Type B Suspensions Status

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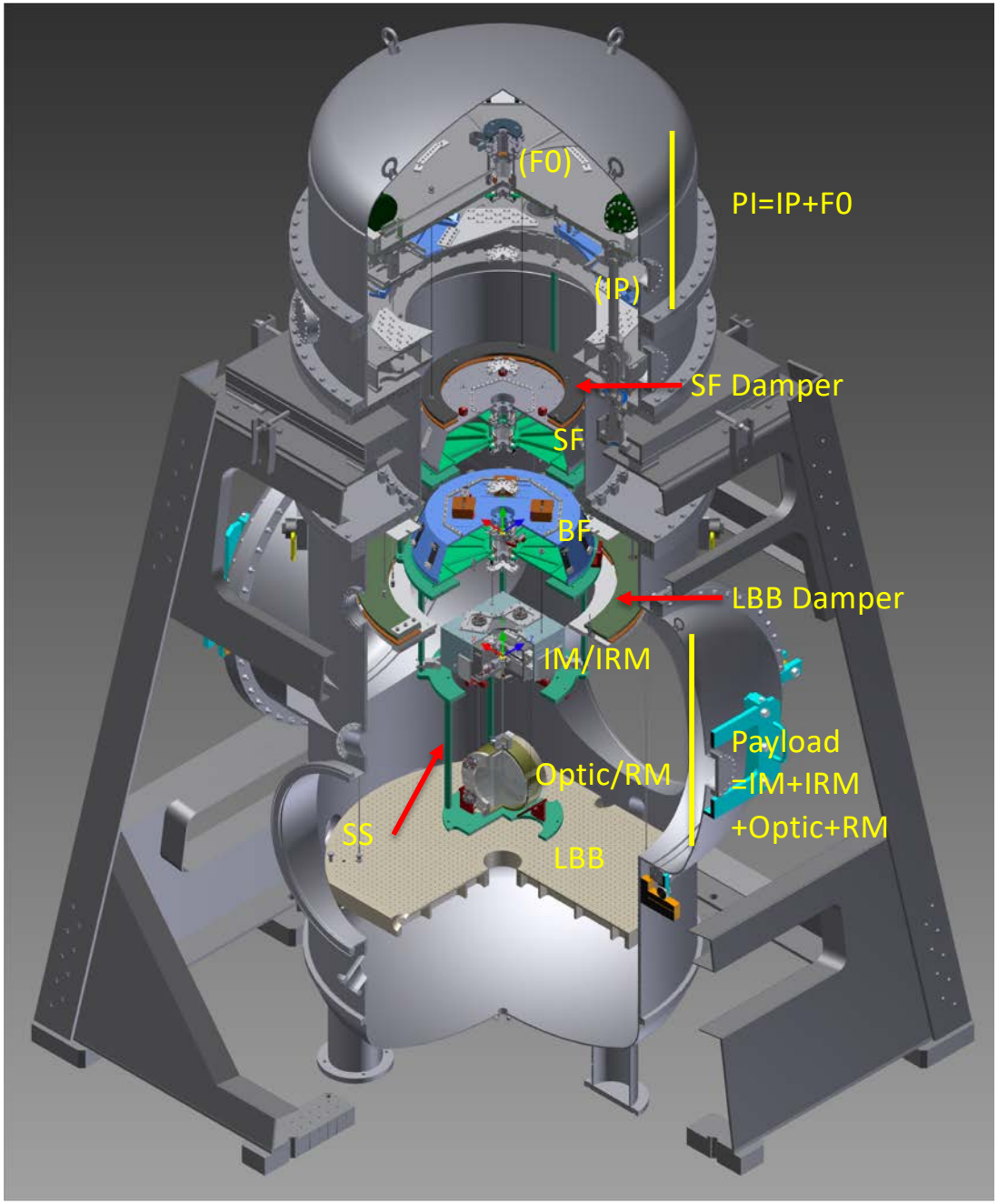
Overview

- This talk will be on the nuts and bolts of the Type B suspensions, and installation.
  - Type B structure
  - Sensors and actuators
  - Installation procedure
  - Timeline
  - Issues
- See also talks by
  - Enzo Tapia – Characterization and Commissioning
  - Ryohei Kozu - State Space Control of Payload, and GAS Filter Tuning

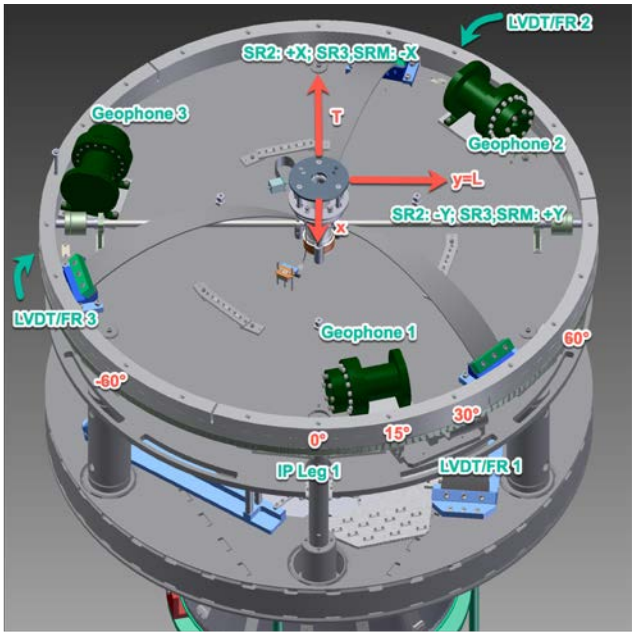
Scope

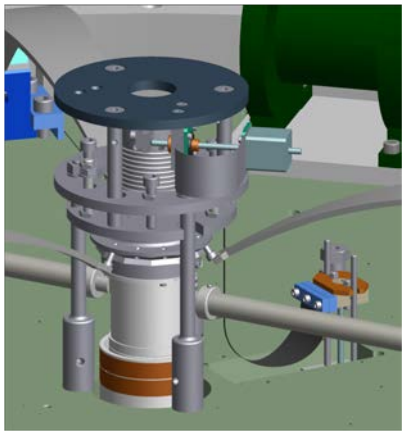
- One BS suspension
- Three SR suspensions (SR2, SR3, SRM)
- Each has
  - Preisolator (PI) with Inverted Pendulum table (IP) and GAS filter (F0)
  - Standard Filter (SF) and eddy-current damper ring (DR)
  - Bottom Filter (BF)
  - Intermediate Mass (IM) and Intermediate Recoil Mass (IRM)
  - Optic (a.k.a., TM) and Recoil Mass (IM)
  - Lower breadboard (LBB), blade springs, and damper rings.
  - Security Structure (SS).
- SRx payload (TM/RM/IM/IRM) is similar to PRx (250mm x 100 mm optic).
- BS payload has different optic.

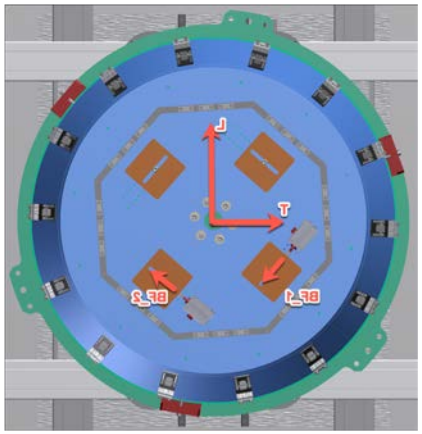


Sensors and Actuators (i)

- Inverted Pendulum (IP)
  - 3 LVDTs with coil actuators plus 3 geophones for L, T, Y dynamic control
  - 3 stepper actuated “fishing rods” springs for L, T, Y static adjustment.
- Geometric antispring (GAS) Filters
  - 3 levels: F0, SF, BF
  - Each has LVDT with coil actuator plus FR
  - F0-SF and BF-IM levels have stepper/pico yaw mechanisms for static adjustments.
  - BF has two pico-driven masses on the cap for static adjustment of the BF and IRM tilt (P, R).

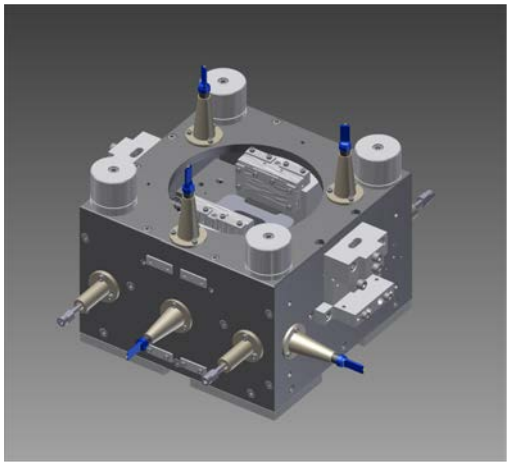
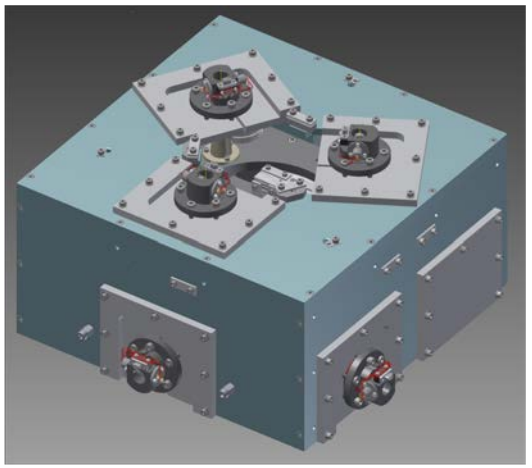
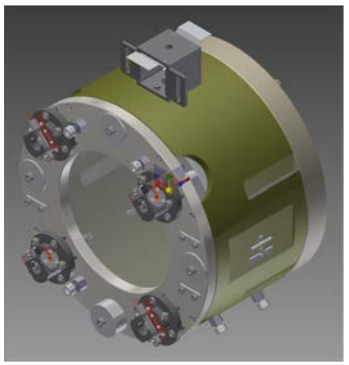
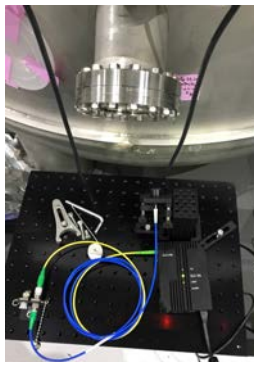
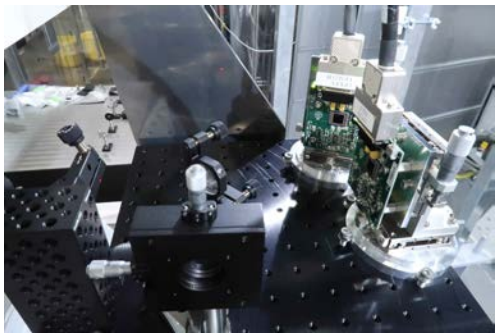
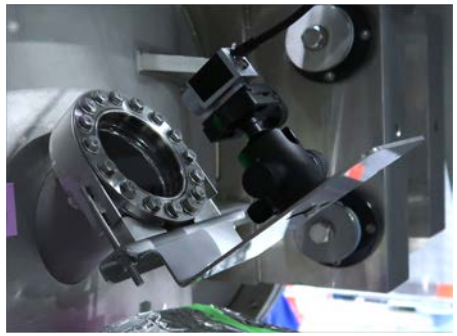






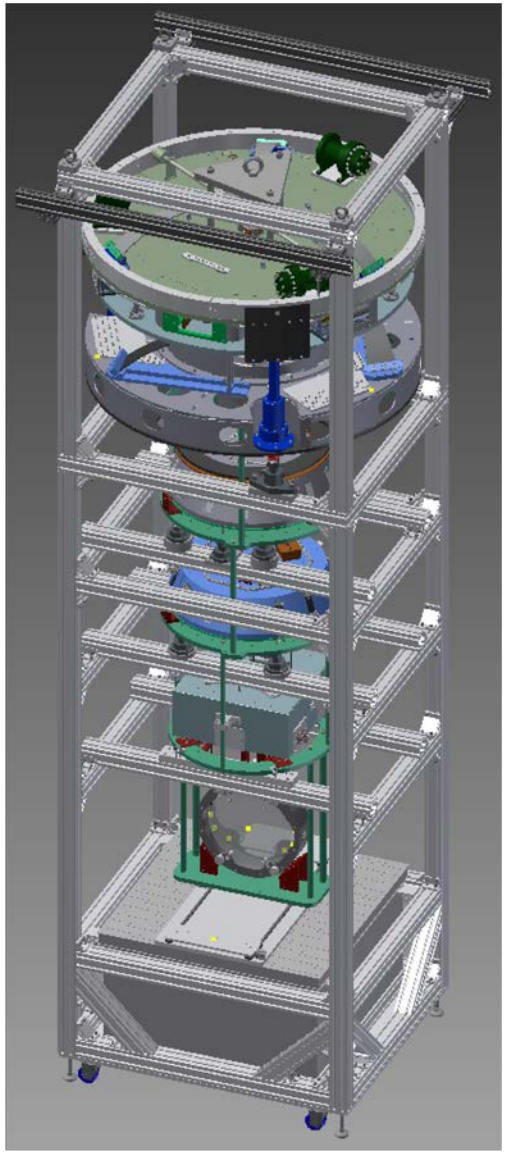
Sensors and Actuators (ii)

- IM-IRM
  - 6 OSEMs (shadow sensor+coil actuators) on IRM with flags on IM for dynamic control of 6 DOFs (L, T, V, R, P, Y).
  - 2 pico-driven masses in IM for static tilt adjustment (P, R).
- Optic-RM
  - 4 coil actuators on RM with magnets epoxied to the optic. (Original design had shadow-sensors and flags, but the flags were prone to damage.)
  - Optical levers with tilt and length sensing.
  - Camera

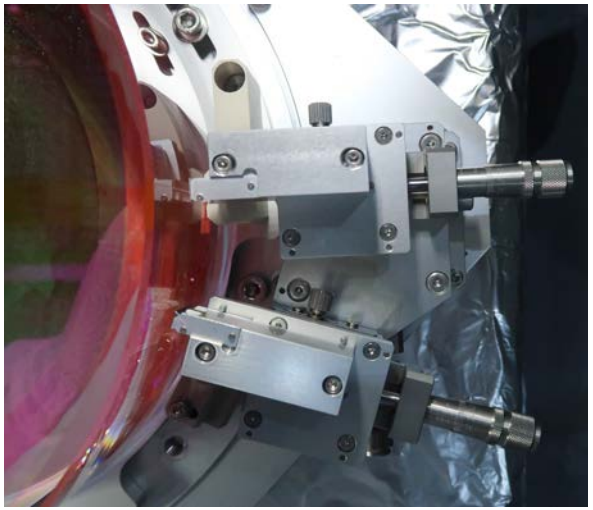
Installation Procedure

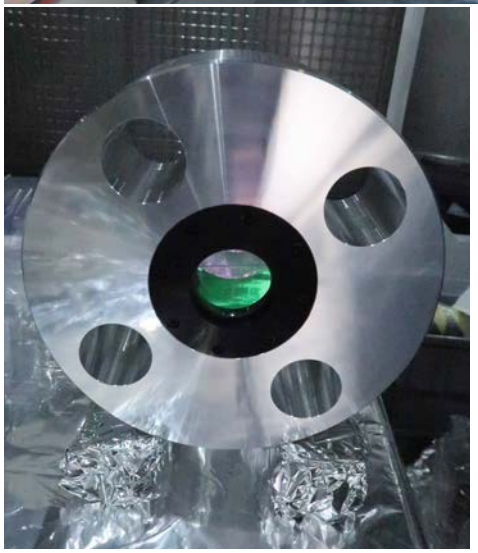
- Assembly frame based on versions for TAMA Type B test and PR3 test.
- Extensive use of jacks to raise and lower sections independently (for hooking of maraging rods) without galling of screws in security structure.
- IM is now supported from main frame while BS and RM are hung from it – no separate hanging frame.
- Frame has extensions to hold cloth cover clear of PI.
- Frame is set up next to the tank, under the crane path (+Y for BS, -X for SR).

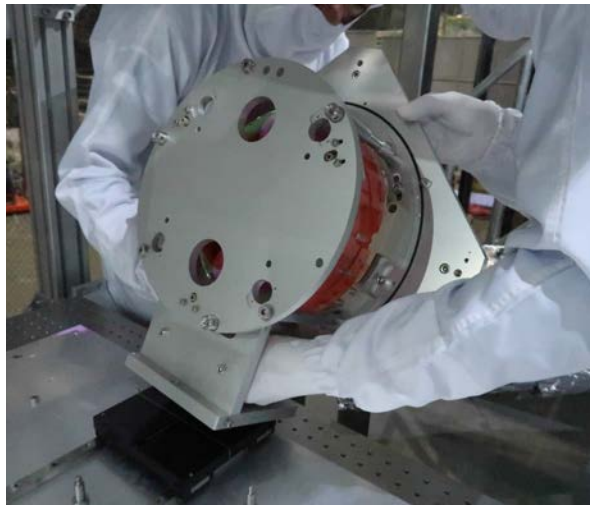


Preparation of optic

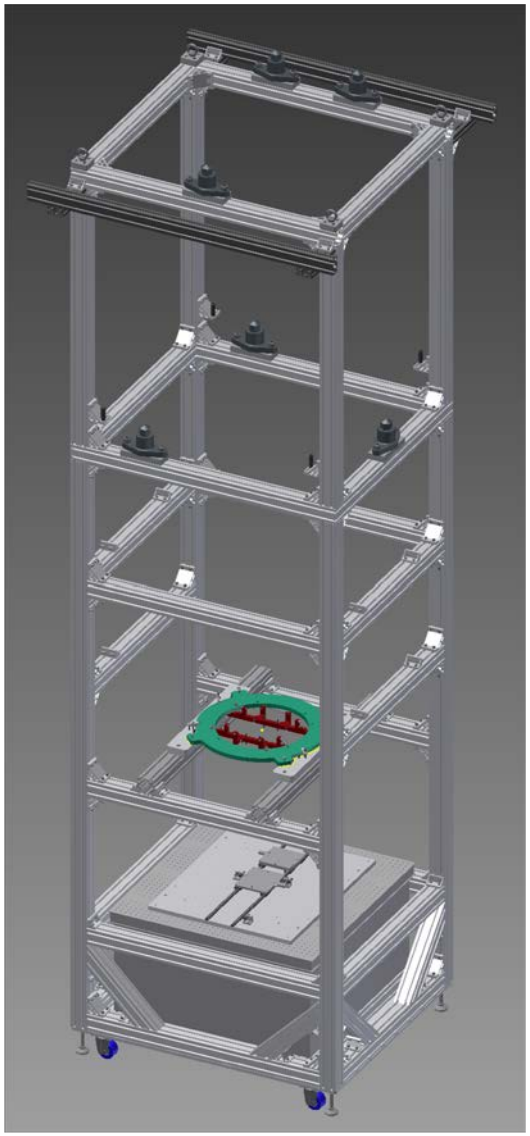
- Optic is prepared in its mirror box, which also serves as a jig for applying prisms and magnets.
- Main wire breakers are sapphire prisms with laser ablated grooves. They are place on the vertical COM line.
- Secondary wire breakers are stainless prisms.
- Prisms are attached equal distances from the HR face, on the front/back COM line, to allow for the wedge on the AR side.
- Magnets are attached to the AR face with standoffs of different sizes to allow for the wedge.
- SRM is currently a metal mass with glass insert.
- The mirror box is stood up onto a trolley system on the AF and rolled into position for hanging.



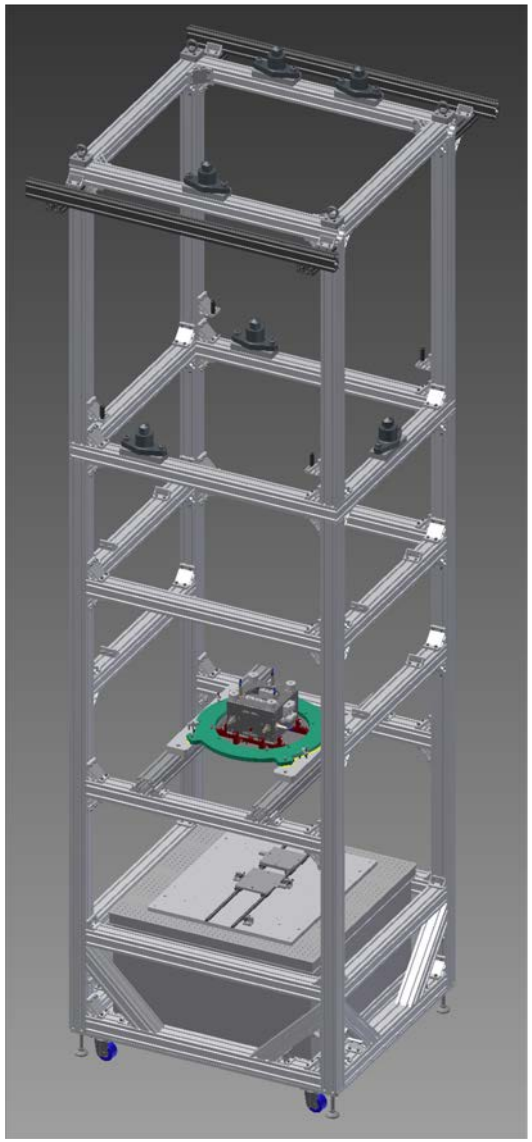




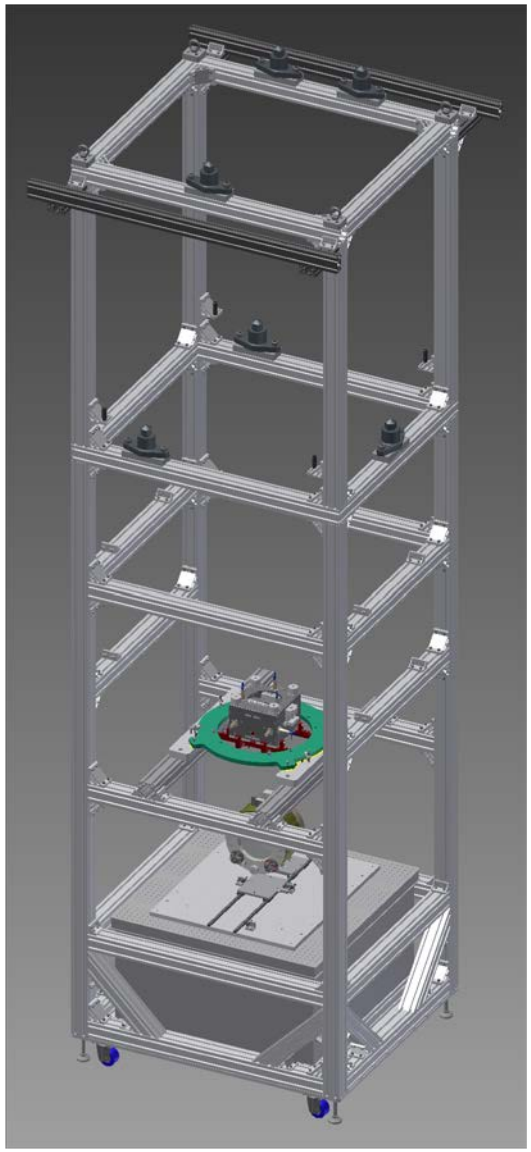
Adding the IM



Add IM ring (of SS)



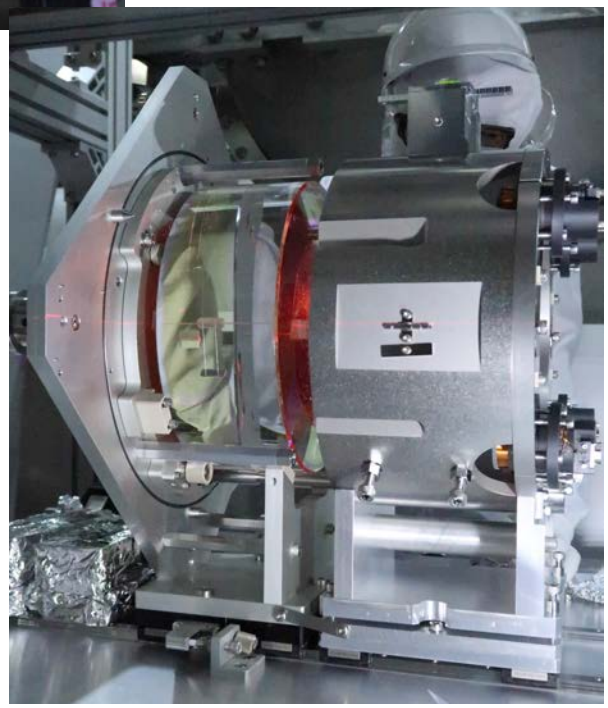
Add IM



Hang optic and RM

Hanging the optic/RM

- A winch system is installed temporarily on top of the IM.
- The optic is rolled in in the mirror box.
- Wires (Ø0.2 mm piano) are threaded under the optic and up to the winches.
- Optic is lifted ≈3 mm to desired height and wire clamps are added.
- RM (less rear ring with OSEMs) is brought in on a second trolley around the optic and hung similarly (Ø0.6 mm W).



Prepare for BF

Add SS bottom ring

Add BF crossbars

Add BF ring (of SS)

Add BF and IRM

Add BF baseplate

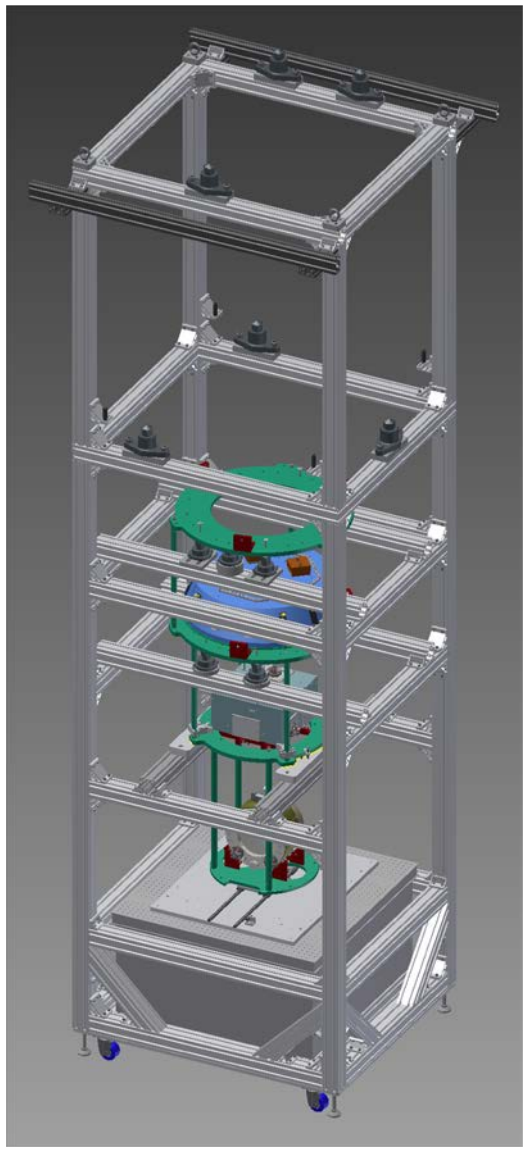
Add IRM top, suspend IM

Add IRM sides

Prepare for SF

Add BF cap

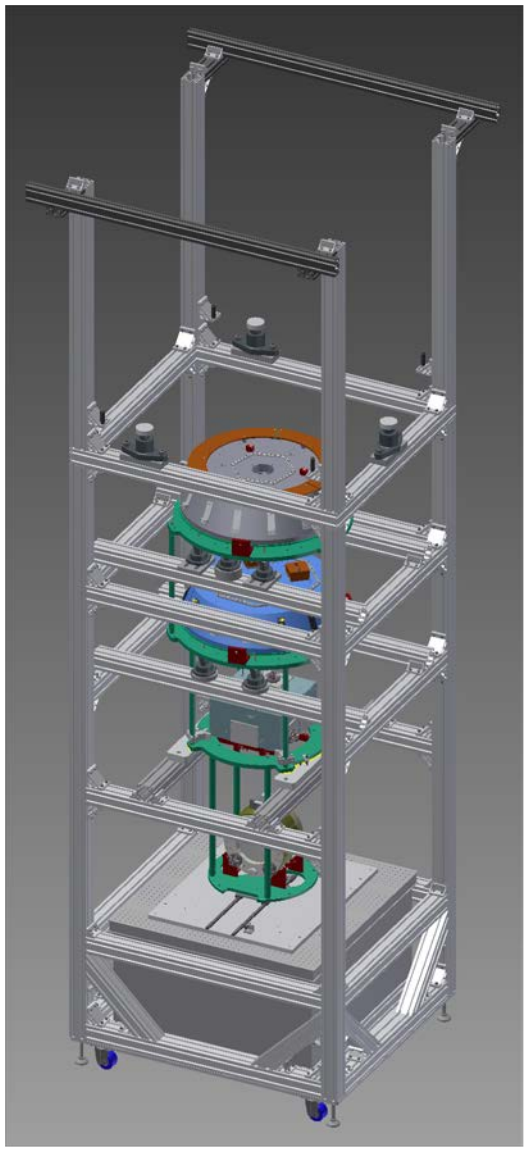
Add SF crossbars



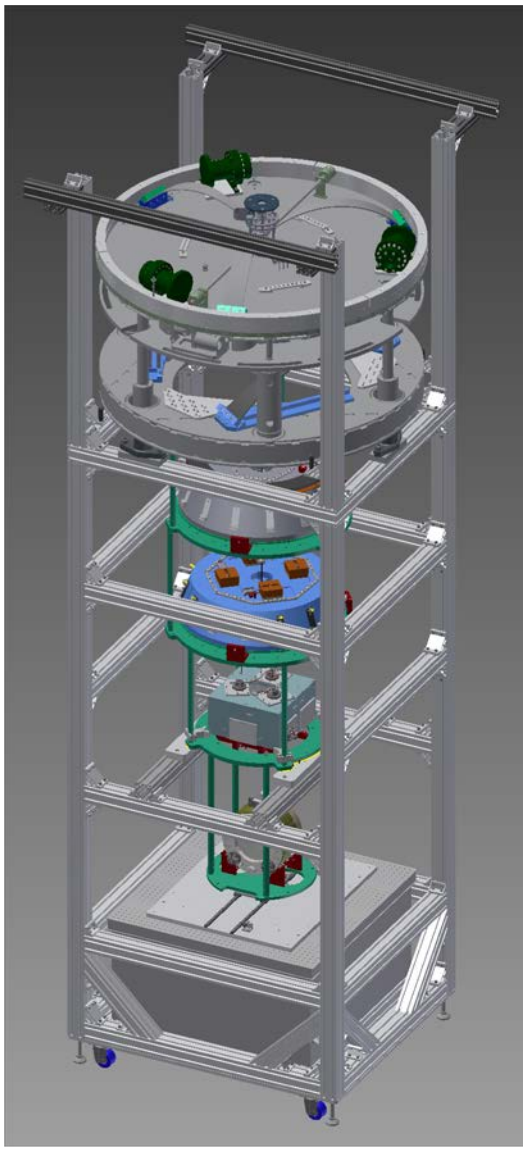
Add SF ring of SS

Add SF and PI

Add SF baseplate and hook BF/…



Add SF cap with Cu ring



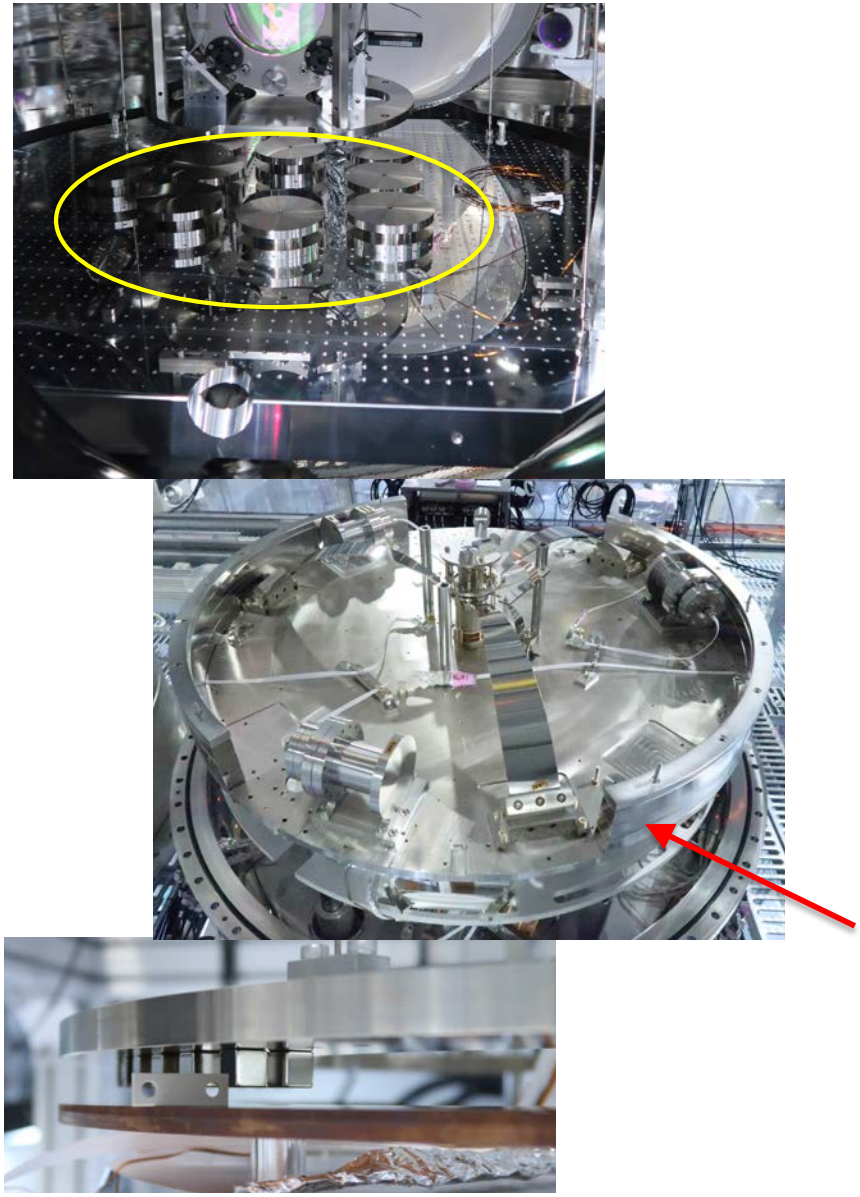
Add PI with magnet ring

Crane!

- The LBB and LBB damper rings are staged in the tank.
- The rest of the suspension is craned in as a unit.
- The LBB damper rods are hooked at the top as the suspension descends, and at the bottom by a brave person (Hirata-san!) in the tank.

LBB and IP adjustments

- The LBB damper ring sandwich in the top of the lower tank is unclamped to free the LBB, and ballast mass is added to set the height.
- Arc weights are stacked on the IP to tune the frequency to ≈0.06 Hz.
- The SF damper gap may be adjusted to ensure the yaw mode is damped within 1 min.

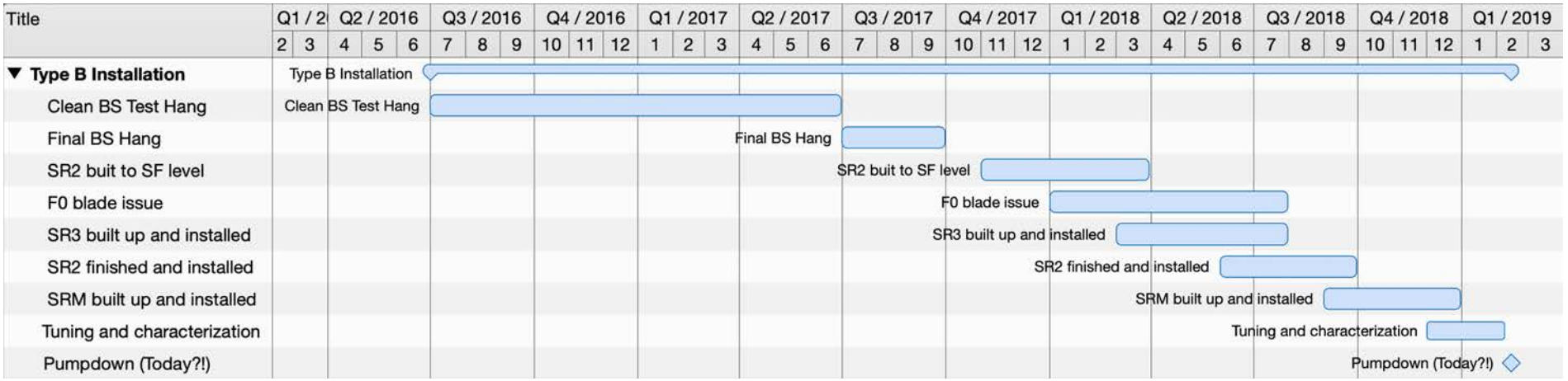


Buoyancy correction

- Loss of buoyancy from air causes the suspension to sag on pumpdown.
- Typical values: F0 0.3 mm; SF 0.5 mm, BF 0.5 mm.
- Strategy is to pre-apply as much correction using fishing rods in air (in case of malfunction in vacuum) and then temporarily cancel with LVDT coil actuation to keep the optic height correct for initial alignment.
- We'll see how well this works this week…

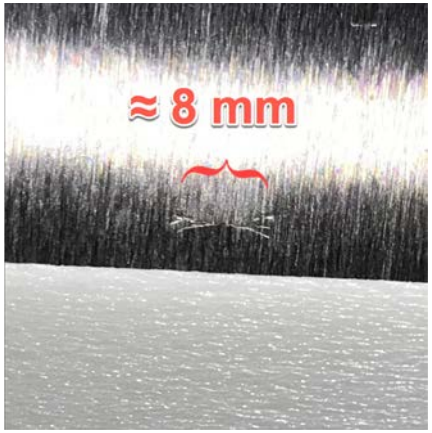
Timeline

- ≈SR Test Hang at TAMA 300 - 2015
- Clean BS Test Hang with dummy BS at KAGRA – Jun 2016 to Jun 2017
- Final BS Hang – July 2017 to Sep 2017
- SR2 built up to SF level – Nov 2017 to Mar 2018
- F0 blade issue – Jan 2018 to Jul 2018
- SR3 built up and hung – Mar 2018 to Jul 2018
- SR2 finished and hung – Jul 2018 to Sep 2018
- SRM built and hung – Sep 2018 to Dec 2018
- Tuning and characterization (all) – Dec 2018 to Feb 2018
- Pumpdown – this week!



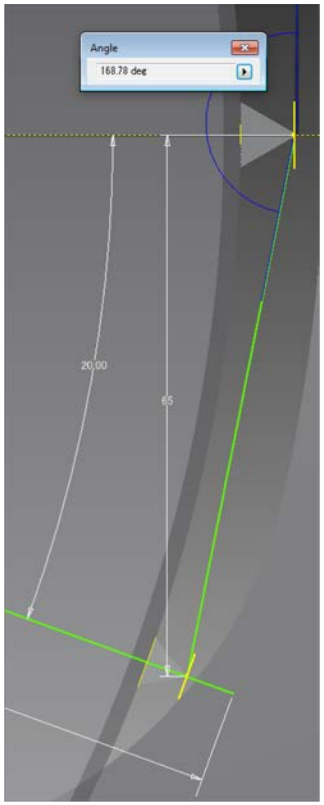
Blade issue

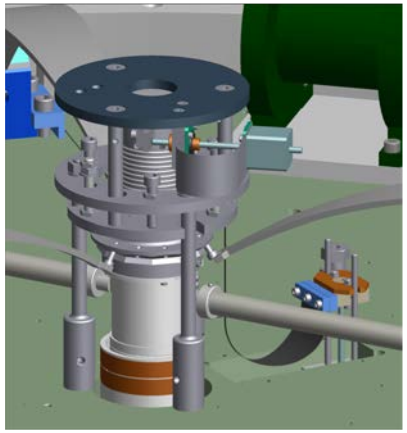
- Most of the initial blades on the SR PIs broke or had conspicuous cracks.
- All were replaced.
- BS blades have been inspected twice (one year apart) and seem fine.
- Cause is not certain but suspects are
  - Hydrogen embrittlement bake step skipped
  - Over-enthusiastic grinding of the surface.
- New blades were produced for all Type A and B suspensions – only SR ones were installed.
- Preparation tasks were brought forward in the schedule to minimize delays.



Other Issues (i)

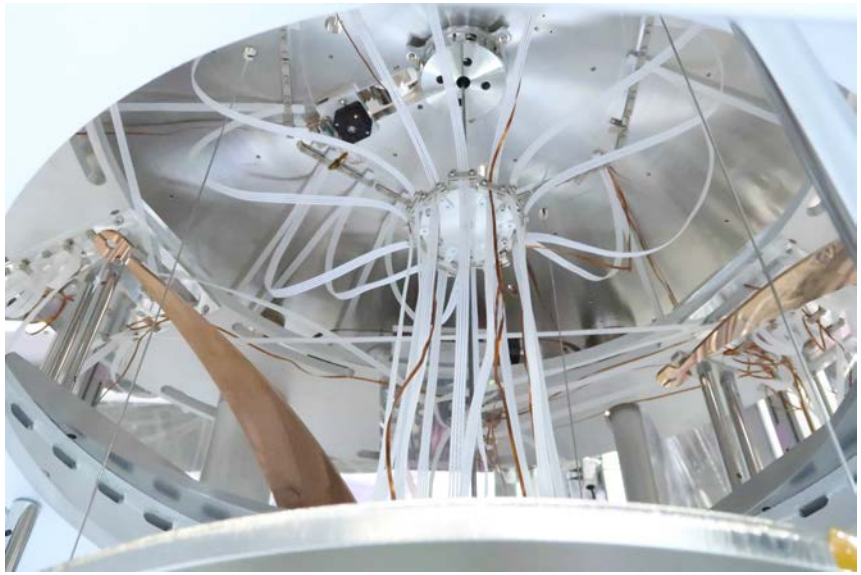
- Shadow sensors and flags were eliminated at the optic level (fragile and unnecessary). Magnets were reduced in size and attached with standoffs to improve Q and thermal noise of optic.
- Wire breakers were made LIGO-style: primary sapphire prisms plus secondary stainless prisms.
- Wire clamps in SR IMs and slots in SR RMs were too narrow for new prisms – needed modifications.
- GAS FRs stuck on several occasions (BS Test Hang, SR3). Only one (in SR3) couldn't be fixed. Advanced KAGRA FRs will have limit switches!
- All the F0 FRs jammed because of single-blade design -> new double-blade design.
- The BS F0 yaw adjuster jammed due to poor design and will not be fixed because the thrust bearing is also suspect.

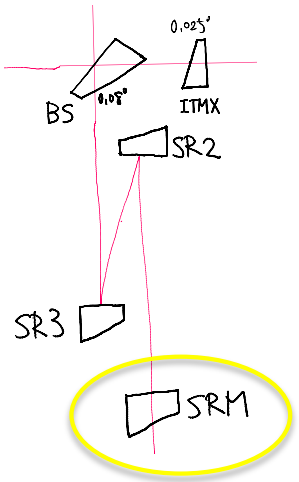




Other Issues (ii)

- The LBB blade springs in the BS were inconveniently strong so those for the SR were made narrower.
- “Low power coil drivers” were inadequate for IM and TM levels. IM-H drivers were modified for lower output resistance; TM and IM-V drivers were replaced with high-power design.
- Arrangement of jacks on BS tank was 180° off from CAD. BS Test Hang was installed backwards; final hang was correct.
- The wedge orientation of the SRM had to be flipped at the last minute because of an inconsistency between the main IFO design and the OMMT design!
- Not enough anchor points for cables – many cable clamps had to be designed and added, using random spare holes for attachment.
- Cabling takes a huge fraction of installation time: 4 cables at TM level up to 28 cables at PI level!
- *But*, overall quite good – our thanks to Riccardo De Salvo and Promec.





Team

- Core team
  - Mark Barton – leader, NAOJ, physicist
  - Fabian Peña Arellano – NAOJ/ICRR, physicist
  - Naoatsu Hirata – NAOJ, engineer
  - Enzo Tapia San Martin – NAOJ, electrical engineer
- Students
  - Yuhang Zhao – Beijing Normal U
  - Kazuya Yokogawa – Toyama U
  - Yuya Kuwahara – U Tokyo
  - Yingtang Liu – ICRR
  - Toshiya Yoshioka
  - Perry Forsyth – ANU
  - Panwei Huang – WIPM
  - Rikako Hatoya - Sokendai
  - Terrence Tsang – CUHK
  - Ryohei Kozu – ICRR

- Additional help from
  - Riccardo De Salvo and Promec – much of the original design.
  - Yoichi Aso – lots of helpful guidance
  - Yoshinori Fujii – geophone assembly and characterization
  - Koki Okutomi, Keiko Kokeyama, Takahiro Yamamoto – real time model
  - Ryutaro Takahashi – large purchases
  - Naohisa Sato – PI testing

Thanks to all for a successful installation!