BSC System Testing
Rough Plan

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Blade Test Fixture

- Proof test to 1.5X with extra-thick blade
  - One time only for each of two blade lengths
- Repeatability test
  - Either length blade is ok
  - Prefer testing with maraging 300 blade, but stand-in is probably ok
  - Prefer using flight-like fasteners
  - Test consists of measuring load/deflection curve at least 5 times, with the blade removed and reinstalled between measurements
- Stiffness characterization of each flight blade
  - Minimum requirement is to measure load/deflection curve for each blade
  - It is possible we will need to shave some of the blades and then retest

More Detail on Todd's Assembly Step 10

- Starting state
  - Stage structures positioned with dry tooling
  - Lockdowns installed, engaged, but not bolted at stage 0 or 2, and adjustable feet retracted (lockdown tooling in place to maintain lockdown halves relative position, allowing clocking about radial axis only)
  - Stage 1-2 actuators and displacement sensors installed, with shorting bars left on, and stage 1 adapters "cinched" to provide a gap to stage 1
  - All mass simulators (pods and payload) installed
  - No stage 0-1 actuator posts
  - No stage 0-1 actuators or displacement sensors
  - Mass "placeholders" on stage 1 arms so its floating mass is correct
  - "Compensation" mass removed from stage 2 so its floating mass is correct (maybe not needed?)

More Detail on Todd's Assembly Step 10 (Cont.)

- Step 10 detail
  - Transfer load from dry tooling to blades using blade preload tools
  - Remove dry tooling (may require jacking screws, or moderate lateral force, to get tooling ends out of their slots, due to system clocking)
  - Set lockdowns to the new floating position
    - Lower adjustable feet until all four just touch stage 0 (or 2) or a feeler gage, simultaneously
    - Turn all four feet X turns past this point (X to be determined by trial and error?)
    - Torque four bolts on feet
    - Check that lockdowns engage/disengage smoothly
  - Engage lockdowns
  - Adjust and torque stage 1 side of stage 1-2 actuators, remove shorting bars
  - Install stage 0-1 actuator posts

More Detail on Todd's Assembly Step 10 (Cont.)

- Step 10 detail (cont.)
  - Install stage 0-1 actuators
    - Torque stage 1 side while stage 0 side is loose, shorting bar present
    - Adjust and torque stage 0 side
    - Remove shorting bar
  - Remove mass "placeholders" from stage 1 arms
  - Reinstall "compensation" mass on stage 2 (maybe not needed?)
  - Check that lockdowns disengage and engage smoothly

- Final state: completed assembly ready for measurements (parallelism of stages, static stiffness testing)

More Detail on Todd's Assembly Step 10 (Cont.)

- To go back to starting state
  - Engage lockdowns
  - Remove "compensation" mass from stage 2 (maybe not needed?)
  - Install mass "placeholders" on stage 1 arms
  - Remove stage 0-1 actuators
    - Install shorting bar
    - Detach stage 0 side
    - Detach stage 1 side and remove actuator subassembly
  - Remove stage 0-1 actuator posts
  - Install shorting bars on stage 1-2 actuators
  - Detach stage 1 side of stage 1-2 actuators, "cinch" adapters to create a gap
  - Disengage lockdowns, remove stage 0 & 2 foot bolts, retract adjustable feet
  - Install dry tooling (may require moderate lateral force to re-insert tips)
  - Transfer load from blades to dry tooling using blade preload tools

Step 11

- Measure absolute height between each of the three datum surfaces (stage 1 to 2, or stage 0 to 1) to 0.0005” accuracy, with lockdowns disengaged
- Tooling to measure these heights should be a deliverable to LIGO, so they can repeat the measurements when balancing the final payload

Static Stiffness Testing

- Test configuration
  - Full assembly, from step 10 (no height indicators from step 11)
  - All actuators and displacement sensor cables routed to accessible point

- Support equipment
  - Caltech provided
    - Drive electronics for one of each type of actuator, allowing manual (open loop) command of actuator force
    - Electronics for reading 6 displacement sensors simultaneously, with analog voltage outputs to BNC cables (need to know how to calibrate)
  - ASI provided
    - Data acquisition system to read 6 displacement sensor readings simultaneously

Static Stiffness Testing (Cont.)

- Test sequence
  1) Engage stage 1-2 lockdowns, disengage stage 0-1 lockdowns
  2) Connect stage 0-1 displacement sensor outputs to data acquisition system
  3) Connect actuator drive electronics to first stage 0-1 actuator
  4) Energize actuator so stage displaces without lockdown contact, recording displacement sensor readings
  5) Repeat steps (3) and (4) for all six stage 0-1 actuators
  6) Engage stage 0-1 lockdown, disengage stage 1-2 lockdowns
  7) Connect stage 1-2 displacement sensor outputs to data acquisition system
  8) Repeat steps (3) and (4) for all six stage 1-2 actuators

- Based on step 11 measurements and stiffness measurements, new shim dimensions are calculated so that the stages will be parallel and the system stiffness requirements are met

System Dynamic (Modal) Testing

- Test configuration
  - Full assembly, from step 10 (no height indicators from step 11)
  - No need for actuators or displacement sensors to be active

- Support equipment
  - Caltech provided
    - Electronics for reading 6 displacement sensors simultaneously, with analog voltage outputs to BNC cables (desirable, not necessary)
  - ASI provided
    - Data acquisition system (4 outputs, 8 inputs) [We already own this]
    - Impact hammer (rented)
    - Six high-sensitivity single-axis accelerometers and cables (rented)
    - Two electromagnetic shakers, amplifiers, and stingers (rented)
    - Two miniature in-line load cells (rented)
    - Adapter from load cell to structure (ASI fab)

Possibly I will decide we don't need shakers

System Dynamic (Modal) Testing (Cont.)

- Test phase 1: suspension modes
  - Attach both shakers/stingers to structure in skew directions
    - I'm hoping I can use an impact hammer instead, but still not sure
    - With impact hammer, no need to rent shakers or make stinger adapters
  - Install 6 accelerometers on stage 1
    - I'm hoping I can use the displacement sensors instead
    - Then instead of installing accelerometers, we connect stage 0-1 displacement sensors to the data acquisition system
  - Excite structure with shakers (or hammer), measure accel-over-force transfer functions (20 averages)
  - Move accelerometers from stage 1 to stage 2 (if using accelerometers), or connect stage 1-2 displacement sensors to data acquisition system
  - Repeat excitation and transfer function measurement
  - Test duration approximately 1 hour per stage
  - Estimated total test time for phase 1: two days

System Dynamic (Modal) Testing (Cont.)

- Test phase 2: high frequency modes of stage 1 and stage 2
  - Install 6 accelerometers on stage 1
  - Excite stage 1 with impact hammer at multiple locations/directions, and measure accel-over-force transfer functions (3 to 5 averages)
  - Move accelerometers from stage 1 to stage 2
  - Excite stage 2 with impact hammer at multiple locations/directions, and measure accel-over-force transfer functions (3 to 5 averages)
  - Test duration approximately 5 minutes per hammer location
  - Estimated total test time for phase 2: two days