A# BHQS parameters - version 4

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0.1 Introduction

This is a compendium of the parameters and details shown in the talks at the March 2023 BHQS workshop. These parameters are represented in [1][2]. **v1 comes from the original parameter set presented at the first Heavy SUS workshop (March 2023)**

v2 updates the transverse separation parameters due to a transcription error from v1.

v3 updates the blade spring sizes. They were incorrect by a factor of fourth root of 2

v4 contains the change to 105 kg test mass and 420 kg payload suggested at the third Heavy SUS workshop (December 2024)

0.2 Mechanical parameters in QUAD model notation

The BHQS parameters are listed in Table 1 using the same convention as the QUAD model [3], which is summarized in Figure 1.

Symbols	**Description**	**Units**	**TOP**	**UIM**	**PUM**	**TST**
$m_n/m_1/m_2/m_3$	Mass	[kg]	123	87	105	105
$I_{n,x}/I_{1,x}/I_{2,x}/I_{3,x}$	Roll moment of inertia	[kg·m^2]	10.2	6.3	2.65	2.65
$I_{n,y}/I_{1,y}/I_{2,y}/I_{3,y}$	Pitch moment of inertia	[kg·m^2]	11.2	6.8	2.1	2.1
$I_{n,z}/I_{1,z}/I_{2,z}/I_{3,z}$	Yaw moment of inertia	[kg·m^2]	19.1	10.9	2.1	2.1
$I_{n,xy}/I_{1,xy}/I_{2,xy}/I_{3,xy}$	R-P cross moment of inertia	[kg·m^2]	0	0	0	0
$I_{n,yz}/I_{1,yz}/I_{2,yz}/I_{3,yz}$	P-Y cross moment of inertia	[kg·m^2]	0	0	0	0
$I_{n,zx}/I_{1,zx}/I_{2,zx}/I_{3,zx}$	Y-R cross moment of inertia	[kg·m^2]	0	0	0	0
$k_{cn}/k_{c1}/k_{c2}$	Vertical spring stiffness (per side)	[kN/m]	6.85	9.75	5.8	N/A
$k_{xn}/k_{x1}/k_{x2}$	Lateral spring stiffness (per side)	[kN/m]	3200	3200	2700	N/A
$Y_n/Y_1/Y_2/Y_3$	Young's moduli of wires	[GPa]	212	212	212	72
$l_n/l_1/l_2/l_3$	Stretched wire length	[m]	0.34	0.34	0.34	0.60
$r_n/r_1/r_2/r_3$	radii of wires	[µm]	1400	1200	1000	220
$d_{\rm top}/d_n/d_1/d_3$	(upper) wire vertical attachment distance	[mm]	0	0	0	0
$d_m/d_0/d_2/d_4$	(lower) wire vertical attachment distance	[mm]	0	0	0	0
$s_n/s_u/s_i/s_l$	front-back wire attachment distance	[cm]	16.5	17	12.5	2.95
$n_{n0}/n_0/n_2/n_4$	(upper) wire transverse attachment distance	[cm]	22.0	26.2	22.5	22.5
$n_{n1}/n_1/n_3/n_5$	(lower) wire transverse attachment distance	[cm]	22.0	26.2	22.5	22.5

Table 1: BHQS parameters in MATLAB model QUAD notation [3].

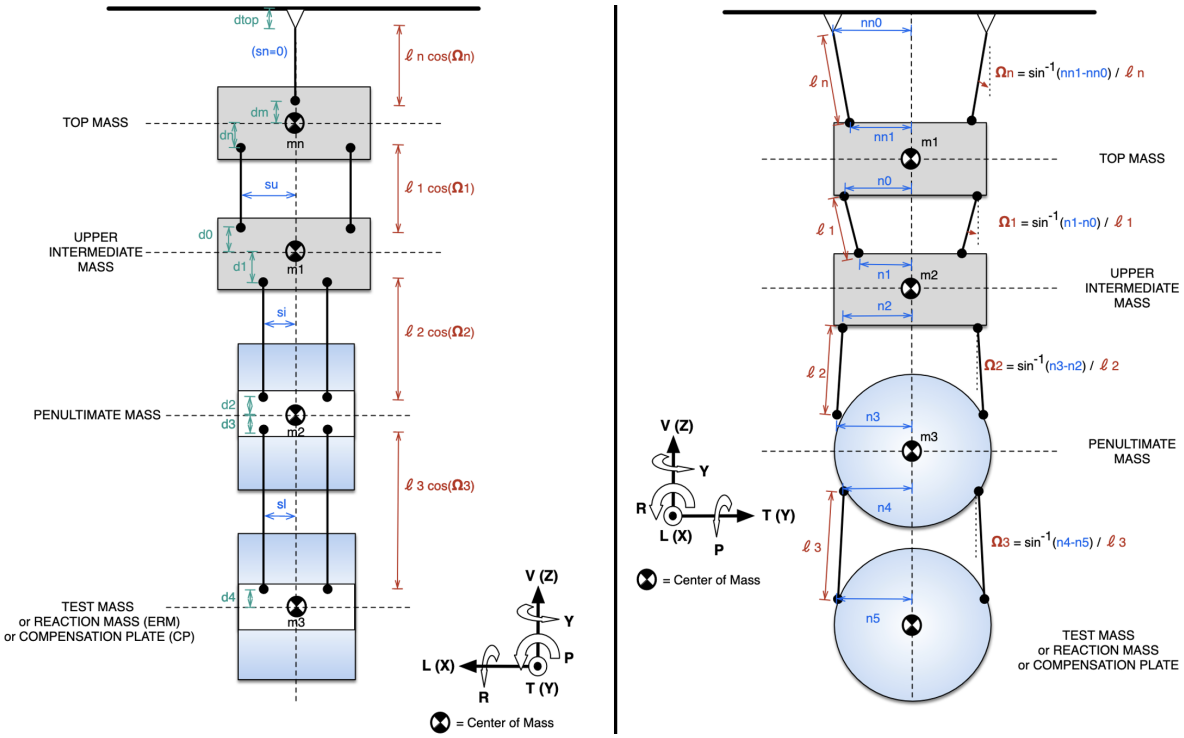

Figure 1: Quadruple suspension parameter definitions. Figure taken from [3]. The figure summarizes the notation used in Table 1

0.3 Other parameters and dimensions of interest

The test mass dimensions are summarized in Table 2. The fused silica fiber parameters are included in Table 3. Finally, we include the parameters describing the blade springs for each stage of the BHQS in Table 4. The values for the deflection and internal modes are calculated following the guidelines of [4] and [5].

Description	**Units**	**Value**
Test mass radius	[cm]	45
Test mass thickness	[cm]	30

Table 2: Test mass parameters.

Description	**Units**	**Value**
Diameter of thin section	[µm]	453
Diameter of nulling section	[µm]	1300
Length of nulling regions	[mm]	40
Stretched length between bending points	[mm]	600
Estimated Bending length	[mm]	6.5
Estimated Length of thin section	[mm]	533
Estimated stiffness	[kN/m]	21.5

Table 3: Fused silica fiber parameters.

Description	**Units**	**ST2**	**TOP**	**UIM**
Length	[cm]	44.6	28.8	28.8
Width	[cm]	22.3	14.4	14.4
Thickness	[mm]	3.5	3.0	2.5
Stress	[MPa]	1000	1000	1000
Deflection	[cm]	26.5.8	13.1	15.6
Radius of curvature	[cm]	31.8	29.1	23.4
Internal mode	[Hz]	66.5	134	113

Table 4: Blade Spring parameters

0.4 Simplified parameters for the BHQS

Since we assume the 'd' parameters for the wire attachments in Table 1 to be zero, we assume the wires are all vertical, and we consider the inertias of all masses to be diagonal; it is possible to decouple all degrees of freedom and simplify the modelling of each one as a spring-mass system with four masses and four springs. These parameters are summarized in Table 5.

Symbols	**Description**	**Units**	**TOP**	**UIM**	**PUM**	**TST**
L	Distance to the previous stage	[cm]	34	34	34	60
m	Mass of the stage	[kg]	123	87	105	105
I_{RR}	Stage moment of inertia (Roll)	[kg·m^2]	10.2	6.3	2.65	2.65
I_{PP}	Stage moment of inertia (Pitch)	[kg·m^2]	11.2	6.8	2.1	2.1
I_{YY}	Stage moment of inertia (Yaw)	[kg·m^2]	19.1	10.9	2.1	2.1
k_L	Longitudinal stiffness above stage	[kN/m]	12.1	8.6	6.1	1.7
k_T	Transverse stiffness above stage	[kN/m]	12.1	8.6	6.1	1.7
k_V	Vertical stiffness above stage	[kN/m]	13.7	19.5	11.6	86.2
k_R	Roll rotational stiffness above stage	[N·m]	660	1340	590	4360
k_P	Pitch rotational stiffness above stage	[N·m]	385	600	185	77.5
k_Y	Yaw rotational stiffness above stage	[N·m]	930	850	400	88

Table 5: Simplified parameters for quick (and approximate) computation.

Degree of freedom	**Units**	f_1	f_2	f_3	f_4
Longitudinal	[Hz]	0.45	0.96	1.7	2.6
Transverse	[Hz]	0.45	0.96	1.7	2.6
Vertical	[Hz]	0.67	1.9	3.6	6.6
Roll	[Hz]	0.78	1.87	3.4	9.3
Pitch	[Hz]	0.55	0.93	1.75	2.2
Yaw	[Hz]	0.68	1.04	1.85	2.7

Table 6: Resonant frequencies for BHQS

Bibliography

[1] E. Bonilla, "BHQS dynamics tradeoff notes," tech. rep., LIGO Internal Document G2300711, 2023.

[2] E. Sanchez, "BHQS, VE, BSC CHAMBER COLLAR (CONCEPTUAL)," tech. rep., LIGO Internal Document D2300150, 2023.

[3] J. Kissel and M. Barton, "QUAD Pendulum Parameter Descriptions and Naming Convention," tech. rep., LIGO Internal Document T1400447, 2014.

[4] N. Robertson, "Design Notes for Production Blades for HAM Suspensions," tech. rep., LIGO Internal Document T1000351, 2010.

[5] N. Robertson and C. Torrie, "EXCEL spreadsheet for design of HSTS Blades," tech. rep., LIGO Internal Document T1000352, 2010.