skyguide

Ground Based Augmentation System Technology

ION-CH / SATTA
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member of FABEC

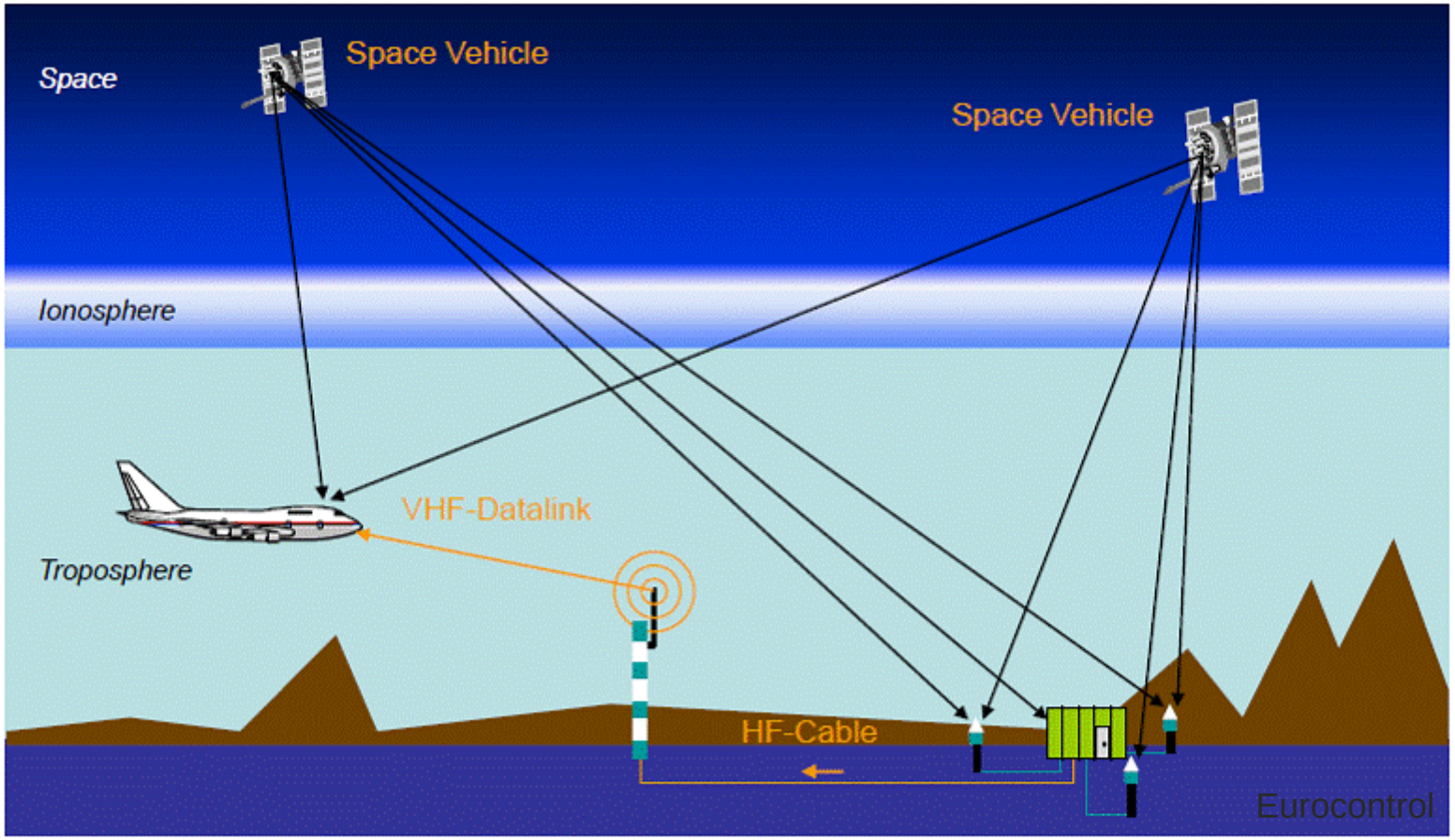
Why GBAS?

1. Improved accuracy by correcting measurement errors.
   ⇨ *Differential GPS (DGPS)*

2. GPS cannot provide integrity.
   Safety critical applications require integrity.
   ⇨ *GBAS provides integrity.*

3. Approach path:
   ⇨ Final Approach Segment (FAS) is provided.

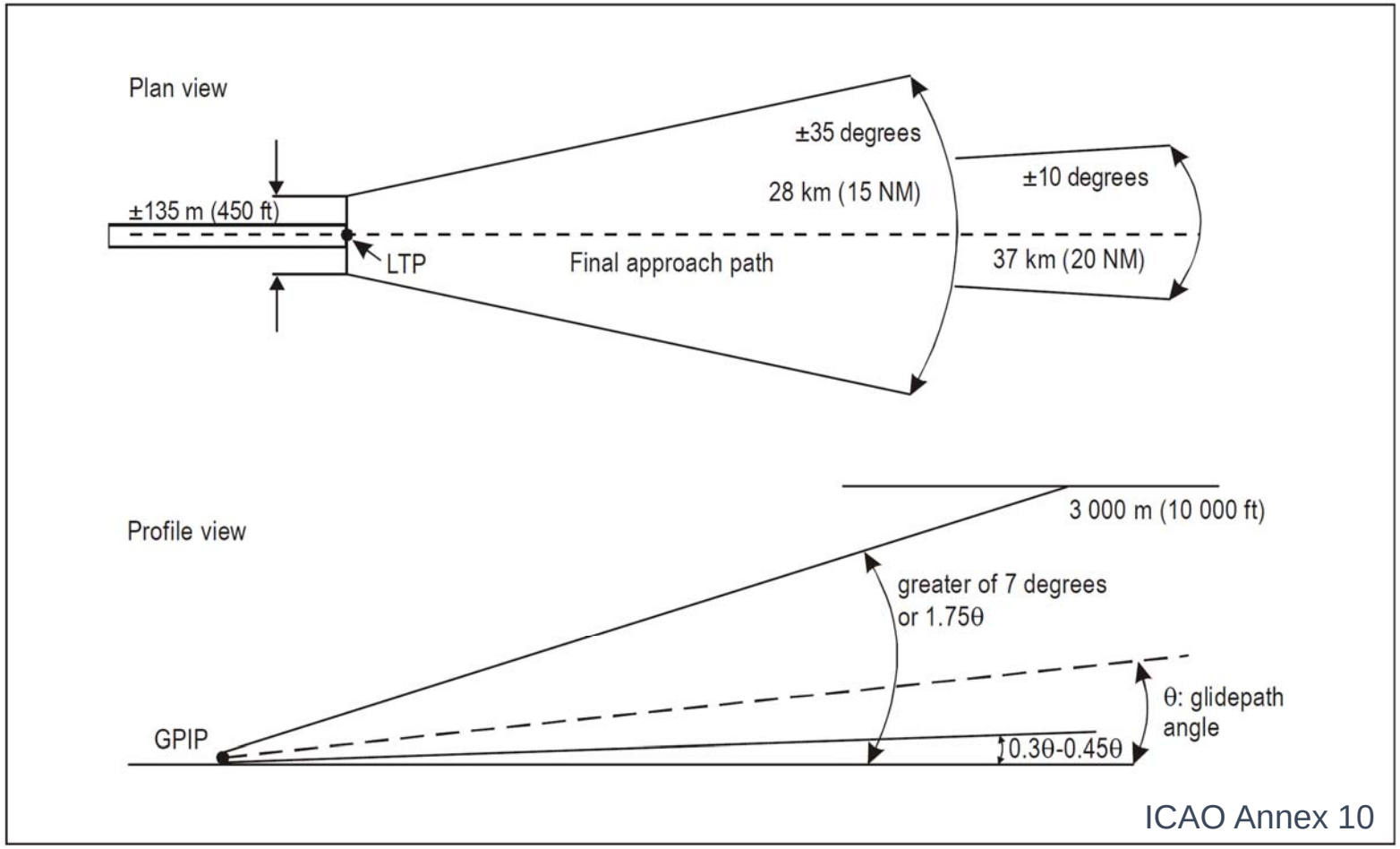
GBAS Basics



Ground Subsystem

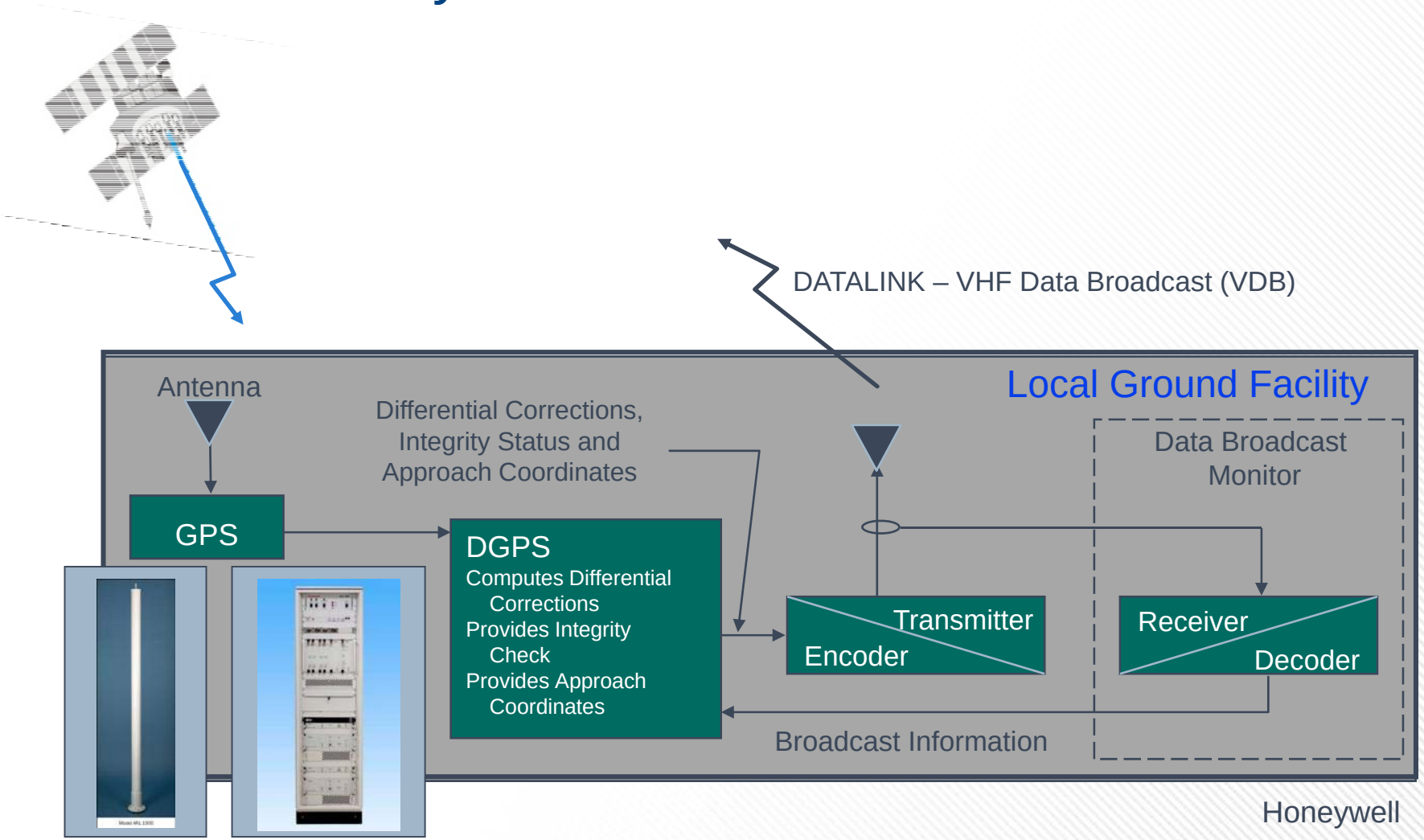
- The Ground Subsystem consists of two to four GNSS reference receivers, ground processing functions, data broadcast transmitters and integrity monitoring.
- Time-tagged differential correction information is generated for each satellite. Satellite integrity data is also elaborated. This is obtained by processing the received satellites' signals by reference to the surveyed and stored antenna co-ordinates.
- The GBAS Ground Subsystem stores FAS path construction data. It consists of path points describing approaches for each related runway end (WGS-84)
- The data broadcast uses the VHF band 108.000 – 117.975 MHz

Ground System Coverage



ICAO Annex 10

Ground Subsystem



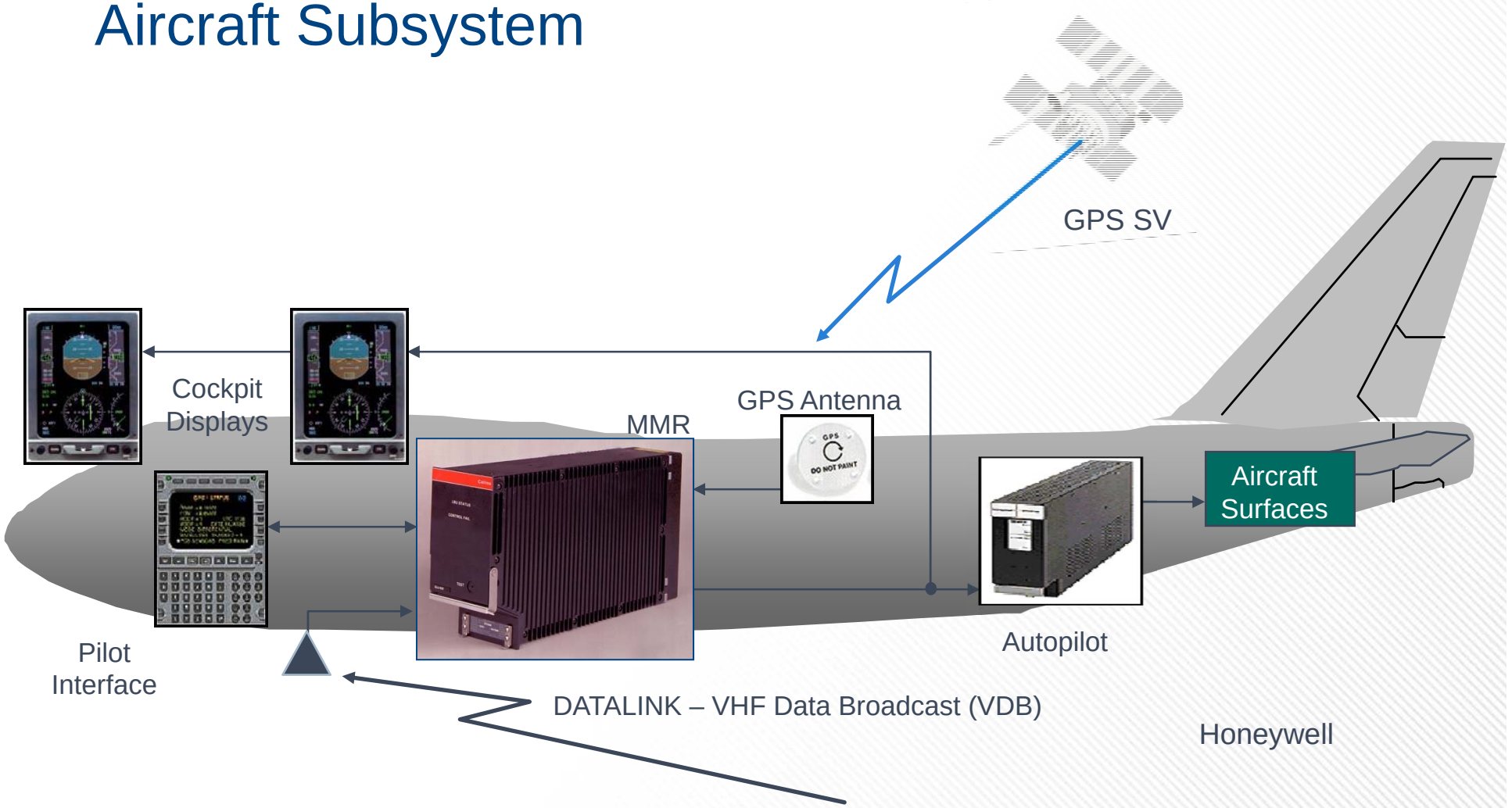
VHF Data Broadcast Signal

- **Broadcast of Type 1 message, “GNSS Pseudo-range Corrections”**
  pseudo-range corrections with associated integrity parameters

- **Broadcast of Type 2 message, “GBAS Related Data”**
  number of reference receivers installed,
  the Ground Accuracy Designator letter,
  the GBAS Continuity/ Integrity Designator
  the local magnetic variation,
  the local tropospheric delay parameters,
  the location of the GBAS Reference Point (WGS 84).

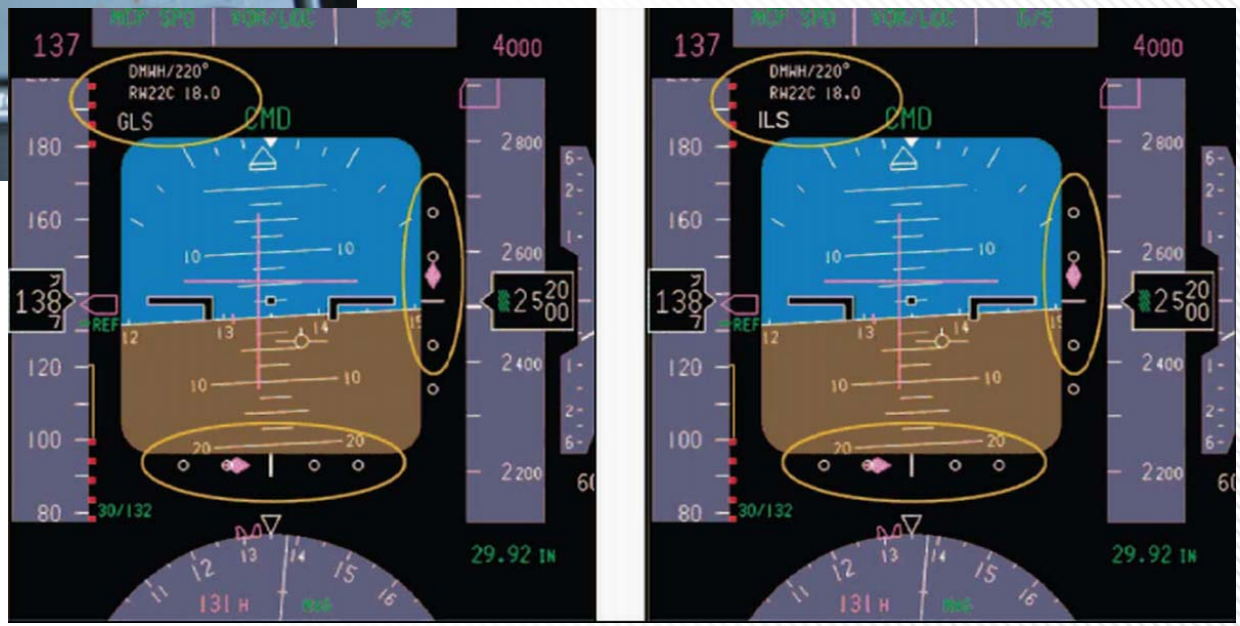
- **Broadcast of Type 4 message, “Final Approach Segment Data”**
  includes the FAS which consists of Path Points describing approaches for each related runway end, the FAS Vertical Alert Limit/ Approach Status, and the FAS Lateral Alert Limit/ Approach Status.

Aircraft Subsystem



Aircraft Subsystem

NAV Tuning Unit (MMR)



GBAS vs. ILS

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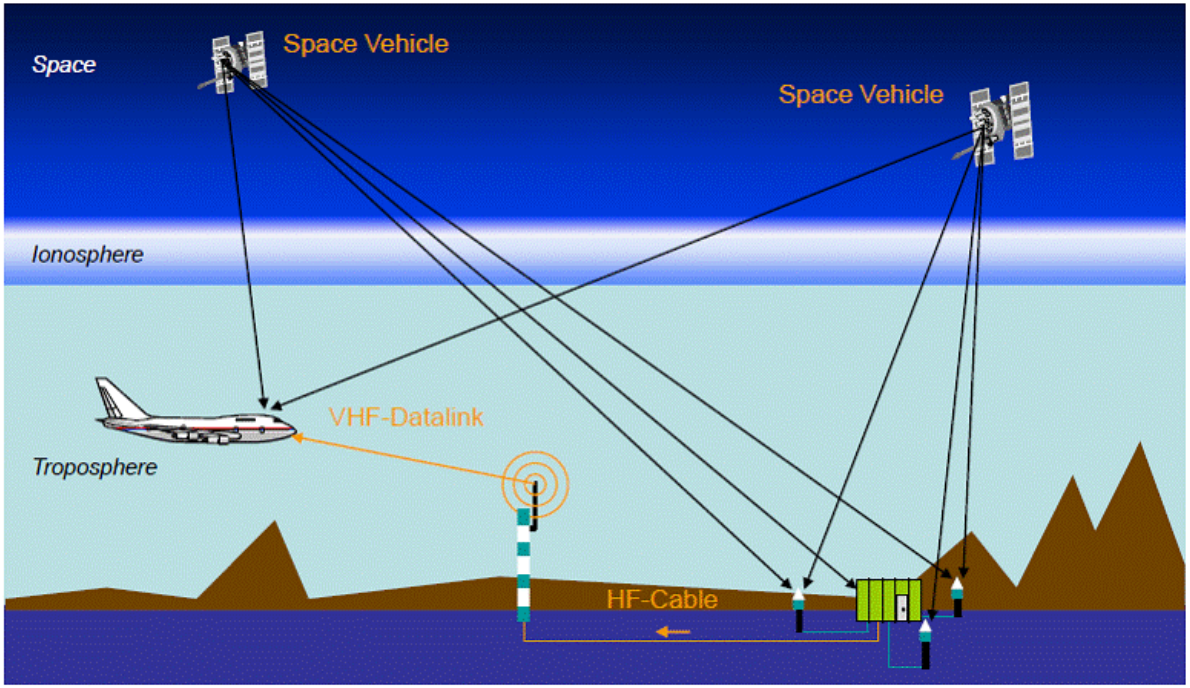
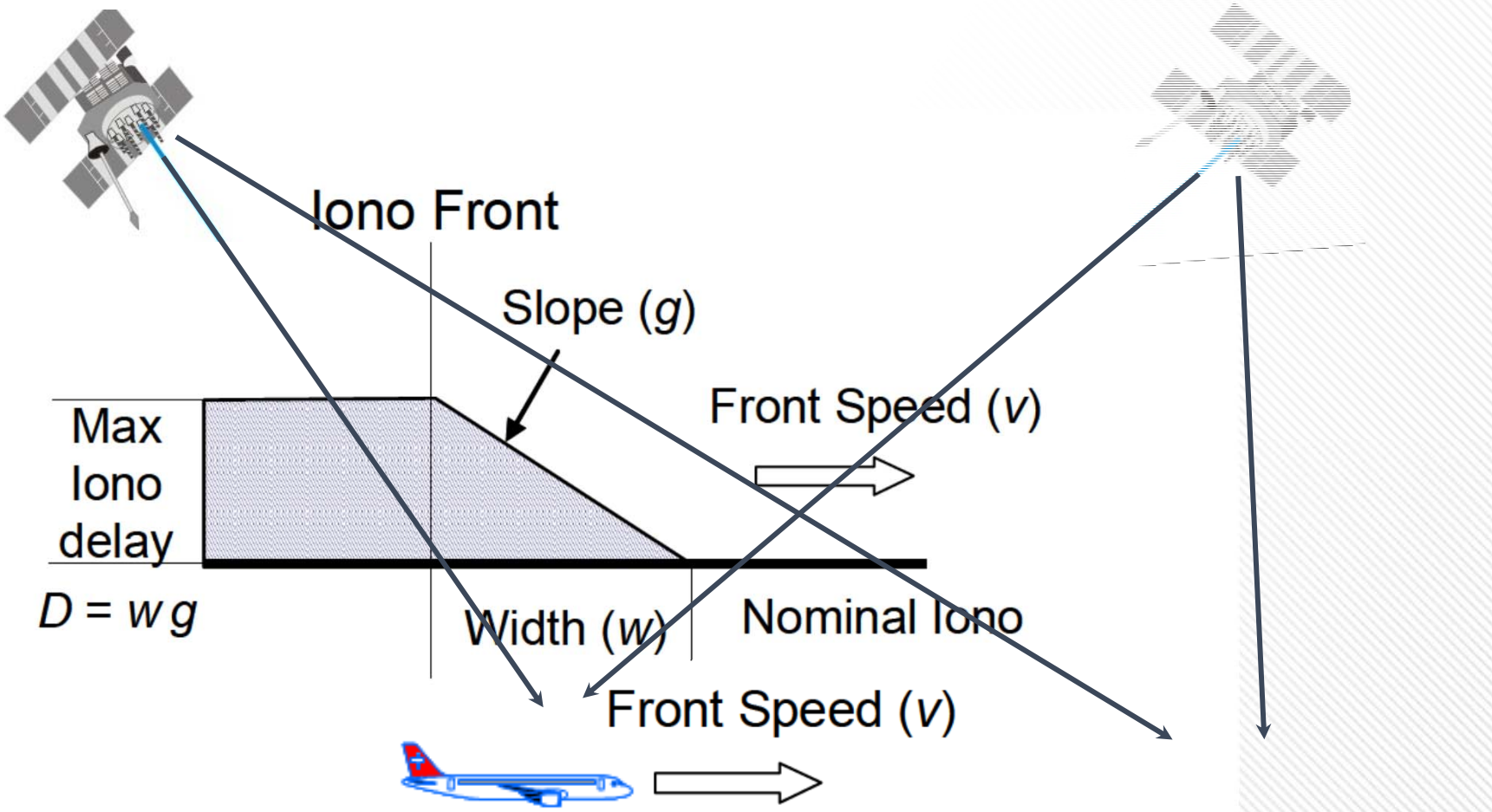
Differential GPS (DGPS)

› DGPS corrects measurement errors common to both, aircraft and ground station:

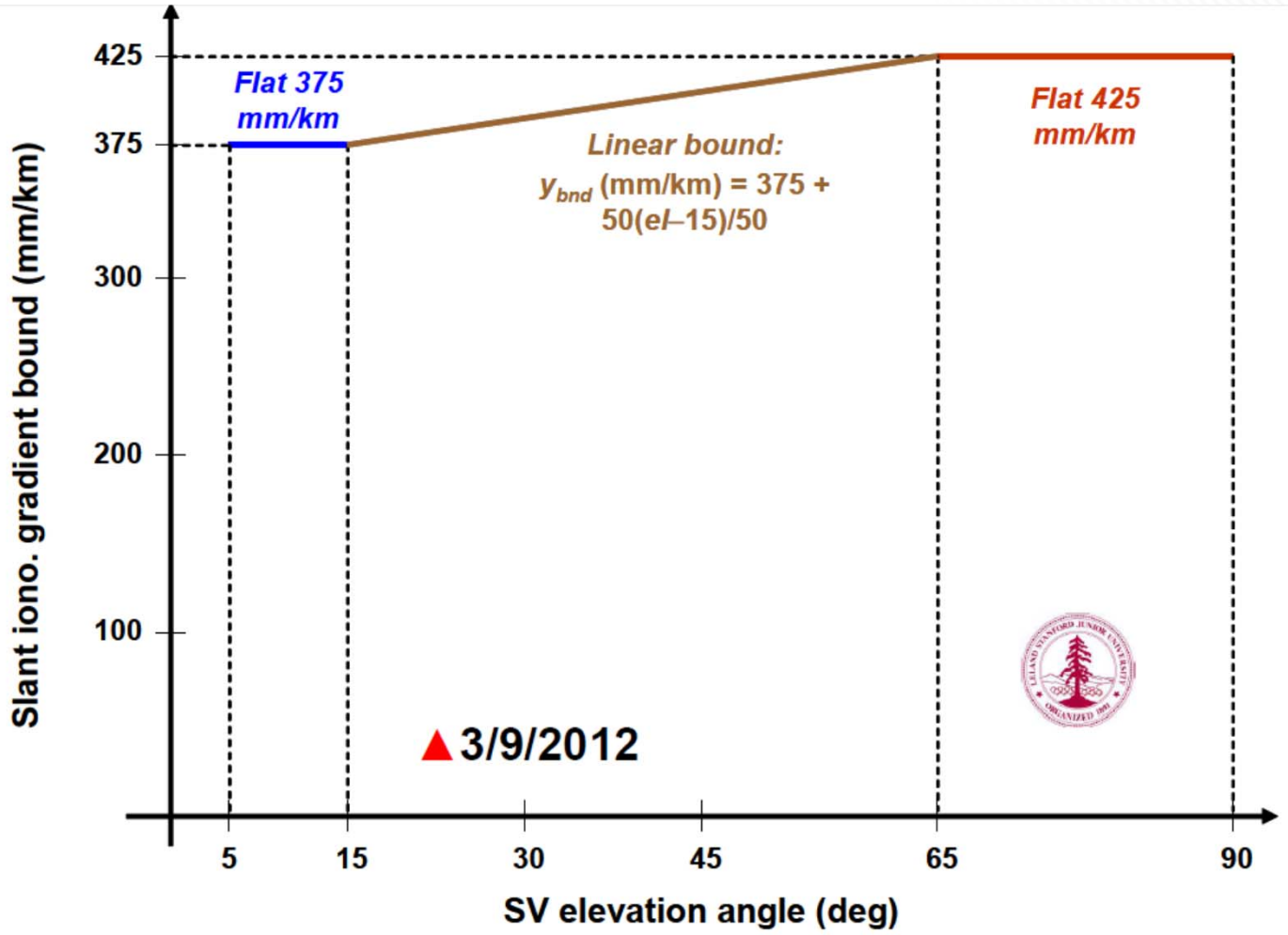
- Troposphere
- Ionosphere
- Satellite clocks
- Satellite position
- **NOT** multipath



Stanford Model for Iono Strom Front



CONUS Threat Model (Stanford)



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Definition of GBAS Integrity

ICAO (International Civil Aviation Organisation)
Annex 10, Volume 1:

- *Integrity is a measure of the trust which can be placed in the correctness of the information supplied by the total system.*

- *Integrity includes the ability of a system to provide timely and valid warnings to the users (alerts) when the system must not be used for the intended operation*.

Integrity Concept

- Alert Limit:
  error tolerance not to be exceeded without issuing an alert

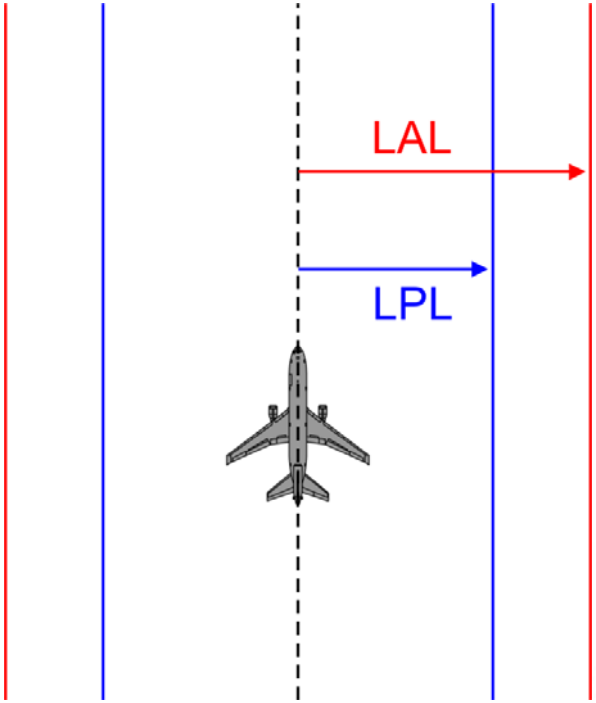
- Protection Level:
  bound on the position error with a certain probability
  (e.g. 10^{-7} per flight hour)

- Ideal case:
  compare true position error with alert limit, but true error unknown

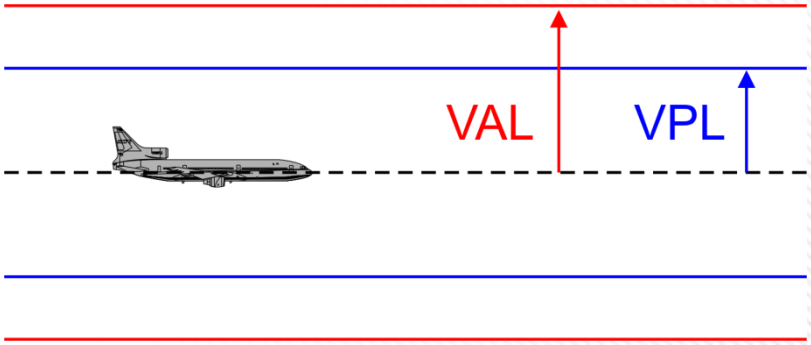
- Protection level: conservative estimate of position error

Integrity Concept

- LPL: Lateral Protection Level
- LAL: Lateral Alert Limit



- VPL: Vertical Protection Level
- VAL: Vertical Alert Limit



- VPL < VAL ⇨ Approach available
- VPL > VAL ⇨ Approach n/a

- LPL < LAL ⇨ Approach available
- LPL > LAL ⇨ Approach n/a

M. Scaramuzza

Integrity Concept

› Annex 10 requirement:

Integrity risk for CAT-I approaches shall be < 1.5 x 10-7

⇨ 1 integrity event every 6’666’667 approaches

Typical operation	Horizontal alert limit	Vertical alert limit
En-route (oceanic/continental low density)	7.4 km (4 NM)	N/A
En-route (continental)	3.7 km (2 NM)	N/A
En-route, Terminal	1.85 km (1 NM)	N/A
NPA	556 m (0.3 NM)	N/A
APV-I	40 m (130 ft)	50 m (164 ft)
APV- II	40.0 m (130 ft)	20.0 m (66 ft)
Category I precision approach	40.0 m (130 ft)	15.0 m to 10.0 m (50 ft to 33 ft)

GBAS Integrity

- Simplified derivation of protection level
- Assumption
  - Independent errors
  - Zero mean Gaussian distributed errors
- range errors of i^{th} satellite:

$$\sigma_i = \sqrt{\sigma^2_{pr\_gnd,i} + \sigma^2_{tropo,i} + \sigma^2_{pr\_air,i} + \sigma^2_{iono,i}}$$

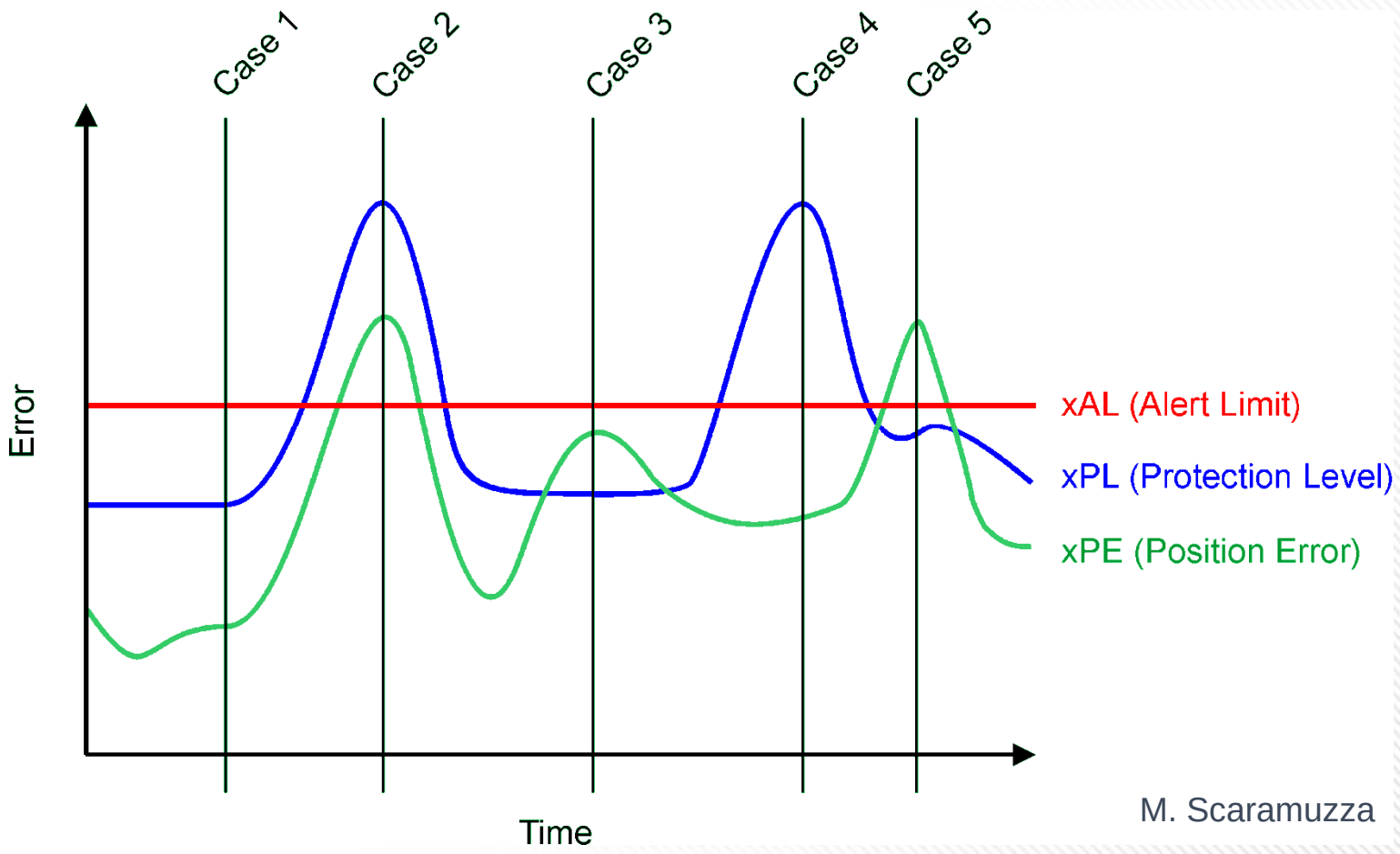
$\sigma_{pr\_gnd,i}$: *standard deviation of ground station pseudorange error of i^{th} satellite*

$\sigma_{tropo,i}$: *standard deviation of residual pseudorange of tropospheric correction of i^{th} satellite*

$\sigma_{pr\_air,i}$: *analogous to $\sigma_{pr\_gnd,i}$, but for aircraft*

$\sigma_{iono,i}$: *standard deviation of residual pseudorange of ionospheric correction of i^{th} satellite*

GBAS Integrity



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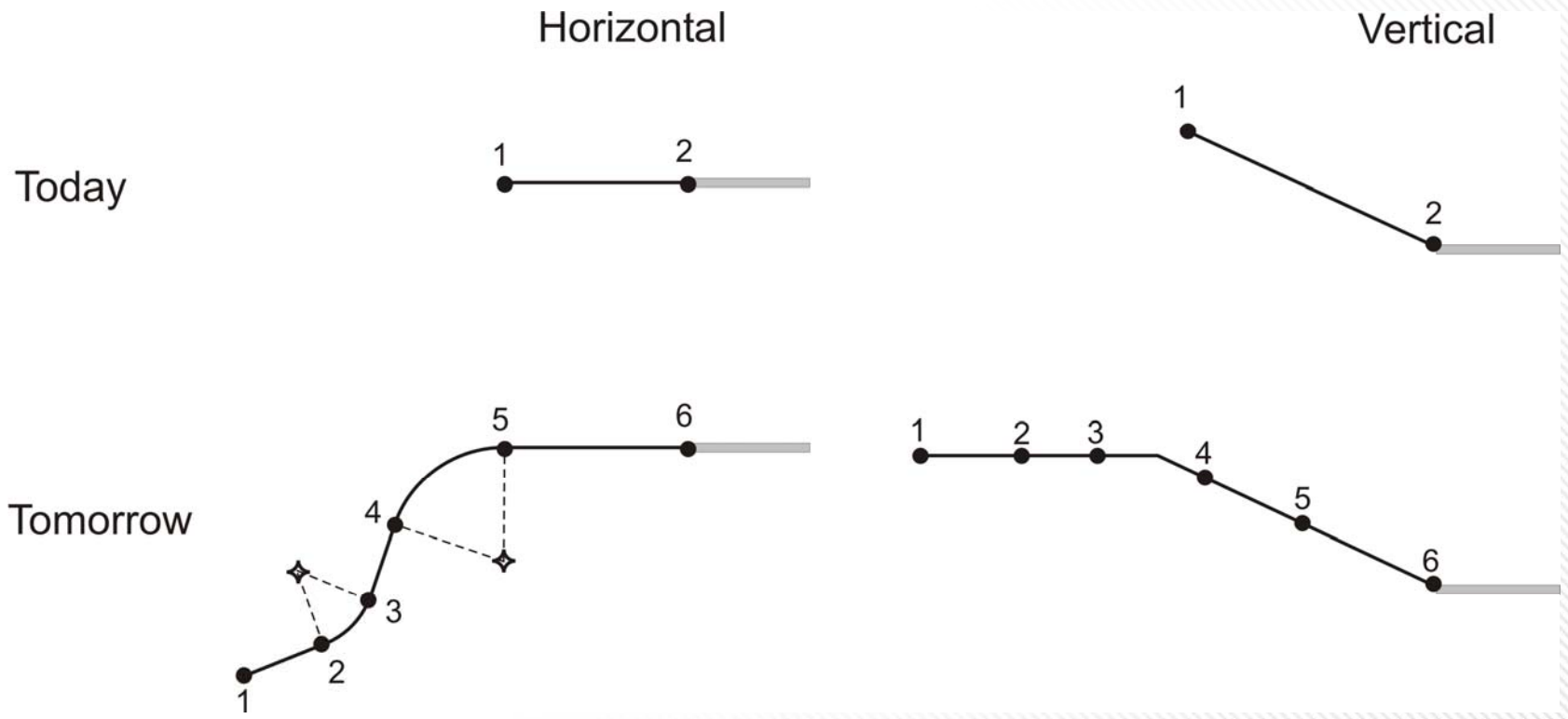
Terminal Area Path (TAP)




Questions?