DORIS DAYS 2025

November, 3 and 5

DORIS System Overview

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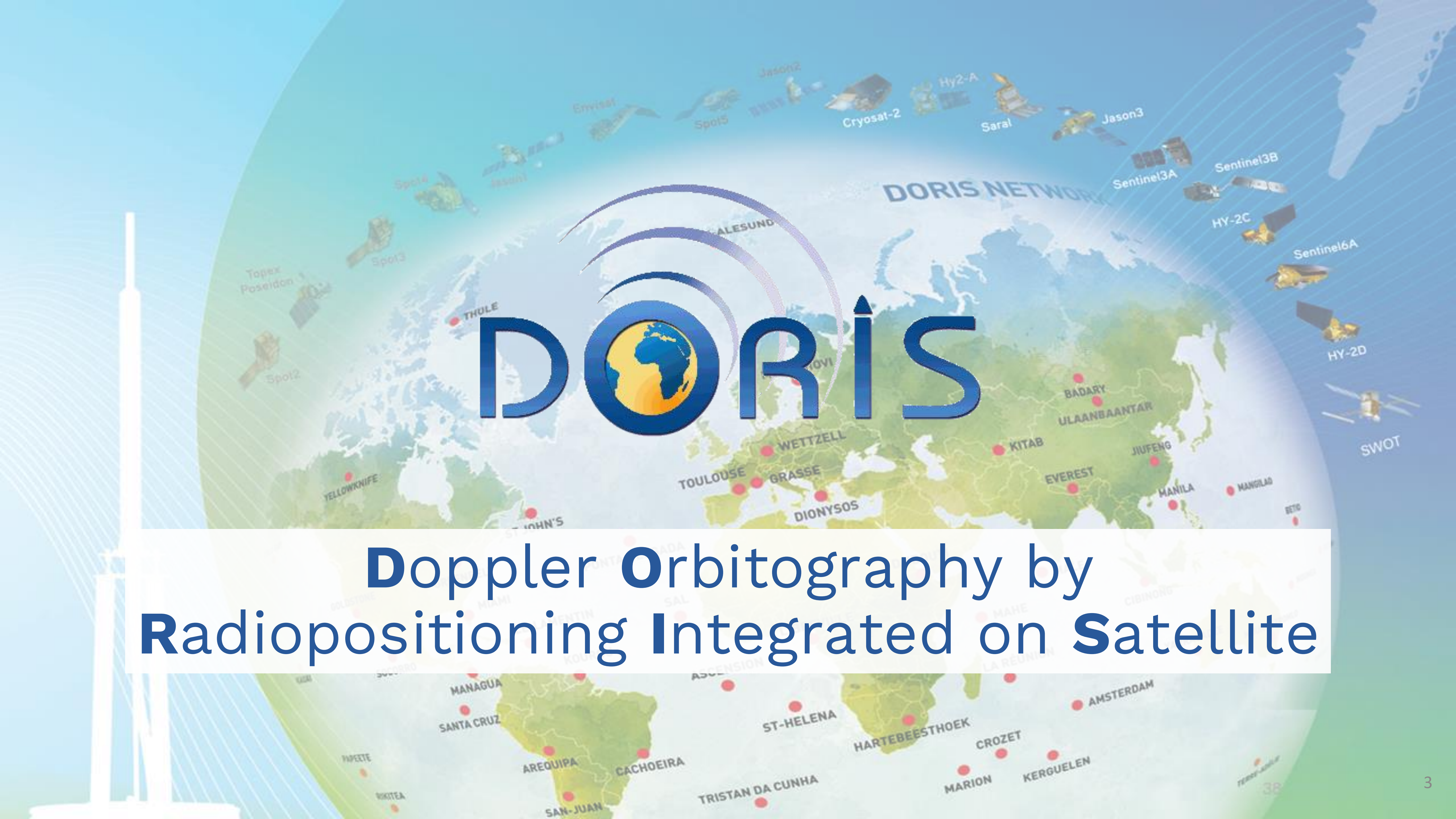
Session 1 – Presentation 2

IDS

What we will cover

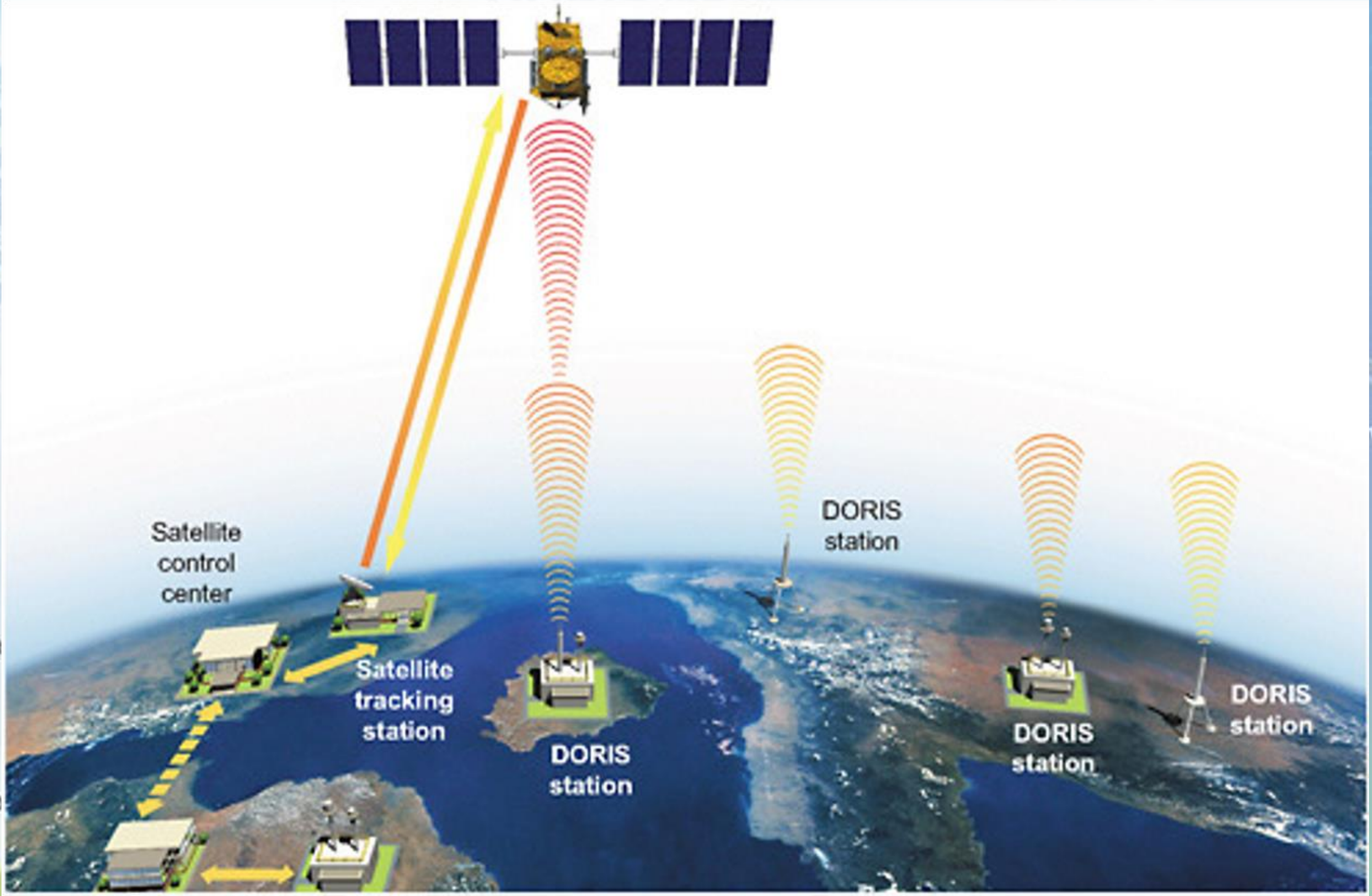
- The DORIS System (overall concept)
- Space and Ground Segments (satellite constellation, station network, instrumentation)
- The DORIS Measurement (Doppler shift, measurement corrections)
- Genesis mission and upcoming developments



Doppler **O**rbitography by **R**adiopositioning **I**ntegrated on **S**atellite

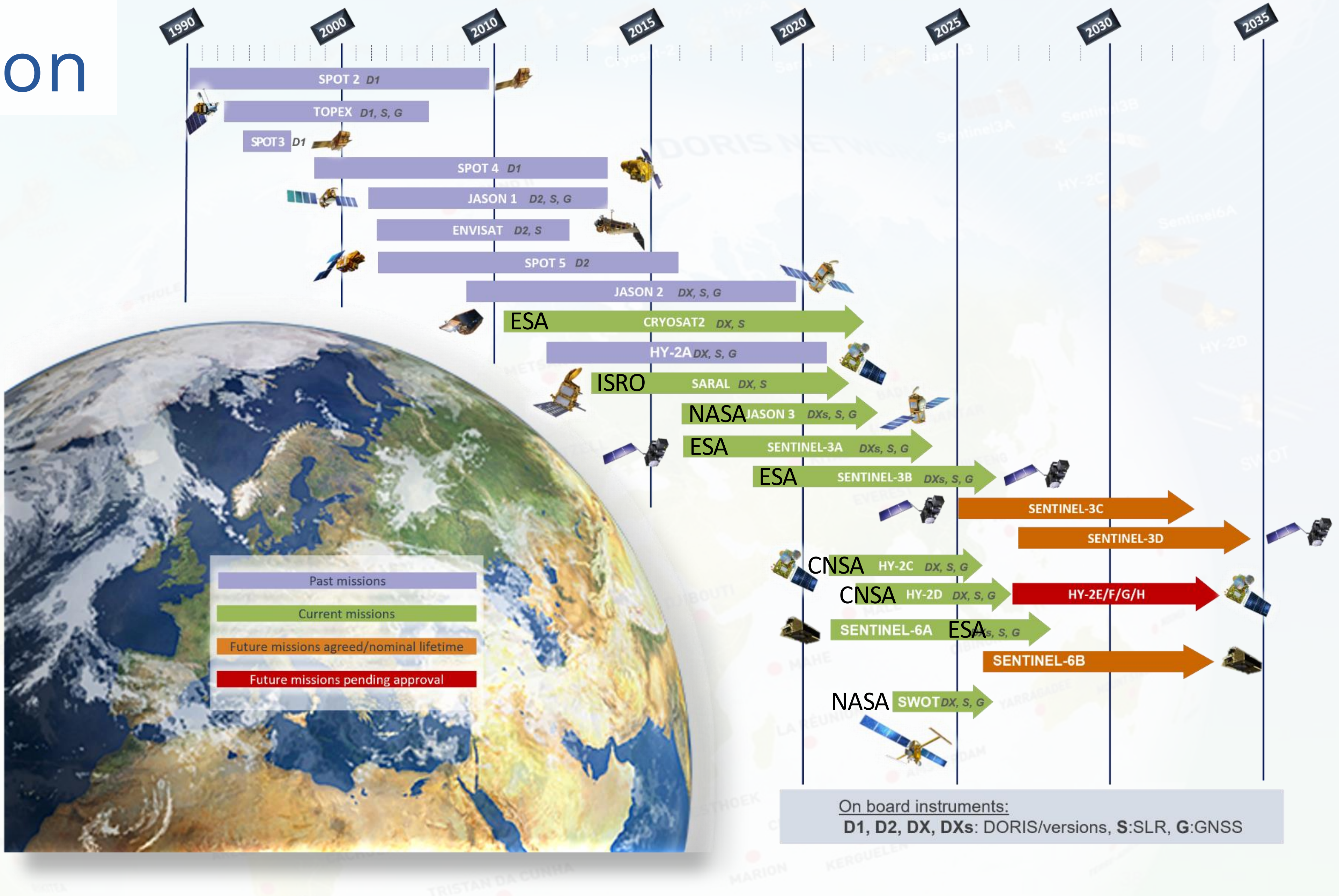
The DORIS System

- A global network of transmitting stations,
- The DORIS signal,
- On-board satellite receivers,
- Control center to receive the DORIS satellite observations.



The Space Segment

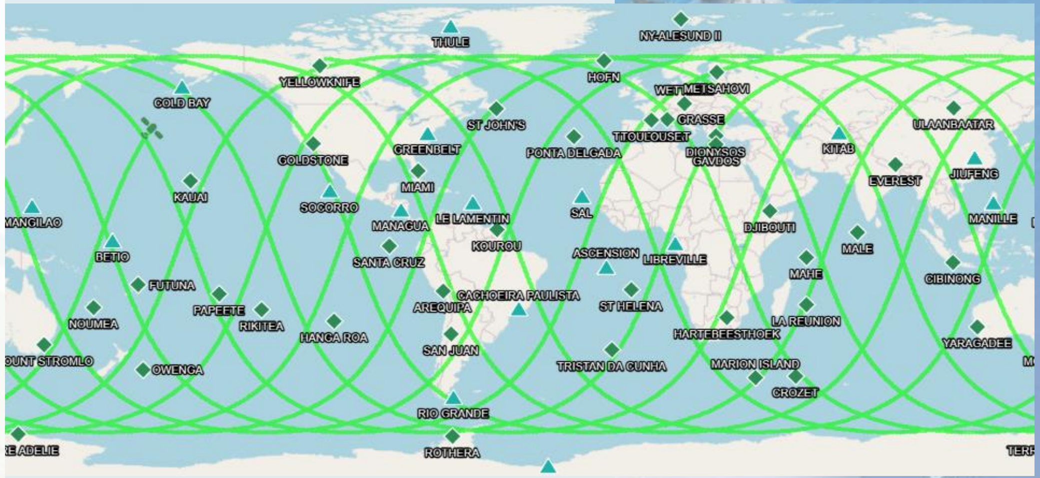
The DORIS constellation



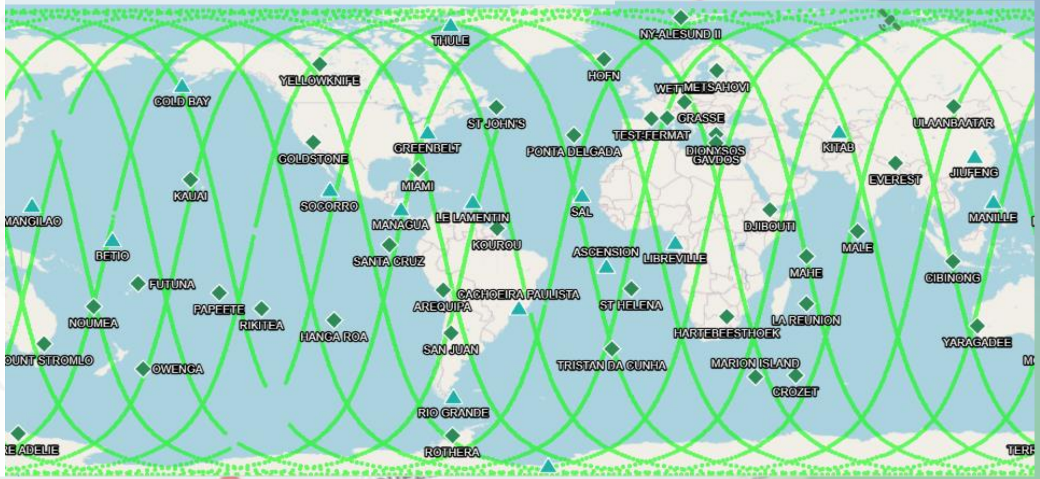
The orbits of the satellites

- Inclination:
  - 66° (near circular) e.g. Sentinel-6A,
  - 77° e.g. SWOT,
  - 92° e.g. Cryosat-2,
  - 98° (near polar) Sentinel-3B.
- Altitude: 700 km to 1400 km (LEO: Low Earth Orbit).
- Affected by:
  - Atmospheric drag (Low Earth Orbit),
  - Solar Radiation Pressure (shape of the satellite).

Satellite tracks Sentinel-6A



Satellite tracks Sentinel-3B

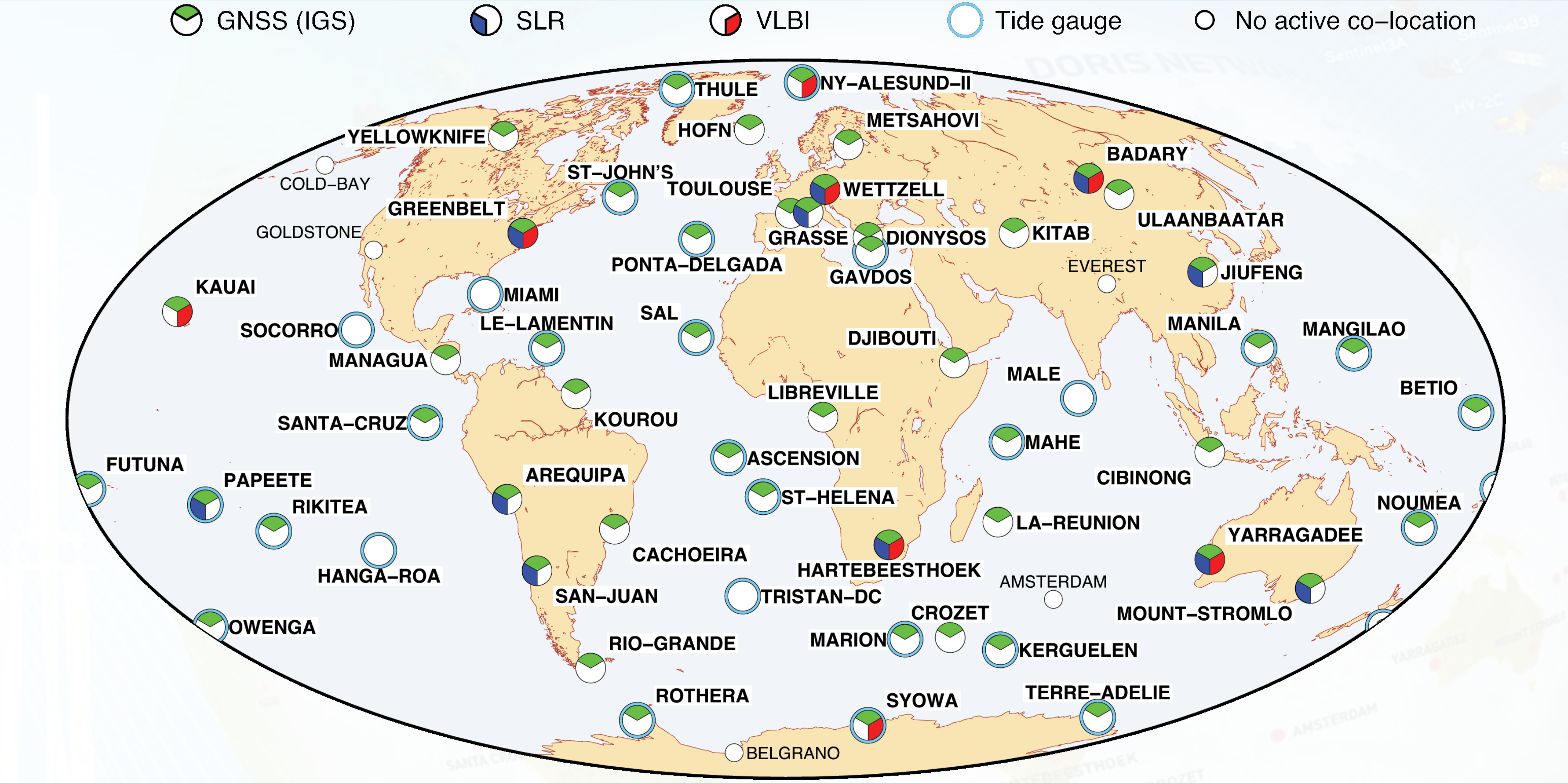


The DORIS On-Board Instrument

- Includes:
  - A dual-frequency omnidirectional antenna,
  - A receiver with two receiving chains (nominal + redundant),
  - Two Ultra Stable Oscillators (one per chain – kind of ultra stable clock),
  - + DIODE software for on-board real-time orbit determination.
- 5th generation DORIS receiver under development (CNES).

The Ground Segment

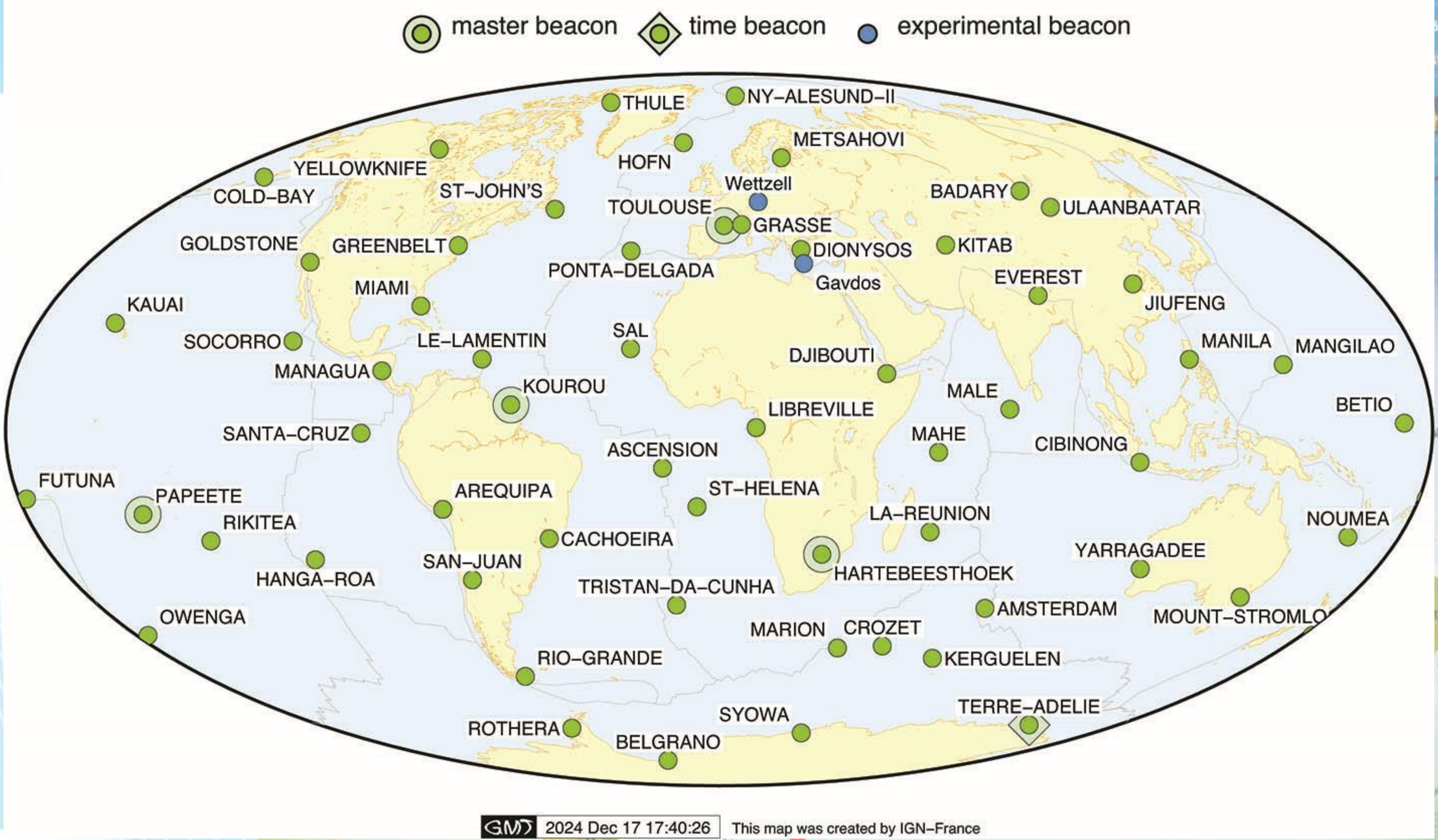
The DORIS Network



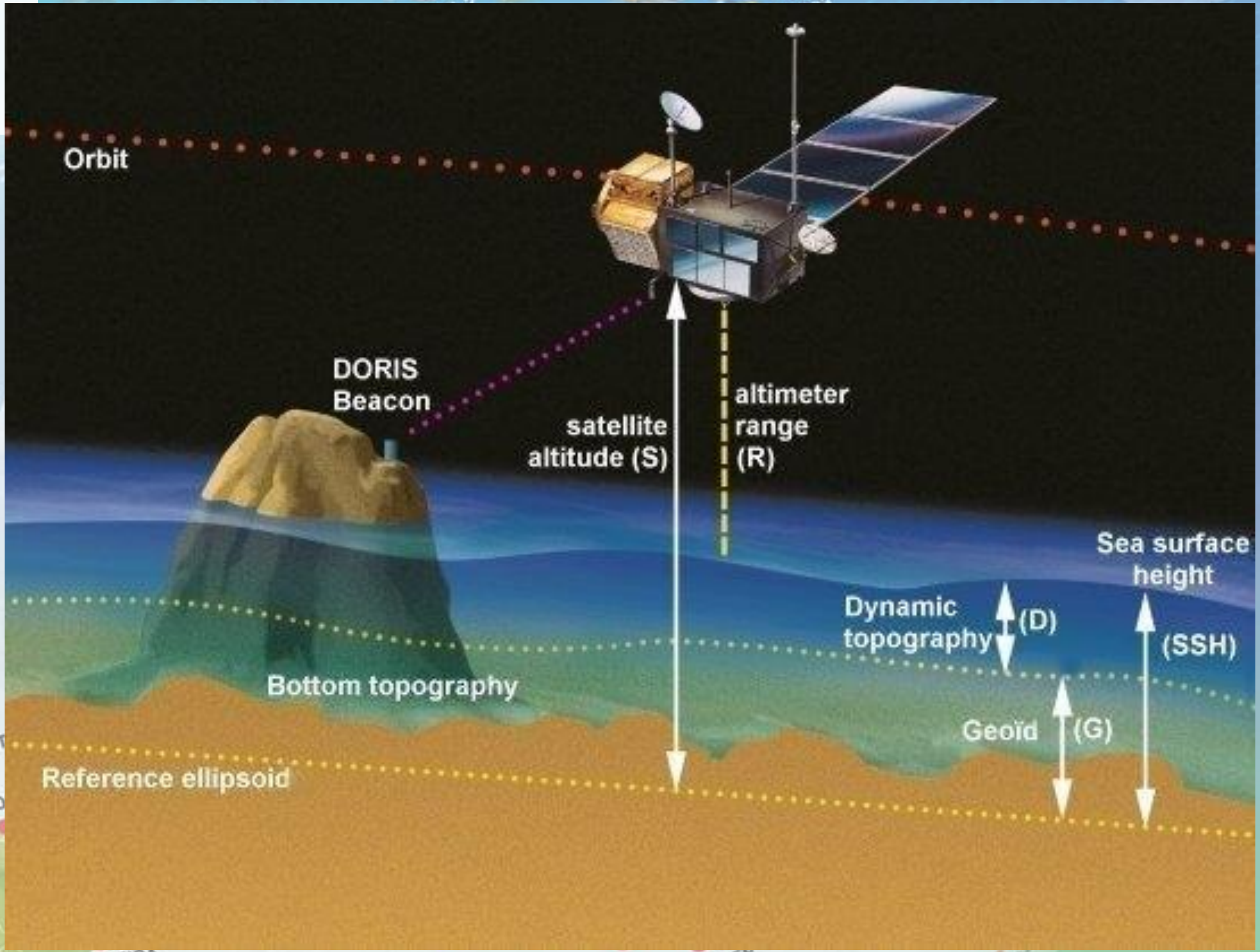
The DORIS Ground Station Components

- Beacon (4.0) - *indoor equipment*
  - generates two modulated signals:
    401.25 MHz / 2.03625 GHz.
  - contains the reference oscillator, the frequency synthesizer, the management board, the power pack and the battery.
- Omnidirectional Antenna (Starec C): transmits the signal generated by the beacon.
- External MGM box contains a remote-control system, an Iridium modem, a GPS sensor, meteorological sensors.
- External Amplifier box contains the amplification and the remote-control systems.
- Main requirements: continuous service 24/7 365 days operation, clear view of sky: visibility from LEO satellites, stability of the monument.

The DORIS Network



The DORIS Measurement



How DORIS Measures Doppler Shift (1/3)

- Radial velocity:

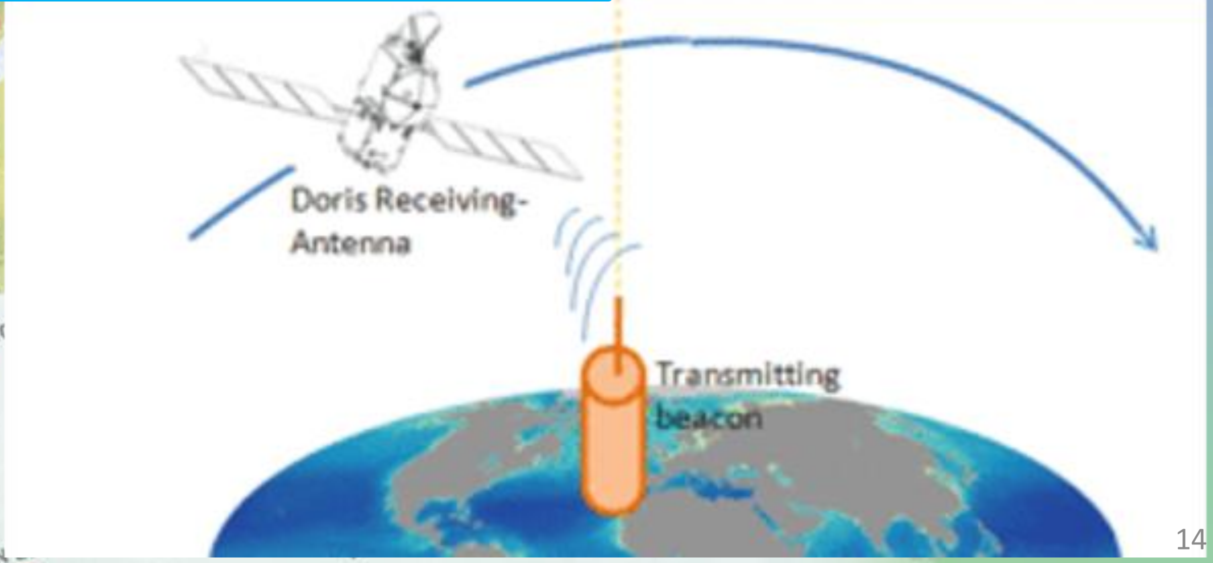
$$f_r = f_e\left(1 - \frac{v}{c}\right)$$

  - f_e: beacon frequency,
  - f_r: received frequency,
  - c: speed of light,
  - v: relative velocity between the beacon and the satellite.
- **DOPPLER effect**

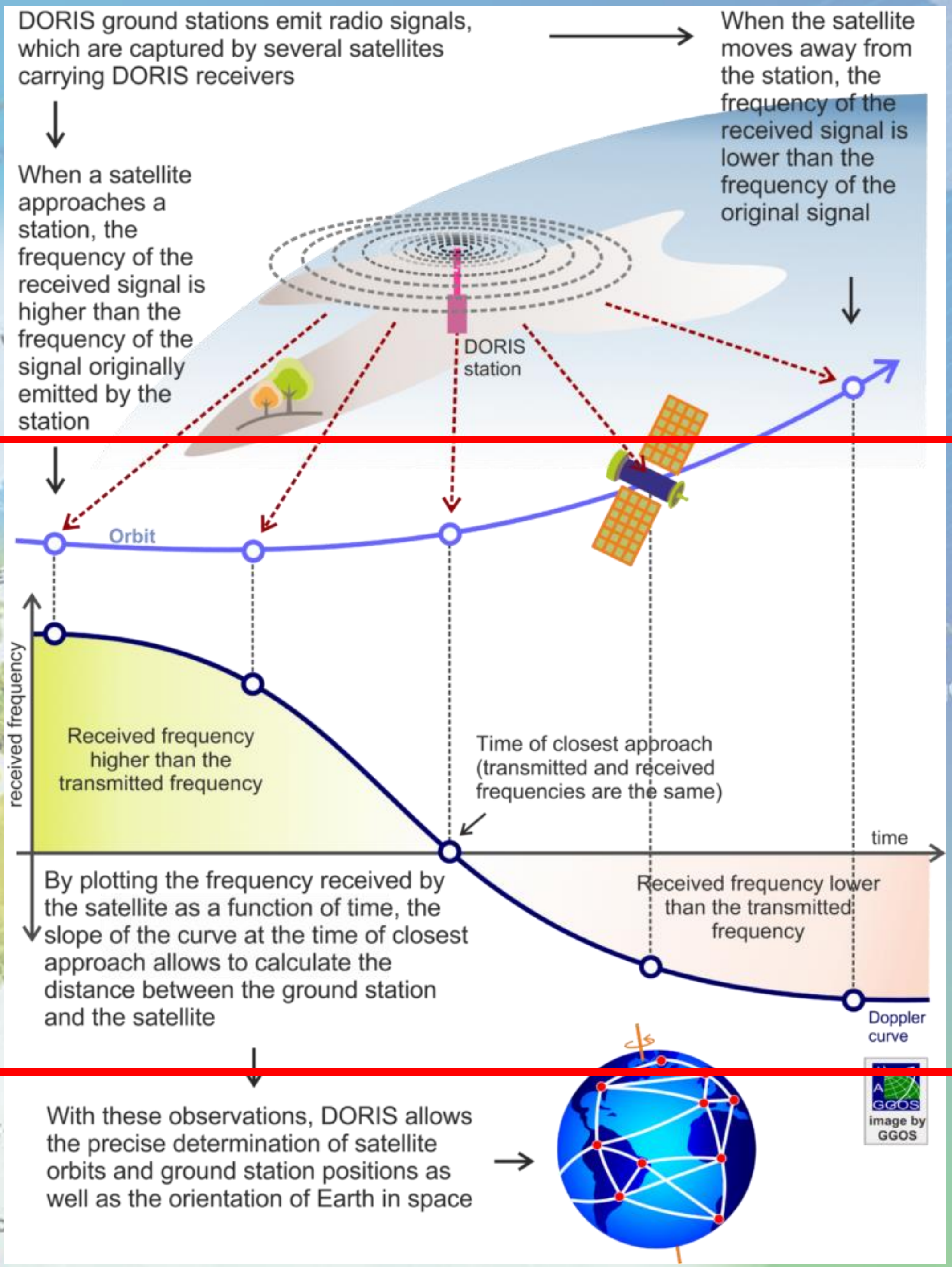
The satellite is **upright** the beacon, it's the TCA point (Time of Closest Approach).
The frequency of the received signal is **equal** to the frequency of the transmitted signal.

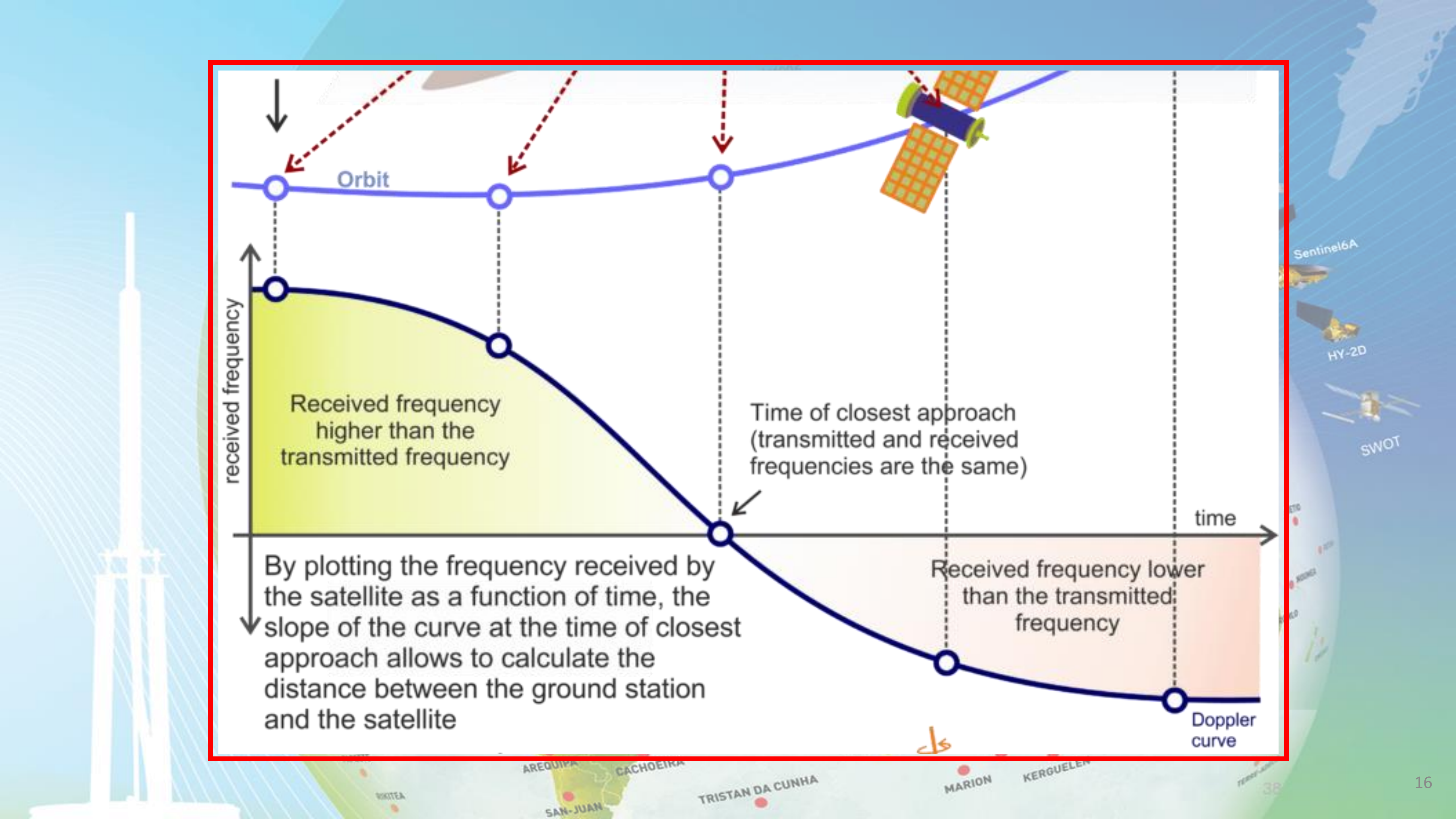
The satellite is **approaching** the beacon:
The frequency of the received signal is **greater** than the frequency of the transmitted signal.

The satellite is **moving away** the beacon:
The frequency of the received signal is **lower** than the frequency of the transmitted signal.



How DORIS Measures Doppler Shift (2/3)




Orbit
received frequency
Received frequency higher than the transmitted frequency
Time of closest approach (transmitted and received frequencies are the same)
time
By plotting the frequency received by the satellite as a function of time, the slope of the curve at the time of closest approach allows to calculate the distance between the ground station and the satellite
Received frequency lower than the transmitted frequency
Doppler curve
Sentinel6A
HY-2D
SWOT
AREQUIPA
CACHOEIRA
TRISTAN DA CUNHA
MARION
KERGUELEN
SAN-JUAN
RIKITEA

How DORIS Measures Doppler Shift (3/3)

- Measurement every 10 seconds,
- Radiofrequencies:
  - 2.03625 GHz precise measurements,
  - 401.25 MHz ionospheric correction.
- Up to 7 beacons.

The satellite is **upright** the beacon, it’s the TCA point (Time of Closest Approach).
The frequency of the received signal is **equal** to the frequency of the transmitted signal.

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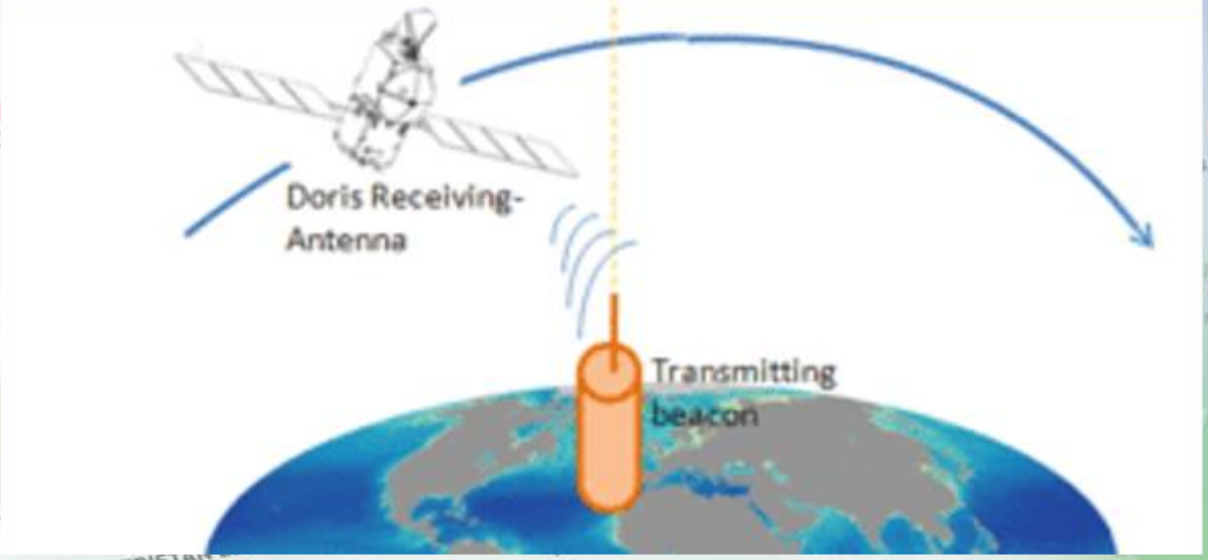

The Measurement Corrections

- **Ionospheric correction:** the first order correction is obtained thanks to the dual frequencies.
- **Tropospheric correction:** the dry and wet parts are computed either from meteorological data collected at the station, or from models (e.g. VMF-1). In any case, an additional tropospheric zenithal bias has the be adjusted at each pass (at least).
- **Frequency offsets** of the beacon and receiver oscillator: an empirical frequency bias has to be adjusted at each pass.
- **Relativity:** the effect of relativity on the beacon and receiver clock oscillators has to be taken into account, as well the elongation of the travel time of the RF signal.
- Products: **Precise Orbit Ephemerides**

→ accurate location of satellites in the International Terrestrial Reference Frame (ITRF)

Exciting Future…
The **genesis** Mission

Key points

- DORIS is one of the four space-geodetic techniques.
- DORIS is based on Doppler measurements at 401.25 MHz and 2.03625 GHz.
- The signal is transmitted by the ground stations and received on board the satellites.

- DORIS missions until 2035 and beyond, including the ESA genesis mission dedicated to the ITRF.
- The DORIS ground beacon network includes 60 sites with a very even distribution.
- New DORIS sites to come.