TCAS RA events during independent parallel approaches at LEMD

SAFOPS #10

ENAIRE

The Context 1/3

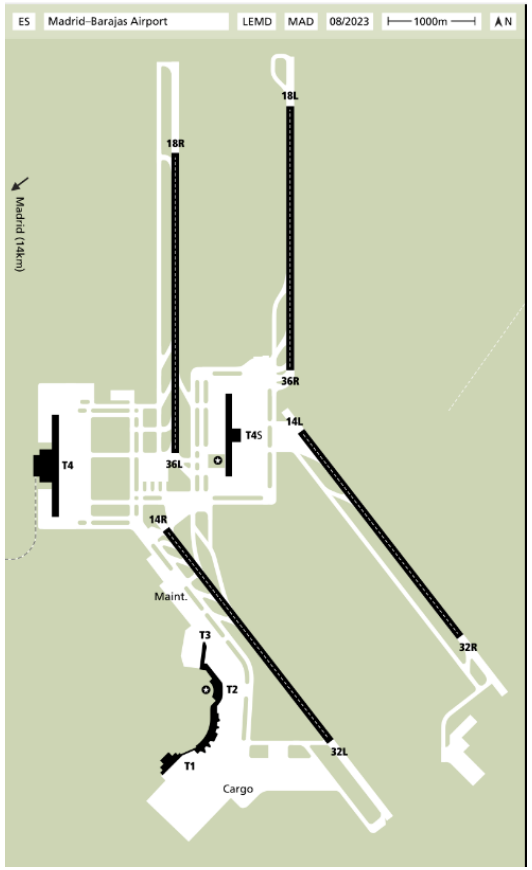
LEMD is a 4 Runway airport, located at 2000ft AMSL

2 Sets of parallel runways

RWY 18L/36R and 18R/36L separated by 0,7NM
RWY 14L/32R and 14L/32R separated by 1,0NM

18R/L and 32R/L are used for landings
14R/L and 36R/L are used for departures

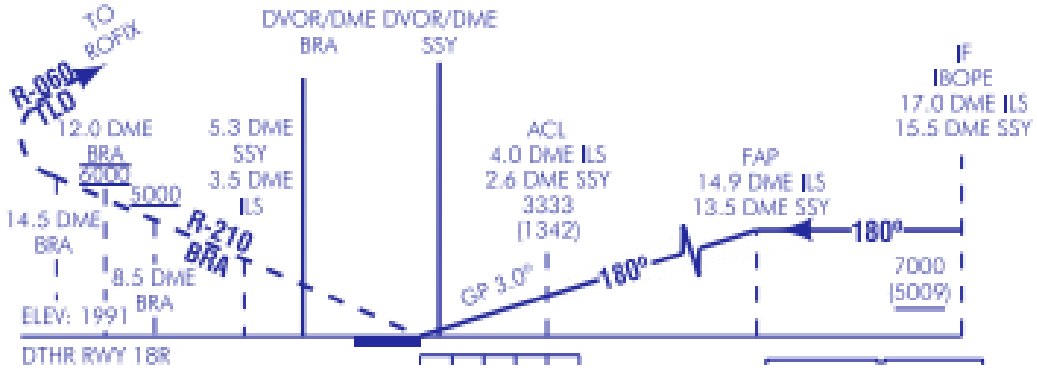
Until February 2023 approaches were managed in Simultaneous Parallel Dependent Mode, requiring 1,5NM between aircraft in adjacent localizers. In order to increase capacity, Independent Mode was implemented.

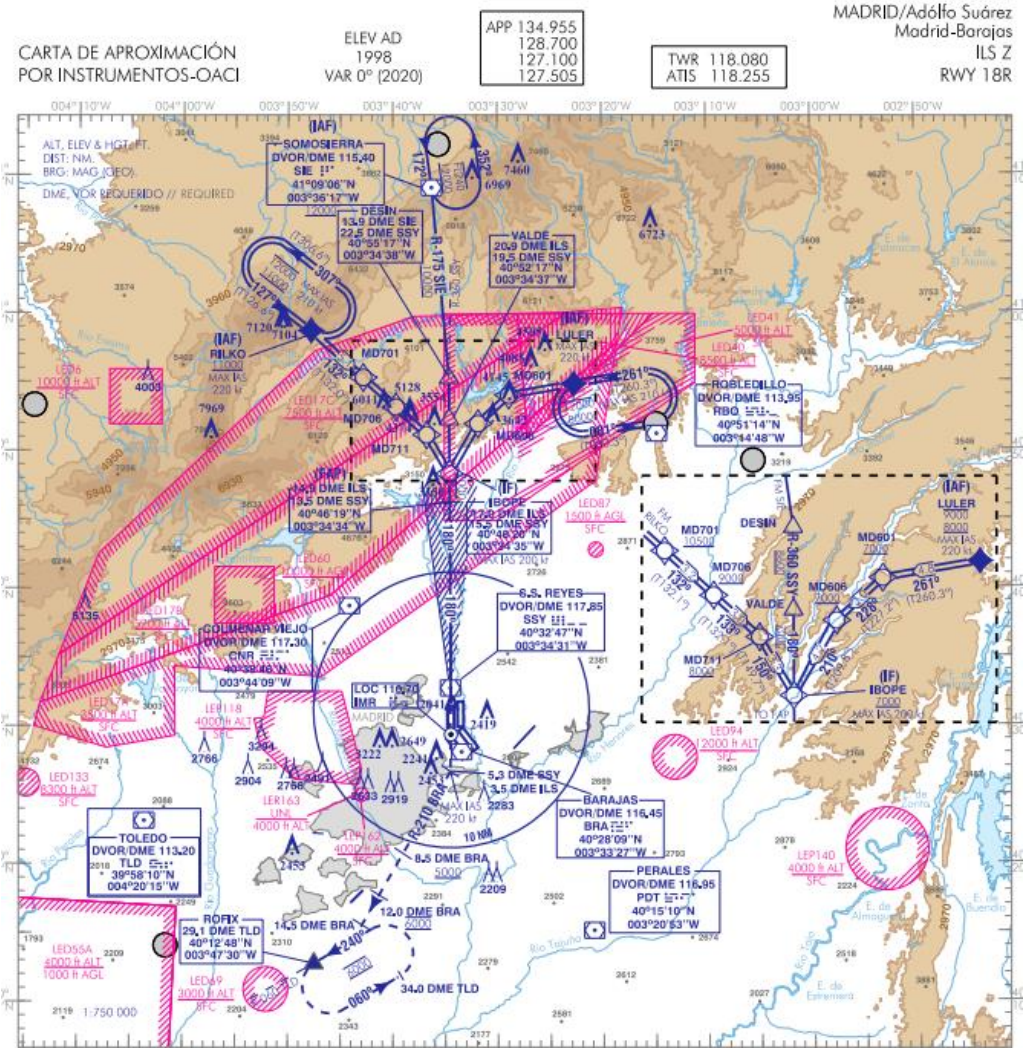


The Context 2/3

Designing approaches to RWY 18R/L that could comply with SOIR/EU 373 requirements was challenging, owing to high terrain, an abundance of military restricted areas and environmental restrictions.

The resulting approach procedure has a glide path interception altitude on the high side of 7000’





The Context 3/3

Implementation of the new independent mode was carried out in February 2023 with initial impressions being good

Several glitches were easily dealt with:

- Minor errors in publication were corrected
- A specific radar introducing artifacts in the presentation was removed and fixed
- Some instances of localizer overshoots were addressed both with operators and ATC personnel

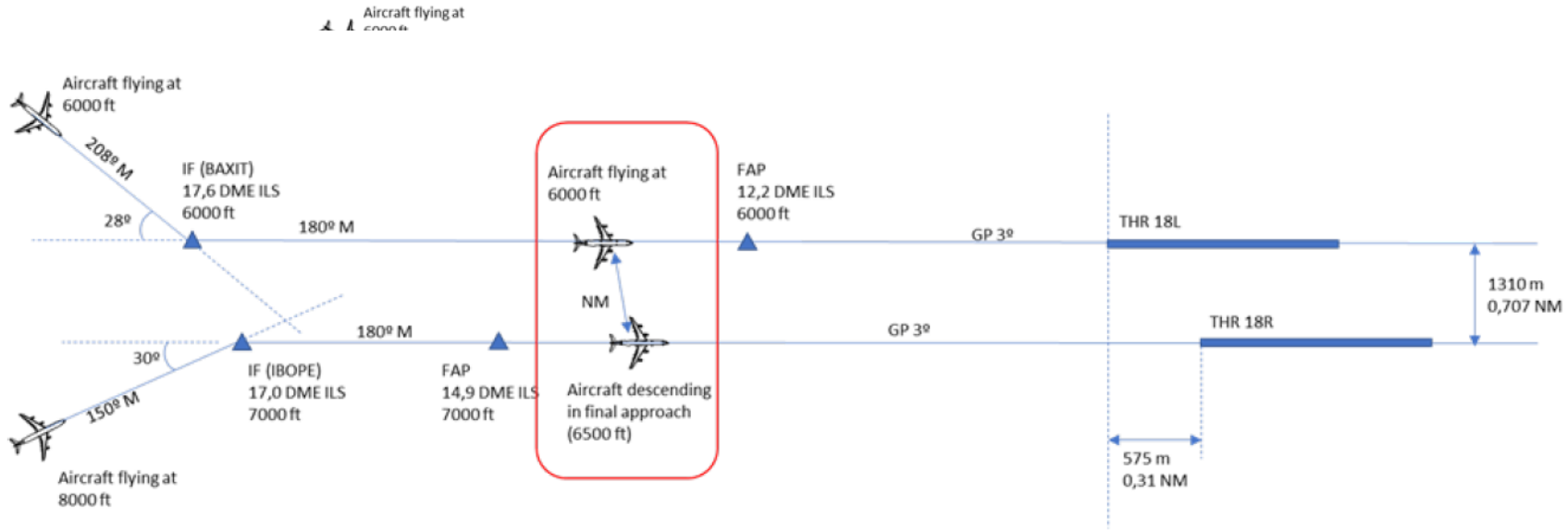
One issue that would become a major headache:

- When RWY 32R/L were used for arrivals, everything was fine. But when RWY 18R/L were in use, we started receiving some very baffling TCAS RA notifications.

A picture emerges

Reports of TCAS RA events started to come in. Some had obvious causes, but a significant number remained unexplainable. Analyzing our radar data, plus FDR information provided by the operators, the picture that emerged was at follows

- Both aircraft involved were correctly established in their respective localizers, with stable headings
- Speeds and all other data were nominal. Weather was not a factor
- No initial TCAS warnings were recorded before the FAP
- TCAS TA/RA were triggered when the aircraft flying the high side started their descent, according to the glide path
- In some instances, there were no TCAS advisories of any kind though no difference was initially apparent

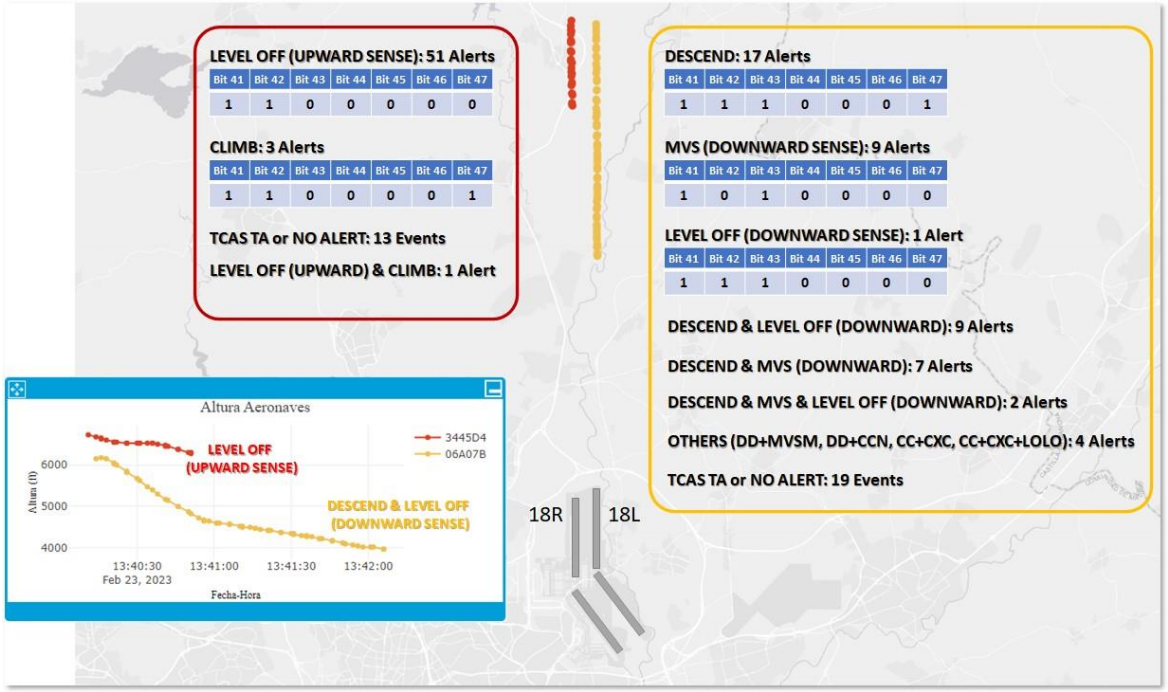


The stopgap measure

TCAS reports became a daily occurrence the moment RWY 18R/L were in use. We started looking for common factors or patterns that could help us to prevent the issue, initially to no avail. We sought help from many parties, including the School of Aeronautical Engineering of Madrid's Universidad Politécnica.

Brainstorming sessions were held proposing all kinds of solutions, but none actually addressed the matter without potentially creating greater issues. We gathered all available data on each individual TCAS event to try to identify and troubleshoot the issue.

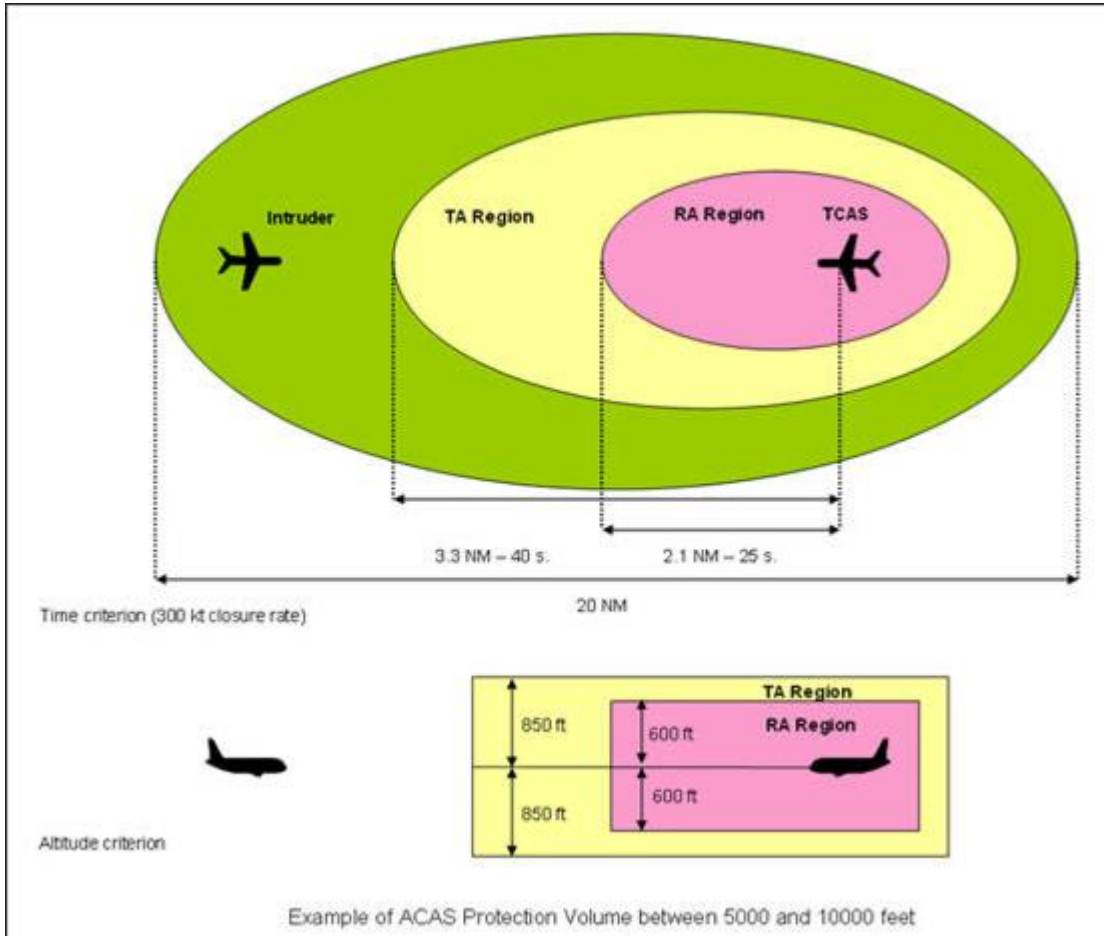
In July 2023 after more than 80 TCAS events, the decision was taken to revert to Dependent Mode until the problem was fixed.



Tracking the issue: TCAS Internal Logic (very simplified) 1/3

This is the typical representation of TCAS. A bubble that surrounds the aircraft with an outer and an inner layer. An intruder in the outer layer will trigger a TA and an intruder in the inner layer will trigger an RA. Looks simple enough.

But as anybody that has ever participated in the actual specifications of such an alerting system can tell you, things can get *really complicated* the moment one starts considering marginal cases or minimising nuisance alerts.



Example of ACAS Protection Volume between 5000 and 10000 feet

Tracking the issue: TCAS internal logic (very simplified) 2/3

A TCAS TA/RA should be triggered when aircraft are expected to be too close, but what exactly does ‘too close’ mean?

Table 2. Sensitivity Level Definition and Alarm Thresholds

Own Altitude (feet)	SL	Tau (Seconds)		DMOD (nmi)		ZTHR (feet) Altitude Threshold		ALIM (feet)
		TA	RA	TA	RA	TA	RA	RA
< 1000 (AGL)	2	20	N/A	0.30	N/A	850	N/A	N/A
1000 - 2350 (AGL)	3	25	15	0.33	0.20	850	600	300
2350 – 5000	4	30	20	0.48	0.35	850	600	300
5000 – 10000	5	40	25	0.75	0.55	850	600	350
10000 – 20000	6	45	30	1.00	0.80	850	600	400
20000 – 42000	7	48	35	1.30	1.10	850	700	600
> 42000	7	48	35	1.30	1.10	1200	800	700

At an altitude of 6500, you would need at the same time an expected horizontal distance of less than 0.55NM and a vertical distance of less than 600 ft at the same time for an RA to be triggered and yet we were having TCAS RA when the horizontal distance was never less than 0,7 NM

Tracking the issue: TCAS internal logic (very simplified) 3/3

In slowly converging situations, because the time to CPA is so large there are situations where TCAS could fail to trigger.

On the other hand, a Nuisance Alarm Filter is implemented, which attempts to prevent TCAS triggering when there is sufficient separation at all times.

The interaction of this two aspects of TCAS result in undesirable advisories in some instances of simultaneous parallel operations.

Again: When building alert systems, things can get *really complicated* the moment one starts considering marginal cases or minimising nuisance alerts.

Why on 18R/L and not anywhere else

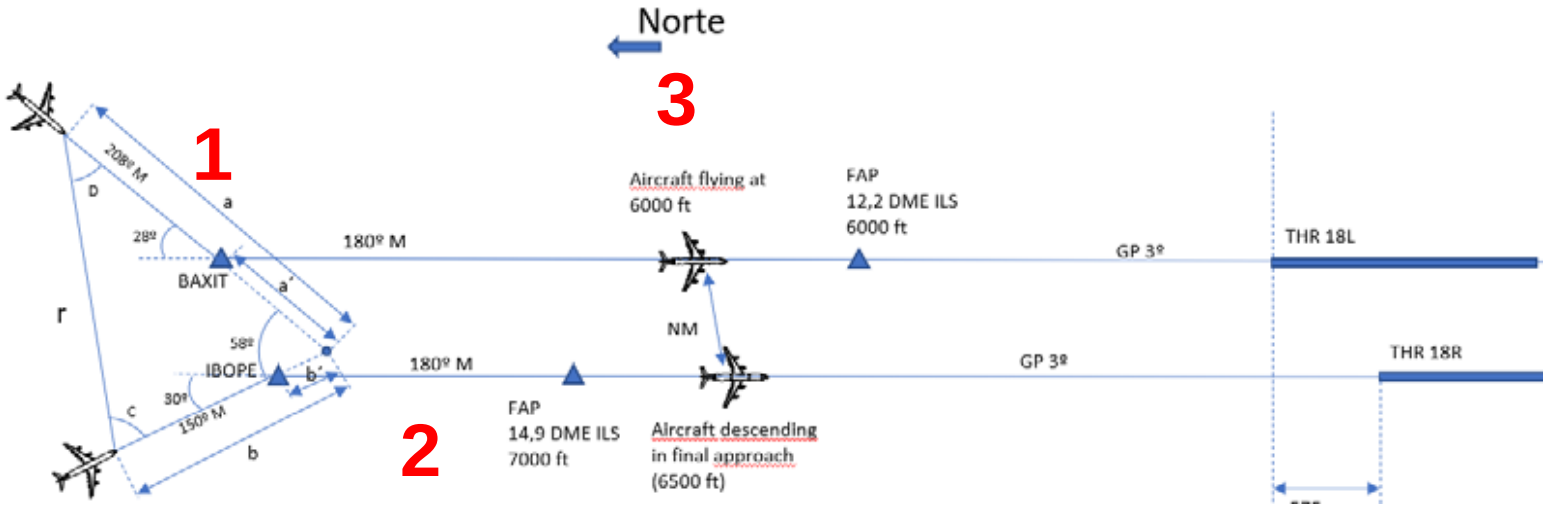
A combination of factors

1. LEMD sits relatively high, at 2000’ elevation. The sensitivity of TCAS at the FAP for RWY 18R/L is SL5, while for RWY 32R/L is SL4. The DMOD for RWY 18R/L is 0.55NM and for RWY 32R/L is 0.35NM

2. Runway centerlines are at approximately 0.7NM for RWY 18R/L and 1.0NM for RWY 32R/L. Threshold staggering is not large, so vertical profiles are similar for both runways.

3. Surrounding terrain forces the 18R/L approaches to have a relatively high FAP, meaning that the initial loss of vertical separation happens at 6.600 ft rather than the 4.600ft for RWY 32R/L, thus keeping TCAS at SL5 rather than SL4

The explanation.



1. Traffic converge at BAXIT and IBOPE. TCAS computes that in less than 25 seconds the horizontal separation will be below the DMOD for this altitude (0.55NM). Vertical distance is 1000’ so no TCAS RA is triggered, but the horizontal threat remains active

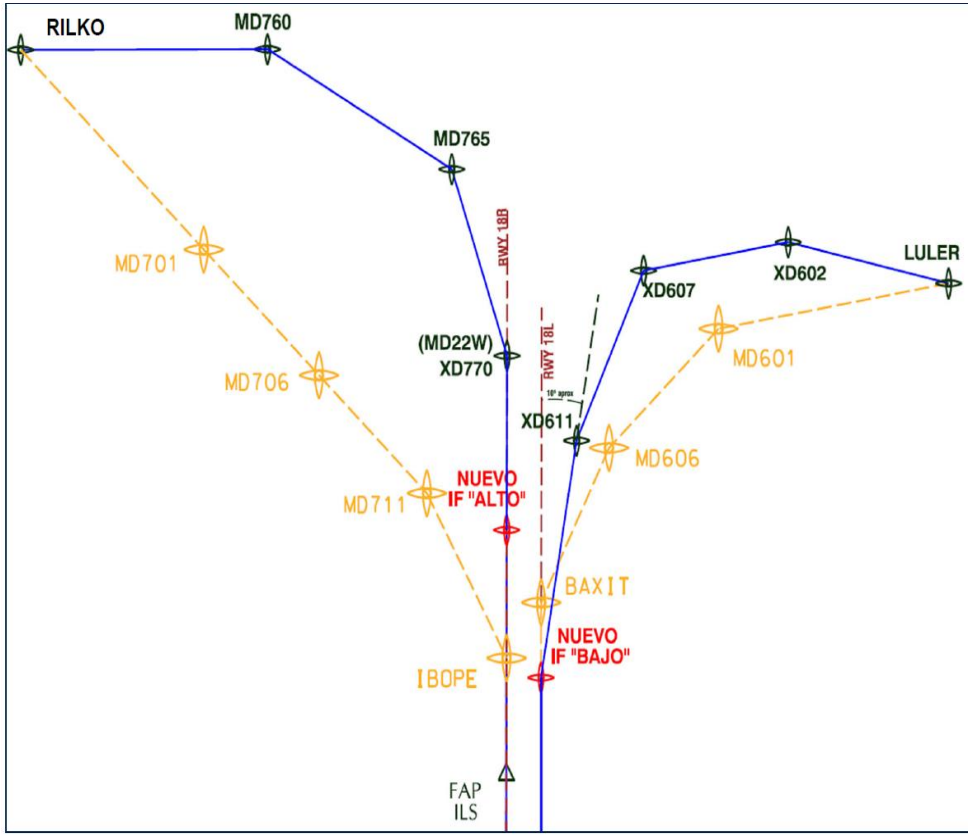
2. Localizers are intercepted. Expected minimum horizontal distance increases but still below the distance needed to activate the NAF which cancel the advisory based on horizontal distance.

3. Aircraft flying the high side start descending, while traffic flying the low side maintains 6000’. The moment vertical separation reaches 600’ both vertical and horizontal triggers are reached and TCAS generates an RA event.

The Way Forward

A new set of approach procedures has been designed with intermediate phases were there isn't so much track convergence.

Our simulations, undertaken with the help of the School of Aeronautical Engineering of Madrid's Universidad Politécnica predict that the horizontal TCAS alert won't be triggered so the problem will disappear, allowing for the reintroduction of independent approaches.



WEF will be somewhere between an optimistic early autumn 2024 and a pessimistic early 2025.

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Thank you