ACIGA (AIGO)

Australian National University (Canberra)

Adelaide University (Adelaide)

University of Western Australia (Perth)

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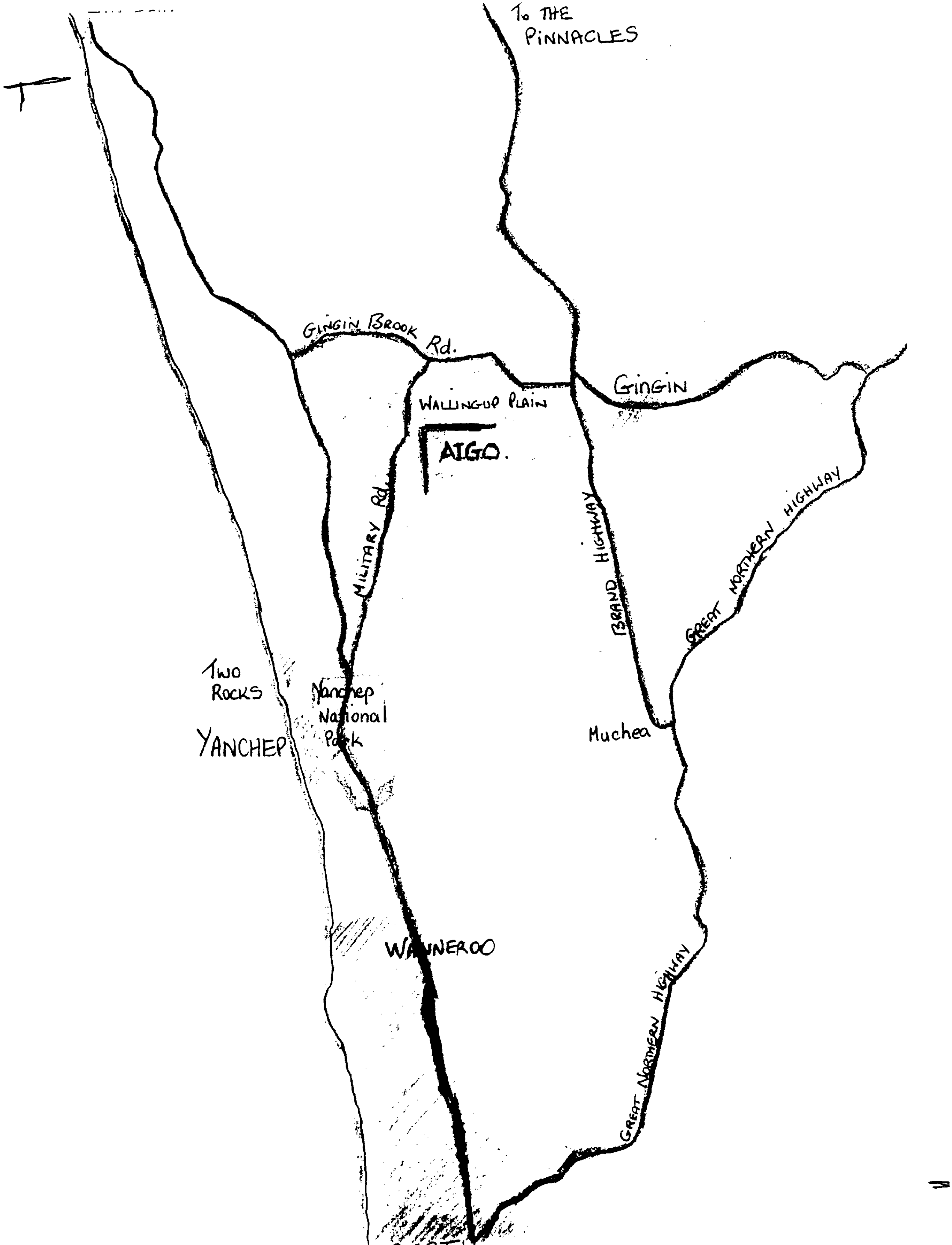
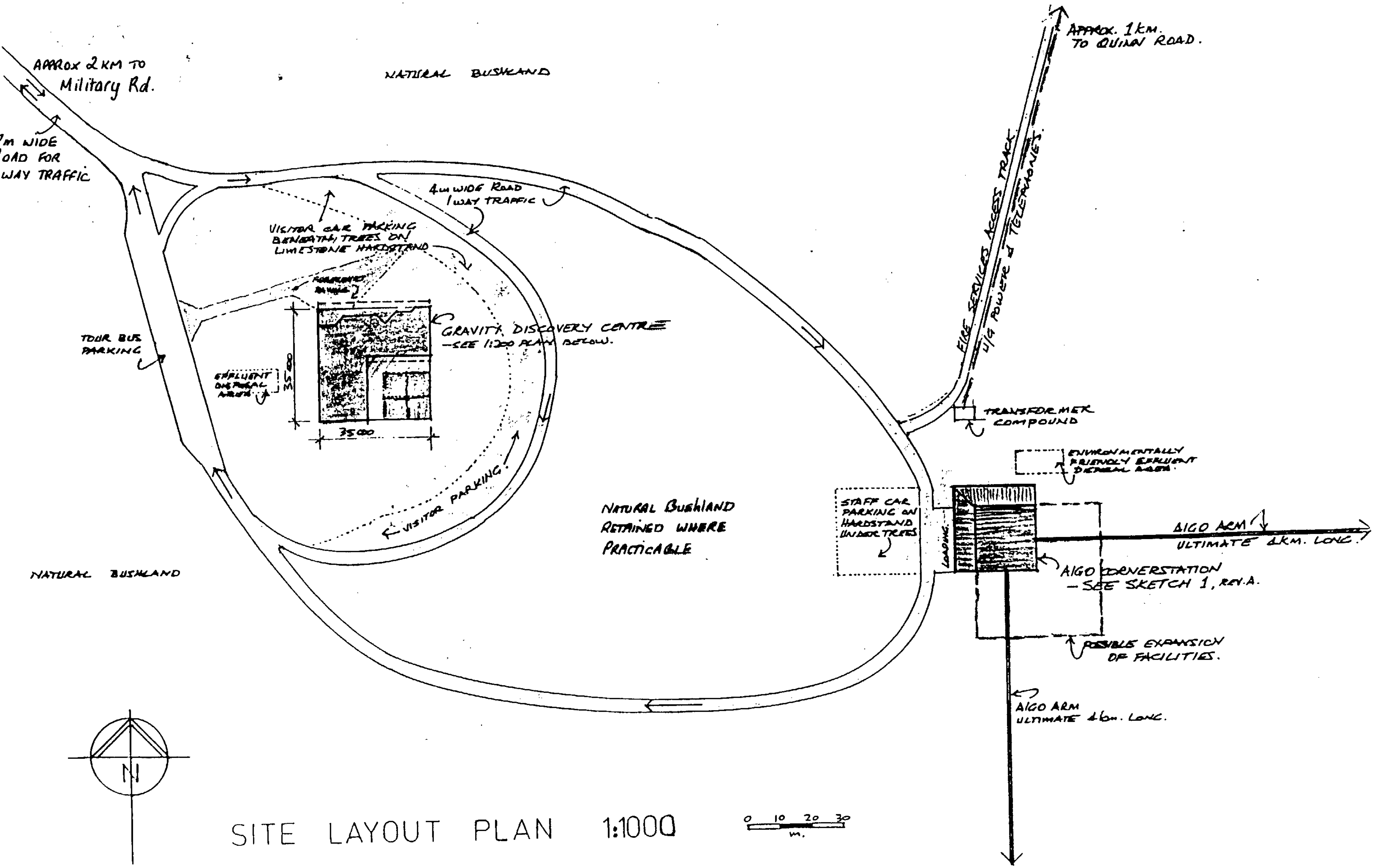
AIGO site — Perth

LIGO-G980049-20-M

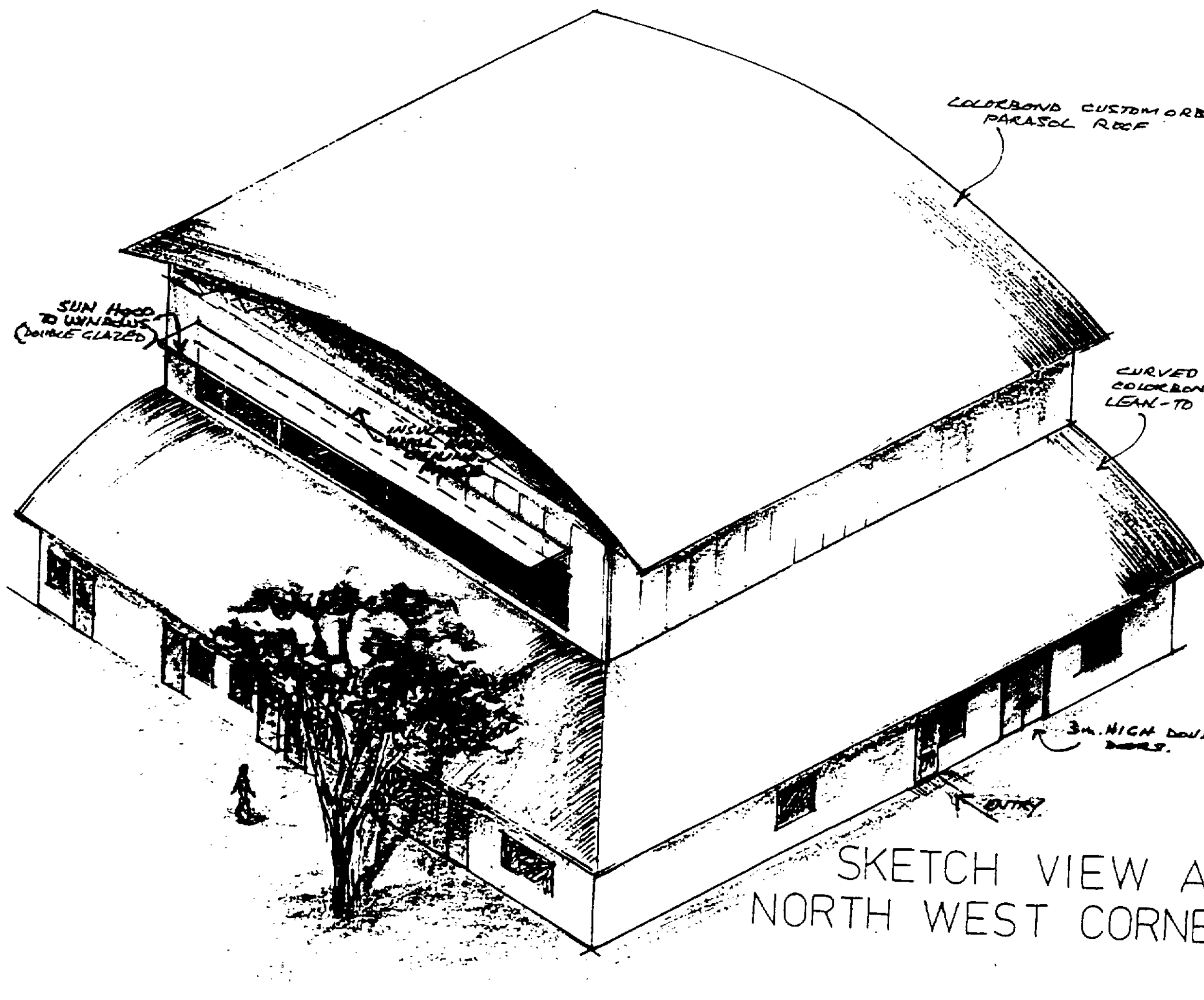
Julie



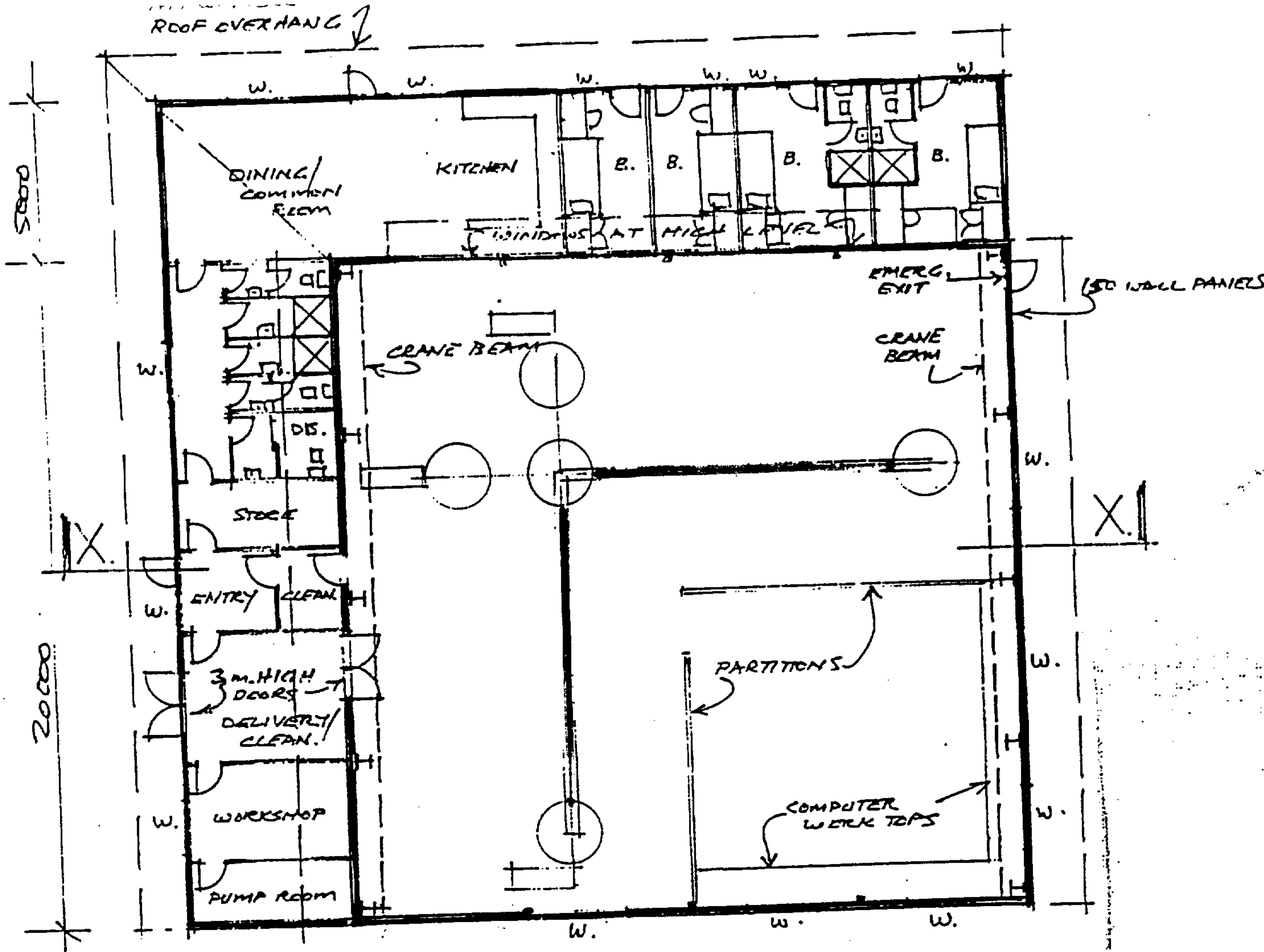
To THE PINNACLES
GINGIN BROOK Rd.
GINGIN
WALLINGUP PLAIN
AIGO.
MILITARY Rd.
BRAND HIGHWAY
GREAT NORTHERN HIGHWAY
TWO ROCKS
Yanchep National Park
YANCHEP
Muchea
WANNEROO
GREAT NORTHERN HIGHWAY



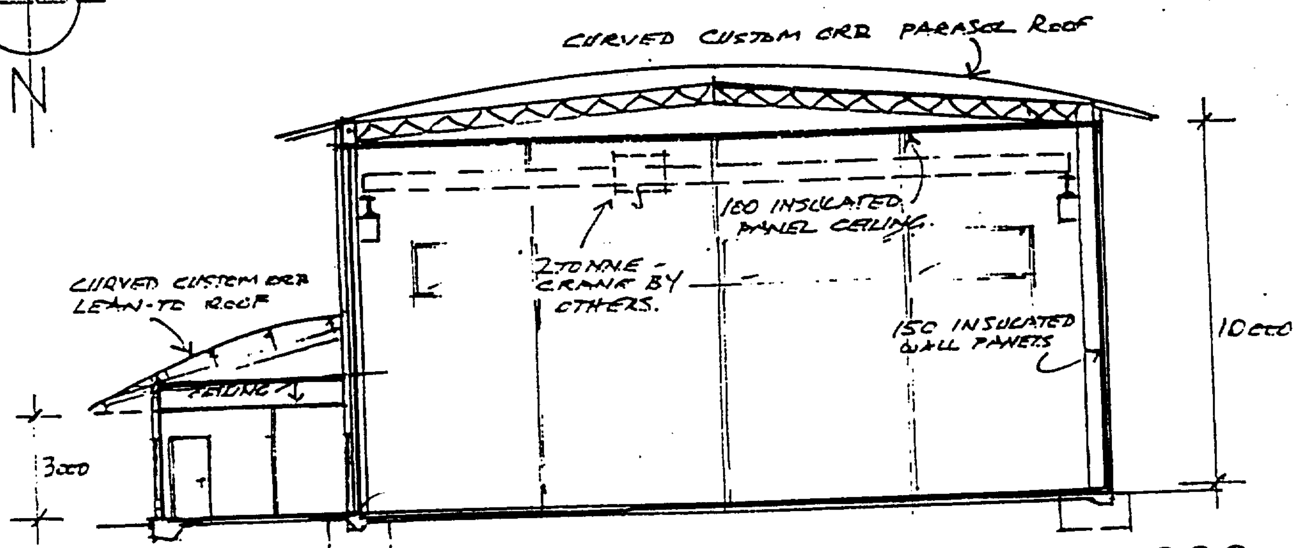
SITE LAYOUT PLAN 1:1000



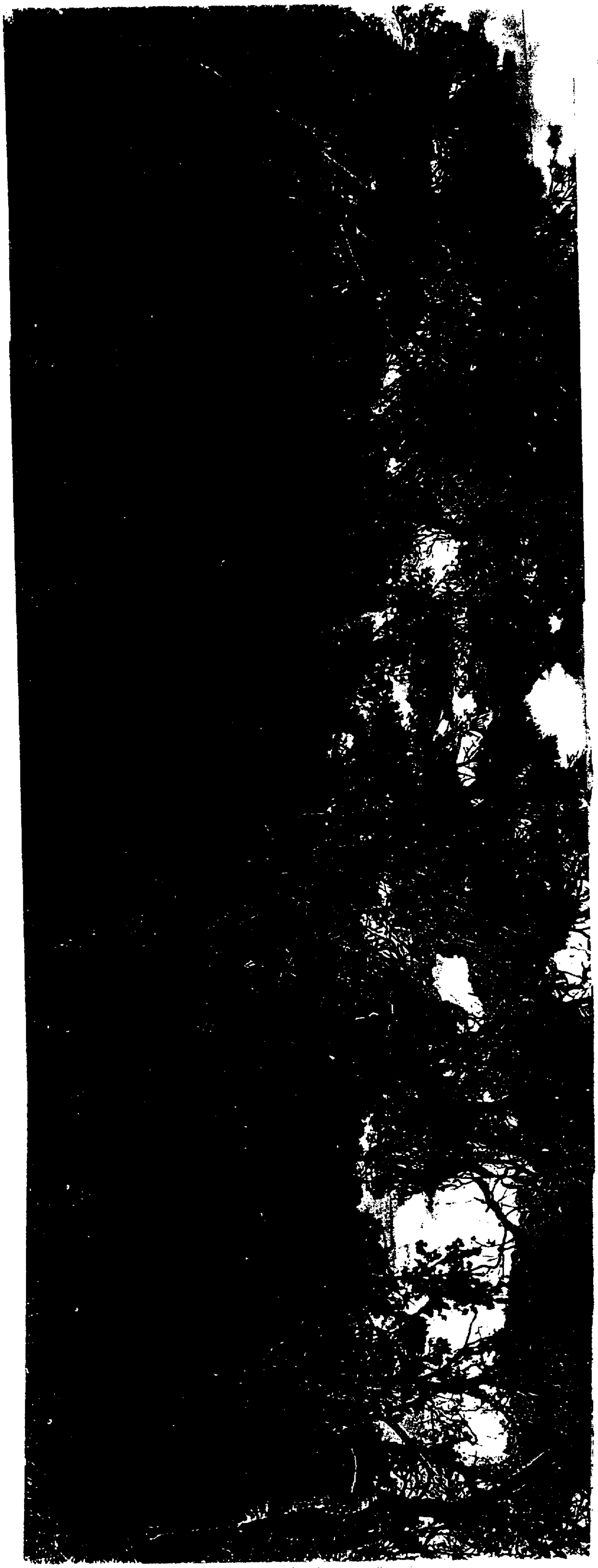
SKETCH VIEW AT NORTH WEST CORNER



FLOOR PLAN 1:200



CROSS SECTION AT X–X 1:200



Isolation and Suspension systems for AIGO

Low frequency isolators

Number of stages: 4
Springs: Steel cantilevers
Corner frequency: Vertical: ~7 Hz, Horizontal:~3 Hz

Ultra-low frequency pre-isolators

	Design goal:	*Achieved:*
Vertical:	30 mHz (T=30s)	40 mHz (T= 25s)
Horizontal:	30 mHz	7 mHz (T=150s)

Test masses

Material: sapphire
Dimensions: ϕ250 mm x 100 mm
Internal Q-factor: $Q>10^8$

Test mass suspension system

Thin niobium membrane flexure bonded to test mass
Dimensions: ~30 μm x 20 mm

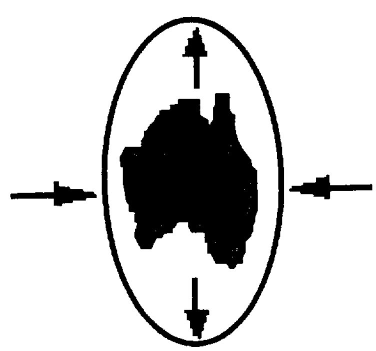
Bonding

Sapphire to niobium bonding: Cusil: M_{Nb}/M_{sapp} : 10^{-3}
Bond loss: 2×10^{-2} for $Q_i = 10^8$
Membrane loss: 10^{-4} for $Q_i = 10^8$
Membrane loss: 10^{-5} for $Q_p = 10^9$
Alternatives: diffusion bonding , Ti-V high temp bonding, silicate bonding

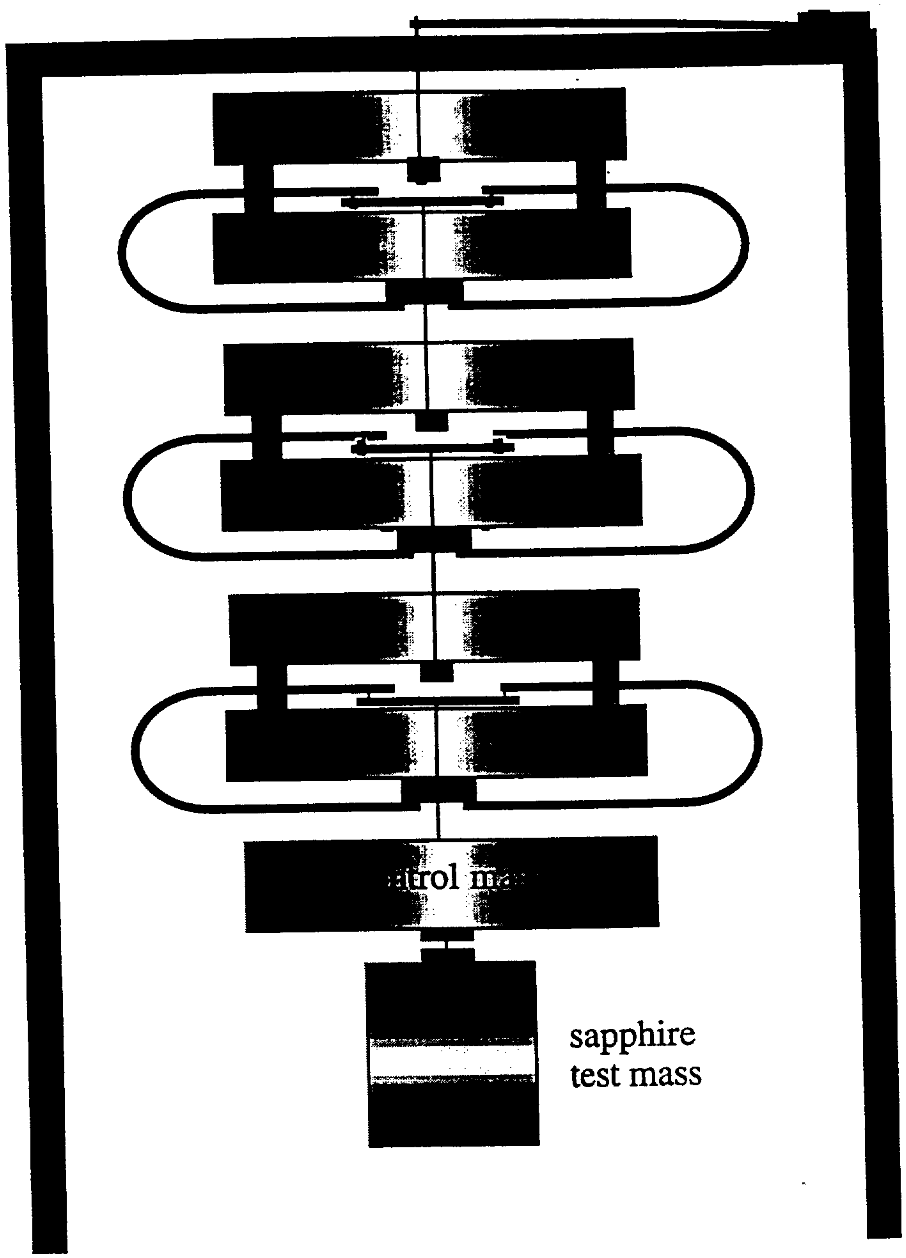
Vibration Isolation for Laser Interferometer Gravitational Wave Detectors

Department of Physics
The University of Western Australia
Nedlands, WA 6907

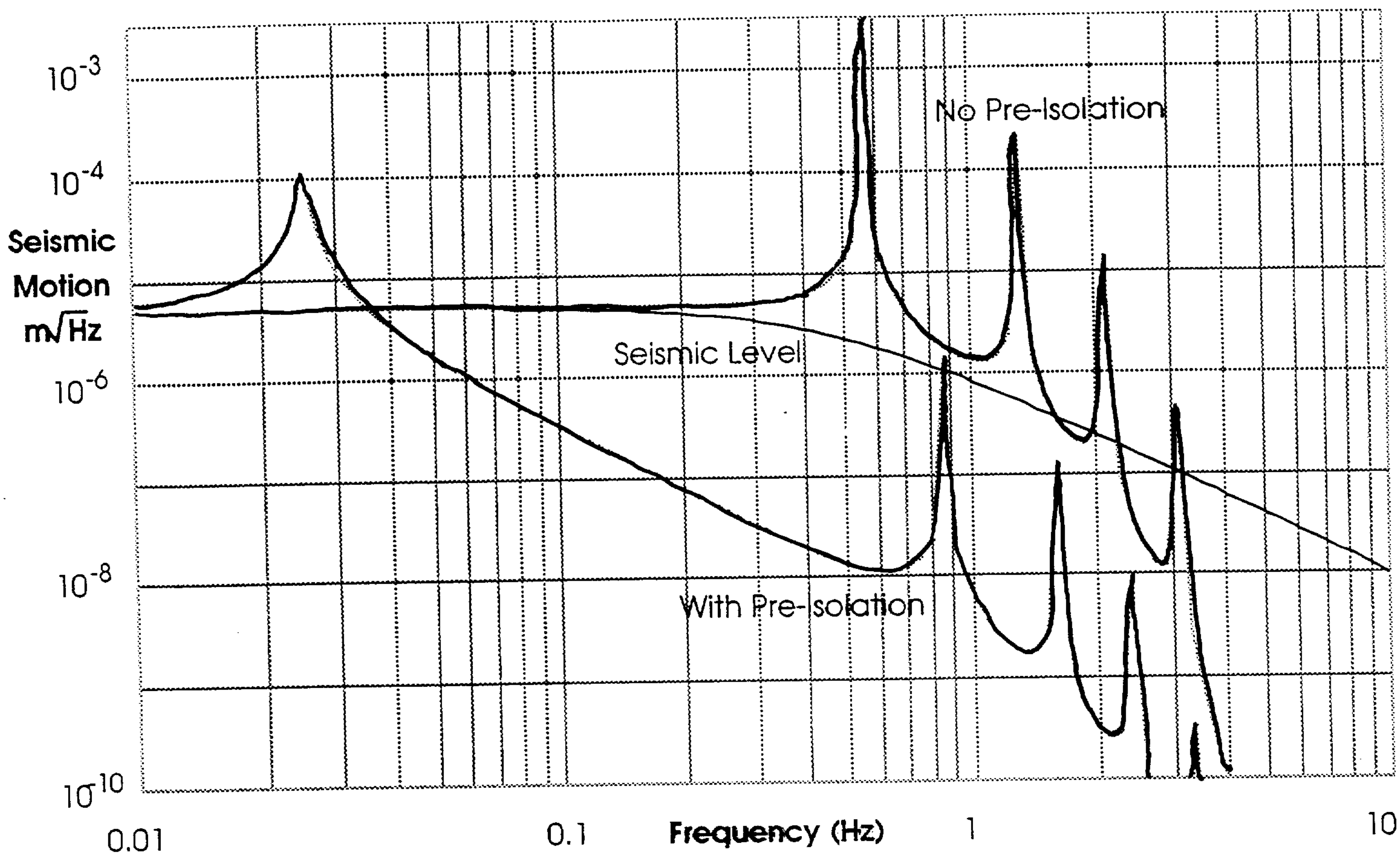
David Blair
Li Ju
John Winterflood
Jiangfeng Liu



Vibration Isolator and Test Mass Suspension



Predicted Level of Seismic Motion

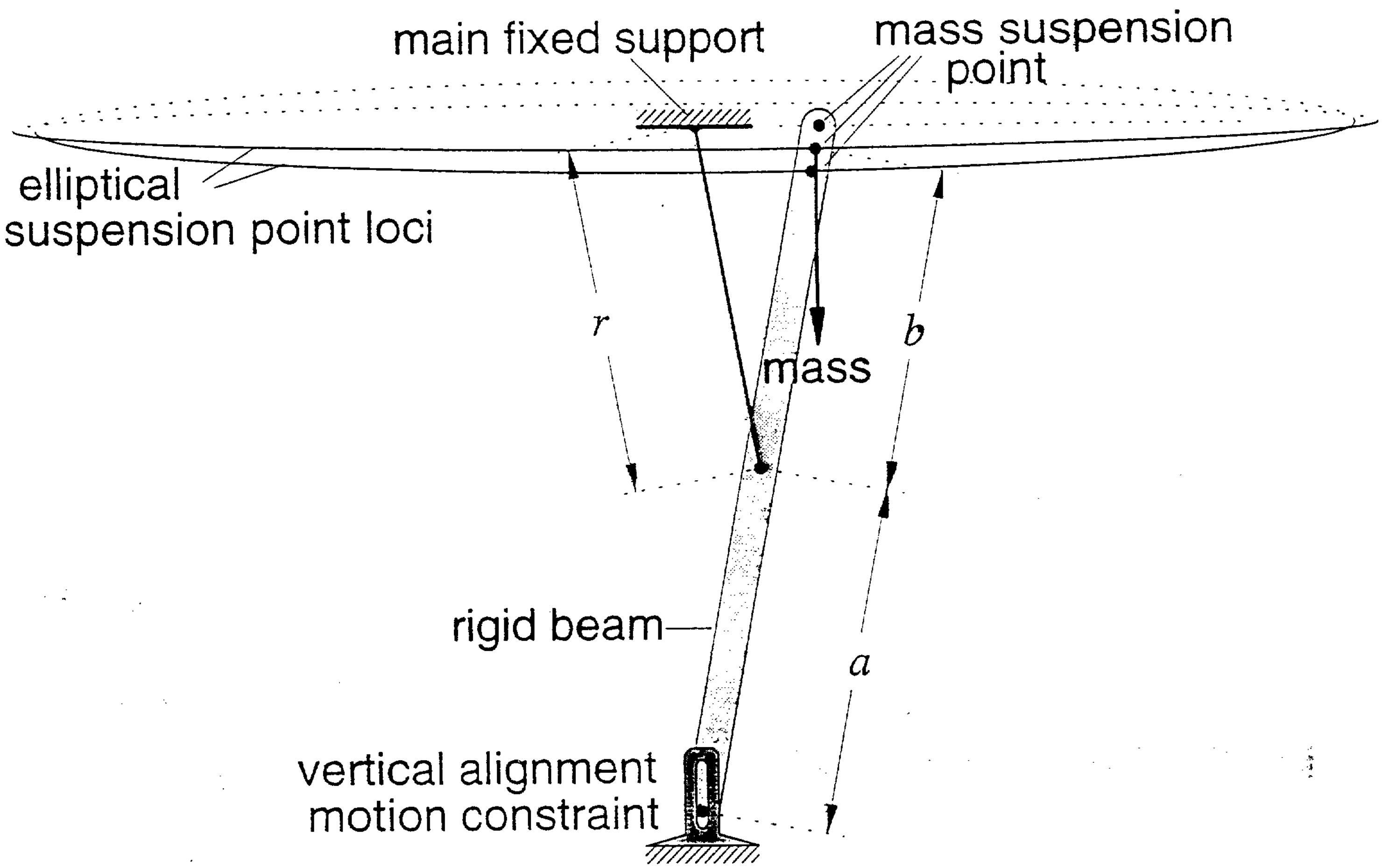


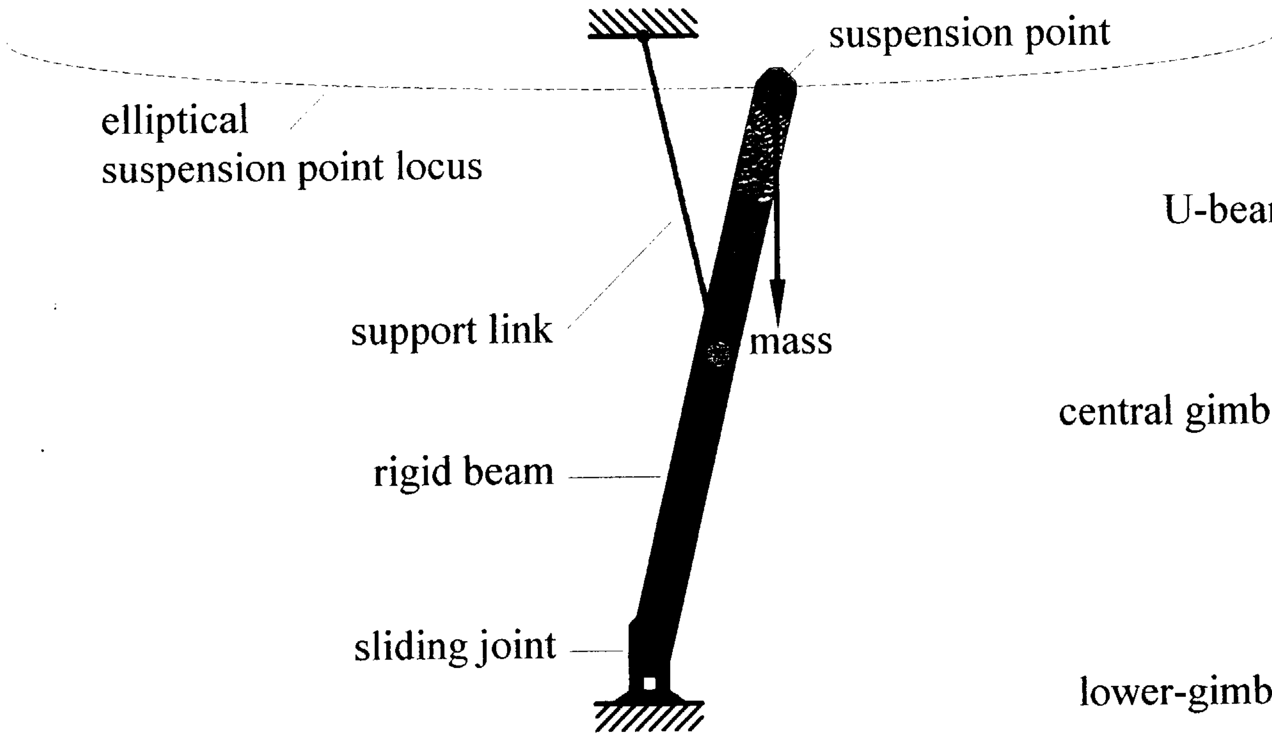
Expected Performance :-

Estimating RMS content of dominant peaks with the formula $RMS = A_0\sqrt{\frac{f_0 \pi Q}{2}}$ gives :-

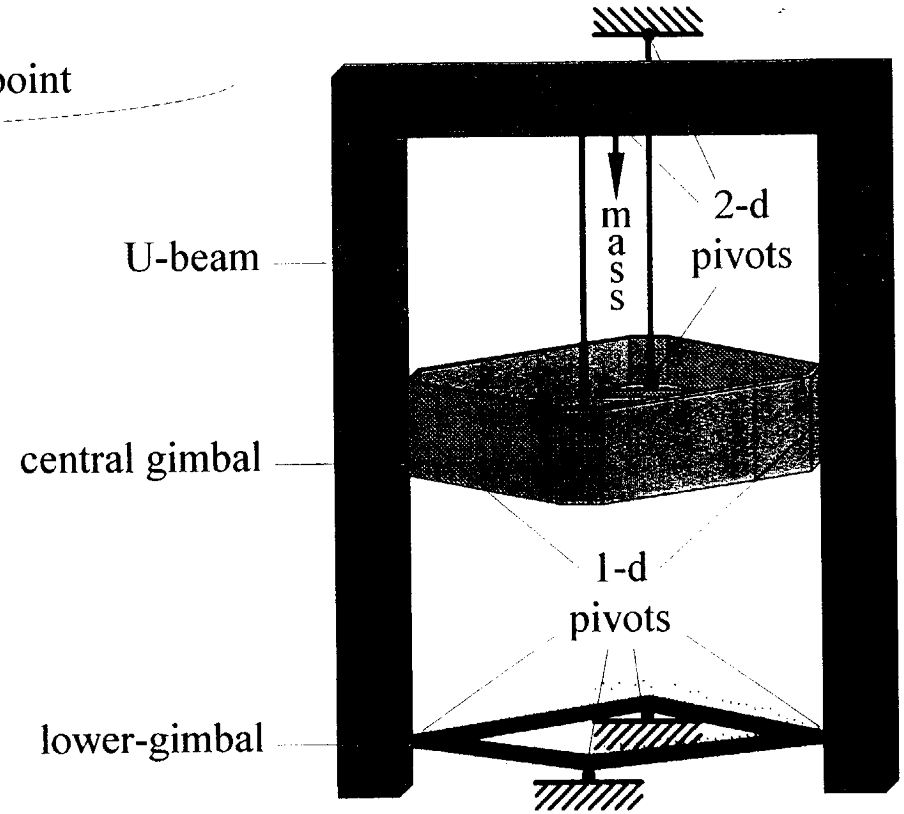
Undamped motion without pre-isolation = 0.13mm RMS @ 0.5Hz.

With pre-isolation reduces to 4.7µm @ 25mHz and 0.074µm @ 0.9Hz !

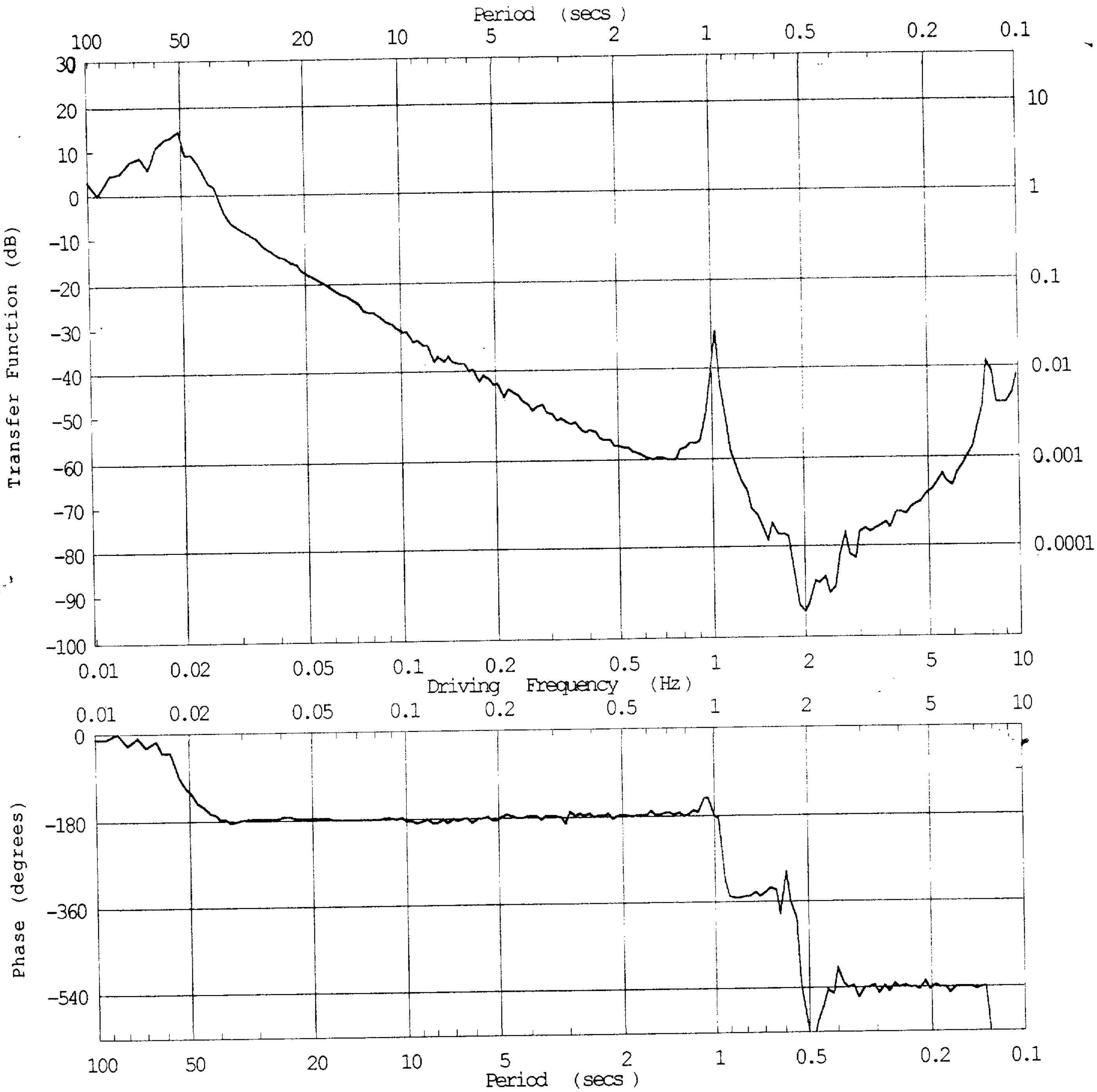

main fixed support
mass suspension point
elliptical suspension point loci
r
b
mass
rigid beam
a
vertical alignment motion constraint



Scott-Russel linkage basic geometry

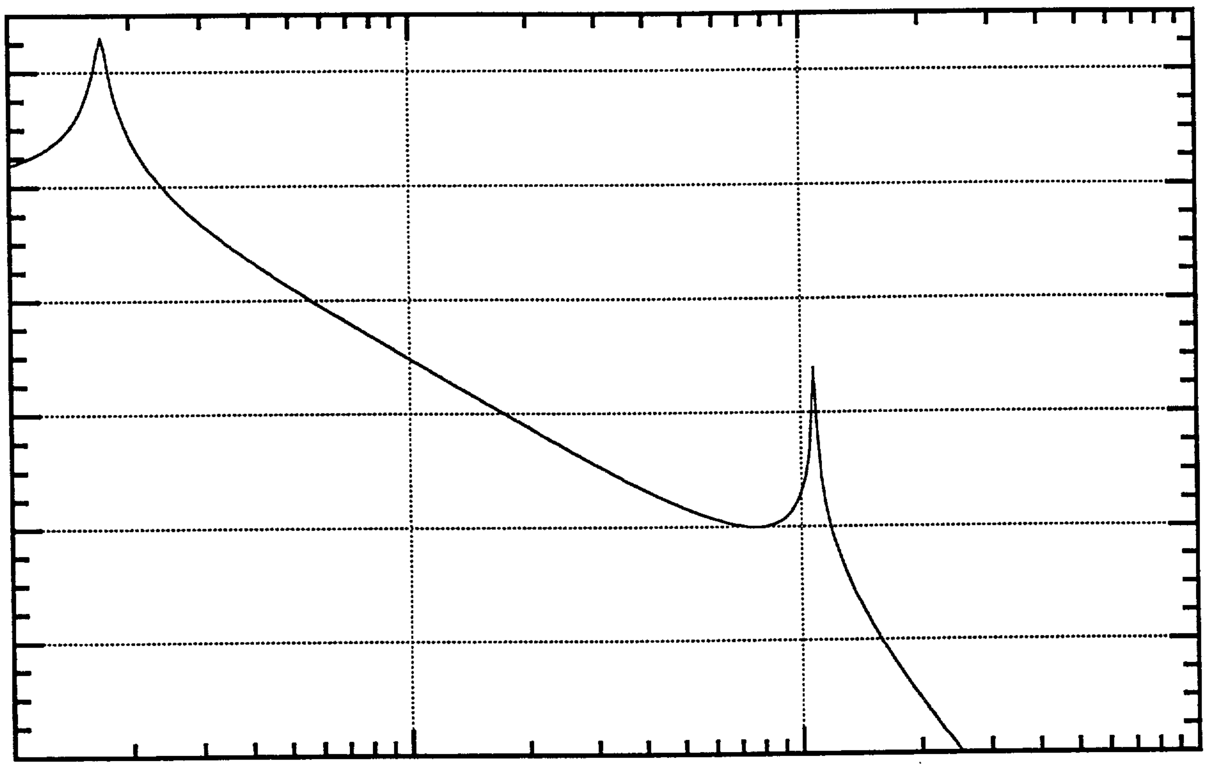


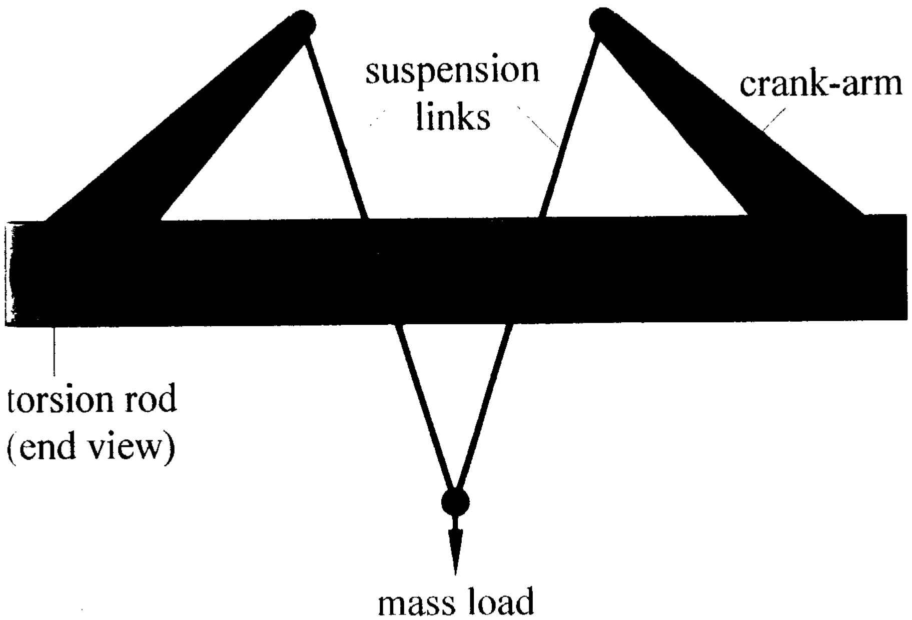
One Pre-isolator Realisation



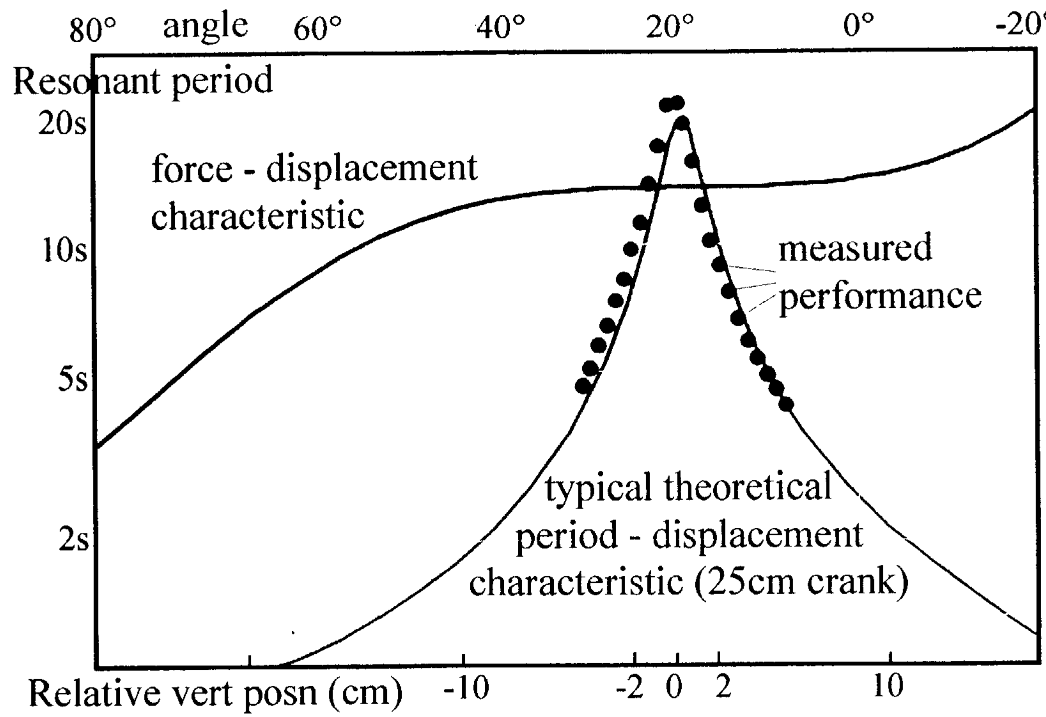
Transfer Function for y-axis (flat profile motion)

(~160kg load, x-axis c.o.p well nulled)

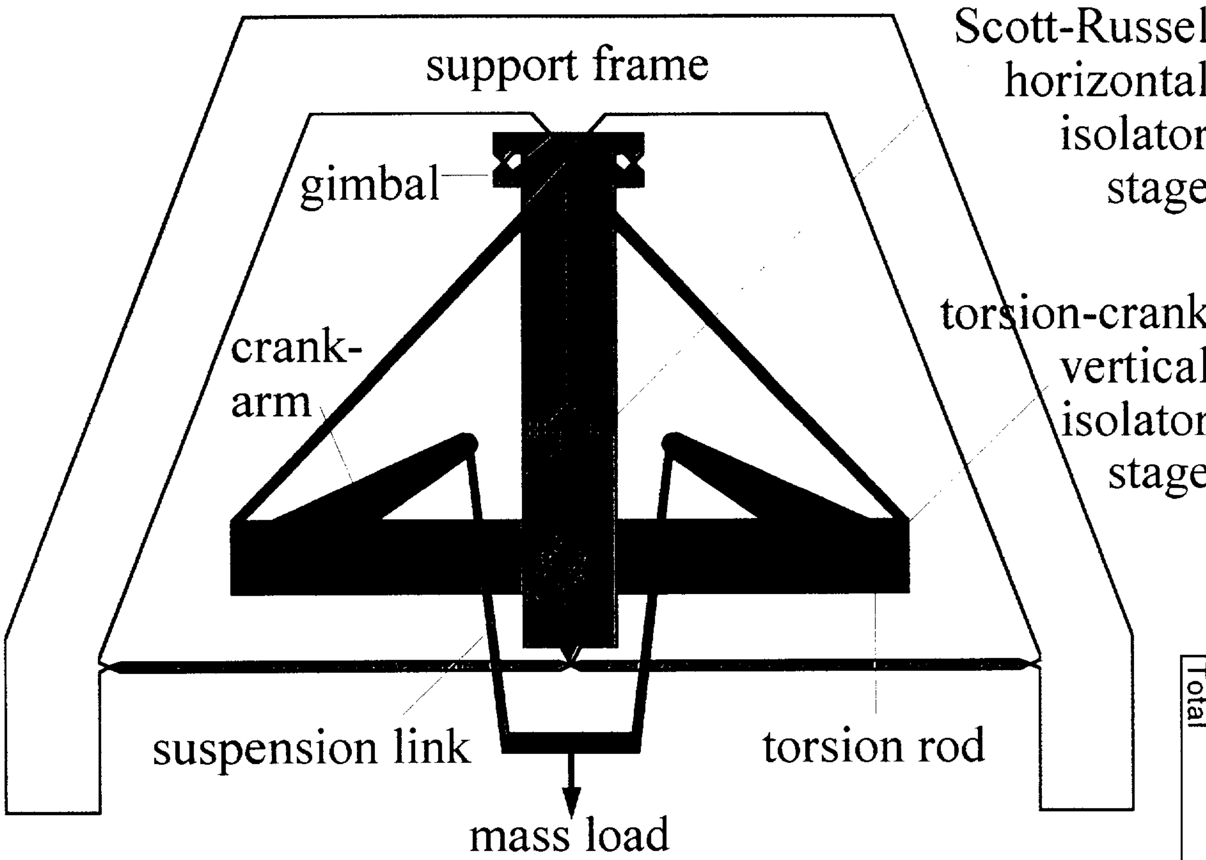




Torsion crank vertical pre-isolator.

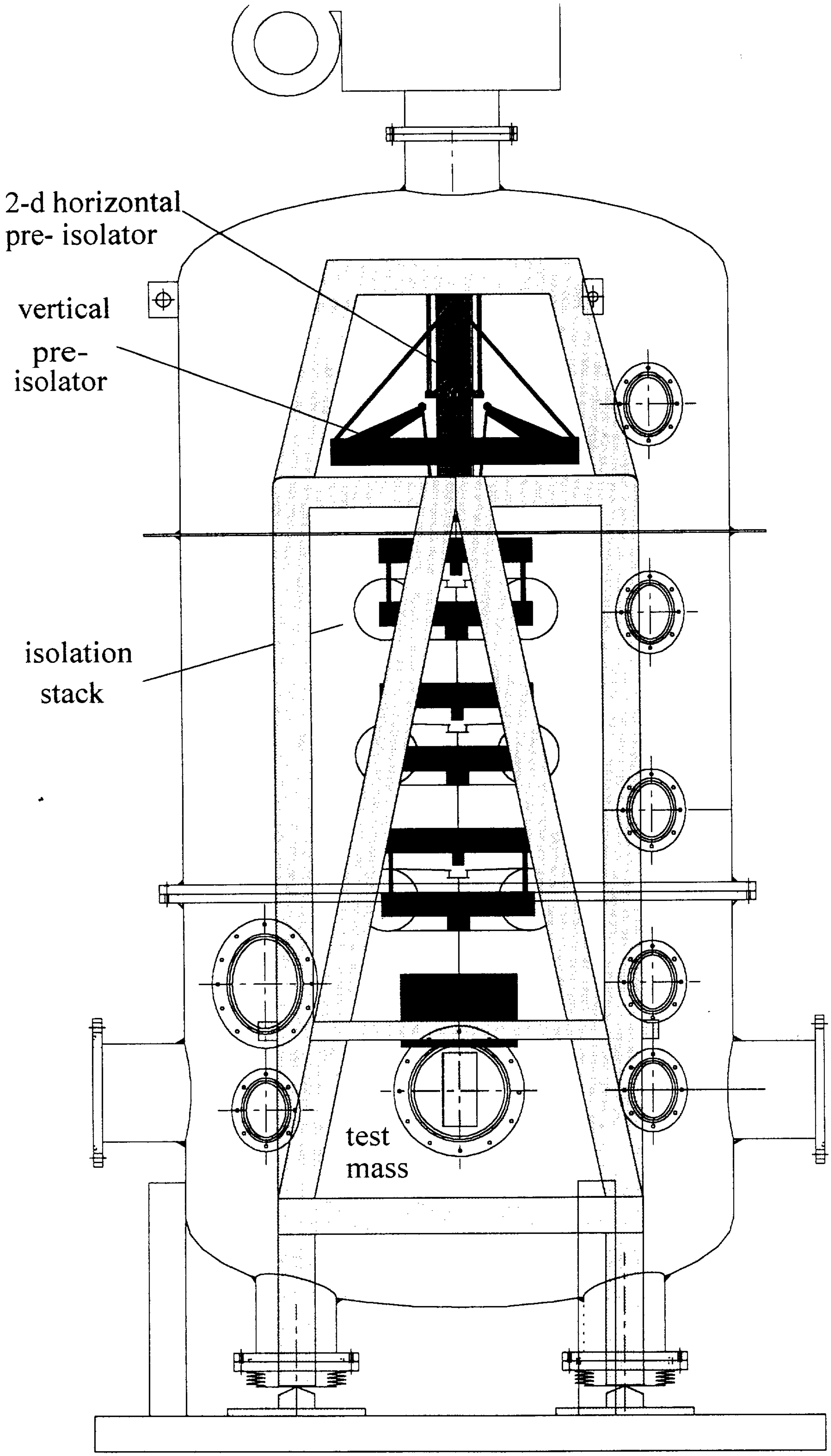


Theoretical curves and measured performance



Cascaded horizontal and vertical pre-isolators

maintenance	$2,000
Total	$24,265


2-d horizontal
pre- isolator
vertical
pre-
isolator
isolation
stack
test
mass

Sapphire Test Masses for Laser Interferometer Gravitational Wave Detectors

Australian International Gravitational Research Centre
Department of Physics
The University of Western Australia

David Blair
Eugeng Ivanov
Mark Notcutt
Ju Li
Mitsuru Taniwaki
Fetah Benabid
Zhao Chunnong

Properties of Sapphire

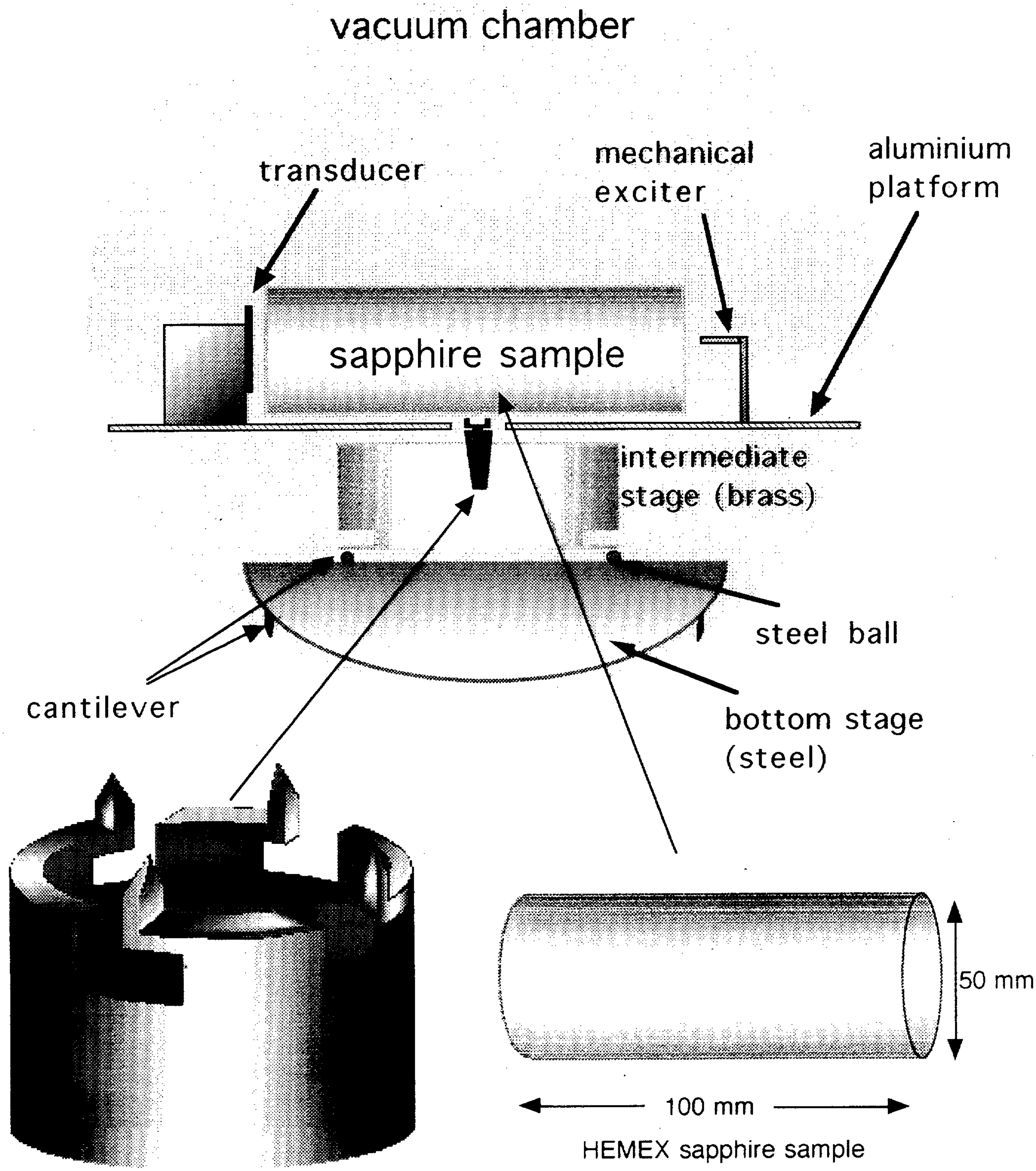
Advantages

	sapphire	fused silica
Very low acoustic loss ***(low thermal noise)***	**$< 10^{-8}$**	$\sim 10^{-7}$
Very high sound velocity ***(high internal mode frequency, hence low thermal noise)***	**$\sim 10^{4}$ ms^{-1}**	$\sim 6 \times 10^{3}$ ms^{-1}
Low optical absorption	**$\sim 3 \times 10^{-6}$/cm**	$\sim 1 \times 10^{-6}$/cm
High Thermal Conductivity ***(low thermal lensing)***	**46 W/m-K**	14 W/m-K
High quality mirrors	**few ppm losses**	ppm losses

Disadvantages

Birefringence ***(need accurate alignment and control)***	**Intrinsic**	Isotropic
Rayleigh Scattering ***(extra loss)***	**19×10^{-6}/cm**	2×10^{-6}/cm

Suspension System



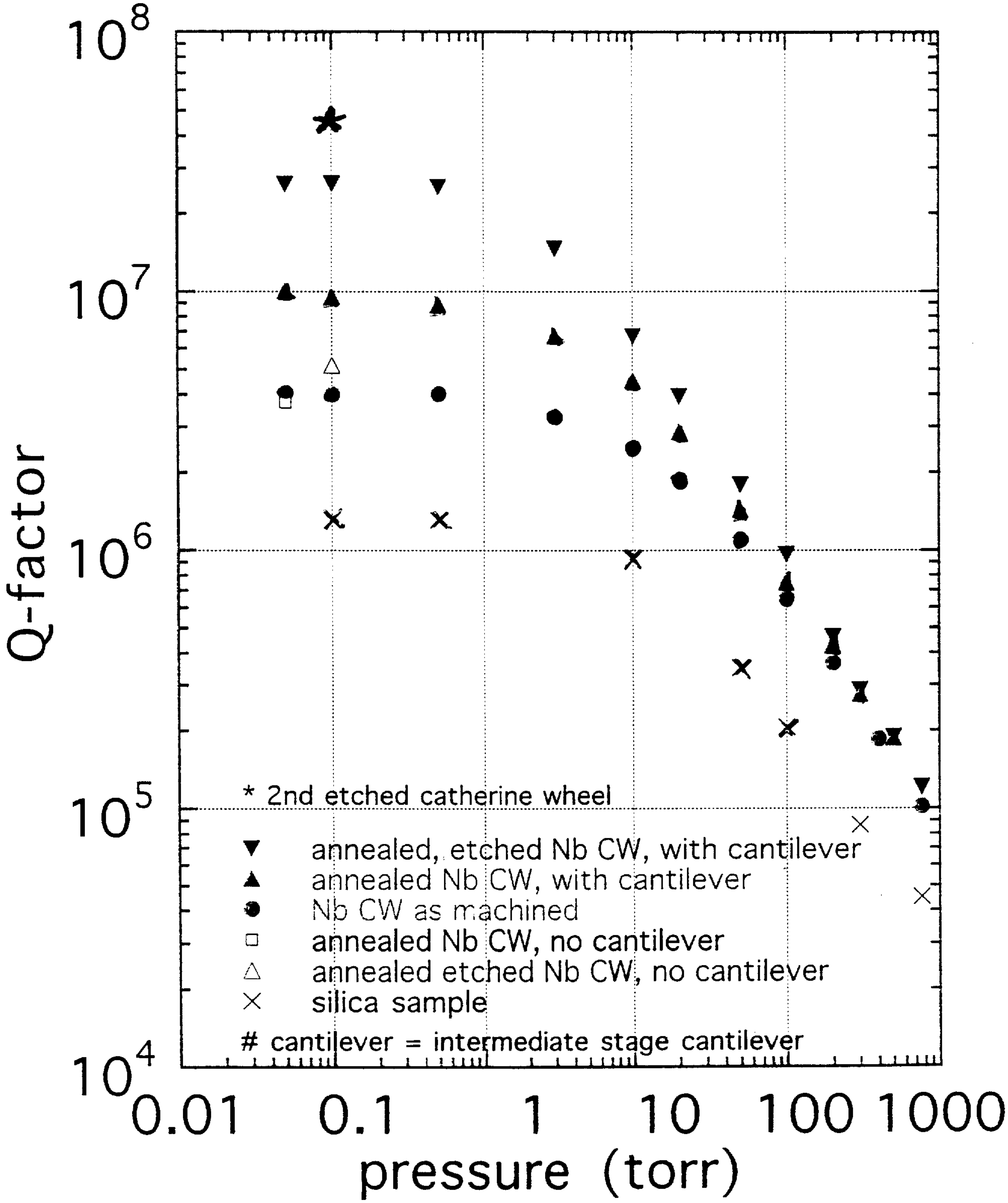
HEMEX sapphire sample

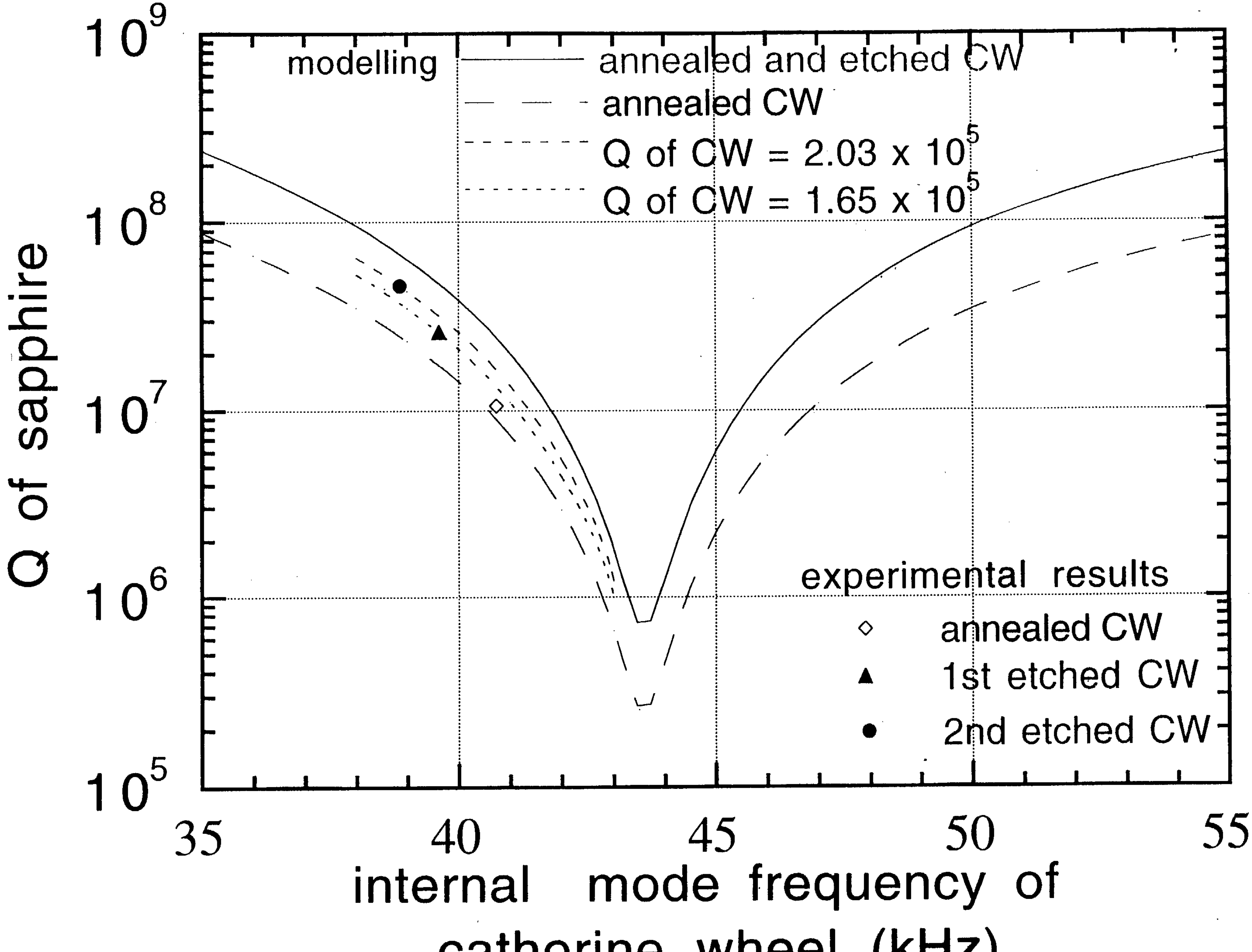
niobium catherine wheel

(as machined, annealed, etched)

lowest longitudinal mode 53.4kHz

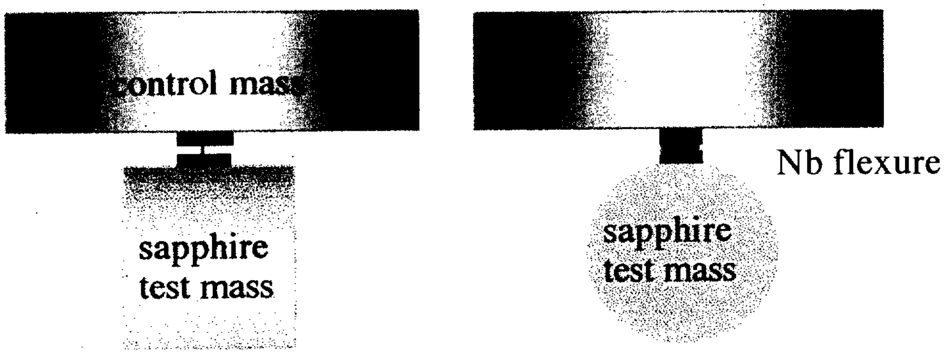
Q-factor of sapphire and silica vs. pressure





modelling
annealed and etched CW
annealed CW
Q of CW = 2.03 x 10^5
Q of CW = 1.65 x 10^5
experimental results
annealed CW
1st etched CW
2nd etched CW
10^9
10^8
10^7
10^6
10^5
Q of sapphire
35
40
45
50
55
internal mode frequency of catherine wheel (kHz)

Compound Pendulum Suspension



Advantages:

- Avoid violin string modes: $f_{vio} >$ 4kHz
- High pendulum Q-factor : $Q_p \sim 10^{10}$
- High mechanical integrity: well defined boundary conditions
- Easy to control
- Negligible thermoelastic losses

Choice of Nb flexure

- Thermal expansion matching sapphire
- Low acoustic loss

  $Q \sim 5 \times 10^6$ (1ton)

  $Q \sim 1.4 \times 10^6$ (3mm thick disk)

  Q expect 10^5 (assuming 30μm)

Thermoelastic effect of niobium flexure at room temperature

The thermoelastic loss of a flexure $\phi_{th} = \Delta \dfrac{\omega\tau_{th}}{1+(\omega\tau_{th})^2}$,

$$\Delta = \frac{E\ \alpha^2\ T}{C_v\ \kappa_{th}},$$

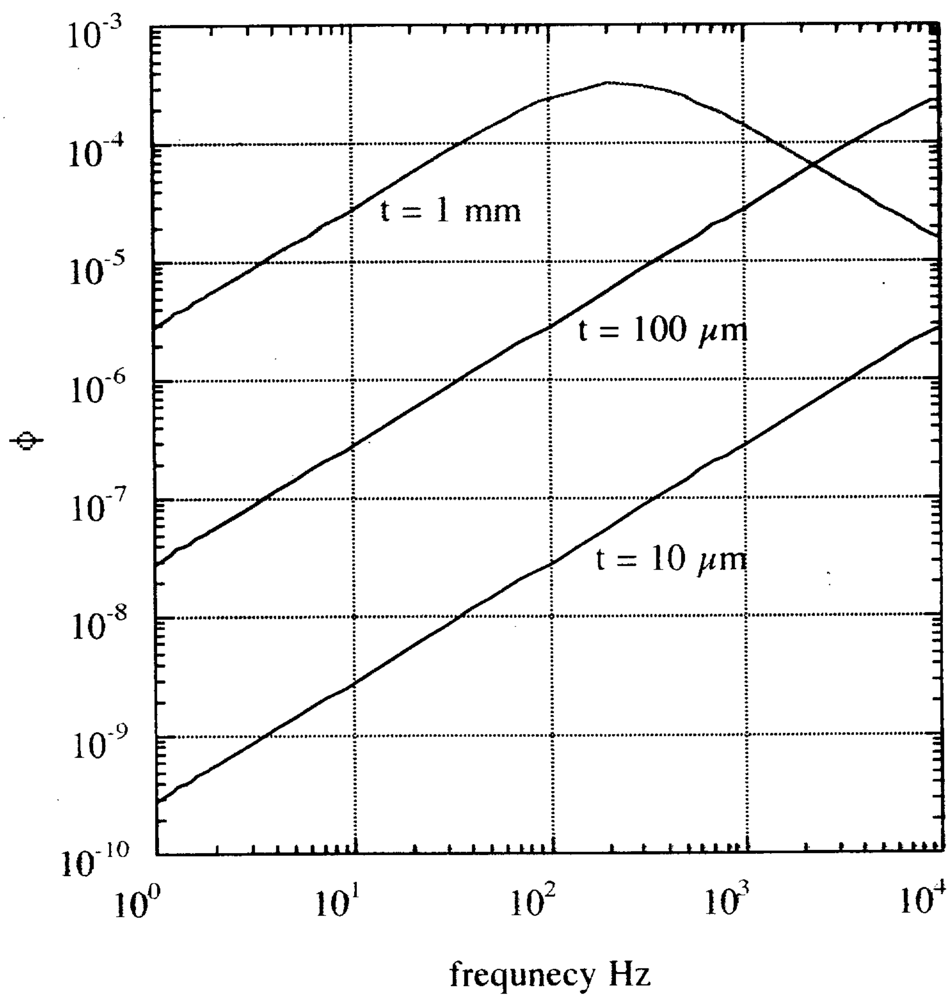
$$\tau_{th} = \frac{C_v\ d^2}{\pi^2\ \kappa_{th}} \quad \text{(foil)}$$

$$\tau_{th} = \frac{C_v\ t^2}{4.32\ \pi\ \kappa_{th}} \quad \text{(wire)}$$

E-- Young's modulus; α--thermal expansion coefficient;
κ_{th} -- thermal conductivity; C_v -- specific heat per volume;
T -- temperature; t -- thickness of the flexure; d -- diameter of the flexure.

* For same relaxation time τ_{th}, the wire diameter d= 1.17t

Nb:, E= 10^{11} Nm^{-2}, $\alpha = 7 \times 10^{-6}$ /K, $\kappa_{th} = 52$ w m^{-2} k-1. $C_v = 2.25 \times 10^6$ J m^{-3}K^{-1}



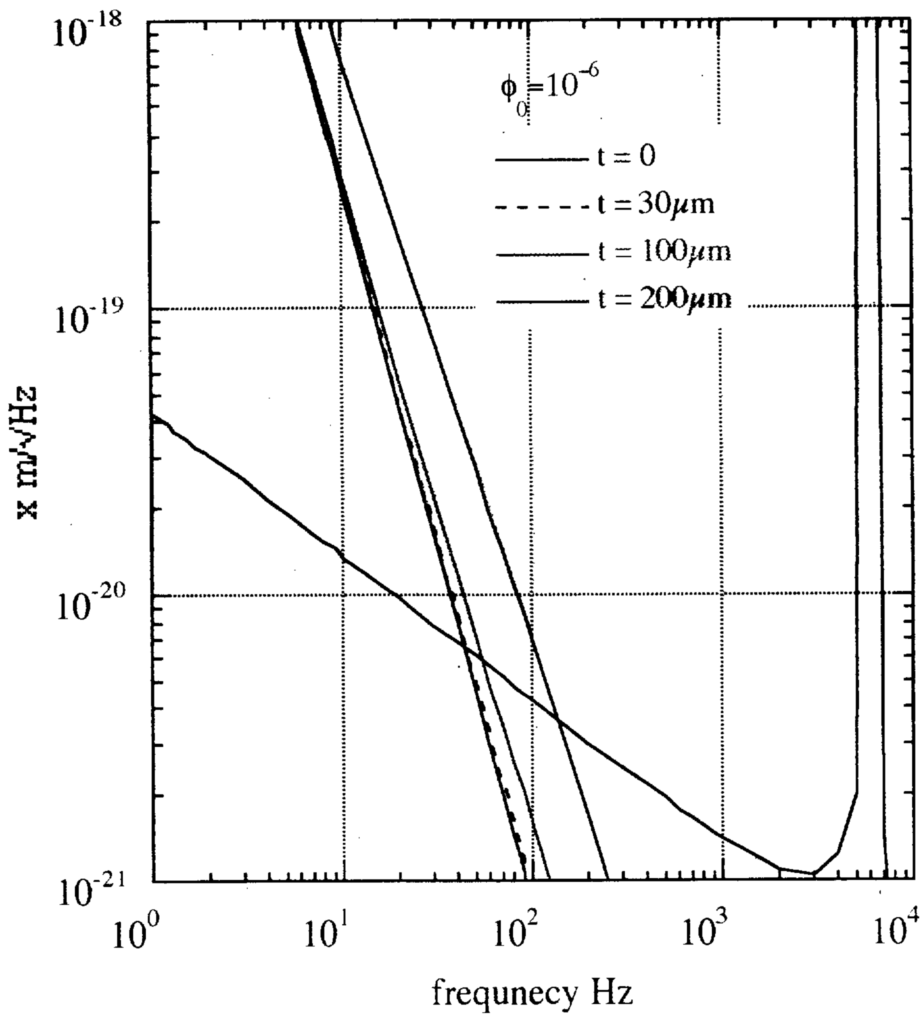
The thermal noise of a pendulum

$$x^2 = \frac{4\,k_B T\,\phi_p\,\omega_{p2}}{m\,\omega^5} \quad (\mathrm{m}/\sqrt{\mathrm{Hz}})$$

$$\phi_p = (\phi_o + \beta^{-1}\phi_{\tau h}).$$

β -- Pendulum Q-enhancement factor, ϕ_o-- intrinsic loss of the flexure material

If m=10kg, $\beta = 10^3$, $\phi_o = 10^{-6}$



* $\beta \propto t^{3/2}$. The flexure hase to satisfy the strenth requirement. Propose use of ~ 30 μm foil.

Sample	Size	Q	absorption	birefringence
Crystal Systems Hemex	ϕ50x100	5×10^7		>0.05°/cm
Crystal Systems ?	Φ30x100	2.6×10^6	>20 ppm/cm	>0.06°/cm
Rusian	ϕ30 x 100	1.6×10^7	—	—
Chinese (RISC)	ϕ20 x 80	2×10^5	~200 ppm/cm	
C.S HEMEX	10x10x20		~55 ppm/cm	>0.02°/cm
CSI White	"		~3 ppm/cm	—

Table 2: The PEM Carts instrumentation (one per site).

	Equipment	*Chan (units)*	*Unit*	*Total k$*
Sensing Equipment	**on**	**carts**		
Seismic Noise	3x3 accelerometer	9	1.1	10
Acoustic Noise	Electret Microphones	2	1.2	3
Magnetic Field	3 axis magnetometer	3 (1)	6	6
	Custom magnetometer	3	3	3
RF Interference	Broadband RF Receiver	1 RS232	2.5	3
Contam +RGA	Contr.head control RGA	1 RS232	50	50
Weather Mon	T and RH	10 (5)	0.2	1
Excitation Equipment	**on**	**carts**		
Signal Generator	SRS DS 335	3 (3) RS232	1.5	5
Seismic Noise	PZT shakers	NONE (12)	8(TBD)	96
	E-M Shaker	NONE (3)	8(TBD)	32
Acoustic Noise	Loudspeaker	NONE (1)	2	2
Magnetic Field	Custom design	NONE (1)	2 TBD	2
RF noise	RF Generator	1 (1) RS 232	13	13
DAQ cart: TOTAL	parts and	(estimated)	90	
Other carts, TOTAL	tools, parts and	(estimated)	14	
TOTAL	**COST**	**per site:**	**330**	

Table 3: Initial PEM System characteristics and estimated costs. (For carts see table 2)

	Detector	Nr WA+LA	Cost k$ Unit	Total
Seismic Noise	3 axis seismometer	5 + 3	14	112
	2 axis tiltmeter	5 + 3	10	80
	1 axis accelerometer	99+36	1.1 149	
Acoustic Noise	B&K Microphone	29+12	1.5	62
Magnetic Field	3 axis magnetometer	7 + 1	6.5	52
Thunderstorm Mon	satellite service	1 + 0	28y1	18/y
RF Interference	Broadband Receivers	4 + 4	2.5	20
RF Interference	Narrowband Receiver	2 + 1	.5	8
Cosmic Muons	Scintilator Detector	1 + 1	10	20
Power Line	Line Monitor	2 + 1	6.	18
Residual Gas RGA	Head; controller	9+5 & 6+4	35&25	490&250
ContaminationTBD	Crystal Head controller	8 + 5 5 + 3	4 10	52 80
Weather Monitor	Weather Station T and T/RH	5 + 3 25 + 12	0.8 0.24	7 9
Dust Monitor	Dust Part. Det.	21+13	3.2	109
TOTAL	**COST**	**(no carts)**	**1546**	
Other costs:	**Mechanical:**	**(no CDS)**	**164**	
TOTAL	**COSTw/carts**	**(No CDS)**	**2370**	

Note 1, Linda Turner, 04/20/98 05:21:58 PM
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