Based on TEG-047
29 Nov. 2007
JAMA-JARI

TEG-056-Rev.1

First Technology Safety Systems

Design Freeze Status

Flex-PLI-GTR Development
Full Calibration Test Procedures

Bernard Been
FTSS Europe
Comments addressed from Design Freeze meeting
February 20th 2008, JARI, Tsukuba, Japan
Update March 31st, 2008

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Current Status

- Flexible bone material calls for new approach and new lines of thought
- Some details presented may change

Flex-GTR Full Calibration Test Procedures (Overview)

- ✓ Evaluate Long Bone Cores Bending Characteristic
- ✓ Obtain Strain (mV) to Moment Conversion values
- ✓ Frequency
  - ✓ After manufacturing
  - ✓ Each year
  - ✓ [After exceeding 400Nm (~125% of IARV*)]
  - ✓ After failure of dynamic test

Step 1: Bone Core 7 tests
Quasi-static 3-Point Bending Test
(Femur bone core, Tibia bone core)

- ✓ Evaluate Assembly Bending Characteristics
- ✓ Check ultimate bending moment
- ✓ Frequency
  - ✓ After manufacturing
  - ✓ Each year
  - ✓ [After exceeding 400 Nm (~125% of IARV)]
  - ✓ After femur or tibia assembly-/parts exchange
  - ✓ After failure of dynamic test

Step 2: Femur and Tibia 2 tests
Quasi-static 3-Point Bending Test
(Femur, Tibia)

- ✓ Evaluate Knee Bending Characteristics
- ✓ Evaluate Knee Ligament Elongation Values
- ✓ Frequency
  - ✓ After manufacturing
  - ✓ Each year
  - ✓ [After exceeding IARV]
  - ✓ After knee assembly-/parts exchange
  - ✓ After failure of dynamic test

Step 3: Knee, 1 test
Quasi-static 3-Point Bending Test

- ✓ Evaluate consistency of the assembly
- ✓ Frequency
  - ✓ Each [1-10] tests
  - ✓ After exceeding IARV
  - ✓ After knee or femur or tibia assembly-/parts exchange

Step 4: Assembly 1 test
Femur-Knee-Tibia
Dynamic Calibration Test

*IARV : Injury Assessment Reference Value

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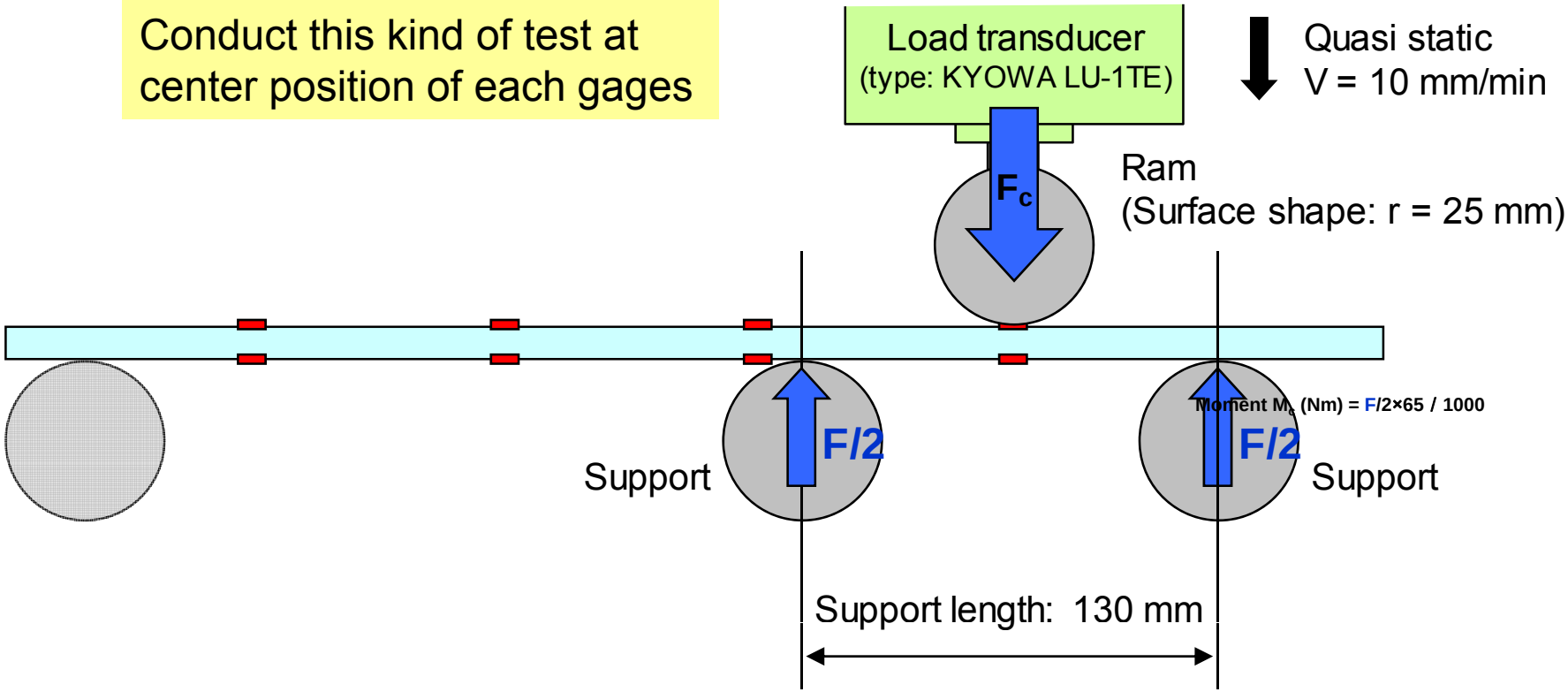
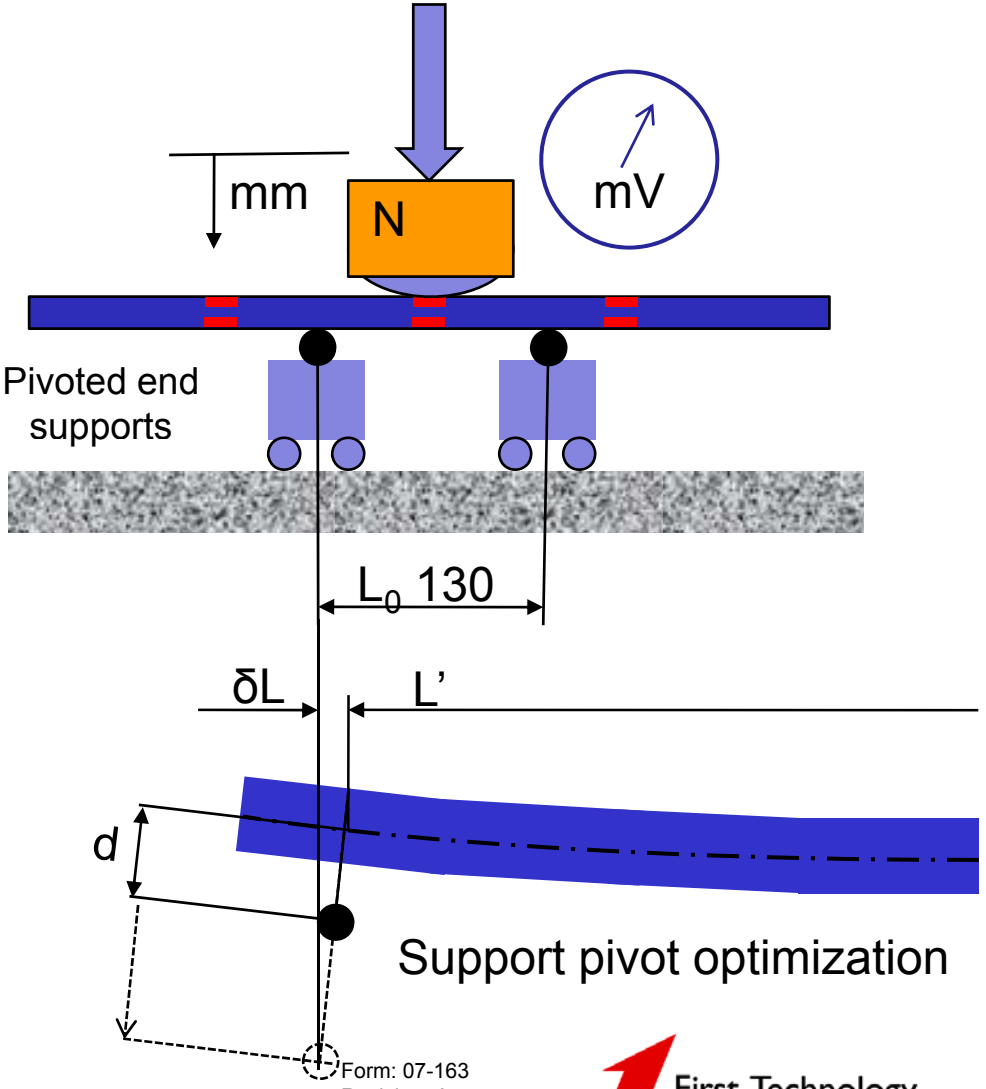
NEW JARI Proposals February 01

Conduct this kind of test at center position of each gages



Step 1: Bone Core 7 tests
Quasi-static 3-Point Bending Test

- Quasi static test
  - Loading rate 10mm/min.
- Calibration of bone only
  - Supply of calibrated spare parts
- Measurement of test force, deflection and strain gauge voltage
- Force deflection corridor
- Accurate control of probe and support distance L_0
- Roller support to annihilate tension - compression in bone
- Compensation for support distance change δL due to bending



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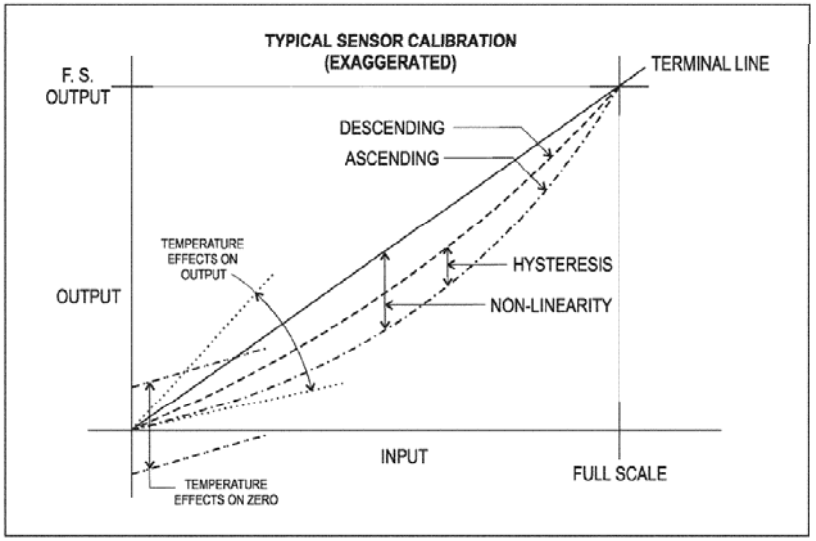
SAE J2570
Performance Specification Transducers

- SAE J2570 is not applicable to FLEX-PLI bone by definition
  - Max deflection < 0.254mm
- Relevant criteria
  - Hysteresis ≤ 1% of full scale capacity
  - Non-linearity ≤ 1% of full scale capacity
- These are design goals!
- May be difficult to meet due to flexible nature of the bone
- Little experience with high deflection!



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SURFACE VEHICLE INFORMATION REPORT

SAE J2570 | ISSUED Prop Dft JUN2001

Issued Proposed Draft 2001-06

Performance Specifications for Anthropomorphic Test Device Transducers

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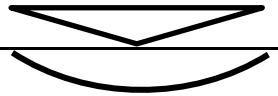
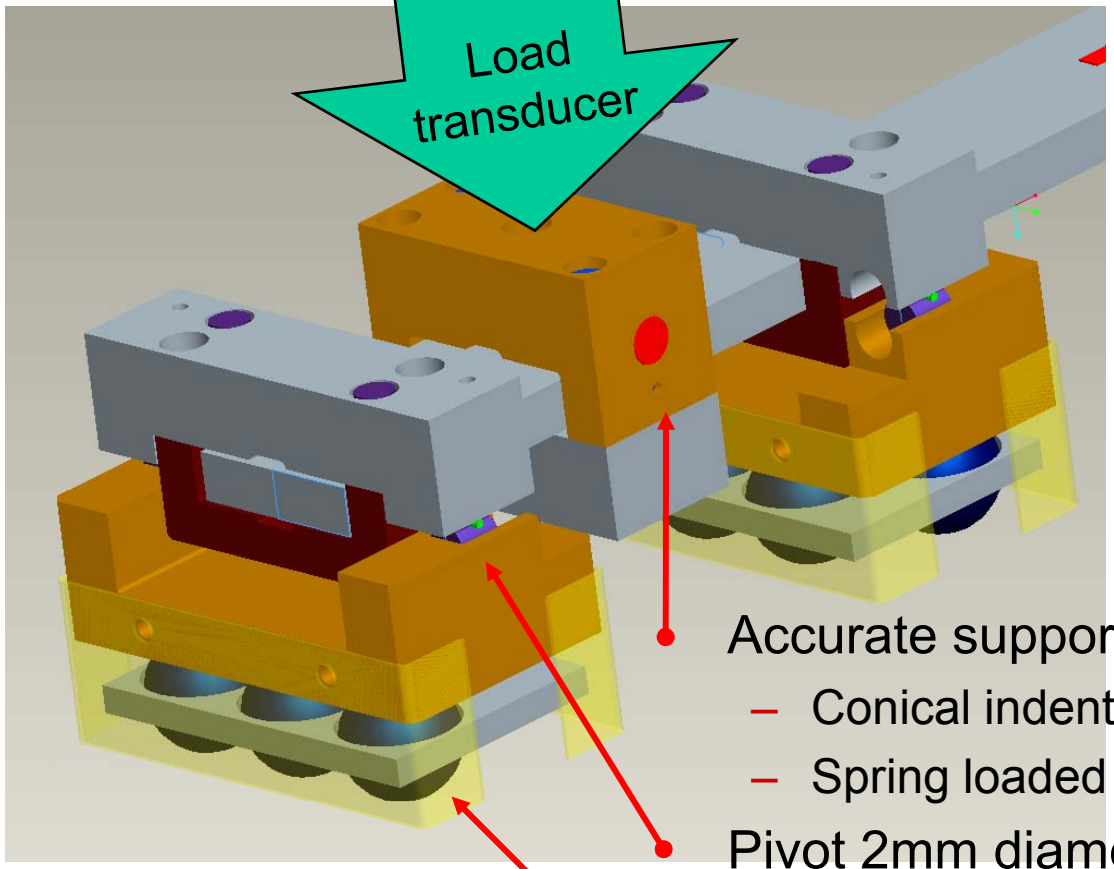
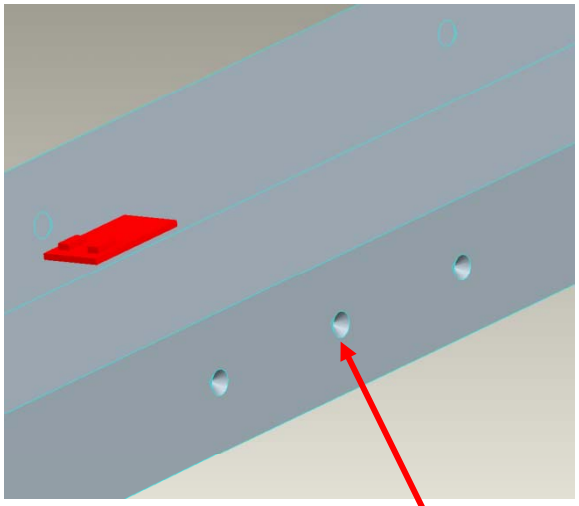
Bone Calibration Analysis

Bone Calibration Procedure	GTR
thickness [mm]	10.5
Width [mm]	40
Youngs modulus JARI spec F45 **4500 kg/mm^2** [N/mm^2]	44145
Ultimate strength **70kg/mm^2** [N/mm^2]	687
Distance support [mm]	**130**
Test load [N]	**10000**
Test load centre [N*m] (peak 350 Nm)	**325**
Bone bending Radius at loading point [mm]	524.1
Vertical deflection [mm]	2.69
Horizontal bone shortening estimate triangle [mm]	0.19
Horizontal bone shortening estimate Circle [mm]	0.33
Horizontal bone shortening average Circle/triangle [mm]	**0.26**
Error due to support distance variation [%]	-0.00247
Error due to support distance accuracy 0.2mm [%]	0.15385
Error due to friction roll pin 2.0mm diam [%]	0.15385
Max error due to calibration load cell [%]	0.12000
Total error [%]	**0.43017**
Peak strain [micro strain]	10.0



Details of Calibration Fixtures





- Accurate support distance control
  - Conical indents on sides at neutral plane of bone
  - Spring loaded ball for positioning
- Pivot 2mm diameter for minimum friction
  - Hardened steel pin 60HRc
- Roller end supports

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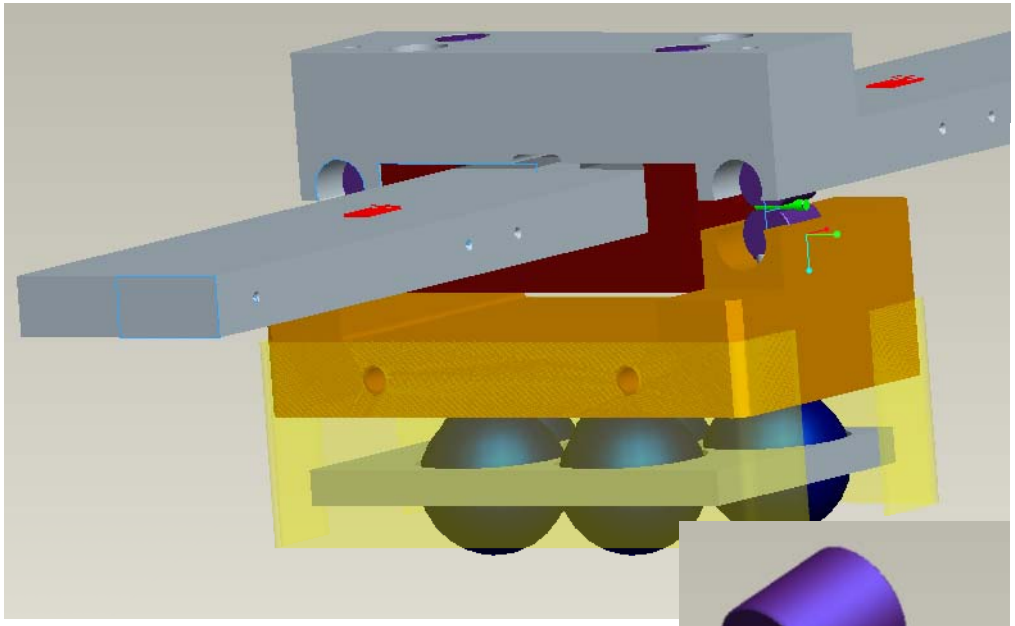
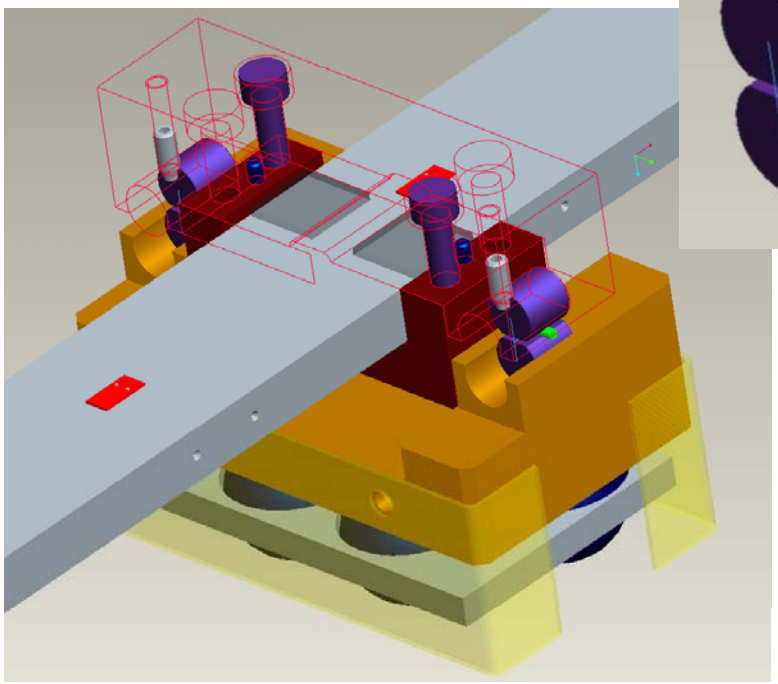
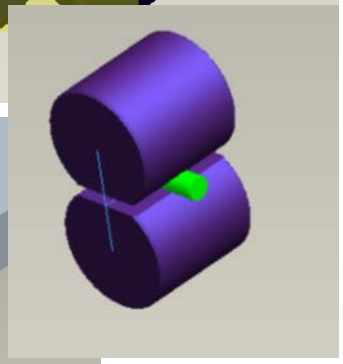
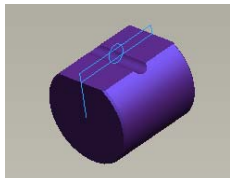


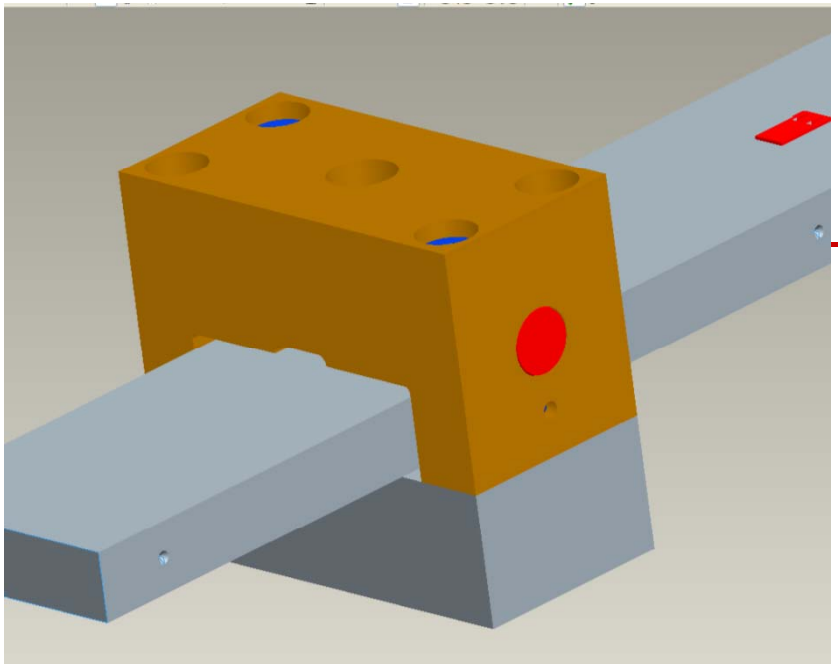






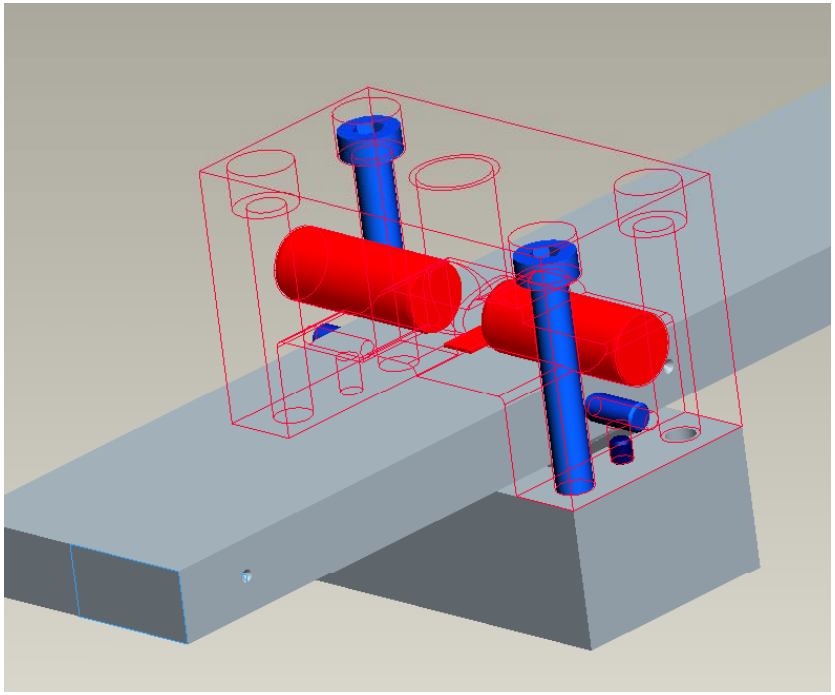
End fixtures

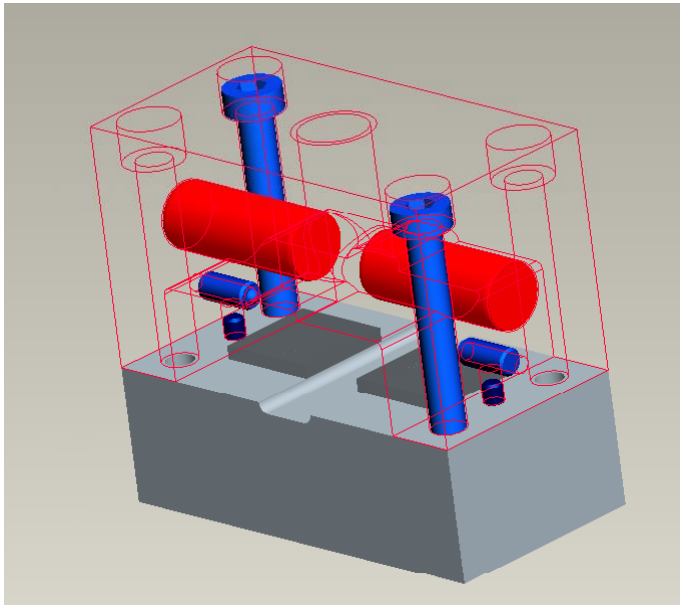
- Pivots made from hardened dowels
- Simple parts and easy replacement
- 2mm diameter pivot
- 10mm diameter with ground flat and groove
- 10mm dowels allow alignment and load distribution of 2mm dowel
  - Surface strain on 2mm dowel 290MPa, 60HRc equals 2300MPa (1MPa=1N/mm2)
  - Surface strain on 10mm dowels 25MPa
- Rubber pads to fill space and clamp



Middle loading fixtures

- Loading point with 10mm dowels
- Rubber pads to fill space and clamp
- Central threaded hole for connection to calibration load cell
- Accurate positioning to bone





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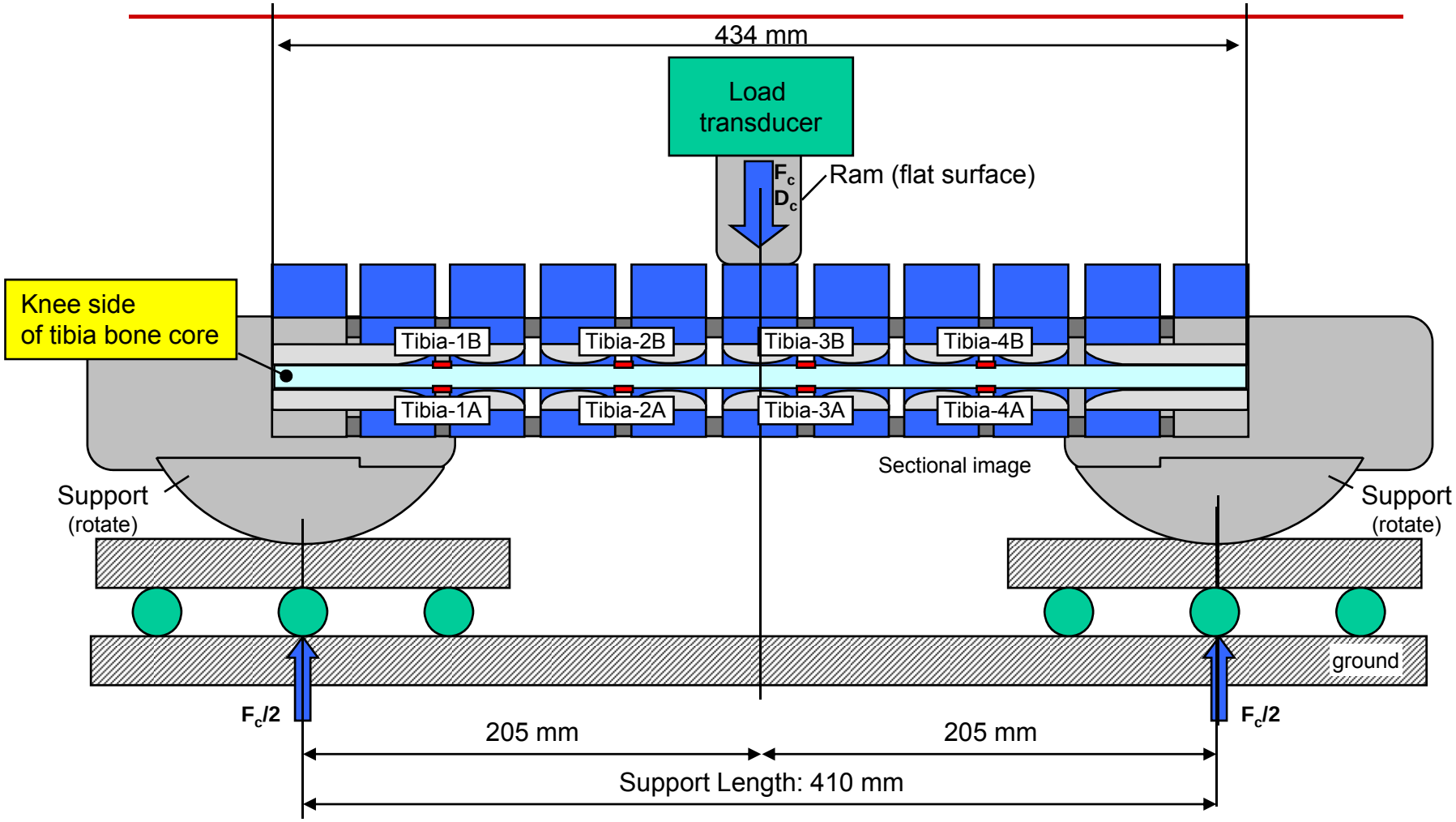
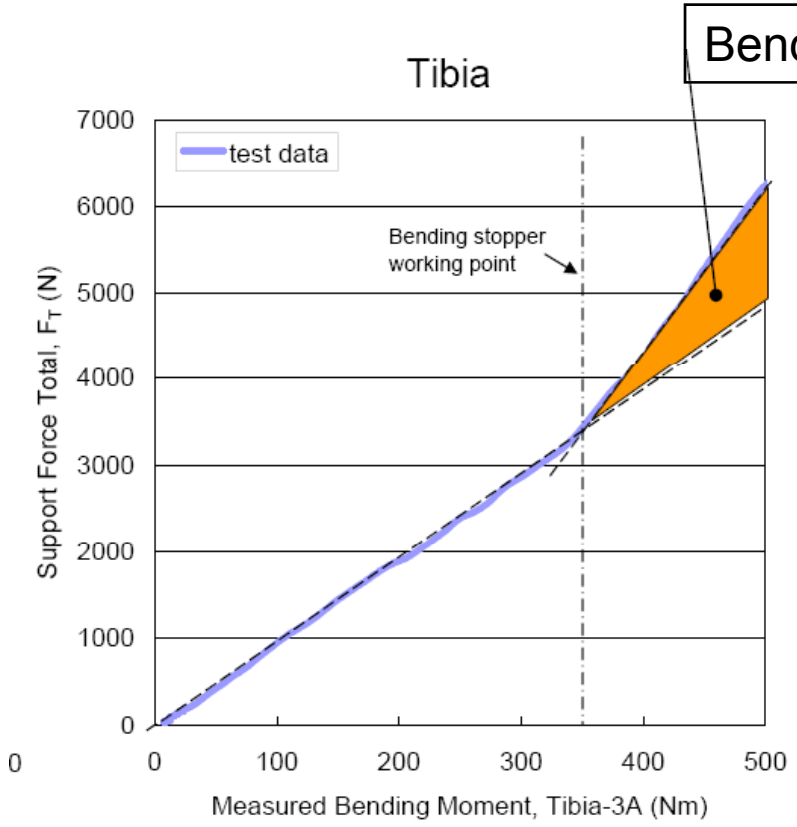
Step 2: Long Bone Tibia and Femur Quasi-static 3-Point Bending Test

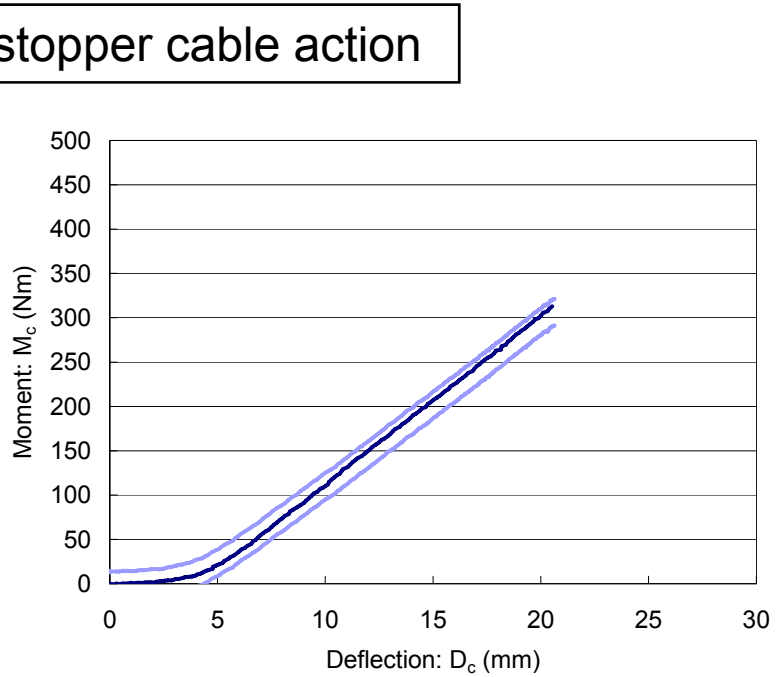


•Maintain existing procedure, Without Neoprene layer Drawings of the fixtures available

Long Bone Assembly Calibration

- Load up to IRAV [300Nm] to ensure correct IARV measurement below bending stopper working point





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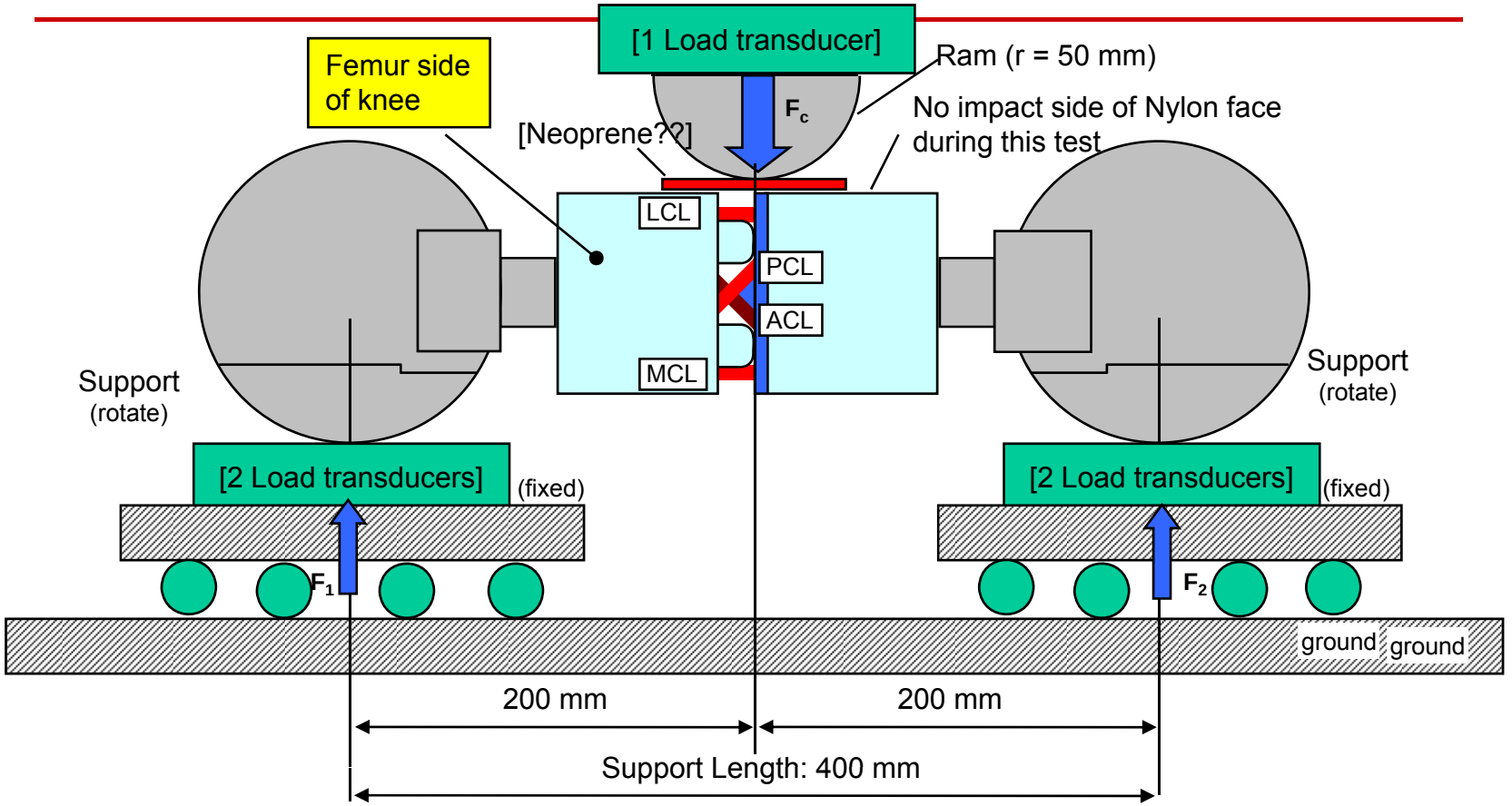
Step 3: Knee
Quasi-static 3-Point Bending Test



F_1: Support force of Femur side of knee
M_c: Moment Center - at Knee joint surface (Nm) = F_1 (N) x 0.2 (m)

- May use single central load cell
- if loading position well controlled

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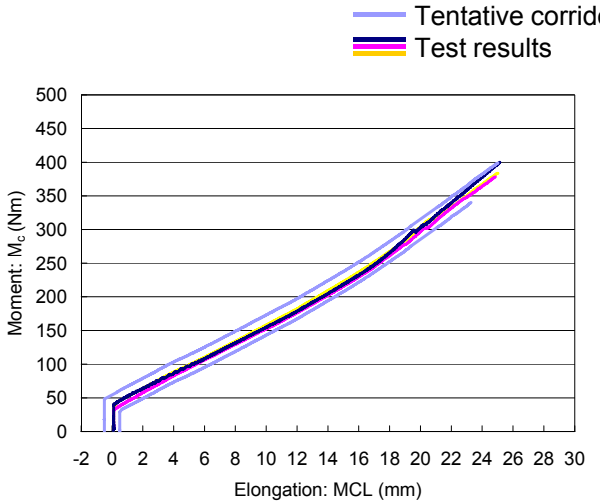
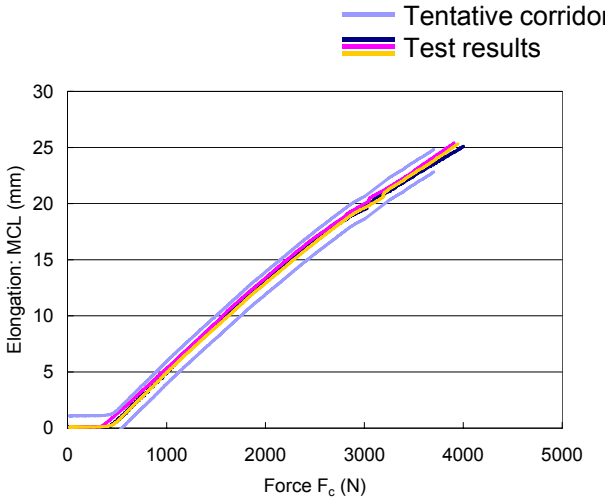
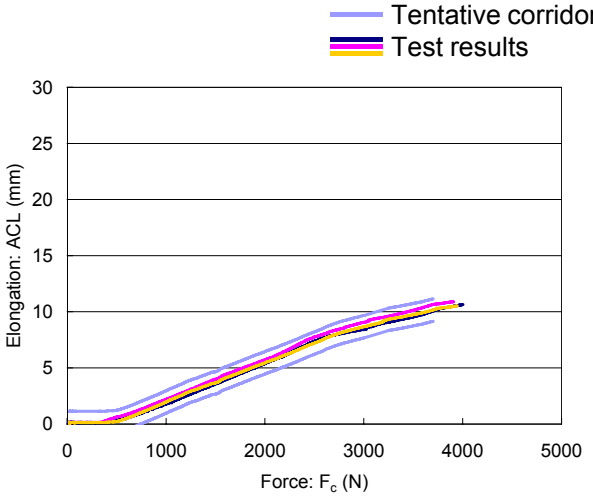
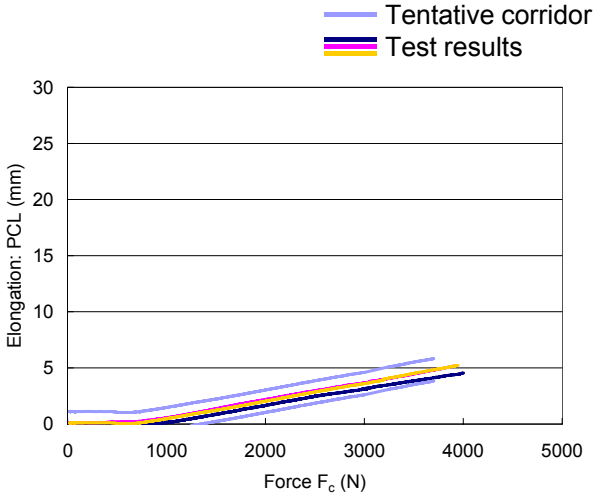
Step 2: Knee
Quasi-static 3-Point Bending Test









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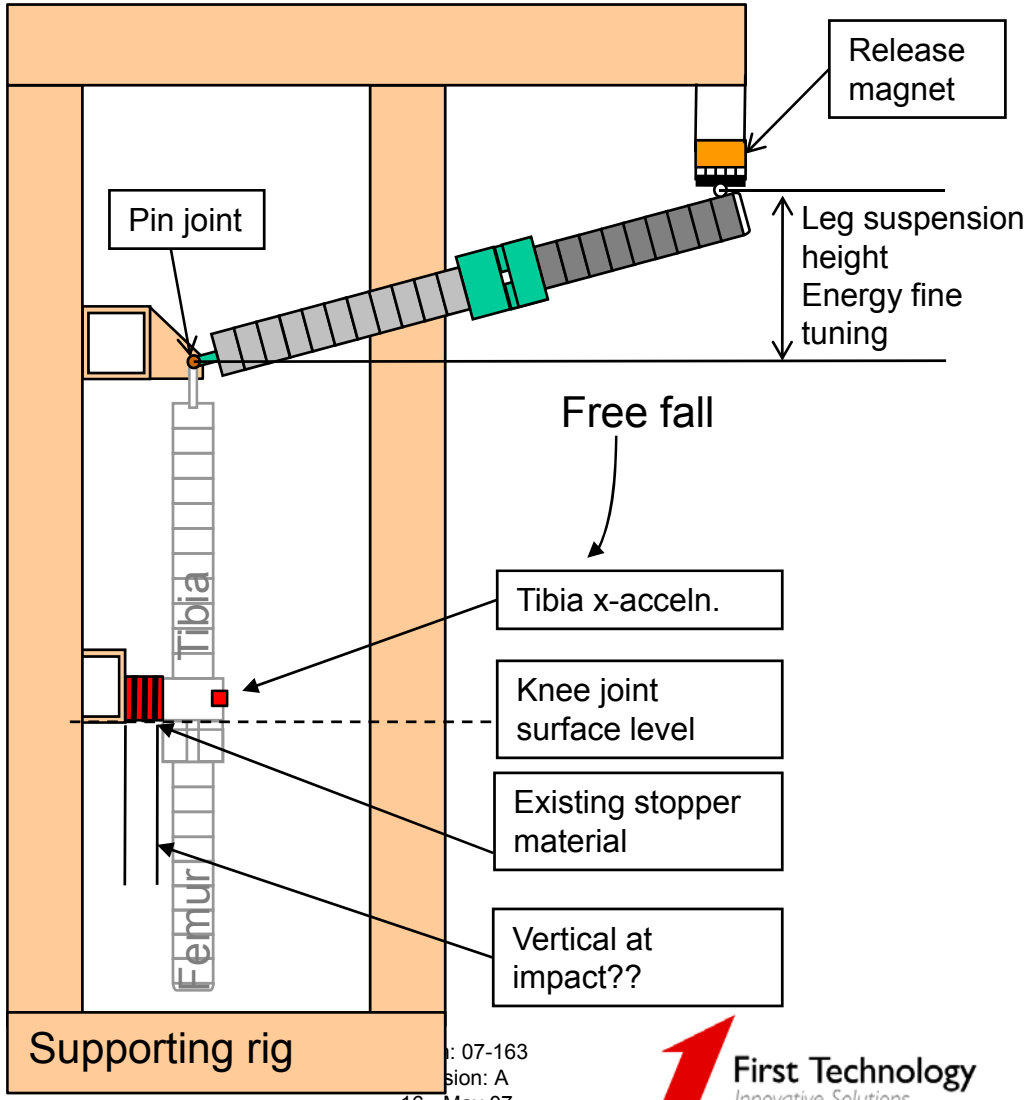
Dynamic Calibration Procedure

- Calibration rig with support arm and release magnet
- Control input pulse with tibia x-acceleration
- Control parameters
  - Drop height
  - Ax tibia proximal
  - MCL, ACL, PCL (and LCL)
  - Tibia bending moments
  - No pass-fail parameter femur bending moments
  - Target corridor ±10% from average



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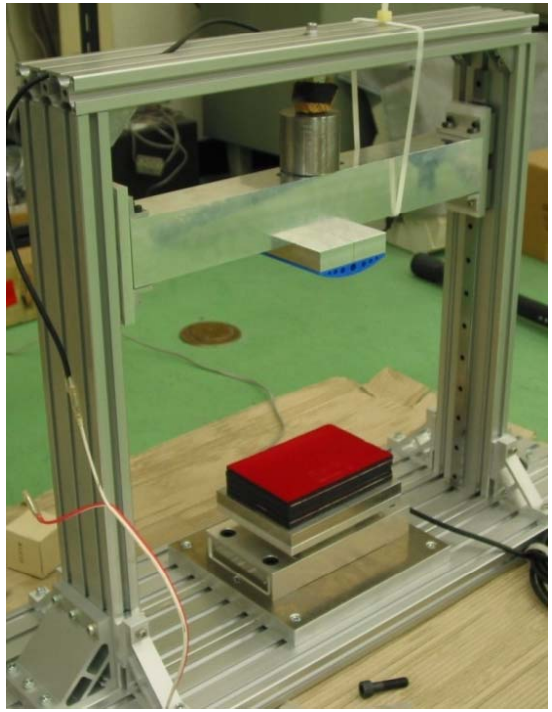
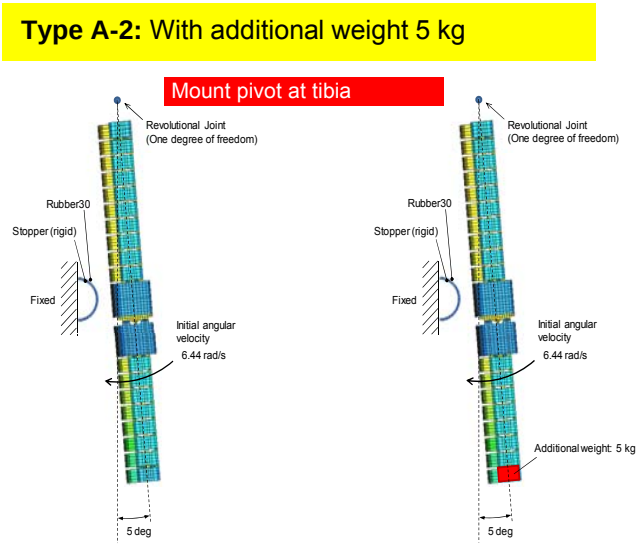
Stopper material consistency test

- Tibia acceleration may be dependent from two parameters
  - stopper material
  - tibia response
- To be able to identify problem in case of calibration failure: tibia or stopper material
- Need to have additional procedure for stopper material test
  - Control stopper material over extended time of loading/use
  - FTSS to make proposal for dynamic (drop?) test



Dynamic Calibration Development Testing

- Continue JARI FE Model study parameter variation for calibration development
- Complete test matrix (example)
  - Base line test
  - Mount at Tibia (upside down)
  - Added mass to bottom segment
  - [Free fall height increase]
  - Loading surface Flat and Curved



- Decide on final procedure parameters based on model parameter variation
- Verify procedure details with FLEX-PLI-GT
- Calibrate GTR prototypes with final procedures

Design frozen!