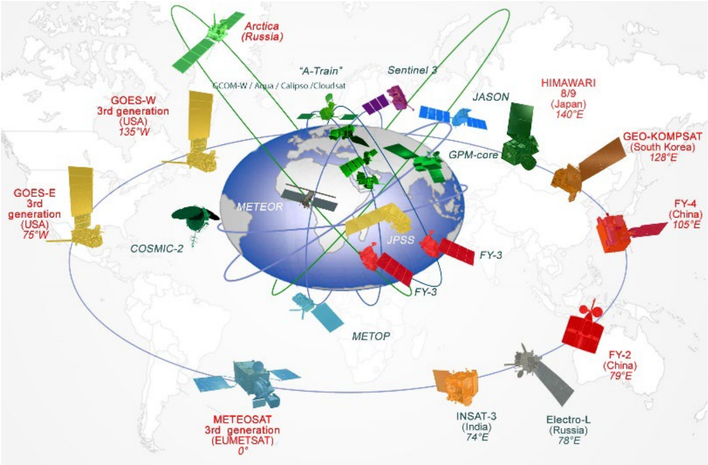


Update on the WIGOS Vision 2050

(S.-A. Boukabara, NASA and Shannon Kaya, ECCC)

On Behalf of the WIGOS Vision Update Drafting Team

Coordination Group for Meteorological Satellites

WIGOS Vision update group

Group members:

•Sid Boukabara (WMO/ET-EOSDE/RRR, NWP, NASA, US)
•Shannon Kaya (WMO/SC-ON, MSC, Canada)
•Sean Burns (CGMS, EUMETSAT, Europe)
•Mary-Jane Bopape (SAEON, GBON, South Africa)
•Jianxia Guo (GSRN, ET-EOSDE, CMA, China)
•Fiona Smith (WMO ET-SSU chair, Australia)
•Lihang Zhou (WMO ET-SSU co-chair, US)
•Elian Wolfram (Ground Based Network, Argentina)
•Mike Seablom (Office of Technology, NASA, US)
•Tony McNally from ECMWF (NWP, ESP, Europe)
•Osamu Ochiai (CEOS, JAXA, Japan)
•Junhong Wang (WMO SC-MINT, MesoNet, US)

Subgroup contributors:

- Paolo Ruti
- Stephan Bojinski
- Agnes Lane
- Erik Andersson
- Rosemary Munro
- Vijay Tallapragada
- Niels Bormann

WMO secretariat support:

- Albert Fischer
- Jitsuko Hasegawa
- Natalia Donoho
- Heikki Pohjola
- Mikael Rattenborg
- Roger Saunders
- Jesse Andries
- Kruno Premec
- Nicolas Rivaben

Special guest speakers to meetings:

- John Eyre, WIGOS 2040 Learned lessons
- Melissa Martin, Commercial data
- Amy Chen, Citizen data
- Diego Ellis Soto, IoA
- Helen Burdett, WEF, Economic Value of EO
- Curtis Marshall, public-private partnership
- Xichuan Liu, on utilizing EO from IoT/DEN
- Hong Liang, on utilization of EO from IoT/5G-PWV
- Ze Zhang, on utilizing EO from IoT/Public Cameras

A small, agile but representative team was setup, representing various regions of the globe, several fields of expertise, and several sectors of users and applications. Additional contributors joined to subgroups, based on interest and needs

Content

General Goal of the Vision

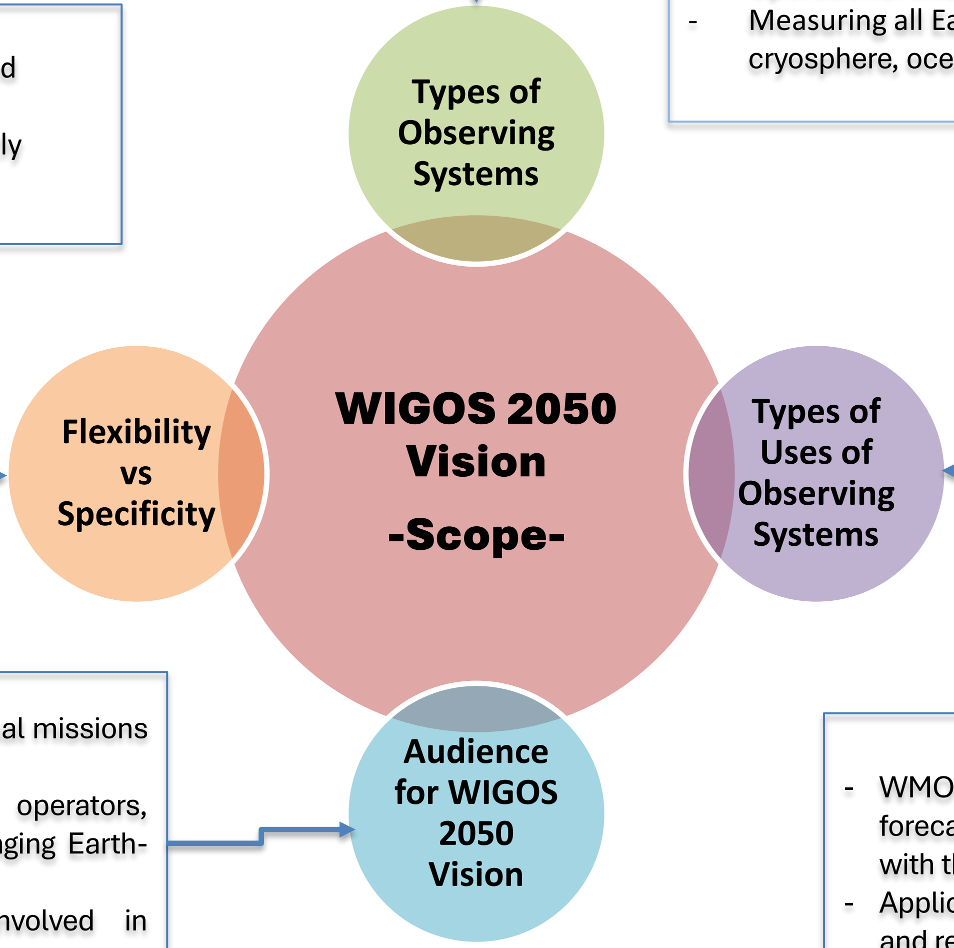
"The Vision for WIGOS in 2050 presents a likely scenario of how user requirements for observational data may evolve over the next 25 years, and an ambitious, but technically and economically feasible vision for an integrated observing system that will meet them. It provides high-level targets to guide the evolution of the WIGOS in the coming decades. It anticipates a fully developed and implemented WIGOS framework that supports all activities of WMO and its Members within the general areas of weather, climate and water."

Vision should achieve a balance of being inspiring and visionary while at the same time, being feasible, realistic and mindful of operational constraints.

Scope of WIGOS 2050 Vision

- Earth-Based observing systems (including surface, sub-surface, airborne, ocean-based, land-based, cryosphere-based, etc)
- Space- and near-space based observing systems
- In-situ and remote sensing
- Operational and research and opportunistic observing systems
- Measuring all Earth system components: atmosphere, hydrology, cryosphere, ocean, terrestrial surface, and space weather

- Balance between scientific ambition, technical feasibility, and economic realism.
- Provide specific-enough guidance while remaining sufficiently flexible to accommodate evolving landscape



- Meant to inspire future designs of both individual missions and integrated architectures.
- Broad audience: space agencies, satellite operators, national and international organizations managing Earth-based networks.
- Both public and private stakeholders involved in observation system design and deployment.

- WMO-relevant applications/users—such as modelers, forecasters, and application developers—consistent with the WMO Rolling Review Requirements (RRR).
- Applications in weather, climate, hydrology, marine, and related services (WMO official scope)

Community Engagement

Inclusive and Balanced Representation:

- Space/Surface balance
- Geographic representation
- Gender balance
- Applications representation
- Institutions representations

Team members are also reps of or familiar with: CGMS, CEOS, GOOS, WMO, ET-EOSDE, RRR, NWP, NASA, SC-ON, EUMETSAT, SAEON, GBON, JAXA, ET-SSU, BOM, ECMWF, Academia, private sector and non-traditional EO sector

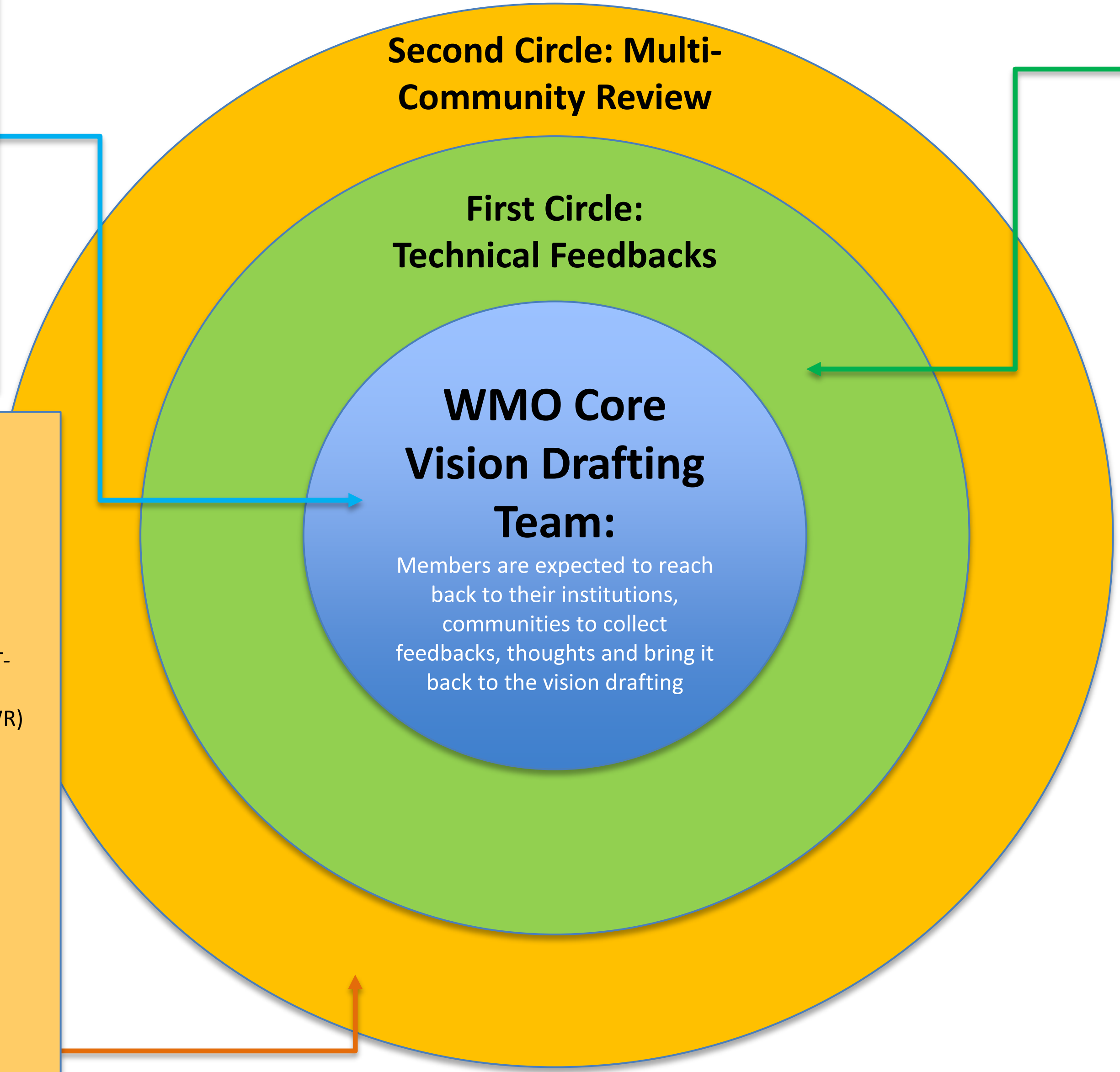
They are also from:
US, Canada, Japan, South Africa, Argentina, Europe, Australia, China, etc

Second Circle: Review

Satellite operators: CGMS, CEOS

WMO subsidiary bodies and co-sponsored entities:
- INFCOM Management Group
- SC-ON
- ET chairs (ET-EOSDE, ET-ABO, ET-SON, ET-SSU, ET-SWx, ET-RFC, ET-WTR) representative of GAW
- SC-MINT plus ET chairs (ET-SSM, ET-UAM, ET-OWR)
- AG-Hydro
- AG-GCW, TT-CPOS
- AG-G3W
- JCB subgroup on basic observing networks
- SC-WIPPS
- SC-IMT
- SOFF
- GCOS SC, including AOPC, OOPC, TOPC chairs
- GOOS
- WMO SERCOM Management Group
- WMO Research Board RB

Private sector: HMEI



First Circle: Technical Feedbacks

- Organized Vision workshop
- Direct invites of SMEs to participate in deliberations: WEF, UKMO, IoT, etc.
- Two surveys were conducted: one for members of the team and one for several thematic/users/Earth system domain communities:
  - GCOS (AOPC, TOPC),
  - Ocean (GCOS/OOPC),
  - Atmospheric composition (GAW and G3W communities),
  - Cryosphere (AG-GCW, GCW community),
  - Terrestrial (GCOS/TOPC),
  - Hydro (AG-Hydro, TT-EHN community),
  - Regional networks (WG chairs of RBON design groups), Space Wx.
- Major surveys organized by CGMS and CEOS to coalesce the feedbacks/inputs from space agencies
- Direct engagement activities:
  - MesoNet
  - CGMS WGs, plenary
  - CEOS, Joint CEOS/CGMS WG on Climate
  - WMO: ET-EOSDE, ET-SSU, ET-SWx, GCOS steering committee, RRR workshop
  - Etc.
- Etc.

***HMEI: HydroMeteorological and Environmental Industry association**

Major Driving Factors and Implications on WIGOS

2050 Context

Overall Context:

- Observing Systems Increasingly Becoming a Critical Infrastructure
- Evolving Roles of Public and Private sectors in Addressing Users Observational Needs
- *Increasing Diversity and Rapid Growth of Observing Systems*
- Increased, wider spread dependance on EO beyond WMO scope, Increased economic Value of EO,

Technical Offer:

Technology Opportunities,

(Quantum computing & sensing, AI, IoT, IoA, Space 3.0, Internet 2.0, Commercial sector, etc.)

Technical Demand:

Users Demands/Expectations

Earth System Approach demands, Increased importance of urban/Local scale information, Increased # of users, etc.

We envision Users will realistically expect information that is:

- *Instantaneous, Sub-hourly*
- *Relevant -i.e. as close as possible to the location desired, likely within tens of meters-,*
- *Time insightful -for both hindcasting and forecasting, at various desired lead times-*
- *As accurate as possible*
- *Diverse and varied, various types of information*
- *Uses new delivery approaches (Personal Agents, etc.)*

Helped formulate → WIGOS 2050 Vision

Utility of EO will increase across scientific, operational, economic, and societal applications, reinforcing their role as a foundational infrastructure for decision-making across local, regional, global scales. WMO-relevant applications will benefit from the resulting enhancements of the global observing system.

Implications for WMO Integrated Global Observing Systems

Characteristics of the Future Earth Observing System Characteristics:

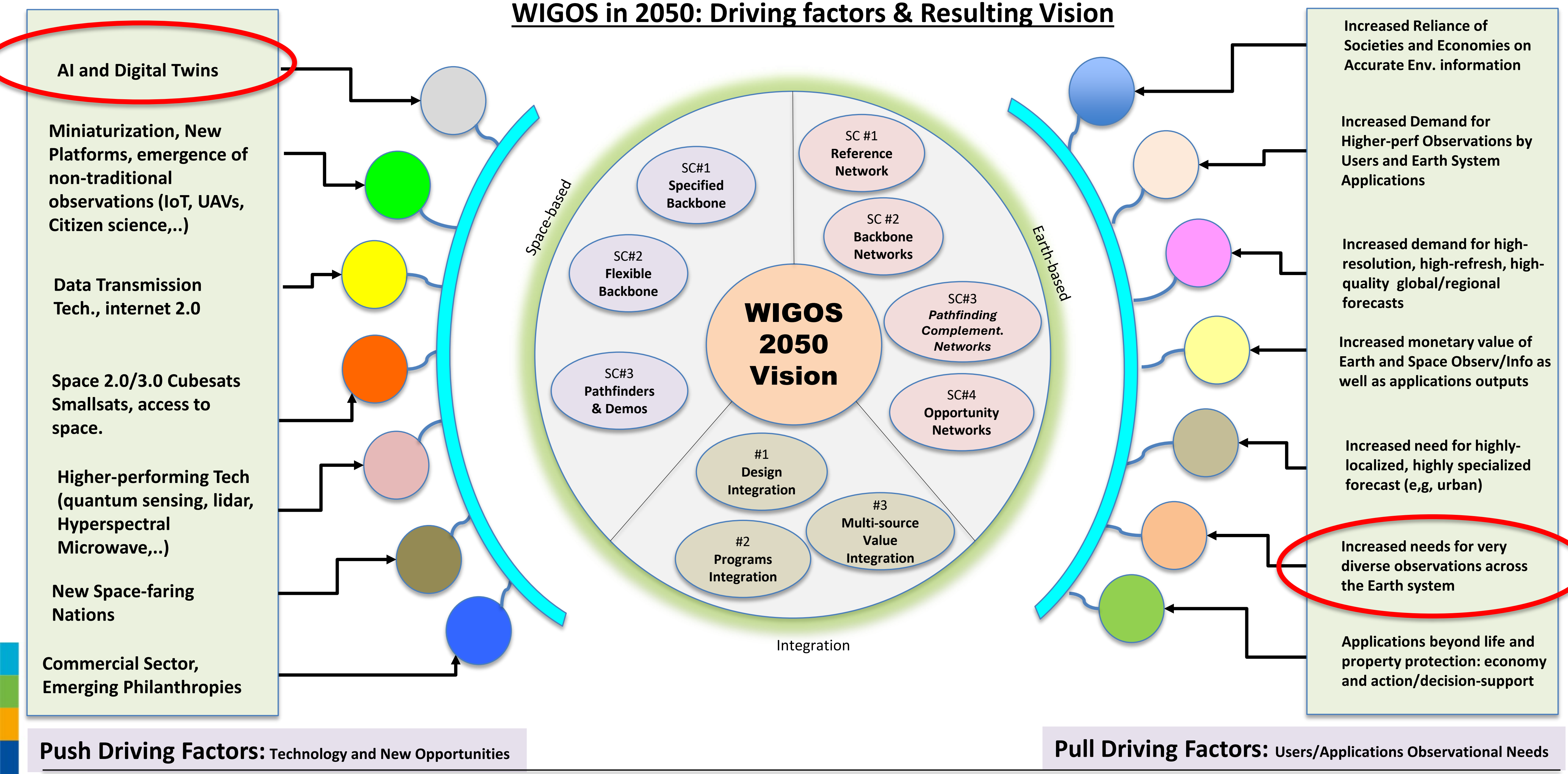
- **Extended Variety:** covering virtually all Earth system components.
- **Ever more stringent Accuracy**: to enhance quality of Information
- **Sensitivity/Low noise;** to allow ability to detect subtle changes
- **Long-term sustainability:** to assess trends, provide sustained services
- **Global coverage of more variables:** for spatial interdependence
- **Spatio-temporal-vertical resolutions**: for high-resolution environmental Info.
- **Diurnal and seasonal cycles sampling**: for diurnal, seasonal cycles in models.
- **Resilience, and trust in its Outputs**
- **Super-Fast execution for short latency**

No single observing system will achieve this alone !

Implications for WIGOS

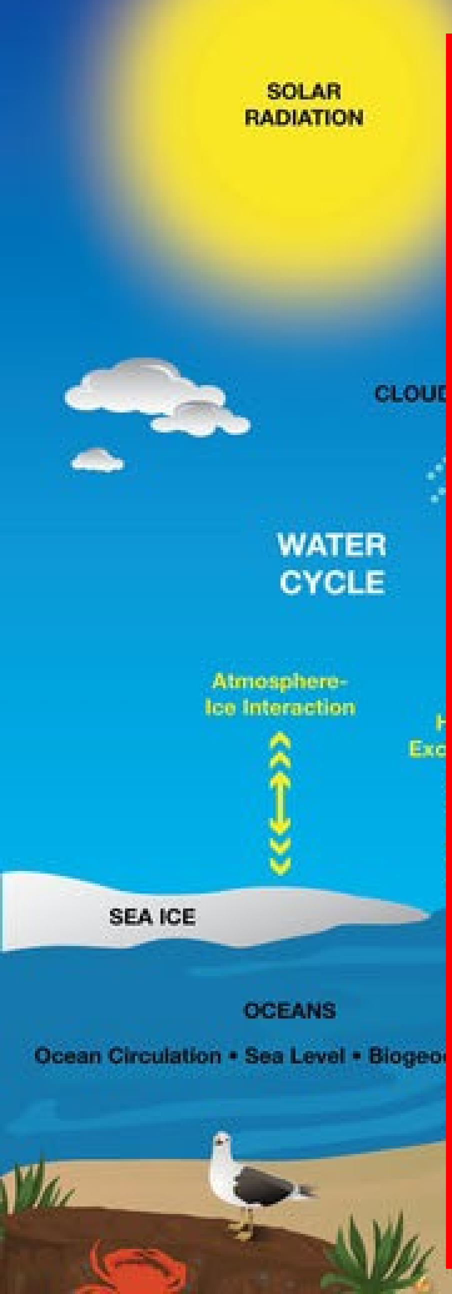
- Importance to conceive the global observing system as a **coordinated, system of systems,** including Earth- and space-based components
- Importance of integration from multiple sources to achieve the performances expected by users
- Maintain/Ensure/Enhance quality, trust, sustainability and resilience of the system
- Flexibility in leveraging assets but accounting for various stages of maturity
- Governance and cooperation across sectors
- Speed in the EO -> Action value chain at all scales

WIGOS in 2050: Driving factors & Resulting Vision



WMO OMM

Earth as a Complex Interrelated System



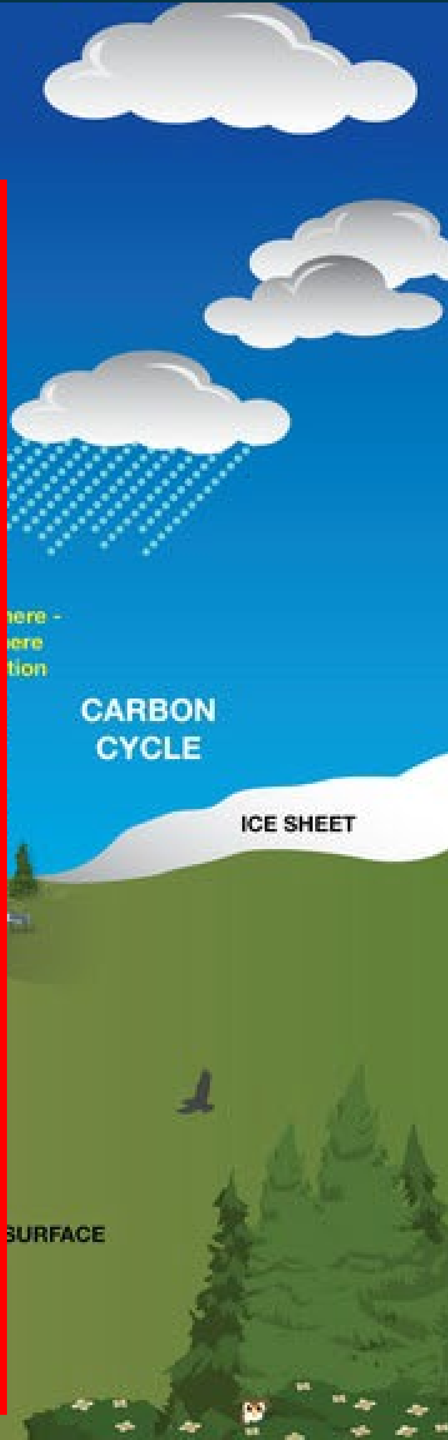
Trend Toward Comprehensive Earth System:

- Scientifically driven due to :
  - Interconnectedness of the Earth system: various applications requiring EO from a wide range of Earth system components.
  - Cascading effects of applications outputs: e,g. NWP -> hydrology -> Agriculture -> Wildfire-> Air quality->….
  - Discoveries of coupling processes and feedback loops between atmosphere, hydrosphere, biosphere, land, etc.

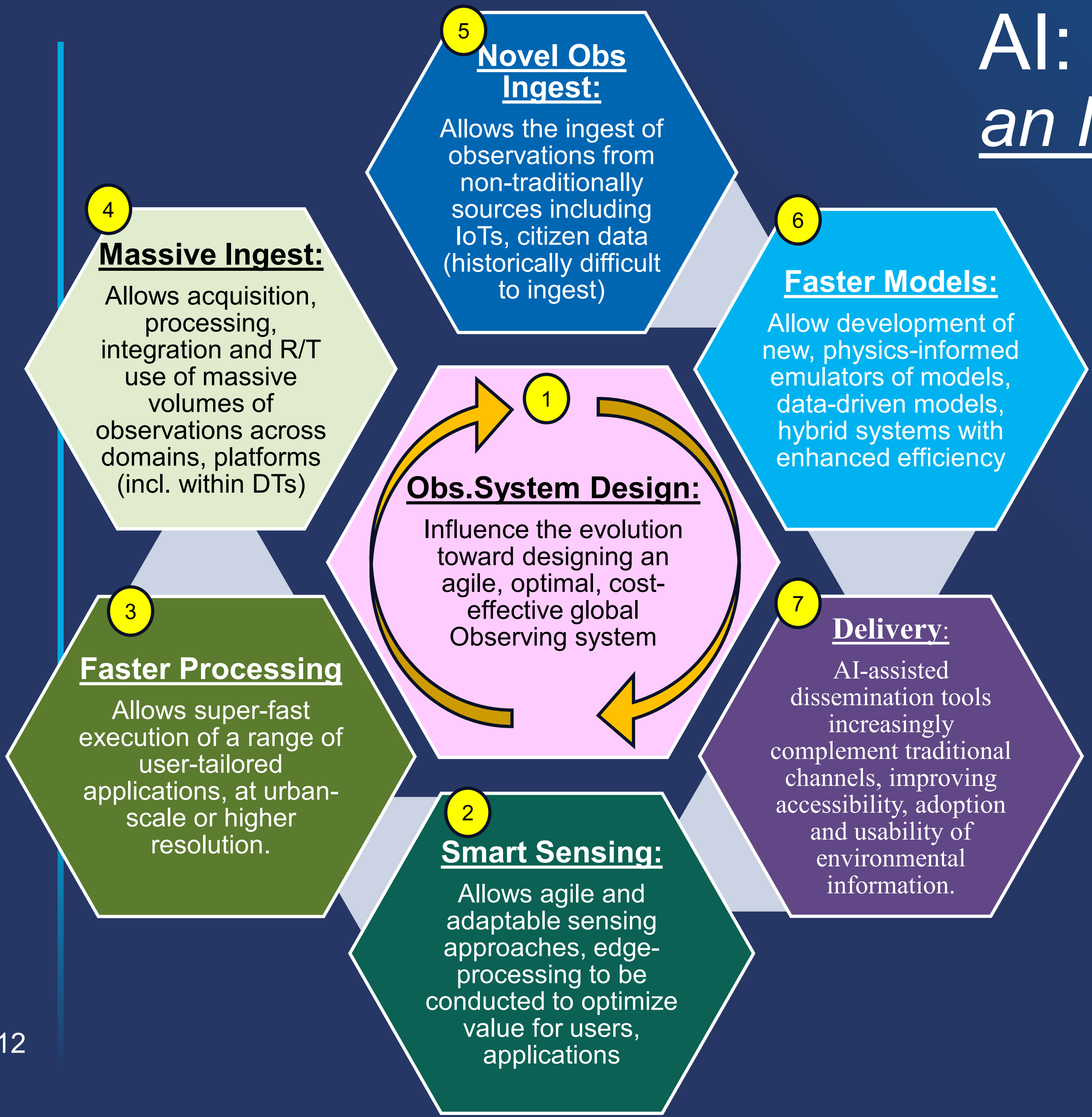
- Already adopted in various global climate models albeit with limitations (speed, resolution, etc).

- Made increasingly more performant with AI and DTs technologies (e.g. destinE in Europe, Today's Earth TE in Japan) at various spatiotemporal scales.

- Implications on WIGOS:
  - Observations, beyond those traditionally important for WMO, increasingly important
  - Coordination of both Meteorological and non-Meteorological Observations



AI: *A Major Enabling Function for an Integrated Observing System*



AI major advantages:

(1) Efficiency, (2) Emulation of physical processes, (3) Information extraction, (4) Multi-Source Aggregation, (5) Pattern recognition, (6) Tailoring, (7) Optimization, (8) Cross-field leveraging (e.g. social science)

Expected Impact on (Satellite) Observations in the Future:

Thanks to AI, the diversity, high-quality and high resolution of observations, will be fully leveraged and likely have a more direct impact on the quality, resolution and scope extent of models and applications. Observational requirements including from satellites will likely evolve as a result.

Caution:

Several challenges must be addressed when adopting AI: Ensuring transparency and interpretability of AI-based methods, maintaining rigorous standards for cal/val, uncertainty characterization, establishing governance frameworks that support trust, interoperability, and access to data and derived products and their QC processes.

The WIGOS 2050 Vision

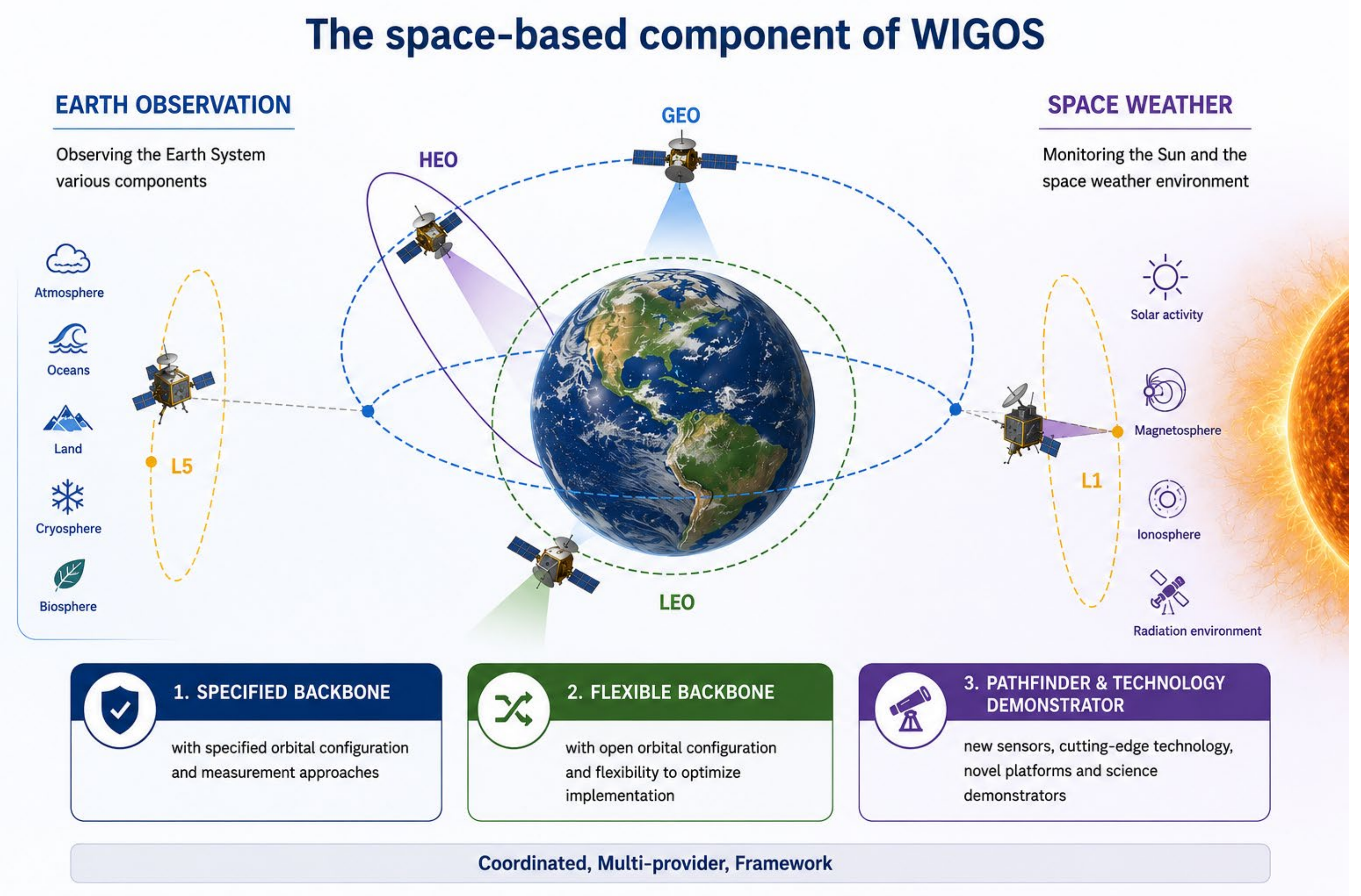
WIGOS in 2050: Space-Based Component

<u>Three</u> sub-components, designed to balance robustness/continuity with flexibility and innovation with multiple Providers (public, commercial, academic, philanthropic) but coordinated.

- **A) Backbone with specified orbit configuration and measurement approaches:**
  - “high-consensus” foundation, underpinning WMO applications and aligned with space agencies plans.

- **B) Backbone with open orbit configuration and flexibility to optimize implementation**
  - Established/demonstrated capabilities *enhancing performance*, but implementation choices are still open—especially orbits and instrument specs.

- **C) Pathfinders, technology & science demonstrators:**
  - Represents the innovation supporting R&D needs from evolving applications and Earth system science, plus multi-sector partnership opportunities and innovative payload-hosting options for example.



WMO OMM

WIGOS in 2050: Earth-Based Component

Earth-based component is envisioned with 4 sub-components, designed to span a wide spectrum of observing systems and networks with varying levels of sustainability, accuracy, technology innovation, maturity, and coordination.

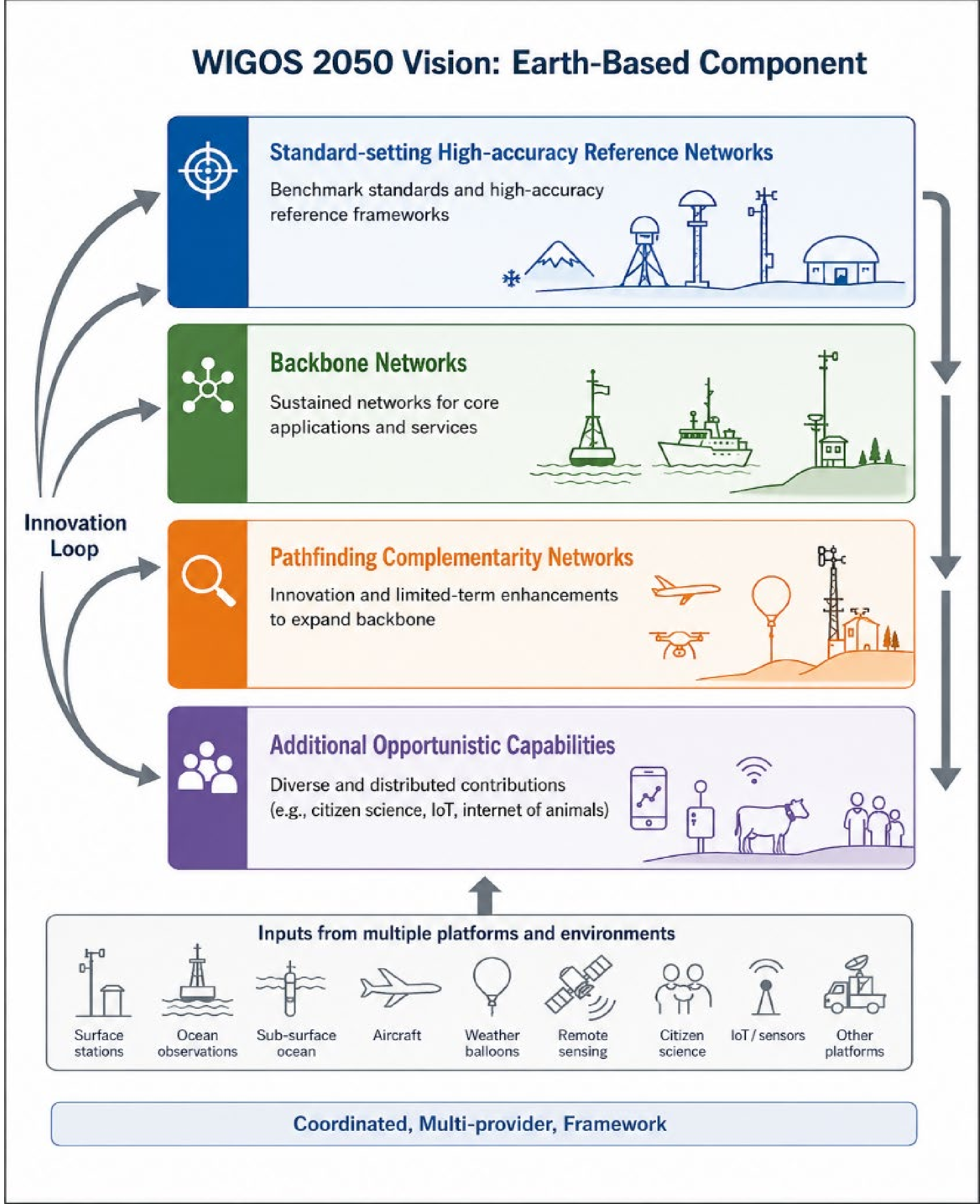
This component is envisioned to evolve dynamically over time, with an innovation-infusion loop where capabilities in one network could evolve to be used in other networks

- **A) Standard-setting High-accuracy Reference Networks:** to Establish benchmark standards that underpin data quality and measurement consistency.

- **B) Backbone Networks:** to deliver obs. for core applications and services. It includes standardized, proven capabilities with high-quality data from stable platforms.

- **C) Pathfinding Complementarity Networks:** its role is to be a bridge between R&D and sustained operations—a complementary system that supports proof-of-concept demonstrations and targeted enhancements to the backbone.

- **D) Additional Opportunistic Capabilities:** Its role is to Aggregate diverse, emerging, and distributed contributions to expand coverage and diversity. E.g. Citizen science, Internet of Animals (IoA), IoT, infrastructure-based sensing (telecom/power towers), emerging platforms (e.g., stratospheric balloons and uncrewed vehicles. This is envisioned to be a great way to incentivize a wide number of WMO members to be active contributors to WIGOS.



WIGOS in 2050: An Integrated Vision

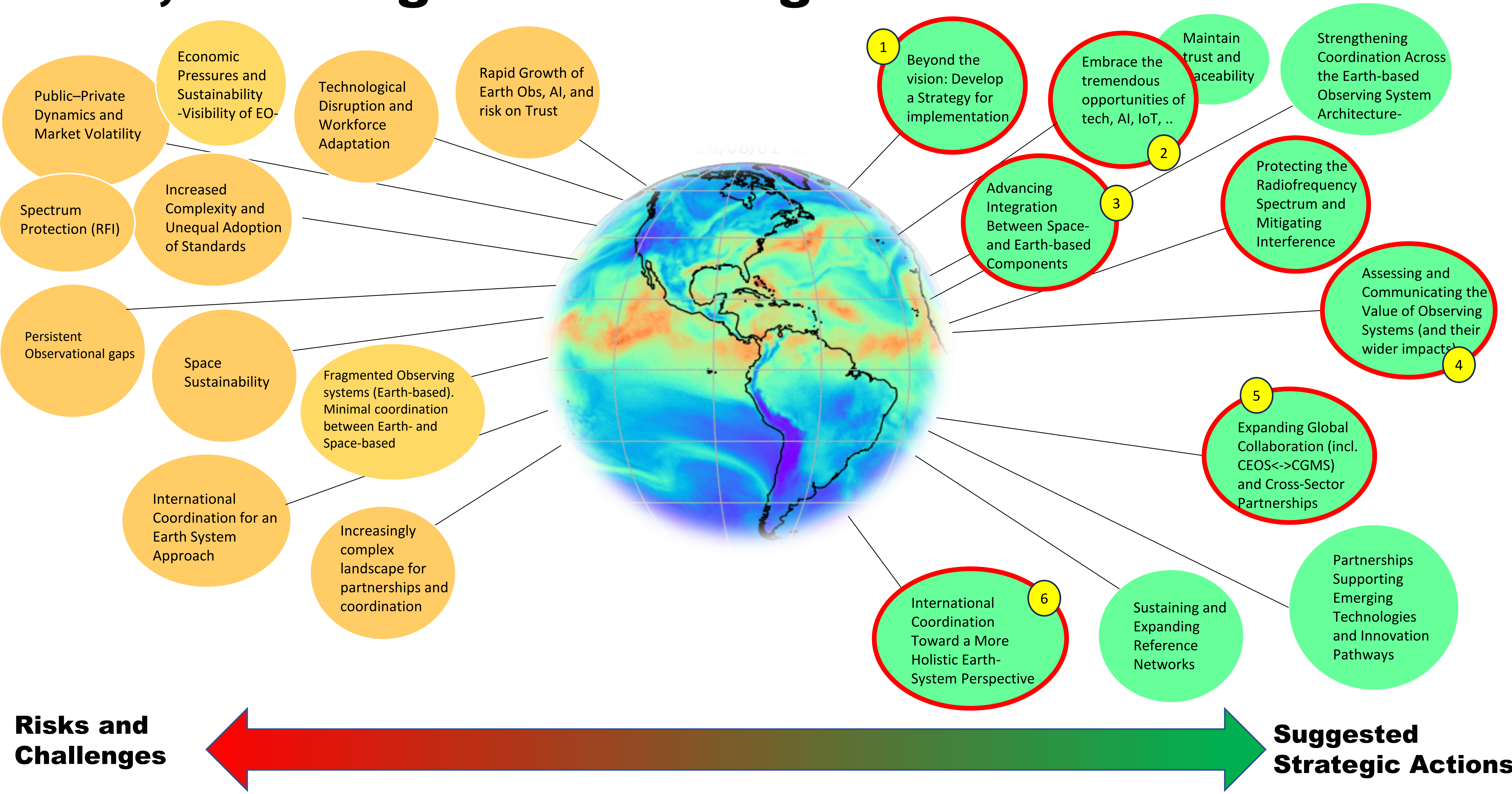
(Space-based and Earth-Based)

- **The global observing system in the 2050 timeframe is envisioned to be integrated.** This will allow tapping into the complementarity of various tiers of the observing systems and networks (space-based and Earth-based)
- **This will result in:**
  - Efficiency
  - Cost effectiveness
  - Enhanced value to the users
  - Resilience of the global system
- **This integrated vision, has to consider 3 pillars:**
  - Integration at the Design stage
  - Programmatic Integration
  - Value Integration
- For each pillar, a set of mechanisms/activities are proposed in the vision.

WMO OMM

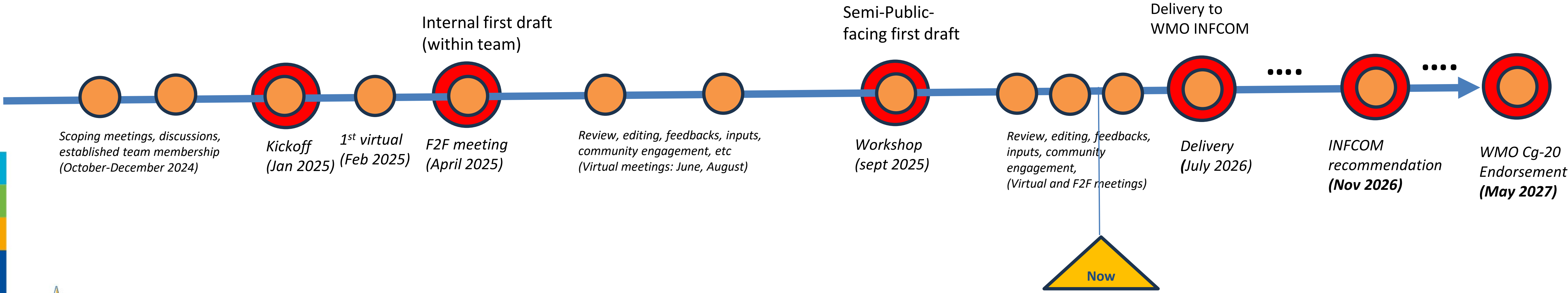
Risks, Challenges, and Suggestions to Enable Implementation

Risks, Challenges and Strategic Actions



Next Steps and Timeline

- Engagement & formal review with various communities conducted.
- **CGMS inputs, feedbacks were an integral part of the drafting of the vision. Especially the space component.**
- Adjudication of all feedbacks tentatively completed.
- Professional Communication & Editorial Review in progress
- Next major steps:
  - Formal Delivery to WMO INFCOM in July 2026
  - Conduct Q&A sessions with communities as needed including HMEI
  - Formal recommendation by INFCOM in November 2026.
  - Formal endorsement by WMO expected in May 2027 (at Cg-20).



WMO OMM

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

Thank You

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale