First Technology Safety Systems

Design Freeze Status

FLEX-PLI-GTR Development
Mechanical Design

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Updated according Design Freeze meeting
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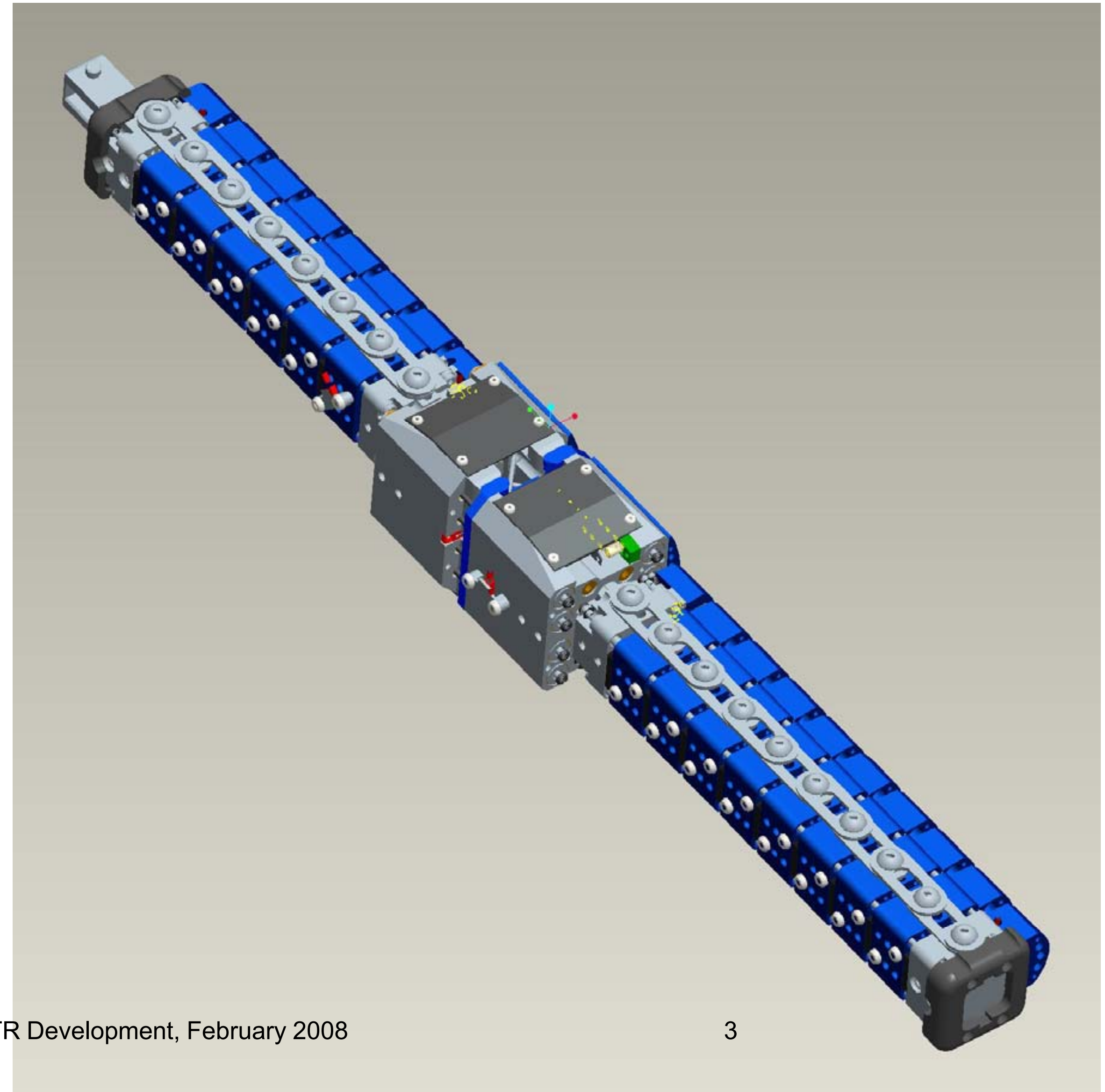
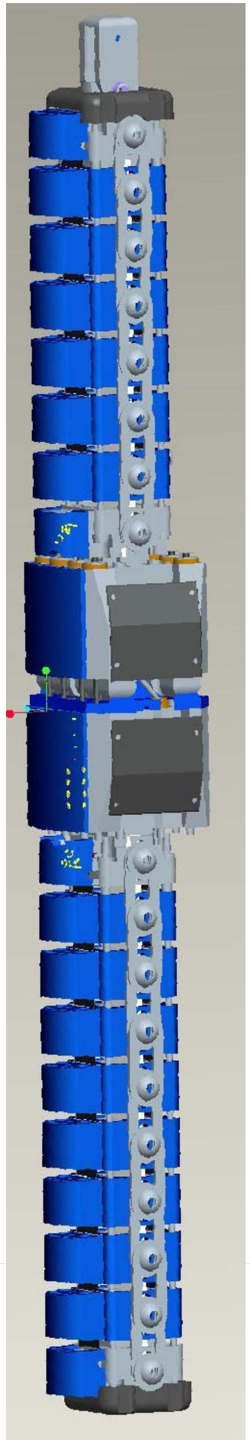
First Technology
Innovative Solutions

Content

- Mechanical design
- Problems addressed
- Packaging standard components

Introduction

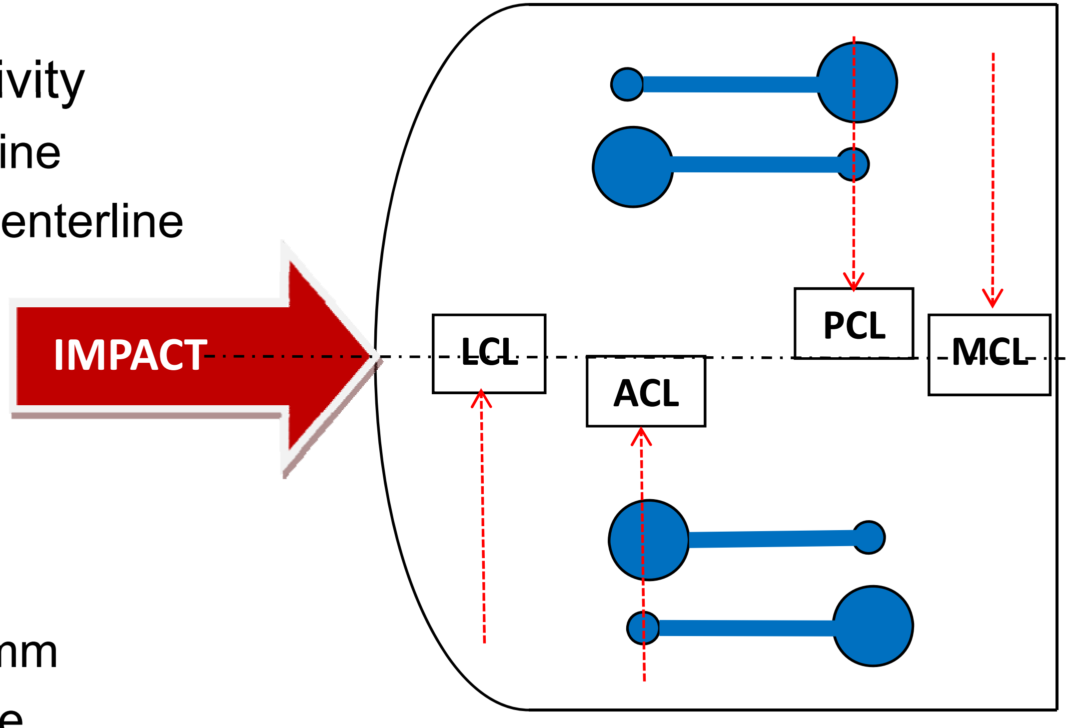




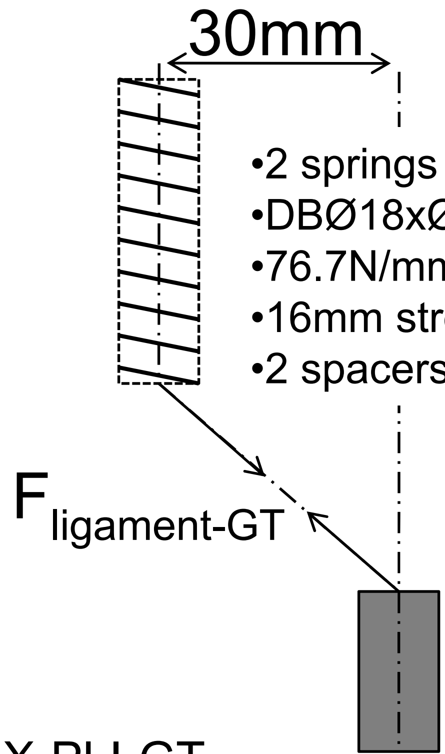
Channel	Purpose	Standard	Option	DAS
Femur moment 1, 2 and 3	Calibration	3	0	Standard option i-dummy
Tibia moment 1, 2, 3 and 4	Injury	4	0	
Tibia top acceln ax	Calibration	1	-1	
MCL elongation	Injury	1	0	
ACL elongation	Calibration	1	0	
PCL elongation	Calibration	1	0	
LCL elongation	Calibration	1	0	
Femur top acceln ax, ay, az	Motion	0	3	Lab
Femur bottom acceln ax, ay, az	Motion	0	3	Lab and optional i-dummy If feasibl
Tibia top acceln ax, ay, az	Motion	0	3	
Tibia angular rate ωx, ωy, ωz	Motion	0	3	
Femur angular rate ωx, ωy, ωz	Motion	0	3	
Tibia bottom acceln ax, ay, az	Motion	0	3	Lab
Segment acceln ax	Research	0	15	Lab
Total		**12**	**32**	

Conceptual Design

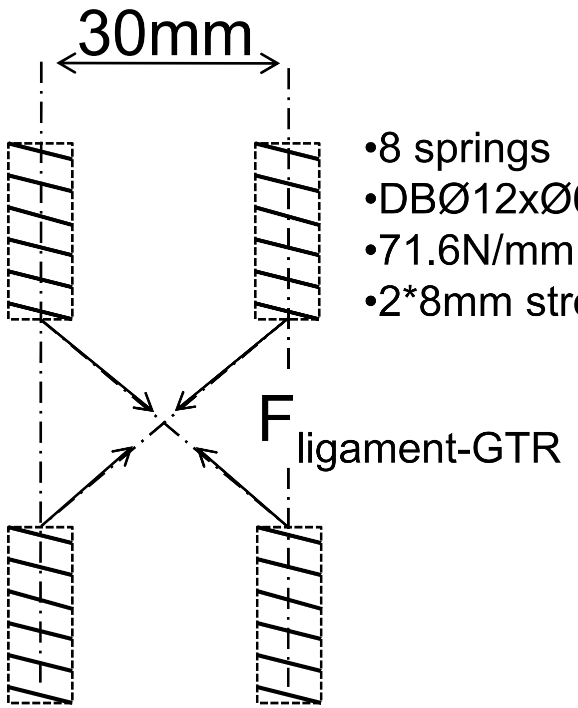
- To avoid A-symmetric sensitivity
  - Move MCL & LCL at centerline
  - Move ACL & PCL close to centerline
- To avoid knee twist
  - Use two sets of cruciate ligaments
  - To neutralize twist moment
- Cruciate ligaments 8 springs
  - DBØ12xØ6x40mm; 71.6N/mm
  - May need to go Ø3mm cable
  - Optimized space for DAS & connector
- Lateral ligaments 16 springs same
  - DBØ18xØ9x80mm; 76.7N/mm



Cruciate Ligament Springs



- 2 springs
- DBØ18xØ9x80mm
- 76.7N/mm rate
- 16mm stroke
- 2 spacers



- 8 springs
- DBØ12xØ6x40mm
- 71.6N/mm rate
- 2*8mm stroke

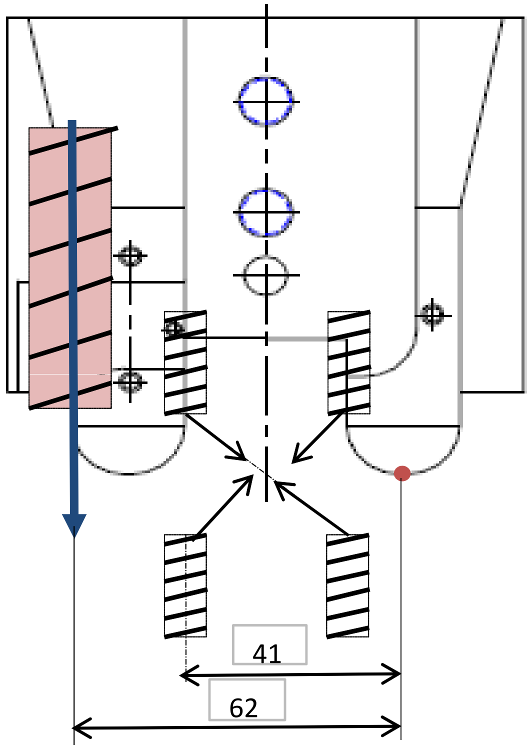
- FLEX-PLI-GT
- $F_{ligament\ GT}$ = 76.7*16 = 1227N
- Total $F_{ligament\ GT}$ = 2 * 1227 = 2454N

- FLEX-PLI-GTR
- $F_{ligament\text{-}GTR}$ = 71.6*8 = 573N
- Total $F_{ligament\text{-}GTR}$ = 4*71.6*8 = 2292N

- 8 Lateral ligaments DBØ18xØ9x80mm
- Cruciate ligaments contribute ~22% to bending moment
- Effect ~-1.3%

Knee Bending Moment Comparison

Knee Bending Moment Comparison GT-GTR	GT	GTR
Lateral ligament peak force FL	1227	1227
Cruciate ligament peak force FC	1227	573
Distance lateral ligament- Rotation point 72-10=62	62	62
Distance crucuate ligament- Rotation point 26+15=41	41	41
Lateral ligament Moment peak contribution ML [Nm]	304	304
Cruciate ligament Moment peak contribution MC [Nm]	71	66
Total moment before spring bottom out [Nm]	375	371
Difference GT-GTR [%]	**1.3**	



GT version
*ML=4*FL*62/1000*
*MC=2*FC*41/ √2/1000*

GTR version
*ML=4*FL*62/1000*
*MC=4*FC*41/ √2/1000*

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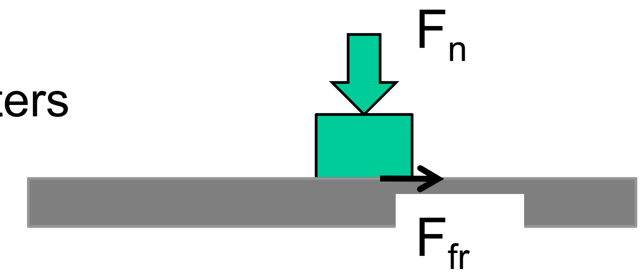
Ligament Wear

- Prevent wear of ligament cable plastic sleeves
  - Remove plastic sleeves from cables
  - Apply bronze guides cross ligaments
- The plastic tube is the source of the problem; it cannot sustain high surface strain
- Omitting plastic sleeve will avoid the damage
- Larger bending radius and reduced friction will protect the cable
- Ø3mm cable for cruciate ligaments agreed
  - May go to Ø4mm if problems arise
- Ø4mm 7*19 cable break strength 8.73kN
  - Alternative 7*7 cable break strength Ø4mm 9.52kN
  - Knee bending moment break strength 60mm * 9kN * 4 = 2160Nm
- Ø3mm 7*19 cable break strength 5.00kN

Friction Double Cruciate Ligaments

- A concern raised on change in friction of the double cruciate ligaments
- Friction is **undesired** unpredictable phenomena
  - Static and dynamic friction, slip-stick effect, effect of wear, state of lubrication, moisture
- GT version is unpredictable because of three material layers: steel-PVC tube-aluminium
- Friction force (F_{fr}) is dependent on two parameters
  - material pairing and friction coefficient (c)
  - force perpendicular to friction plane (F_n)



- In GTR version the total perpendicular force remains the same
- In GTR version friction coefficient will reduce
  - GT Plastic to steel ~ 0.2-0.5 friction coefficient
  - GTR Steel to bronze ~ 0.1 friction coefficient
- Cruciate ligaments only contribute ~ 20% to knee bending moment
  - Influence of friction is further reduced in GTR version
  - Knee bending characteristic dependent on spring tension and controlled by calibration

Ligament Spring Adjustment

- Problem of spring adjustment access
- Problem of spring adjustment loss (no retention of position)

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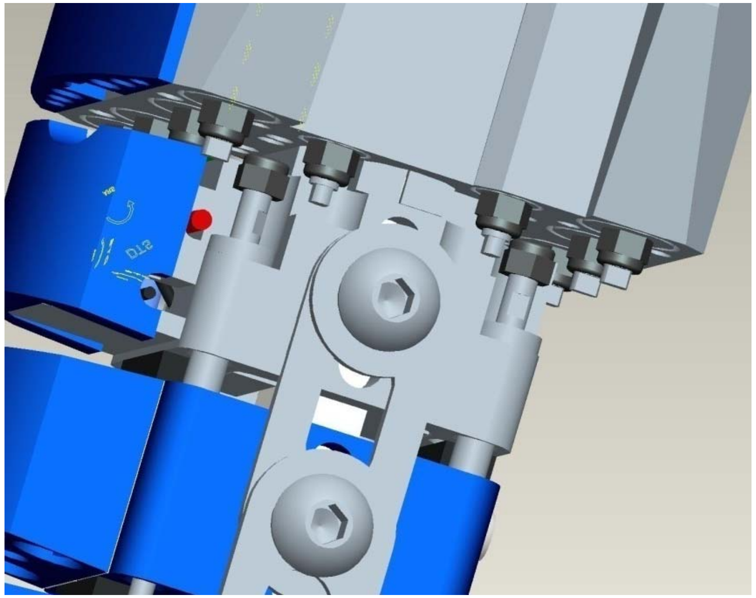
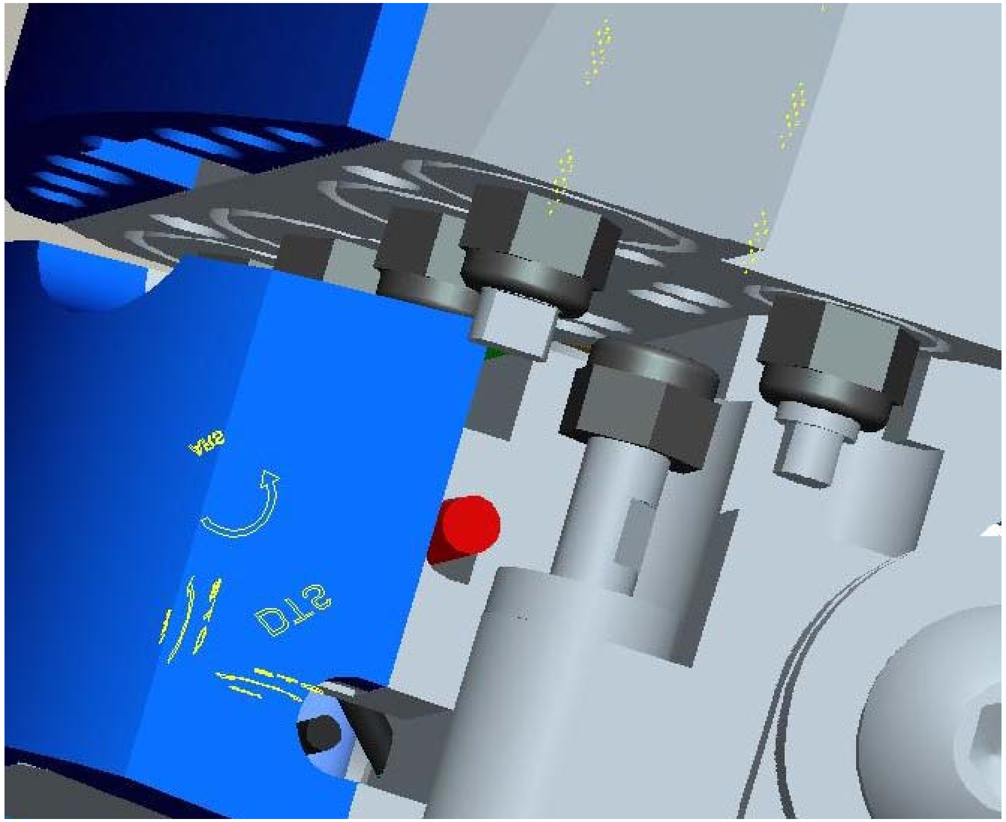
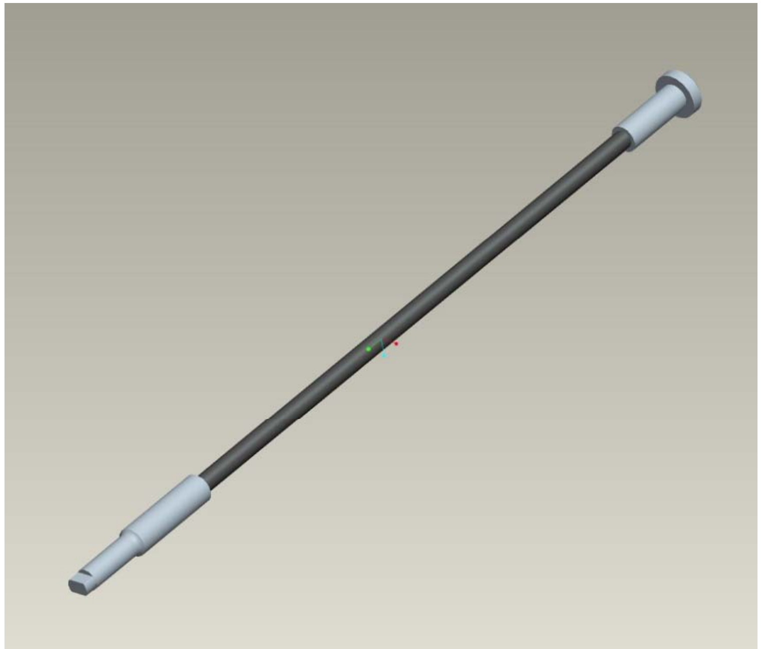
Ligament Spring Adjustment



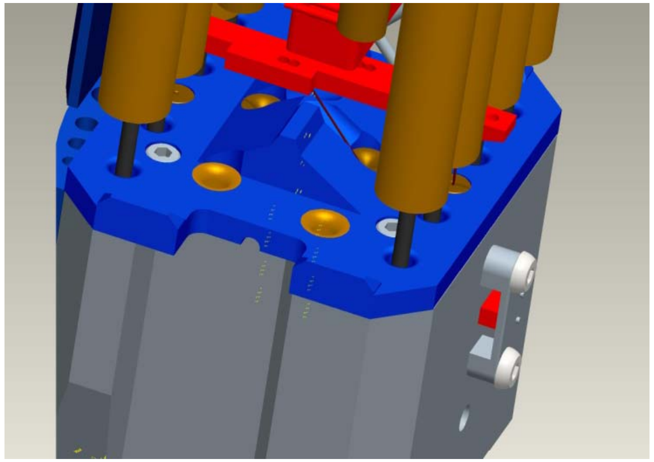


- Ligament springs made flush
- M5 Nyloc locking nuts
- Male thread on ligament wires
- Flats on end fittings for locking
- Improved access for ligament adjustment
- Less frequent adjustments required with locking nut

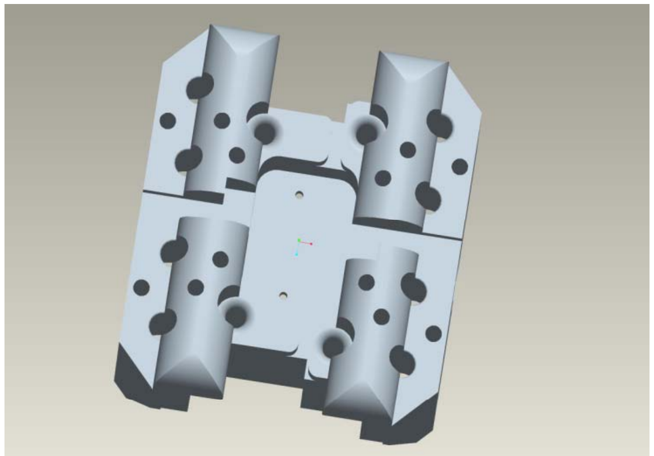
Proposed Cables



•New cable end fitting design
•Metric threads and fasteners

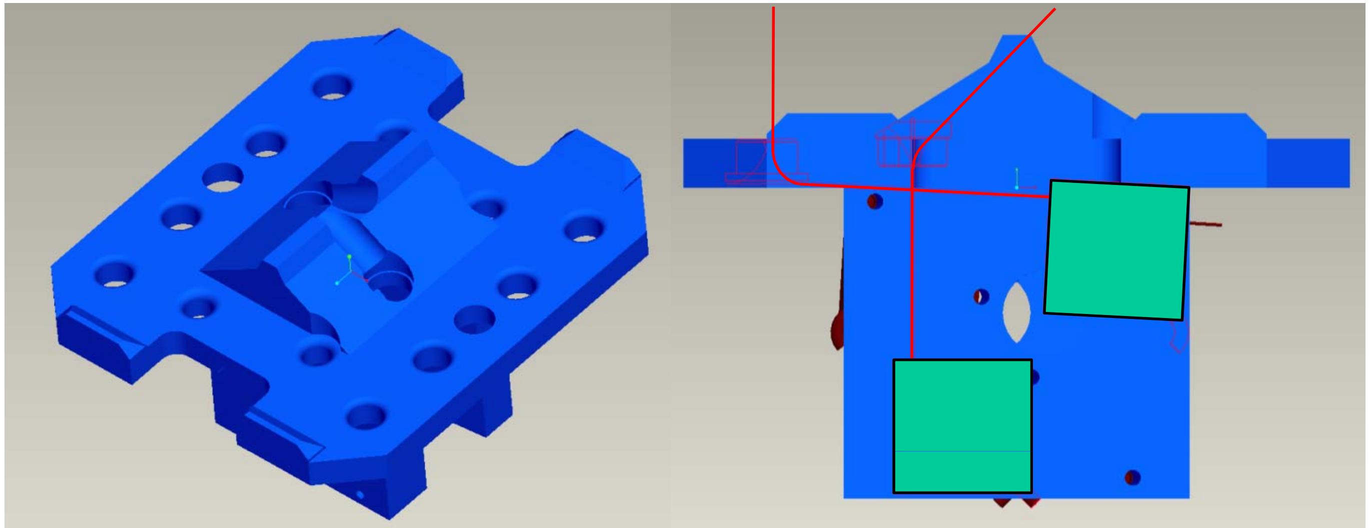


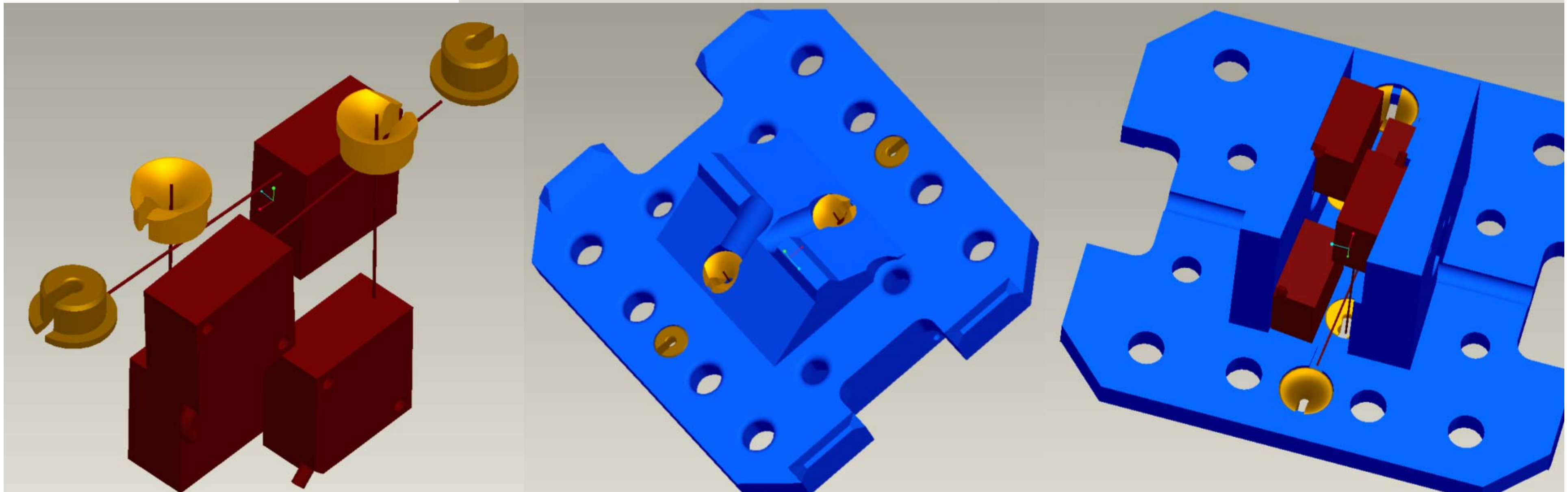
Bronze bushing
Rounded corners



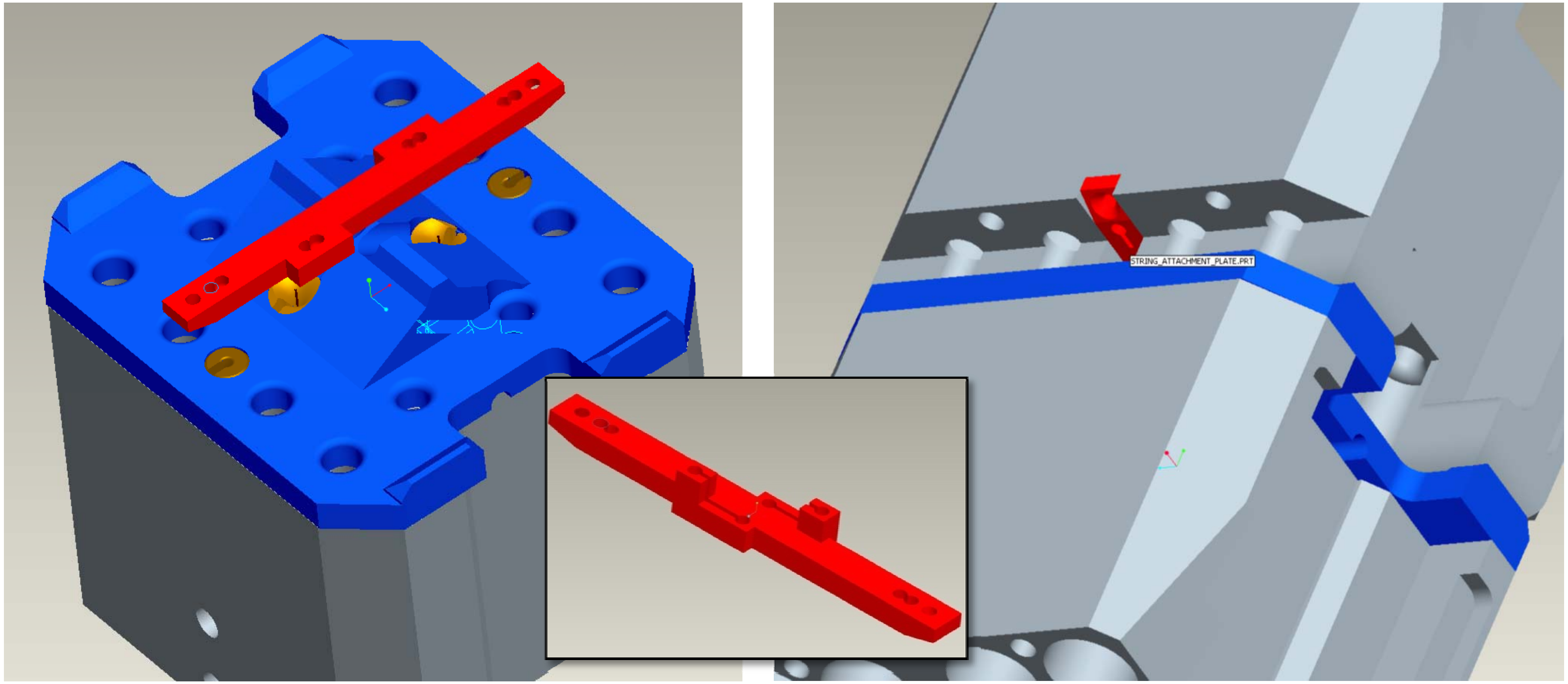
Packaging Ligament Elongations Sensors at Centre Line

Space Age Control
150 series
19*19*10mm
49G acceleration
38mm stroke
2xLH & 2xRH pull
Bronze wire guides



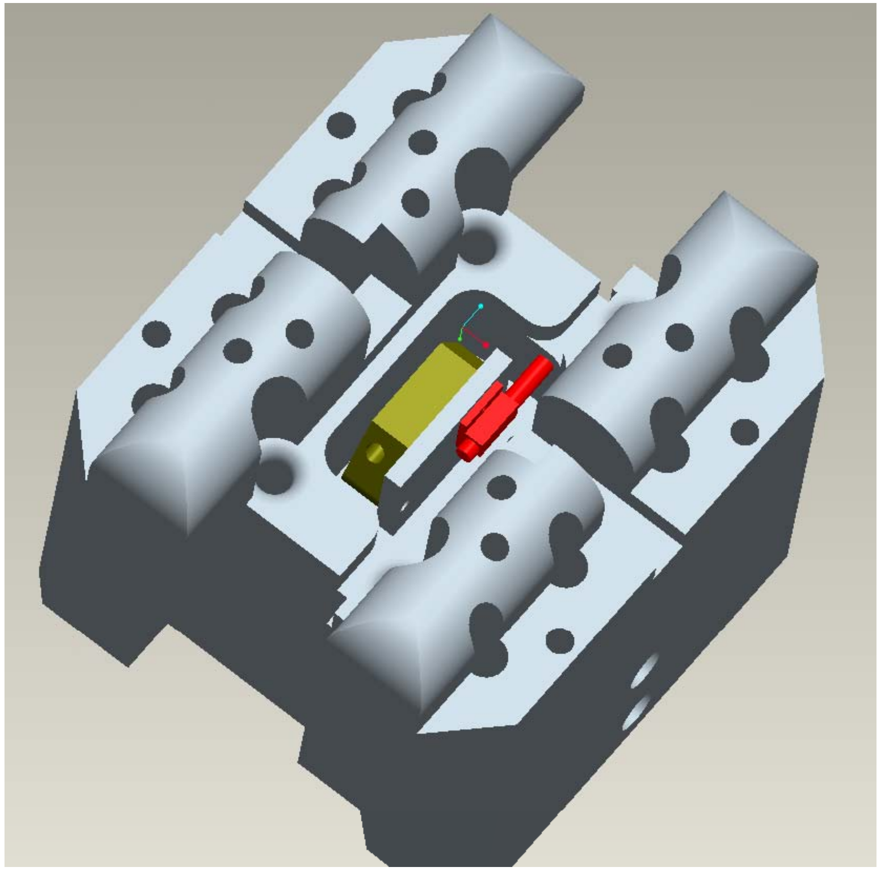


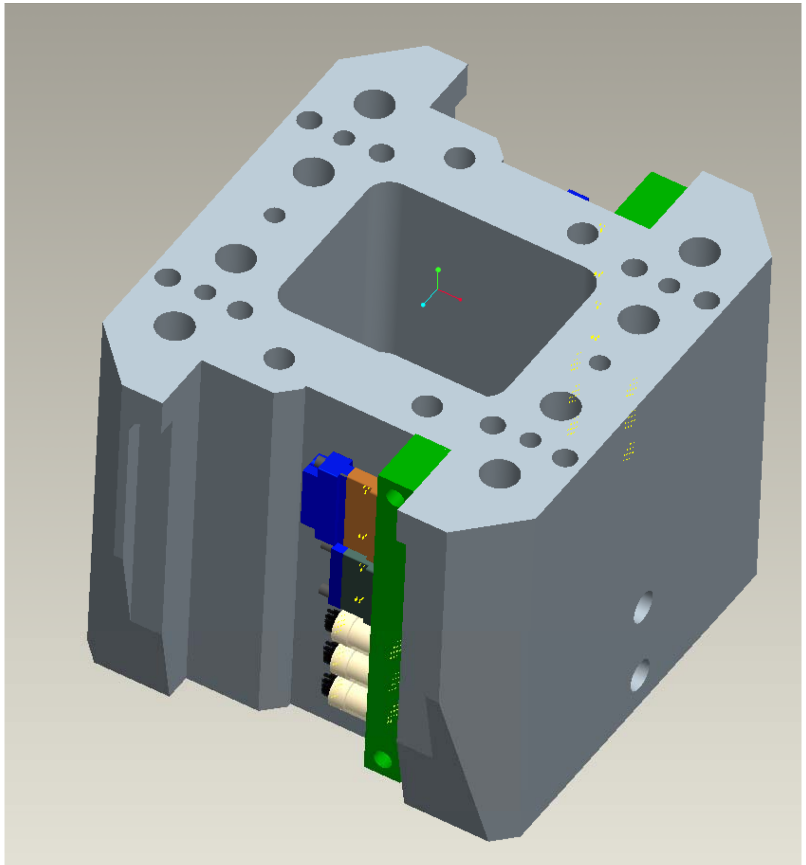
Potentiometer String Assembly



- Assembly of potentiometer string fittings is always difficult due the tension on the string and small fitting size
- This method enables mounting string fittings without tension

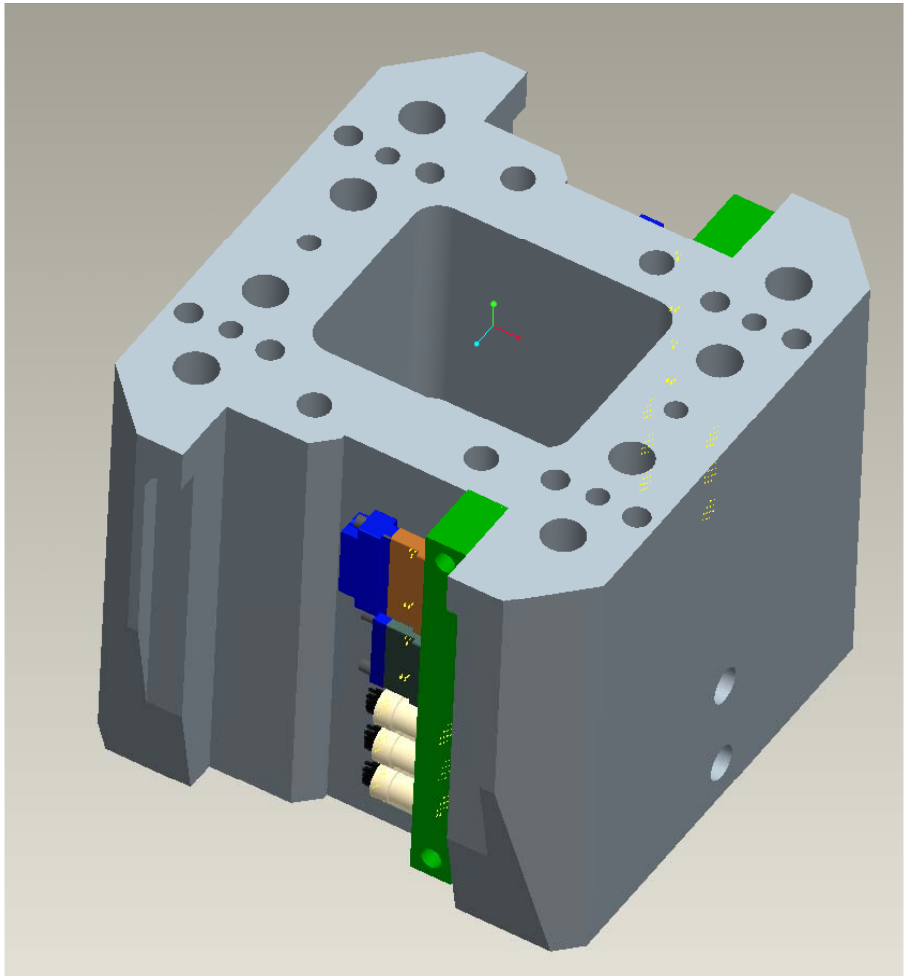
Packaging Space

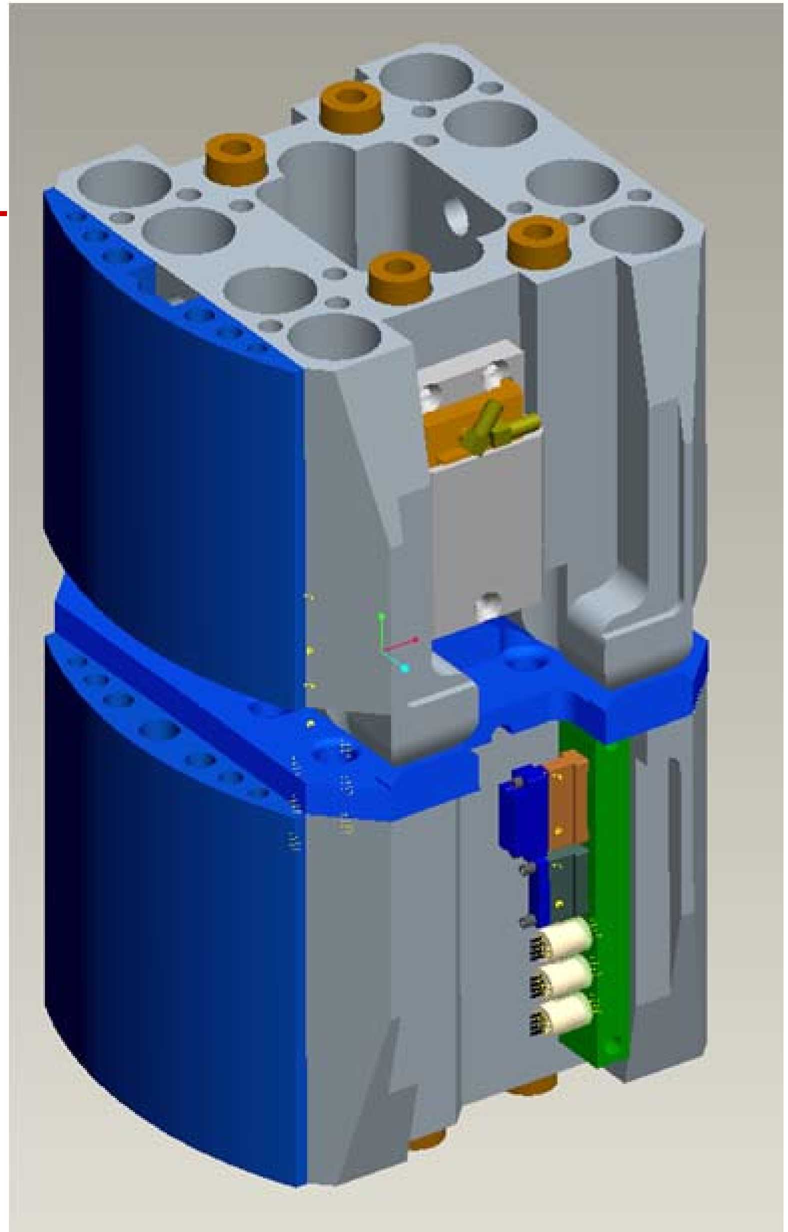




Side cavities: DAS, wiring, connectors
Central cavity: Auxiliary components: battery, terminator, etc.

Integration of connector blocks and wiring





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