# STS-1 and STS-2 Sensors in National Seismic Networks

## Application Note #40

**Amadej Trnkoczy**

**Kinematrics SA**
Z.I.Le Tresi 3
CH-1028 Preverenges
Switzerland

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## Introduction

During goal setting phase and feasibility study of a new national or regional seismic network many countries encounter the question of proper seismic sensor selection. In a legitimate desire to purchase modern technology, which means nowadays digital equipment and broad band seismic sensors, many desire 'the best' available on the market. However the term 'the best' is closely related to the goals of the new network and also with the required conditions in which 'the best' technology will generate adequate results. This application note is intended to help in clarifying the question which sensor to select between two of probably the most broadly used broad band sensors on the market – Streckeisen STS-1 and STS-2 seismometer.

# STS-2 Very Broad Band Seismometer

The STS-2 is very broad band (VBB) seismic sensor capable of recording a very broad band of frequencies of seismic signals. The low and the high corner frequencies of the velocity-proportional output are 120 s $\rightarrow$ 0.00833 Hz and 0.02 s $\rightarrow$ 50 Hz (at ±15% change in amplitude frequency response function between 20 and 50 Hz). The low corner frequency  is essentially a two-pole +12 dB/octave high pass filter and therefore seismic signals with frequencies lower than 0.0833 Hz can be recorded and analyzed. Seismic vault design, local seismic noise conditions, and the quality of sensor installation and thermal insulation largely determine the lowest recording frequency where signal to noise ratio is still satisfactory.

The STS-2 dynamic range is >140 dB from 0.001 Hz to 5 Hz (relative to clipping amplitude in peak RMS 1/2 octave $m/s^2$). The sensor's dynamic range -- between 0.1 and 10 Hz, where regional events produce most of their high amplitude seismic signal -- is superior to that of the STS-1 seismometer. Its sensitivity is $G_o$ = 1,500 Vs/m. Due to its design (capacitive bridge displacement transducer), it has an excellent clipping level of 13 mm/s, which typically corresponds to 0.1g at short periods around 0.1 sec, which is also better than the STS-1. As a VBB sensor it is suitable for recording local, regional earthquakes, body and surface waves, and general tele-seismic uses. Due to limitations at high frequencies, it is less suitable for local seismicity studies and micro-earthquakes recording, however the latest research shows that a sensor like the STS-2 in the near-field of a local event does in fact produce excellent seismic information.

The STS-2 requires careful seismic site selection, although it allows for a wider variation in vault temperature (± 10% without re-centering of mass position) and is much simpler to install than the STS-1. Special shielding is not normally required unless one would like to take advantage of the extreme low frequency potentials of the sensor. The STS-2 must be installed very carefully for a high frequency range of 10 to 50 Hz or its transfer function may be compromised. Care must be taken to assure that the stable transfer function is known at the high frequency end of the sensor's pass-band for proper signal waveform analyses.

## STS-1 Very Broad Band Seismometer

The STS-1 was designed in 1976 and is a VBB seismometer mainly dedicated to global seismology and strong earthquakes. Its low frequency corner is at 360 s → 0.0028 Hz (approximately one-and-a-half octaves lower than the STS-2). It is essentially a two-pole +12 dB/octave high pass filter and therefore seismic signals with frequencies lower than this can be recorded and analyzed. Its high frequency end of pass-band is fairly limited, having its corner frequency at 10 Hz (approximately two-and-a-half octaves lower than the STS-2). Total frequency pass-band is approximately one octave narrower than that of the STS-2. The high frequency deficiency makes the sensor unsuitable for local seismology studies and poses some limitations in regional seismology as well, but it has no effect in tele-seismic studies, which are the main goal of the sensor design.

Its sensitivity is 2,400 Vs/m, approximately the same as the STS-2. Its dynamic range is better than 140 dB in the frequency range of 0.0001 Hz to 10 Hz relative to 1 [$m^2/s^3$] (not relative to the sensor's clipping level). Its clipping level equals 8 mm/s signal over the period band from 360 s to 0.1 s. The sensor resolves ground seismic noise of the LNM model (Peterson & Tilgner, 1985) from 3 Hz to 0.3 mHz. This, of course, presumes an excellent site, seismic vault, and installation. The sensor is specially suited for studies of very low frequency surface waves, Earth tides, free oscillations of the Earth, slow and silent earthquakes. Any advantages the STS-1 may have over the STS-2 do not apply to local or regional seismicity studies and most definitely not to seismic alarm or warning systems.

Special thermal enclosures (styrofoam), pressure (glass bell, 5 kg, vacuum-packed), and EMI shielding (permalloy, 1.8 kg) and glass-plate installation base (9 kg) must be used to take full advantage of the low frequency characteristics of the STS-1. Maximum $5^0$ C operational temperature changes are allowed, requiring very stable temperature control in seismic vaults. Special knowledge about geology, seismo-geology and seismic noise properties is required for proper selection of seismic sites. Extensive noise measurements and proper seismic vault design are also prerequisites before the benefits of the STS-1 can be fully utilized. Seismic vaults must be carefully designed so that mechanical deformations and tilts caused by thermal and air pressure changes don't degrade the extreme low-frequency characteristics of the STS-1. Experience shows that seismic site selection and proper seismic vault preparation could cost up to $100,000 per site. Without these expensive and time-consuming measures in site selection and preparation, the STS-1 could be easily out-performed by an STS-2 at the same seismic station.

## Conclusions

The STS-1 and STS-2 are very comparable VBB seismic sensors from many points of view. The two differ in that the STS-1 has better properties at the low-frequency end and significantly less favorable characteristics at the high-frequency end. In regard to installation and environmental conditions required for proper functioning, however, the STS-1 is a much more demanding sensor than STS-2.

Installing an STS-1 seismometer rather than an STS-2 makes sense only if seismic signals around 1 mHz and lower are of explicit interest. This frequency range is required for some, though not all, relatively unique studies related to deep Earth structure and global seismology. These scientific goals have nothing in common with regional and local seismicity studies for a particular country, nor are they useful for earthquake hazard assessment studies.

The STS-1 sensor can record seismic waves with extremely long wavelengths -- on the order of 5,000 km. Therefore, all but the very largest countries need very few seismic stations equipped with an STS-1 type sensor. Installation of several STS-1 seismometers within distances less than the wavelengths of the signals studied makes little sense. At the very least, it is an extremely expensive approach to global seismology. At present, global seismology suffers more from unequally spaced VBB sensor distribution (ocean and polar regions are inadequately covered) than from an insufficient number of them. For many small countries, STS-1 type seismic station(s) will contribute little to global seismology and nothing to local seismology. It is likely that only educational purposes for global seismology would be well served by such a system.

If regional and local seismicity is the main interest, then acquiring seismic data with an STS-1 seismometer is highly inefficient. It requires an thorough feasibility study, costly site preparation and installation of an additional three-component sensor to cover short period signals of 1-50 Hz or higher -- a range in which short period seismometers do an excellent job.

Perhaps the most important issue to remember is that poor site selection or preparation or improper sensor installation can easily destroy all the characteristic benefits of an STS-1 seismometer. With modern, high quality seismic equipment, any seismic station is only as good as station site conditions allow. The era when technical deficiencies of seismic equipment limited the sensitivity and general quality of the recorded seismic data is definitely over.