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# Mass Limits & Balancing

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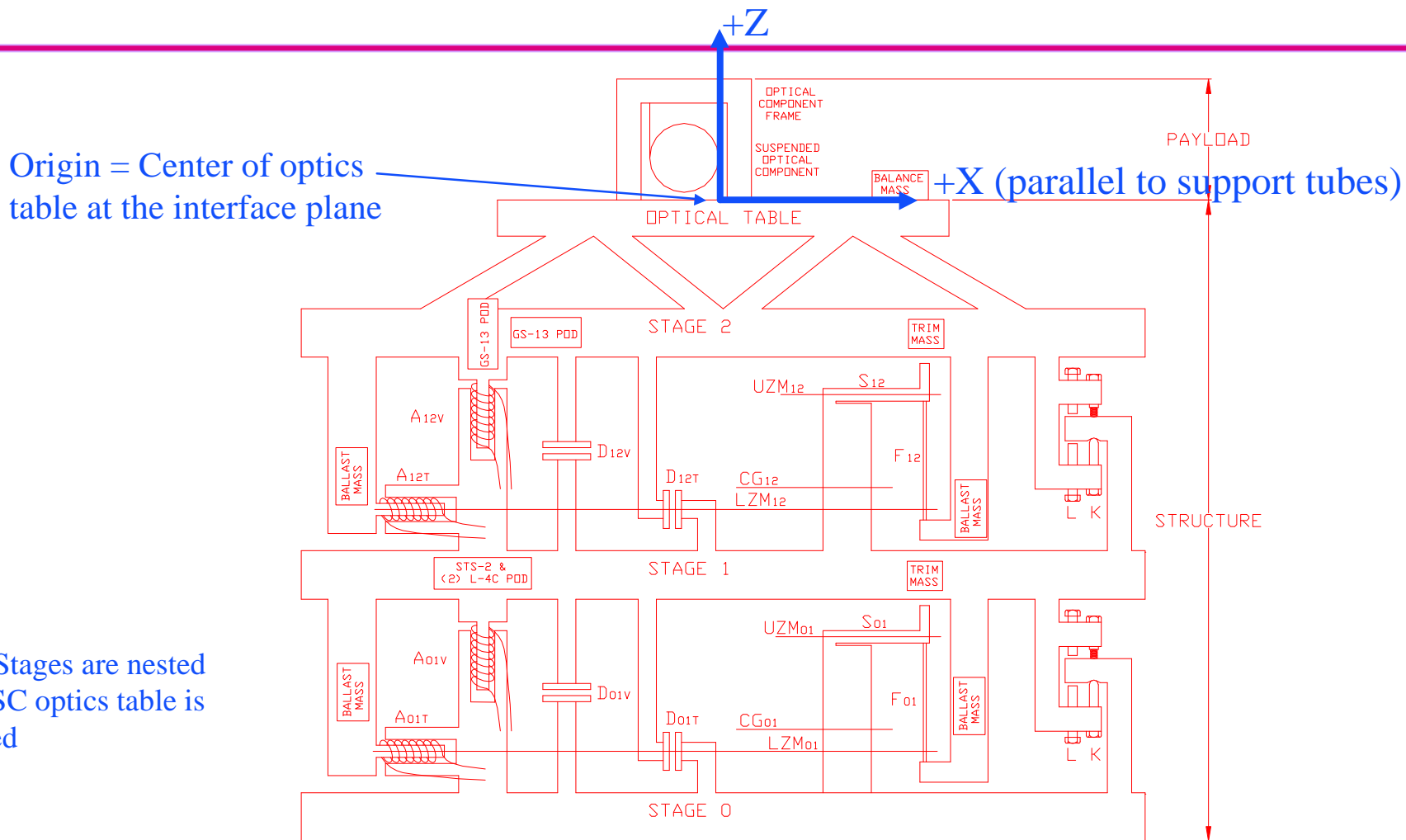
# Mass Limits & Balancing

## Scope & Definitions

- Section H, Design Requirements for the In-Vacuum Mechanical Elements of the Advanced LIGO Seismic Isolation System:
  - » BSC Chamber
  - » HAM Chamber
- Mass Definitions
  - » Structure
    - all Structure elements defined elsewhere in these requirements, except for the Payload described in H.2 below, including structural members, pods, seismometers, actuators, displacement sensors.
    - trim masses, which shall be bolted to Stages 1 and 2 in locations and in increments of mass to make each loaded spring flat (correcting the levelness of each stage for variations in spring stiffness) which will level the optical table (to within 0.2 mrad).
    - balance masses, which shall be bolted to Stages 1 and 2 in locations and in increments of mass to properly locate the center of gravity (CG) of Stages 1 and 2 in accordance with H.4, when a Payload (see H.2) is installed.
  - » Payload
    - the aggregate of masses of individual non-suspended optical components mounted on the optical table in a chamber
    - the aggregate of masses of individual suspended optical components mounted on the optical table in a chamber

# Mass Limits & Balancing

## Mass Definitions



Note: Stages are nested and BSC optics table is inverted

# Mass Limits & Balancing

## Payload Mass Property Limits

- $M_x$  = total Payload mass times the composite center-of-mass x-position (direction parallel to the support tubes, referenced to optical table center)
- $M_y$  = total Payload mass times the composite center-of-mass y-position (direction perpendicular to the support tubes, referenced to table center)
- $M_z$  = non-suspended mass times the composite center-of-mass z-position (vertical, referenced to optical table surface)

System	Total (kg)	non-sus	sus.	$M_x$ (kg-m)	$M_y$ (kg-m)	$M_z$ (kg-m)	stage 1	stage 2
HAM	510	435	75	0	0*	+112	+/- 4 cm w.r.t. stage 2	0 - 8 cm below w.r.t. actuator plane
BSC	800	630	170	+/- 185	+/- 185	-439 to -459		0 - 8 cm above w.r.t. actuator plane

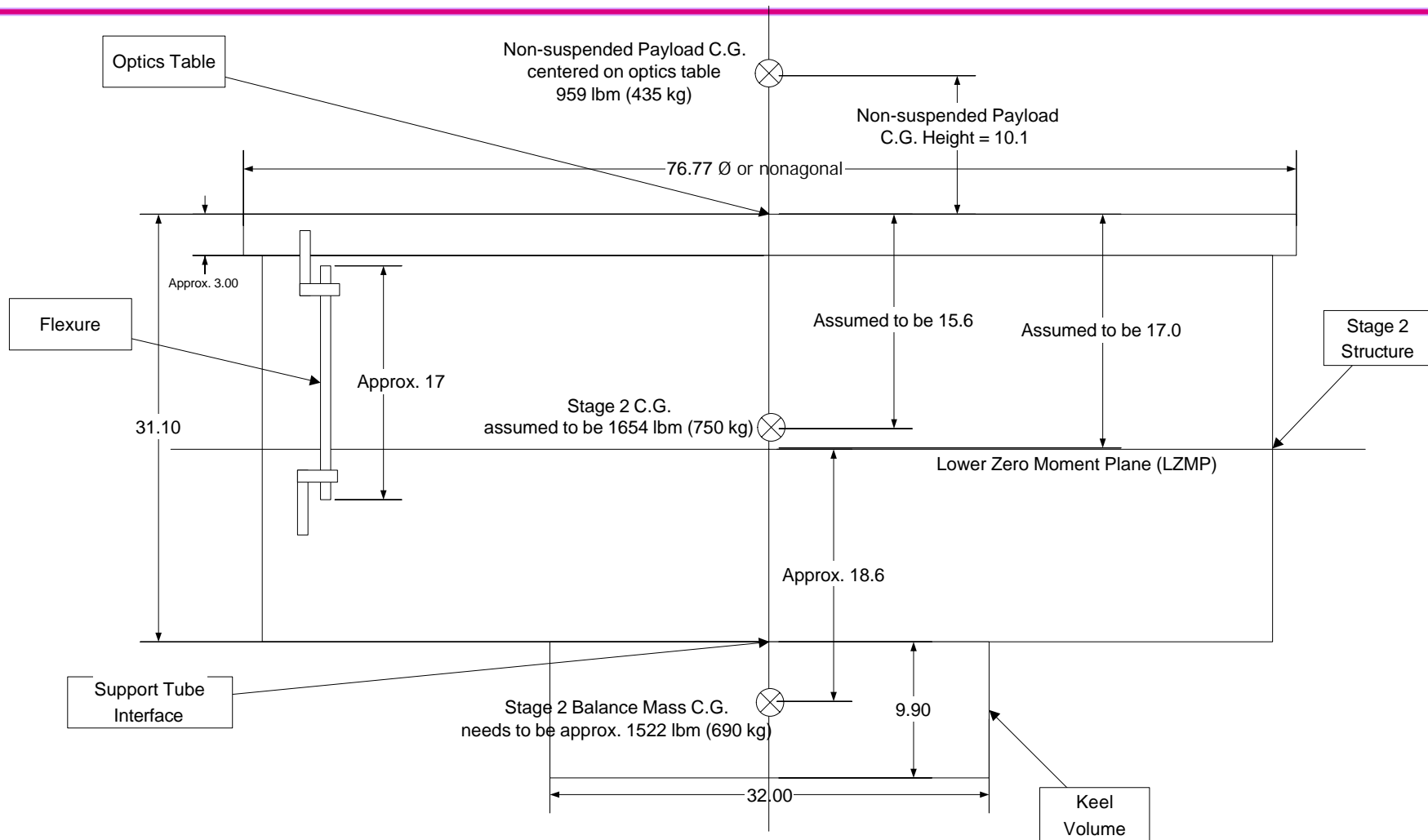
\* not -300 as indicated in the section H of the design requirements  
(This will be corrected in a new revision.)

\* CG vertical positional requirements are in cm, not mm, as stated in section H

# Mass Limits & Balancing Interpretation for the HAM

- Given
  - » envelope restrictions
  - » anticipated mass of Stage 2 [approx. 1654 lbm (750 Kg)]
  - » anticipated position of the Stage 2 (structure-only) Center of Gravity (CG) [15.6 in. (396 mm) below optics table]
  - » anticipated position of the Lower Zero Moment Plane (LZMP) of the Stage 2 Flexures [17 in. (432 mm) below the optics table]
- the above mass requirements imply
  - » a total addition of non-structural mass (payload plus balance and trim mass) on Stage 2 of approximately 2646 lbm (1200 kg) total
  - » a requirement to provide balance masses which total approximately 1522 lbm (690 kg) (i.e., 2646 lbm (1200 kg) less the optics table mounted elements totaling 1124 lbm (510 kg))
  - » A capability to place these masses in the keel of the Stage 2 envelope for the purpose of setting the composite C.G. vertical position within the prescribed tolerance of H.4

# Mass Limits & Balancing Interpretation for the HAM



# Mass Limits & Balancing Interpretation for the BSC

- Given
  - » envelope restrictions
  - » anticipated mass of Stage 2 [approx. 1654 lbm (750 Kg)]
  - » anticipated position of the Stage 2 (structure-only) Center of Gravity (CG) [18 in (457 mm) above the optics table]
  - » anticipated position of the Lower Zero Moment Plane (LZMP) of the Stage 2 Flexures [9 in. (229 mm) above the optics table]
- the above mass requirements imply
  - » a total addition of non-structural mass (payload plus balance and trim mass) on Stage 2 of approximately 2646 lbm (1200 kg) total
  - » a requirement to provide balance masses which total approximately 882 lbm (400 kg) (i.e., 2646 lbm (1200 kg) less the optics table mounted elements totaling 1764 lbm (800 kg))
  - » A capability to place these masses at the top of the Stage 2 envelope for the purpose of:
    - leveling the table, i.e. countering the payload horizontal first moments by positioning this balance mass up to 18.2 in (462 mm)
    - setting the composite C.G. vertical position within the prescribed tolerance of H.4

# Mass Limits & Balancing Interpretation for the BSC

