EPS-Sterna and EPS-Aeolus Mission Analysis

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Abstract **– This paper presents the most relevant mission analysis activities carried out during phase A of the EPS-Sterna and EPS-Aeolus missions for supporting the system design and definition of concept of operations.**

The objective of the EPS-Sterna mission is to provide microwave observations to support global and regional Numerical Weather Prediction (NWP) and Nowcasting (NWC) at high latitudes with the goal to minimize to the time to achieve 90% of global coverage. The EPS-Sterna mission complements, increasing their frequency and availability, the microwave observations from the EPS-SG, JPS and Fengyun polar-orbiting satellites. The EPS-Sterna mission consists of a constellation of small satellites providing passive microwave sounding of the atmosphere. The EPS-Sterna satellites are based on the ESA Artic Weather Satellite (AWS) Proto-Flight Model (PFM) satellite that will fly on a Sun-Synchronous Orbit (SSO) at a reference altitude of 595km and 22:30 local time at ascending node (LTAN). The EPS-Sterna satellites will fly on the same SSO reference altitude at three different orbital planes, namely 15:30, 19:30 and 23:30 LTAN.

The objective of the EPS-Aeolus mission is to support global NWP, enhancing the services provided by EPS-SG satellites, with a focus on atmospheric wind profile measurements. The EPS-Aeolus mission consists of up to two satellites embarking a Doppler Wind Lidar (DWL) instrument and a Radio Occultation (RO) instrument (TBC). The EPS-Aeolus satellites, a.k.a. Aeolus-2 satellites, are the follow-on of the ESA Aeolus satellite. The EPS-Aeolus satellites will fly on a Sun-Synchronous Orbit (SSO) at an altitude between 360 and 400km (TBD) with 18:00 local time at ascending node (LTAN).

This paper focuses on the following mission analysis activities:
- **EPS-Sterna Constellation Architecture;**
- **EPS-Sterna Payload Ground Stations Network;**
- **EPS-Aeolus Payload Ground Stations Network.**

I. EPS-STERNA

A. Mission Description

The objectives of the EPS-Sterna mission are:
- to complement the microwave observations from the EPS-SG, NOAA JPSS and Fengyun polar-orbiting, meteorological satellites;
- to contribute to improved global NWP accuracy, including Nowcasting over the Arctic region;
- to increase the frequency and availability of microwave observations over the polar regions;
- to contribute and support climate monitoring.

The primary products necessary for NWP and NWC which shall be delivered by the EPS-Sterna mission are:
- Water-vapour profiles in clear and cloudy conditions,
- Temperature profiles in clear and cloudy conditions.

To meet these objectives, the EPS-Sterna system consists of a constellation of small satellites providing passive microwave soundings of the atmosphere and ground segment for monitoring and control (M&C) and data processing, archiving and dissemination. The operational lifetime of the system will be 13 years and each satellite will be designed for a nominal lifetime of 5 years.

The EPS-Sterna satellites are based on the ESA Artic Weather Satellite (AWS) Proto-Flight Model (PFM) satellite that will fly on a Sun-Synchronous Orbit (SSO) at reference altitude of 595km altitude. The EPS-Sterna satellites will fly on SSO with the same reference altitude at 3 different orbital planes: 15:30, 19:30 and 23:30 LTAN.

The EPS-Sterna satellites will provide three telemetry data streams:
- The satellite housekeeping telemetry (HKTM) data from the platform and instrument;
- The Stored Mission Data (SMD) stream, needed for the global mission;
- The Direct Data Broadcast (DDB) stream, needed for the regional and local missions.

The Tracking, Telemetry and Telecommand (TT&C) communication will be in S-band. This will be supported by the TT&C ground stations. The TT&C ground stations will be located at Svalbard and at other location complementing short passes from Svalbard.

It will be possible to receive the real-time and stored House Keeping Telemetry (HKTM) via S-band. The stored HKTM will be received also via the Stored Mission Data (SMD).

The SMD will be downlinked in L-Band to the Payload Ground Stations. One payload ground station will be located at Svalbard. The selection of the additional ground station is pending finalisation of a trade-off analysis. The current candidate stations are Troll, McMurdo, O'Higgins and Punta Arenas.

The Direct Data Broadcast (DDB) data will be downlinked in L-Band to the Direct Broadcast Acquisition (DBA) ground stations. The DBA ground stations include Svalbard and the EUMETSAT Advanced Retransmission Service (EARS) core stations: Maspalomas, Kangerlussuaq, Athens and Lannion.

B. Constellation Architecture

The reference orbit is defined as a near circular Sun-Synchronous Orbit (SSO) with a repeat cycle of 9 days and a cycle length of 134 orbits. Figure 1 shows the location of this orbit on a SSO repeating orbits diagram.

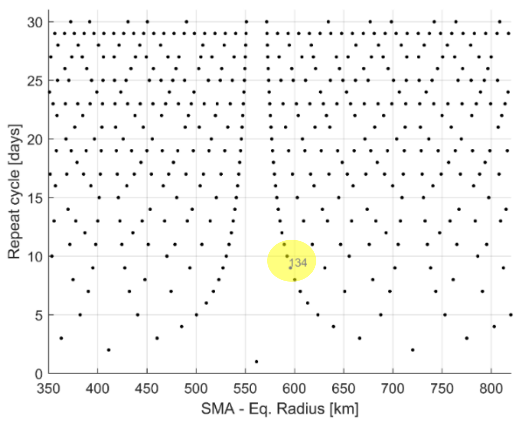


Fig. 1. EPS-Sterna Repeat Cycle Map

The main properties of the reference orbit are summarized in Table 1.

Table 1. EPS-Sterna Orbit

General Properties			
Orbit type			Repeating Frozen Sun-Synchronous
Repeat cycle [days]			9
Cycle length [orbits]			134
Repeat cycle (i,j,k) parameters			14 + 8/9
Mean Semi-major axis - Eq. radius [km]			595.6
Nominal nodal period [min]			96.716
Mean Local Solar Time at ascending node			15h30min, 19h30min, 23h30min
Minimum altitude over ellipsoid [km]			600.3
Maximum altitude over ellipsoid [km]			628.2
Mean altitude over ellipsoid [km]			610.5
Mean elements in True of Date		**Repeat cycle properties**	
Semi-major axis [km]	6973.702	Orbits per day	14.889
Eccentricity	0.001214	Fundamental interval [deg]	24.179
Inclination [deg]	97.794	Fundamental interval [km]	2691.606
Arg. Of Perigee [deg]	90	Track Spacing [km]	299.067

The EPS-Sterna constellation architecture is mostly driven by the minimization of the time, averaged during a repeat cycle, to achieve 90% of global coverage. A secondary optimisation criterion is to minimize revisit time on the polar regions and load on ground stations. A third optimisation criterion is to minimize the average time to achieve 90% of global coverage when accounting for the additional contribution of the EPS-SG, JPSS and Fengyun satellites sounder instruments.

The user needs for the average time to achieve 90% of global coverage are:

- Threshold: 5 hours
- Breakthrough: 4 hours
- Objective: 3 hours

This need can only be achieved with a constellation of satellites. The next figure shows the geographical area covered by the EPS-Sterna instrument with 54.5 degrees of Field of View (FoV) during one orbit.

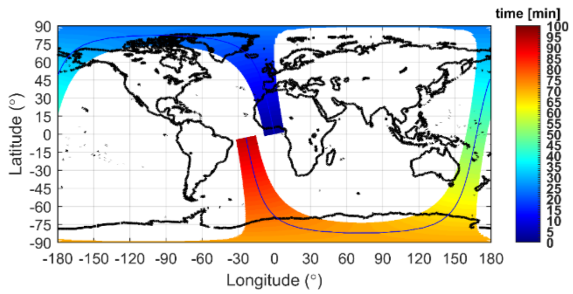


Fig. 2. Coverage during one orbit

Selection of number of planes and satellites

For the selection of the number of planes and satellites, it is initially assumed that the planes are homogeneously distributed along 180degrees in ascending node and the satellites phasing is homogeneously distributed as a Walker-Star pattern. These assumptions will be revisited.

The next figure shows the average time to achieve 90% global coverage for multiple constellations configurations. Each line corresponds to different number of planes.

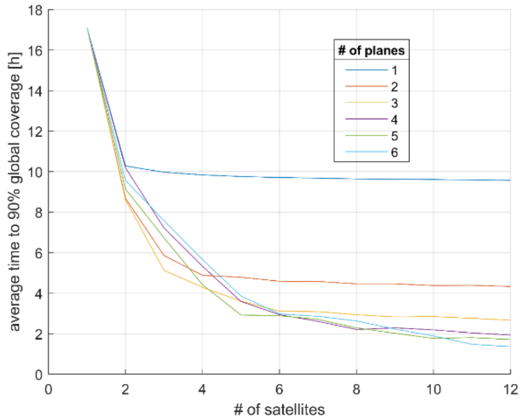


Fig. 3. Coverage performance

Notes:
- Planes are homogenously spread, i.e. line of nodes are separated by 90, 60, 45, 36 and 30degrees for 2, 3, 4, 5 and 6 -plane configuration, respectively;
- Satellites are homogenously spread as per Walker-Star constellation which maximizes revisit time on the polar regions and minimize load on ground stations.

The following table shows the same information in numerical form.

Table 2. Coverage performance (h)

		N. of planes					
		1	2	3	4	5	6
N. of satellites	**1**	17.1					
	2	10.3	8.7				
	3	10	5.9	5.1			
	4	9.8	4.9	4.3	5.3		
	5	9.8	4.8	3.6	3.6	3.0	
	6	9.7	4.6	**3.1**	3.0	3.0	3.0
	7	9.7	4.6	3.1	2.6	2.7	2.9
	8	9.6	4.5	2.9	2.2	2.3	2.6
	9	9.6	4.5	2.8	2.3	2	2.2
	10	9.6	4.4	2.9	2.2	1.8	1.9
	11	9.6	4.4	2.8	2	1.8	1.5
	12	9.6	4.3	2.7	1.9	1.7	1.4

Notes:
- Figures below objective, breakthrough and threshold requirements (3h, 4h and 5h) are highlighted in blue, green and orange, respectively;
- Figures for incomplete planes are not shown;
- Figure for nominal constellation (6 satellites on 3 planes) is shown in bold.

It can be seen that the performance increases (average time to achieve 90% global coverage reduces) as the number of planes and number of satellites increases. For a constellation with a given number of planes, the performance increases with the number of satellites with diminishing return reaching an asymptotic behaviour, i.e. the increase in performance by adding the (N+1)th satellite is lower than increase in performance by adding Nth satellite. Moreover, this asymptotic behaviour manifests earlier (with fewer number of satellites) with low number of planes and later (with larger number of satellites) with higher number of planes. A similar behaviour is observed as well for increasing the number of planes. This is explained by the fact that the instrument FOV on the satellites in adjacent planes start partially overlapping with each other before 90% of the Earth surface has been observed.

The one-plane constellation configuration provides poor performance below threshold level regardless of the number of satellites.

The two-plane constellation configuration provides relatively poor performances too. It allows for achieving threshold level, but it does not provide any potential capacity for achieving breakthrough level regardless of the number of satellites.

The three-plane constellation configuration allows for meeting threshold level with just four satellites. It is to be noted that this is, however, not possible with a constellation configuration optimized for a higher number of planes. This configuration allows also for meeting breakthrough and goal level with higher number of planes.

A constellation configuration with higher number of planes allows for slightly higher performance but at the expense of low operational robustness, when factoring in the reduced on-board redundancy of the satellites.

The operational robustness of the 6-satellite and 3-plane configuration is shown in the next table. If one satellite is lost, breakthrough performance level is still met.

Table 3. Three-plane constellation resilience

# Satellites (total)	Constellation Configuration [P1, P2, P3]	Time to 90% global coverage
6	[2,2,2]	**3.1h**
5	[2,2,1]; [2,1,2]; [1,2,2]	3.6h
4	[1,1,2]; [1,2,1]; [2,1,1]	4.3h
4	[2,2,0]; [2,0,2]; [0,2,2]	6.0h
3	[1,1,1]	5.1h*
3	[2,1,0]; [2,0,1]; [1,2,0]; [0,2,1]; [1,0,2]; [0,1,2]	~ 7.0h

The three-orbital planes configuration has been chosen as it maximizes both performance and in-orbit redundancy given the low reliability of each satellite. Six satellites, two on each plane, is the target configuration.

Selection of planes separation

The next figure shows the performance evolution as a function of the separation between the first and second plane (horizontal axis) and the separation between the second and the third plane (vertical axis).

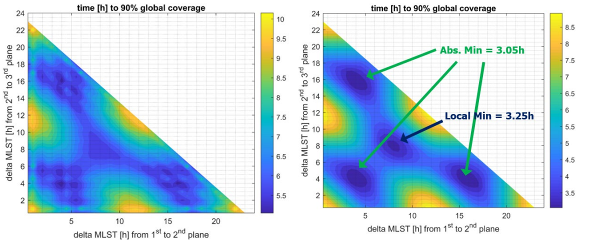


Fig. 4. *Time to 90% global coverage as function of planes separation (left: 3 s/c, right 6 s/c)*

The local minima of 3.25h appear with 4h (60degrees) separation between the line of nodes of the 3 orbital planes but the ascending nodes of the 3 orbital planes are separated by 8h (120degrees). This corresponds to the Walker-Delta pattern with the ascending nodes homogeneously distributed along 360degrees.

The absolute minimum of 3.05h appears with 4h (60degrees) separation between the ascending nodes This corresponds to the Walker-Star pattern with the ascending nodes homogeneously distributed along 180degrees.

Selection of local time

The selection of the local time of each orbital plane is driven by the combined coverage performance of the EPS-Sterna constellation in cooperation with the microwave instruments on-board the EPS-SG, JPSS and Fengyun polar orbiting satellites. The next figure shows the evolution of this performance as function of the local time of each EPS-Sterna plane on the horizontal axis.

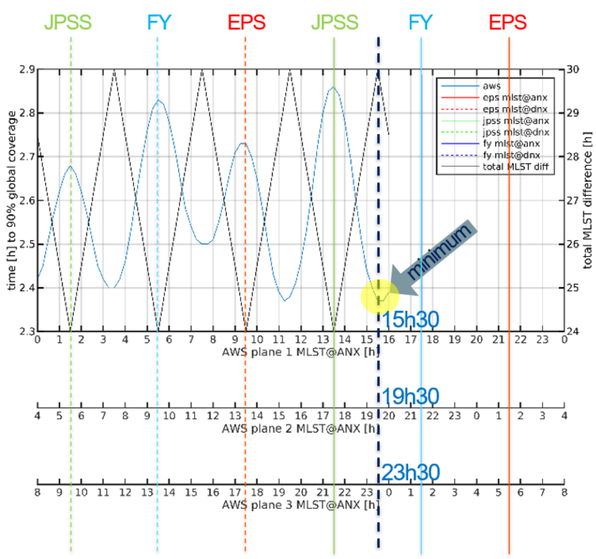


Fig. 5. *Multi-mission coverage performance*

The LTAN values that minimize the average time to achieve 90% global coverage are 15h30, 19h30 and 23h30. The next figure shows the line of nodes of the EPS-Sterna planes together with the 3rd party microwave sounder missions.

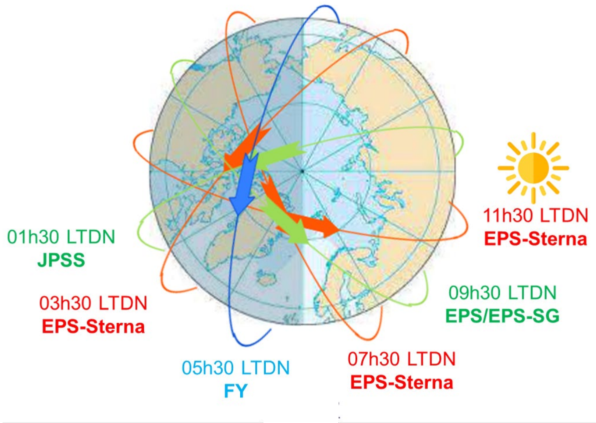


Fig. 6. *EPS-Sterna, EPS-SG, JPSS and FY line of nodes*

Selection of phasing

The inter-plane and intra-plane phasing follow the Walker-Star constellation. This allows for minimizing revisit time and load on ground stations over the polar regions. The next figure shows the achieved revisit time with the 3-plane constellation, with 2 S/C per plane.

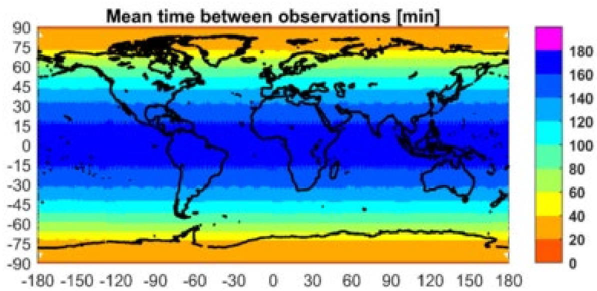


Fig. 7. *EPS-Sterna revisit time*

There is a small optimization potential to further increase the coverage performance by optimizing this phasing. The next table show the impact of this phasing optimization on 3-plane constellation configuration.

Table 4. Coverage performance (h) vs relative phasing

S/C per plane	***Phasing***	***Time to 90% global coverage***
[1, 1, 1]	Walker Star (F parameter >= 1)	5.1 h
[1, 1, 1]	P: 0 & P: 90 & P: 180deg	5 h
[2, 2, 2]	Walker Star (F parameter >= 1)	3.1 h
[2, 2, 2]	P: 0,180 & P: 40,220 & P: 80,260deg	3.08 h

It can be seen that the improvement in performance by optimizing further the phasing is very small. This optimized phasing has, however, a significant detrimental impact on the revisit time over the polar regions and lead to higher load on ground stations on the polar regions (need of higher number of antennas).

Conclusion

The EPS-Sterna constellation comprises of nominally 6 satellites placed in SSO at around 595km altitude, with 2 satellites placed evenly in each of 3 orbital planes with 15h30, 19h30 and 23h30 LTAN.

Actual Performance Evolution

The local time of the satellites will not be actively controlled during the nominal lifetime of 5years due to Delta-V budget constraints. To overcome this, an optimal offset in inclination and local time will be applied at the beginning of the mission in order to minimize the local time deviation.

The next figures show the evolution of the inclination and the local time during the extended lifetime of the satellites of 7.5 years.

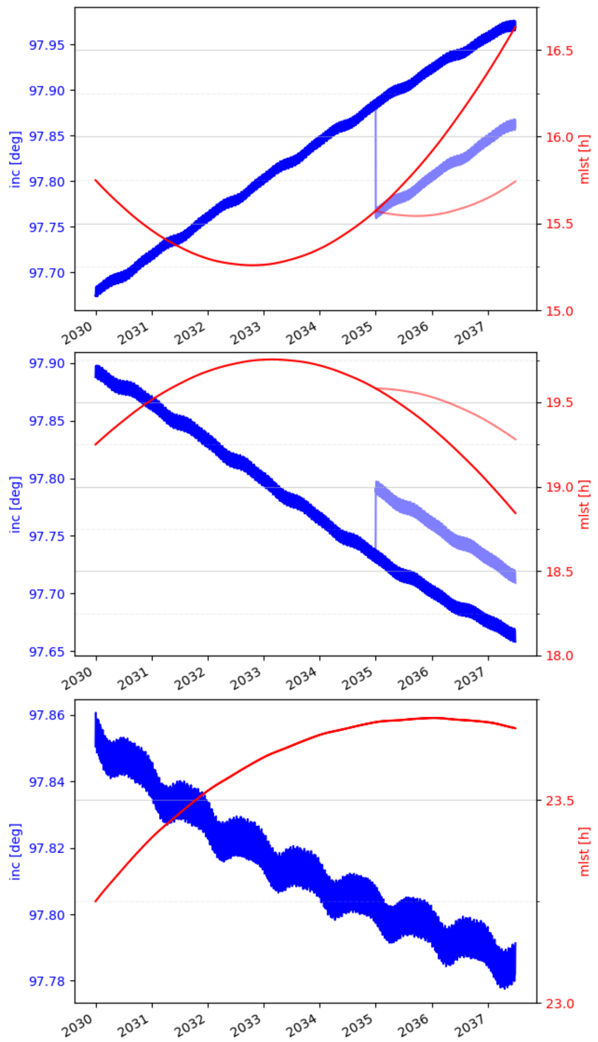
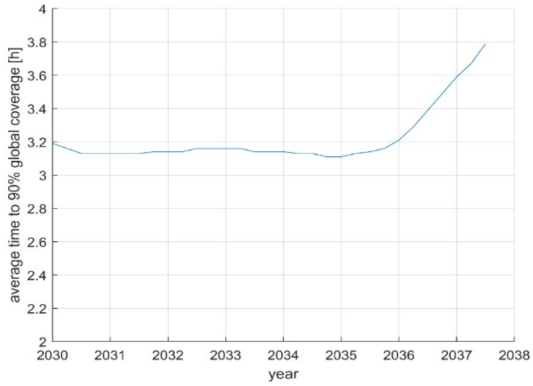


Fig. 8. EPS-Sterna inclination (blue line; right axis) and local time (red line; left axis) evolution

It can be seen that the 3 orbital planes remain within 15minutes from the reference local time during the nominal satellite lifetime of 5years. The 23h30 plane will even remain within these 15minutes during the extended satellite lifetime of 7.5years. The 15h30 and 19h30 planes will need corrective inclination manoeuvres to remain within the 15minutes threshold for the extended satellite lifetime.

The next figure shows the actual evolution of the constellation performance accounting for the actual drift of the local time.



It can be observed that the constellation performance remains stable within the nominal satellite lifetime of 5years. After that, it starts degrading rapidly if local time drift of the first and second plane are not contained within the 15minutes threshold.

C. Payload Ground Station Network

The selection of the payload ground station network is mostly driven by the end-to-end timeliness user needs. The data timeliness (overall data latency) refers to the total time elapsed when data is acquired by a sensor and when these data is made available to the users. The data timeliness equals to the sum of both the space segment delay and the on-ground segment delay. The space segment delay, a.k.a. on-board data latency refers to the total time elapsed between when data is acquired by a sensor and when this data is downloaded to a ground station. The on-ground segment delay refers to the time required for data repatriation to the processing centre, the data processing itself and the dissemination to the users.

The end-to-end timeliness user needs are shown in the next table.

Table 5. EPS-Sterna Timeliness Requirement

Req. Level	**Threshold**		**Breakthrough**	
Data (%)	50	80	50	80
Time (min)	75	100	45	75

The payload ground station network includes the EUMETSAT assets at Svalbard. To meet the breakthrough end-to-end data timeliness user requirements additional ground stations are required. Multiple ground station locations were considered including SSC [1], KSAT [2], ESTRACK [3] and DLR [4] ground station network as well as the NOAA ground stations used for Joint Polar Satellite System (JPSS).

The shortlisting of all these ground stations is mainly driven by the minimization of the number of stations required to build a ground station network that allows for meeting the end-to-end data timeliness user requirement (the space-segment delay). This, in turn, leads to the selection of ground stations with none or as few as possible blind orbits. These are stations near the South or the North Pole (see Appendix C).

The list of additional ground stations considered are listed in the next table.

Table 6. Potential ground stations

Station	Latitude
Svalbard, Norway	78.2°N
Jan Mayen, Norway	71.0°N
Vardø, Norway	70.4°N
Tromsø, Norway	69.6°N
Inuvik, Canada	68.3°N
Kiruna, Sweden	67.9°N
Poker Flat, Alaska, US	65.1°N
Fairbanks, Alaska, US	65.0°N
Alaska, US	64.8°N
Nuuk, Greenland	64.2°N
Ågesta, Sweden	59.2°N
Latvia	56.9°N
Punta Arenas, Chile	52.9°S
Tolhuin, Argentina	54.5°S
O'Higgins, Antarctica	63.2°S
Troll, Antarctica	72.0°S
McMurdo, Antarctica	77.8°S

- Note 1: Only polar or close to polar stations have been considered. See Appendix C with ground station performance as function of their geographical latitude.
- Note 2: Sites close to Svalbard (Jan Mayen, Vardø, Tromsø, Kiruna, Agesta, Nuuk, Latvia) are greyed-out. Svalbard provides overlapping passes and outperforms these stations for SSO.
- Note 3: Sites close to Fairbanks (Poker Flat, SSC Alaska) are greyed-out. Fairbanks is geographically very close (less than 50km away) to these stations. These stations provide same level of performance than Fairbanks.
- Note 4: Site close to Punta Arenas (Tolhuim) is greyed-out. This station provides same level of performance than Punta Arenas.

The next figure illustrates the visibility circles for Svalbard plus the candidate ground stations.

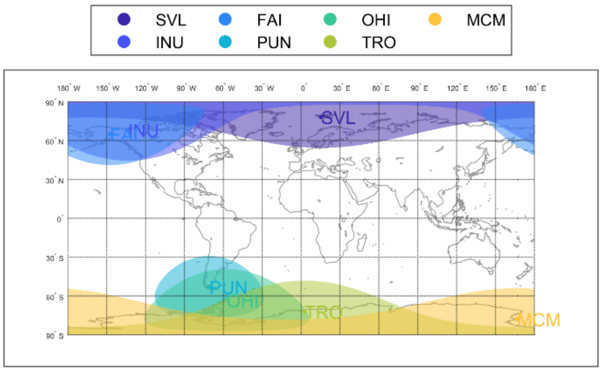


Fig. 9. *EPS-Sterna ground stations*

Appendix A shows the achieved end-to-end timeliness for Svalbard alone and each pair of stations.

It can be seen that Svalbard alone meets threshold level user requirement. The addition of another station on the northern hemisphere does not help meeting breakthrough level. The addition of any of the other analysed station on the southern hemisphere allows for achieving breakthrough requirement. As expected, the overall performance increases as the ground station is closer to the South Pole.
The final selection of the additional ground station is pending trade-off analysis including other criteria such as cost, cooperation agreement opportunities and synergies with other EUMETSAT missions.

II. EPS-Aeolus

A. Mission Description

The objective of the EPS-Aeolus mission is to support numerical weather prediction (NWP), enhancing the core relevant services provided by EPS-SG, with a focus on atmospheric wind profile measurements.

The mission primary products are global wind and aerosol observations with high vertical resolution and (TBC) global radio-occultation products.

To meet these objectives, the EPS-Aeolus system consists of up to two satellites embarking a Doppler Wind Lidar (DWL) instrument and a RO instrument (TBC) and ground segment for M&C and data processing, archiving and dissemination. The operational lifetime of the system will be greater than 10 years and each satellite will be designed for a lifetime longer than 5.5 years.

The EPS-Aeolus satellites, a.k.a. Aeolus-2 satellites, are the follow-on of the ESA Aeolus satellite, a.k.a. Aeolus-1 satellite. The EPS-Aeolus satellites will fly on a Sun-Synchronous Orbit (SSO) at an altitude between 360 and 400km with 18:00 local time at ascending node.

The EPS-Aeolus satellites will provide three telemetry data streams:

- The satellite housekeeping telemetry (HKTM) data from the platform and instrument(s);
- The Stored Mission Data (SMD) stream, needed for the global mission;
- The Real-Time Mission Data (RMD) stream, for enhanced performances of the global mission;

The TT&C communication will be in S-band. This will be supported by the TT&C ground stations. The TT&C ground stations will be located at Svalbard and at other location complementing blind orbits from Svalbard.

The real-time and stored HKTM will be received via S-band. The stored HKTM will be received also via the SMD.

The Stored Mission Data (SMD) and the Real-Time Mission Data (RMD) will be downlinked in X-Band to the Payload Ground Stations. One payload ground station will be located at Svalbard. The location of the additional ground stations is pending a trade-off analysis. As for EPS-Sterna, the candidate additional stations are Inuvik, Fairbanks, Troll, McMurdo, O'Higgins or Punta Arenas.

B. *Orbit Information*

The reference orbit is defined as a near circular Sun-Synchronous Orbit (SSO) with an altitude (semi-major axis minus Earth equator) between around 360 and 400km. The next figure shows the selection of this orbit (shaded area) on a SSO repeating orbits diagram (including ESA Aeolus-1 repeat cycle).

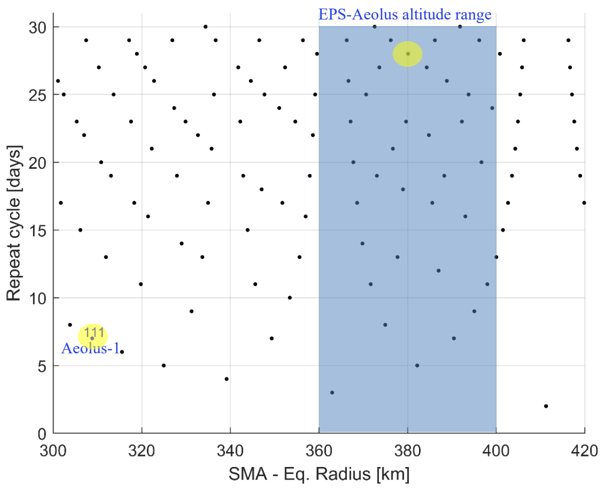


Fig. 10. *EPS-Aeolus Repeat Cycle Map*

For the purpose of this paper, the following orbit is selected: 28-day repeat cycle and 437 cycle length. The main properties of this reference orbit are summarized in the next table.

Table 7. EPS-Aeolus Orbit (TBC)

General Properties			
Orbit type			Repeating Frozen Sun-Synchronous
Repeat cycle [days]			28
Cycle length [orbits]			437
Repeat cycle (i,j,k) parameters			15+17/28
Mean Semi-major axis - Eq. radius [km]			379.5
Nominal nodal period [min]			92.265
Mean Local Solar Time at ascending node			6h or 18h
Minimum altitude over ellipsoid [km]			384.4
Maximum altitude over ellipsoid [km]			412.5
Mean altitude over ellipsoid [km]			394.7
Mean elements in True of Date		**Repeat cycle properties**	
Semi-major axis [km]	6757.608	Orbits per day	15.607
Eccentricity	0.001293	Fundamental interval [deg]	23.066
Inclination [deg]	96.980	Fundamental interval [km]	2567.736
Arg. Of Perigee [deg]	90	Track Spacing [km]	91.705

C. *Payload Ground Stations Network*

The selection of the payload ground station network is mostly driven by the end-to-end timeliness user needs (the space-segment contribution).

The end-to-end timeliness user needs are shown in the next table.

Table 8. EPS-Aeolus Timeliness Requirement

Req. Level	Threshold	Breakthrough
Data (%)	100	90
Time (min)	90	60

The payload ground station network includes the EUMETSAT assets at Svalbard. To meet the end-to-end data timeliness user needs, additional ground stations are required.

Table 4 shows the candidate stations (same as for EPS-Sterna for synergy reasons). The next figure illustrates the visibility circles for these stations.

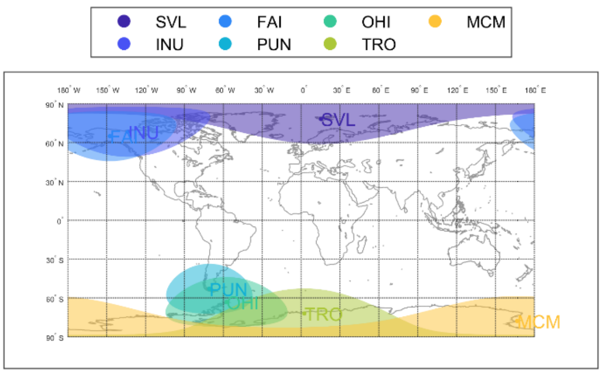


Fig. 11. *EPS-Aeolus ground stations*

The achieved end-to-end timeliness is shown in Appendix B.

The following conclusions can be drawn:

- **No single station option:**
  - One station cannot meet threshold level;
  - All stations have blind orbits.
- **2-station network:**
  - This is the minimum number of stations to achieve threshold level;
  - Troll, on the southern hemisphere, provides the best performance as it complements best the blind orbits from Svalbard.
  - Inuvik, on the northern hemisphere, is the second-best option as it also covers for Svalbard blind orbits.
- **3-station network:**
  - This is the minimum number of stations to achieve breakthrough level;
  - McMurdo is needed on the southern hemisphere to achieve breakthrough level. This option needs further support from either Inuvik or Troll;
- **4-station network:**
  - Network is not bound to McMurdo;
  - The most performing option allows for no blind orbits on both hemispheres:
    - North: Svalbard + Inuvik
    - South: Troll + McMurdo

The final selection of the additional ground station is pending trade-off analysis including other criteria such as cost, cooperation agreement opportunities and synergies with other EUMETSAT missions.

III. Future Activities

The following topics are currently under analysis and will be presented in future publications:

- Accuracy of predicted antenna pointing data at low altitude
- Automatic station-keeping with electric propulsion and one TT&C uplink pass per week;
- Long orbit raising phase with electric propulsion;
- EUMETSAT multi-mission TT&C stations capacity;
- Handling of Radio-Frequency Interference (RFI);
- Instrument cross-calibrations;
- EPS-Aeolus laser instrument calibration with on-ground telescope;
- EPS-Aeolus Radio Occultation Mission characterisation.

IV. References

[1] SSC (2023) The SSC Stations. Available at: https://sscspace.com/services/satellite-ground-stations/our-stations/ (Accessed: 21 November 2023).

[2] KSAT (2023) The KSAT Global Ground Stations Network. Available at: https://www.ksat.no/ground-network-services/the-ksat-global-ground-station-network/ (Accessed: 21 November 2023).

[3] ESA (2023) The SSC ESA ESTRACK Network. Available at: https://www.esa.int/ESA_Multimedia/Images/2013/01/Network_map/ (Accessed: 21 November 2023).

[4] DLR (2021) DLR Ground Stations and Network Operations Centre. Available at https://www.dlr.de/rb/PortalData/38/Resources/dokumente/leistungen/DLR_RB_Portfolio_NetworkOperationsCenter.pdf (Accessed: 21 November 2023)

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V. Appendix A: EPS-Sterna Timeliness data

Table 9. EPS-Sterna Timeliness Data

G/S Network	*Percentage of data*					
	50%	**60%**	**70%**	**80%**	**90%**	**100%**
SVL	56.4	65.4	74.4	84.4	93.4	105.4
SVL+INU	56.4	65.4	74.4	84.4	93.4	112.4
SVL+PUN	42.4	49.4	58.4	70.4	86.4	105.4
SVL+OHI	38.4	44.4	50.4	58.4	77.4	104.4
SVL+TRO	36.4	41.4	47.4	54.4	64.4	103.4
SVL+MCM	33.4	38.4	42.4	47.4	52.4	61.4

Note: 564.9s is assumed as worst-case for the ground-segment contribution to the end-to-end timeliness.

VI. Appendix B: EPS-Aeolus Timeliness data

Table 10. EPS-Aeolus Timeliness Data

Hemisphere distribution	**G/S Network**	**90% data**	**100% data**
Only SVL	SVL	318	480
SVL + 1 N	SVL+INU	96	113
	SVL+FAI	184	373
SVL + 2 N	SVL+INU+FAI	96	114
SVL + 1 S	SVL+PUN	101	255
	SVL+OHI	96	162
	SVL+TRO	86	112
	SVL+MCM	112	250
SVL + 1 S + 1 N	SVL+PUN+INU	91	119
	SVL+PUN+FAI	98	247
	SVL+OHI+INU	89	114
	SVL+OHI+FAI	95	162
	SVL+TRO+INU	75	112
	SVL+TRO+FAI	83	112
	SVL+MCM+INU	58	111
	SVL+MCM+FAI	75	152
SVL + 1 S	SVL+PUN+INU+FAI	91	119
	SVL+OHI+INU+FAI	89	114

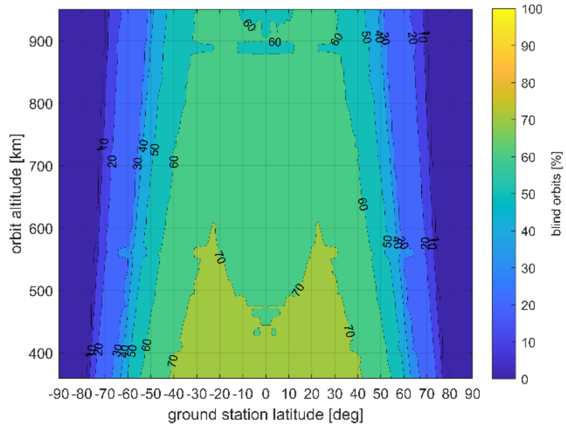
Hemisphere distribution	G/S Network	90% data	100% data
+ 2 N	SVL+TRO+INU+FAI	75	112
	SVL+MCM+INU+FAI	58	111
SVL + 2 S	SVL+PUN+OHI	96	162
	SVL+PUN+TRO	79	118
	SVL+PUN+MCM	77	147
	SVL+OHI+TRO	81	116
	SVL+OHI+MCM	70	150
	SVL+TRO+MCM	65	119
SVL + 1 N + 2 S	SVL+INU+PUN+OHI	88	119
	SVL+INU+PUN+TRO	62	119
	SVL+INU+PUN+MCM	57	112
	SVL+INU+OHI+TRO	63	112
	SVL+INU+OHI+MCM	56	112
	SVL+INU+TRO+MCM	54	75
	SVL+FAI+PUN+OHI	94	162
	SVL+FAI+PUN+TRO	74	118
	SVL+FAI+PUN+MCM	66	126
	SVL+FAI+TRO+OHI	76	116
	SVL+FAI+OHI+MCM	62	124
	SVL+FAI+TRO+MCM	59	119
SVL + 2 N + 1 S	SVL+PUN+INU+FAI	91	119
	SVL+OHI+INU+FAI	89	114
	SVL+TRO+INU+FAI	75	112
	SVL+MCM+INU+FAI	58	111

Notes:

- 20 minutes is assumed for the ground-segment contribution to the end-to-end timeliness.
- For the 90% column:
  - Cells highlighted in blue indicates fulfilment of breakthrough level;
  - Cells highlighted in yellow indicates NOT fulfilment but close to the breakthrough level.
- For the 100% column:
  - Cells highlighted in green indicates fulfilment of threshold level;
  - Cells highlighted in yellow indicates NOT fulfilment but close to the threshold level.
- For the GSN column:
  - Cells highlighted in blue indicates fulfilment of breakthrough level;
  - Cells highlighted in yellow indicates NOT fulfilment but close to the threshold and/or breakthrough level.

VII. APPENDIX C: BLIND ORBIT MAP

The ground stations near the Poles offer better visibility for Sun-Synchronous Orbit (SSO). The next figure illustrates this by showing the percentage of blind orbits as function of the geographical latitude of the ground station.



Notes:

- *Orbit type = SSO*
- *Minimum pass duration (blind orbit) = 0 minutes*
- *Ground station altitude = 0m*
- *Ground station horizon mask = 0degree*

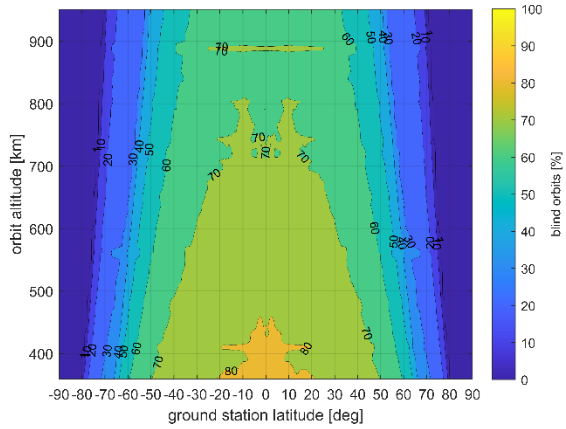


Fig. 12. Blind Orbits Map

Notes:

- *Orbit type = SSO*
- *Minimum pass duration (blind orbit) = 5 minutes*
- *Ground station altitude = 0m*
- *Ground station horizon mask = 0degree*