That depends on what you are looking for.

GTSM instrumentation has very broad bandwidth. To get data of equal quality across the full available range of amplitudes (0.1 nanostrain to 1 millistrain) and periods (0.05 seconds to several years) requires, as well as a good instrument, a good site in a well planned array, top quality drilling, good borehole preparation and fluid control and a perfect installation procedure. Some sites are not suitable for very long period data, but have excellent performance in the seismic band and so on, because borehole strain data quality depends strongly on the local environment which includes the geology, the borehole quality and uniformity, the near field hydrology, the deployment procedure, the coupling factors and nearby cultural noise sources.

Below are some of the performance criteria which can be used to determine the suitability of the instrument/site combination for your specific needs.

General Performance Criteria

Before advanced processing it is wise to evaluate the site performance in relation to the target of a particular investigation. This evaluation should include at least the following parameters:

1. **The type of drilling used at target depth**: Best practice here is coring. For the PBO array, an early recommendation of the Standing Committee aimed at saving resources directed Unavco to use alternate procedures (rotary/hammer drilling). There are several installed systems which are located in hammer drilled sections of the borehole, and though this does not necessarily compromise the data for some studies, there may be impact from the vertical non uniformity of the borehole or from the quality of the surface layer of the rock due to radial fracturing during drilling. Elimination of coring brings the need to select target depths from geophysical logs which brings significant un-resolvable uncertainty on the actual quality and modulus of the rock at the target depth, and further uncertainty on the vertical uniformity at the site.

2. **The state of compression of the borehole:** The instruments are installed in an expansive grout, so there should **always** be net compression on the instrument. Particular channels may be lesser compression than the average or even in expansion if the predrilled material was in shear. If there is no overall compressive areal strain, the quality of coupling will probably vary significantly with time which is not a problem for studies at the high frequency end of the band, and often comes with an increased sensitivity to atmospheric pressure. In the worst case where all channels show expansion, the instrument may ultimately become uncoupled from the rock mass. Fortunately, the borehole normally creeps in a compressive sense due to the vertical stress at the target depth. The instrument is usually softer than the original rockmass, and it sometime occurs that an instrument not in compression initially will ultimately begin to be compressed by the borehole's progressive visco-elastic creep towards the instrument.

3. **Exponential curing profile:** Within the first 30 days of installation, well coupled systems begin to show net compression and usually exhibit an exponential compressive profile extending to a linear long term drift. This may not be strongly evident for holes which were drilled a year or so before the deployment occurred. In this case the borehole compression towards equilibrium with the local environment may be well advanced before the instrument is deployed.

4. **Coupling Quality:** In an ideal environment, the overall response of the four gauges will be similar in form. However, the four gauges are at different levels in the borehole, and, particularly when no core is available for examination during target level selection, there can be significant differences of borehole response at each level. These differences need to be calibrated out except when studies require only time signatures (rather than amplitudes), and this calibration process must be done at the particular gauges (not in the composite implied strains). Signs of poor coupling or of unequal coupling or rock anisotropy are to be found in strong variations of response to atmospheric pressure, or to strong inequality of areal strain response measured by using one third of the summed response of channels 0, 1, and 2 versus one half of the summed response for channels 1 and 3. Calibration can be performed using atmospheric response, earth tidal response, earthquake offsets or the response of long period surface arrivals from distance sources. None of these are trivial eg the earth tidal models available may be totally inadequate at some sites due to loading factors or to hydrological perturbations (enhancements, attenuations or delays), and for many studies (particularly those related to time signatures of events in regional studies), direct use of the provided laboratory responses will be adequate.

5. **Tidal Shear Response:** The response to earth tide should show clear shear ie the phases of signals due to earth tides will not be the same on all channels. This shear response can also be used as a criterion whether or not the theoretical tides for the site are adequate for calibration of the site. Adequate prediction of the theoretical tides (body tide plus ocean loading plus geological, topographic and hydrological effects) cannot be performed to the precision of the actual measured values and are usually significantly in error. Timing of the system is GPS locked for all channels to 10 ms, so the maximum observed phase error in a 12 hour tide component is necessarily less than one microradian in the observations. Significant departures of the theoretical estimates from the observations point unambiguously to inadequacy in the theoretical tides and is a strong caution against using such estimates for any calibration procedure.

6. **Shear Response in Seismic Signals:** The horizontal components of seismic signals contain strong shears. A site which does not show these shears (particularly for teleseismic signals) is probably poorly coupled or sited.

7. **Smoothness of the Data:** Some channels at some sites show significant slow steps in the early stages of compression. These steps which look like offsets in 10 minute data, usually take from 30 seconds to a few hours to occur and should be identified

using 20 Hz or 1 Hz data. These steps indicate damaged rock surfaces in readjustment under the site compression. These channels should be avoided if possible. (it is usually better to choose the best three channels at a site rather than to attempt to use step noisy data in any inversion). These steps are real in the ground, but normally irrelevant to tectonic geophysics. They index compromised sites particularly if they are still common after about twelve months of operation.

8. **Cultural Isolation:** In many instances, nearby cultural effects (in particular hydrological effects due to domestic pumping as is occurring at the B001 site, agricultural pumping of the water table or large scale surface remodeling as has occurred at B089) are large, and difficult to remove from the data. Again these signals are real in the earth, but normally irrelevant to the geophysics under study unless those studies are focused on hydrological issues. Sometimes, these signals can present as long term changes of strain rate associated with rainfall cycles which can easily be confused with tectonic signals. In many instances these hydrological cultural effects can cause shears as well as hydrostatic signals due to the asymmetry associated with the azimuth to the source.

9. **Downhole Thermal Stability:** Thermoelastic strains due to changing temperatures can be very large particularly if the instrument is close to active or poorly constrained aquifers.

10. **Fluid Control in the borehole:**
    In some instances very large excursions occur in the data (eg Parkfield group) due to progressive aging failure of packers used in the PBO program or general failure to control fluid flow into boreholes during installation. The issue is particularly serious in artesian boreholes. Many of the PBO driller's logs indicate large inflows (to 50 or 100 gallons per minute at various depths) and in most cases there are no detailed records of flow depth at or below target depths or of mitigation procedures carried out during drilling. In some cases the logs indicate back cementing for stability, but rarely for water control. It is probable that no mitigation procedures occurred when none are documented.

    Preparation of a strain borehole requires careful control of all fluid flow from at or below the target depth. Water inflow from this region can seriously compromise the setup of the expansive grout in the 20 mm thick annulus surrounding the instrument by fluid leaching or erosion of the mix before it is set. Water make zones in the borehole must be isolated and measured using packer tests at multiple depths around the target zone. Any water make more than a few cubic centimeters a minute needs to be sealed off to ensure proper grouting conditions.

    Sealing of flow zones at or below target depth is performed by re-cementing the borehole over the flow zone with ultra fine expansive grout, followed by re-drilling and repeated packer testing. In most boreholes in-flows of less than 2 cubic centimeters per minute is achieved after three or four cycles. The procedure is performed while the drill is on site. Fluid in-flow boreholes which have not been treated in this way show either no compression of the grout (normally caused by outwash of the grout) or massive random steps in the data for the first several years of measurement as residual grout wedges equilibrate around the circumference. Such holes may ultimately recover because relaxation of the borehole walls under the influence of the virgin stress field tends to re-couple the instrument to the borehole wall.

Measurement of water in-flow were performed for only the first 6 PBO sites, but was abandoned in 2005. In prior studies (1983 to 2005) using this instrument all boreholes were also back cemented to the surface to assist in water control within the borehole.

11. **Microseismic noise:** Microseismic noise response is a good indicator of instrument coupling for small amplitude signals. Typically on the 20 Hz data, noise levels vary from as low as 3 counts to about 50 counts, and again you should expect to see clear phase variations between the channels in a good site.

12. **Rainfall Effects:** Many sites are nearby streams or rivers which in recent years have suffered major flooding. Surface loadings and associated thermoelastic effects can be significant and in many instances the events are associated with major disruptions of the local hydrology (as are occurring at B076). Most of these issues map dominantly into the areal strain, but there is often a shear component driven by the lack of symmetry of the site with respect to underground water table changes of pressure and temperature. The sites have rain gauges, but often you need to look much further afield to find the source of particular changes of strain before associating these with tectonic sources.

13. **Notified Deployment Issues:** Unavco staff sometimes indicate issues which may have occurred during deployments on the main individual station notes pages. Unfortunately these notes do not include drillers notes. The installation process is quite complex, and, like the instrument, cannot compensate for problems at target depth from the drilling or the geology. Departures from normal installation procedures and general comments on the sites, their stability and their hydrology are usually reported. In some instances, major cultural disturbances have occurred after installation (eg nearby earth works as at B082, the Pathfinder Ranch), and these effects are reported when they are noted by field staff. These notifications should **always** be reviewed for possible impact on your particular study.

In Summary

Excellent Data requires

- **In the Instrument**
  - **Good State of Health Parameters**
  - **Good Noise levels**
- **At Site preparation**
  - **Good Geology**
  - **Good Topography**
  - **Core Drilling and an adequate target length of continuous rock**
  - **Good control of water in-flow rates at or below target depths**
  - **Good hole preparation and installation process**
  - **Good grouting procedures**
- **After installation**
  - **Good Communications**
  - **Good net Compression**
  - **Clear Exponential Borehole recovery process**
  - **Reasonably Uniform Coupling**
  - **Shears in Earth Tides**
  - **Shears in Seismics**
  - **Shears in Microseismics**
  - **No “Steps”**

Good Data requires

- **Some adequate combination of the above which suits your current objective**