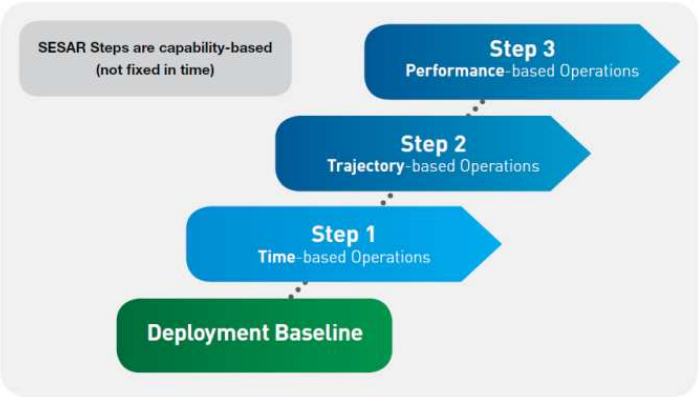
Initial 4D Trajectory Management Concept Evaluation

Tenth USA/Europe ATM R&D Seminar
Dr. Laurence Mutuel

The 3 SESAR Concept Steps



Step 1: Time-Based Operations → 2025

- Time prioritisation for arrivals at airport is initiated
- Datalink is widely used
- Initial trajectory-based operations are deployed through the use of airborne trajectories (by ground systems), and a Controlled Time of Arrival (CTA) to sequence traffic and manage queue

Step focused on flight efficiency, predictability and the environment

Step 2: Trajectory-Based Operations → 2030

- 4D-based business/mission trajectory management using System Wide Information Management (SWIM)
- Air/Ground trajectory exchange to enable tactical planning and conflict-free route segments

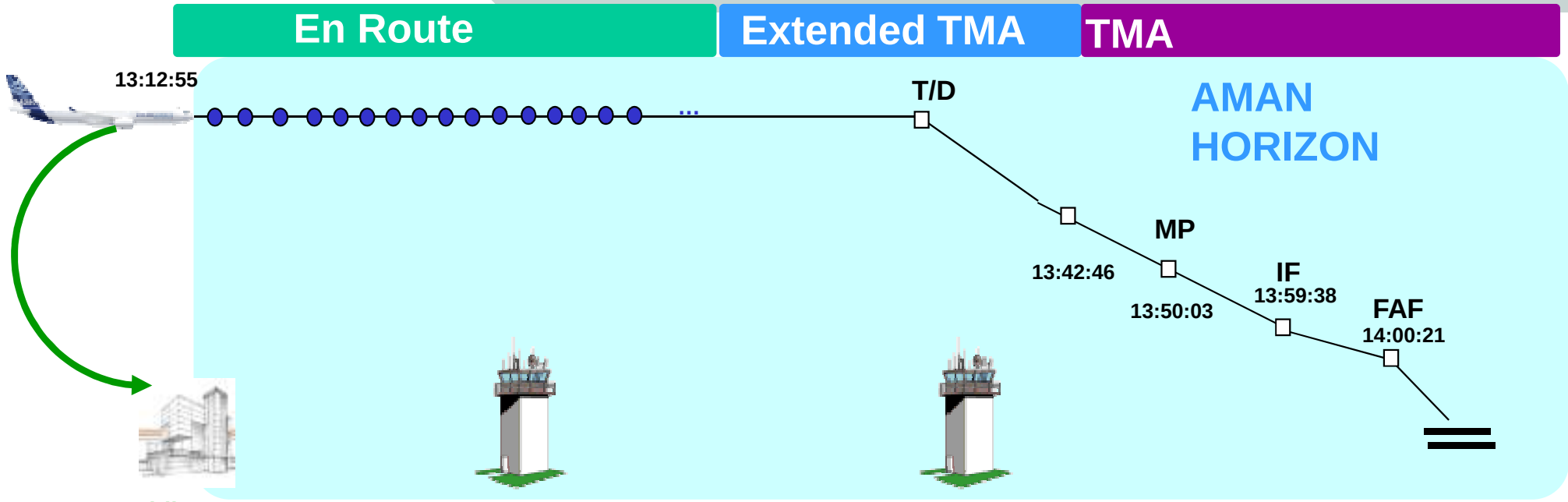
Adds capacity to step 1

Step 3: Performance-Based Operations → 2030+

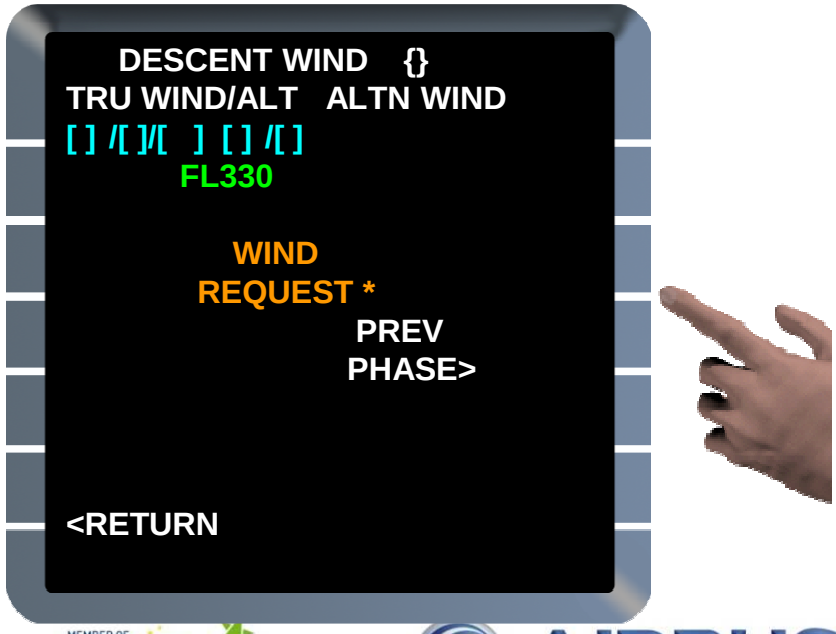
- Achievement of SWIM
- Collaboratively planned network operations with User Driven Prioritisation Processes (UDPP)

Step 3 achieves the European High-Performance, integrated, network-centric, collaborative and seamless air/ground ATM system

Initial 4D Concept Overview



MP : Metering point



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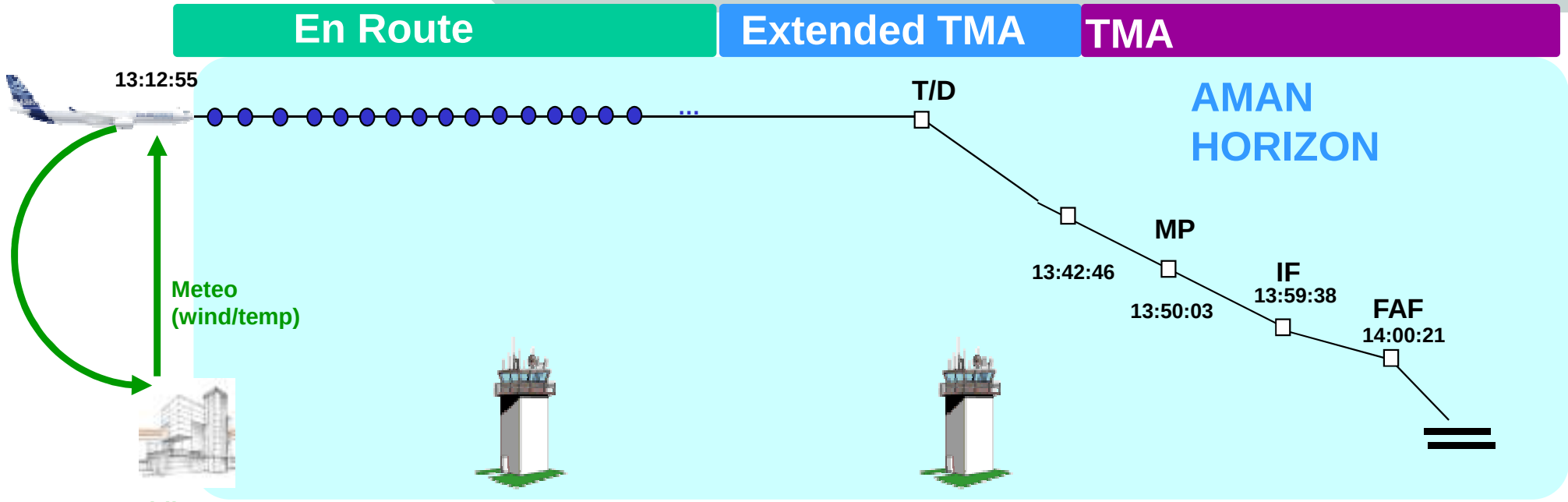


```
    DESCENT WIND    {}
TRU WIND/ALT   ALTN WIND
060  /060/FL320  010  /065
            FL330
055  /058/FL300
            WIND
040  /055/FL270   REQUEST*
            PREV
020  /050/FL250     PHASE>

015  /045/FL200

<RETURN
                          $
```

```
    DESCENT TEMP    {}
SAT  /ALT
-40   /FL320

-35   /FL270
          WIND/TEMP
-33   /FL230     REQUEST*

-35   /FL200

-25   /FL150

<RETURN
                          $
```

MP : Metering point

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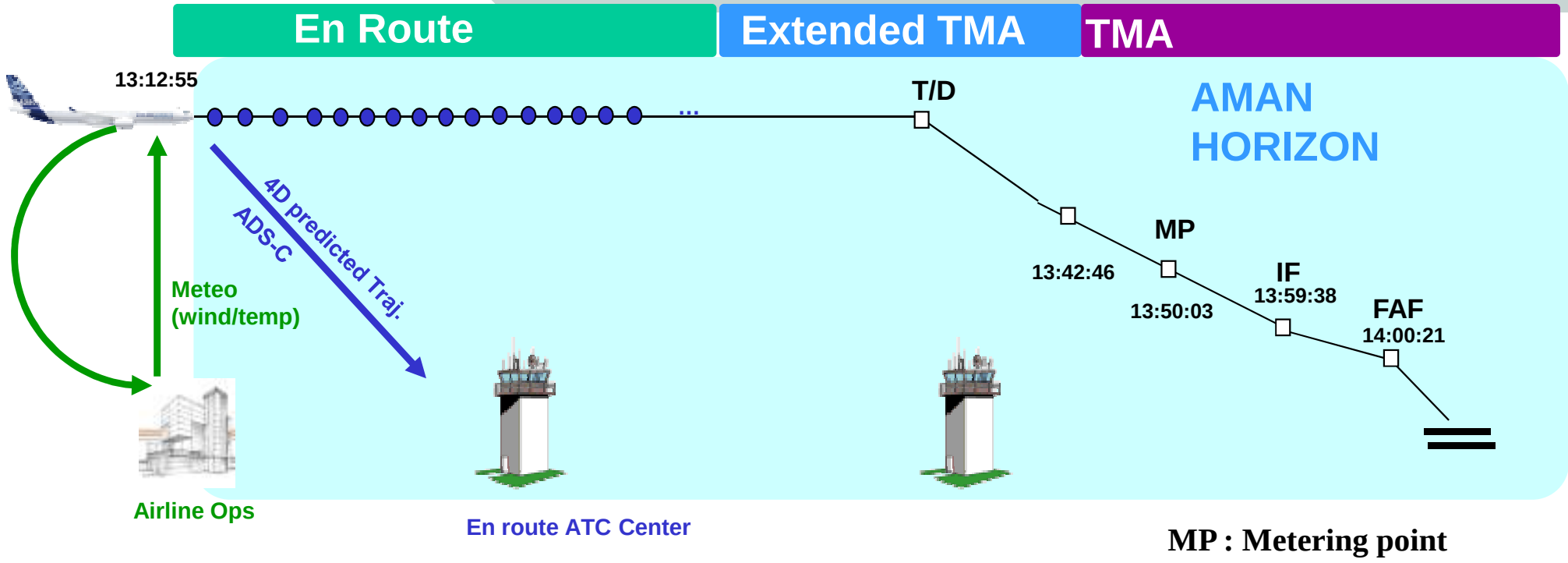

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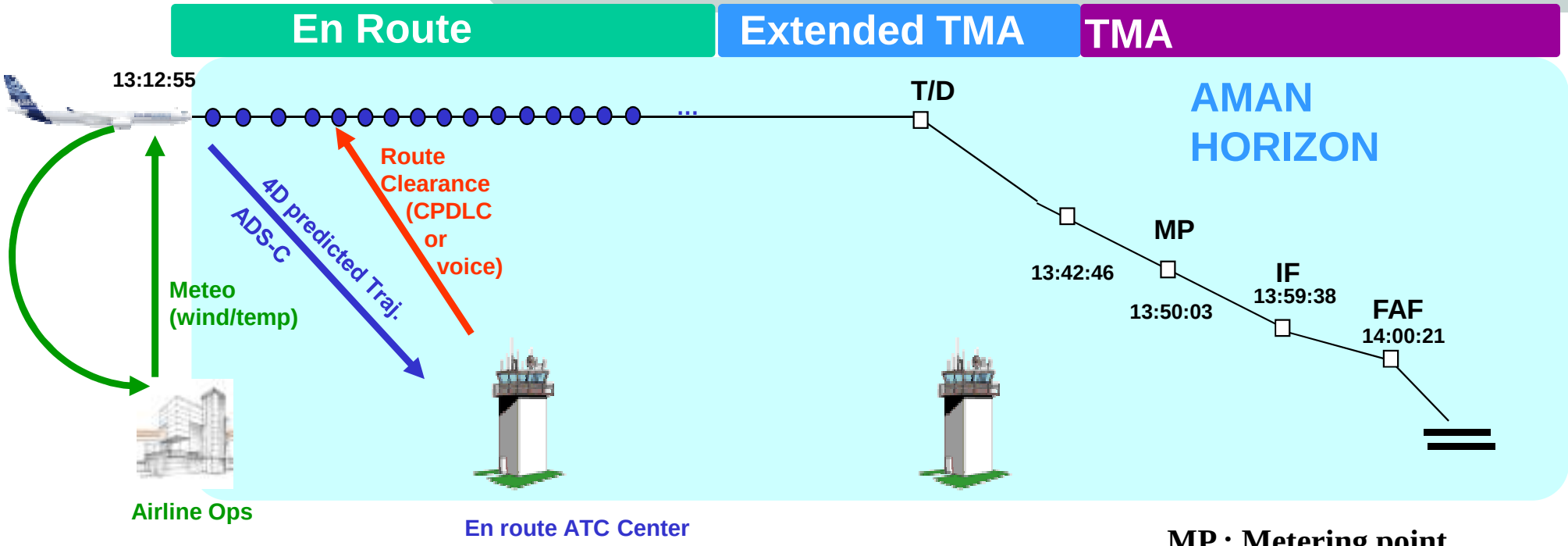

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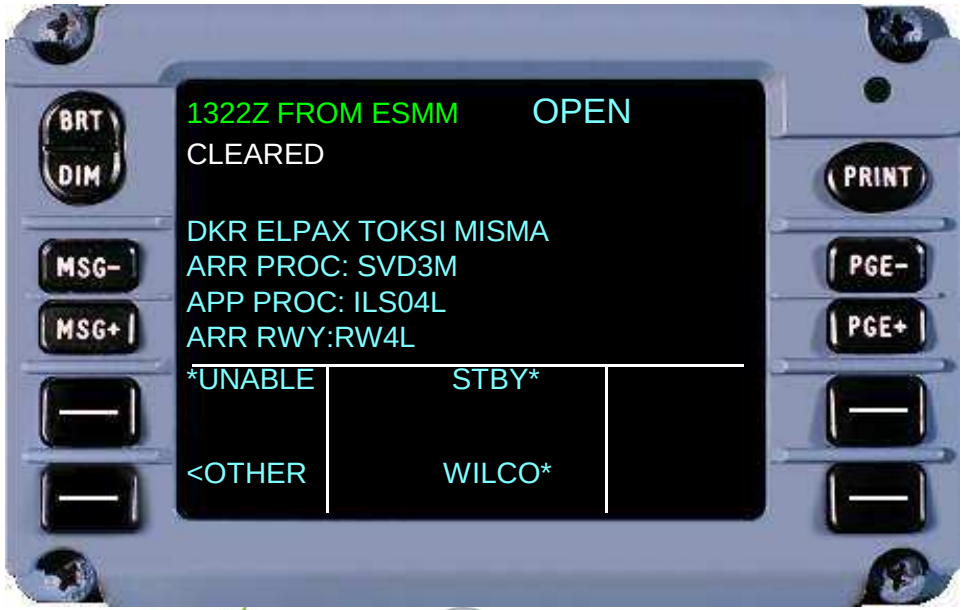

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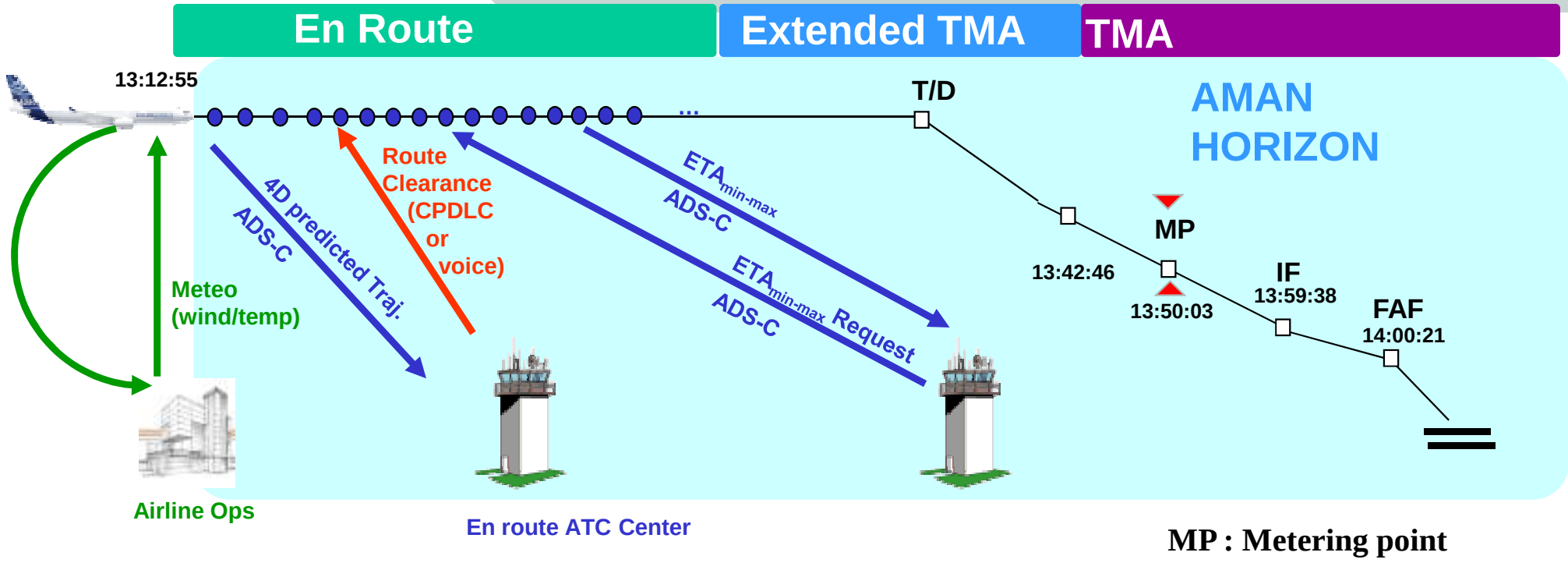

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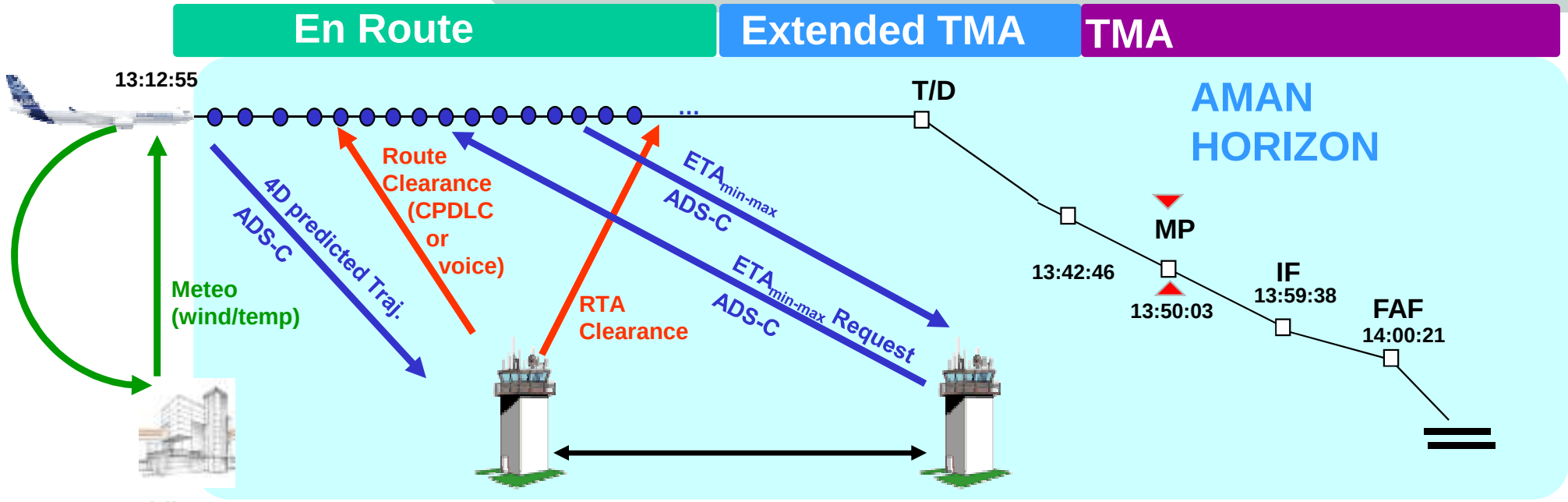

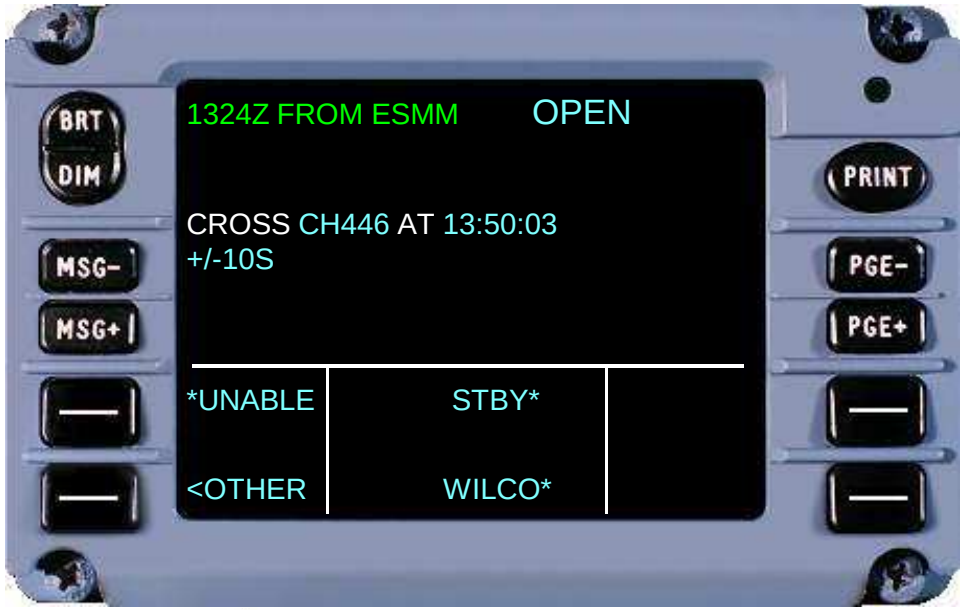

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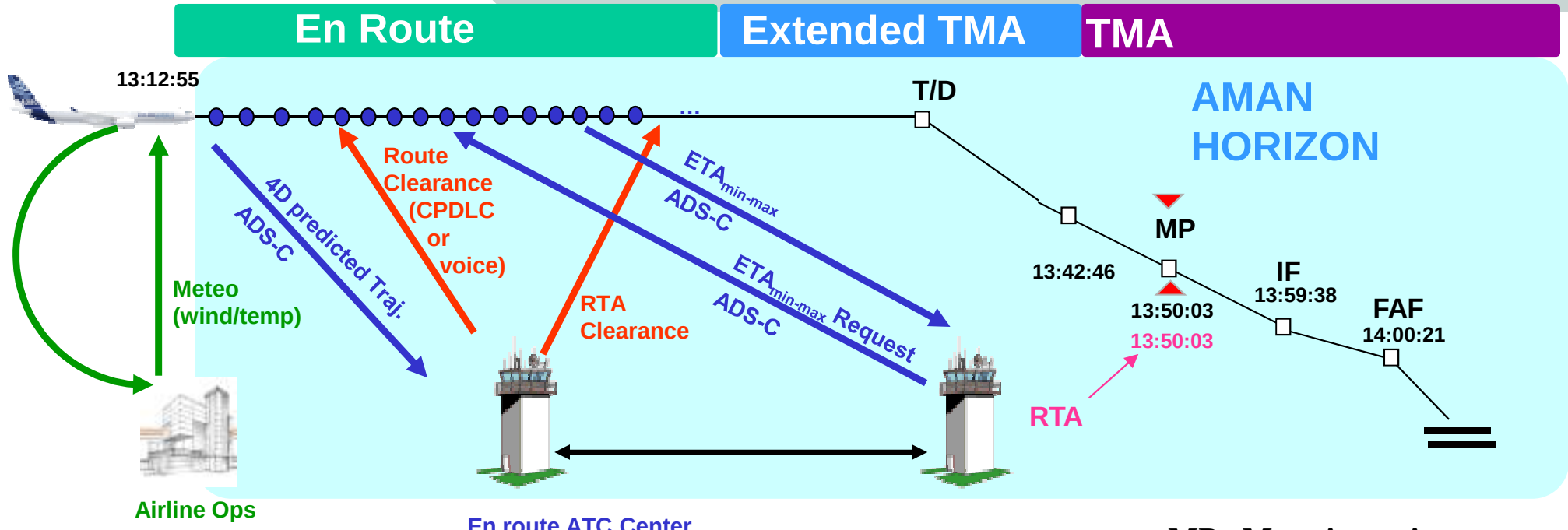


MP : Metering point

RTA
AT WPT DIST RTA
CH446 42 13:50:03
MANAGED ETA
270 13:55:04
ACT MODE
MANAGED
VMAX UTC
290/0.79 13:24:35
£$ACCUR
+/-10

<RETURN

Initial 4D Implementation

Airborne Segment

- **Cockpit Display Systems**
  - Engagement of I4D operations
  - Monitoring of I4D operations
- **Flight Management System**
  - I4D Predictions
  - I4D navigation performance
  - I4D guidance
- **Data Communication System**
  - ADS-C application
  - CPDLC application

Prototype equipments installed onboard Airbus 320 test aircraft; FMS prototypes from Thales/GE and Honeywell.

Ground Segment

- **Arrival Manager (AMAN)**
  - Arrival sequence with I4D CTA
  - Ground/Ground coordination
- **Other ATC systems**
  - Distribution of AMAN CTA
- **Data Communication System**
  - Dispatch of aircraft trajectory info
  - Emission of I4D messages
- **Datalink Service Providers**

Thales automation system in shadow mode , dedicated controller position, flight tests over French, Maastricht and Danish/Swedish airspaces

MEMBER OF SESAR JOINT UNDERTAKING

AIRBUS AN EADS COMPANY

Honeywell

THALES

Initial 4D Flight Tests

- **Objectives**
  - Confront the onboard design with real conditions and environment
  - Demonstrate technical feasibility of I4D in nominal operations
  - Assessment of avionics interoperability (FMS)
- **Performance**
  - I4D flight trial was successfully executed on 10 February 2012
  - Round-trip flight from Toulouse to Stockholm with loop about Stockholm
  - Flight controlled by voice by operational controllers to ensure separation
  - Datalink used between aircraft and dedicated controller position for all I4D
- **Scenario**
  - 6 individual demonstration tests
  - 6 flight legs with each a single time constraint (Controlled Time of Arrival (CTA))
    - 2 en route CTAs, 4 descent CTAs

I4D Flight Tests Results

- **Feasibility of Onboard Nominal Operations**
  - Task sharing aligned with existing philosophy and well balanced
  - No missing or out-of-sequence task
  - Automation level satisfactory
  - Manual entry of temperature in descent
- **I4D Onboard Functions Definition and Navigation Performance**
  - Level of definition satisfactory, including HMI and A320 cockpit integration

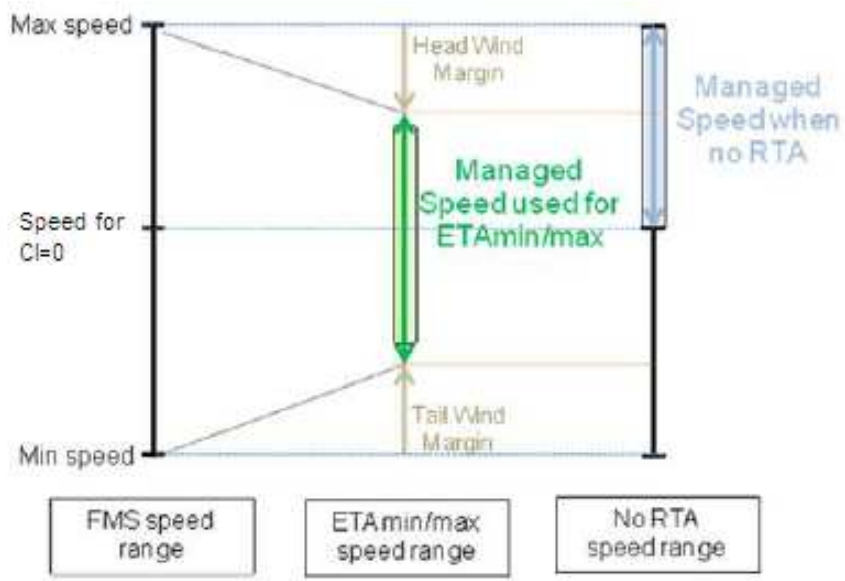
CTA	Overfly time and error			Comment
	FMS log	Crew log	ATC log	
1	08:27:04 +4s	08:27:06+6s	08:27:09 +9s	Sizeable wind/temp errors
2	08:59:59 -1s	09:00:02 +2s	09:00:02 +2s	
3	09:56:15 +0s	09:56:16 +1s	09:56:13 -2s	No descent temp, unusual QNH
4	13:03:38 +2s	13:03:39 +3s	13:03:37 +1s	Unusual QNH
5	13:50:04 +1s	13:50:04 +1s	13:50:04 +1s	
6	14:39:01 +1s	14:39:02 +2s	14:39:03 +3s	

Navigation Performance: all CTAs met within prescribed tolerance

I4D Flight Tests Results

I4D Onboard Functions Time Performance

- Deceleration when RTA set in the middle of ETAmin/max window
  - Recommendation1: AMAN favoring CTA values close to the aircraft initial ETA
  - Recommendation2: simple algorithm on the ground to estimate initial speed adjustment at CTA insertion
- Initial ETA possibly outside the ETAmin/max window
  - Limited to cases of high initial aircraft speed or high cost index



I4D Flight Tests Results

- **I4D Datalink aspects**
  - VDL2 coverage limitations to be taken into account in I4D planning
  - Process time to downlink ADS-C EPP dataset after receipt of route clearance expected to be significantly improved for next flight test
  - CPDLC message set complete and understandable
  - Recommendation to directly load CTA clearance into active flight plan
  - Uplink of CLEARED [route clearance enhanced] erased all winds/temps; issue when this message is used for route amendment
- **Technical Feasibility of ground and air segments integration**
  - Demonstration of air/ground trajectory synchronization and CTA assignment
  - Demonstration of usability of CPDLC and ADS-C

Wide scale Flight Test Evaluation

- **Wider scale evaluation and without added supporting tools**
  - Commercial flights into Stockholm-Arlanda:
    - Scandinavian Airlines, Novair and Lufthansa; B737-600, -700 and -800; A320 and 321
  - FMS with RTA function, CTA set at waypoint in descent about FL100
  - Low to medium traffic densities
- **Main findings**
  - 92% of all flights achieved their assigned CTA within 30seconds (tolerance)
  - CTA operations are positive method to absorb delays and sequence arrival flow
  - Airborne ETA function performs well for CTAs between FL70 and FL202
  - ATC cross-coordination possible but increases workload and requires time
  - Large difference between FMS ETA and ground ETA at metering fix and runway
  - More mature tools on the ground needed for CTA operation in medium/high traffic
  - Long time interval between assignment of inbound clearance and FMS ETA receipt
  - Ground systems require more trajectory information from aircraft to reduce uncertainty in CTA operations

Next Steps

- **Further air/ground coupled simulation validation exercises ➔ 2013/2014**
  - Maastricht and Noracon control centers
  - Complete the coverage of I4D validation scope
    - Acceptability of I4D nominal operations (incl. workload)
    - Use-case development for abnormal operations
  - Address some of the recommendations from previous validation exercises
    - ETA outside ETAmin/max window
    - Monitoring of erroneous implementation of clearance message
    - Consolidation of the maturity assessment of I4D Trajectory Management
  - Issue validation reports and recommendations from various points of view
    - Aircraft/onboard systems
    - ATC/control center/ATM automation systems

Standards

- **Safety and Performance Requirements (SPR) of ATS datalink services (RTCA SC-214 / Eurocae WG-78)**
  - [no impact] 4DTRAD service supports I4D on ATN as part of new standard ATN Baseline 2 / FANS C
- **Minimum Aviation System Performance Standard (MASPS) / Required Navigation Performance for Area Navigation (RTCA SC-227 revision of DO-236B and Eurocae WG-85 revision of ED-75)**
  - [convergence required] Navigation performance requirements for I4D RTA to be re-including before closure of the standard
- **ICAO**
  - Revision of ICAO PANS-ATM for data communications
  - Revision of ICAO Performance-Based Navigation manual
- **AEEC standards**
  - A702A AOC portion revised to support FMS loading of temperatures in descent

Conclusions

- Flight trial of the I4D concept successfully demonstrated the operational and technical feasibility from both airborne and integrated air/ground perspectives
- All key concept elements exercised
- Avionics interoperability shown
- Trajectory synchronization realized through data communications
- Integration of airborne trajectory in ATM automation shown to improve trajectory prediction and computation of achievable CTA
- Stakeholders favorably assessed concept in terms of procedures, expected tasks, Human-Machine Interface design, and workload
- Sufficient feedback received to plan next validation exercises (flight tests and integrated air/ground simulations)

Thank you for your attention

Questions?

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