HIGH DENSITY EN ROUTE AIRSPACE SAFETY LEVEL AND COLLISION RISK ESTIMATION BASED ON STORED AIRCRAFT TRACKS

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CRIDA an Initiative from Aena

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I+D+i - ATM

University

Spanish Air Navigation Service Provider

ineco

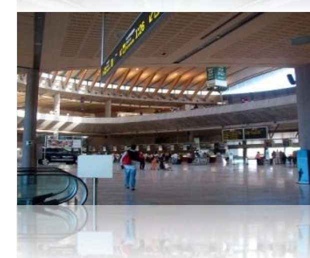
Transport Engineering Company

Result Oriented

Scientific Rigour

Flexibility



Outline

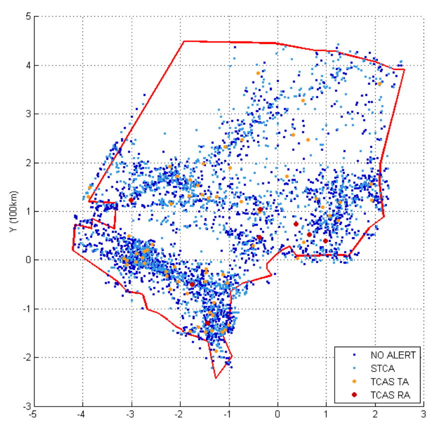
- INTRODUCTION
- NEED FOR A NEW COLLISION RISK MODEL
- BACKGROUND
- 3D CRM – GOAL
- 3D CRM – GENERAL DESCRIPTION
  - RADAR DATA PROCESSING
  - SAFETY METRICS
- CONCLUSIONS AND WORK IN PROGRESS

INTRODUCTION

EUROCONTROL has worked in the last years to develop the 3-D collision risk model (CRM).

ATCO

The 3-D collision risk model was developed as a general mathematical framework to assess the **level of safety in continental en-route airspace**, where controllers monitor air traffic by means of radar surveillance and provide aircraft with tactical instructions

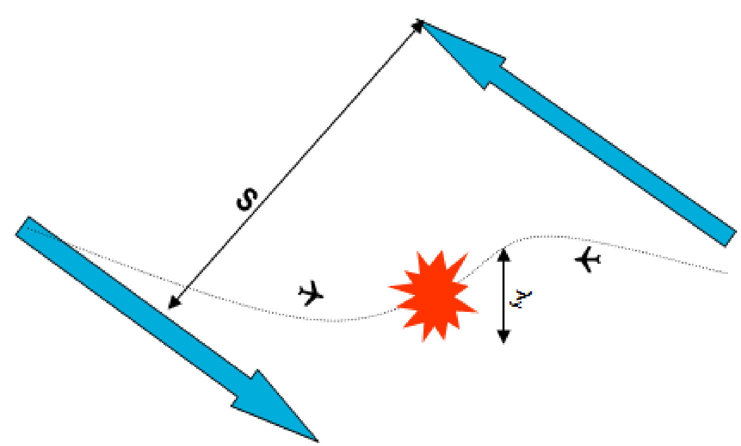


The objective of the software prototype tool is not only to eventually produce an estimation of the level of safety achieved in the airspace under assessment but also to **provide safety-related metrics and trends, which can be monitored over time**.

NEED FOR A NEW COLLISION RISK MODEL

Previous models no not appropriate **<u>assess and monitor the level of safety in high density en-route radar airspaces</u>** using **as a sole source of input data the recorded aircraft trajectories**. Traditional approaches to Collision Risk Models (CRM), do not capture the **<u>complexity inherent to an operational radar environment like the one in Europe,</u>** with high amount of traffic, a large number of crossings tracks, climbing and descending aircrafts and complicated route structure.

PHASE	MODELO	
EN-ROUTE	Airway structure consisting of one or more parallel routes. No radar surveillance.	CRM Reich (1960)
	Improvement of Collision Risk Models	Extended CRM Reich (1993)
	Parallel routes. Surveillance base don ADS.	CRM ADS (1993)
TMA	Precision approaches	CRM ILS (1980)
	Landing on closely and ultra closely spaced runways	BRM (1990) MIT (1997)
	Future operational concepts	NLR (2001)

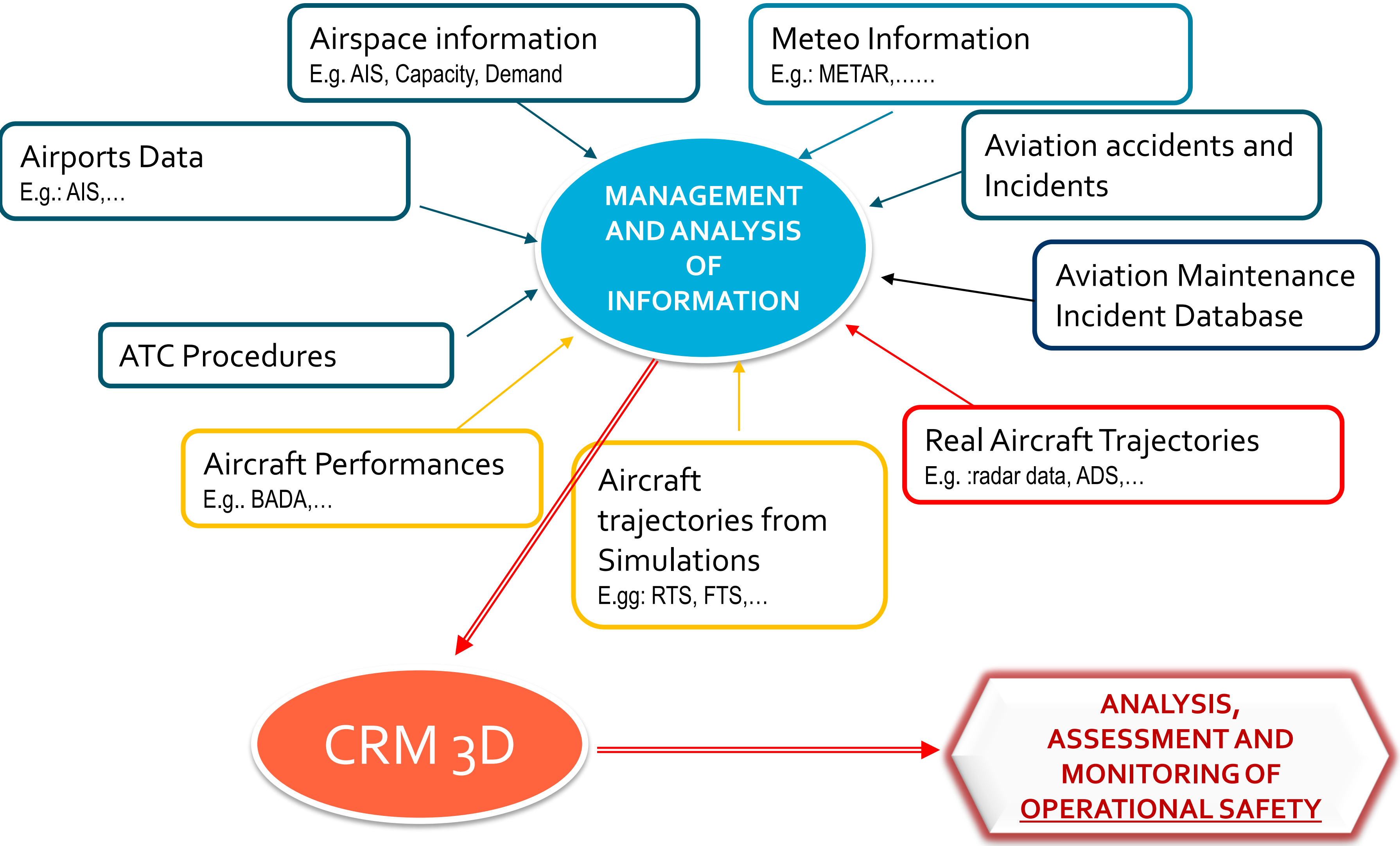


BACKGROUND

Nowadays, ANSP and Civil Aviation Authorities (CAA) mainly use ATM **accident and incident databases** to monitor and provide evidence of levels of safety. However, although these databases are very powerful tools and are improving constantly, they still have some weak points that need to be considered:

- **Not all incidents are reported by pilots and air traffic controller**s. In fact, it is very difficult to infer how many real incidents have occurred for each one that is reported.
- **Incident severity is generally ranked solely on how close aircraft get**, without considering the geometry of the event or other parameters, e.g. closure rate.
- **Incident Classification is not homogeneous in all databases**. Furthermore, special care has to be taken to train database personnel so that the same classification criteria always apply.

BACKGROUND



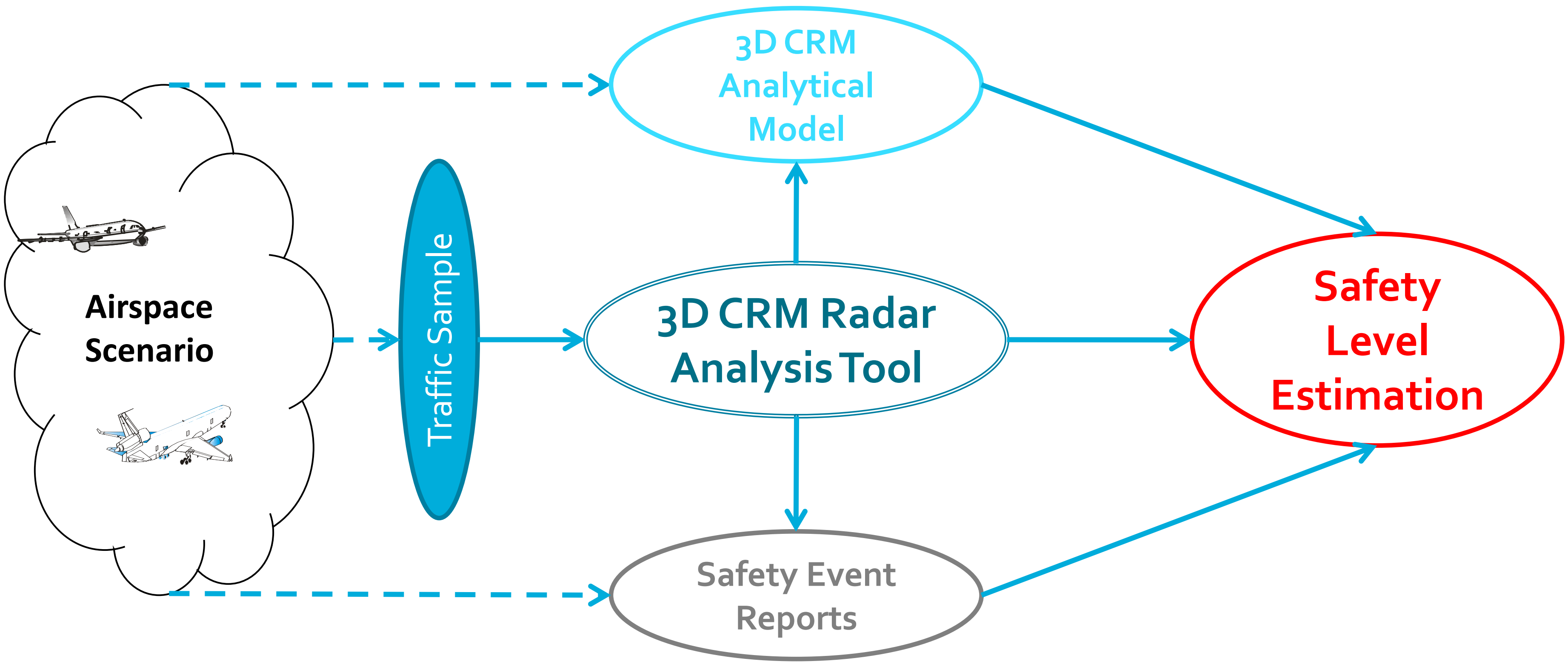
Airspace information
E.g. AIS, Capacity, Demand
Meteo Information
E.g.: METAR,……
Airports Data
E.g.: AIS,…
Aviation accidents and Incidents
MANAGEMENT AND ANALYSIS OF INFORMATION
Aviation Maintenance Incident Database
ATC Procedures
Real Aircraft Trajectories
E.g. :radar data, ADS,…
Aircraft Performances
E.g.. BADA,…
Aircraft trajectories from Simulations
E.gg: RTS, FTS,…
CRM 3D
ANALYSIS, ASSESSMENT AND MONITORING OF OPERATIONAL SAFETY

3D CRM – GOAL

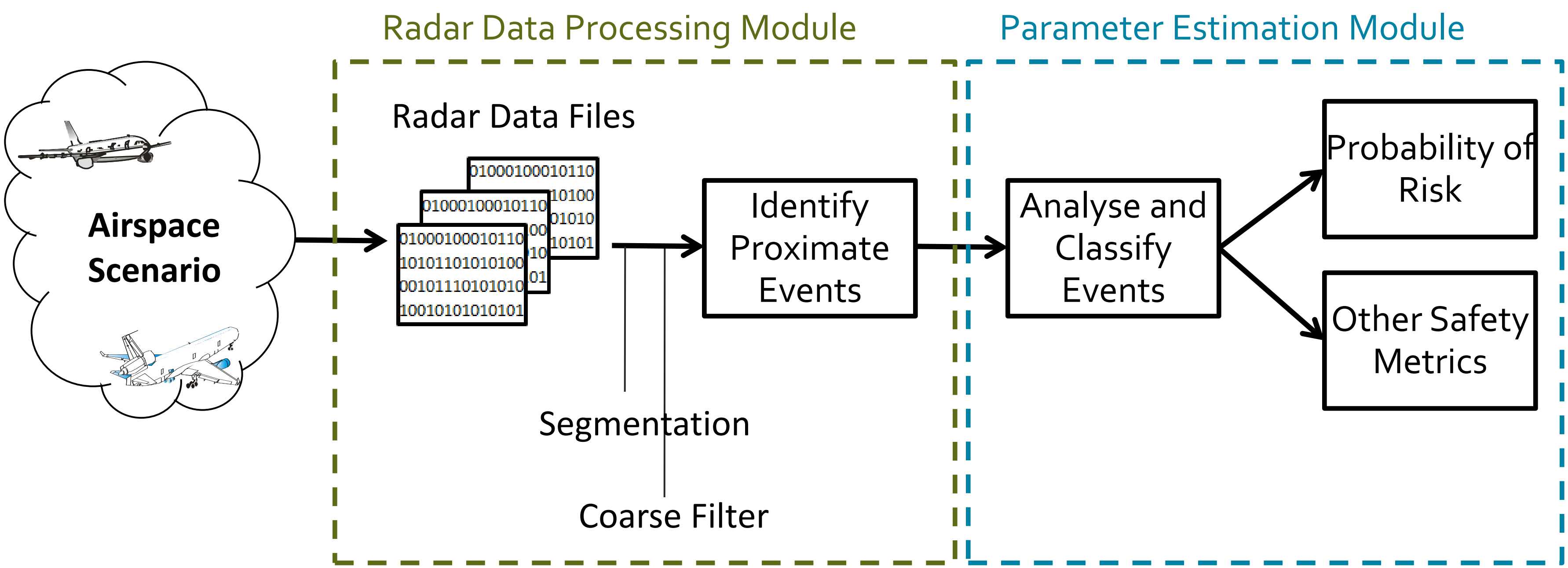
A major objective of the 3-D CRM tool is to complement the information collected in the accident and incident databases, thereby providing:

1. Identification of all proximate events based on radar data.
2. Complete classification of all proximate events using clear and consistent criteria.
3. Detailed information on the evolution of each proximate event.
4. Collision risk estimate

3D CRM – GENERAL DESCRIPTION



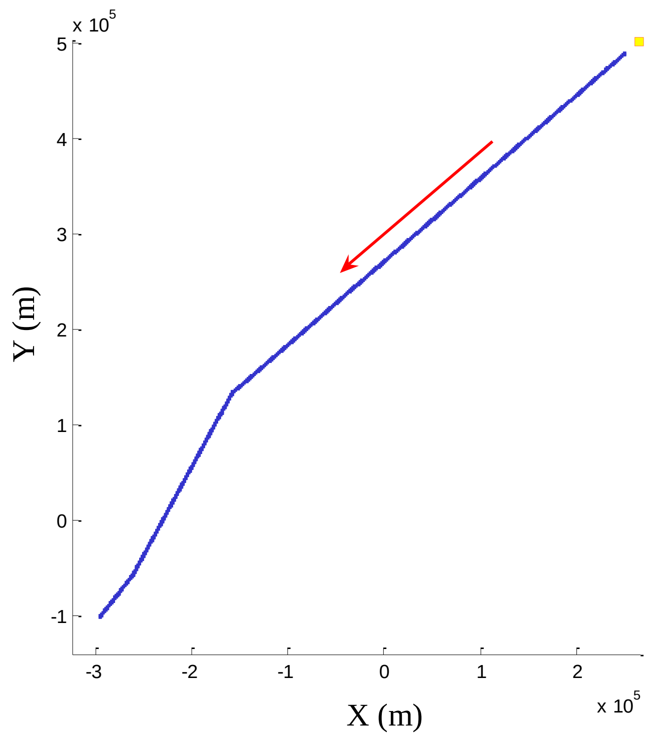
3D CRM – GENERAL DESCRIPTION

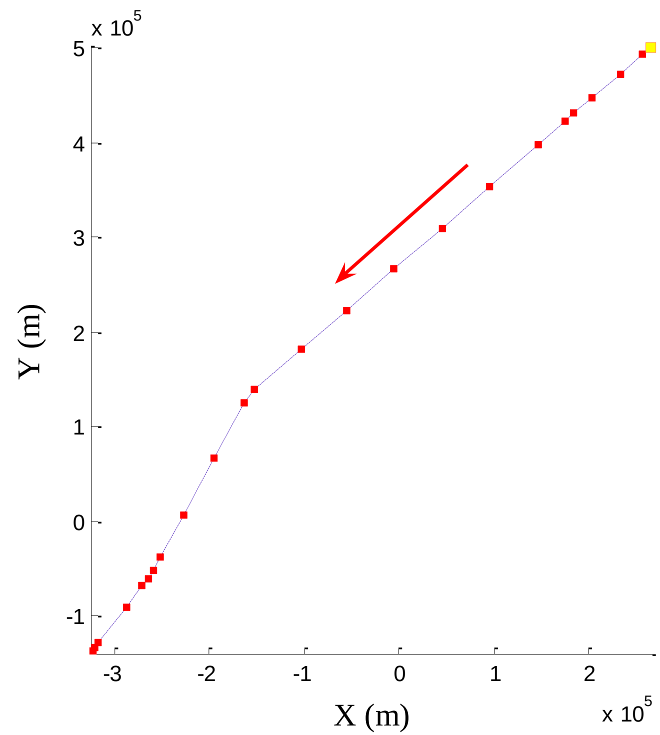


RADAR DATA PROCESSING

The radar data processing module comprises two different :

- decoding and storage of radar track and flight plan files, and
- track segmentation of radar data.

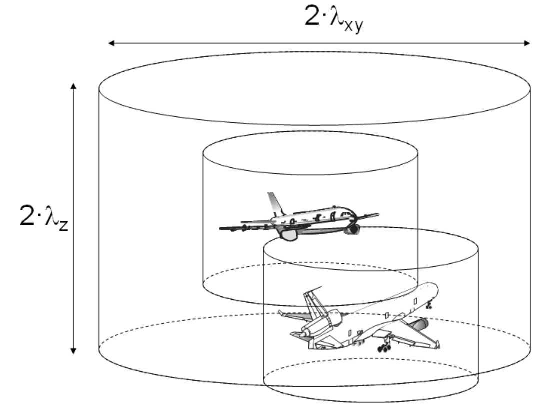




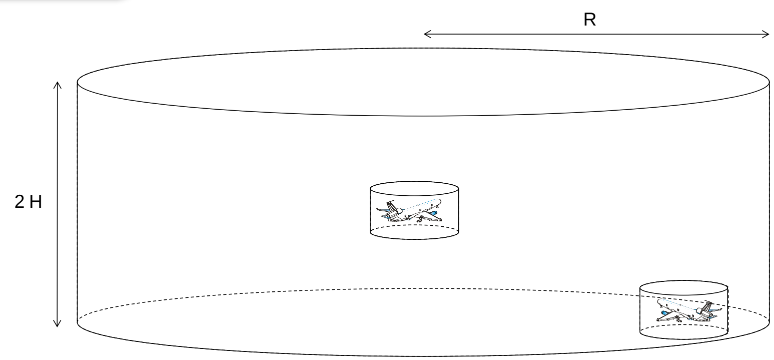
RADAR DATA PROCESSING

GOAL ->Identify Proximate Events:

- Conflicts
- Potential Conflicts
- Potential Collisions



Collision:
Aircraft physical separation
< aircraft physical sizes

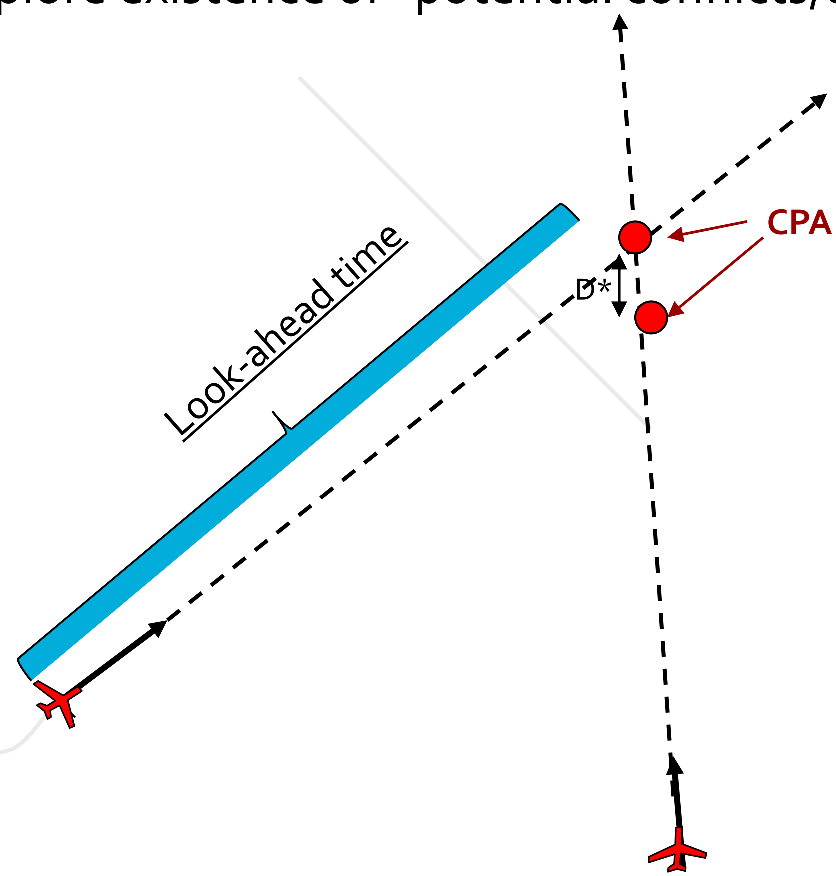


Conflict:
Aircraft physical separation
< *intended* margin (D, H)

RADAR DATA PROCESSING

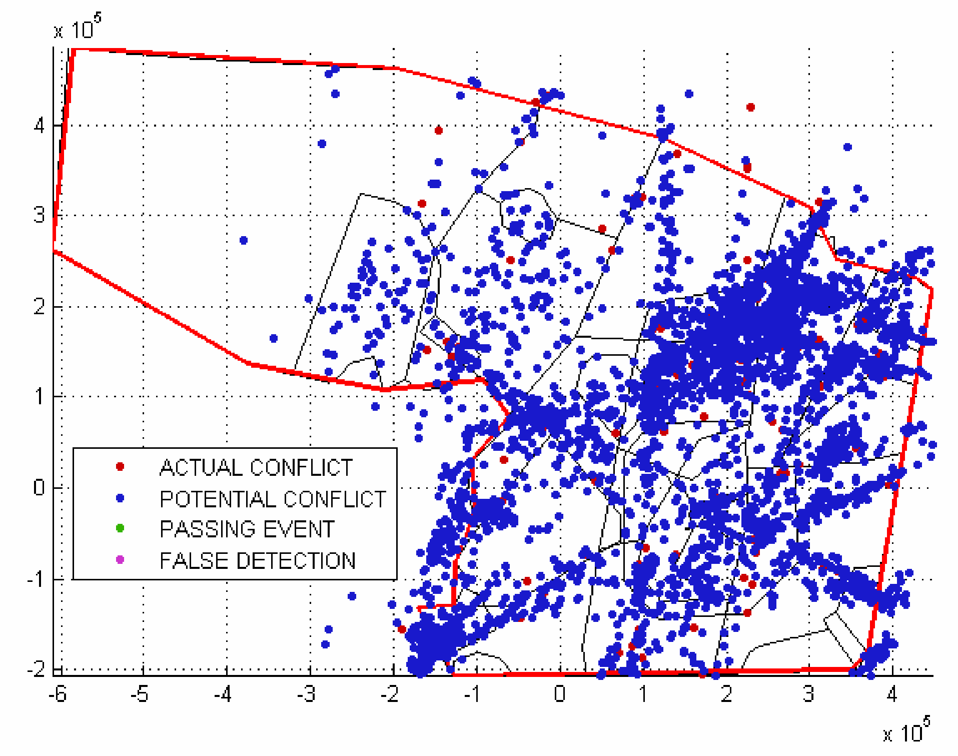
Look-ahead time (LAT): is the time horizon within which all aircraft positions are projected to explore existence of "potential conflicts/collision".

-> 10 minutes



RADAR DATA PROCESSING

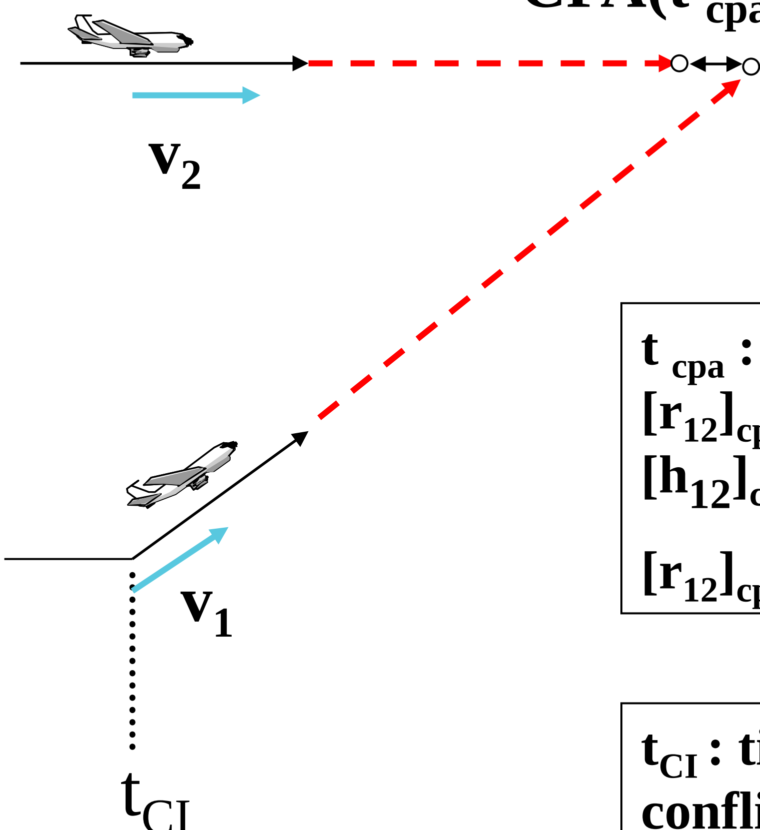
MAP of HOT SPOTS



SAFETY METRICS ESTIMATION

- Analysis of Proximate Events
- Classification of Proximate Events
- Detection of Activated Alert Systems
- Identification of ATM System Weaknesses

SAFETY METRICS ESTIMATION
Analysis of Proximate Events



t_{cpa} : time at CPA
$[r_{12}]_{cpa}$: horizontal separation at CPA
$[h_{12}]_{cpa}$: vertical separation at CPA

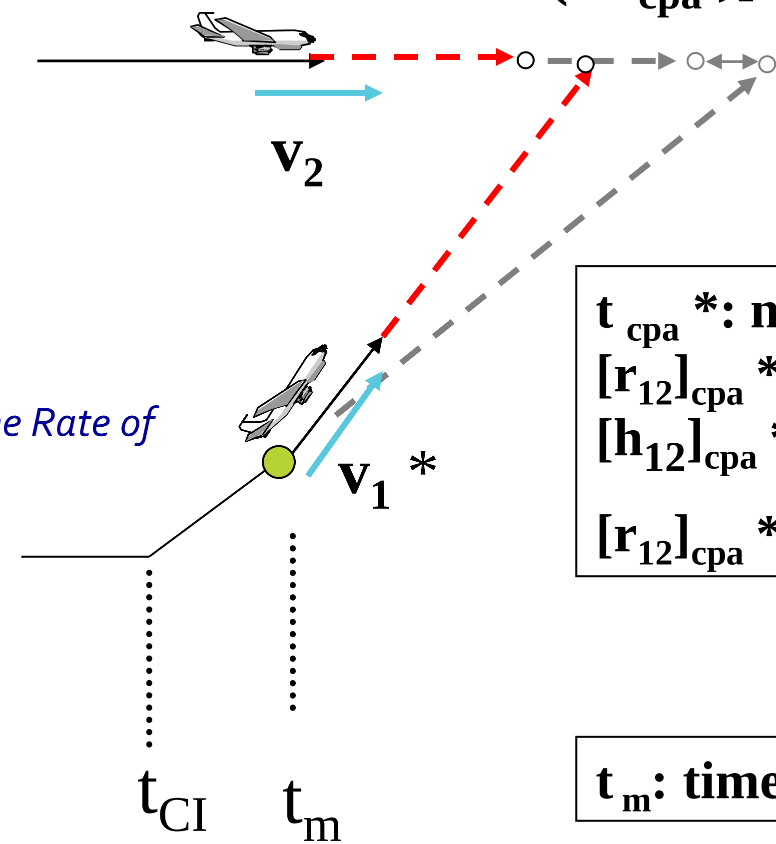
$[r_{12}]_{cpa} < R$ & $[h_{12}]_{cpa} < H$

t_{CI} : time of identification of potential conflict

SAFETY METRICS ESTIMATION
Analysis of Proximate Events

New CPA*(t^*_{cpa}, $[r_{12}]^*_{cpa}$, $[h_{12}]^*_{cpa}$)

Change in the Rate of Climb (ROC)

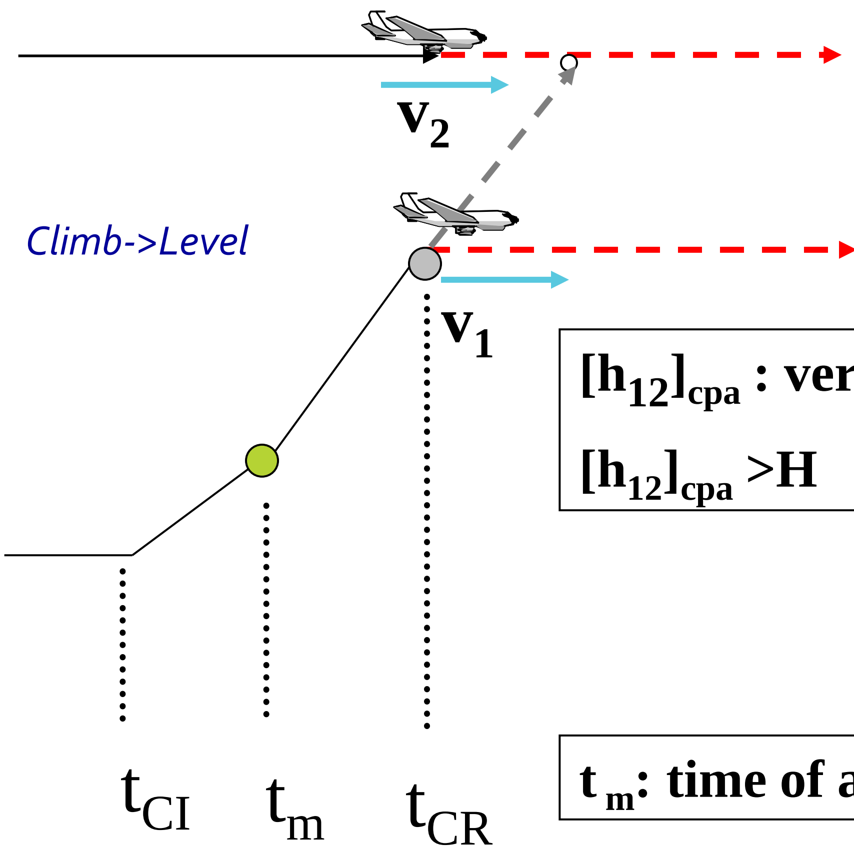


t_{cpa}*: new time at CPA
$[r_{12}]_{cpa}$*: new horizontal separation at CPA
$[h_{12}]_{cpa}$*: new vertical separation at CPA

$[r_{12}]_{cpa}^* < R$ & $[h_{12}]_{cpa}^* < H$

t_m: time of maneuvre

SAFETY METRICS ESTIMATION
Analysis of Proximate Events

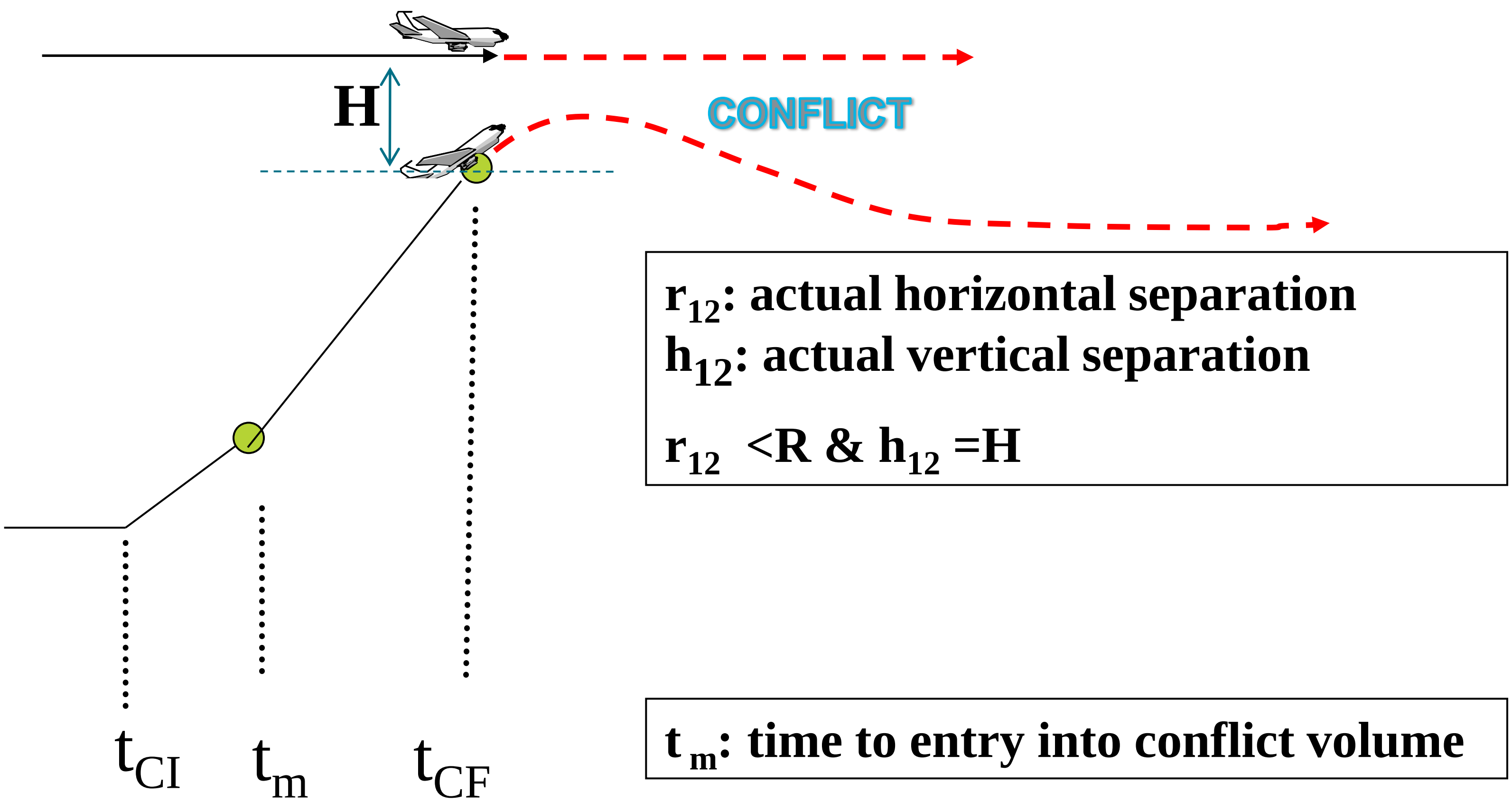


$[h_{12}]_{cpa}$: vertical separation at CPA

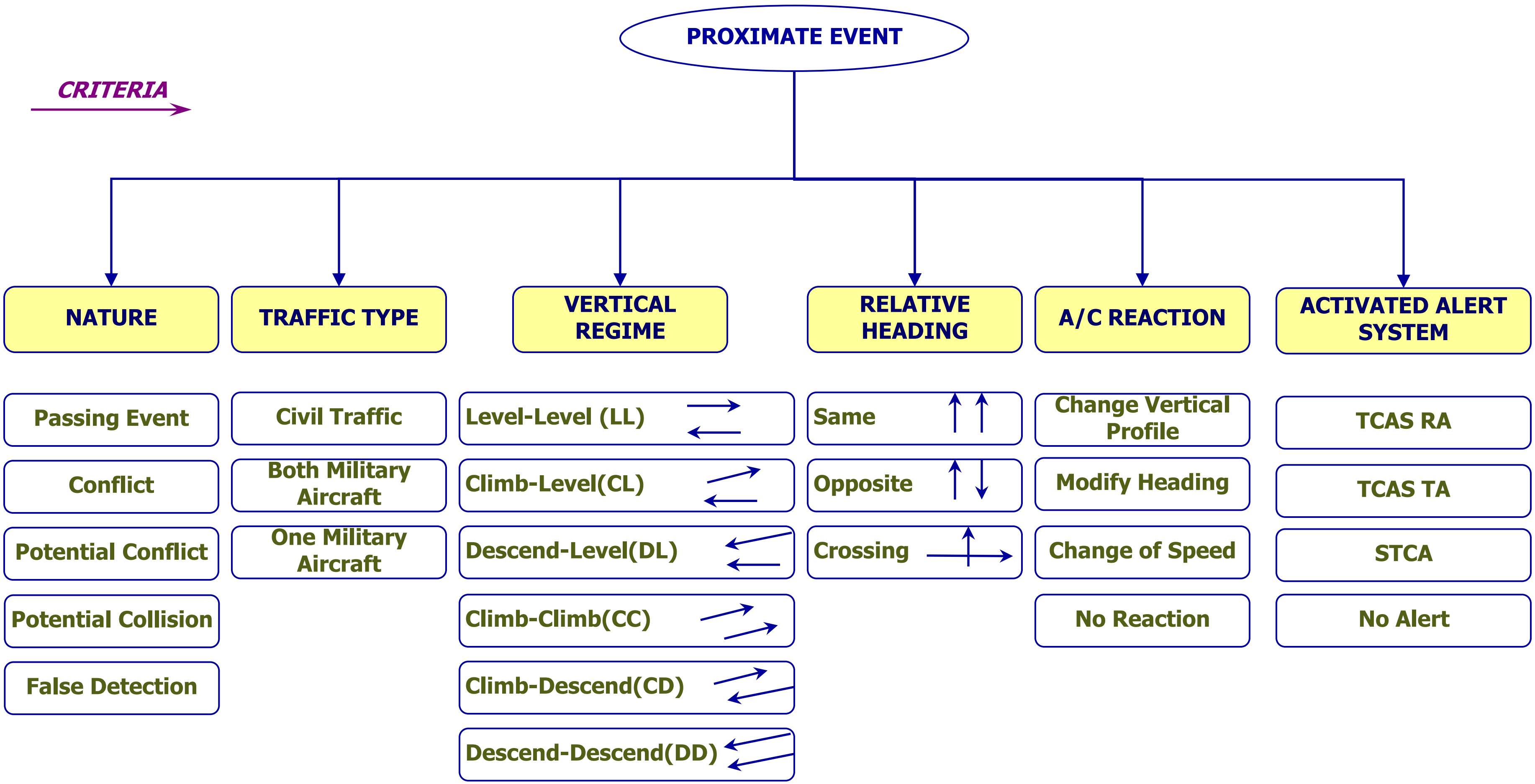
$[h_{12}]_{cpa} > H$

t_m: time of a conflict resolution manoeuvre

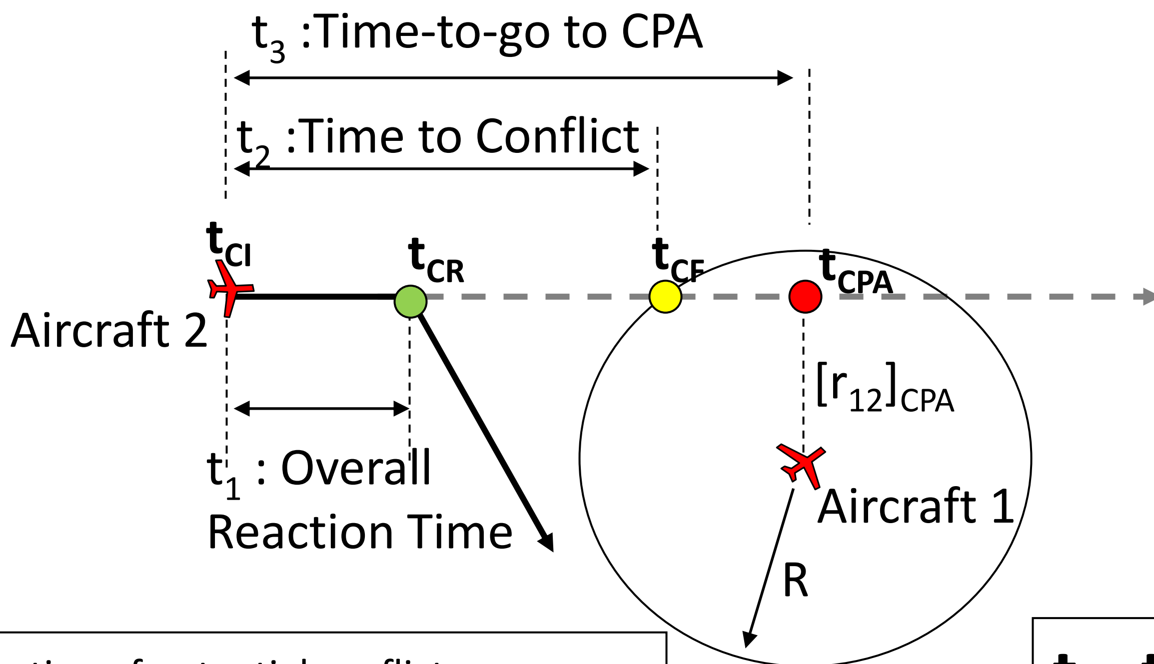
SAFETY METRICS ESTIMATION
Analysis of Proximate Events



SAFETY METRICS ESTIMATION
Classification of Proximate Events



SAFETY METRICS ESTIMATION
Detection of Activated Alert Systems

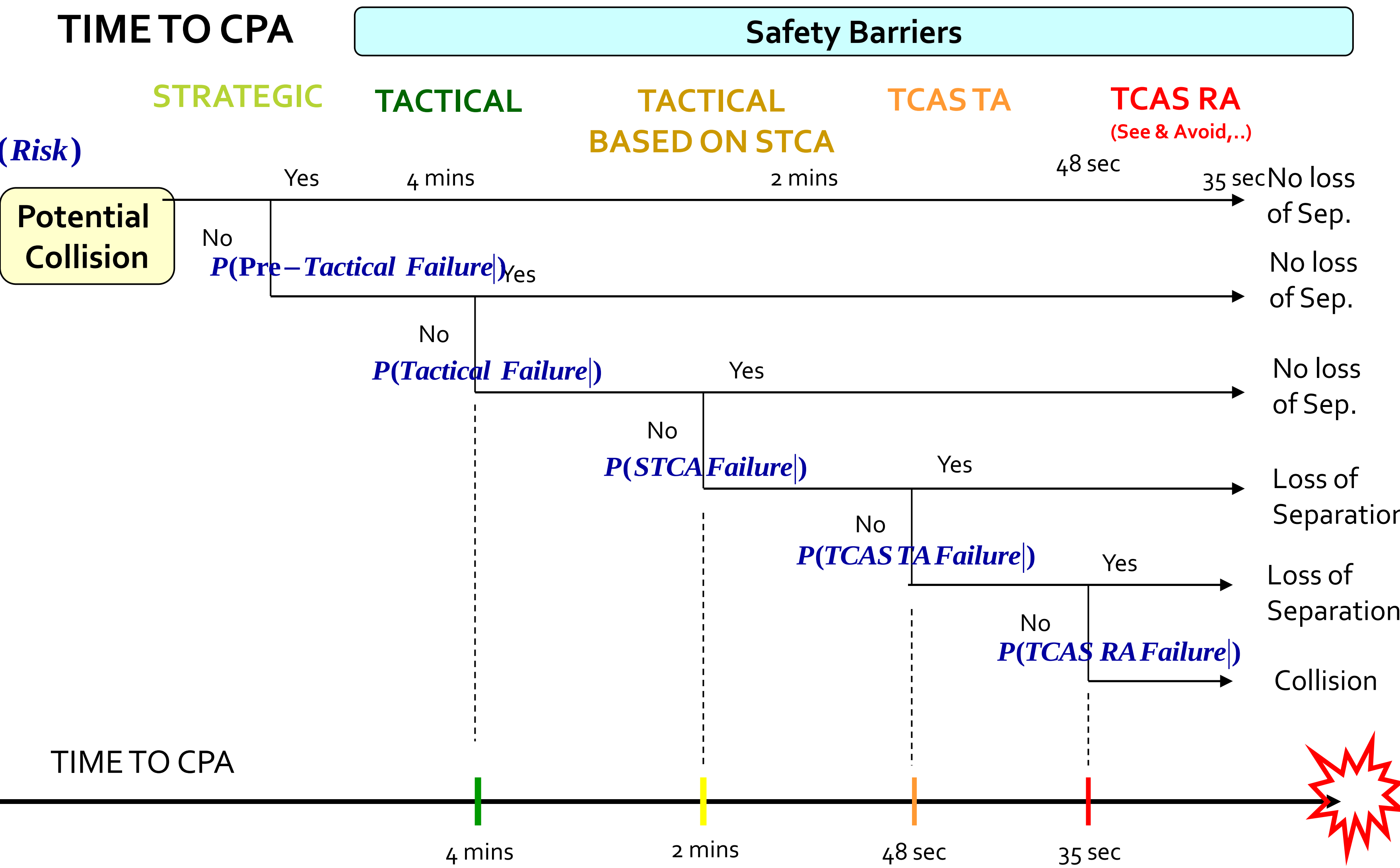


t_{CI}: identification of potential conflict
t_{CR}: start of a conflict resolution manoeuvre
t_{CF}: *predicted* time of entry into conflict volume
t_{CPA}: *predicted* time of CPA
$[r_{12}]_{cpa}$: horizontal separation at CPA

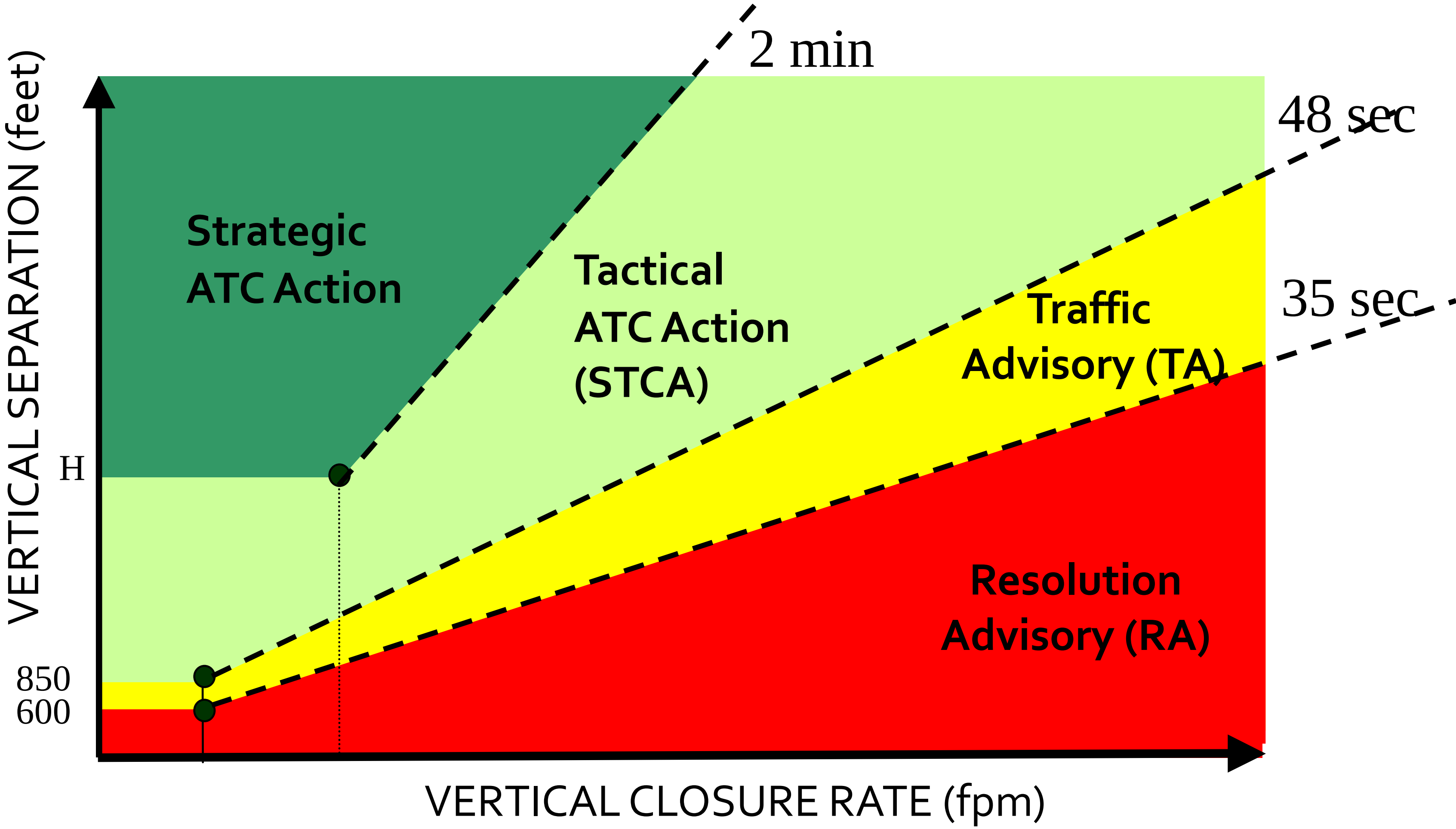
$t_1 = t_{CR} - t_{CI}$
$t_2 = t_{CF} - t_{CI}$
$t_3 = t_{CPA} - t_{CI}$

- - ▸ *Predicted trajectory*

SAFETY METRICS ESTIMATION
Detection of Activated Alert Systems

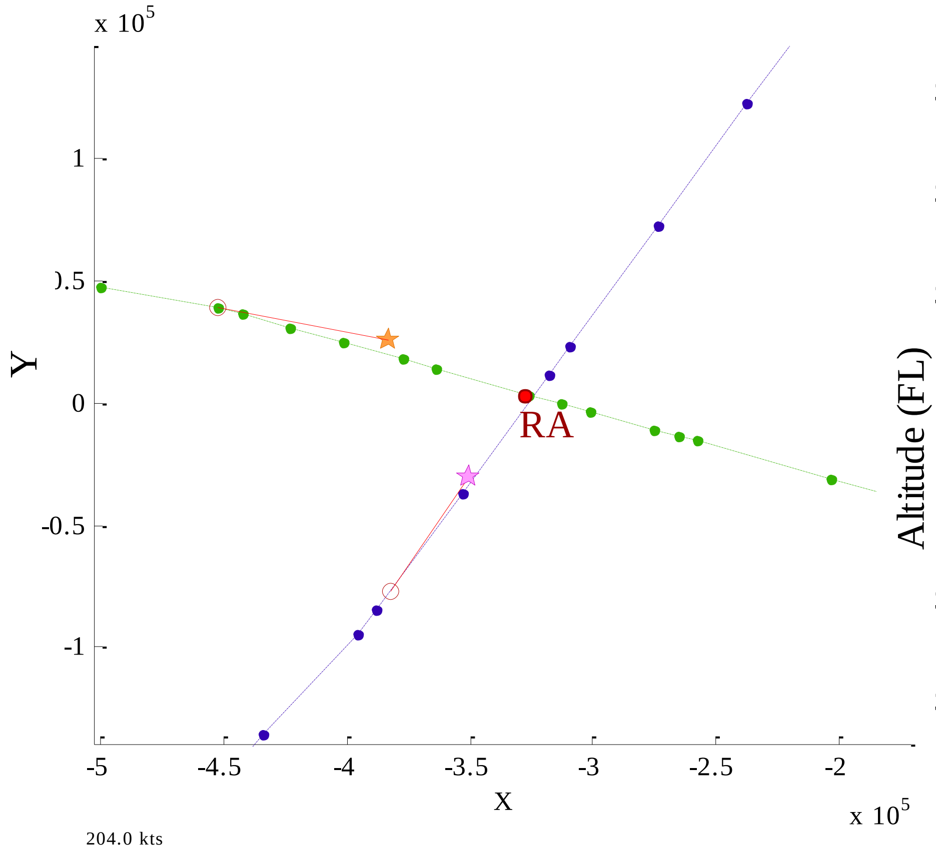


SAFETY METRICS ESTIMATION
Detection of Activated Alert Systems

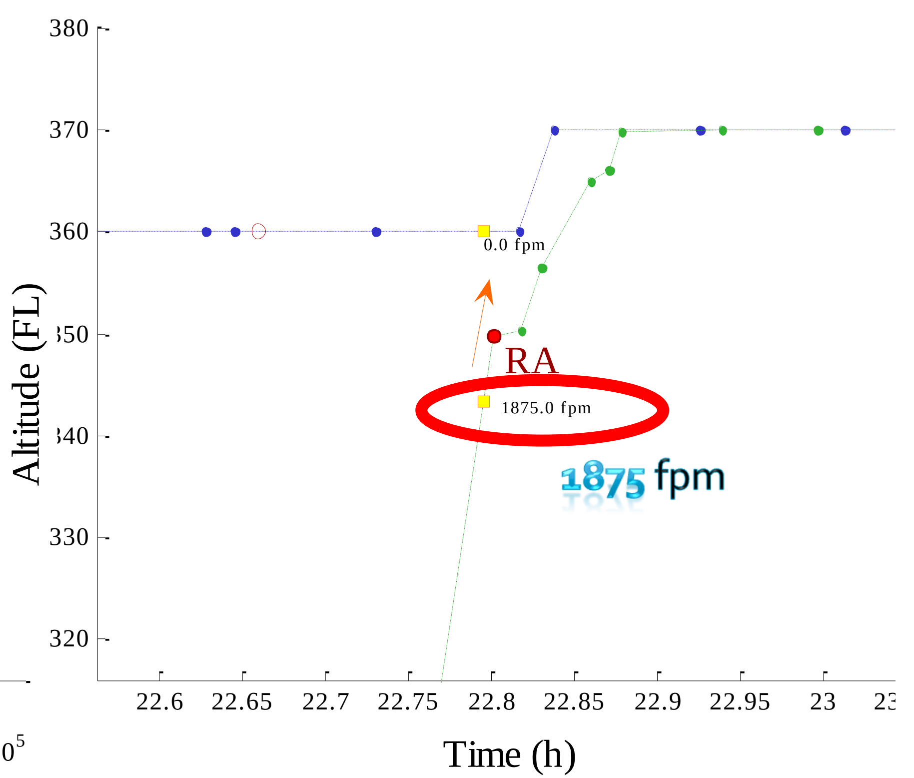


SAFETY METRICS ESTIMATION
Detection of Activated Alert Systems

HORIZONTAL PLANE

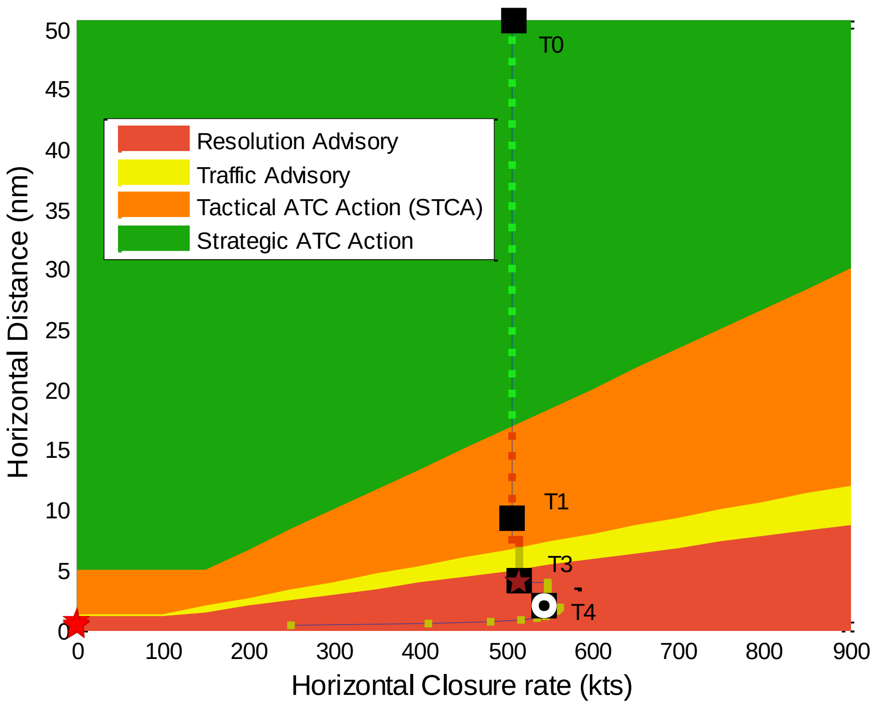


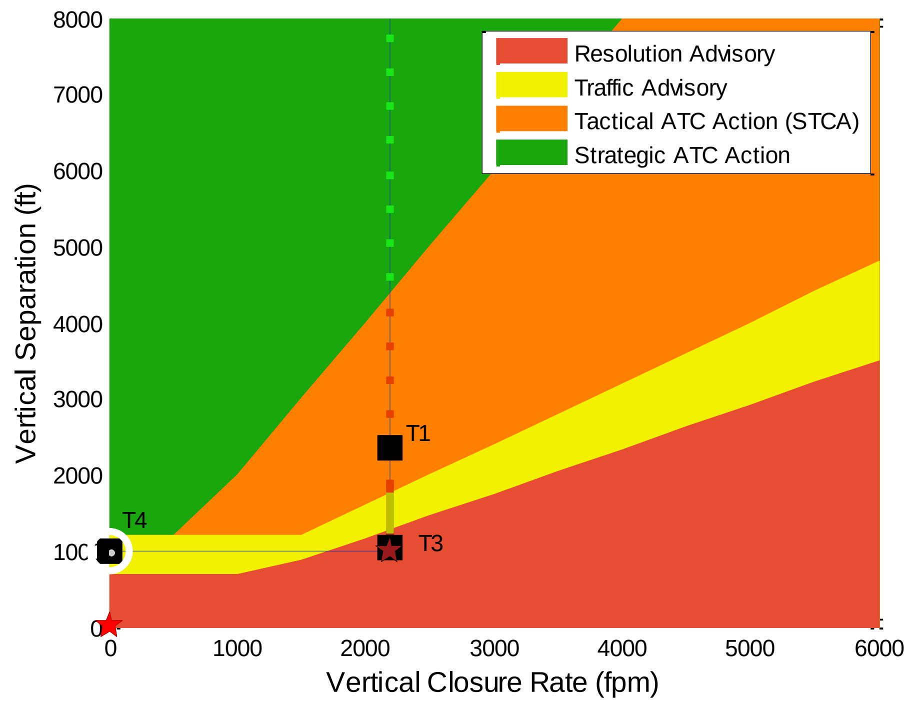
VERTICAL PLANE



Proximate Event Data: AC 1 - AC 2

Tm	$[r_{12}]_{cpa}$ (NM)	$[h_{12}]_{cpa}$ (ft)	TTC (min)	Dur (min)	TCPA rel	Manoeuvre AC1	Manoeuvre AC2	Legend
T0	0.66	-0.00	5.99	1.67	0.00			
	-0.42	00.00	-5.12		-0.00			>Conv(85º)<
T1	0.24	0.00	0.86	5.12	-0.00			
	0.01	-0.00	-0.40		-0.00	**Turn 5.7º**		**AC1** Turn ; ><
T2	0.25	0.00	0.46	0.40	-0.00			TCAS RA
	0.11	1000.00	-0.23		0.00		**CL → FL**	**AC2** CL → FL ;↑ VER SEP; >Conv(88º)<
T3	0.36	1000.00	0.22	0.24	0.00			CONFLICT RESOLVED-VERTICAL PLANE
	-0.01	00.00	-0.22		-0.03			>Conv(93º)<
T4	0.34	1000.00	0.00	0.48	-0.03			MIN REAL SEP: 0.3 NM 1000 ft
	2.44	-0.00	0.00		0.29			<Div(99º)>
T5	2.79	1000.00	0.00	0.80	0.26			





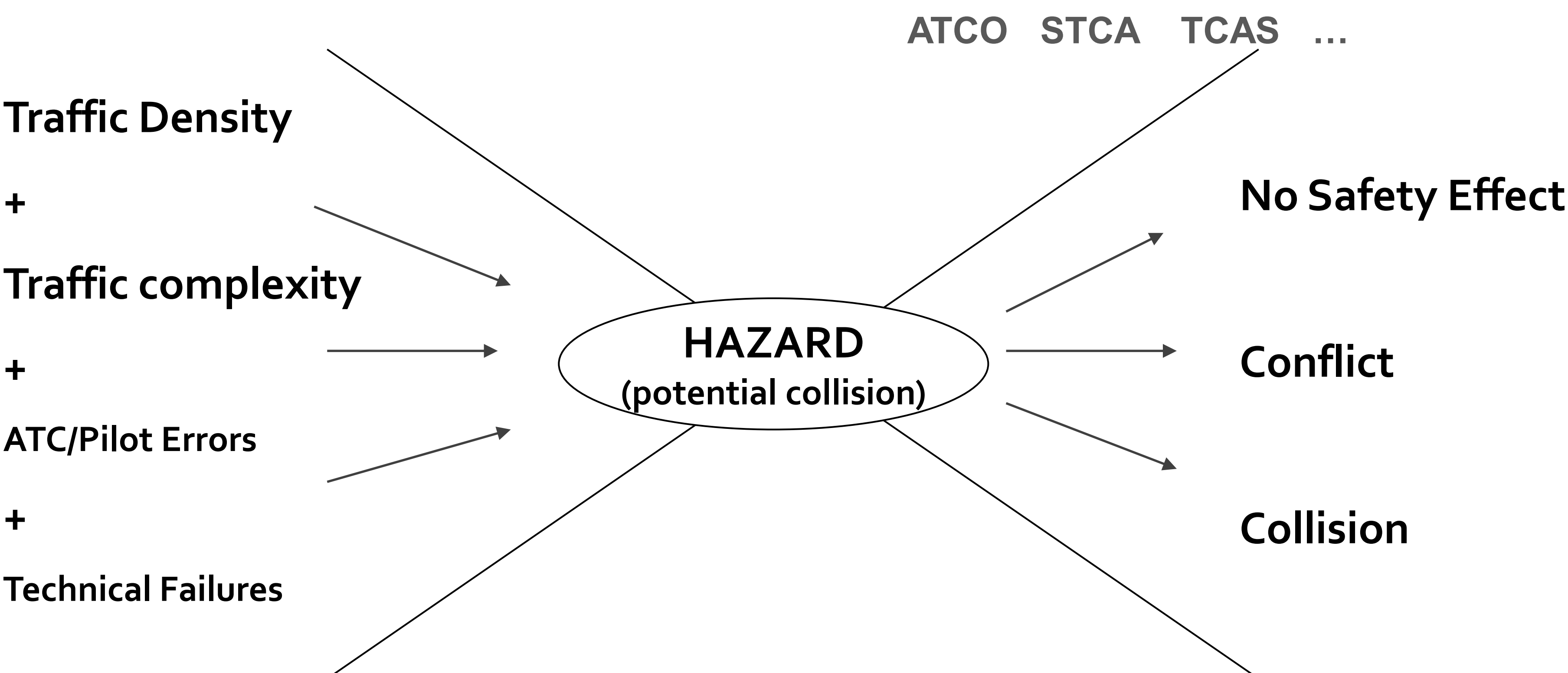
As an example, this figure represents in the TCAS and STCA diagram the evolution of the encounter described beforte. A TCAS RA is activated if the kinetic and geometric characteristics of the event in the horizontal plane and in the vertical plane are in the red area at the same time.

SAFETY METRICS ESTIMATION
Identification of ATM System Weaknesses

Risk Context	Qualification of Hazards	Effectiveness of Safety Barriers

Initiating events leading to potential collisions

Detection / Resolution of potential collisions

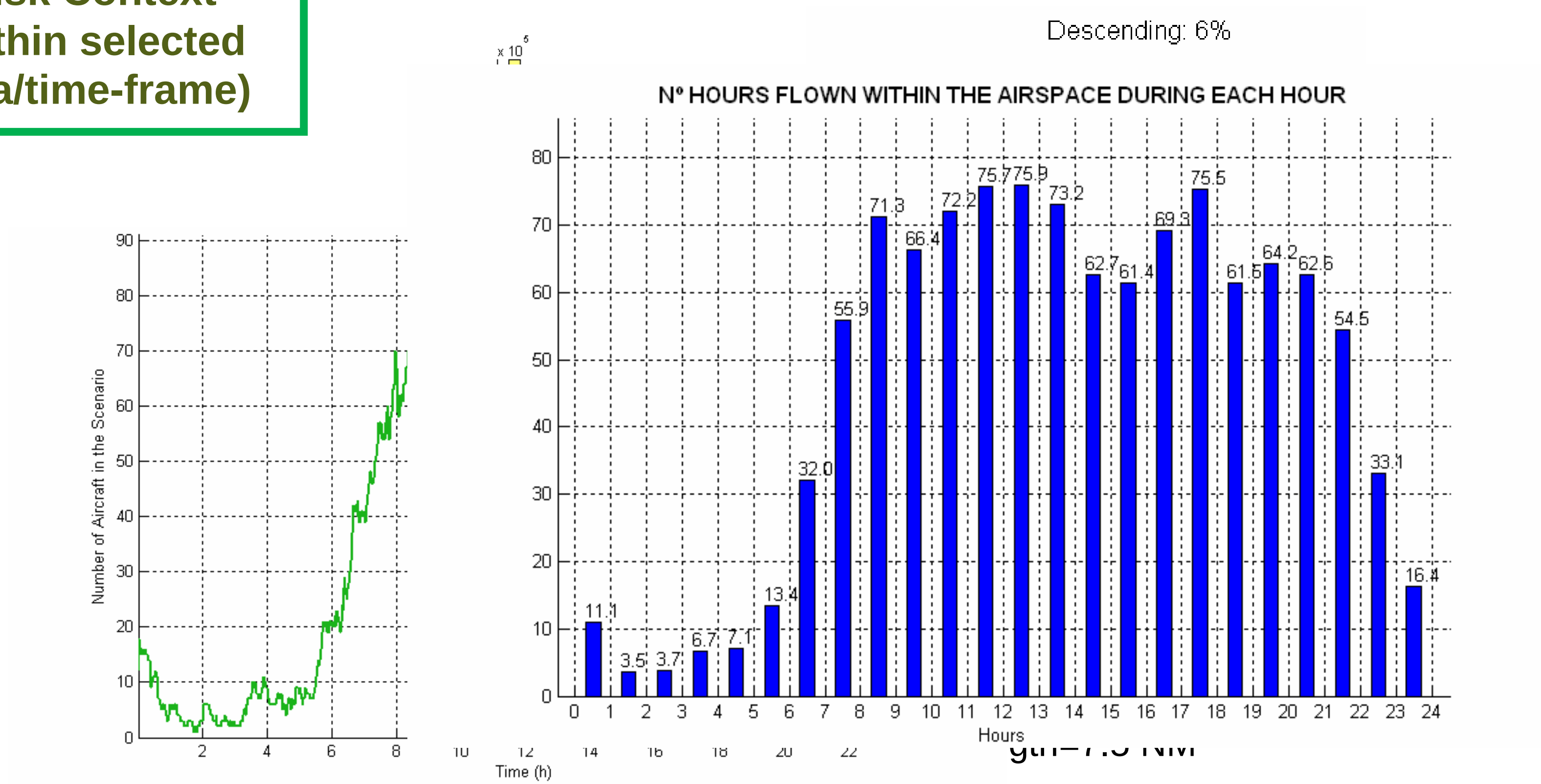


SAFETY METRICS ESTIMATION
Identification of ATM System Weaknesses

Risk Context (within selected area/time-frame)	Qualification of Hazards	Effectiveness of Safety Barriers
Flight-Time	Hot Spots	Number of Real Conflicts
Number of Movements	Classification of Proximate Events: • Nature • Traffic Type • Vertical regime • Relative heading • A/C Reaction • Activated Alert System (TCAS, STCA)	Overall Reaction Time
Kinematics (Speed, Type of Aircraft)		Time Margin
Nº of Entries and Exits		Time to Conflict
Route structure		Time-to-go to the CPA
Traffic Density		% of Potential Conflicts solved in: • vertical plane and • horizontal plane
Number of Routes	Correlation between Hot Spots and Traffic Density Maps.	Average Nº of Aircraft “near” a Proximate Event
% Evolving (non-level) Aircraft	Nº of potential collisions	
Separation Rules		

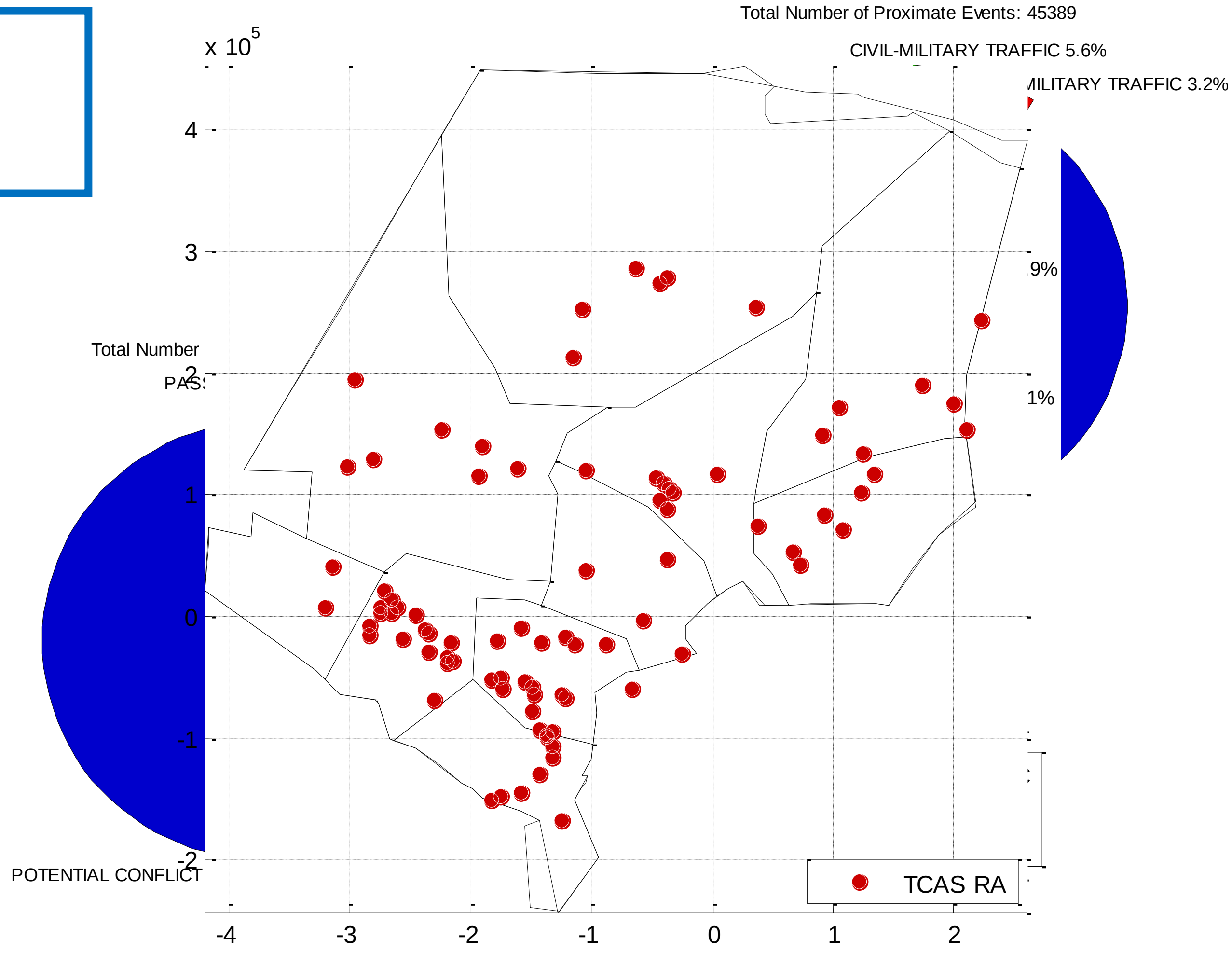
SAFETY METRICS ESTIMATION
Identification of ATM System Weaknesses

Risk Context (within selected area/time-frame)



SAFETY METRICS ESTIMATION

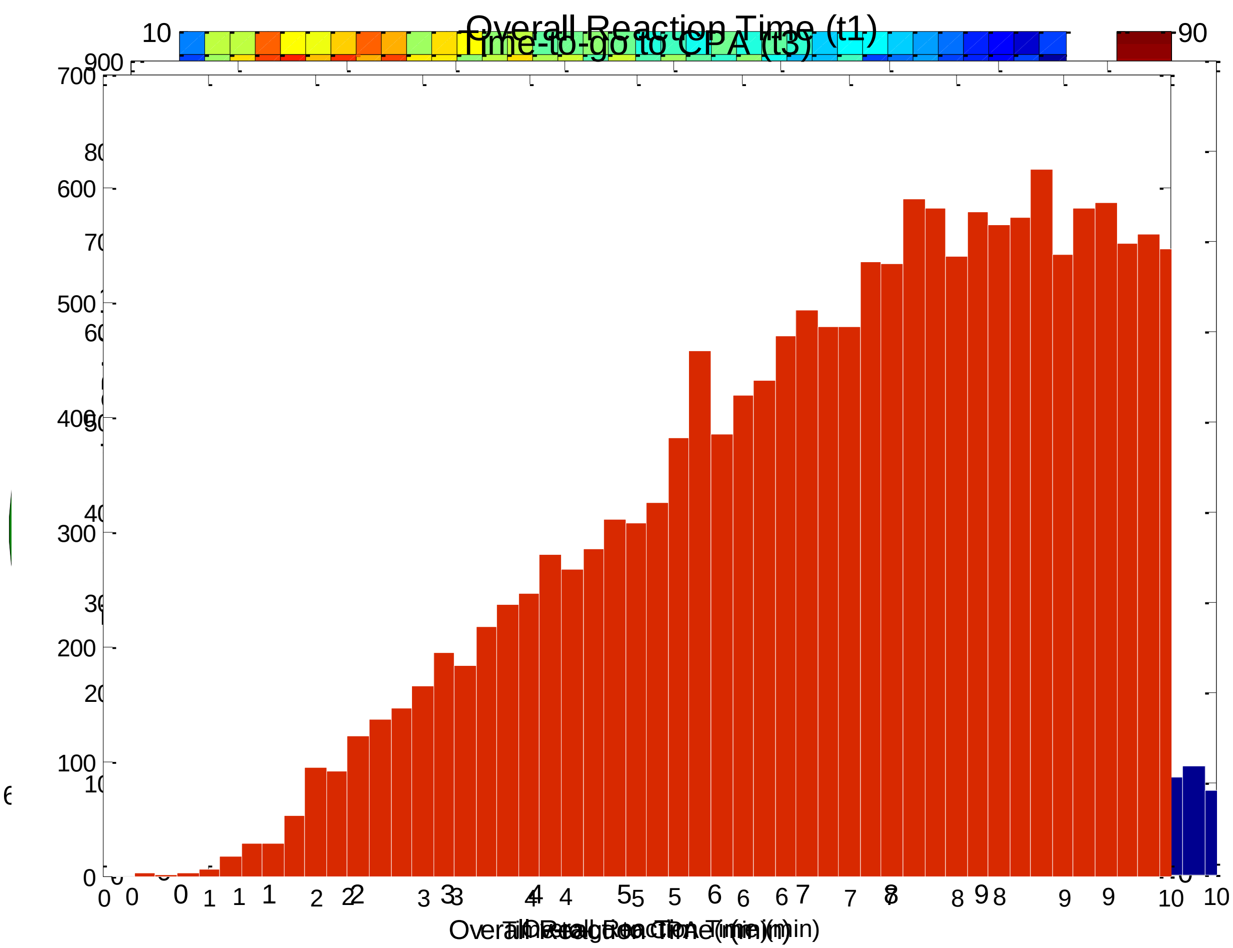
Qualification of Hazards



SAFETY METRICS ESTIMATION

Effectiveness of Safety Barriers

ATC STRATEGY



CONCLUSIONS

The 3-D CRM tool has been designed to complement the information collected in the accident and incident databases, thereby providing the following information inferred from the in depth assessment of proximate events:

Identification of all proximate events based on radar data.

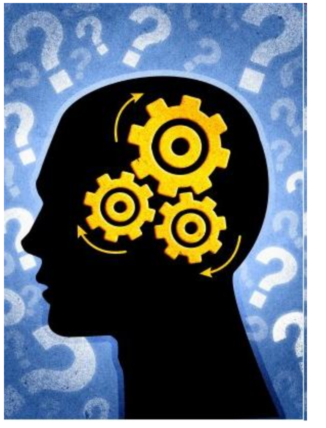
Complete classification of all proximate events using clear and consistent criteria.

Detailed information on the evolution of each proximate event.

Safety metrics and other air traffic factors

WORK IN PROGRESS

•Apply the 3-D CRM too to traffic samples of different airspaces and extend the principles of 3-D CRM from en-route to **Terminal Manoeuvring Area (TMA)** scenarios;



•Develop a **methodology** to provide a complete risk picture of the scenario, identifying the ATM system weakness and characterizing the performance of the safety barriers, using all the information provided by the 3-D CRM tool that could be used by ATM service providers to monitor and improve safety levels in their operation;

•Complete **an analytical model** based on the 3-D CRM tool to provide true collision risk values.

Questions

CRIDA (Centro de Referencia I+D+i ATM)