International Flight Inspection Symposium
Oklahoma City, OK USA June 2008

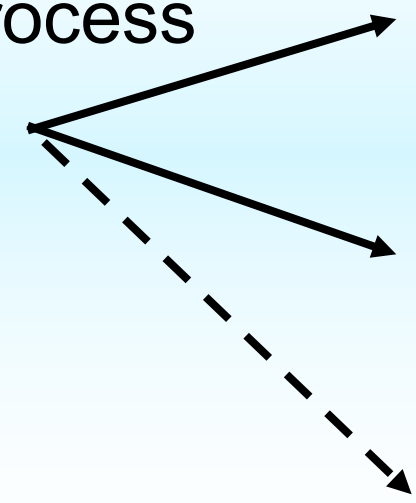
Qualifying DME for RNAV Use

Gerhard Berz, EUROCONTROL

Jochen Bredemeyer, FCS

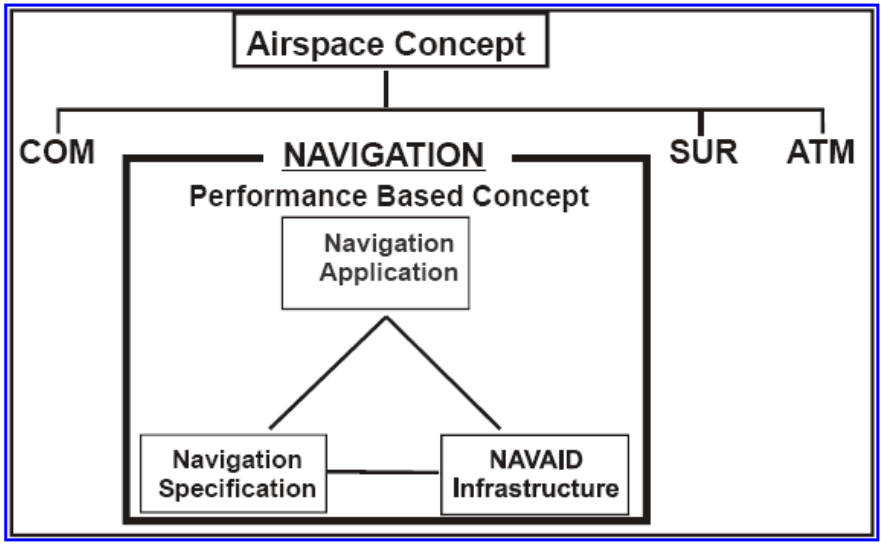
Overview

- **RNAV Infrastructure Assessment Guidance**
  - Infra Requirements
  - Assessment Process
  - Special Eval's



- Multi-channel DME Assessment
  - Feasibility
- DME First Installed Prior to 1989
  - Interoperability
- Many more…

ICAO PBN Context



- ICAO RNAV-1
  - U.S. (FAA): AC90-100
  - Europe: JAA TGL-10
    (Becoming EASA AMC20-16)
  - Performance & Functional Rqmts for Aircraft
- $P\text{-}RNAV_{EUROPE} \leq RNAV\text{-}1_{ICAO}$

Infrastructure needs to *support* Navigation **Application**

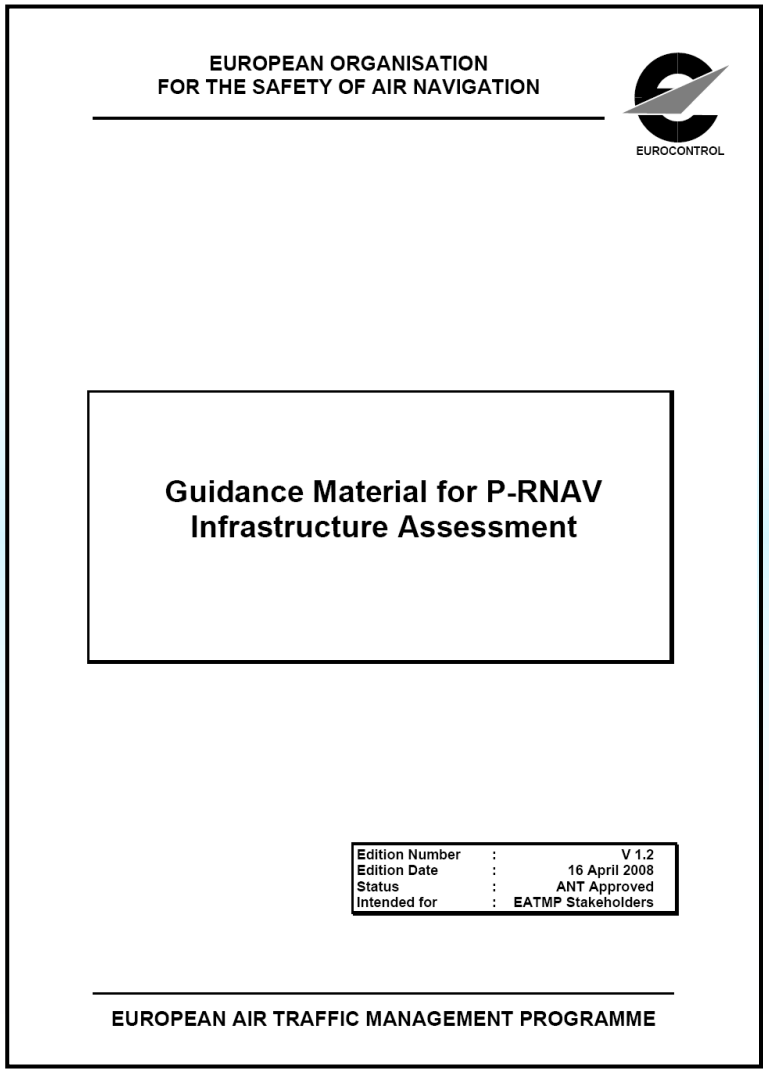
- for airspace users that have been certified to RNAV-1 **Specification**
- Supported by GNSS or DME/DME or D/D/Inertial

P-RNAV Infrastructure Guidance

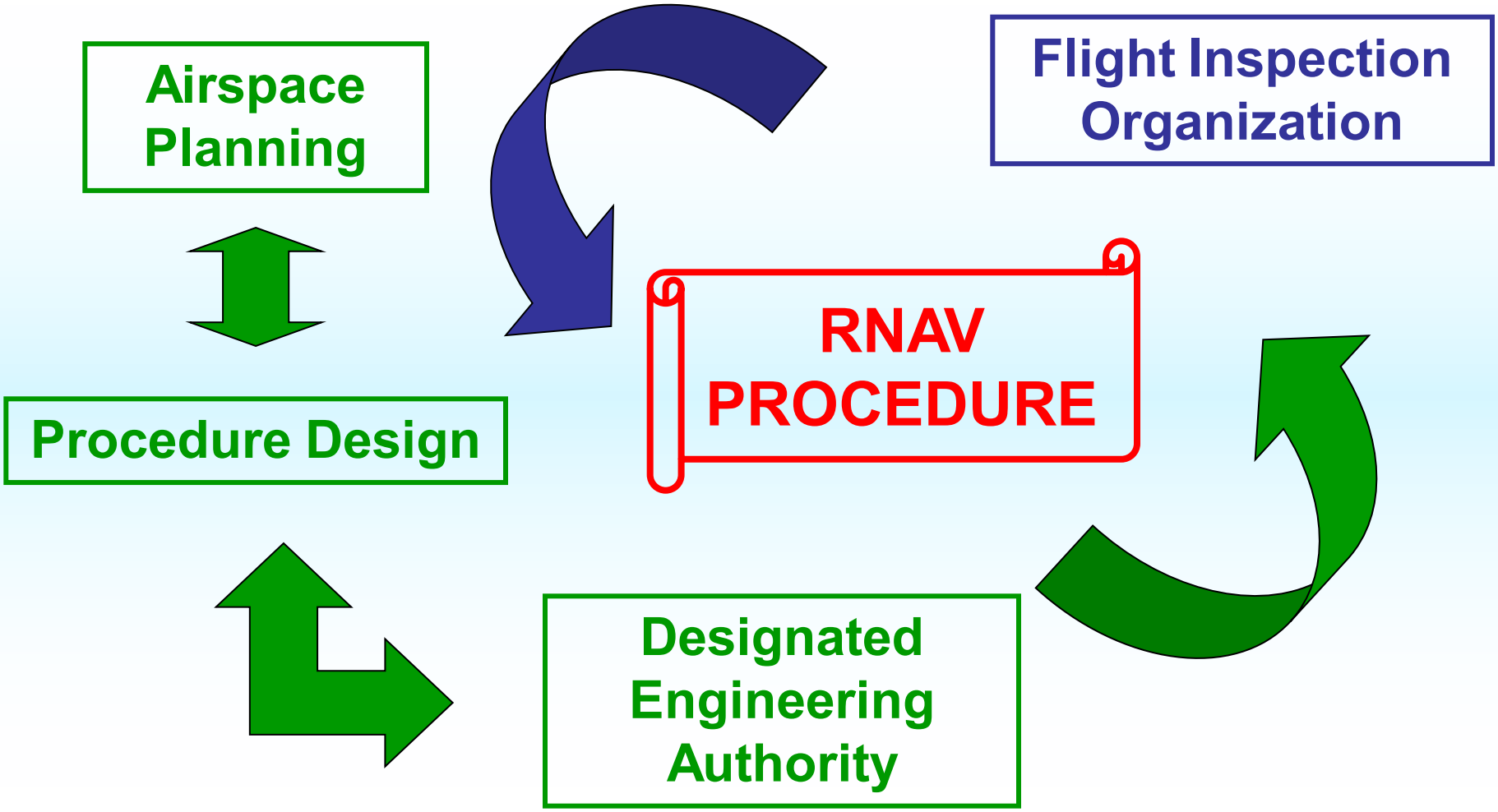
- Deals with infrastructure only, NOT with procedure
  - GNSS ➔ Ref ICAO Doc 9849, GNSS Manual
  - Primary focus on DME

TOC:

1. Intro: Actors & Tools
2. Requirements
3. Process
4. Technical Topics



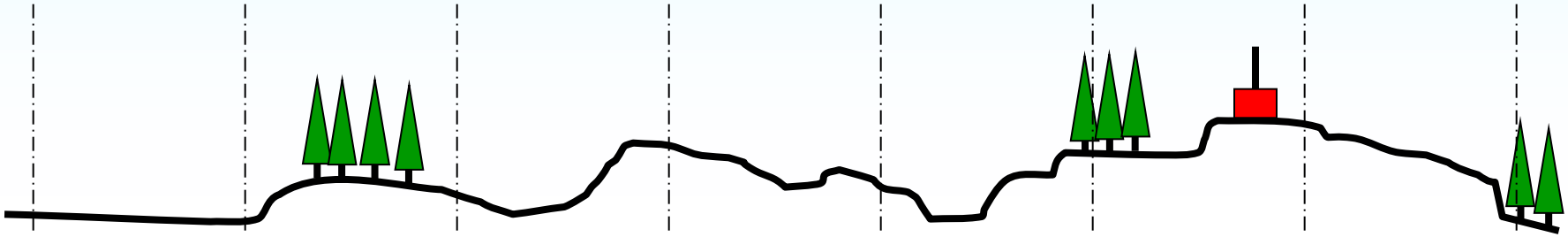
Infra Assessment Actors & Process



Use of Software Tools

- Use of tools is *recommended*
  - Line-of-sight prediction based on terrain model
  - To incorporate requirements from Guidance Material

- Assessment without Flight Inspection *is possible* **provided experience**
  - Existing Flight Inspection reports (individual DME)
  - Current use of airspace **and** DME aids
  - Procedure altitude (TMA SID/STAR vs. B-RNAV)
  - Engineering judgement



Requirements (Extracts)

- ICAO NSP decided to rely on DOC
  - Aircraft uses non-standard FOM
  - Use outside of DOC is avionics responsibility
- Accuracy Error Budget, TSO C66C
  - PBN Manual, Annex 10 and PANS-OPS aligned
- FMS Criteria
  - Subtended angle criteria etc. documented such that ANSP does not need to undertake avionics study
- SID and STAR
  - Establish limits of DME/DME Coverage (30 sec)

Assessment Objectives

1. Prove procedure is supported by usable DME within DOC range
   - Confirm PANS-OPS Assumptions about SIS
2. Identify DME that could degrade RNAV solution
   - Critical DME
   - Receivable DME far outside of DOC
   - TACAN or DME Installed Pre-1989
   - Co-Channel DME

Technical Topics

- Negative Elevation Angles
- DME not under ANSP control (cross-border)
- Critical DME
- Gaps in DME/DME RNAV Service
  - DR, INS, Resiting
- Offsets and Direct-To
- DME First Installed Prior to 1989

SOME TESTS (UK, Japan)

Flight Inspection Challenge !

3rd Part of this Presentation

Part II

- Infrastructure Assessment Guidance Material Summary
- **Multi-channel DME Inspection Capability**
- DME First Installed Prior to 1989

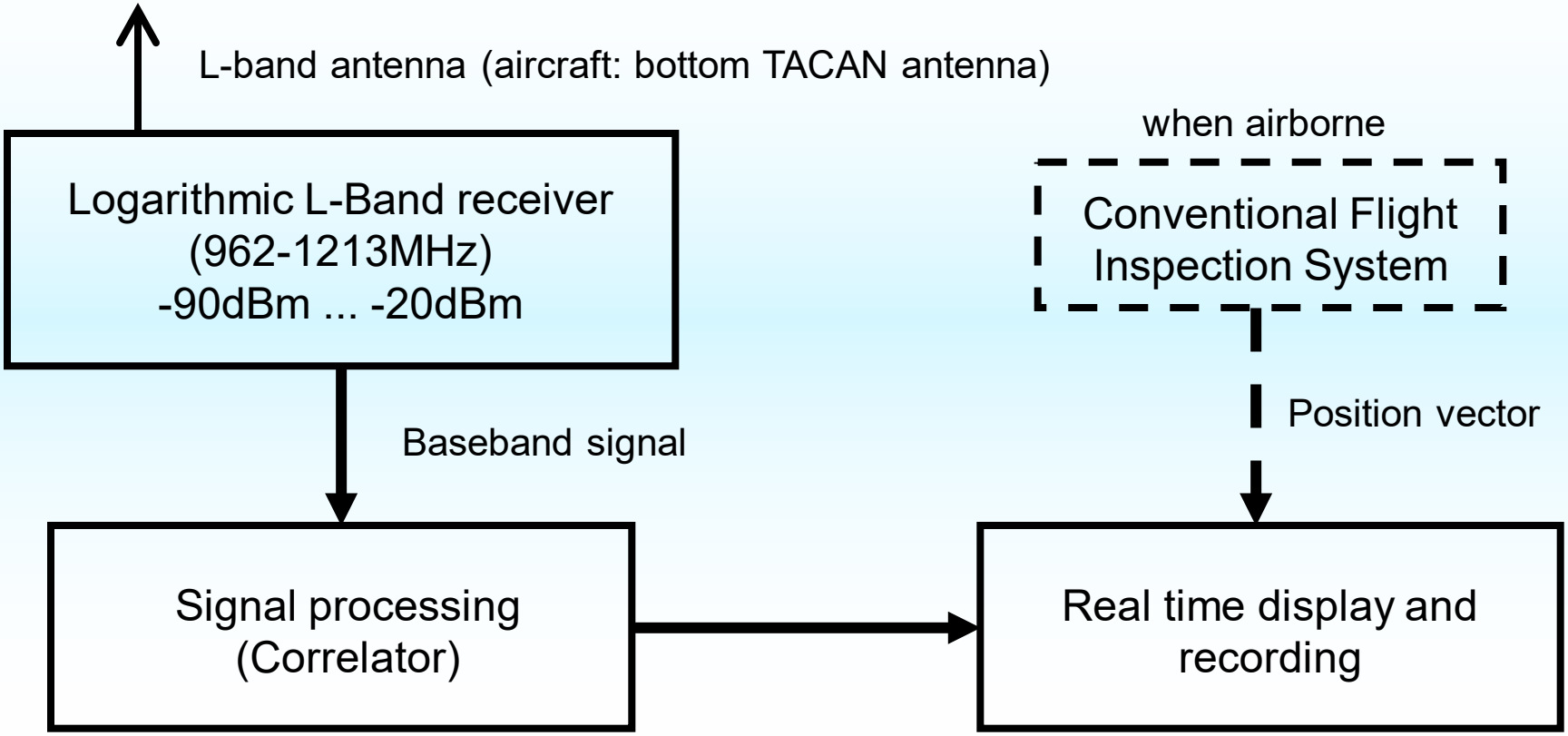
Multi-Channel DME Inspection

- Aircaft and FIS time expensive
- FI airspace access becoming more limited
  - Especially in busy TMA's
- It is clearly recognized that conventional scanning DME are not suitable for measurement purposes

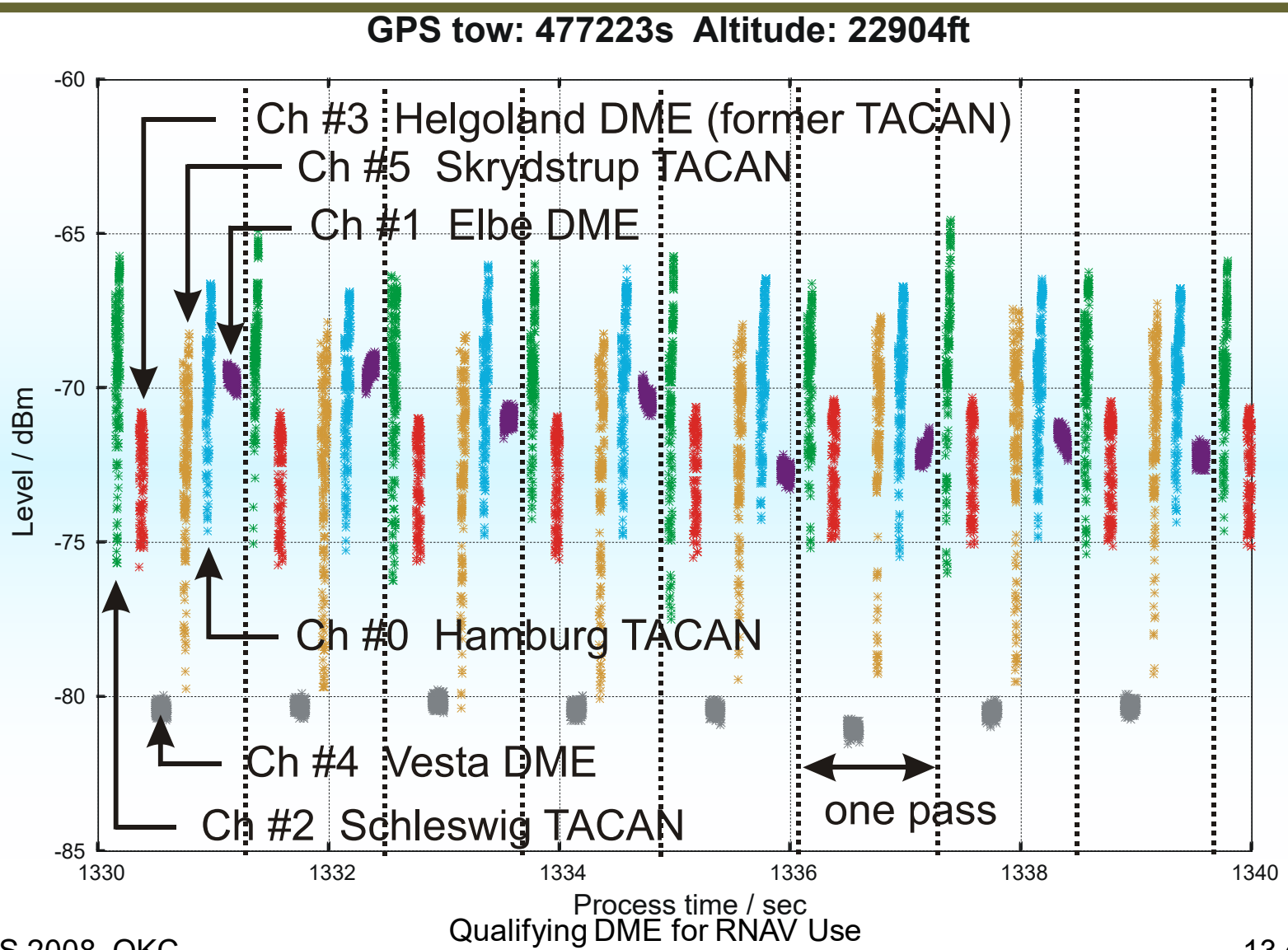
- Receiver requirements
  - Reliably measure received signal strength
  - Detect multipath distortion
  - Complement typical FI receivers
- Specifically developed receiver (SISMOS / DME)
  - Presenting test results of multi-channel capability

Signal-In-Space Monitoring System

Receiver and processor for DME/SSR channels



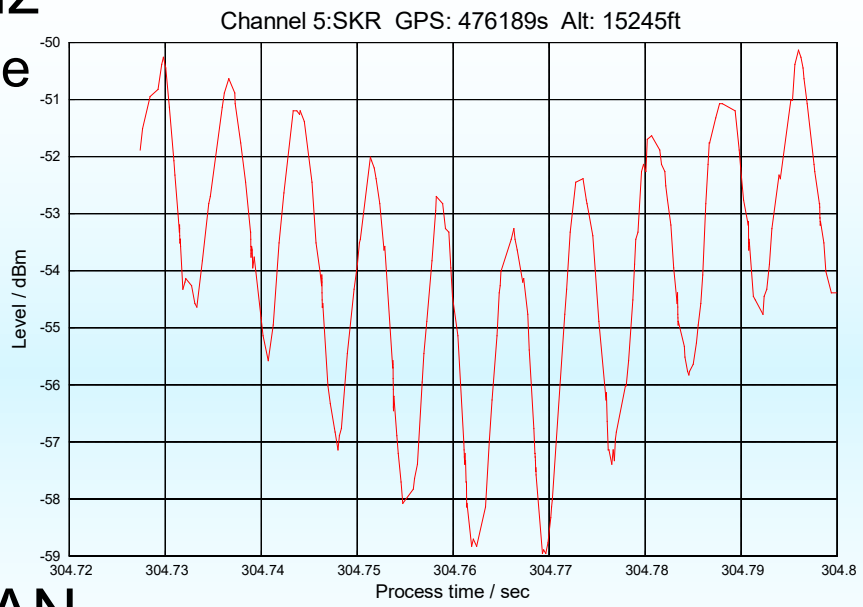
Six Channel Reception



Qualifying DME for RNAV Use

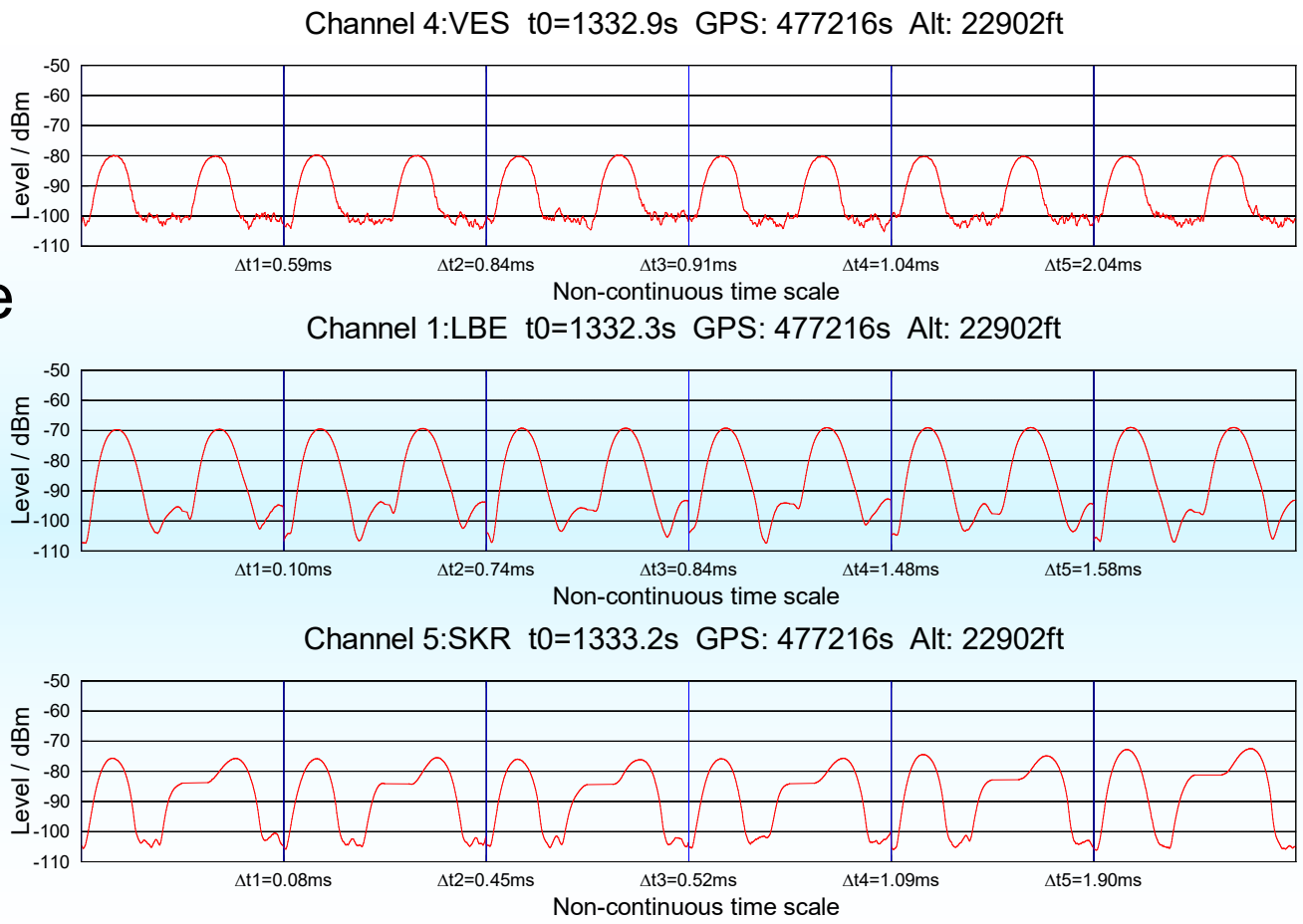
Signal Level Reception

- Sufficient sampling to detect relevant multipath fading ~ 1Hz
  - More channels possible, could be adapted to environment
- TACAN signal levels are modulated by bearing component ~10dB
  - Figure shows Skrydstrup with 135Hz fine and 15Hz coarse modulation
- Trial revealed Helgoland TACAN with partial modulation
  - Incomplete change to DME operation



Six Channel Pulse Video

- Multipath distortions clearly visible
- Correlation Algorithm to detect abnormal pairs for closer engineering inspection



etc . . . . . .

Multi-Channel DME Inspection

- Receive ONLY
  - Not possible to measure ranging accuracy
    - But unprecedented clarity of signal effects
  - Classical DME still needed for this
    - But low field strength / multipath / low accuracy is well correlated..
- Advantage of Passive Device
  - Continuous DME network monitoring possible
  - Take advantage of ALL other FI and ferry flights
  - Receiver concept and feasibility demonstrated

Part III

- Infrastructure Assessment Guidance Material Summary
- Multi-channel DME Inspection Capability
- **DME First Installed Prior to 1989**

DME First Installed Pre 1989

- 1989 ICAO Annex 10 Change
  - Requires transponder to use first pulse timing
  - All TSO-C66 interrogators use first pulse timing today
- Eurocontrol Navigation Subgroup
  - Can these 20+ year old DME support P-RNAV?
    - Potential for “deleterious effects to NAV solution”…
    - Accuracy error budget SIS allocation: 0.1NM (95%)
  - PANS-OPS Tolerances
  - Cross-border issue (difficult to identify)
    - Europe-wide forced upgrade was considered
- Thales / Face FSD-15
  - Anticipated standards change and made time reference configurable
  - Enables tests using *either* pulse reference in *identical* environments

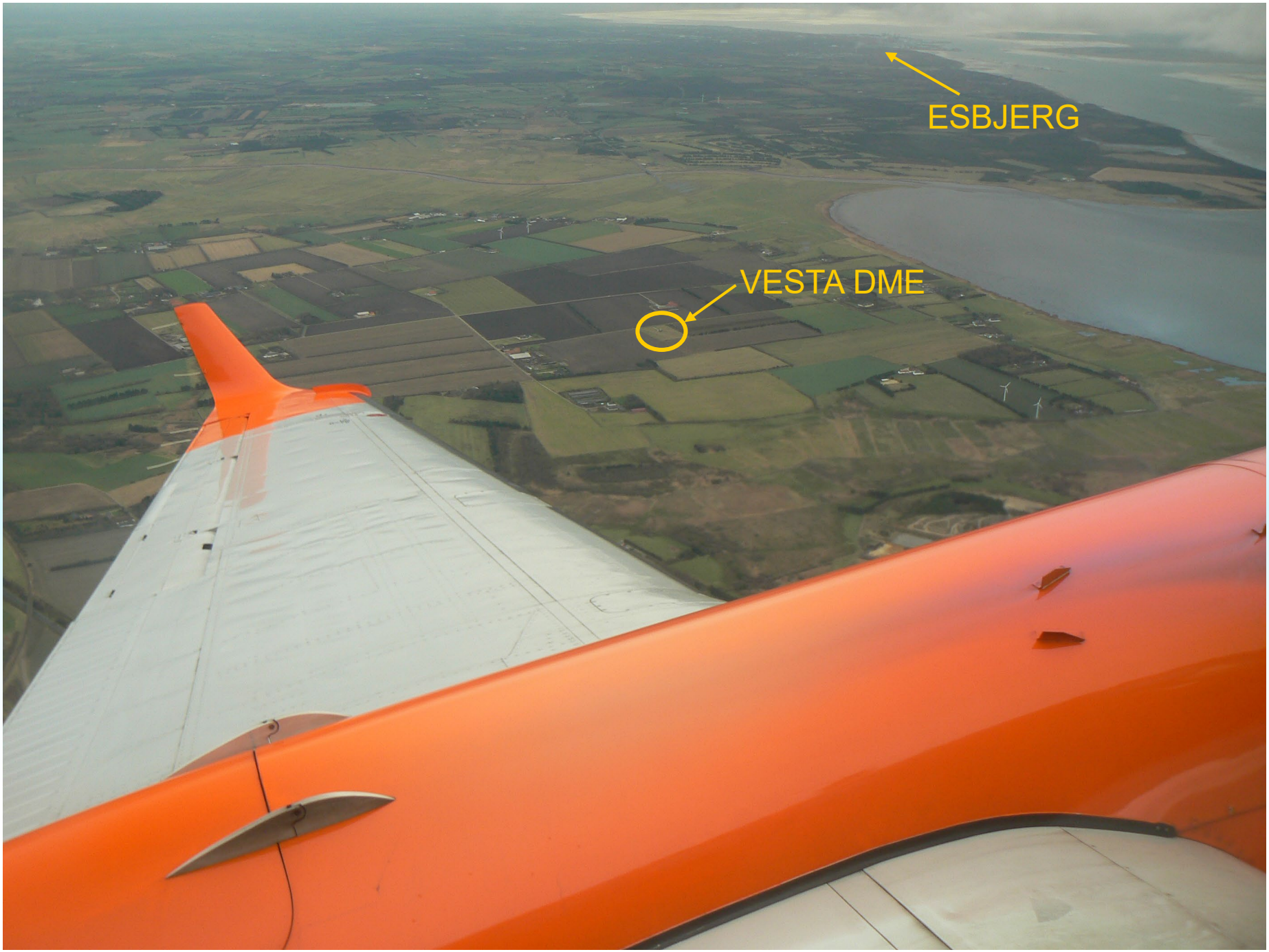
Vesta DME near Esbjerg, DK

Vesta DME

- Flight Calibration Services (FCS)
  - Beech B300 Super King Air D-CFMD
  - 2 Honeywell DME
  - 2 Collins TACAN

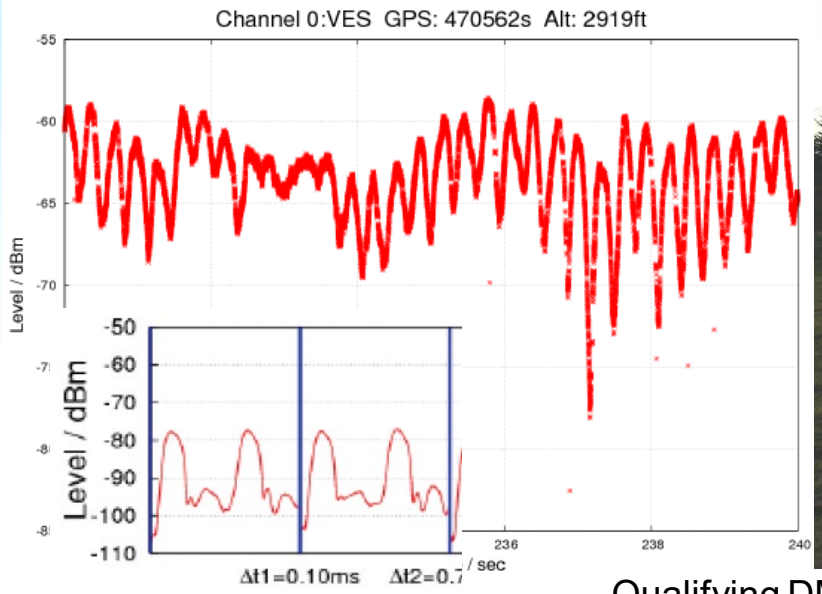
  Error Budget
  - SISMOS
    - Reciprocity

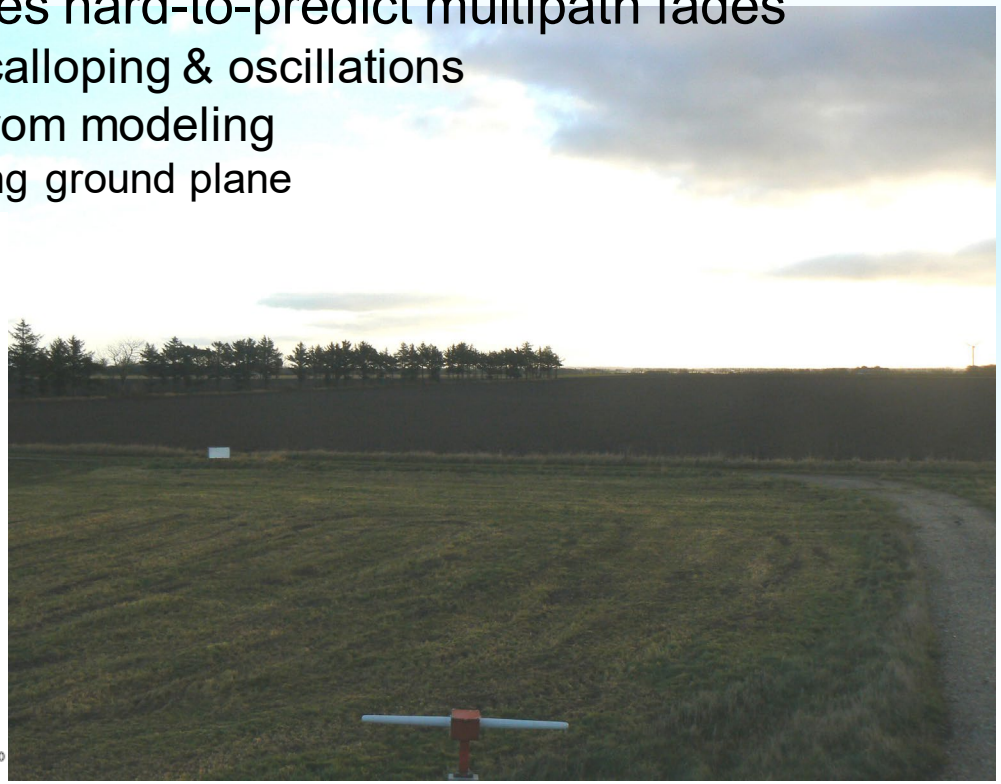
  MP Impact on 2nd Pulse
- Test Program
  - 10NM Orbit 3000 ft
  - Inbound and Outbound Radials 3000 ft
  - Once in 1st Pulse and once in 2nd Pulse Mode


ESBJERG
VESTA DME

Test Results - Multipath

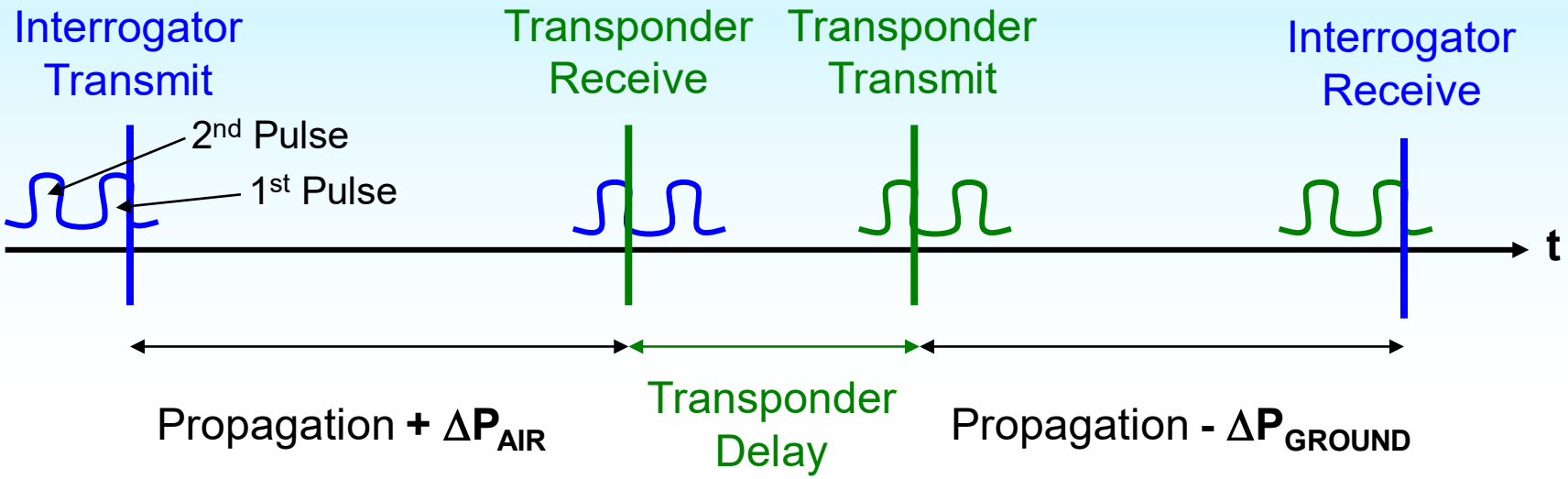
- NO *nominal* SiS performance difference between 1st and 2nd Pulse
  - Possible to meet P-RNAV Accuracy Error Budget on 2nd Pulse TXPDR
  - Requires “clean” environment: IF multipath issues exist, they will be greater
- Even clean environment creates hard-to-predict multipath fades
  - In addition to characteristic scalloping & oscillations
  - Effect would not be obvious from modeling
    - Vertical dipole over conducting ground plane





Test Results - Interoperability

- While obvious from theory, bias is observable in flight test data & lab
- If aircraft uses 1st pulse reference and ground 2nd pulse, then aircraft pulse spacing becomes relevant for error budget
- Interrogator OEM's take full advantage of the ±0.5µs (±0.04NM) tolerance
  - Resulting "interoperability error" has been allocated to transponder
  - VESTA FSD-15 total range error remains around 0.03NM regardless of pulse reference (Root-Sum-Square Effect)



Pre-1989 DME Conclusions

- 2nd Pulse Timing
  - Key vulnerability is reflection delay of 1st pulse around 12µs (X-channel)
  - Such delays are actually "difficult to create"
    - Reflector needs large conducting surface coincident with suitable reflection angles and
    - To be located on ellipse of pulse spacing path delay (hangars or lakes / snow covered plains with DME on hill)
- Multipath fading and scalloping can be observed independent of time reference
  - Impossible to predict with modeling, but normally of limited magnitude
- Infrastructure Assessment Guidance Updated
  - Pulse spacing tolerance error acceptable for such few DME
    - Most such DME will be replaced in the coming years
  - P-RNAV support is *possible* – but needs to be verified as for 1st pulse DME's
    - "Interoperability Error" needs to be taken into account

Conclusions

- P-RNAV Infrastructure Assessment Guidance Material is available
  - Summarizes about 3 years of effort (Standards harmonization, establishment of process and technical topics)
- RNAV / DME Inspection requires Innovation from Flight Inspection
  - New receiver concepts for concurrent measurements
  - Integration with Pre- and Post-Flight Analysis

Questions?

- Thank You for Your Attention !
- Feedback of RNAV / DME Flight Inspection Experience is WELCOME
  - gerhard.berz@eurocontrol.int
- Free Copies of “P-RNAV Infrastructure Assessment Guidance Material” Document are available on request