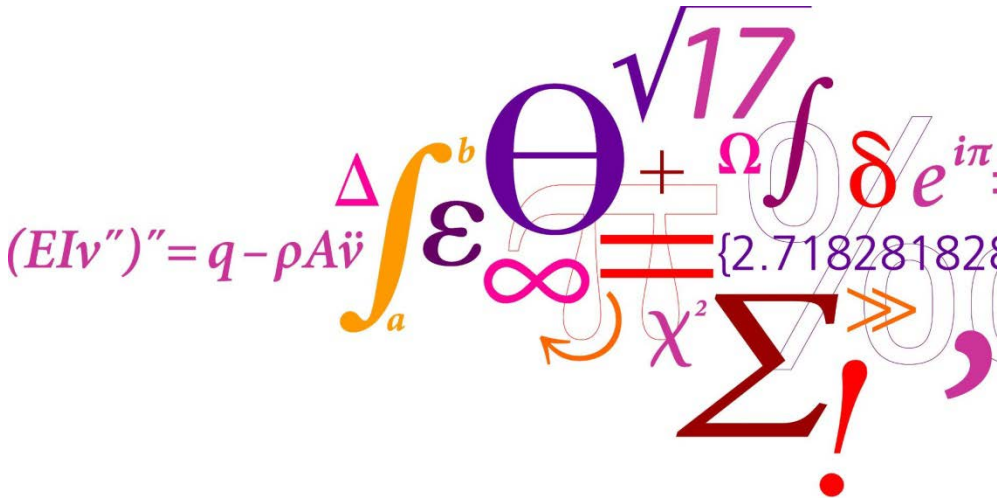
Robust Design:
Reducing Variation and its Impact

Design → Production → Measurement → Reliability

Thomas J. Howard

Head of Robust Design Group



DTU Mechanical Engineering
Department of Mechanical Engineering

Exemplifying Robust Design

Functional Performance: Chair must not rock more than 2 mm

Design Parameters:

1. Length of legs
2. Angle of legs
3. Flatness of seat
4. Flatness of ground
5. …

Design Parameters:

?

Functional Variance $\propto$ Parameter Variance **x** Design Sensitivity

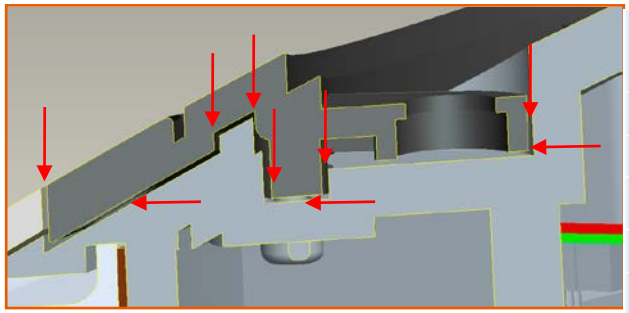
Six Theta®

Robust Design

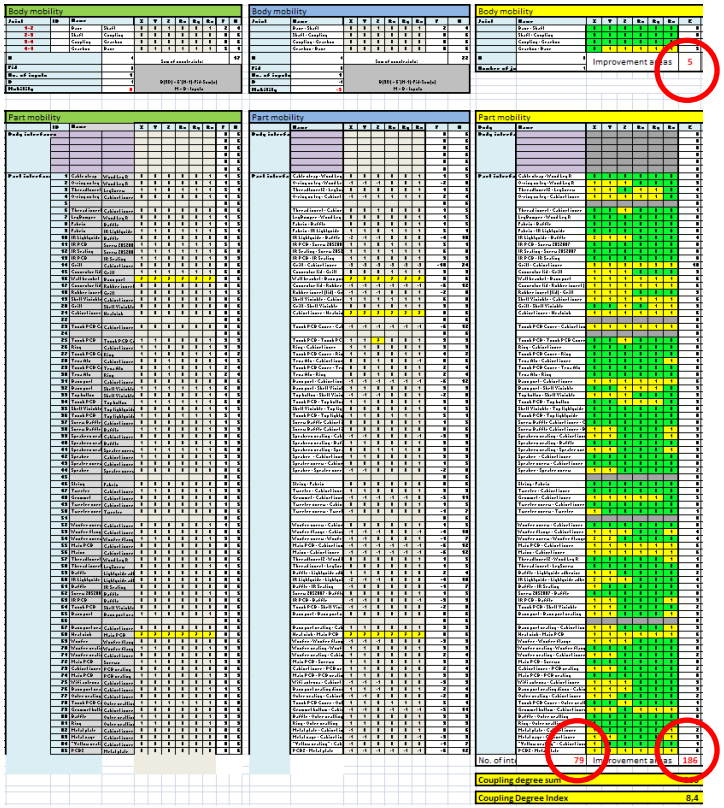
Six Theta® Robust Design: Design Clarity

Parts have intended constraining surfaces, but too many potential and unnecessary constraining surfaces lead to a lack of predictability in terms of how the part will actually function.

The intended and actual number of constraining surfaces can be visualised in a cockpit, thereby providing an overview of the current state of sensitivity in the design.



Intended mobility		
X 0	Y 0	Z 0
Rx 0	Ry 0	Rz 0
Actual Mobility		
X -3	Y -3	Z -3
Rx -3	Ry -3	Rz -3



Impact of ambiguous interfaces:

- Variation in performance
- Unclear tolerance chains
- Unclear load transmission

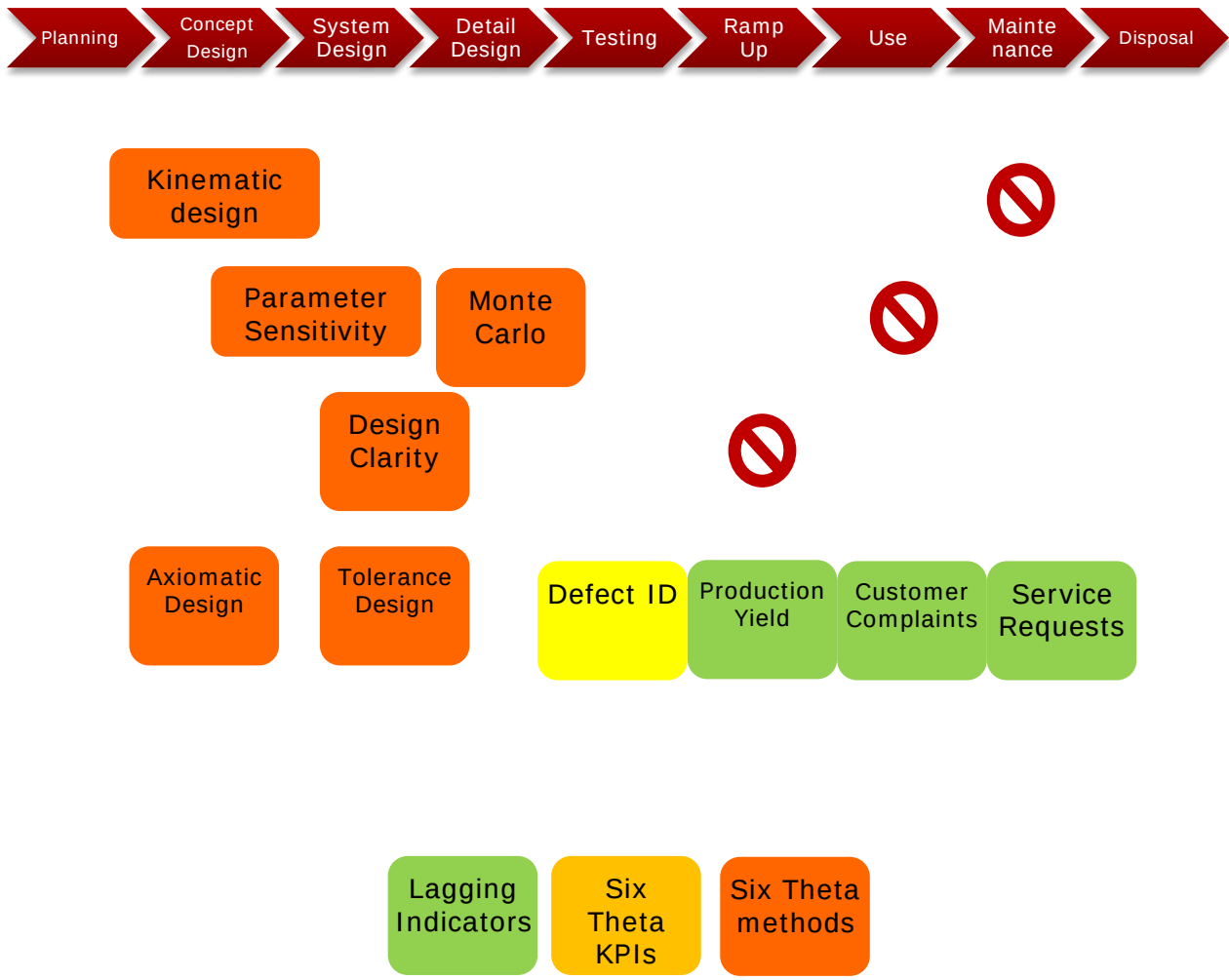
Six Theta® Robust Design Methods

Issues faced

Unpredictable wear and life of turbines, costly and frequent maintenance

Posible quality issues damaging premium brand image, missing launch dates

Long rampup times, delayed launches and low yields due to safety critical product



Six Theta® Robust Design Indicators

Issues faced

Unpredictable wear and life of turbines, costly and frequent maintenance

Posible quality issues damaging premium brand image, missing launch dates

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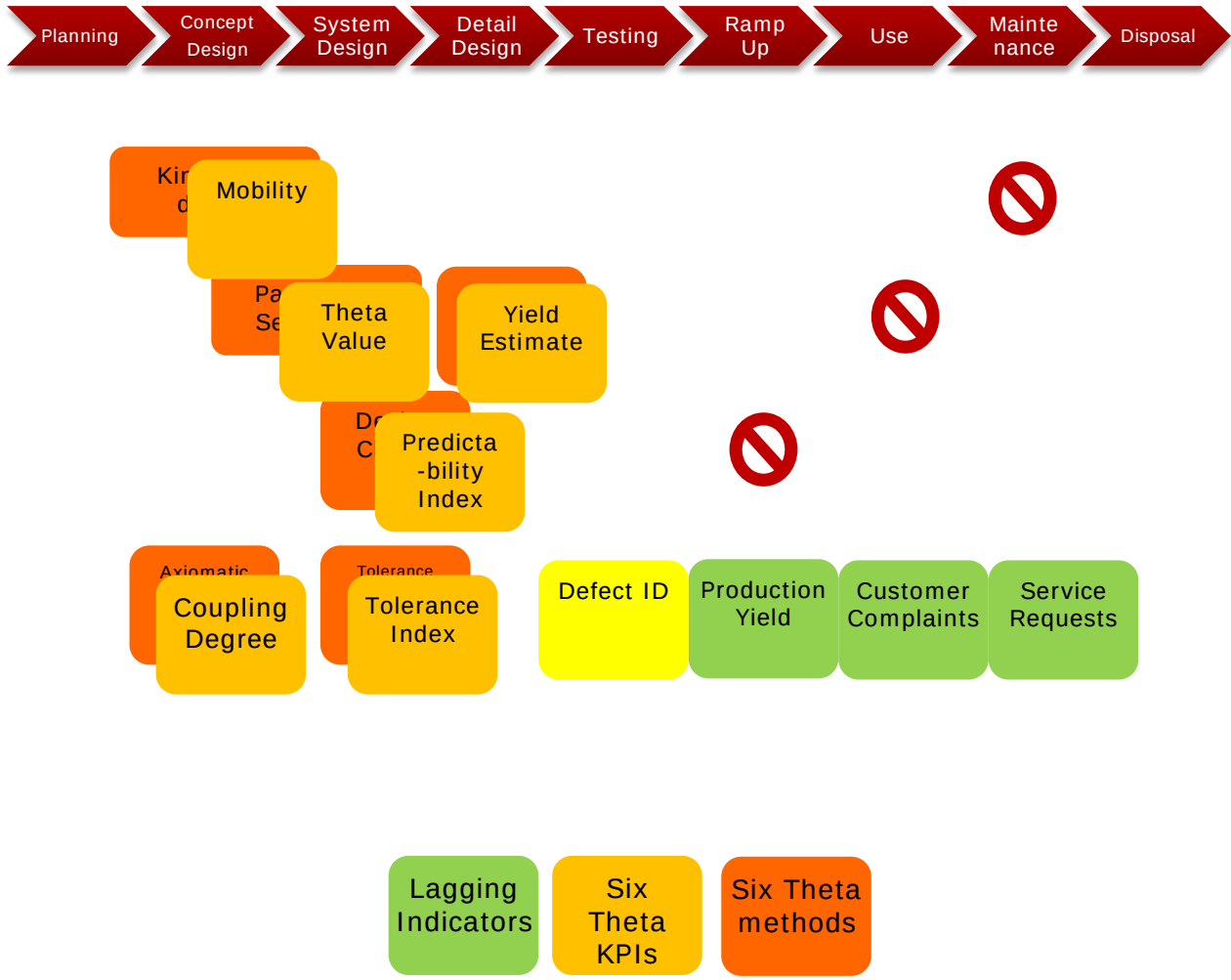


In general Robust Design focusses on the Design phase removing reliability issues before production or measurement. However, some nasties sneak through from time to time, where CT scanning could assist.

GM Ignition Switch Recall

- fine of $35 million
- recall of 2.6 million vehicles
- death of at least 13 people.

GM to Pay Record $35 Million Fine Over Ignition Switch Recalls

TIME

16th May 2014

Alex Rogers @arogDC | May 16, 2014

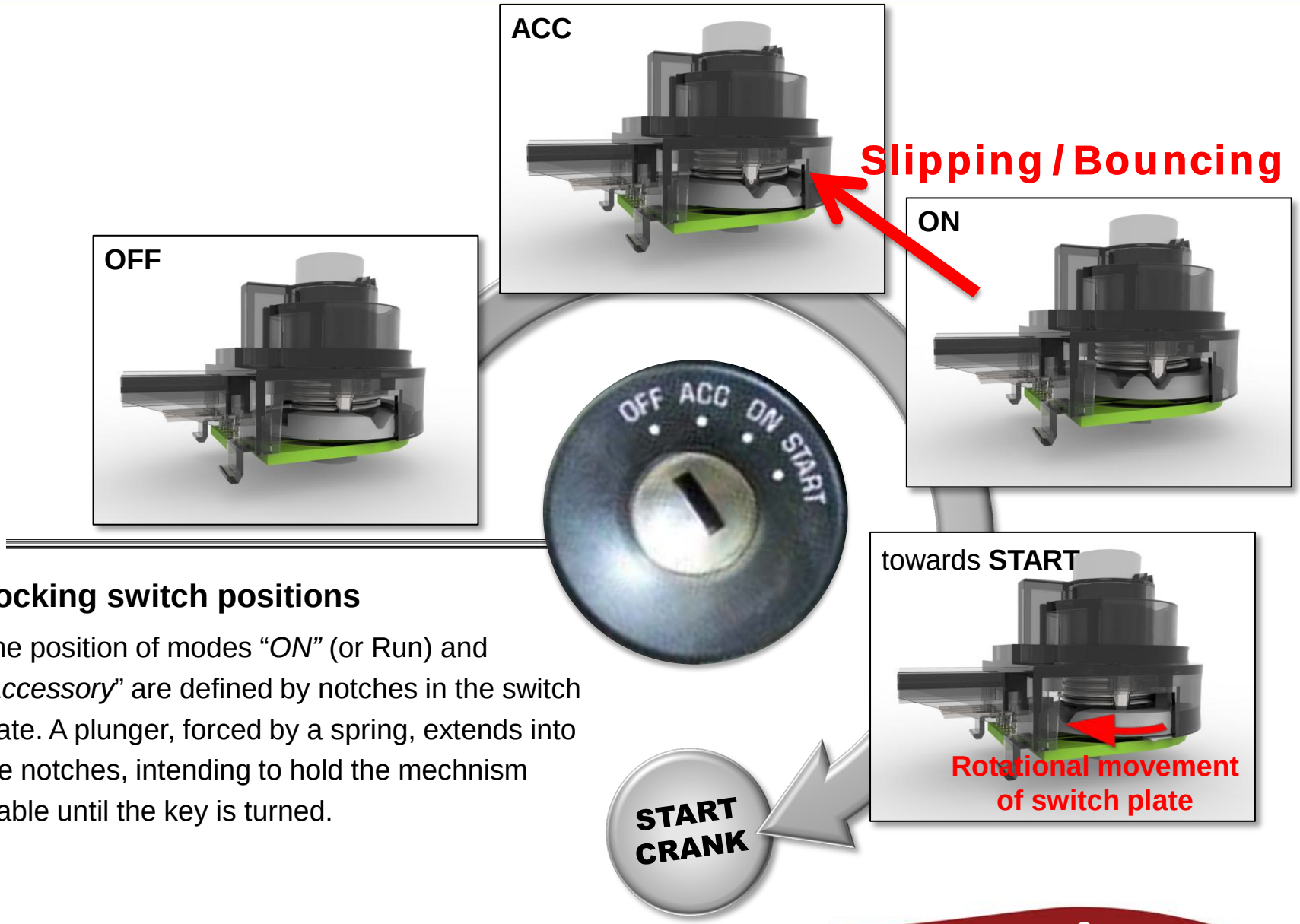
The federal government struck a $35 million settlement with General Motors after the company failed to act for 10 years on an ignition switch defect that led to the death of at least 13 people and recall of approximately 2.6 million vehicles

General Motors will pay $35 million to settle a federal probe into its 10-year delay of recalls related to an ignition switch flaw, the Department of Transportation announced Friday. The switch problem led to the death of at least 13 people and recall of ...ately 2.6 million vehicles.

Gary Pittam performs a recall service on a Chevrolet Cobalt at Al S... Mich., April 17, 2014.

John F. Martin–General Motors/Reuters

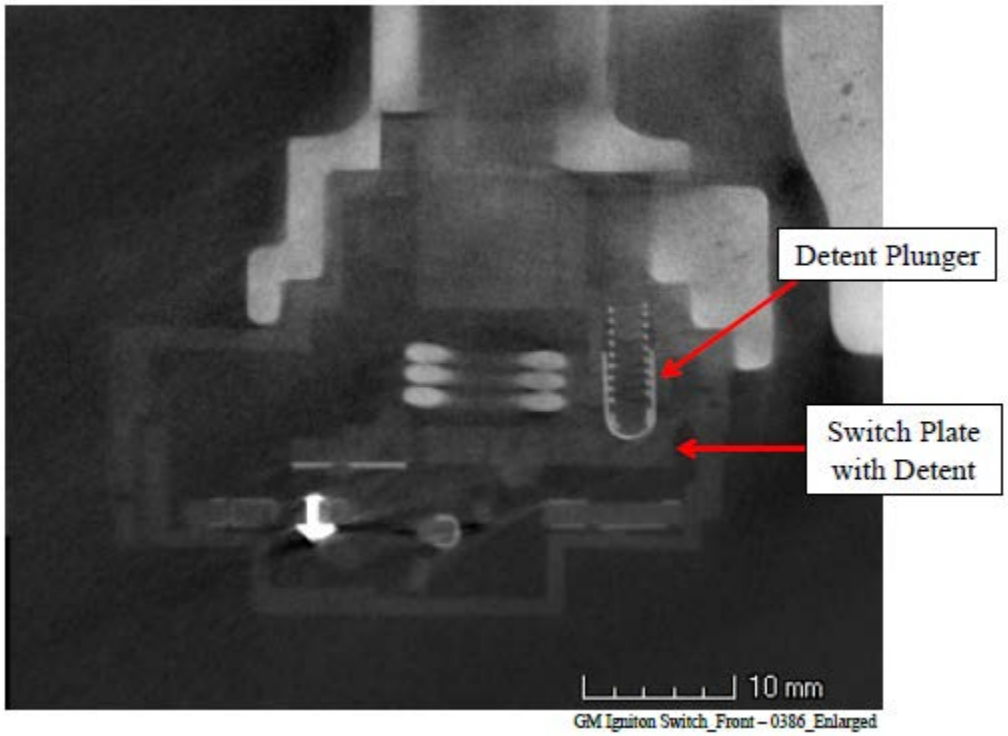
Ignition Swtich Mode of Action



Locking switch positions

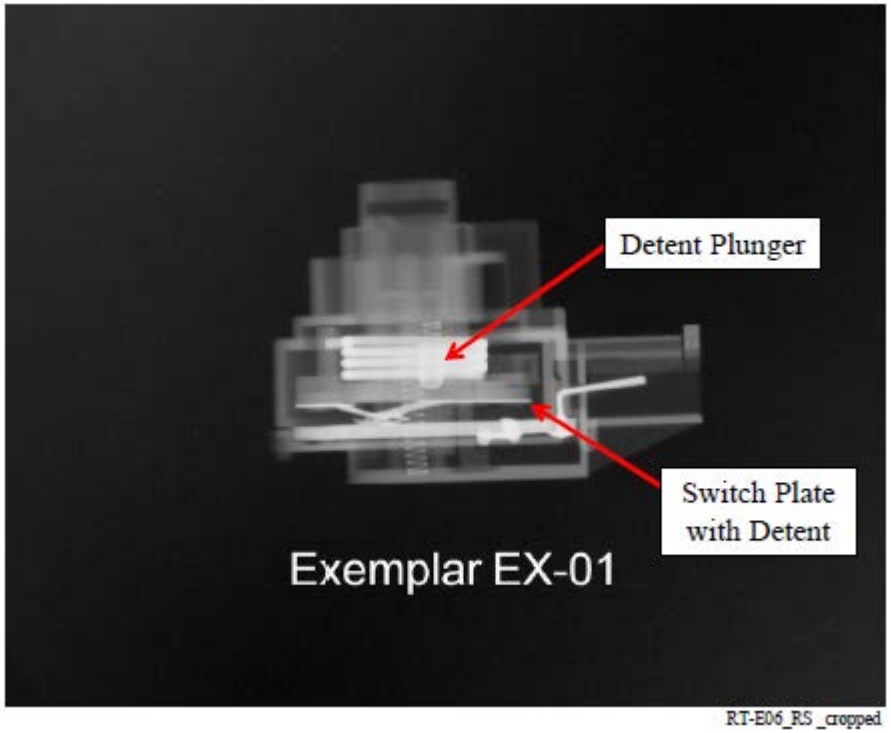
The position of modes "*ON*" (or Run) and "*Accessory*" are defined by notches in the switch plate. A plunger, forced by a spring, extends into the notches, intending to hold the mechnism stable until the key is turned.

McSwain Engineering CT Scans

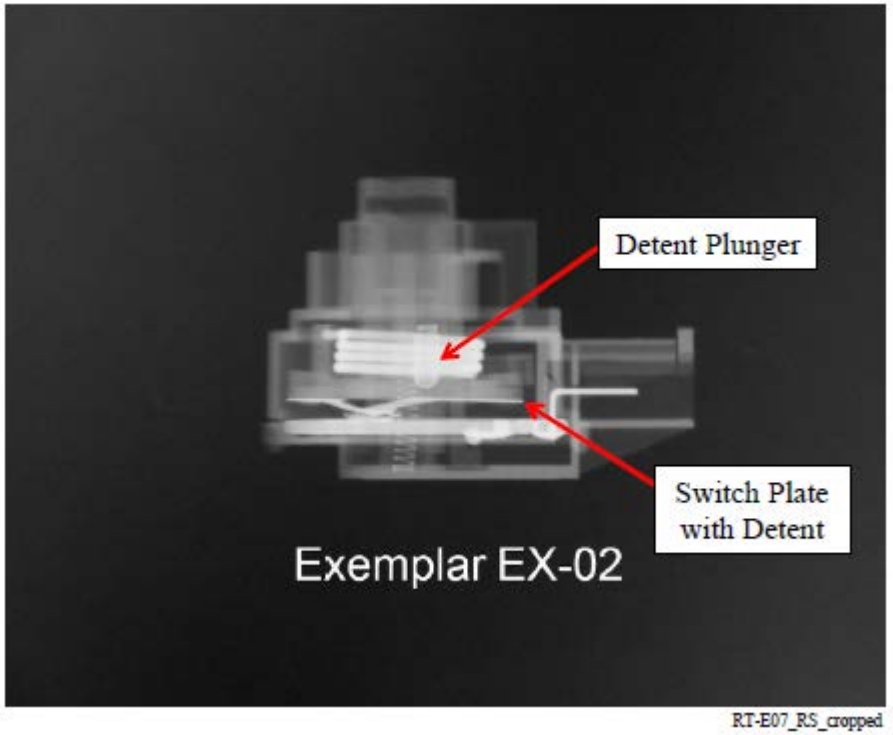


McSwain Engineering CT Scans

Failed Product (2005)



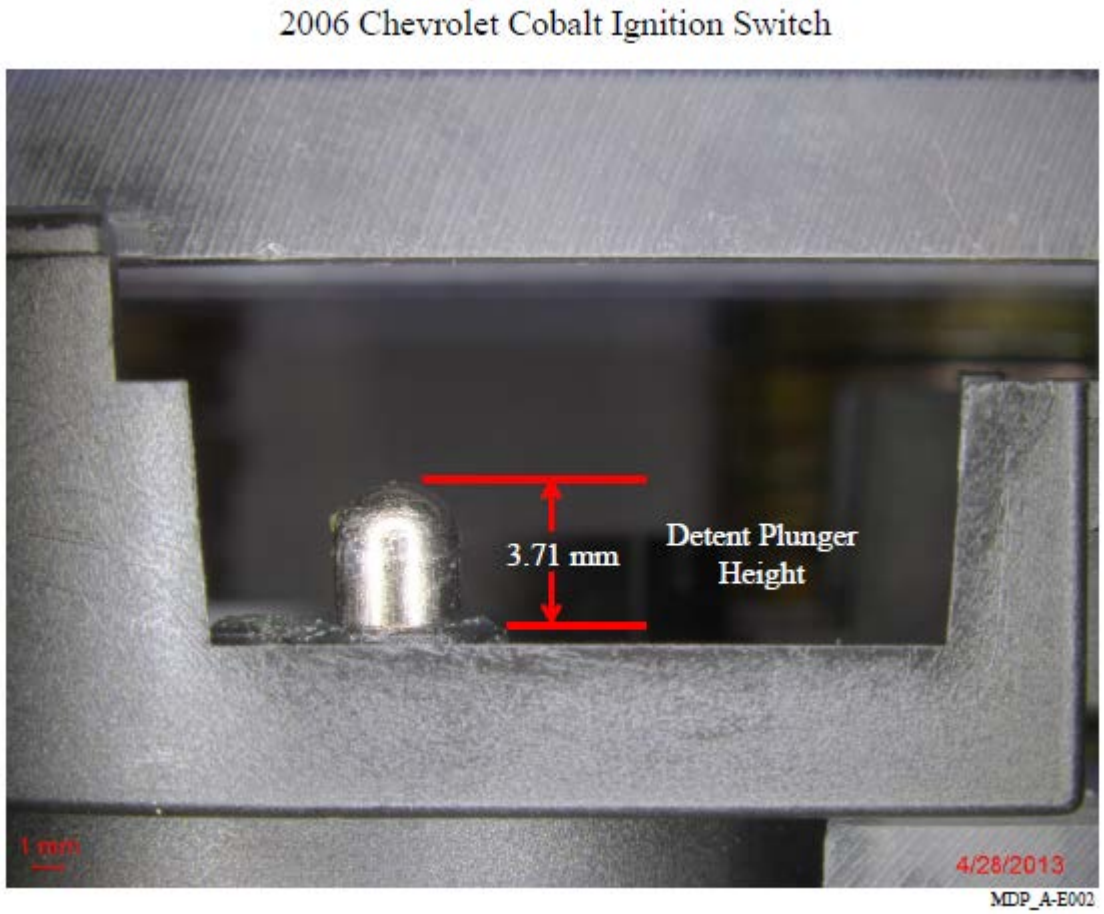
New Version (2008)



2005 – 3.68mm

McSwain Engineering images

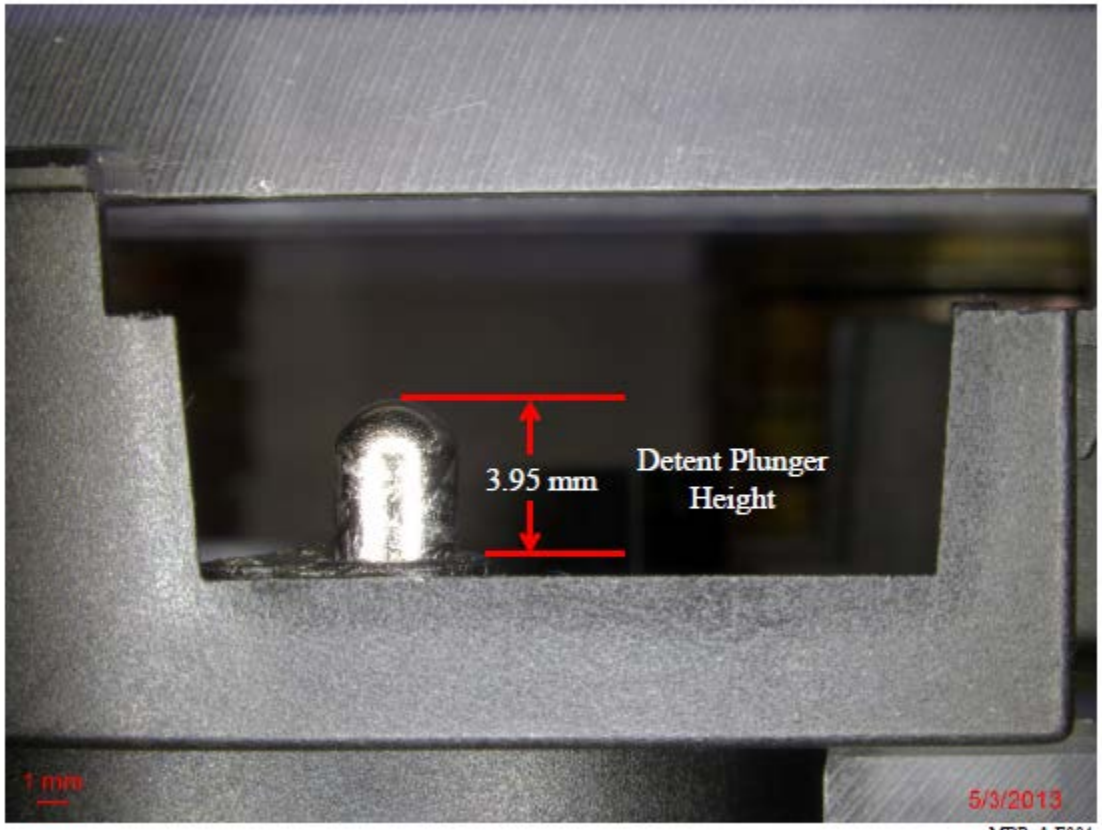
2006 – 3.71mm



McSwain Engineering images

2007 – 3.95mm

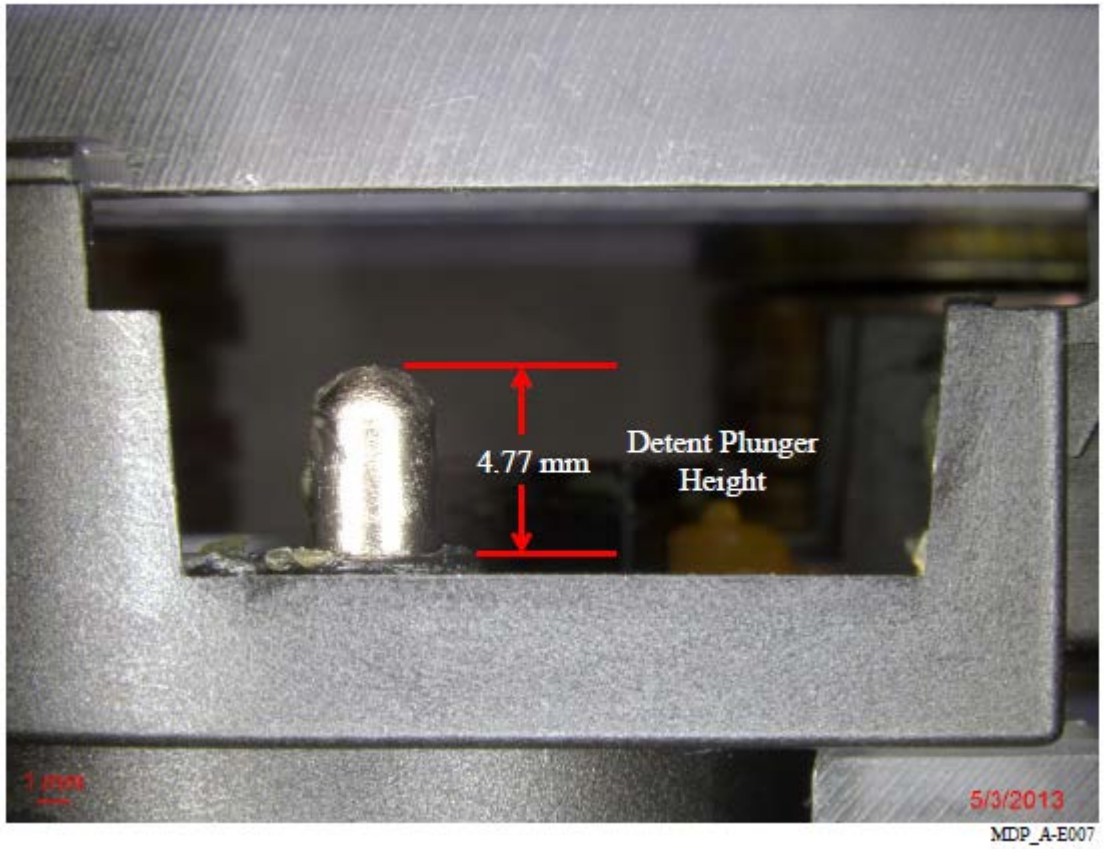
2007 Chevrolet Cobalt Ignition Switch (August 2006 Build Date)



McSwain Engineering images

2007 – 4.77mm

2007 Chevrolet Cobalt Ignition Switch (March 2007 Build Date)



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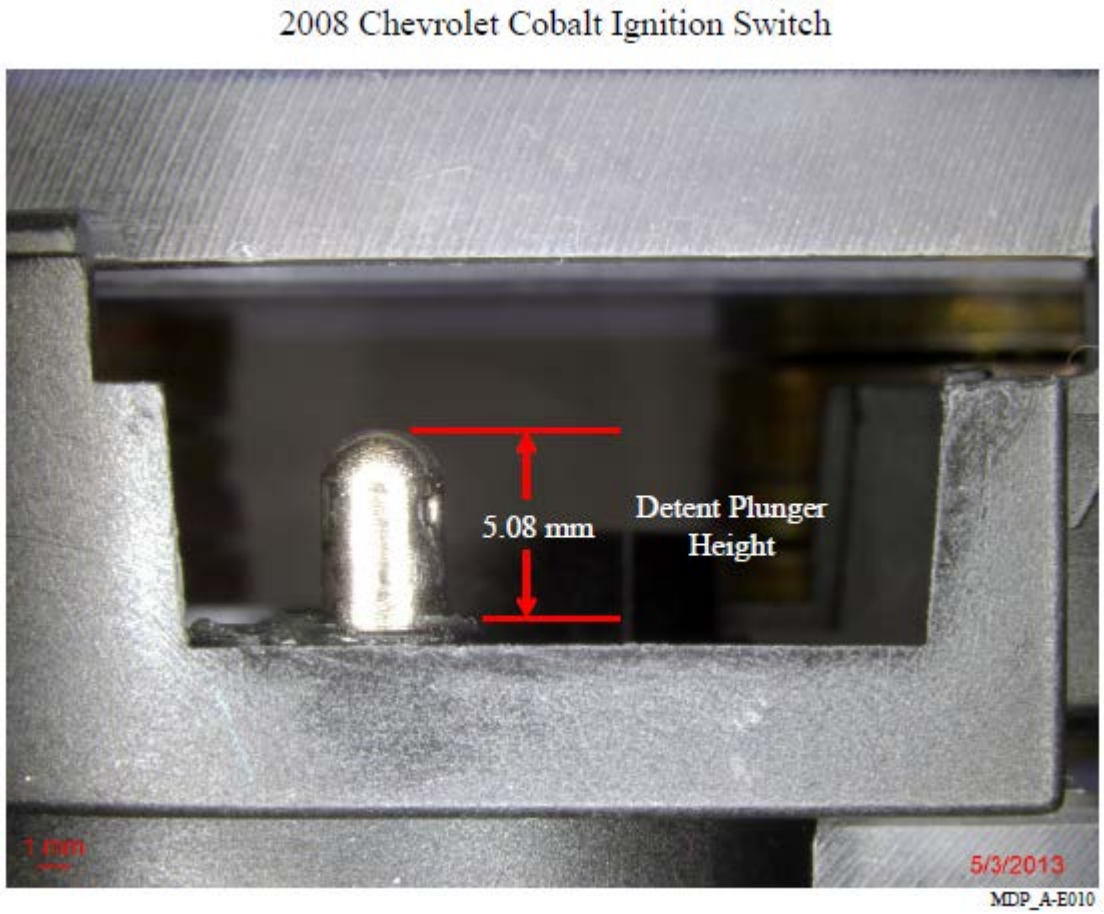
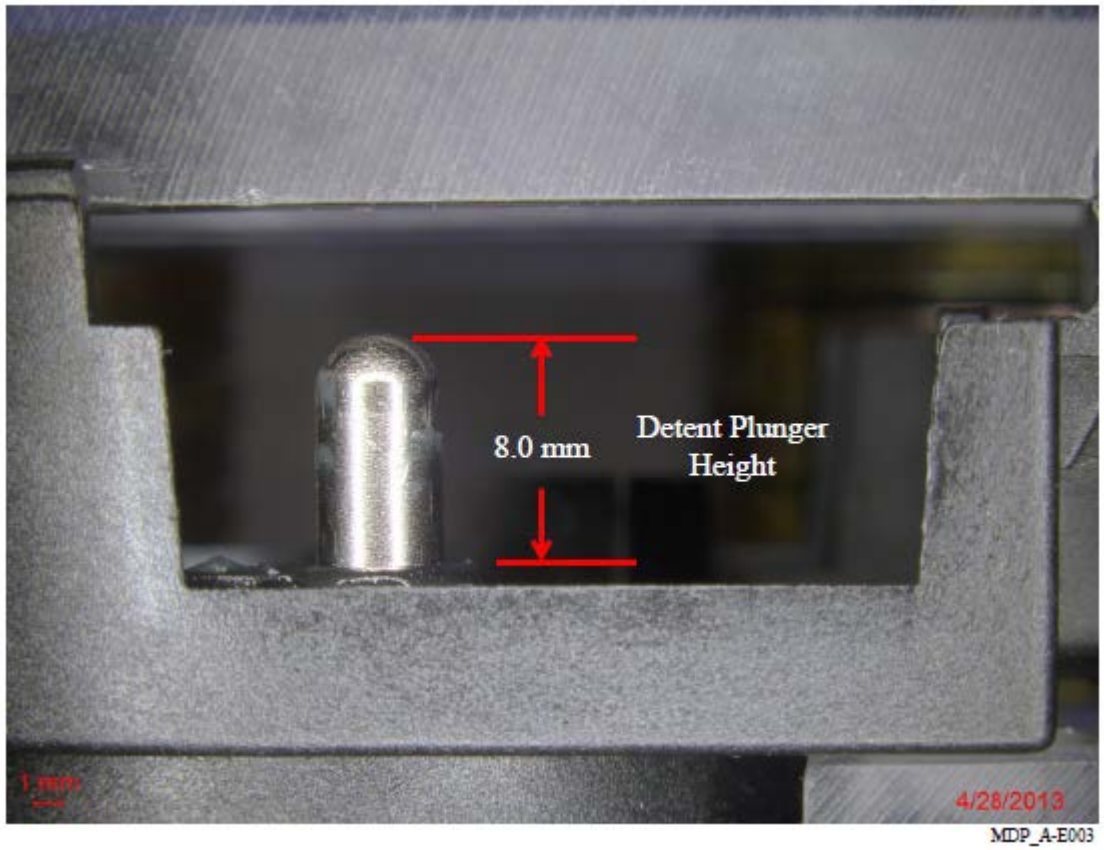
2008 – 5.08mm



McSwain Engineering images

The new chevy – 8.00mm

New Chevrolet Cobalt Ignition Switch Service Replacement Part

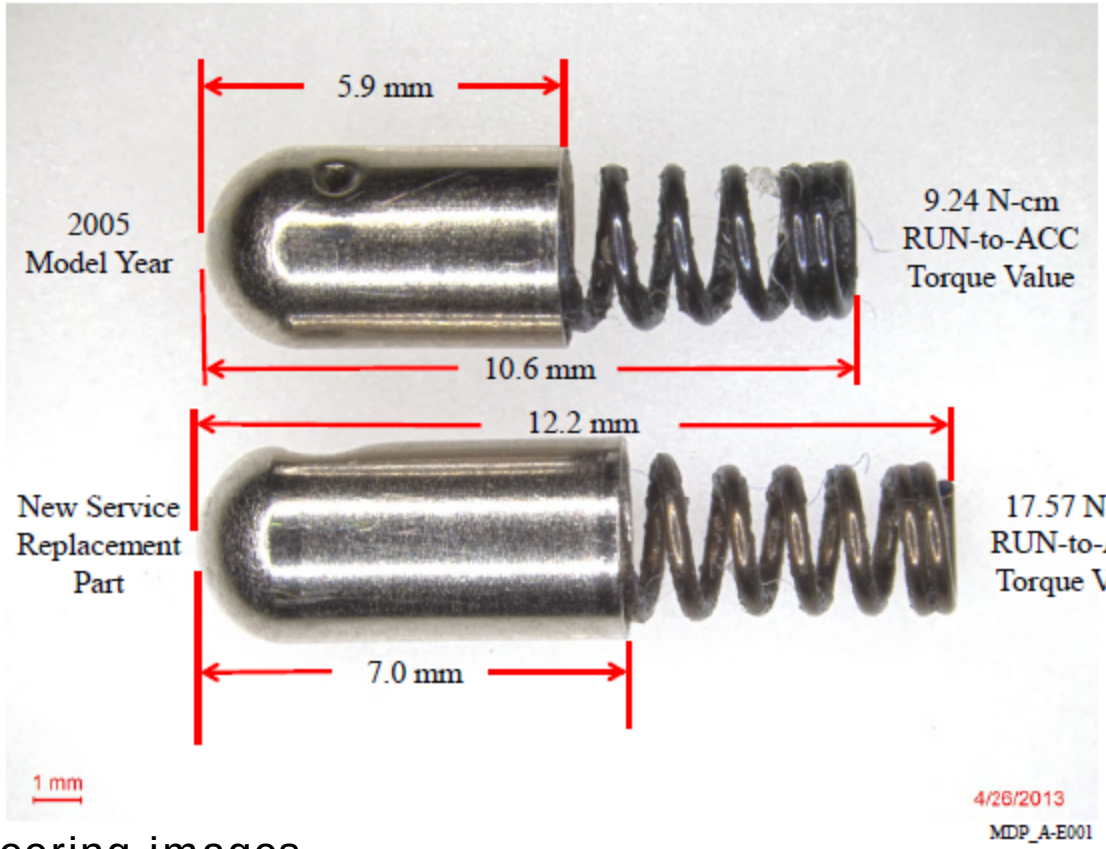


McSwain Engineering images

McSWAIN ENGINEERING, INC.

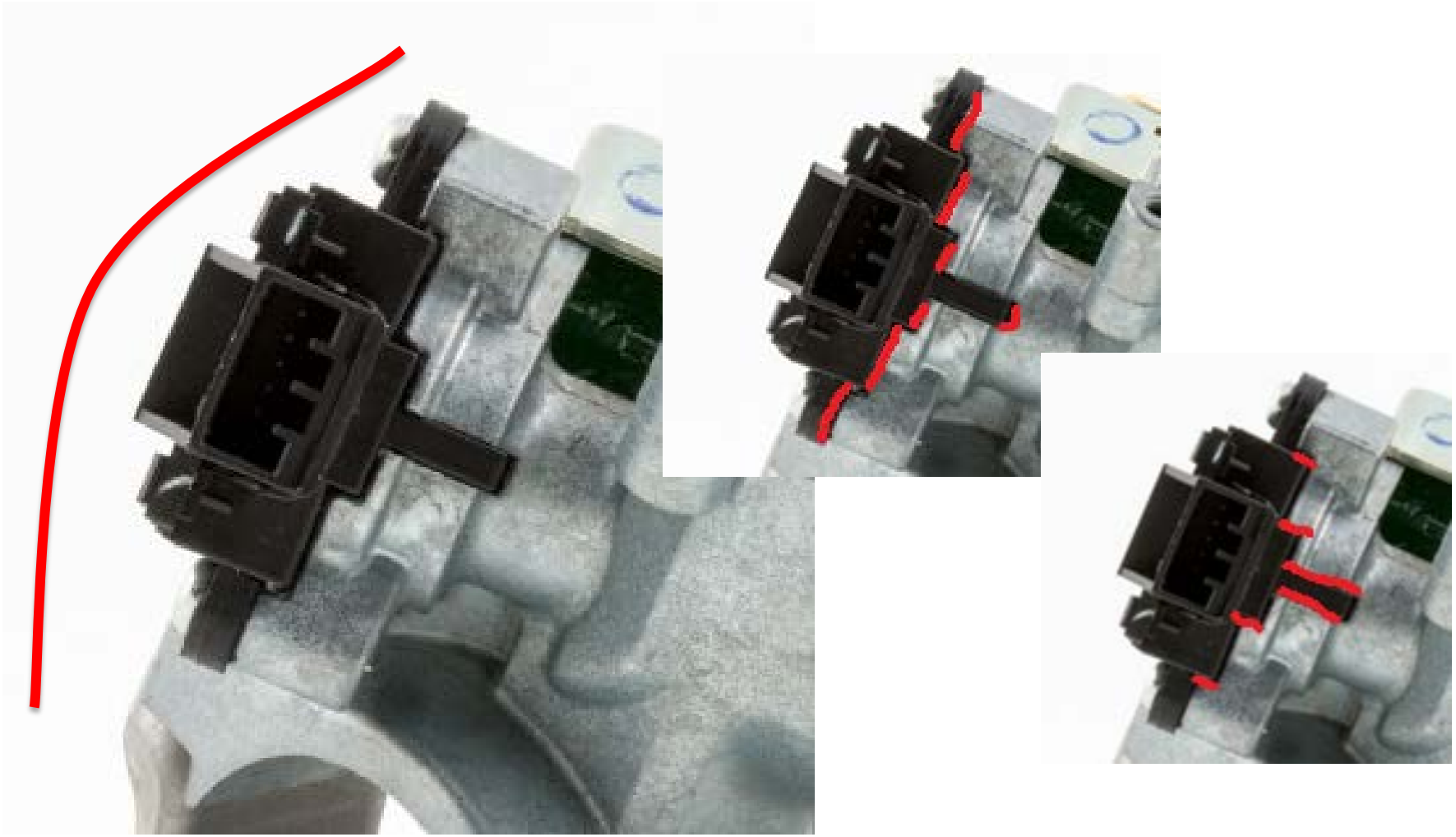
PROJECT:	General Motors Ignition Switch

Exemplar Chevrolet Cobalt Switch Detent Plungers

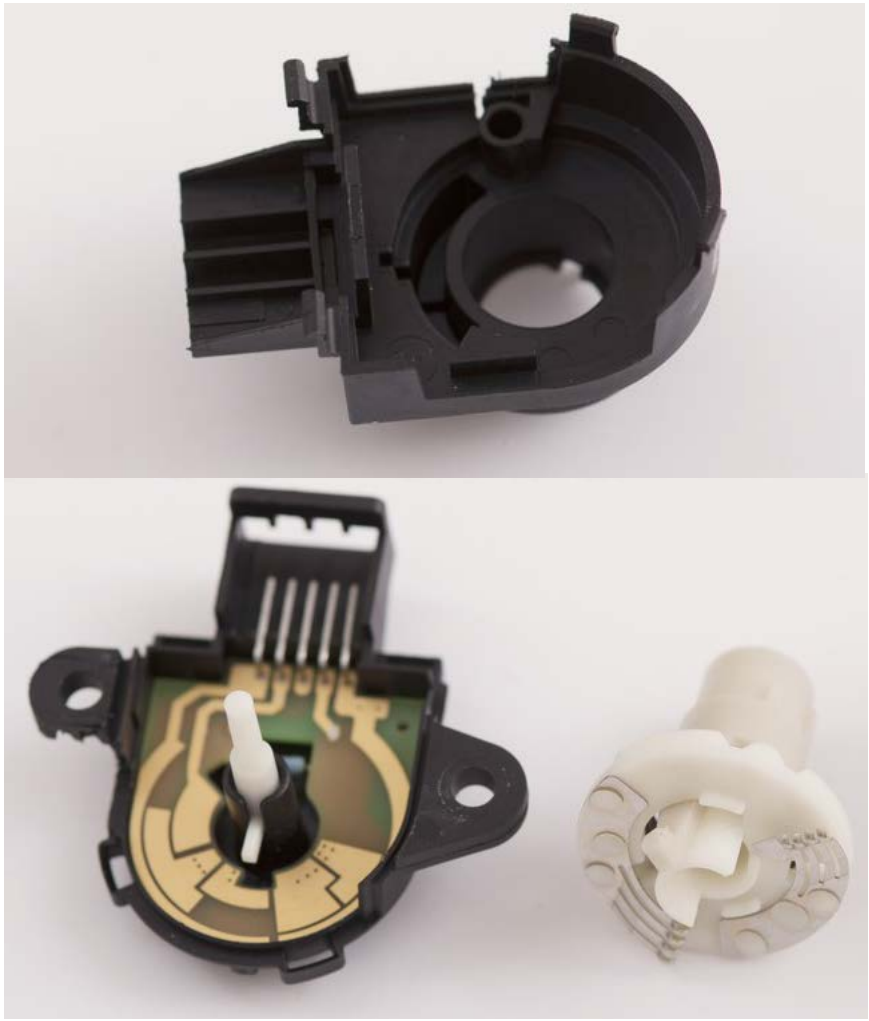


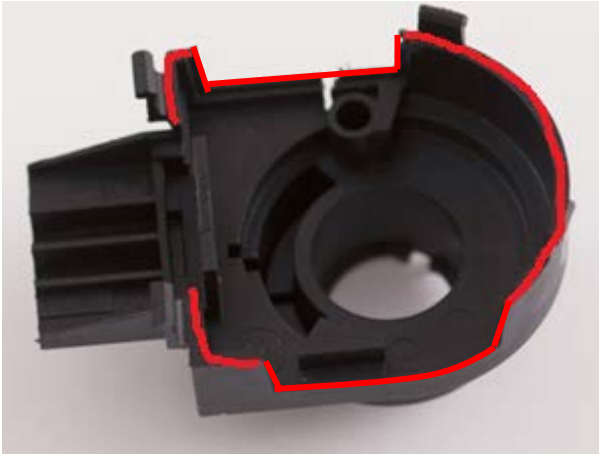
McSwain Engineering images

Minimal constraints theory!!



LONG contact surfaces



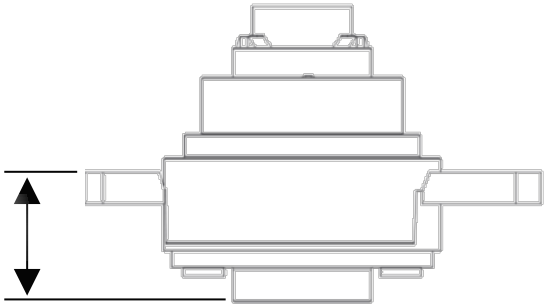


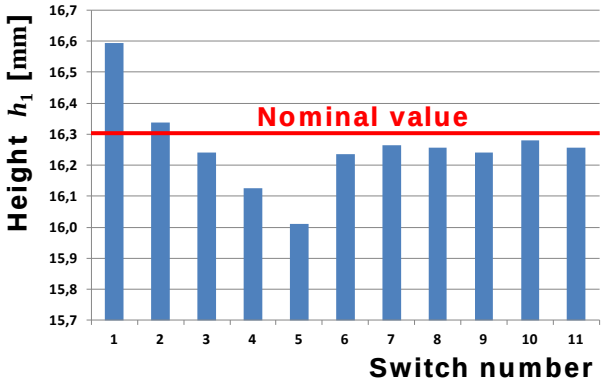
Source: Eifler T., Olesen J.L. and Howard T.J.: Robustness and Reliability of the GM Ignition Switch - A forensic Engineering case. In: Howard T.J. and Eifler T.: Proceedings of the International Symposium on Robust Design - ISoRD14. Copenhagen, Denmark.

Specified nominal values

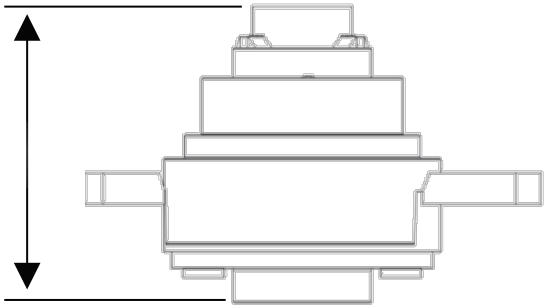
Measured variation of example ignition switches

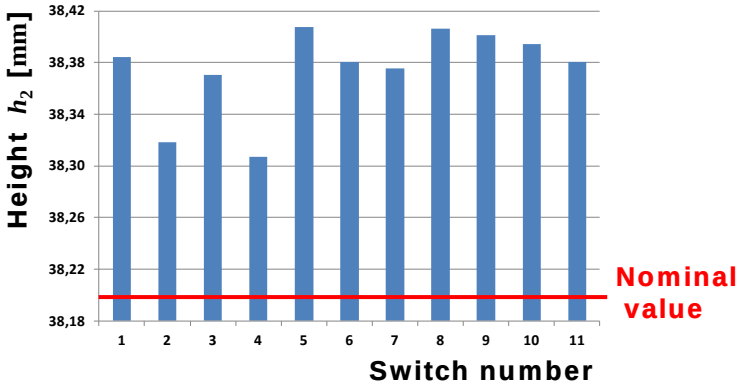
Dimensions of components

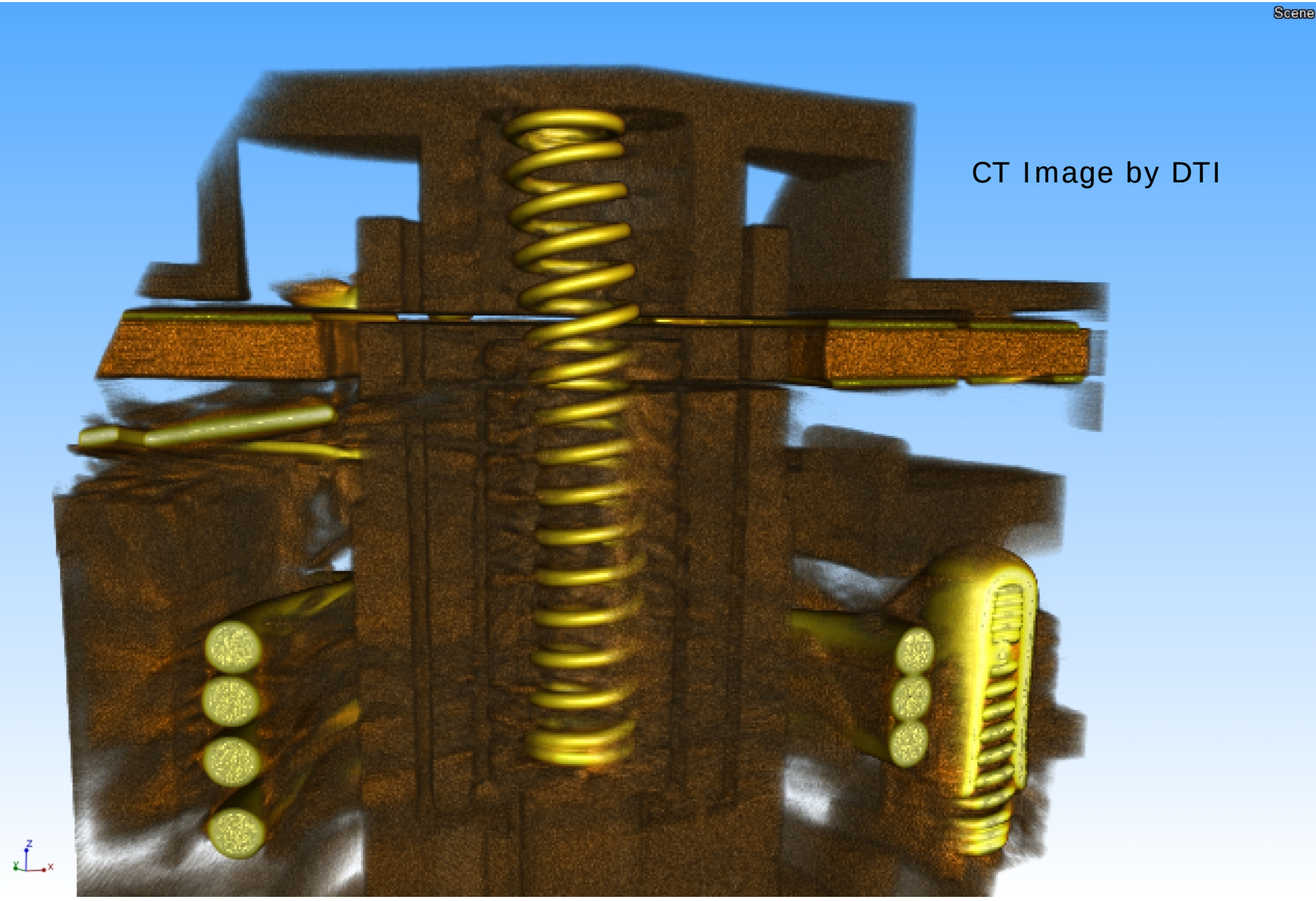


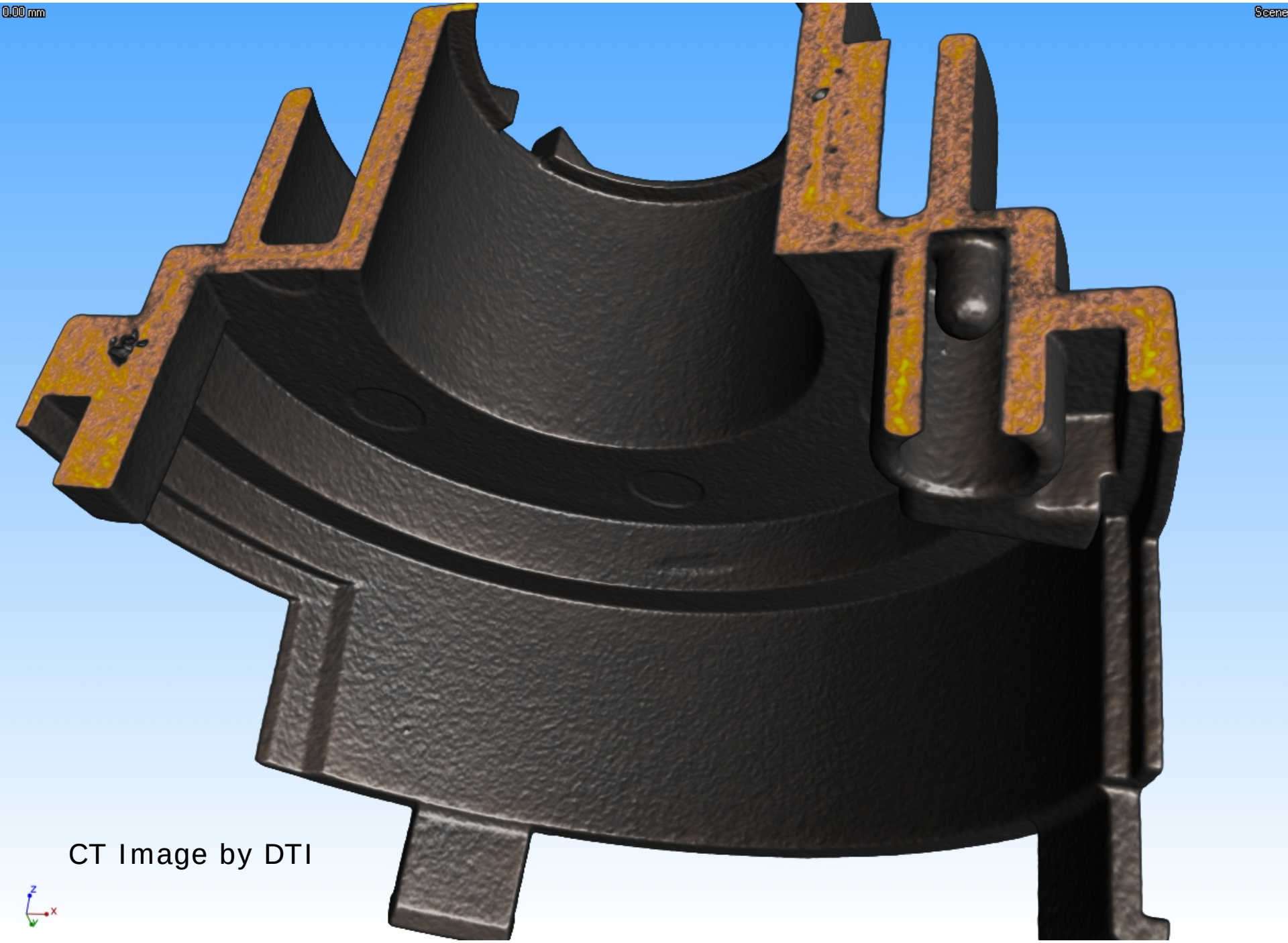


Dimensions of assembled device

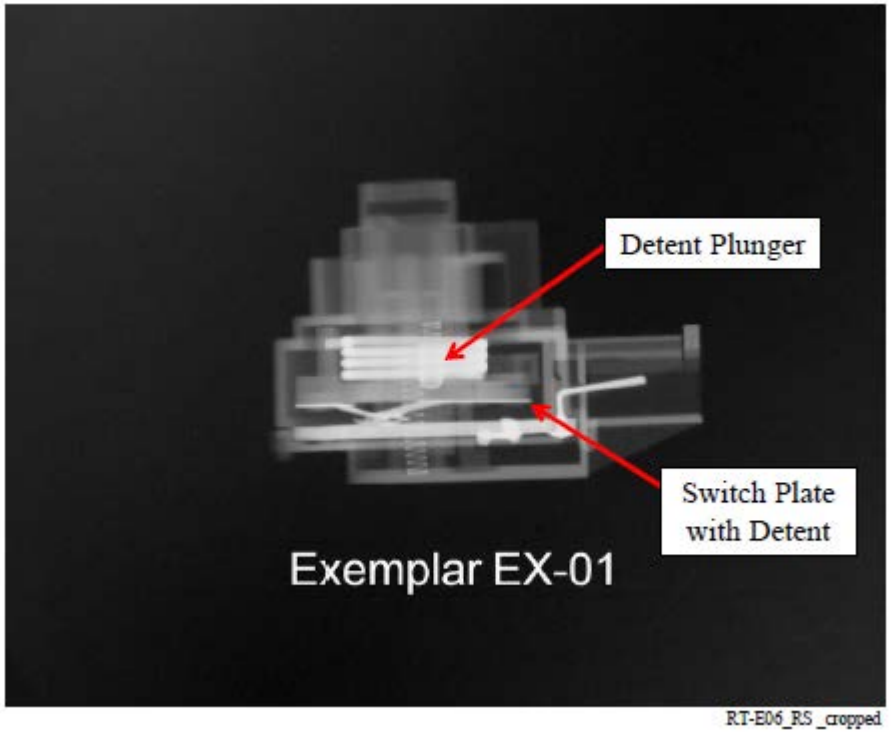


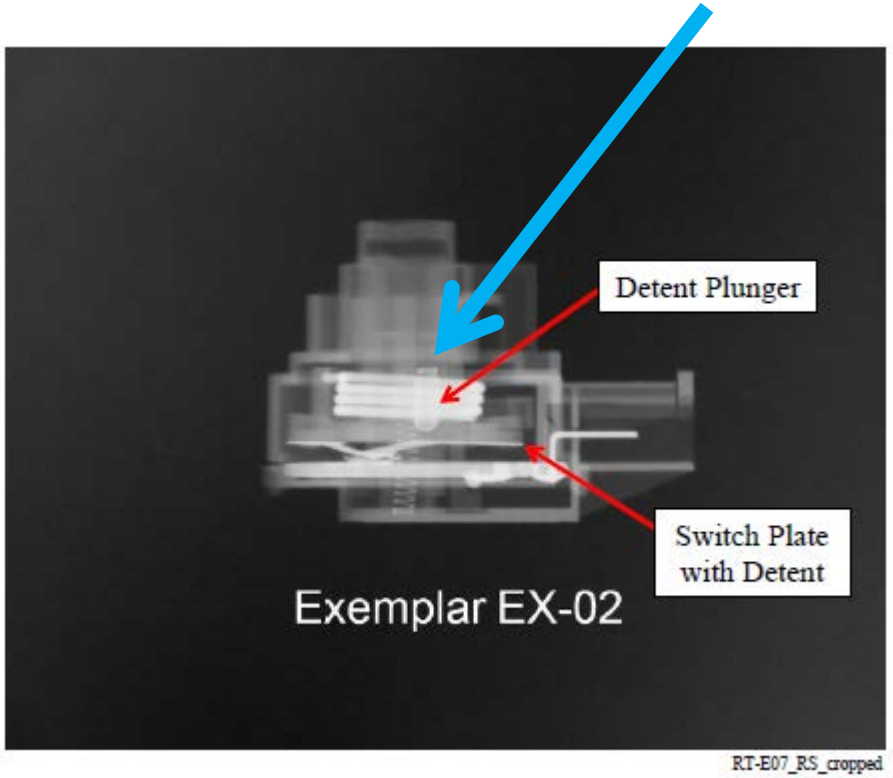



Scene
CT Image by DTI


0.00 mm
Scene
CT Image by DTI

McSwain Engineering CT Scans





McSwain Engineering images

CT Scanning as a great tool for Forensic Engineering to uncover sources of variation…

…when the product is not robust enough!

GMσD

Global Manufacturing Variatiσn Database

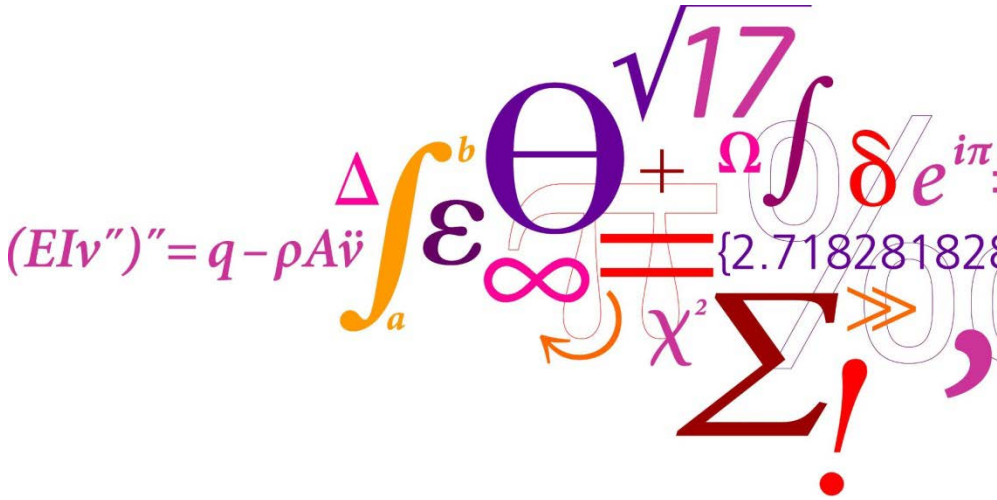
Horizon 2020 application

Factories of the Future (FoF-14-2015)

Topic: Integrated design and management of production machinery and processes

Deadline: Feb 2015

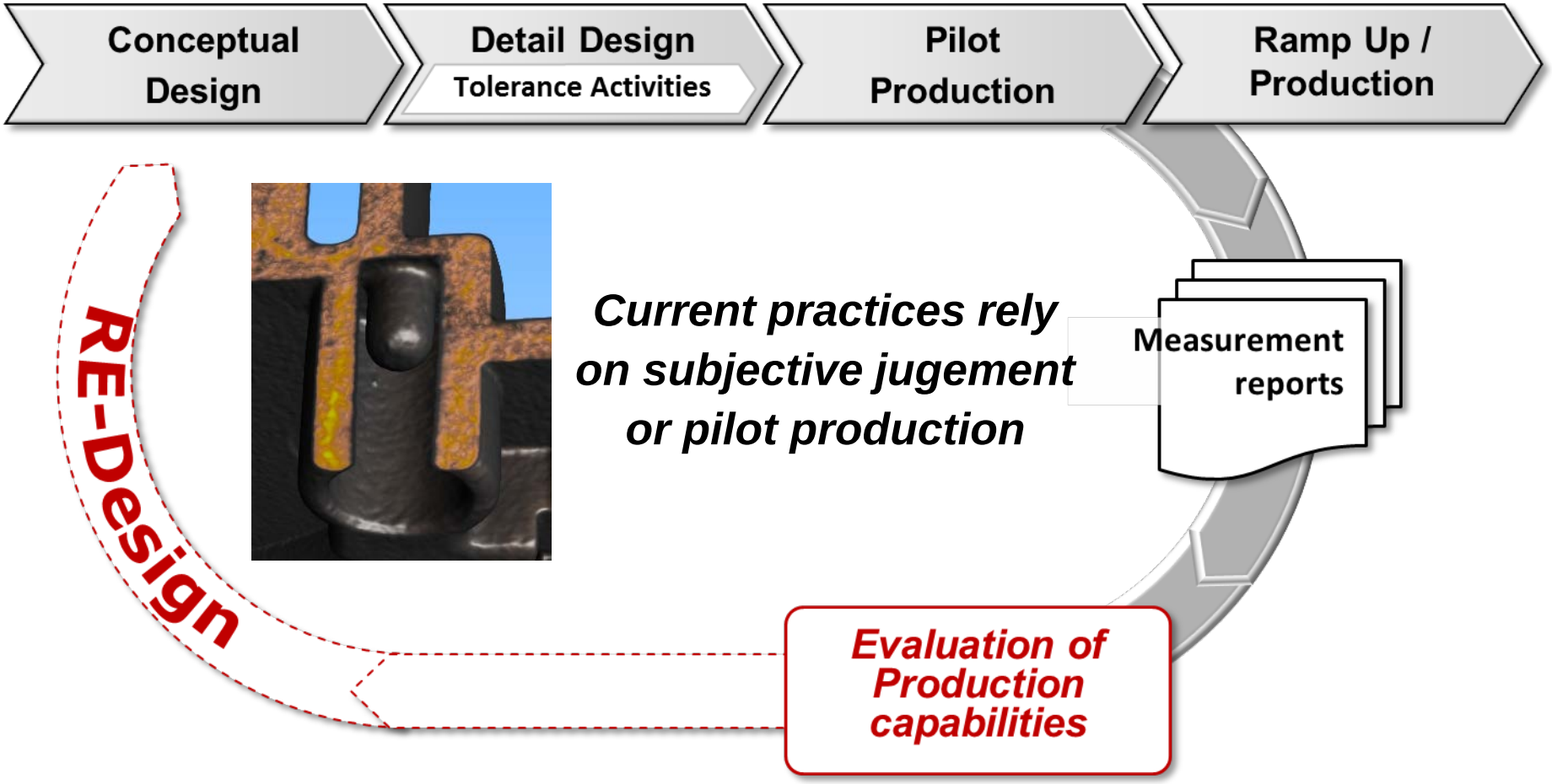
Duration: 4years



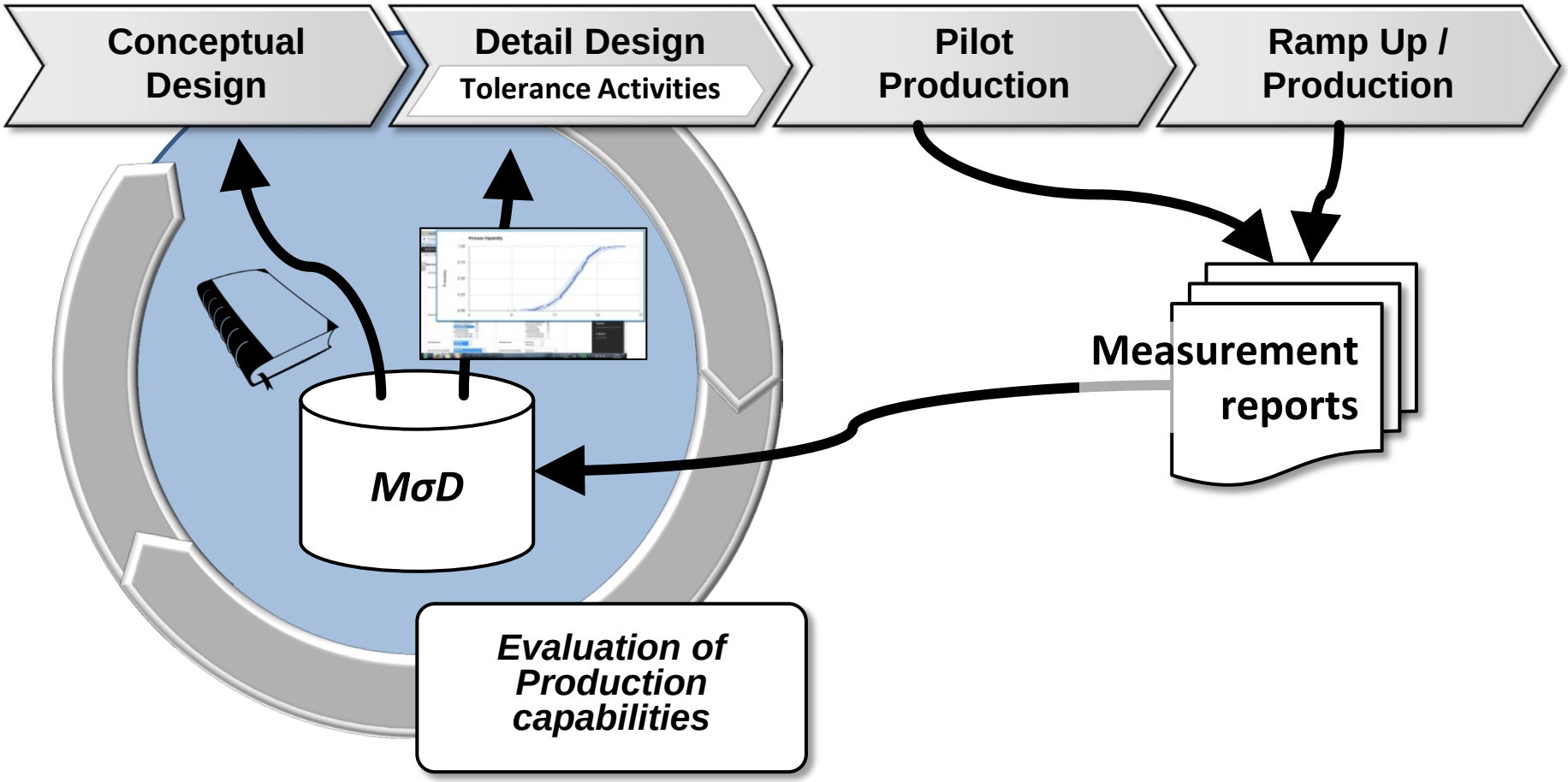
DTU Mechanical Engineering

Department of Mechanical Engineering

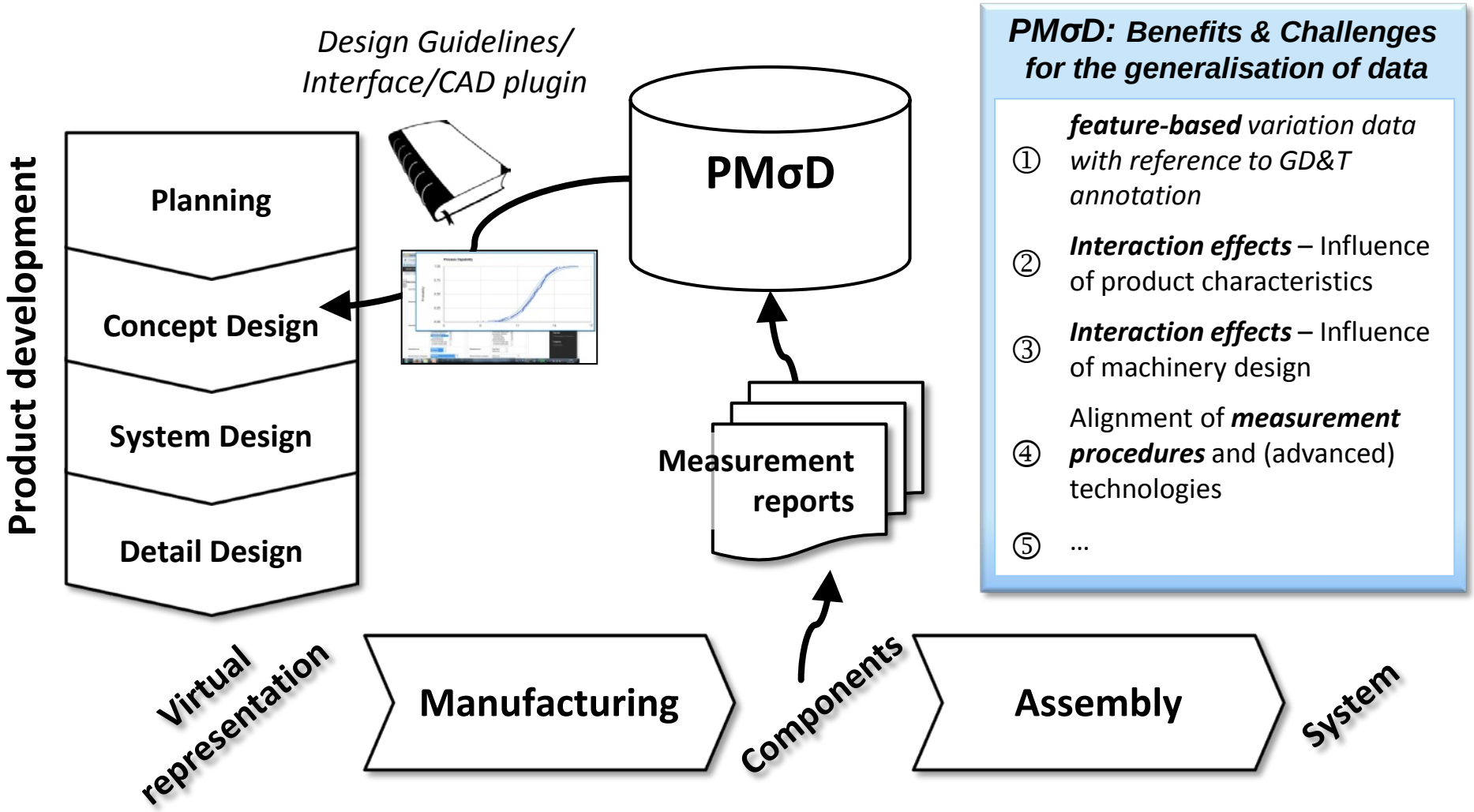
Challenges in Industrial Practice



Aim – Design to Process Capabilities (DtPC)



PMσD Structure
(Local Manufacturing Variation Database)



PMσD: Benefits & Challenges for the generalisation of data

① ***feature-based*** *variation data with reference to GD&T annotation*

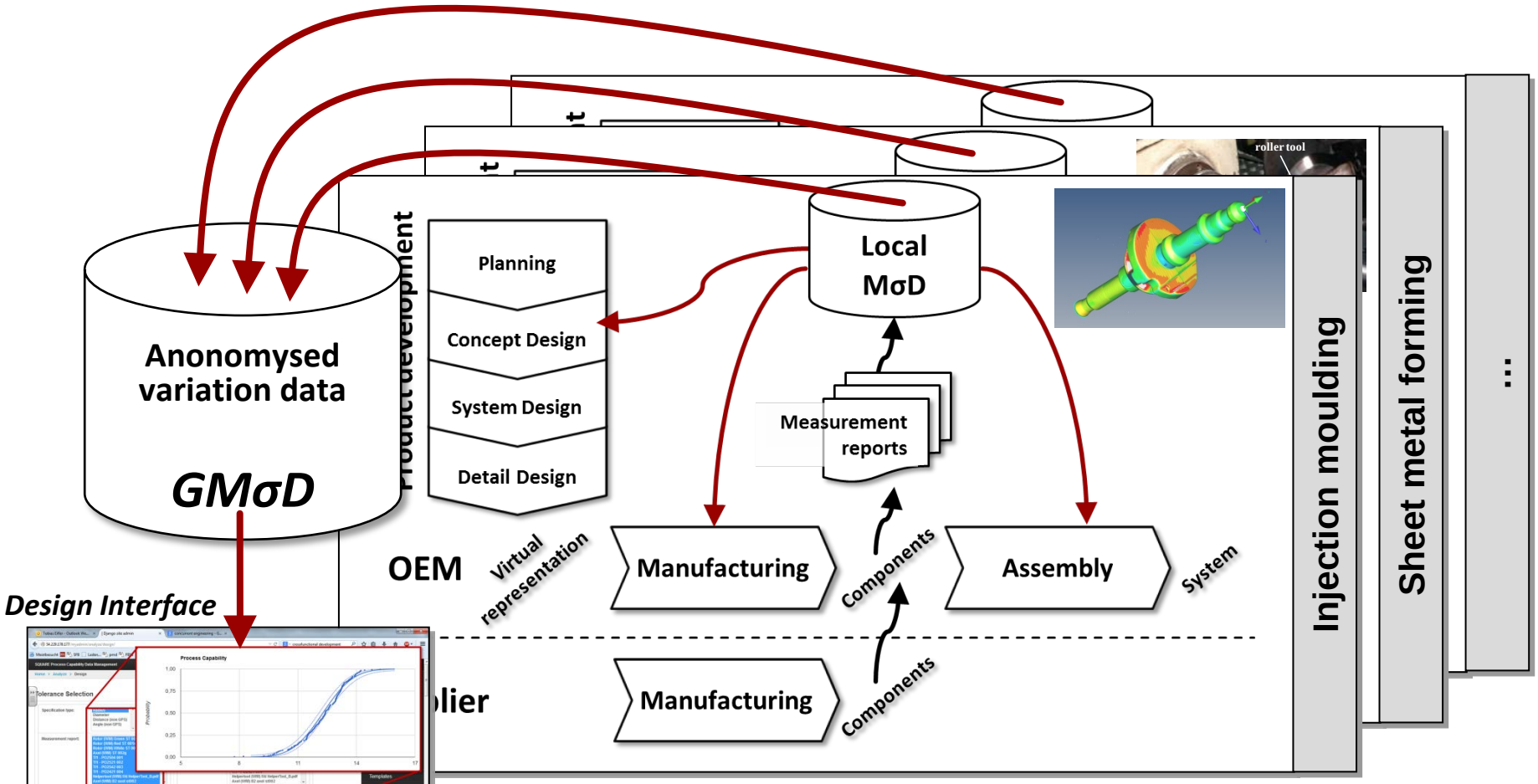
② ***Interaction effects*** – Influence of product characteristics

③ ***Interaction effects*** – Influence of machinery design

④ Alignment of ***measurement procedures*** and (advanced) technologies

⑤ …

GMσD Structure
(Global Manufacturing Variation Database)



Design Interface

Quantifying manufacturing capabilities across processes and industries, leading to a new standard for tolerance allocation.

Questions?

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