AATT RTO 6 and RTO 9 NRA Workshop

RTO6 EDA - Preliminary En Route Descent Advisor Potential Benefits Assessment

RTO9 EDX - Preliminary En Route Data Exchange Potential Benefits Assessment

Tara Weidner
Goli Davidson

Seagull Technology, Inc.
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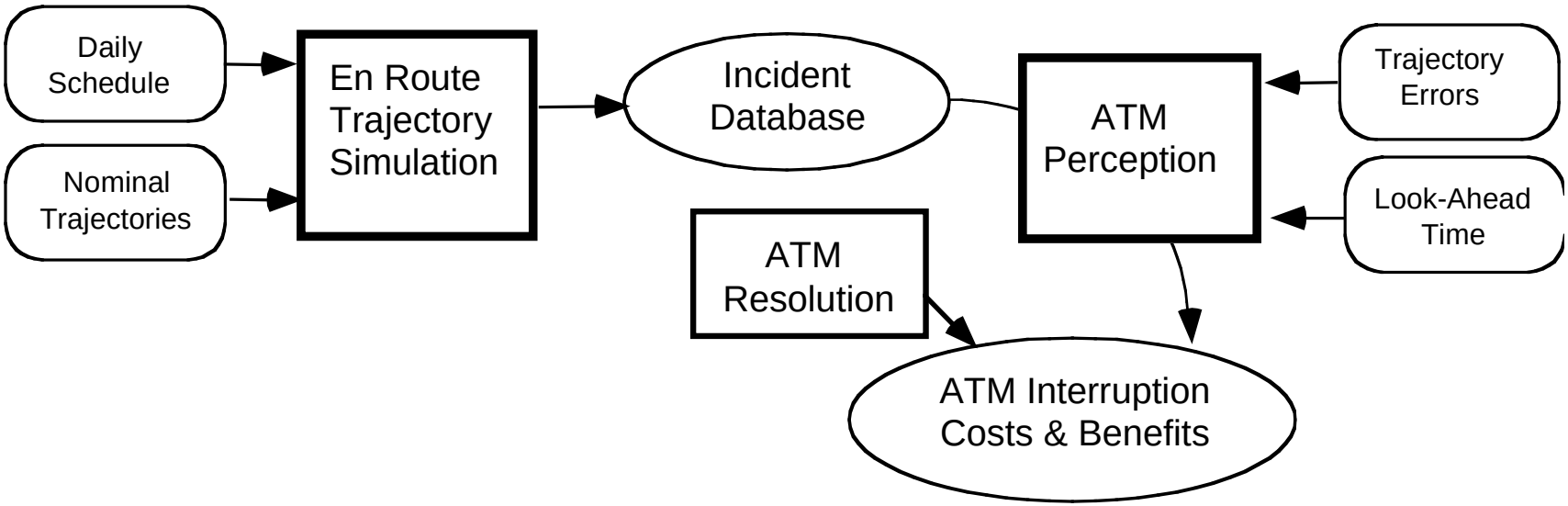
Outline

- **ATM Interruptions Benefits Estimates**
  - Project Scope
    - Focus on methodology
    - Future improvement of parameters/assumptions with operational data
  - Common RTO 6/RTO 9 Methodology
    - Overview
    - Model Components
  - Parameters/Results - RTO 6 EDA
  - Parameters/Results - RTO 9 EDX
  - Recommendations
- **RTO6 Fuel Benefit of Optimized Climb Trajectories**
  - Vertical Profile Optimization
  - Direct Routing Optimization
  - Conclusions

ATM Interruptions Methodology

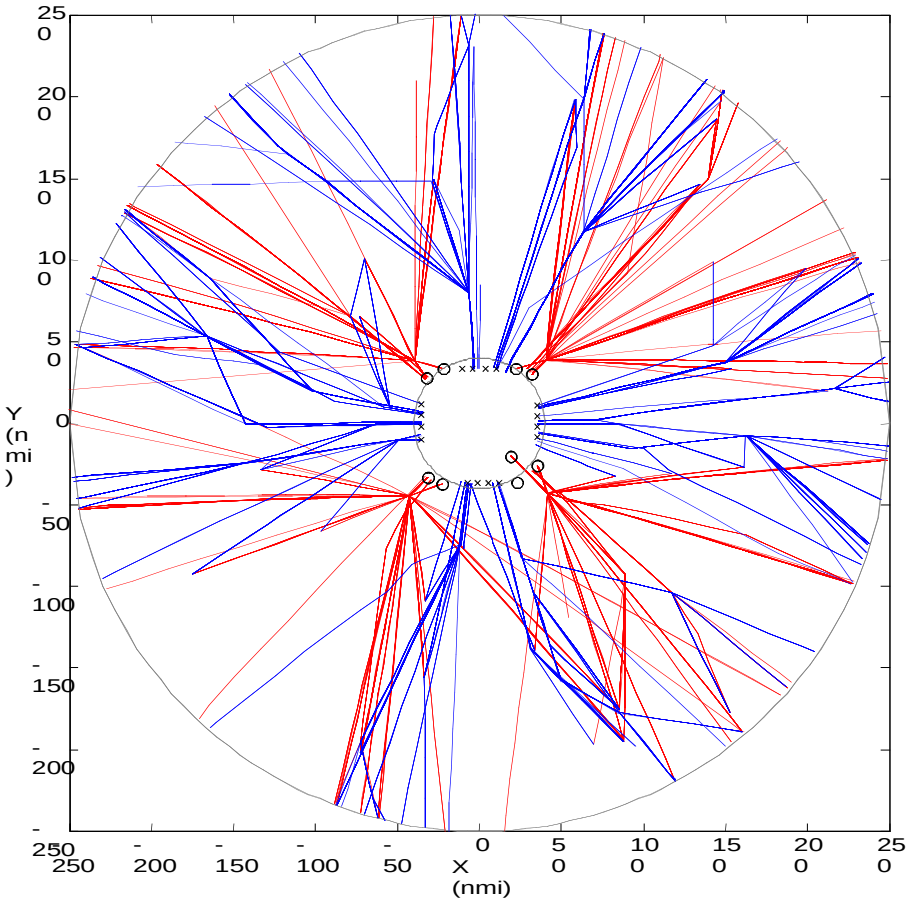


ATM Interruptions

- Meet-Time (Metering Delay Absorption)
- Traffic Avoidance

Nominal Trajectories: Arrivals/ Departures

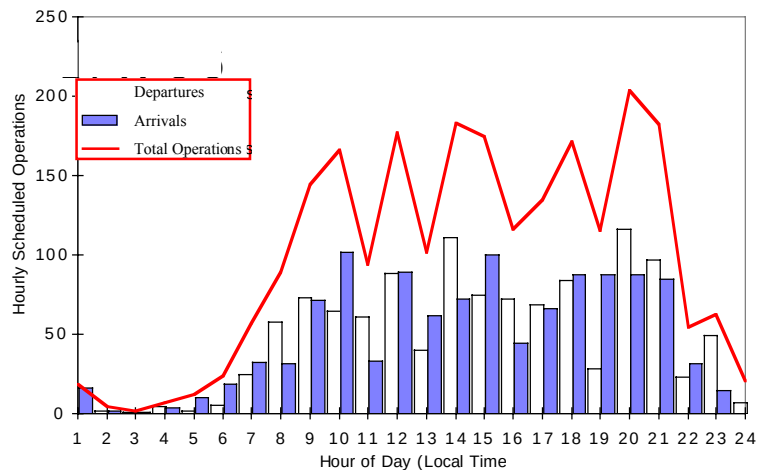
Analyzed all operations within 40-250 nm from DFW, above FL100



Arrivals

Departures

ETMS flight plans from Friday, June 14, 1996



Satellite Airport/Overflight Trajectories

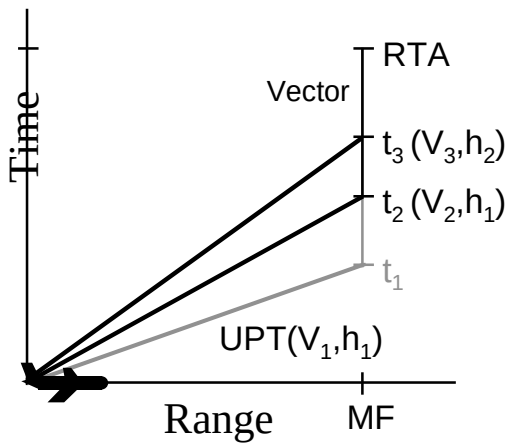
Profile View (S-N)

	DFW Satellite Airport	Daily Ops
IAH	Houston Apt	1,043
HOU	William Hobby Apt	497
DAL	Dallas Love Field Apt	468
SAT	San Antonio Intl Apt	432
AUS	Robert Mueller Muni Apt	377
OKC	Will Rogers World Apt	276
TUL	Tulsa Intl Apt	261
SPS	Wichita Falls Muni Apt	156
SHV	Shreveport Regional Apt	136
LBB	Lubbock Intl Apt	128
	Top 10 DFW Satellite	3,774 (83%)
	DFW Satellite Ops	4,005
	DFW Overflight Ops	527

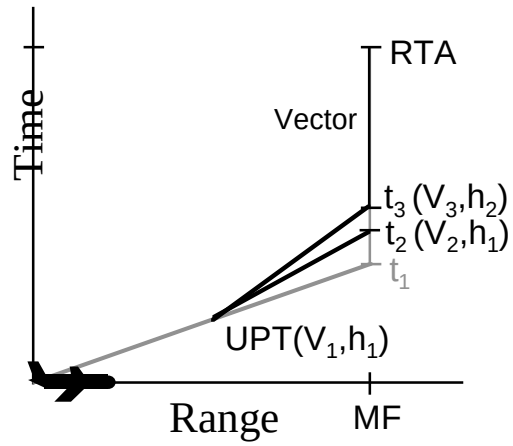
Plan View

Meet-Time ATM Interruptions

DFW Scheduling Criteria	Parameter Value
Arr/Dep Fix Separations	5.50 nm
TRACON Acceptance Rates	
Arrival AAR	150 ac/hr
Departure AAR	115 ac/hr



Long look-ahead time



Short look-ahead time

t1: Undelayed RTA
t2: Maximum delay that can be absorbed with speed control alone
t3: Maximum delay that can be absorbed with speed control and altitude change
RTA: Required time of arrival at the metering fix (MF)

Absorb delay to meet airport throughput rates

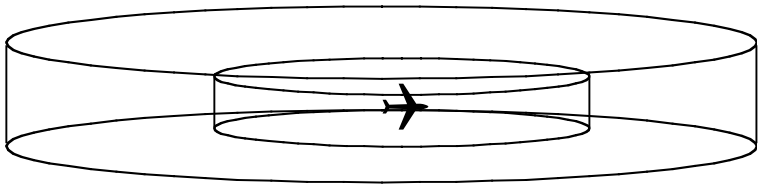
- Speed Control (V_1>V_2)
- Altitude Change (V_1>V_2>V_3 and h_1>h_2)
- Vectoring (increase range at V_1)

Incident Database

Objective:

Create database of all conflicts/near-conflicts from DFW Airspace Model trajectories (x,y,z,t)

- Filter to identify unique 2-aircraft incidents
  (less than 12 nm horizontally & 1400'/2400' vertically)



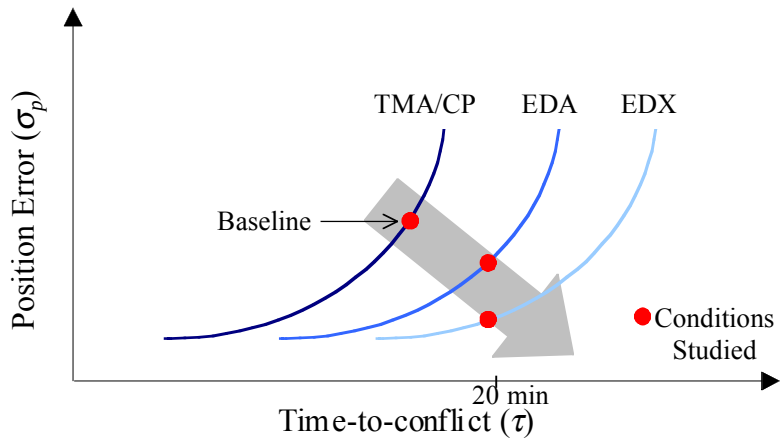
Min Sep. Requirement + Buffer

- Calculate incident attributes
  - Miss distance (horiz/vert distance, time, location)
  - Operations Type (arrival, departure, overflight)
  - Flight mode (climb, descent, cruise)
  - Other as needed to categorize incident or ATM perception accuracy (arr/dep fix, relative speeds and headings)

ATM Perception

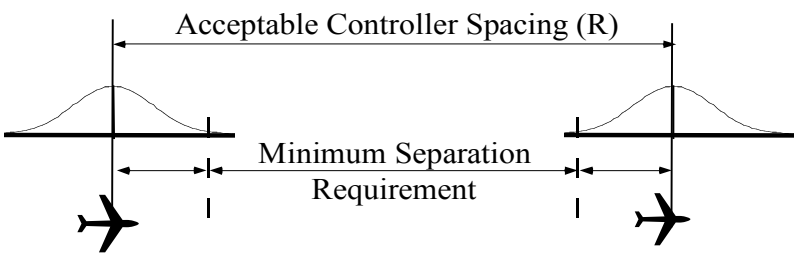
Tool Accuracy...

$\sigma_{position}$ & σ_{speed}



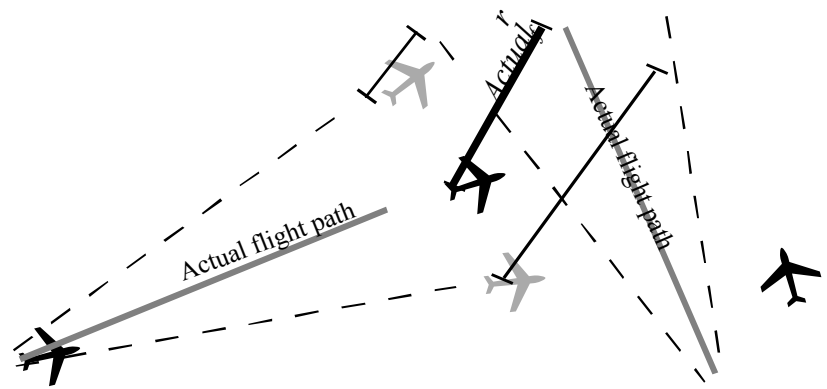
Acceptable Controller Spacing (R)

$$R = n\sigma_p + \textit{Min Sep Reqmn't}$$



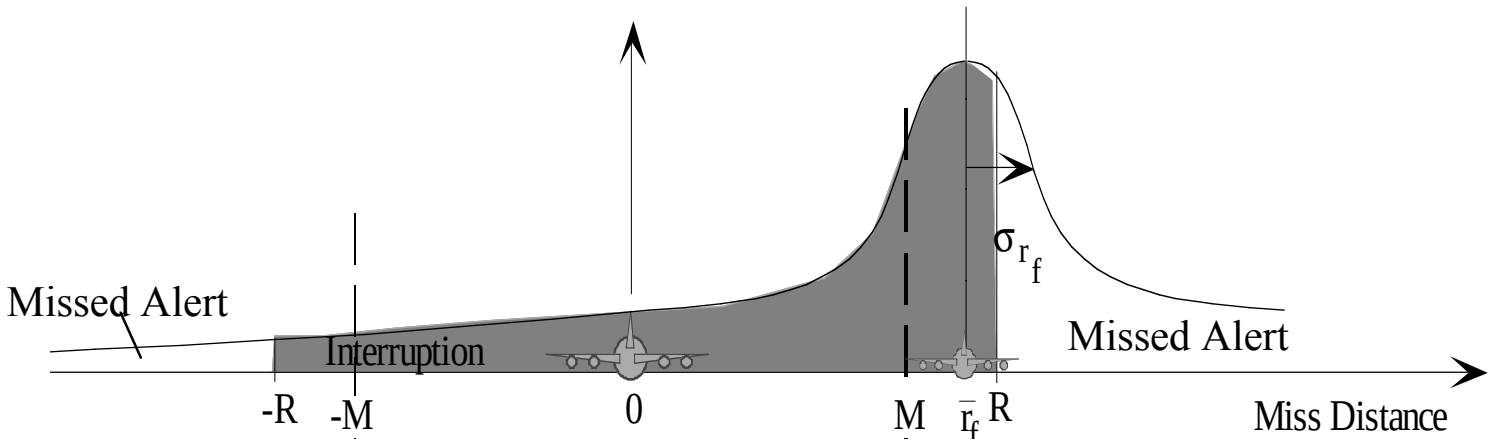
Perceived Miss Distance ~N(r_f, σ_{rf})

$$\sigma_{r_f} = \sqrt{2\sigma_p^2 + 2\sigma_v^2\tau^2}$$



Perceived ATM Interruptions (1 of 2)

- **For Each Incident…**



- **Incident, Miss Distance (r_f)**
- **Perception**
  - Distribution of Perceived Miss Distance ~N(r_f, σ_{rf})
  - Acceptable Controller Spacing (± R)
    (Min Sep Reqmn't, ± M + buffer)
- **Intervene when Perceive Miss Distance < ±R**
  (shaded area)

$$P(conflict) = \frac{1}{2} erf\left(\frac{R + r_f}{\sqrt{2}\sigma_{r_f}}\right) + \frac{1}{2} erf\left(\frac{R - r_f}{\sqrt{2}\sigma_{r_f}}\right)$$

Perceived ATM Interruptions (2 of 2)

For each incident, at a given tool accuracy...

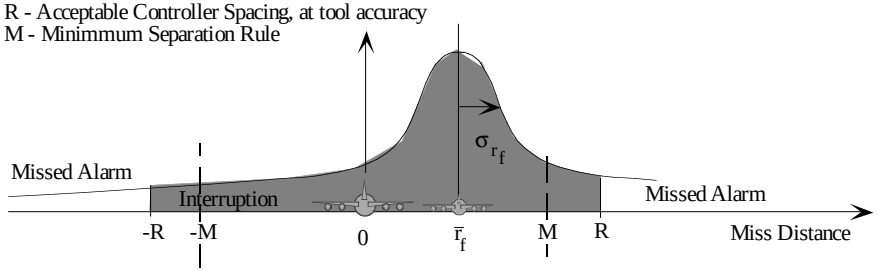
Compare
Incident Minimum Distance ($\bar{r}_f$)
with Perception (σ_{r_f},R)

Probability of Interruption

Resolution Cost

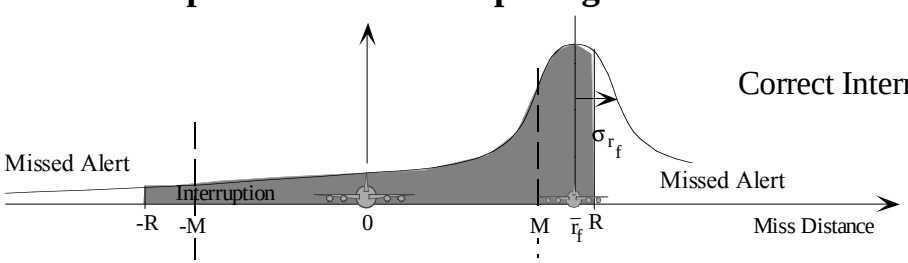
Violate Minimums

R - Acceptable Controller Spacing, at tool accuracy
M - Minimmum Separation Rule



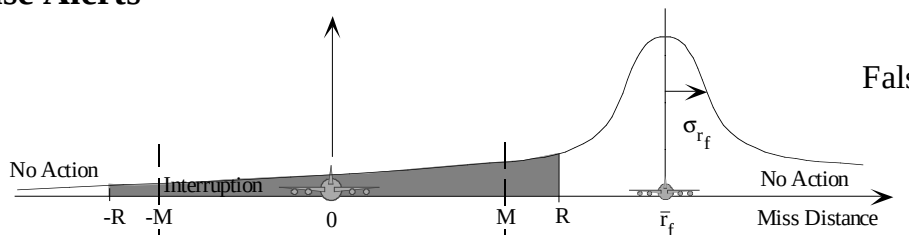
Correct Interruption	▒	$ C, strategic
Missed Alarm	□	$ C^+, tactical
	100%	

Violate Acceptable Controller Spacing



Correct Interruption at tool accuracy	▒	$ C, strategic
Missed Alarm	□	$$C^+$, tactical
	100%	

False Alerts



False Alert Interruption	▒	$ C^-, strategic
No Action	□	$ 0
	100%	

EDA Study Scenarios

- **TMA/CP Baseline:**
  - Flight plans using SIDs and STARs
  - TMA sequencing & scheduling
  - Basic conflict probe (detection & resolution)
  - Manual flight control (no FMS)
- **EDA:**
  - TMA/CP baseline
  - EDA-improved conflict probe
- **EDA Direct Routing**
  - TMA/CP baseline
  - EDA-improved conflict probe
  - EDA-enabled arrival/departure Direct Routes

EDA Perception Parameter Values: First Cut

- Tool Accuracy

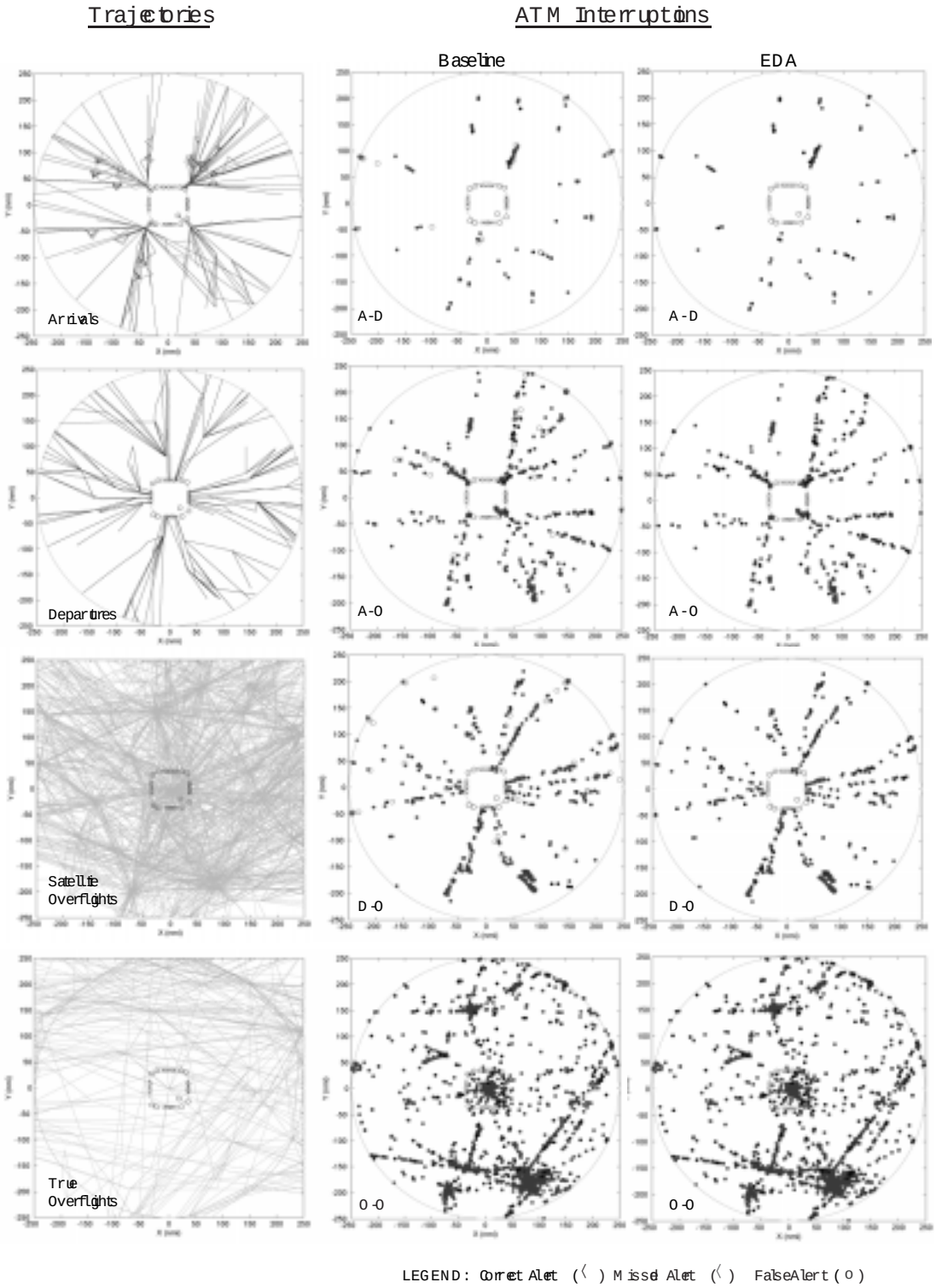
Scenario	Time-to-Conflict (min)	Pos. Accuracy Rate (nm/min lookahead)			Position Accuracy (nm)			Speed Accuracy (kt)		
		Climb	Cruise	Dscnt	Climb	Cruise	Dscnt	Climb	Cruise	Dscnt
TMA/CP (for reference)	12	1.00	**0.25**	**0.56**	12.00	**4.25**	**6.72**	20	10	20
EDA (1)	19	0.63	0.22	0.35	12.00	**4.25**	**6.58**	15	10	10
EDX										
1 FMS	19	0.47	0.20	0.33	8.93	3.80	**6.24**	10	2	7
2 FMS+Wt Dx	19	0.46	0.20	0.32	**8.65**	3.80	**6.16**	10	2	7
3 FMS+Wt+Spd Dx	19	0.41	0.20	0.32	**7.75**	3.80	**6.05**	7	2	2
4 FMS+Wt+Spd+Wx Dx	19	0.13	0.05	0.08	2.5	1.00	**1.58**	7	2	2

- Acceptable Controller Spacing

Scenario	Horizontal (nm)			Vertical (ft)	
	Climb	Cruise	Descent	?FL290	< FL290
TMA/CP (for reference)	**6.00**	**8.00**	**6.00**	2400	1400
EDA	6.00	8.00	5.98	2400	1400
EDX					
1 FMS	5.74	7.68	5.93	2400	1400
2 FMS+Wt	5.72	7.68	5.92	2400	1400
3 FMS+Wt+Spd	5.65	7.68	5.90	2400	1400
4 FMS+Wt+Spd+Wx	5.21	5.71	5.23	2400	1400

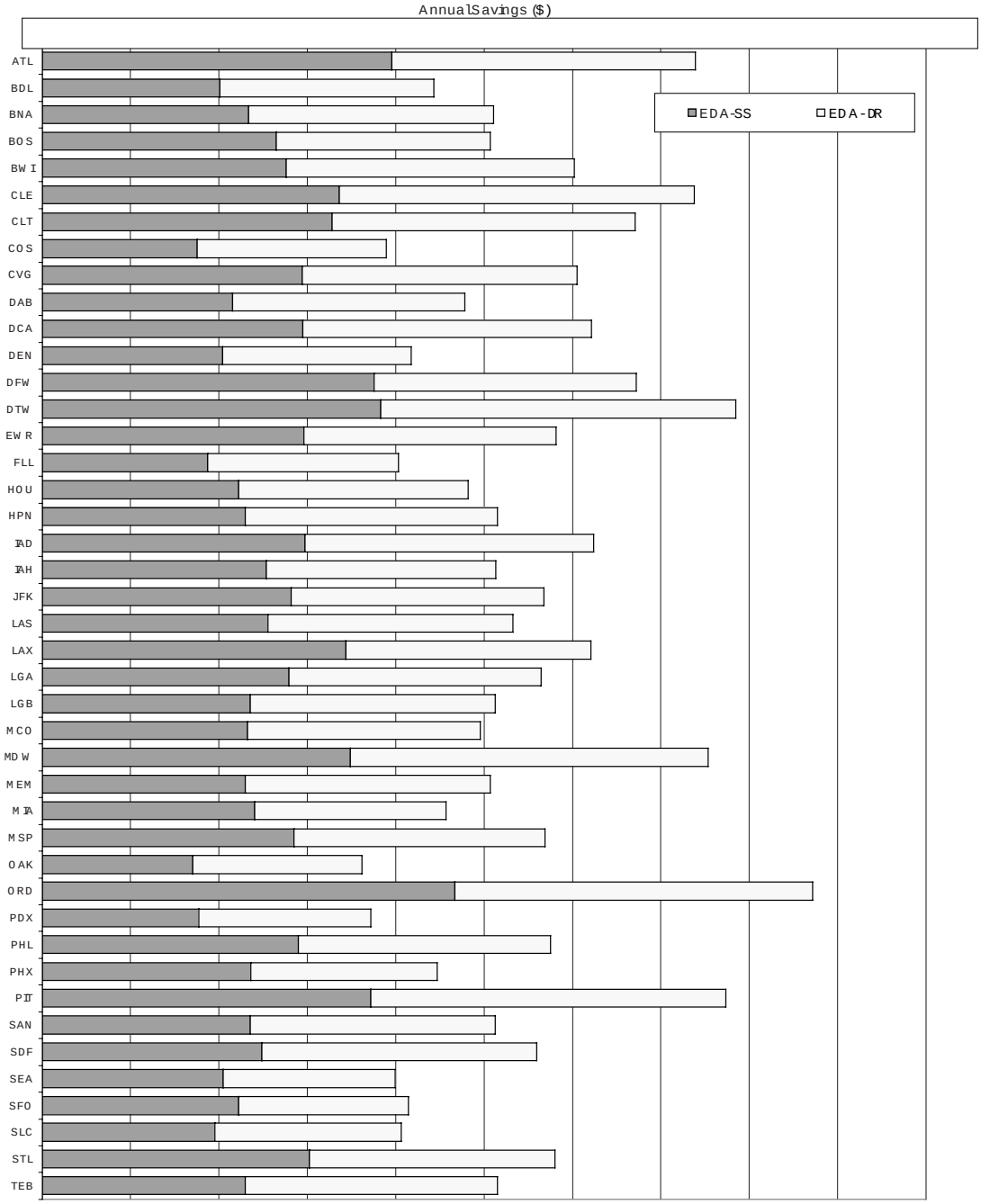
(1) 100% conventionally equipped aircraft
Note: Shading indicates improvement from prior scenario. Bold values are taken from other report estimates.

EDA Interruptions in Plar



EDA 1996 NAS Benefit Estim

Annual Cost = (Annual Ops) x (Interrupt Rate) x (Cost Per Interrupt)



EDX Study Scenarios

- **EDA Direct Routing Baseline**
  - TMA sequencing & scheduling with DA advisories,
  - Conflict Probe (detection & resolution),
  - Manual flight control (no FMS)
  - EDA-enabled arrival/departure Direct Routes
- **Enhanced EDX Scenarios:**
  - EDX1 FMS flight control
  - EDX2 FMS + A/C Weight DX
  - EDX3 FMS + A/C Weight, Speed Preference DX
  - EDX4 FMS + A/C Weight, Speed Preference, Wx DX
- **EDX does not Improve Meet-time ATM Interruptions** (no improvement in Meet-Time time-to-conflict)

EDX Perception Parameter Values

First-Cut Perception Parameters…

- Tool Accuracy

Scenario	Time-to-Conflict (min)	Pos. Accuracy Rate (nm/min lookahead)			Position Accuracy (nm)			Speed Accuracy (kt)		
		Climb	Cruise	Dscnt	Climb	Cruise	Dscnt	Climb	Cruise	Dscnt
TMA/CP (for reference)	12	1.00	**0.25**	**0.56**	12.00	**4.25**	**6.72**	20	10	20
EDA (1)	19	0.63	0.22	0.35	12.00	**4.25**	**6.58**	15	10	10
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- Acceptable Controller Spacing

Scenario	Horizontal (nm)			Vertical (ft)	
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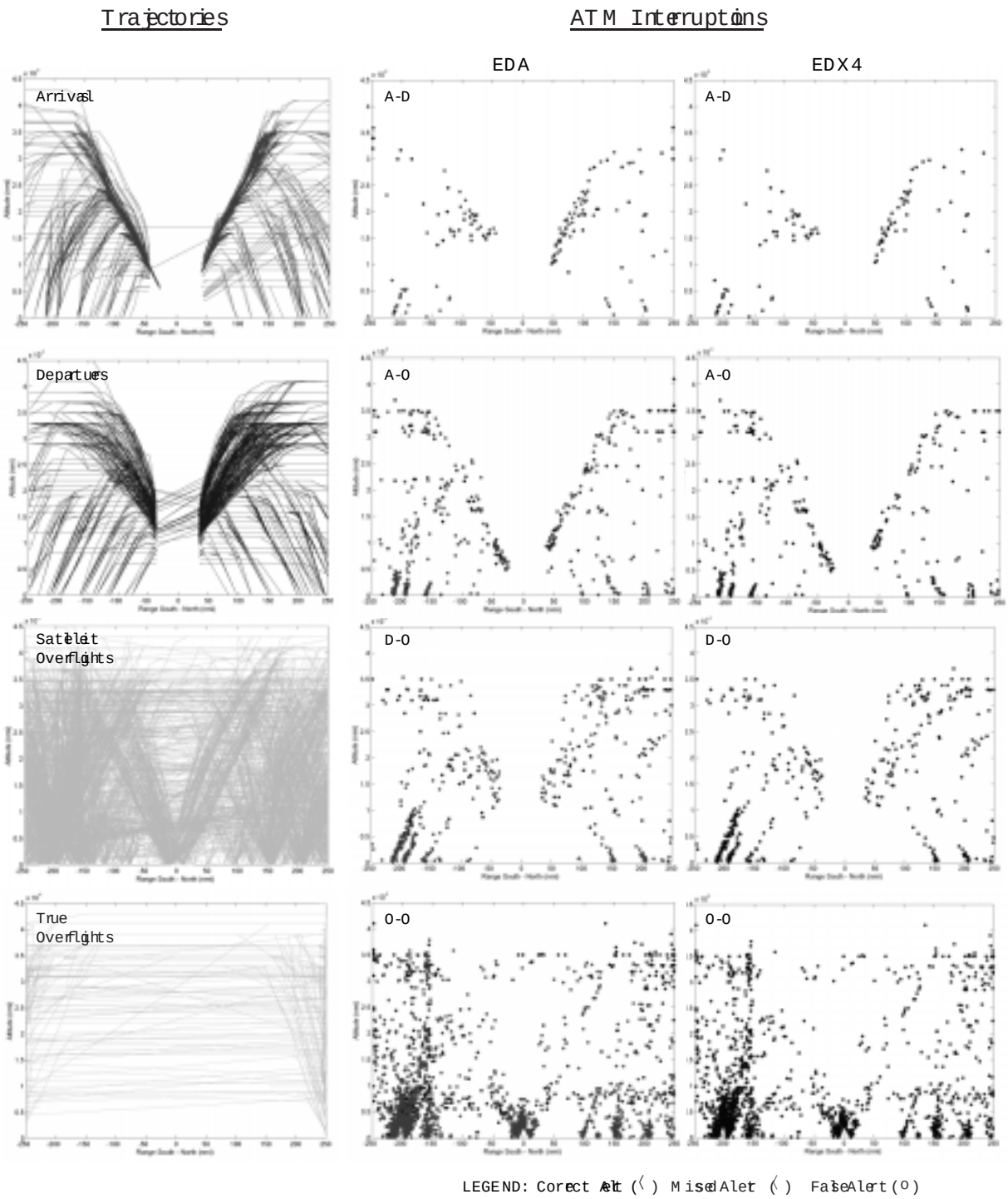
4 FMS+Wt+Spd+Wx	5.21	5.71	5.23	2400	1400

Note: Shaded values indicate improvement from baseline/prior scenario.

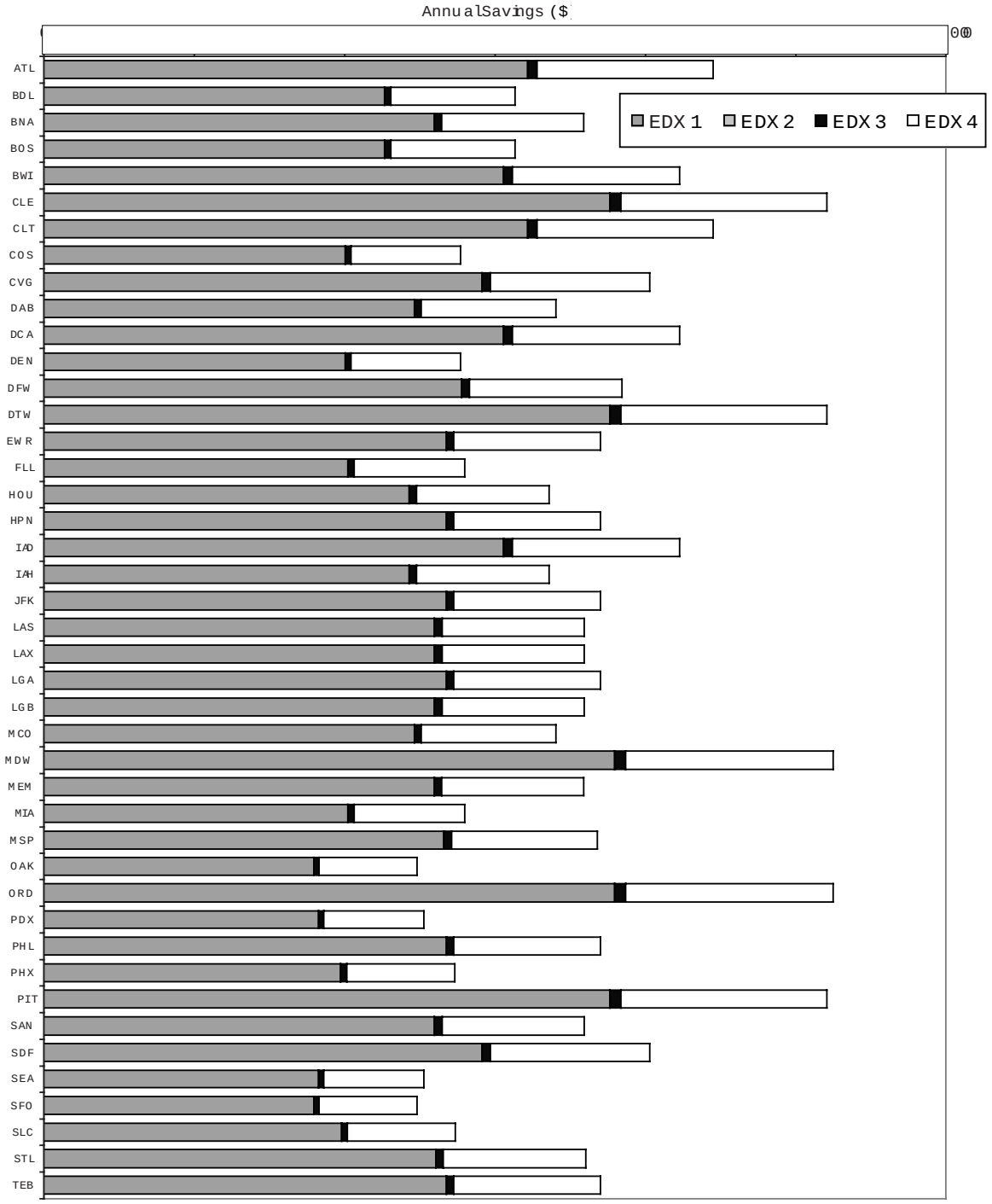
Interruptions in Review



Note: Interruptions below FL100 not assessed.

EDX 1996 NAS Benefit Estim

Annual Cost = (Annual Ops) x (Interrupt Rate) x (Cost Per Interrupt)



ATM Interruptions Recommendations

- **Improve Trajectory Parameter Accuracy Values**
  - Review/revise parameter assumptions
  - Develop model to link accuracy components to position error for cruise/climb/descent trajectories
  - Analyze airline data for EDX parameter improvement
  - Include additional errors (pilot actuation, cross-track components, etc.)
- **Improve Meet-Time ATM Interruptions Modeling**
  - Remove restriction to complete the maneuver by TOD
  - Review Ability to initiate Meet-time interruptions earlier
- **Multiple Initial Conditions**
  - Account for variations in no., loc., type, geometry, and cost of conflicts
  - Vary initial simulation entry times, airport capacity, multiple days, etc.
- **Additional Traffic Avoidance Resolution Strategies**
- **Sensitivity Analyses**
  - review cost components & assumptions
  - Other (e.g. optimal lookahead time for given tool accuracy)
- **Other** (Sector boundaries, other apts, Host data, multiple aircraft conflicts)