Vision for the space-based component of WIGOS in 2040

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

Stephan Bojinski, WMO Space Programme
Toshiyuki Kurino, WMO Space Programme

Corresponds to version 1.1 of the 2040 Vision Document

2017 GRWG/GDWG Annual Meeting
SSEC, Madison, WI, 2017-03-20/24

WMO OMM
World Meteorological Organization
Organisation météorologique mondiale

Overview

1. **Background and initial assumptions**
2. **Main drivers *and guidance* for the Vision 2040 Space**
   - *Evolving user needs*
   - *Evolving technological capabilities*
   - *Increasing number of space-faring agencies and entities*
3. **Components of the draft Vision 2040 Space**

Background

- **The Vision of GOS in 2025** developed in 2007-2008 needs updating
  - just as it replaced the Vision in 2015 adopted in 2002
- **A long-term perspective** is needed to *support* satellite agency planning
  - Some agency plans are confirmed until the early 2030s
  - Based on anticipated user needs and expected technological capabilities
- WMO started developing the **2040 *Vision of the components of WIGOS*** in 2015-2016, under CBS leadership, as requested by Executive Council,
- *Final step is* **the submission to Cg-18 in 2019**.
- The Vision is intended to provide a ***challenging but achievable, high-level goals***

Background

Initial draft prepared by WMO/CBS Expert Team on Satellite Systems (ET-SAT), using input from:

- the WIGOS Space 2040 workshop, Geneva, 18-20 Nov 2015;
- the Coordination Group for Meteorological Satellites (CGMS);
- the Inter-Programme Coordination Team on Space Weather (ICTSW).

Draft v1.0 ***was*** **based on feedback received from a series of consultations**:

- WMO Presidents of Technical Commissions meeting (19-20 January 2016);
- Consultative Meeting on High Level Policy on Satellite Matters (CM-13, 28-29 January 2016);
- WMO CBS Inter-Programme Expert Team on Satellite Utilization and Products (IPET-SUP-2, 23-26 February 2016);
- 2016 meeting of the Coordination Group for Meteorological Satellites (CGMS);
- *CBS-16 in Guangzhou in November 2016.*

Initial Assumptions

- **Current structure of the space-based observing system is a solid foundation underpinning the success story of the «World Weather Watch» and essential to WIGOS**

  (Ref: Manual on WIGOS endorsed by Cg-17, and CGMS baseline)

  - Geostationary constellation
  - 3-orbit sun-synchronous constellation for sounding and imagery
  - Complementary missions on appropriate orbits
  - *Also essential is a near-real time data availability*

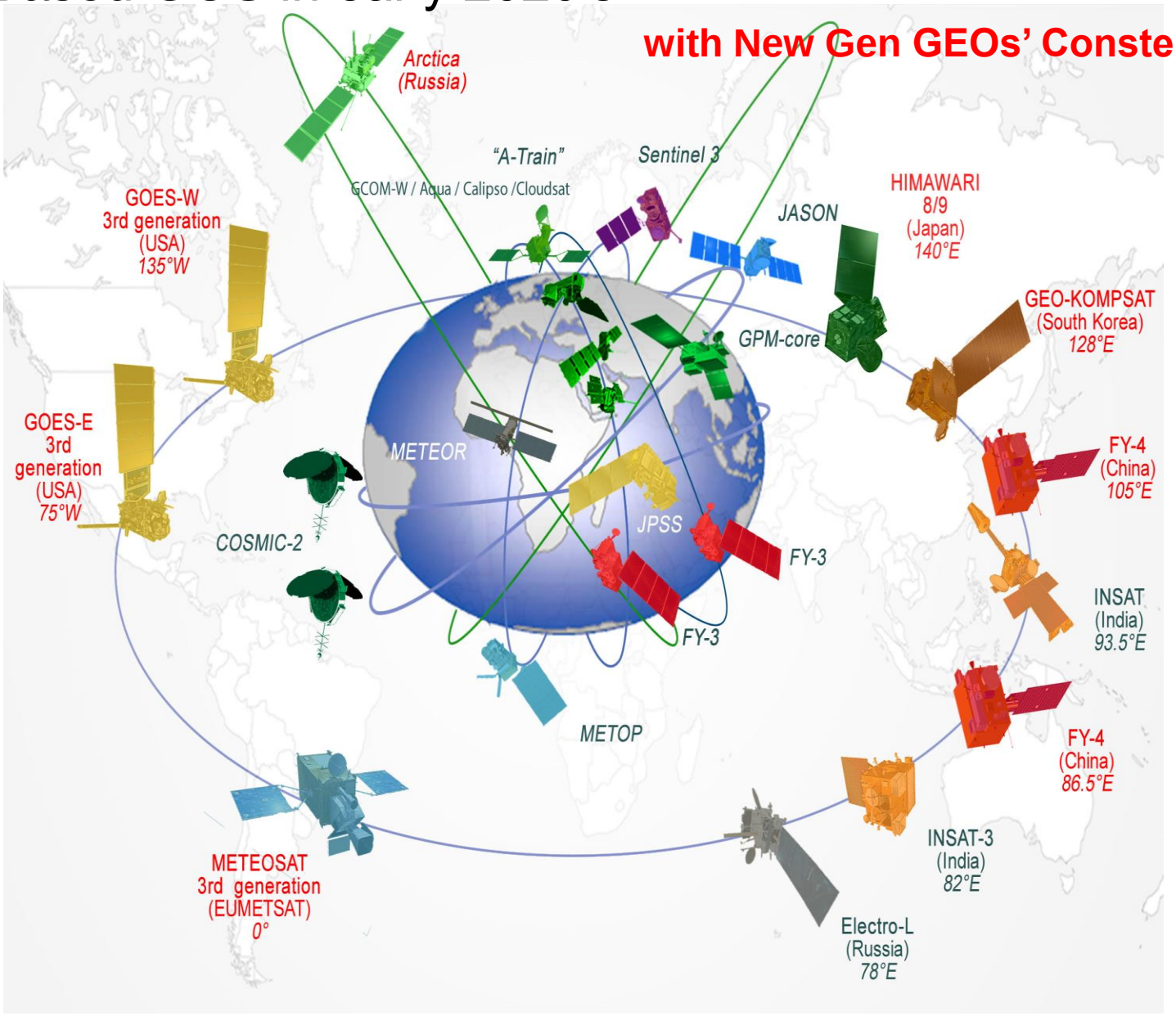
- **Questions were raised with reference to the Vision 2025**
  - What should be added ?
  - What is at risk and should be reinforced ?
  - What should be improved (performance, coverage) ?
  - What could be performed differently in the future ?
  - What are the major challenges?

Main Drivers for the Vision 2040 Space

- **Evolving and emerging user requirements**
  - Future modelling requires increased resolution (spatial, temporal, spectral)
  - Consistent, comprehensive data records (calibration, *characterisation* & traceability)
  - Applications related to atmospheric composition (e.g. air quality), cryosphere, hydrology, space weather, *have matured* and *are* addressed
- **Recent/anticipated advances in technology enable new capabilities**
  - Sensor technology
  - Orbital concepts
  - Satellite programme concepts (small satellites, constellations)
  - Data system architecture
- **Evolution of satellite programmes**
  - More space faring nations – Vision should promote *established and new modes of* cooperation
  - Enhanced pressure to provide cost/benefit justification
  - Increased *interest and capability* from private sector *to provide observational* data

Space-Based GOS in early 2020's

with New Gen GEOs' Constellations



WMO OMM

→ Space-Based GOS in 2040's ???

Approach to developing the Vision 2040 Space

- **Approach is to strike a balance and be**:
  - Specific enough to provide guidance on *the* system to be achieved
  - Open to opportunities and encouraging initiatives to realise opportunites

- **Vision for the space segment is useful in support of long-lead decisions needed by space programmes**

- **Some generic considerations *are* included on:**

  - how the 2040 Vision for space and surface, respectively, will complement one another

  - ground segments, applications development including faster path towards full utilisation of new observations, user support, capacity building

Components of the draft Vision 2040 Space

Vision 2040 Space consists of 4 components

- **Component 1: Backbone Component,** with specified orbital configuration and measurement approach
  - basis for Members' commitments *and* responds to the vital data needs
  - similar to the current CGMS baseline with addition of new capabilities
- **Component 2: Backbone Component,** with keeping open the orbital configuration and measurement approach
  - leaving room for further system optimization
  - basis for open contributions of WMO Members, to optimize *and enhance* the backbone
- **Component 3: Operational Pathfinders,** with technology and science demonstrators
  - responding to R&D needs; exploratory data for applications
- **Component 4: Additional Capacities and other Capabilities** (e.g. academic, commercial)
  - exploiting technical/business/programmatic opportunities
  - WMO to recommend standards, best practices, guiding principles

Component 1. Backbone System - with specified orbital configuration and measurement approaches (1/2)

- **Geostationary** ring providing frequent multispectral VIS/IR imagery
  - *and additionally* IR hyperspectral sounding, lightning imagers, UV/VIS/NIR sounder
- **LEO sun-synchronous core constellation** in 3 orbit planes (am/pm/early morning)
  - with hyperspectral IR sounder, VIS/IR imager, *possibly a* Day/Night band
  - with MW imager, MW sounder, Scatterometer
- **LEO sun-synchronous at 3 additional *orbits*** for improved robustness and improved time sampling, particularly for monitoring precipitation
- Wide-swath radar altimeter, and high-altitude, inclined, high-precision orbit altimeter
- IR dual-angle view imager (for SST)
- MW imagery at 6.7 GHz (for all-weather SST)
- Low-frequency MW imagers (for soil moisture and ocean salinity)
- MW cross-track upper stratospheric and mesospheric temperature sounder
- UV/VIS/NIR sounder , nadir and limb (for atmospheric composition)

Component 1. Backbone System - with specified orbital configuration and measurement approaches (2/2)

- Precipitation and cloud radars
- MW sounder and imagery on inclined orbits
- Absolutely calibrated broadband radiometer, and TSI and SSI radiometer
- GNSS radio-occultation (basic constellation) for temperature, humidity and electron density
- Narrow-band or hyperspectral imagery (ocean colour, vegetation)
- High-resolution multispectral VIS/IR imagery (land use, vegetation, flood, landslide monitoring)
- SAR imagery (sea state, sea ice, ice sheets, soil moisture, floods)
- Gravimetry mission (ground water, oceanography)
- Solar wind and energetic particles, magnetic field, at L1
- Solar coronagraph and radio-spectrograph, at L1
- In situ plasma, energetic particles at GEO and LEO
- Magnetometers in GEO orbit
- On-orbit reference standards for VIS/NIR, IR, MW absolute calibration

Component 2. Backbone System – with open measurement approaches (flexibility to optimize the implementation) 1/2

- GNSS reflectometry missions, passive MW, SAR, for measuring surface wind and sea state
- Wind and aerosol profiling by lidar (Doppler and dual/triple-frequency backscatter)
- Sea-ice thickness *(free board)* by lidar (in addition to radars mentioned in Component 1)
- Interferometric radar altimetry (for deriving sea ice parameters)
- Cloud phase detection, e.g. by sub-mm imagery
- Carbon Dioxide and Methane by NIR imagery
- Aerosol *parameters* by multi-angle, multi-polarization radiometers; *also supports radiation budget*
- High-resolution land or ocean observation (multi-polarization SAR, hyperspectral VIS)
- High temporal frequency MW sounding (GEO or LEO constellation)
- Stratosphere/mesosphere monitoring by UV–VIS–NIR–IR-MW limb sounders

Component 2. Backbone System – with open measurement approaches (flexibility to optimize the implementation) 2/2

- HEO *(highly elliptical orbit)* VIS/IR mission for continuous polar coverage (Arctic & Antarctica)
- Solar magnetograph , solar EUV/X-ray imager, and EUV/X-ray irradiance, both on the Earth-Sun line (e.g. L1, GEO) and off the Earth-Sun line (e.g. L4, L5)
- Solar wind in situ plasma and energetic particles and magnetic field off the Earth-Sun line
- Solar coronagraph and heliospheric imager off the Earth-Sun line (e.g. L4, L5)
- Magnetospheric energetic particles (e.g. GEO, HEO, MEO, LEO)

Component 3. Operational Pathfinders and Technology and Science Demonstrators

- GNSS-RO constellation for enhanced atmospheric/ionospheric soundings
  - Including additional frequencies optimized for atmospheric sounding
- Surface pressure by NIR spectrometry
- Atmospheric moisture profiling by lidar (DIAL)
- Radar and lidar for vegetation mapping
- Hyperspectral MW sensors
- Solar coronal magnetic field imager, solar wind beyond L1
- Ionosphere/thermosphere spectral imager (e.g. GEO, HEO, MEO, LEO)
- Ionospheric electron and major ion density
- Thermospheric neutral density and constituents
- *Missions to study physical processes* (content and duration TBD depending on process cycles)
- Use of nanosatellites for demonstration or science missions, and for contigency planning as gap fillers (notwithstanding their possible use in Component 2)
- Use of orbiting platforms (like the International Space Station) for demonstration or science missions

Component 4. Additional Capacities and Other Capabilities

- Governmental or academic EO projects
- Private sector initiatives
- Individual or constellations of small satellites (cubesats, nanosats)
- Exploiting technical or market opportunities

- **WMO would not assume to coordinate these contributions**
- **WMO rather can recommend standards and best practices that the operators may consider to comply with**,

  with the aim to:
  - maximize *interoperability* with Components 1 - 3
  - *assure* that data are accessible and *comply with user* needs
  - assist *in*

  i) ensuring the complementarity to existing systems, and

  ii) enhancing the resilience of the overall global observing system

Next steps

- Draft version 1.0 of the "Vision for the WIGOS space-based component in 2040" was submitted to CBS-16

- CBS agreed to send draft v1.0, for wider consultation in 2017

- *CBS-16 approved sending the document to WMO members and selected entities* such as space agencies, user communities and additional groups representing a variety of viewpoints, including the research community.

  - Q1/2017: Letter sent by WMO SG to CEOS
  - *4-6 April 2017: draft v1.1 will be rewiewed by ET-SAT-11*
  - *Q3+4/2017: the further updates to 2040 Vision*
  - *2-6 October 2017: a progress will be presented in EUMETSAT Meteorological Satellite Conference 2017 in Rome*

- *Finally*, the Vision shall be endorsed by WMO Congress in 2019.

Comments from GSICS community are highly appreciated !!!

WMO OMM

WEATHER CLIMATE WATER

7L30

Thank you

WORLD METEOROLOGICAL ORGANIZATION

Questions:
tkurino@wmo.int