Modern Seismometers Design and Calibration

(Material of E. Wielandt)

Design of seismic sensors

- Basic mechanical design

Sensitivity to tilt

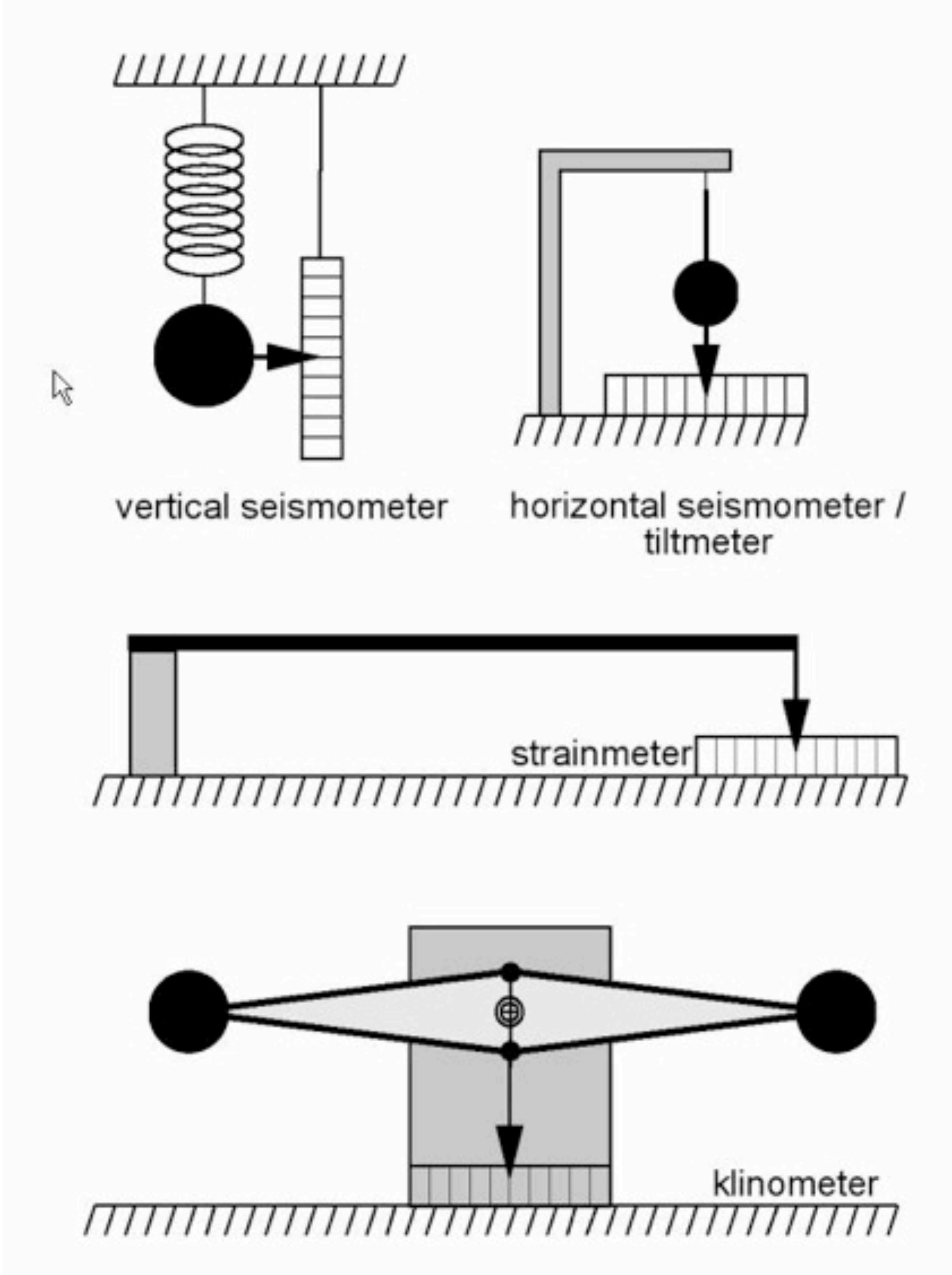
Environmental disturbances:

- Temperature
- Barometric pressure
- Magnetic fields
- Electrical ground loops
- Radio waves
- Corrosion

Transducers

Feedback

Installation


vertical seismometer
horizontal seismometer / tiltmeter
strainmeter
klinometer

Why does the mechanical free period matter?

When S is the stiffness of the spring and M the seismic mass, then the free period of the suspension is

$$T_0 = 2\pi \sqrt{M / S}$$

An acceleration Δg causes an inertial force $f = M \Delta g$ and a deflection $\Delta x = M \Delta g / S$, thus

$$\Delta x = (T_0 / 2\pi)^2 \Delta g = \Delta g / \omega_0^2$$

In order to obtain a sufficiently large displacement from a given acceleration, the suspension must have a long free period.

For a resolution of 10^{-12} of gravity, valid combinations are:

0.6 s and 10^{-13} m, 6 s and 10^{-11} m, 20 s and 10^{-10} m.

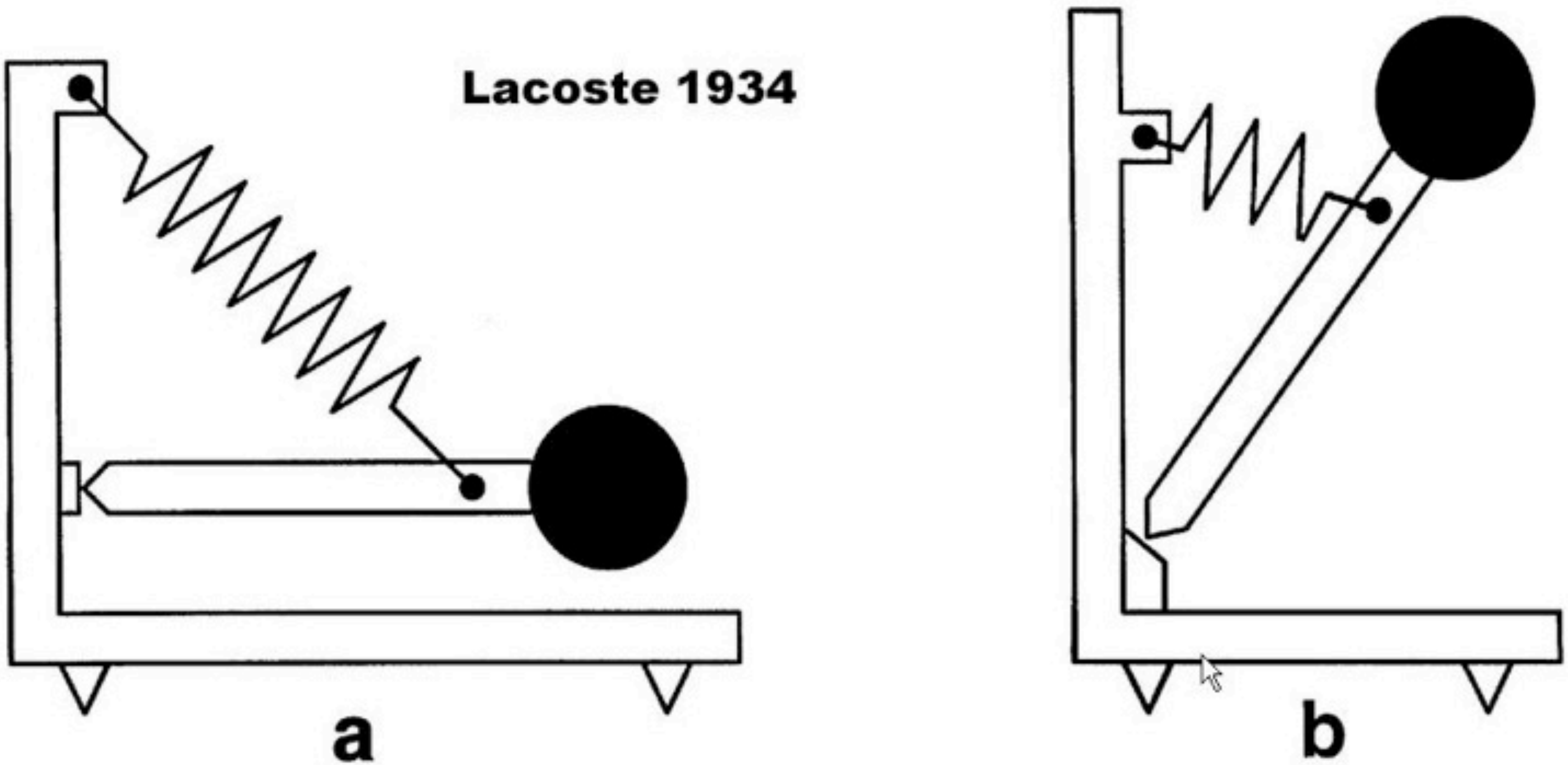
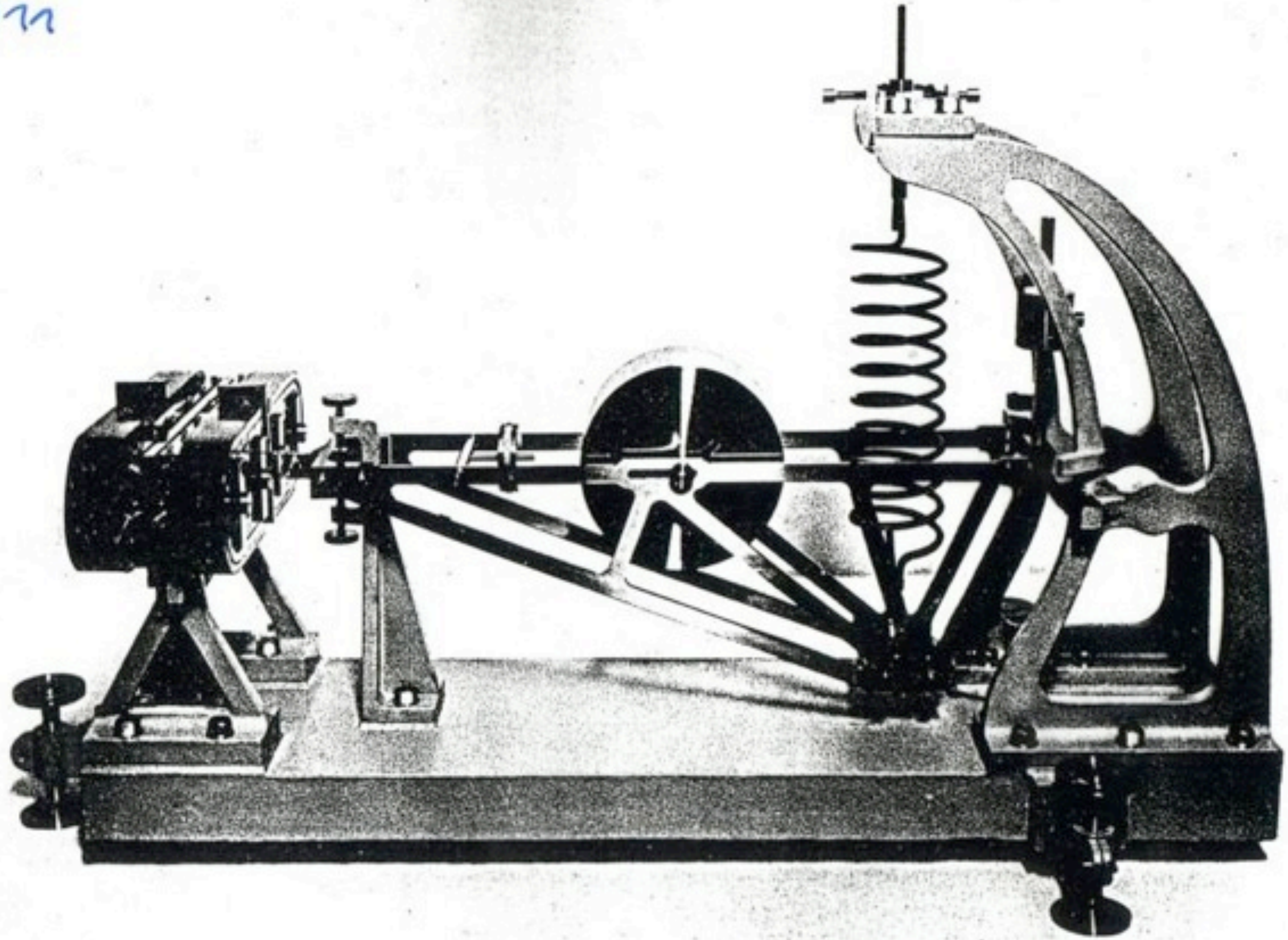
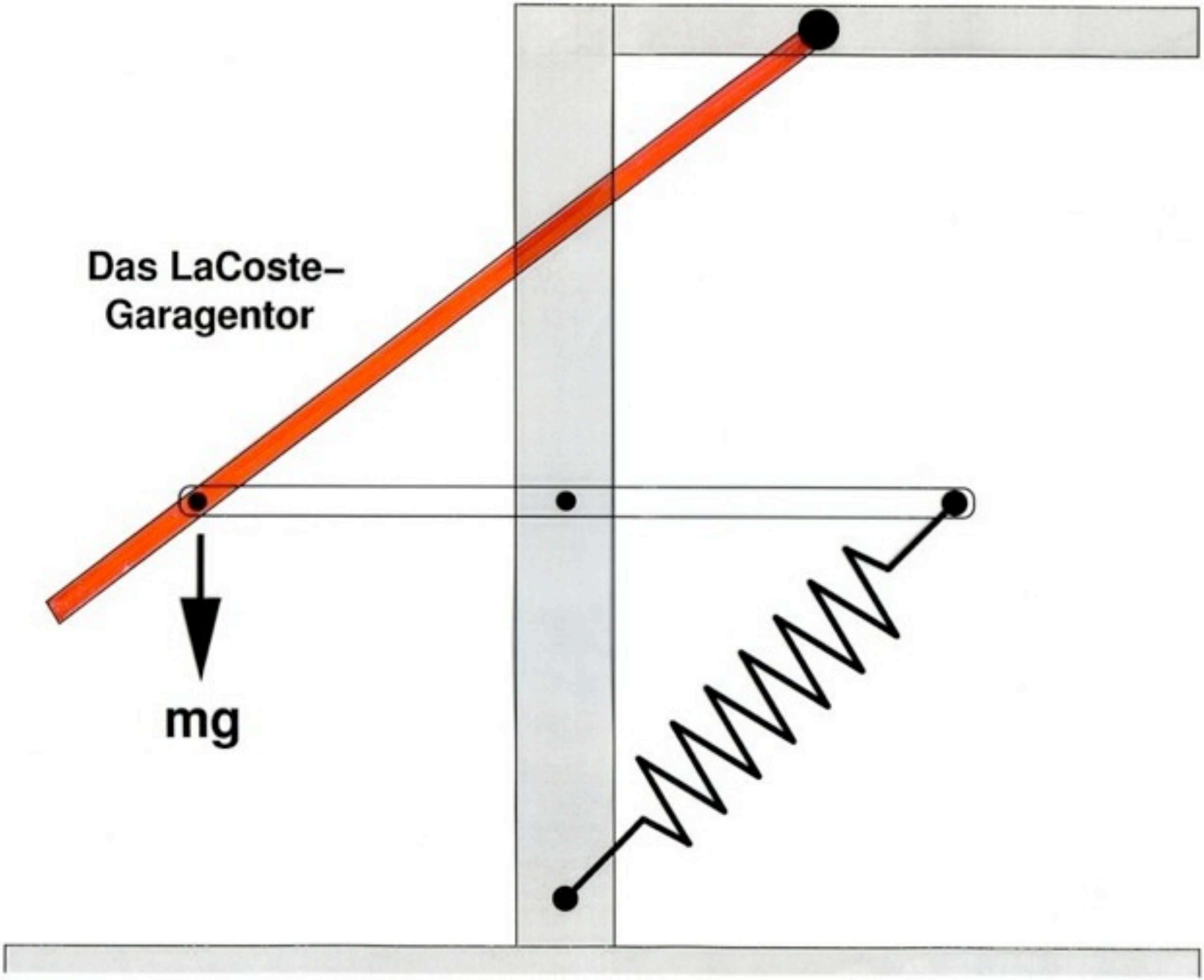
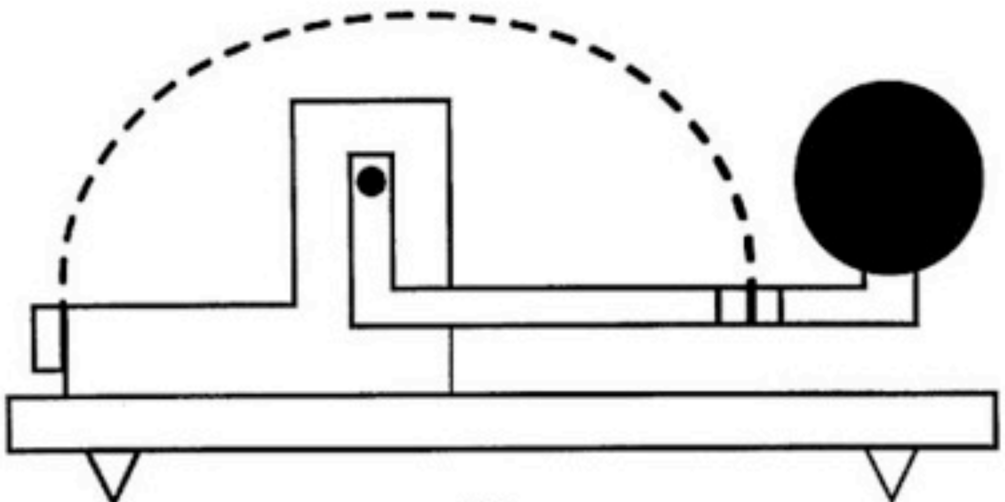

Lacoste 1934
a
b

Рис. 84.

GALITZIN
1904 – 1911

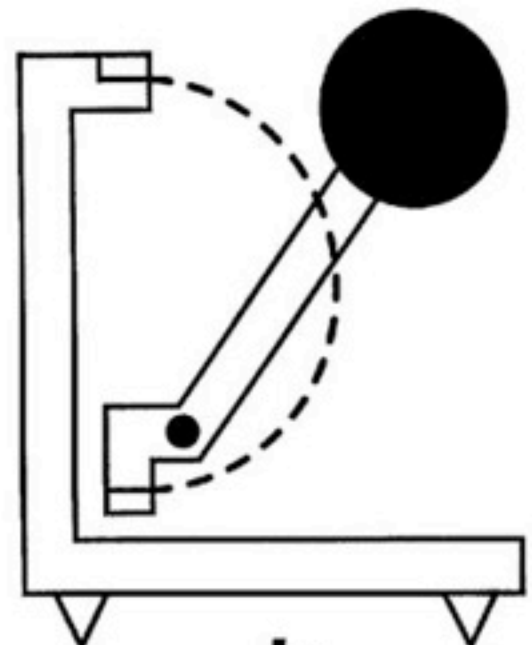



Das LaCoste–
Garagentor
mg



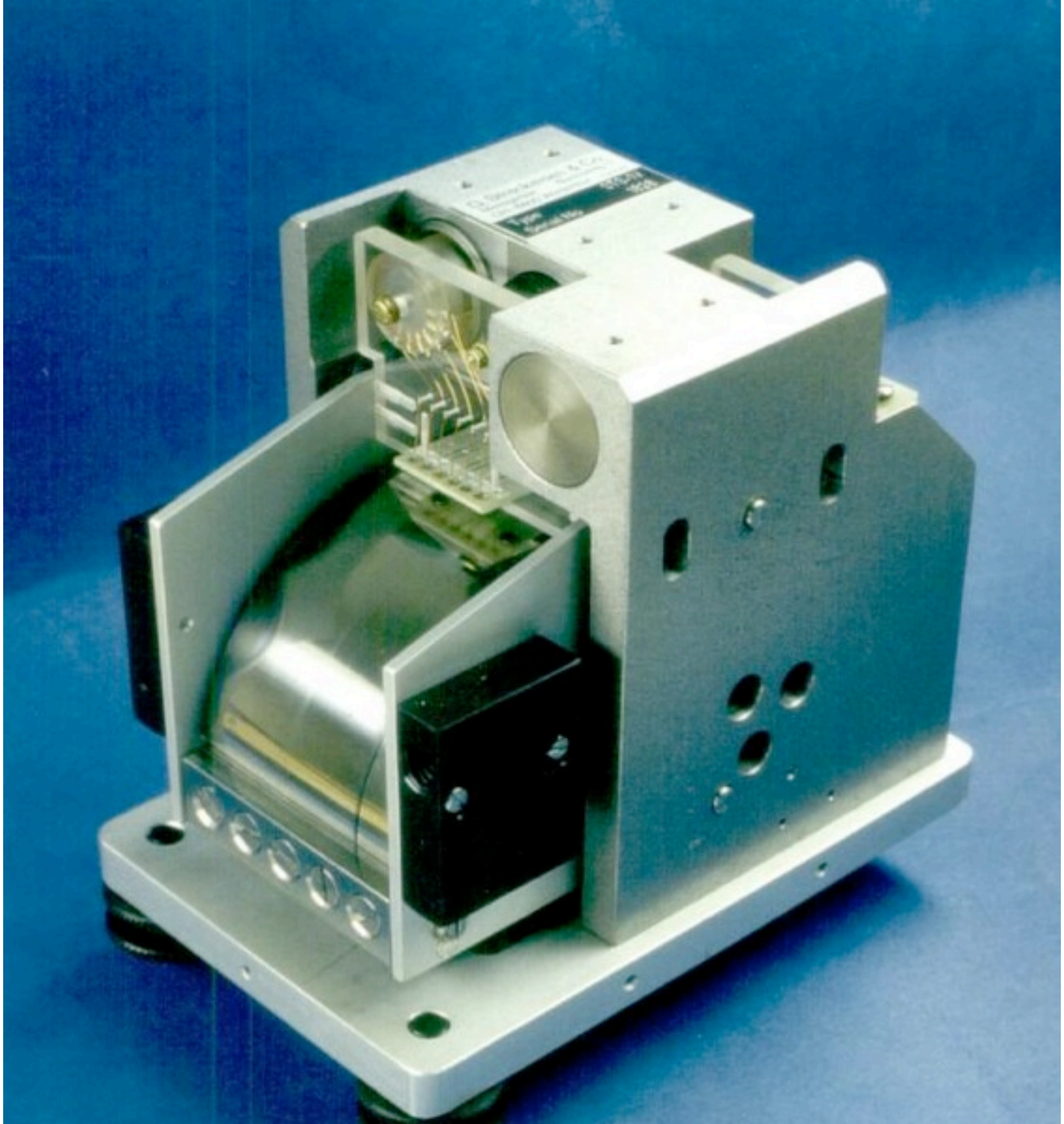
a

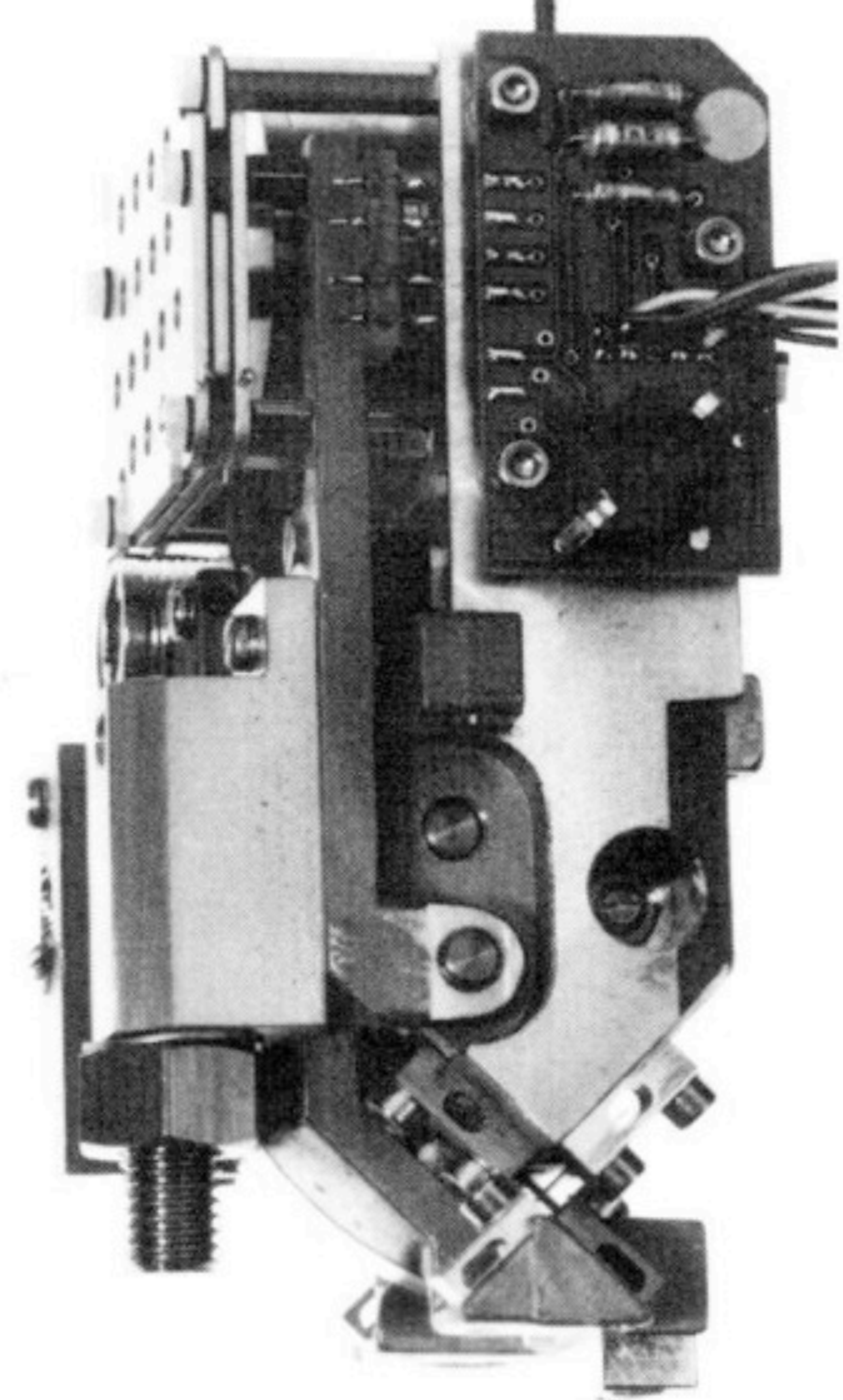
STS1



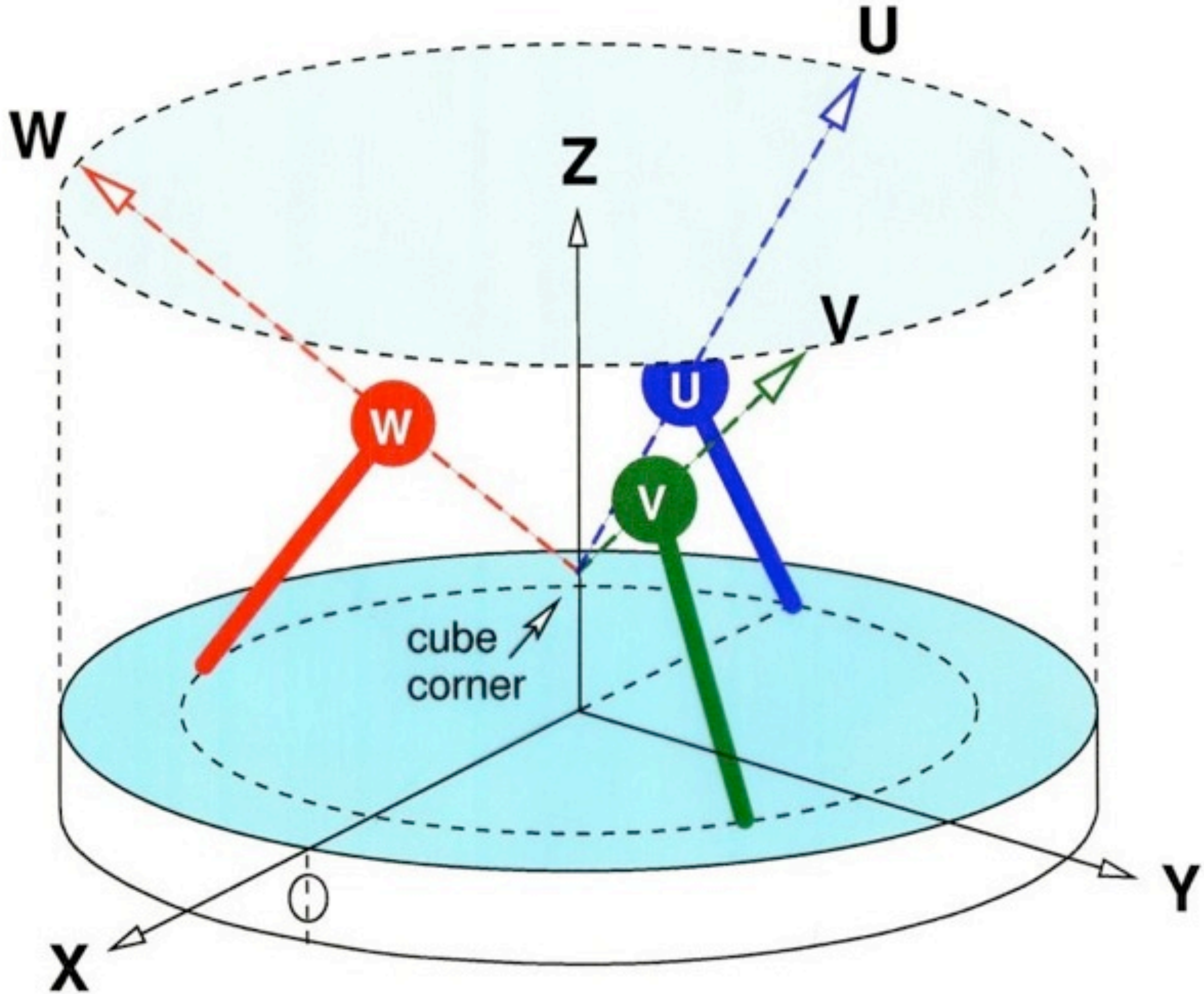
b

STS2



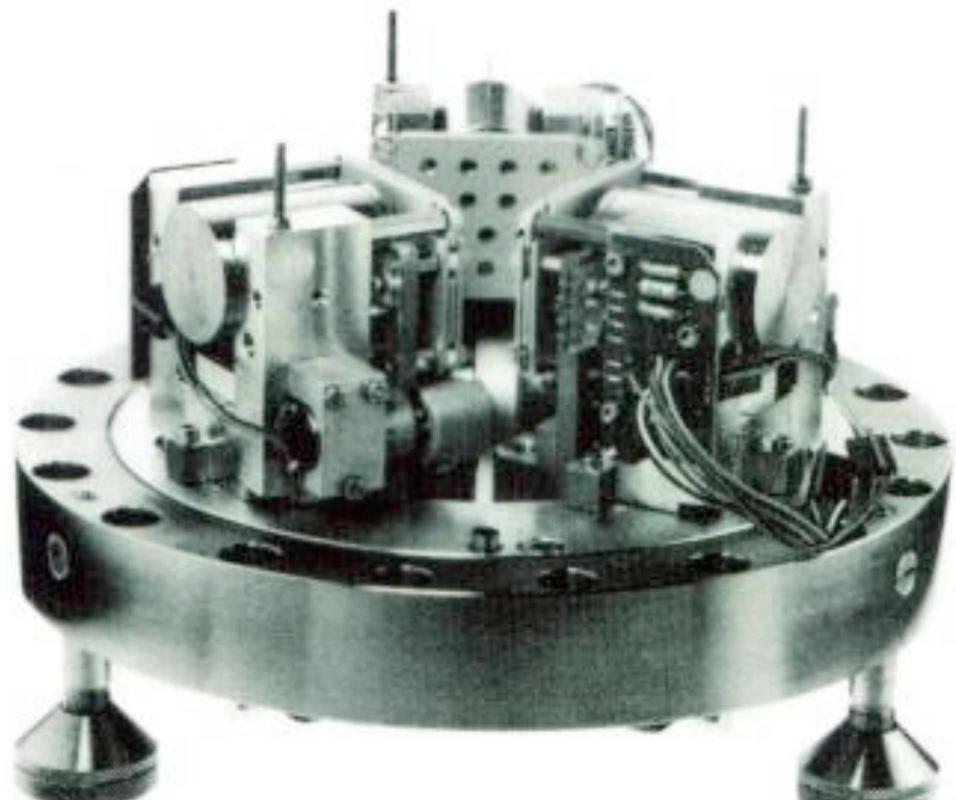


STS-2 SINGLE SENSOR



U
W
Z
V
W
U
V
cube
corner
Y
X

STS-2 INNER SHIELD
REMOVED




SWITZERLAND
TYPE STS2

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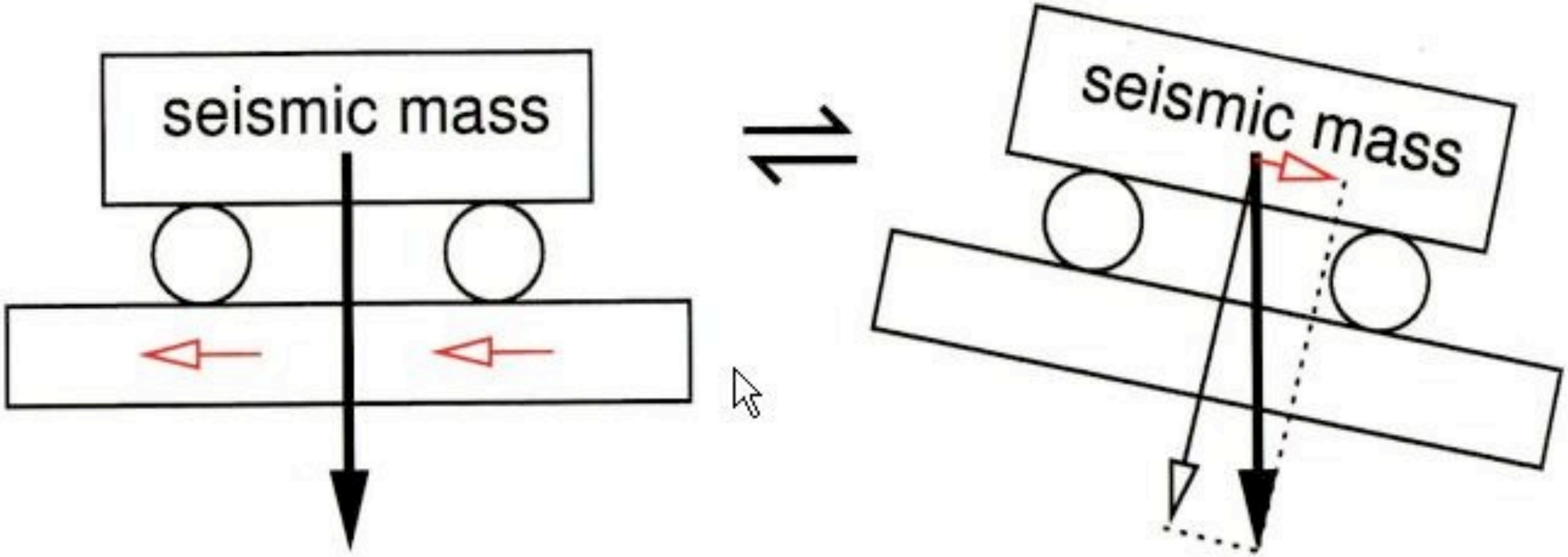
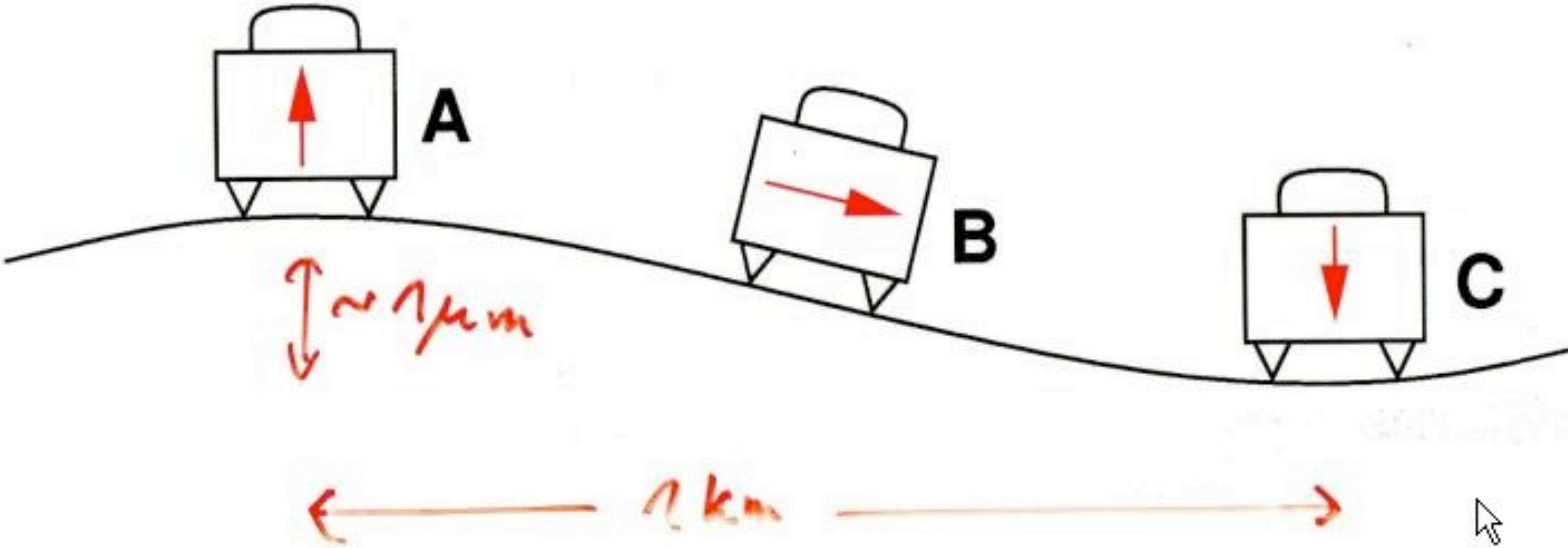
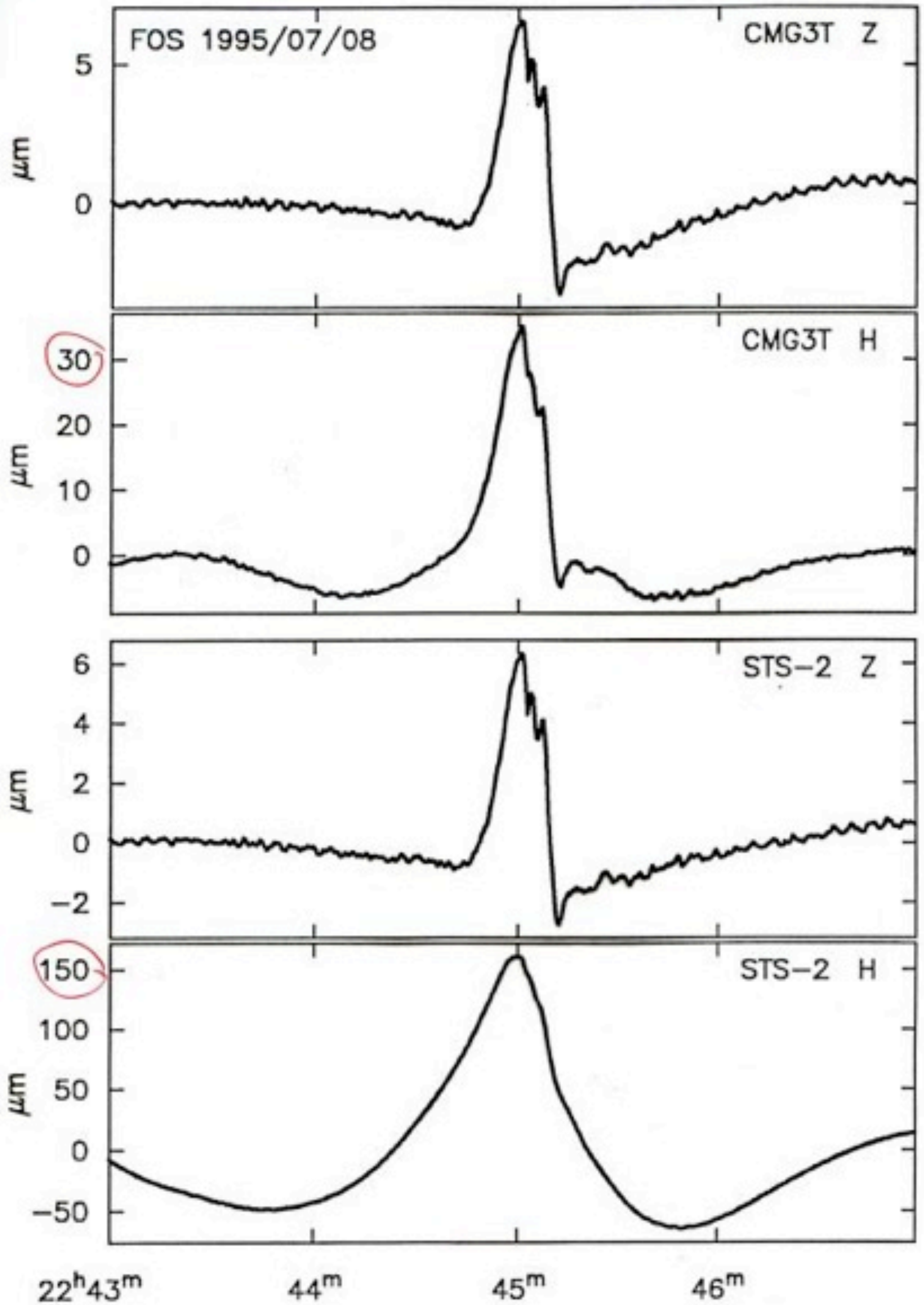

seismic mass
seismic mass


A
B
C
~ 1μm
1 km



FOS 1995/07/08
CMG3T Z
CMG3T H
STS-2 Z
STS-2 H
μm
5
0
30
20
10
0
6
4
2
0
−2
150
100
50
0
−50
22h43m
44m
45m
46m

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Thermal coefficient of the spring force

ordinary steel springs have .... – 0.03% per K

special alloys
Elinvar, Thermelast, Ni-Span C go down to ± 0.001% per K

but we want to detect signals of .... 0.000 000 000 2% g

without liquid helium, high vacuum, pumping, power consumption, and $$$ ... so how stable must the temperature be?

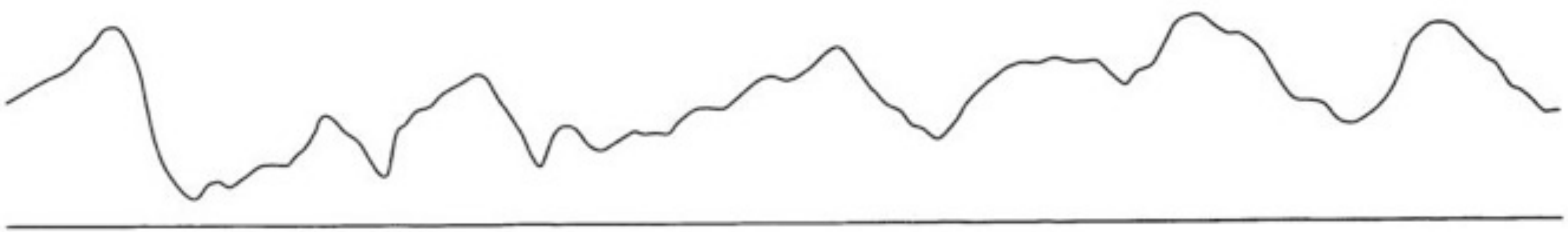
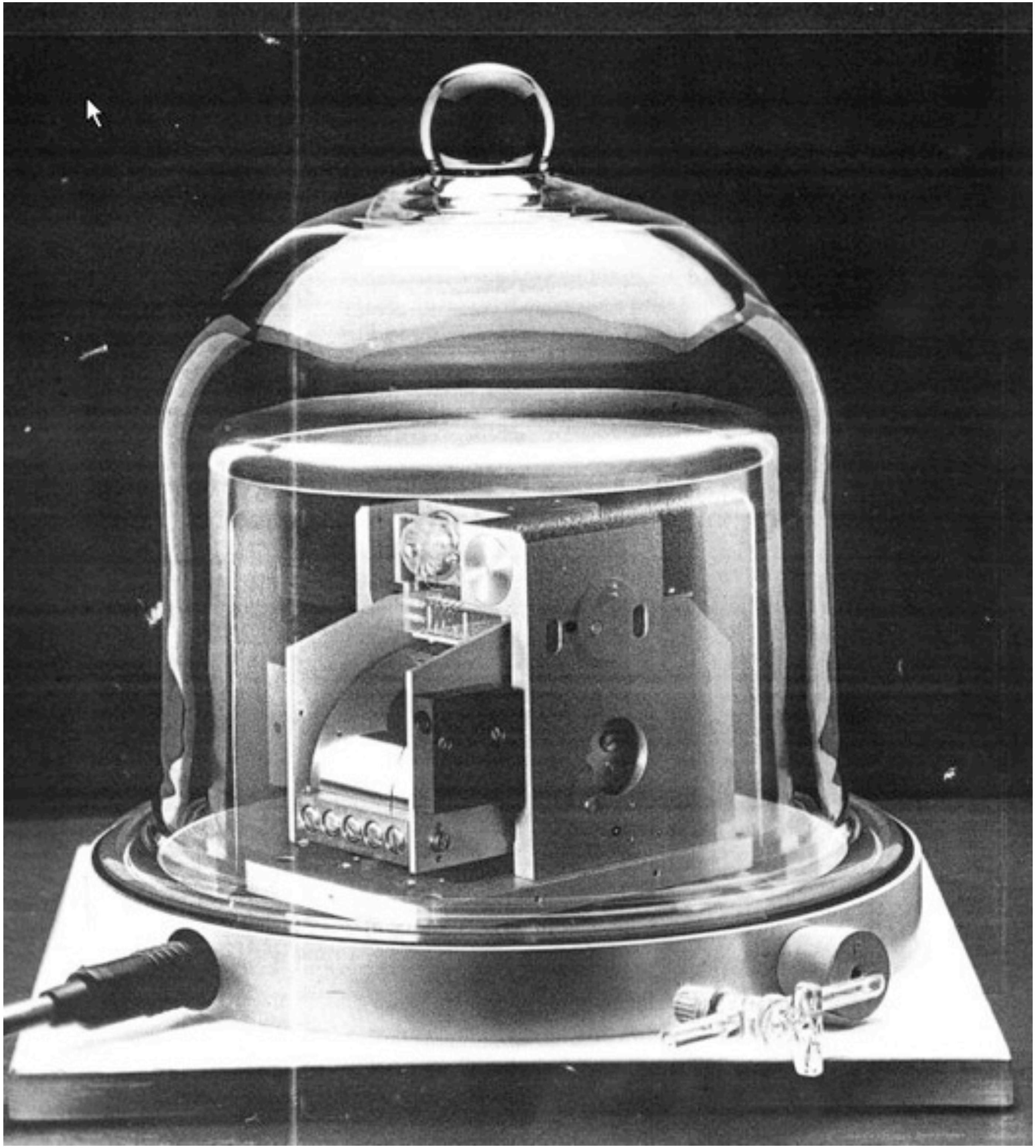
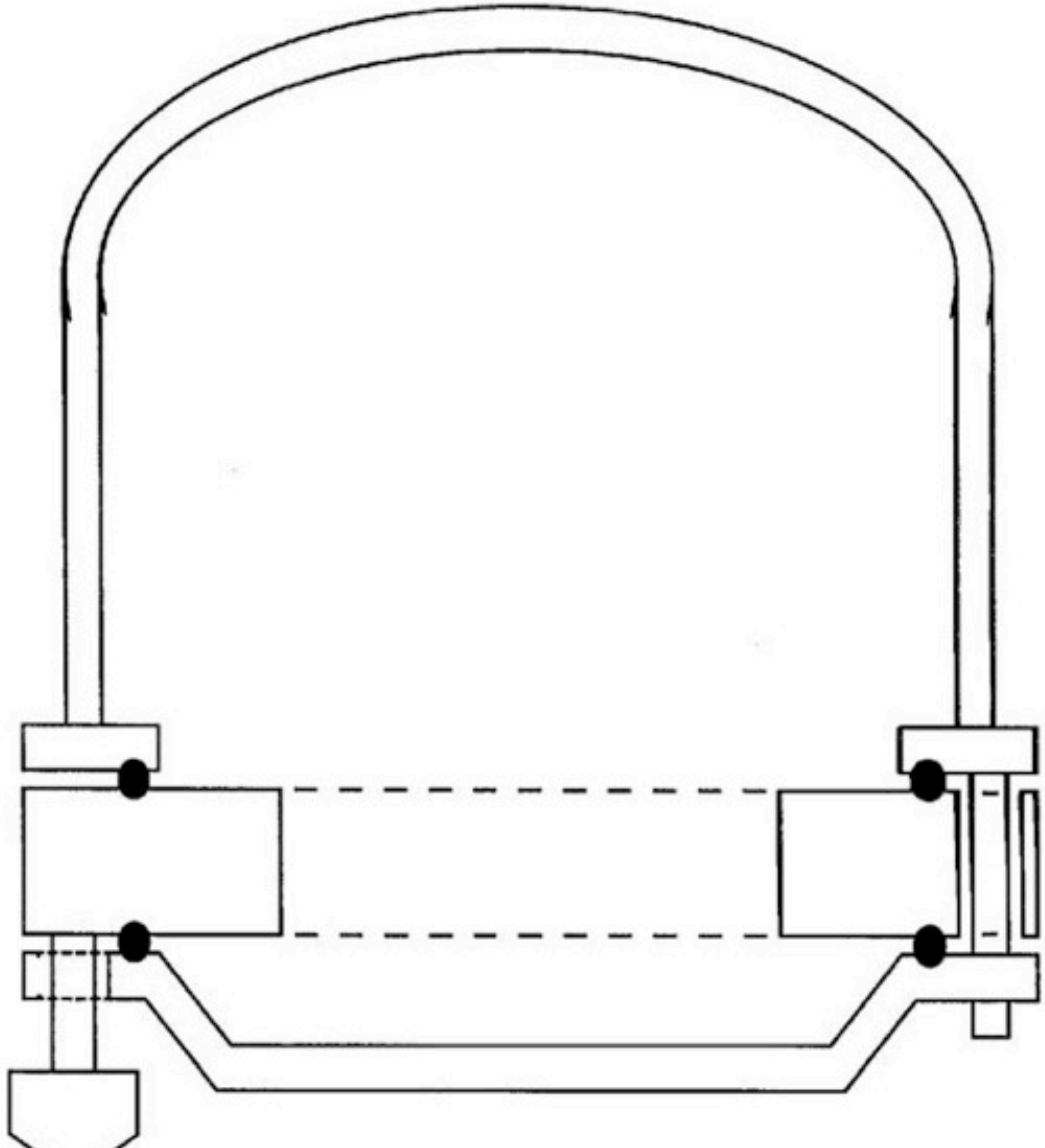


FIG. 3. VLP seismic traces from a completely shielded leaf-spring sensor, with the vacuum bell open (*top*) and sealed (*bottom*). The length of each trace is 75 min. This test indicates that variations of the atmospheric pressure must be suppressed at least by three orders of magnitude to become insignificant.





Magnetic Noise from the tramway system

STU-Z MAY 2-8, 1992


active magnetic
shielding at STU

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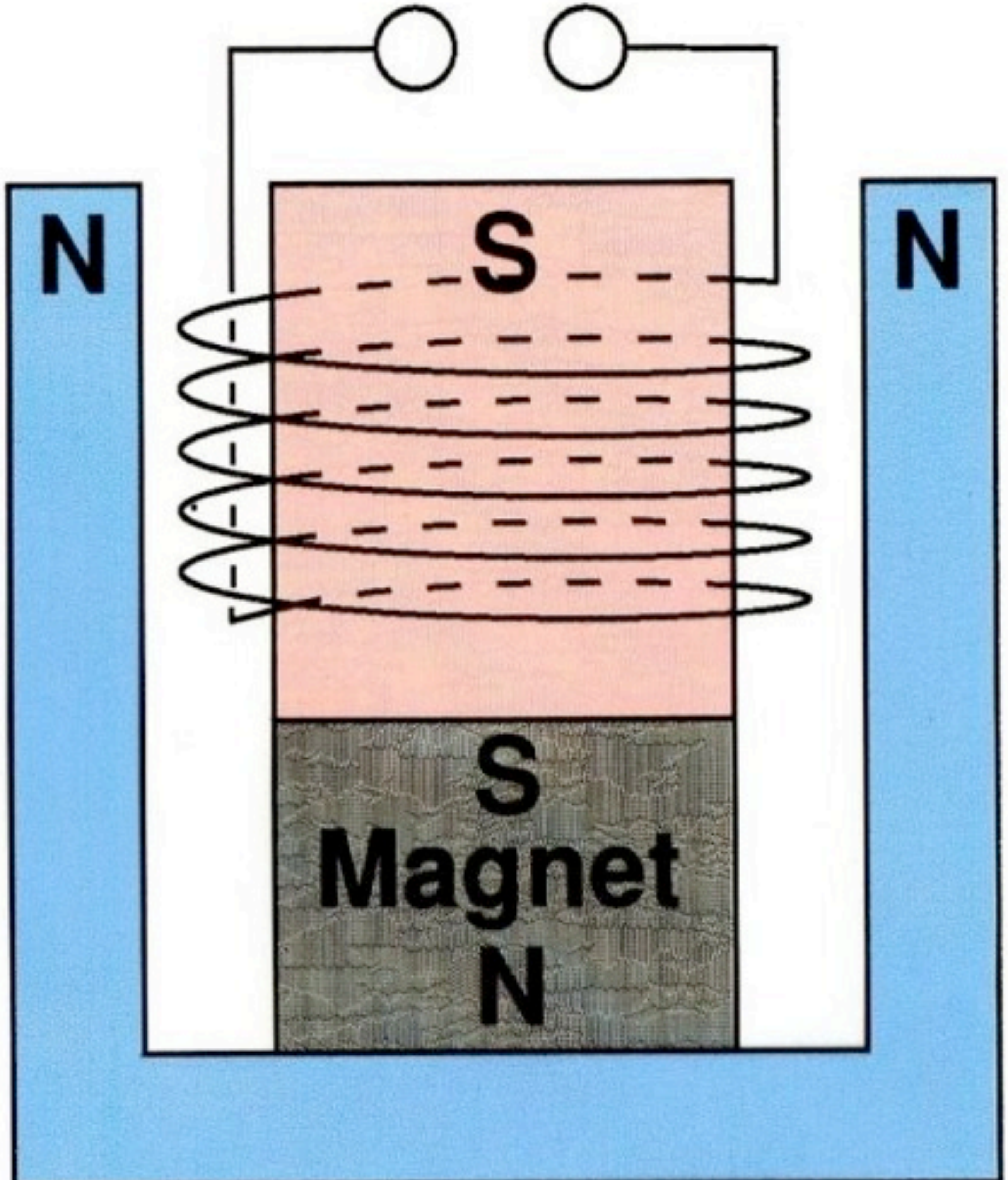
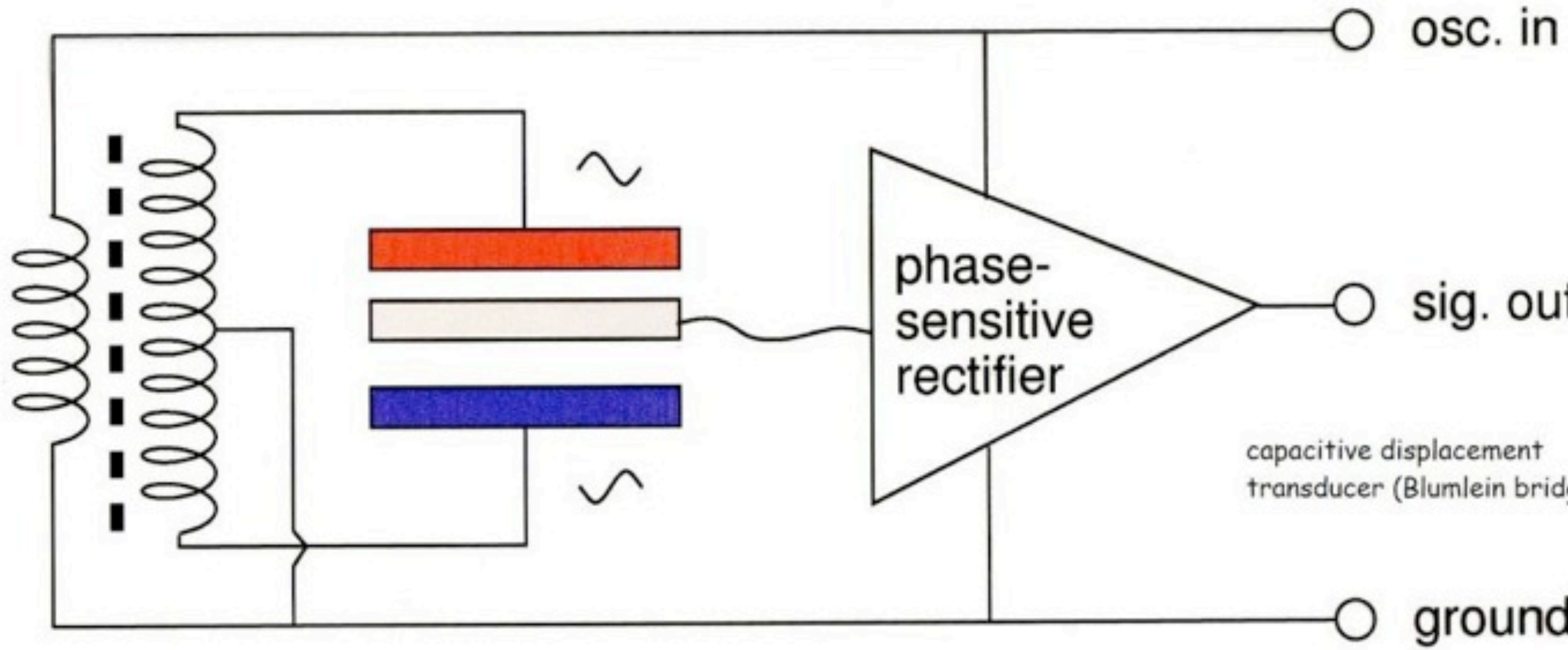
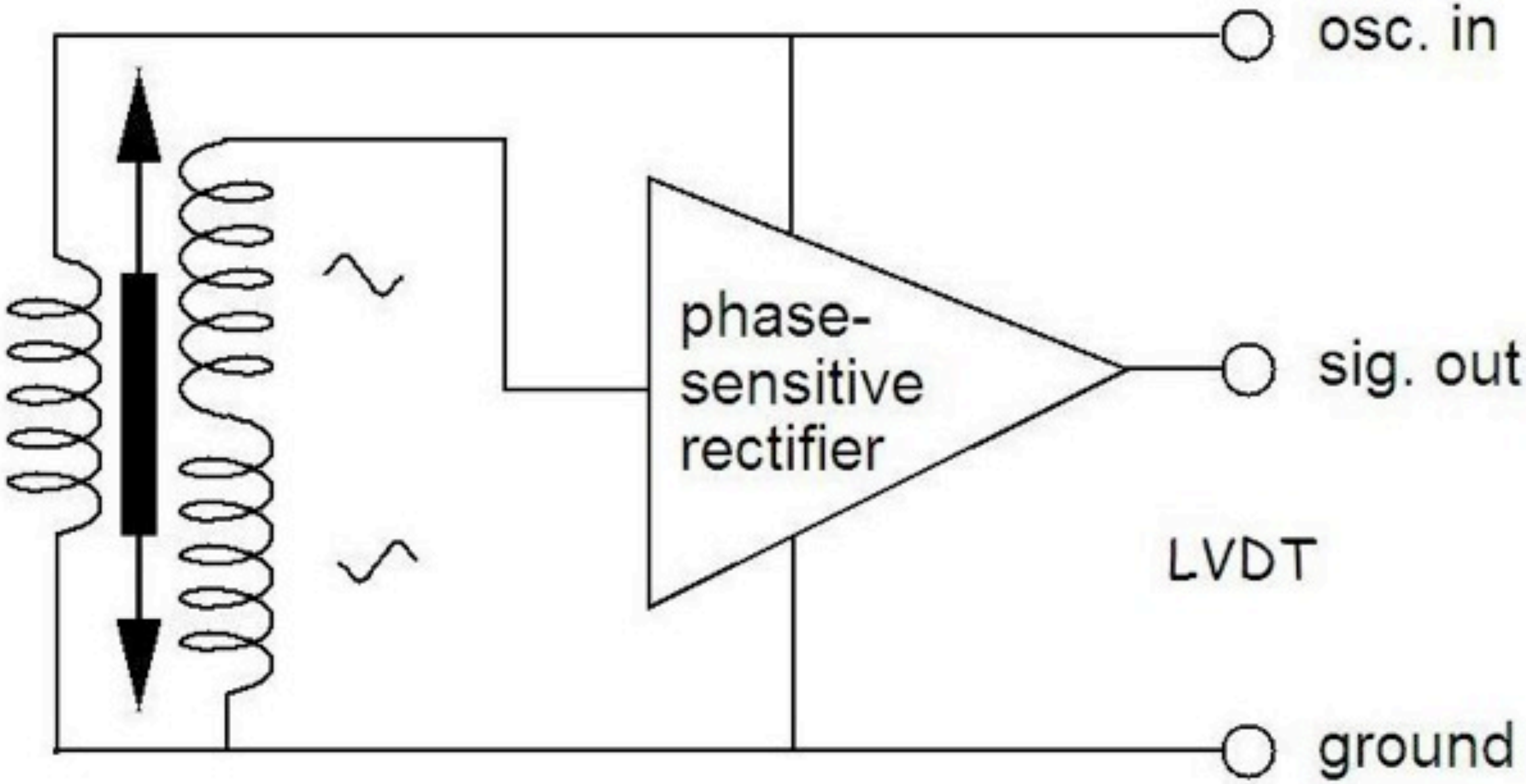

N
S
N
S
Magnet
N

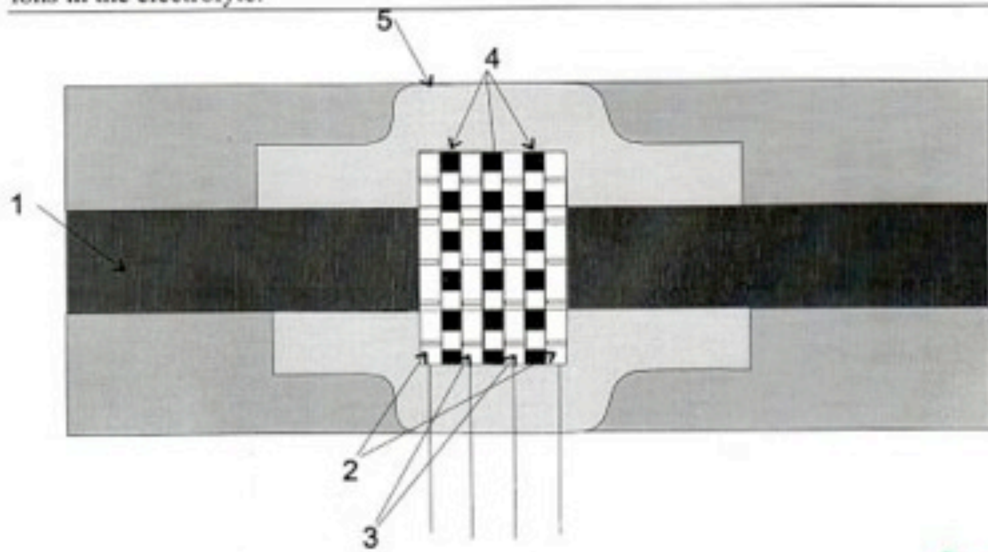


capacitive displacement
transducer (Blumlein bridge)


osc. in
phase-
sensitive
rectifier
sig. out
LVDT
ground

ELECTROCHEMICAL (MOLECULAR ELECTRONIC TRANSFER) MOTION SENSOR TRANSDUCERS

The basic design of the existing transducer, shown in Figure 1. The transducer is contained in a channel, 1, of a sensor filled with a specially prepared electrolytic solution. It consists of four fine platinum mesh electrodes, two anodes, 2, and two cathodes, 3, separated by thin, microporous ceramic or polymer spacers 4. Such an assembly is held together by a housing 5. To measure the motion of the fluid, it must be converted into an electrical signal. One way of achieving this is by using the convective diffusion of the ions in the electrolyte.



PMD sci.
EENTEC

FIGURE 1: MET TRANSDUCER

1 - Electrolyte channel
2 - Platinum mesh anodes
3 - Platinum mesh cathodes
4 - Microporous spacers
5 - Housing

When a small dc offset is applied between the anodes and cathodes, the flow of ions of each type is given by the following expression:

Equation 1: $$\mathbf{j}_a = -D \cdot \nabla c_a + q_a \cdot c_a \cdot \mu \cdot \mathbf{E},$$

where D = diffusion coefficient, μ = mobility, c_a = concentration of ions of the type "a", **E** = the electrical field vector. Since the electrolyte is a good conductor, the electric potential drops rapidly in the vicinity of the electrodes, and there is no electric field, **E**, in

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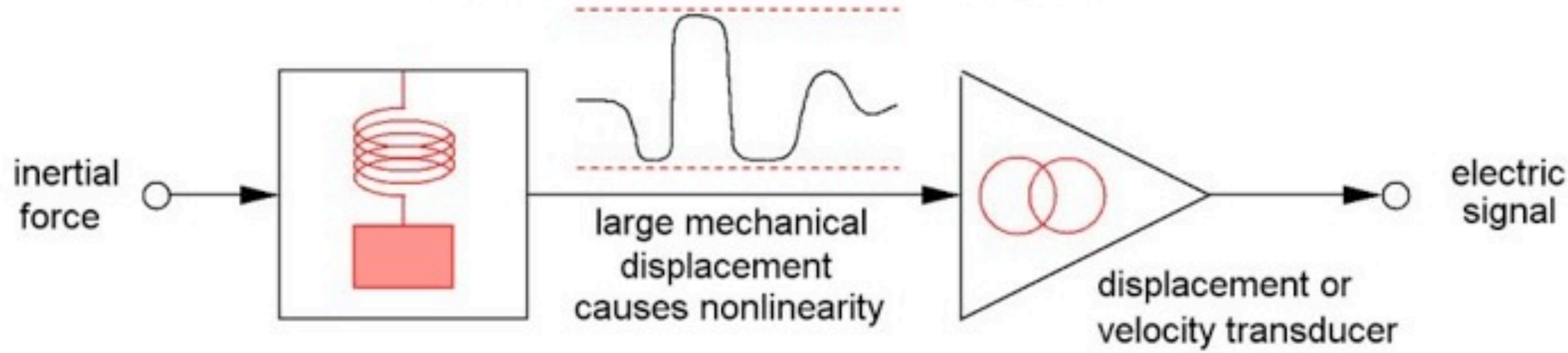
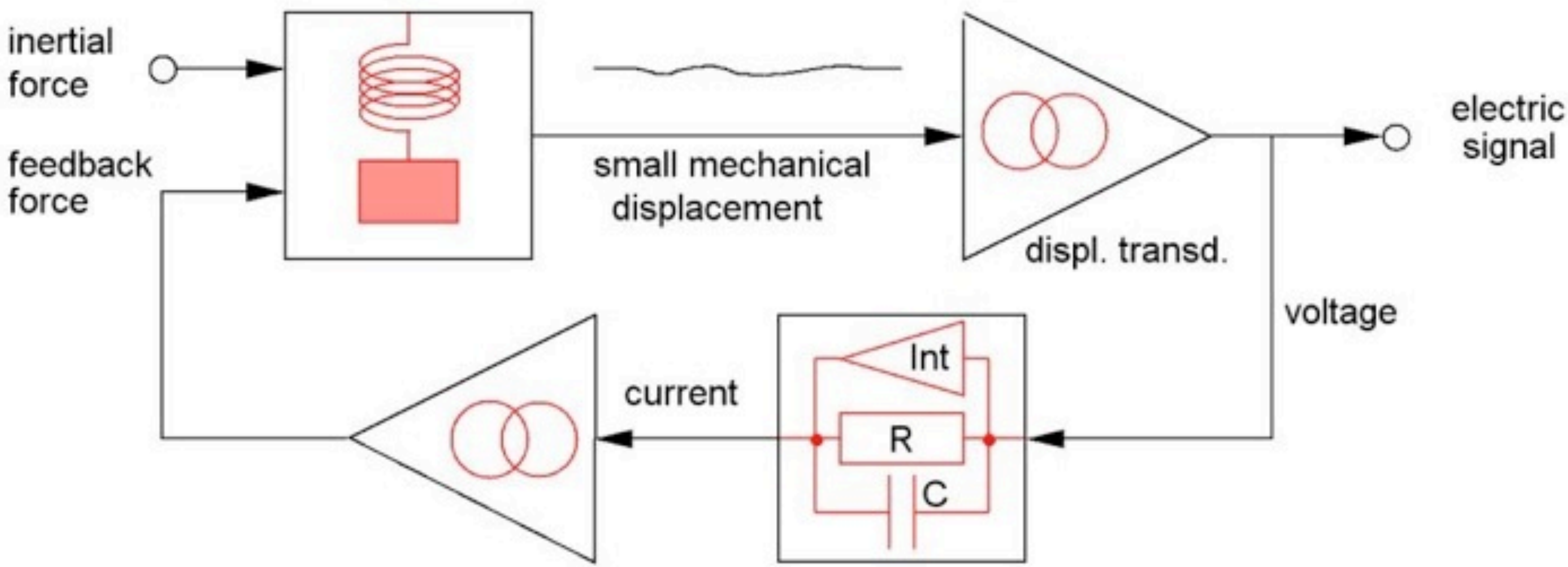
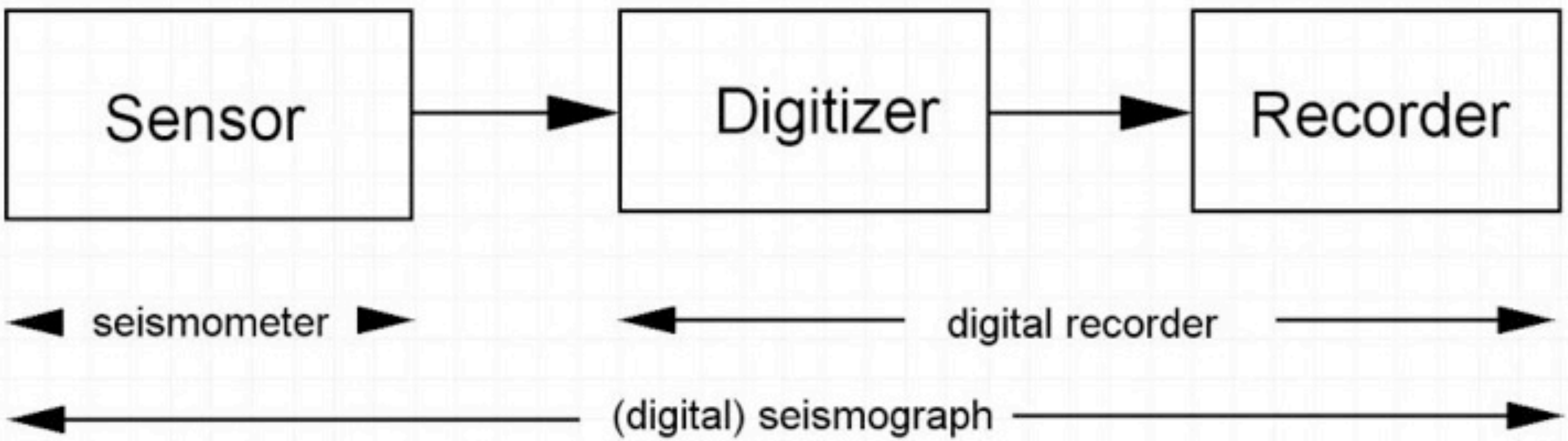
Seismometer without feedback



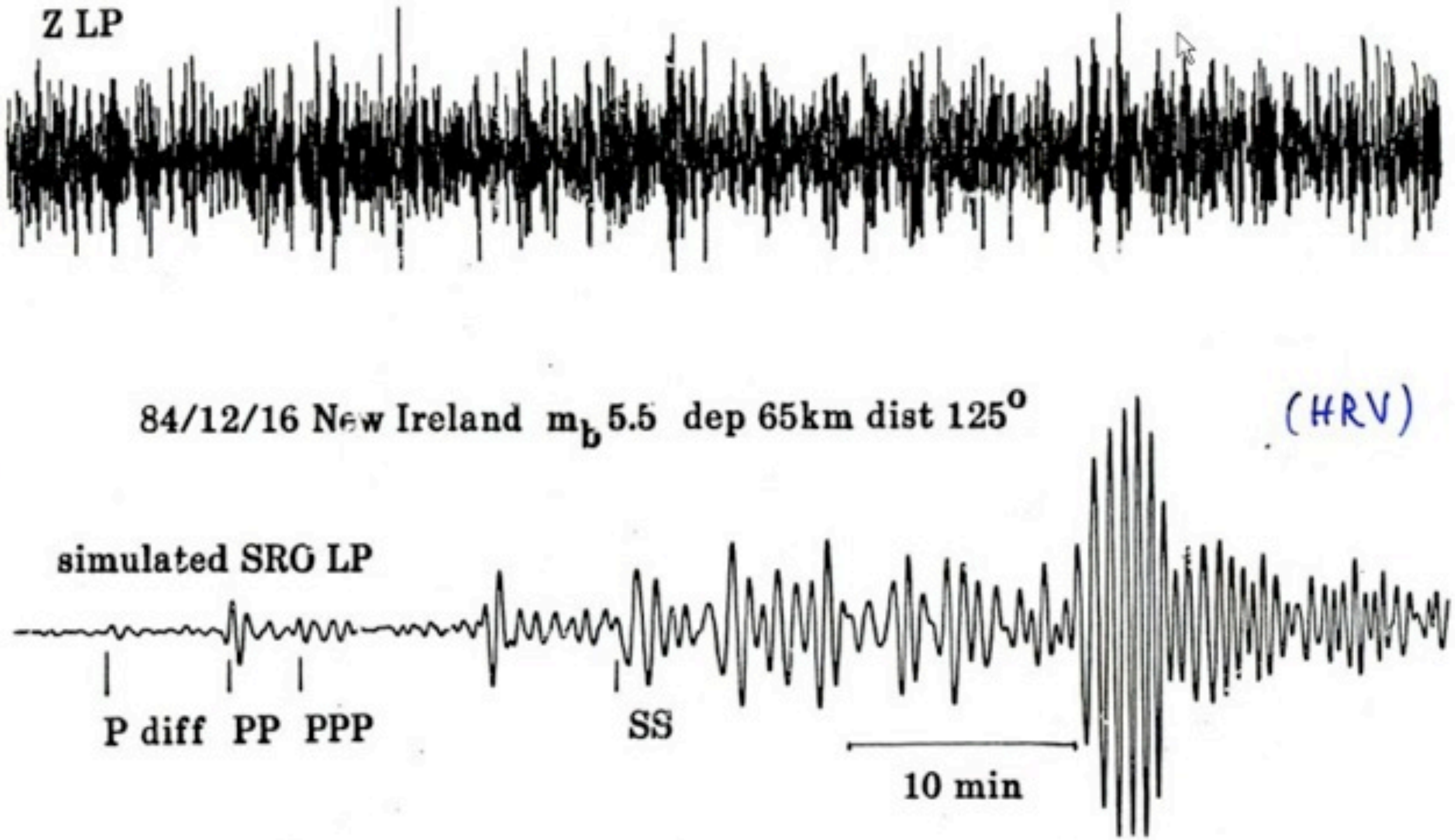
Force-Balance Seismometer



Block Diagram of a Digital Broadband Seismograph



2



Station HRV (Harvard, Ma., USA)
Courtesy of J. M. Stein

Fig.

What a seismograph must do:

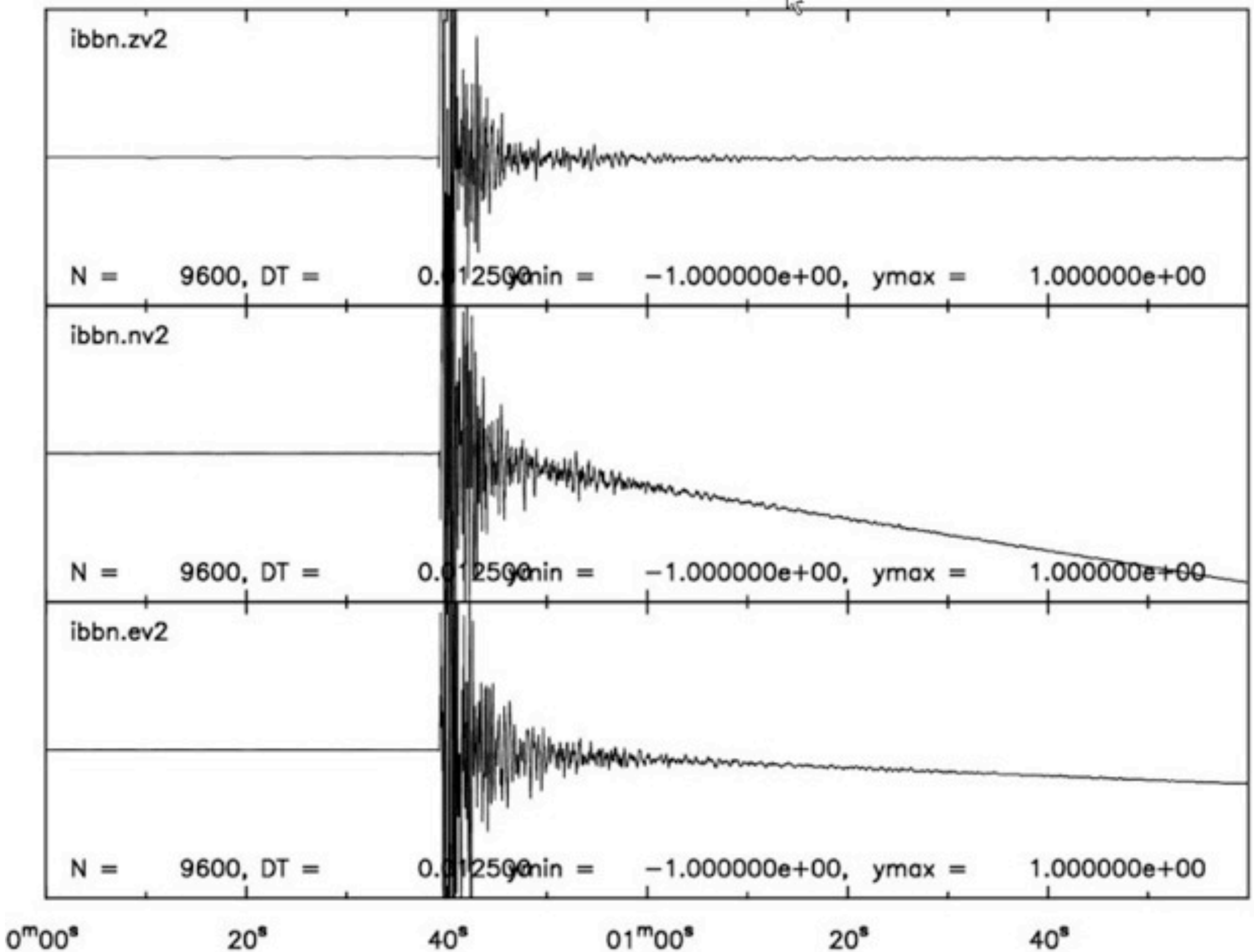
- sense earth motion
- store the signal
- display the signal
- suppress undesired signal components

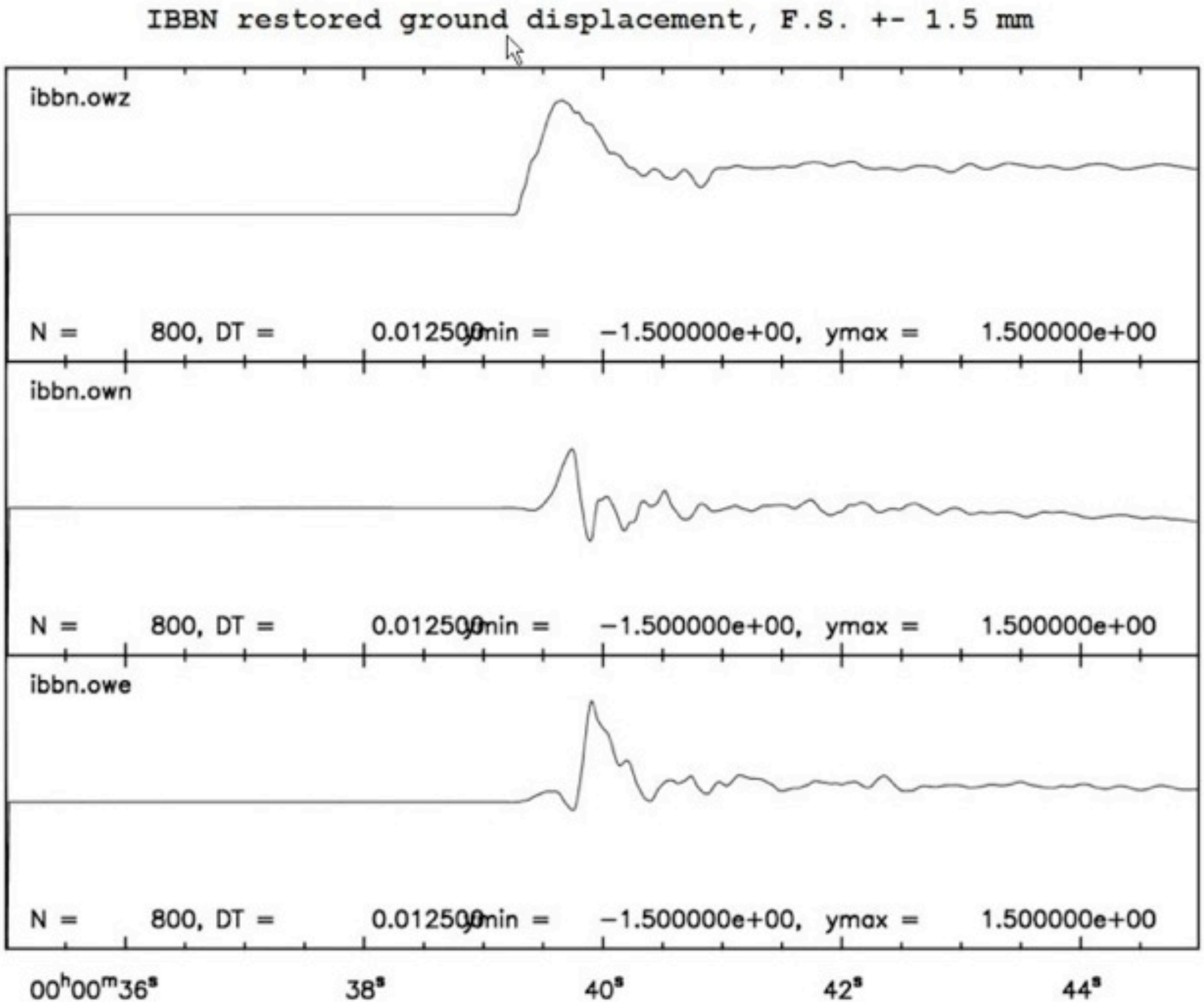
The dynamic range of the recording medium limits the performance of a seismograph.

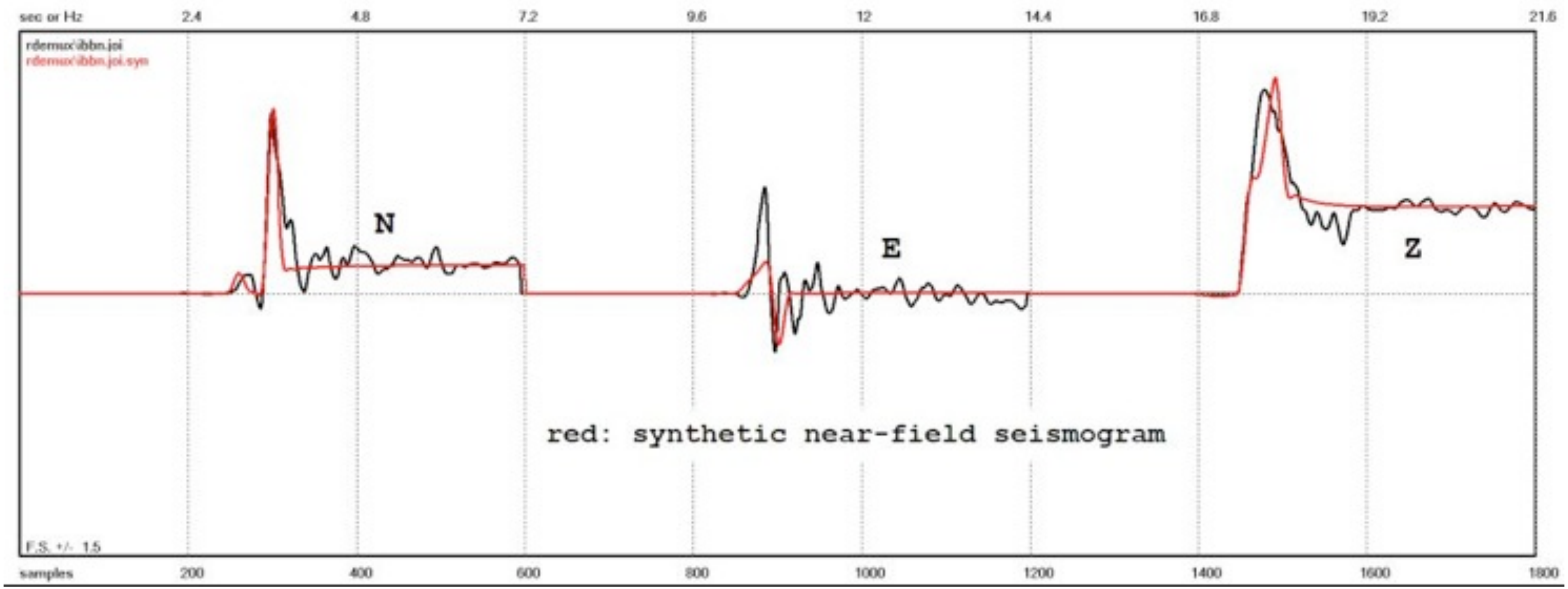
Visual recording: the seismograph must act as a bandpass filter and have a suitable magnification (depending on its purpose) in order to produce a legible record.

Digital recording: bandwidth and dynamic range are almost unlimited. We can afford to record all seismic signals at the same time. Bandwidth and magnification of the display are optimised at play-back time. Thus it makes sense to use broadband sensors.

IBBN restored ground velocity, F.S. +-1 mm/s




IBBN restored ground displacement, F.S. +- 1.5 mm
ibbn.owz
N = 800, DT = 0.012500 ymin = −1.500000e+00, ymax = 1.500000e+00
ibbn.own
N = 800, DT = 0.012500 ymin = −1.500000e+00, ymax = 1.500000e+00
ibbn.owe
N = 800, DT = 0.012500 ymin = −1.500000e+00, ymax = 1.500000e+00
00h00m36s
38s
40s
42s
44s



sec or Hz
2.4
4.8
7.2
9.6
12
14.4
16.8
19.2
21.6
rdemux\ibbn.joi
rdemux\ibbn.joi.syn
N
E
Z
red: synthetic near-field seismogram
F.S. +/- 1.5
samples
200
400
600
800
1000
1200
1400
1600
1800

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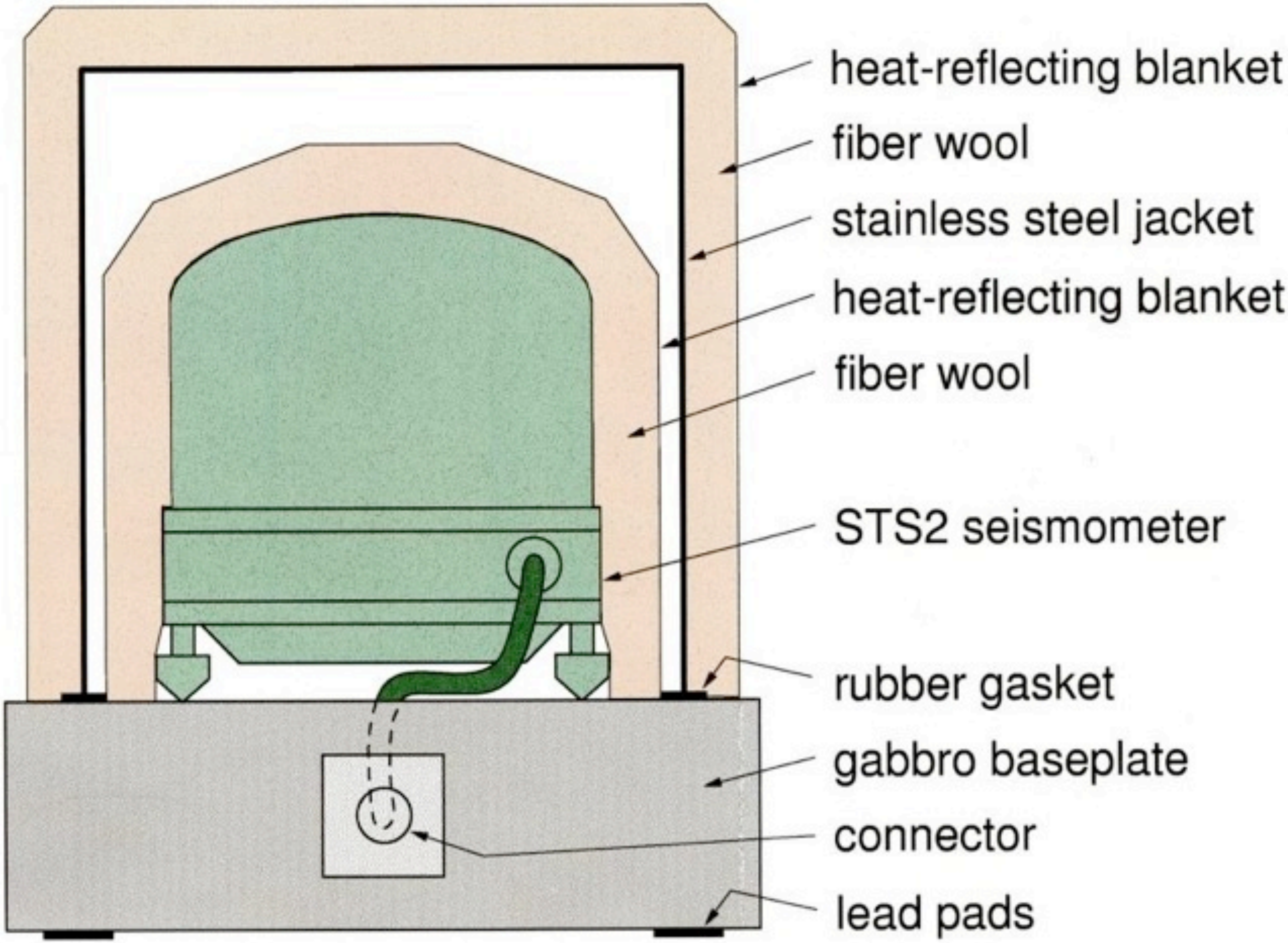
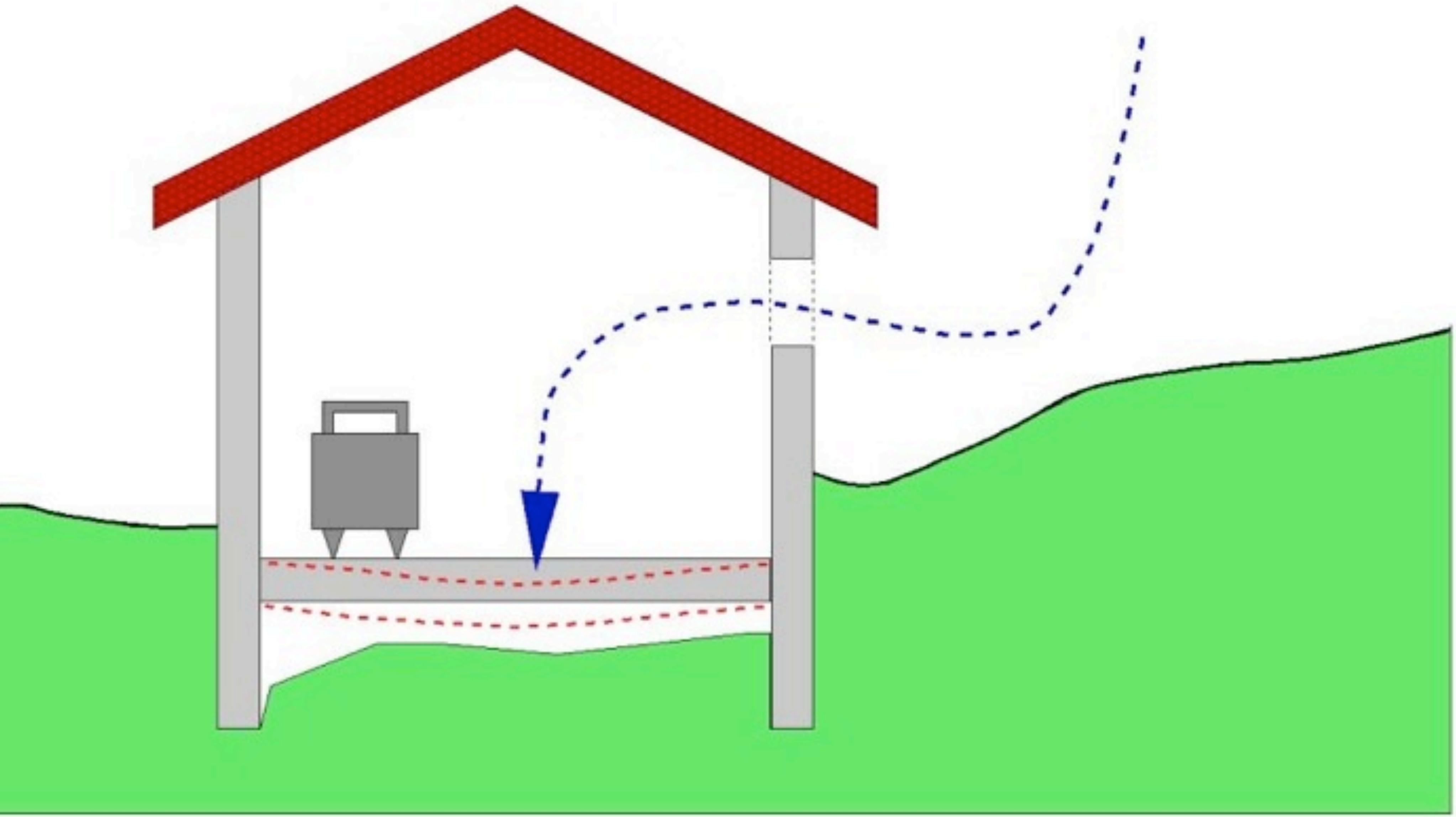

heat-reflecting blanket
fiber wool
stainless steel jacket
heat-reflecting blanket
fiber wool
STS2 seismometer
rubber gasket
gabbro baseplate
connector
lead pads



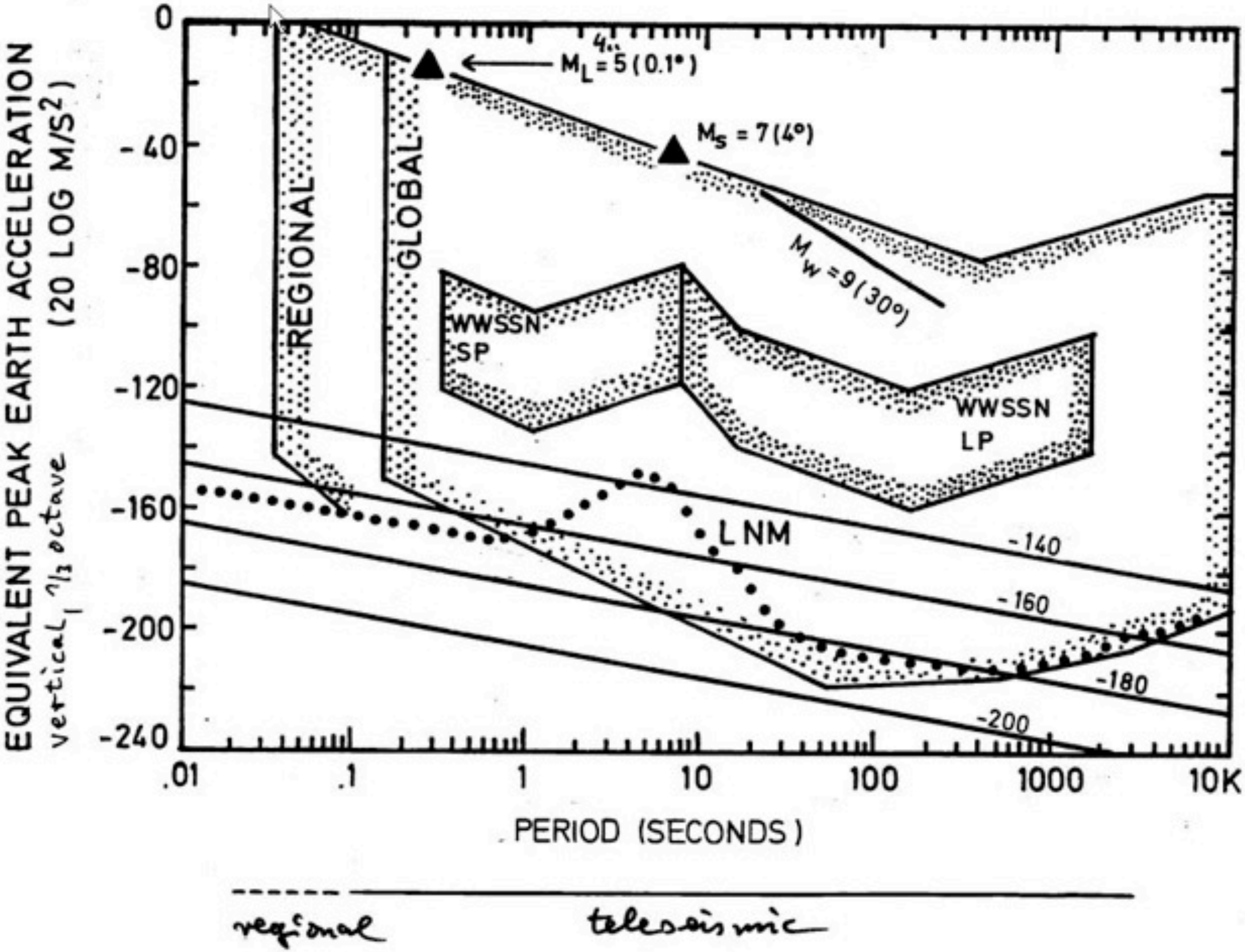
Don't install seismometers on membranes!

The three essentials of broadband seismometer installation

1. Avoid air drafts and thermal convection. Fill any space around the seismometer with soft isolating material (e.g. cotton-like fiber wool).

2. Don't install sensors on membranes: poorly cemented base plates, soft containers, cracked or detached piers, a concrete slab or floor over a closed cavity.

3. Prevent corrosion. Put a bag of desiccant into STS1 or STS2 sensors. Protect cable connectors and electronic modules with plastic bags and desiccant.


EQUIVALENT PEAK EARTH ACCELERATION
(20 LOG M/S^2)
vertical, 1/3 octave
PERIOD (SECONDS)
$M_L = 5\,(0.1°)$
$M_S = 7\,(4°)$
$M_W = 9\,(30°)$
REGIONAL
GLOBAL
WWSSN
SP
WWSSN
LP
LNM
-140
-160
-180
-200
0
-40
-80
-120
-160
-200
-240
.01
.1
1
10
100
1000
10K
regional
teleseismic