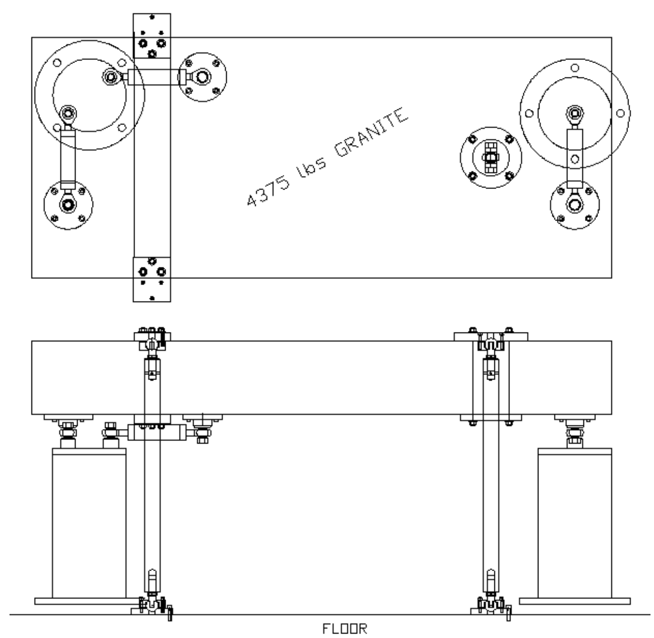
Rigid, Adjustable Support via Six Struts

Adapted from "Rigid, adjustable support of aligned elements via six struts" by W. Thur, R. DeMarco, B. Baldock, K. Rex, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley CA 94720 (1997). Work supported by US-DOE #DE-AC03-76SF00098

There are many ways of adjustable mounting position sensitive hardware. Jack screw and shimming is often troublesome, a drain on manpower and time. Multiple precision stages with capacity for heavy items are very expensive. LBNL's synchrotron storage ring the Advanced Light Source relies on a simple and cost effective "six-strut" mechanical support system. It meets seismic requirements, minimizes vibration, and allows easy and precise alignment of a wide variety of hardware.

The basic idea:

The position of a rigid body in space has six-degrees of freedom; translational: X, Y, Z; and angular: pitch, roll, and yaw. A support system, which uses six orthogonal struts, provides "kinematic" support; that is with no additional constraints, to stress or distort the body itself. The struts have ball-joint connections, and are arranged orthogonally to simplify adjustments. Each strut is rigid along its axis, and six struts together provide solid (and seismically adequate) support. It is usually possible to make the system rigid enough so natural frequencies of vibration are above 20 Hz. In practice, this eliminates nearly all floor-transmitted vibration.



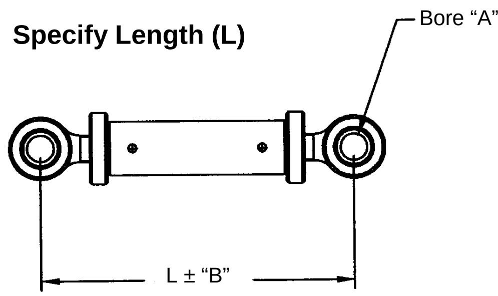
These stiff support systems are precisely adjustable. Modified ball joint rod ends are used with tightly fitting ball elements that are bolted to solid support. The result is an almost ideal strong, rigid system that allows heavy equipment to be easily adjusted and fixed in all six degrees of freedom with .0005-inch (10 micron) sensitivity over a generous range of travel.

Wide variations in supported hardware do not allow "standard" six strut systems. We have standardized several sizes of strut components, their length and position are tailored to specific hardware configurations. Many variations of the six-strut system are possible.

Strut hardware variations exist as specials (metric, invar, differential, etc.) but most struts use ball-jointed end attachments provided by "rod end bearings". For a rigid system, normal clearance in the rod end is eliminated with "tight-swaged" balls. A threaded collet joins the rod end to strut body. An important point is that this clamp is adjusted to a specified "breakaway torque" at assembly, and left alone. It is set to be stiff enough to prevent casual twisting by hand, but loose enough for smooth operation with a wrench. This eliminates backlash and the need for tightening / clamping after ideal adjustment is achieved. Thus, there is no disturbance of critical adjustments, a big advantage over most other systems.

McPHERSON

Strut assemblies:



Part No. (with scale)	181-100333-L	181-100334-L	181-100335-L	181-100336-L
Part No. (without scale)	181-100317-L	181-100318-L	181-100319-L	181-100320-L
Bore (A)	1/4 in (6.35 mm)	3/8 in (9.53 mm)	1/2 in (12.70 mm)	3/4 in (19.05 mm)
Adjust Range (B)	±.39 in (10.0 mm)	±.44 in (11.2 mm)	±.44 in (11.2 mm)	±.44 in (11.2 mm)
Min. Length (L)	3.25 in (83.0 mm)	4.75 in (121.0 mm)	5.75 in (146.0 mm)	6.10 in (168.0 mm)
Max. Length (L)	20.00 in (508.0 mm)	25.00 in (635.0 mm)	30.00 in (762.0 mm)	40.00 in (1016 mm)
Thread	1/4-28 in	3/8-24 in	1/2-20 in	3/4-16 in
Capacity	1000 lbs 500 kg	2000 lbs 1000 kg	3000 lbs 1500 kg	6000 lbs 3000 kg

Standard strut sizes are available and with a variety of options for customization.

The six strut system is a proven, simple, and cost effective way of rigidly supporting hardware with precise adjustability. Some components are not "position sensitive". Position requirements coarser than 1 mm may be more economically supported by arrangements of double-nutted threaded rods with spherical washer sets in oversize clearance holes. Clamp bolts in slotted holes and various shimming arrangements can also be used if the necessary degrees of freedom are provided. Cruder adjustment approaches should not be used if positioning requirements are tighter than + 1 mm. In these cases, a six strut system will be well worthwhile.

McPHERSON

Designing a six-strut support system?

- Safety: Because the six strut system does not over constrain supported equipment, **it will fall down if any one strut is disconnected**! Emphasize this to all those working with this hardware.

- Keep the struts orthogonal. Three in one dimension, two in another, and a single strut in the third dimension. **Tip:** Put three struts in the dimension in which rigidity (vibration resistance) is most critical. This is usually the vertical, but not always. The single strut is then placed parallel to the beam, where rigidity is least important.

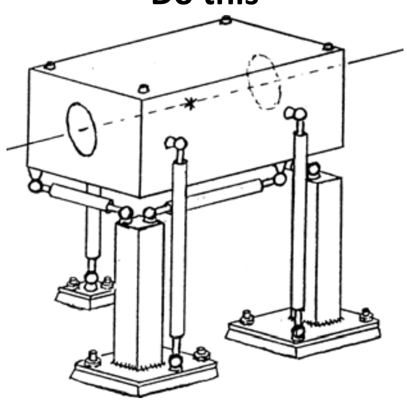
- Use long struts wherever possible. Long struts minimize the arc "cosine effects" which cause minor coupling of otherwise independent axes. Vertical struts can extend all the way to the floor.

- Space struts as far apart as possible so that angular adjustments (pitch, roll, and yaw) are less sensitive and more rigid.

Tip: It is often not possible but ideally and to minimize cross-coupling of adjustments, mount the movable ends of the three parallel struts in a plane passing through the alignment-critical parts of hardware. The movable ends of the two parallel struts should lie on or near a line which passes through the alignment-critical part of the hardware too. For optimum rigidity, the axis of the single strut would be aligned with the center of mass.

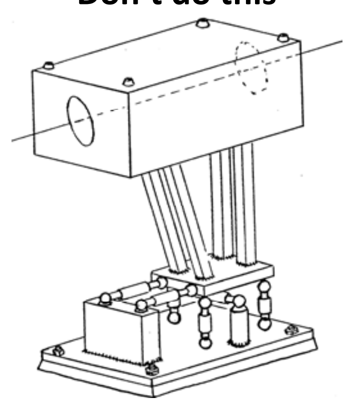
- For equipment that is extremely position sensitive, thermal expansion of the struts can become important, even in a temperature-controlled environment. Invar strut components have been used in some cases.

Do this



The struts are long and well separated. Two simple pedestals are tucked under the equipment to maintain a narrow footprint. The lower and upper faces of the equipment are kept clear

Don't do this



A small, low six strut table carries a tall setup. Short struts cause cross coupling of adjustments due to "cosine errors" over normal adjustment ranges. The close separation of parallel struts makes angular adjustments very sensitive, and encourages angular modes of vibration due to the low stiffness. The considerable height of the equipment causes further cross-coupling. For example, angular "roll" adjustment will cause transverse movement of the equipment. All these were minimized in the previous sketch.

McPherson, 7-A Stuart Road, Chelmsford MA 01824-4107 USA | Telephone 1-978-256-4512 | www.McPhersonInc.com