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New Infrasound Monitoring Capabilities in Sweden

Jon Grumer, Monika Ivandic, Henrik Olsson, Patrik Kekkonen, Anders Ringbom & Michael Roth (SNSN, Uppsala University)

FOI - Swedish Defence Research Agency

INTRODUCTION AND MAIN RESULTS

Infrasound sensors have been installed for national purposes at the site of the Hagfors seismic array in Sweden, co-located with the central elements of the International Monitoring System (IMS) auxiliary station (AS101). Furthermore, FOI is building a new seismo-acoustic array in northern Sweden, and initiatives are also taken to modernize older existing, national infrasound stations in collaboration with other national authorities.

The addition of new national acoustic sensors strengthens Swedens national ability to detect and analyse both natural and human-made events across seismic and infrasound domains.

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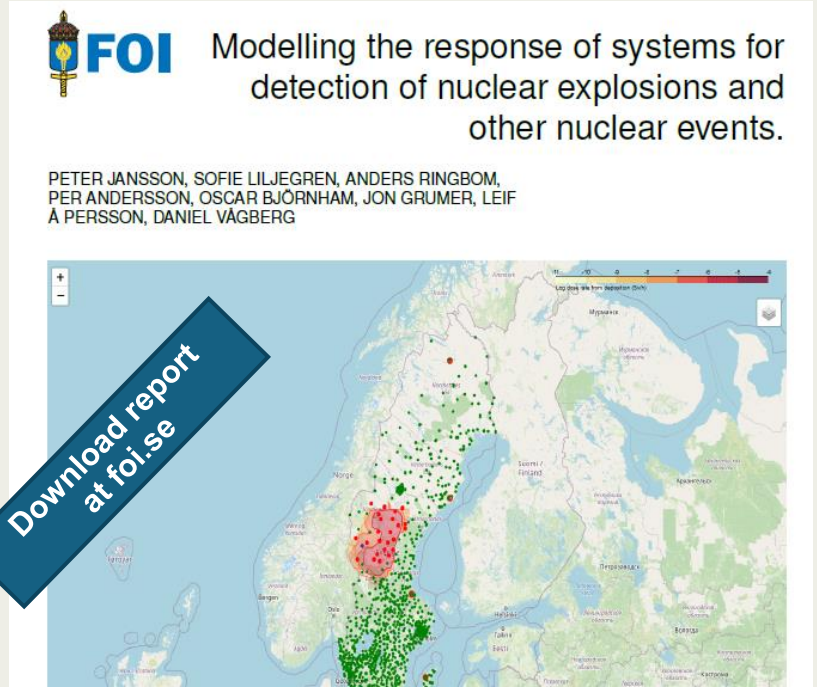
Motivation

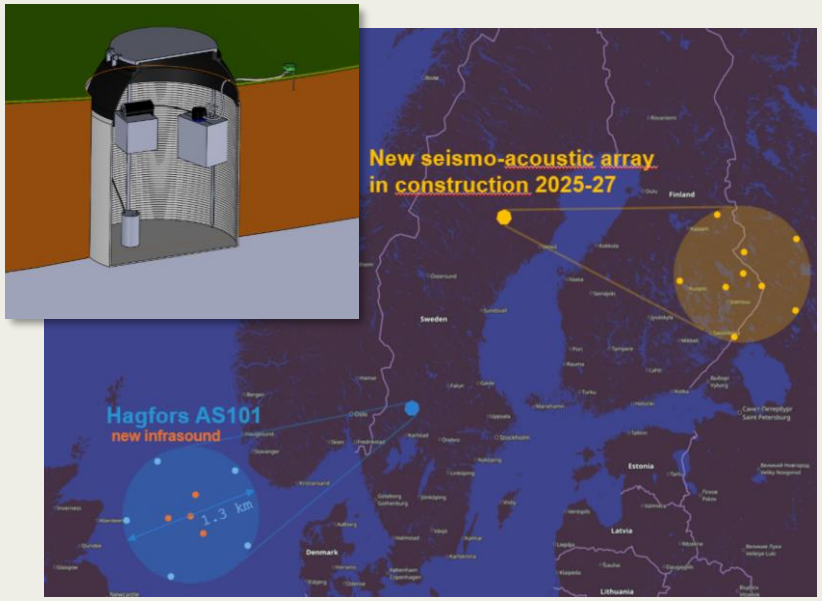
- Recent network response studies performed at FOI strongly point to a necessary increased national capability for nuclear weapons detection, especially in the infrasound sensor domain.
- These studies where carried out with the in-house software **NEMOS** - a tool for simulating sensor network responses from nuclear explosions, assuming a variety of sensor technologies (**P3.4-517** *Ringbom et al.*)



Summary of current activities

- **Hagfors upgrades** Hyperion IFS-3102 infrasound sensors were installed in September 2024 at Hagfors in Sweden, co-located with the central elements of the International Monitoring System (IMS) auxiliary seismic station (AS101).
- The seismic instrumentation at the Hagfors station has recently undergone a major upgrade, now comprising Güralp T3-120 sensors and Affinity digitizers. (**P. 4.2-721** *Olsson et al.)*

- **Increased wo/man power** The waveform staff working with nuclear weapons related issues at FOI has during the last year been increased from one to 5-6 permanent researchers - including seismologists, geophysicists and one meteorologist. Close interaction with the staff working with radionuclides is strongly encouraged.
- **Software and analysis** We are re-building our seismo-acoustic analysis pipeline from scratch with modern tools and data formats.
- **Collaborations** Old and new, national and international, collaborations are (re-)established.



- **A new array station** During 2025-2027**,** a new seismo-acoustic array is going to be constructed in Västerbotten county, in mid-northern Sweden, as a necessary complement to the other Nordic array stations, and other existing sensor infrastructure.
- The array will consist of ca 10 elements, equipped with 3-component seismographs and infrasound sensors.

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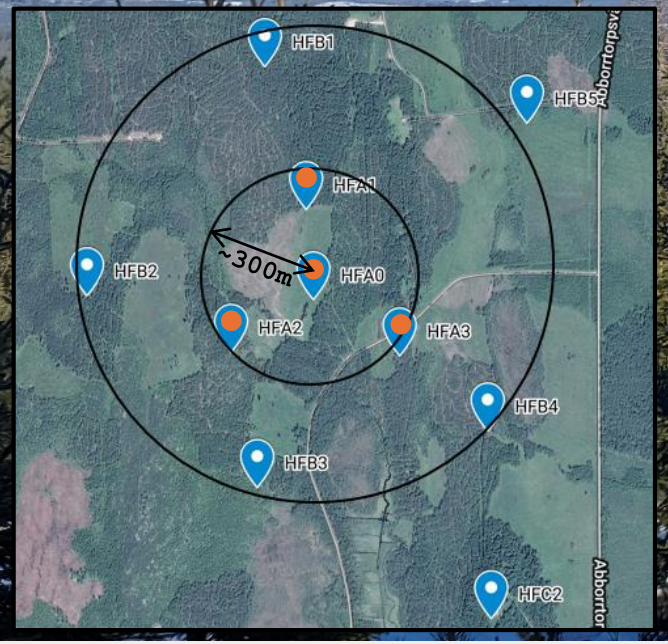
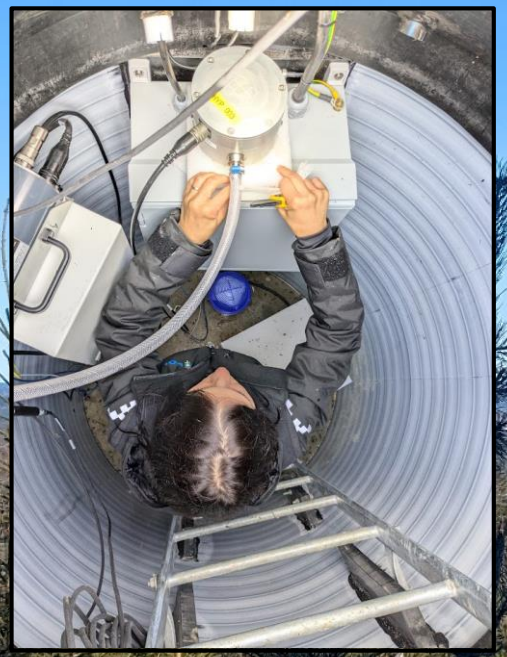
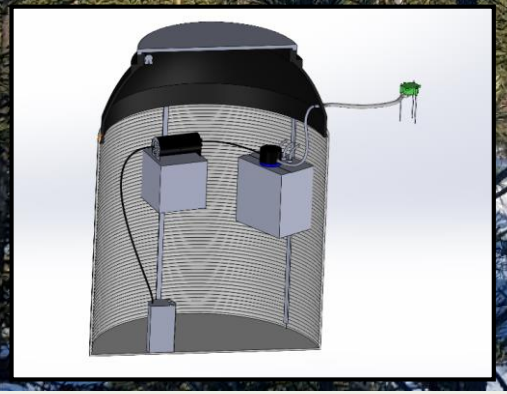
Infrasound upgrade of the Hagfors station

HFS central facility, since late 60's



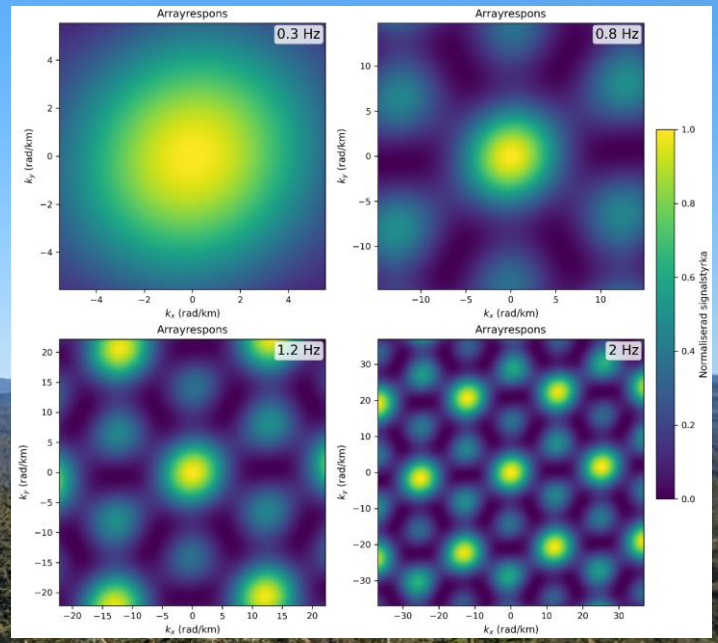
Hyperion IFS 3102





Forested area
→ single-inlet design

Response functions
for inner 4 elements



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Noise condition analysis

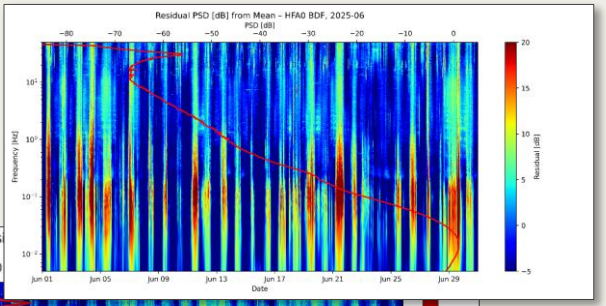
- A time–frequency overview of the station's noise conditions, with both variability (residuals) and the long-term mean noise spectrum, has been carried out.
- All hourly PSDs are archived, and monthly or multi-month overviews are generated
  - The plots to the right show how each hourly PSD deviates from the monthly mean (blue = below, red = above).
  - The red curve shows the average PSD spectrum for the whole period.

Conclusions

- Microbaroms (ca 0.2 Hz) show seasonal variation with a strong peak in winter/early spring.
- Noise bursts linked to storms and frontal passages are concentrated below ~0.2 Hz but extend into higher frequencies, often persisting for several days. These events correspond with wind observations from Hagfors on 21–23 October, 17–22 November, and 25–28 November.
- High-frequency noise (>1 Hz) is intermittent and likely tied to local sources (wind, human activity).
- The average spectra (red lines) show secondary peaks above 1 Hz that may affect detection of local infrasound events.

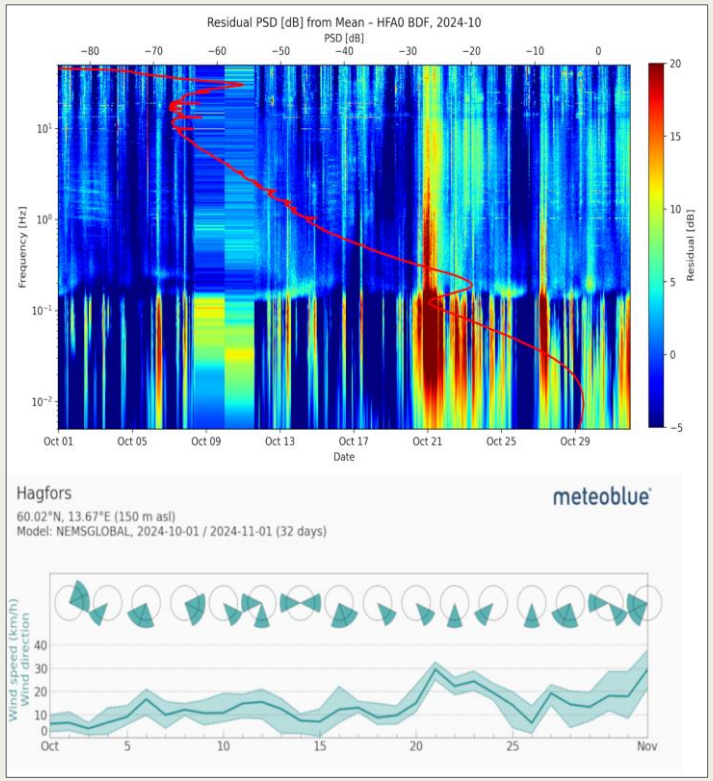
Residual Infrasound PSD at station HFA0 with local wind

June 2025

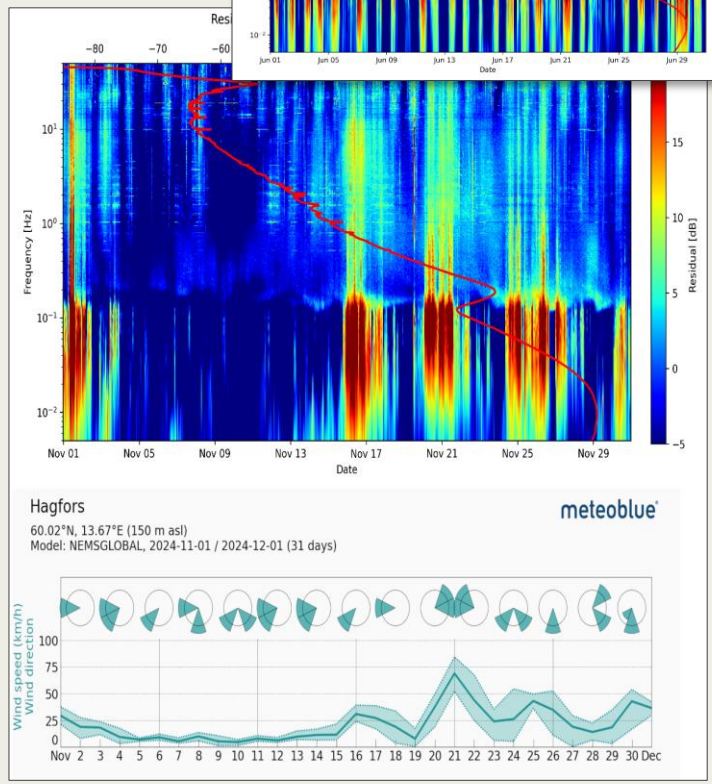


Residual PSD plots

Meteorological data



October 2024



November 2024

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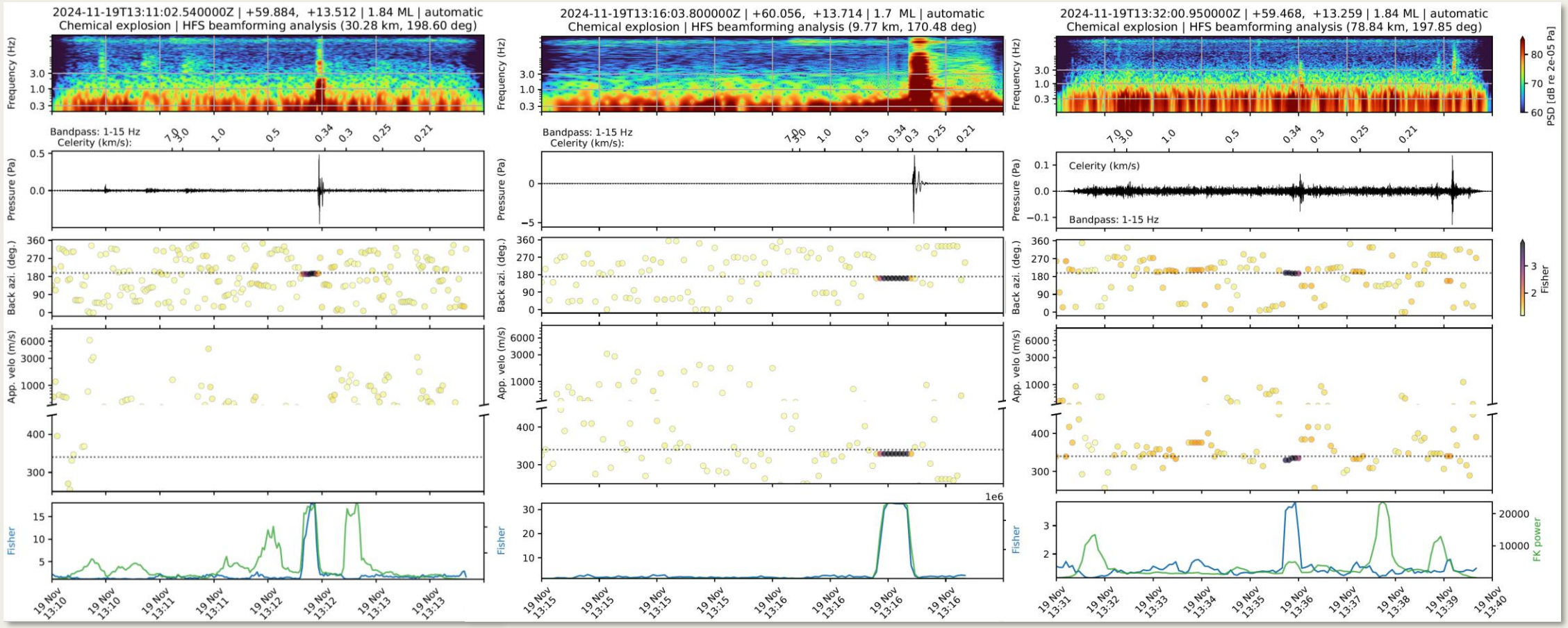
Initial tests – local quarry blasts

- Test analyses of three local quarry blasts, south of the Hagfors array at 10, 30 and 80 km distances.
- Separate quarries within a 30-minute period on Nov 19 2024.
- The seismic location and magnitude are taken from the automatic analysis of the Swedish National Seismological Network
- Infrasound array analysis inspired by J. Assink's (KNMI) ROSES 2021 tutorial on Seismoacoustic Processing
- Detection works well - Fisher ratio shows a clear advantage over standard FK power

SNSN Svenska nationella seismiska nätet
www.snsn.se

Remote Online Sessions for Emerging Seismologists



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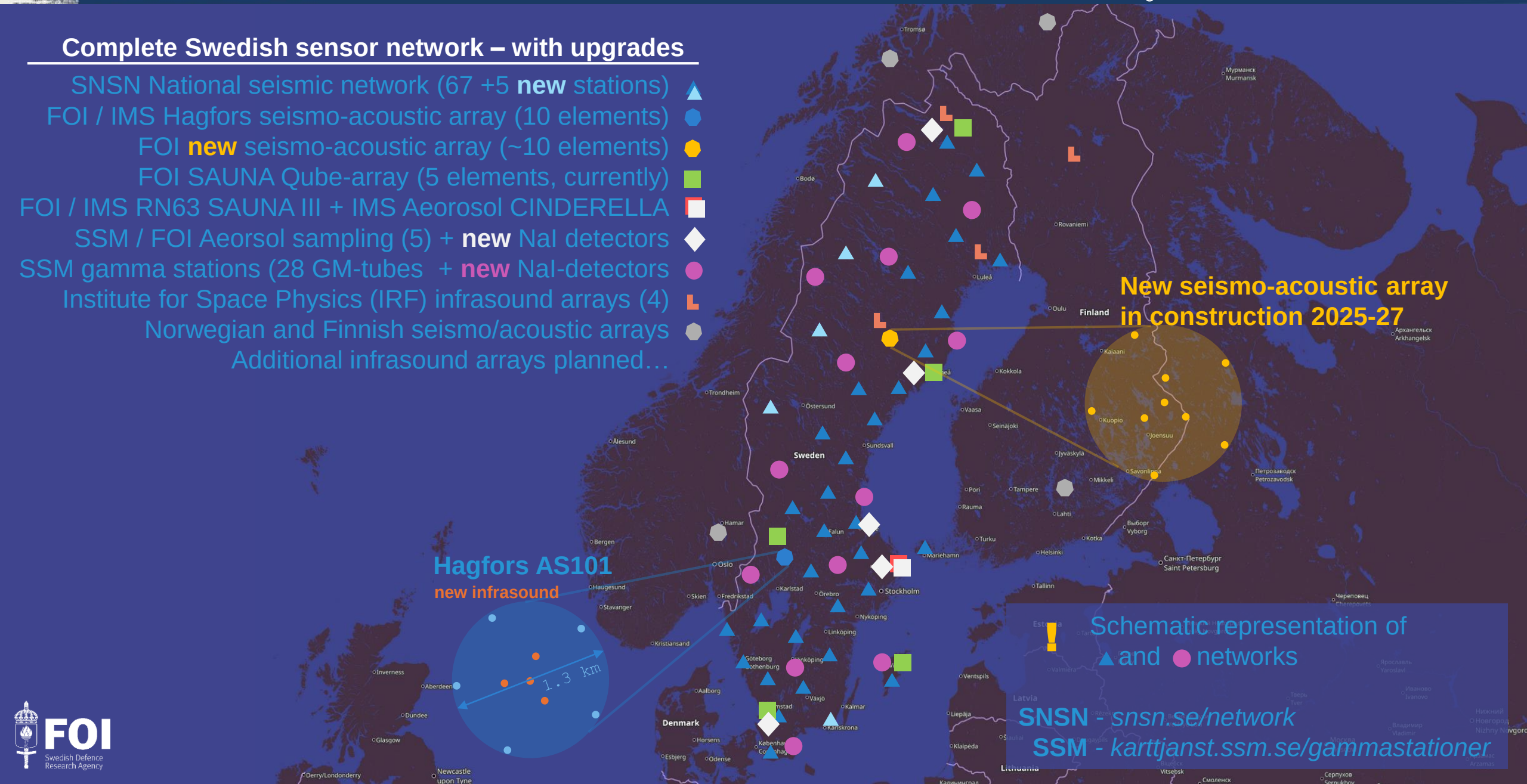
Complete Swedish sensor network – with upgrades

- SNSN National seismic network (67 +5 **new** stations)
- FOI / IMS Hagfors seismo-acoustic array (10 elements)
- FOI **new** seismo-acoustic array (~10 elements)
- FOI SAUNA Qube-array (5 elements, currently)
- FOI / IMS RN63 SAUNA III + IMS Aeorosol CINDERELLA
- SSM / FOI Aeorsol sampling (5) + **new** NaI detectors
- SSM gamma stations (28 GM-tubes + **new** NaI-detectors
- Institute for Space Physics (IRF) infrasound arrays (4)
- Norwegian and Finnish seismo/acoustic arrays
- Additional infrasound arrays planned…



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