



Oceanic Tailored Arrivals

Project Overview

Environmental Work Group – CDA Workshop
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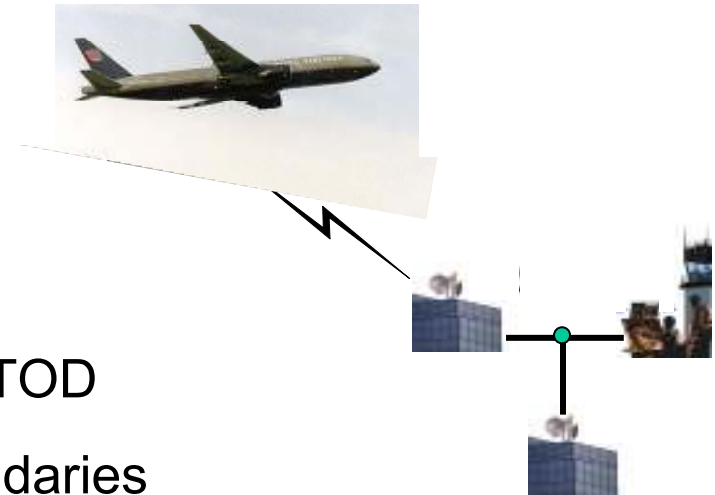
Outline

- Concept Overview
- R&D Objectives
- SFO Field Trials Description
- Some Initial Findings
- Concluding Remarks

What is a Tailored Arrival?

An trajectory-based clearance that enables an efficient descent from cruise to landing

- Allows a continuous descent at low engine power
- Tailored to:
 - Avoid conflicts
 - Meet traffic-flow constraints
 - Avoid restricted airspace, weather, terrain
 - Accommodate specific aircraft constraints
- Given as a single clearance well prior to TOD
- Coordinated across airspace/facility boundaries
- Loaded into and flown using aircraft FMS
- Delivered by data-link for minimal workload



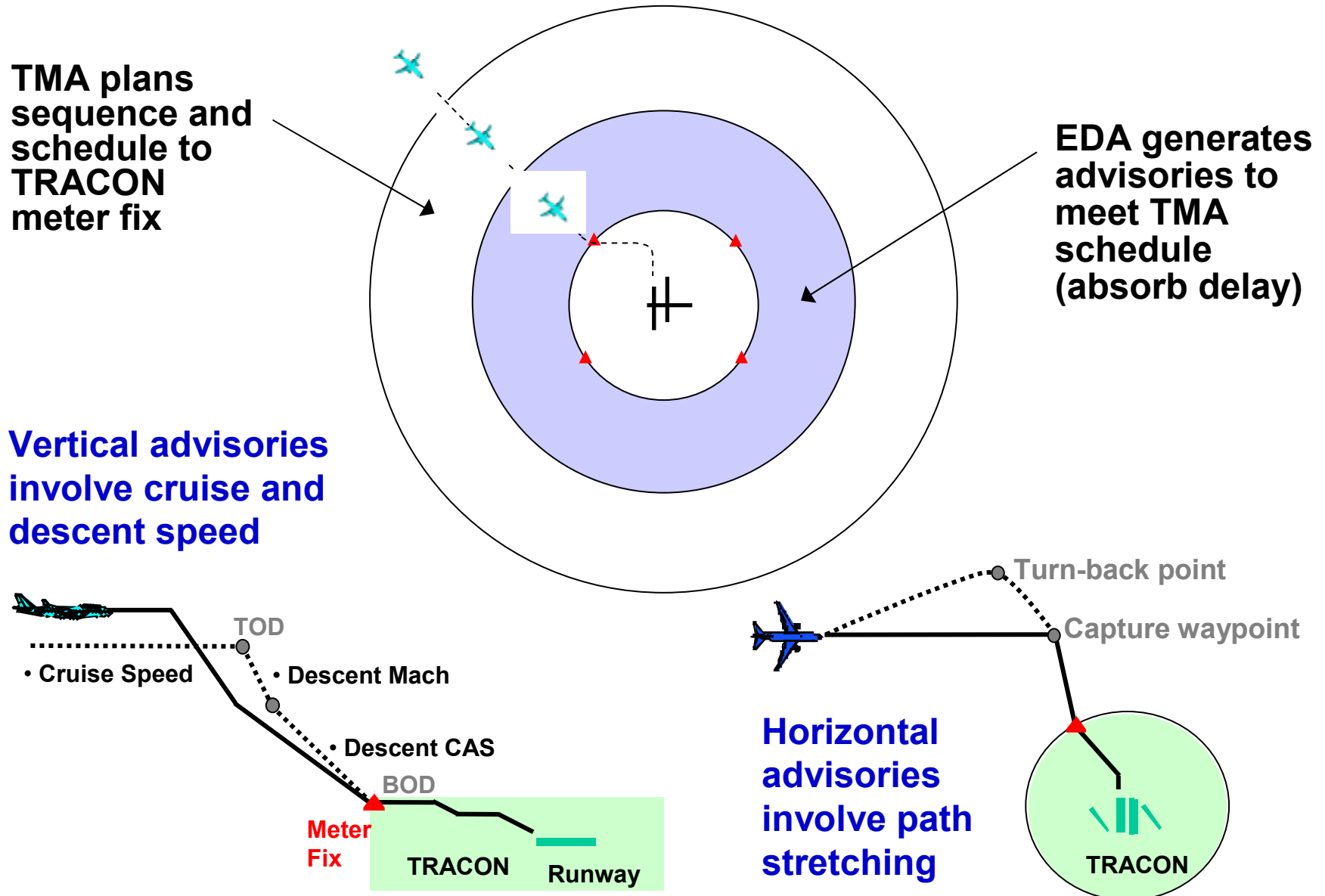
Why Tailored Arrivals?

- **Reduced fuel burn**
- **Reduced noise**
- **Reduced emissions**
- Improved engine life (due to fewer level-off power cycles)
- Reduced controller and pilot workload
- Improved arrival trajectory certainty and situational awareness
- Return on airline CNS avionics investment

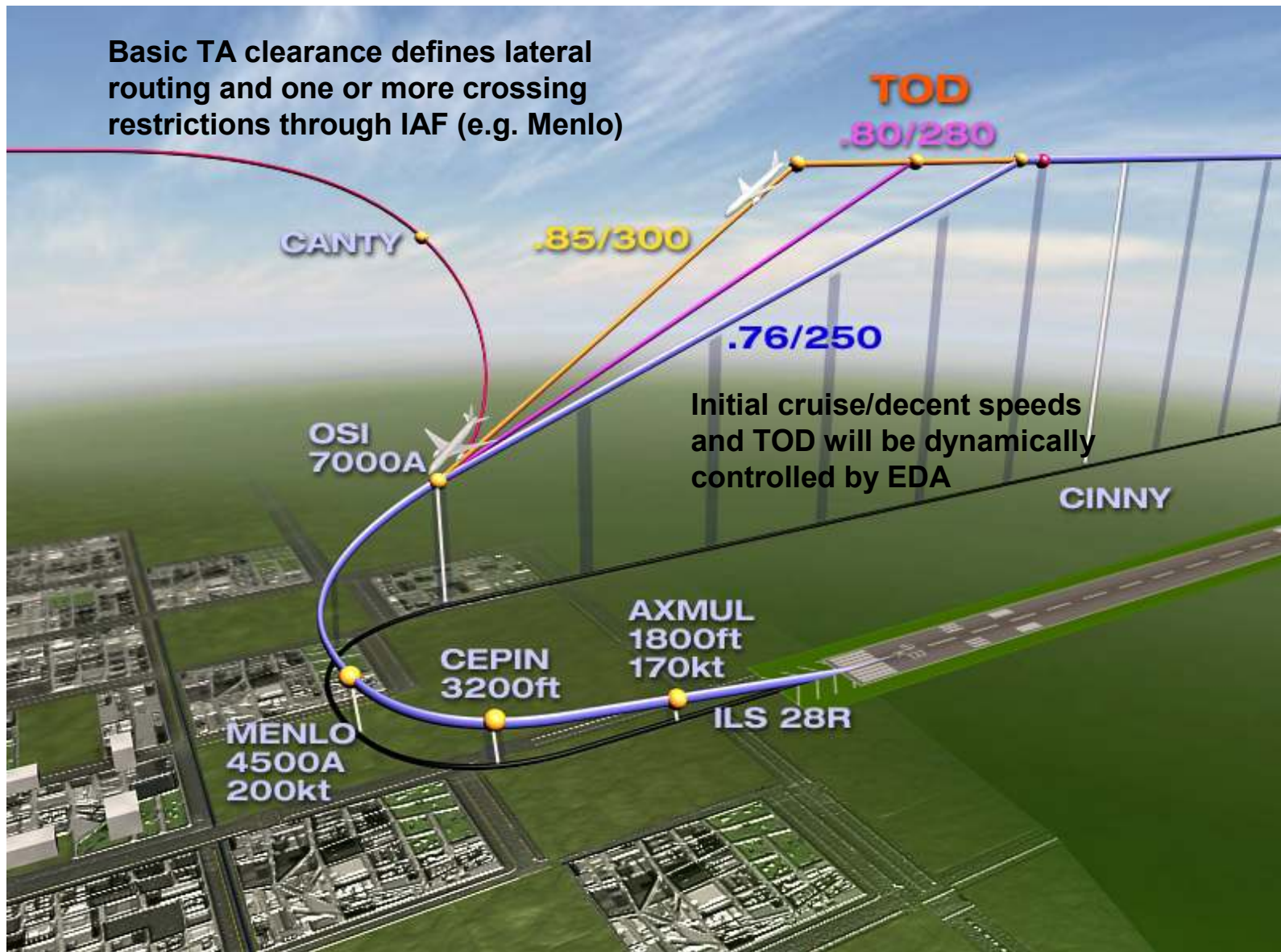
NASA Research Focus in Support of NGATS

- Conduct R&D needed for Tailored Arrival CDA operations under all traffic conditions, regardless of congestion
- Data-link and FMS technologies likely to remain core to long-term concept
- Long-term concept will exploit ATC time-based metering and strategic conflict avoidance capabilities: e.g., EDA and TMA
- NASA effort will be focused on foundational R&D:
 - Develop and prove Tailored Arrival concept for congested ops
 - ❑ Maximize flight efficiency
 - ❑ Maximize throughput
 - Extend TMA/EDA capabilities to support this concept
- Work in parallel with Boeing-led efforts to identify near-term opportunities
 - Obtain immediate benefits under accommodating conditions
 - Blaze a logical implementation path towards further-term concept

En Route/ Descent Advisor Automation



Tailored Arrival Specification



Oceanic Field Trials: Scope

- Involved a single FANS-equipped Boeing 777 flight from HNL to SFO (UAL 76), on Central-East Pacific route structure
- Early morning arrival time chosen to minimize traffic interruptions
- Data-link communications provided through FAA's newly deployed ATOP/Ocean-21 system at ZOA
- EDA prototype used to select upper-airspace speed profile to target arrival time at TRACON boundary
- Trials conducted in two phases: Aug-Sept, 2006; Dec-Jan, 2007
- 40 flight opportunities, 35 Tailored Arrival events

Trajectory Profile

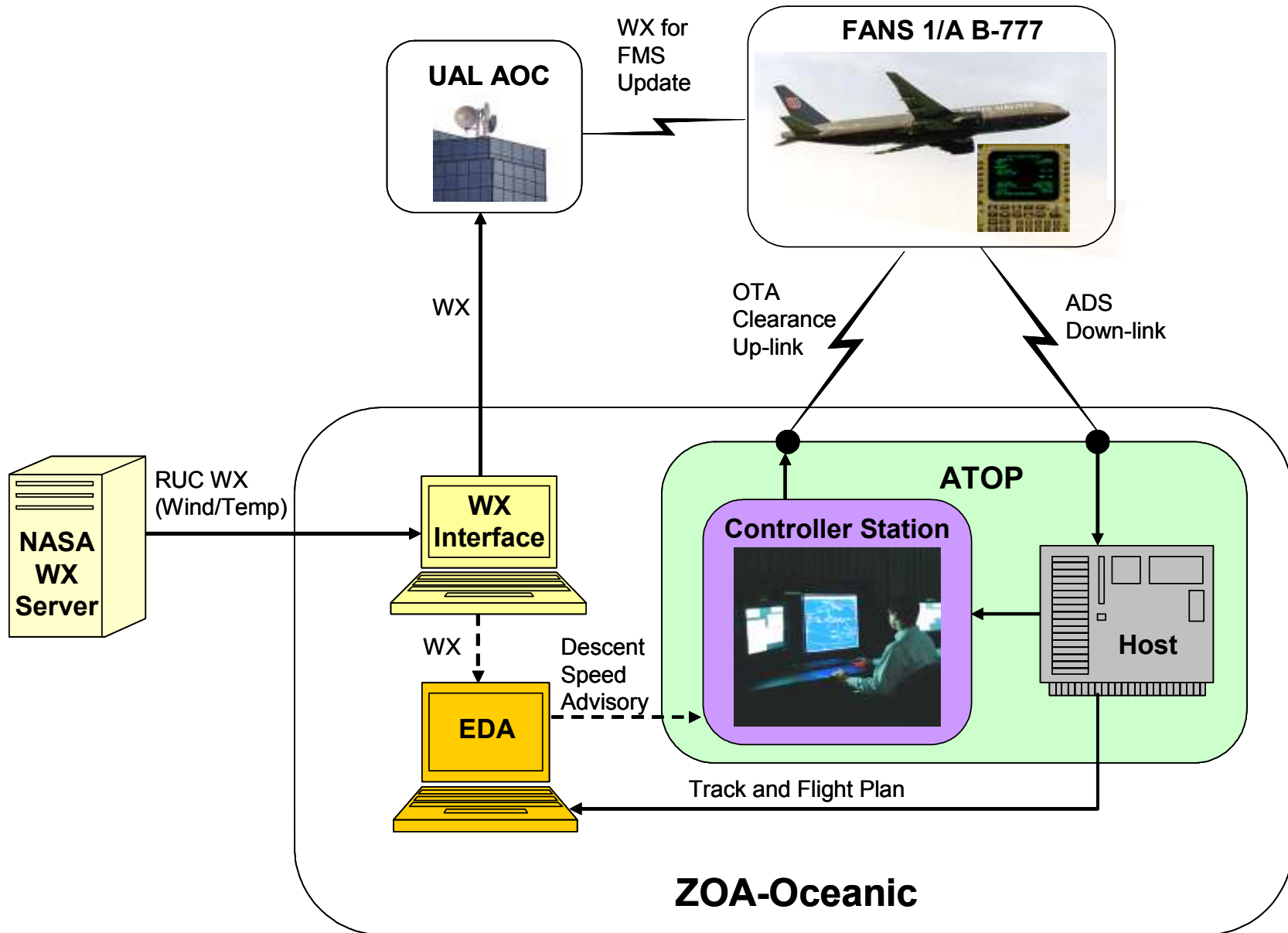
- Lateral and vertical profile constraints developed through flight simulation at UAL, Boeing, NASA Ames
- Observed how pilots managed aircraft energy state in using FMS LNAV/VNAV to control path under various wind conditions

At COSTS cleared to:

- CINNY
- BRINY 11000/240kt
- OSI 7000A/210kt
- MENLO 4500A
- ILS28R Approach
- Runway 28R

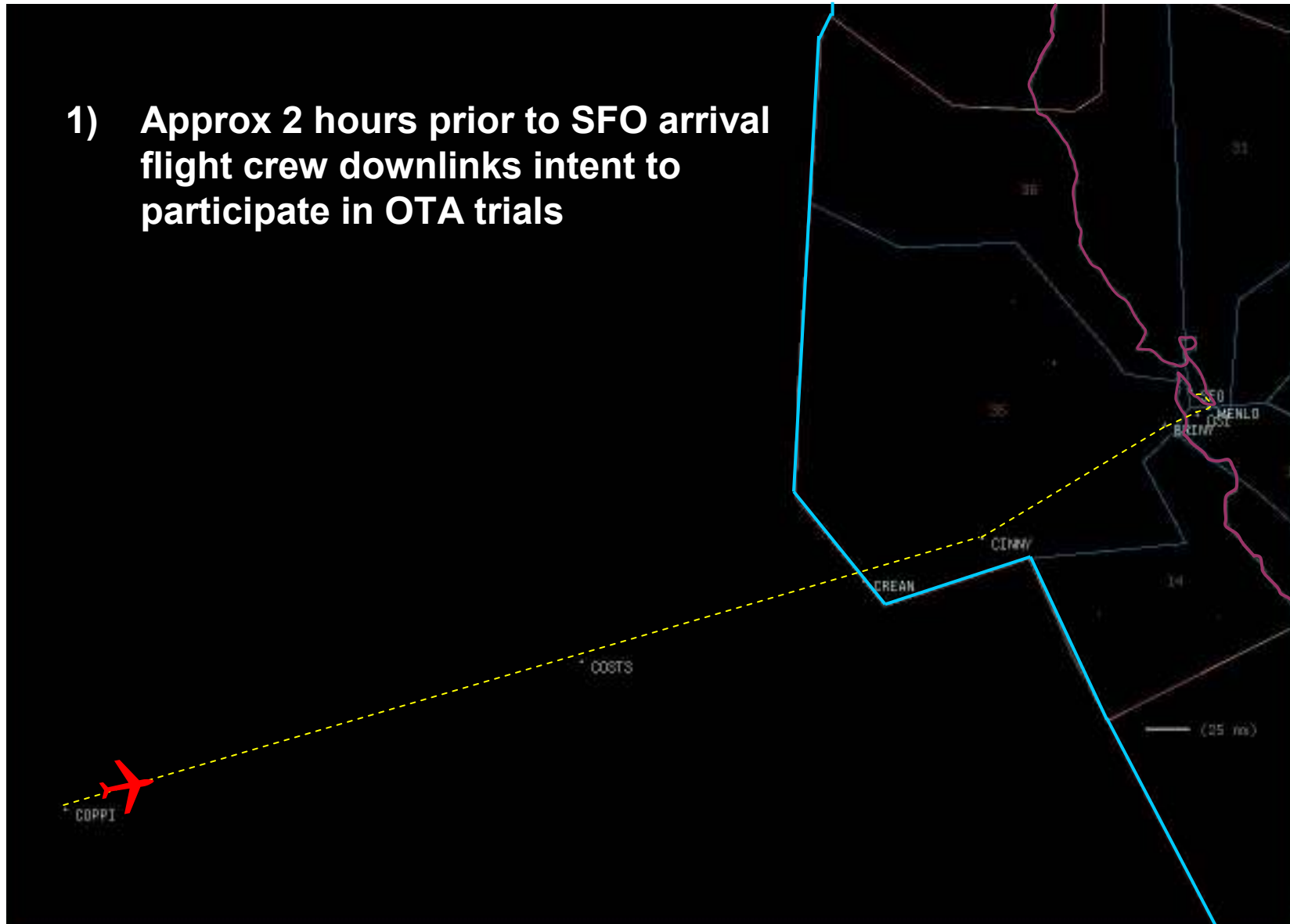


Systems Involved

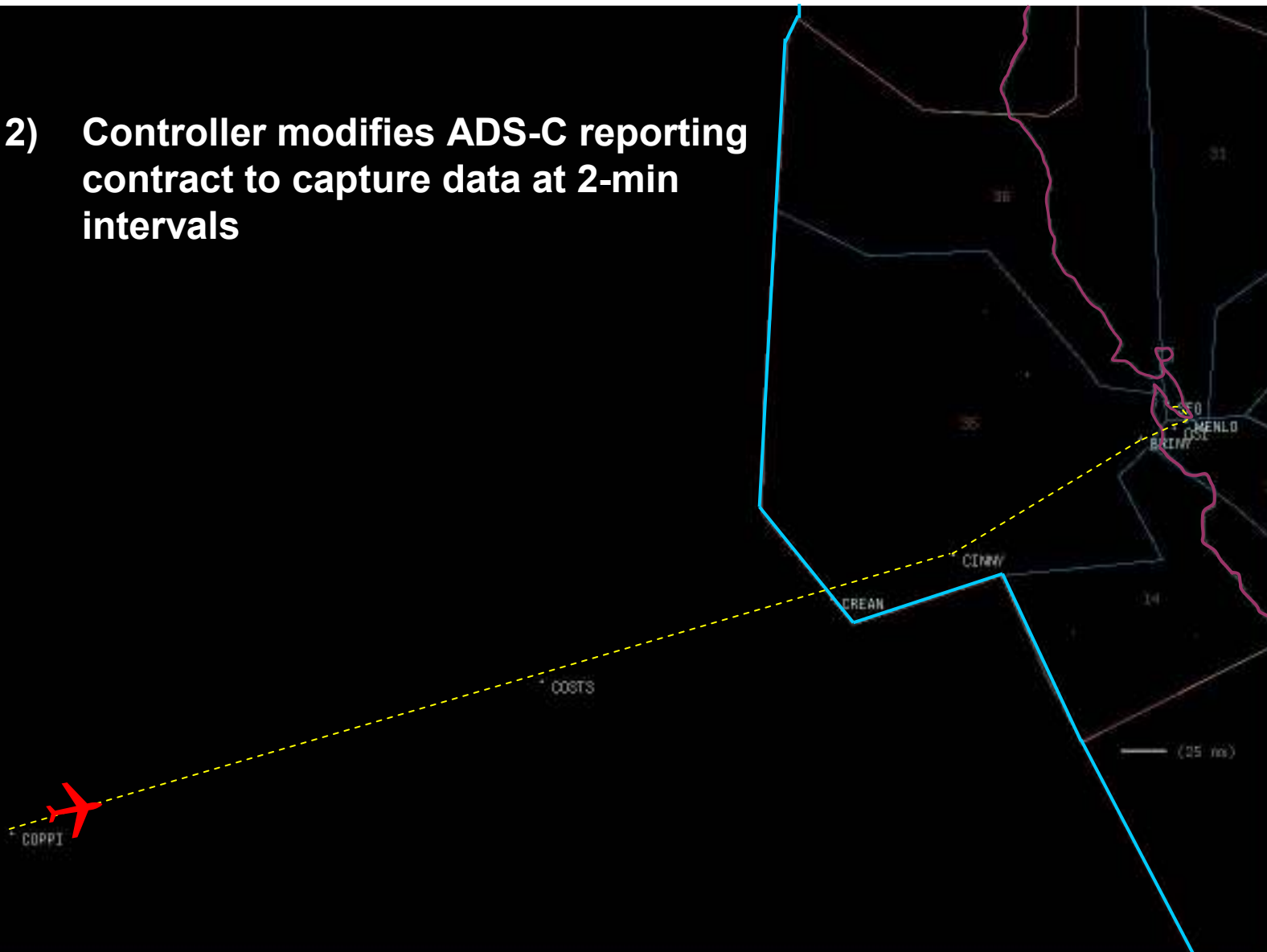


Basic Event Series

- 1) Approx 2 hours prior to SFO arrival flight crew downlinks intent to participate in OTA trials

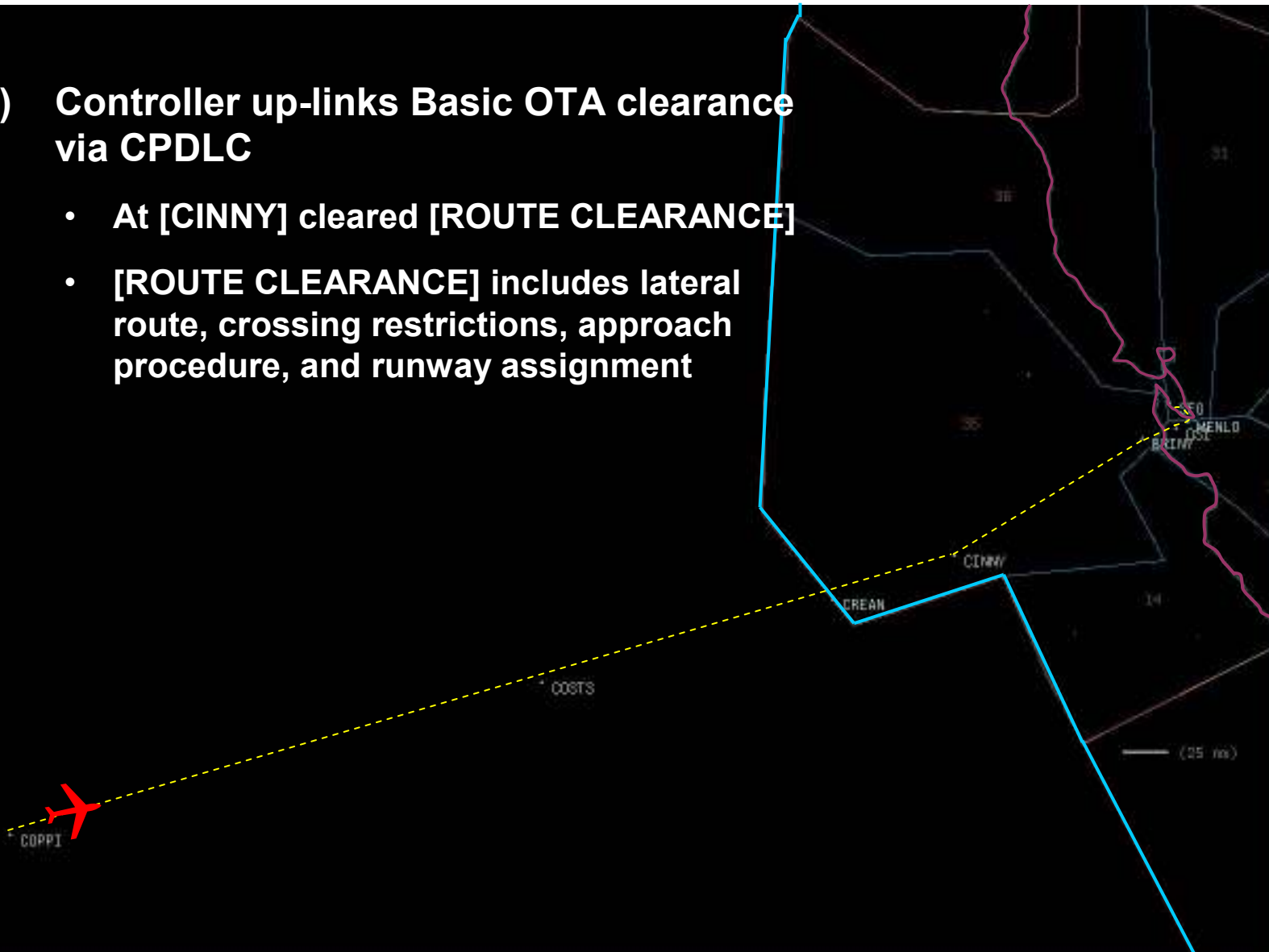


2) Controller modifies ADS-C reporting contract to capture data at 2-min intervals



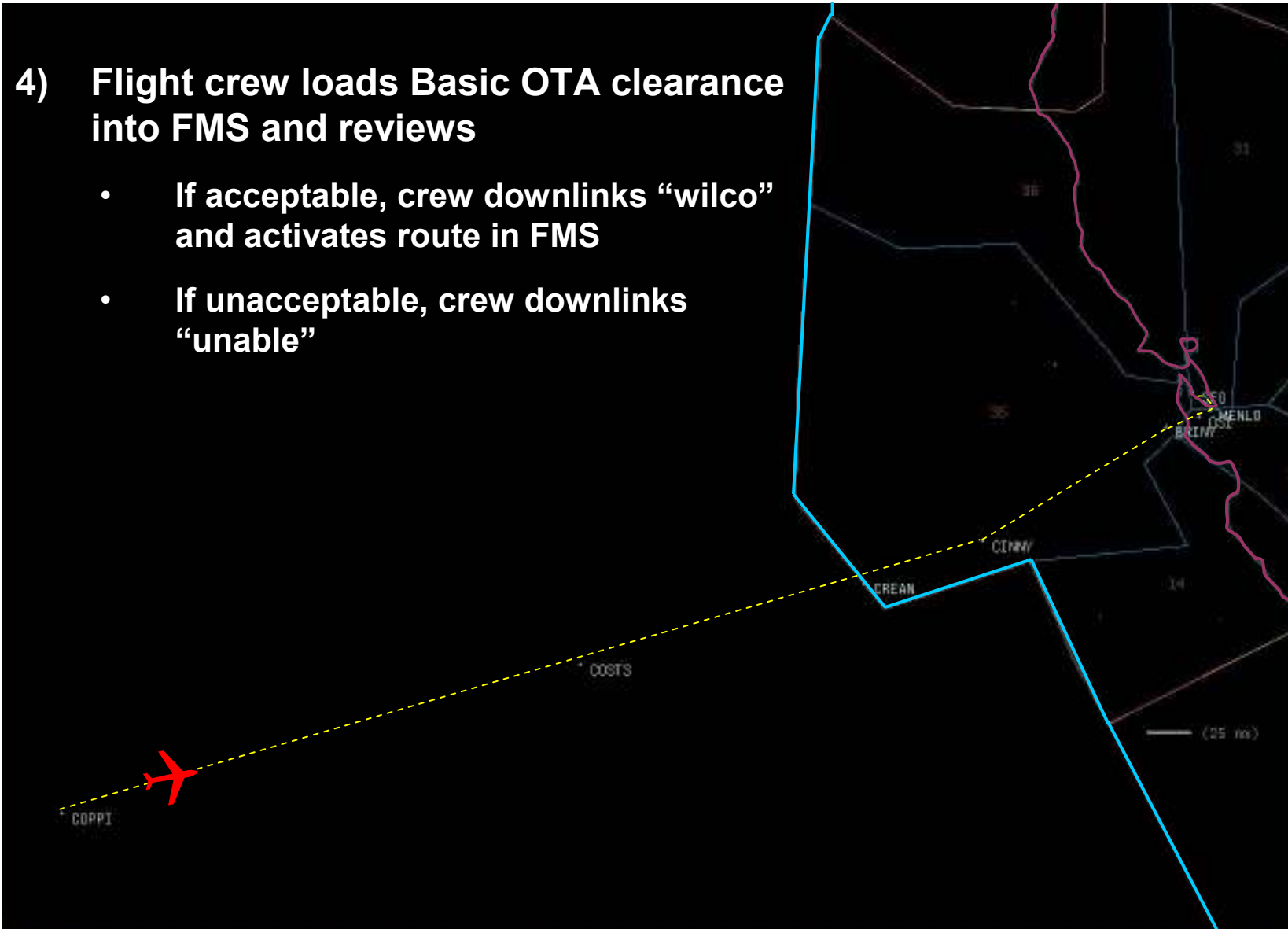
3) Controller up-links Basic OTA clearance via CPDLC

- At [CINNY] cleared [ROUTE CLEARANCE]
- [ROUTE CLEARANCE] includes lateral route, crossing restrictions, approach procedure, and runway assignment



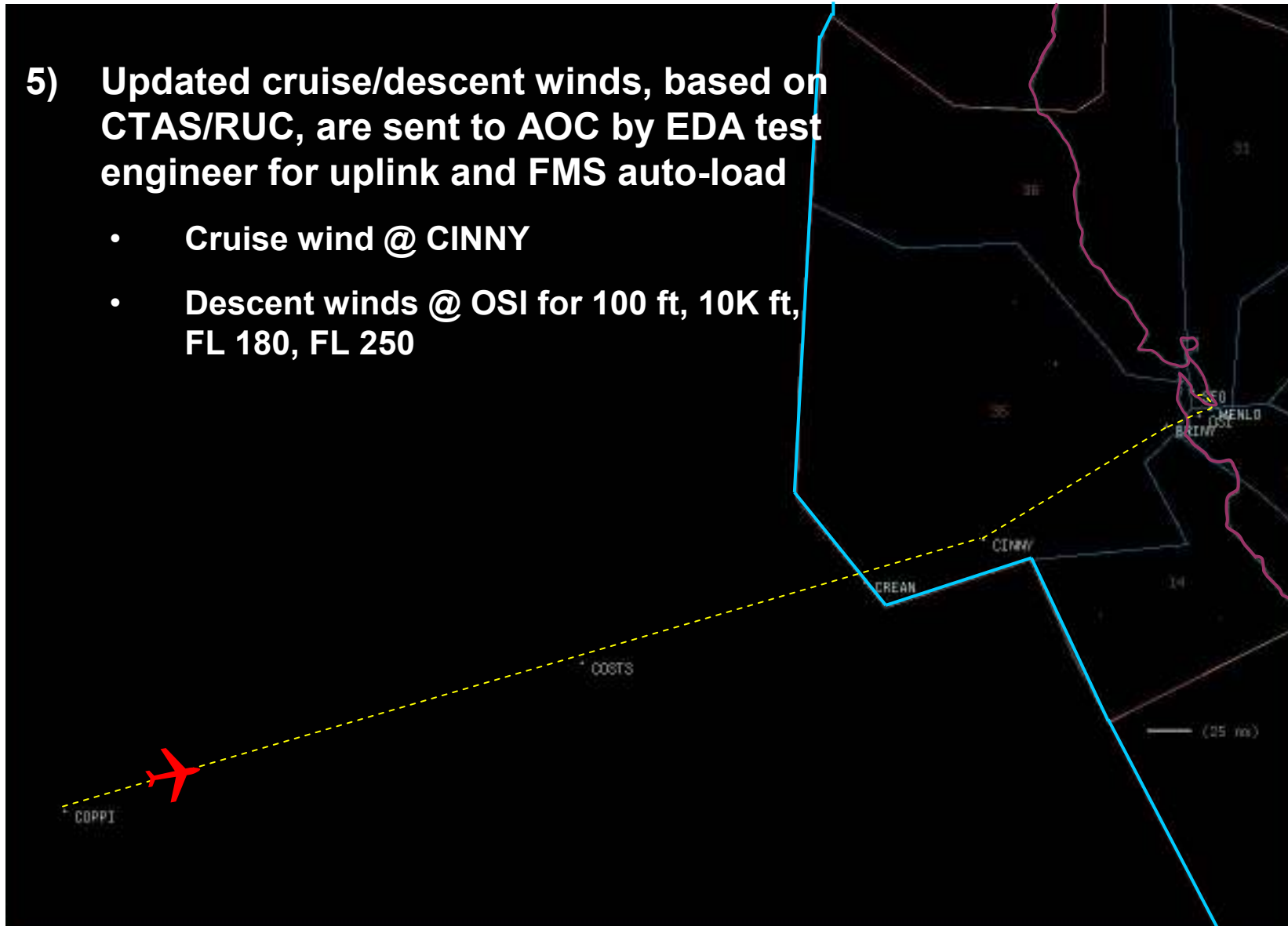
4) Flight crew loads Basic OTA clearance into FMS and reviews

- If acceptable, crew downlinks “wilco” and activates route in FMS
- If unacceptable, crew downlinks “unable”



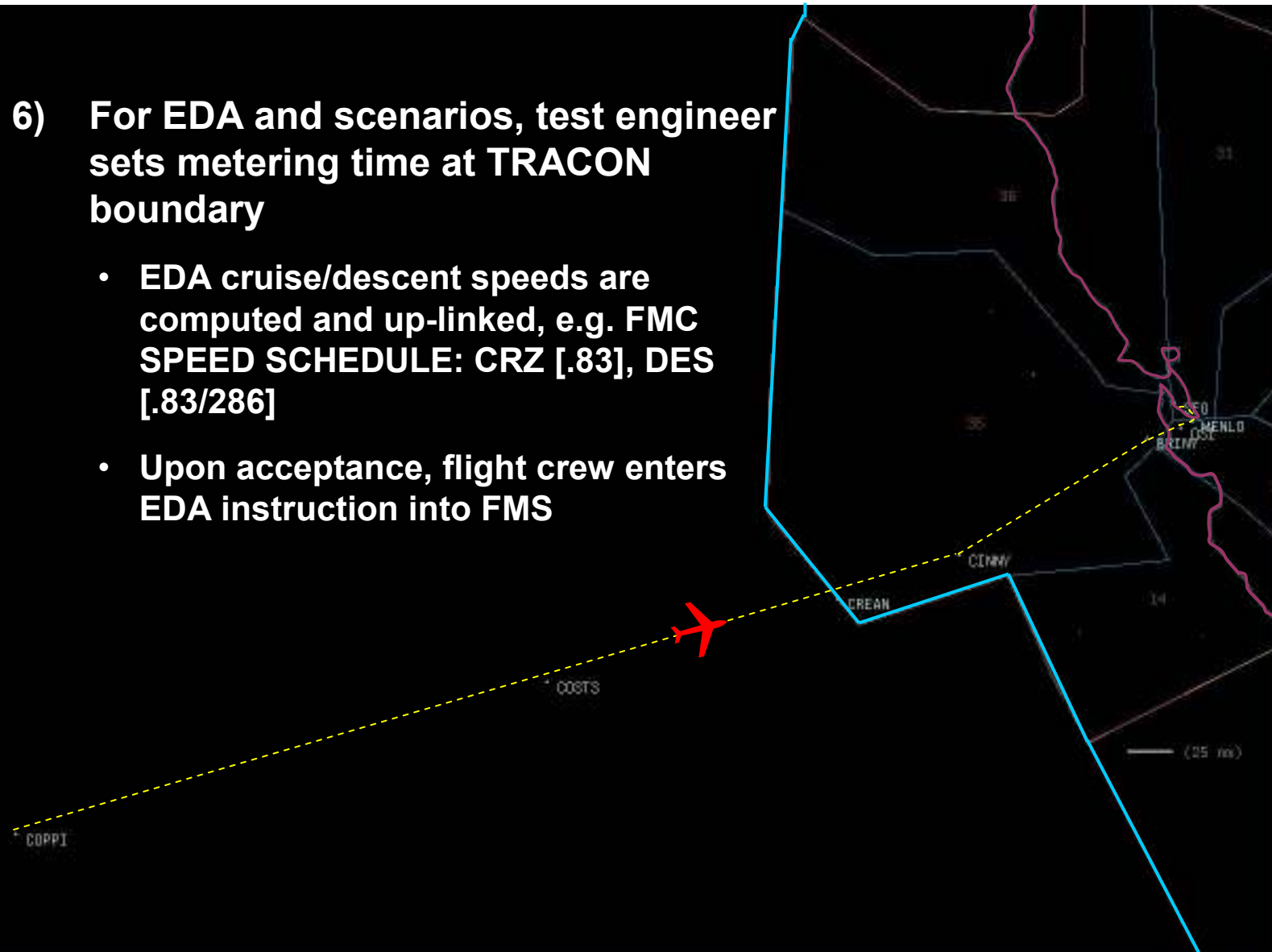
5) Updated cruise/descent winds, based on CTAS/RUC, are sent to AOC by EDA test engineer for uplink and FMS auto-load

- Cruise wind @ CINNY
- Descent winds @ OSI for 100 ft, 10K ft, FL 180, FL 250

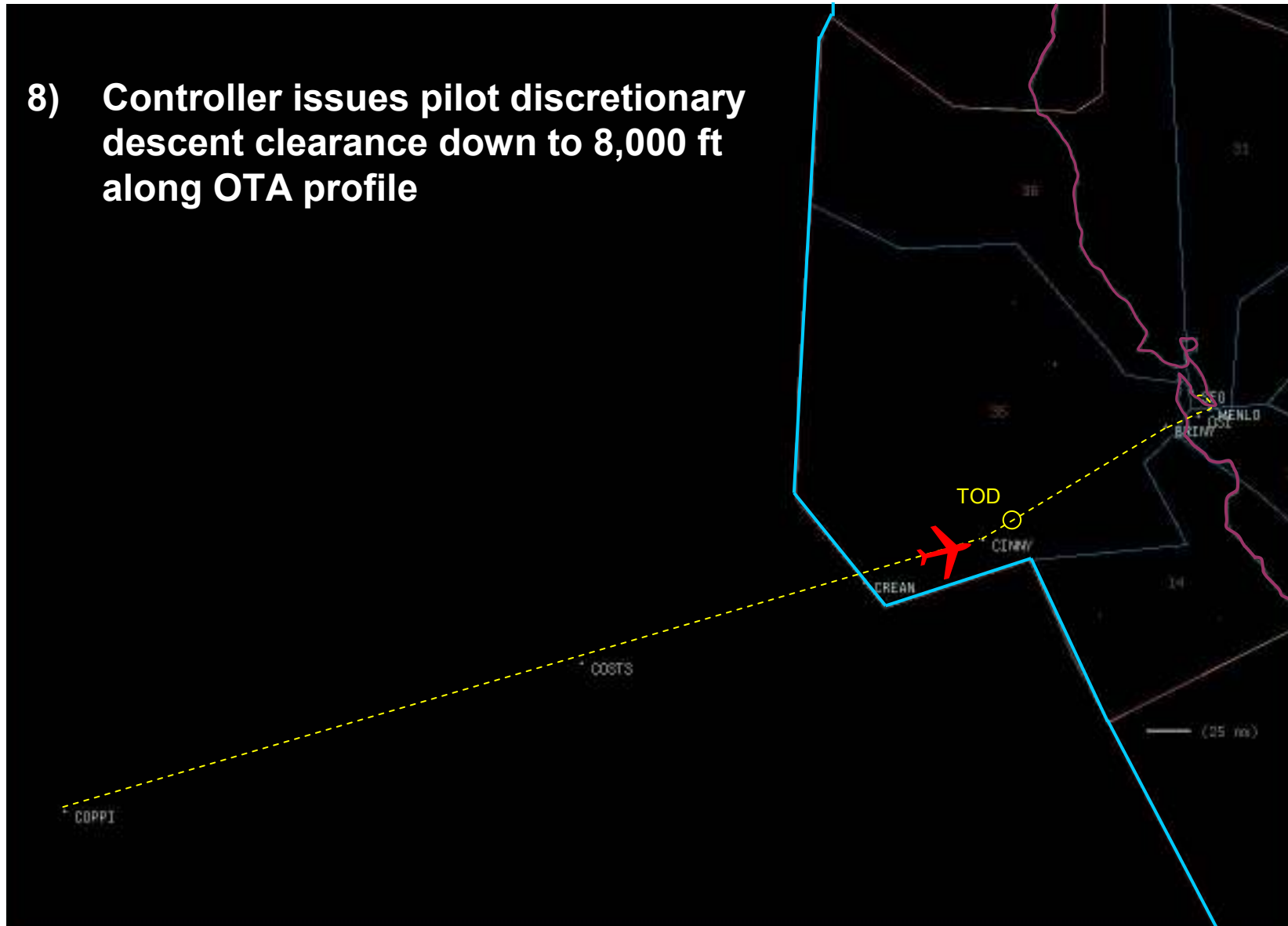


6) For EDA and scenarios, test engineer sets metering time at TRACON boundary

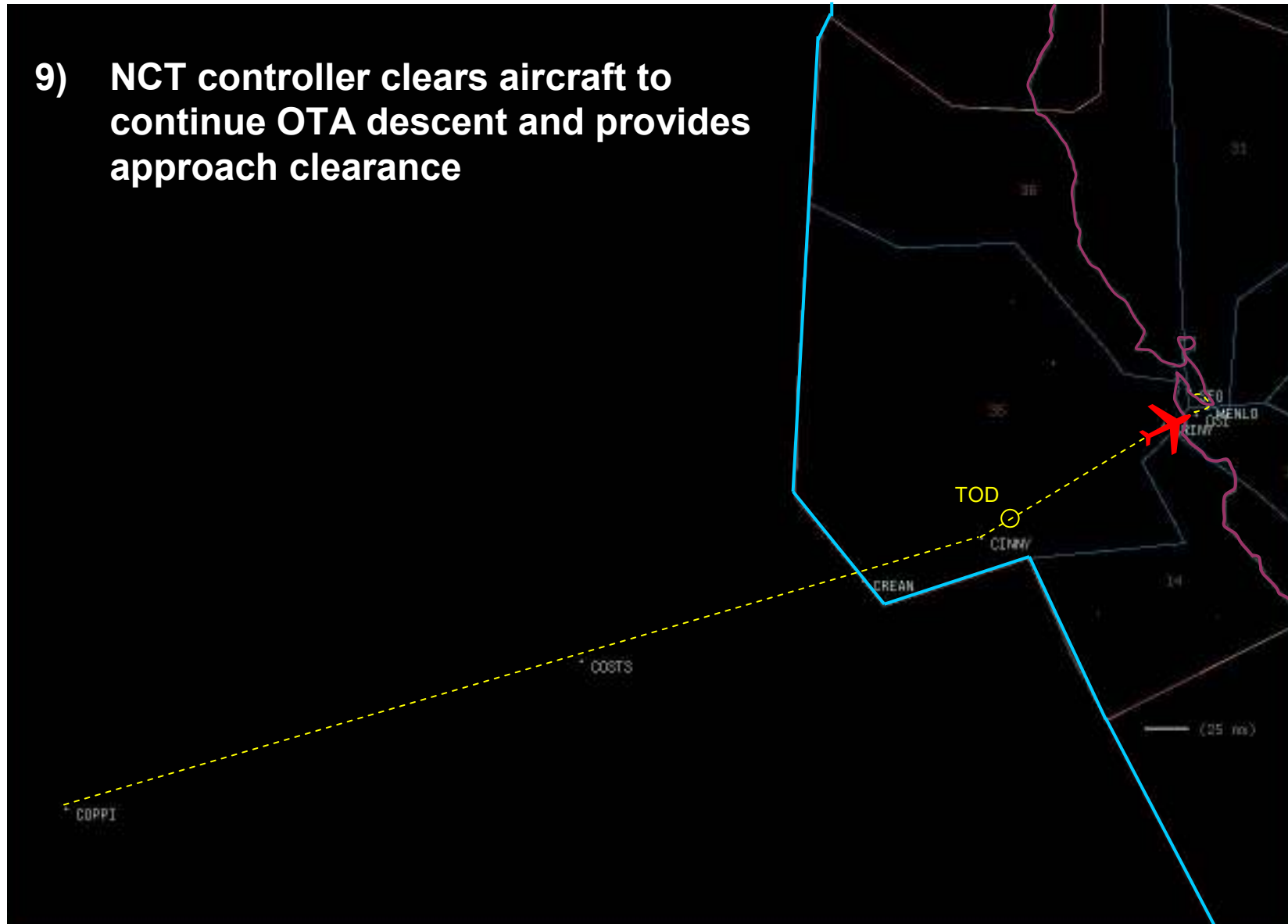
- EDA cruise/descent speeds are computed and up-linked, e.g. FMC SPEED SCHEDULE: CRZ [.83], DES [.83/286]
- Upon acceptance, flight crew enters EDA instruction into FMS



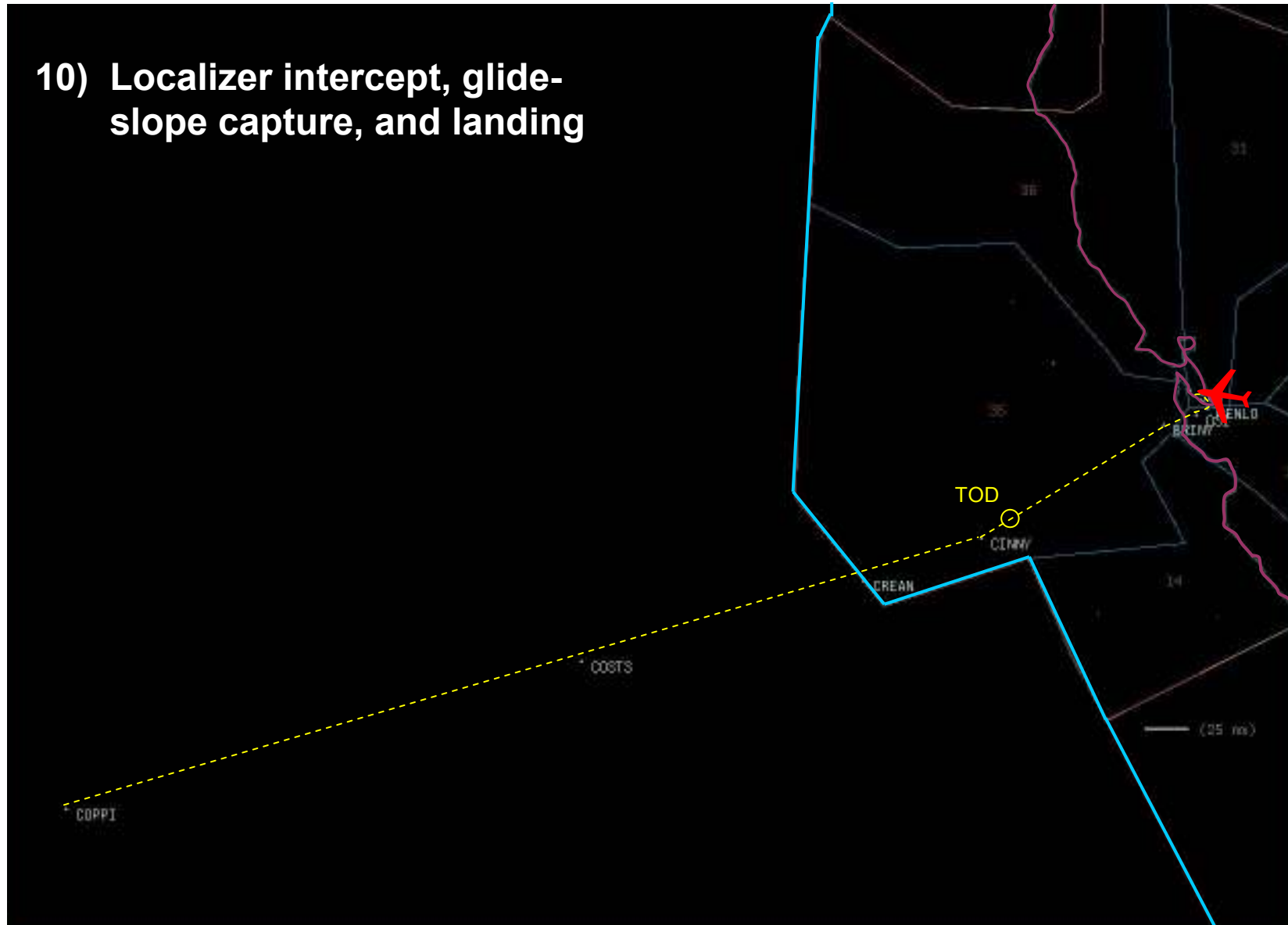
- 8) Controller issues pilot discretionary descent clearance down to 8,000 ft along OTA profile



9) NCT controller clears aircraft to continue OTA descent and provides approach clearance



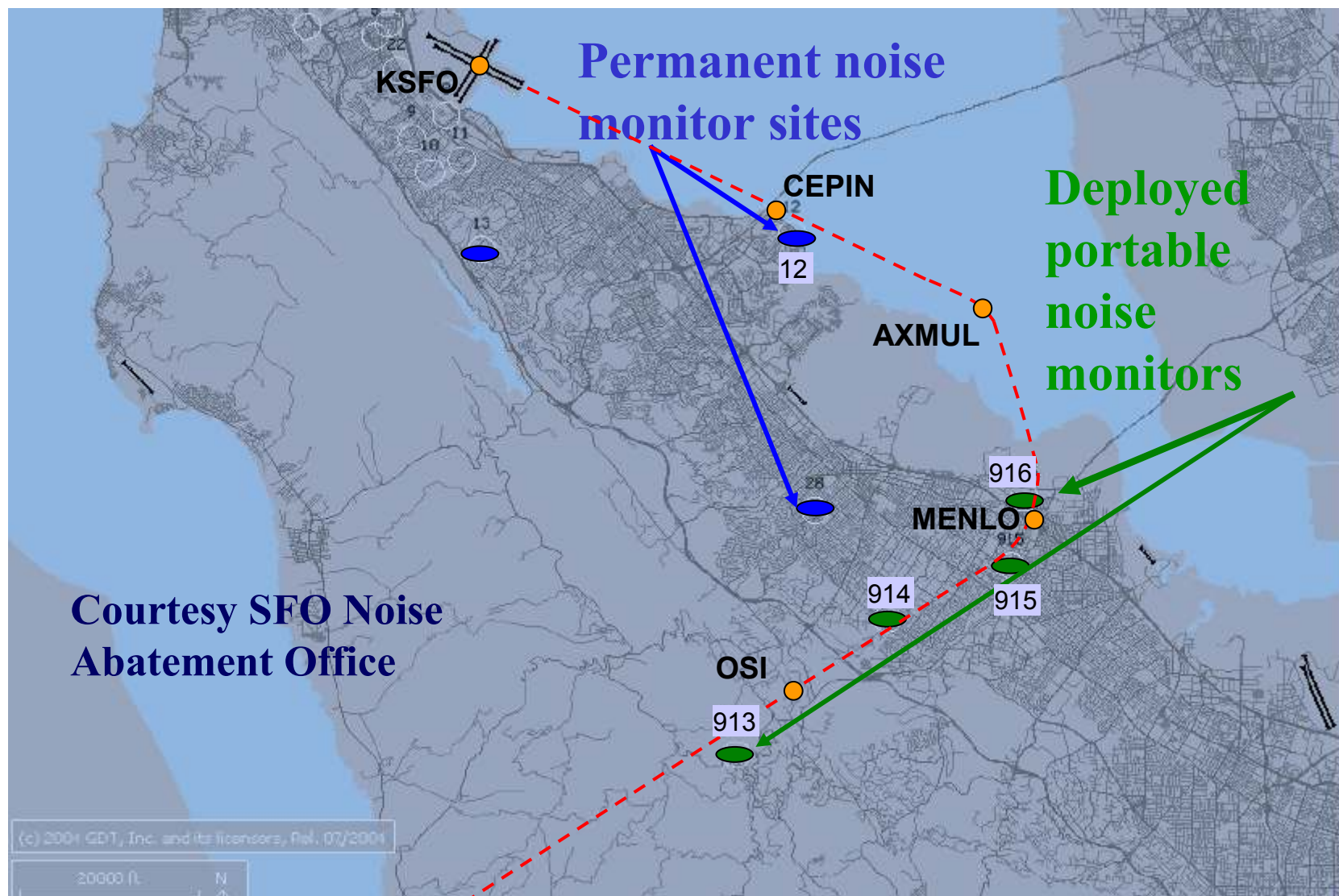
10) Localizer intercept, glide-slope capture, and landing



Data Collection (Quantitative)

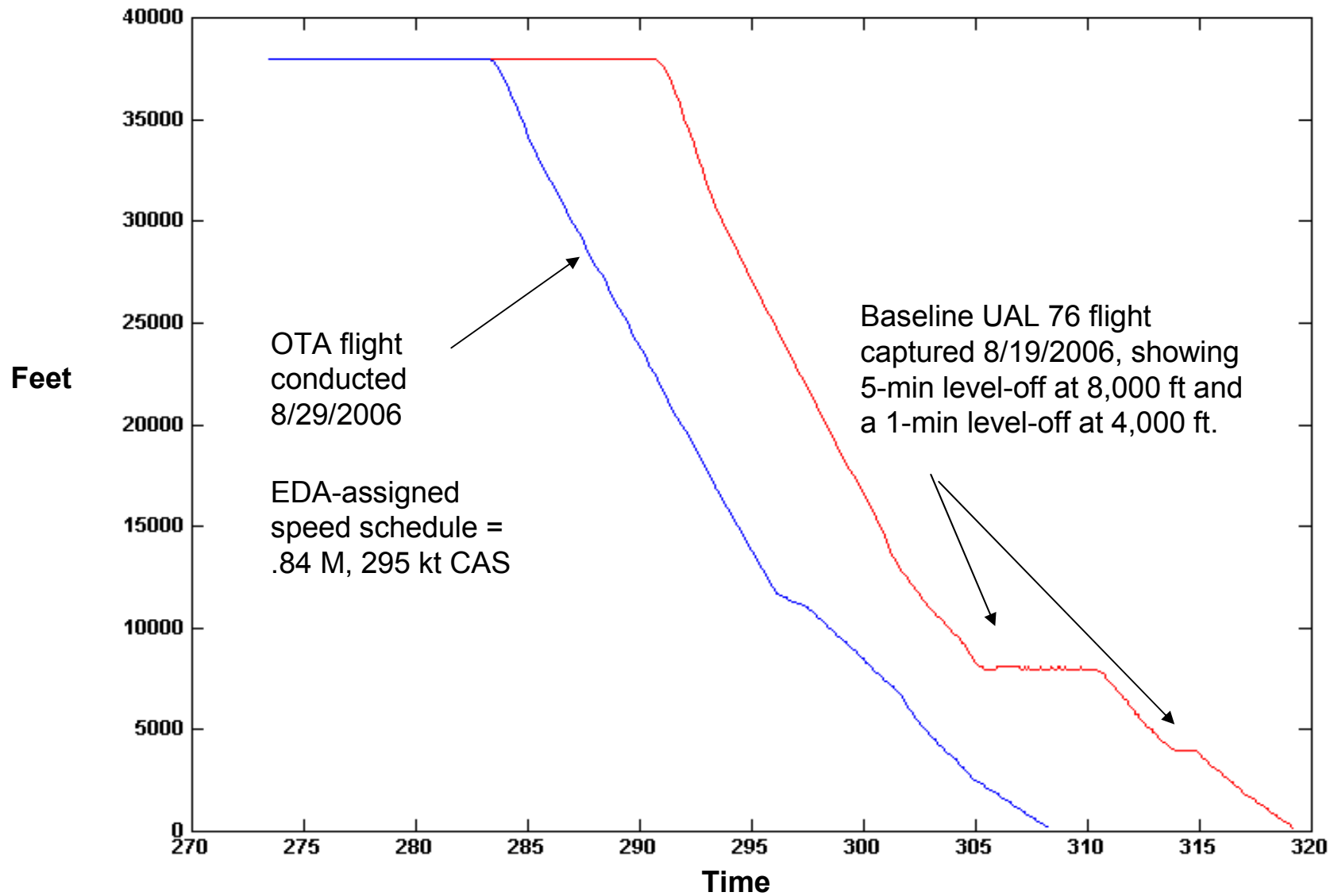
Source	Elements	Frequency
ADS-C	<ul style="list-style-type: none"> • Position group (lat/long, altitude, time stamp) • Weather group (wind speed, wind direction, temperature) • Earth reference group (ground speed, vertical rate, track angle) • Air reference group (Mach, heading) • Projected intent (ETAs at all downstream waypoints) 	1/ (2 min)
ZOA Host Track and FP	<ul style="list-style-type: none"> • Position • Ground speed, track heading 	1/(12 sec)
NCT ARTS Track and FP	<ul style="list-style-type: none"> • Position • Ground speed, track heading 	1/ (5 sec)
EDA outputs	<ul style="list-style-type: none"> • Trajectory predictions • Advisories 	Event based
RUC	<ul style="list-style-type: none"> • Grid wind speed/direction • Grid T, P 	1/hr
SFO Microphone	<ul style="list-style-type: none"> • Noise level 	10 Hz

Microphone Deployment



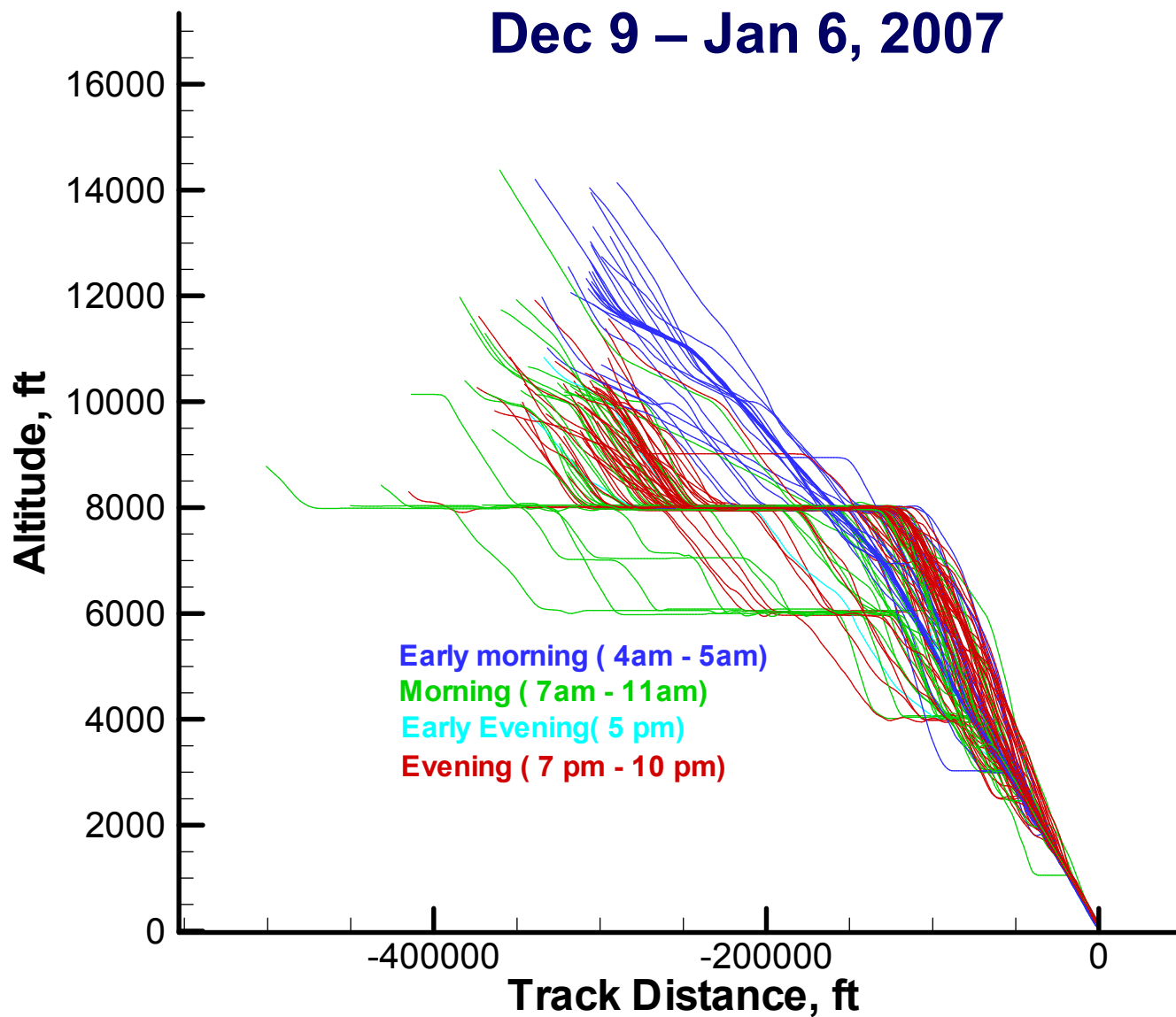
Some Initial Findings

Example Vertical Profiles



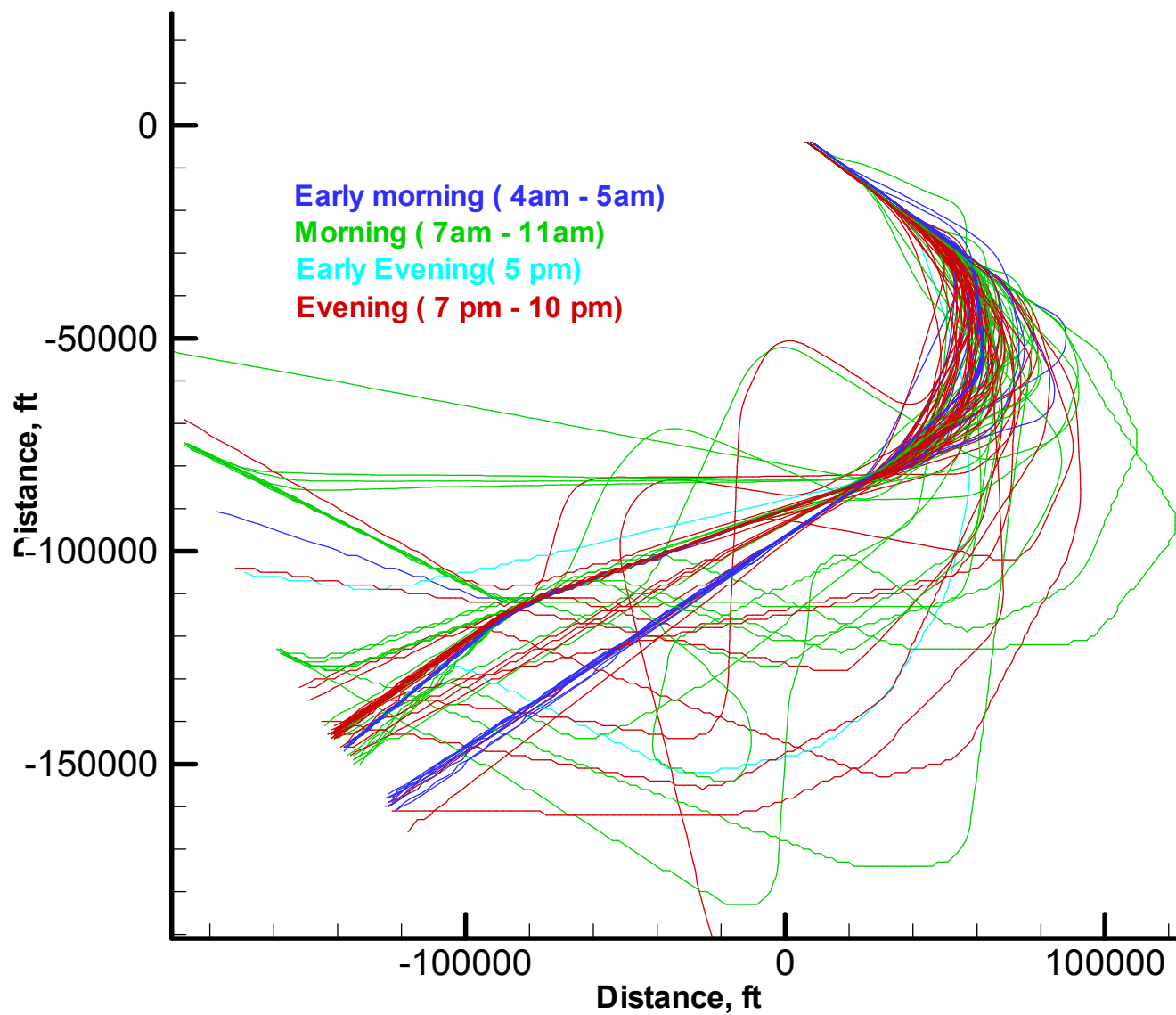
All B-777 CEP Track C Vertical Tracks

Dec 9 – Jan 6, 2007

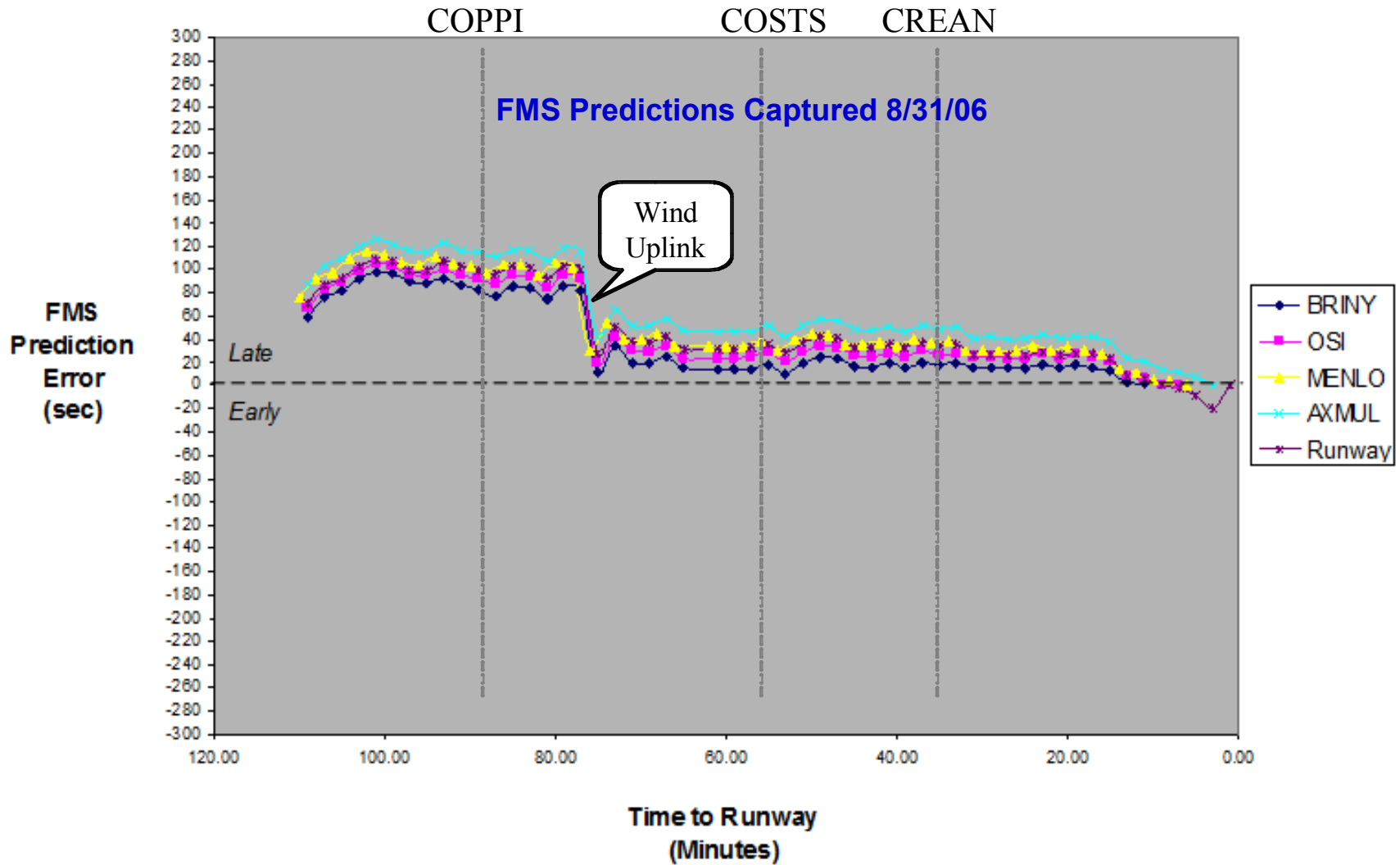


All B-777 CEP Track C Lateral Tracks

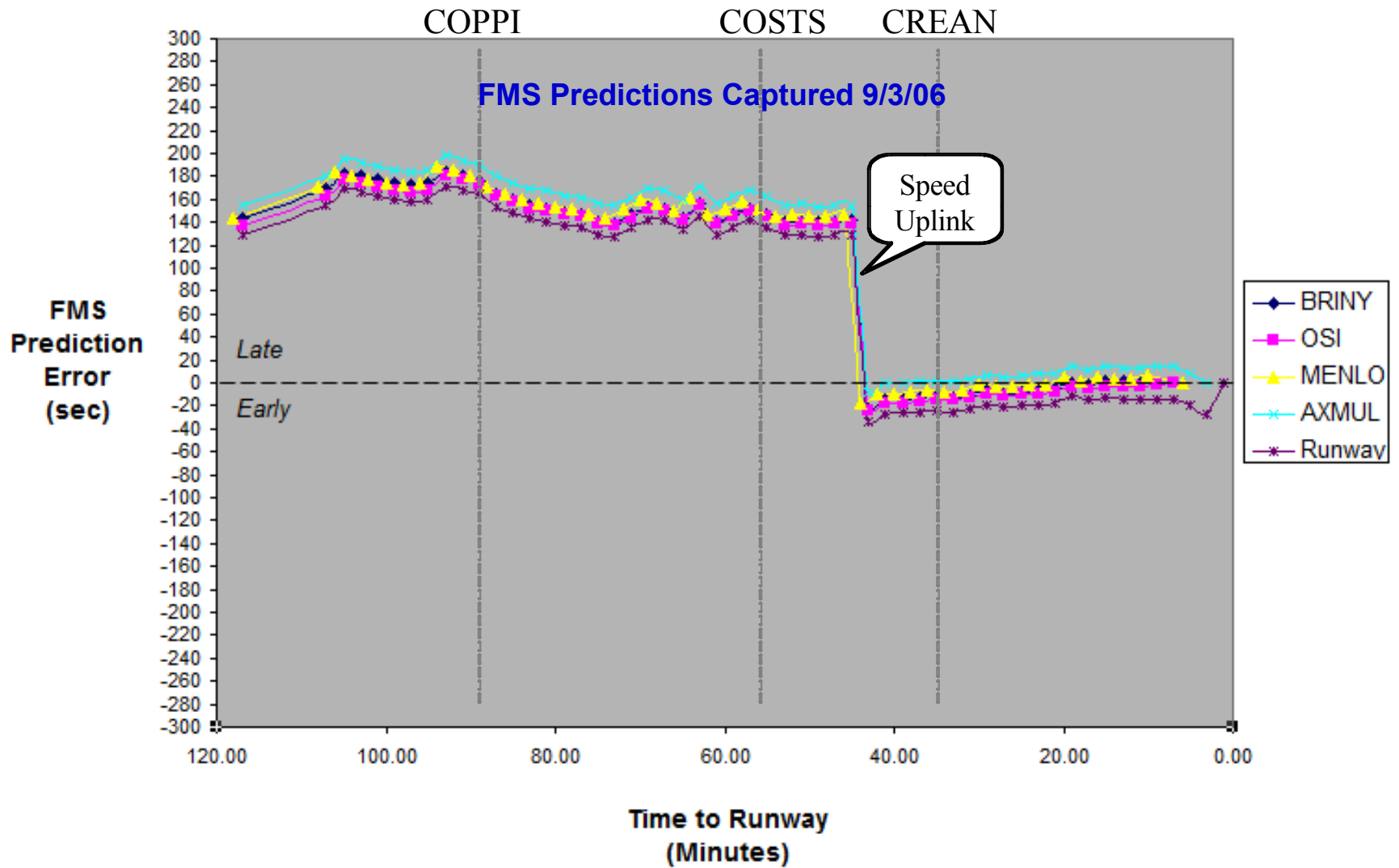
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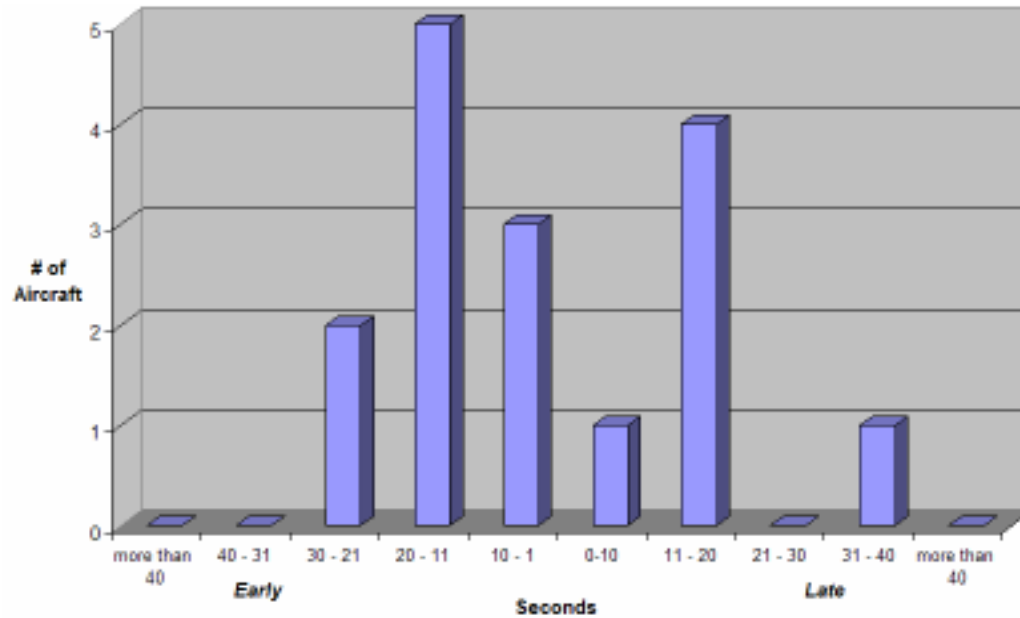
FMS Trajectory Prediction



FMS Trajectory Prediction

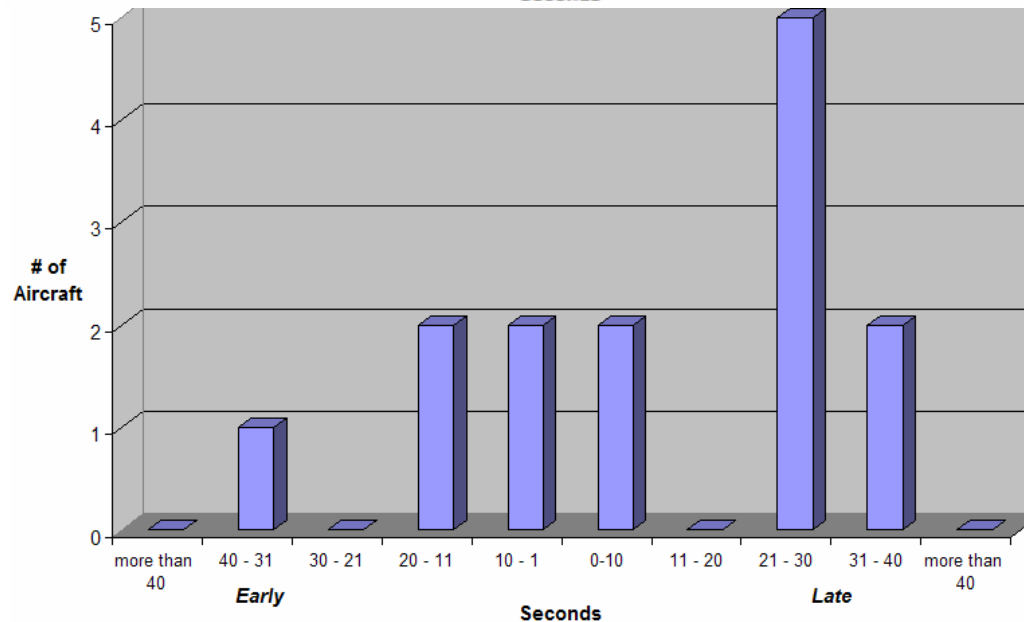


FMS and EDA Time Prediction Comparison



FMS Time Prediction at CREAN to BRINY:

Mean = 3 seconds early
Max Early = 35 seconds
Max Late = 38 seconds
Std Dev = 20



EDA Time Prediction at CREAN to BRINY:

Mean = 9 seconds late
Max Early = 34 seconds
Max Late = 38 seconds
Std Dev = 22

Summary

- Tailored Arrivals has potential for economic and environmental benefits: fuel, noise, and emissions reduction through CDA
- Challenge is to plan and execute CDA trajectories in congested traffic conditions. *This is where the benefits are!*
- Problem requires predictive, ground-based automation for generating conflict-free, flow-conformant trajectory solutions
- EDA automation is a start, but further capabilities needed to support further-term Tailored Arrivals concept
- Air/ground oceanic infrastructure has provided excellent environment for validating Tailored Arrivals procedures, communications and system interoperability
- SFO results analysis in progress to validate benefit assumptions and establish operational feasibility
- Success of SFO trials has provided NASA the incentive needed to continue R&D efforts in this important area