The IGSO SBAS:
DFMC Seamless and Robust Navigation

Presented to Working Group B of ICG/13

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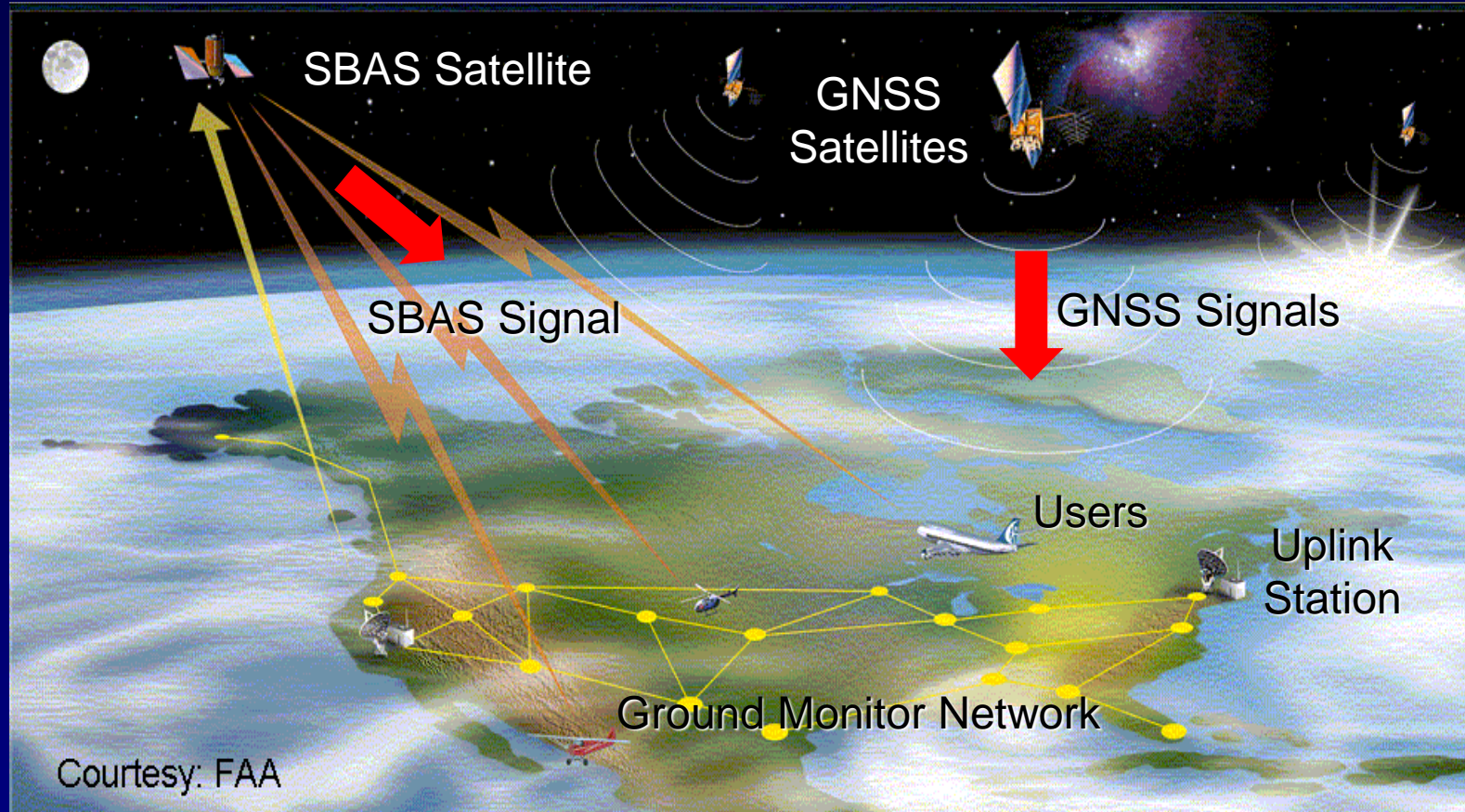*National Institute of Maritime, Port and Aviation Technology, Japan*

Introduction

- ## SBAS: Satellite-Based Augmentation System
  - International standard augmentation system.
    - *Transmits Augmentation information from the SBAS satellite.*
      - Augments GNSS in terms of integrity and accuracy.
    - *Current standard: Single-frequency SBAS on L1 transmitted by GEO.*
    - *US WAAS, Japanese MSAS, European EGNOS, Indian GAGAN.*

- ## DFMC SBAS: The Second Generation SBAS
  - Dual-Frequency Multi-Constellation SBAS.
  - ENRI has been conducting DFMC SBAS experiment via QZSS L5S signal.

- ## New Capability: Augmentation Service from the Zenith
  - DFMC SBAS could be transmitted by non-GEO SBAS satellite.
    - *Possible solution for applications where GEO signal is likely blocked.*
      - High latitude/polar regions, mountain area, urban canyon,…
    - *Enables SBAS service independent of the latitude of the service area by combination of dual-frequency operation and non-GEO transmission.*

SBAS Architecture

SBAS Satellite

GNSS Satellites

SBAS Signal

GNSS Signals

Users

Uplink Station

Ground Monitor Network

Courtesy: FAA

- Monitors consistency of GNSS signals on the ground.
- Transmits differential correction and integrity information via SBAS satellite.

Limitation: The current standard (L1 SBAS) allows transmission only from GEO
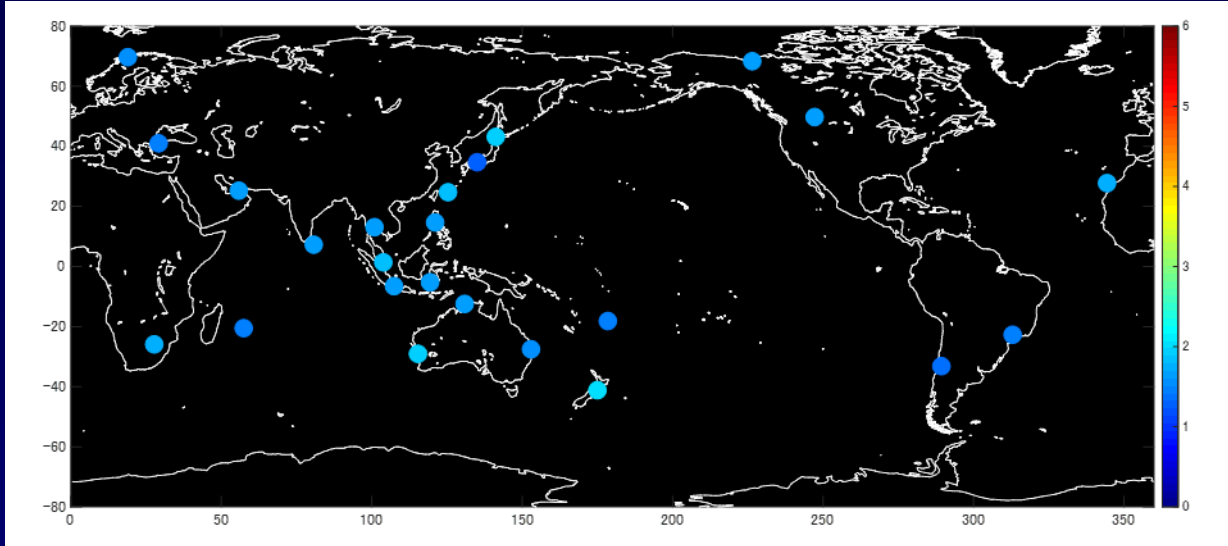
Improvements: DFMC SBAS

- ## The Current SBAS
  - Single-Frequency service transmitted by GEO.
    - ➤ *Limited availability in the low latitude regions due to the ionospheric activities.*
    - ➤ *GEO signal is likely blocked for some applications.*

- ## DFMC (Dual-Frequency Multi-Constellation) SBAS
  - The second generation SBAS following the current SBAS.
    - ➤ *Eliminates ionospheric effects thanks to dual-frequency operation.*
      - ◆ Robust navigation service everywhere in the coverage.
    - ➤ *Could be transmitted by non-GEO SBAS satellites like QZSS IGSO.*
  - Standardization activities ongoing by the ICAO.

- ## New Feature: Transmission by Non-GEO SBAS
  - DFMC SBAS could be transmitted by non-GEO satellites like QZSS IGSO.
  - Improves availability of augmentation signals where GEO signal is blocked.
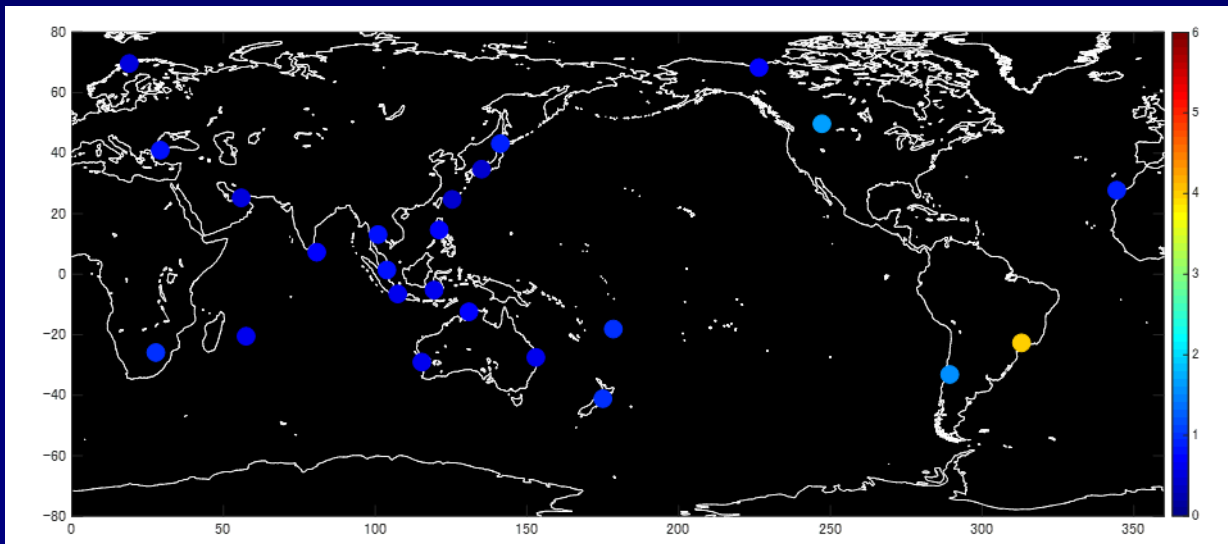   - ➤ *Enables navigation service in High latitude/polar regions, mountain area, urban canyon,…*

DFMC: Improved Accuracy

Without Augmentation (No SBAS)

Augmented Accuracy (DFMC SBAS)

DFMC SBAS
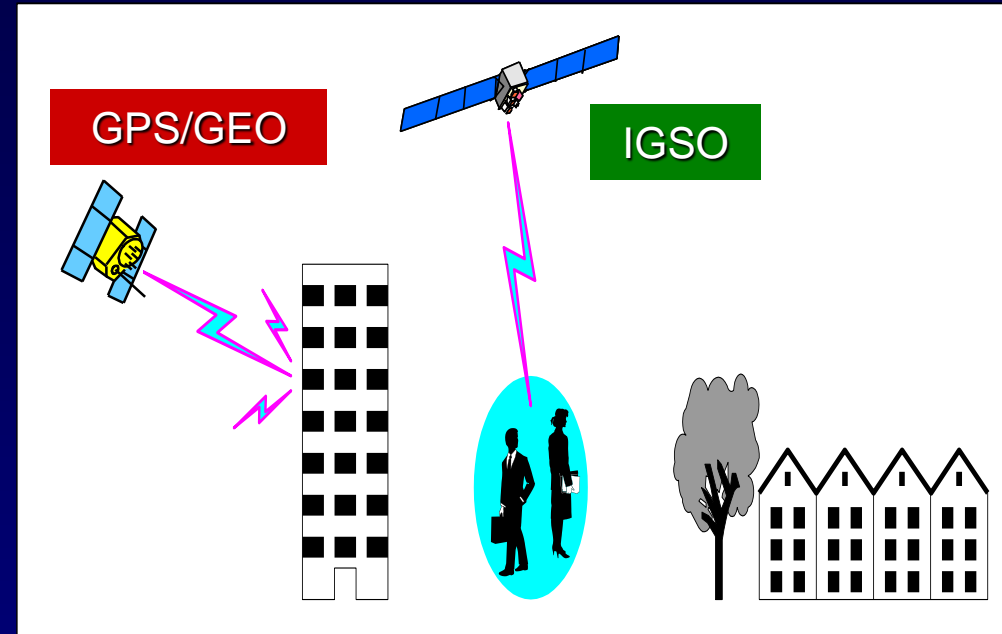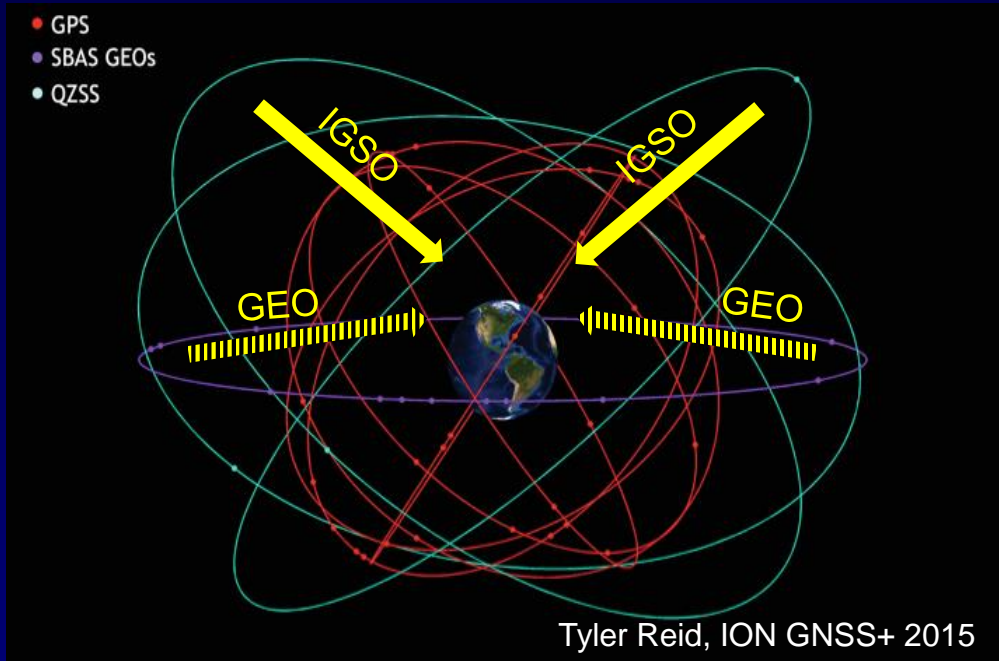
Core systems:
- GPS
- Galileo
- QZSS

Monitor stations:
- 24 worldwide

Date:
- 2017/11/27

Courtesy: Dr. Mitsunori Kitamura, ENRI/MPAT

IGSO SBAS Concept

Tyler Reid, ION GNSS+ 2015

- GPS
- SBAS GEOs
- QZSS

IGSO
IGSO
GEO
GEO

GPS/GEO
IGSO

- DFMC SBAS could be transmitted by non-GEO satellites like QZSS IGSO.
- Improves availability of augmentation signals where GEO signal is blocked.
  - *High latitude/polar regions, mountain area, urban canyon,…*
  - *Note DFMC SBAS is not influenced by ionosphere even in Equatorial regions.*
    - Seamless service from Equator to Poles.
- Standardization Activities Ongoing at the ICAO (Civil Aviation Organization)
  - *Incorporating non-GEO SBAS into the international standards.*

Visibility from Alaska, US
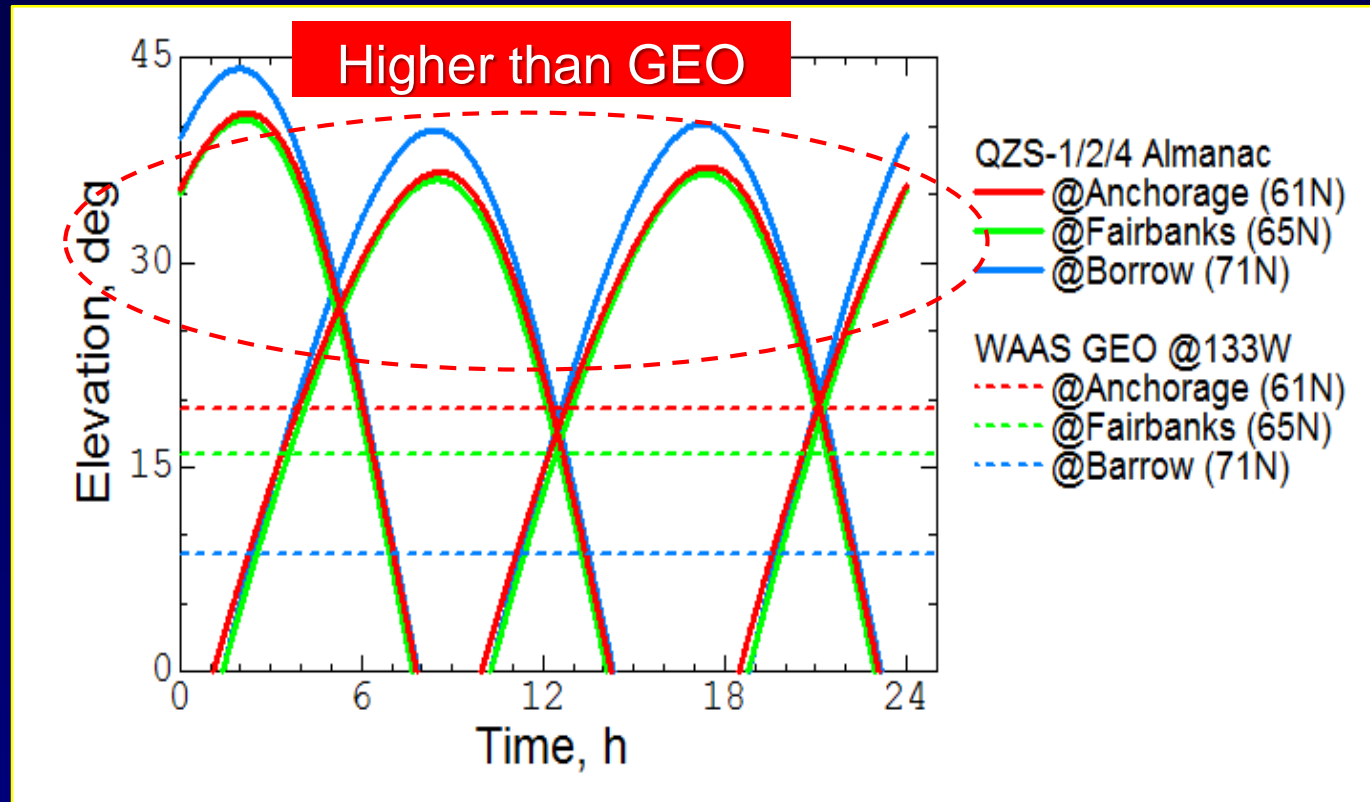
- Satellite visibility computed from QZS-1/2/4 almanacs and visibility of GEO @133W.
- QZSS IGSO satellites are visible in Alaska region.
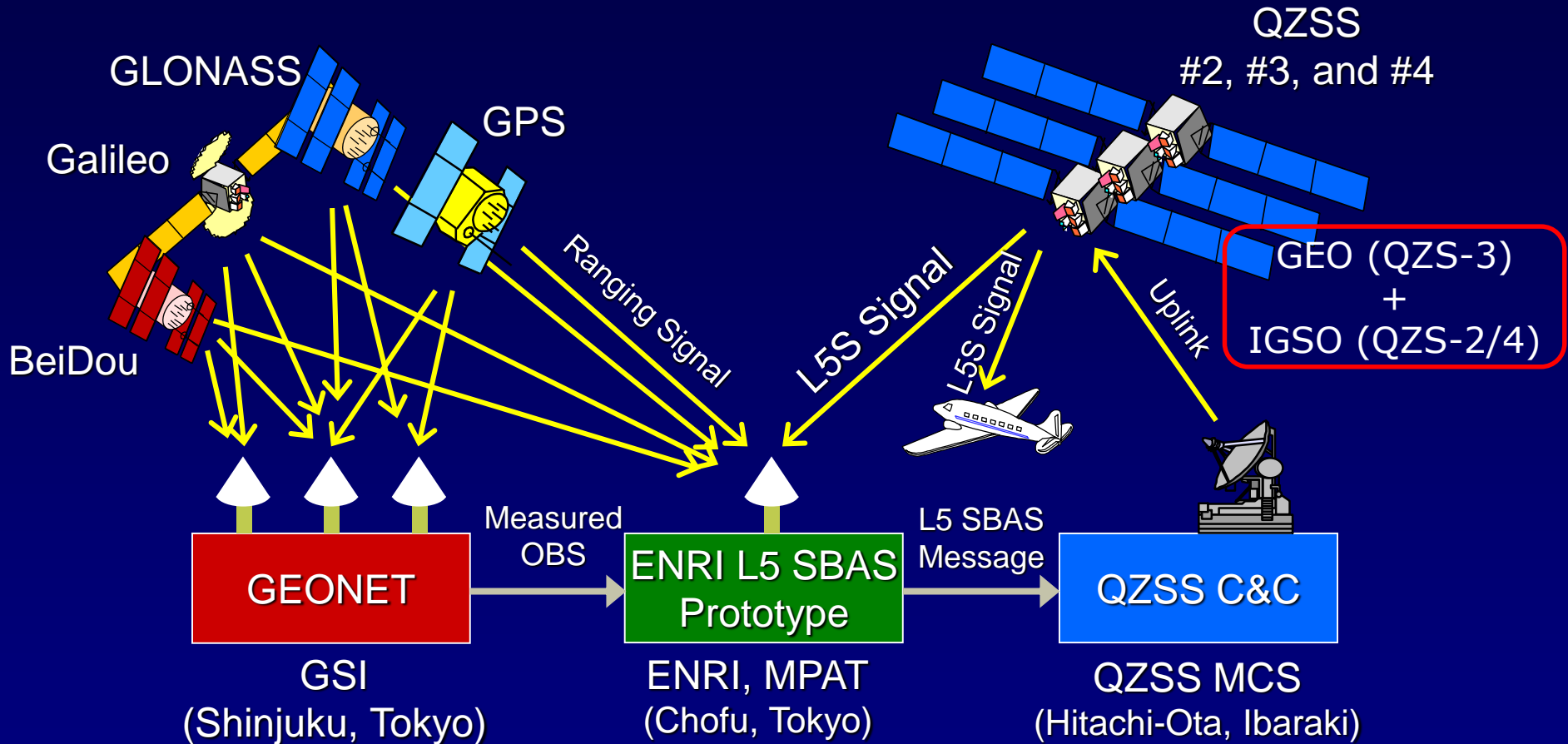- Transmission from higher elevation than WAAS GEO.

Prototype DFMC SBAS

- Prototype DFMC SBAS Developed by Japan
  - The second generation SBAS following L1 SBAS.
    - ➢ *Eliminates ionospheric effects thanks to dual-frequency operation.*
      - ◆ Vertical guidance service everywhere in the coverage.
  - Electronic Navigation Research Institute, National Institute of Maritime, Port and Aviation Technology has developed the prototype.
    - ➢ *GPS/GLONASS/Galileo/QZSS-capable dual-frequency SBAS.*
    - ➢ *Compliant with the draft standards of L5 SBAS being discussed at ICAO.*
      - ➢ Helps validation activities ongoing at ICAO.

- DFMC SBAS Experiment has been Conducted with QZSS
  - The first L5 SBAS experiment with live L5 signal from the space.
    - ➢ *Using QZSS L5S augmentation signal transmitted from QZS-2, -3, and -4.*
  - Prototype DFMC SBAS is used for the experiment.
  - Began the experiment on 23 Aug. 2017 via L5S signal of QZS-2 IGSO.
    - ➢ *Now, transmission also from QZS-3 GEO and QZS-4 IGSO.*
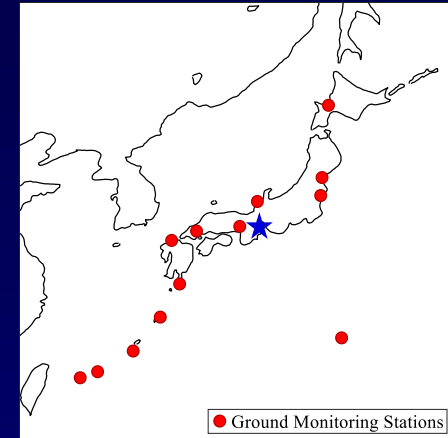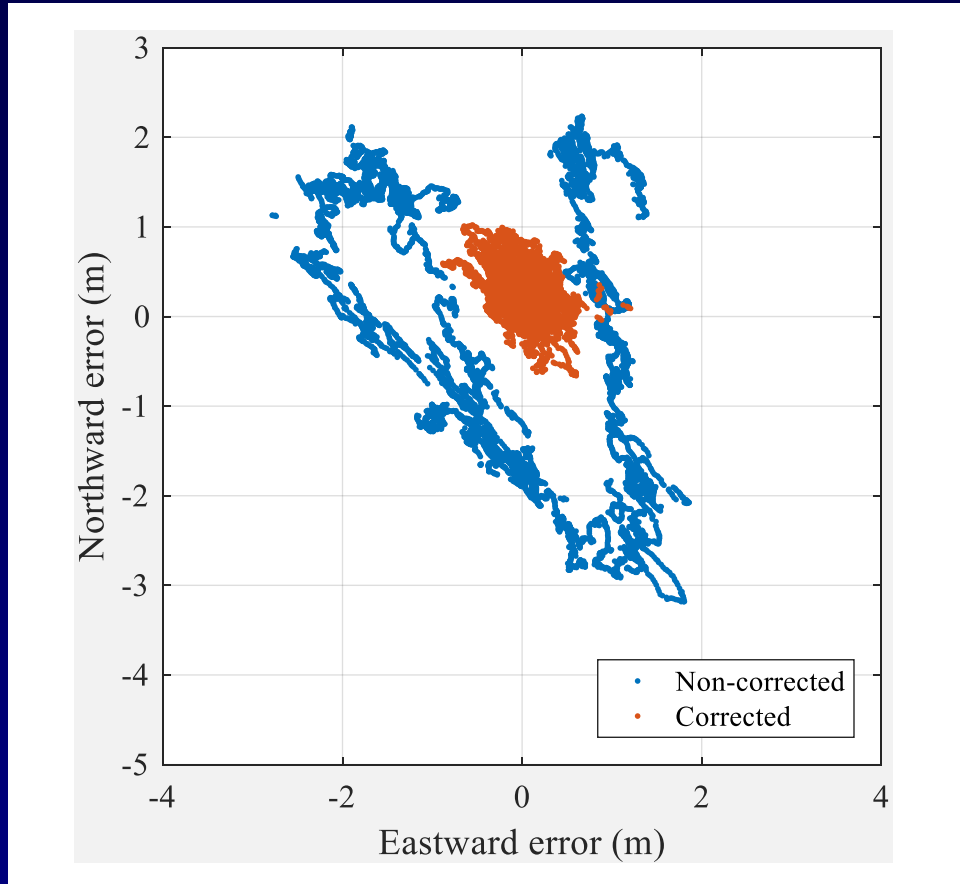
Experimental Configuration

Real Time Experiment

Monitor Stations

- GPS+Galileo+QZSS
- Dual Frequency (L1+L5)
- DFMC L5 SBAS
- Location:
  GEONET 950369 (Wakayama)
- Period:
  2017/11/13 01:00 - 07:00 (6H)

- Evaluation of DFMC SBAS message generated in real time.
  ➤ *Supporting GPS, Galileo, and QZSS in L1/L5 dual-frequency mode.*
- Confirmed that DFMC SBAS augments multi-constellation of GPS+Galileo+QZSS.

Recommendation

- Working Group B is invited to
  - Recognize that:
    - *SBAS augmentation realizes robust navigation primarily for aviation and useful for all modes of transportation including SSV.*
    - *The new DFMC SBAS being standardized at the ICAO could be transmitted from IGSO satellites while the current L1 SBAS is limited to GEO.*
    - *This new capability achieves the truly seamless navigation, from Equator to Poles, from mountain to urban cities, and from the ground to the space.*
      - DFMC SBAS eliminates ionospheric effects thanks to dual-frequency operation.
      - IGSO SBAS transmits augmentation signals to polar regions and polar orbits with reasonable elevation.
  - Support this IGSO SBAS concept and related standardization activities; and
  - Propose discussion on this issue to the Committee.

- Contact for more discussion:
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