Northern European and Transatlantic Security (NOTS)

Potential Contribution by Swedish Sensors to Western Ballistic Missile Defence

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The Swedish government is procuring high-performance radar stations with the capability to detect and track ballistic missiles. This paper discusses the possibility of such sensors, based in Sweden, to contribute to the ballistic missile defence of Western Europe and North America. The analysis is limited to geographical factors, given some basic assumptions about radar performance. It is concluded that, since many long-range ballistic missile trajectories from countries known to possess ballistic missiles towards targets in Western Europe and North America pass over or in the vicinity of Swedish territory, radar sensors located in Sweden would be geographically well placed to detect and track such missiles. This in turn opens up the possibility to contribute sensor data to a Western ballistic missile defence system.

Under its New Sensor Programme, the Swedish Defence Materiel Administration (FMV) is renewing the chain of fixed radar stations of the Swedish Armed Forces.[1] The new radars are, in general, of high performance quality with long ranges and the capability to detect objects on the surface, in the air and in space. This paper discusses the possibility that such sensors, based in Sweden, could contribute to the ballistic missile defence of Western Europe and North America.

A full analysis of this topic would require in-depth consideration of the ballistic missile threat from various countries as well as the defensive capabilities of several Western nations and the NATO alliance. In the interest of brevity, the present dicussion will be limited to showing that sensors in Sweden would be geographically well placed to detect or track ballistic missiles on many trajectories from possible launch locations in countries known to possess ballistic missiles towards targets in NATO countries (other than Sweden itself), thus being potentially able to contribute sensor data to a Western ballistic missile defence system. The details of this contribution – such as the probability of detection of different targets, the technical quality of provided tracks, whether it duplicates capablities already in place and so on – will not be analysed.

Ballistic missile defence

At launch, a ballistic missile is powered by a rocket engine or motor and accelerated to high speed; this is known as the boost phase of the missile's trajectory. After the engine burns out, the missile continues in the midcourse phase on a ballistic trajectory towards its target. A missile intended to travel more than a few hundred kilometres will reach high enough altitudes to exit the Earth's atmosphere. Having passed the apogee (the trajectory's highest point), the missile begins to descend. On its way down through the atmosphere, in the terminal phase, the missile may be manoeuvring in order to hit a specific target or to avoid interceptors launched by the defending side.

Ballistic missile defence (BMD) is concerned with countering the ballistic missile threat, typically by kinetically hitting the ballistic missile in flight. This can in principle be achieved at any point during the missile's flight, but missile defence faces different challenges in the different trajectory phases.

In the boost phase, which typically lasts somewhere between one and five minutes, depending on missile size and range, the missile is relatively easy to detect and follow, due to the burning engine and associated heat and visual signature. It is also beneficial, from the defender's point-of-view, to counter the ballistic missile before it has had a chance to disperse its warhead (or warheads) and any decoys or other countermeasures. However, since the launch typically would take place within enemy controlled territory or from a submarine at an *a priori* unknown location at sea, boost phase BMD has to deal with the challenge of somehow having countermeasures (interceptors, directed energy weapons, or whatever) in place close enough to the launch point to be able to effectuate anything within the time-span of the boost phase.

For long range ballistic missiles, the midcourse phase takes up the largest portion of the flight time and is mostly located outside the Earth's atmosphere. In this phase, the missile trajectory is highly predictable, and it

[1] For information about the acquisition programme, see for instance https://www.fmv.se/projekt/program-sensorsystem-ny/ (in Swedish, accessed 22 April 2026) or Tamara Rozouvan, "Swedish radar programme refocuses on high-end ballistic threats," *Jane's Defence Weekly*, 12 August 2025.

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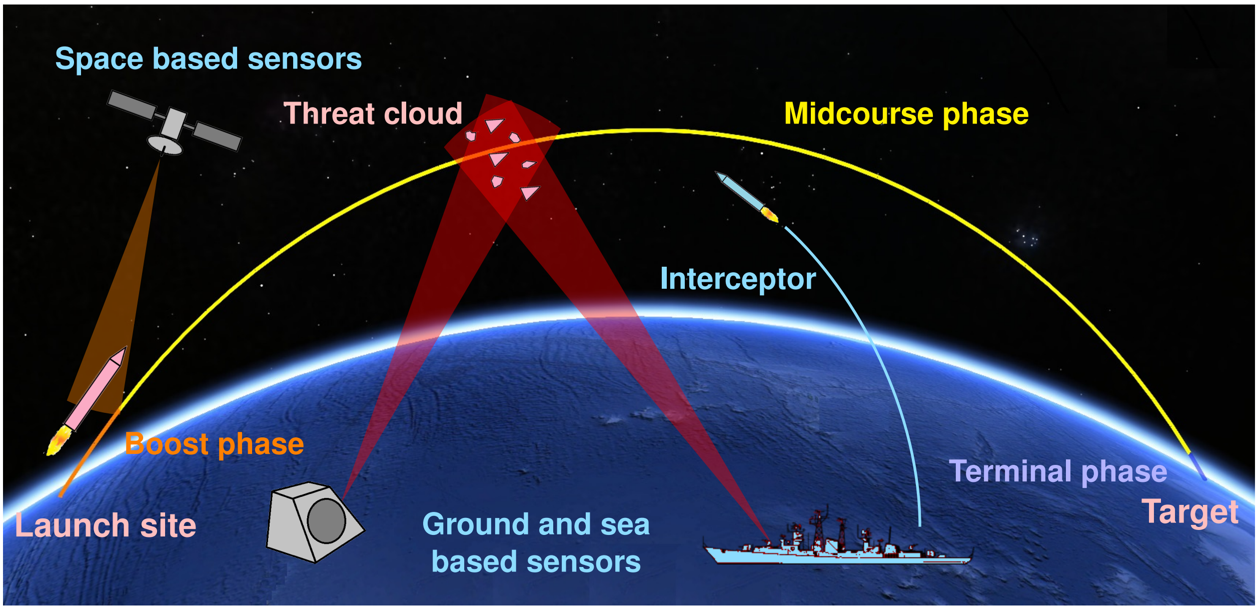

Figure 1. Schematic view of a ballistic missile's trajectory phases and some components of a missile defence system. The defending side can detect and track a missile by means of sensors based in space, in the air or on the surface. After engine burnout, the missile releases its warhead(s) and possibly decoys and other countermeasures. Together with remaining rocket debris, this forms what is known as a *threat cloud*, within which the defending side has to discriminate the actual warheads in order to target them. Interceptors may be launched from sea or land. In the terminal phase, due to the short time of missile flight remaining, interceptors must be launched from locations close to the ballistic missile's target. The defending side additionally requires a sophisticated command and control system to merge sensor data and execute timely interceptor launches.

is relatively straight forward to calculate ahead of time where the missile will be and select a suitable point for intercept. At this point, the missile may have dispersed its warheads and released decoys, forming what is known as a *threat cloud*, which would pose challenges of target discrimination and selection. Since there is no air in outer space, the interceptor will have to hit the ballistic missile warhead directly (known as *hit-to-kill*) in order to destroy it; an interceptor which explodes in the vicinity of the missile (like an anti-aircraft missile) cannot be expected to destroy the missile since the blast is not transmitted through empty space in the same way as in air. The closing speed between the missile and the interceptor will be very high, on the order of several kilometres per second, which demands sophisticated control of the interceptor.

In the terminal phase, while the ballistic missile may be manoeuvring as mentioned above, it is somewhat limited insofar as it is getting close to its target and cannot deviate too far from the trajectory leading directly to the target. In this phase, the missile's speed decreases and its heat signature increases due to interaction with the atmosphere. Both benefit the defender, who however still has to deal with target discrimination and selection. The terminal phase is short, often less than one minute, and an interceptor has to be launched close to the ballistic missile's target in order to have a reasonable chance of reaching the missile in time.

Regardless of trajectory phase, a defender has to detect and track the ballistic missile in order to be able to intercept it. Detection and tracking can be done with radars and infrared sensors based on land, at sea, on board aircraft or in space. Different sensors will be more useful in different phases. The sensor information must be analysed and decisions to intercept must be taken. Orders must then be passed to the interceptors, which need to be launched in time. All this requires a solid communications network as well as a command and control structure. An overview is sketched in Figure 1.

For the current discussion, it is assumed that a ballistic missile defence system exists. The question is whether a radar sensor based in Sweden could contribute in any meaningful way to such a system.

Trajectories and radars

For this analysis, ballistic missile trajectories from launch sites in Iran, Russia, China and North Korea towards targets in Western Europe and North America are considered. To get a reasonably wide spread of trajectories, the following launch sites are used: Khorramabad and Mashhad in Iran, Kozelsk and Novosibirsk in Russia, as well as the Sea of Okhotsk in the Far East, Hami and Hainan in China and Samsok in North Korea. Whether there actually exist missiles in the respective countries'

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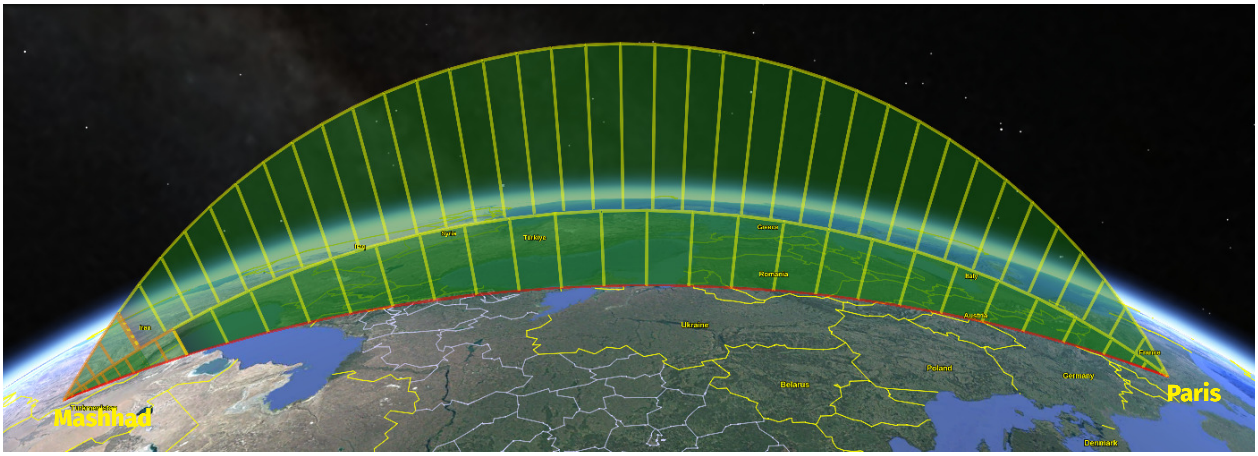

Figure 2. Google Earth view looking south of two ballistic missile trajectories from Mashhad in eastern Iran to Paris in France. The higher yellow arc corresponds to the minimum-energy trajectory between the two locations. The lower yellow arc has an apogee approximately one-third of that of the higher trajectory. The “fence poles” are spaced at 30 second intervals along the track, indicating that the missile moves faster along the lower trajectory. The red line shows the missile’s ground track. The distance from launch site to target is approximately 4 800 km and the apogees are 950 km and 320 km.

arsenals capable of reaching the various targets is not taken into account. While the number of possible targets is great, the analysis is limited to two examples, Paris in France and Washington, DC, in the United States.

Depending on the burn out speed (the speed at the moment the rocket engine burns out) of a ballistic missile, there are an infinite number of possible trajectories between any two points on Earth. A missile shot to its maximum achievable range will follow a trajectory known as *the minimum-energy trajectory*[2] between its launch and touchdown points. A missile with a longer maximum range will have to follow either a higher (lofted) or a lower (depressed) trajectory in order to reach the same target. Since it takes longer to traverse a higher trajectory than a lower one to the same target, it makes sense to shoot the missile along the depressed trajectory, if it has longer than required range.

For each launch site and target, two ballistic missile trajectories are calculated. An example is shown in Figure 2. One trajectory is (approximately) the minimum-energy trajectory. It indicates the highest ballistic missile trajectory likely to be used between the launch site and the target. The other trajectory is chosen to have an apogee approximately one-third of that of the minimum-energy trajectory, as an example of a trajectory taken by a missile with excess maximum range. All trajectories are calculated based on the launch site, target location and selected apogee only, and not on the properties of any particular type or model of ballistic missile. The ranges and apogees of all trajectories are summarised in Table 1.

One of the radars FMV is procuring is the Thales SMART-L MM/F. According to Thales, this radar has an instrumented range against ballistic missiles of 2 000 km.[3] While this does not mean that the radar will detect any target within this range under any circumstances, it does mean that the radar *can* detect targets at up to 2 000 km range. Furthermore, the radar antenna is mounted on a turntable that can be directed horizontally in any direction, and the radar beam can be elevated from the horizon up to zenith. This means that there is

Table 1. Distances and apogees in kilometres for trajectories to Paris and Washington, DC.

From	Paris Distance		Paris Apogee	Washington, DC Distance		Washington, DC Apogee
Samsok, North Korea	8 800 km	high low	1 310 km 440 km	11 100 km	high low	1 310 km 440 km
Hainan, China	9 600 km	high low	1 330 km 440 km	13 500 km	high low	1 160 km 390 km
Hami, China	6 700 km	high low	1 170 km 390 km	11 000 km	high low	1 320 km 440 km
Kozelsk, Russia	2 400 km	high low	540 km 180 km	7 900 km	high low	1 260 km 420 km
Novosibirsk, Russia	5 300 km	high low	1 010 km 340 km	9 400 km	high low	1 320 km 440 km
Sea of Okhotsk, Russia	8 200 km	high low	1 280 km 430 km	8 800 km	high low	1 300 km 440 km
Khorramabad, Iran	4 100 km	high low	850 km 290 km	10 200 km	high low	1 320 km 450 km
Mashhad, Iran	4 800 km	high low	950 km 320 km	10 600 km	high low	1 330 km 450 km

[2]The meaning of minimum-energy in this context is that the specific mechanical energy associated with this trajectory is lower than the specific mechanical energy of any other ballistic trajectory between the two points.

[3]See Thales SMART-L MM/F Datasheet, available at https://lp.thalesgroup.com/SMART-L_MM-F_Datasheet (downloaded 26 March 2026).

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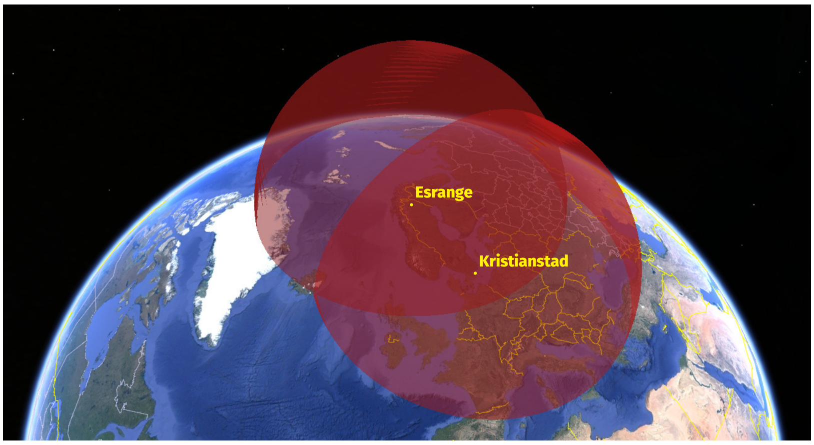

Figure 3. Google Earth view of two 2 000 km radius hemispheres, one centred in the vicinity of Kristianstad in southern Sweden and one at Esrange in the north. Note that since the bottom of the hemisphere is flat, the edges do not reach down to the ground around the periphery.

a hemisphere with a 2 000 km radius above and around the radar's location, within which it could, in principle, detect and track objects.

For the present analysis, two 2 000 km radius hemispheres are calculated and centred on two locations in Sweden, one in the south and one in the north of the country (see Figure 3). The locations are arbitralily chosen, in the sense that they are not indicative of the actual placement planned for the radar stations being acquired by FMV. Sweden is on the order of 1 500 km long from north to south, so the two hemispheres will intersect. For simplicity, no consideration is given to the effects of terrain shadowing or atmospheric refraction. While the Earth's surface is curved, it is considered to be entirely smooth (without hills, buildings or any other obstructions), and radar pulses propagate along straight lines without being affected by atmospheric conditions. This means that while the southern of the two hemispheres reaches as far south as Sicily in the Mediterranean Sea, anything that is not at least a couple of hundred kilometres above Sicily will actually be outside (below) the hemisphere.

Trajectories towards Paris

Displaying missile trajectories towards Paris along with the radar hemispheres (see Figure 4), it is clear that all trajectories intersect the radar hemispheres to various degrees. Table 2 shows the timings involved (in minutes and seconds): flight times for the different trajectories, how long before impact the missile enters the radar hemisphere, and the time the missile spends inside the hemisphere. As it turns out, some trajectories do not enter the northern radar hemisphere. Trajectories from launch sites in Iran are too far south, and the low trajectory from Kozelsk flies below the horizon seen from the northern radar site.

A missile launched from the Sea of Okhotsk towards Paris on a minimum-energy trajectory will enter the northern radar hemisphere almost 13 minutes before reaching its destination and fly within that hemisphere for more than eleven minutes. A missile from Kozelsk on the lower trajectory has a flight time of only ten minutes, but six of those will be spent within the hemisphere of the southern radar.

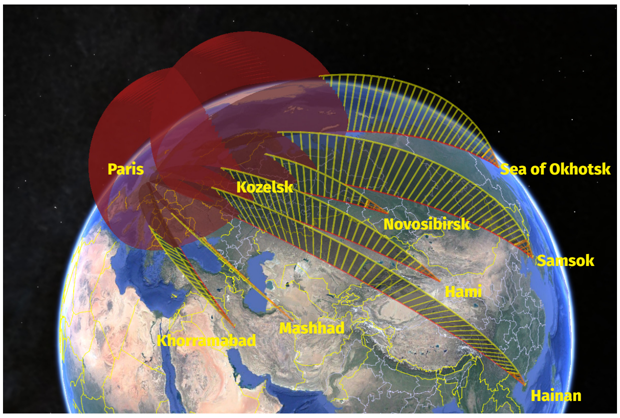

Figure 4. Google Earth view of trajectories towards Paris intersecting the radar hemispheres.

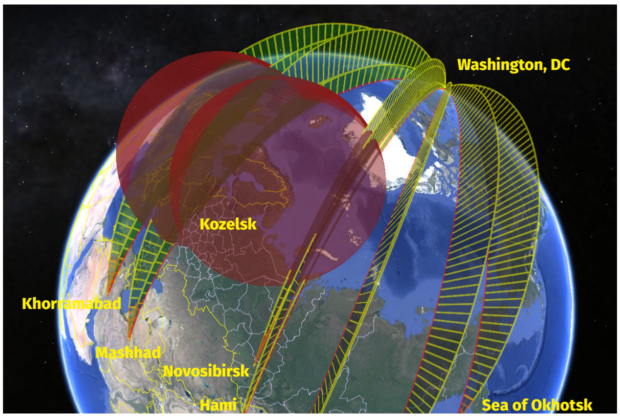

Figure 5. Google Earth view of trajectories towards Washington, DC, intersecting the radar hemispheres.

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Tables 2 and 3. Various times associated with trajectories towards Paris and Washington, DC. All times are in minutes and seconds. The *Flight time* column shows the duration of the entire missile flight. *Entry* shows when the missile enters a hemisphere; the minus sign indicates that it is time left until touchdown (and not time passed since launch). *Duration* is the time spent inside the hemisphere. A long dash indicates that the missile does not enter the hemisphere.

Table 2. Trajectories towards Paris.

From		Flight time	Radar North Entry	Radar North Duration	Radar South Entry	Radar South Duration
Samsok, North Korea	high	31:10	−10:10	8:30	−8:20	7:50
	low	24:20	−10:00	6:50	−8:00	6:40
Hainan, China	high	32:30	−4:20	1:40	−7:30	6:50
	low	25:50	−6:20	1:30	−7:20	6:00
Hami, China	high	26:00	−7:10	4:50	−9:00	8:30
	low	19:40	−8:10	4:30	−8:10	6:50
Kozelsk, Russia	high	14:10	−11:20	6:50	−12:00	11:30
	low	10:00	—	—	−7:20	6:00
Novosibirsk, Russia	high	22:40	−12:30	10:20	−10:50	10:20
	low	16:40	−10:10	7:00	−8:50	7:40
Sea of Okhotsk, Russia	high	30:00	−12:50	11:10	−8:30	8:00
	low	23:10	−11:20	8:30	−8:00	6:40
Khorramabad, Iran	high	19:30	—	—	−8:50	8:20
	low	14:10	—	—	−7:00	5:40
Mashhad, Iran	high	21:20	—	—	−9:10	8:40
	low	15:30	—	—	−7:40	6:20

Table 3. Trajectories towards Washington, DC.

From		Flight time	Radar North Entry	Radar North Duration	Radar South Entry	Radar South Duration
Samsok, North Korea	high	36:40	—	—	—	—
	low	29:50	—	—	—	—
Hainan, China	high	40:20	—	—	—	—
	low	34:40	—	—	—	—
Hami, China	high	35:50	−22:30	5:10	—	—
	low	29:10	−19:20	6:50	—	—
Kozelsk, Russia	high	29:10	−26:20	7:50	−26:50	8:50
	low	22:20	−18:50	6:20	−19:40	7:00
Novosibirsk, Russia	high	32:40	−25:40	7:50	—	—
	low	25:50	−19:40	7:10	—	—
Sea of Okhotsk, Russia	high	32:10	—	—	—	—
	low	25:10	—	—	—	—
Khorramabad, Iran	high	33:50	—	—	−26:40	9:50
	low	27:10	−17:30	3:00	−20:50	8:40
Mashhad, Iran	high	34:40	−24:10	6:50	−26:20	10:00
	low	28:00	−20:10	8:10	−21:00	9:00

Trajectories towards Washington, DC

Looking at the trajectories towards Washington, DC (Figure 5 and Table 3), it is seen that trajectories from the Far East (Samsok, Hainan and the Sea of Okhotsk) all pass outside the Swedish radar hemispheres. While the lower trajectory from Khorramabad to Washington, DC, passes through the northern radar hemisphere for a couple of minutes, the corresponding higher trajectory actually passes over the hemisphere at its southern edge (both trajectories spend around nine minutes inside the other radar hemisphere).

While all trajectories towards Washington, DC, leave the potential Swedish radar coverage well before they reach their target, several trajectories enter the radar hemispheres 20 to 25 minutes before touchdown and spend up to ten minutes inside. The low trajectory from Mashhad, as an example, has a total flight time of 28 minutes. With 21 minutes still to go, it enters the southern radar hemisphere and remains there for a full nine minutes.

Discussion

Ballistic missile defence is a very complex undertaking. It requires sensor networks, interceptors and command and control systems. For best results, sensor coverage from launch to intercept is necessary.

Based on the simplified assumptions, the above analysis of ballistic missile trajectories and radar hemispheres has shown that many potential ballistic missile trajectories would pass within range of high quality radar sensors located in Sweden. While every situation is unique – and the above analysis has not taken into account such aspects as target radar cross section or speed, possible countermeasures on the part of the ballistic missile, meteorological conditions or a range of other complicating factors – it is clear that high performance radar sensors in Sweden would be geographically well placed to contribute to that launch-to-intercept sensor coverage. Such radars could cover significant portions of many ballistic missile trajectories aimed at targets in Western Europe and North America, providing radar tracking data that could be fed into the command and control system and merged with information from other sensors, either filling gaps in the coverage or improving the quality of existing tracks.

Before such a contribution could be realised, there are a number of open questions that require further study. In addition to the technical details that need to be analysed (probabilities of detection of various targets, command and control issues, and so on), there are important security and defence policy issues for Sweden to address, if it were to enter into a collaborative BMD programme with NATO allies. As with any defence materiel programme, there are also financial implications to consider. Geographically, however, it is clear that the possibility for a Swedish contribution is there.

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