Tailored Arrivals

Elements of this presentation courtesy of Airservices Australia, the Air Traffic Alliance, Eurocontrol, LVNL, Martinair, NASA Ames, Qantas, Transavia, United & other Tailored Arrivals partners

Rob Mead
9 Jan 2007

Topics

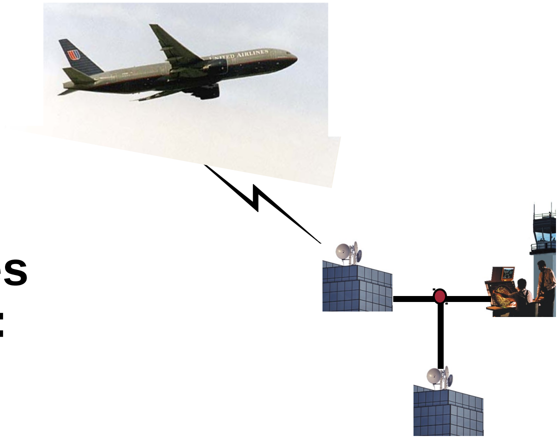
- **Tailored Arrivals overview**
- **Tailored Arrivals development framework**
- **Sample technical results**
  - **focus on latest trials**
- **Applicable areas of discussion**
- **Conclusion**

Tailored Arrivals Overview

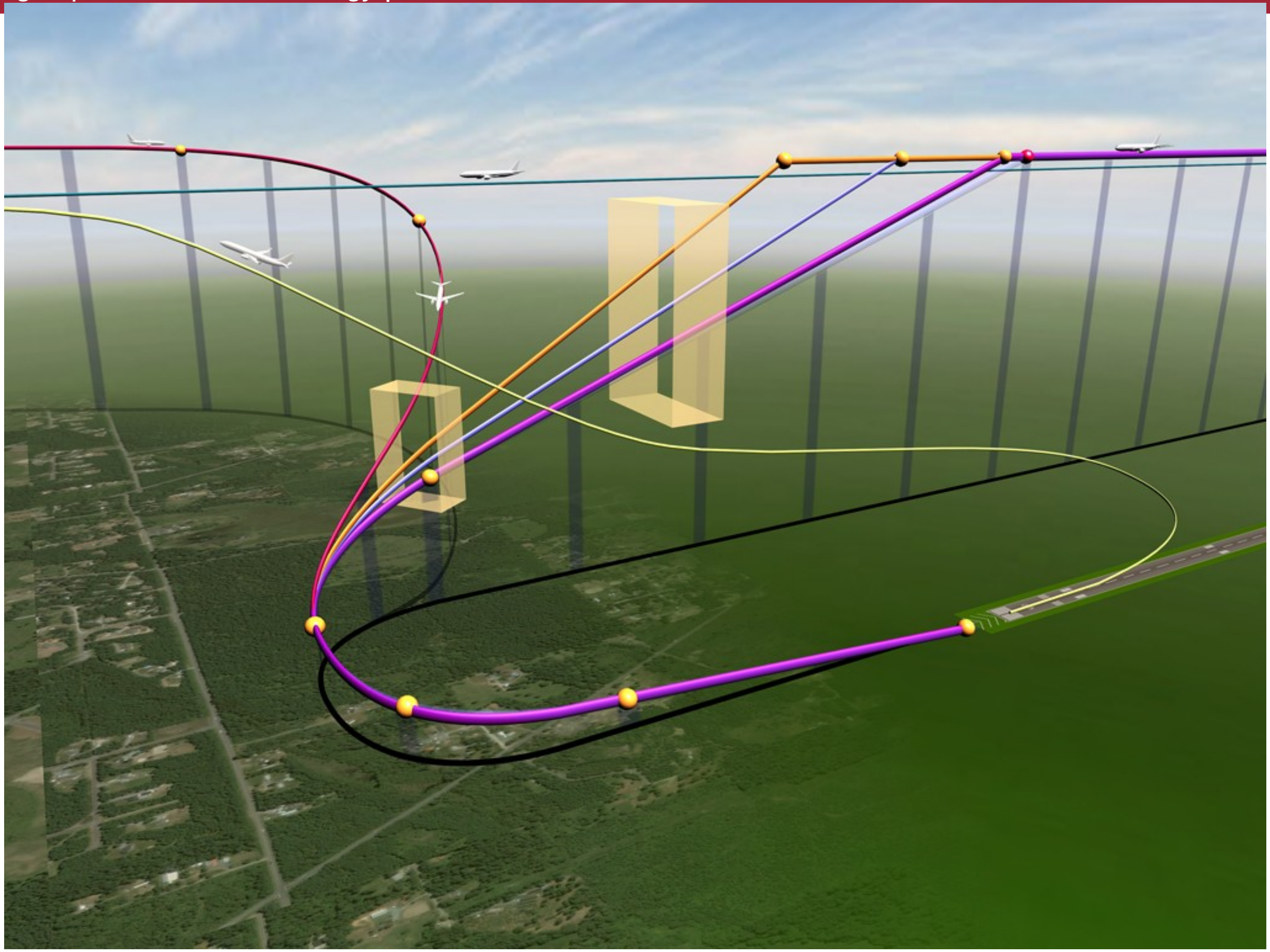
What is a Tailored Arrival?

Ideally: A smooth, efficient descent from cruise altitude to runway enabled through use of existing aircraft automation

- **Final cruise segment routing and descent profile are tailored to achieve waypoint arrival times required for spacing**
  - **Requires coordination across ATC boundaries**
- **Delivered by data-link well prior to TOD**
- **Loaded into and flown by aircraft FMS, achieving a continuous, near idle descent**
- **New ground automation generates custom routes that are reviewed and uplinked by controllers to:**
  - **Avoid conflicts**
  - **Meet sequence and schedule constraints**
  - **Avoid weather, terrain, and restricted airspace**
- **Reduces workload and the potential for pilot & controller error**
  - **Allows pilots to take full advantage of existing aircraft automation**
  - **New ATC automation tools aid controller**
  - **Reduces VHF congestion – factor in many incidents, multiple accents**



Tailored Arrivals

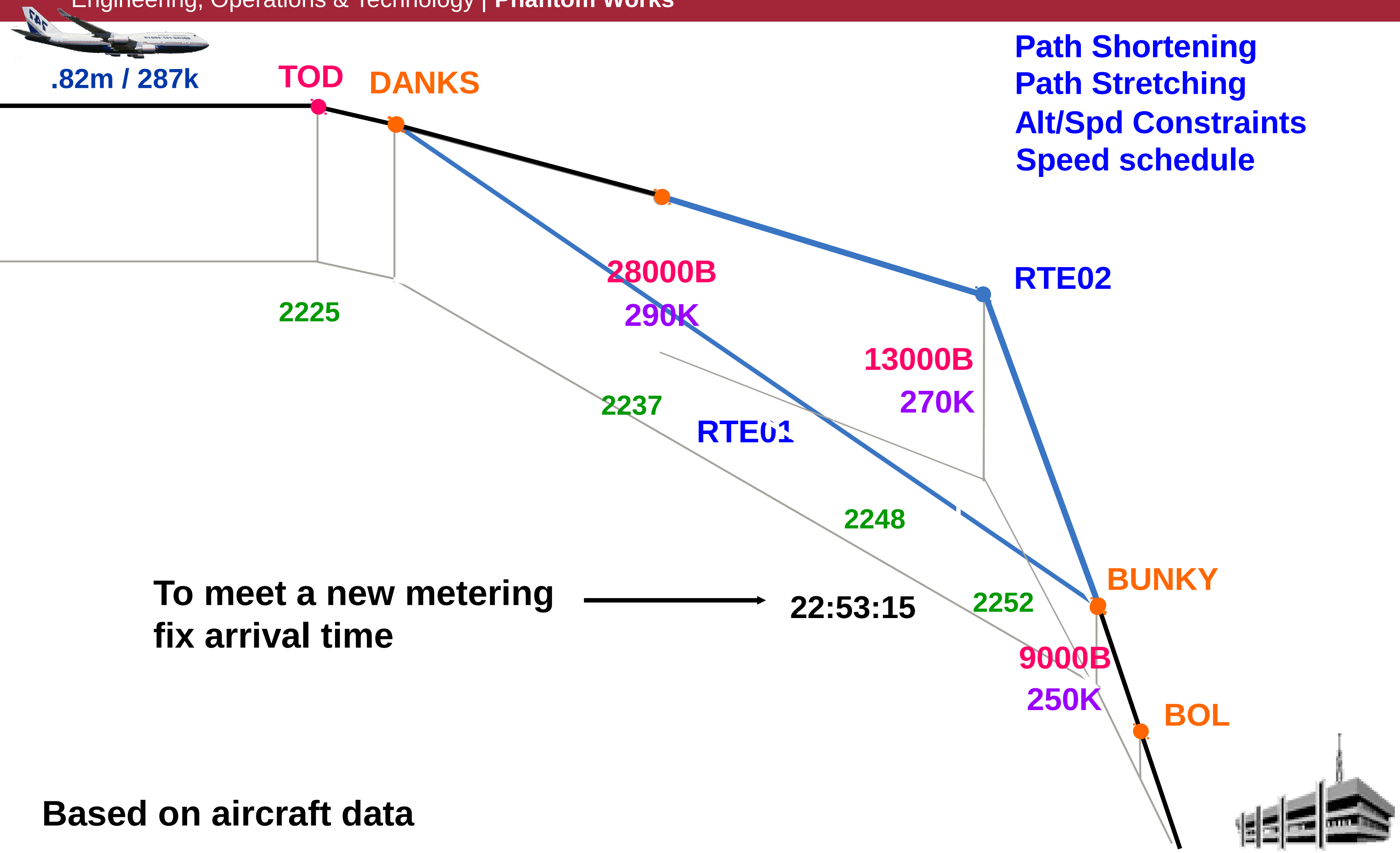


- **Clearances based on merge point time delivered prior to TOD for maximum use of automation**
- **“Windows” used to ensure separation from other streams, and to optimize for a/c type**
- **Lower fuel burn, lower environmental impact, increased predictability**

Tailored Arrival Components

Engineering, Operations & Technology | **Phantom Works**

Path Shortening
Path Stretching
Alt/Spd Constraints
Speed schedule



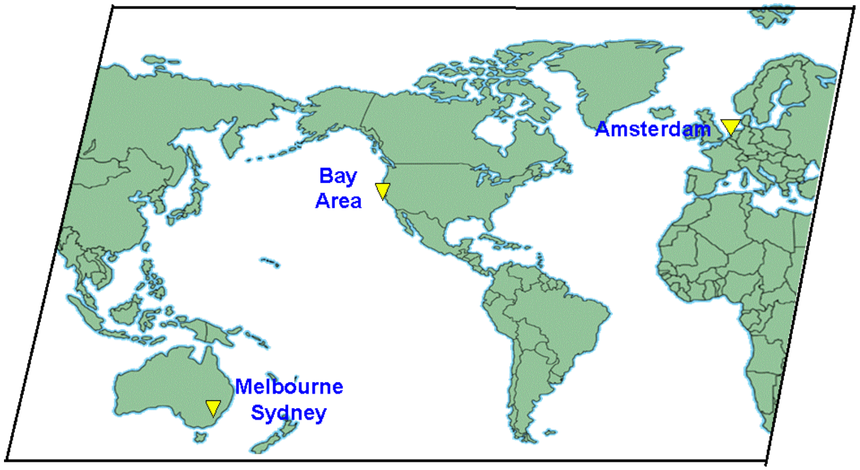
To meet a new metering fix arrival time → **22:53:15**

Based on aircraft data

Development framework

Tailored Arrivals Development framework

Engineering, Operations & Technology | **Phantom Works**



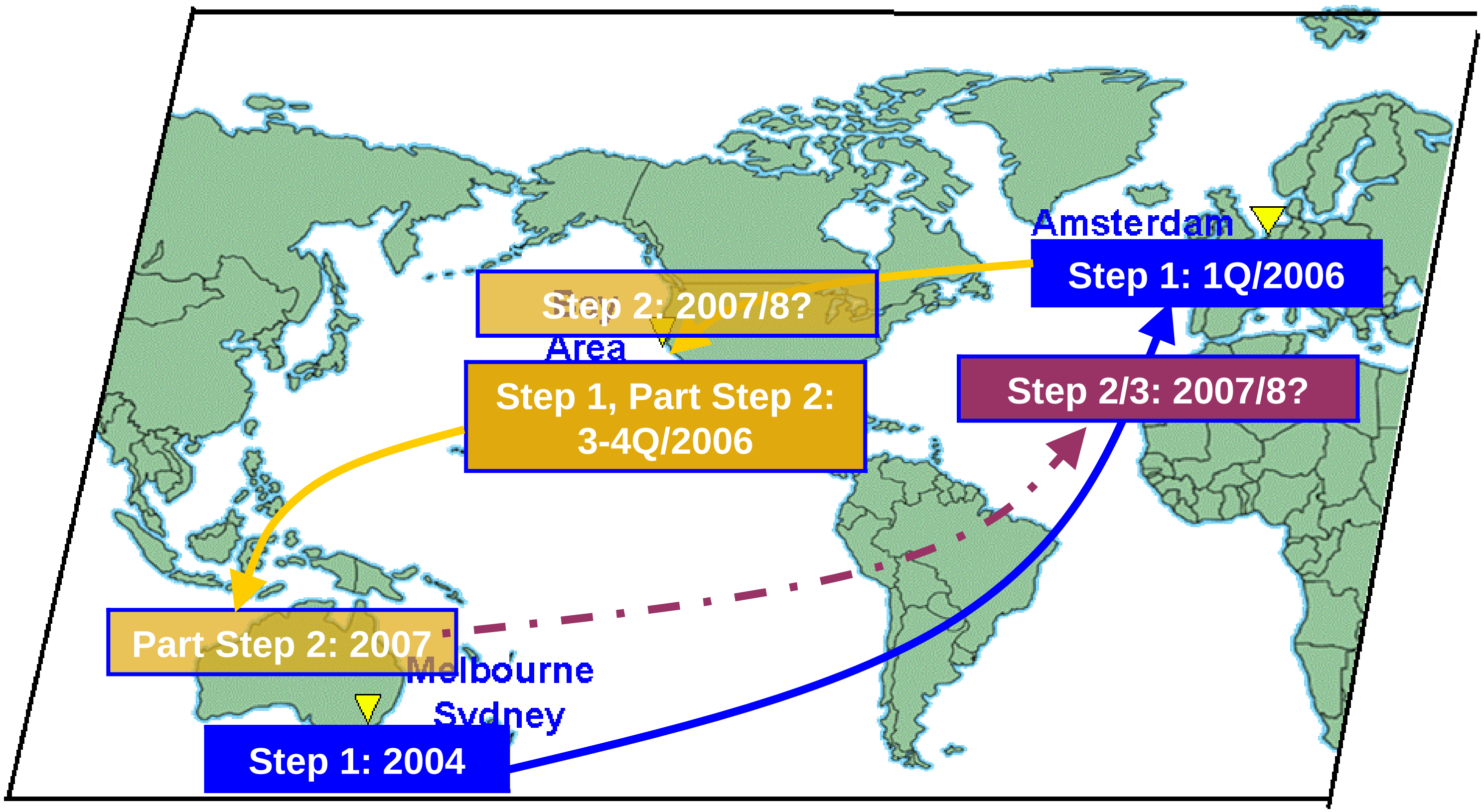
General Format for development

- **Step 1**
  - Verify and demonstrate a/c capability to follow pre-determined profiles and achieve predicted times
  - Begin airspace integration
    - cross-center/sector clearances
- **Step 2**
  - Routine use of pre-defined profiles
    - Supports ground tool requirements capture
    - provides early benefits
  - Design advanced ground tools for time-based sequencing and conflict avoidance, and profile clearance generation
- **Step 3**
  - Introduce advanced ground tools
  - Dynamically generate clearances in congested periods

Datalink clearances become essential at this point

Benefits of global format

- **Global format established to ensure global procedures**
- **Unplanned benefit of the format has been steady, timely progress**



What we need …

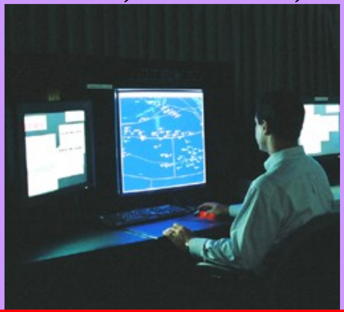
FANS (or other integrated datalink)

4 TA trajectory received and loaded into FMS on pilot concurrence

5 TA trajectory flown with FMS

6 Aircraft downlinks ETA info (at waypoints) along with other useful parameters for ATC trajectory confirmation/tuning

Ground automation, e.g. ATOP, ERAM, TAATS



3 **CPDLC**

TA clearance delivered to aircraft over data-link

7 TA procedure broken off if trajectory can't be continued for any reason

1 **e.g. EDA, TAATS**

Ground automation generates TA trajectory clearance

2 TA clearance coordinated across ATC domains/systems

The key hurdles

Basic Oceanic Tailored Arrival 28R, Track C

Clearance includes published procedure, transition, and runway

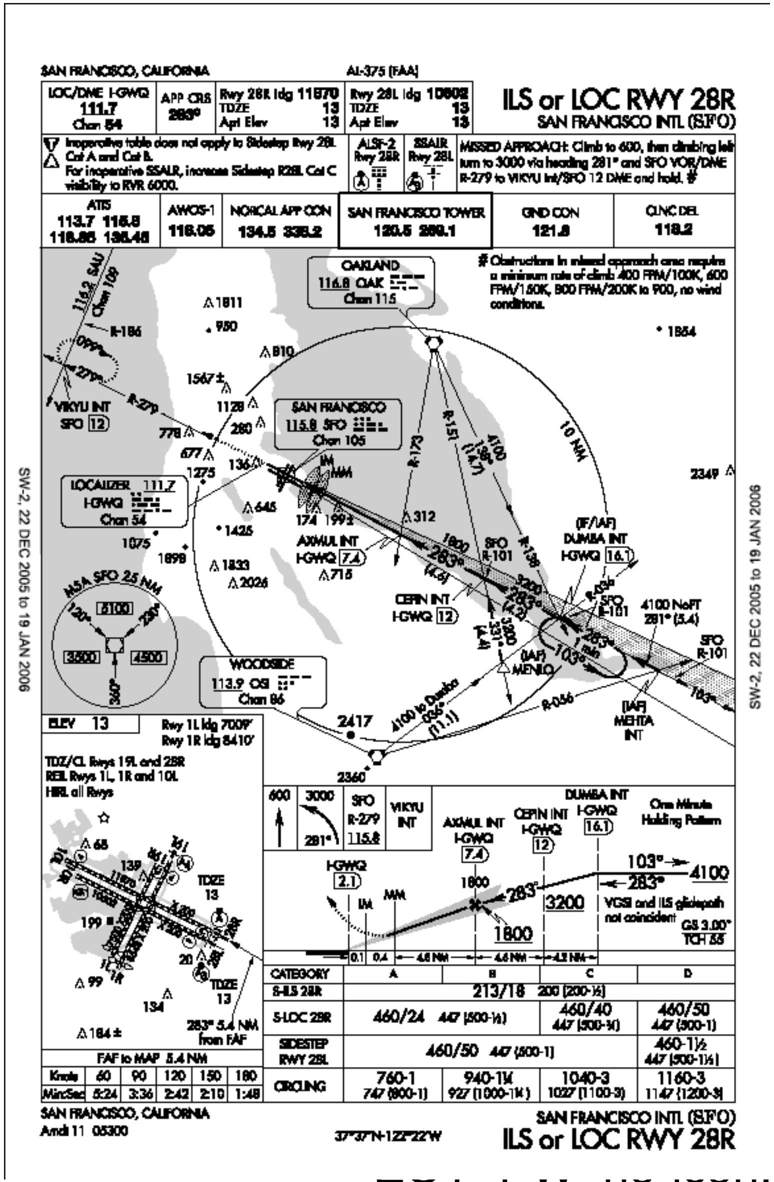
Clearance includes vertical, lateral, and speed constraints

Clearance is from en-route airspace through to destination

Additional speed schedule clearance used to fine-tune TOD and arrival time

At COSTS cleared to:

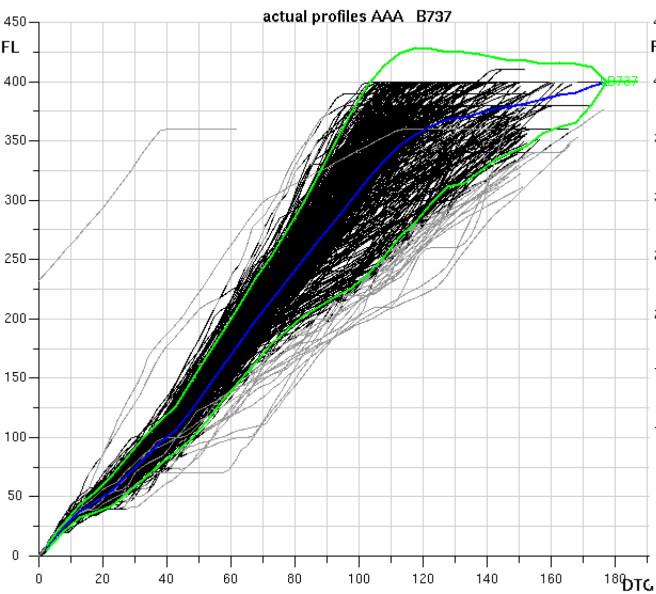
- **CINNY**
- **BRINY**
- **N37W122210/7500A**
- **OSI ----/----**
- **MENLO ----/4500A**
- **ILS28R Approach**
- **Runway 28R**

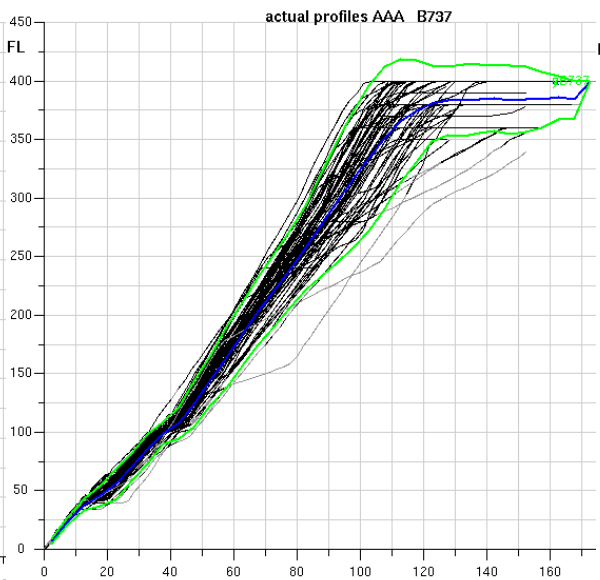


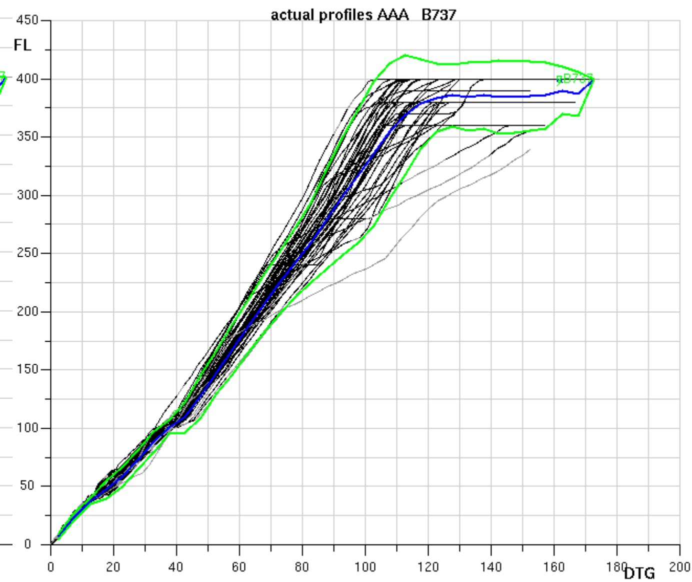
Sample technical results

Profile predictability

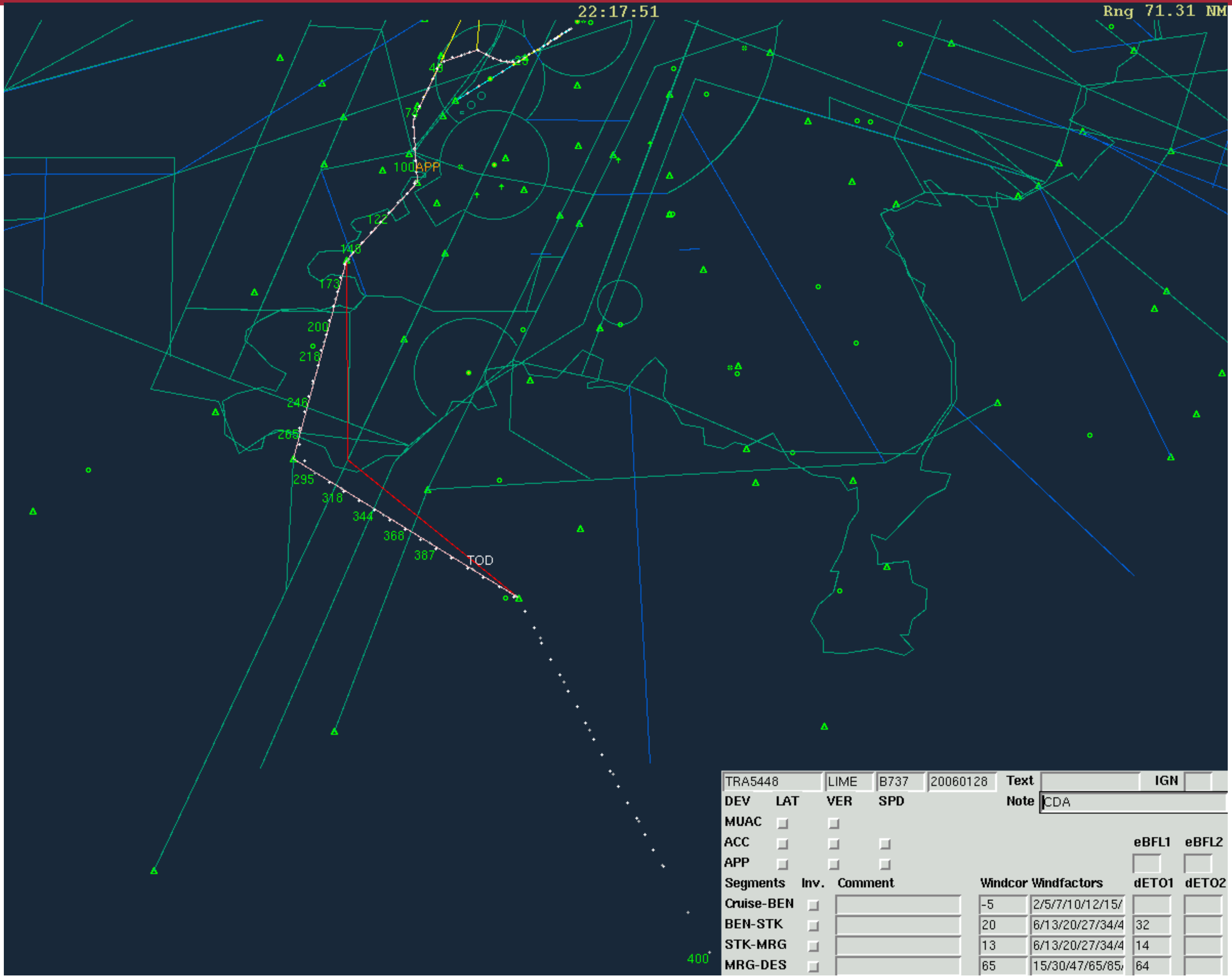
All flights	Standard Procedure	Refined procedure





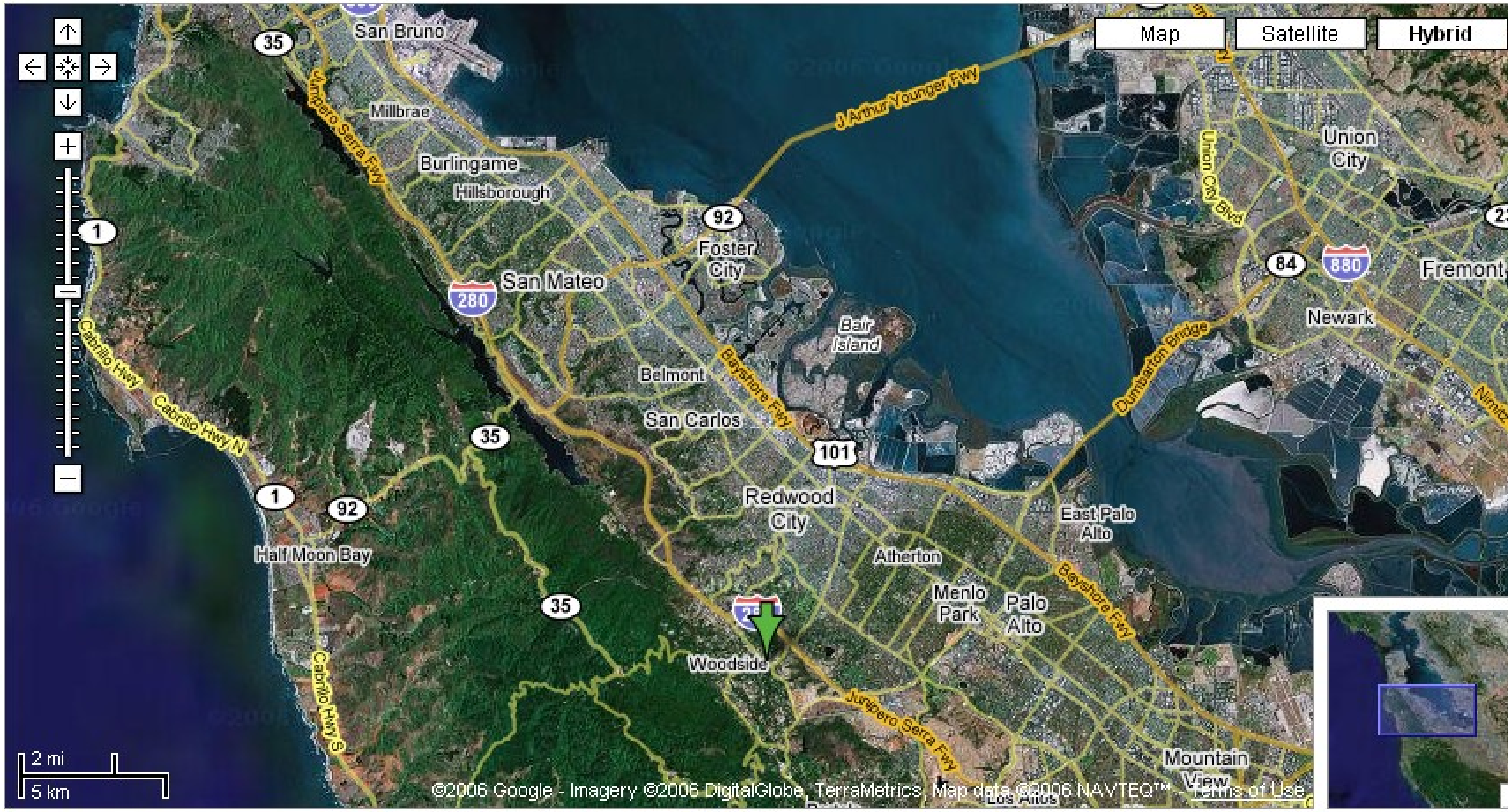


Time predictability

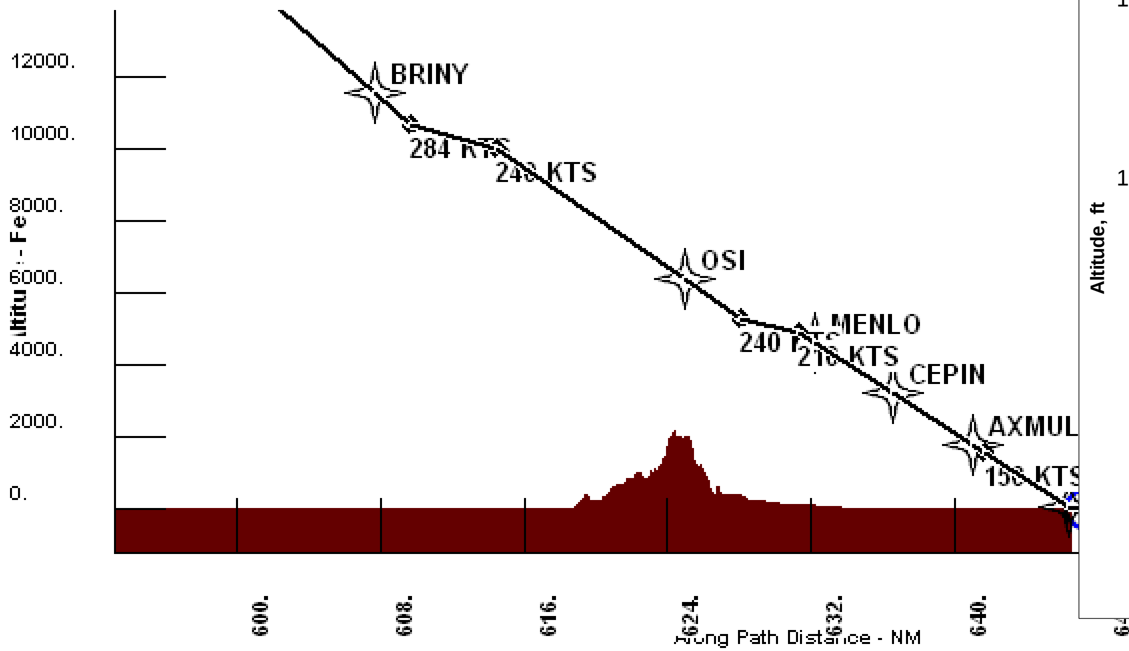


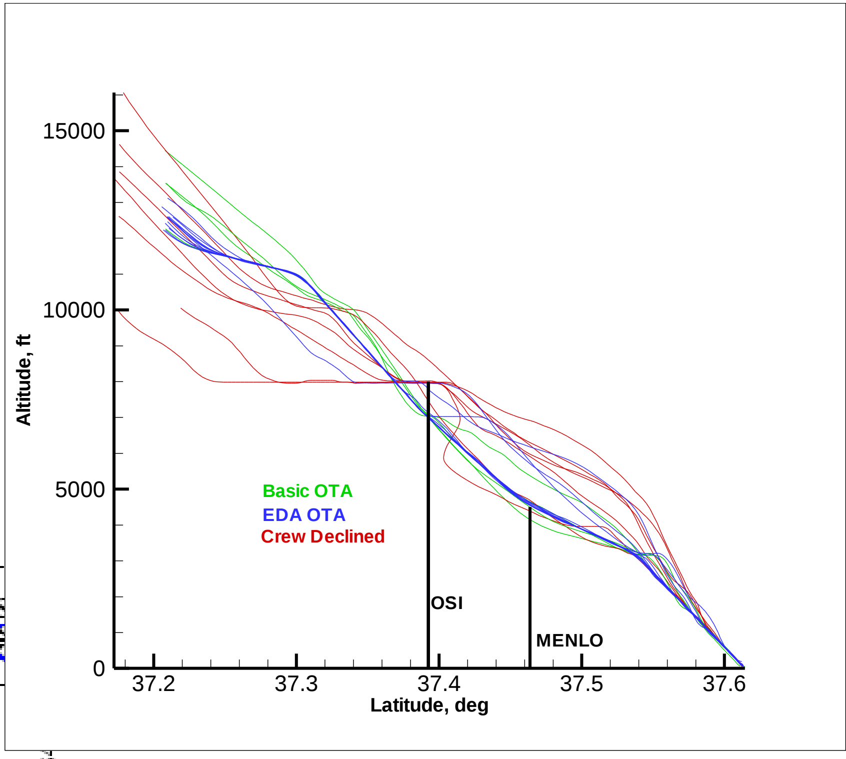
Bay Area trials

They build airports where people live



1st Round of SFO Oceanic Tailored Arrivals



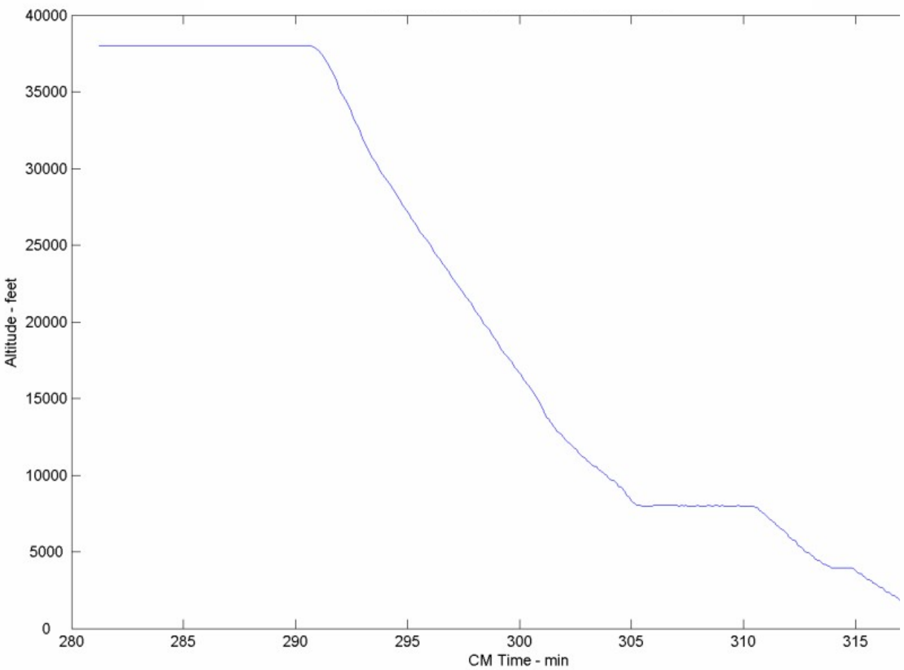


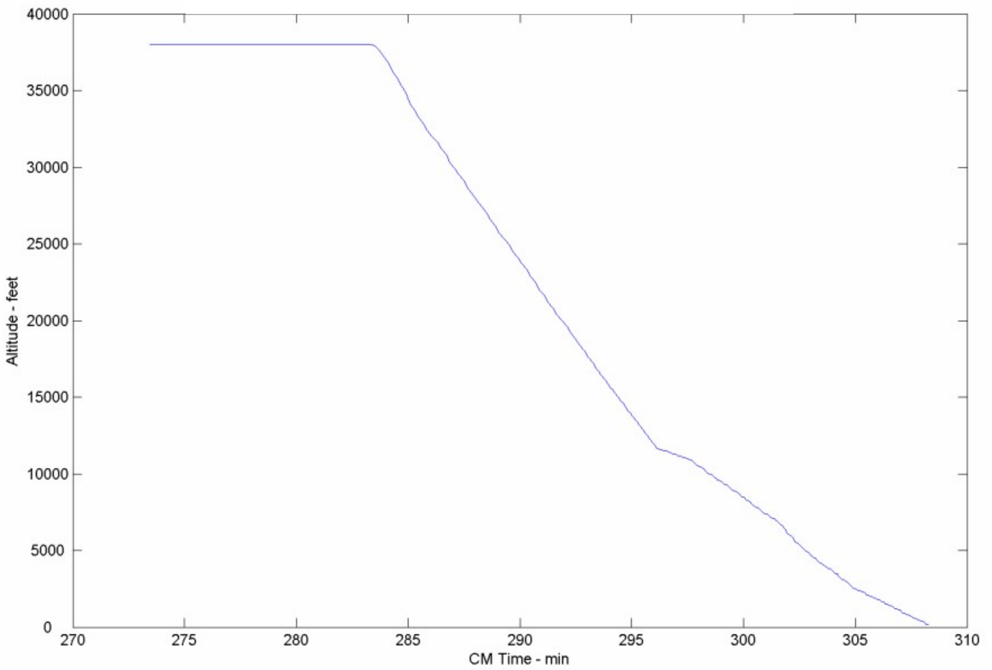
Potential SFO benefits

	Δ Fuel(lbs)	Δ Time(sec)	Δ Distance(nm)
747/220	392.8	37.0	5
	782.5	73.7	10
	1568.0	147.9	20
	3123.0	296.5	40
757/220	77.0	42.5	5
	154.0	85.0	10
	306.0	168.0	20
	612.0	336.0	40
767/240	135.2	34.7	5
	270.4	69.4	10
	540.8	138.8	20
	1081.6	277.6	40
777/240	192.0	36.8	5
	384.0	73.6	10
	768.0	147.2	20
	1536.0	294.4	40

- Time and fuel savings based on OTA vs. baseline scenarios with an 8000’ level flight segment of the listed distances added, at 220 knots or 240 knots for the 747/757 and 767/777 respectively.
- Baseline scenario with level segment of 5 NM may be considered representative of a low congestion period whereas the 20NM level segment case would represent a congested period
- Estimates based simply on the difference in flight time and fuel burned compared to the OTA procedure from a cruise condition of 37,000’ and flight Mach number 0.863, 0.798, 0.802, and 0.845 for the 747, 757, 767, and 777, respectively.
- Assessment requires confirmation with simulator data and / or flight data.

Sample Flights: Current vs. OTA





- **Noise levels unchanged compared with existing nighttime procedure**
- **Vertical and Lateral Path variation reduced**
- **Flight efficiencies in accordance with predictions**

The Key Issues

- **Ground automation still under development**
- **Capability to coordinate, issue, and execute cross-center clearances requires operational change**
  - **Ground systems and staff are not used to working like this**
  - **Today's aircraft have the needed capabilities, but currently aircrews and controllers don't get to routinely use them**
    - **Small issues with loading a datalink route clearance**
    - **Voice clearances that pass through constraints in the route clearance**
    - **Managing VNAV in the descent**
    - **Impact of loading (or not) weather information**
- **These issues are *<u>not</u>* exclusive to Tailored Arrivals**
  - **But Tailored Arrivals are a good way to work them!**

Summary

- **Three branches of development activity in progress**
  - **San Francisco conducting Oceanic Tailored Arrivals, covering development Step 1 and parts of Step 2**
  - **Australia conducting Phase 2 Tailored Arrivals flights, targeted at Step 2**
  - **The Netherlands launching second project, targeted at completing Step 2**
- **Collectively, these provide the platform for global development of Tailored Arrivals**
  - **Covering Airbus and Boeing aircraft**
  - **Using existing aircraft capabilities**
  - **Tackling two major issues for 4D operations**
  - **Providing step-wise benefits**

Thanks to our Partners!

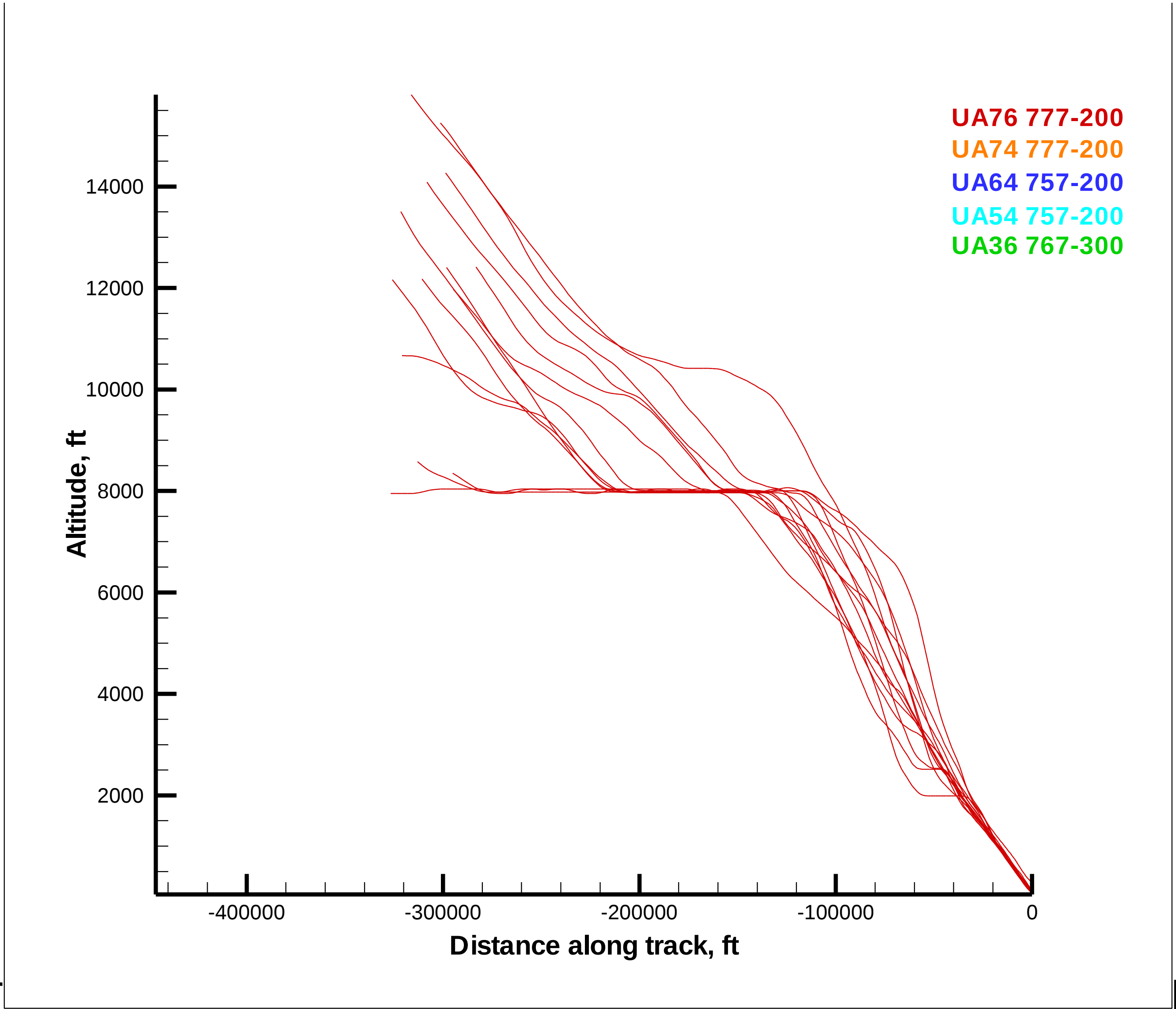
The key work areas

1. **The ability to coordinate a clearance across multiple centers / sectors, and deliver it prior to TOD**
   - **Not a "technology issue", but without it there is no 4D**

2. **Ground functionality that:**
   - **Produces sufficiently accurate a/c profiles to identify the constraints. To do this, the ground needs**
     - **Sufficiently accurate a/c models**
     - **Up-to-date weather models**
     - **<u>Sufficient</u> information about each a/c**
       - **Aircraft use current speed, gross weight at TOD, and the speed envelope for descent calculation**
   - **Uses these profiles to sequence and de-conflict a/c across the ATS Centers & Sectors involved**

And some of those people have influence

Five United Flights from 2/1/06 – 2/15/06



Clearance for Option 1

ATC DL Uplink Message AT1 - ATCCTR1 - .N777BO - CRC is valid
19,,
0(83) : At [pos] Cleared [routeclr]
pos(fix): COSTS
dest airport(): KSFO
arr runway(): 28R
app proc(): APP,ILS28R,MENLO
route info(): 5
(pub): CINNY
(pub): BRINY
(l/l): N37W122
(pub): OSI
(pub): MENLO
route info add():
wp spd alt: 2
pos(l/l): N37W122; spd(ias): 210; ATWalt(qnh): 7500A
pos(fix): MENLO; ATWalt(qnh): 4500A

SAN FRANCISCO INTL ATIS **113.7 118.85**

24 October 06

OSI TA/CDA ARRIVAL

SAN FRANCISCO, CA
SAN FRANCISCO INTL

OSI UA TA/CDA RNAV ARRIVAL

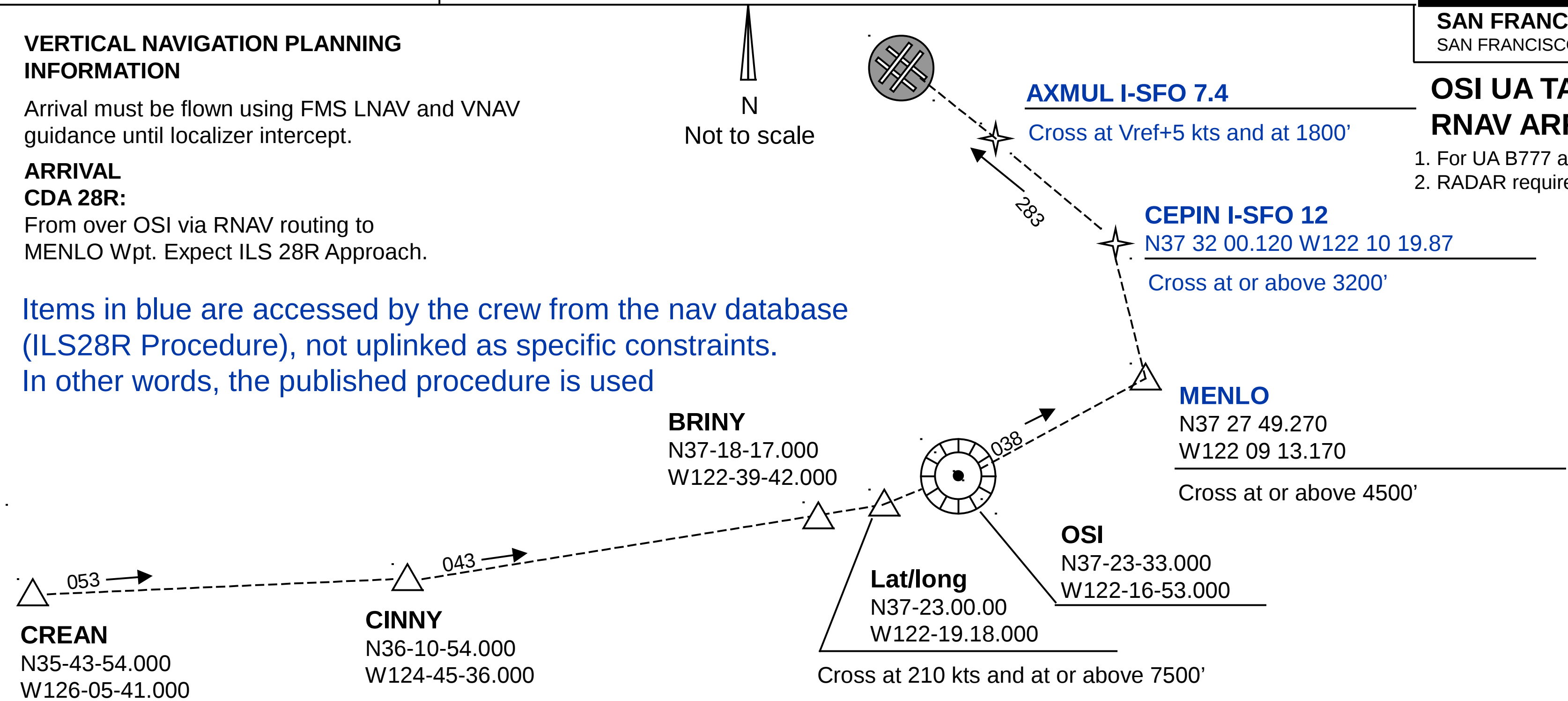
1. For UA B777 aircraft only
2. RADAR required

VERTICAL NAVIGATION PLANNING INFORMATION

Arrival must be flown using FMS LNAV and VNAV guidance until localizer intercept.

ARRIVAL
CDA 28R:
From over OSI via RNAV routing to MENLO Wpt. Expect ILS 28R Approach.

Items in blue are accessed by the crew from the nav database (ILS28R Procedure), not uplinked as specific constraints.
In other words, the published procedure is used



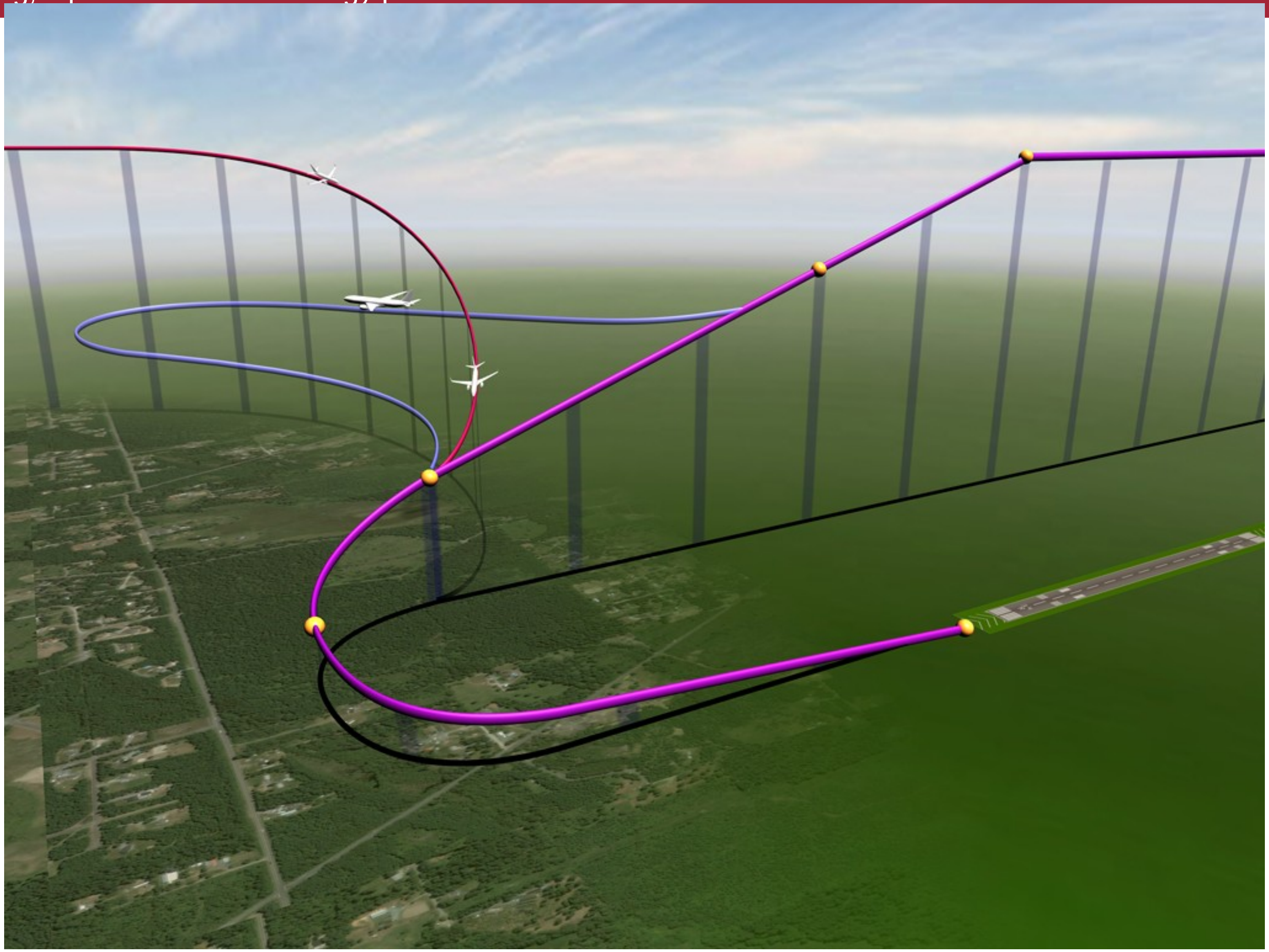
PILOT NOTES

1. Load TA Clearance in FMS
2. Verify speed and altitude constraints on MCDU LEGS page
3. Enter VREF +5 as speed constraint for the final approach fix
4. Altitude clearance required to initiate descent
5. Add drag when indicated airspeed exceeds FMC speed + 10 kts
6. Use Speed brakes above 10000 feet as required to maintain VNAV path and speed, use flaps after OSI
7. Arm APPROACH after starting turn on the localizer and receiving ATC clearance for ILS
8. After glide slope capture, manage approach and landing normally
9. Set gear and flaps as needed for normal landing No later than 1 mile prior to final approach, select gear down and landing flap

ATC CLEARANCE INFORMATION (from flight test plan)

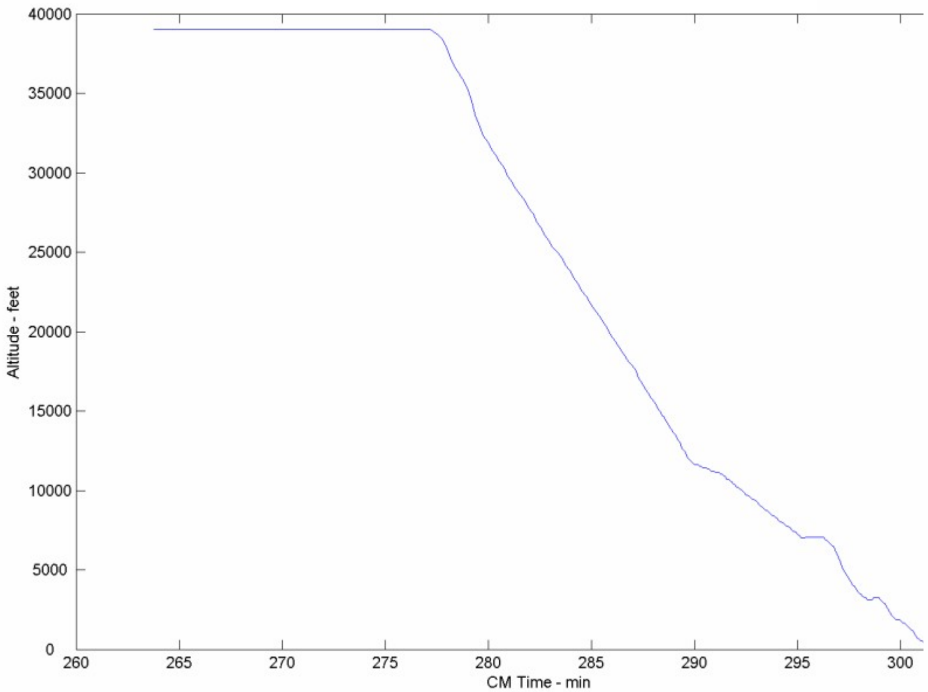
1. The data linked route clearance is to ILS28R using MENLO Transition, BRINY, NW37 W122 at or above 7500 and speed 210 kts, OSI, MENLO at or above 4500
2. Initial TA Descent Clearance:
   “Descend at pilot’s discretion, maintain 7500 ft””
3. TA continuation clearance:
   “Cross MENLO at or above 4500 feet, cleared ILS approach 28R”
4. Contact SFO TWR on final.

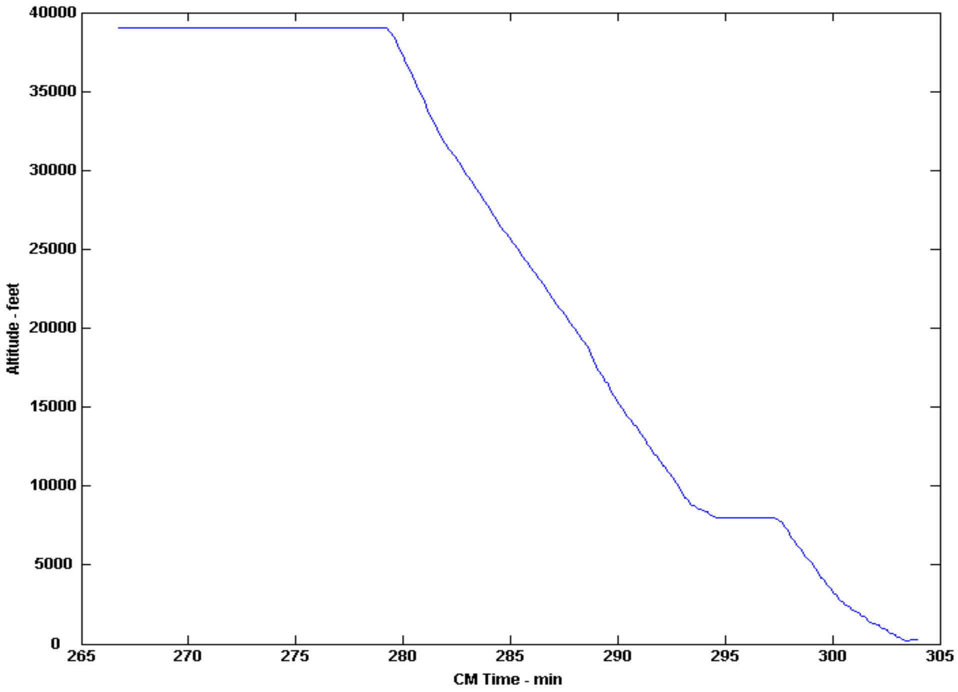
Today



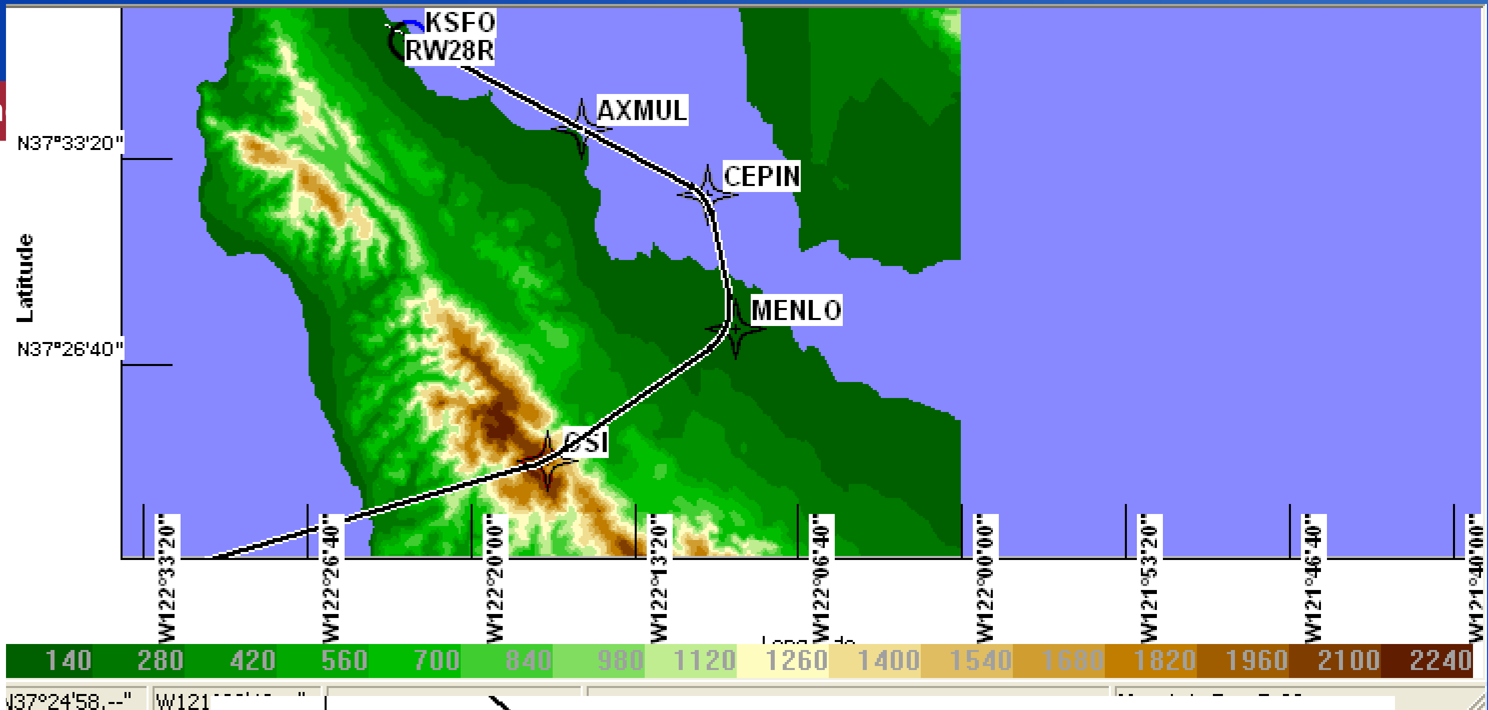
- Lower airspace “manually” adjusts streams to correct merge point times
- Higher fuel burn, higher environmental impact, decreased predictability

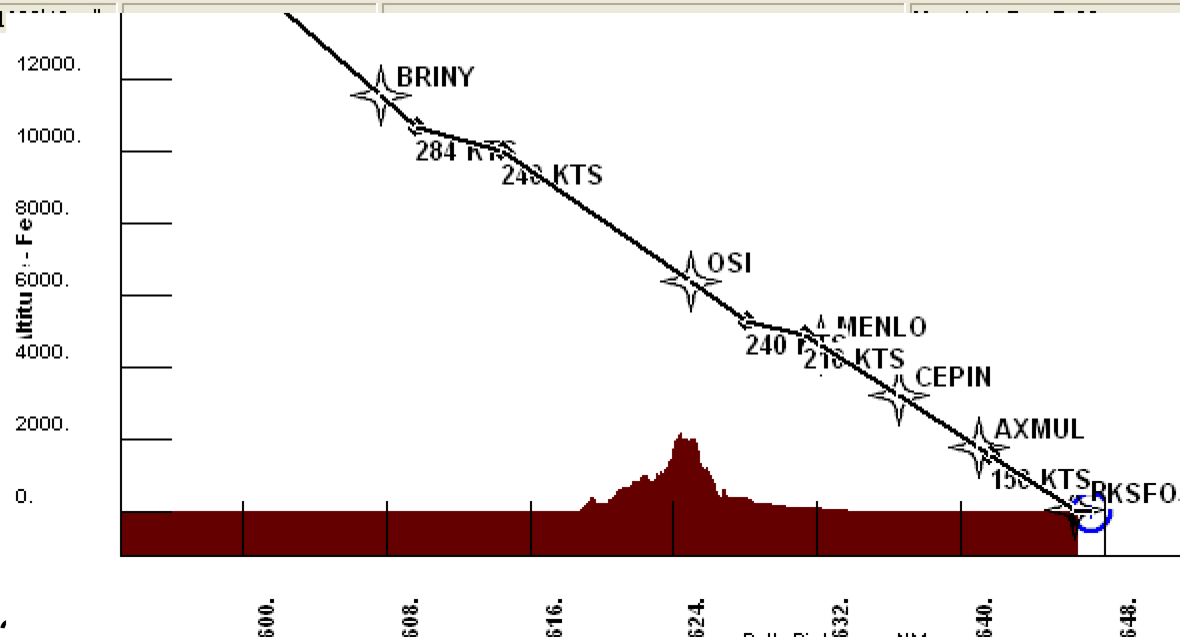
Sample Non-Oceanic Tailored Arrivals flights





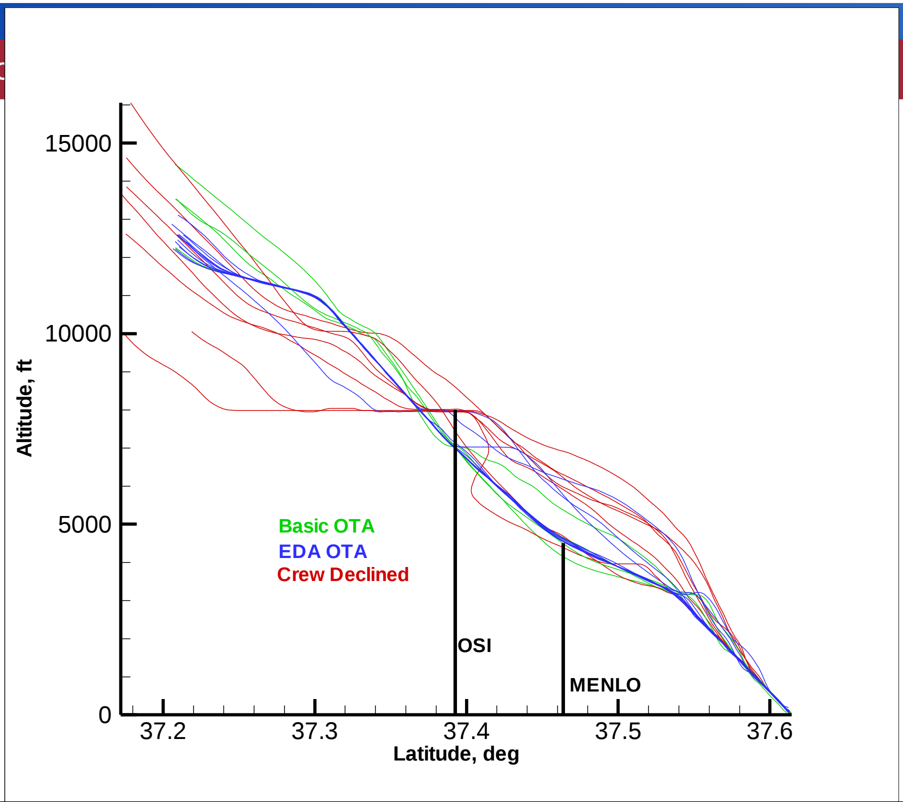
Engin





Copyright © 2 ... PW_no-icon.ppt

1st Round of SFO OTA Testing



OTA Opportunities		Attempted OTAs		Successful Route Uplink		Successful Wind Uplink		Successful** CDA (ZOA)		Successful** CDA (NCT)	
21		17		17		13		16*		8*	
Basic	EDA	Basic	EDA	Basic	EDA	Basic	EDA	Basic	EDA	Basic	EDA
7	14	3	14	3	14	3	10	6	10	0	8

* Data not yet available for 1 flight so it is not included

** Non-CDA success characterized by short level-off segments.