

# Key Characteristics

- Goals of this class
  - Introduce Key Characteristics (KCs)
  - Define the notions of KC delivery and KC delivery chain
  - Understand the relationship between KC delivery chains and part-to-part location
  - Appreciate how many KCs an assembly can have, including the concept of KC conflict
  - See some examples

# Key Characteristics (KCs)

- Key characteristics are product requirements that demand attention because
  - they are critical for performance, safety, or regulations
  - AND
  - they are at risk of not being achieved due to process variations
- Usually, KCs are geometric relationships between features on non-adjacent parts
- Two basic issues for KCs are
  - priorities
  - flowdown

# “Chain of Delivery” of Quality

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Source:

Figure 2-1 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

No single part “delivers” the KC.

# Chains Deliver KCs

- KCs are delivered by chains that must operate repeatedly
- Chains are made up of:
  - μ physical elements: parts, sub-assemblies, tools, and fixtures
  - μ the associated organizations (supply chain)
  - μ the capability of the processes (technology)
- Each KC is delivered when its chain is complete

# KC Priorities

- Everything is important to someone
- KCs should be confined to things that are not only important but are at some risk of not being achieved
- Usually, manufacturing or assembly variation are considered to be the main threat
- So there is a direct link between KCs and assembly tolerances
- If there is no systematic process for identifying KCs, and if priorities are not assigned, then KCs tend to proliferate

# When Can Key Characteristics Be Used?

- During concept design, to capture customer req'mts
- During system engineering, to flow down req'mts to lower levels of the design process
- During detail design, to deliver req'mts via tolerances and process planning
- During supplier selection and preparation of specs, to define deliverables
- During program management, to track and assure achievement of requirements

# Desktop Stapler

Image removed for copyright reasons.

Source:

Figure 1-1 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

# Stapler Parts

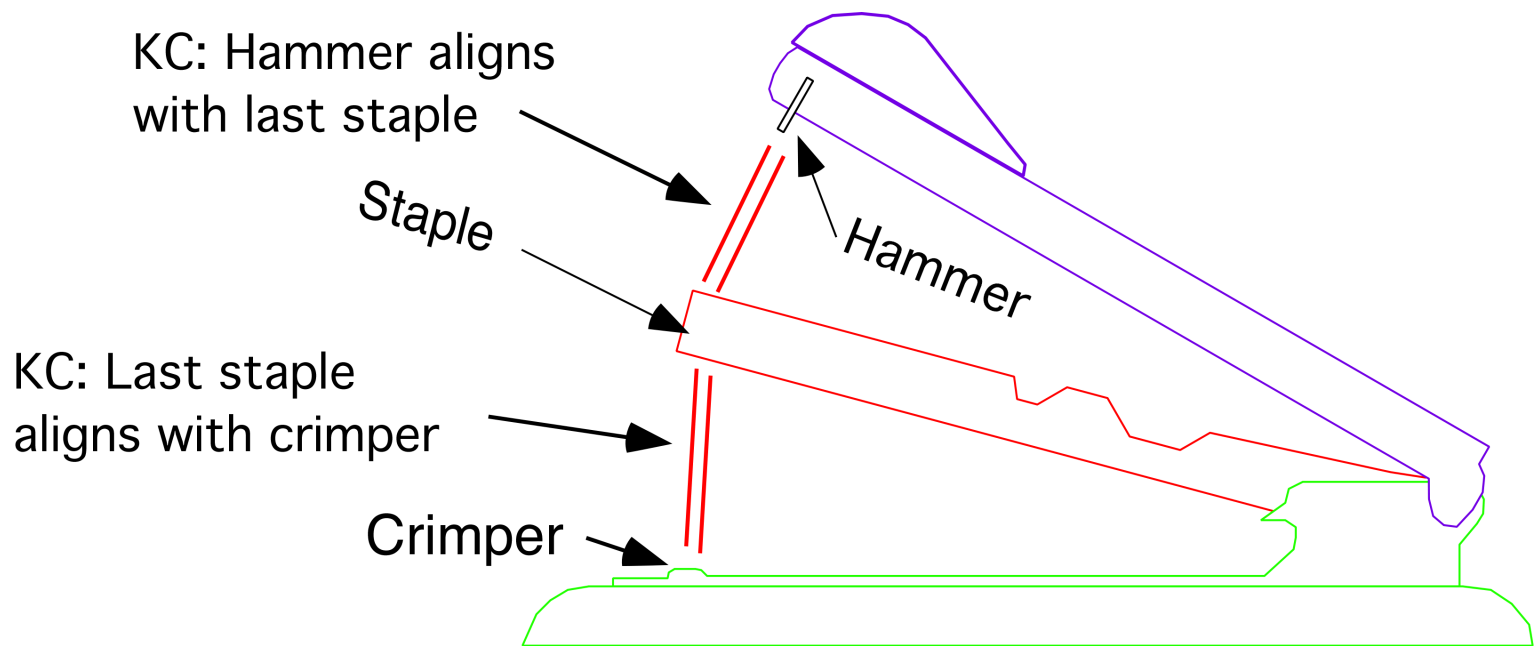
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Source:

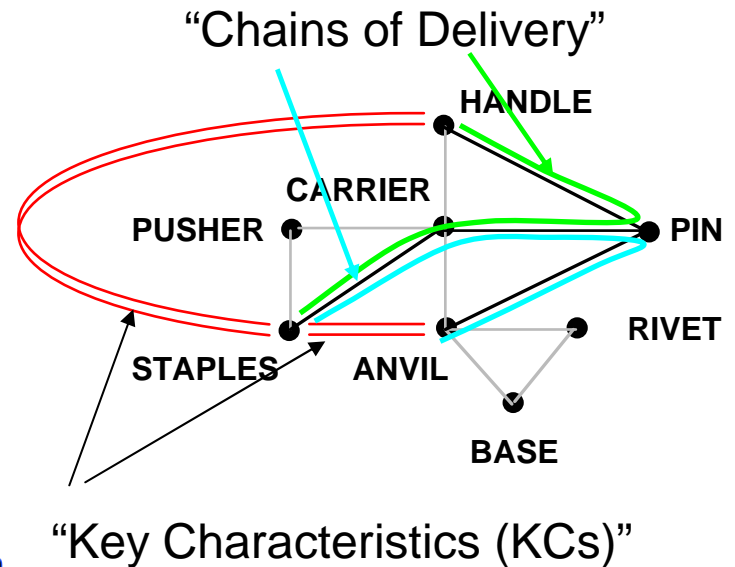
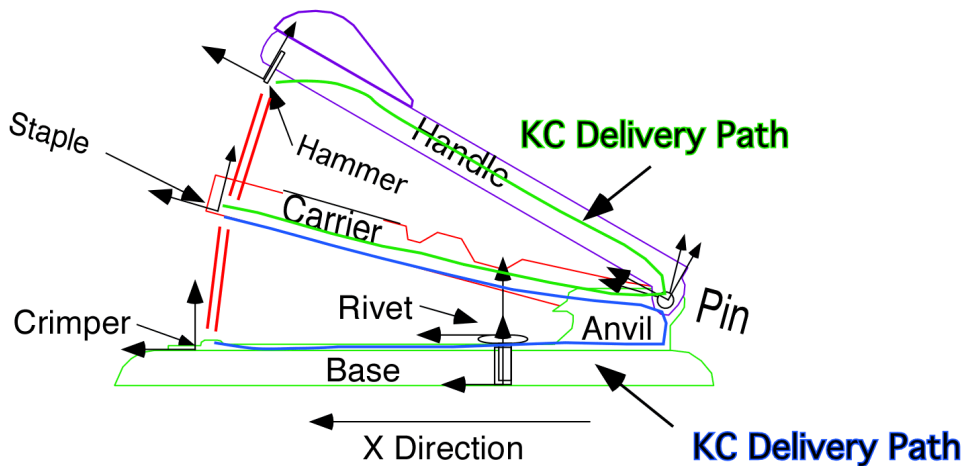
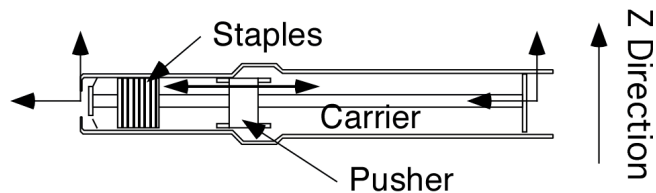
Figure 1-2 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.



# Stapler KCs



# Each KC is Delivered by a Chain



# Key Characteristics and the Liaison Diagram

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Source:

Figure 1-3 in [Whitney 2004] Whitney, D. E.  
*Mechanical Assemblies: Their Design, Manufacture,  
and Role in Product Development.*  
New York, NY: Oxford University Press, 2004.  
ISBN: 0195157826.

Liaison Diagram

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Source:

Figure 1-4 in [Whitney 2004] Whitney, D. E.  
*Mechanical Assemblies: Their Design, Manufacture,  
and Role in Product Development.*  
New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

KCs

# Only Some Liaisons Matter in KC Delivery

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Source:

Figure 1-5 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

# The Delivery Path for Each Stapler KC

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Source:

Figure 1-6 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

# Optical Disk Drive KCs

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Source:

Figure 2-7 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

# KC Flowdown

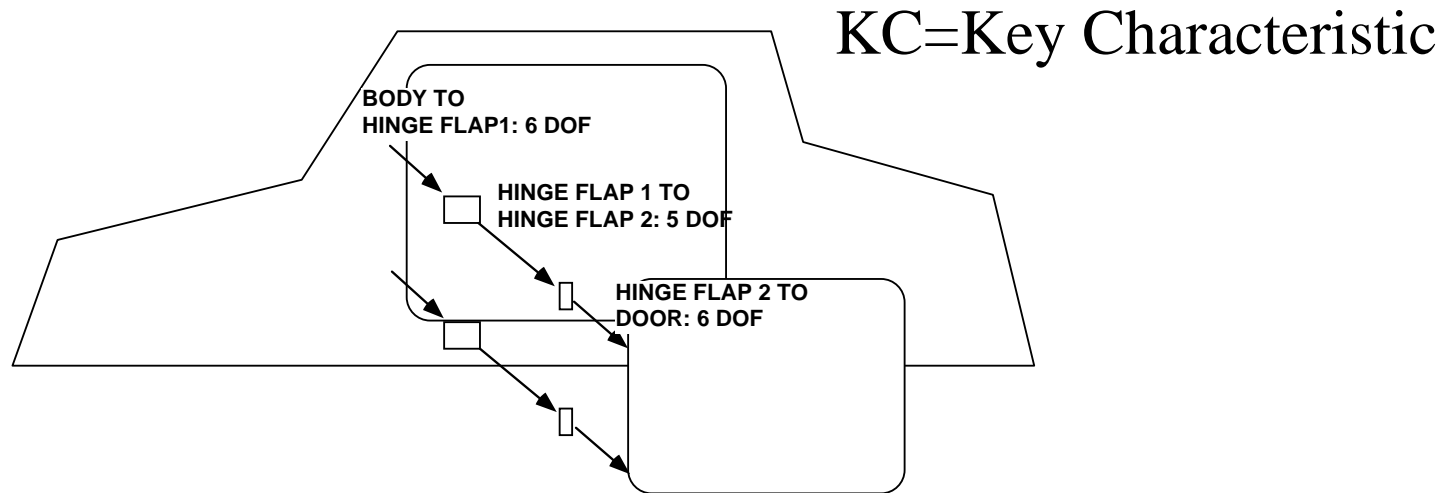
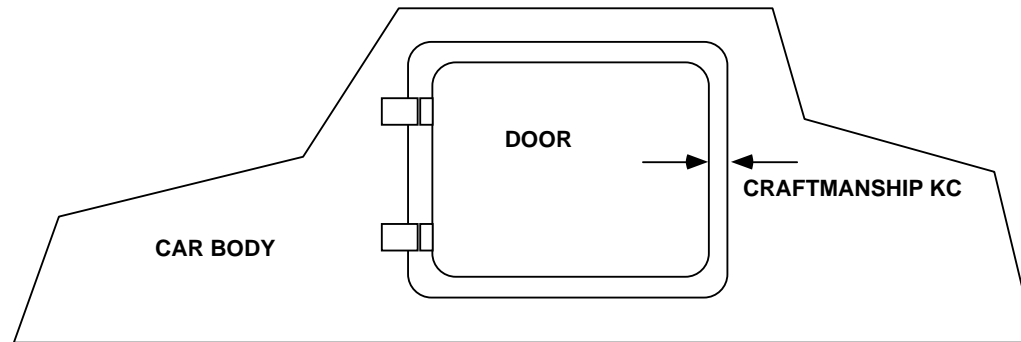
- Product KCs can be defined for customer requirements and then decomposed into lower level Assembly and Manufacturing KCs
- Achievement of the PKCs requires achievement of the AKCs and MKCs
- Full implementation requires that each AKC and MKC meet a specific tolerance or Cpk
- Suppliers' capability may limit AKCs and MKCs, requiring *flow-up* and negotiation

# Some “Statistics”

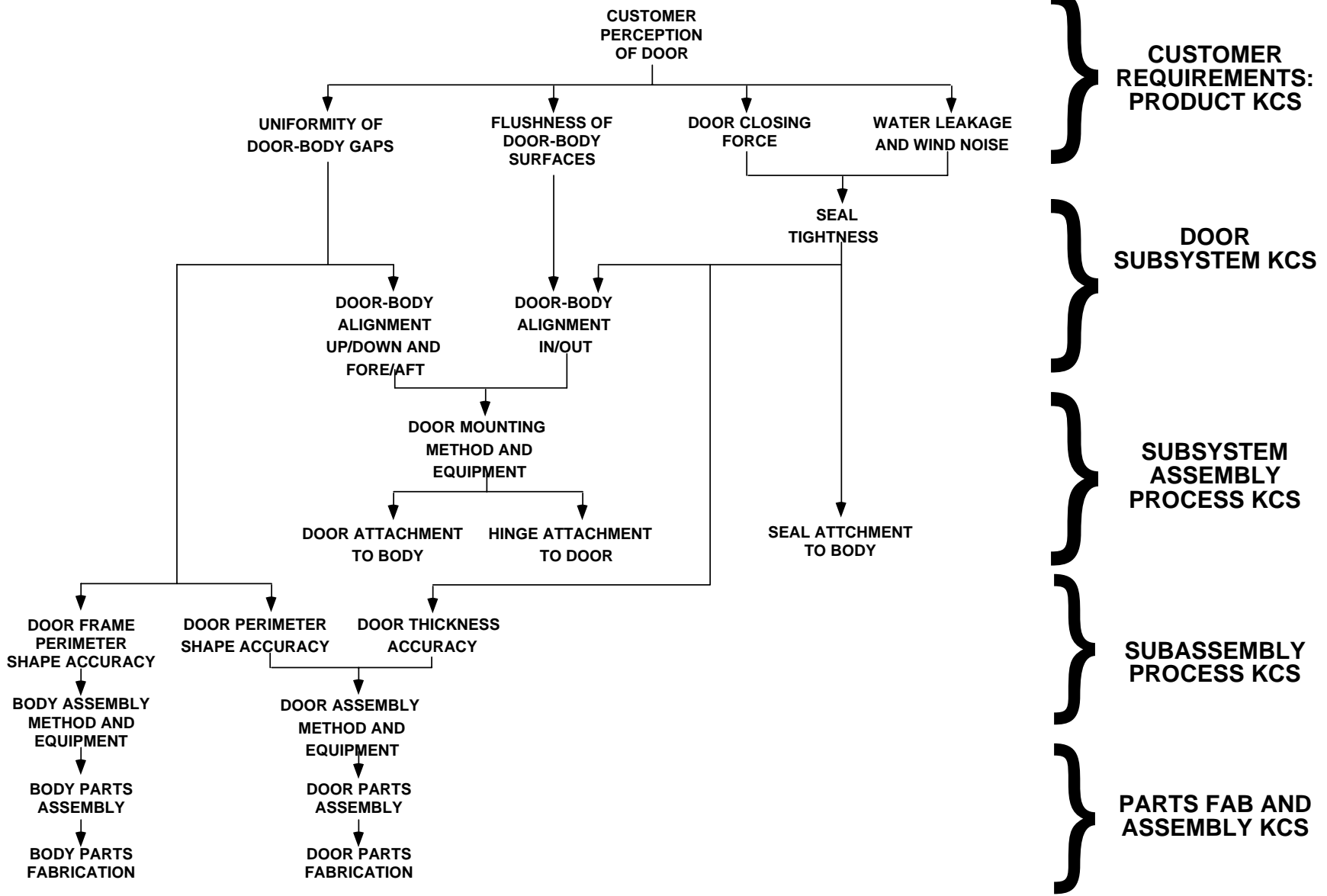
- A person at GM said
  - 60% of body sheet metal tolerances can be met
  - 40% must be altered to meet shop capabilities
- A patent from Boeing on tolerancing says that typically 8 parts are involved in a tolerance chain (probably similar to the length of a KC chain for us)
- A survey of 600 consumer products by Ulrich and Ellison reveals that about 6 parts are involved in delivering functions that differentiate the product in the marketplace
- You don't get real numbers like this every day



# How Parts Locate Each Other to Deliver Quality at the Customer Level



# Car Door KC Flowdown



# Car Door Exterior Gaps

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Source:

Figure 2-8 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

# Door Assembly

Image removed for copyright reasons.

Source:

Figure 2-10 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

# How Doors are Built

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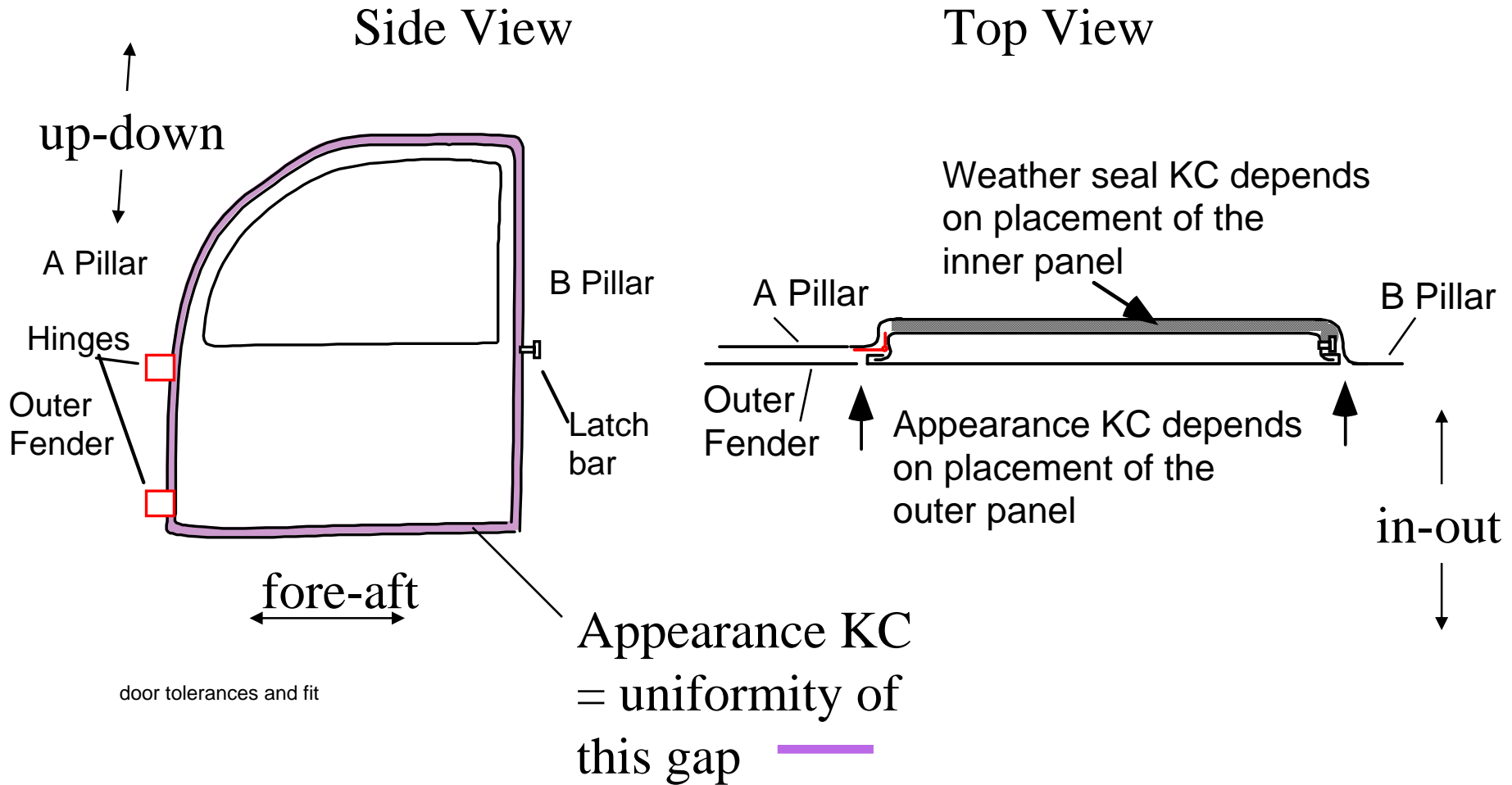
Source:

Figure 2-10 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.



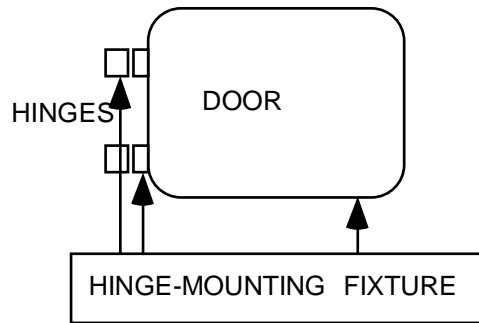
# Door Hem

# Car Door Design KCs

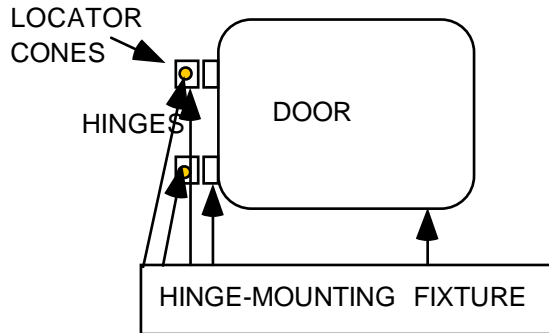


# Two Door Methods - There Are Many

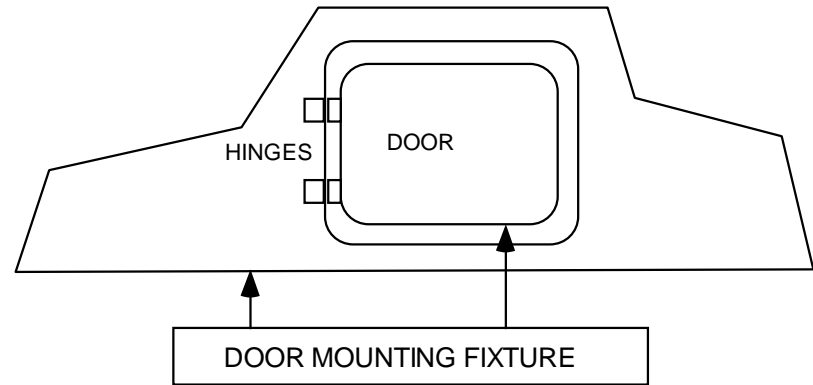
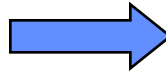
→ = 6 DOF LOCATION



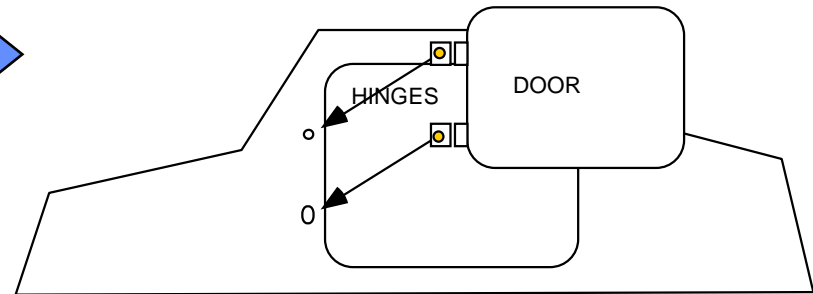
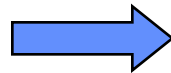
Assembly Step 1a



Assembly Step 1b



Assembly Step 2a

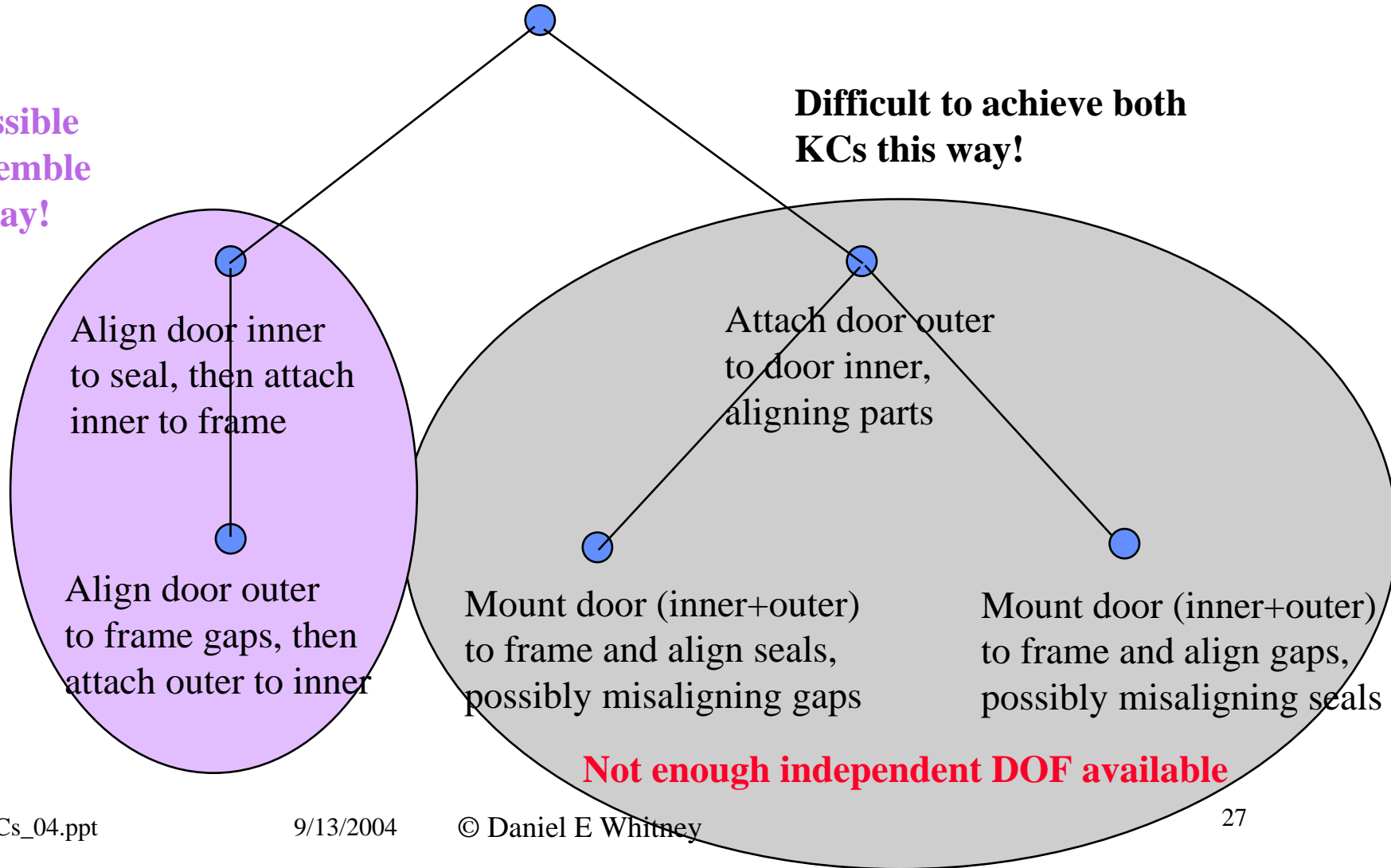


Assembly Step 2b



# KC Conflict in Door Assembly

Impossible to assemble this way!



# Ford Hinge Mounting

Image removed for copyright reasons.

Source:

Figure 2-12 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

# Ford Hinge Mounting Fixture

Photo removed due to copyright restrictions. (Detail of car door front and rear locator pins and holders for hinges.)

# Door on Hinge-Mounting Fixture

Photo removed due to copyright restrictions. (Detail of front and rear car door mounting locators.)

# Ford Door Mounting to Car

Images removed for copyright reasons.

Source:

Figure 2-12 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

# Mustang Body in White

Photo removed due to copyright restrictions. (Detail of car door front and rear locators.)

Image removed for copyright reasons.

Source:

Figure 8-48 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

# An Interesting Wrinkle

- Doors are usually installed on a car before painting and removed for trim installation
  - you can grab a door rigidly (accurately) when there is no paint to scratch
  - it is easier to install stuff on/in the door and in the car if the doors are separate
- The challenge is to get them back on in the right place without the benefit of assembly tooling
- It is done cleverly with the hinges
  - install door+hinges to car, remove door from hinges
  - remove a temporary hinge pin, reinstall a final one
  - check which bolts have paint to see how it was done



# GM Hinge Mounting

Image removed for copyright reasons.

Source:

Figure 2-12 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

## GM Method

# GM Take-apart Car Door Hinges

Photo removed due to copyright restrictions. (Detail of car door hinges and locator cone.)

# GM Door Mounting to Car

Images removed for copyright reasons.

Source:

Figure 8-47 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

# Ford Locator Drawing

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Source:

Figure 2-13 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

# Conclusions

- KCs are the link between functional customer needs and physical realizations at the assembly level
- KCs are delivered by chains of parts
- KCs can be delivered in more than one way
- Design of KC delivery requires definition of location schemes by which parts are related to each other in 6 dof
- Assemblies typically have many KCs, and they can conflict