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# (M)SIL – recent updates and operation at the Swedish National Seismic Network

**Peter Schmidt** and the SNSN team



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## **Brief history of (M)SIL**

- 1988, the South Iceland Lowland, SIL, system was initiated as a joint Nordic effort to construct an automatic near-real time data acquisition and event detection system
- 1990 – 1991, SIL system implemented in Iceland by IMO
- 2000 Aug., SIL system implemented at SNSN
- 2013 – 2014, Multi-SIL, MSIL, developed
- 2014 summer, MSIL put in operation at IMO
- 2014, Auxiliary scripts for running/maintaining MSIL data handling and phase detection developed at SNSN
- 2019, code base of MSIL data handling and phase detection revised and updated
- 2019 Sep. – present, MSIL gradually phased in at SNSN

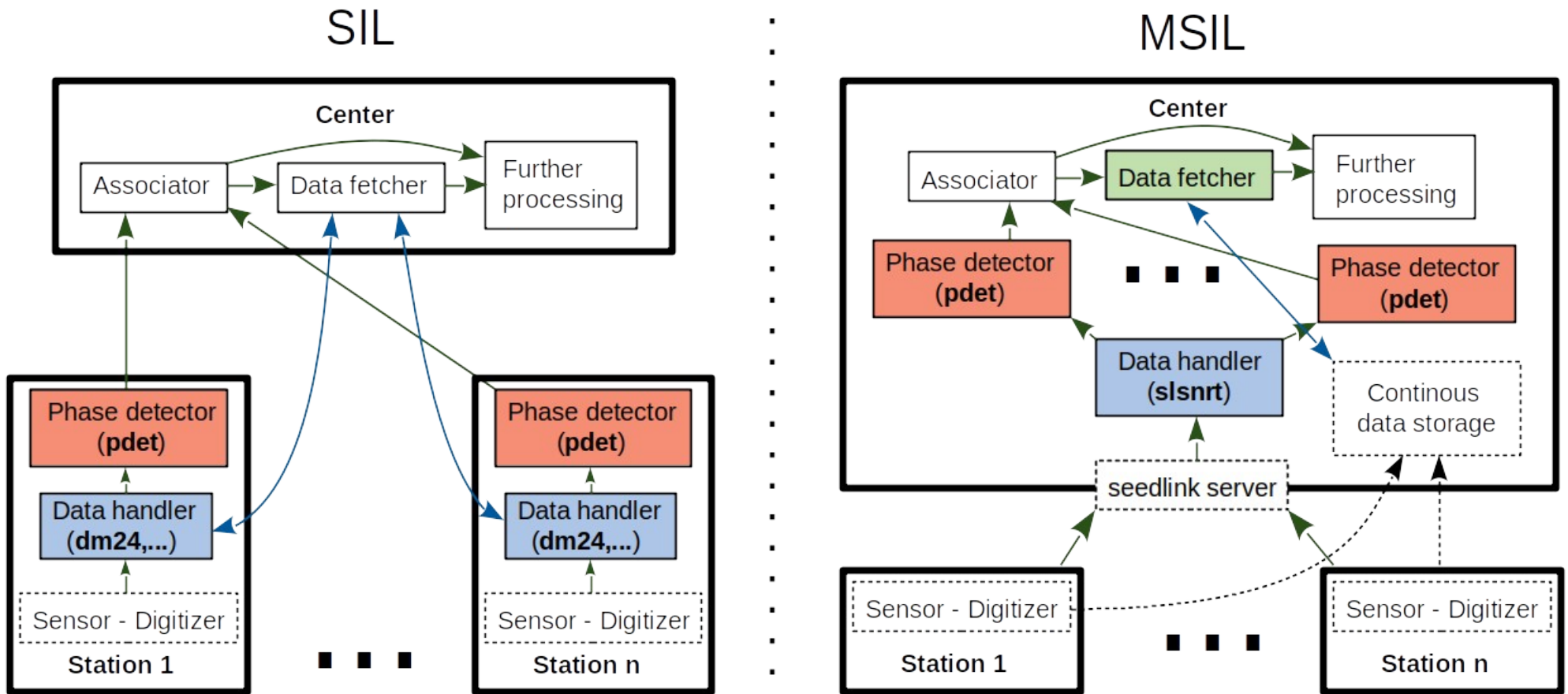


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## SIL vs MSIL



Dashed lines & boxes – not part of (M)SIL  
Colored boxes – modified parts in MSIL



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## slnrnt (data handler)

- C-source command line utility based on slinktool by Chad Trabant, IRIS
- Modified to maintain ring buffers in SHared Memory, SHM
- Options to inspect/monitor current content of SHM, e.g.

```

sil@center$ slnrnt -l 0x8000 bju
  station chn  sps          start          ---          end
    bju    Z   100  2020-08-12 11:43:01.000 --- 2020-08-12 13:23:01.000
    bju    N   100  2020-08-12 13:13:15.000 --- 2020-08-12 14:53:15.000 (2 gaps)
    bju    E   100  2020-08-12 13:12:45.000 --- 2020-08-12 14:52:45.000 (2 gaps)
sil@center$ slnrnt -m 0x8000 bju
Network metadata: -----
MAGIC: 1000003
SHM id: 7
  pid: 25162 (owning process)
  nsta: 20
  free: 0
Station metadata: -----
  code: bju
  sps: 100
  pid: 25162 (owning process)
Channel metadata: -----
Components:           Z           N           E
Buffer size:         600000     600000     600000
Buffer filled:       Yes         Yes         Yes
First write: 2020-08-11 14:46:08 | 2020-08-11 14:46:10 | 2020-08-11 14:46:07
Oldest data: 2020-08-12 11:43:01 | 2020-08-12 13:13:15 | 2020-08-12 13:12:45
Newest data: 2020-08-12 13:23:01 | 2020-08-12 14:53:15 | 2020-08-12 14:52:45
Data gaps:           0           2           2
-----
sil@center$

```



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## **slnrnt** (data handler)

### Updates 2019 (selection of):

- Compiles on 64 – bit system
- Cleaned up and modularized code base related to SHM handling, removed options controlling action of slinktool but not needed by **slnrnt**
- Sealed memory leakage during run-time and upon termination
- Replaced previous read/write protection by of semaphores
- Cleaned up SHM data model
- Implemented configurable size of checked SHM segment to fit configured number of stations
- Added method for tracking data gaps
- Added configurable method for handling data backfill
- Added guard against future data
- Added options to inspect/monitor data segments currently in SHM
- Updated configuration file syntax
- Expanded logging and added user configurable verbosity levels

### TODO:

- Do not allocate space for channel descriptors not accepted by seedlink server, alternatively implement regularly re-checking if data is available
- Update configuration file syntax for additional optional station meta data, e.g. sensor orientation
- Move size of channel ring buffers from hard-coded parameter to configuration parameter
- Review SHM data model to minimize SHM memory required



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## **pdet** (phase detector)

- Command line utility handling 1 station at the time
- 3-component C-source STA/STA (yes!) phase detector capable of tracking up to 20 phases simultaneously
- Runs on real time data read from SHM or offline data from either our in-house Seismic Waveform Data server or gcf data files on disc.
- Makes use of two neural networks, one for phase type discrimination (P or S) and one for phase verification (phase or not)
- Produces short (128 kB) compact phase logs containing:
  - **Phase:** onset, duration, type, polarity, seconds to previous/next and position (if multiple phases are tracked)
  - **Single component:** signal/noise level, DC-level, corner frequency, signal peak-2-peak value, quality of DC-level and corner frequency estimates
  - **3 – component:** coherency, azimuth, apparent velocity and associated uncertainties
  - **Neural networks:** phase type, phase verification
  - Network, station, detector
  - Detector settings (partially)
- Configurable to any (integer) sampling rate



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## **pdet** (phase detector)

### Updates 2019 (selection of):

- Compiles on 64 – bit systems
- Major clean-up and re-structuring of code base
- Removed memory leakages during run-time and upon normal termination
- Fixed several write-out-of-memory issues
- Removed termination of detector when no data has been retrieved for ~10 minutes
- Adjusted data vector used for spectral computations and polarity estimate to include phase arrival
- Adjusted size of vector used for spectral computations to be a power of 2
- Removed requirement that utility is run by user sil
- Added handling of data gaps
- Updated configuration file syntax and moved of most configuration parameters from hard-coded parameters to configuration file
- Updated instrument response removal algorithm to handle 0 poles and 0 zeros responses
- Added computation of coefficients for simulation of Lennartz 1 Hz instrument (code by Einar Kjartansson) to be tunable to data sampling rate (to run on any (integer) sampling rate)
- Added offline processing using in-house data server or gcf files
- Expanded logging and added user configurable verbosity levels

### TODO:

- Add user configurable filter parameters
- Investigate known oddity of gap duration reported to log files
- Review spectral and 3-component analysis part of the code (mostly un-touched at present)
- Add offline data source miniseed files
- Replace real-time data source **slnrt** by retrieval of data directly from seedlink server



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## **pdet** (phase detector)

### phase detection:

- Input data prepared by simulating 1 Hz Lennartz instrument, bandpass filtering, and first difference filtering.
- Phase-detection using STA/STA with 100 samples adjacent windows, triggering at 3 – component  $S/N > 5.0$  for first phase, if signal energy decays sufficiently fast (maximum squared amplitude, MSA, in window after signal window  $< 100$  MSA in signal window)
- Triggering on sub-sequent phases if horizontal  $S/N > 2 \times 5.0$  or horizontal signal increase by factor 1.2 over a sample
- Phases tracked until  $S/N \leq 1$  for last phase
- Phases discarded if duration  $< 20$  samples
- Phase type set to **p** if vertical MSA  $> 2 \times$  horizontal MSA (1 x for second or latter phases) in signal window, else **s**
- Signal window scanned for phase onset at trigger time. Algorithm used depends on phase type and first or latter phase.





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## **pdet** (phase detector)

### phase analysis:

- Input data prepared by removal of instrument responses
- DC-level and corner frequency estimated by fitting spectra to Boatwright model
- Polarity determined from sign of maximum S/N ratio using window lengths equal to half period of dominant frequency in spectra, evaluated over 16 samples before and 16 samples after phase onset.
- Coherency, azimuth, apparent velocity and associated uncertainties estimated using 3-component analysis using methodology of Roberts & Christoffersson (1990) and a 5-15 Hz bandpass (butterworth) filter



## Auxiliary scripts

### msild

- Daemon-like bash script, reads configuration files of **slsnrt** and **pdet** and handles (re-)start and stop of processes for real-time processing.
- Defines paths and seedlink servers to use.

#### TODO:

- Update to handle multiple seedlink servers

### msild\_config

- Python script to update configuration files for slsnrt and pdet and terminate affected instances (terminated processes will be re-started by msild)
- Retrieves station meta data from Seismic Meta Data server at specified time

### silDog

- Assembles and reports on statics on picked phases and data gaps registered by **pdet**
- Reruns analysis offline if archived data is available in gaps registered by **pdet**

### SHMpopulate

- C-source utility to populate SHM step by step. Mainly intended for debugging purposes



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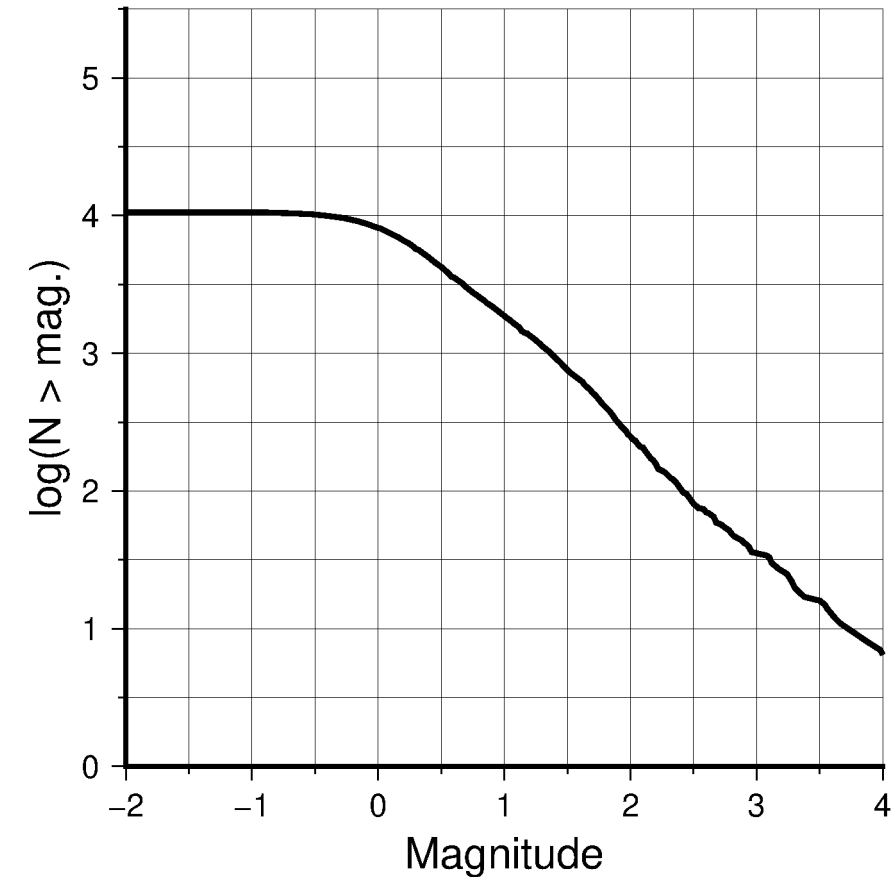
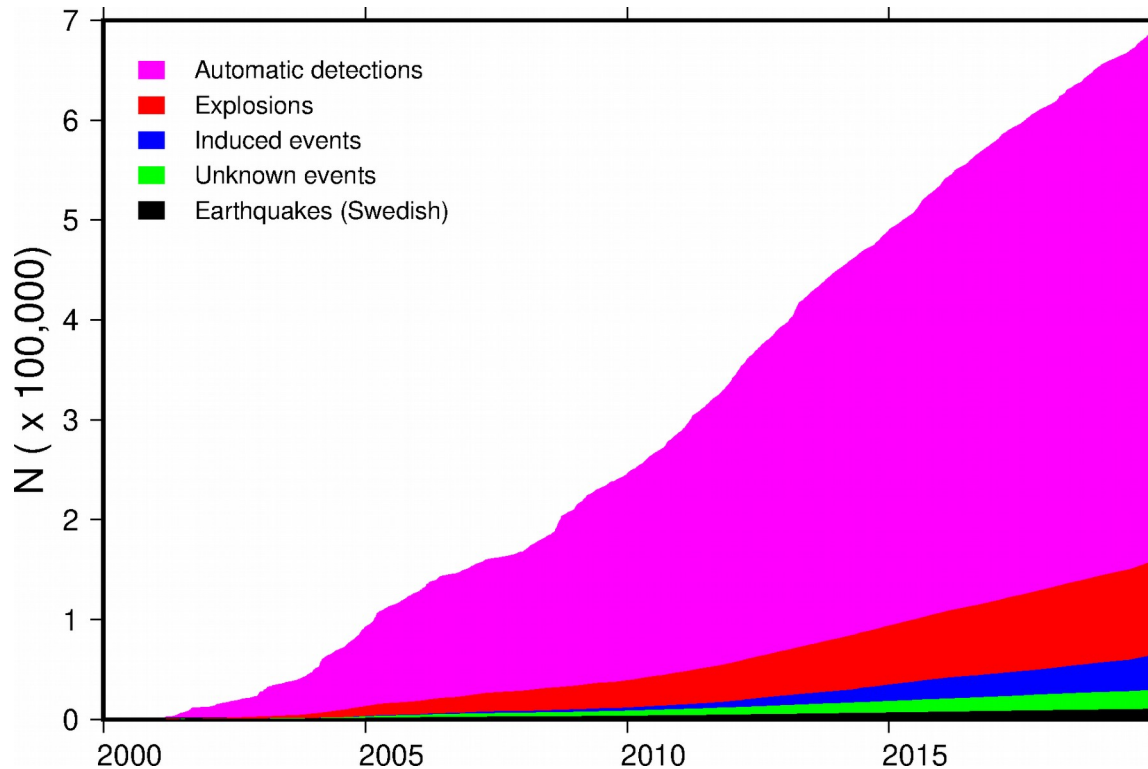
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## 20 yr anniversary @ SNSN

- 102,618,734 Automatic phase detections
- 717,374 Automatic detections
- 10,879 Earthquakes
- 38,944 Induced events
- 98,785 Explosions
- 20,362 Unknown events





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## Summary and concluding remarks

- Code base of data acquisition and phase detection in MSIL has undergone a major overhaul during 2019
- Changes to algorithms has resulted small differences in picked phases (mainly associated with fictitious energy transients due to data gaps and use of ring buffers) as well as computed spectral parameters.
- MSIL has been running stable at SNSN since Sep. 2019 (no crashes)
- Data handler and phase detector can now (in principle) run on any (integer) sampling rate
- Phase detection based on STA/STA with 100 samples windows S/N threshold of  $(2 \times) 5.0$  and criteria that energy decays sufficiently fast. This makes detector less sensitive to emergent phases and teleseisms
- Phase type discrimination both using energy ratios and using neural network
- Phase verification using neural networks
- Ongoing work to update neural networks
- MSIL has gradually replaced SIL at SNSN, currently for 60 out of 68 stations MSIL are used in production. Remaining stations are also analysed by MSIL and a migration from SIL to MSIL is planned.
- Phase detection algorithm and/or settings used at SNSN not the same as those used at IMO.