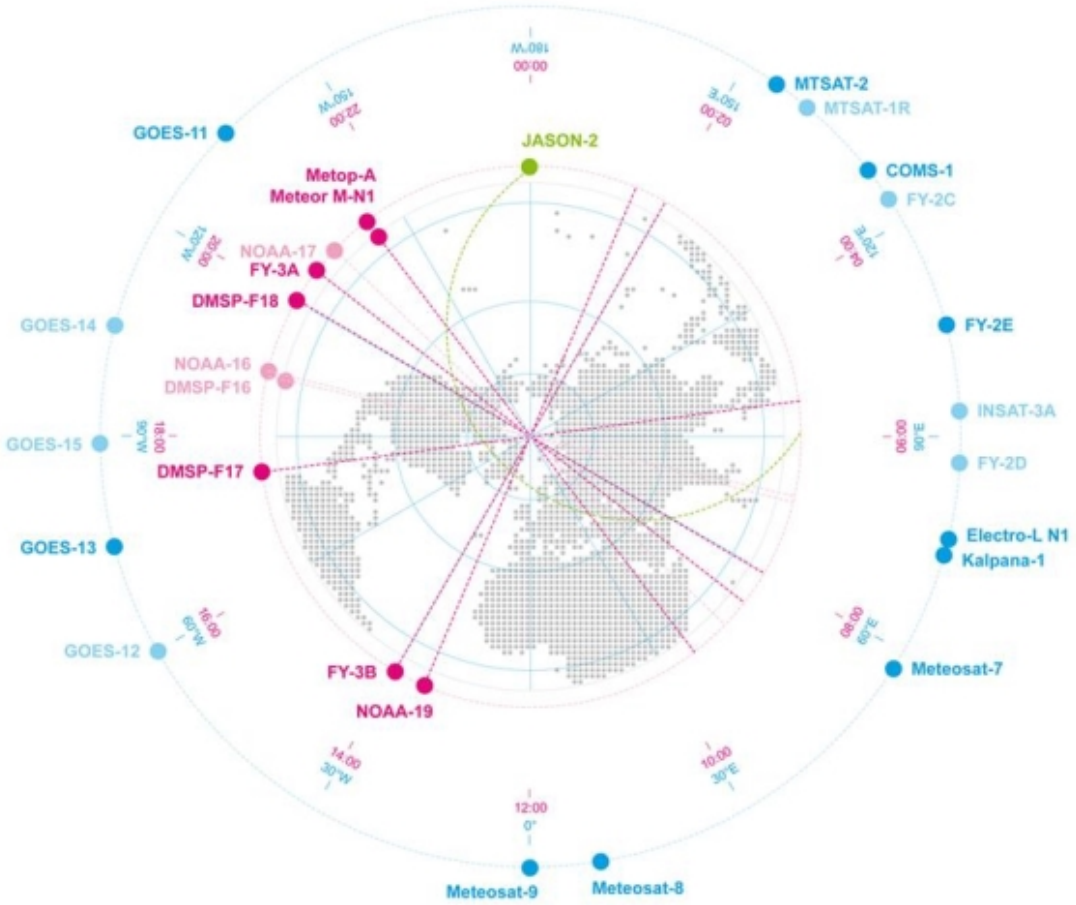
Key Outcomes of the 6th CGMS Risk Assessment

Presented to CGMS-52 Plenary, agenda item 3

The CGMS Baseline:

- ***Enumerates the sustained observations, measurements, and services*** that form the CGMS contribution to observing the Earth System, Space Environment and the Sun, and responds to end-user requirements expressed in ***WMO's Rolling Review of Requirements (RRR)***.
- Constitutes the ***CGMS response to the WMO Integrated Global Observing System (WIGOS) 2040 vision*** to document what missions are currently being, or planned on being flown.



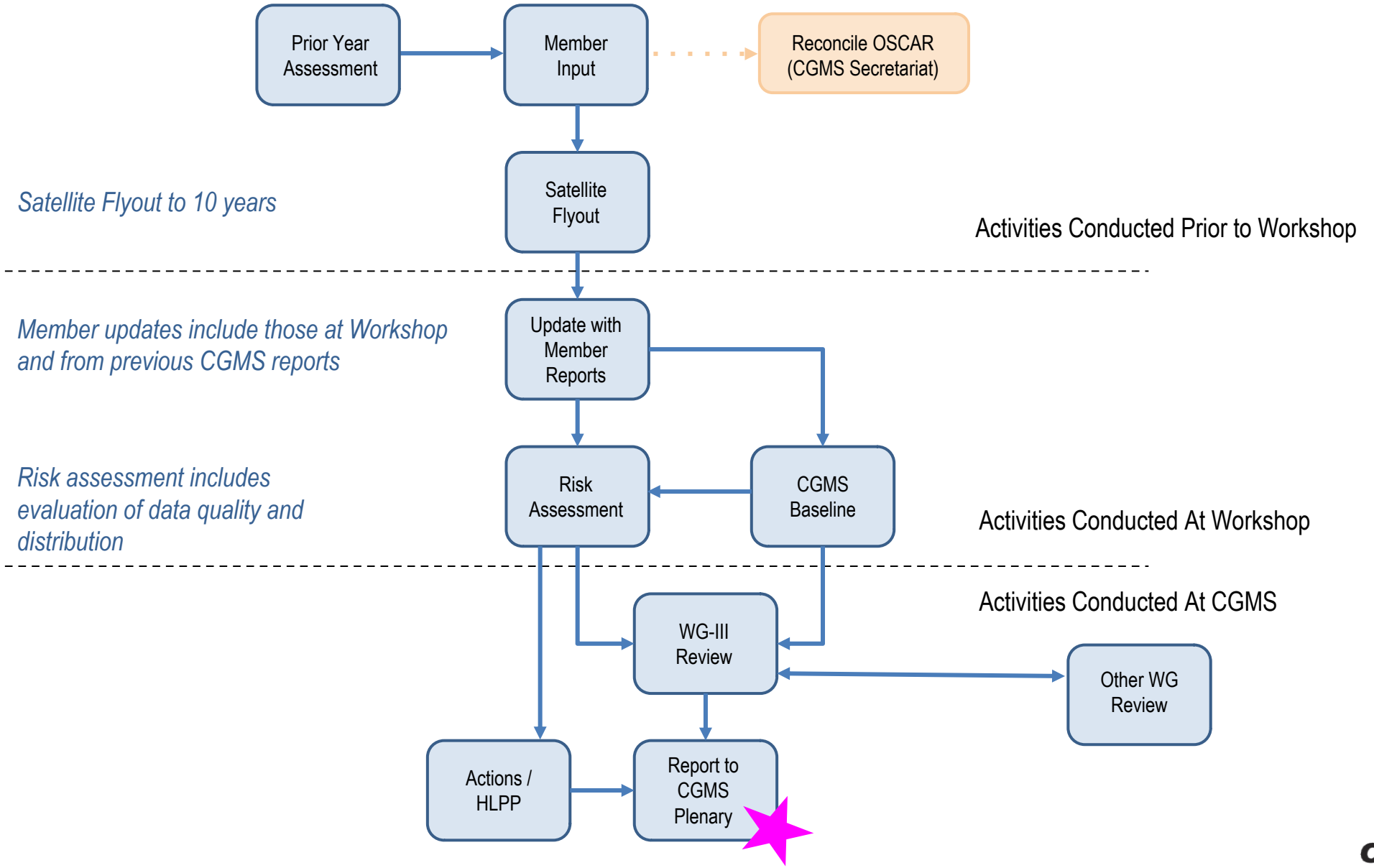
Key Principles of the CGMS Baseline:

- *Commitment*: The CGMS Members are providing, or have firm plans to provide, the observations, measurements, and services
- *Sustained*: The observations, measurements, and services are provided on a sustained basis
- *Available*: The observations, measurements, and services are available on a free and open basis
- *Operational*: The data and products can be utilized in operational applications

CGMS Risk Assessment

- ***CGMS conducts an annual risk assessment against the CGMS baseline*** to track how well CGMS is meeting its commitments.
- The top-level risk assessment for each sensor/observation is based on a qualitative analysis of all the orbits and satellite missions from which the observation is provided.
    - This assessment is given from a CGMS Member prospective and may not:
        - Include contributions from non-CGMS agencies
        - Include contributions from commercial providers
        - Incorporate all WMO requirements (which are covered by the gap analysis).
    - The assessment is based on planned launch dates, design life, and updated by operational experience.
    - System resiliency, nor the consequence of not meeting commitments was not specifically addressed.
    - Quality and availability were not analyzed in detail for all measurements.
    - Member owned and operated payloads hosted on commercial platforms are included when launch dates are determined
    - CGMS members may provide commercially sourced data to meet commitments to the CGMS Baseline, with the understanding that they commit to the provision of such data consistent with the Baseline principles.

CGMS Baseline Update / Risk Assessment Process



CGMS Risk Assessment Assumptions

- CGMS Risk Assessment uses **Green**, Yellow, and Red to graphically represent the overall status of that sensor/observation. The criteria for each colour is as follows:
  - **Green:** CGMS Baseline met with a low risk of a gap.
  - **Yellow:** The CGMS Baseline is at moderate risk of not being fully met. Some mitigation by CGMS Members may be required.
  - **Red:** There is a high risk of not meeting the CGMS Baseline without CGMS Member action
  - No Colour: Observation is not planned to be available until a later date

Top-Level Risk Assessment - Earth Observations (2024)

Top-Level Risk Assessment - Solar/Space Observations (2024)

BACKUP

Full Risk Assessment

Updates

- Updates to mission data were received January-February, and and reviewed at the 6th RAW, 21-22 February 2024
- Each flyout chart has been updated with the new launch and EOL information:
  - ACE EOL moved to 2027
  - ALOS-2 EOL moved to 2024
  - CO2M-A launch moved to 2026 and EOL to 2033
  - CO2M-B launch moved to 2027 and EOL to 2034
  - CO2M-C launch moved to 2029 and EOL to 2036
  - CryoSat-2 EOL moved to 2025
  - DSCOVR EOL moved to 2027
  - Electro-L N5 launch moved to 2025 and EOL to 2035
  - FY-3H launch moved to 2025 and EOL to 2031
  - FY-4C launch moved to 2025 and EOL to 2032
  - GCOM-C and GCOM-W EOLs moved to 2024
  - GEO-XO I1 launch moved to 2033 and EOL to 2039
  - GOES-16 EOL moved to 2033
  - GOES-18 EOL moved to 2038
  - GOES-U EOL moved to 2033
  - GOSAT and GOSAT-2 EOLs moved to 2024
  - GPM Core EOL moved to 2026
  - HY-2C EOL moved to 2025
  - HY-2D EOL moved to 2026
  - INSAT-3D EOL moved to 2025
  - INSAT-3DS launch moved to 2024
  - JPSS-3 launch moved to 2032 and EOL to 2039
  - JPSS-4 launch moved to 2027 and EOL to 2034
  - SNPP EOL moved to 2028
  - NOAA-20 EOL moved to 2030
  - NOAA-21 EOL moved to 2031
  - Meteor-M N2-3 launch moved to 2023 and EOL to 2028
  - Meteor-M N2-4 launch moved to 2024 and EOL to 2029
  - Meteor-M N2-5 launch moved to 2025 and EOL to 2030
  - Meteor-M N2-6 launch moved to 2026 and EOL to 2031
  - Meteor-MP N2 launch moved to 2026 and EOL to 2033
  - Meteosat-9 EOL moved to 2027

Updates cont.

- Launch and EOL updates continued:
  - MetOp-B EOL moved to 2026
  - MetOp-C EOL moved to 2027
  - MetOp-SG-A1 EOL moved to 2033
  - MetOp-SG-A2 launch moved to 2032 and EOL to 2040
  - MetOp-SG-B1 launch moved to 2026 and EOL to 2033
  - MetOp-SG-B2 launch moved to 2033 and EOL to 2041
  - MicroCarb launch moved to 2025 and EOL to 2030
  - MTG-I1 EOL moved to 2032
  - MTG-I2 EOL moved to 2036
  - MTG-I3 launch moved to 2032 and EOL to 2042
  - MTG-S1 launch moved to 2025 and EOL to 2035
  - MTG-S2 launch moved to 2035
  - OceanSat-3A launch moved to 2025 and EOL to 2030
  - OCO-2 EOL moved to 2026
  - Sentinel-1A EOL moved to 2024
  - Sentinel-1B EOL moved to 2021
  - Sentinel-1C launch moved to 2024 and EOL to 2030
  - Sentinel-1D launch moved to 2025 and EOL to 2031
  - Sentinel-2A EOL moved to 2025
  - Sentinel-2B EOL moved to 2027
  - Sentinel-2D launch moved to 2028
  - Sentinel-3A EOL moved to 2026
  - Sentinel-3B EOL moved to 2028
  - Sentinel-3C launch moved to 2024 and EOL to 2030
  - Sentinel-6B launch moved to 2025
  - SOHO EOL moved to 2026
  - SWFO-L1 EOL moved to 2030

Updates cont.

- The flyout charts also reflect the following additional updates:
  - Himawari-10 is now included in the assessments for the Hyperspectral Infrared Sounder, Multi-purpose Meteorological Imager GEO, and energetic particle sensor charts for high and very high
  - FY-3G is now included in the assessment for Meteorological Imager in LEO
  - FY-3I is now included in the assessments for Meteorological Imager in LEO and Microwave Imager
  - FY-4A is now included in the assessments for Energetic Particle Sensor GEO - High and Very High energy electrons and protons
  - FY-4C has been removed from the assessment for Magnetometer
  - FY-3F and FY-3H have been removed from the assessment for Narrow Band Visible & Near Infrared Imager
  - HY-2C and 2D are now included in the assessments for Radar Altimetry and Scatterometer
  - NOAA-15, -18 and -19 have been removed from all relevant assessments as they are now on-orbit residuals
  - GOES-15 has been removed from all relevant assessments as it is no longer a NOAA mission
  - GOES-17 has been removed from all relevant assessments as it is now in storage
  - JPSS-4 is now included in the assessment for the Broadband Radiometer and JPSS-3 has been removed
  - Meteor-M N2-5 is now included in the assessments for Microwave Sounder and Hyperspectral Sounder
  - Meteor-M N2-2/3/4/5/6 are now included in the assessment for Synthetic Aperture Radar
  - Meteor-MP N1/2 are now included in the assessment for Scatterometer
  - Vigil at L5 is now included in the assessments for EUV Imager, Plasma analyzer, Coronagraph and Magnetometer

CGMS Risk Assessment Assumptions

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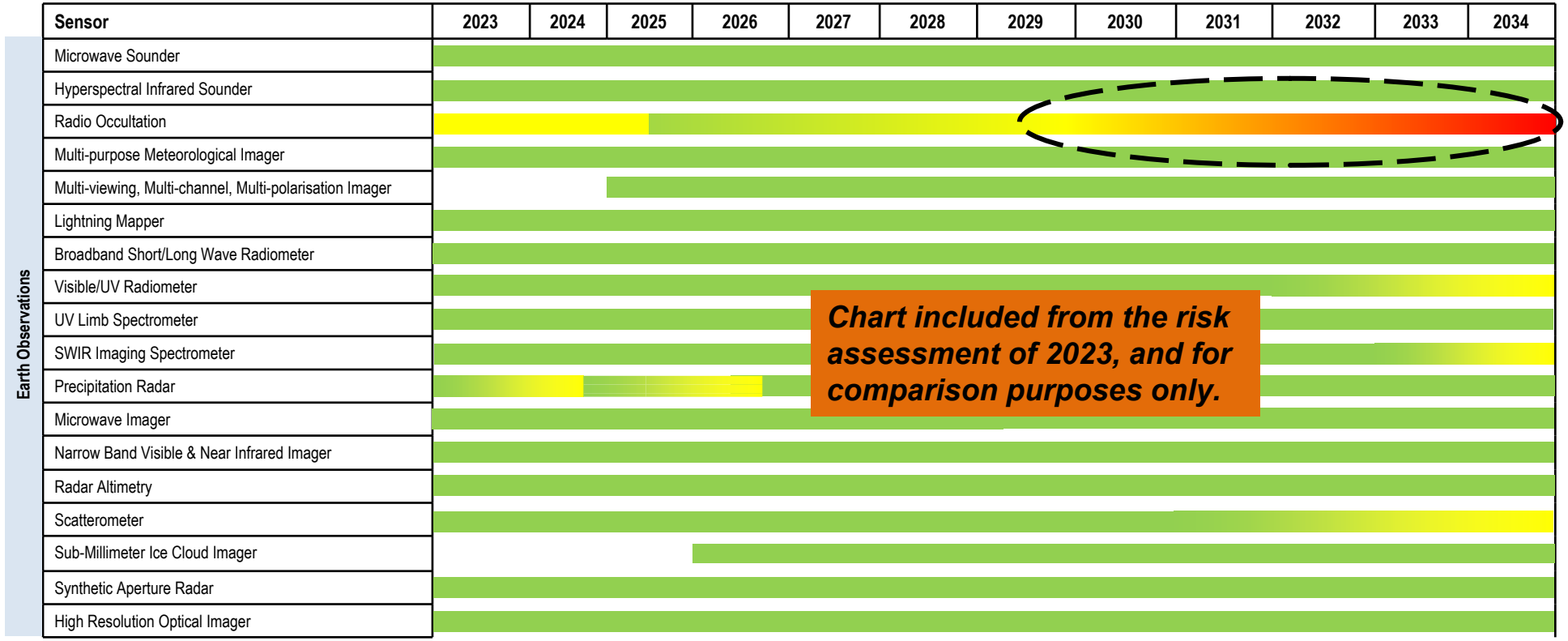
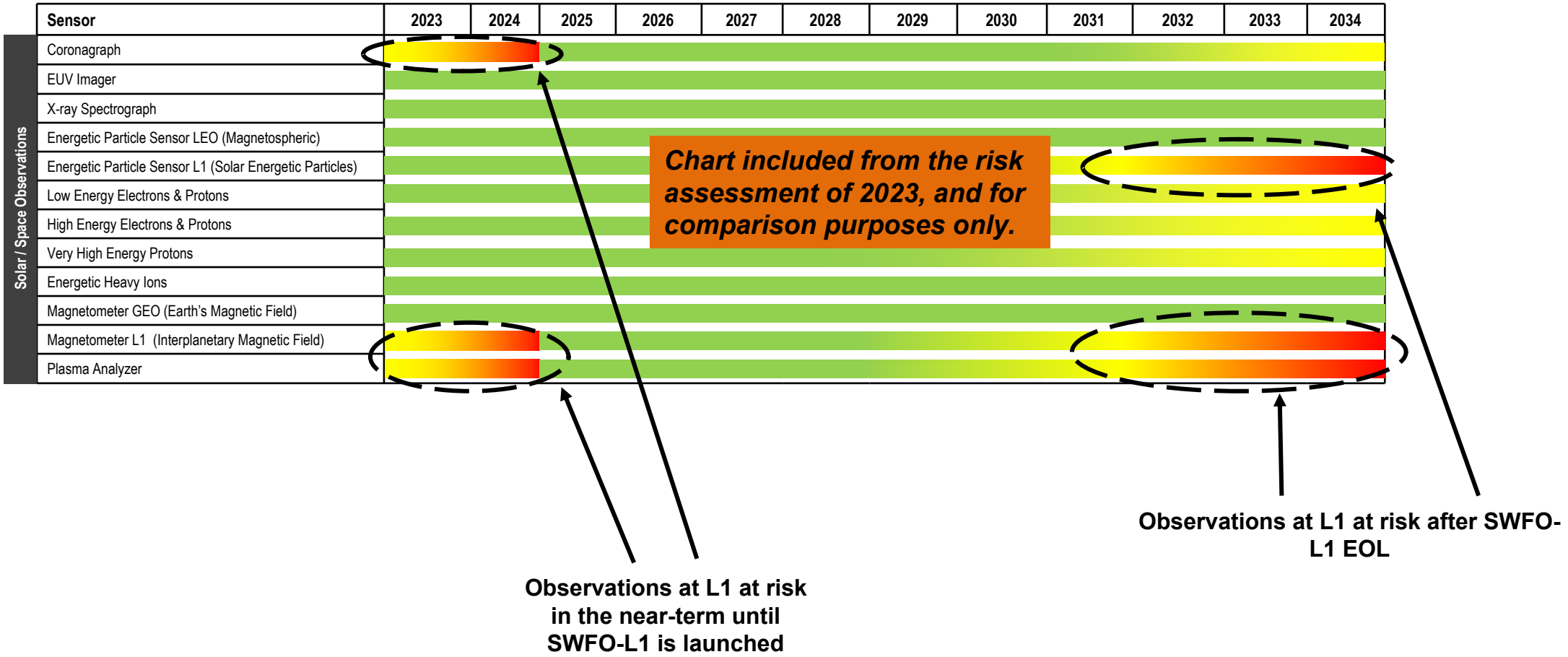
Top-Level Risk Assessment - Earth Observations (2024)

Top-Level Risk Assessment - Solar/Space Observations (2024)

Top-Level Risk Assessment - Earth Observations (2023)



Top-Level Risk Assessment - Solar/Space Observations (2023)



Top-Level Risk Assessment – Focus Areas

High risk of a gap in service

- Continuity risk from RO observations in low inclination orbits in the later part of the decade as there is no commitment for a follow-on to COSMIC-2. *(slides 21-23)*
    - The CGMS Baseline commitment for RO observations is now being met in the short-term with the inclusion of data from commercial providers.
- Long-term continuity risk to Synthetic Aperture Radar and High Resolution Optical Imager observations. *(slides 39-40)*
- Long-term continuity risk to Energetic Particle Sensor observations at L1. *(slide 45)*
- Long-term continuity risk to L1 Magnetometer and Plasma Analyzer observations. *(slides 51-52)*
    - Vigil at L5 is now included in the assessments but is considered complementary and does not mitigate the risk.

Top-Level Risk Assessment – Focus Areas

Moderate risk of gap or performance degradation

- Slight long-term continuity risk for the SWIR Imaging Spectrometer. *(slide 31)*
  - The Joint Working Group on Climate is working to coordinate long-term CO2 monitoring.
- Slight long-term continuity risk for the Precipitation Radar. *(slide 32)*
  - NASA and JAXA presented plans beyond the GPM Core at the 6th RAW, with the goal to add to assessment during the 7th RAW.
- Slight long-term continuity risk for the Microwave Imager. *(slides 33-34)*
  - ESA has reported on plans for the CIMR mission with the goal to add to assessment during the 7th RAW.
- Slight continuity risk for Scatterometry. *(slide 37)*
  - ISRO continues to provide updates on plans beyond OceanSat-3A.
- Risk of near-term gap in Coronagraphy in the early part of the decade has been mitigated as NOAA is prepared to provide STEREO-A coronagraphy from Wallops and Fairbanks in the event of loss of SOHO/LASCO before 2025, but long term continuity at L1 is still at risk. *(slide 41)*

Top-Level Risk Assessment – Associated Actions

Associated Open Actions

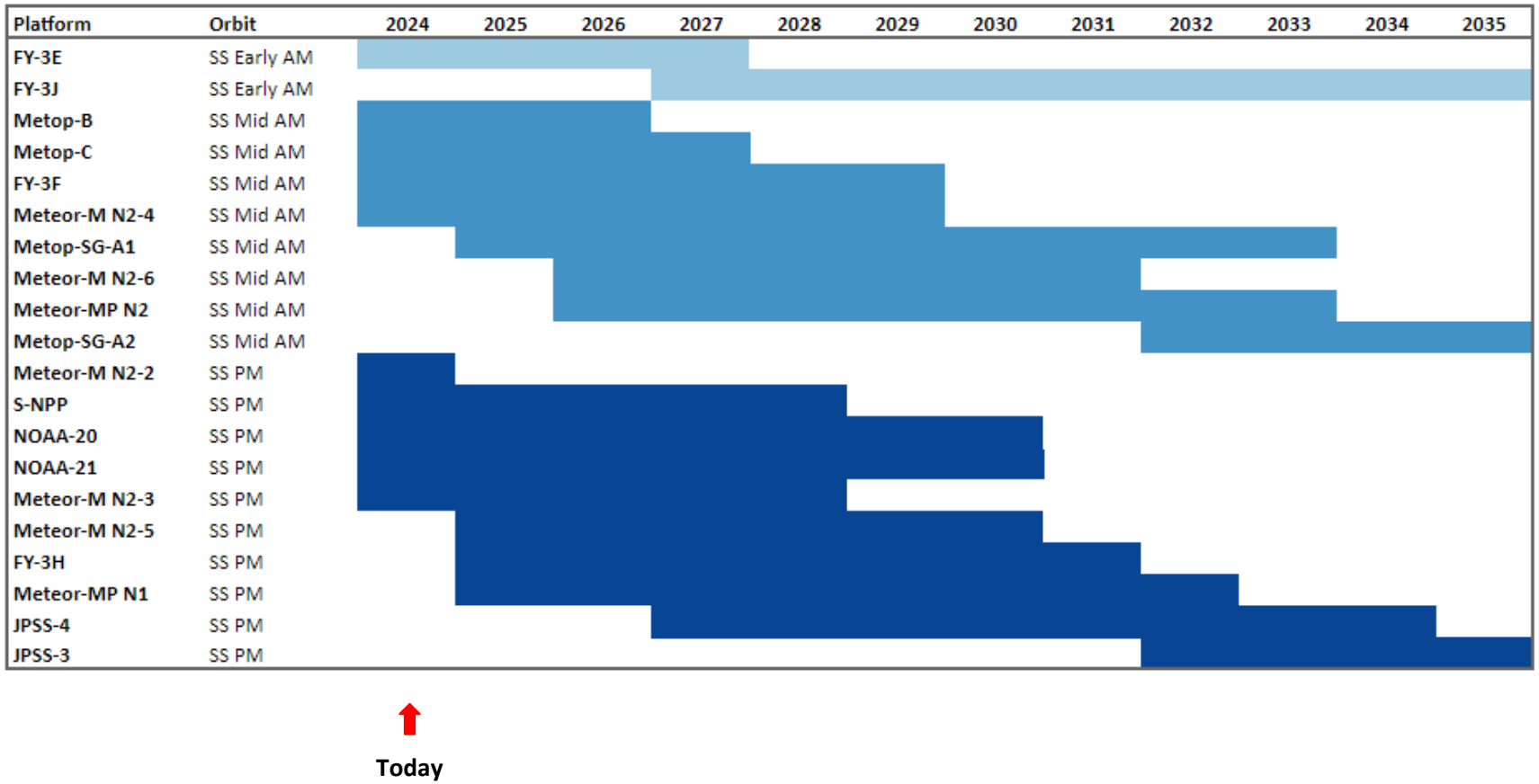
- WGII to consider whether observations from geostationary orbit should be added to the CGMS baseline requirements for the broadband short/long wave radiometer
- WMO to implement the feature of SunEarth line instrument filtering for the OSCAR/Space Gap Analysis.

Recently Closed Actions (@ 6th RAW, February 2024)

- ISRO to confirm plans beyond OceanSat-3.
- ISRO to provide update on their plans for a geostationary hyperspectral infrared sounder.
- NASA and JAXA to confirm plans to fly a precipitation radar beyond the GPM Core.
- CMA to look into the potential of the operational use of Chinese commercial RO data.
- KMA to report on plans beyond GK2B for visible/UV spectrometer and Narrow Band imager.
- ESA has existing associated action to report on plans for the CIMR (Copernicus Imaging Microwave Radiometer) and CRISTAL (Copernicus Polar Ice and Snow Topography Altimeter) missions.
- WMO to implement energy ranges for high energy particle classification to OSCAR/Space as defined in the CGMS Baseline.
- NOAA should review additional ground resources needed to track STEREO-A and PUNCH to provide additional coverage in the near-term.

Coordination Group for Meteorological Satellites - CGMS

Microwave Sounder (Atmospheric Temperature, Humidity, and Precipitation)



LEO - 3 Orbits

Sun-synchronous early morning

Sun-synchronous mid-morning

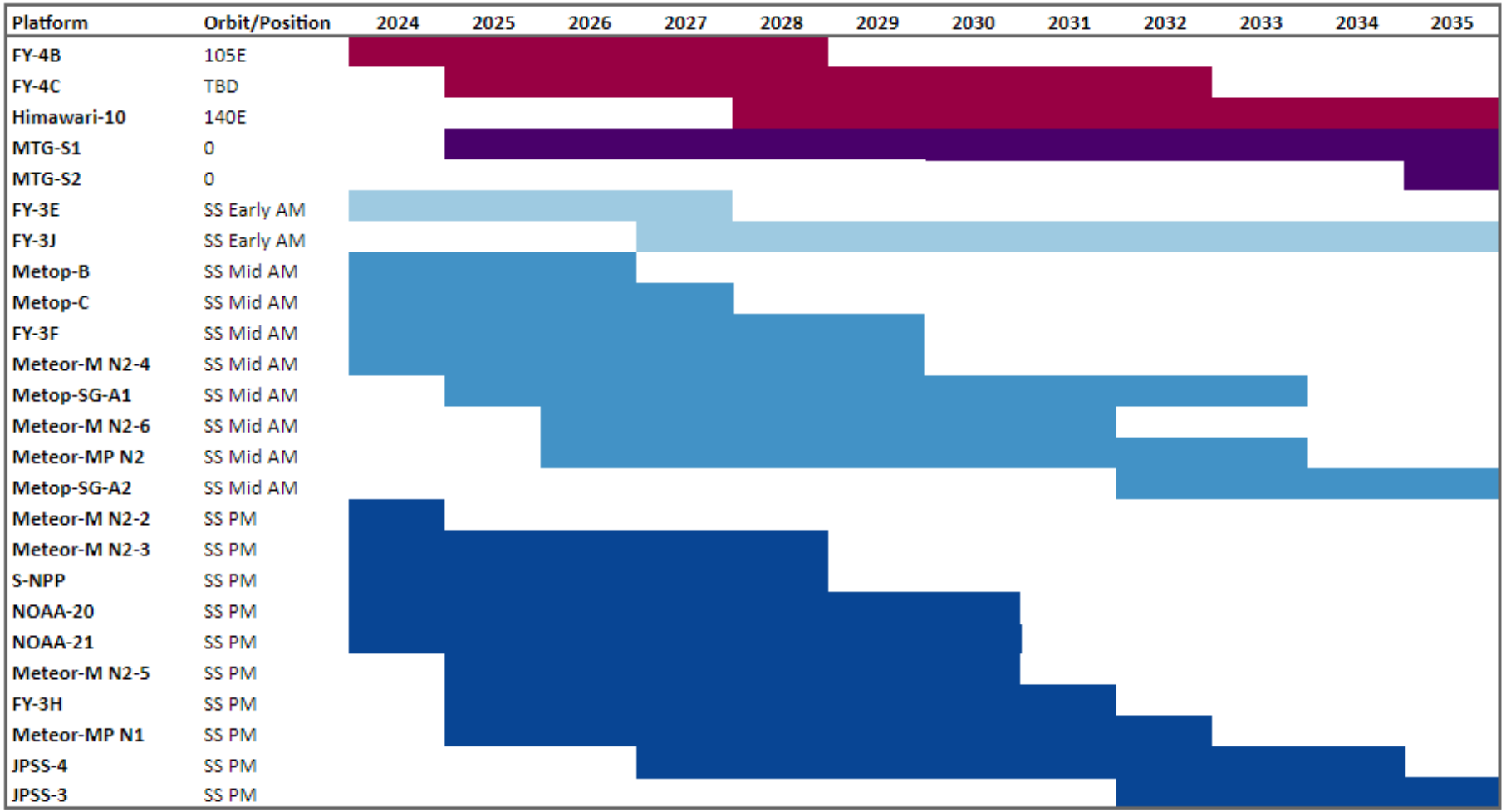
Sun-synchronous afternoon

WGIII Assessment:

Low risk of not meeting the Baseline commitment.

Coordination Group for Meteorological Satellites - CGMS

Hyperspectral Infrared Sounder (Atmospheric temperature, humidity, and winds Atmospheric composition: CO, CO2, SO2 , depending on spectral band also CH4 and NH3)



Today

GEO - 2 Slots

0°

86.5°-105°E range

LEO - 3 Orbits

Sun-synchronous early morning

Sun-synchronous mid-morning

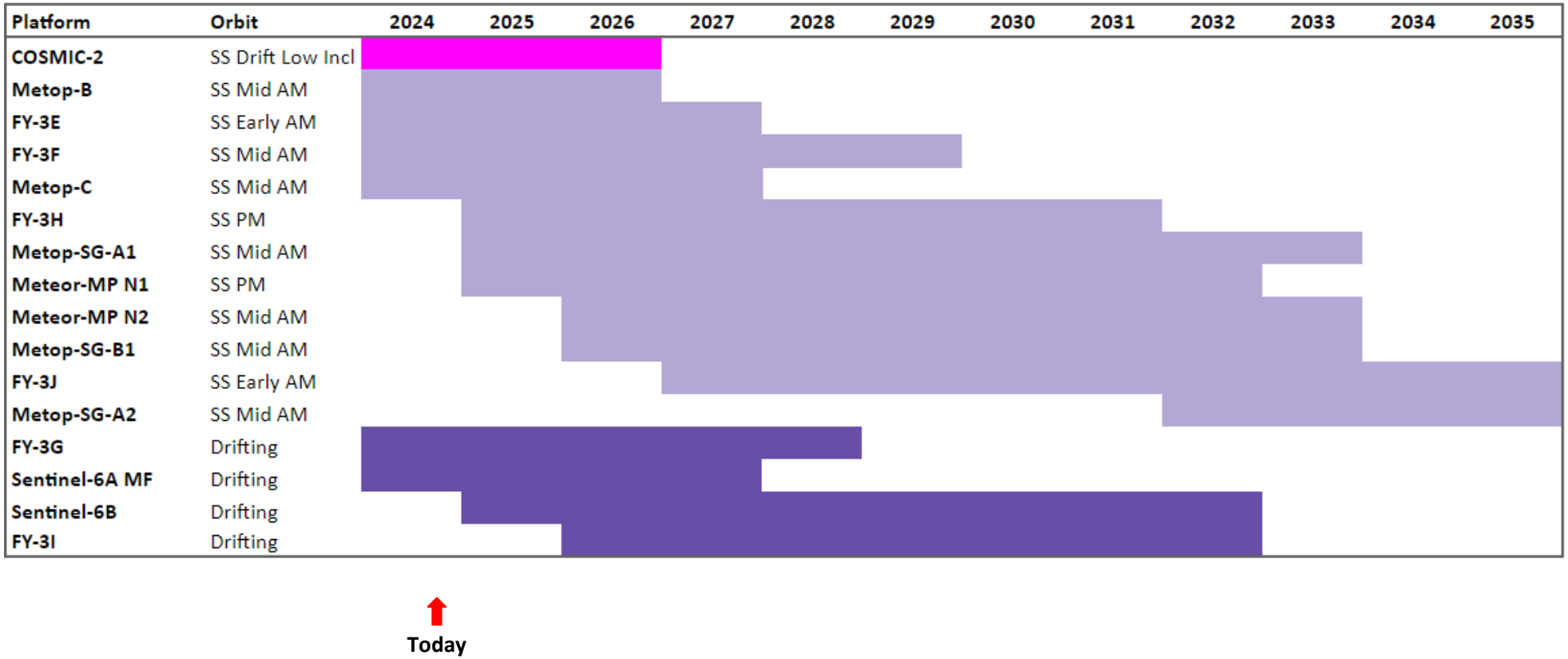
Sun-synchronous afternoon

Hyperspectral Infrared Sounder (Atmospheric Temperature, Humidity, Atmospheric Composition & Winds)

WGIII Assessment:

Low risk of not meeting the Baseline commitment. Note the HLPP objective (1.2) to expand hyperspectral sounding from GEO to the full geostationary ring. ISRO provided status to the 6th RAW on their plans for a hyperspectral sounder in geostationary orbit, and will provide report to plenary in June.

Radio Occultation (Atmospheric Temperature, Humidity, and Ionospheric Electron Density)



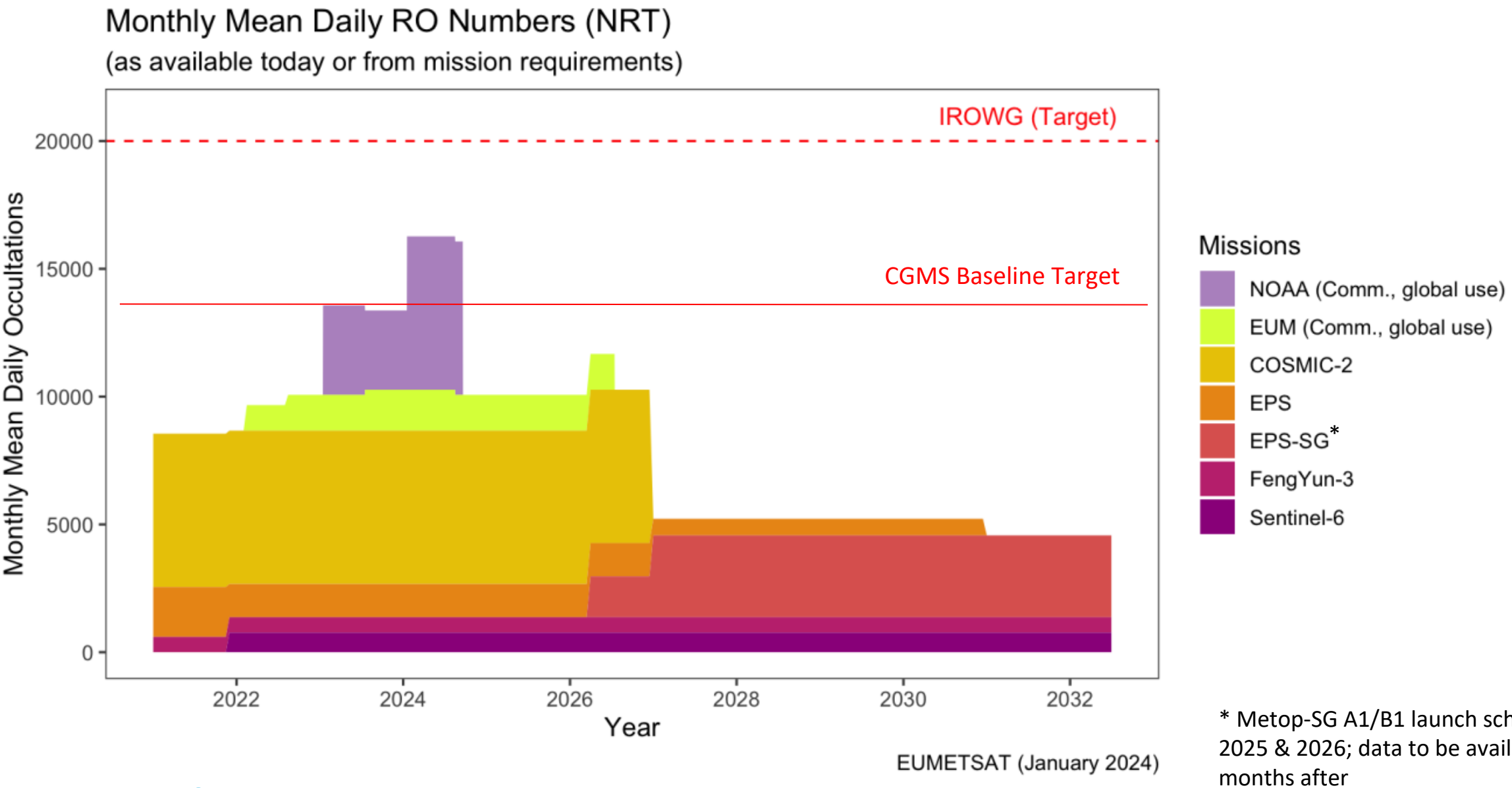
LEO - 3 Orbits

6000 occultations from **low inclination (<30°)**

7600 occultations from **sun-synchronous**

1000 occultations from **other drifting orbits**

Radio Occultation (Atmospheric Temperature, Humidity, and Ionospheric Electron Density)



* Metop-SG A1/B1 launch scheduled 2025 & 2026; data to be available 6 months after

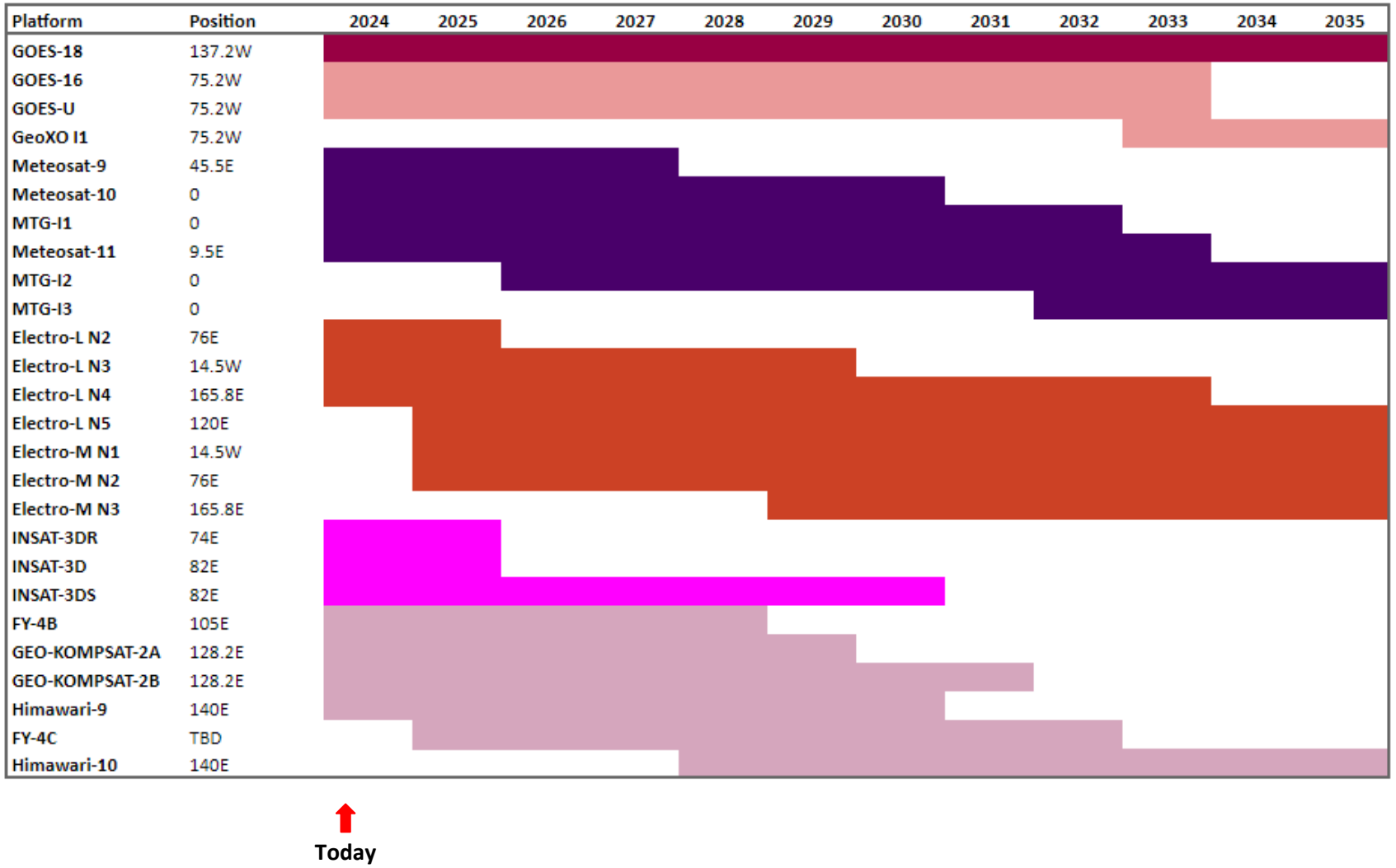
Radio Occultation (Atmospheric Temperature, Humidity, and Ionospheric Electron Density)

WGIII Assessment:

Risk of not meeting the CGMS Baseline commitment in low-inclination RO observations after COSMIC-2 at the end of the decade. CGMS is currently meeting the baseline commitment of 14,600 occultations with the inclusion of data from commercial providers, which is acceptable as long as agencies ensure providers commit to providing data on a free and open basis and meet the data integrity qualifications for those measurements. An HLPP objective (1.2) already exists to advance the atmospheric Radio Occultation constellation, with the long-term goal of providing 20000 occultations per day on a sustained basis; consider an additional recommendation for tropical missions to carry RO sensors. CMA provided a presentation on the commercial Yunyao and Tianmu (RO) satellite constellations at the 6th Risk Assessment Workshop, and the associated data policy is currently under elaboration.

Coordination Group for Meteorological Satellites - CGMS

Multi-purpose Meteorological Imagers (multispectral, visible and IR) (Sea Surface Temperature, Aerosols, Land Surface Temperature, Cloud Properties, Feature Tracking Winds (AMV), Flood Mapping, Fires, Cryosphere Applications (sea ice, snow cover, etc.)



GEO - Evenly spaced satellites

137°W

75.2°W

0°-45.5°E range

14.5°W-165.8°E range

74°-82°E range

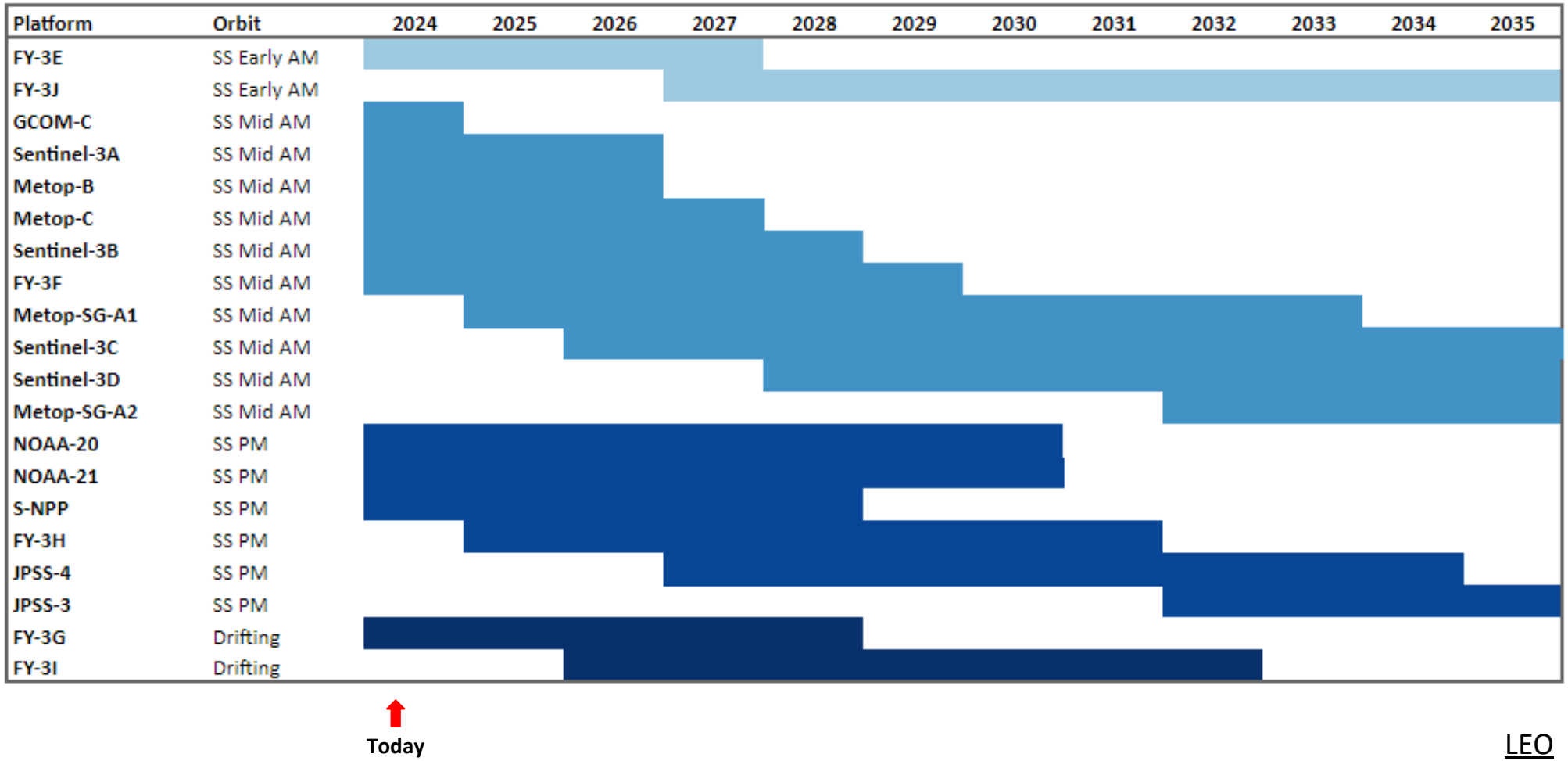
86.5°-140°E range

WGIII Assessment:

Slight risk of not meeting the CGMS Baseline commitment in the early 2030s in the 74°-82°E range.

Coordination Group for Meteorological Satellites - CGMS

Multi-purpose Meteorological Imagers (multispectral, visible and IR) (Sea Surface Temperature, Aerosols, Land Surface Temperature, Cloud Properties, Feature Tracking Winds (AMV), Flood Mapping, Fires, Cryosphere Applications (sea ice, snow cover, etc.),



LEO

Sun-synchronous early morning

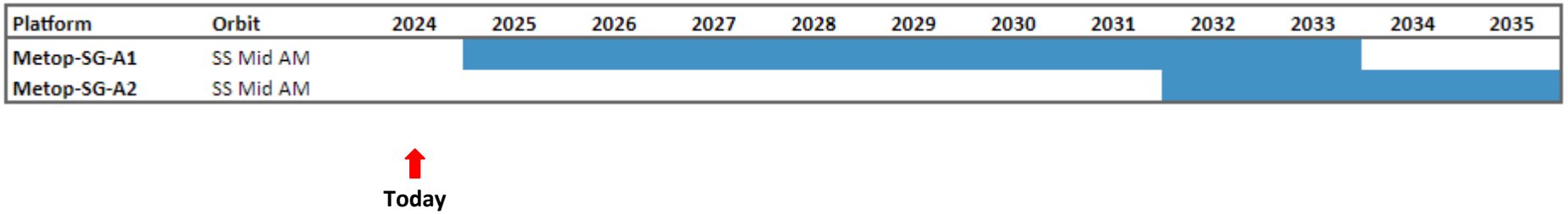
Sun-synchronous mid-morning

Sun-synchronous afternoon

WGIII Assessment:

Low risk of not meeting the CGMS Baseline commitment.

Multi-viewing, Multi-channel, Multi-polarisation Imager (Aerosol)



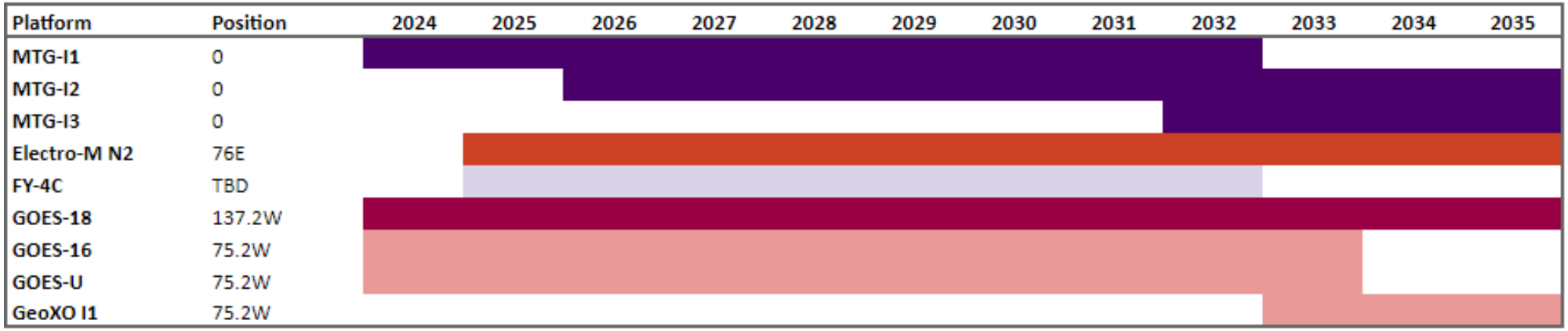
LEO - 1 orbit

Sun-synchronous

WGIII Assessment:

Low risk of not meeting the CGMS Baseline commitment.

Lightning Mapper (Lightning)



GEO - 5 slots

0°

76°E

86.5°-105°E range

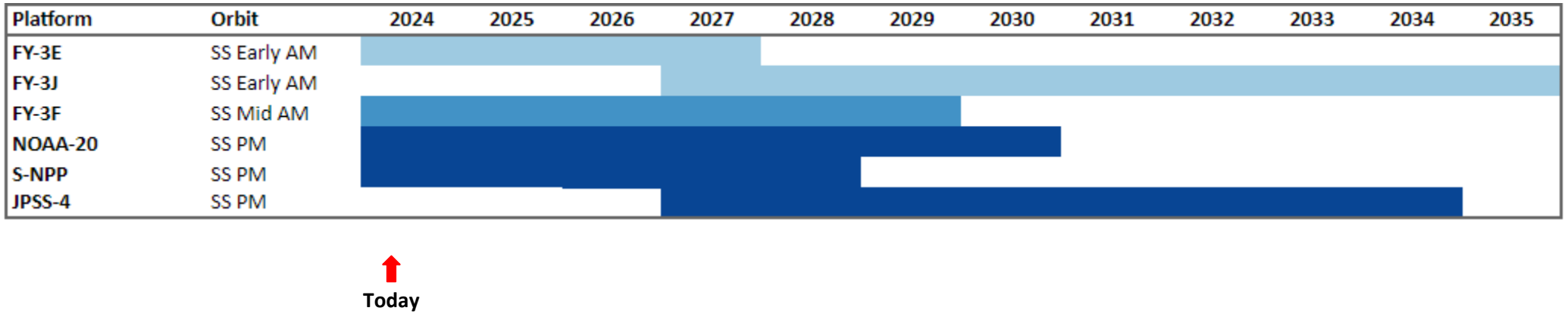
137°W

75.2°W

WGIII Assessment:

Low risk of not meeting the CGMS Baseline commitment. An HLPP objective (1.2) exists to provide the capability for the whole geostationary ring.

Broadband Short/Long Wave Radiometer (Radiation Balance)



LEO - 2 Orbits

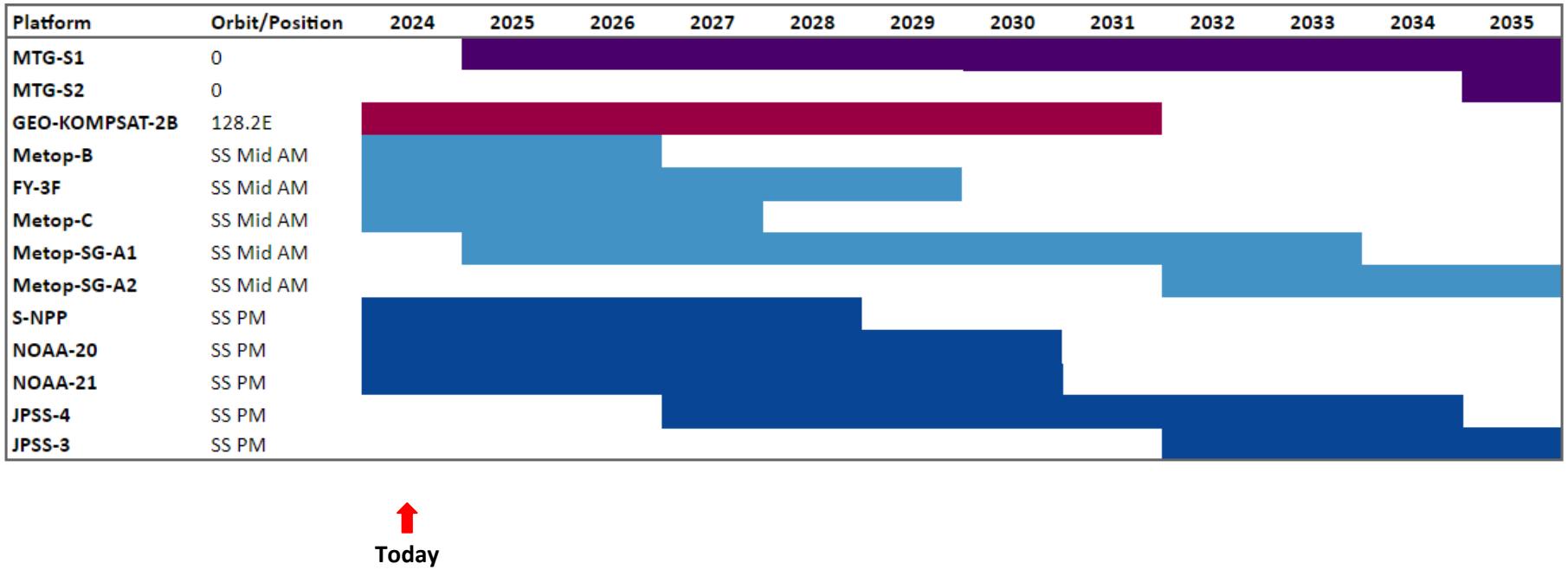
Sun-synchronous morning

Sun-synchronous afternoon

WGIII Assessment:

Low risk of not meeting the CGMS baseline commitment. Action on WGII to investigate the addition of GEO contributions to the CGMS Baseline.

Visible / UV Spectrometer (Aerosol, Atmospheric Composition: O3, CO2, NO2, SO2, BrO. C)



GEO - 2 Slots

0°

128.2°E

LEO - 2 Orbits

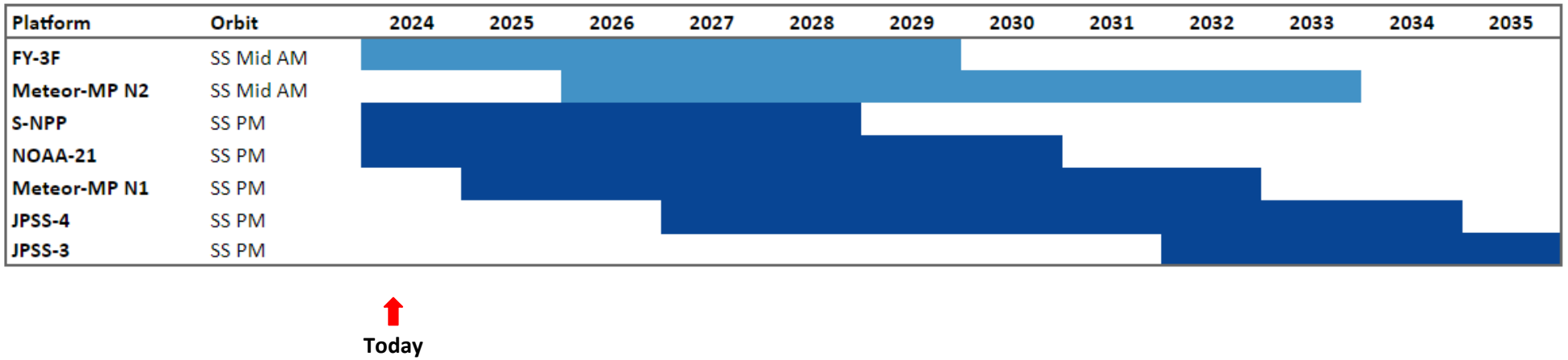
Sun-synchronous mid-morning

Sun-synchronous afternoon

WGIII Assessment:

Low risk of not meeting CGMS Baseline commitment. KMA confirmed GK-2B follow-on at the 6th RAW, with the goal to add to assessment during the 7th RAW. An HLPP objective (1.2.3) exists to extend the capability to the whole geostationary ring.

UV Limb Spectrometer (Aerosol, Atmospheric Composition: O3)



LEO - 2 Orbits

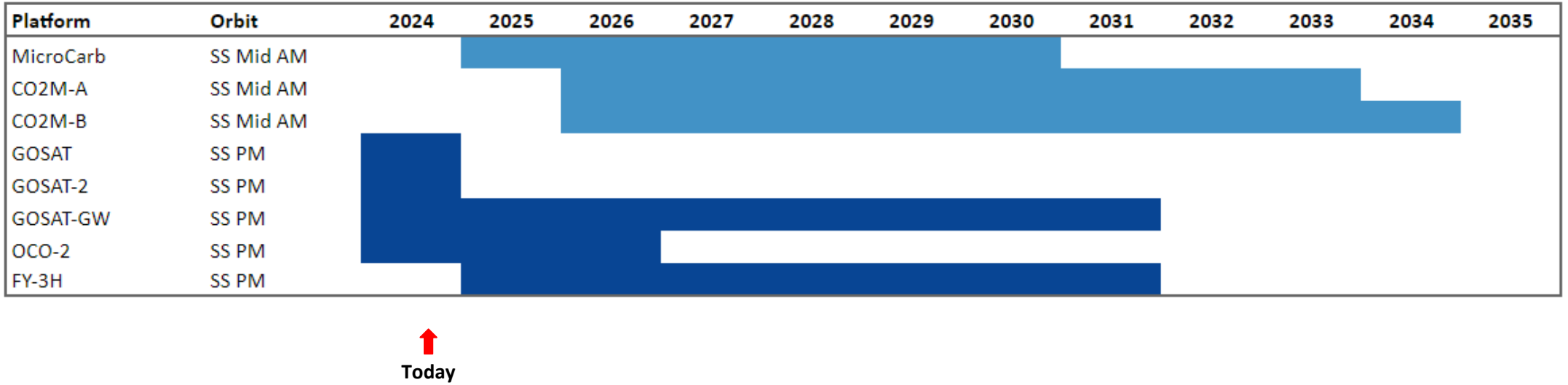
Sun-synchronous mid-morning

Sun-synchronous afternoon

WGIII Assessment:

Low risk of not meeting the CGMS Baseline commitment.

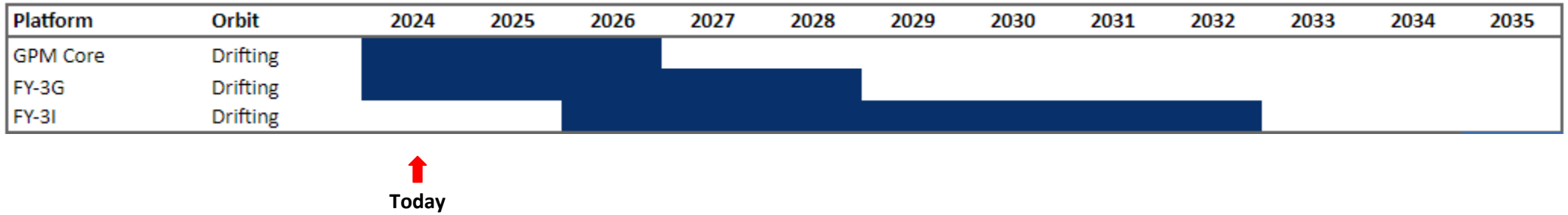
SWIR Imaging Spectrometer (Atmospheric Composition: CO2, CH4)



LEO - 2 Orbits
(late morning or afternoon)
Sun-synchronous late morning
Sun-synchronous afternoon

WGIII Assessment:
Risk of not meeting CGMS Baseline commitment in the afternoon orbit in the early 2030s. The Joint Working Group on Climate is working to coordinate long-term CO2 monitoring.

Precipitation Radar (Precipitation)

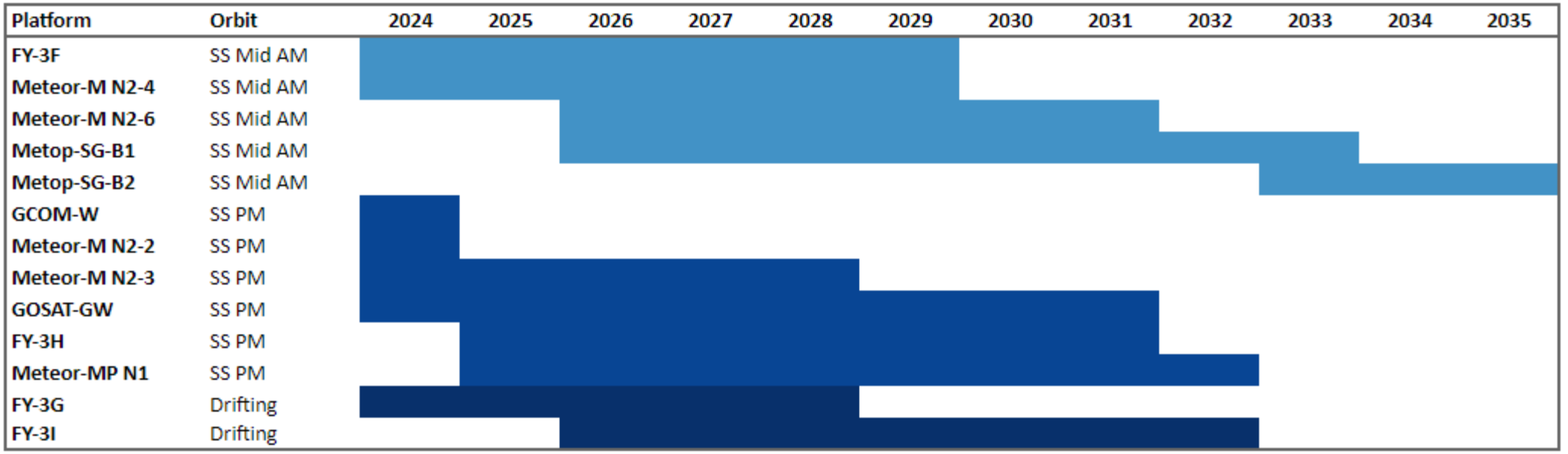


LEO - 1 orbit
Drifting

WGIII Assessment:
Slight risk of not meeting the CGMS Baseline commitment in the early 2030s. NASA and JAXA presented plans beyond the GPM Core at the 6th RAW, with the goal to add to assessment during the 7th RAW.

Coordination Group for Meteorological Satellites - CGMS

Microwave Imager (Sea Surface Temperature, Ocean Surface Winds, Precipitable Water, Soil Moisture, Snow and Ice properties, Sea Ice Properties)



Today

LEO - 2 Orbits

Sun-synchronous mid-morning

Sun-synchronous afternoon

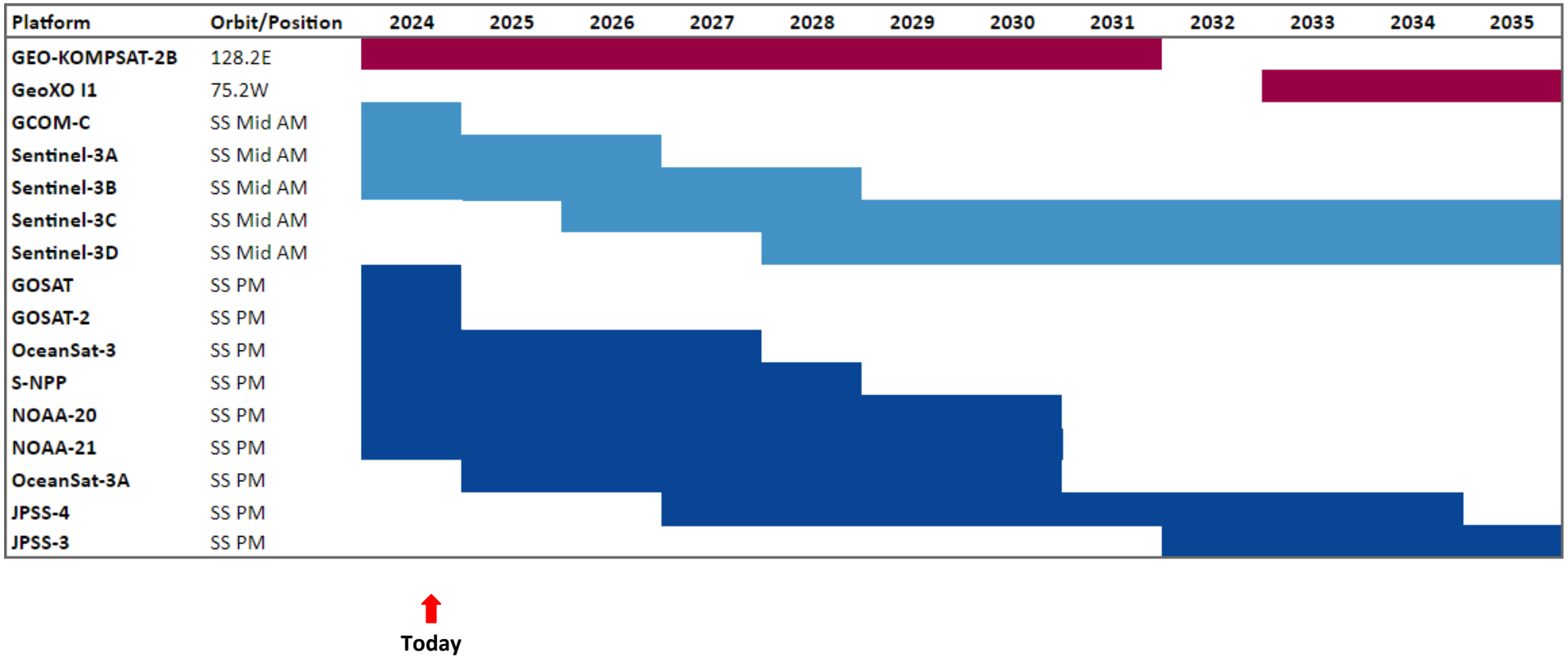
Microwave Imager (Sea Surface Temperature, Ocean Surface Winds, Precipitable Water, Soil Moisture, Snow and Ice properties, Sea Ice Properties)

WGIII Assessment:

Slight risk of not meeting the CGMS Baseline commitment in the afternoon orbit in the early 2030s. Sensor performance requirements for different environmental parameters vary; ~6 GHz frequency microwave imaging critical for all weather SSTs, and >90 GHz frequency critical for precipitation. ESA has reported on plans for the CIMR (Copernicus Imaging Microwave Radiometer) mission with the goal to add to assessment during the 7th RAW.

Coordination Group for Meteorological Satellites - CGMS

Narrow Band Visible Imager (Ocean Colour, Aerosols)



LEO - 2 Orbits

Sun-synchronous mid-morning

Sun-synchronous afternoon

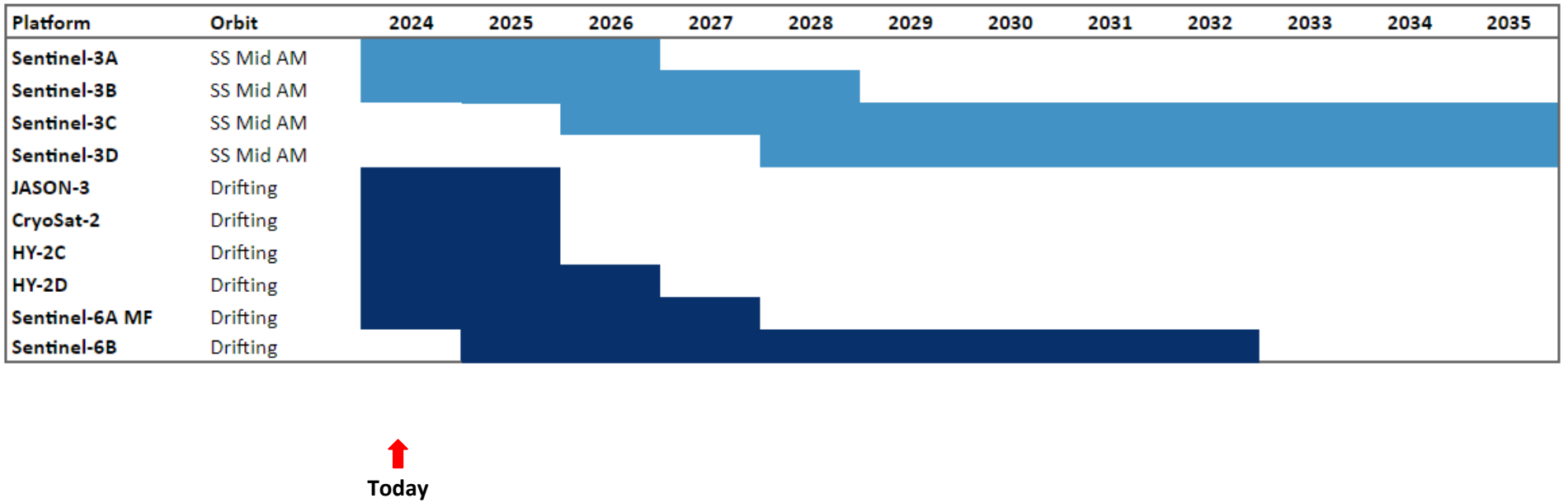
GEO - 1 Slot

128.2°E

WGIII Assessment:

Low risk of not meeting the CGMS Baseline commitment. KMA confirmed GK-2B follow-on at the 6th RAW, with the goal to add to assessment during the 7th RAW.

Radar Altimetry (Ocean Surface Topography)



LEO - 1 Orbit

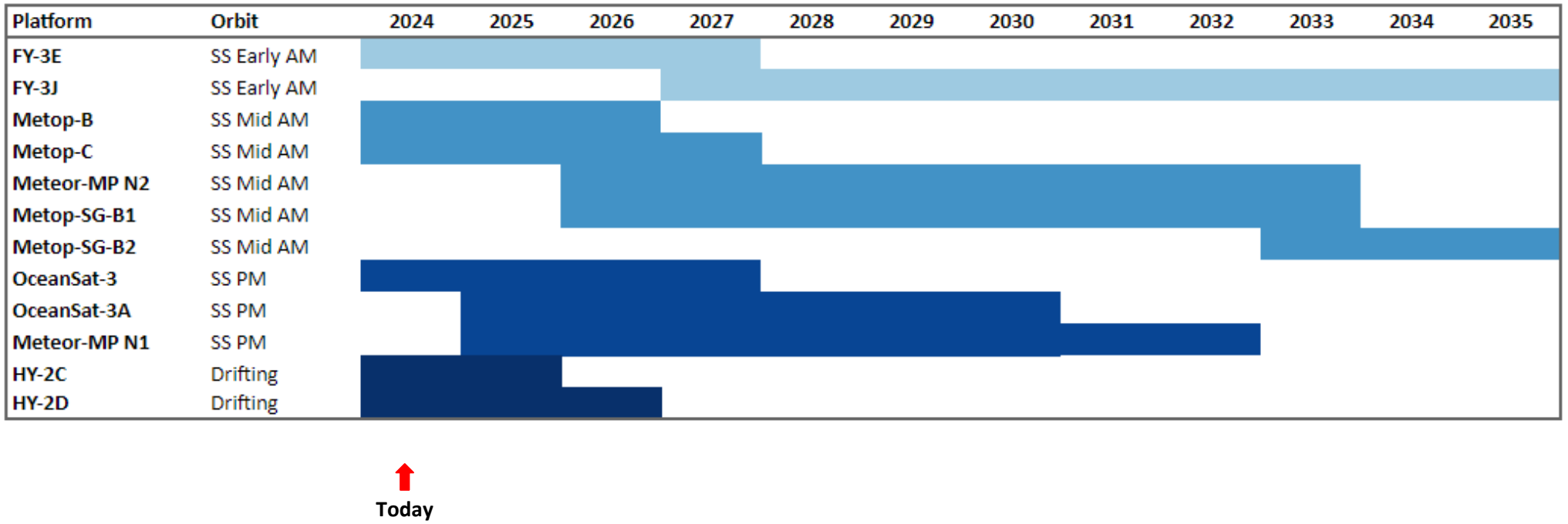
Sun-synchronous mid-morning

WGIII Assessment:

Low risk of not meeting the CGMS Baseline commitment.

Coordination Group for Meteorological Satellites - CGMS

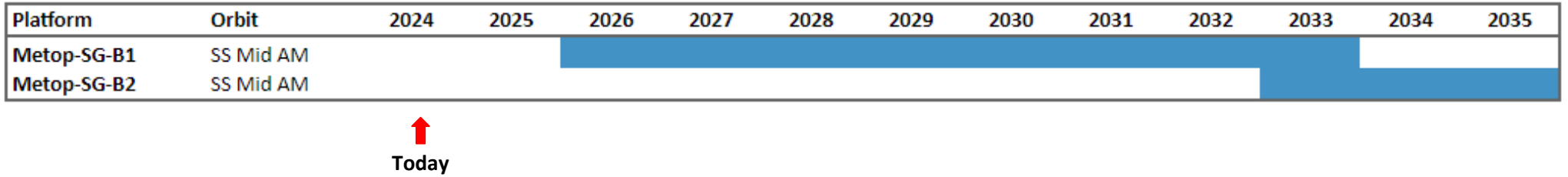
Scatterometry (Ocean Surface Winds)



<u>WGIII Assessment</u>:
Slight risk of not meeting the CGMS Baseline commitment in the early 2030s. ISRO provided update on plans beyond OceanSat-3A at the 6th RAW.

<u>LEO</u>
Sun-synchronous early morning
Sun-synchronous mid-morning
Sun-synchronous afternoon

Sub-millimetre Ice Cloud Imager (Cloud Ice)



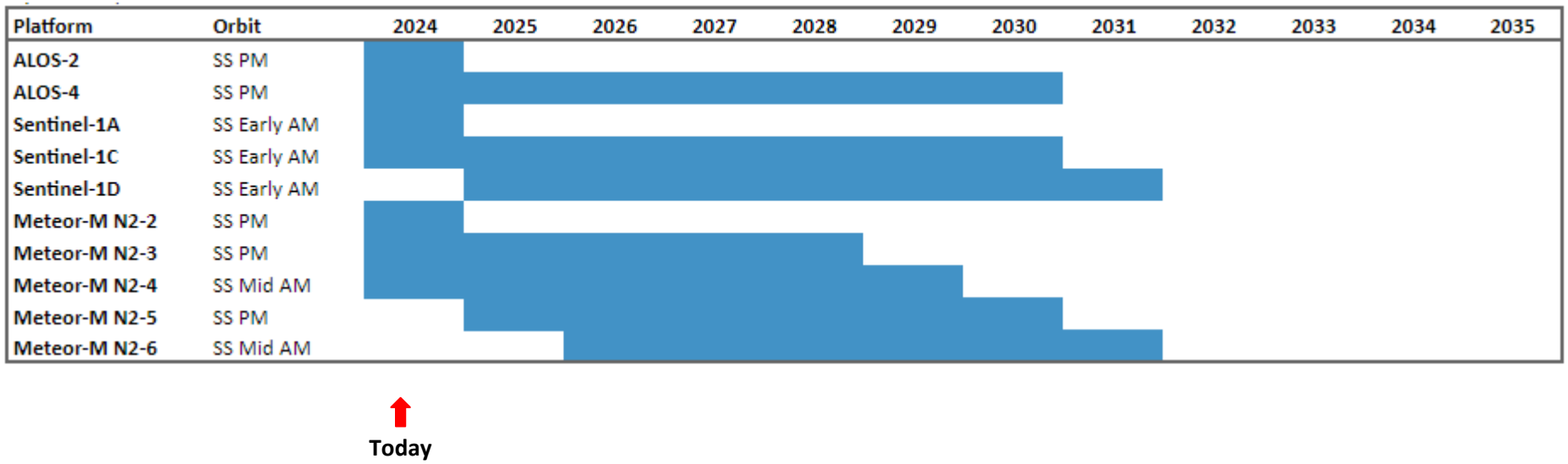
LEO - 1 Orbit

Sun-synchronous mid-morning

WGIII Assessment:

Low risk of not meeting CGMS Baseline commitment.

Synthetic Aperture Radar (Soil Moisture, Sea Ice)



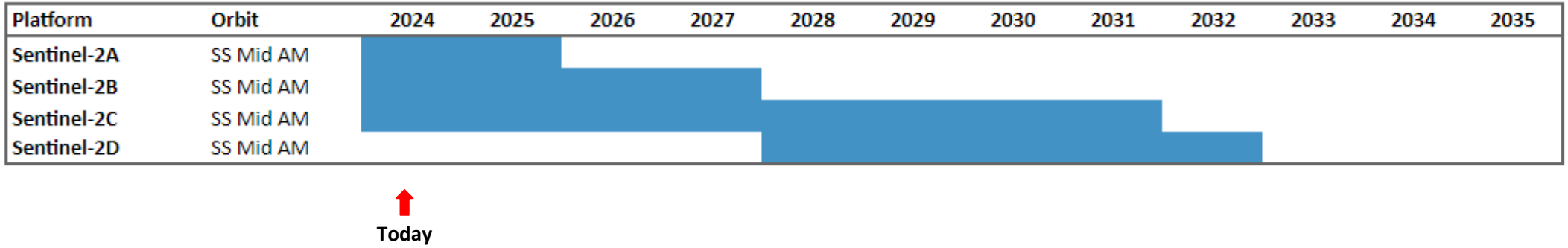
LEO - 1 Orbit

Sun-synchronous

WGIII Assessment:

Risk of not meeting the CGMS Baseline commitment in the in the early 2030s.

High Resolution Optical Imager (Land Use, Vegetation Type and Status, Aerosols)



LEO - 1 Orbit

Sun-synchronous

WGIII Assessment:

Risk of not meeting the CGMS Baseline commitment in the in the early 2030s.

Coronagraph (Coronagraphy)

Platform	Position	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
GOES-U	75.2W												
SOHO	L1												
SWFO-L1	L1												
Vigil	L5												

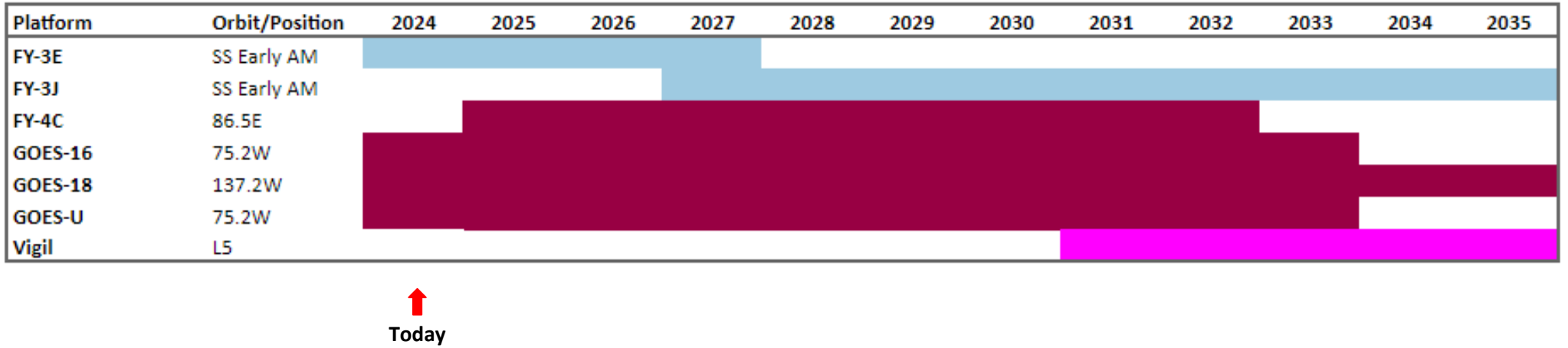
Today

GEO - 1 slot
L1
L5

WGIII Assessment:

Risk of gap in long term continuity at L1 and risk of partial coverage in GEO in the mid 2030s. Slight risk of a gap until GOES-U and SWFO-L1 are launched and operational as SOHO is operating well past design life, but NOAA is prepared to provide STEREO-A coronagraphy from the Wallops and Fairbanks stations in the event of loss of SOHO/LASCO before 2025.

EUV Imager (EUV Imagery)



LEO - 1 slot
GEO - 2 slots
L5

WGIII Assessment:
Low risk of not meeting CGMS Baseline commitment.

X-Ray Spectrograph (X-Ray Flux)

Platform	Position	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Electro-L N2	76E												
Electro-L N5	76E												
GOES-16	75.2W												
GOES-18	137.2W												
GOES-U	75.2W												
FY-4C	86.5E												
Electro-M N1	14.5W												
Electro-M N2	76E												

Today

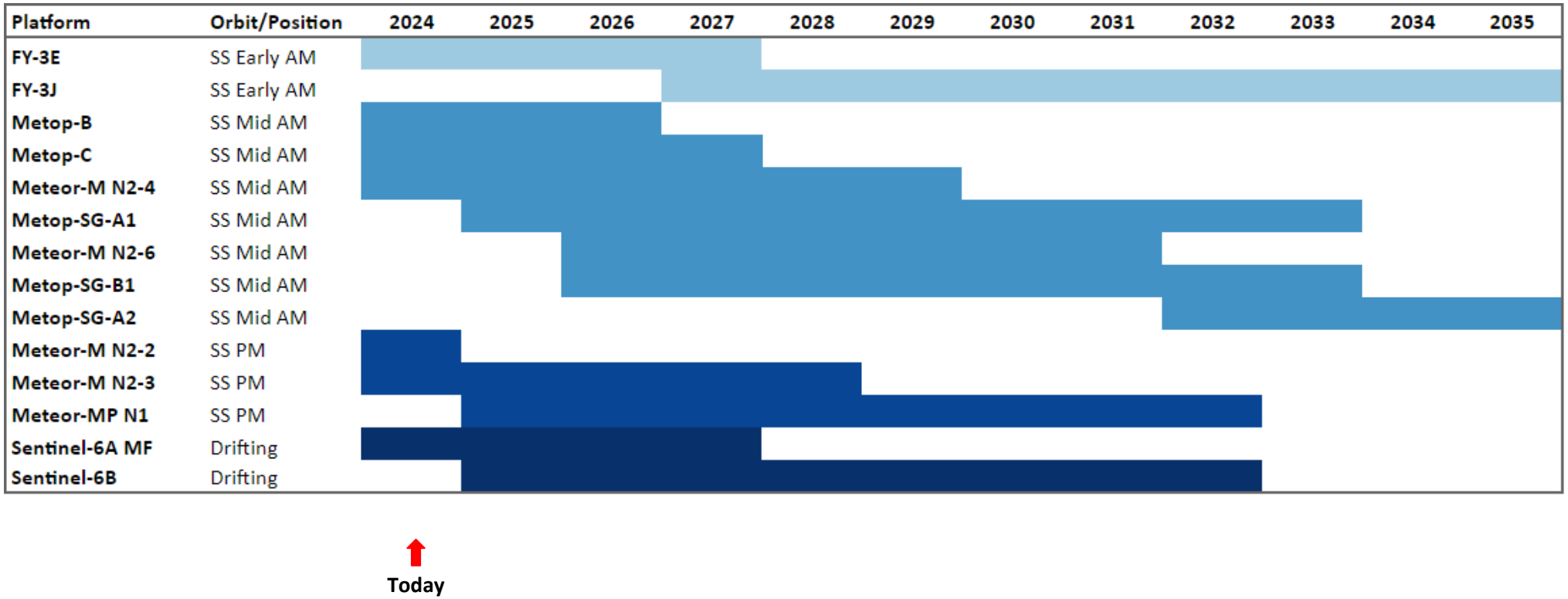
GEO - 2 slots

WGIII Assessment:

Low risk of not meeting CGMS Baseline commitment.

Coordination Group for Meteorological Satellites - CGMS

Energetic Particle Sensor LEO (Magnetospheric)



WGIII Assessment:

Slight risk of not meeting the CGMS Baseline commitment in the afternoon orbit in the mid 2030s.

LEO - 3 Orbits

Sun-synchronous early morning

Sun-synchronous mid-morning

Sun-synchronous afternoon

Energetic Particle Sensor L1 (Solar Energetic Particles)

Platform	Orbit/Position	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
ACE	L1												
DSCOVR	L1												
SWFO-L1	L1												

Today

L1

[WGIII Assessment](): Risk of a gap in the early 2030s.

Low Energy Electrons and Protons (Energetic Particles)

Platform	Position	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
FY-4B	105E												
GOES-16	75.2W												
GOES-U	75.2W												
GOES-18	137.2W												

Today

GEO - 2 slots

86.5°-123°E range

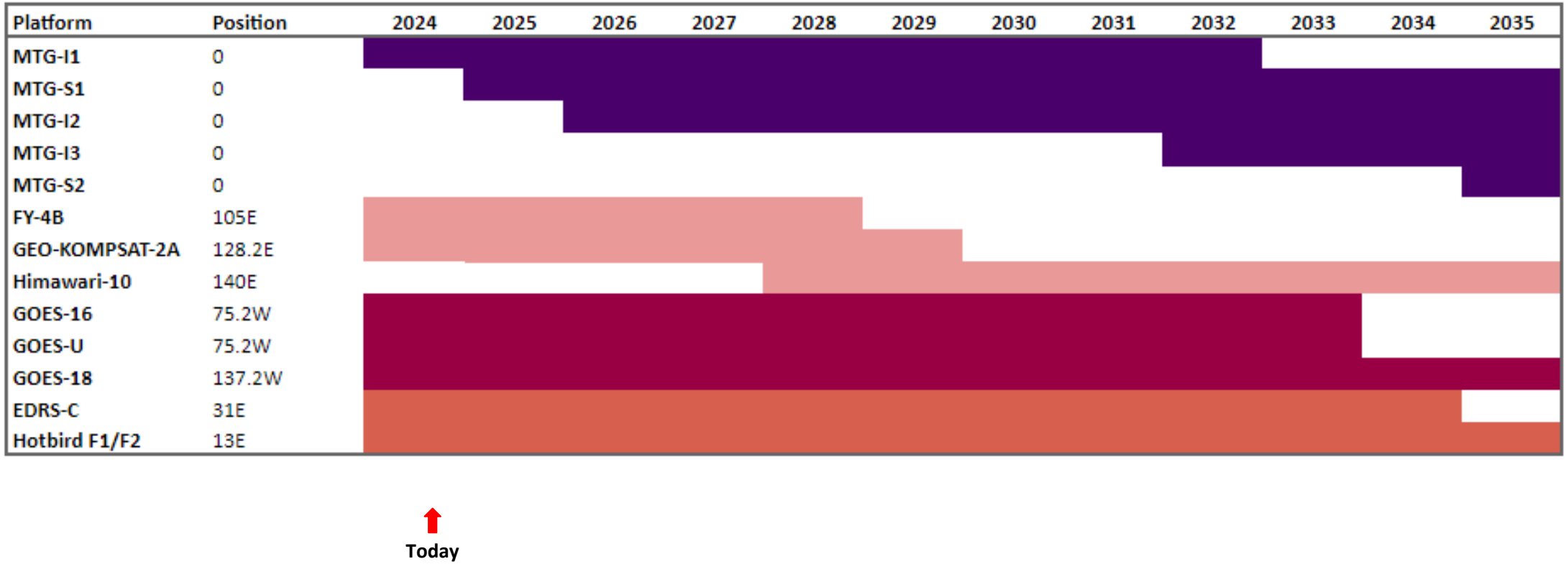
75.2°- 137°W range

WGIII Assessment:

Increasing risk of a gap at the end of the decade in the 86.5°-123°E range.

Coordination Group for Meteorological Satellites - CGMS

High Energy Electrons and Protons (Energetic Particles)



GEO - 3 slots

0°

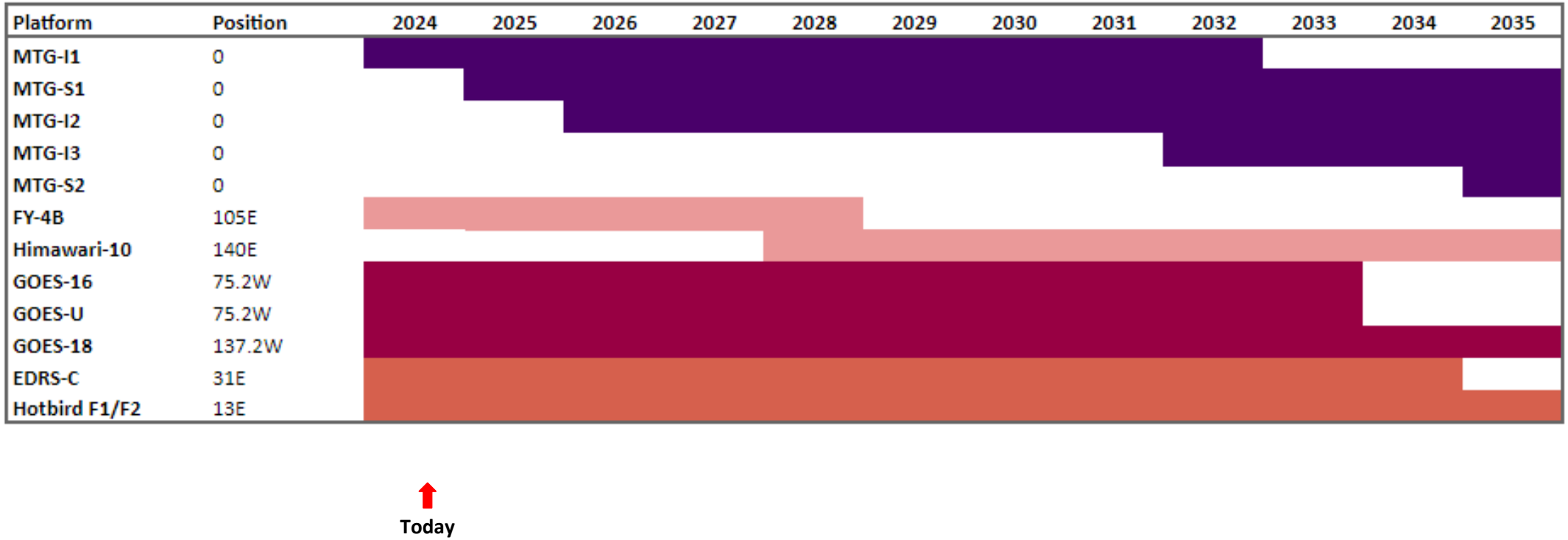
86.5°-123°E range

75.2°- 137°W range

WGIII Assessment:

Low risk of not meeting CGMS Baseline commitment.

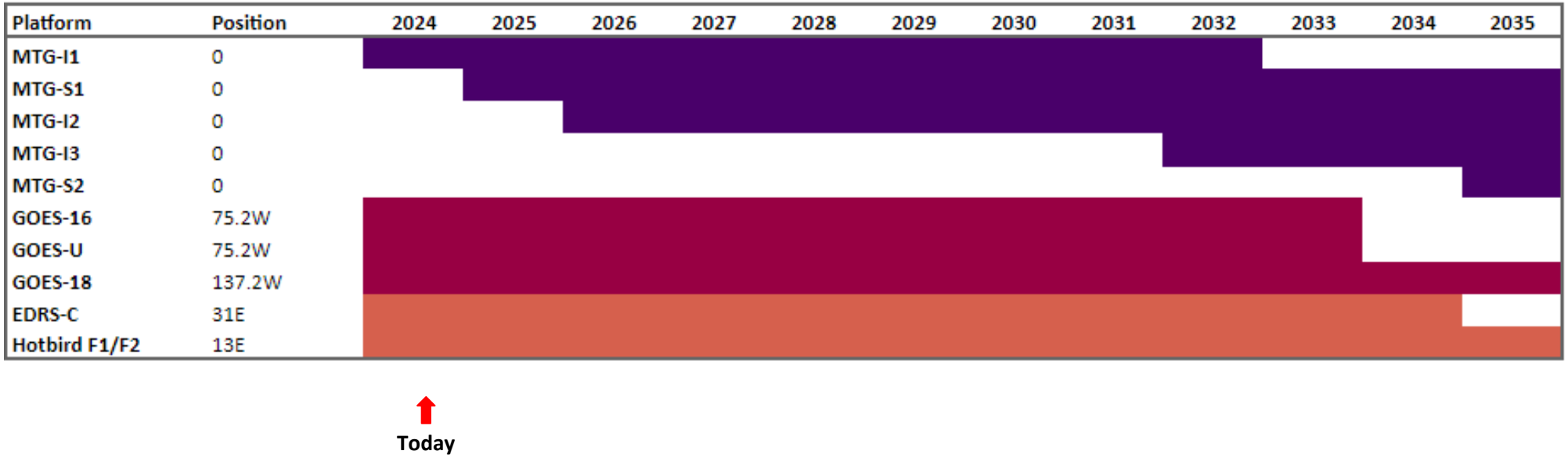
Very High Energy Protons (Energetic Particles)



GEO - 3 slots
0°
86.5°-123°E range
75.2°- 137°W range

WGIII Assessment:
Low risk of not meeting CGMS Baseline commitment.

Energetic Heavy Ions (Energetic Particles)



GEO - 2 slots

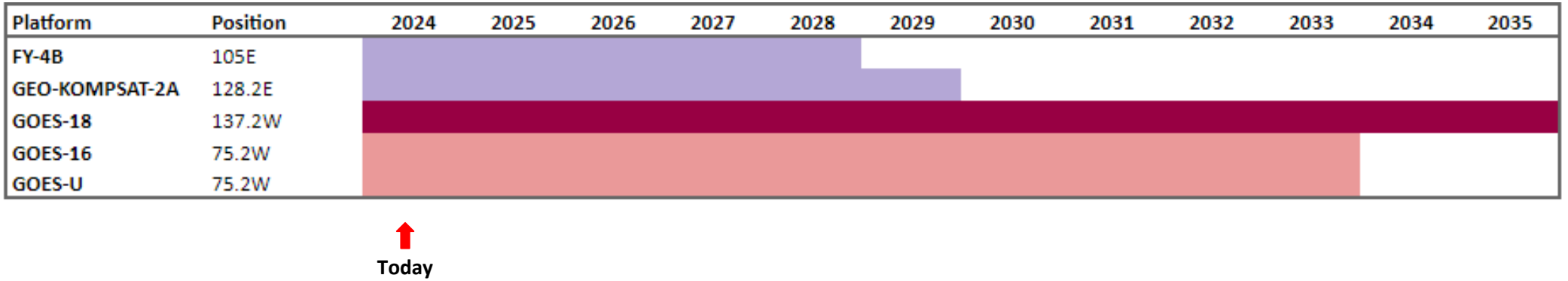
0°

75.2°- 137°W range

WGIII Assessment:

Low risk of not meeting CGMS Baseline commitment.

Magnetometer GEO (Earth's Magnetic Field)



GEO – 2 Slots
75.2°W
137°W
86.5°-128°E range

WGIII Assessment:
Risk of gap in the 86.5-128 range in the early 2030s. KMA confirmed GK-2B follow-on at the 6th RAW, with the goal to add to assessment during the 7th RAW.

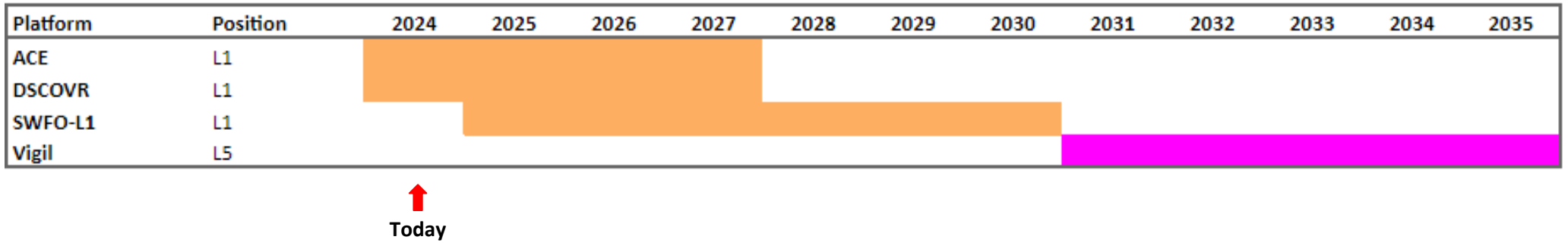
Magnetometer L1 (Interplanetary Magnetic Field)

Platform	Position	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
ACE	L1												
DSCOVR	L1												
SWFO-L1	L1												
Vigil	L5												

L1, as an in situ measurement
L5

WGIII Assessment:
Risk of gap at L1 in the early 2030s. Data from L1 and L5 are complementary but are not the same, so launch of Vigil does not reduce the risk.

Plasma Analyzer (Solar Wind)



L1, as an in-situ measurement
L5

WGIII Assessment:
Risk of gap at L1 in the early 2030s. Data from L1 and L5 are complementary but are not the same, so launch of Vigil does not reduce the risk.