

Informal document GRSP-49-23  
(49th GRSP, 16-20 May 2011,  
agenda items 4(a))

# Update on Pedestrian Leg Testing

**National Highway Traffic Safety  
Administration**

**49<sup>th</sup> GRSP Session**

**May 2011**

**Nha Nguyen**



# Pedestrian Leg Testing

- Projectile leg simulates a moving vehicle hitting a stationary pedestrian



# Pedestrian Legforms



TRL



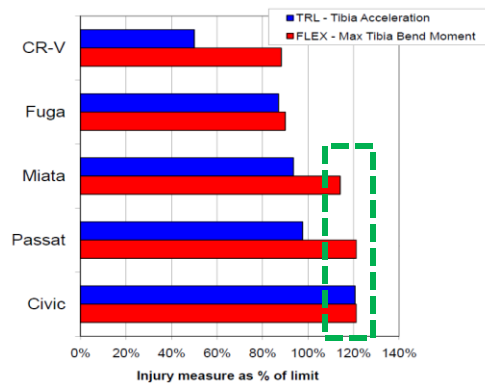
Flex-GT



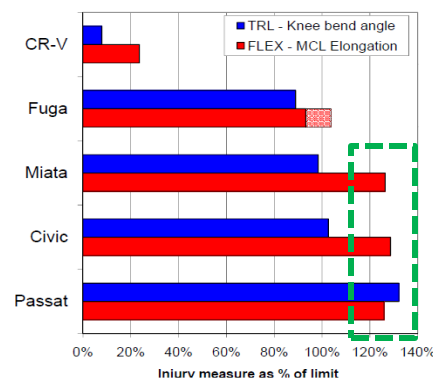
Flex-GTR

# Background

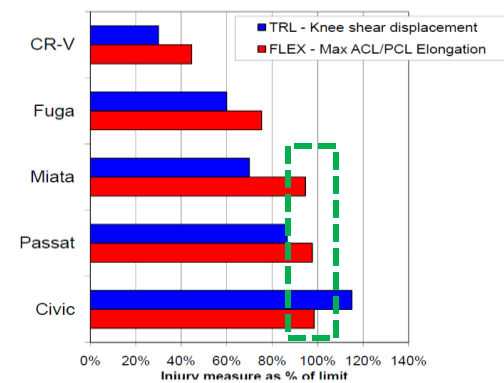
- The Flex-GTR had not been tested against aggressive vehicles in the US fleet and there was concern about its durability
- There was also concern about topping out the Flex-GTR's measurement limits (Mallory, 2010)



Fracture



Bend



Shear

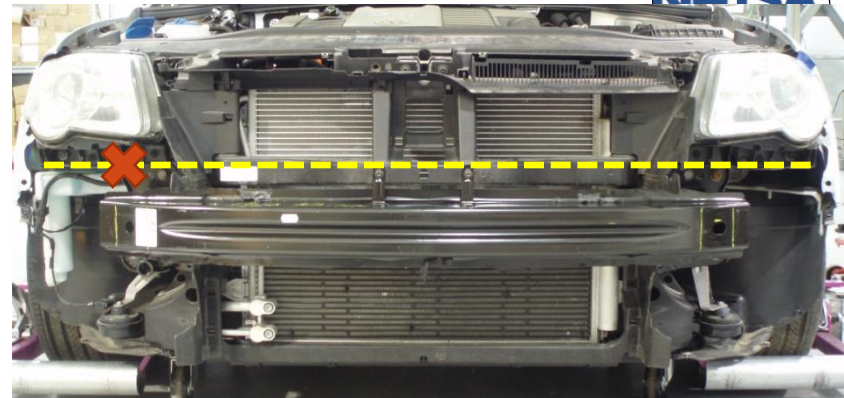
# Goals of the Testing

- This series of impacts was done to test the Flex-GTR against aggressive US vehicles to see if it would survive
- Confirm whether the Flex-GTR legform can distinguish marginally performing vehicles from poor performing vehicles

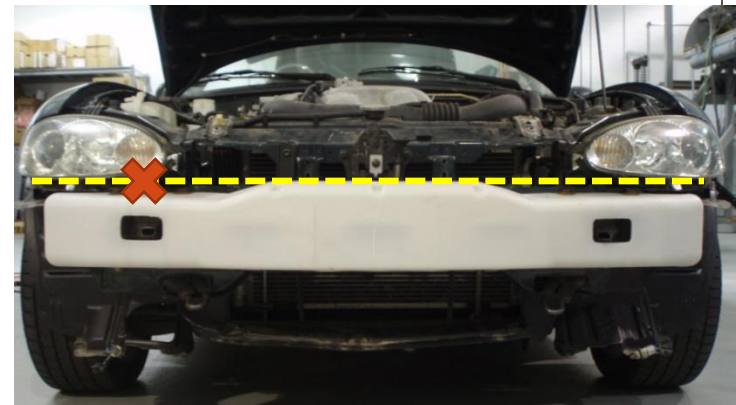
# Test Sequence

- Due to durability concerns, the TRL legform was tested on each vehicle first to rank the vehicles in order of increasing aggressiveness
- The Flex-GT was then tested on each vehicle to rank them for the Flex-GTR tests
- This allows us to get in as many tests as possible before possibly damaging the legform

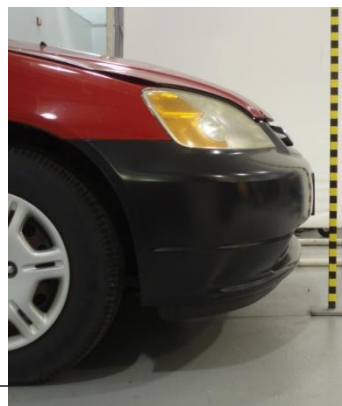
# Volkswagen Passat



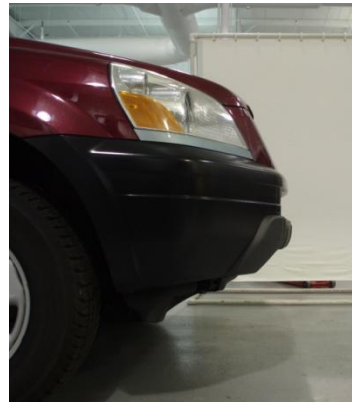
# Mazda Miata



# Honda Civic



# Honda Pilot



# Chevrolet Silverado



# Chevrolet Equinox

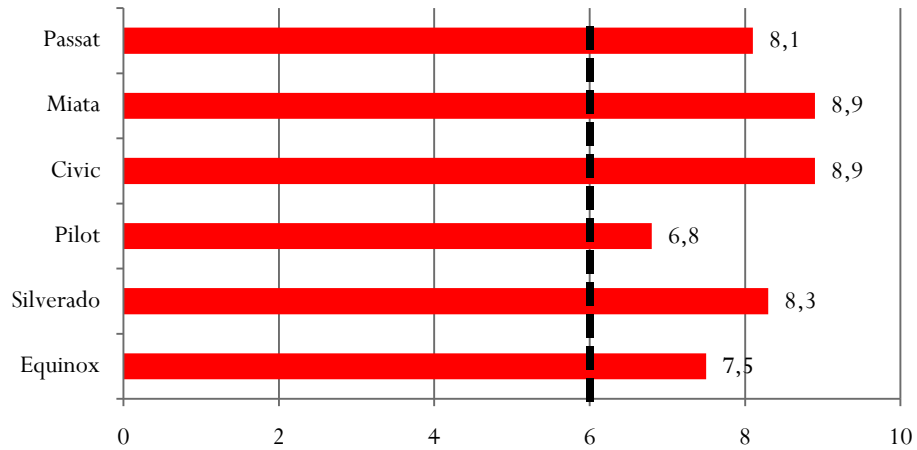




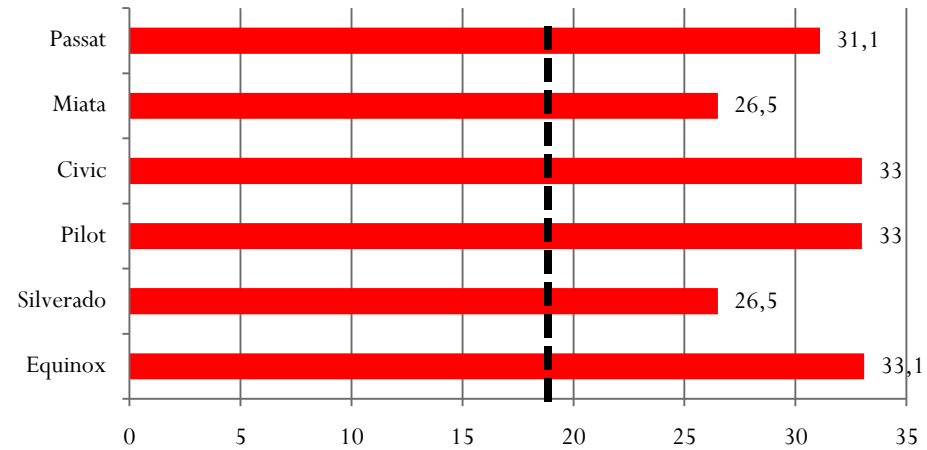
# Test Results

# TRL Test Results

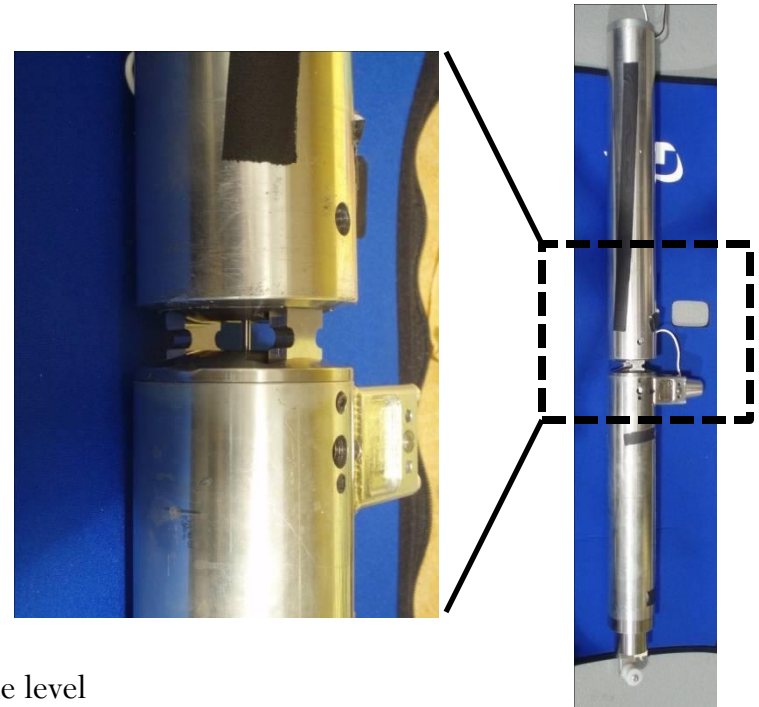
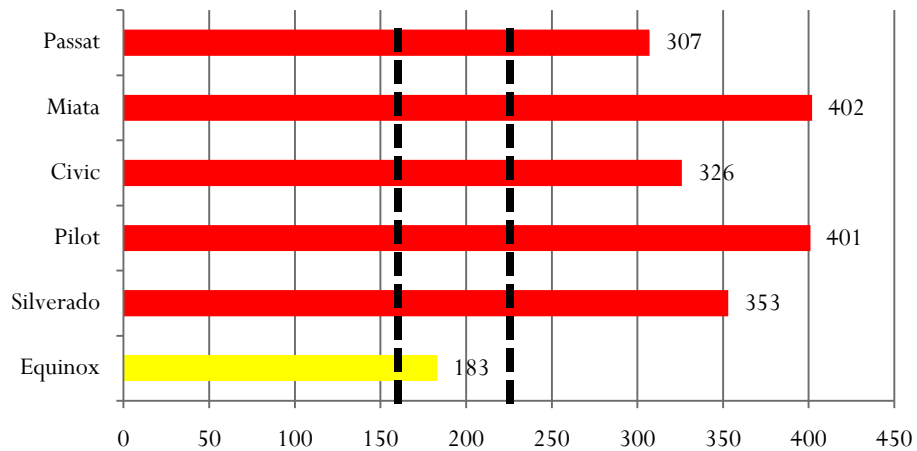
## Peak Shear Displacement (mm)



## Peak Bending Angle (deg)

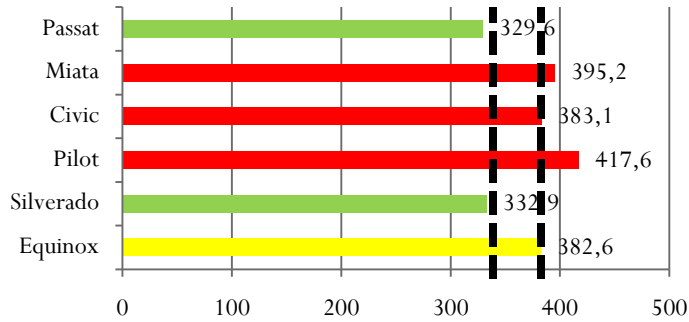


## Peak Tibia Acceleration (g)

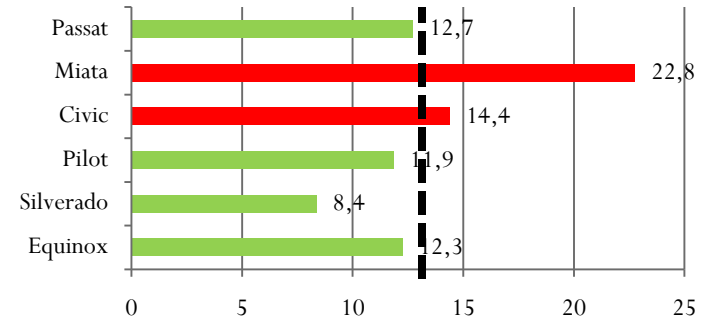


# Flex-GT Test Results

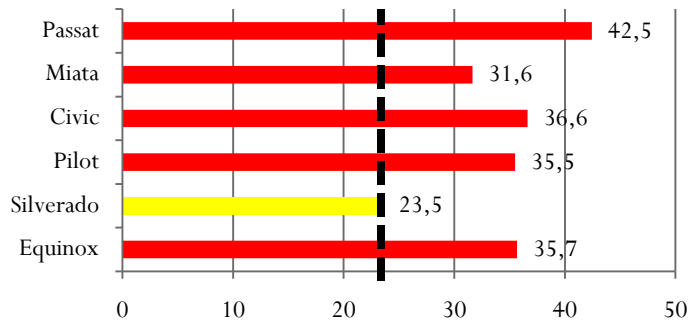
### Peak Tibia 1 Moment (Nm)



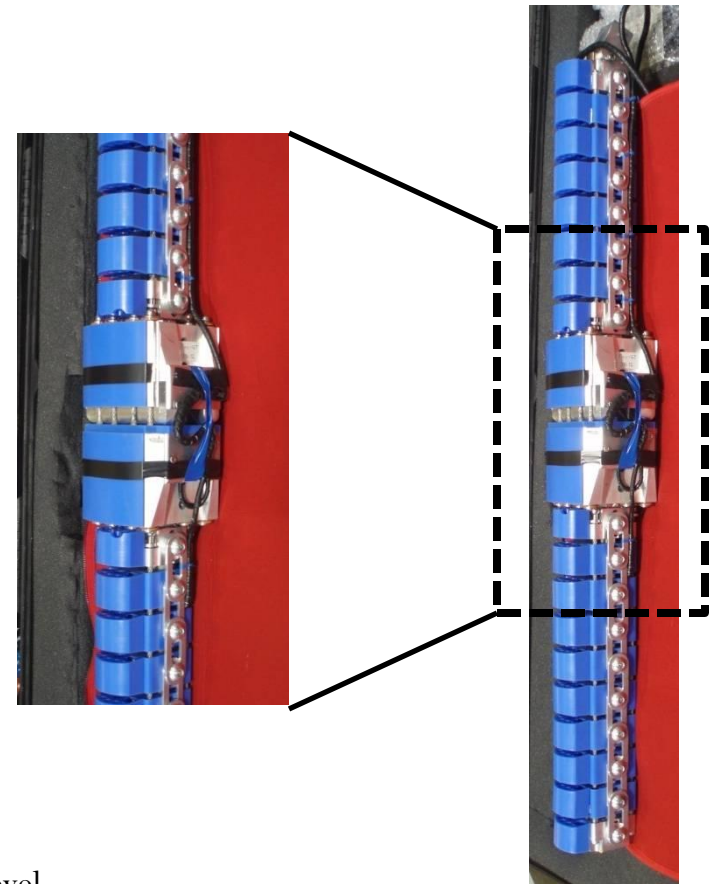
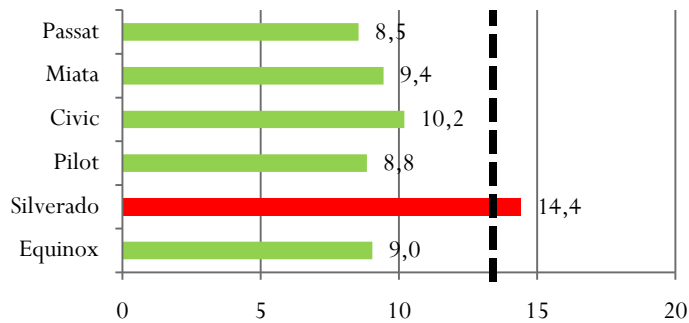
### Peak ACL Elongation (mm)



### Peak MCL Elongation (mm)

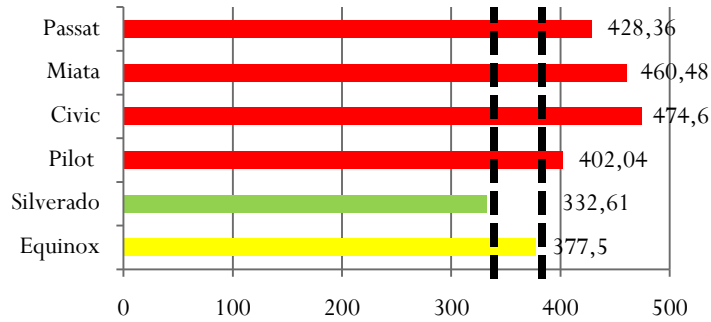


### Peak PCL Elongation (mm)

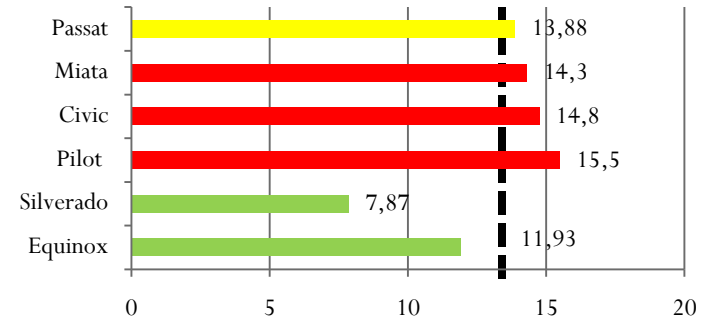


# Flex-GTR Test Results

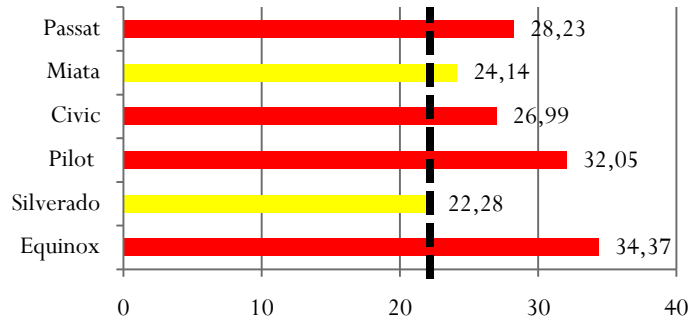
### Peak Tibia 1 Moment (Nm)



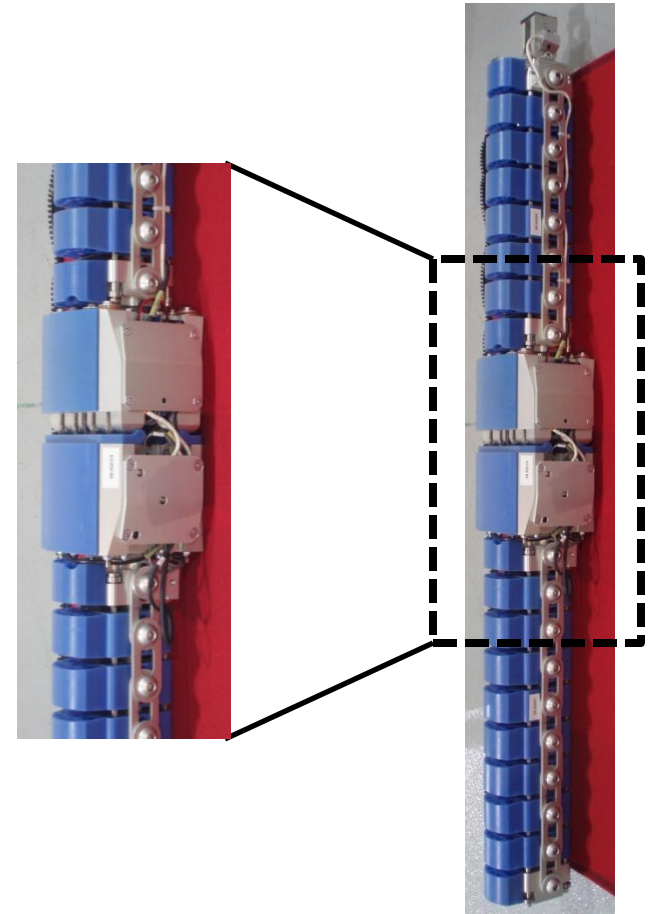
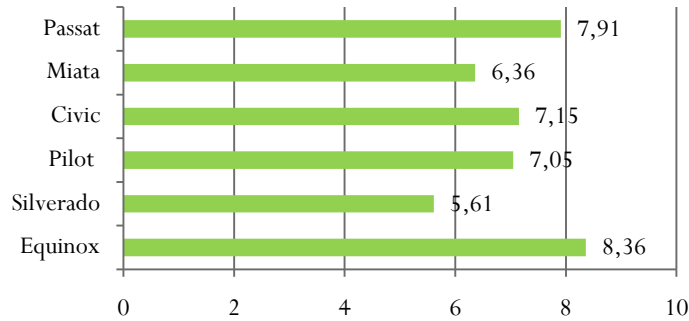
### Peak ACL Elongation (mm)



### Peak MCL Elongation (mm)



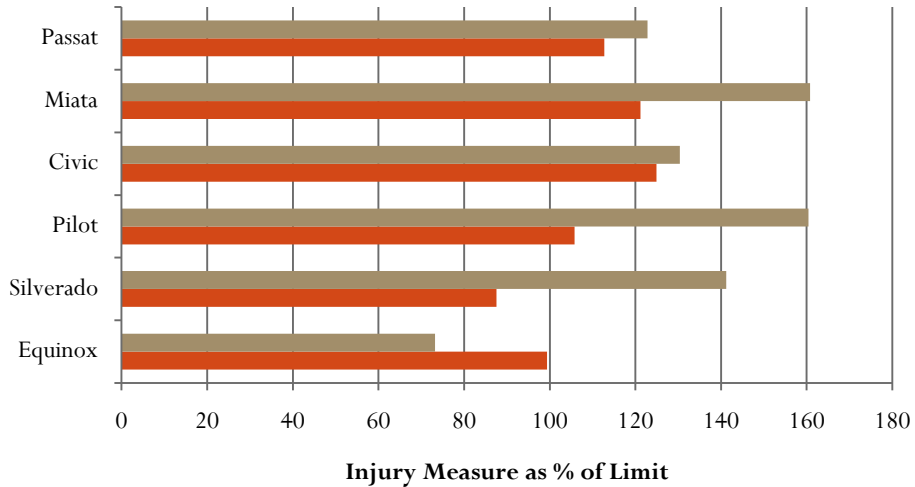
### Peak PCL Elongation (mm)



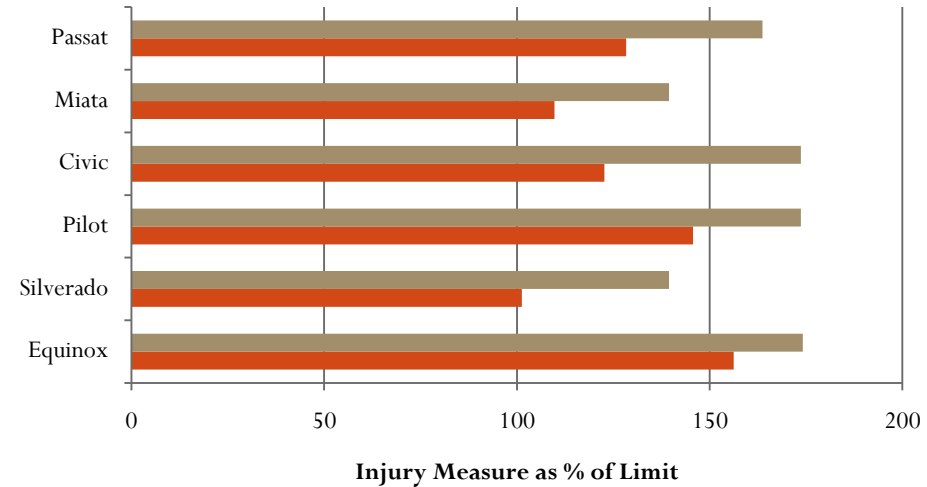
# Comparison of Results TRL vs GTR

# Comparison of Results – TRL vs Flex-GTR

## Fracture Measures



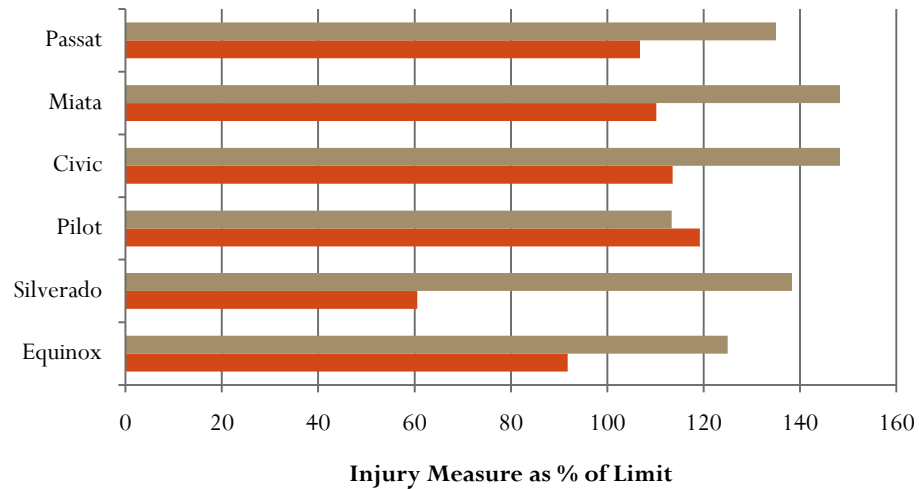
## Bending Injury Measures



■ TRL - Tibia Acceleration    ■ Flex-GTR - Max Tibia Bend Moment

■ TRL - Knee Bending Angle    ■ Flex-GTR - MCL Elongation

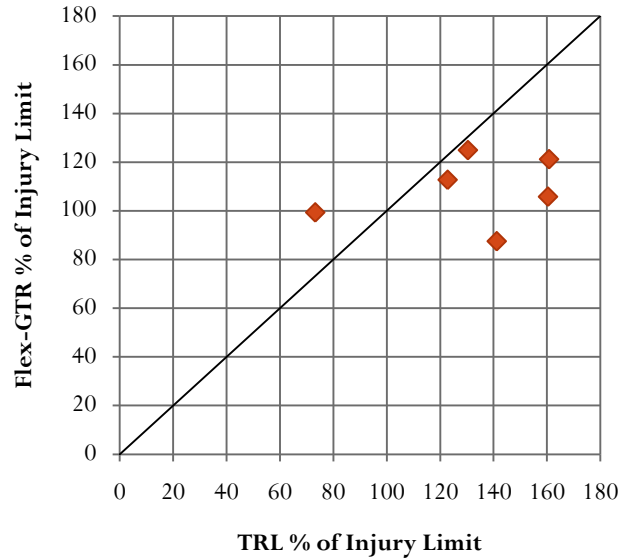
## Shear Injury Measures



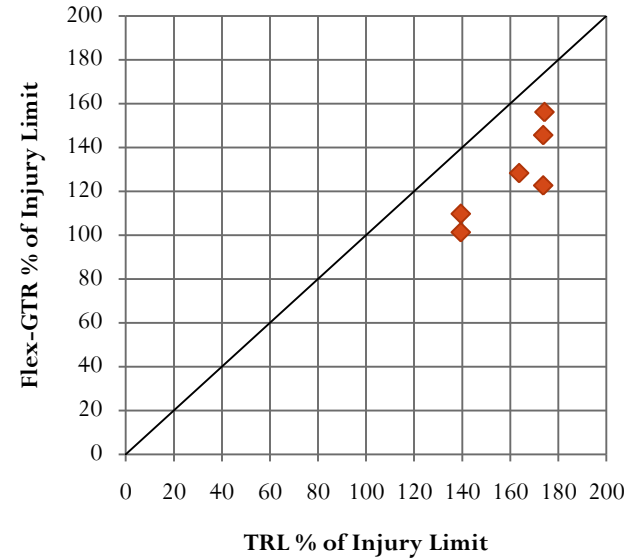
■ TRL - Knee Shear Displacement    ■ Flex-GTR - Max ACL/PCL Elongation

# Comparison of Results – TRL vs Flex-GTR

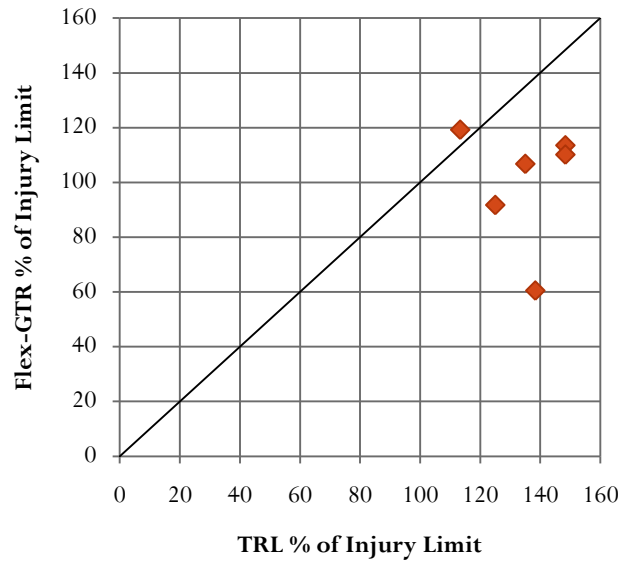
## Fracture Measures



## Bending Injury Measures



## Shear Injury Measures



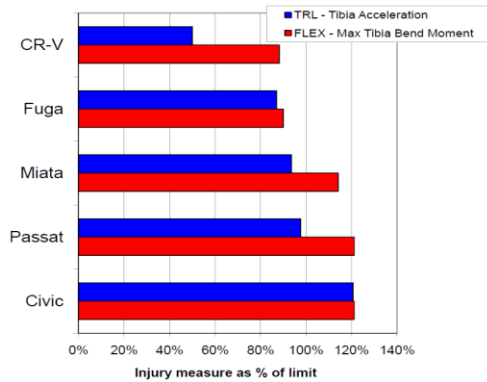
# Summary of Findings

- The Flex-GTR measures lower values than the TRL legform
- The current Flex-GTR seems to be able to distinguish differences in relatively aggressive vehicle bumper designs better than the previous version

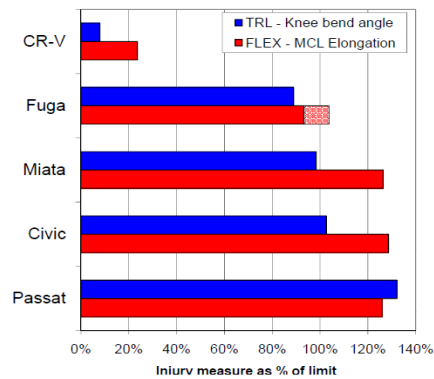


# Sensitivity

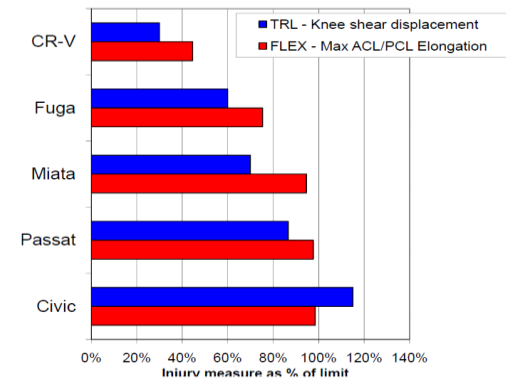
- Testing with a previous version of the Flex-GTR legform showed an inability of the legform to distinguish among vehicles that performed poorly
  - Measurements reached a limit (Mallory, 2010)



Fracture

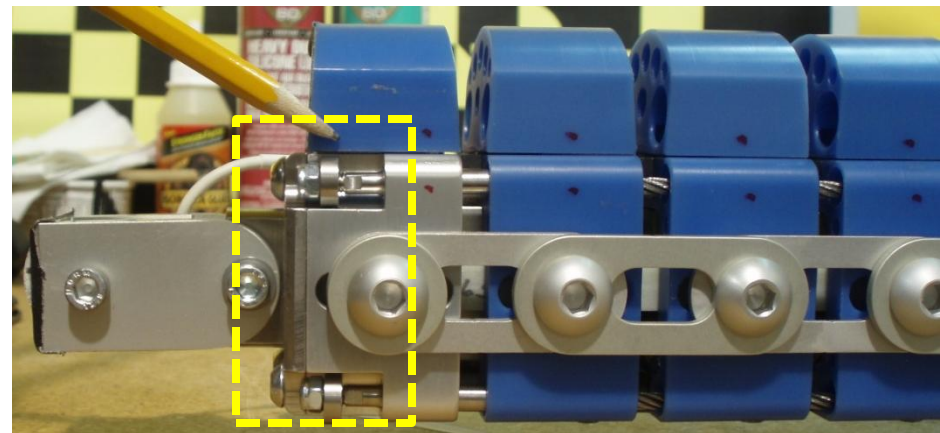


Bend

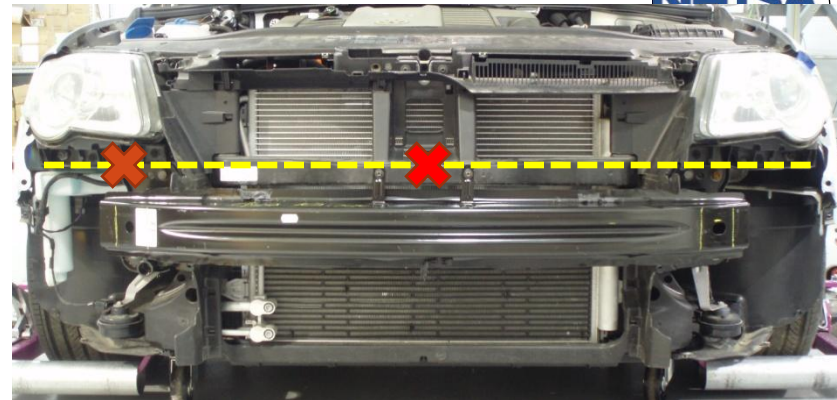


Shear

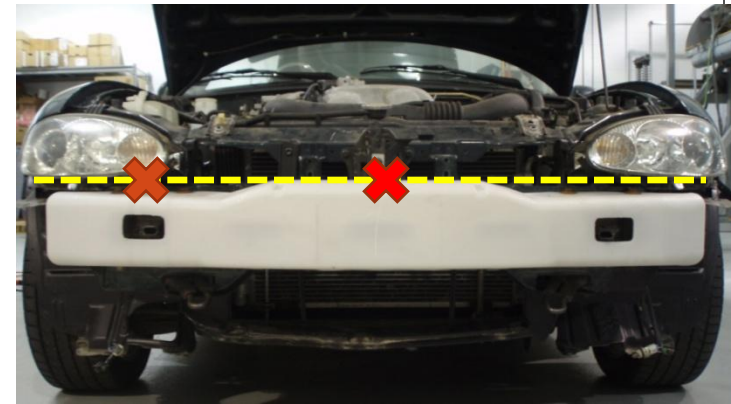
- Improvement in the current series of tests may be due to changes in Flex-GTR legform
  - Cable stop gap increase
    - Femur: 8 mm → 9.1 mm
    - Tibia: 9 mm → 10.3 mm



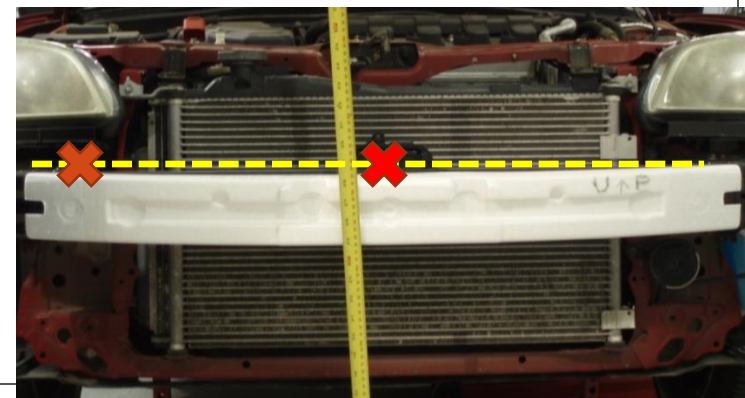
# Volkswagen Passat



# Mazda Miata



# Honda Civic

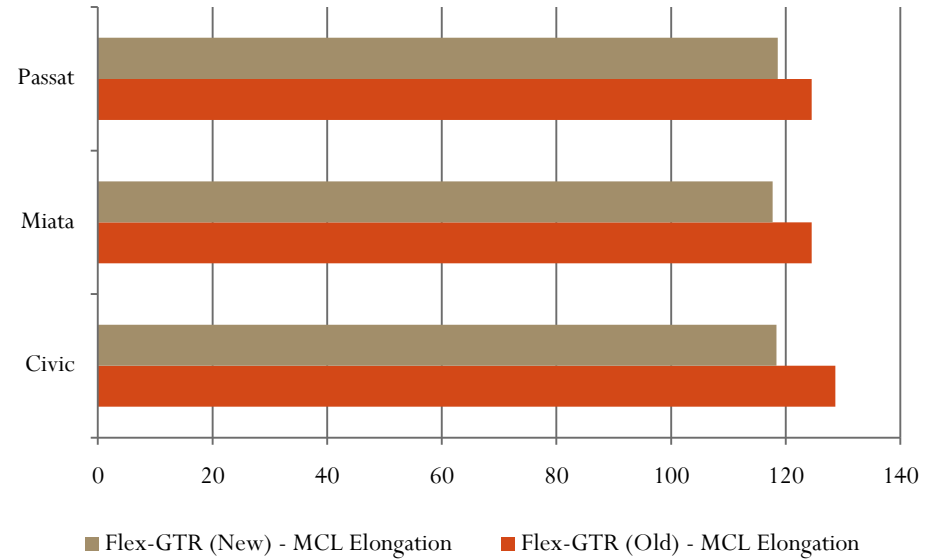


# Comparison of Old and New Flex-GTR Data – Center Impacts

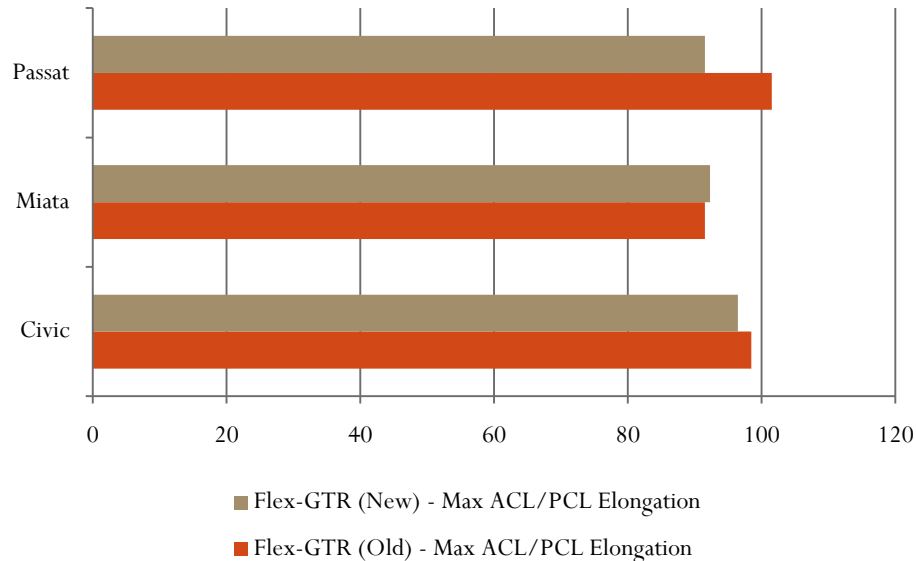
## Fracture Measures



## Bending Injury Measures



## Shear Injury Measures



# Summary of Findings

- The Flex-GTR measures lower values than the TRL legform
- The current Flex-GTR seems to be able to distinguish differences in relatively aggressive vehicle bumper designs better than the previous version
  - Topping out is not a concern with the current Flex-GTR
- Flex-GTR repeatability was not directly evaluated, but
  - Silverado Flex-GTR tests 1001 and 1002 showed similar numbers at the same impact location, which is promising

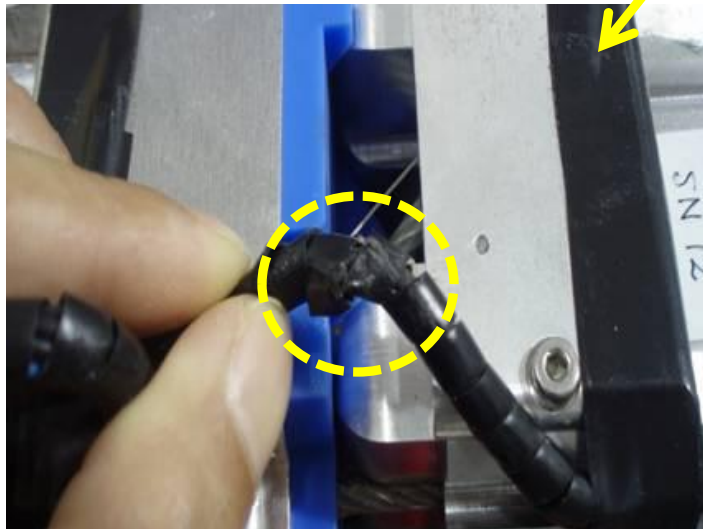
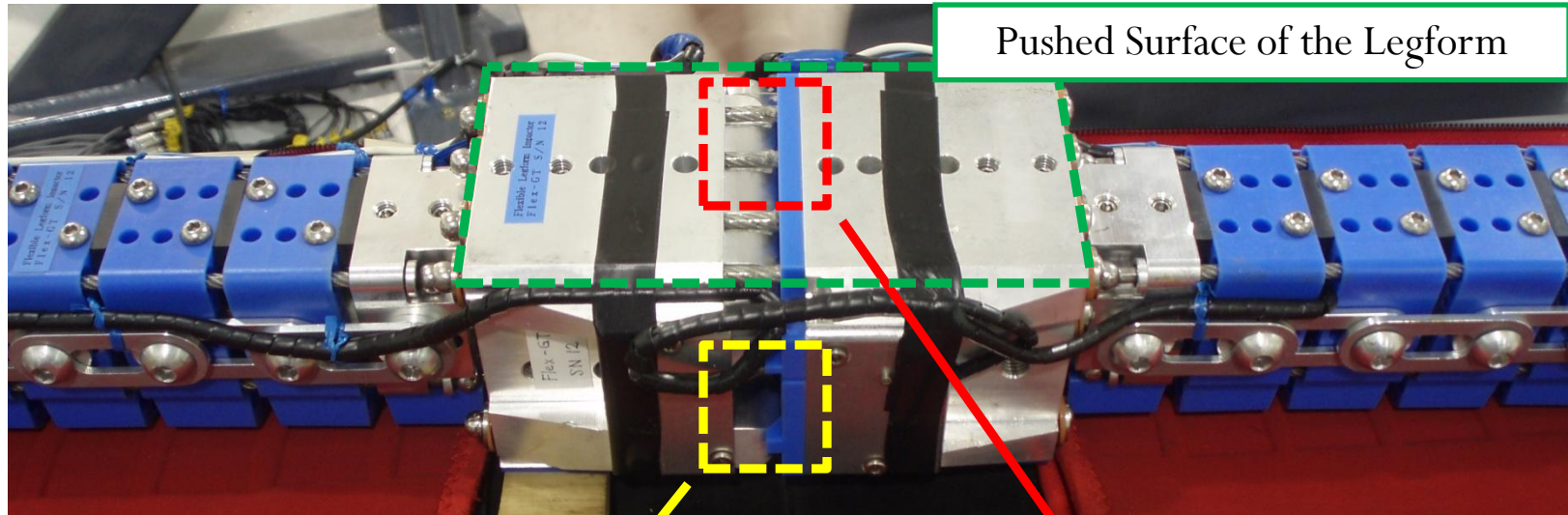
# Flex-GTR Repeatability – Chevy Silverado

Injury Measurement		Injury Reference Value (FlexTEG)	Chevrolet Silverado	
Impact Location			Center	
			GTR (1001)	GTR (1002)
Femur Moment (Nm)	Femur 3 (Upper)	--*	73.67	77.28
	Femur 2 (Middle)		139.48	138.52
	Femur 1 (Lower)		252.05	245.58
Tibia Moment (Nm)	Tibia 1 (Upper)	340 Nm (380 Nm)	332.73	332.61
	Tibia 2 (Mid Upper)		311.07	319.53
	Tibia 3 (Mid Lower)		233.53	237.41
	Tibia 4 (Lower)		110.52	107.91
MCL Elongation (mm)		22 mm	--	22.28
ACL Elongation (mm)		13 mm	8	7.87
PCL Elongation (mm)		13 mm	5.41	5.61
LCL Elongation (mm)		--*	-4.16	-3.76
Tibia Acceleration (g)		--*	-59.21	-59.39
Velocity (m/s)		--*	11.055	11.137

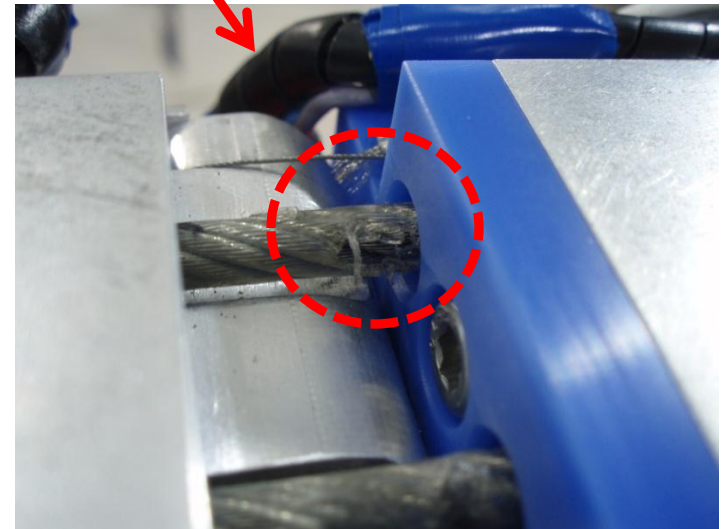
# Summary of Findings

- The Flex-GTR measures lower values than the TRL legform
- The current Flex-GTR seems to be able to distinguish differences in relatively aggressive vehicle bumper designs better than the previous version
  - Topping out is not a concern with the current Flex-GTR
- Flex-GTR repeatability was not directly evaluated, but
  - Silverado Flex-GTR tests 1001 and 1002 showed similar numbers at the same impact location, which is promising
- The Flex-GTR was observed to be durable
  - Survived US vehicles
  - A majority of the issues that were observed were minor and repairable

# Observations and Durability Assessment (Flex-GT)

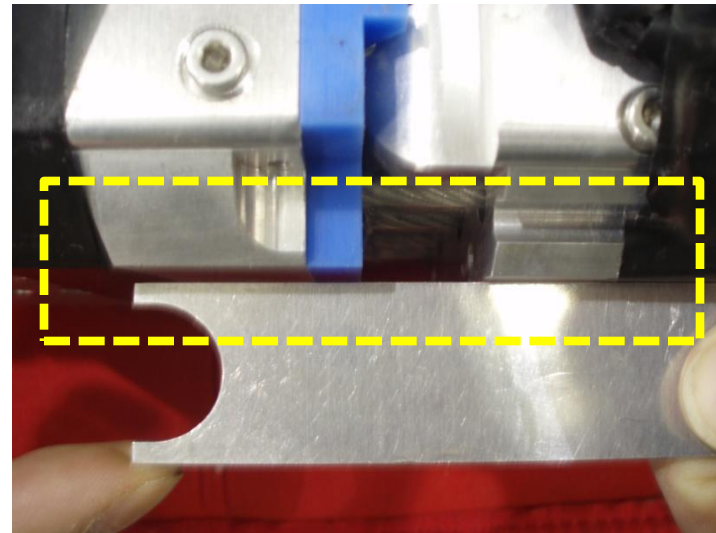
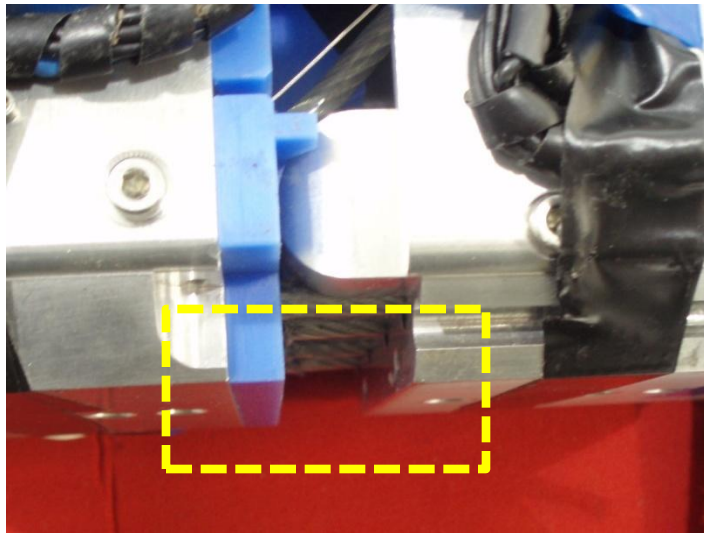
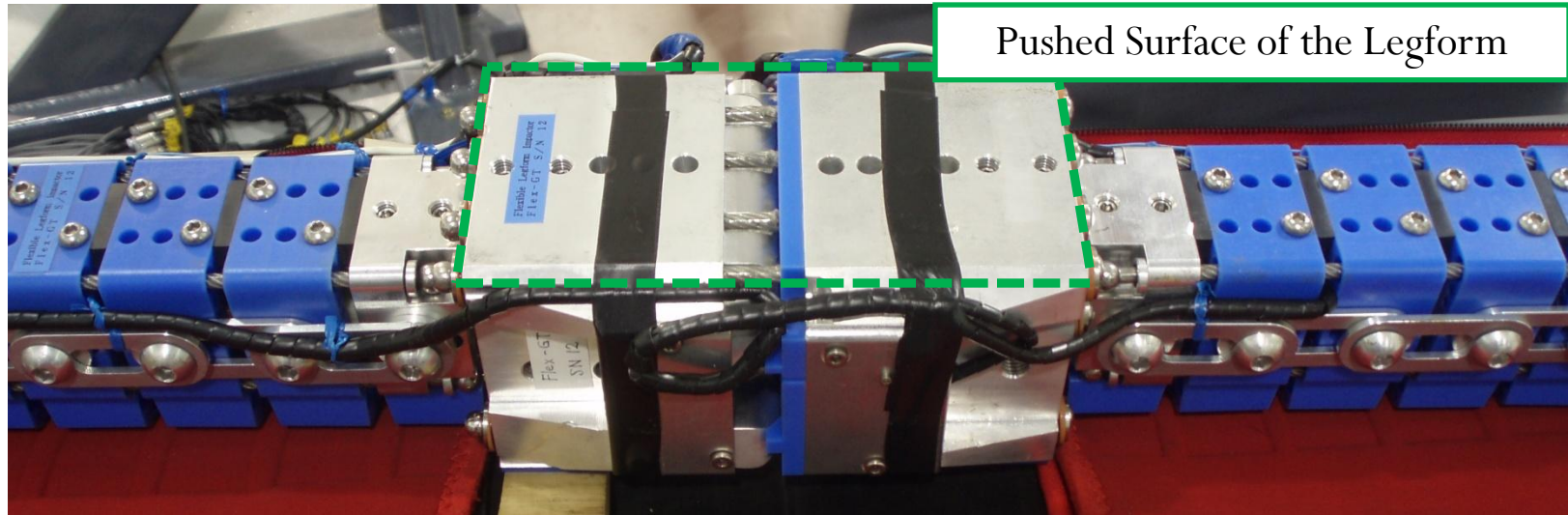


Pinching of wires between blue tab and metal knee condyle



Wear and tear of plastic sheath around knee tension cables

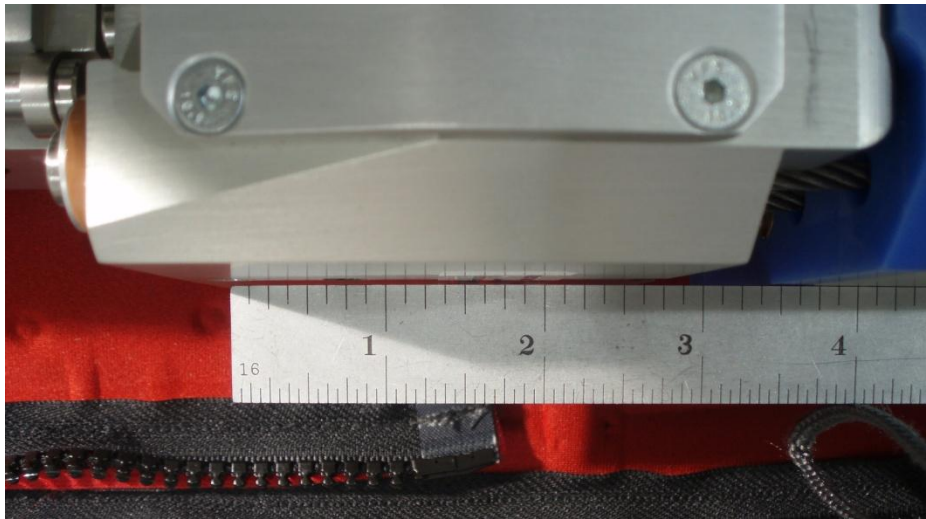
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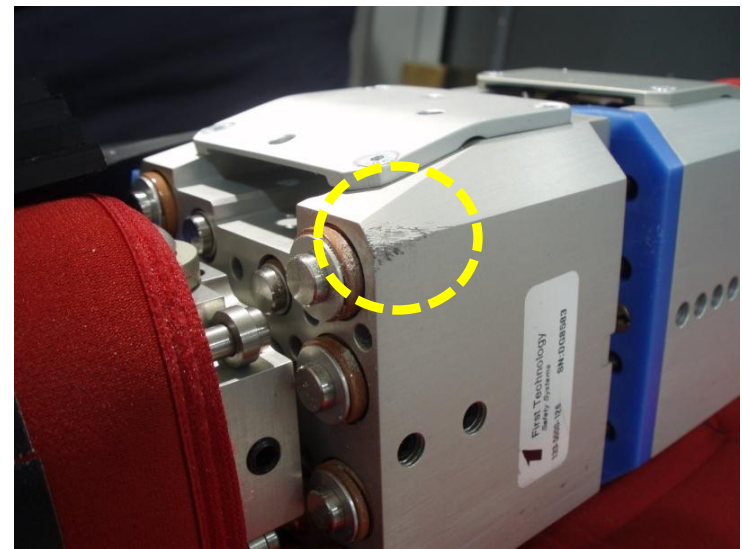
Tibia and Femur knee blocks are rotated/not flush with each other



# Observations and Durability Assessment (Flex-GTR)



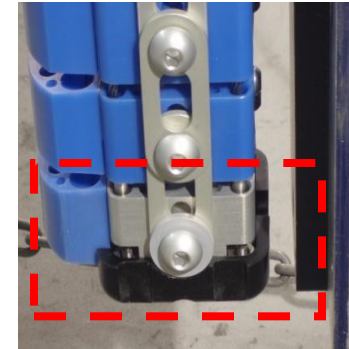
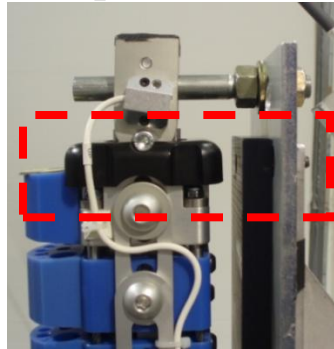
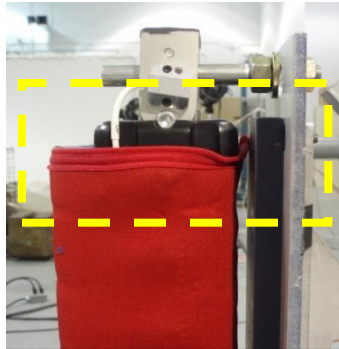
Misalignment of the knee after Passat and Miata impacts



Tear in the neoprene skin and scratches on the femur knee block

# Issues with Flex-GTR

- Needed to modify the legform in order for its flight to be within GTR tolerances for forward pitch (specific to the VRTC launch system)
  - Removed black protective end caps



- Konosu-san (JARI) informed us that they cut out notches at the top and bottom of the launch plate to accommodate for the end caps
- Femur strain gauge #2 (middle gauge)
  - Broken gauge/wire
  - Still being investigated

# Summary of Findings

- Durability:
  - The Flex-GTR seems to be able to distinguish differences in relatively aggressive vehicle bumper designs better than the previous version
  - Flex-GTR repeatability was not directly evaluated, but
    - Silverado Flex-GTR tests 1001 and 1002 showed similar numbers at the same impact location, which is promising
  - The Flex-GTR was observed to be durable
    - Survived US vehicles
    - A majority of the issues that were observed were minor and repairable

# Summary of Findings

- Injury criteria:
  - The Flex-GTR measures lower values than the TRL legform
  - Injury results were not consistent with previous testing:
    - Previous study has shown that it's rare to injure the ACL or PCL without injuring MCL. However, in the VW and Honda Civic tests, we observed ACL elongation that exceeded the injury criteria before the MCL exceeding injury criterion.
  - The findings raise concerns on whether the Flex GTR is properly modeling the impact or that the injury criteria are appropriate

# Conclusion

- Flex-GTR legform is found to be durable
- Additional research and testing needed to address the injury criteria concerns
- Currently, more world fleet data is needed
- Different evaluation criteria may result in different counter-measures (design and cost benefit)

Thank you