Risk Analysis Process (RAP) Tool for Surface Loss of Separation Events

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What is the RAP Tool?

A tool originally developed by EUROCONTROL for quantifying the level of risk present in any air traffic incident

Shows relationships between actions and consequences and provides a quantifiable value to these relationships.

Prioritizes mitigation actions

Adopted for use by the FAA in 2011

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FEDERAL AVIATION ADMINISTRATION

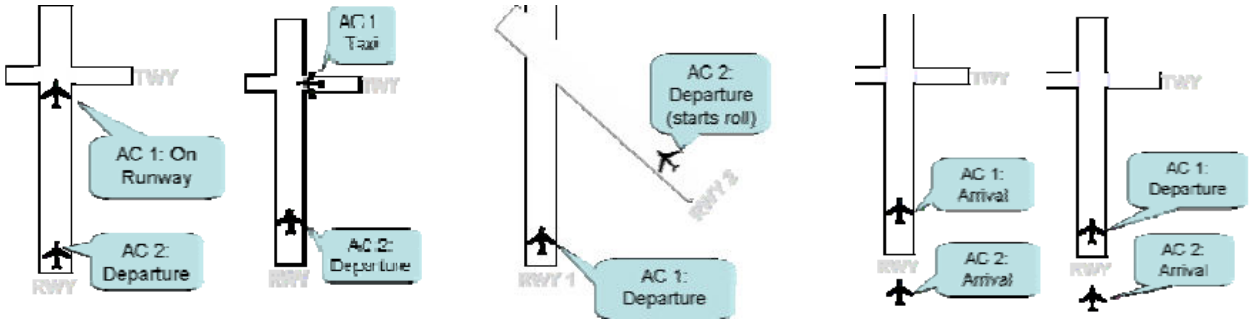
EUROCONTROL

What Kind of Air Traffic Incidents?

The FAA has applied the RAP Tool to non-wake, loss-of-separation events involving airborne aircraft with a Measure of Compliance (MOC) of **less than 66 percent.**

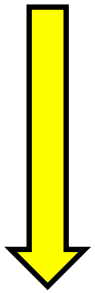
The FAA made modifications to the airborne RAP Tool and customized it for loss-of-separation events involving surface based aircraft and vehicles/pedestrians with a slant range of **less than 6000 feet.** **Adopted for use in 2013.**

This presentation will focus on surface incidents



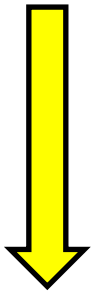
Risk in the Context of Loss of Separation

***Severity X Repeatability* = Risk**



"How bad was it?"

- **Separation**
- **Rate of Closure**
- **Controllability**
- **Weather**

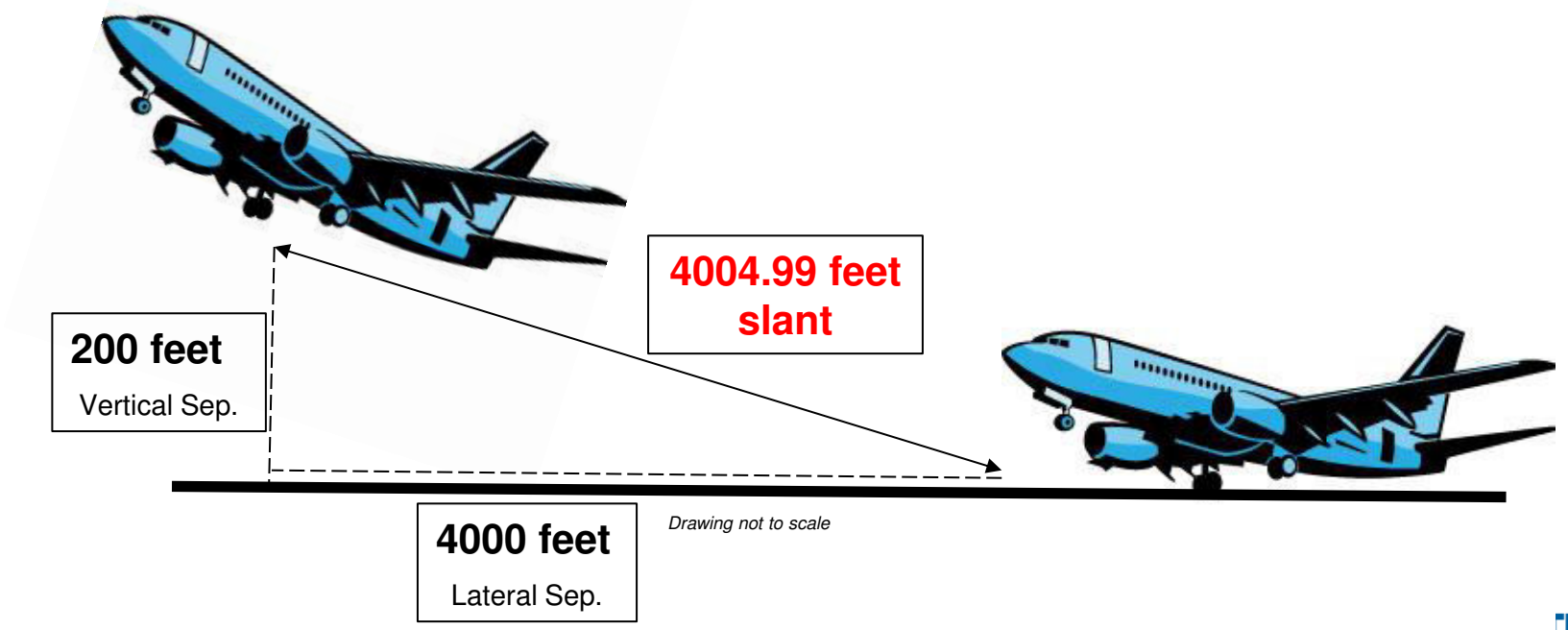


"Likelihood of the event recurring"

- **Systemic Factors**
- **Window of Opportunity**

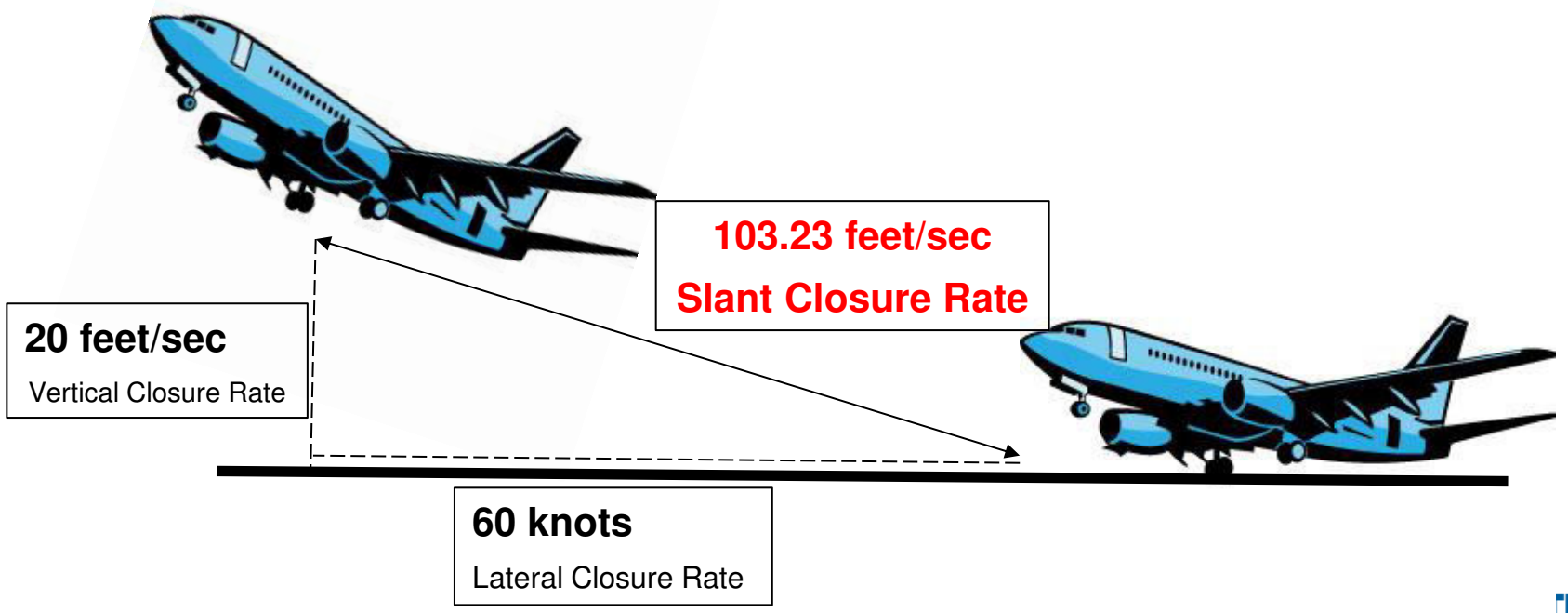
Risk of Collision: Separation

Proximity of two aircraft or an aircraft with a vehicle/pedestrian is measured in the form of the slant range between the two at the closest point during the loss of separation. Only events involving at least one aircraft/vehicle on the ground and less than 6000 feet slant range are considered.



Risk of Collision: Closure Rate

The rate at which an aircraft approaches another aircraft or vehicle/pedestrian. Measured as the slant closure rate at the location of the highest closure rate during the window of risk. Window of risk begins at the start of the loss of separation and ends when risk is abated (when aircraft are no longer converging).



Quantifying the Risk

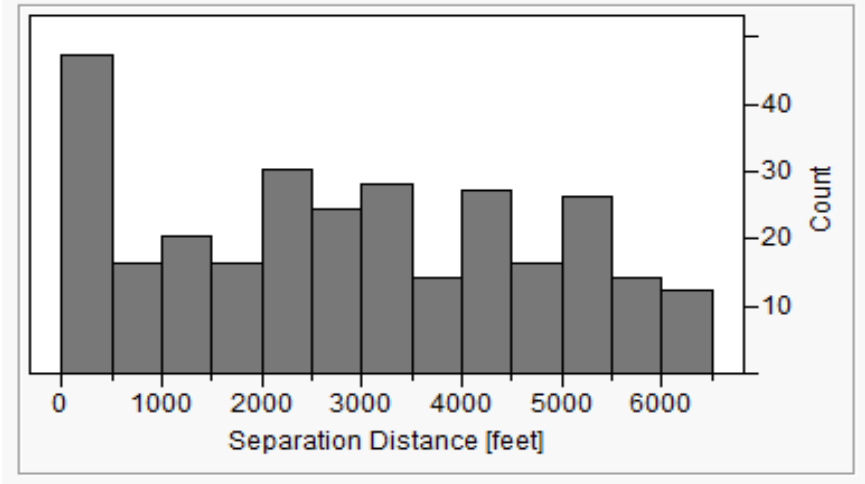
- **287 Class A-C surface events from RAP Surface and Runway Incursion (RI) databases**
  - Only included Runway Incursion Database events with sufficient information to be reviewed using ASDE-X surveillance data
  - 120 from Runway Incursion Database, 167 from RAP Database
- **Distinction made for Aircraft with Vehicle-Pedestrian and Aircraft-Aircraft events**
  - Severity of an event are much worse in situations of lower closure rates when vehicle/pedestrians involved
  - 26 out of 287 events (9%) were Aircraft with Vehicle-Pedestrian events

Quantifying Separation

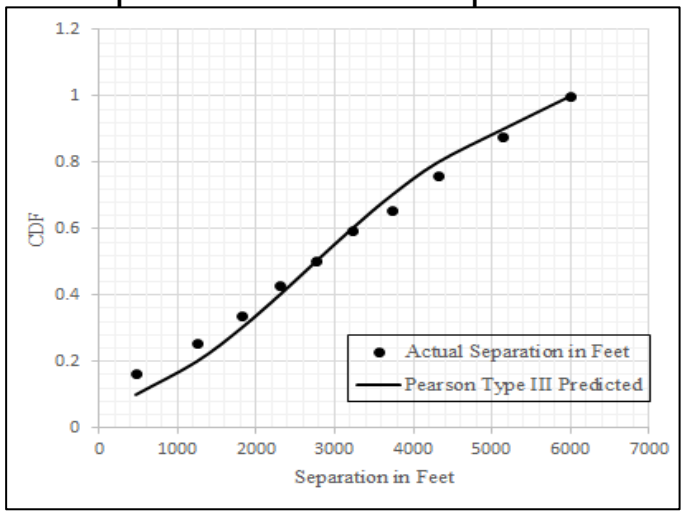
Separation Scores by Percentile Rank

Score	Percentile	Separation Distance Range [feet]
1	90 – 100	5139.9 - 6000
2	80 – 90	4309.5 - 5139.9
3	70 – 80	3718.1 - 4309.5
4	60 – 70	3217.6 - 3718.1
5	50 – 60	2754 - 3217.6
6	40 – 50	2294.1 - 2754
7	30 – 40	1806.5 - 2294.1
8	20 – 30	1241.4 - 1806.5
9	10 – 20	467.8 - 1241.4
10	0 – 10	0 - 467.8

Distribution of Separation Values



Separation CDF Comparison



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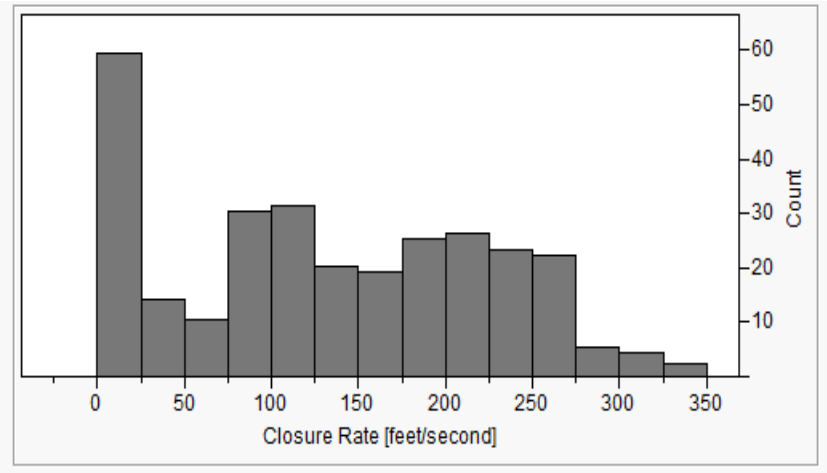
Quantifying Closure Rate

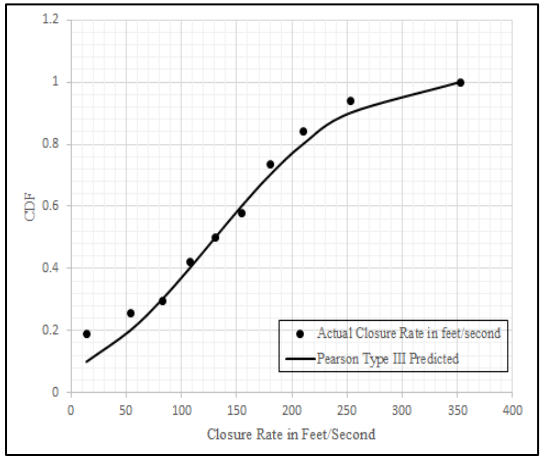
Closure Rate Scores by Percentile Rank

Score	Percentile	Closure Rate [feet per second] Aircraft- Aircraft Events
0	0	Diverging
1	0 – 10	0 - 13.7
2	10 – 20	13.7 - 53.3
3	20 – 30	53.3 - 82.1
4	30 – 40	82.1 - 107.0
5	40 – 50	107.0 - 130.5
6	50 – 60	130.5 - 154.2
7	60 – 70	154.2 - 179.7
8	70 – 80	179.7 - 209.9
9	80 – 90	209.9 - 252.3
10	90 - 100	> 252.3

Distribution of Closure Rate Values



Closure Rate CDF Comparison



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Vehicle-Pedestrian Events

- **Early versions of the tool used distributions for Vehicle-Pedestrians based on historical data**
  - Problem with data availability (Only 26 historical events)
  - Yielded higher than expected final risk scores

- **Solution: Use a modified scale for all events until we can collect enough data to better model VPD events**

Controllability

Levels of NAS controls at work to prevent a collision or the factors that ultimately help avoid a collision

ATC

- ✓ Conflict Detection
- ✓ Conflict Plan
- ✓ Execution of Plan
- ✓ See & Avoid Decision
- ✓ Recovery Decision
- ✓ Crossing Traffic Location

Pilot

- ✓ Execution of Plan
- ✓ Recovery Action
- ✓ Actions following See & Avoid

NAS

- ✓ Ground Safety Net Detection
- ✓ Runway Guard/Safety Light Function
- ✓ Airport Signage/Markings Function

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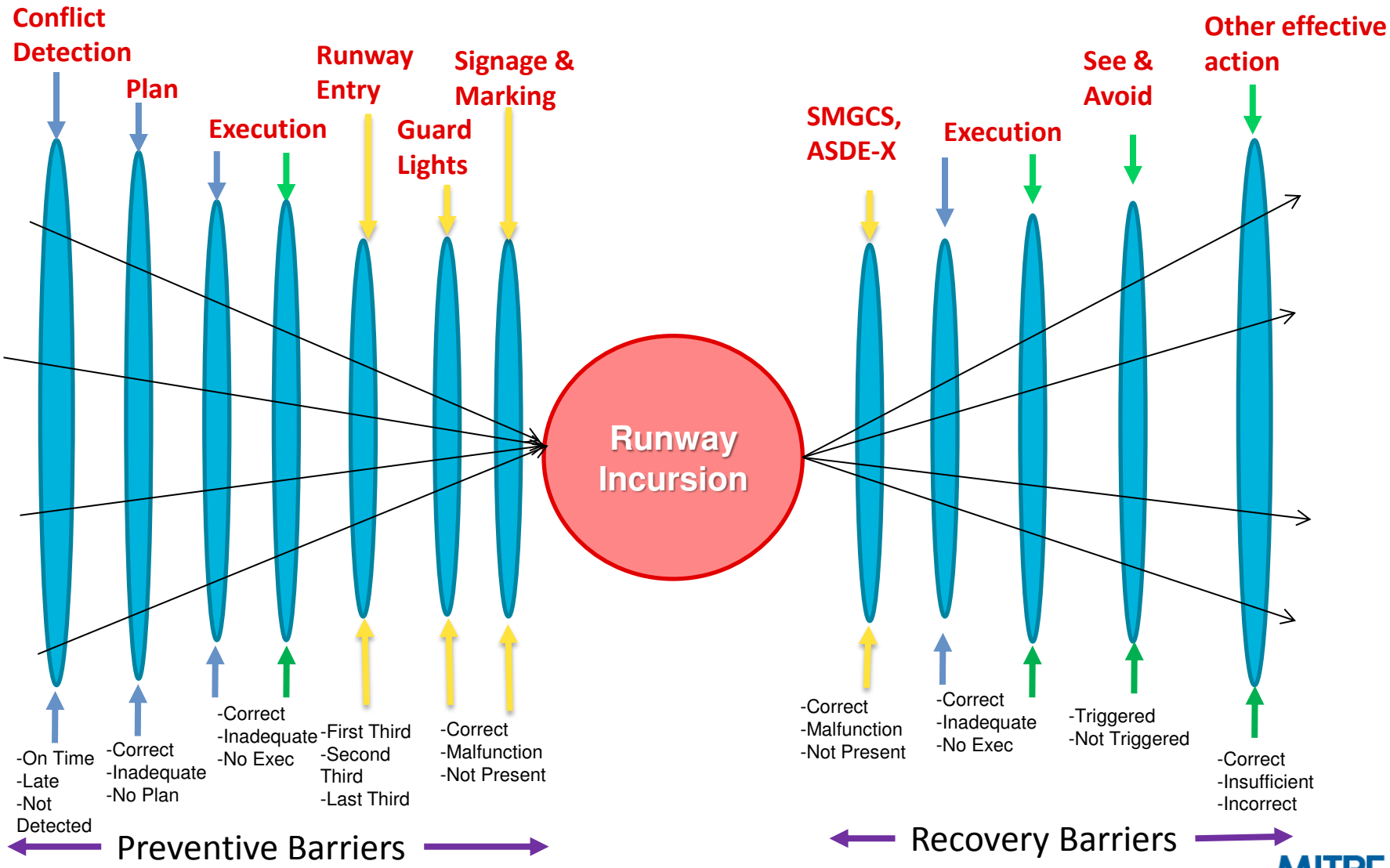
Controllability - Barriers



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Calculation of Controllability

$$Controllability\ \% = \frac{\sum Complete\ Breakdowns + \frac{1}{2}\sum Partial\ Breakdowns}{\sum Controls\ in\ Place}$$

Example of Complete Control Breakdown: Incorrect Execution of Plan

Example of Partial Control Breakdown: Insufficient Execution of Plan

Control Breakdown Percentage	Score
0%	0
1 – 10%	5
>10 – 20%	10
>20 – 30%	15
>30 – 40%	20
>40 – 50%	25
>50 – 60%	30
>60 – 70%	35
>70 – 80%	40
>80 – 90%	45
>90 – 100%	50

Number of Barriers in Place

ATC Barrier	Barrier Available?	Point Value
Conflict Detection	Always Present	0, ½, 1
Plan	Always Present	0, ½, 1
Execution	Always Present	0, ½, 1
Recovery	Always Present	0, ½, 1
See & Avoid *	Flexible	0, 1
Runway Entry	Flexible	0, ½, 1
Ground Safety Net *	Flexible	0, 1

4 ATC controls always in place. Up to 7 controls possible

2 Pilot controls always in place. Up to 4 controls possible

0 NAS controls always in place. Up to 2 controls possible

1 Point for COMPLETE control breakdown
½ Point for PARTIAL control breakdown

$$Percentage\ of\ Breakdowns = \frac{(Complete\ Control\ Breakdowns)+\frac{1}{2}(Partial\ Control\ Breadowns)}{Number\ of Available\ Controls\ in\ Place}$$

Percentages mapped to a severity score.

Control Breakdown %	Scores
0 %	0
1%-10%	5
11% - 20%	10
21% - 30%	15
31% - 40%	20
41% - 50%	25
51% - 60%	30
61% - 70%	35
71% - 80%	40
81% - 90%	45
91% - 100%	50

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Example Computation

ATC Controls	ATC Score	Pilot Controls	Pilot Score	NAS Controls	NAS Score	Available Controls
Conflict detected **ON TIME**	0			Runway Lights **NOT PRESENT**	0	1
Plan **LATE**	0.5			Signage **CORRECT-PART 139**	0	2
Execution **CORRECT**	0	Execution **INADEQUATE**	0.5			2
Recovery **CORRECT**	0	Recovery **INADEQUATE**	0.5			2
NO See & Avoid Action	0	**NO** See & Avoid Action	0			2
Runway Entry **First Third**	1	**INSUFFICIENT** action	0.5			2
Ground Safety Net **DETECTED**	0					1
Total	1.5		1.5		0	12

12 of the 13 Maximum possible controls available (Runway Lights NOT PRESENT)

25% of the controls failed (3 out of 12)

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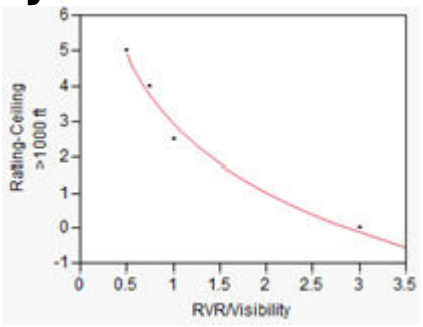
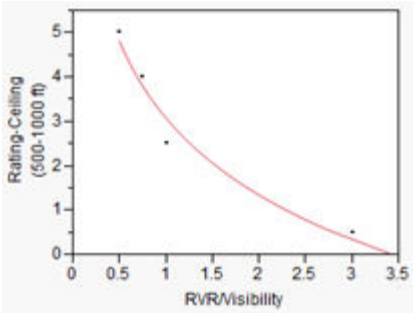
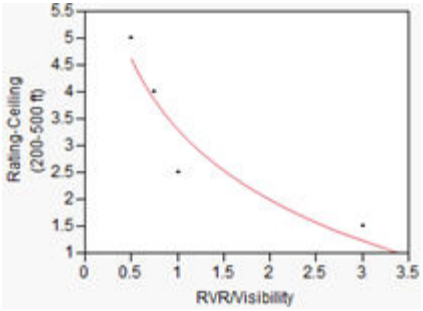
Weather

Models fit to the ICAO Runway Incursion Severity Classification Version 2.0 to evaluate the risk contributions of visibility to runway incursions







Ceiling > 1000 feet

$$Weather\ Severity = 5.915 - 5.609 \cdot \log(RVR)$$

500 feet < Ceiling ≤ 1000 feet

$$Weather\ Severity = 6.147 - 5.004 \cdot \log(RVR)$$

Ceiling ≤ 500 feet

$$Weather\ Severity = 6.612 - 3.793 \cdot \log(RVR)$$

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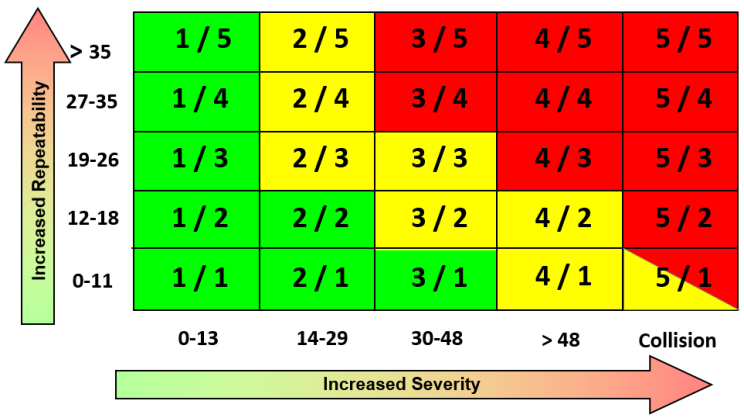
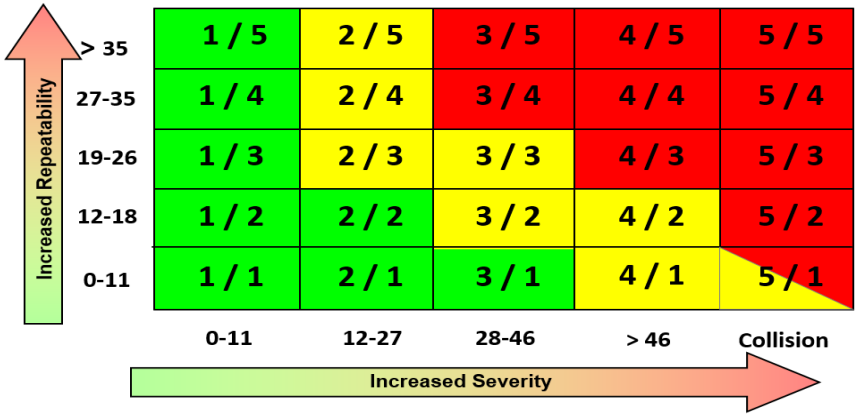
Total Severity

The total severity score is calculated as a summation of the separation, closure rate, controllability, and weather if it is a factor. Depending on the total severity score, the score is mapped to the SMS Risk matrix, which determine risk levels.

$$Severity = Separation + Closure\ Rate + Controllability + Weather$$



Example Mapping of Severity Score to SMS Matrix for Weather-Related Event



Example Mapping of Severity Score to SMS Matrix for Non-Weather-Related Event

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Severity X Repeatability = Risk

- Severity
  - Separation
  - Closure Rate
  - Controllability
- **Repeatability**
  - Systemic Factors
  - Window of Opportunity

Repeatability: Systemic Factors

36 causal factors were identified in addition to the four existing repeatability sections from the RAP Tool. Based on the analysis of the Risk Analysis Events (RAE) and Runway Incursion (RI) data sources, the original list of causal factors was reduced to 10

Factor	Data Source	Rate of Occurrence
ATC Procedures	RAE	0.59%
Pilot Procedures	RAE	0.00%
ATC Equipment	RAE	1.19%
Pilot Equipment	RAE	0.00%
ATC Human Resources	RAE	0.00%
Pilot Human Resources	RAE	0.00%
ATC Human Involvement	RAE	67.26%
Pilot Human Involvement	RAE	44.64%
Airport Construction	RI	0.81%
Runway/Taxiway Closure	RI	0.54%

Repeatability Scores

Factor	Point Value
Procedure Design Issue	12
Procedure Implementation Issue or Lack of	8
No Procedure Issue	0
Equipment Design Issue	12
Equipment Implementation Issue or Lack of	8
No Equipment Issue	0
Human Resources Management Design	12
Human Resources Management Implementation or Lack of	8
No Human Resources Management Issue	0
Airport Geometry Deficiency	12
Airport Geometry Insufficient	8
No Airport Geometry Issues	0
Non-Systemic/Human Involvement Issues with Contextual Conditions	12
Non-Systemic/Human Involvement Issues without Contextual Conditions	8
No Non-Systemic/Human Involvement Issues	0
Airport Construction with Contextual Conditions	12
Airport Construction without Contextual Conditions	8
No Airport Construction Issues	0
Runway Closure with Contextual Conditions	12
Runway Closure without Contextual Conditions	8
No Runway Closure Issues	0

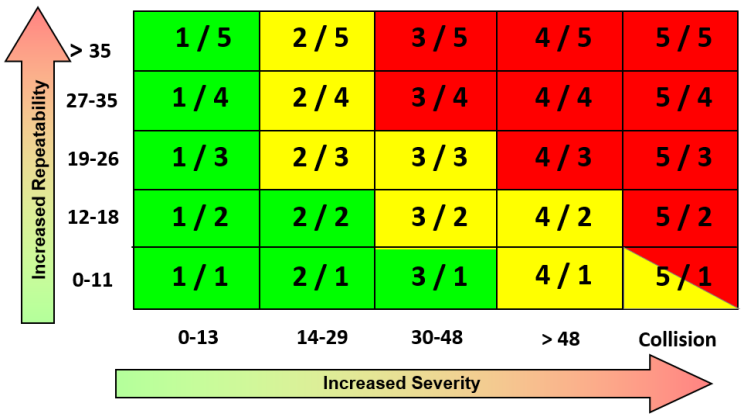
Window of Opportunity

Window of Opportunity	Daily Routine	Workload Peak	Emergency Situations
Normal	7	5	3
Degraded	6	4	2
Exceptional	3	2	1

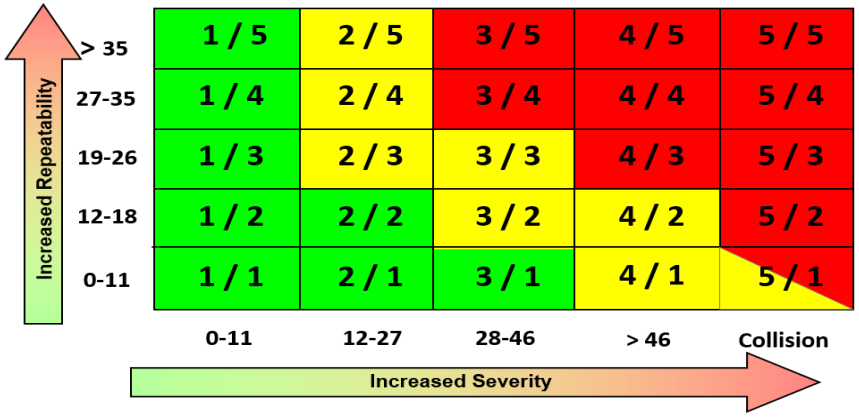
Total Repeatability

The total repeatability score is calculated as a summation of the repeatability factors and window of opportunity. Depending on the total repeatability score, the score is mapped to the SMS Risk matrix, which determine risk levels.

$$Repeatability = Repeatability\ Score + Window\ of\ Opportunity$$



Example Mapping of Severity Score to SMS Matrix for Weather-Related Event



Example Mapping of Severity Score to SMS Matrix for Non-Weather-Related Event

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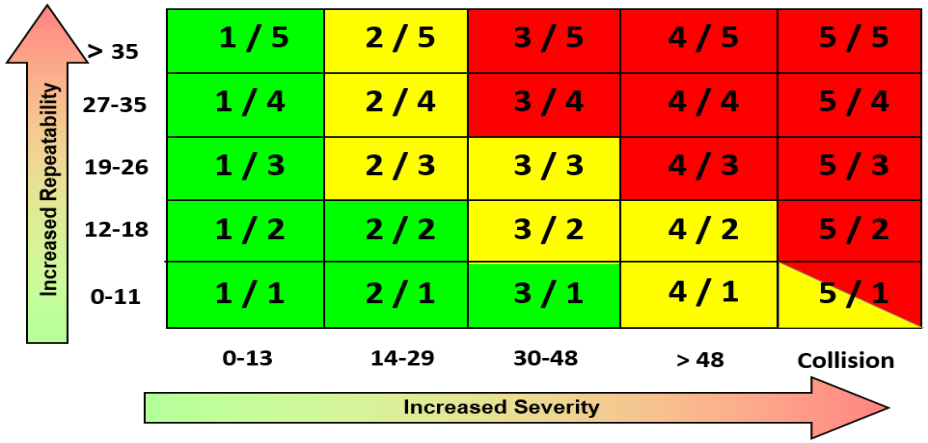
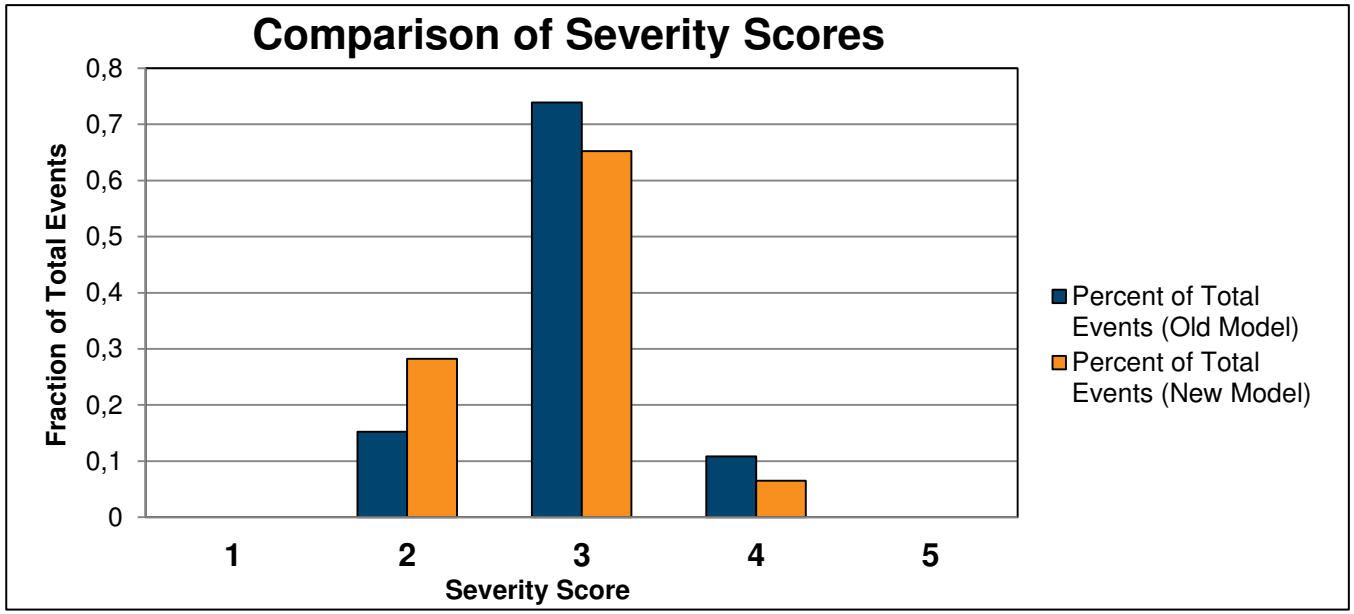
Surface Comparative Analysis: Severity Scores





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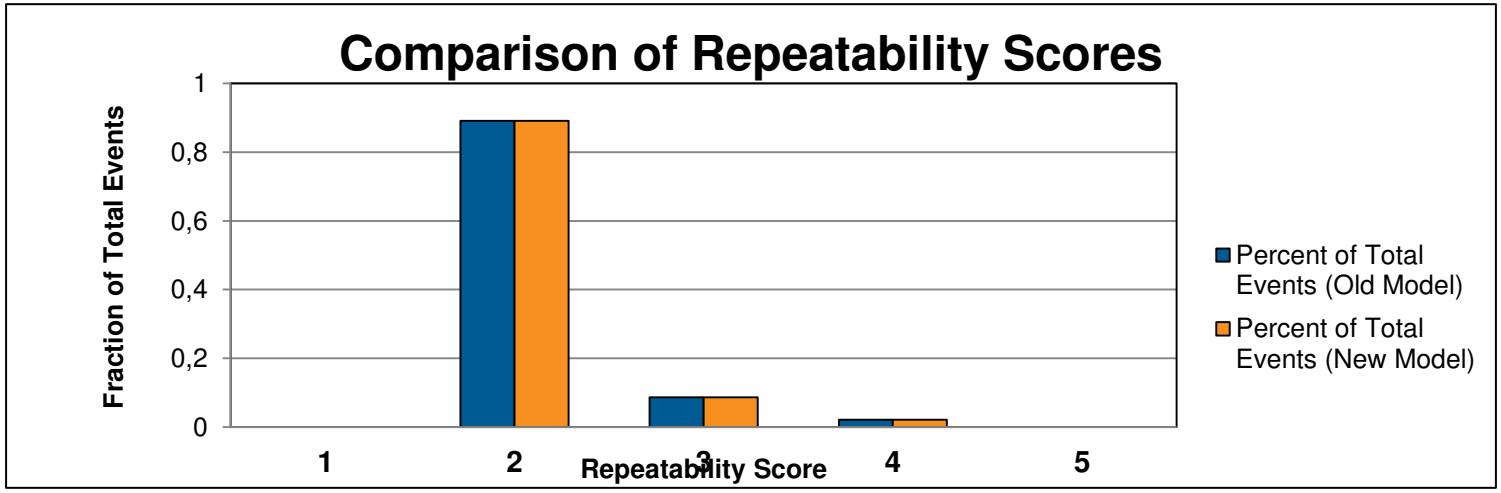
Surface Comparative Analysis: Repeatability Scores

Increased Repeatability	0-13	14-29	30-48	> 48	Collision
> 35	1 / 5	2 / 5	3 / 5	4 / 5	5 / 5
27-35	1 / 4	2 / 4	3 / 4	4 / 4	5 / 4
19-26	1 / 3	2 / 3	3 / 3	4 / 3	5 / 3
12-18	1 / 2	2 / 2	3 / 2	4 / 2	5 / 2
0-11	1 / 1	2 / 1	3 / 1	4 / 1	5 / 1

Increased Severity



- **No change when comparing the Old v. New repeatability sections**
- **The major addition of allowing for flexible repeatability scoring significantly altered the raw scores when those sections are scored, but not the risk score**

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Recap & Future Work

- **RAP Tool is a risk quantification tool that allows the FAA to prioritize risk factors in the NAS**
  - Among them the FAA Top 5 Hazards
  - High priority performance goals
- **Investigate the thickness of each control barrier weighting each differently depending on importance**
- **Develop standardized Closure Rate Calculation for Surface**
- **Repeatability : Evaluate feasibility of using Normal Operations Data analysis and Bayesian Methods**
- **Apply RAP concept to all risk-based processes (MVA, TCAS under development)**
- **RAP will continue to modernize and evolve**

Thank You

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