Using Ensemble Forecasts to Support NAS Strategic Planning

Alex Tien, Christine Taylor, Craig Wanke

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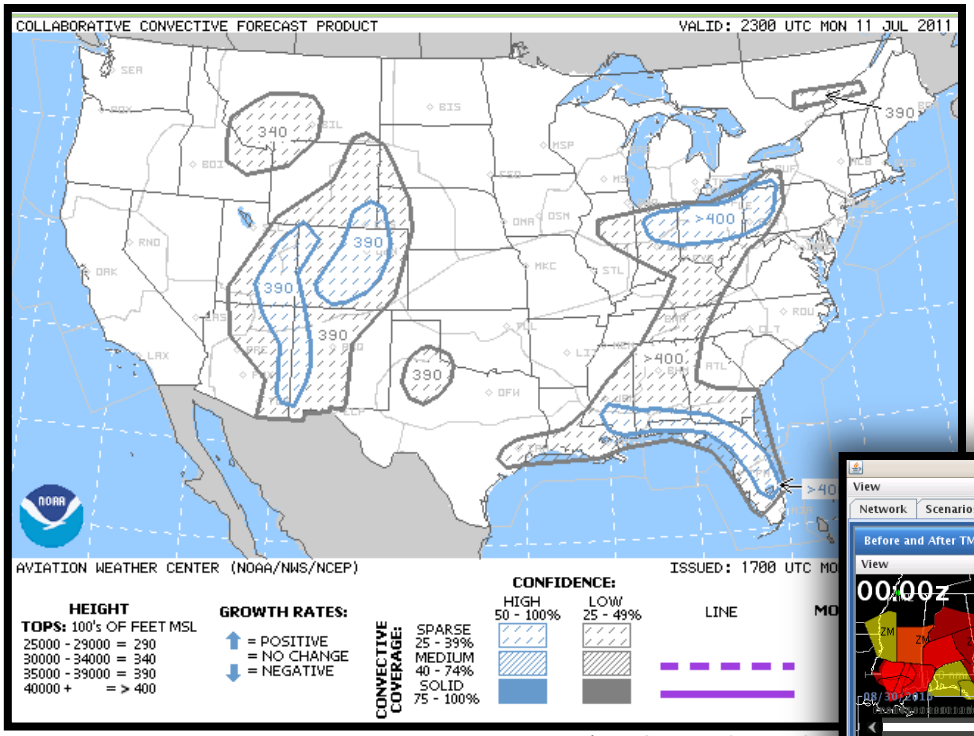
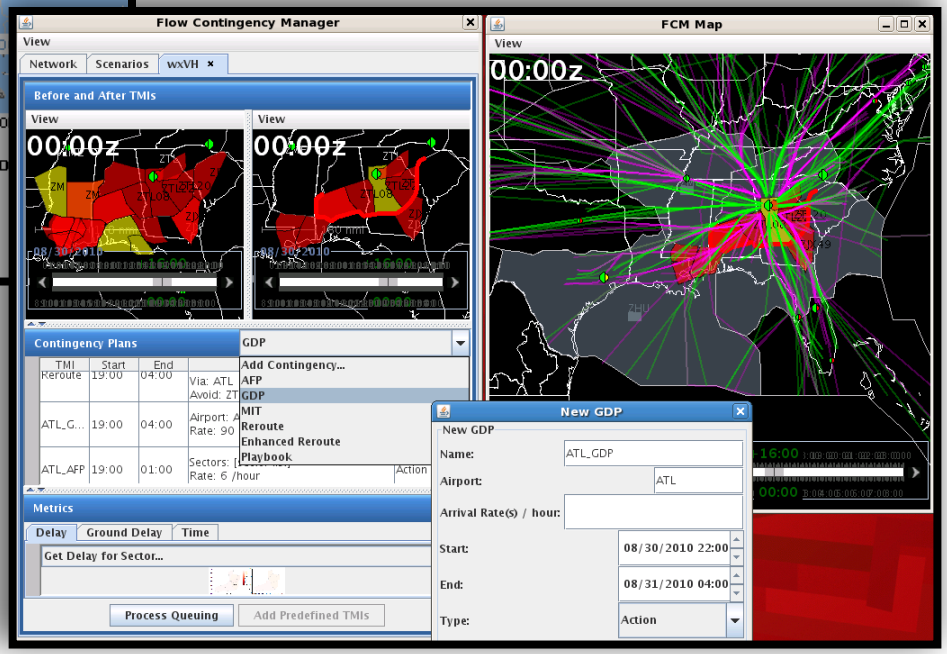
Strategic Planning and Flow Contingency Management (FCM)



Picture Source: NOAA AWC

NAS strategic planning aims to develop a mitigation plan for severe weather event hours in advance.

Flow Contingency Management (FCM) is developed to provide quantitative assessment of weather impact.



Picture Source: MITRE

FCM modeling components:

- *Translate forecast into capacity reduction*
- *Simulate weather-traffic interaction*
- *Plan for delay mitigation strategies*

Ensemble forecast can provide a range of possible scenarios for mitigation planning.

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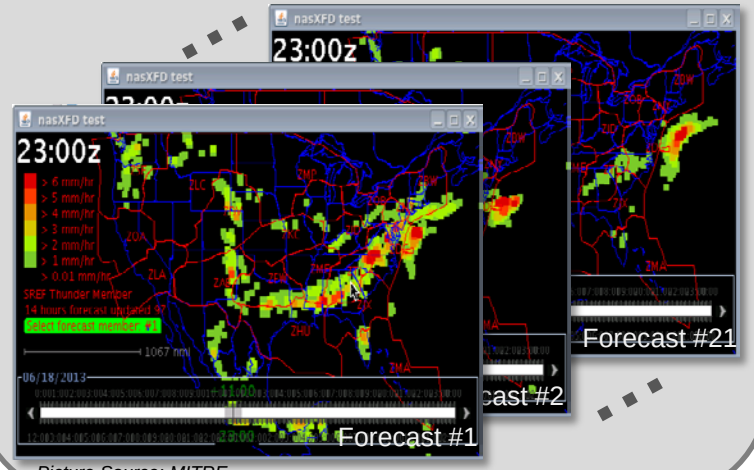
Analyze Multiple Weather-Impact Scenarios

21 Weather Forecasts from Short Range Ensemble Forecast (SREF)



Picture Source: MITRE

Scenario Analysis Methodology

Generate Weather-Impact Scenarios

- Translate weather forecast into NAS capacity loss
- Simulate weather-traffic interaction in FCM

Evaluate Scenarios with Impact Metrics

- Collect sector delays, key airport delays
- Construct a quantitative representation of scenarios

Apply a Clustering Algorithm

Identify Representative Scenarios

Representative Scenarios

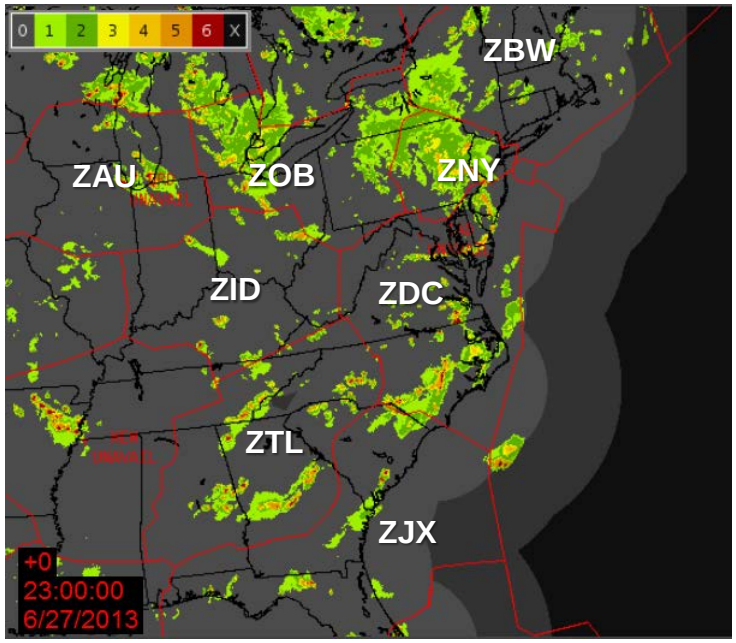
- **Rep. Scenario 1** — High impact over ZOB and ZAU
- **Rep. Scenario 2** — High impact on NY terminal airspace
- **Rep. Scenario 3** — Medium impact on ORD arrivals
- **Rep. Scenario 4** — Low impact

Traffic Management Initiatives

- **Plan 1** — AFP on A05, GDPs on NY Airports
- **Plan 2** — GDPs on NY Airports
- **Plan 3** — GDP on ORD
- **Plan 4** — Do Nothing

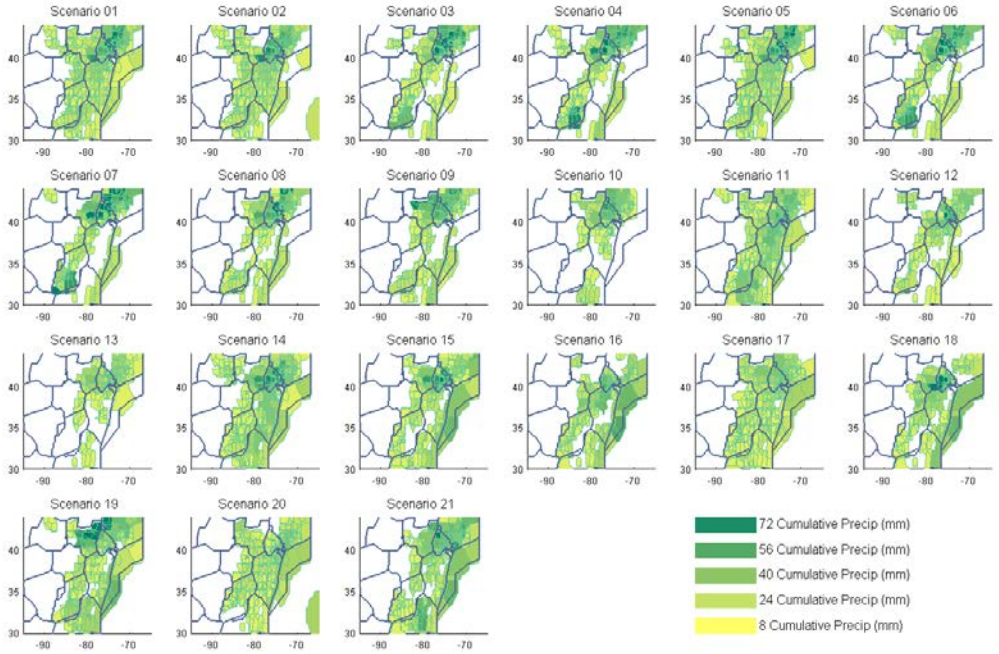
June 27, 2013

Observed Weather (CIWS VIL3+ Coverage)



Picture Source: MITRE

SREF Forecast at 0900Z (21 Scenarios of Hourly Precipitation)



Hourly precipitation aggregated over one day for illustration.

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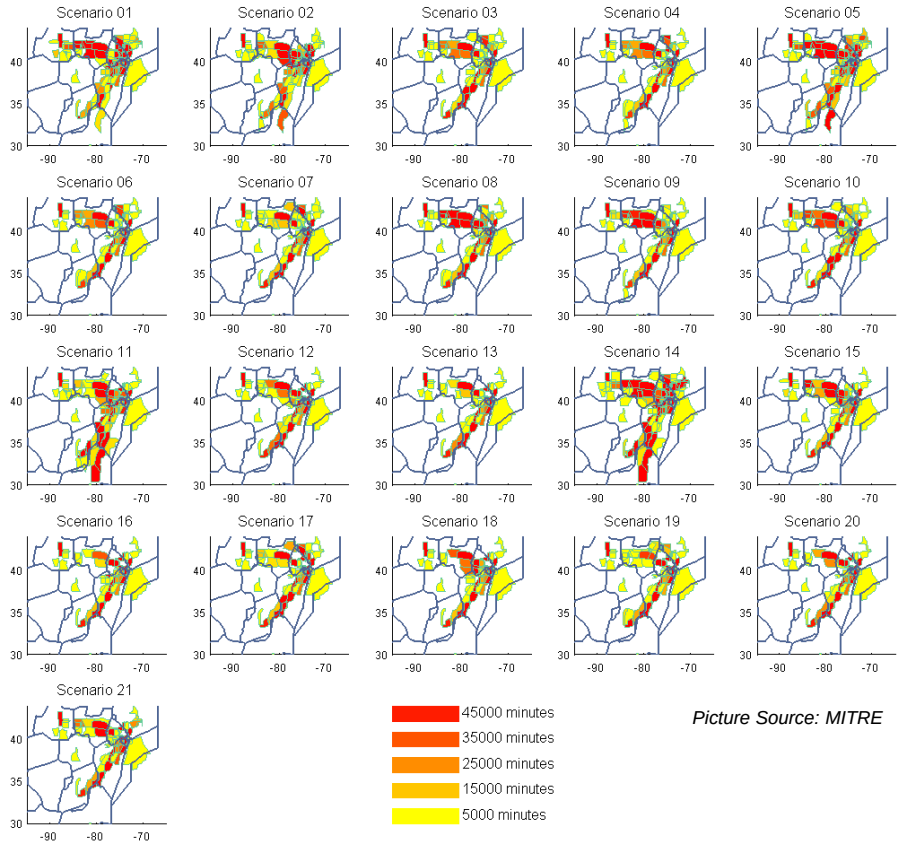
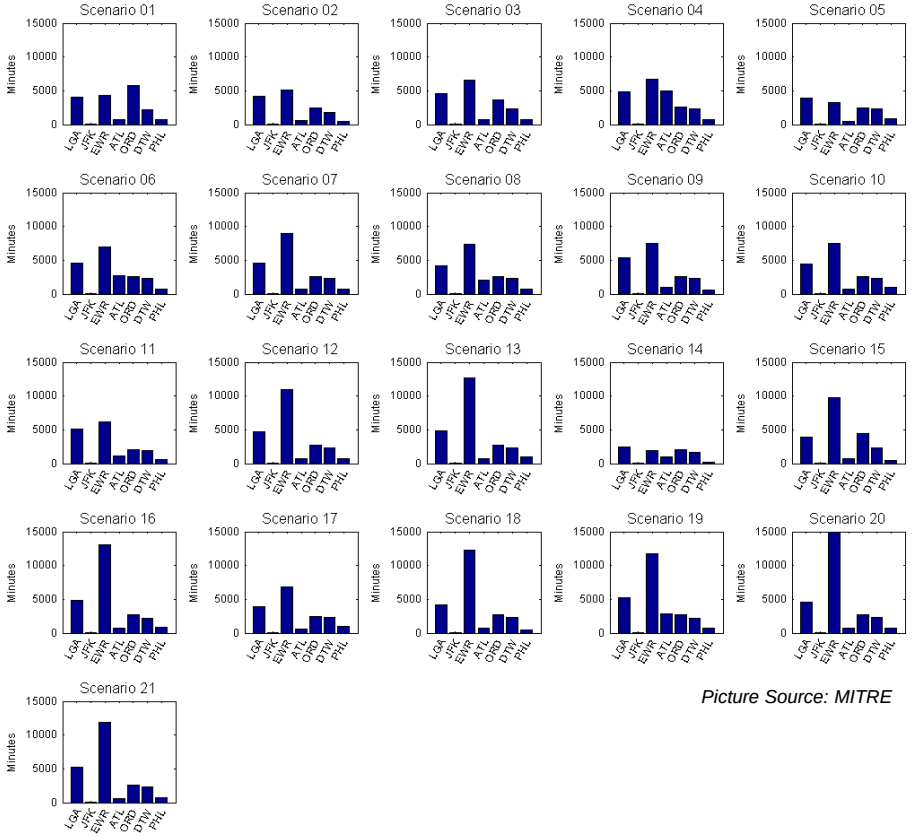
Generate Weather-Impact Scenarios via FCM Simulation

Sector Delays of 21 Scenarios



Picture Source: MITRE

Airport Delays of 21 Scenarios
(LGA, JFK, EWR, ATL, ORD, DTW, and PHL)



Picture Source: MITRE

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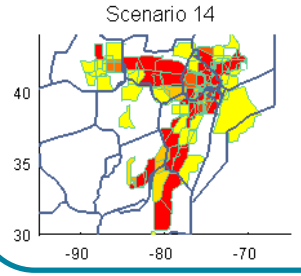
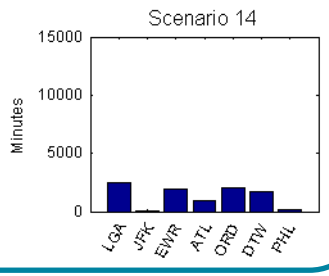
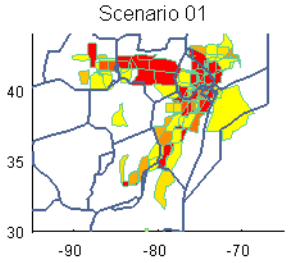
Identify Representative Weather-Impact Scenarios

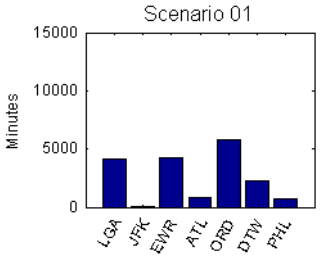
4.8% Likelihood; Highest Impact



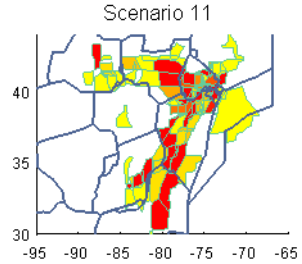


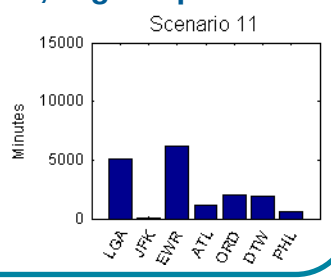
9.5% Likelihood; High Impact



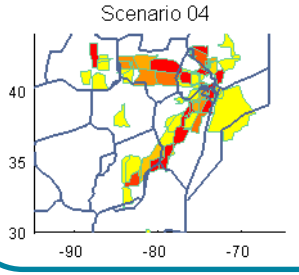


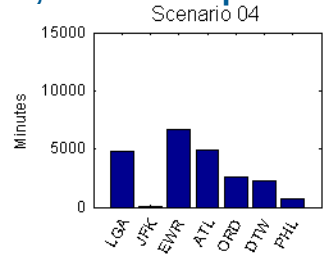
9.5% Likelihood; High Impact



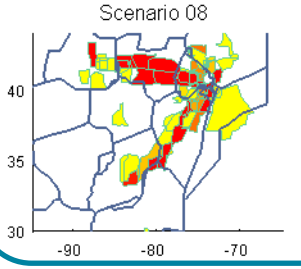


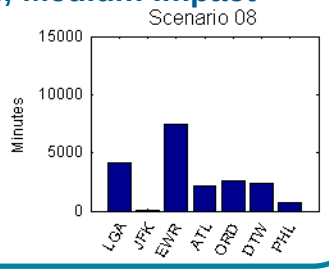
33% Likelihood; Medium Impact



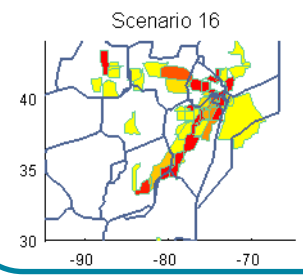


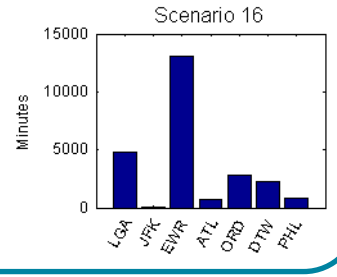
9.5% Likelihood; Medium Impact





33% Likelihood; Low Impact





Picture Source: MITRE

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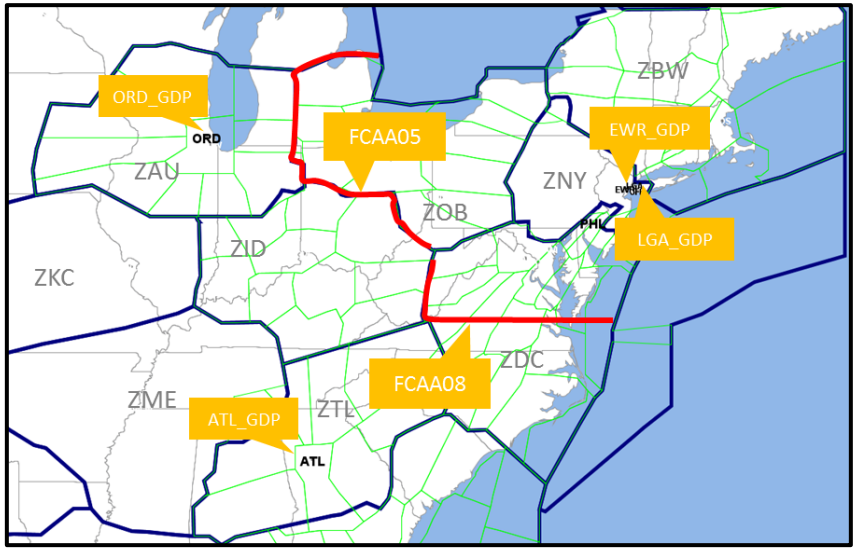
Design Traffic Management Initiatives

- **"Optimize" TMI plans for Representative Scenarios**



Picture Source: MITRE

Optimization capability was developed to efficiently search the combination of TMI parameters.

The objective function is set as ground delay + 2 sector delays.*

TMI Type		Start Time (UTC)	Duration (Hr)	Hourly Rate
GDP	EWR	{16, 17, 18, 19, 20, 21, 22}	{8, 9, 10, 11, 12, 13, 14}	{20, 25, 30, 35, 40}
GDP	LGA	{16, 17, 18, 19, 20, 21, 22}	{8, 9, 10, 11, 12, 13, 14}	{15,20,25, 30, 35}
GDP	ORD	{20, 21, 22, 23, 00, 01}	{2, 3, 4, 5, 6, 7, 8}	{70, 75, 80, 85, 90, 95, 100}
GDP	ATL	{18, 19, 20, 21, 22}	{3, 4, 5, 6, 7, 8}	{70, 75, 80, 85, 90, 95, 100}
AFP	FCAA05	{18, 20, 22, 00}	{6, 8, 10, 12, 14}	{50,60,70, 80, 90, 100}
AFP	FCAA08	{18, 20, 22, 00}	{6, 8, 10, 12, 14}	{70, 80, 90, 100, 110, 120}

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Compare TMI Plans

	TMI Parameters For Each Optimized Plan					
	Plan for Scenario 14* (Highest Impact)	**Plan for Scenario 01 (High Impact)**	**Plan for Scenario 11 (High Impact)**	**Plan for Scenario 08 (Medium Impact)**	**Plan for Scenario 04 (Medium Impact)**	**Plan for Scenario 16 (Low Impact)**
EWR GDP	S**: 22 D: 10 R: 25	S: 21 D: 11 R: 30	S: 22 D: 9 R: 40	S: 22 D: 10 R: 30	S: 22 D: 10 R: 35	S: 21 D: 10 R: 40
LGA GDP	S: 19 D: 13 R: 20	S:22 D: 10 R: 35	S: 22 D: 9 R: 30	-	-	-
ORD GDP	S: 23 D: 4 R: 80	S: 23 D: 3 R: 75	S: 00 D: 4 R: 95	S: 01 D: 4 R: 40	-	-
ATL GDP	-***	-	-	-	S: 22 D: 4 R: 90	-
AFP 05	S: 18 D: 12 R: 80	-	-	-	-	-
AFP 08	S: 00 D: 8 R: 120	S: 00 D: 8 R: 110	S: 22 D: 10 R: 120	-	-	S: 00 D: 8 R: 100

* Plan 01 is a shorthand note for the plan optimized for Scenario 01, and so forth for other plans.
** **S** for start hour in Zulu; **D** for duration in hours; **R** for hourly rate.
*** Empty cell in the table means that the TMI is not part of the optimized strategy.

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Evaluate Clustering Results and TMI Plans

- **The greatest cost reduction percentages correlate with the plan optimized for the corresponding scenario.**

Representative Scenarios	Likelihood of Occurrence	Baseline System Cost Function Value (in Min.)	Cost Reduction (%)					
			Under Plan 14	Under Plan 01	Under Plan 11	Under Plan 08	Under Plan 04	Under Plan 16
Scenario 14 (Highest Impact)	4.8%	2,387,294	-20.38%	-16.48%	-13.69%	-10.49%	-9.16%	-7.66%
Scenario 01 (High Impact)	9.5%	1,547,095	-18.80%	-24.77%	-19.38%	-19.25%	-14.86%	-11.44%
Scenario 11 (High Impact)	9.5%	1,346,795	-12.30%	-17.99%	-20.50%	-12.28%	-12.08%	-13.32%
Scenario 08 (Med. Impact)	9.5%	1,079,934	-10.22%	-22.22%	-22.09%	-22.89%	-22.06%	-20.46%
Scenario 04 (Med. Impact)	33.3%	942,789	4.98%	-9.03%	-8.97%	-10.91%	-11.55%	-11.09%
Scenario 16 (Low Impact)	33.3%	839,426	9.53%	-6.07%	-7.39%	-8.37%	-8.89%	-10.94%

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Concluding Remarks

- **SREF provides a range of possible weather futures for supporting NAS strategic planning.**
- **Methodology for analyzing multiple weather-impact scenarios was proposed.**
  - Evaluate impact → identify representative scenarios → design delay mitigation plans.
- **The performance of the clustering results was examined with the TMI plans designed specifically for the representative scenarios.**
  - Representative scenarios were better mitigated by the TMI plans optimized for them.
- **Next steps:**
  - Explore metrics reflecting stakeholder concerns.
  - More weather days can be analyzed to fine-tune model parameters.
  - Develop methodology for deriving a current decision point plan.

Publications

- **Tien, S-L, Taylor, C., and Wanke, C., "Representative Weather-Impact Scenarios for Strategic Traffic Flow Planning," *AIAA Aircraft Technology, Integration, and Operations* Conference, Atlanta, GA, 16-19 June 2014.**
- **Tien, S-L, Taylor, C., and Wanke, C., "Identifying Representative Weather-Impact Scenarios for Flow Contingency Management," *AIAA Aircraft Technology, Integration, and Operations Conference*, Los Angeles, CA, 12-14 August 2013.**
- **Taylor, C., Masek, T., and Wanke, C., "Designing Strategic Planning Strategies using Multi-Objective Genetic Algorithms," *AIAA Aviation Technology, Integration, and Operations Conference*, June 2014.**
- **Taylor, C., Wanke, C., Wan, Y., Roy, S., "A Decision Support Tool for Flow Contingency Management", AIAA Guidance, Navigation, and Control Conference, Minneapolis, MN, August, 2012.**

Contact: Alex Tien (sltien@mitre.org)

Thank You!

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