GBAS
Where is the world going?

Bodø 2. February 2016

Linda Lavik – Product Manager

Indra Navia AS

Agenda

- **GBAS Objectives and history**
- How does it work?
- GBAS Concept
- Where is the world going?

Why GBAS ?

- No accidents attributed to Precision Approach navigation aids (ILS) - so why change?
  - ILS frequency congestion
  - Airport density/construction causes increasing performance issues
  - Airport capacity restricted by ILS sensitive areas during Low Visibility

- ICAO advocates GNSS for all phases of flight
  - GBAS is part of this policy for the approach phase

GBAS Objectives

- Alternative to ILS – minimum operational change
- Compliance with ICAO ANC recommendation to use satellite navigation for all phases of flight
- ICAO standardized (unlike S-CAT-I)
- Allow ILS overlays, but also more advanced procedures
- Overcome ILS capacity limitations under LVP
- At least as safe as ILS
- Lower operating costs than ILS
- Spectrum efficiency

Some GBAS history

Event	Year
RTCA DO-217 for SCAT	1993
GPS fully operational	1995
RTCA DO-253A (GBAS Airborne MOPS)	2001
ICAO Annex 10 for GBAS CAT I (amnd. 77)	2002
EUROCAE ED-114 (GBAS Ground MOPS)	2003
SCAT-I Ground Station Approval (Norway)	2005
First SCAT-I Operational (Norway)	2007
First GBAS CAT I Operational (Germany)	2009
ICAO Annex 10 for GBAS CAT III	2017?

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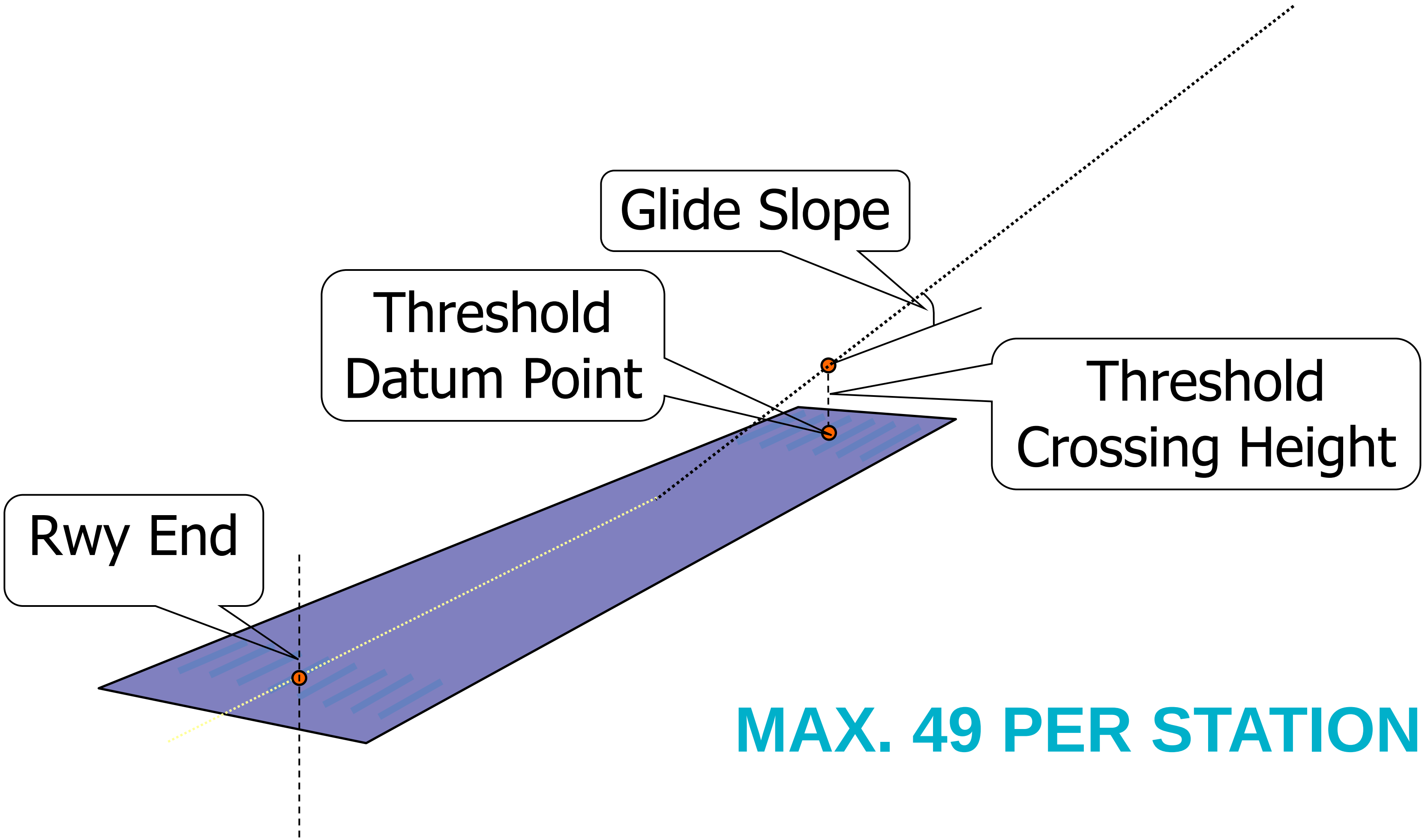
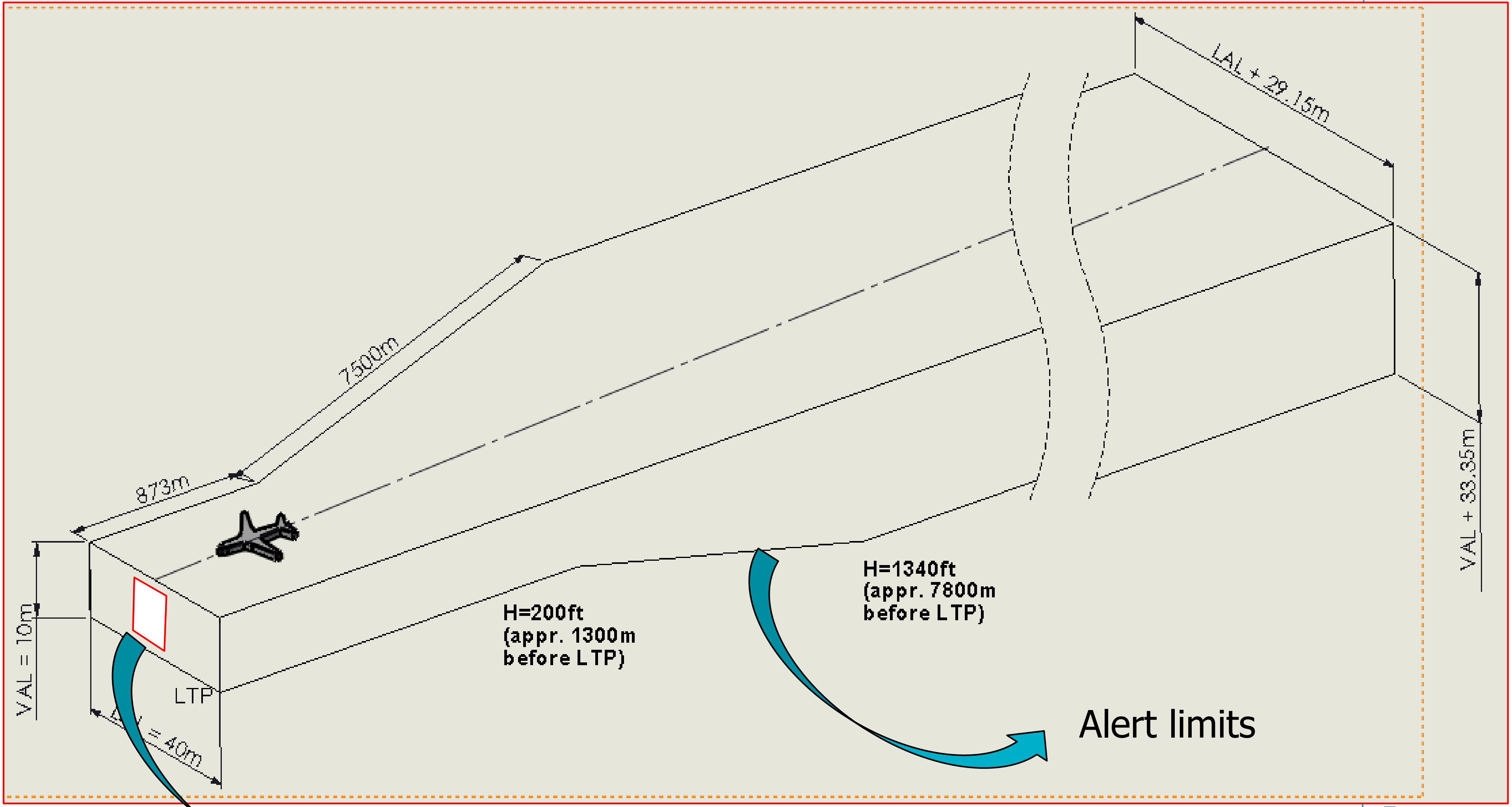
GBAS Concept – how it works

APPROACH DEFINITIONS
FINAL APPROACH SEGMENT (FAS) DATA



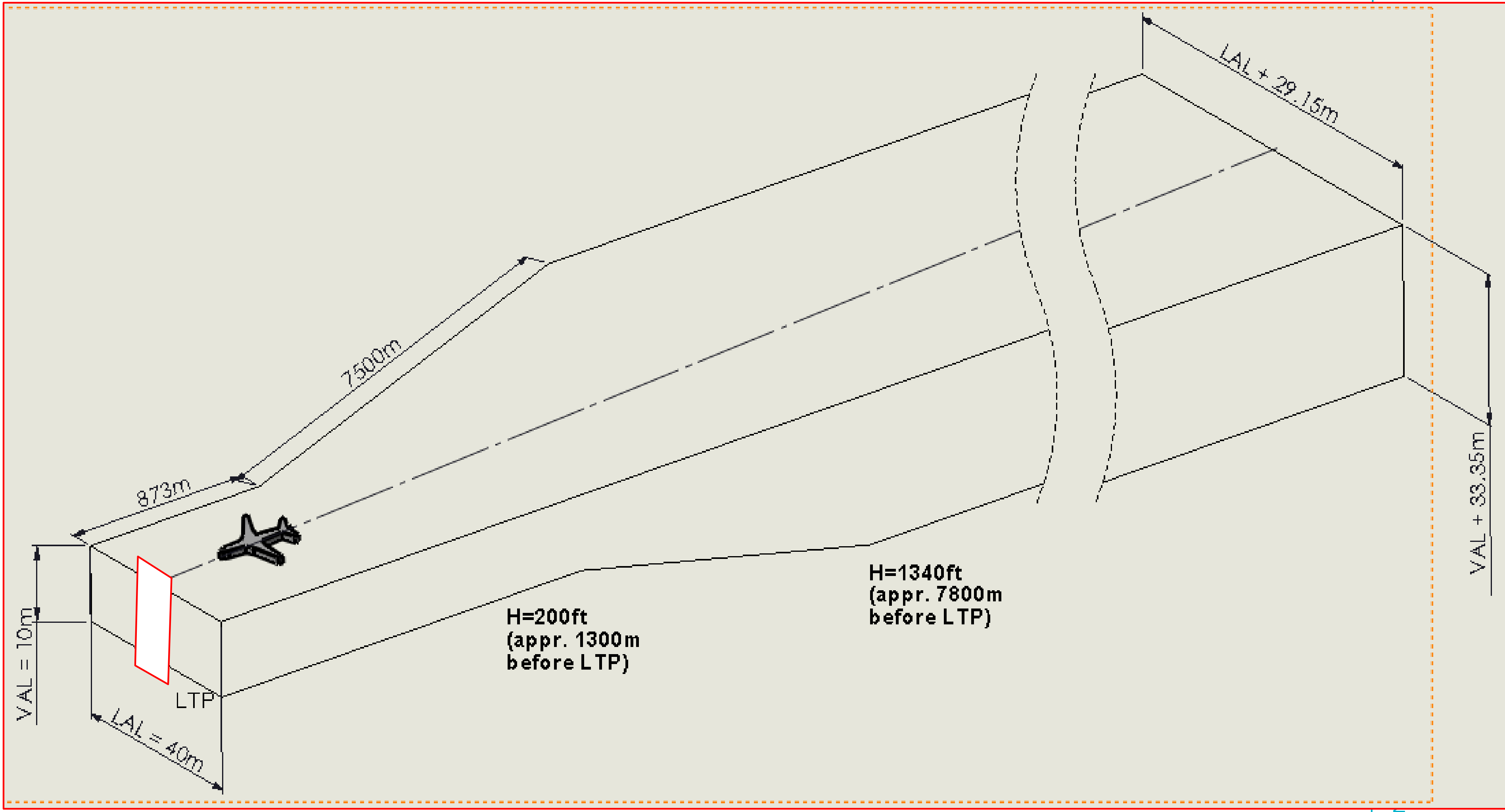
MAX. 49 PER STATION

Performance within limits – Availability OK



Protection levels
(error estimates)

Performance outside limits – availability Not OK



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Approach classification/facility categories

New Approach Classification

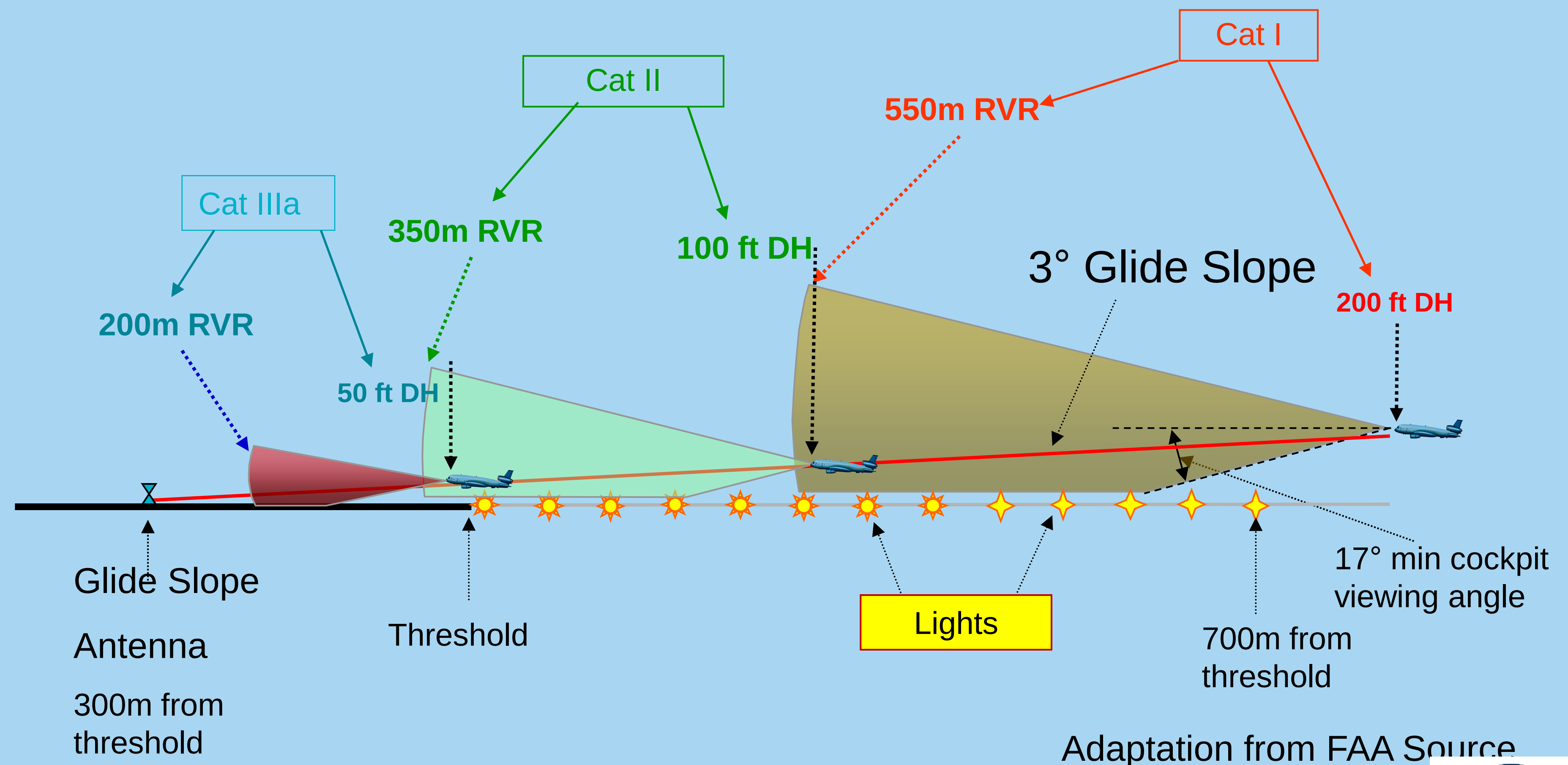
Domain	Document	Aspect					
Approach Operations	Annex 6	Classification	Type A		Type B		
			(>= 250')		CAT I (>= 200')	CAT II (>= 100')	CAT III (<100')
		Method	2D	3D			
		Minima	MDA/H	DA/H*			
Approach Runways	Annex 14	M(DA/H) >= VMC	Non Instrument RWY				
		M(DA/H) >= 250' Visibility=1 000m	Non Precision Approach RWY				
		DA/H >= 200' Visibility>=800m or RVR >= 550m	Precision Approach RWY, Category I				
		DA/H >= 100' RVR >= 300m	Precision Approach RWY, Category II				
		DA/H >= 0' RVR >= 0m	Precision Approach RWY, Category III (A, B & C)				
System Performance Procedures	Annex 10 PANS-OPS Vol. II	NPA	NDB, Lctr, LOC, VOR, Azimuth, GNSS				
		APV		GNSS/Baro/SBAS			
		PA		ILS, MLS, SBAS, GBAS			

* For guidance on applying a continuous descent final approach (CDFA) flight technique on a non-precision approach procedures refer to PANS-OPS (Doc. 8168) Vol. I Section 1.7

Approach Categories

Number of PA Runway Ends:
Worldwide about 3500
Europe: CAT I: ≈ 770
CAT II: ≈ 70
CAT III: ≈ 180

- Scaled illustration

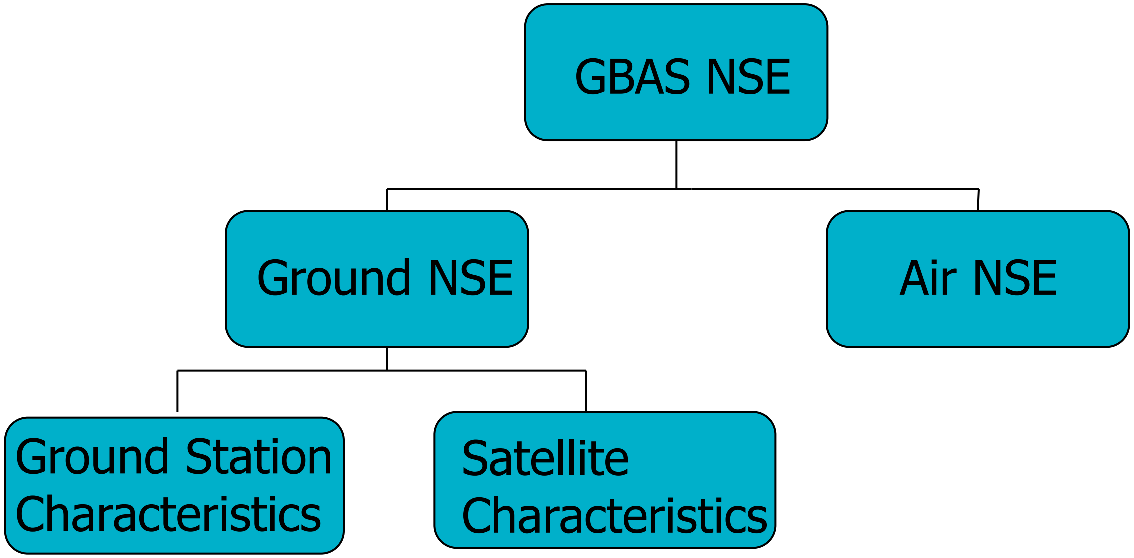


Courtesy of EUROCONTROL

EUROCONTROL

GBAS – can it support CAT III???

- The ICAO Concept for CAT I did not have the potential to meet CAT III
- CAT I Concept: All the monitoring responsibility was on the ground station



NSE: Navigation Sensor Error

- New exercise to split the responsibility between air and ground had to be done

Approach classification/facility categories GAST = GBAS Approach Service Types

	PRECISION APPROACH				
		LOW VISIBILITY OPERATIONS (ALL WEATHER OPERATIONS)			
Definitions of visibility categories	CAT I	CAT II	CAT IIIA	CAT IIIB	CAT IIIC
ICAO Annex 6	DH ≥ 200 ft & [RVR ≥ 550 m Or Visibility ≥ 800 m]	200 ft > DH ≥ 100 ft & RVR ≥ 300 m	DH < 100 ft or no DH & RVR ≥ 175 m	DH < 50 ft or no DH & 175 m > RVR ≥ 50 m	No limitations on DH No limitations on RVR
EU No 965/2012	**DH ≥ 200 ft & RVR ≥ 550 m**	**200 ft > DH ≥ 100 ft & RVR ≥ 300 m**	**DH < 100 ft & RVR ≥ 200 m**	**DH < 100 ft or no DH & 200 m > RVR ≥ 75 m**	---
GBAS Facility	GAST C	N/A	GAST D		N/A

- Amendment 91(?) 2017 (?) – GAST Concept to be introduced in ICAO Annex 10

CAT III – The GAST D Concept

Airworthiness & Operational requirement:
Land in the touchdown box
Safely in nominal, limit and malfunction cases

TSE

NSE Performance

A/C FTE Performance

GBAS Contribution to NSE

Other A/C NAV Sensors (IRS, RA…)

Ground Facility Characteristics

Satellite Charactersistics

GBAS Ground Equipment

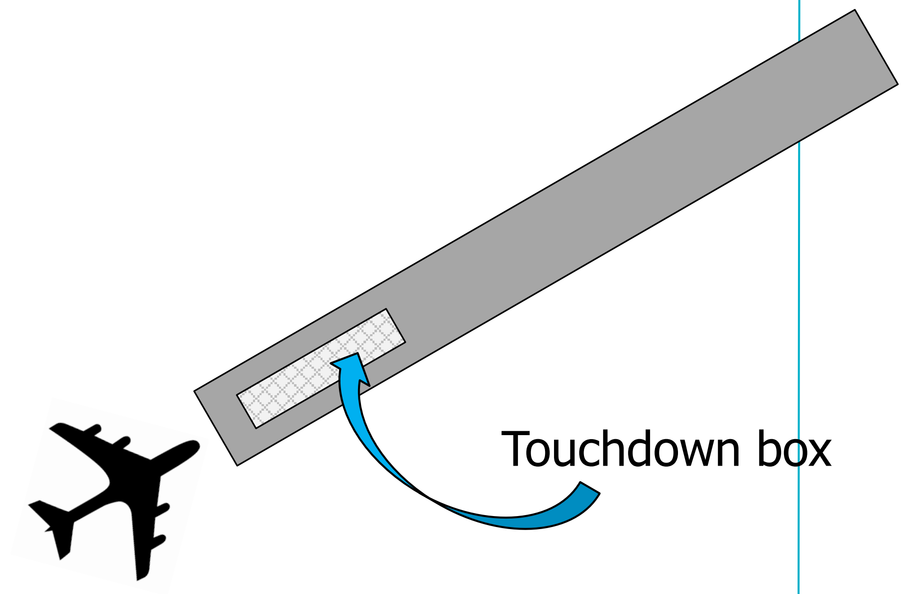
Standard Characteristics (incl. Sat. Monitors)

Non-Standard characteristics

GBAS Airborne Equipment

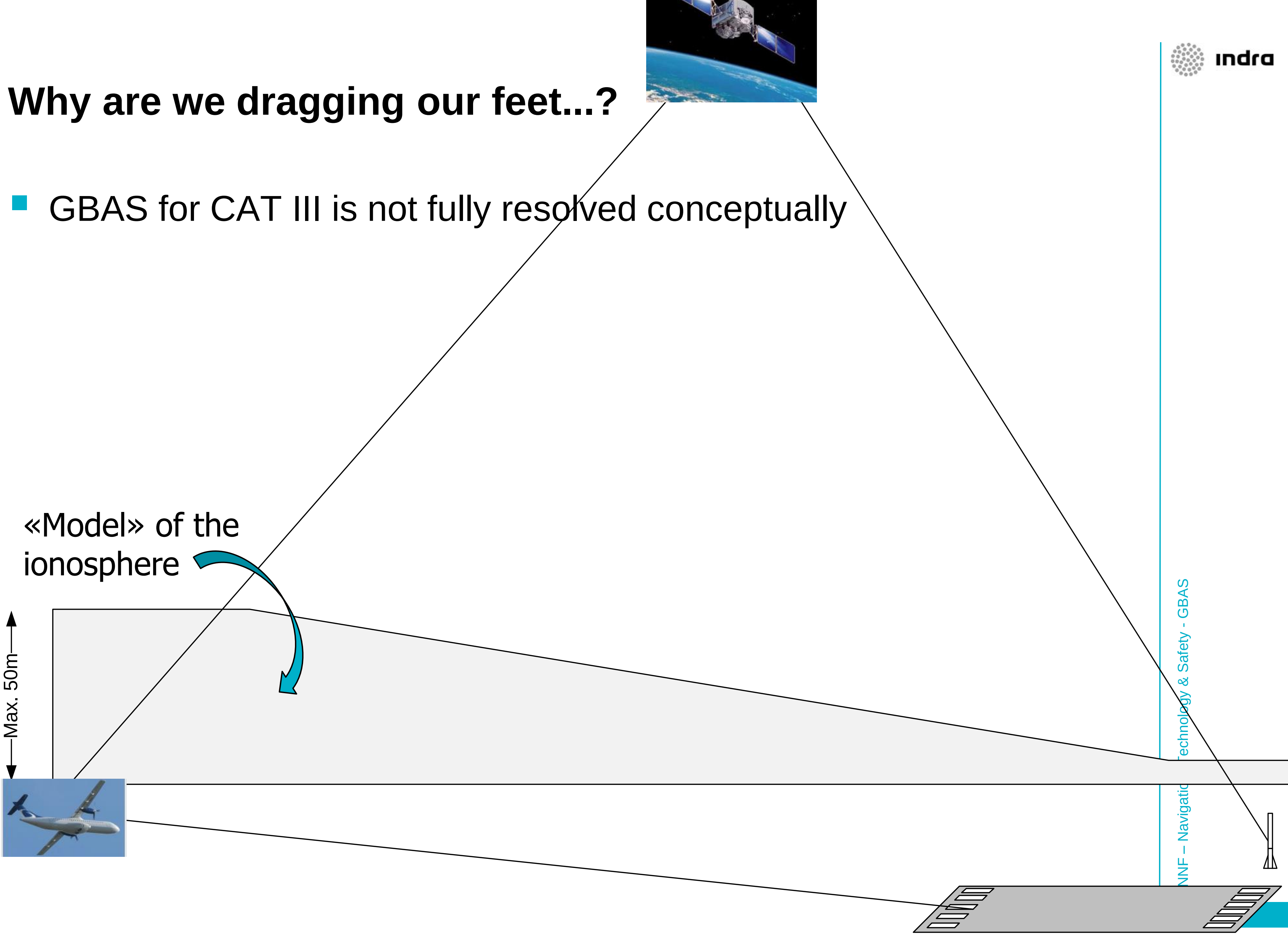
ICAO Annex 10

A/C Specific Requirements



Why are we dragging our feet...?

- GBAS for CAT III is not fully resolved conceptually



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GBAS & SBAS are complementary systems:

GBAS

- Presicion Approach and Landing, CAT I, II, III
  - ILS
  - MLS
  - GBAS
- Intercontinental
- Mainline Aircraft (Boeing, Airbus)

SBAS

- Non-precision approach/ type B?
- Regional
- Smaller, shorter-range aircraft (GA, regional)

GBAS CAT I – AIRCRAFT EQUIPPAGE

Boeing GLS Equipage

737NG GLS certification in 2005

737MAX GLS certification planned in 2017

747-8 GLS certification in 2011

787-8 GLS certification in 2011

787-9 GLS Certification planned in 2014

787-10 GLS certification planned in 2018

777X GLS certification planned in 2019

Over 1000 Boeing Airplanes are equipped with GLS today!

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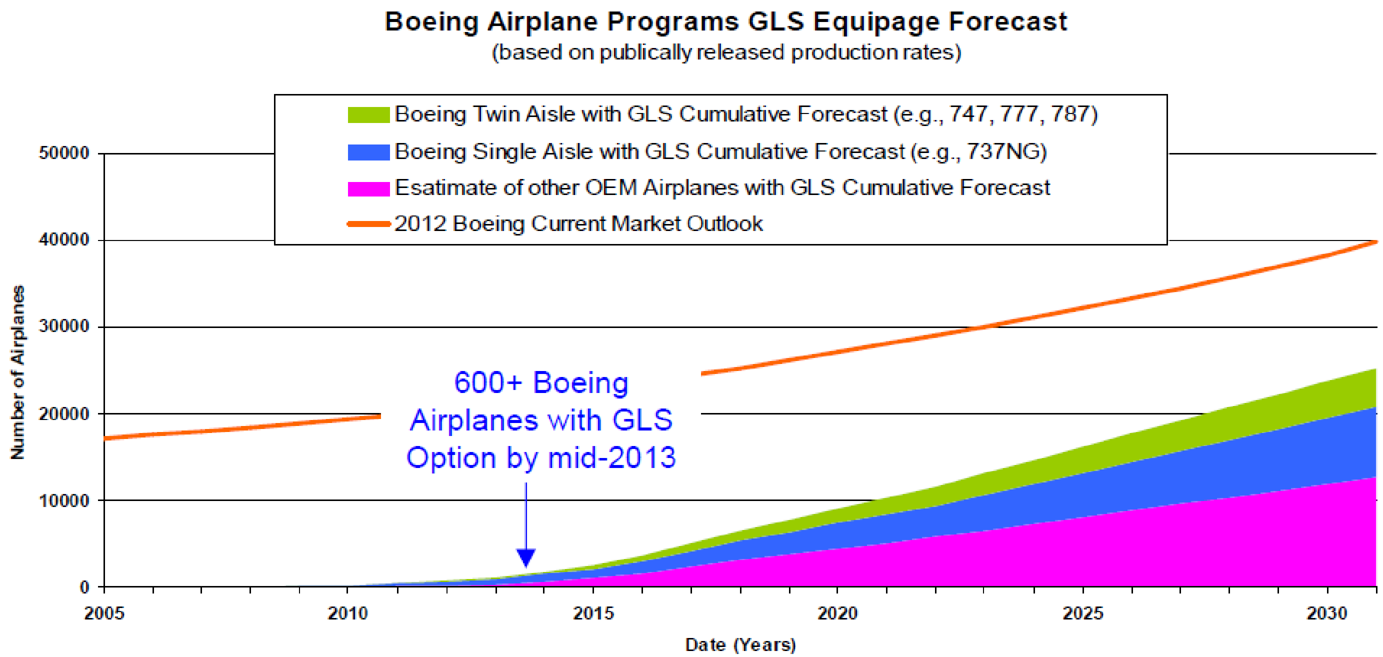
GBAS CAT I – Aircraft equippage (contd)

Boeing GLS Program | Equipage Forecast Update



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An additional 800+ Boeing 737NG Airplanes will have selected GLS provisions by mid-2013

GBAS CAT I – Aircraft equippage (contd)

- A380: GBAS is an option – selected by 9 customers
- A320: GBAS is an option - selected by 8 customers
- A330/340: GBAS is an option - selected by 2 customers
- A350: GBAS is an option - selected by 5 customers

(Data per 2013)

Several airlines now have significant fleets which are GBAS equipped

GBAS CAT I – Aircraft equippage (contd)

15th IGWG - Airbus status - EYIC - Ref. X34PR1411500 - Issue 1 June 2014

GLS option on Airbus fleet

Airbus customers

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Ground installations – flygls.net

Legend:

description

Blue: Prototype/Research (with dot: actively transmitting)

Yellow: S-CAT (with dot: charts published)

Green: Operational (with dot: charts published)

Purple: plannned installations

FRANKFURT INSTALLATION (SESAR)

OSLO AIRPORT
Gardermoen

(Norwegian Research Council)

Site B,
Candidate site
NORGAL

Summary

- Boeing and Airbus are implementing GBAS for precision approach
- Equippage rates still low/moderate
- ILS-only aircraft will be out there for several decades
- GBAS can provide:
  - Higher capacity in LVP
  - Lower maintenance costs due to reduced no. of ILS’s
  - Flexible approaches
    - RNP to GBAS (curved)
    - Different glidepaths & thresholds for same approach
  - Precision approach where none exist today (safety)
  - More effcient spectrum use

Thank you for your attention!

And thanks to:
- Norwegian Space Centre
- Norwegian Research Council
- SESAR

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GBAS BENEFITS – reduced infrastructure

- One GBAS Ground Station can provide up to 48 approaches to an airport
  - Serving multiple runways
  - Providing diverse glidepaths and thresholds

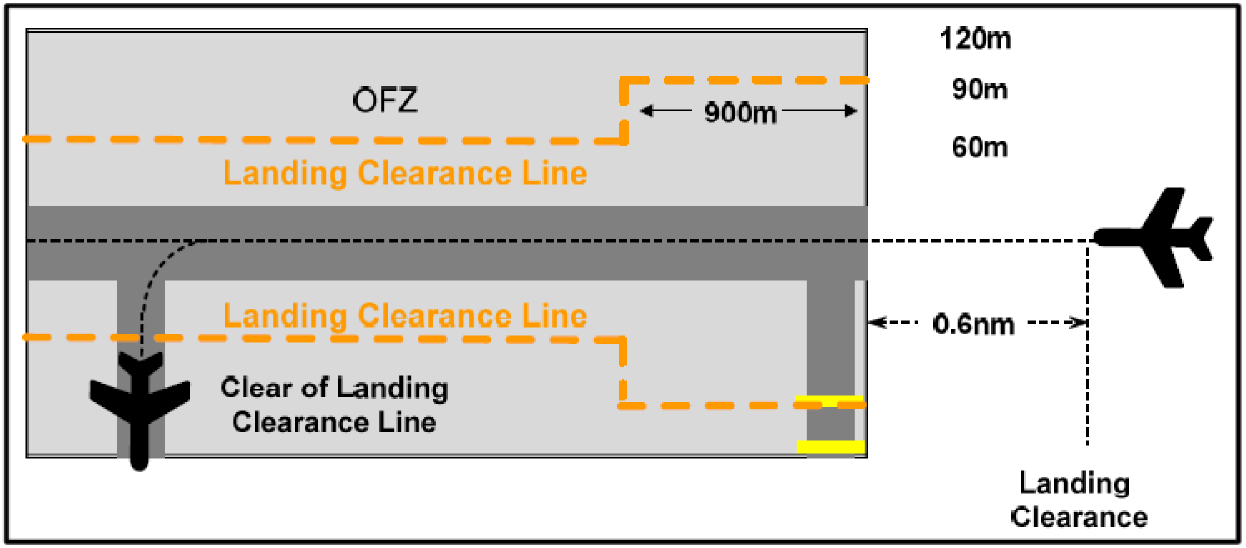
- Thus,
  - Reducing the infrastructure real-estate footprint
  - Reducing maintenance work
  - Reducing / removing need for flight inspection

GBAS BENEFITS –
Precision Approach where none exist today

- **Improved capacity** by enabling precision approach during reduced visibility
- **Reduced risk of diversion, cancellation, go-around** and excess fuel uplift
- **Increased Safety** through guidance where precision approach is not possible today

GBAS BENEFITS - No sensitive areas

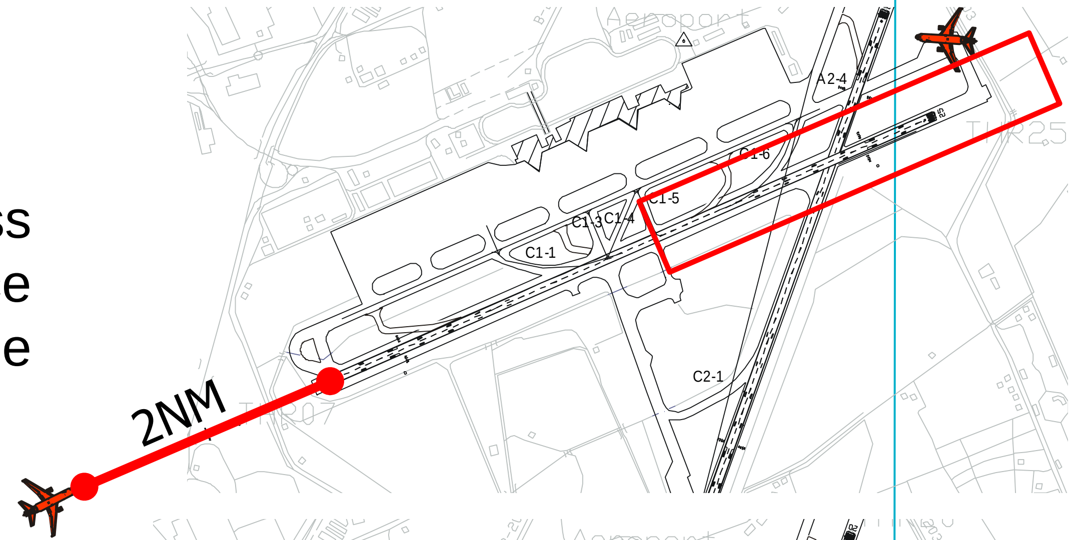
- **Reduced risk of signal loss** and go-around
- **Improved capacity** through enabling departures between sequential arrivals
- **Reduced separation** opens for more effective traffic flow and increased number of movements
- **Reduced ground movement delay**
- Reduced sensitive areas on taxiways and stop bars - **more effective flow on the ground** and **increased number of movements**.



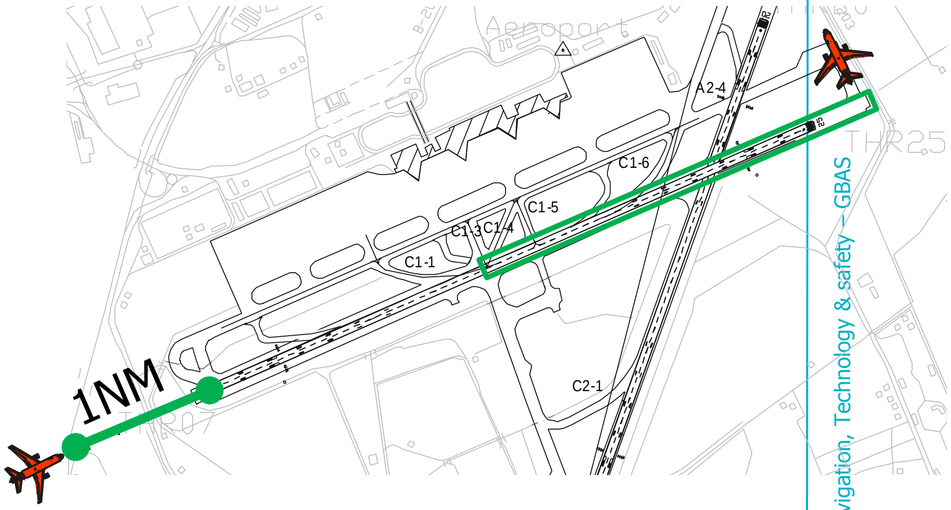
SESAR Simulations and safety assessment

Operational Concept:

- ATC can use a less constraining landing clearance line for aircraft vacating the runway.



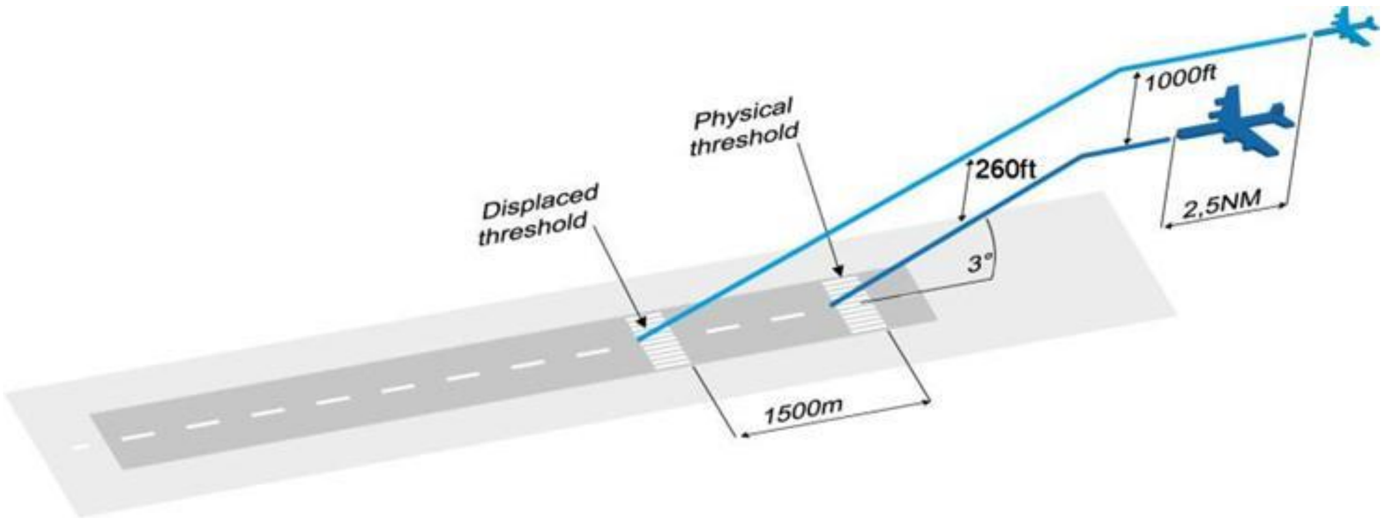
- ATC can provide the pilots with late landing clearance, up to 1NM before threshold



- ATC can reduce the final approach spacing in LVP in front of GBAS equipped aircraft

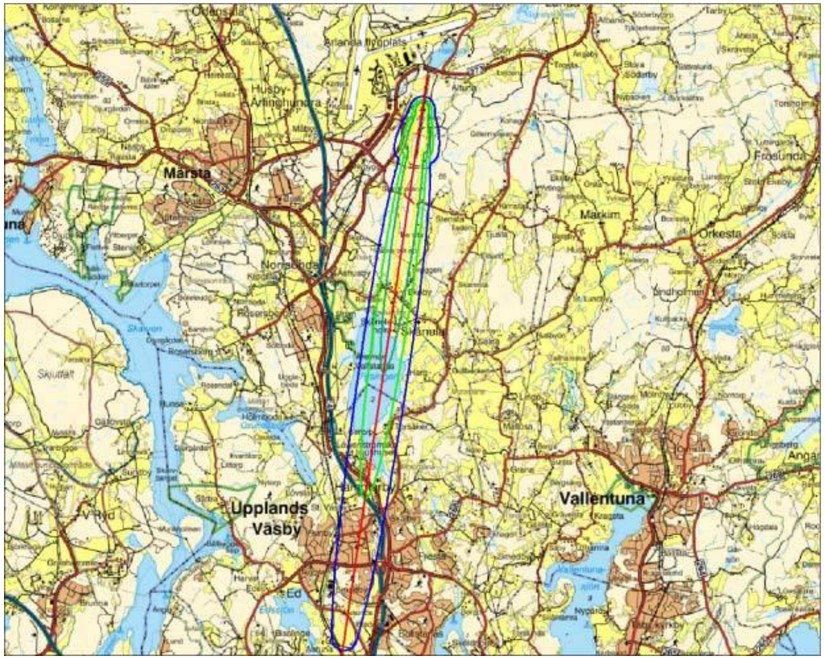
NNF Navigation, Technology & safety – GBAS

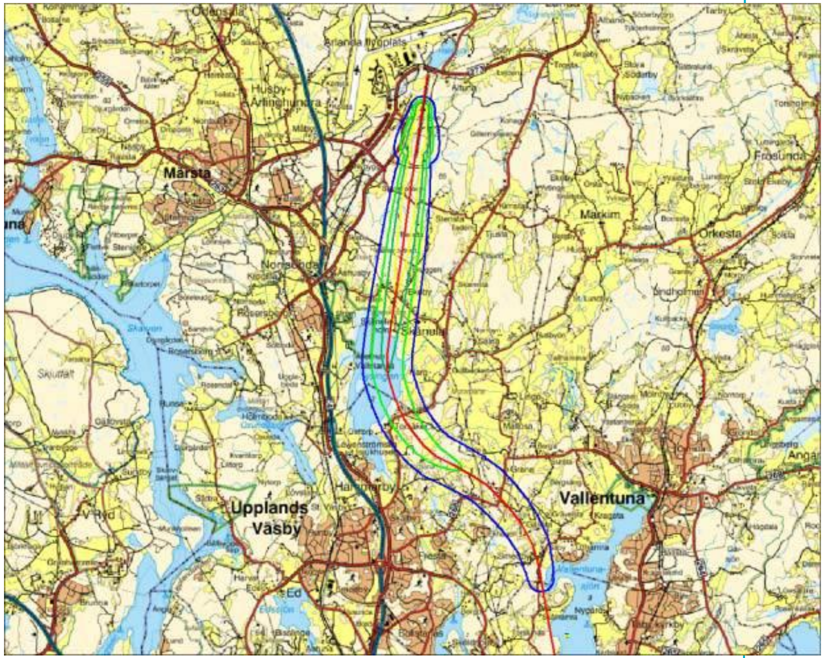
GBAS BENEFITS - Displaced Thresholds



- GLS approach - Less risk of wake vortex encounter: Reduced separation
- Less RWY Occupancy time and noise impact reduction are other benefits.

GBAS BENEFITS –
RNP-GLS-Curved Approches

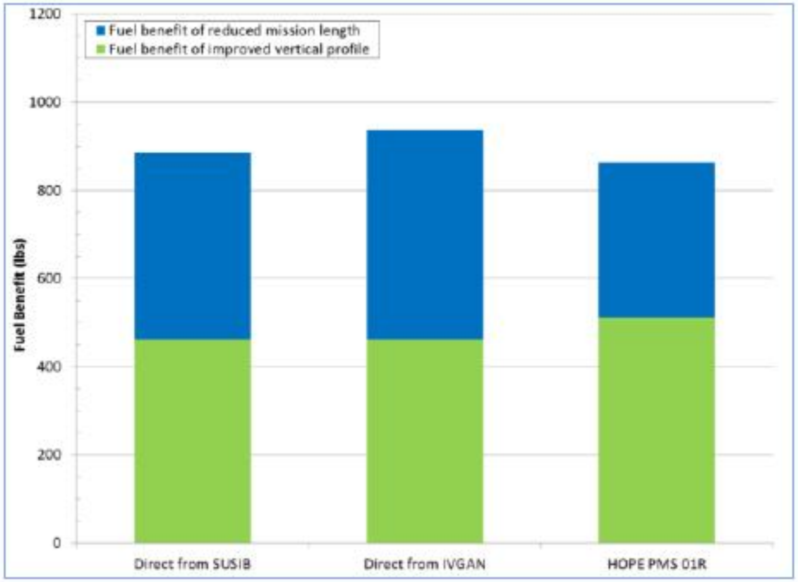




- RNP: Very predictable Initial and Intermediate curved approach segments (Radius to Fix turns)
- GBAS: GLS Final Approach Segment (i.e. different slopes, different THR, shortest possible length)
- Noise-reduced approaches are possible due to a more flexible approach path adaption

Example of OSL Benefits

- 737-800 OSL RNAV Visuals to 01R (assume ~ 250 flights weekly)
  - Savings up to 12M lbs. of fuel per year
  - Savings up to 38M lbs. of CO2 per year



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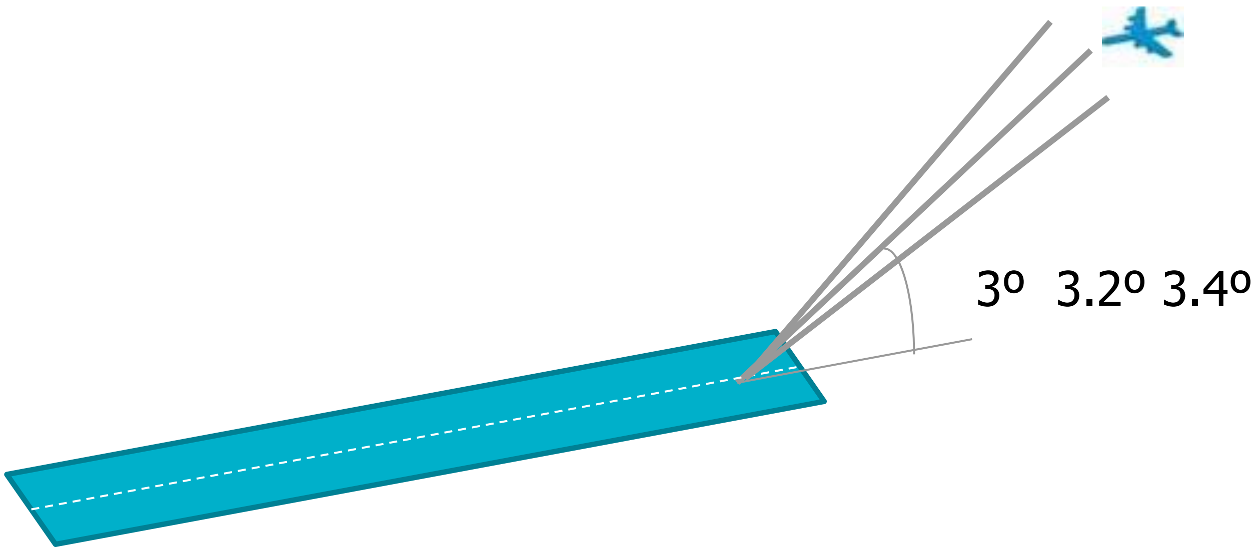
GBAS BENEFITS –
Approaches of various elevation angles



- **Noise abatement**
- **Reduced separation** through Wake turbulence effect reduction
- **Increased safety** through Wake turbulence effect reduction
- **Improved capacity**
  - Through enabling closely spaced parallel independent operations
  - Through wake vortex mitigation

Future benefits – SESAR2020

- Ground movement
- Increased accuracy in terminal area navigation
  - Pilot workload reduction
  - Improved capture – shorter final