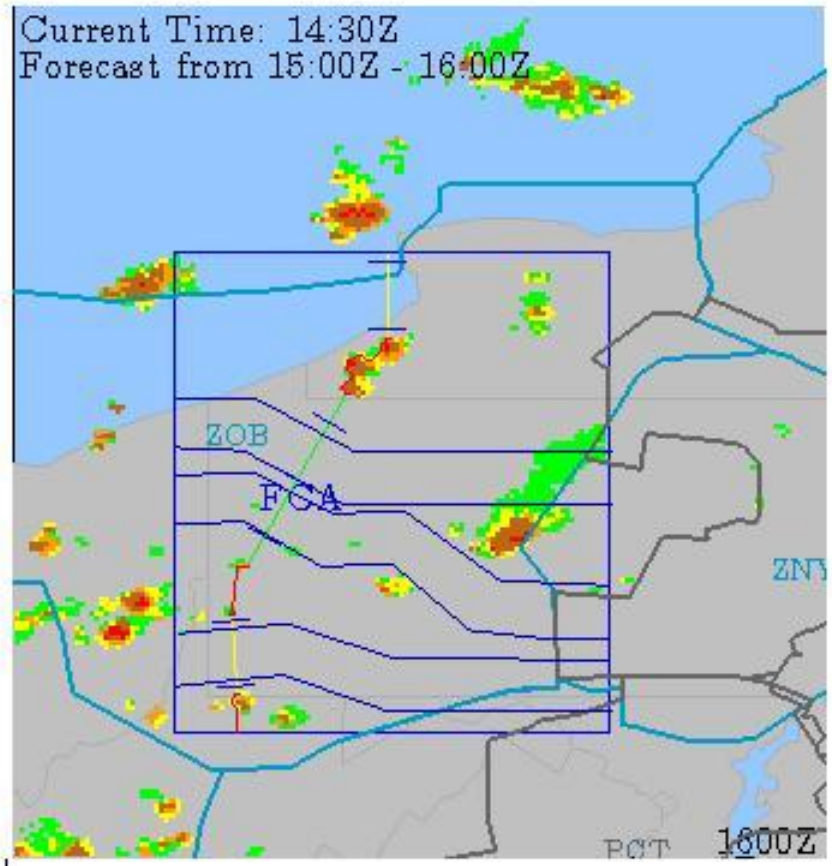

Maximum Number of Air Lanes at Bottleneck
Max Capacity
2 Planned Air Lanes
1500
1515
1530
1545
1600

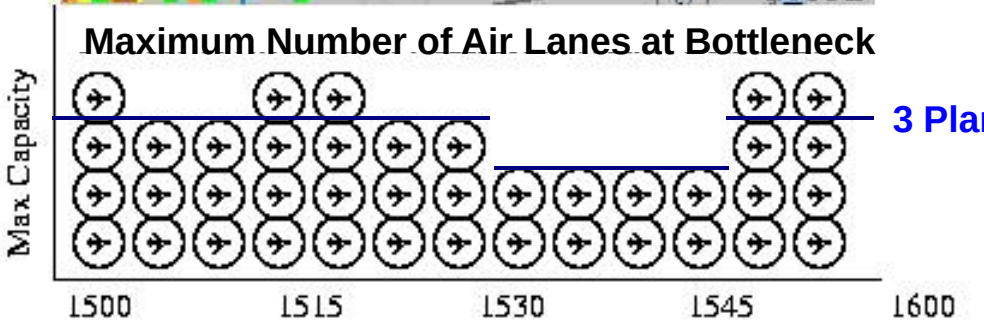

Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1550Z


Maximum Number of Air Lanes at Bottleneck
Max Capacity
2 Planned Air Lanes
1500
1515
1530
1545
1600

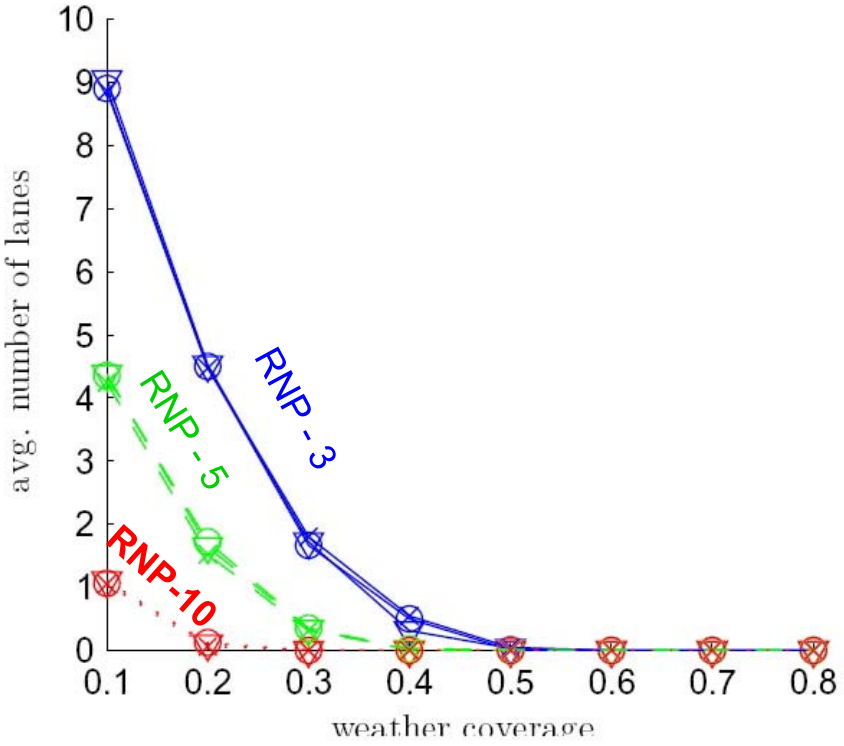

Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1555Z

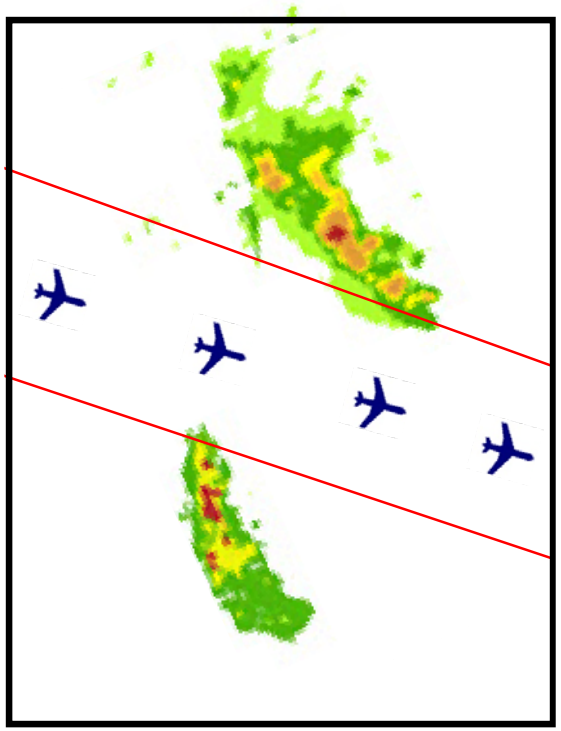

Maximum Number of Air Lanes at Bottleneck
Max Capacity
1500
1515
1530
1545
1600
3 Planned Air Lanes


Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1600Z

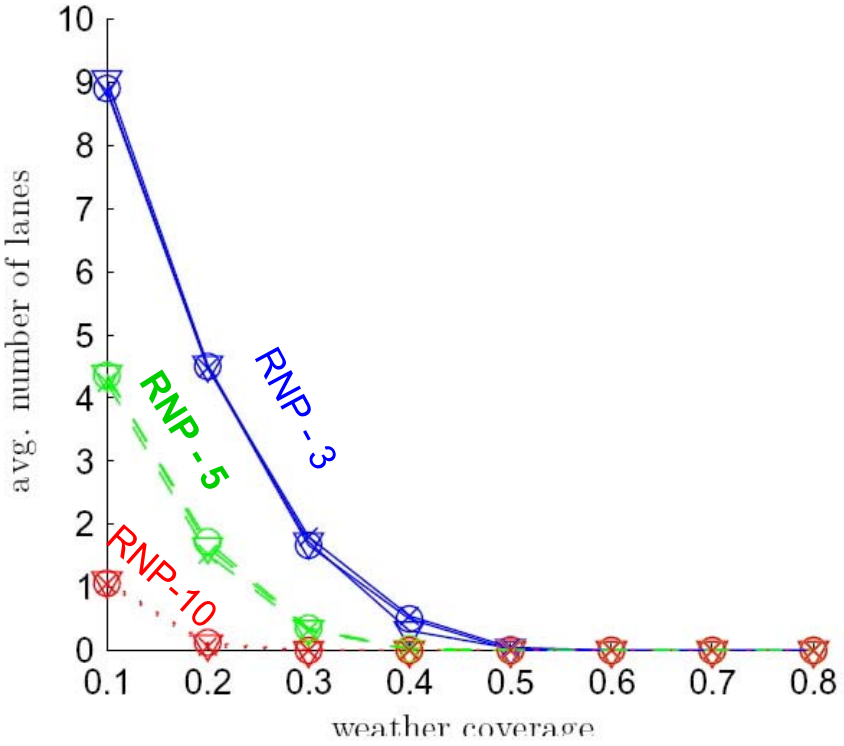

Maximum Number of Air Lanes at Bottleneck
Max Capacity
1500
1515
1530
1545
1600
3 Planned Air Lanes

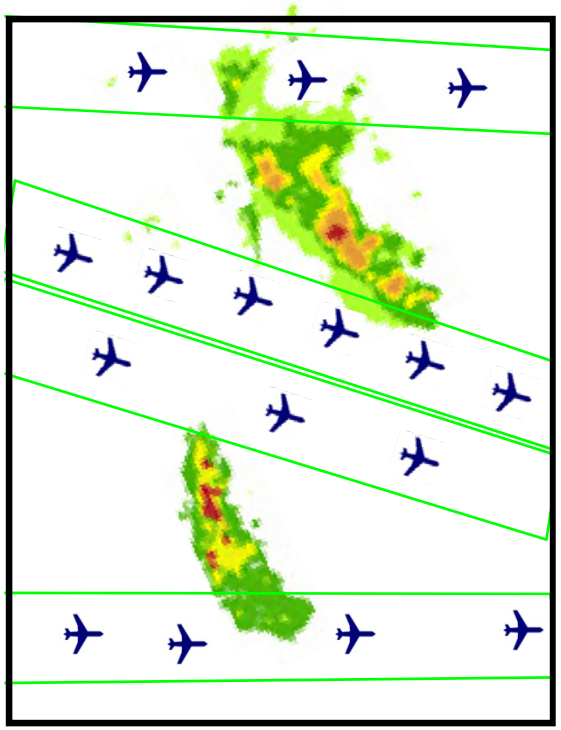
Variations in the Size of the Gap (RNP Requirement)



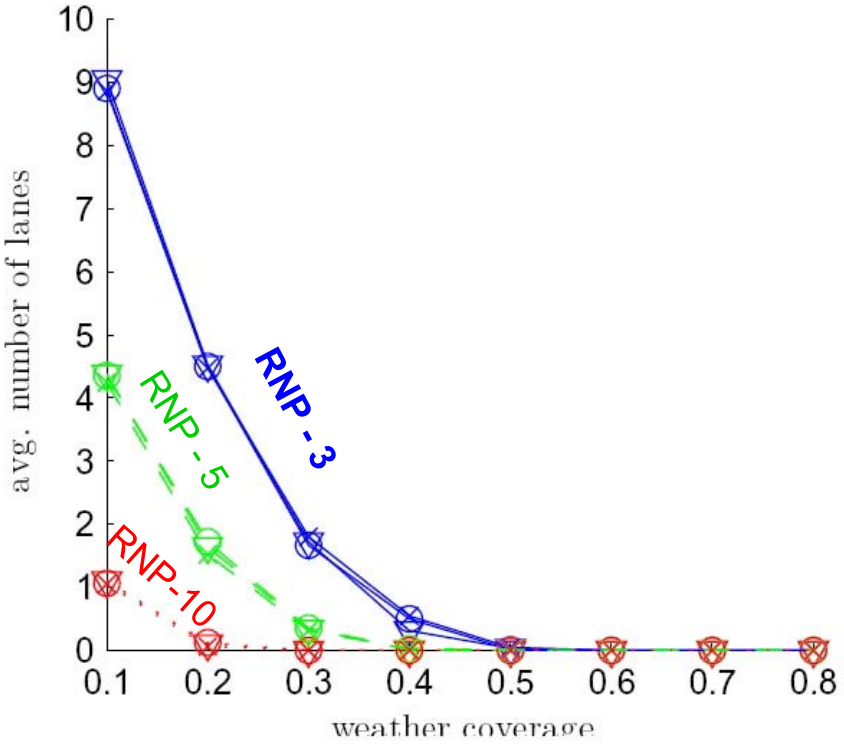


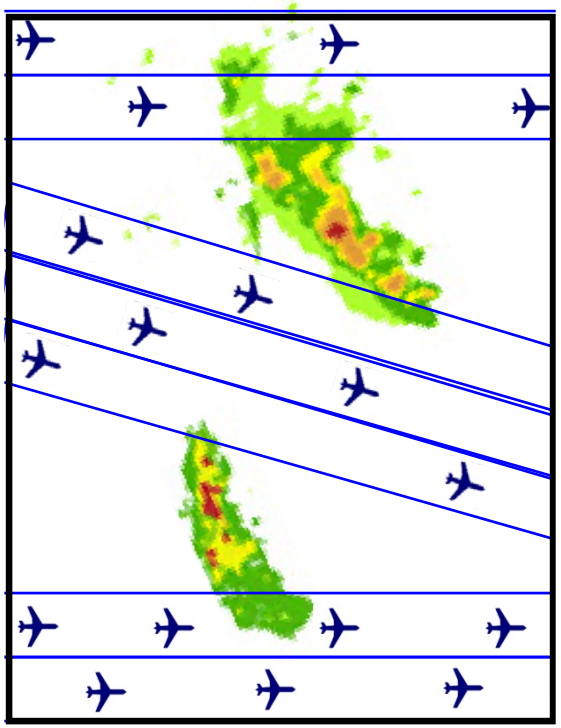
Variations in the Size of the Gap (RNP Requirement)





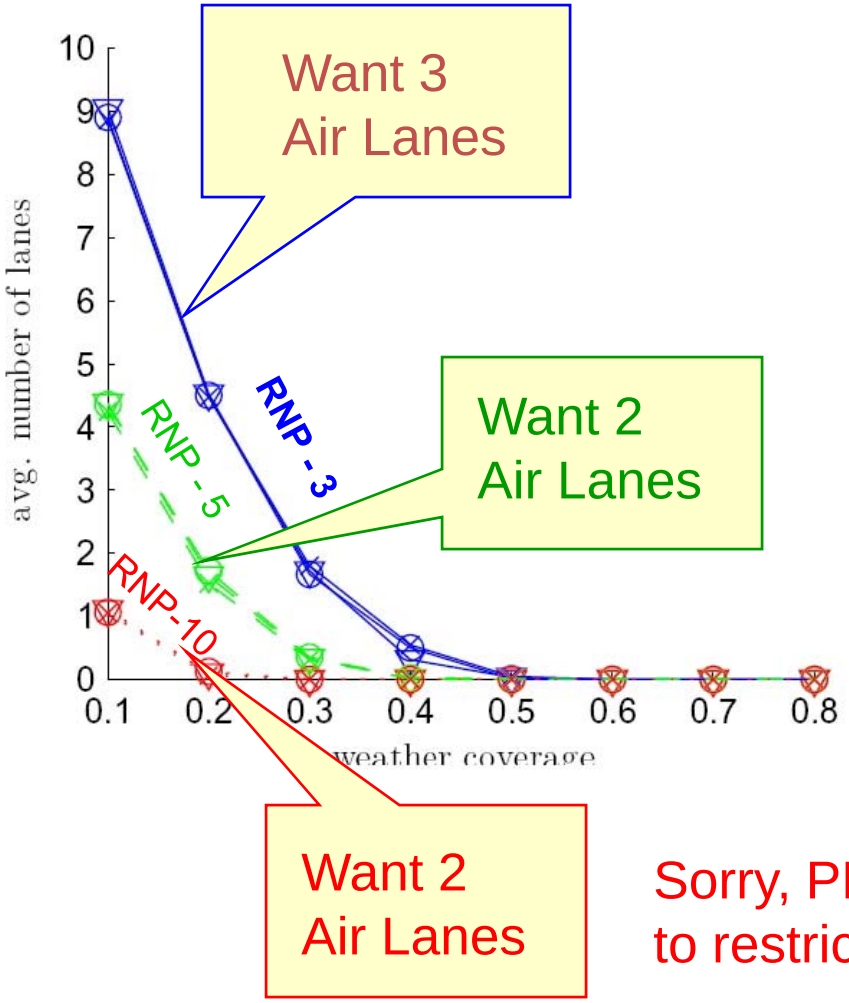
Variations in the Size of the Gap (RNP Requirement)

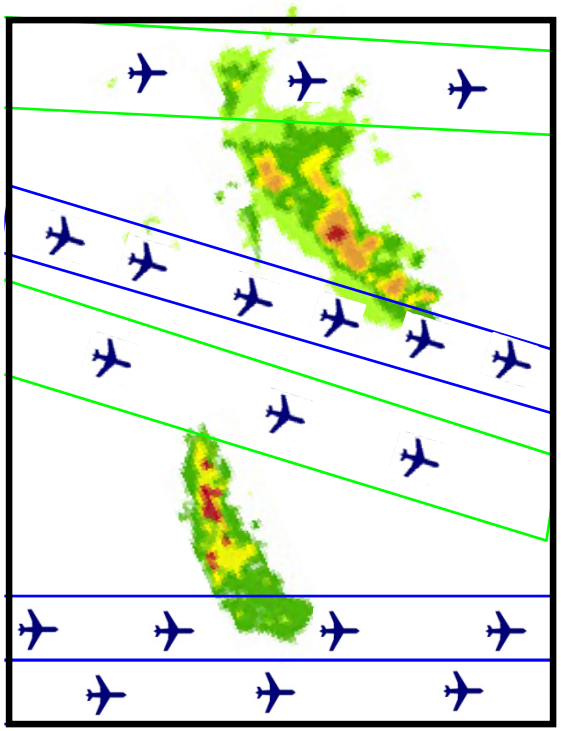




Variations in the Size of the Gap (RNP Requirement)

Mixed-RNP Demand

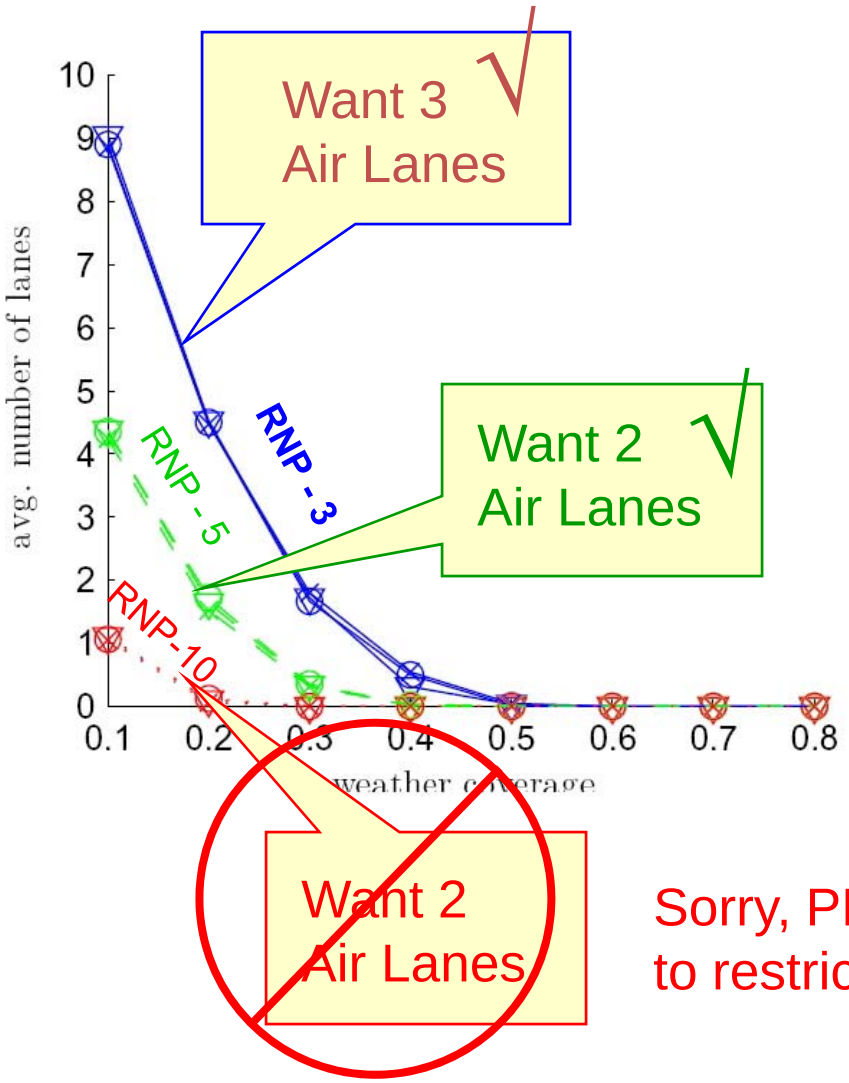


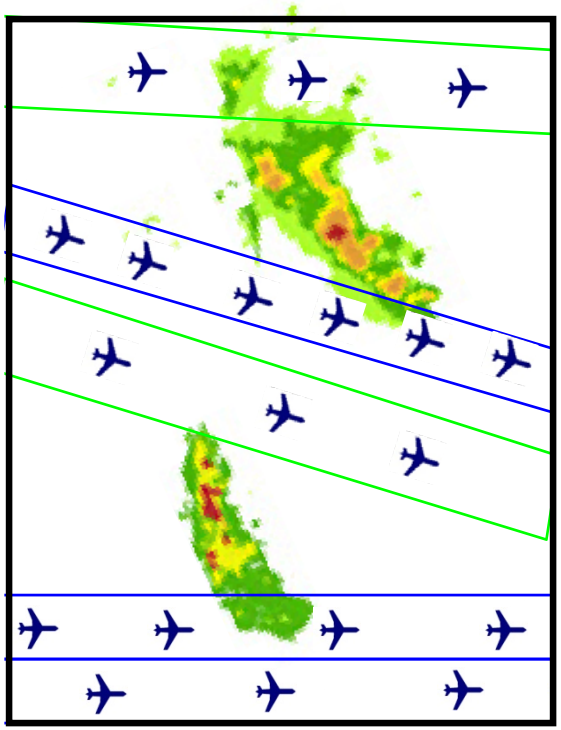


Sorry, PBS-rules… Advisory sent out via SWIM to restrict traffic to RNP-3 and RNP-5 only

Variations in the Size of the Gap (RNP Requirement)

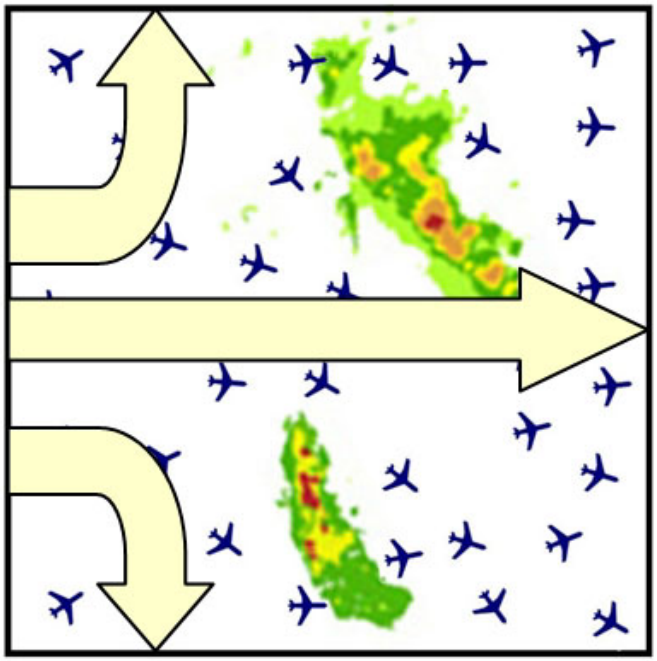
Mixed-RNP Demand



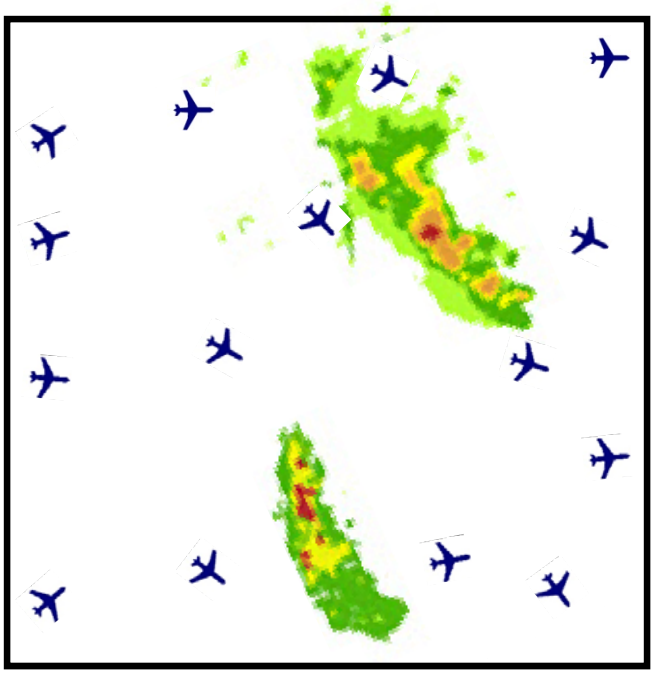


Sorry, PBS-rules… Advisory sent out via SWIM to restrict traffic to RNP-3 and RNP-5 only

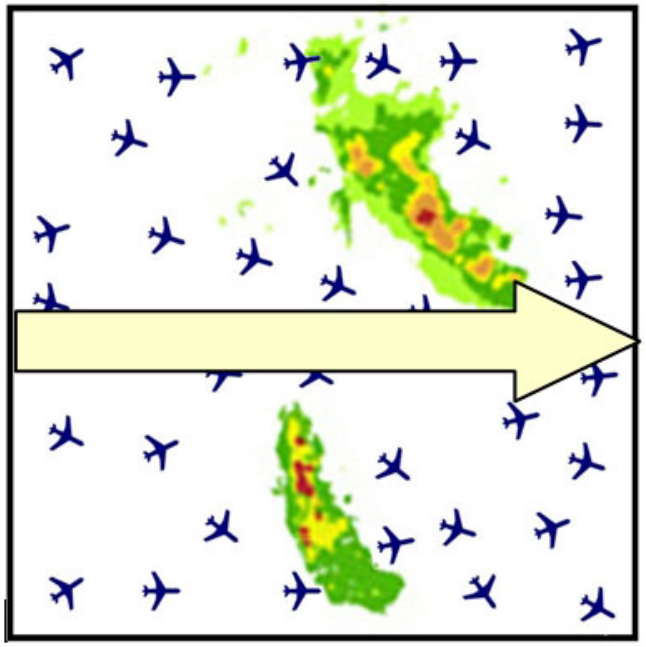
Unidirectional Flows



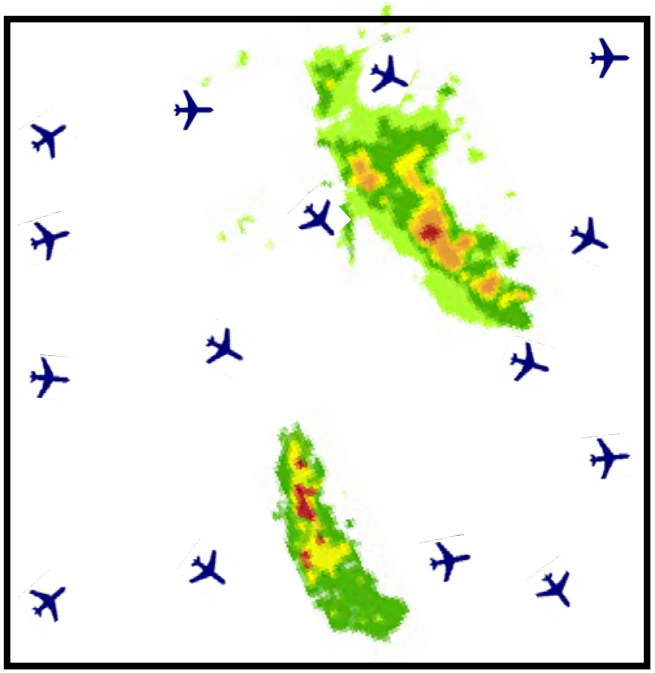
Free Flight (Monotonic Rule)



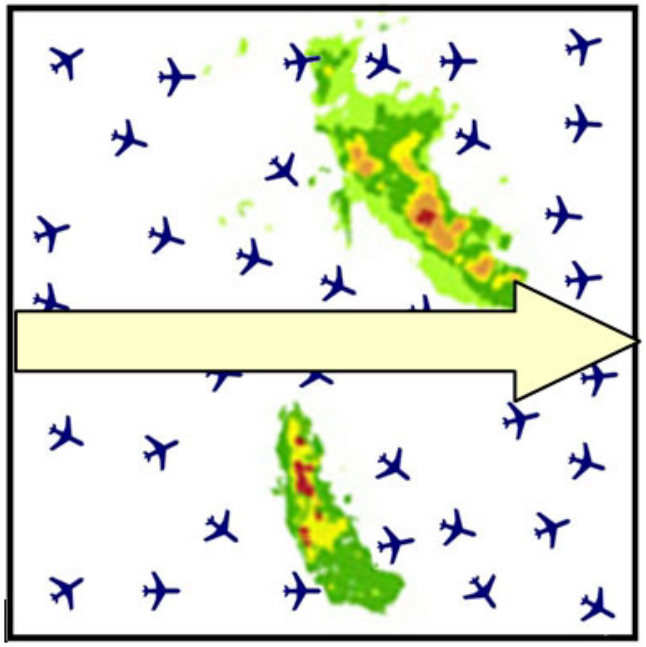
Platooning of 1



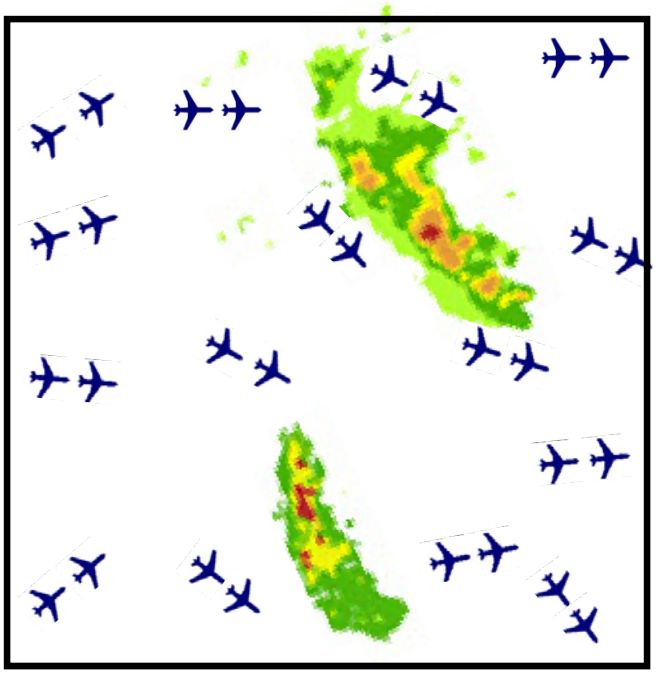
Free Flight (Unidirectional Rule)



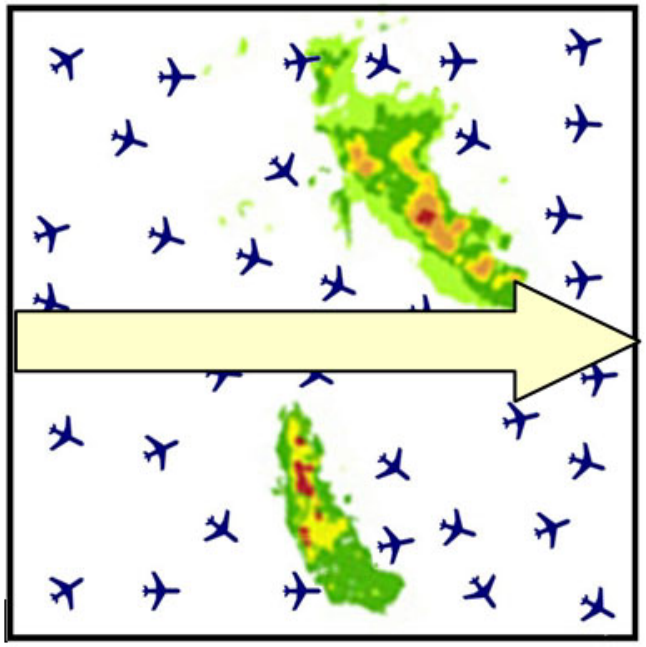
Platooning of 2



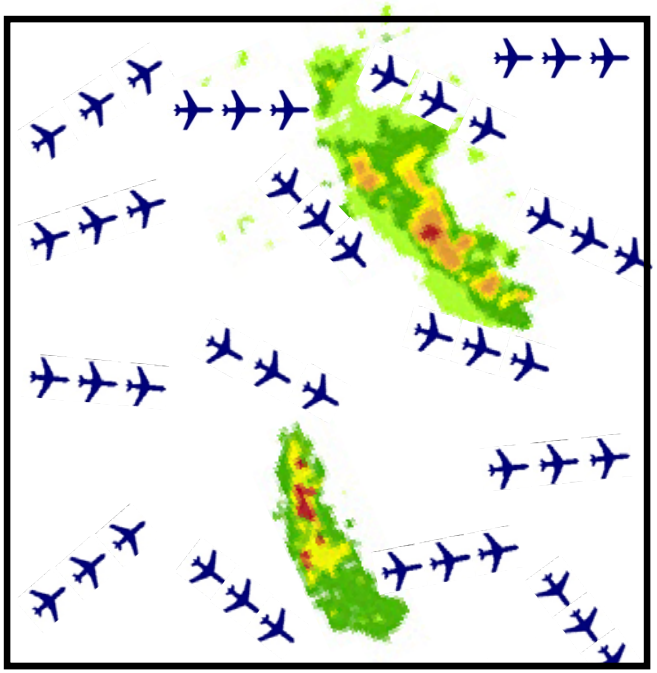
Free Flight (Unidirectional Rule)



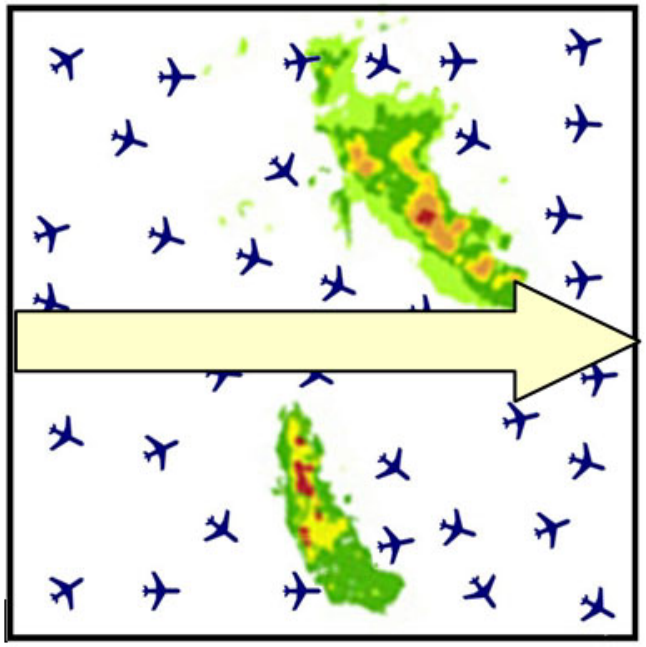
Platooning of 3



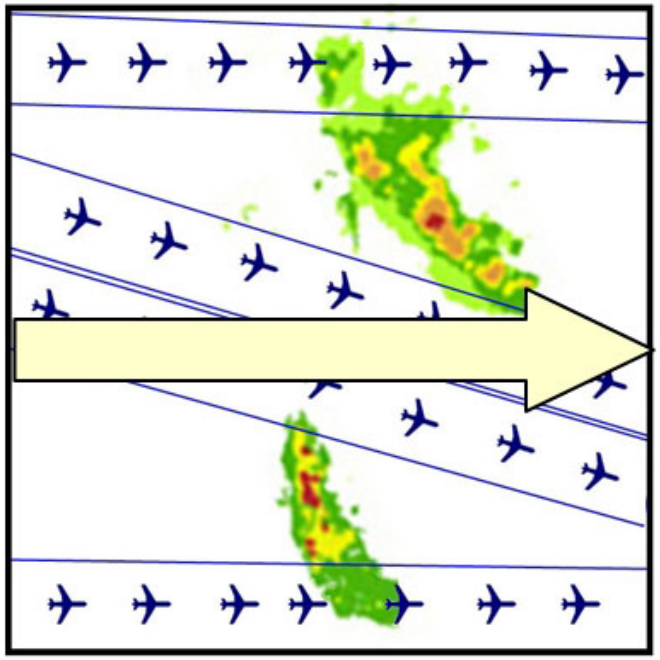
Free Flight (Unidirectional Rule)



Platooning of N → Flow-Based Route Planning



Free Flight (Unidirectional Rule)

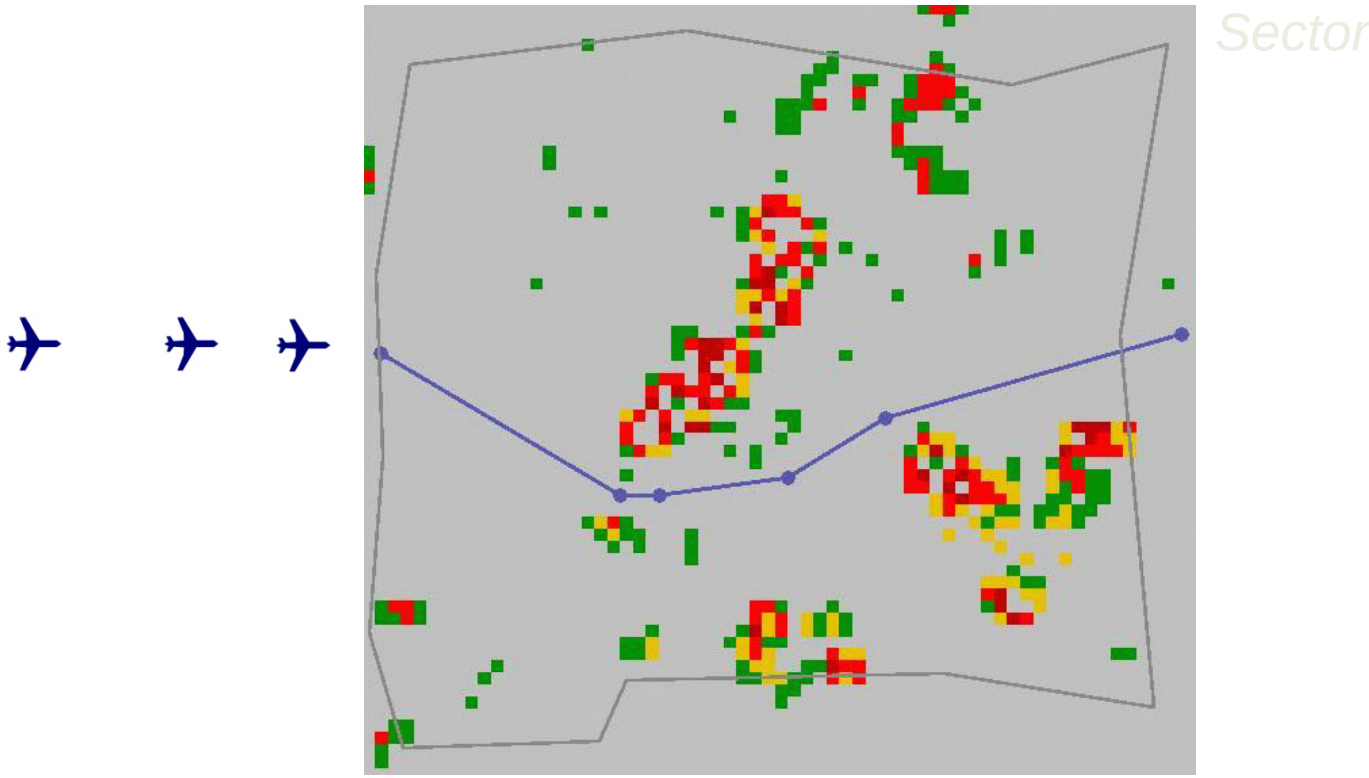


Packed Unidirectional Flow

Example of NASA Weather ATM Integration Research

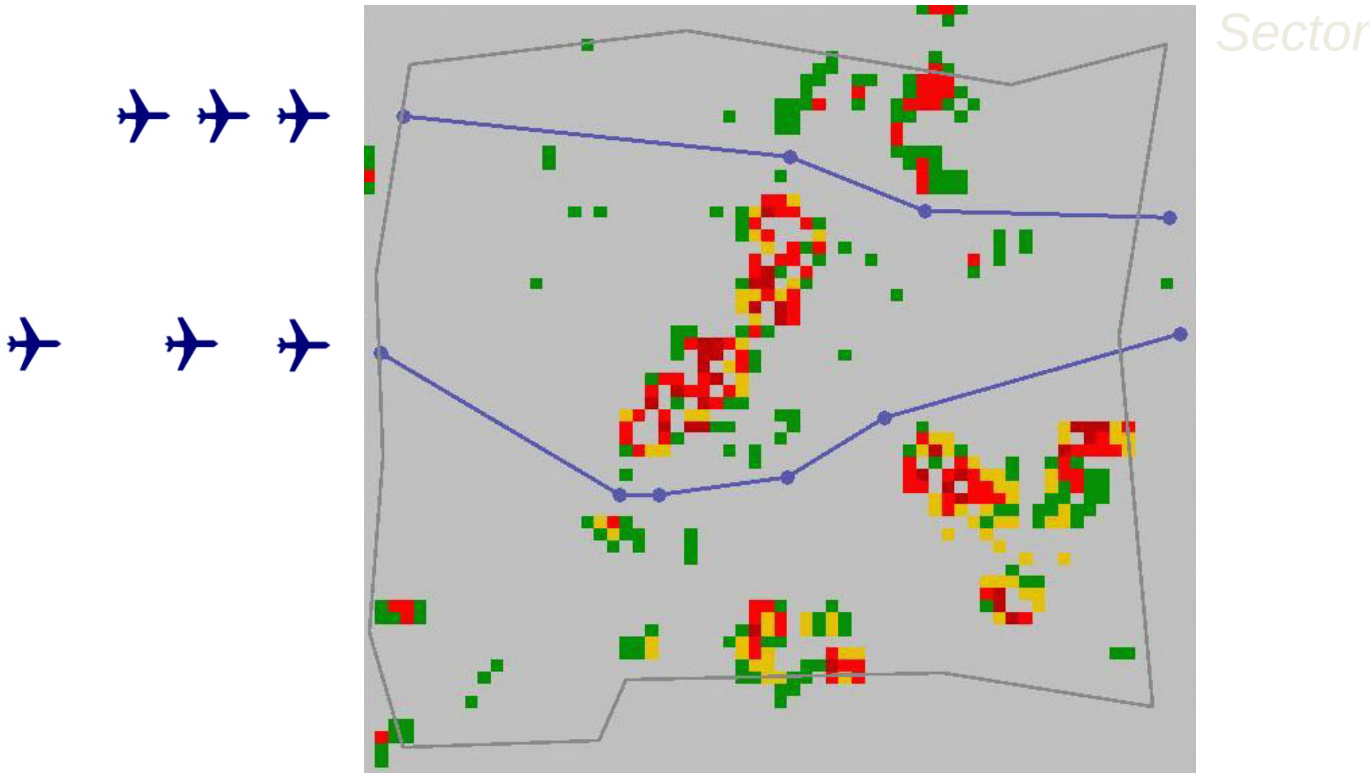
Movie loop shows one way to adjust
to enroute storms

Weather Avoidance Algorithms for En Route Aircraft



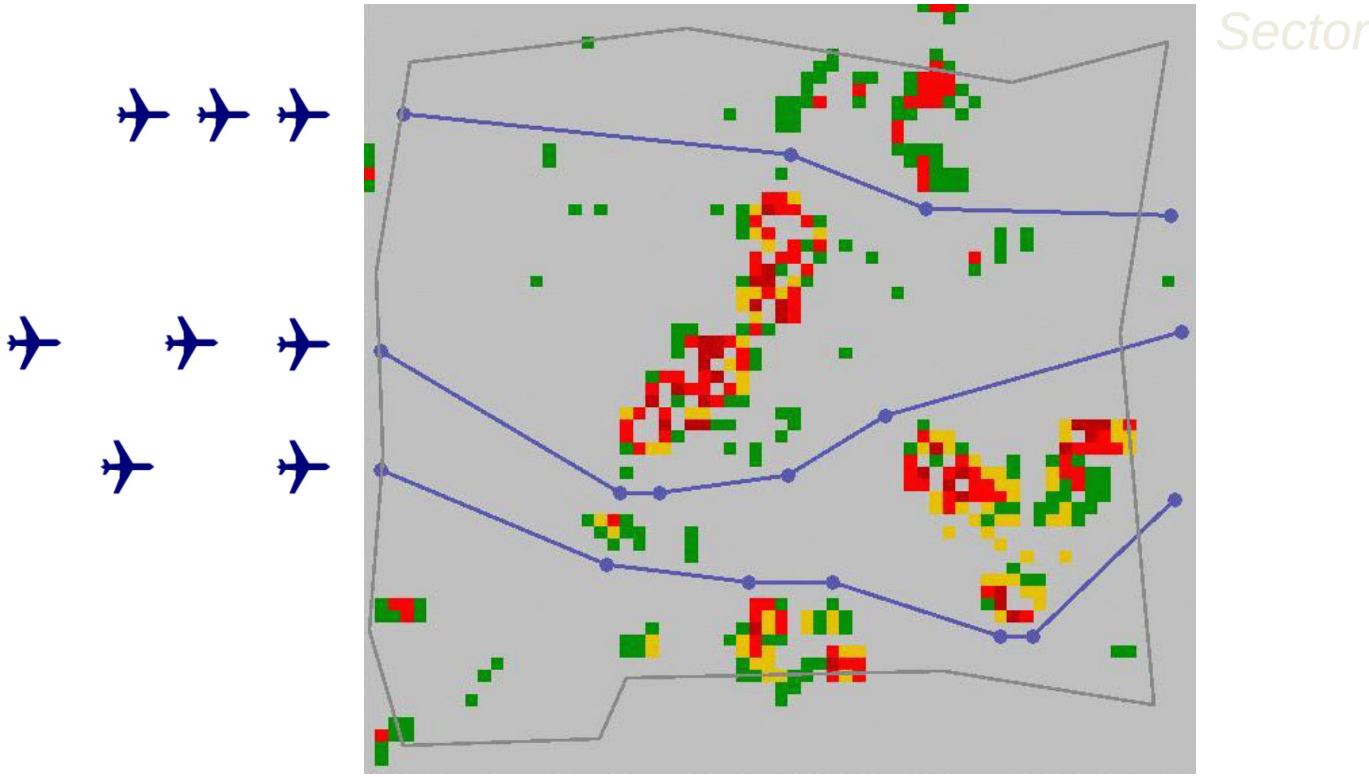
1 Flow

Weather Avoidance Algorithms for En Route Aircraft



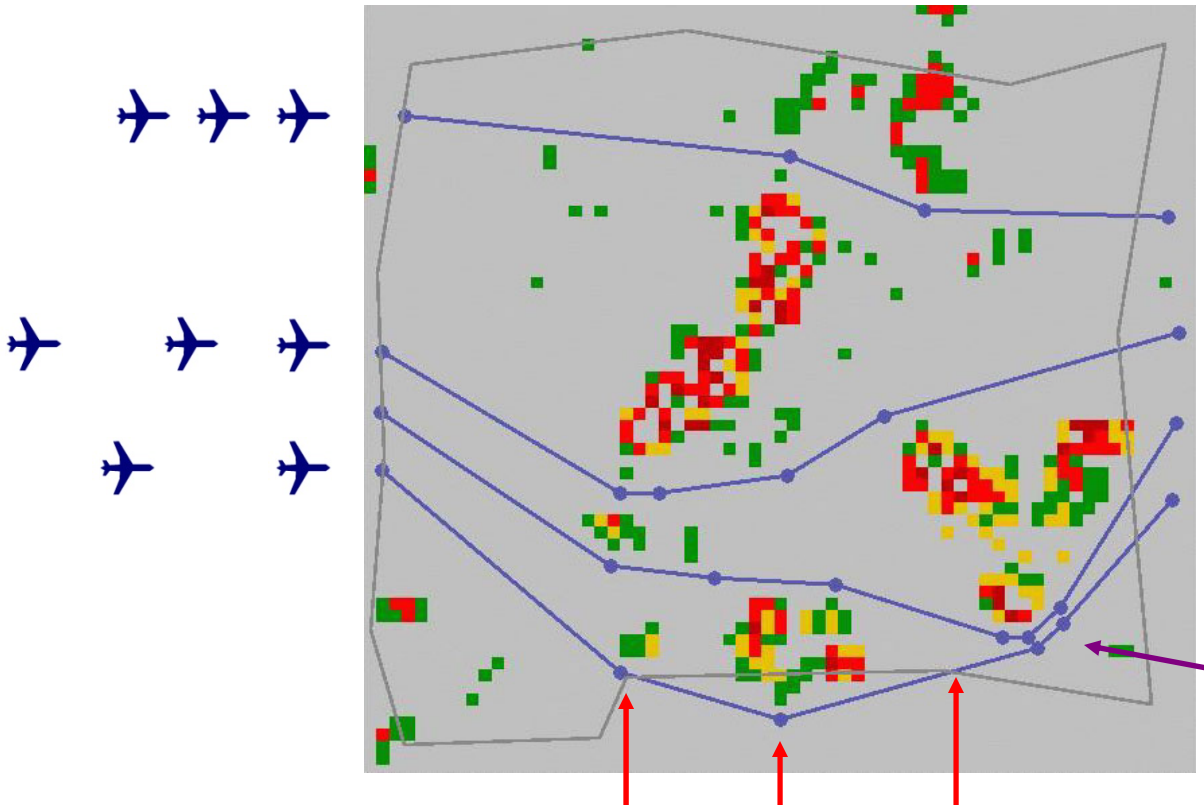
2 Flows

Weather Avoidance Algorithms for En Route Aircraft



3 Flows

Weather Avoidance Algorithms for En Route Aircraft

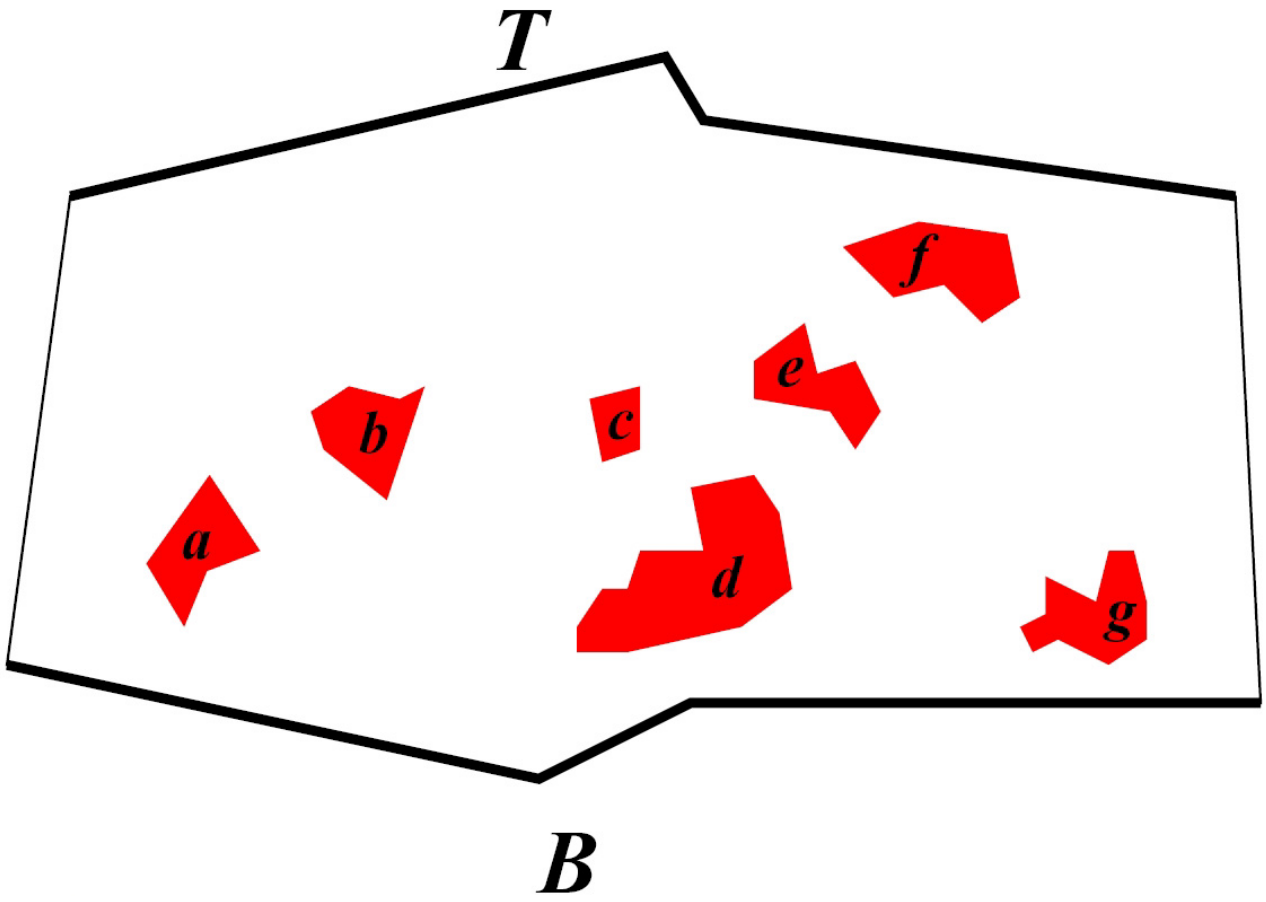


4 Flows

→ Are 3 Routes through the Sector a Maximum?

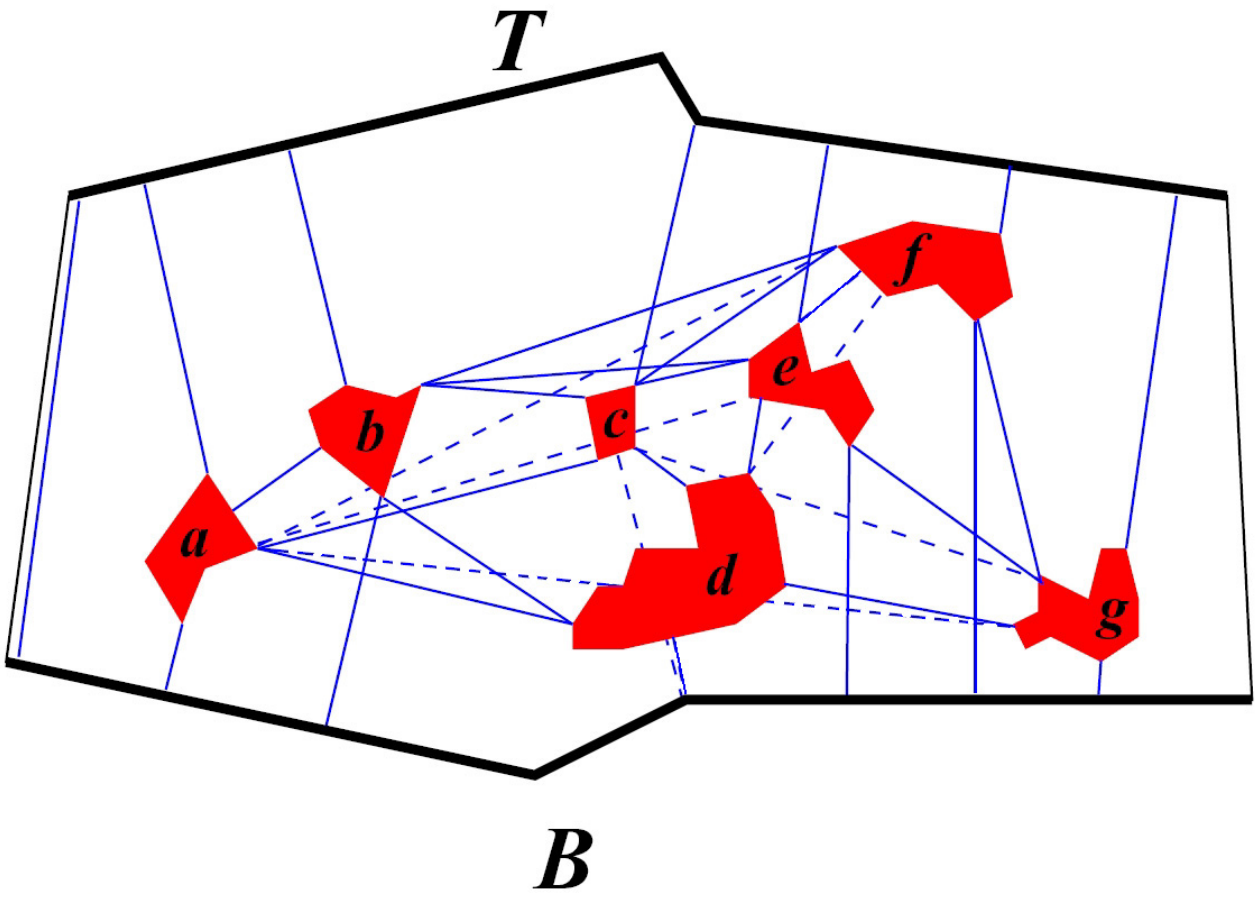
Algorithm: Mincut (Deterministic)

1. Airspace with Hazardous Weather Constraints

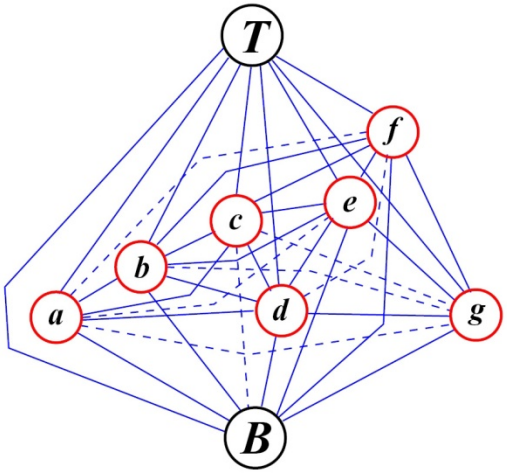


Algorithm: Mincut (Deterministic)

2. Define Critical Graph – connect closest points (B, T, a → g)

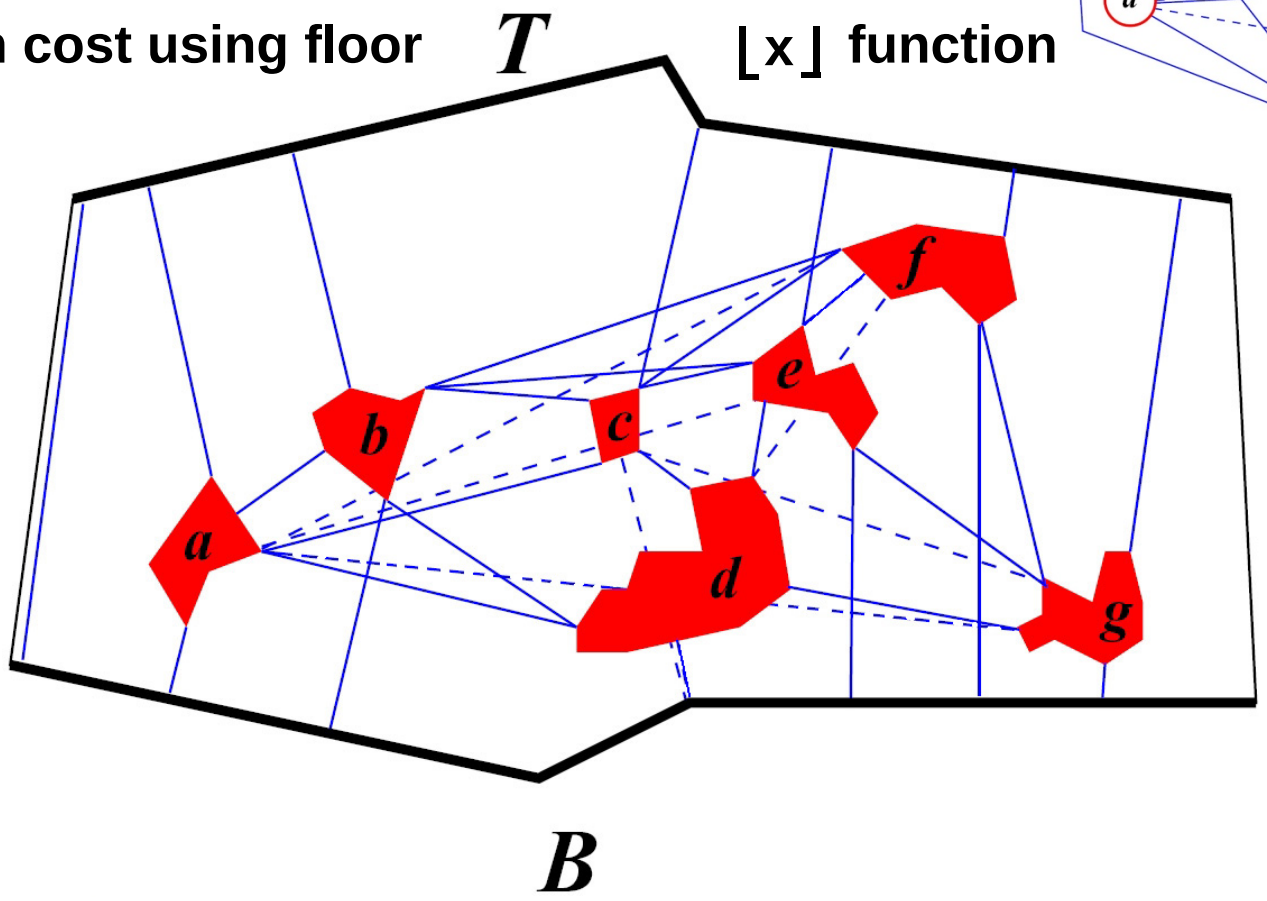


Algorithm: Mincut (Deterministic)



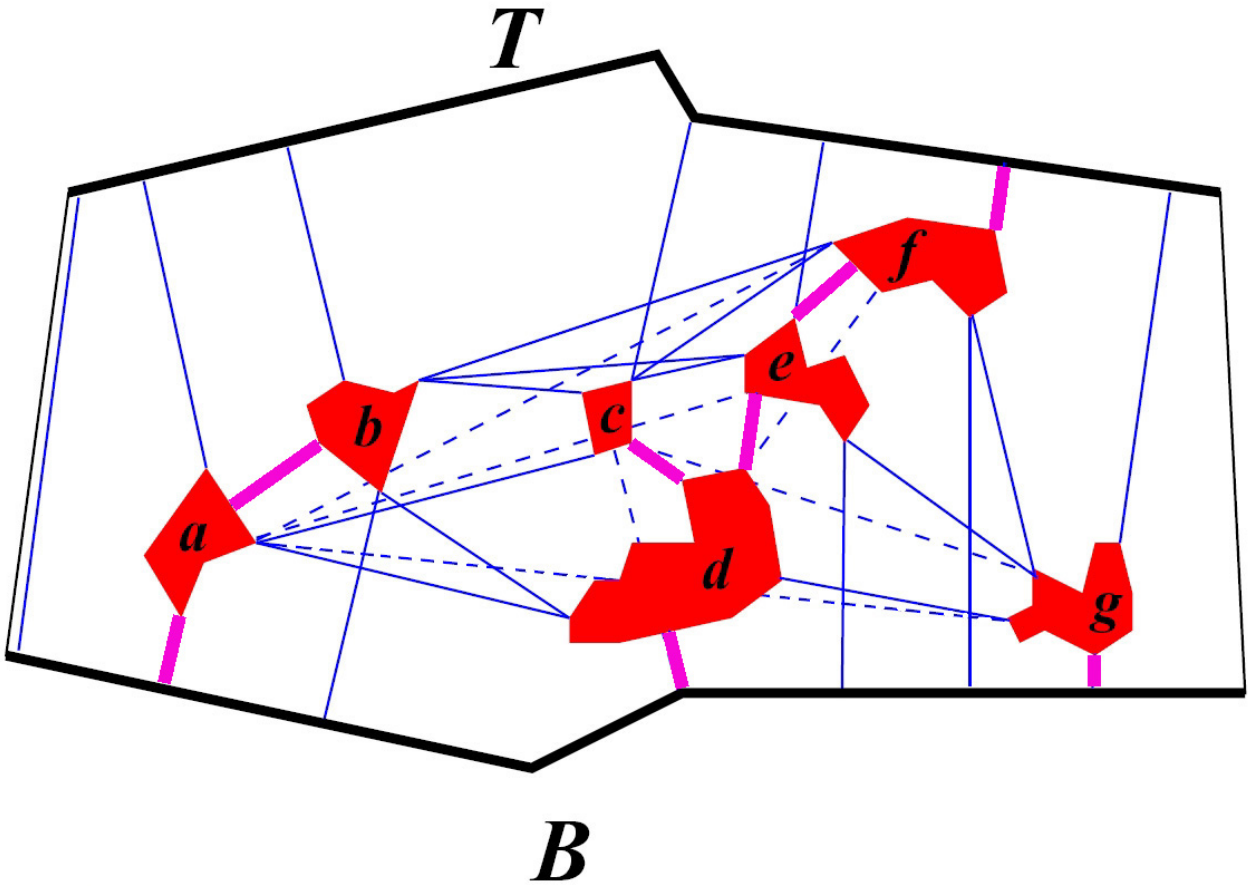
2. Define Critical Graph – connect closest points

Assign cost using floor $\lfloor x \rfloor$ function



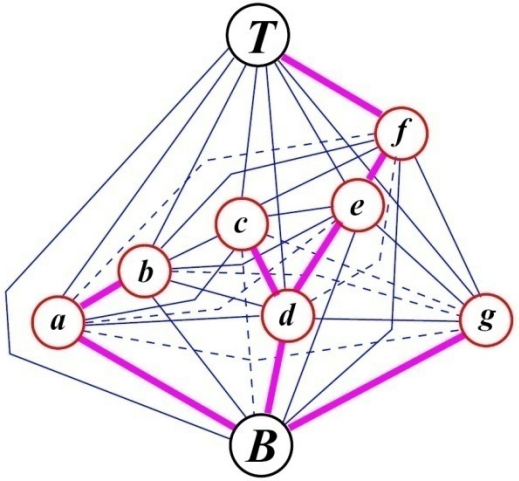
Algorithm: Mincut (Deterministic)

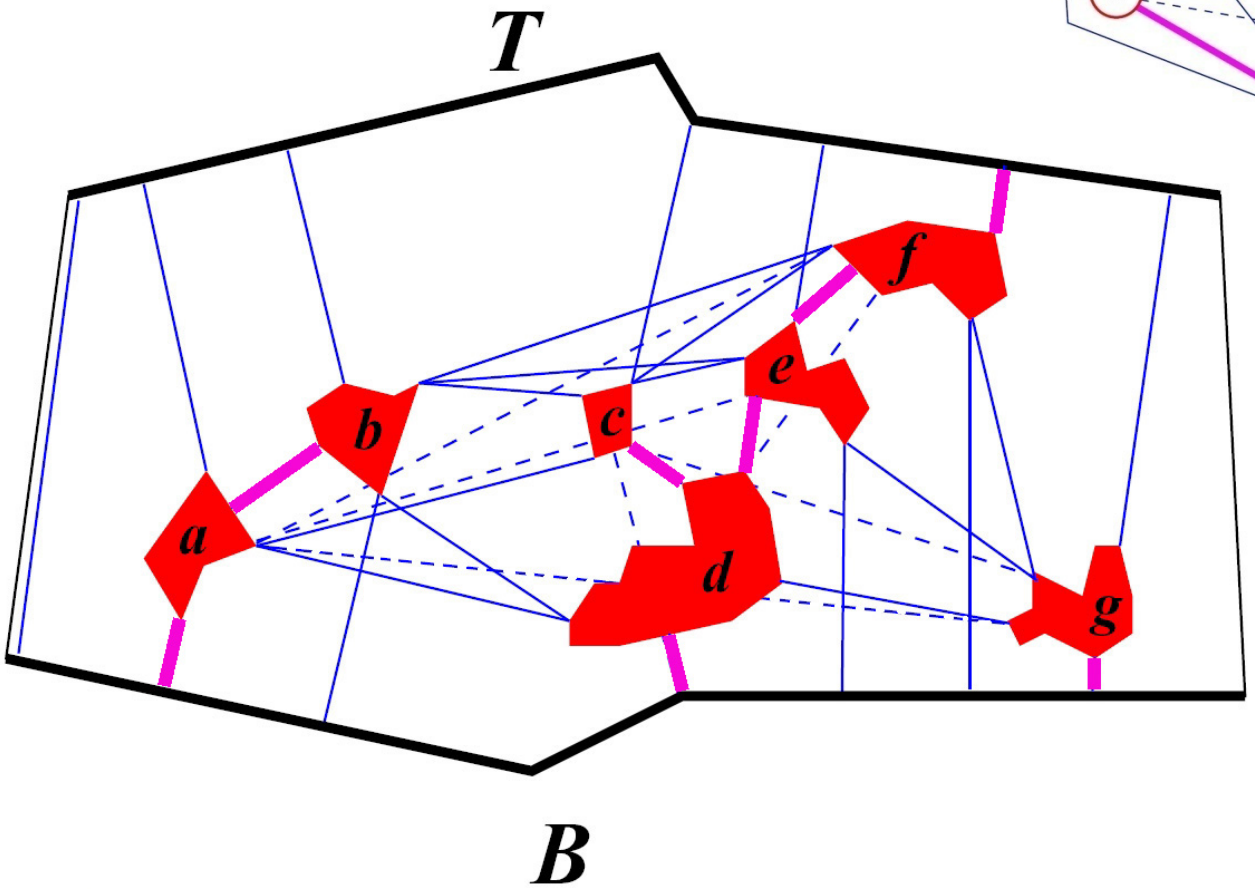
3. Search for Shortest Path Tree within Critical Graph



Algorithm: Mincut (Deterministic)

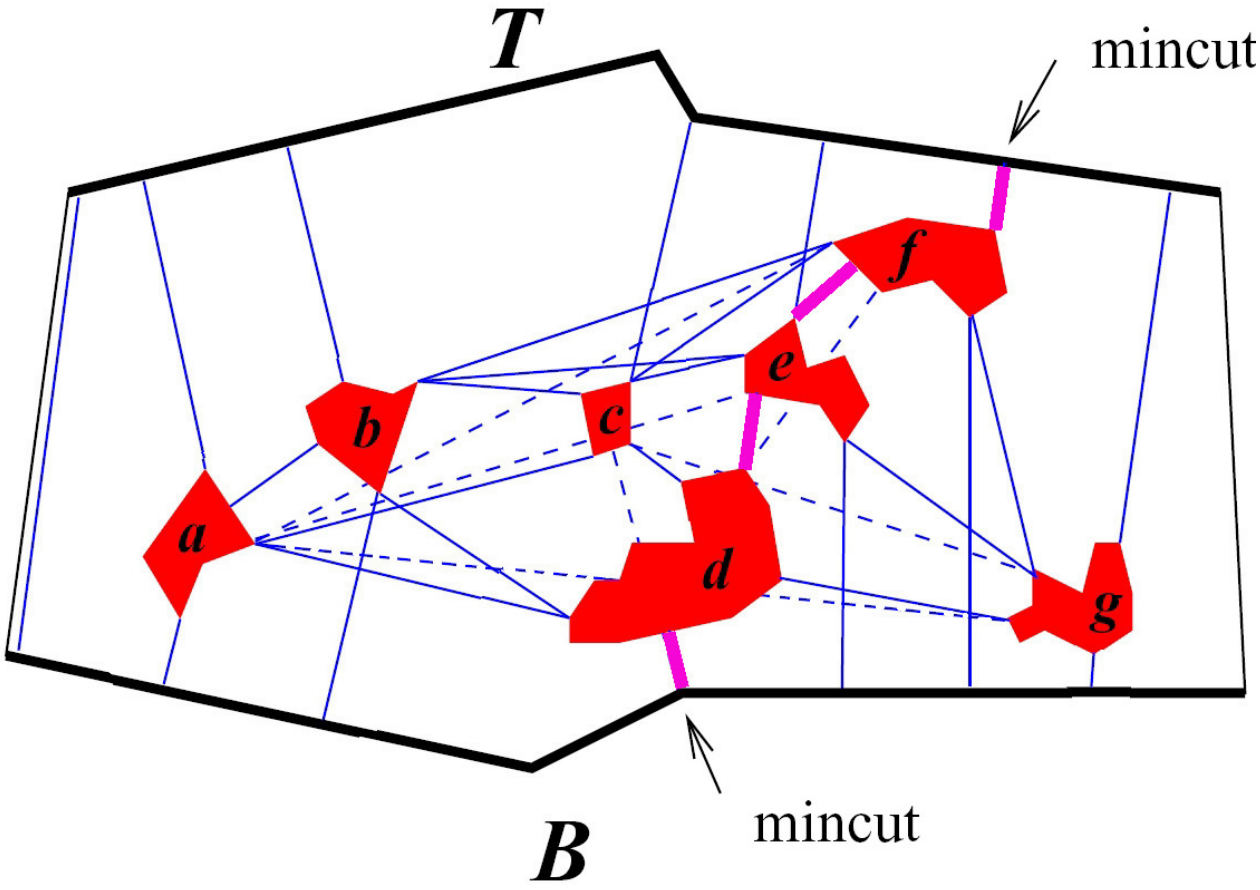
3. Search for Shortest Path Tree





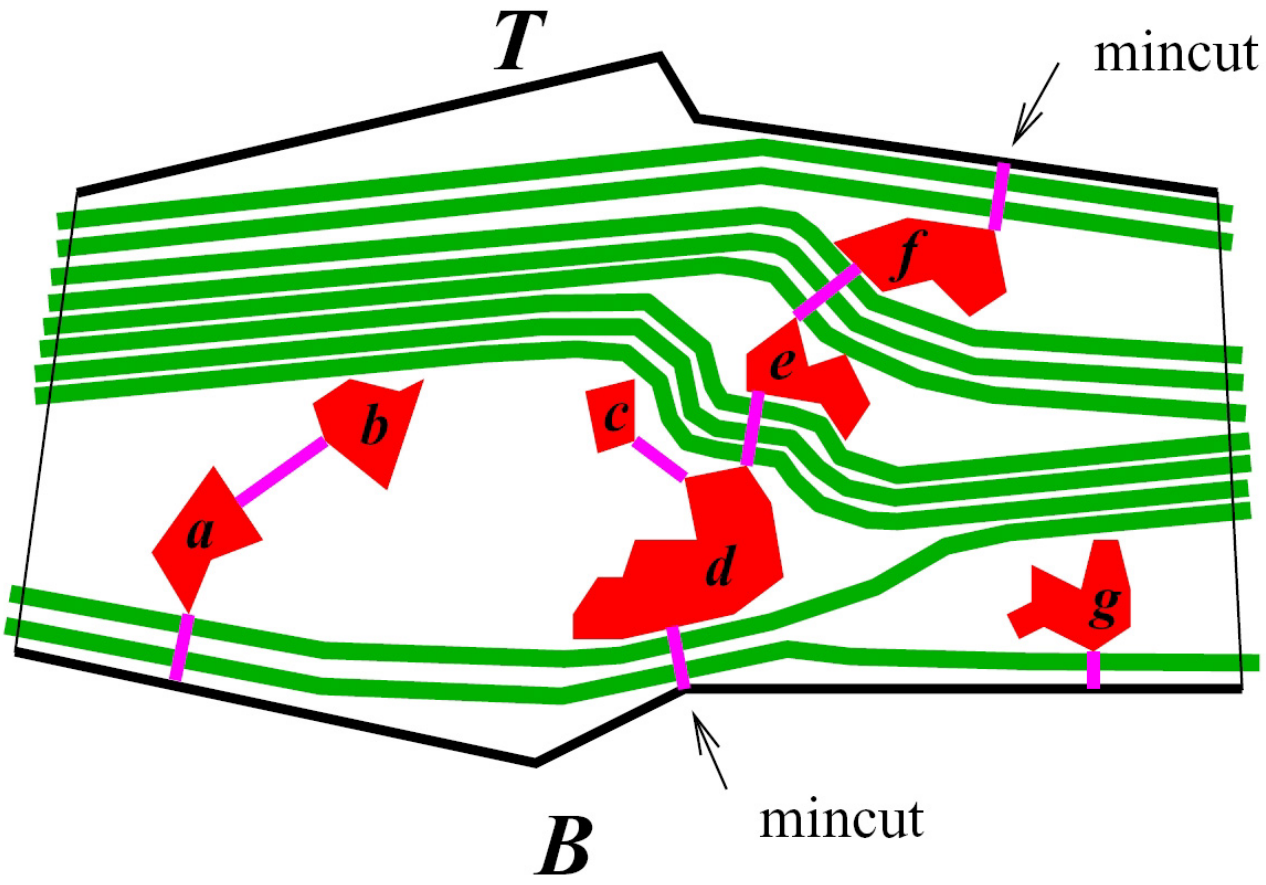
Algorithm: Mincut (Deterministic)

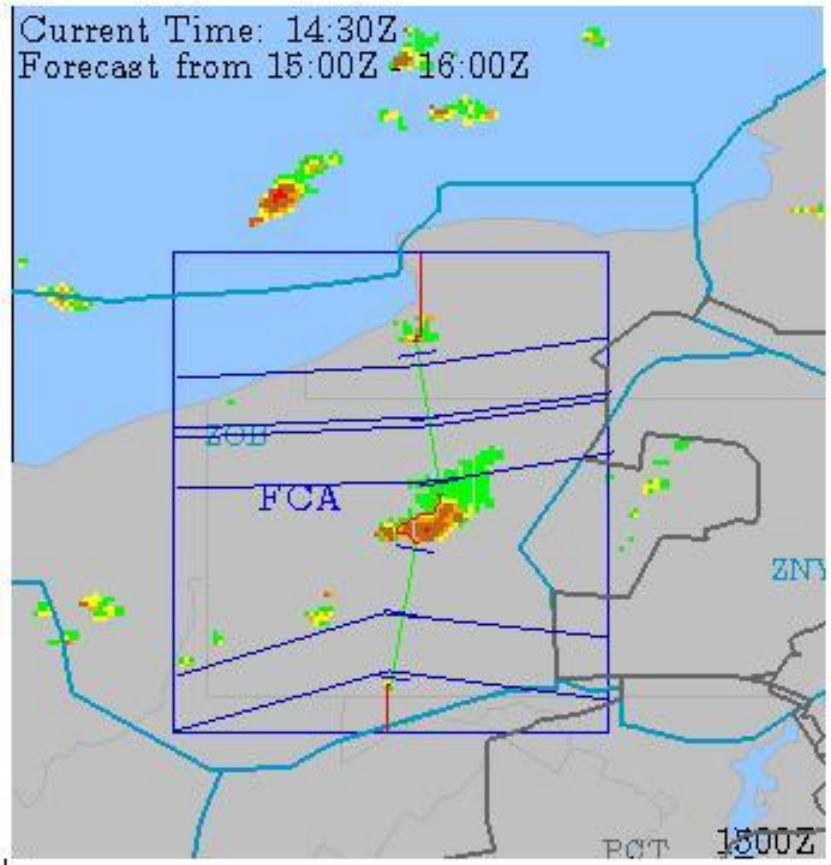
4. Shortest B-T Path in Shortest Path Tree defines the mincut



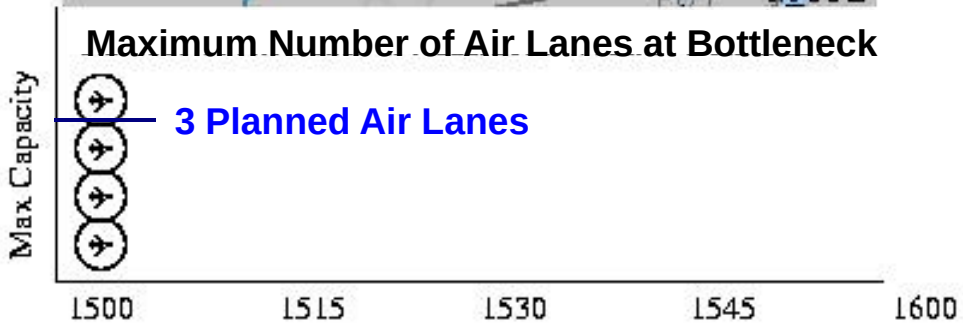
Algorithm: Mincut (Deterministic)

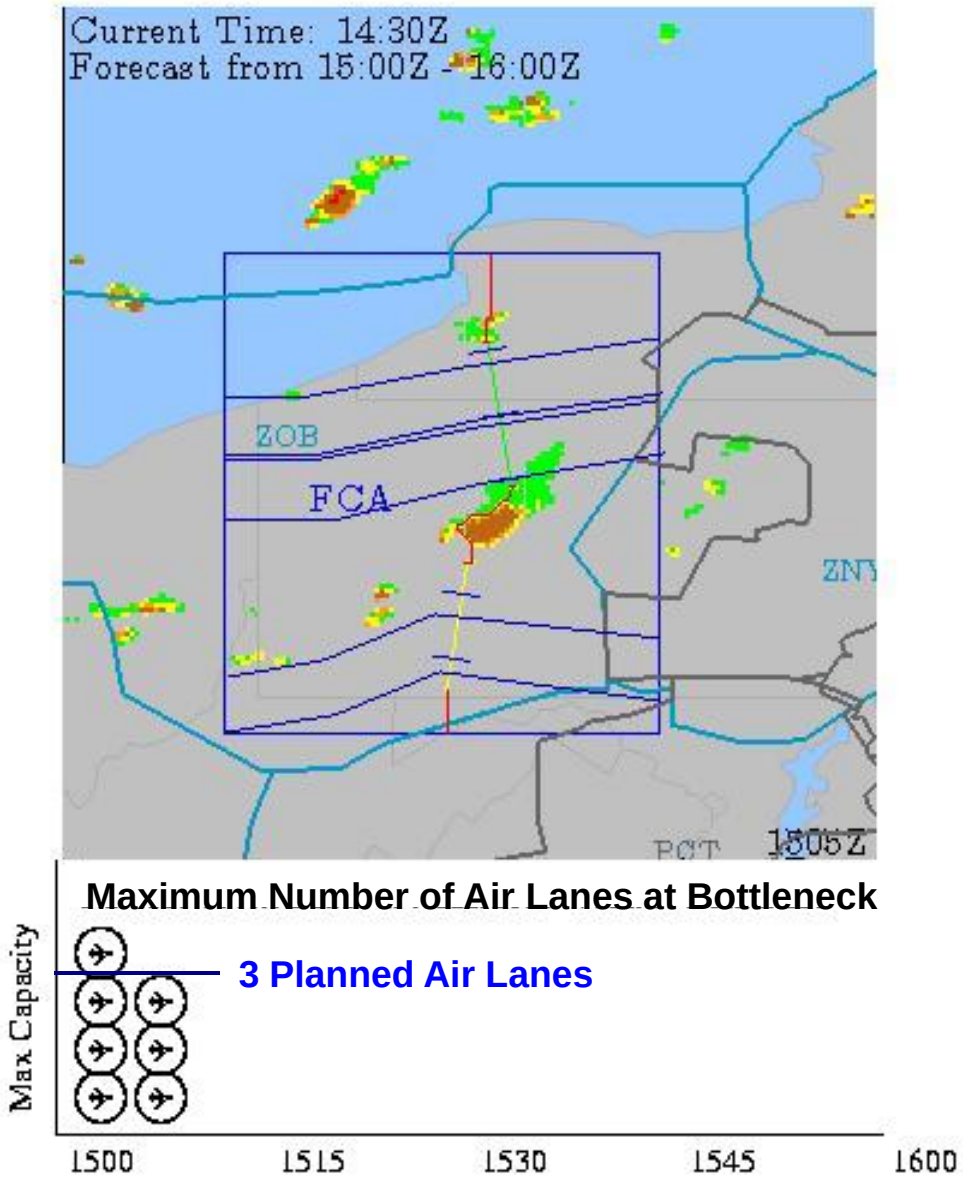
5. Find maximum number of air lanes through the mincut

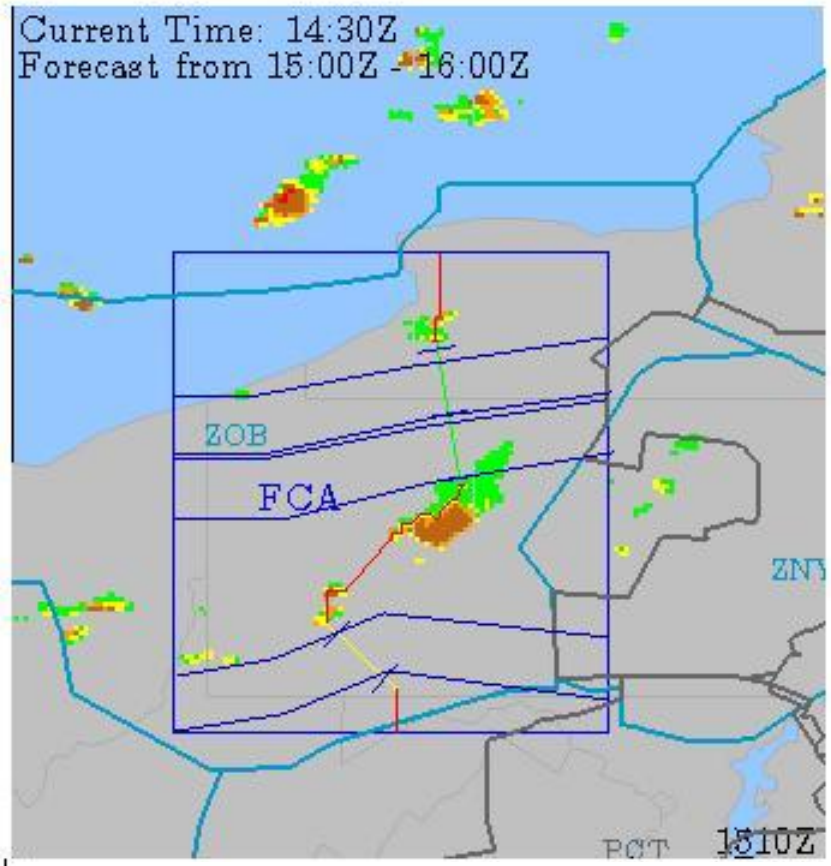




Maximum Number of Air Lanes at Bottleneck




Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1505Z
Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600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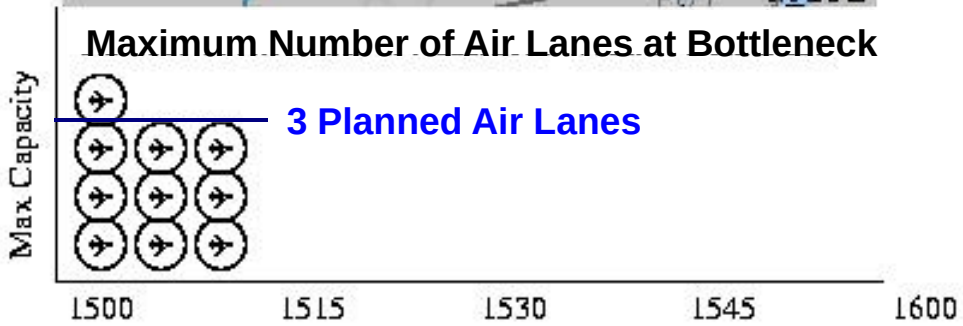
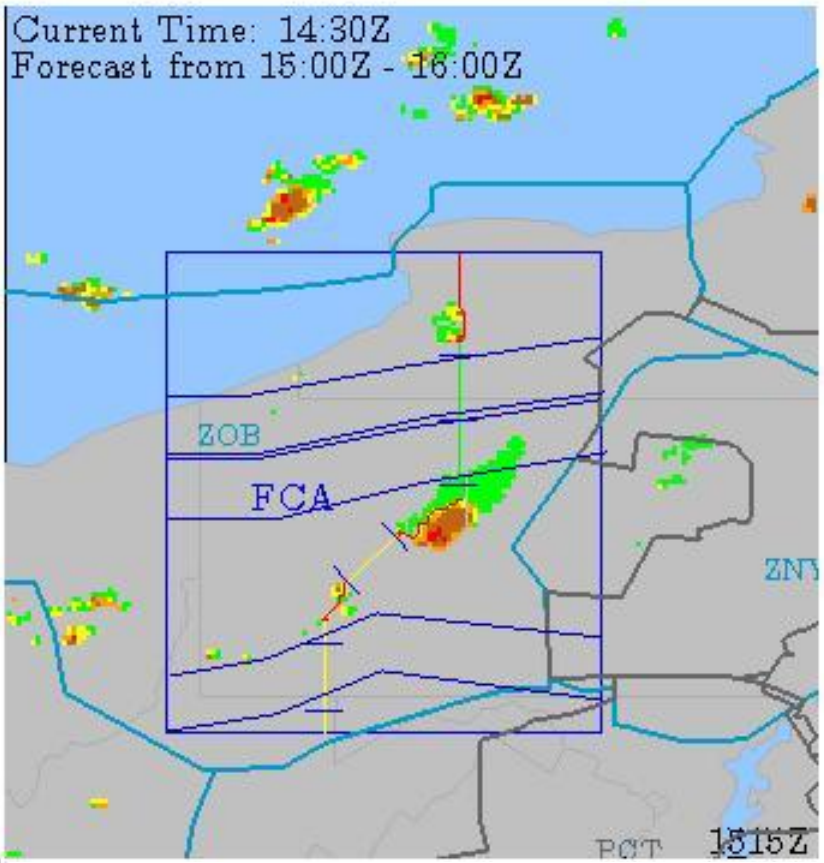
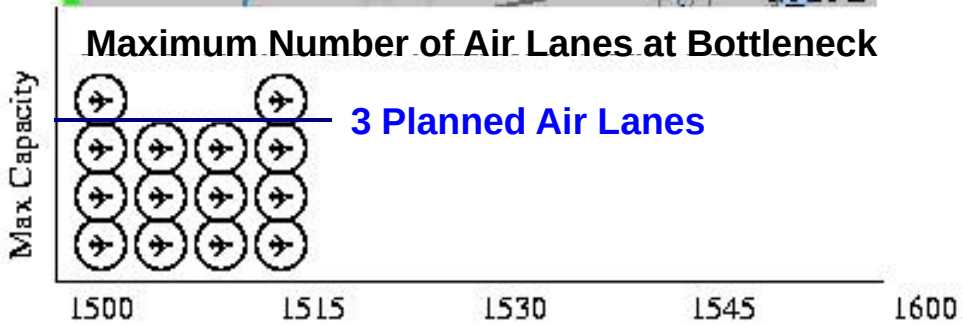
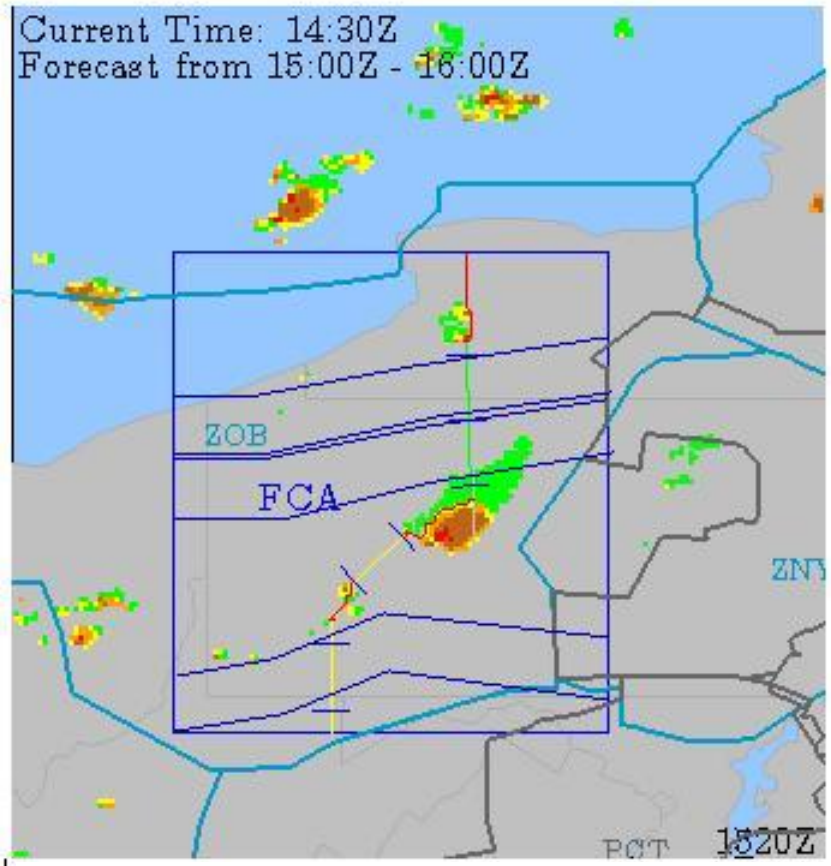
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1510Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600


Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1515Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600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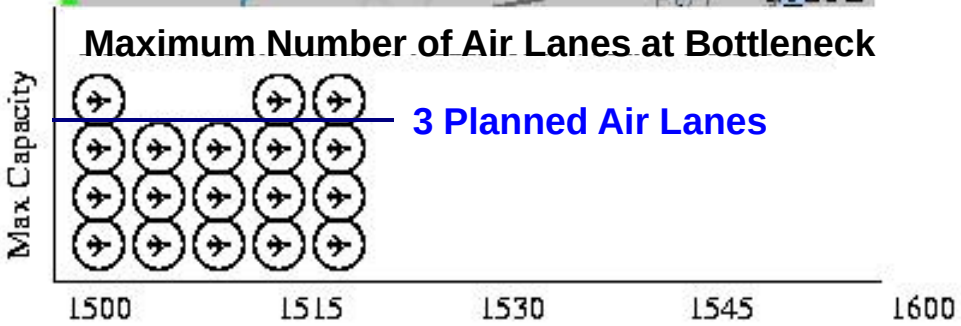
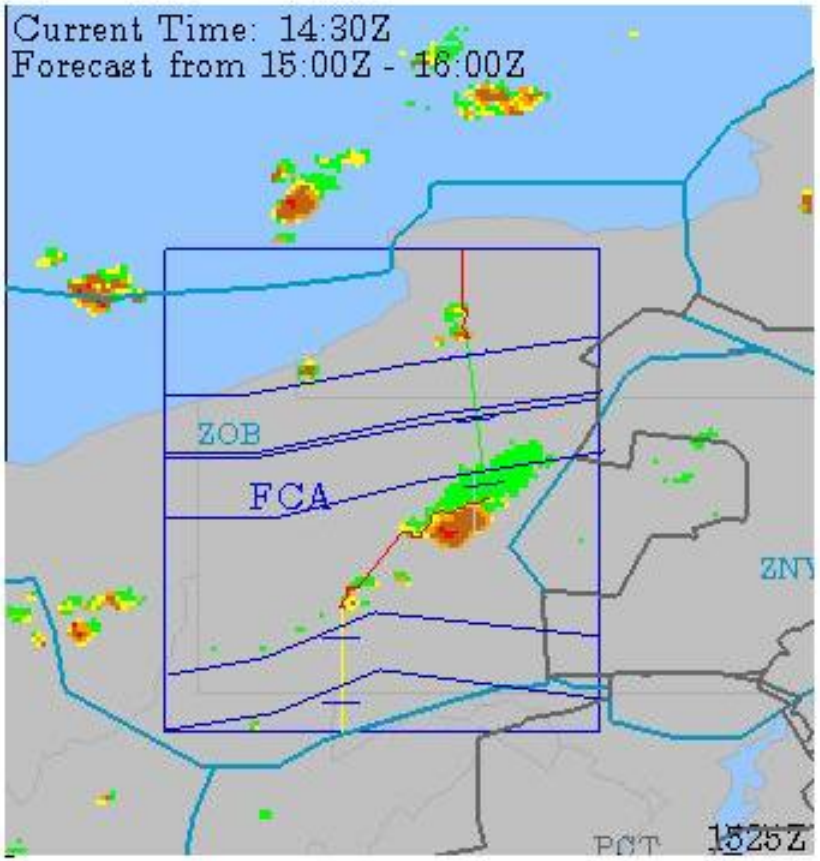
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1520Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600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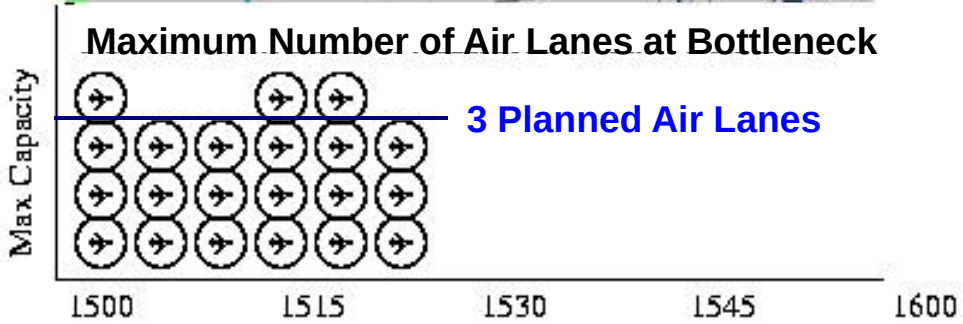
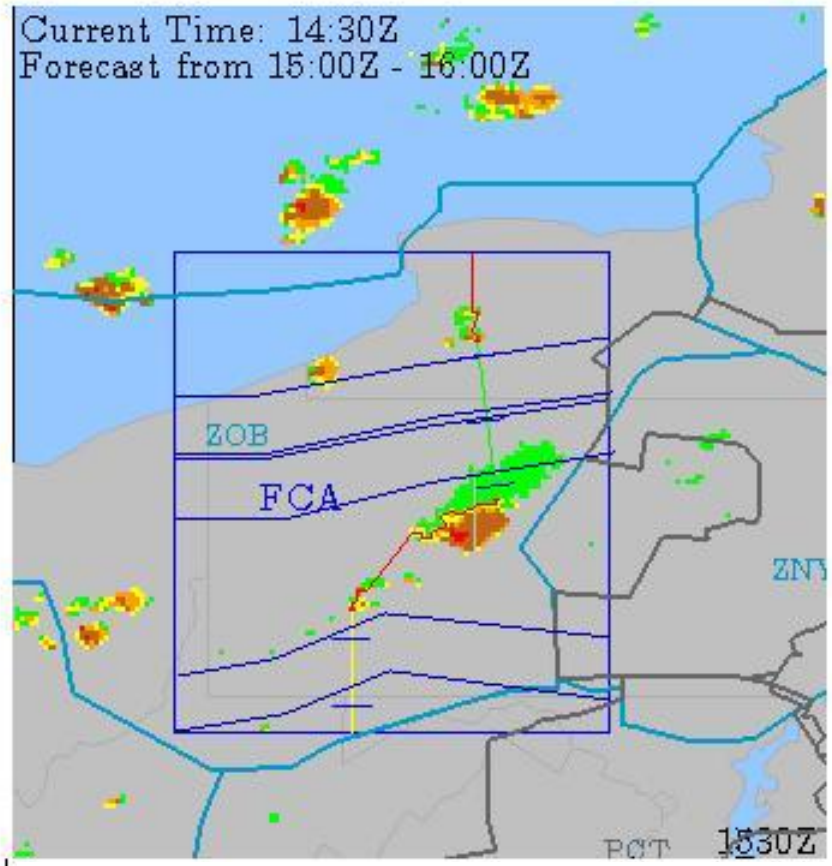
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1525Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600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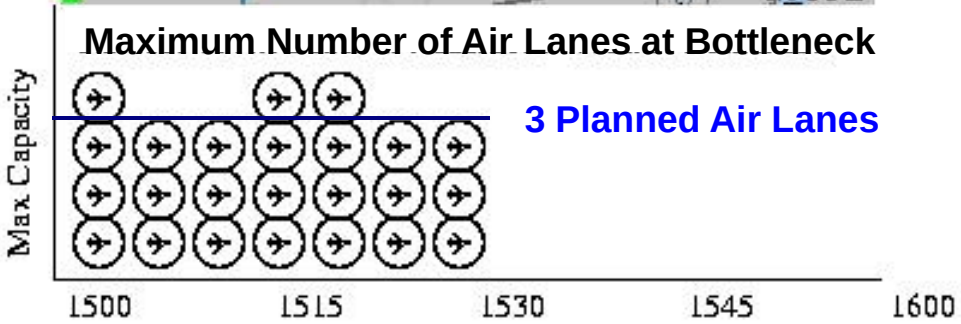
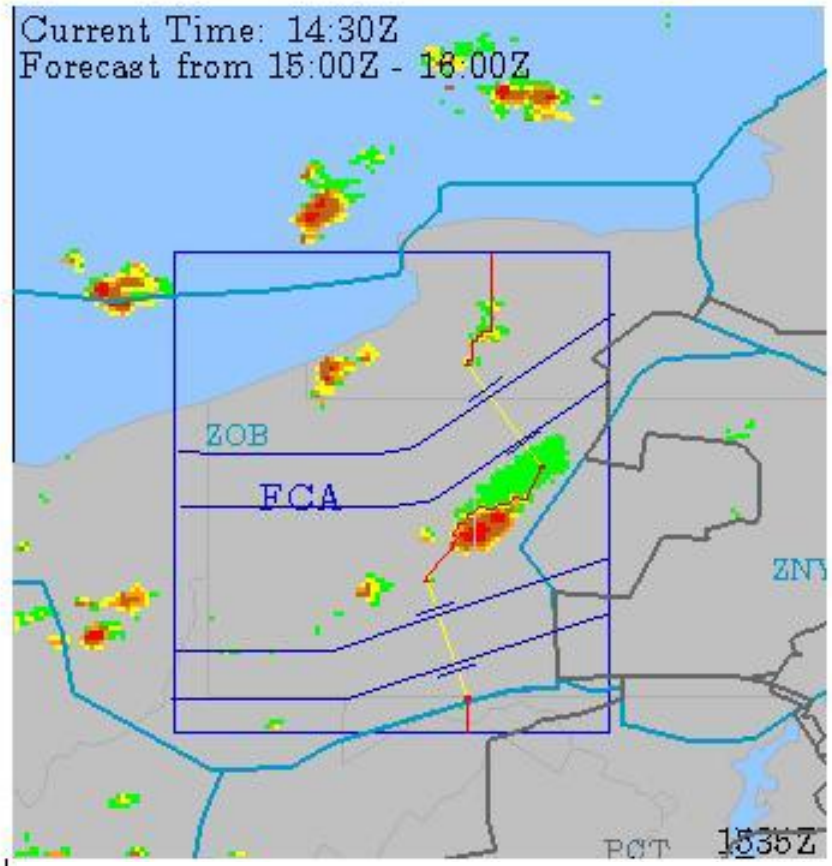
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1530Z


Maximum Number of Air Lanes at Bottleneck
3 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600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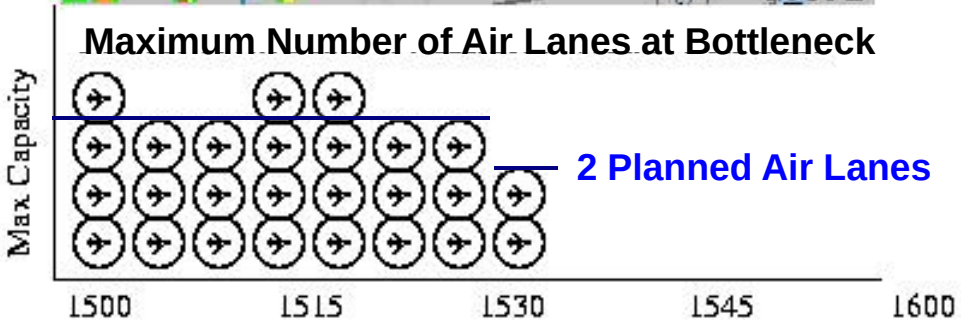
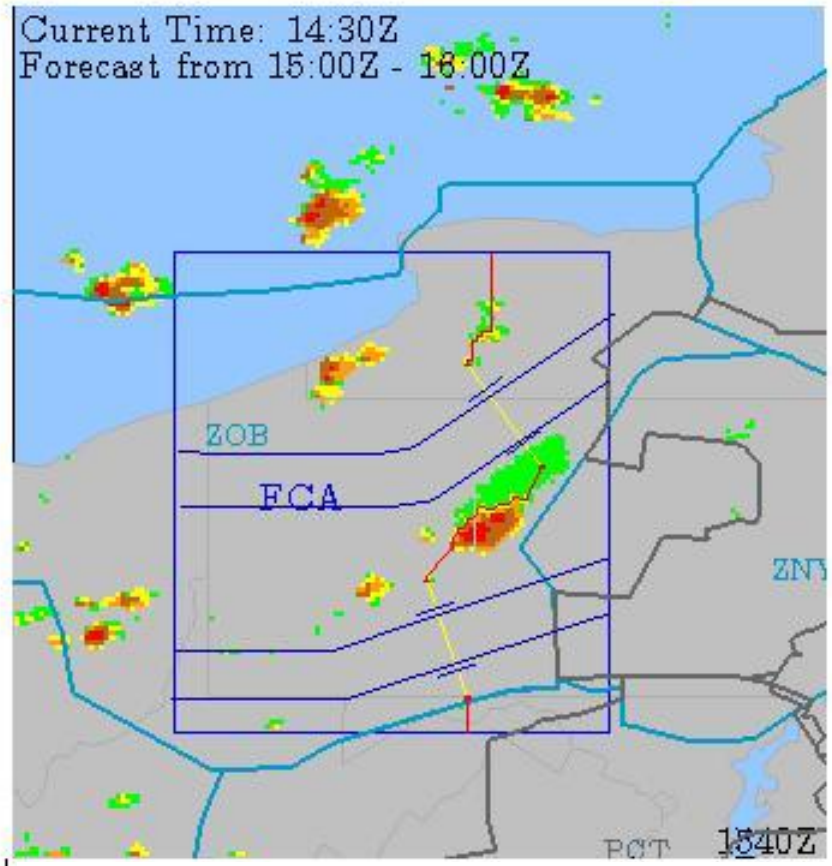
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1535Z


Maximum Number of Air Lanes at Bottleneck
2 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600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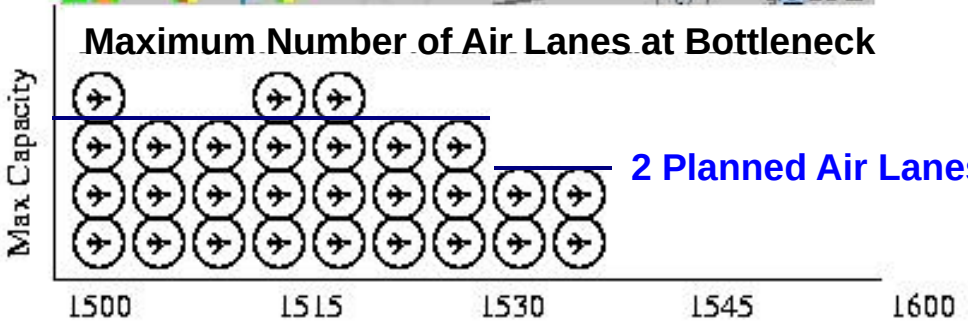
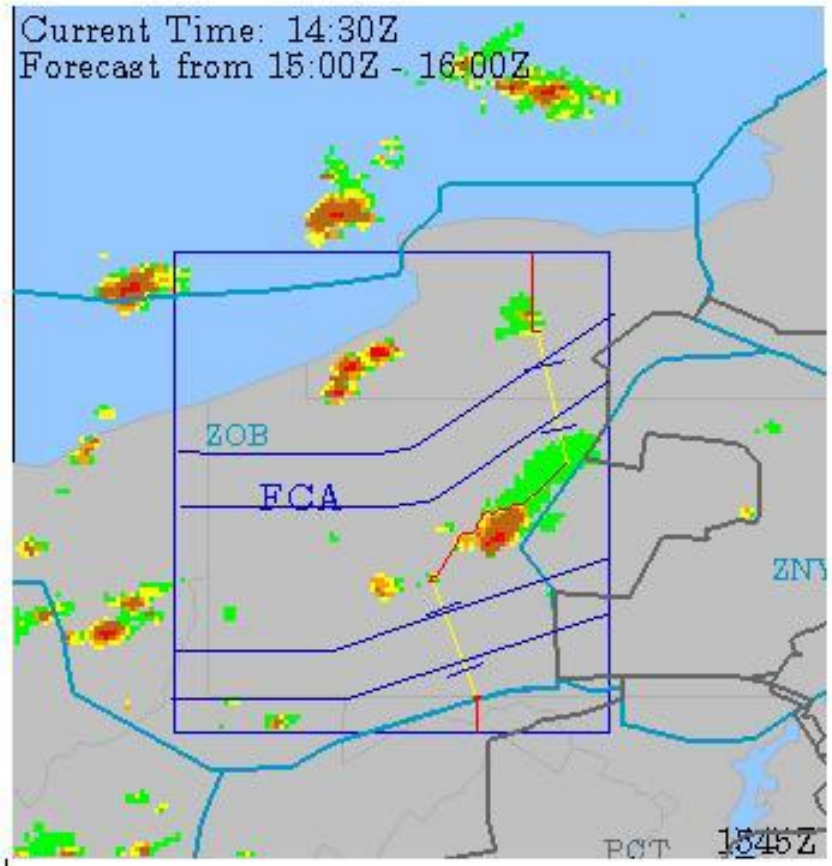
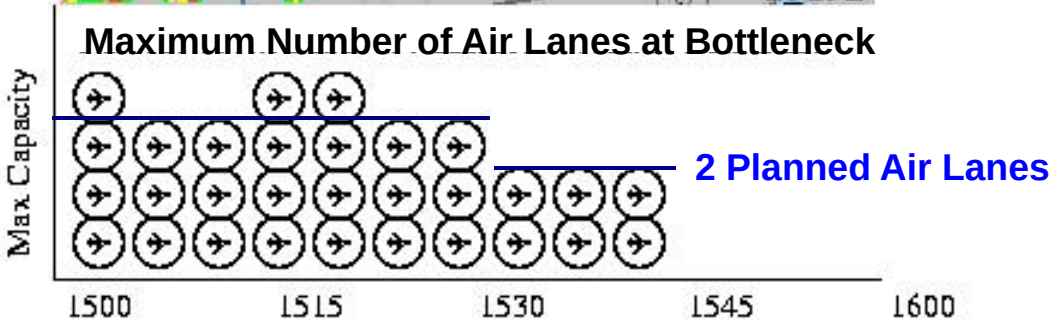
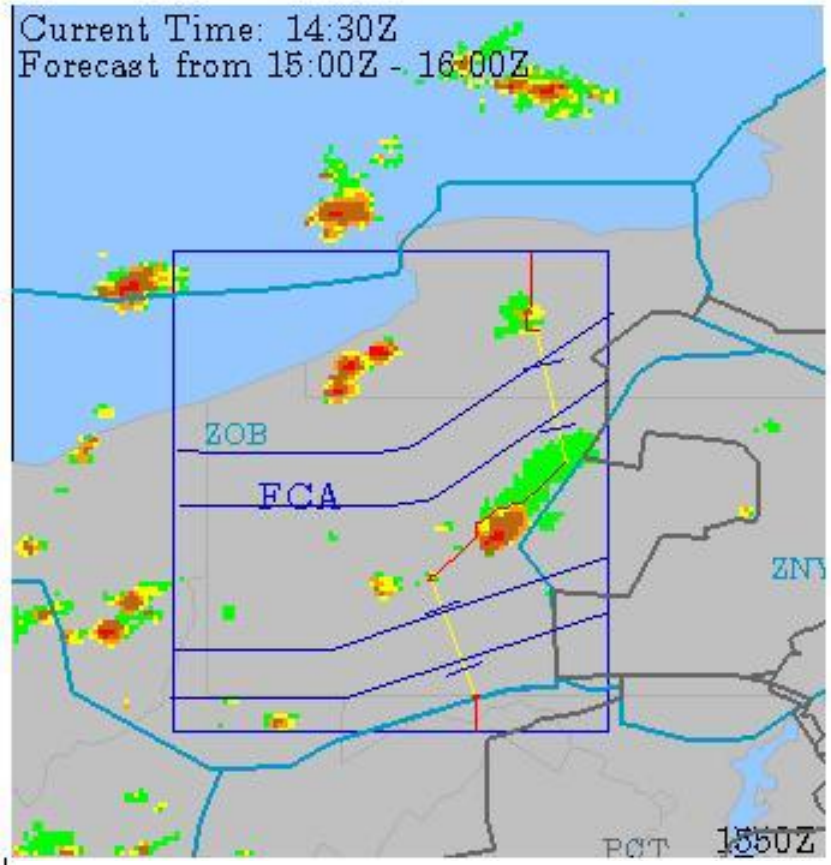
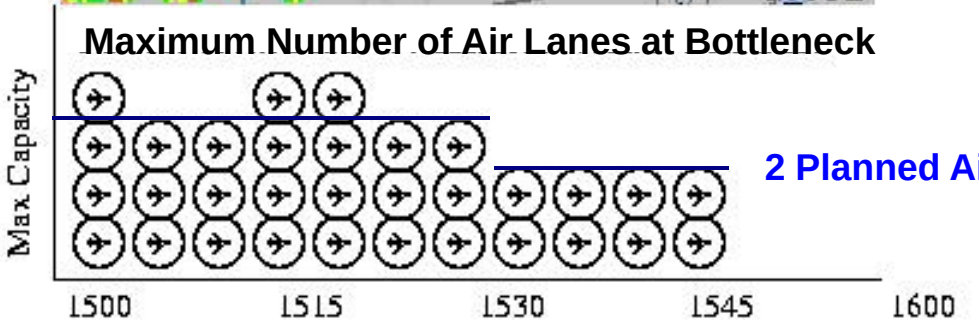
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1540Z

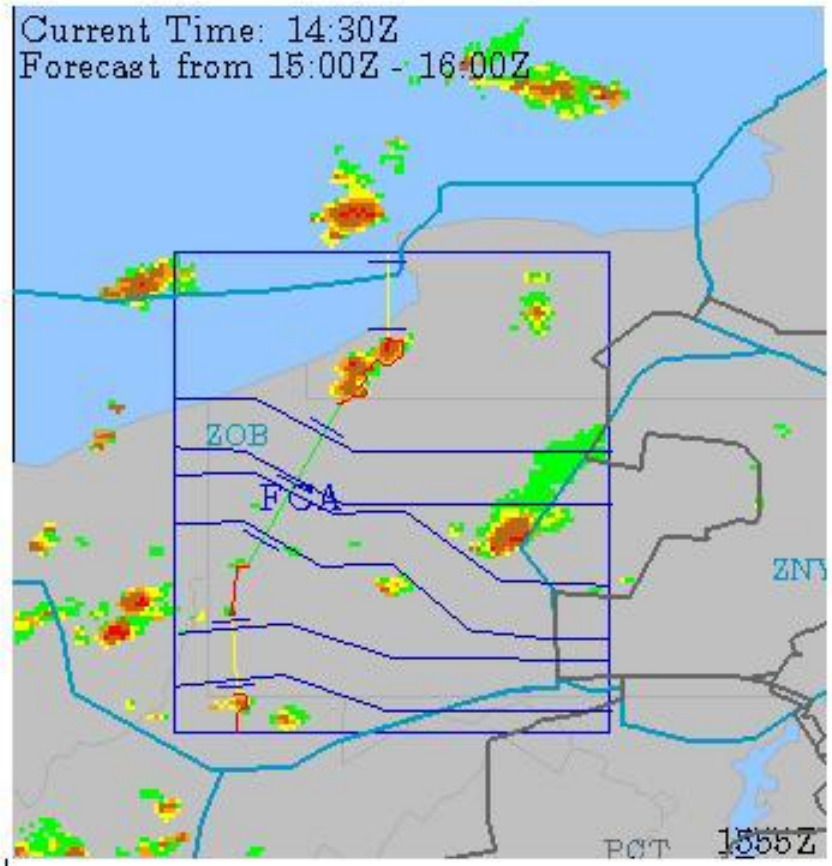

Maximum Number of Air Lanes at Bottleneck
2 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600

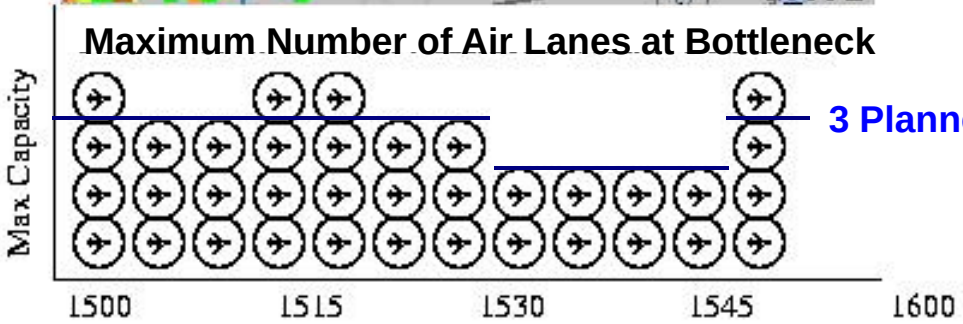

Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1545Z

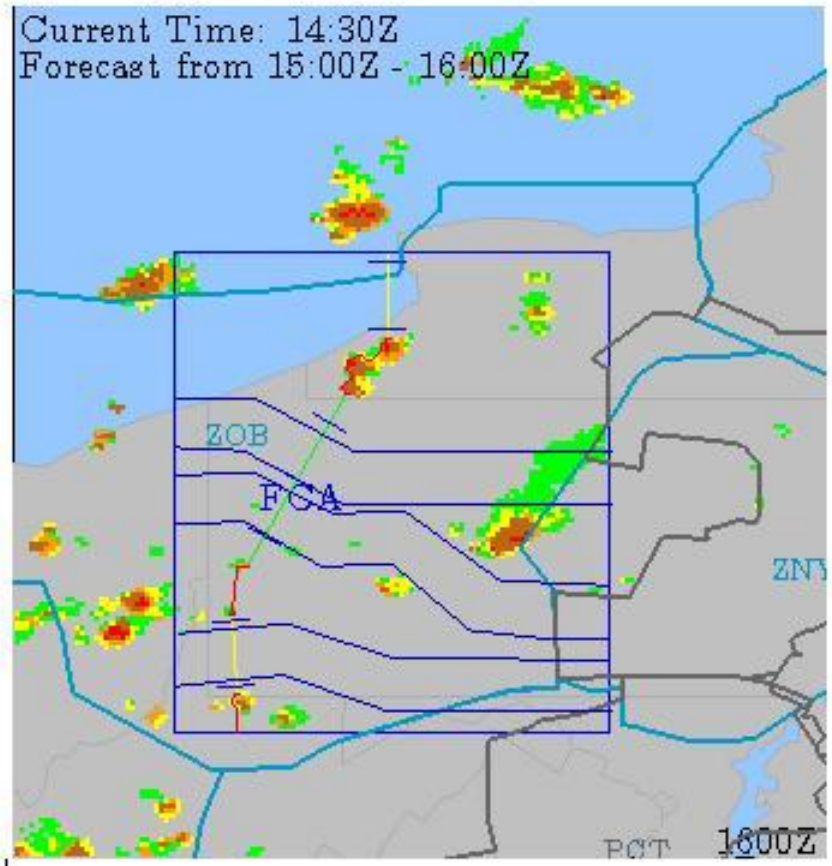

Maximum Number of Air Lanes at Bottleneck
2 Planned Air Lanes
Max Capacity
1500
1515
1530
1545
1600

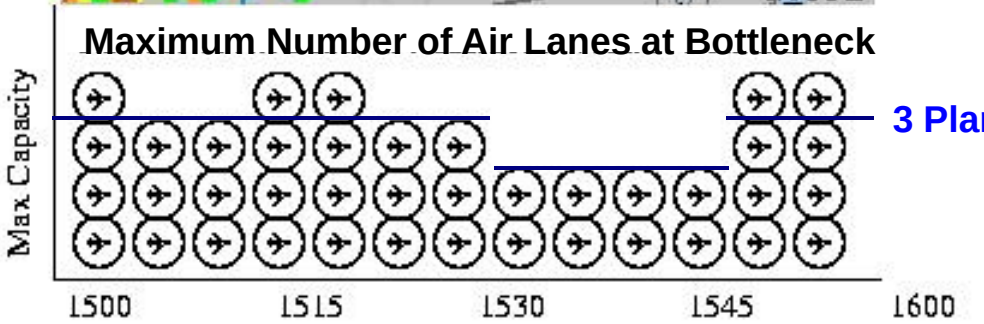

Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1550Z


Maximum Number of Air Lanes at Bottleneck
Max Capacity
2 Planned Air Lanes
1500
1515
1530
1545
1600

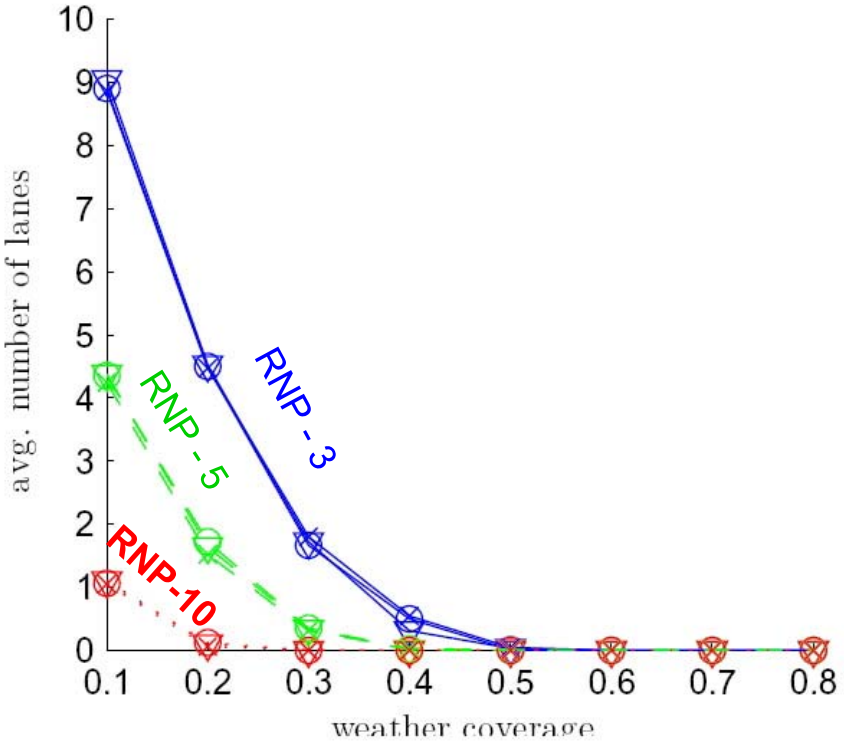

Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1555Z

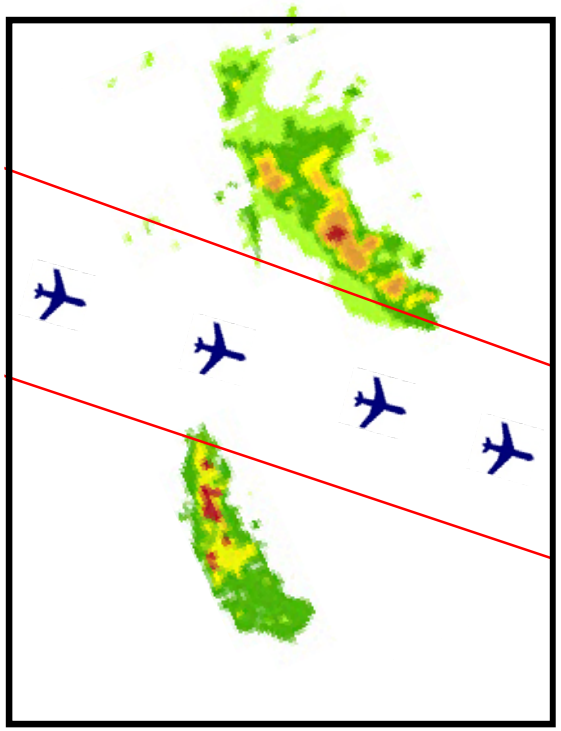

Maximum Number of Air Lanes at Bottleneck
Max Capacity
3 Planned Air Lanes
1500
1515
1530
1545
1600


Current Time: 14:30Z
Forecast from 15:00Z - 16:00Z
ZOB
FCA
ZNY
PCT
1600Z

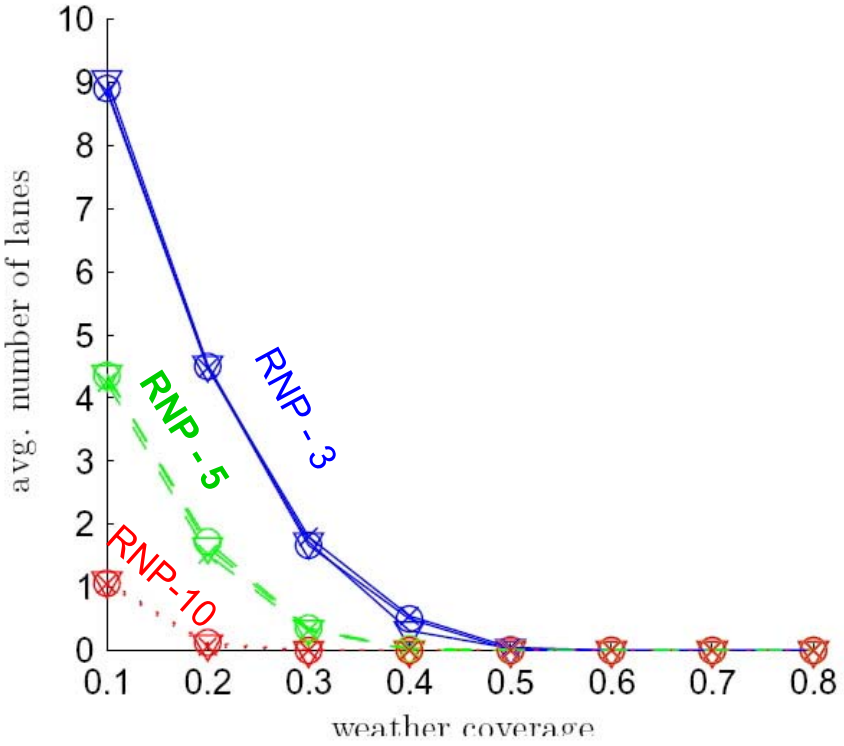

Maximum Number of Air Lanes at Bottleneck
Max Capacity
1500
1515
1530
1545
1600
3 Planned Air Lanes

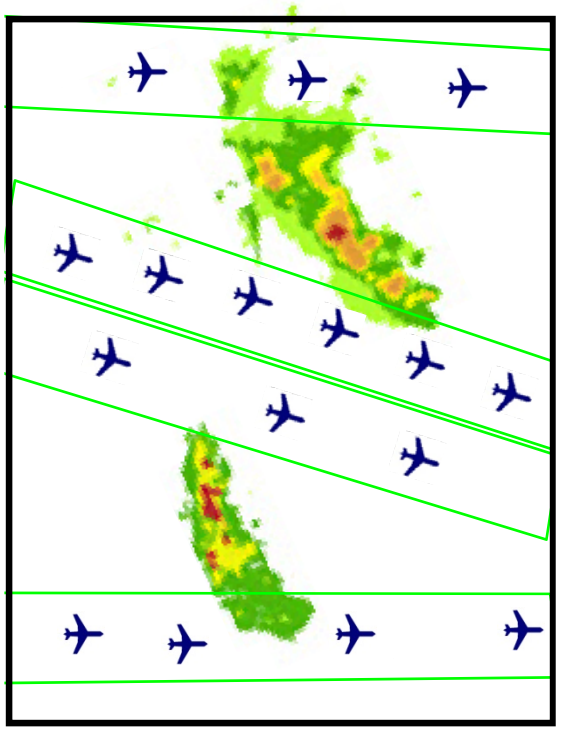
Variations in the Size of the Gap (RNP Requirement)



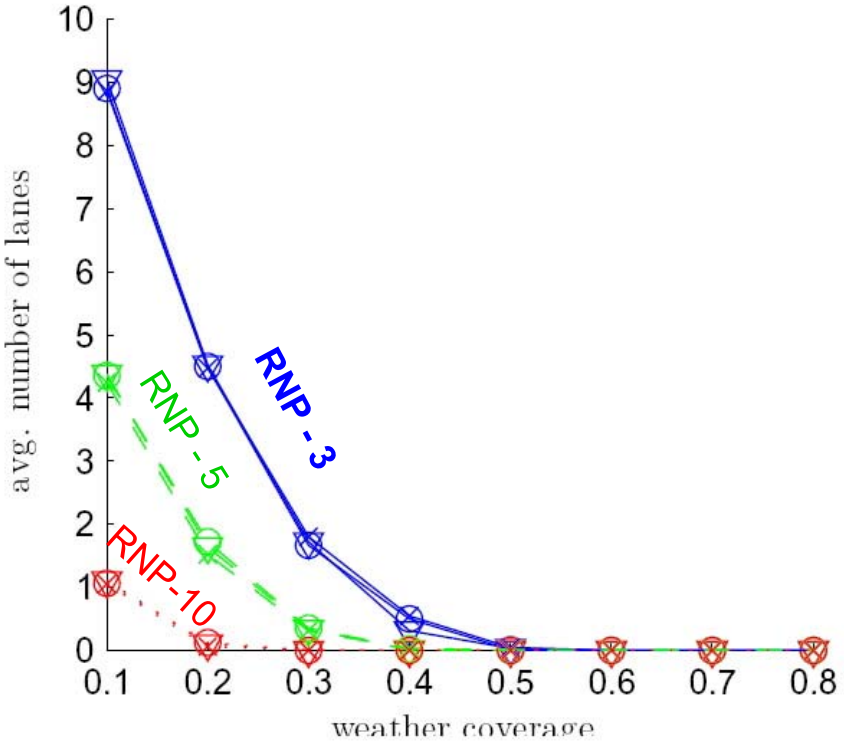


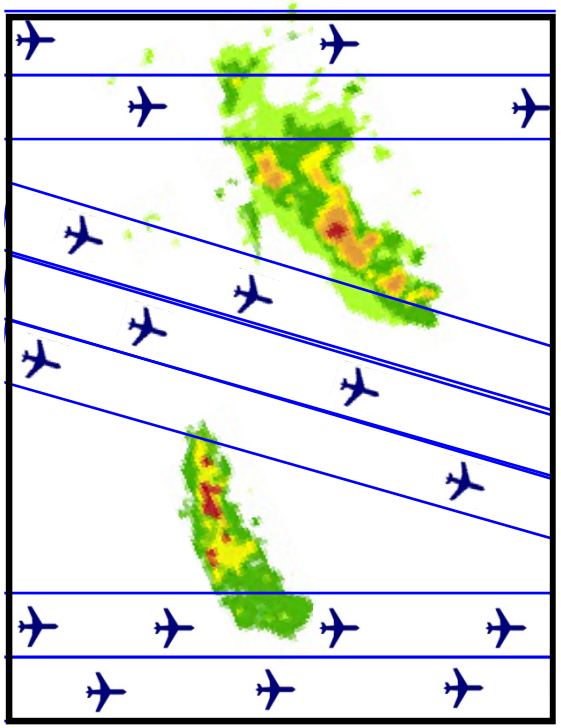
Variations in the Size of the Gap (RNP Requirement)





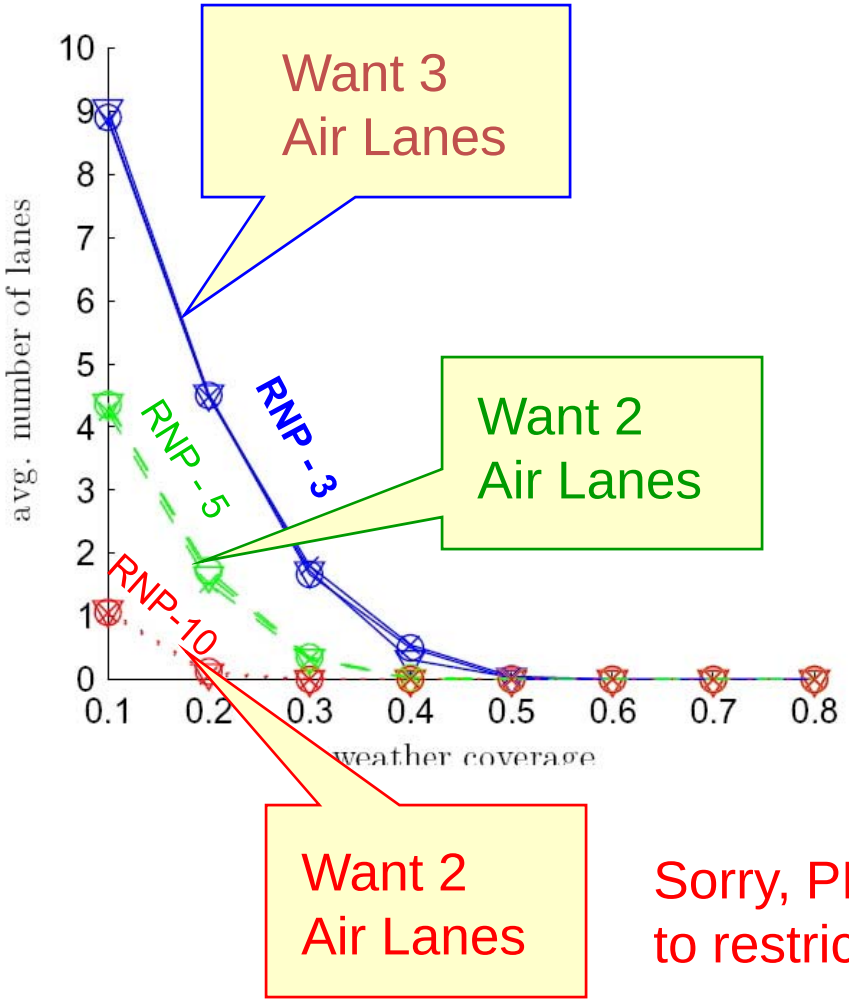
Variations in the Size of the Gap (RNP Requirement)

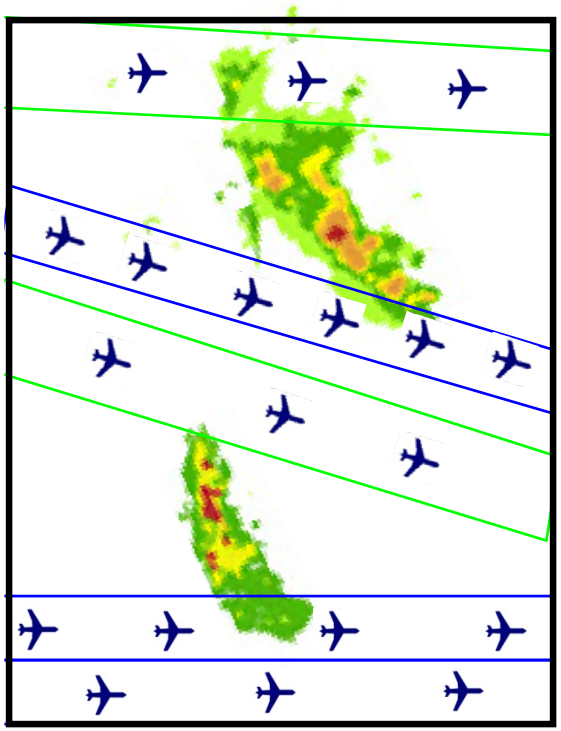




Variations in the Size of the Gap (RNP Requirement)

Mixed-RNP Demand

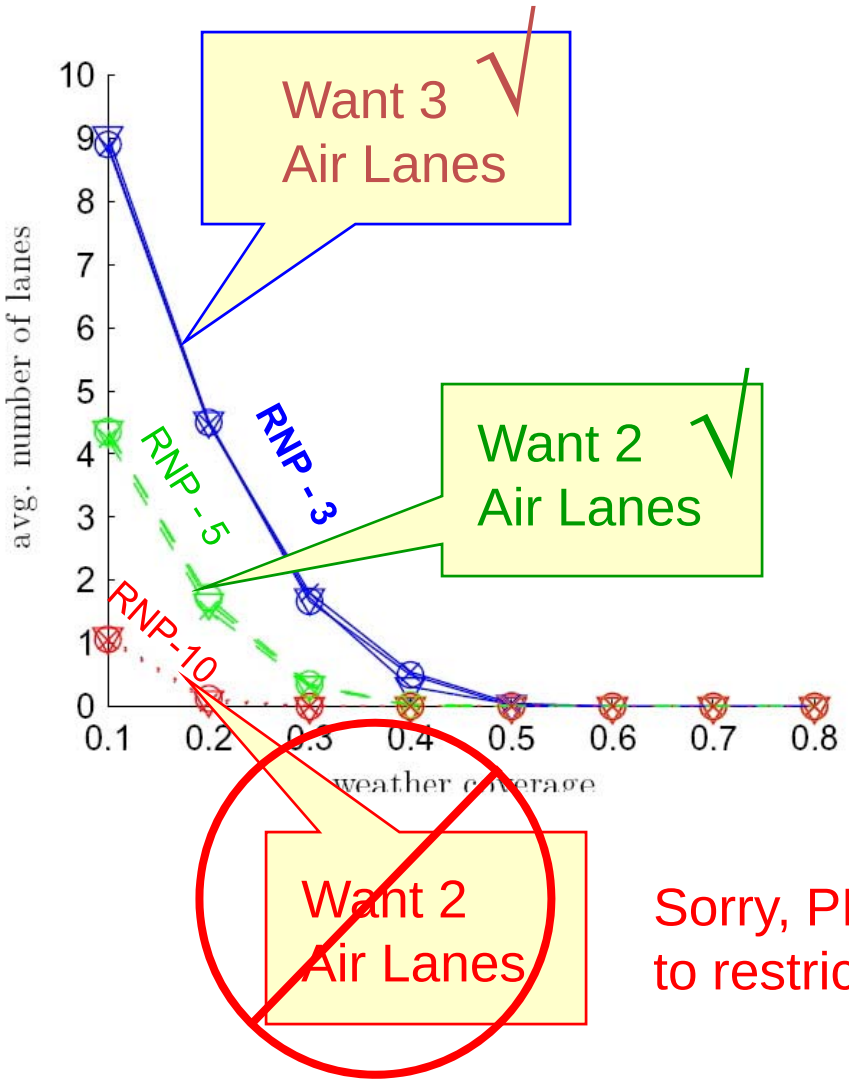


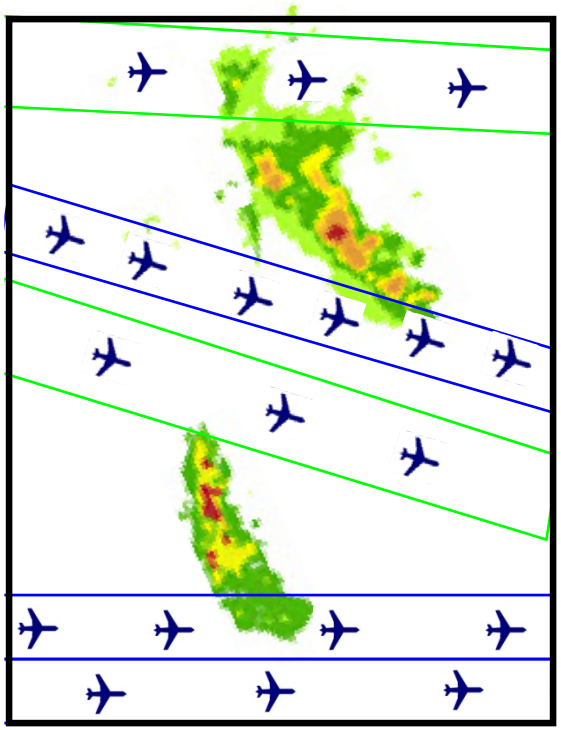


Sorry, PBS-rules… Advisory sent out via SWIM to restrict traffic to RNP-3 and RNP-5 only

Variations in the Size of the Gap (RNP Requirement)

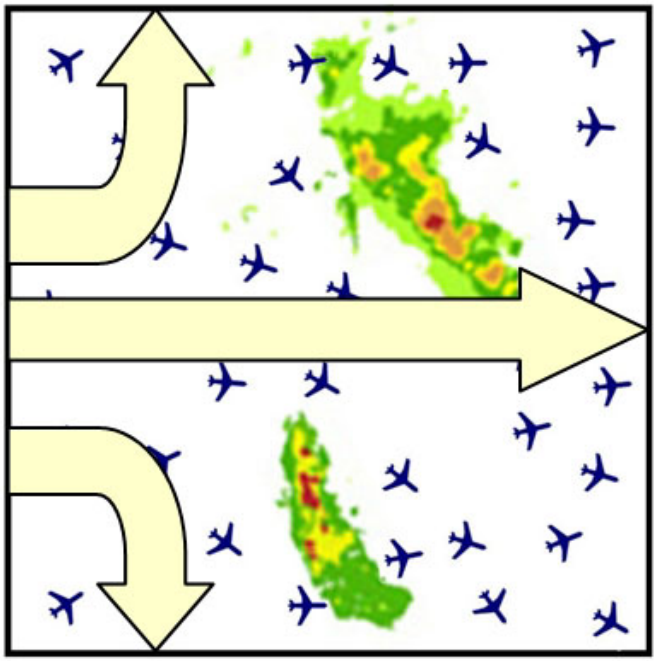
Mixed-RNP Demand



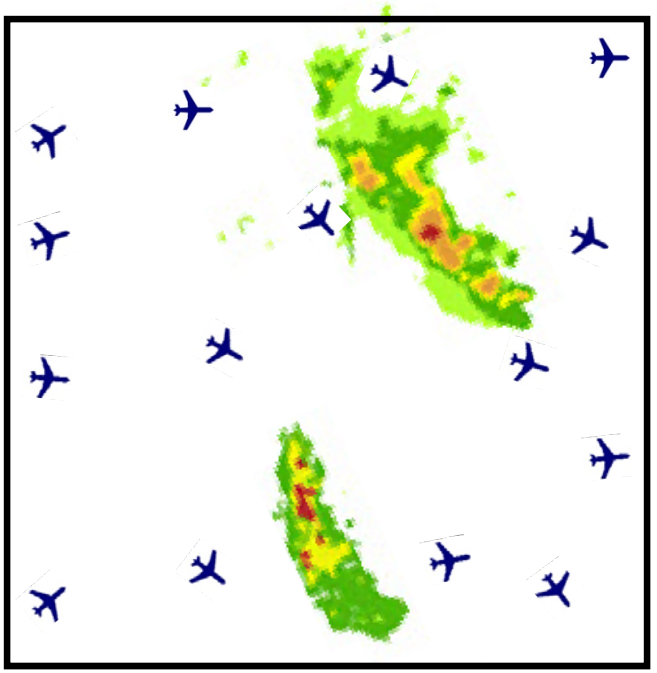


Sorry, PBS-rules… Advisory sent out via SWIM to restrict traffic to RNP-3 and RNP-5 only

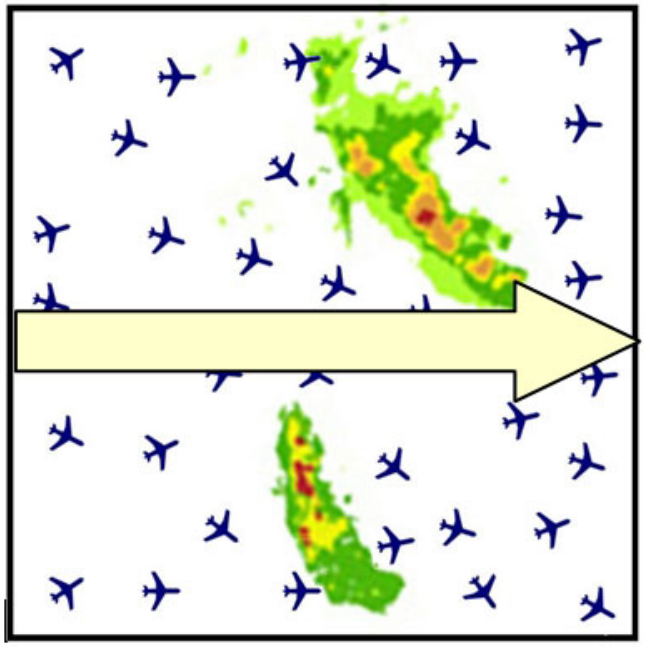
Unidirectional Flows



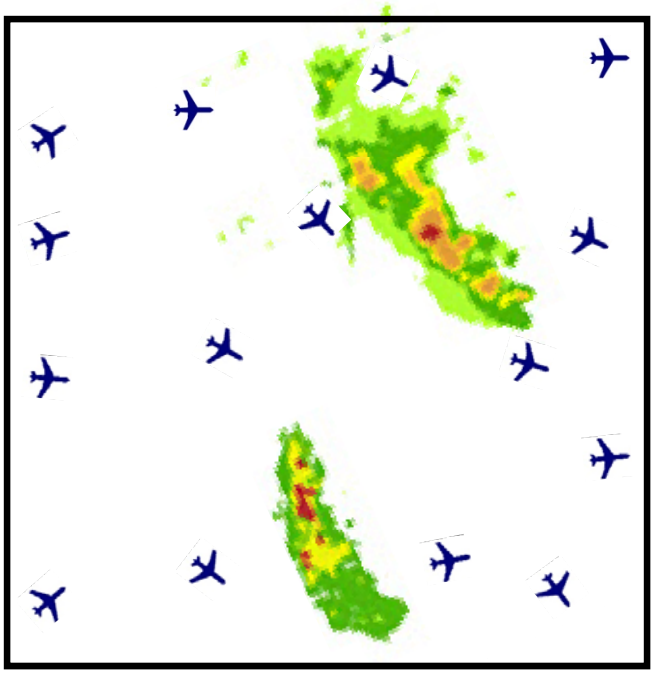
Free Flight (Monotonic Rule)



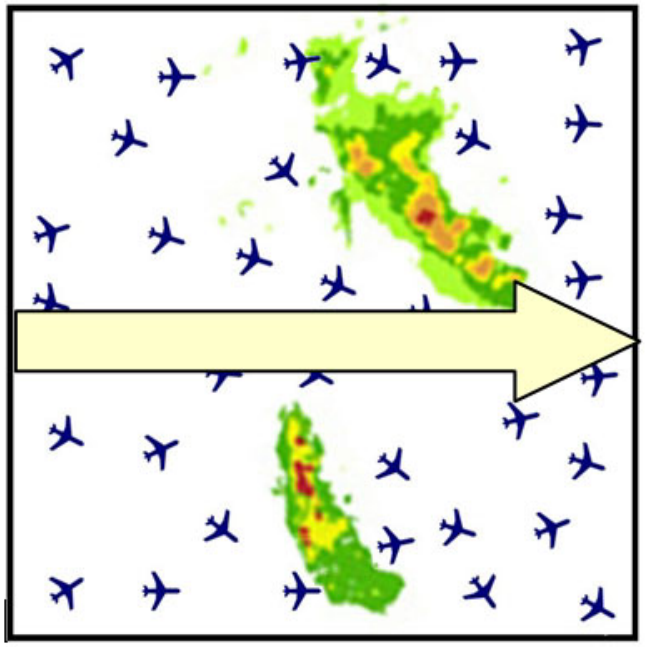
Platooning of 1



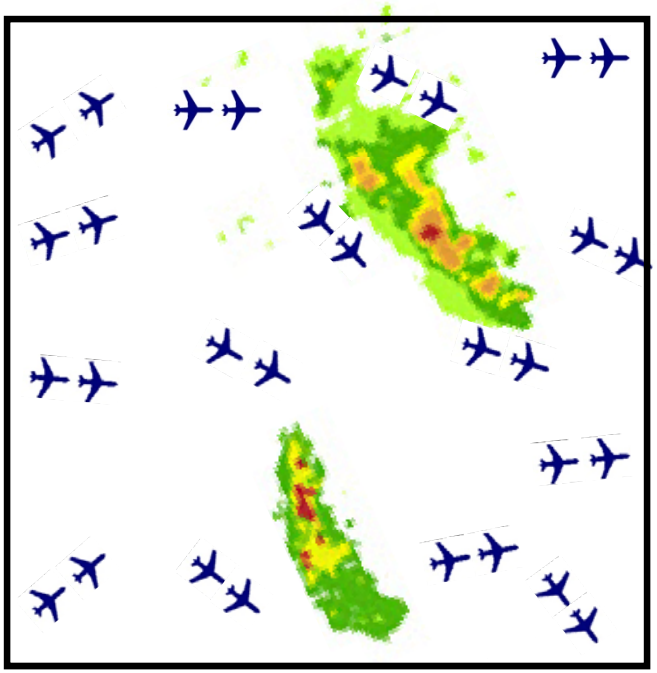
Free Flight (Unidirectional Rule)



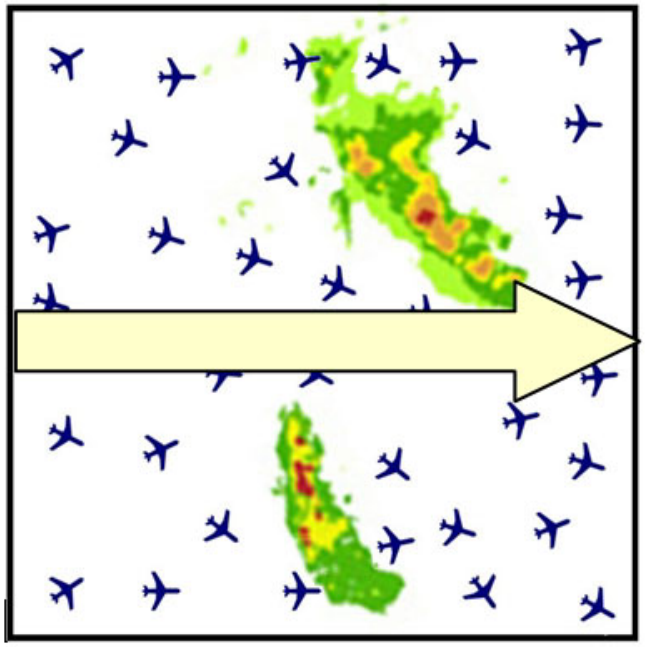
Platooning of 2



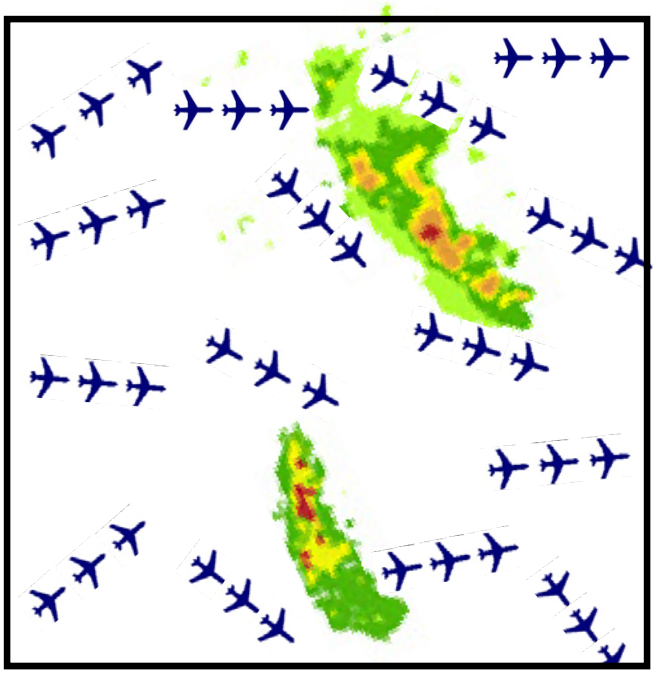
Free Flight (Unidirectional Rule)



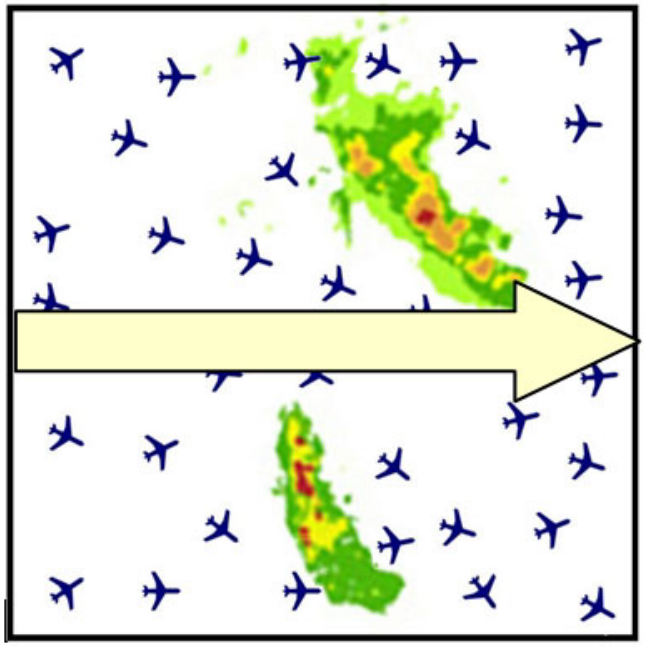
Platooning of 3



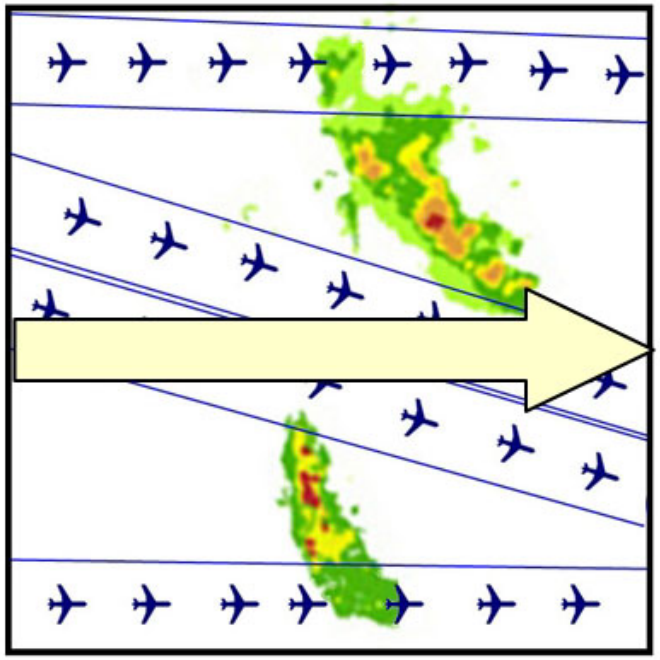
Free Flight (Unidirectional Rule)



Platooning of N → Flow-Based Route Planning



Free Flight (Unidirectional Rule)



Packed Unidirectional Flow

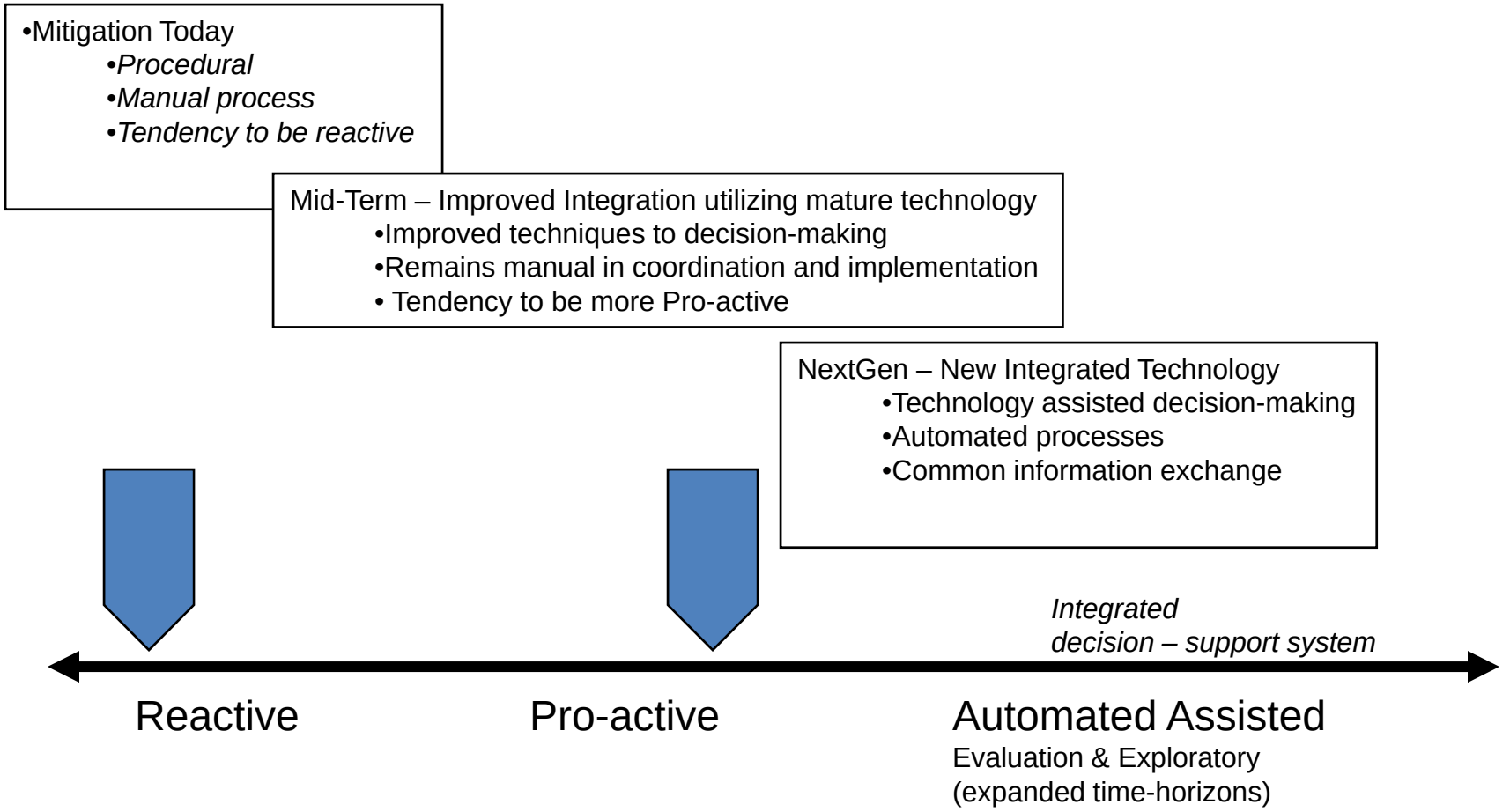
Scenario 3

New York Arrival and Departure

Super Density

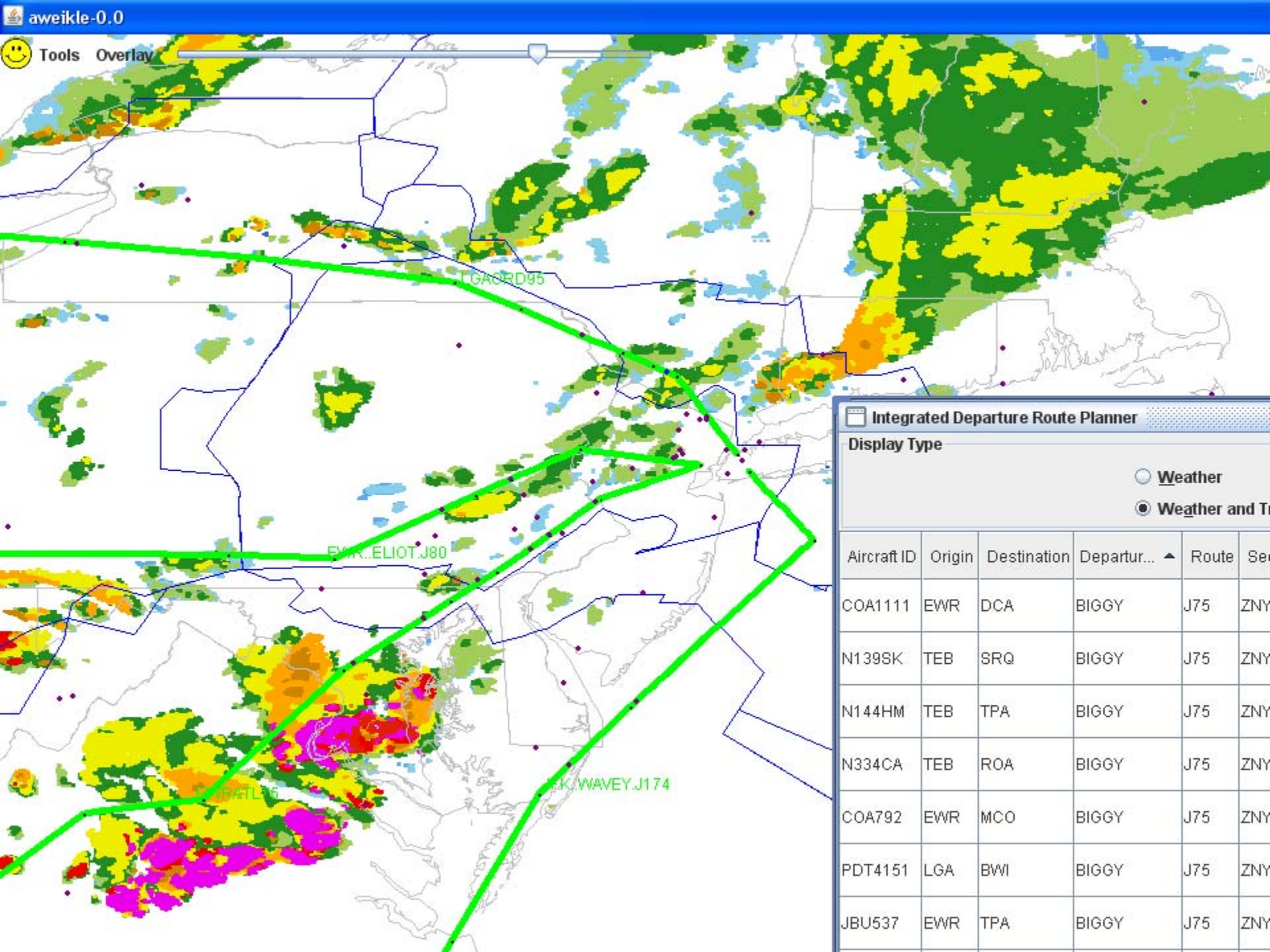
Operations

Now to NextGen



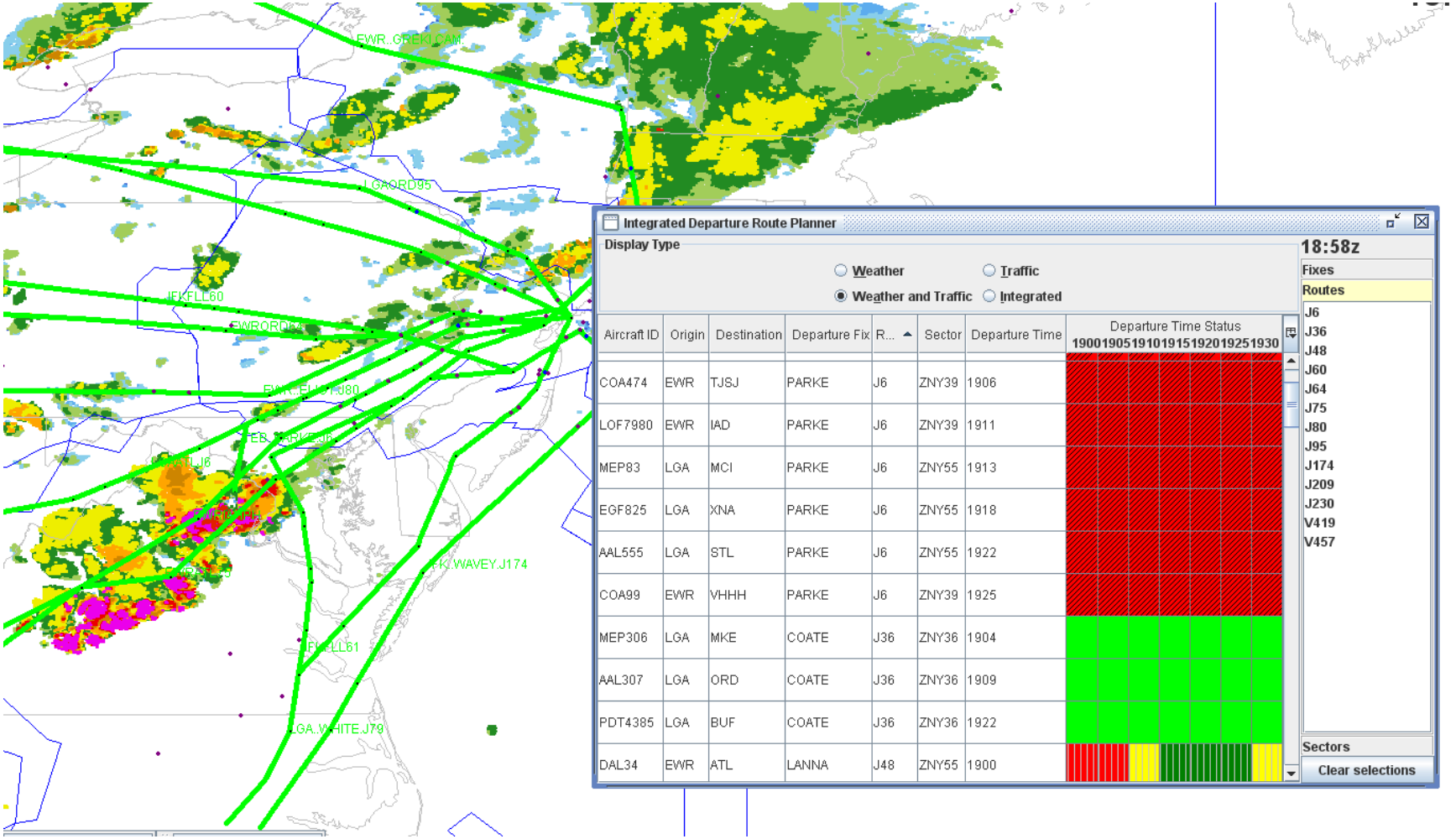
Credits

- FAA/JPDO
- Metron
- MITRE
- MIT/Lincoln Labs
- NASA



Aircraft ID	Origin	Destination	Departur...	Route	Se
COA1111	EWR	DCA	BIGGY	J75	ZNY
N139SK	TEB	SRQ	BIGGY	J75	ZNY
N144HM	TEB	TPA	BIGGY	J75	ZNY
N334CA	TEB	ROA	BIGGY	J75	ZNY
COA792	EWR	MCO	BIGGY	J75	ZNY
PDT4151	LGA	BWI	BIGGY	J75	ZNY
JBU537	EWR	TPA	BIGGY	J75	ZNY

Integrated Traffic and Weather for Departure Planning



Integrated Traffic and Weather for Departure Planning