Normal Paper

Avoidance of Radiofrequency Interferences with Metop-A and Metop-B during Metop-C early Operations

Francisco Sancho [1], Pier Luigi Righetti [1] and Jose Maria de Juana Gamo [1]

[1] *Flight Operations Division, EUMETSAT, Eumetsat Allee 1, Darmstadt, 64295, Germany*

Abstract

Metop-C, EUMETSAT's third low-Earth polar orbit meteorological satellite, was launched on November 7th 2018. Its transponders and instruments use the same radiofrequencies as the ones on its predecessors, Metop-A and Metop-B, still in orbit and operational. Metop-C separation happened close to the nominal launch target orbit, 16km below the orbit of the other two spacecraft, and close to and behind Metop-B's orbital position, which resulted in Metop-C flying below Metop-B during the first days of the mission. It was therefore necessary to predict the times at which special operations, carefully designed and fully rehearsed in advance, had to be performed to avoid radiofrequency (RF) interferences that would result in the inability to properly command and track Metop-C during the critical Launch and Early Operations Phase (LEOP). Those operations were successfully executed without impacting Metop-B mission or the LEOP of Metop-C, later manoeuvred into to its target orbital position, avoiding then further interference risk.

Keywords: Mission execution, Launch and Early Operations Phase, Radiofrequency interferences.

Introduction

The first two Metop satellites (A and B) where launched, respectively, in October 2006 and September 2012, by Soyuz/Fregat launchers from the Baykonur Cosmodrome in Kazakhstan. For the third one, Metop-C, the same type of launcher was selected, but the launch operations were carried out, in November 2018, from the Kourou Space Centre in French Guyana.

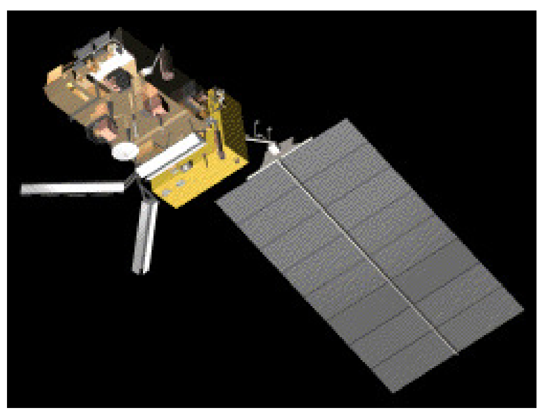

Fig. 1: The Metop satellite

All the satellites of the Metop family (shown in Fig. 1) are operated into a Sun-synchronous repeat orbit with the following characteristics:

- Local Time of the Descending Node (LTDN) of 9:30, with +/-2 minutes of tolerance;
- Repetition cycle of 412 orbits in 29 days, within 5 km from the nominal ground-track;
- Eccentricity kept close to the frozen value, with deviation below 0.0002.

Each Metop satellite makes use of RF communications in S-band for telemetry and telecommand (satellite) operations, in X-band for dumping to ground the collected scientific data (global mission) and in L-band for real-time broadcasting of the observed scene (local mission); moreover, C-band is used by the advanced scatterometer (ASCAT), the only active instrument on board of Metop.

Metop-C uses the exact same frequencies (in S, X, L and C bands) as the equivalent one on the two sister satellites. Therefore, whenever two of the satellites are close enough (in terms of on-orbit position) to be seen from a ground station inside the antenna beam-width, radio-frequencies interferences are observed.

Why radiofrequency interferences?

As mentioned above, the launcher selected for Metop-C is a Soyuz/Fregat launcher. Its trajectory is invariant in the Earth-fixed reference frame. Therefore the in-orbit position (PSO) at separation is always the same, regardless of the date and the time of the launch itself (PSO=216deg, time between launch and separation: 3618 seconds).

As each satellite covers a bit more than 14.2 orbits on an entire day (412 orbits in 29 days, so 14+6/29 orbits per day), the position of the two flying Metop satellites at the Metop-C separation time changes every day by around 74.5 degrees. So the relative position of Metop-C at separation with respect to the flying Metop satellites changes by that same amount (as shown in Fig. 2 for Metop-B), being the same again after one repeat cycle of 29 days.

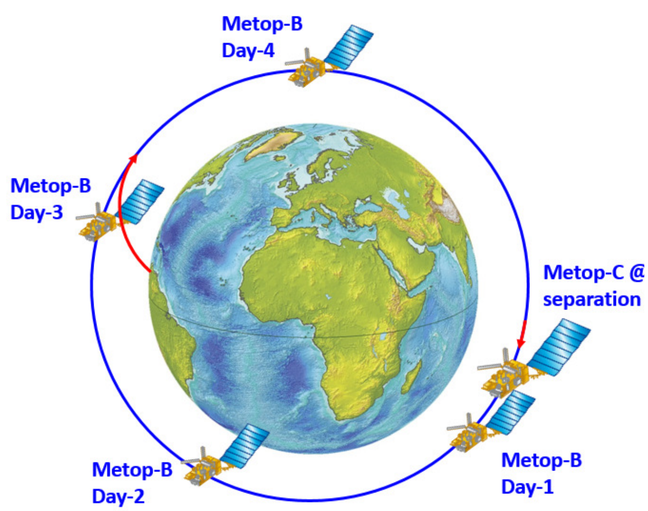

Fig. 2: Relative position between Metop-C at separation and Metop-B on 4 consecutive days

The launch altitude selected for Metop-C is 16km below the nominal value, to avoid any risk of collision with the operational Metop satellites. Because of this an important relative drift of around 17 degrees per day (being Metop-C faster) is induced. As explained in [1], the location selected as target for the commissioning of Metop-C is around 124 degrees in front of Metop-B (Leg-10 in Fig. 3), and therefore a variable drift from separation has to be implemented for each launch day within the 29 days repeat cycle. Moreover, due to constraints imposed by the Satellite In-Orbit Verification (SIOV) activities starting after the end of the LEOP, that target must be reached between 8 and 17 days after launch. This may impose the need of adjusting the drift rate, which can be done not earlier than 2 days after launch. This means that, for certain launch dates, Metop-C would have to overtake one of the operational Metop satellites on its way to target.

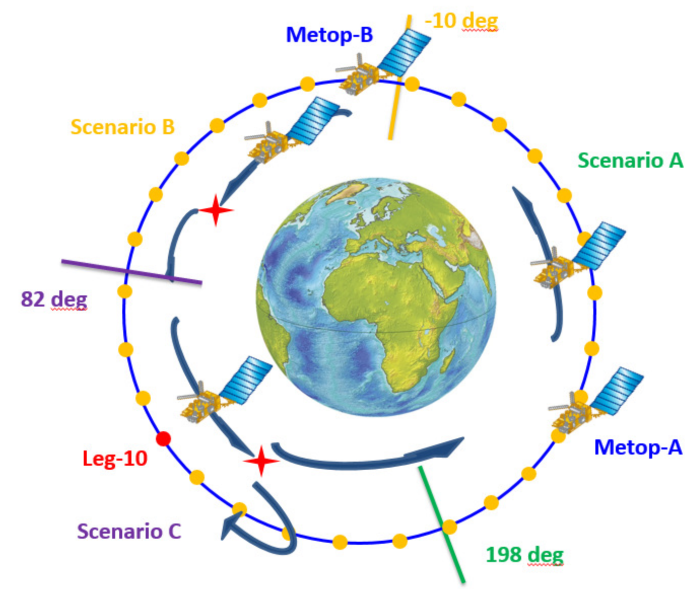

Fig. 3: LEOP scenarios
(for nominal launch altitude)

Fig. 3 shows the different scenarios that can take place, for a nominal launch altitude, depending on Metop-C relative location (with respect to the other two Metop) at separation:

- Scenario A: drift rate permits to reach the target within the required time window after launch;
- Scenario B: drift rate has to be reduced to avoid reaching the target too early;
- Scenario C: drift rate has to be accelerated to avoid reaching the target too late, or reverted if more convenient in terms of overall fuel cost or from an operational point of view.

Metop-C would cross the orbital position of one of the other satellites, leading to possible RF interferences, in the following cases:

- Scenario A: with Metop-B and, in some cases, with Metop-A as well;
- Scenario C: with both satellites, unless the drift is reverted (in which case no interference risk would take place);
- Scenario B: rarely, and very early after separation, with Metop-B.

The boundaries between the different zones in *Fig.* 3 may change with the initial drift rate, which could vary between 30 degrees per day for a 3-sigma (12km) negative altitude error and 4 degrees per day for an equivalent positive altitude error. The duration of the interference risk periods is affected by the drift rate at that point in time (the higher the drift rate, the shorter the interference risk period), which depends on the initial altitude error as well as on the possible execution of an adjustment manoeuvre during LEOP.

The types of RF interferences that can take place between the Metop satellites, and the way to mitigate them, are the following:

- Interferences in ranging and Doppler measurements in S-band; these can be mitigated by avoiding the execution of such measurements on one of the satellites when both are seen with a separation below 22 degrees from any of the ground stations (the accuracy of the radiometric measurements is seriously affected also by a very little spurious signal). In the conditions described above for the Metop-C early operations such an interference risk period can last up to a few days.
- Interferences in S-band TM/TC links can be mitigated by switching off the on-board S-band transponder and avoiding raising the S-band carrier to and commanding one of the satellites when both are seen with a separation below 3.2 degrees from any of the ground stations. The interference risk period can last up to a few hours.
- Interferences in the X-band downlink of scientific data can be mitigated by switching-off the X-band transmitter on-board one of the satellites when both are seen with a separation below 0.5 degrees from any of the X-band antennas. The duration of the interference period can be of the order of minutes. It is to be noted that such interference risk does not exist

during Metop-C LEOP, since its X-band transmitter is switched on for the first time only at the beginning of the SIOV.

- Interferences in the L-band downlink of scientific data and between active instruments can be mitigated by switching off the L-band transmitter and the active instruments on-board one of the satellites when both are less than 60 degrees apart in terms of in-orbit position (only one satellite above the horizon from ground). This interference risk period can be of the order of days. Like in the case of X-band interferences, these are not a concern during Metop-C LEOP, when the affected transmitter and instruments are still off.

Forbidden launch days identification

As mentioned above, the S-band transponders on all Metop spacecraft use the same frequency and therefore if two Metop satellites are too close to each other as seen from the same antenna, S-band interferences can happen. In particular, if this situation materialises on Metop-C during its LEOP, the risk of an operational Metop satellite interfering in RF (jamming its TM/TC communications and thus jeopardising the successful outcome of the LEOP operations) is not negligible.

The first mitigation to that risk would be to mute the S-band transponder on the operational Metop satellite, which has sufficiently large on-board autonomy and does not require continuous TM/TC communications; the operational Metop can use the X band, primarily designed for scientific data downlink, also for health monitoring without risk of interference with Metop-C (as its X band is inactive during LEOP).

Unfortunately, this approach is not fully robust operationally, as a Metop satellite may switch on its S-band transponder autonomously when it enters into safe mode. This means that the risk of RF interferences between the Metop-C satellite in LEOP and an operational Metop satellites, moreover in contingency, cannot be excluded. Though this is a very unlikely situation, it may result in the loss not only of the satellite in LEOP (if the RF interference materialises during a critical phase) but also of the operational one (also reciprocally affected by RF interferences from Metop-C). Consequently, such a risk is clearly unacceptable.

It is therefore necessary to identify the dates when potential interferences could be expected during critical LEOP operations (concentrated during the initial 12 hours after separation). It is also useful to be aware of the dates that may result in interference risk before any manoeuvre, which could be used to avoid those interferences, can be implemented on Metop-C: the first manoeuvre opportunity is 2 days after separation.

Fig. 4 presents the evolution, for 29 consecutive launch dates in November 2018, of Metop-C relative in-orbit position with respect to Metop-B reference orbit during the first 12 and 48 hours after separation, assuming nominal and worst-case relative orbital drift. Metop-C relative position changes by around 74.5 degrees between two consecutive days and the worst-case displacements (3-sigma underperformance) are around 15 and 60 degrees for 12 and 48 hours.

It can be observed that Metop-B itself is displaced with respect to its reference orbit, due to the fact that its LTDN deviation with respect to the reference is slightly above 2 minutes during that period. The relative position of Metop-A with respect to Metop-B is also included in the plot. Its actual position differs even more significantly from the nominal one (at 14/29 orbits from Metop-B reference position), due to the large drift in LTDN (around 14 minutes) accumulated since its last inclination-control manoeuvre in 2016 (as shown in [**Error! Reference source not found.**]).

S-Band interference risk is considered to be present whenever the difference in in-orbit position between the two satellites goes below 2 degrees; for larger differences the angular separation between the two satellites, as observed from ground, remains above the previous mentioned 3.2 degrees threshold always for low elevation passes and most of the time for high elevation passes (whenever the elevation is above 10 degrees), making the risk negligible.

It is also worth mentioning that the exact in-orbit position of each of the operational satellites on the launch date is not fully known a priori, as it is impacted by where the satellite will be within its ground-track margins (i.e. by the atmospheric drag, which effect cannot be predicted exactly). In order to take this into account, an extra margin of 1.2 degrees in PSO (corresponding to 10km in ground-track deviation) is then added to the 2 degrees above.

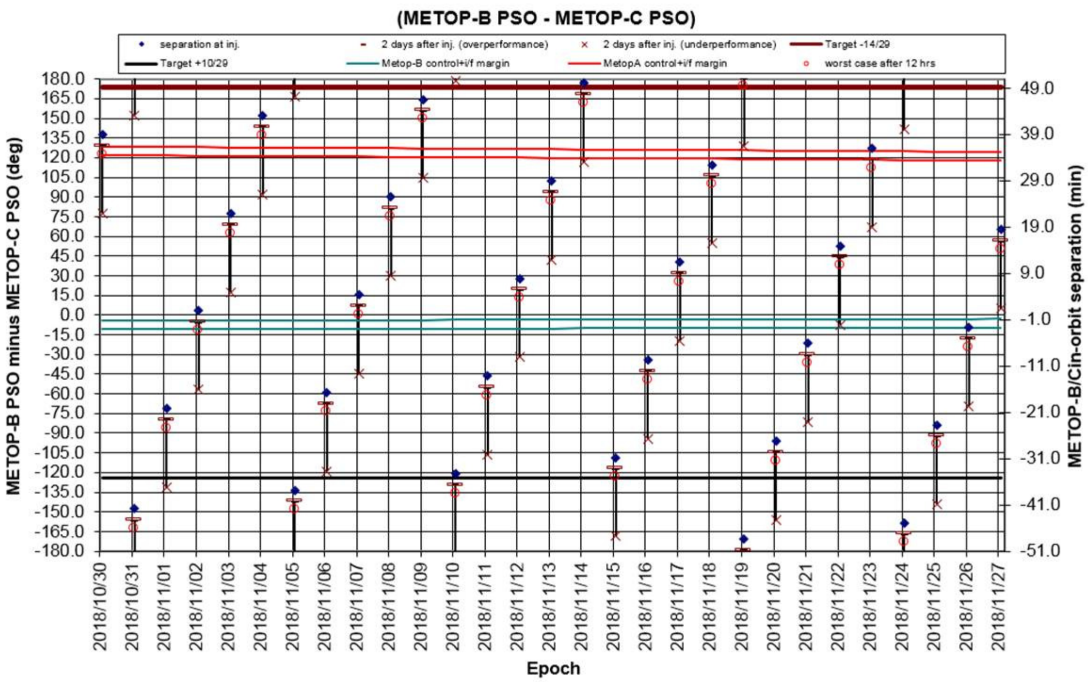

Fig. 4: Metop-C relative position with respect to Metop-B (and Metop-A) during LEOP

With the help of Fig. 4 it is therefore possible to identify the launch dates that could lead to interference risk during the critical first 12 hours of Metop-C LEOP:

- October 30th: possible interferences with Metop-A;
- November 2nd: possible interferences with Metop-B;
- November 23rd: possible interferences with Metop-A;
- November 26th: possible interferences with Metop-B.

In order to avoid the catastrophic risk mentioned above, these dates shall be excluded from the ones on which a launch could take place. Considering that in principle the launch could take place on the selected launch date or any of the 2 following days, also the 2 days before the above dates should be excluded. Therefore the excluded dates are from October 28th to the November 2nd and from the November 21st to November 26th.

Fig. 4 also allows identifying several dates (November 7th being among them) where interferences may happen after those critical first 12 hours but still during the first two days of LEOP. These dates can be considered for launch, though special care is needed in defining the operations for interference risk mitigation, knowing that the probability of needing to execute them is rather high.

Pre-launch preparation and operational rules definition

In order to be prepared for a scenario in which Metop-C and any of the operational Metop satellites would be too close to each other from the point of view of the RF interference risk, different activities were triggered well before Metop-C launch. Actually, most of the preparation had already been performed prior to the launch of Metop-B, when the risk of interferences with Metop-A had already been identified. However, back then the probability of facing a scenario with real risk was significantly lower, since the dates for which this could be avoided were higher than for Metop-C because of the fact that interferences would only be caused by proximity with one satellite, as opposed to two.

First of all, a dedicated tool was developed in-house at EUMETSAT and integrated within the Flight Dynamics System, together with the required operational procedures, to allow the accurate prediction of risk periods for each of the interference types listed above. This information is used both for performing dedicated detailed analyses on possibly conflictive launch dates and as input for the actual risk mitigation operations, whenever needed.

The tool outputs a set of reports identifying, for each interference type, the start and end of each interference risk period (from start of the first event to end of last), as well as information of the affected passes and, if present, of windows within the affected passes where the separation between the satellites is above the threshold defined for the selected RF band. Such a situation is possible as the angular separation between the two satellites, when observed from ground, is larger at higher elevations, as seen in Fig. 5. Those risk-free windows could be used for performing critical operations, otherwise suspended, on one of the satellites in case of long overall interference periods.

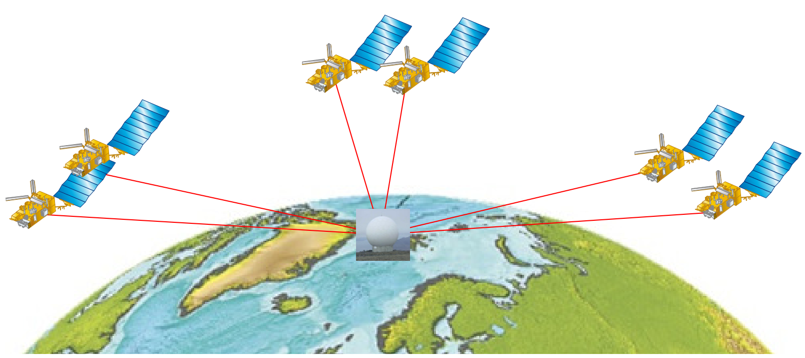

Fig. 5: Larger angular separation of lines of sight for higher elevations

Besides, operational rules were developed to decide which spacecraft should have priority in case of required mitigation actions against interferences. These rules have to take into account the particularities of each mission phase, specifically the fact that LEOP operations are carried out by an external provider (which implies a higher coordination effort in case mitigation actions affect Metop-C) and that due to their criticality and complexity any interruption or impact on them are to be avoided as far as possible. Following are the rules to be applied for each of the possible interference types and the different mission phases:

- Ranging and Doppler interferences: During LEOP priority is generally given to Metop-C. After separation it is critical to estimate the spacecraft orbit, which is moreover affected by the fact that its attitude is controlled by thrusters during the initial acquisition phase, with a resulting impact on the orbit evolution. At that point in time the only operational measurements available for the orbit determination are the ones derived from S-band tracking. Later during the mission, during routine operations, the primary measurements are coming from the on-board GPS receiver, meaning that interruption of tracking on Metop-A or B, even if during a few days, does not have a major impact; the only exception to this general rule would be in case of a contingency causing the switch-off of the payload (and of the GPS receiver with it), especially if that contingency leads to the usage of thrusters for attitude control, and thus to an important degradation of the orbit. During SIOV, once the Metop-C GPS receiver is on, the selection of the satellite to be tracked if performed ad hoc.

- S-band TM/TC interferences: Again, priority is generally given to Metop-C during LEOP. During routine operations, Metop-A and Metop-B have sufficient autonomy to allow muting their S-band transponder for some consecutive passes. Metop-C, on the contrary, needs intensive commanding, while the only source of telemetry is the S-band (as mentioned, X-band is still off at this point in time). During SIOV, priority is given to Metop-B, the prime operational satellite, over Metop-C, and to Metop-C over Metop-A. Again, priorities can shift in case of contingencies.

- X-band interferences: As mentioned, these can only happen during Metop-C SIOV. Priority is given to the prime operational mission (Metop-B), and then to Metop-C over Metop-A. Such a risk period may lead to a delay in the first switch-on of the transmitter, if happening at the beginning of the SIOV, or to its switch-off during one pass or part thereof.

- L-band and instrument interference: Again, this could only be an issue during SIOV. Priority is given to the operational satellites, which could lead to the need of a modification of the Metop-C SIOV timeline in order to delay the switch-on of the affected transmitter and instruments.

Following the establishment of the rules and the procedures and tools allowing their implementation, tests and rehearsals were performed in order to ensure that the system and the operations teams were ready for the execution of the interference avoidance operations, if needed.

As already mentioned, one of the purposes of the interference prediction software was the detailed analysis of specific launch dates identified as possibly conflictive during the mission analysis phase leading to the results shown in Fig. 4. In particular, this was needed for the selected launch date, November 7th, since the actual start of the interference risk period would depend on the actual Metop-B orbit (including its position within the ground-track margins).

This detailed analysis showed that, in case of a launcher underperformance leading to an injection 12km below target (corresponding to a 3-sigma error), the S-band TM/TC interference risk period would start around 16.25 hours after separation. Though strictly speaking this was already outside the critical first 12 hours of LEOP, the decision was made to try and look into options for delaying the start of the risk period, to minimise the possible impact on Metop-C operations. Three possible actions were identified:

- Execution of a Metop-B in-plane manoeuvre in order to place it as close as possible to the Eastern margin of the ground-track dead-band;
- Delay of a scheduled Metop-B out-of-plane manoeuvre;
- Slight modification of the Metop-C launch time for November 7th.

The first option would have a low effect on the start time of the risk period (while being inconvenient from the operational point of view and not guaranteeing the desired effect due to the uncertainties associated to the manoeuvre performances and the resulting ground-track evolution), but the impact of the other two could be high enough for being considered for implementation.

Delay of the Metop-B out-of-plane manoeuvre

As shown by Fig. 6 (left), Metop-B LTDN was already beyond the nominal separation of -120 seconds with respect to its reference. Such a large separation is not a problem, from the mission point of view, in autumn (as explained in [2]), but the drift needed to be reverted in order to avoid problems in spring 2019. Due to platform and operational constraints, two out-of-plane manoeuvres were needed for this, the first of which was executed on September 19th, leading to the evolution presented in Fig. 6 (right).

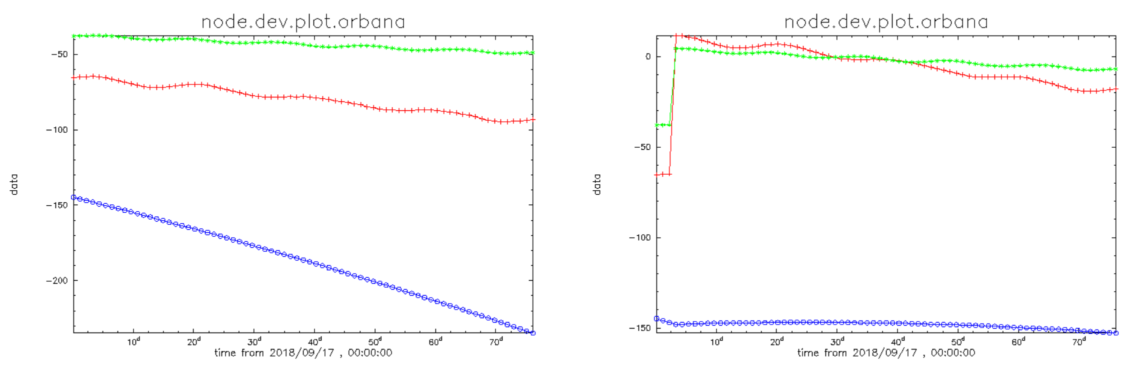

Fig. 6: Metop-B orbit evolution before and after the first out-of-plane manoeuvre

A lower LTDN translates into a larger offset in PSO with Metop-C at separation following a launch on November 7th (and, consequently, more time to the start of the RF interference risk period). This led to the idea of delaying the second out-of-plane manoeuvre, initially scheduled for October 17th. Performing the manoeuvre after Metop-C launch was not convenient, due to the fact that the team required for that operation was expected to be rather busy with Metop-C early operations. Therefore, the alternative date considered for this second manoeuvre was October 31st, one week before the nominal date for Metop-C launch. The LTDN evolution corresponding to each case can be seen in Fig. 7, where the impact in terms of LTDN deviation on the selected Metop-C launch date is evident.

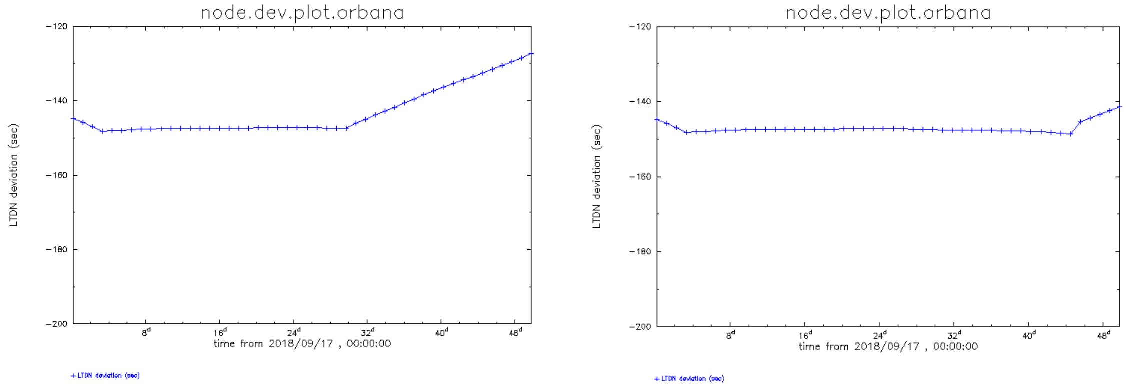

Fig. 7: Metop-B orbit evolution with a manoeuvre on October 17th (left) or on the 31st (right)

Delaying the Metop-B out-of-plane manoeuvre would mean increasing the relative phase with Metop-C at separation time (for a nominal injection) from around 22.7 degrees to around 23.6 degrees. In terms of start of the interference risk period, the modified manoeuvre date would delay it to around 17.75 hours after separation. And this would be possible with a small impact on Metop-B mission (0.6mdeg less of inclination change and 48g more of fuel consumption, while keeping the date of the next required out-of-plane manoeuvre unaffected).

For completeness, it must be noted that delaying the Metop-B manoeuvre to after Metop-C launch would only delay the start of the interference risk period by around further 10 minutes. This benefit was considered too small to justify the delay of this demanding operation to a period of already high operational load, during Metop-C LEOP or early SIOV.

In view of the above results, the modified date of October 31st was accepted as baseline for execution of the second Metop-B out-of-plane manoeuvre.

Modification of the Metop-C launch time

A larger PSO offset between both satellites at Metop-C separation time could be also achieved by delaying that time, i.e. by delaying Metop-C launch time on that particular date. A detailed analysis showed that shifting the launch by 45 seconds would result in a start of the RF interference risk period more than 19.5 hours after separation (considering already the modified date for the Metop-B manoeuver discussed above).

The feasibility of implementing this delay at that point in time, with the launcher flight programme finalised, was questioned, so an internal analysis was performed in order to assess it. According to the launch service provider, the programme was declared valid for 14 days after the nominal launch date. The variation of the Sun angle with respect to the lines of nodes of the orbit was computed for that time window and is shown in Fig. 8. In the same figure, the big dot represents the variation of that same angle caused by postponing the launch time by 1 minute on November 7th. It can be observed that the resulting angle is well within the range of possible angles in the 14 days of the launch window, which proves the feasibility of this delay.

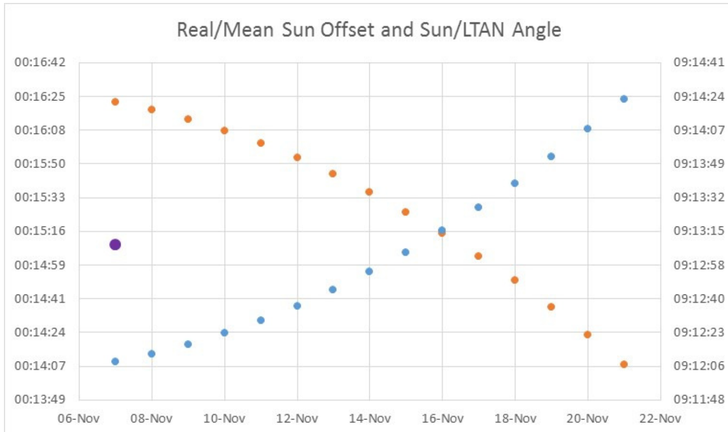

Fig. 8: Feasibility of launch time delay

The only impact of a delay of 45 seconds in the launch time on the optimality of the initial orbital conditions (described in [1]) would be a change in the maximum (positive and negative) injection errors in inclination for which no out-of-plane manoeuvre would be required during LEOP or during the first year of Metop-C operations.

The impact of the above described delay is summarised in Table 1 (40 millidegrees are considered as 1-sigma inclination error).

Table 1: impact of 45 seconds delay on acceptable inclination error window

	Nominal time		**Delayed time**		**Nominal time**		**Delayed time**	
Max positive	**90 mdeg**	**2.25 sigma**	**65 mdeg**	**1.65 sigma**	**13 mdeg**	**0.32 sigma**	**8 mdeg**	**0.2 sigma**
Max negative	**-70 mdeg**	**-1.75 sigma**	**-95 mdeg**	**-2.35 sigma**	**-13 mdeg**	**-0.32 sigma**	**-17 mdeg**	**-0.43 sigma**
	No OOP needed during LEOP				**No OOP needed during first year**			

It can be observed that the change in terms of overall probability to have to perform an OOP during LEOP is small, as the size of the acceptable window remains the same; however, being the window displaced toward negative values, the risk to have to perform a positive manoeuvre (needed if the negative limit is violated) decreases while, symmetrically, increases the risk to have to perform a negative manoeuvre (which is more impacting in terms of fuel, as going in the direction of the natural drift).

The change in terms of overall probability to have to perform an OOP during the first year of operations increases marginally as the size of the acceptable window gets reduced and but less centred around zero; also in that case, the risk of having to perform an inconvenient negative manoeuvre increases.

All in all, the degradation was considered acceptable from a Flight Dynamics point of view. At system level, such a delay did not have any impact on the LEOP timeline and was considered to require only a simple change (just the launch time) in the launch procedure. However, the risk of implementing this "last-minute" modification was considered too high at management level, and the launch time was maintained to the original one.

One lesson learned from this process for future missions is the advantage of keeping the launch window large at launcher mission-analysis level in order to allow for later adjustments of the launch time depending on the operational needs.

Post-launch execution

As stated, Metop-C was finally launched on November 7th. Its injection into orbit was almost nominal, with the actual altitude being a couple of km above the target one. This corresponded to scenario A in *Fig.* 3 (actually, no manoeuvre was needed or executed during LEOP), with the satellite flying below Metop-B during LEOP. Regarding the different RF interference types, this was the situation for each of them:

- Ranging and Doppler interferences: The risk period was predicted to last from 17:27 UTC on November 7th to 17:18 UTC on November 9th. During this time, as per the operational rules and procedures, tracking measurements were suspended on Metop-B. No impact was observed on Metop-C tracking by the LEOP service provider or by EUMETSAT.

- S-band TM/TC interferences: The risk period was predicted to last from 12:42 UTC to 22:17 UTC on November 8th. This period was too long for not commanding Metop-B at all, due to a time-out threshold on-board related to the spacecraft configuration allowing commanding exclusively in authentication mode. Since two risk-free windows were identified during the risk period (between 15:52 UTC to 15:57 UTC and from 20:51 UTC to 21:03 UTC), it was decided not to switch to clear mode. The S-band transponder was muted before the start of the risk period, briefly switched on during those two windows of opportunity, and finally switched back on after the risk period. All commanding was suspended during the whole period, with the exception of the two risk-free intervals, during which TC were sent to re-set the time counter to avoid hitting the time-out threshold. No impact was observed on Metop-C TM/TC activities by the LEOP service provider.

- X-band interferences: Since the proximity with Metop-B happened during LEOP, when Metop-C X-band transmitter was still off, no special operations were required to avoid this type of interferences. Obviously, no impact was observed on Metop-C operations by the LEOP service provider.

- L-band and instrument interferences: The risk period was predicted to last from launch until November 12th at around 19:12 UTC. This time was before the one scheduled for the switch-on of the L-band transmitter and of the active instruments, according to the SIOV timeline, so no modifications to this were required. No impact was observed on Metop-C operations by the LEOP service provider or by the SIOV team.

It is worth mentioning that, besides the risk of interferences, the small PSO separation between Metop-B and Metop-C prevented the usage of the same antenna for their operations during LEOP and early SIOV. EUMETSAT has two antennas in the Svalbard archipelago for Metop operations. These antennas are also used for supporting NOAA-19 operations for the orbits without visibility of the satellite from NOAA's Fairbanks antennas. During LEOP and early SIOV, one of the EUMETSAT Svalbard antennas was devoted exclusively to supporting Metop-C operations, while the other one had to be shared between Metop-A, Metop-B and NOAA-19. Due to the proximity between Metop-B and Metop-C, some conflicts could not be resolved, which resulted in the need to drop a few NOAA-19 passes in favour of Metop-B, the prime Metop spacecraft. Once enough separation between Metop-C and Metop-B was achieved, support to all Metop passes was moved to one of the antennas, making the other one available for supporting NOAA-19 even if in proximity with any Metop.

After the end of the interference risk period

As discussed, the launcher performance for the actual launch date resulted in Metop-C reaching its target position in orbit within the required time window without the need of any orbital correction. In order to stop the drift in time (thus avoiding also further interference risk periods with the other Metop satellites), a manoeuvre strategy, complying with different operational constraints and maximising the probability of achieving the desired target, represented by Leg-10 of *Fig.* 3, was designed. It is outside the scope of this paper to enter into more details on these operations which led to the successful acquisition of the commissioning in-orbit position. All this will be presented in a future paper dedicated to the Metop-C Flight Dynamics operations at EUMETSAT during LEOP and early SIOV. For the purpose of this paper it is sufficient to state that, the spacecraft reached its target position on November 19th. After this, no more interference risk periods are expected until the Metop-A de-orbiting operation (described in [3]). These too will be the subject of future papers.

Conclusions

Due to the spacecraft design, the risk of interferences between different Metop satellites in case of not sufficiently large separation between them was identified. Such a risk can materialise shortly after the launch of the recurrent satellites, as was the case for the Metop-C launch on November 7th. The early identification of this risk allowed defining and putting in place adequate countermeasures and taking mitigating actions that range from the implementation of a dedicated tools and procedures to the postponement of a scheduled Metop-B manoeuvre. This all led to a proper management of the interference risks without any impact whatsoever on any of the operational Metop satellites or on the Metop-C LEOP and SIOV.

With the Metop-C target ground-track acquisition finalised on November 19th, no more interference risk periods are foreseen until Metop-A de-orbiting. EUMETSAT operations teams have demonstrated that, when the time comes, they are ready to handle them properly.

Acknowledgements

The authors would like to thanks the whole EUMETSAT Metop operations team (too large to name each person individually); without their dedication and hard work the excellent results shown in this paper would not have been possible.

References

1. Righetti, P.L., de Juana Gamo, J.M. and Sancho, F., “Metop-C Deployment and Start of 3-Satellite Operations”, 27th ISSFD (2019), Melbourne, Australia.
2. 1. Righetti P.L. and Dyer R.: “Feasibility of Metop-A Mission Extension on Drifting Local Time”, 26th ISSFD (2017), Matsuyama, Japan
3. Damiano A., Lang R., Sancho F. and Righetti P.L.: “Flight Dynamics Support to extend Metop Instruments useful Lifetime”, 26th ISSFD (2017), Matsuyama, Japan
4. Sancho F., Paulino T., de Juana Gamo, J.M. and Righetti P.L.: “Metop-A De-orbiting using very large In-Plane Maneuvers”, 25th ISSFD (2015), Munich, Germany