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Design for Manufacturing and Assembly (DFMA) Using SolidWorks

September 12, 2007

Thomas Allsup

PROPRIETARY

Apologies

This presentation is a 45 minute distillation of an eight hour seminar that Anida Technologies has given in the past with some SolidWorks comments added for flavor. My choice was to talk 10.67 times faster or remove some slides so ***here we go….***

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Why Are We Here?

There are a lot of good “Quality” systems that provide excellent road maps for helping companies delivering the best products and services:

- Six Sigma, TQM, ISO 9000, Quality Circle, Kaizen
- Insert your company Quality Plan Du Jour here

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Six Sigma

- Six Sigma is a disciplined, data-driven approach and methodology for eliminating defects (driving towards six standard deviations between the mean and the nearest specification limit) in any process -- from manufacturing to transactional and from product to service.
- Six Sigma at many organizations simply means a measure of quality that strives for near perfection.
- The statistical representation of Six Sigma describes quantitatively how a process is performing.
- To achieve Six Sigma, a process must not produce more than 3.4 defects per million opportunities.

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6σ

TQM

- TQM stands for Total Quality Management
- TQM is a largescale systems change.
- TQM is a set of guiding principles and considerations that by its name implies that it meant to work across the entire company – from human resources to manufacturing.

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ISO9000

- ISO9000 is an internationally recognized standard of quality.
- ISO9000 is a set of guidelines to accomplish the quality standard.
- ISO9000 in a nutshell is “Say what you do, then do what you say”.
- In Switzerland, I saw a bakery truck that had an advertisement that the bakery was ISO9000.

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Quality Circle

- Quality circle are typically said to have originated in Japan in the 1960s but others argue that the practice started with the United States Army soon after 1945.
- A quality circle is a staff (6-9 people) who meets regularly to discuss quality related work problems so that they may examine and generate solutions to these problems.
- The circle is empowered to promote and bring the quality improvements through to fruition.

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Kaizen

- Kaizen is a focused, results oriented, team approach to rapid continuous improvement.
- It is a proven method, initially developed by Toyota.

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Plan Du Jour?

Everyone in the technical world has been subjected to the passing whimsy of upper management when they read an article in an airline magazine or some management book.

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Viewing the World from 20,000 Feet

- Implementation for these quality systems requires training across the entire company.
  - This training is usually top notch and is comprehensive in nature.
  - The goal of this training is a complete system change.
- This training comes from the top, from people who are traveling in the stratosphere.

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One of My Favorites

I’ve had several managers that particularly enjoy the 20,000 feet management style.

- They fly around for a long time - way up high.
- Out of the blue, they swoop down – stir everything up.
  - This is usually accompanied with an evacuation of excrement.
- Just as unexpectedly – they fly away!

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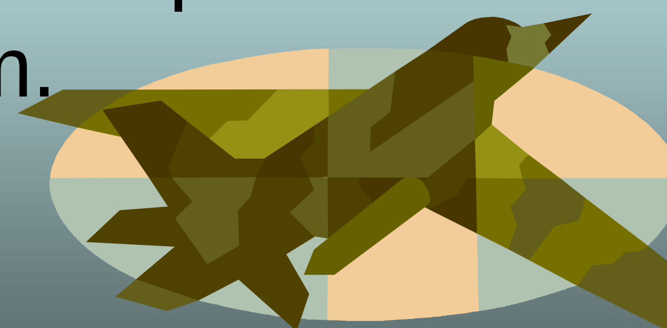
Tactical Responses

- All of the mentioned quality systems and all the yet to be announced programs have their benefits and limitations.
- Regardless of the system there are some techniques that can assist engineering, manufacturing, and quality departments.
- Tonight we will discuss four topics that work in any quality system.



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Topic 1: Poka-Yoke

- Poka-Yoke is a simple common sense concept of "idiot proofing".
  - We'll see that common sense isn't often simple and not as common as we'd like to imagine.
- This technique must begin early in the conceptualization process and continues throughout the design and manufacturing.

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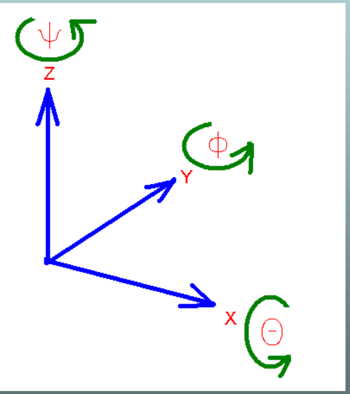
Topic 2: DOF

- The next simple common sense concept we will discuss is the constraining of the degrees of freedom of an assembly without over constraining an assembly.
- We'll define a degree of freedom.
- We'll discuss constraining in the real world and in CAD systems.



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This topic could be subtitled: Designing Assembly Fixtures.

Topic 3: Design Guidelines

Seven common sense simple design for manufacturing guideline concepts that we all know but somehow in the heat of a design battle are forgotten.

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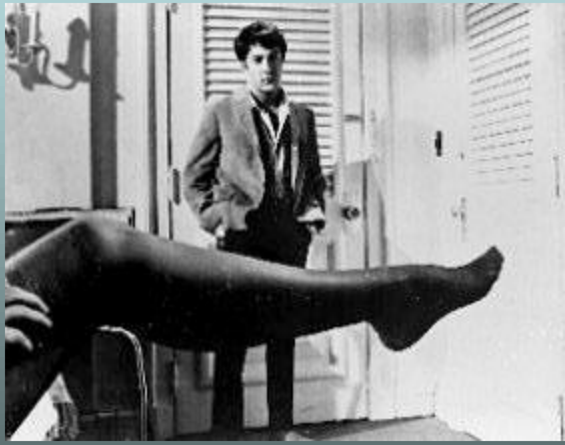
Topic 4: Plastics

- No discussion of Design for Manufacturing would be complete without some mention of tooled piece parts such as progressive die stampings, metal castings and plastic parts.
- *Given our limited time, we will limit ourselves to one word…*



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How can SolidWorks Improve DFMA?

- A powerful tool in design is a parametric CAD system – particularly SolidWorks
- This tool, used properly, is also a powerful manufacturing and quality tool.
- Virtual reality has cheap rent, low rework cost, and can be provide quick alternatives.

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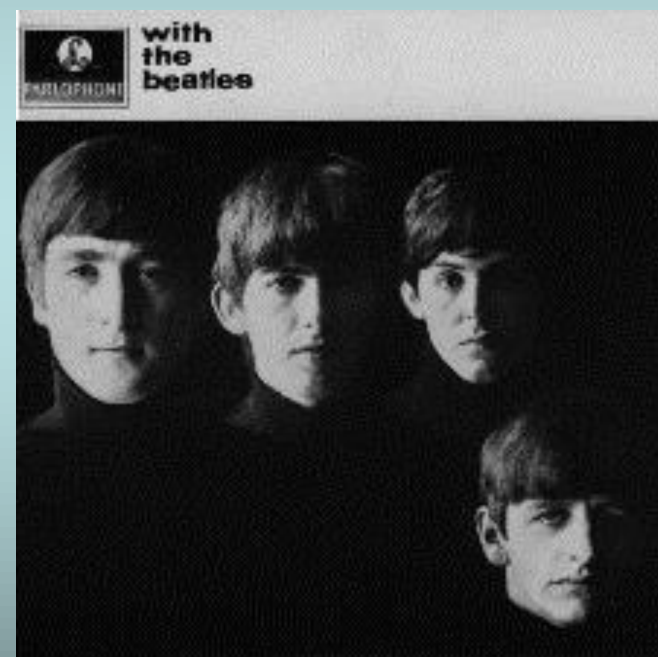
Topic 1 : Poka-Yoke?

THE BEATLES

Isn't she the sister of the woman who broke up the Beatles?



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Poka-Yoke?

Is it a scrambling egg cooking process?

I hope this joke works, because I would hate to have egg on my face.

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But Seriously,

What is Poka-Yoke?

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Poka-Yoke Starters

- Pronounced POH-kah YOH-kay
- Poka-yoke is the Japanese words for mistake-proofing
- Remember the hyphen
- ☺ Although we tend to poke things into poka-yoke devices, the “oke” is only after the “y”
- The idea behind poka-yoke is to develop devices and/or procedures that cannot go wrong – or "idiot proofing a process”.

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Poka-Yoke Symbols

ポカヨケ

Can anyone read Kanji?

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Why do they all look like traffic signs in Downtown Dallas?

Shigeo Shingo: The Poka-Yoke Man

- Wrote about common sense approaches to manufacturing problems
- Called himself "Dr. Improvement"

☺One Handsome devil

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Shigeo Shingo: Life Story

- ☺ Born January 8, 1909 in Saga City in Japan.
- ***Described himself as an "engineering genius“***
- Assisted in the creation of, and wrote about, many of the features of the revolutionary just-in-time manufacturing methods, systems, and processes which make up the renowned Toyota Production System and related production systems.
- ☹ Mr. Shingo died peacefully November 14, 1990 at the age of 81.

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Shigeo Shingo: Style

- He urged audiences at companies to become improvement engineers
- Demonstrated the essence of his ideas by spending the majority of his time on the shop floor observing problems, making suggestions, and working with both the workers and management to find solutions.
- He quoted “My medicine works but only if the patient takes it."

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Shingo's Classic Poka-Yoke Example

- An example cited by Shingo shows how finding mistakes at a glance helps to avoid defects.
- Suppose a worker must assemble a device that has two push buttons.
  - A spring must be put under each button.
- Sometimes a worker will forget to put the spring under one of these buttons.

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Shingo's Classic Poka-Yoke Solution

- The poka-yoke device used was simply a small dish.
- The poka-yoke procedure was for the worker to start by placing two springs into the dish.
- The worker knows that unless the dish is empty, assembly is not complete.

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Shingo's Classic Example Explanation

- The cost of this inspection is minimal, yet it effectively functions as a form of inspection.
  - Counting out two springs into the dish before assembly
  - Looking at the dish after assembly to ensure it is empty
- The cost of rework at this point is also minimal, although the preferred outcome is still to find the dish empty at the end of assembly and to avoid rework even when the cost is small.

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Shingo's Classic Solution Critique

Note that although the assembly operation is much improved, it has not become completely "fail-safe" or "idiot proof".

❶ The worker may miscount the springs or not notice that a spring remains in the dish.

❷ A spring may fall from the dish.

❸ If a defective spring is encountered and discarded, the dish will be empty with only one spring installed.

❹ If the worker finds the procedure irksome or too time consuming, he or she may count out 4 or 6 or 8 springs at once or even omit the procedure entirely.

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What is a Poka-Yoke Device?

Any mechanism that either prevents a mistake from being made or makes the mistake obvious at a glance.

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Poka-Yoke Examples

If a diskette is inserted incorrectly into a computer it will not work and may damage the disk drive.

A 3.5" diskette cannot be inserted unless the diskette is oriented correctly.

A man needs to take a number of pills each morning & evening & sometimes forgets whether he has taken the pills or not.

Pill holder has morning & evening compartments for each day of a week which the man can fill once a week.

File cabinets fall over if too many drawers are pulled out.

File cabinet designed so that opening one drawer locks all the rest so that they cannot be opened.

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Common Poka-Yoke Example

How about checking the height of your vehicle before you enter a parking garage?

I've never had to worry about my Miata!

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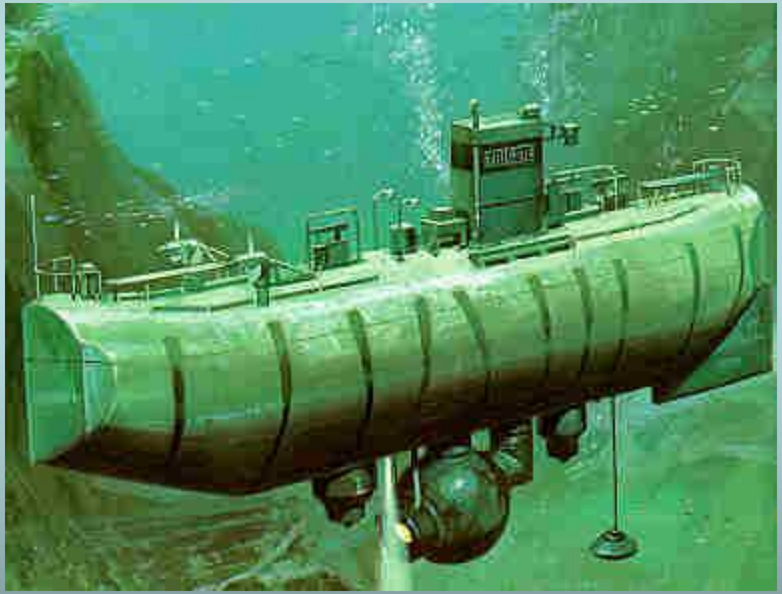
Failsafe Poka-Yoke Example

Ballasts for deep sea vessels are held in place by electro-magnetics so if power is lost, the ballasts open and the ship returns to the surface.



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Two Approaches to Poka-Yoke Design

❶Eliminate the causes that result in product or service defects

❷Allow inexpensive and fast inspection of each product or service to check its quality and correct any defects before the product reaches the customer.

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Poka-Yoke Characteristics

- Simple, usually inexpensive, devices
- Simple and quick procedures
- Minimal disruption to workers
  - low "hassle-factor"
- Low cost to implement into process
- Large impact on quality of production
- Creative Focus on:
  - eliminating the causes of errors or defects, or,
  - enabling inexpensive and fast inspection of product or service.

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How Do I Idiot Proof Something Using SolidWorks?

- Reduce the number of mates on each part or sub assembly and see if you can "put it together wrong".
- Look for symmetric parts that could be swapped, not function, but still go together.

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Poka-Yoke Wrap-Up

- Poka-Yoke is usually thought to be a purely manufacturing concept.
- The next time you use a ***"good"*** Windows program look for Poka-Yoke characteristics.
- ☺ Any questions?

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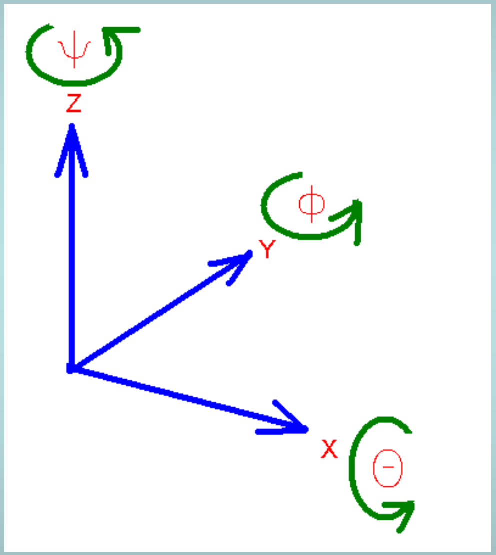
Topic 2: Degrees of Freedom
Explanation

- A part floating in space has six directions of possible motion:
  - Translations in the X,Y, and Z axis
  - Rotations around the X,Y, and Z axis
- Each direction of motion is known as a ***degree of freedom***.



Degree of Freedom
Example #1

- A heavy dictionary is laying on a desk.
  - The book can be pushed on the surface in the X and Y axes
  - Gravity is preventing the book from moving in the “Z” axis
  - The book can not spin about the X and Y axes since it is in contact with the top of the desk
  - The book can be spun around on the desk or on it’s “Z” axis (normal to the desk top)
- The book has three degrees of freedom: X axis translation, Y axis translation, and Z axis rotation.

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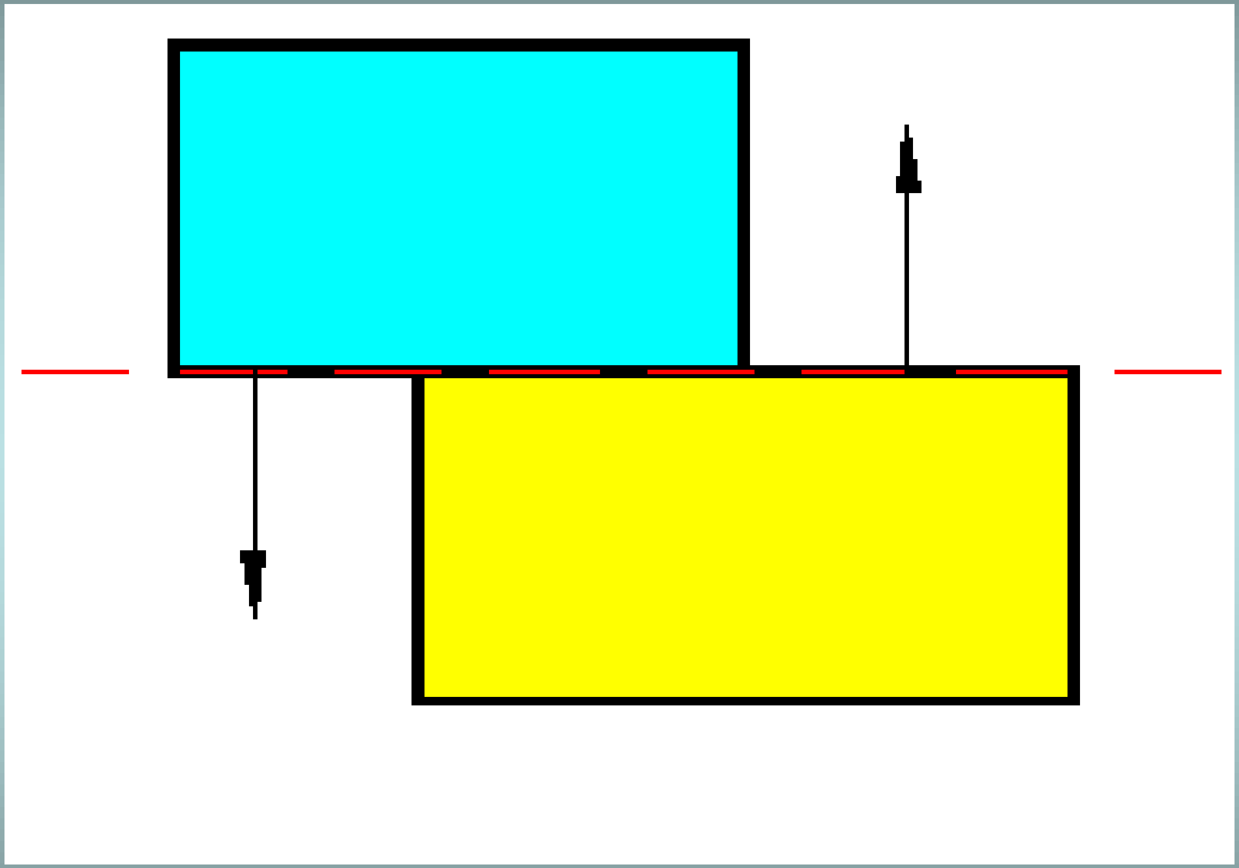
Degree of Freedom

Example #2: Mate



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Degree of Freedom

Example #3

When the round piece starts into the hole, five degrees of freedom are removed leaving only one:

In and Out

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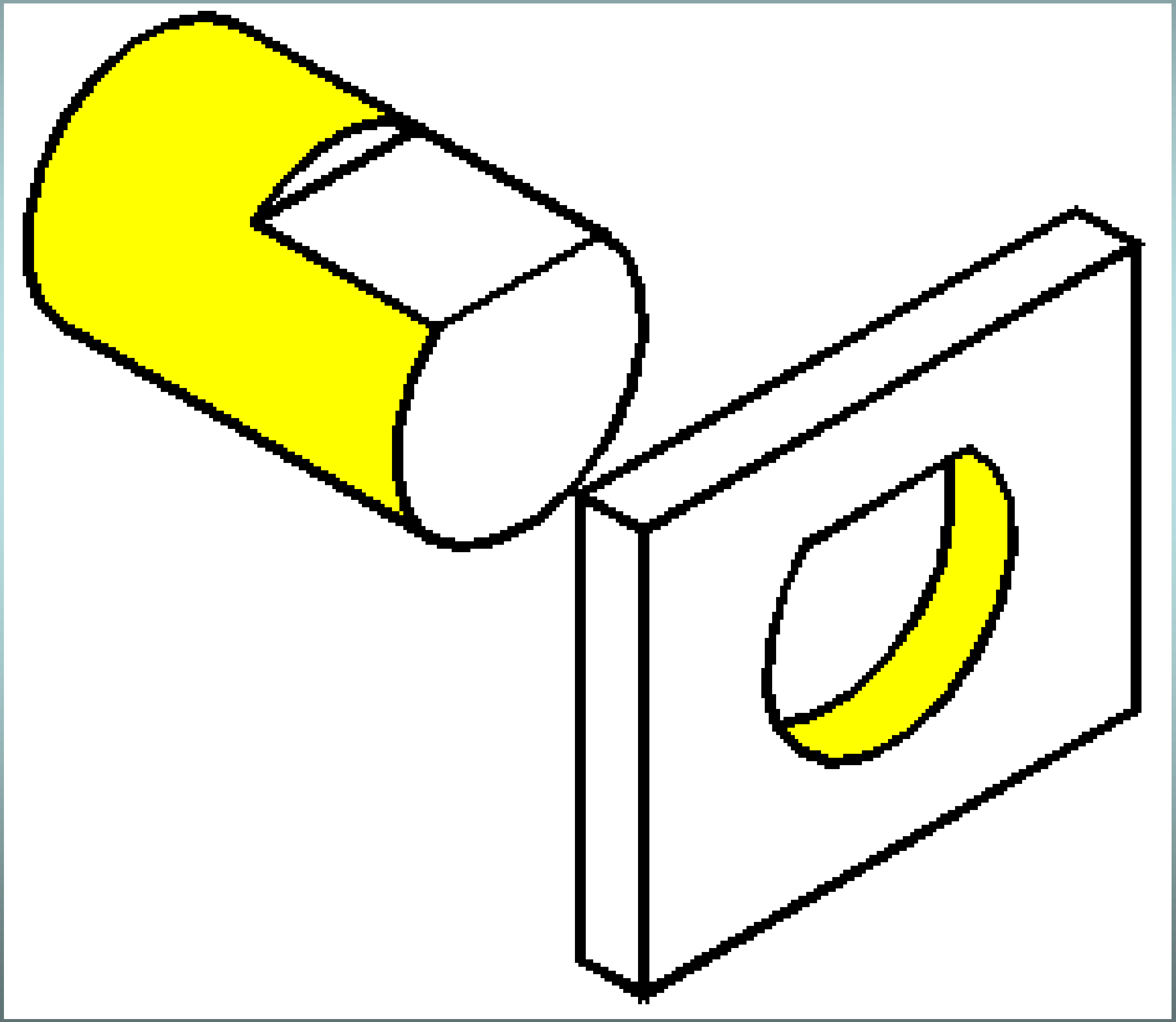
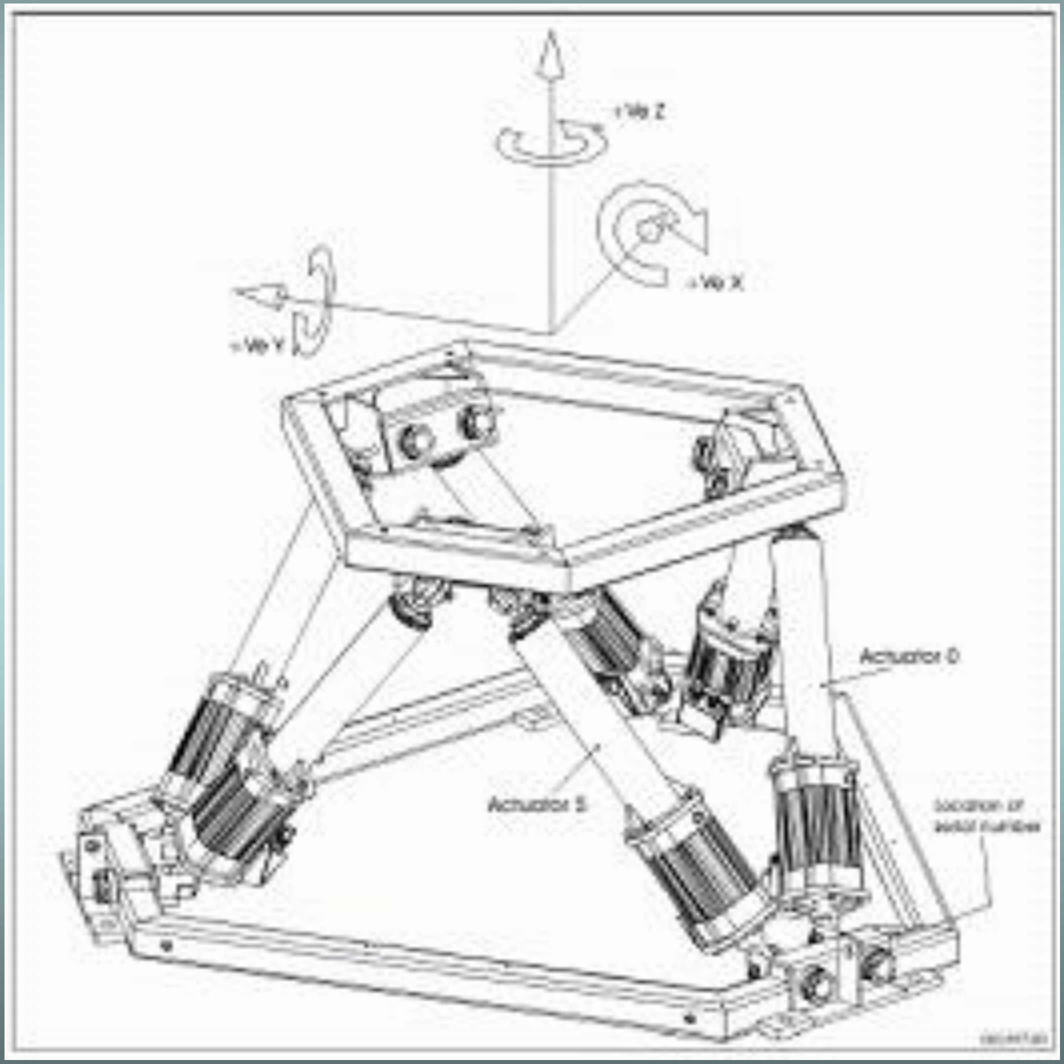


Degree of Freedom

Example #4

This mechanism is used in amusement rides to artificially create movement in all six degrees of freedom.



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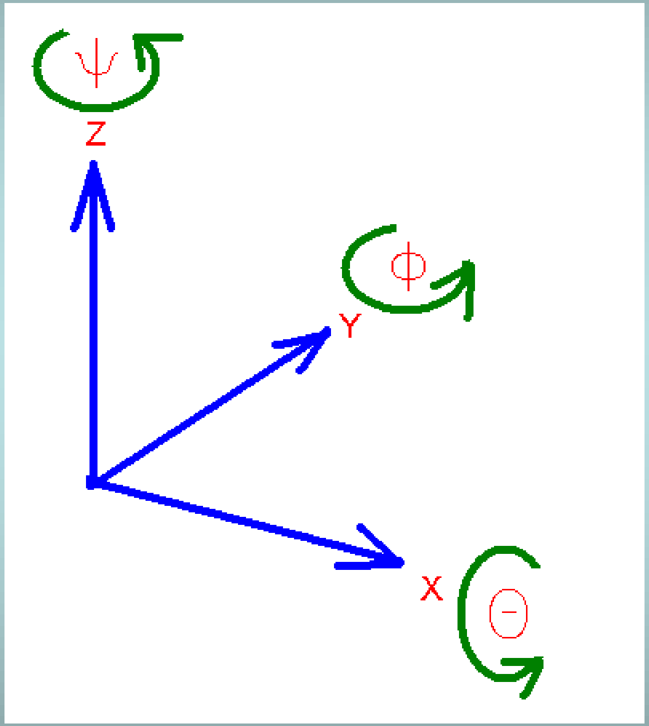
Degrees of Freedom
Parametric Modeling

- The basic parametric model assembly process involves placing parts together by “constraining” or removing degrees of freedom.
- Geometric Modeling:
  – Mate
  – Insert



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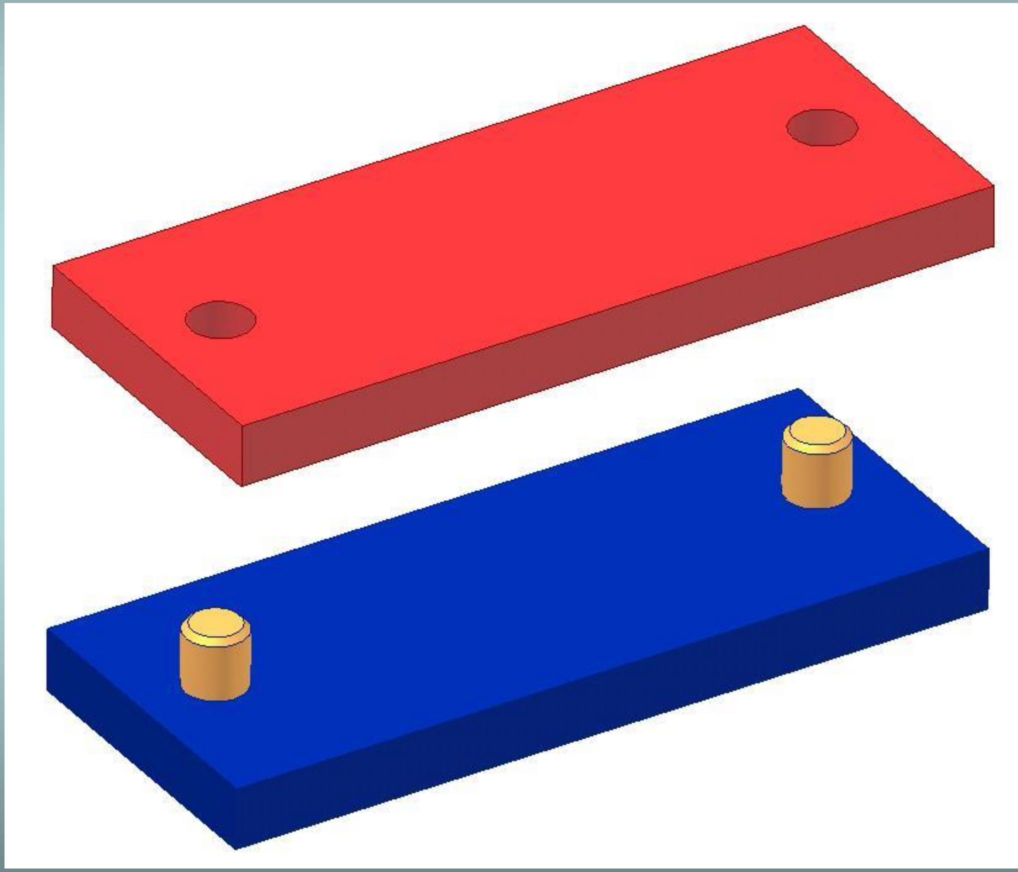
Red Plate Example

- The blue piece with pins is fixed in space.
  - Zero degrees of freedom.
- The red piece with holes is floating free in space.
  - Six degrees of freedom.
  - You can spin it around and move it anywhere.



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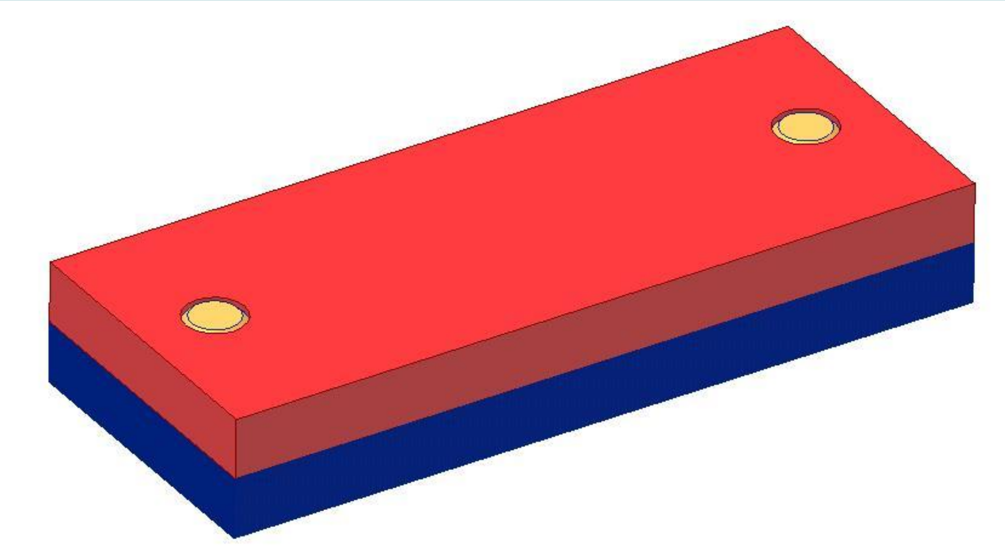
Red Plate Example

- Once the red piece with holes slides onto the pins of the blue piece, it can no longer rotate about any axis and translation is limited to the direction of the pins.
  - One degree of freedom.
- If you pull up on the red piece it will move in only one direction.



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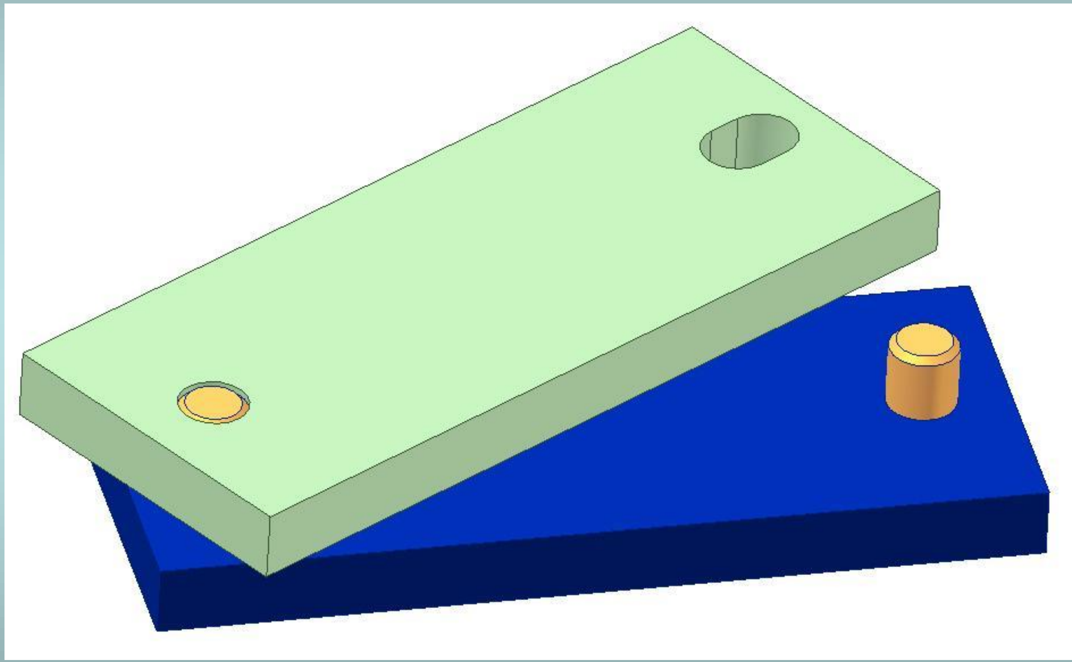
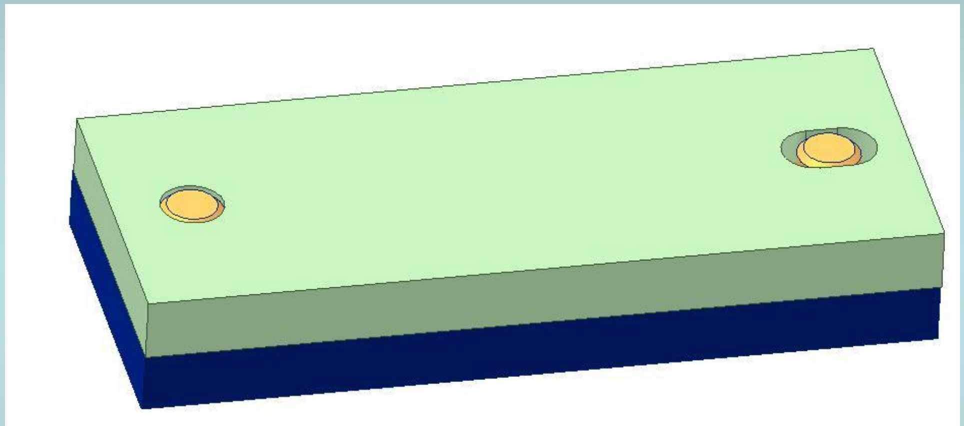
Green Plate Example

- A green plate with a hole and a slot is lowered onto one of the pins of the blue plate.
- The green plate is free to spin around as well as move up and down.
  - Two degrees of freedom.



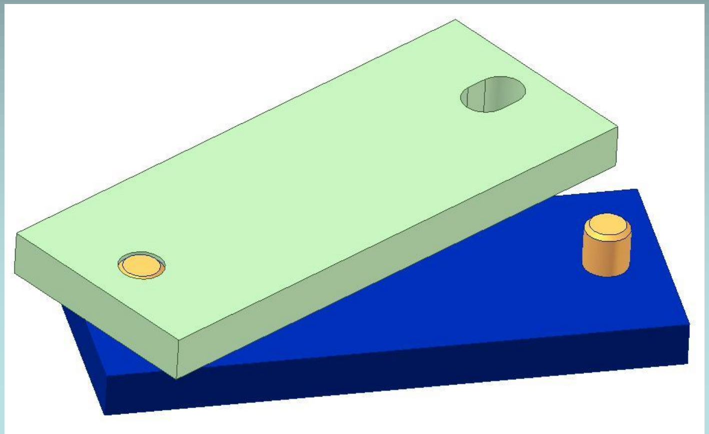
Green Plate Example

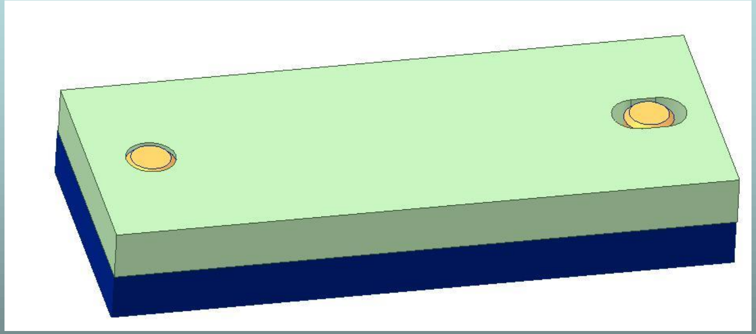
- The green piece with the hole and slot can also be placed onto both pins of the blue piece.
- The green piece can only move up and down on the blue plate pins.
  - One degree of freedom.



Green Plate Example

- The second pin on the blue plate stops the green plate from spinning.
- The second pin is said to remove one degree of freedom from the green plate.
  - Eliminates rotation about the hole on the pin.





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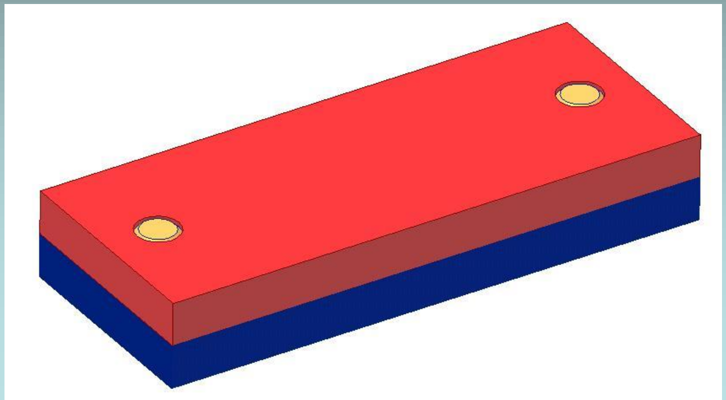
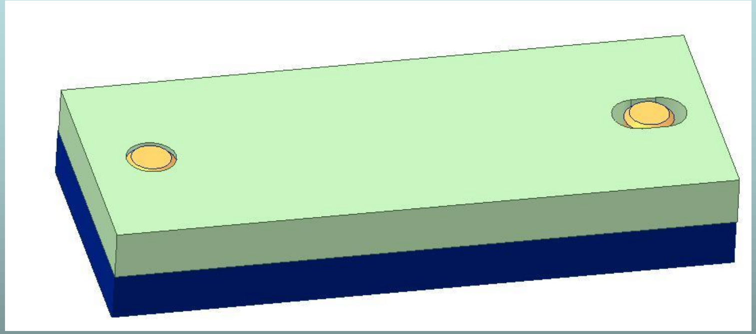
Comparing Designs

- Both of red plate and the green plate can only move up and down on the blue plate pins
  - Both only have one degree of freedom.
- Is there an disadvantage or advantage to either the red or green plates?





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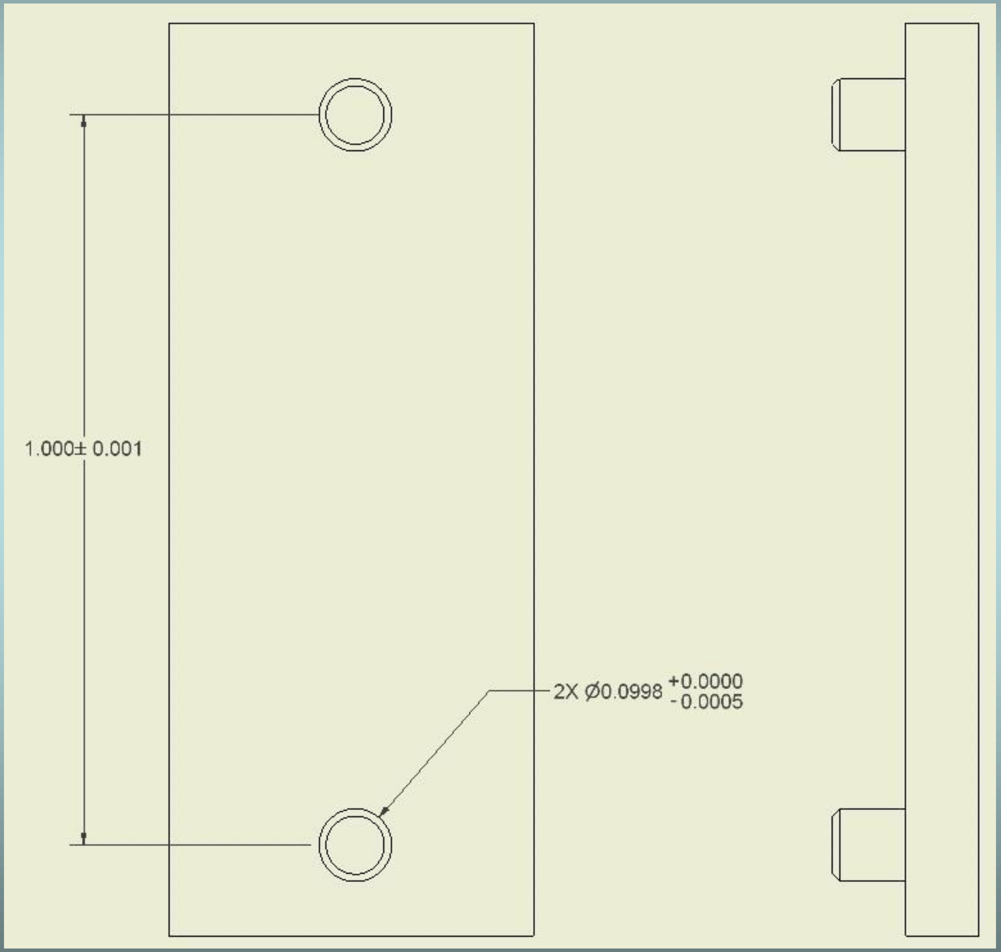
Blue Plate Drawing

- The pins are tight tolerance dowel pins (slightly undersized).
- The pins are spaced according to very tight manufacturing processes.



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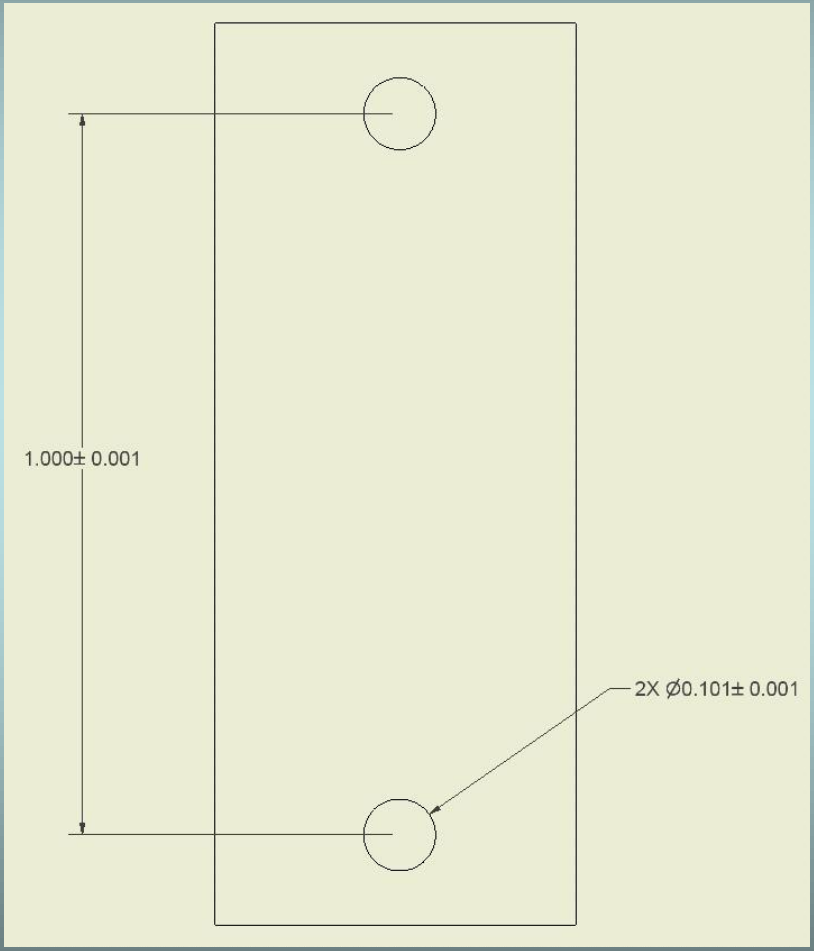
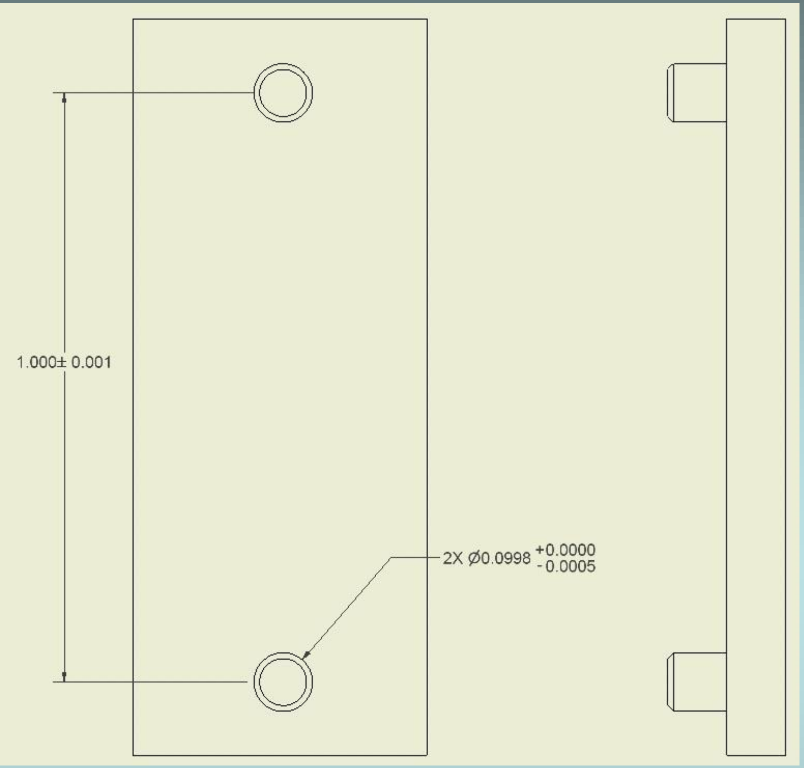
Red Plate Drawing

- The hole diameters are drilled with tight tolerance.
- The holes are spaced with the same tight tolerance as the blue pin plate.
  - Same tolerance?

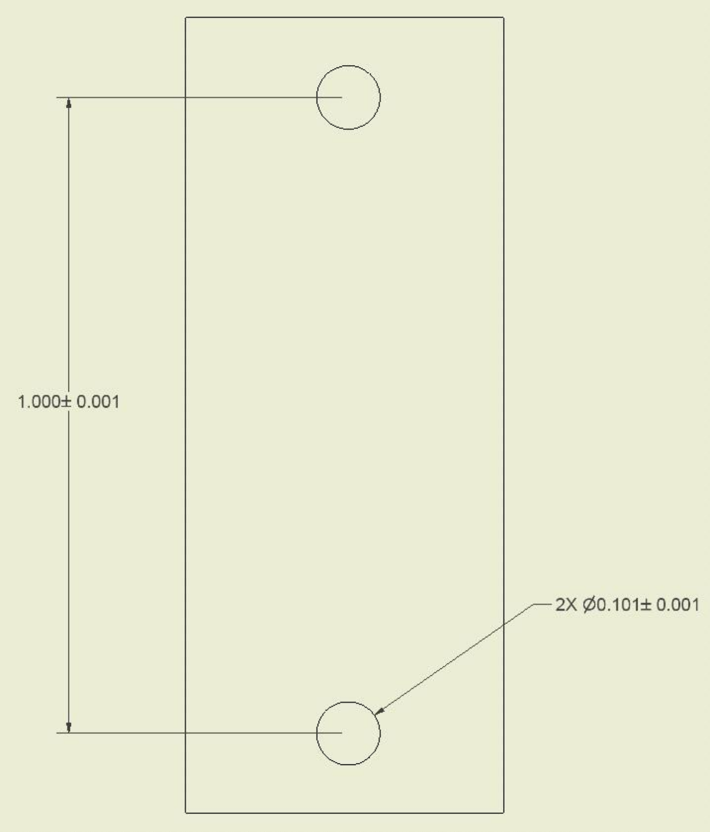


Same Tolerance?



That means the pins could be close together and the holes could be apart and the red plate won't go onto the blue plate!

We can fix that by drilling the holes bigger so it will always fit.



Drilling the holes bigger means the red part can move around pretty sloppy against the blue plate which wasn't our design intent.

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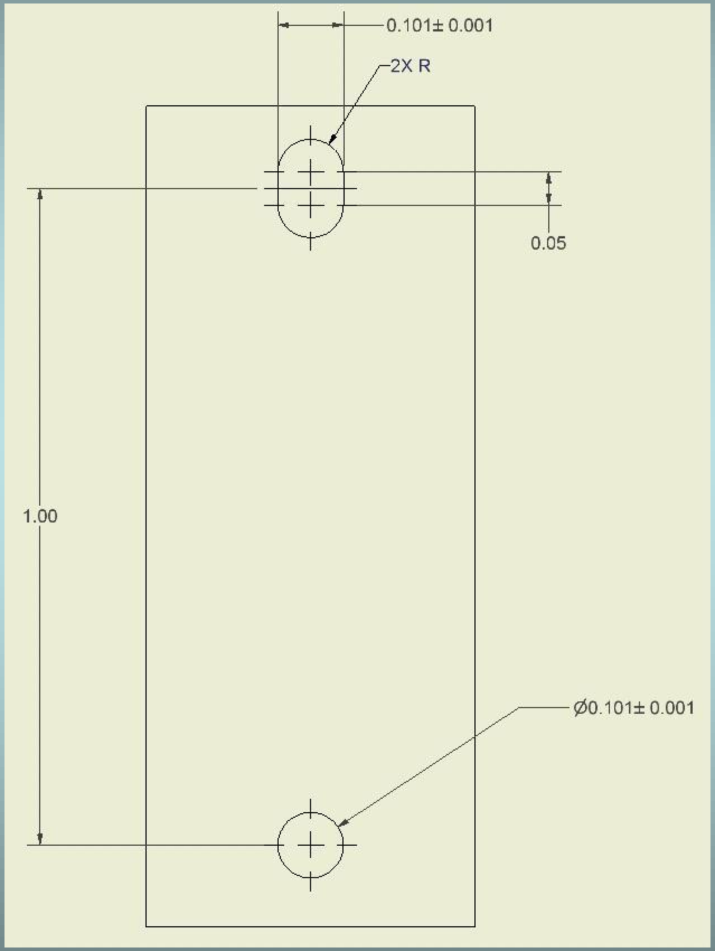
Green Plate Drawing

- The hole has a tight diameter tolerance.
- The slot is milled with a tight width tolerance but loose length requirement and position requirement.
  - The length of the slot has to be at least as long as the tolerance of the pins spacing.
- Regardless of the exact position of the pins, the green plate can always be placed on the pins of the blue plate.
  - This design says you can loosen the positional tolerance on the blue plate pins which makes it cheaper to produce.



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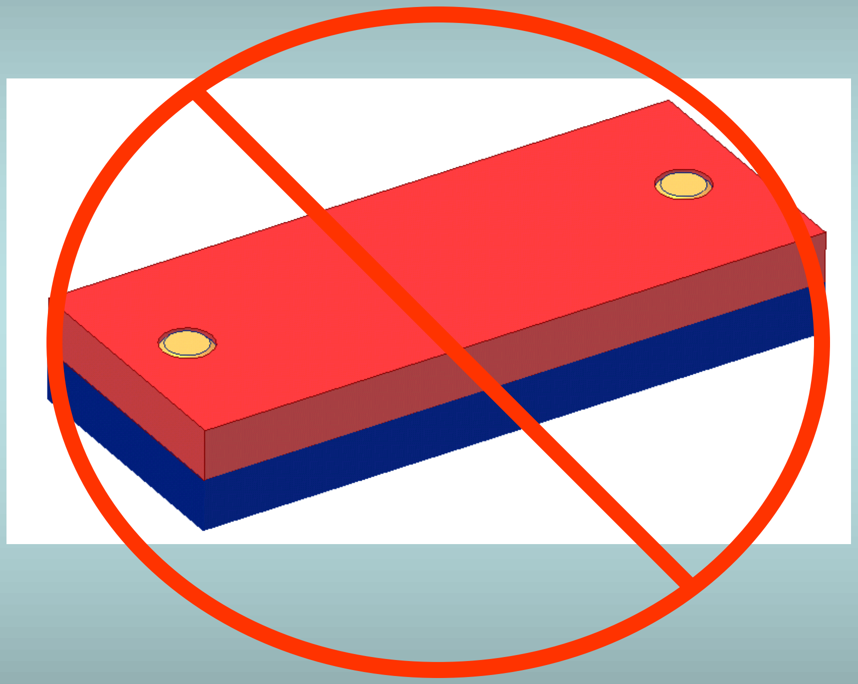
What’s Wrong with the Red Plate?

- Both holes in the red plate try to limit the same two translation degrees of freedom which means the part is “over constrained”.
- “Over constrained” is not inheritably wrong but it is not efficient , may be more costly, and harder to assemble.
- SolidWorks will tell you when a part is over constrained ***with conflicting constraints***.



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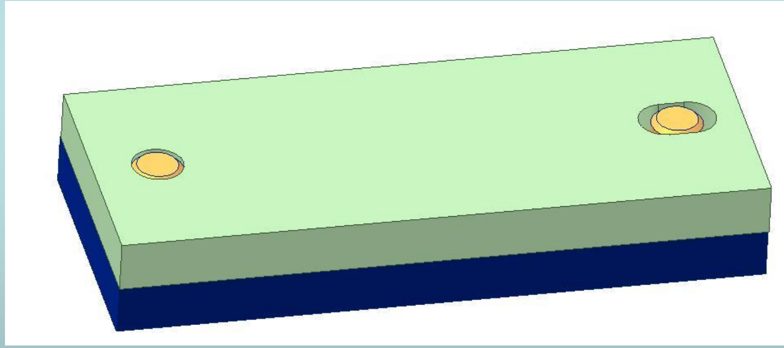
The Moral of the Story

- General Moral: Over constraining assemblies is a problem waiting to happen.
- Specific Moral: When you have two pins holding parts together, the mating part should have a hole and a slot.



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3D Parametric Modeler

The simple concept of degrees of freedom is seen repeatedly in parametric modeling:

- When sketching cross sections for part extrusions, you will try and remove all the degrees of freedom by adding dimensions and geometric constraints.
- When assembling components, parts will move according to their unconstrained degrees of freedom.

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Mating Rituals of SolidWorks

- The name of the mating game is removing degrees of freedom.
- Unlike the real world, if you try and overconstrain something you get an error message.

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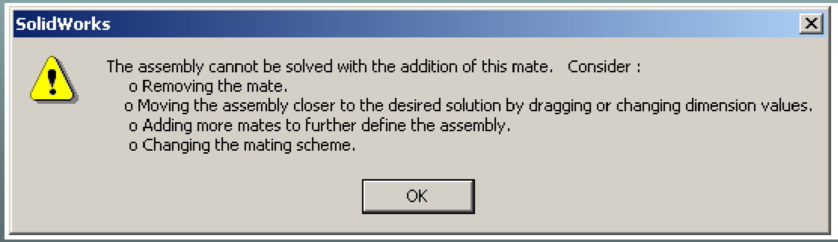

Topic 3: Seven Guidelines

❶ Reduce Part Count

❷ Drive toward Modular Design

❸ Z Axis Assembly / Reduce Processing Surfaces

❹ Process in the Open

❺ Establish Symmetry or Exaggerate Asymmetry

❻ Parts Handling / Mating / Nesting

❼ Avoid Flexible Processes

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Common Sense

- As we've said before, it turns out that common sense is not nearly as common as we would like to believe.
- In the heat of the design battle, the first casualty is always common sense.
- The following seven guidelines should always be in the back of your mind.

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1 - Reduce Part Count

- There’s an old manufacturing saying - “the most reliable part in an assembly, is the one that isn’t there”.
- Designing multiple requirements into a single part can be a challenge and may change the fabrication process:
  - Machined parts become stamped parts.
  - Stamped parts become plastic parts.

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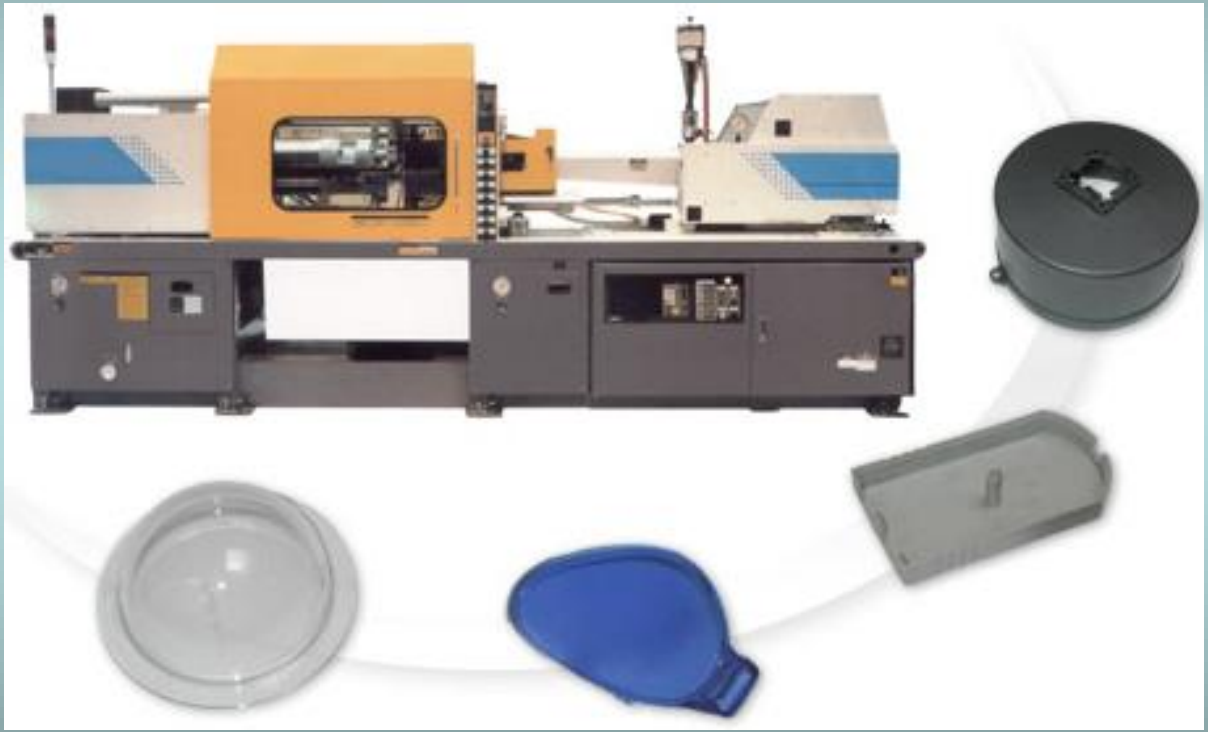
Injection Molding

Buying expensive dies from $5k to $50k allows you to make very inexpensive parts from $0.10 to $5 that can have many features thus lowering the total part count.



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We'll talk about plastics later tonight.

Fasteners

Get rid of them wherever possible!

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Polyclutch

- Original Bill of material was a base ring, 3 springs, 3 pawls with 3 pivot pins, and center ratchet.
- New single piece plastic part is molded in one shot - spring and ratchet break free on first use.

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11 versus 1?

How Do I Reduce Part Count Using SolidWorks?

- Create assembly drawing with a bill of materials early in the design process and constantly want it.
- When designing fixtures, use Toolbox hardware as much as possible.
- When design products, don’t use Toolbox hardware – create all models
  – *make it painful to add new stuff which drives you use existing parts*

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2 - Drive toward Modular Design

- Some people hear this and imagine lots of sub-assemblies - it is much more than that.
- Modules can be designed, built, debugged, and tested separately.
- Common modules can form building blocks for multiple final configurations.
- You're not ***"re-designing the wheel"*** with every project.

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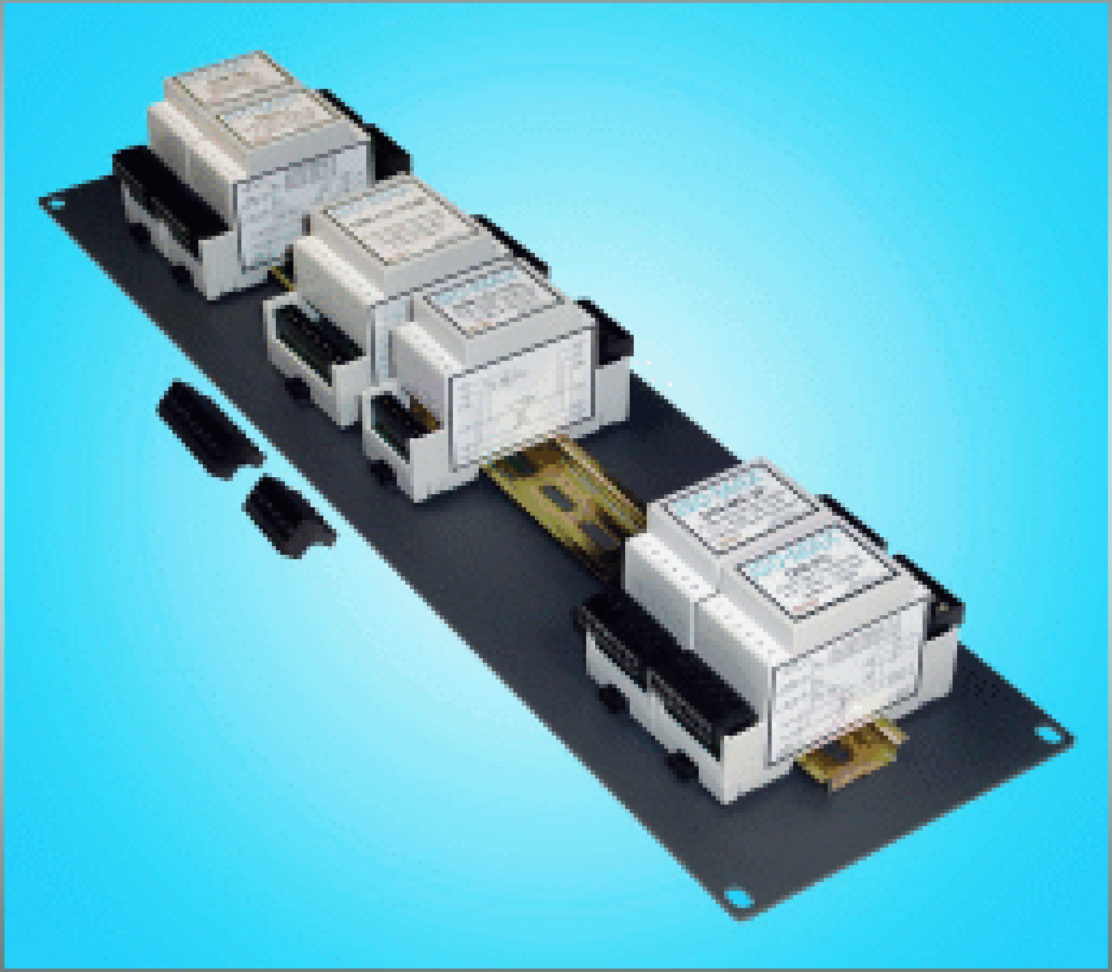
Modular Housing?

Not exactly what I had in mind but it does enhance manufacturing because housing can be built in a factory and not at the job site in the elements.

Modular DIN rails

- One of the best examples of modular design is the use of modular DIN rails for controllers.
- Mix and match your exact requirements from off the shelf solutions.



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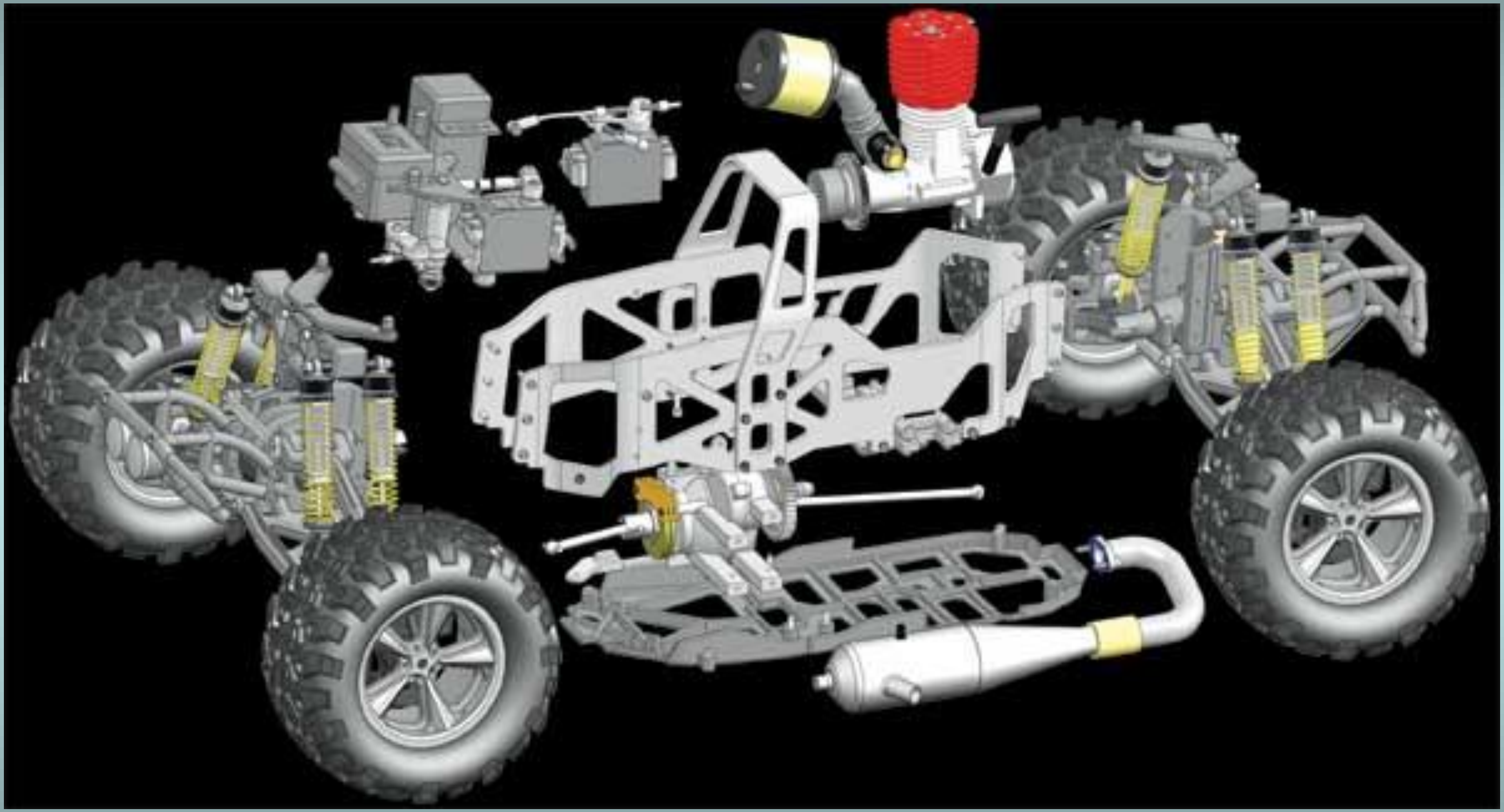
Extreme Modularity



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How Do I Increase Modularity Using SolidWorks?

Create sub-assemblies of common groups of parts early in the design process so it will be easier to add them later.

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3 - Z Axis Assembly / Reduce Processing Surfaces

- The most cost effective robotic or automatic assembly is one that involves placing the component in a pure Z axis direction.
- I have a saying from years of working in Mexican assembly houses that the best manual assembly is one that is designed for automatic assembly.

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Z Axis Assembly

- Robots are great at picking things up and placing them.
- Robots aren't so good at snaking things together.

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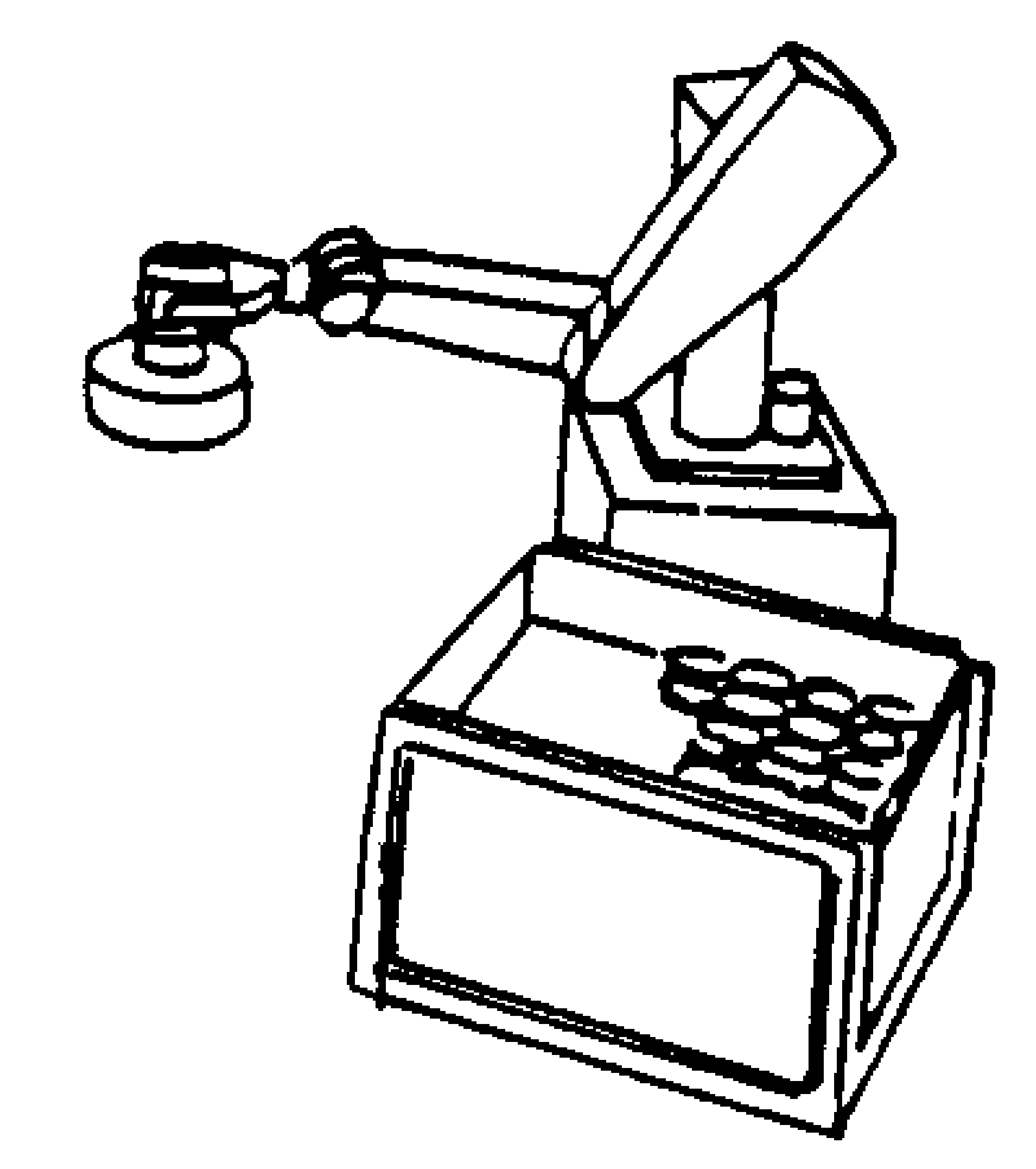
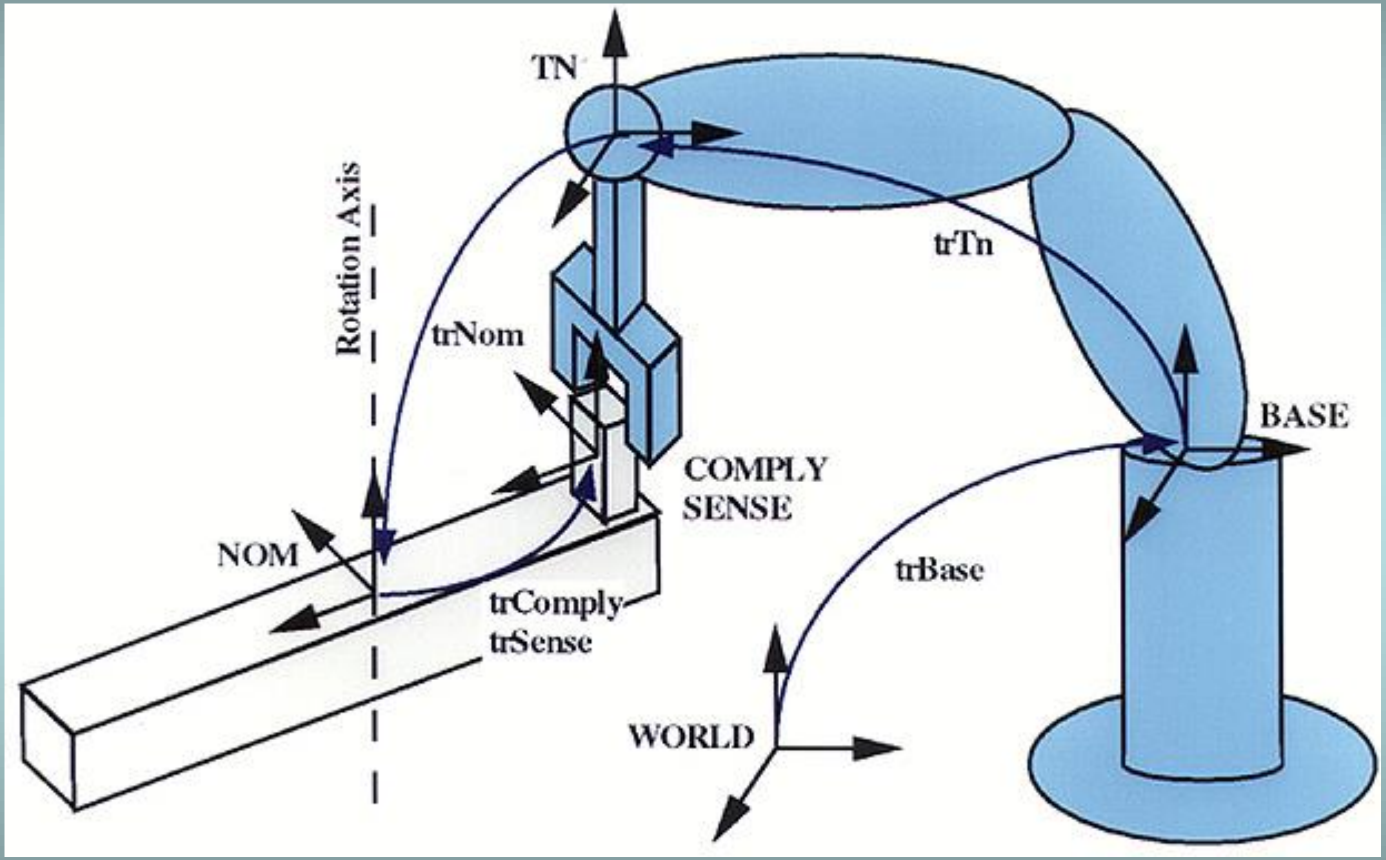


Z Axis Assembly
Articulated Arm



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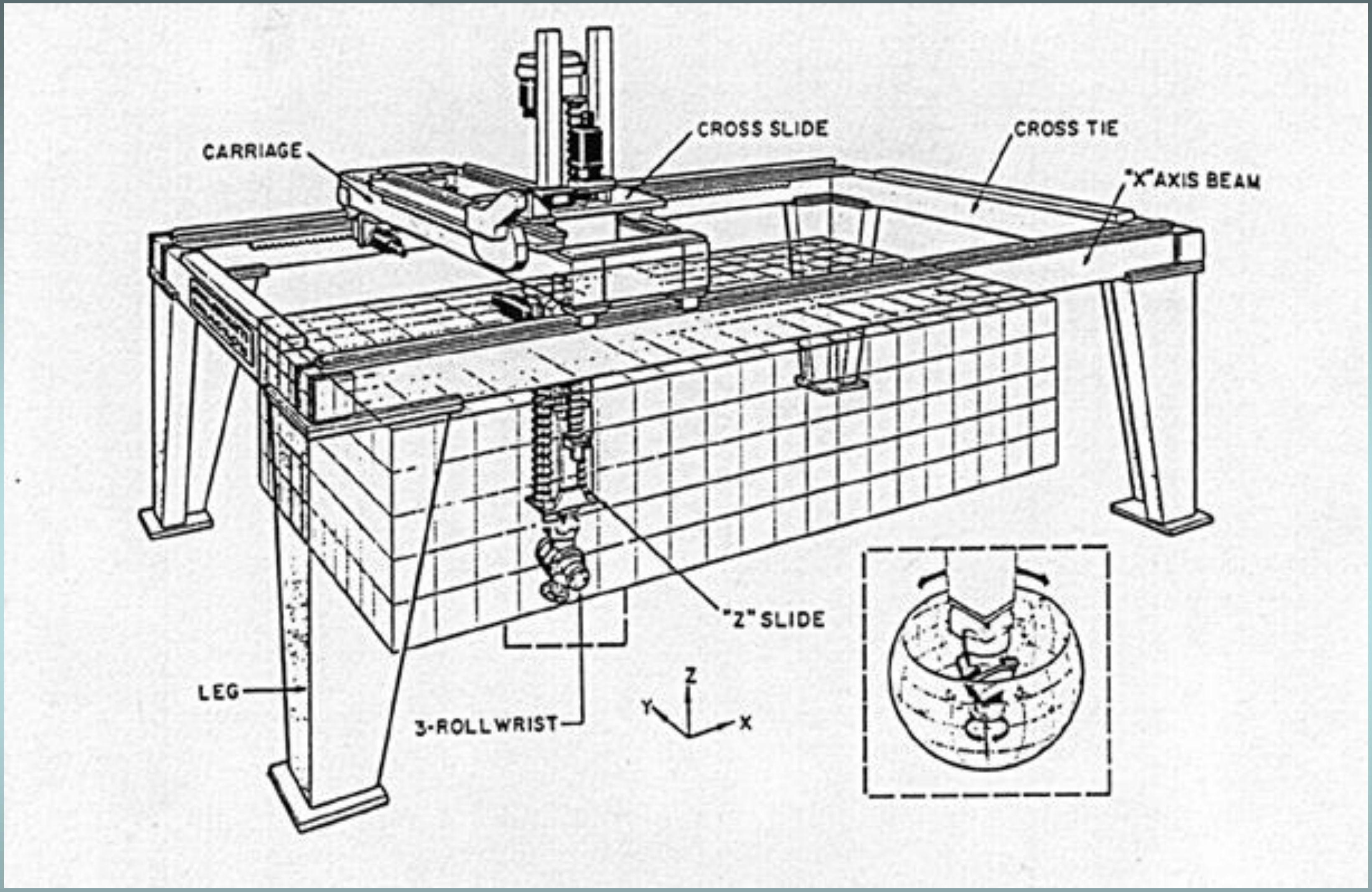

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Z Axis Assembly

Gantry

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Pick and Place Machine

Walther PPK

- Several pieces of this gun must be "snaked" into place.
- Also, parts come in from the bottom, back, and both sides.
- I wonder if James Bond knew he was carrying such a DFMA nightmare.

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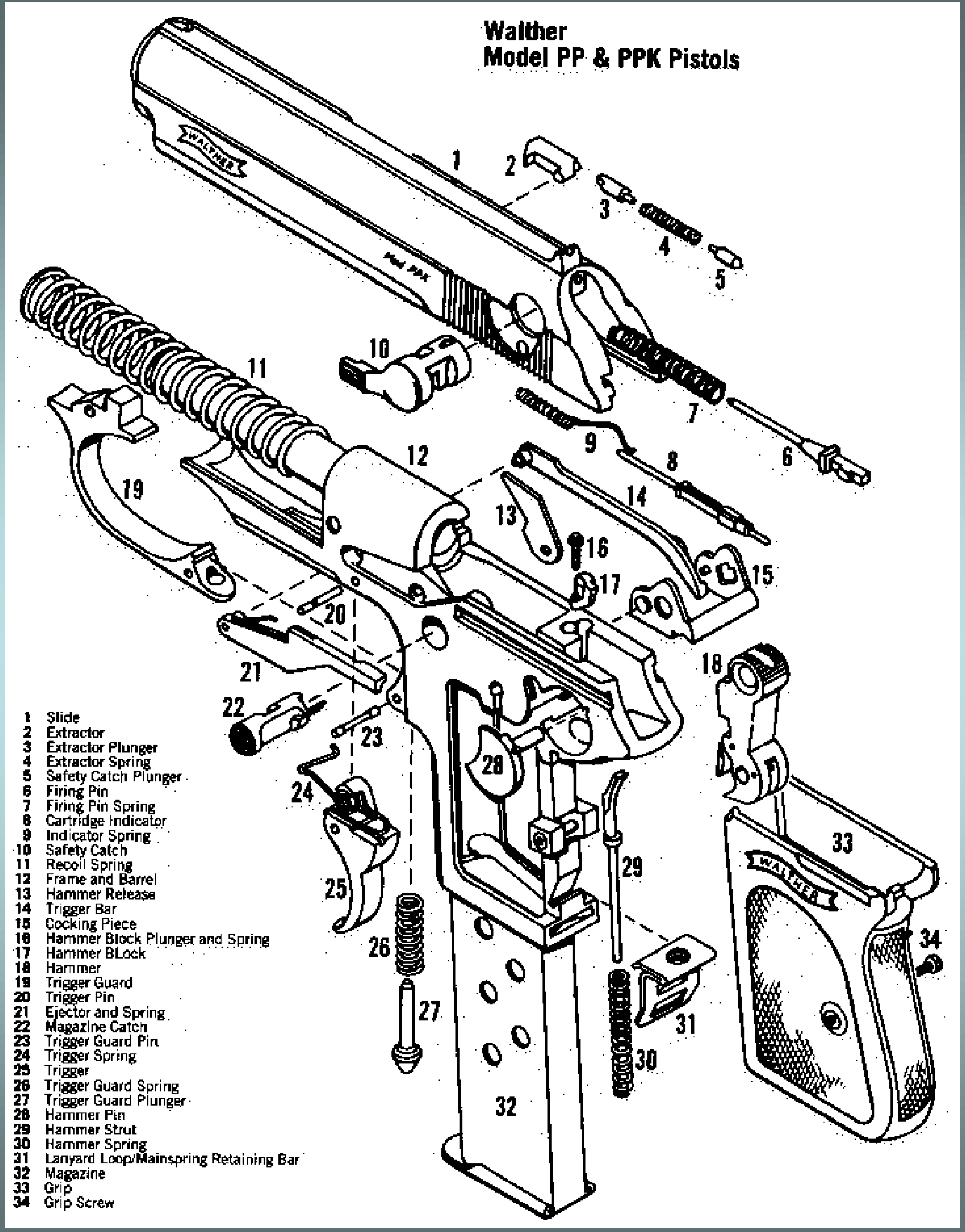
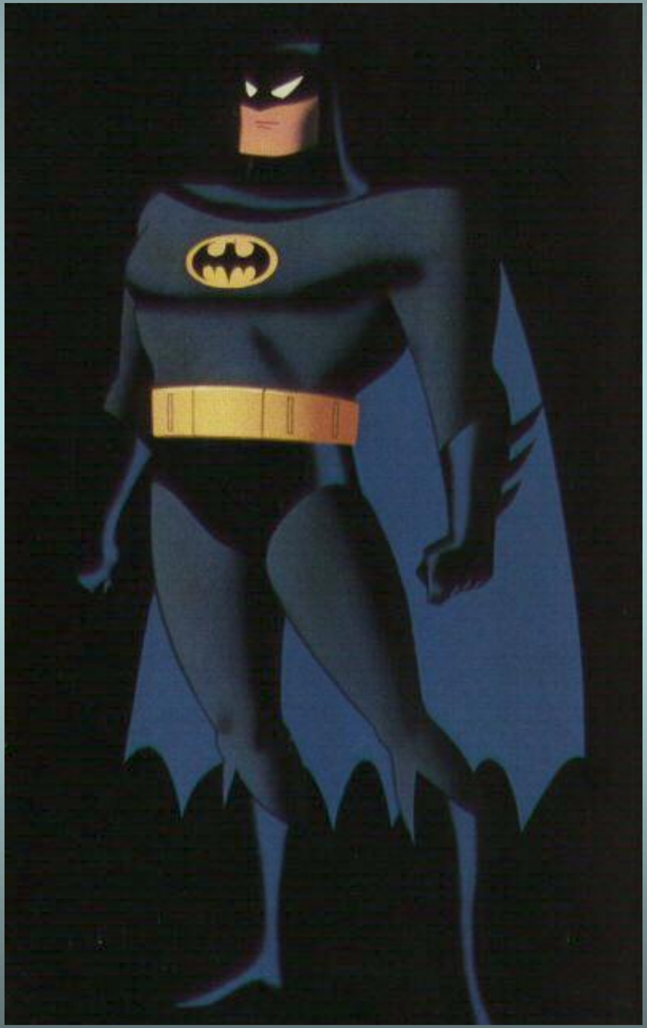


4 - Process in the Open

- Except for cave divers and Batman, most people prefer to work in an open space.
- It is hard to assembly items down in a hole or inside a box but it is easy to work on a plate and then place a cover over it.



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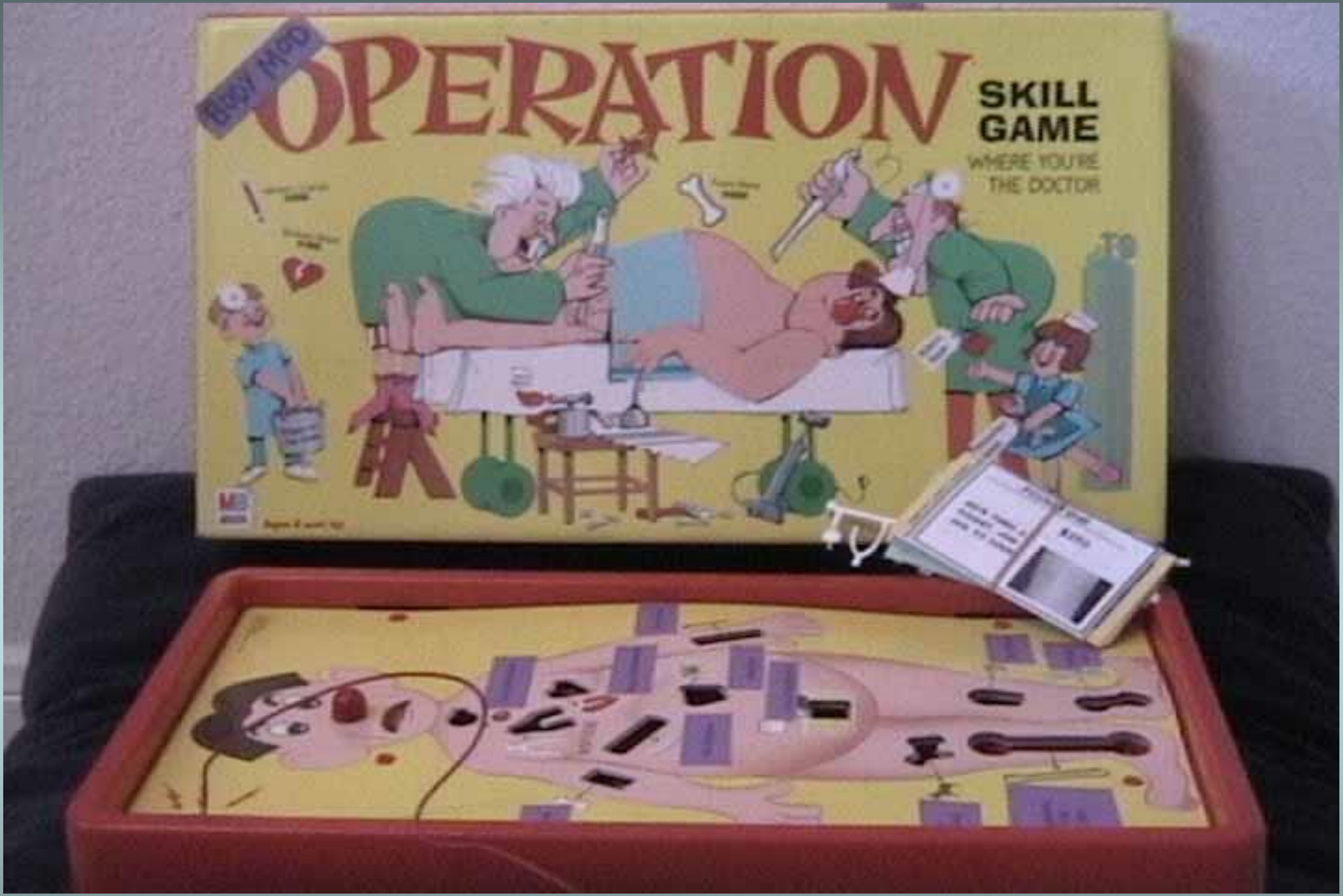

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Nervous about DFMA?

Needle Nose Pliers

- These are a ***great*** tool to have in your toolbox.
- They are a ***lousy*** tool to require on an assembly line.

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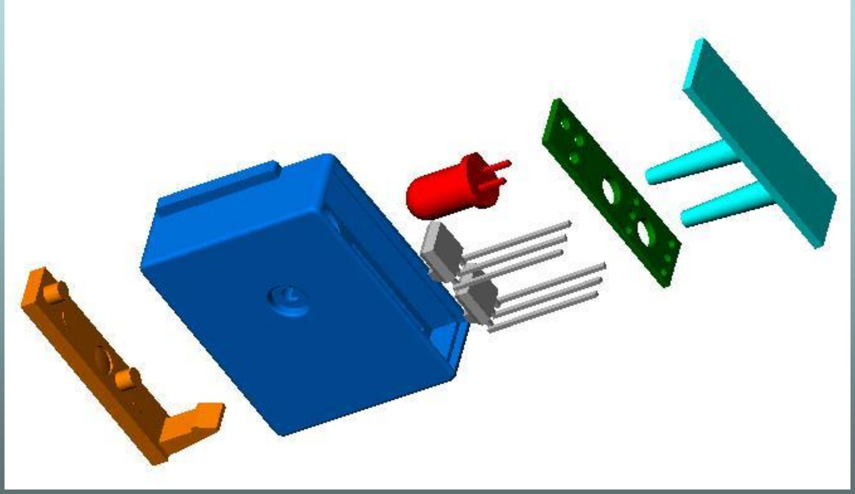
How Do I Reduce Process Surfaces and Increase Processing in the Open Using SolidWorks?

Create exploded views and look for what my CAD students call the "snaky trails".



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5 - Establish Symmetry or Exaggerate Asymmetry

- Every component in an assembly has two geometric shape choices:
  - Symmetric
  - Asymmetric
- There is no inherent benefit to one shape over the other unless you allow an asymmetric part to go into a symmetric position.

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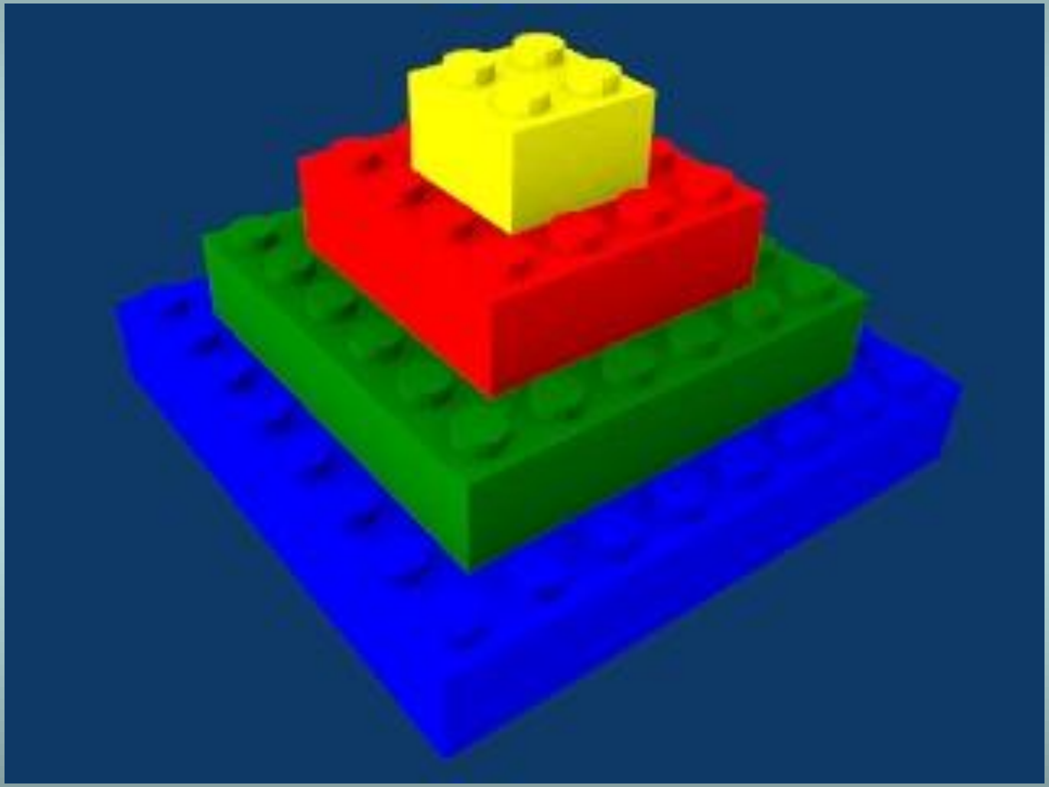
Symmetry



This is something my 4 and 5 year olds understand completely!

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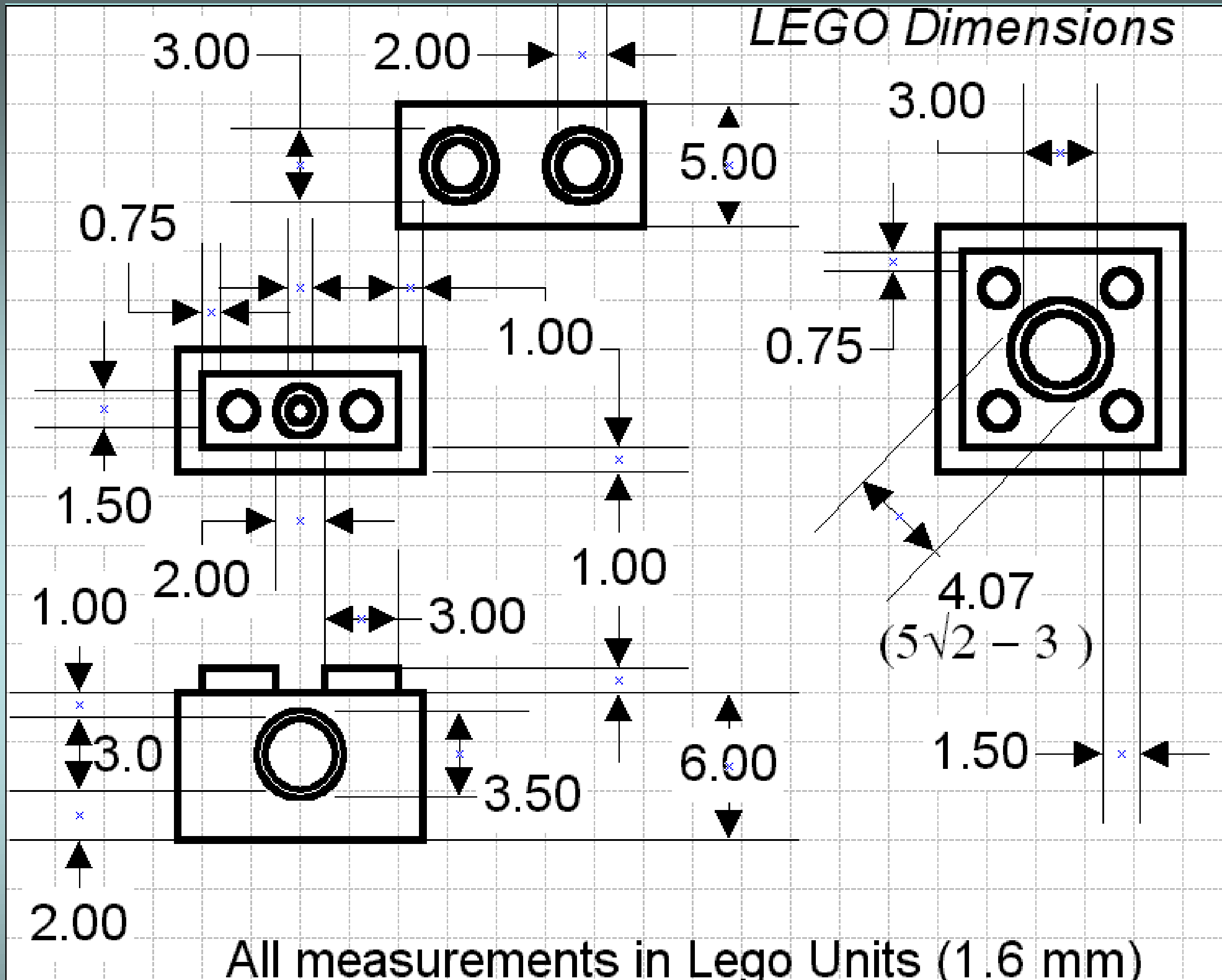

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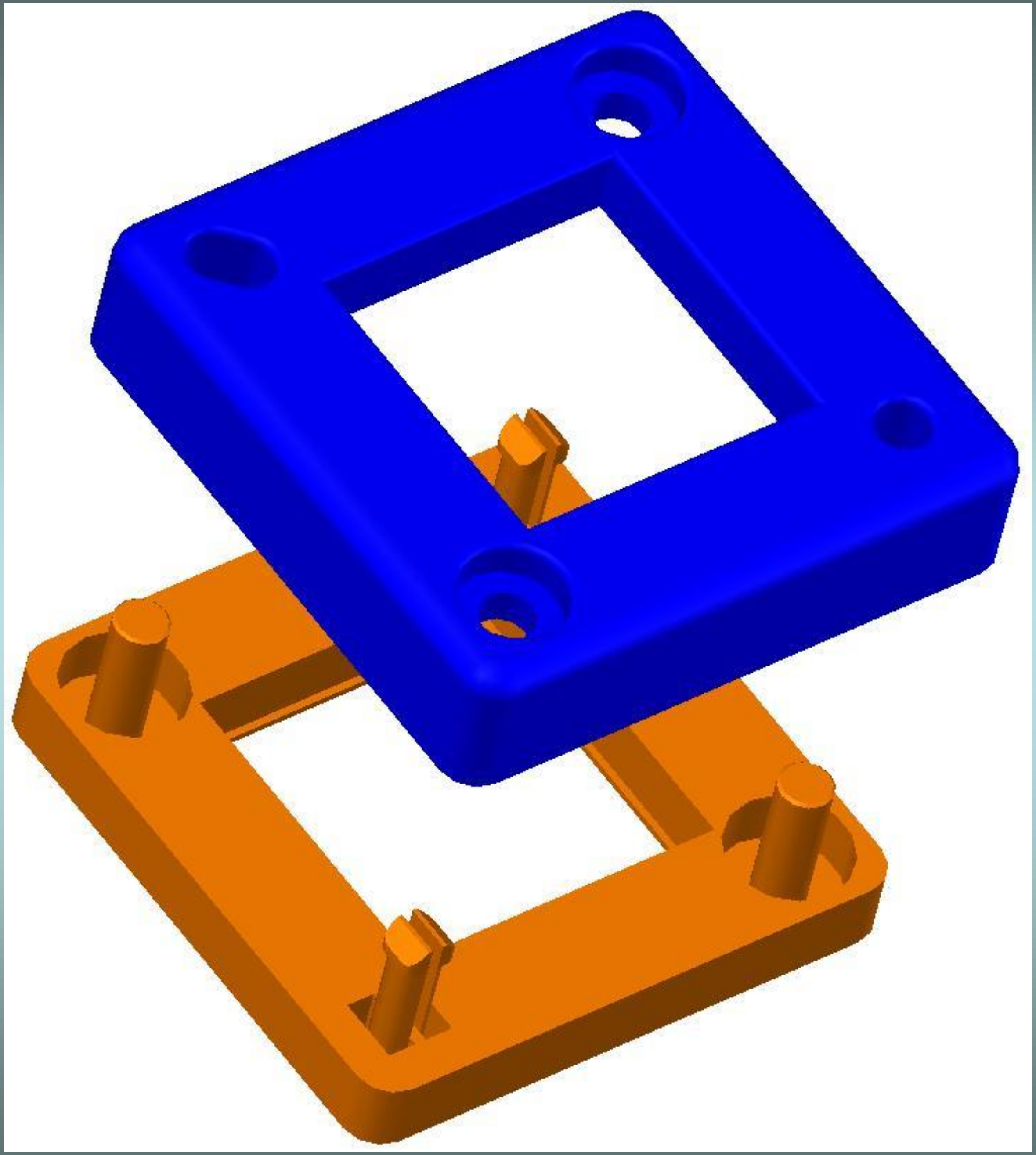
Lego Units? 1/16”

Socket Design 1

- Appears symmetric but it only goes eight possible ways.
  - Bad design.
- Note the hole and slot.



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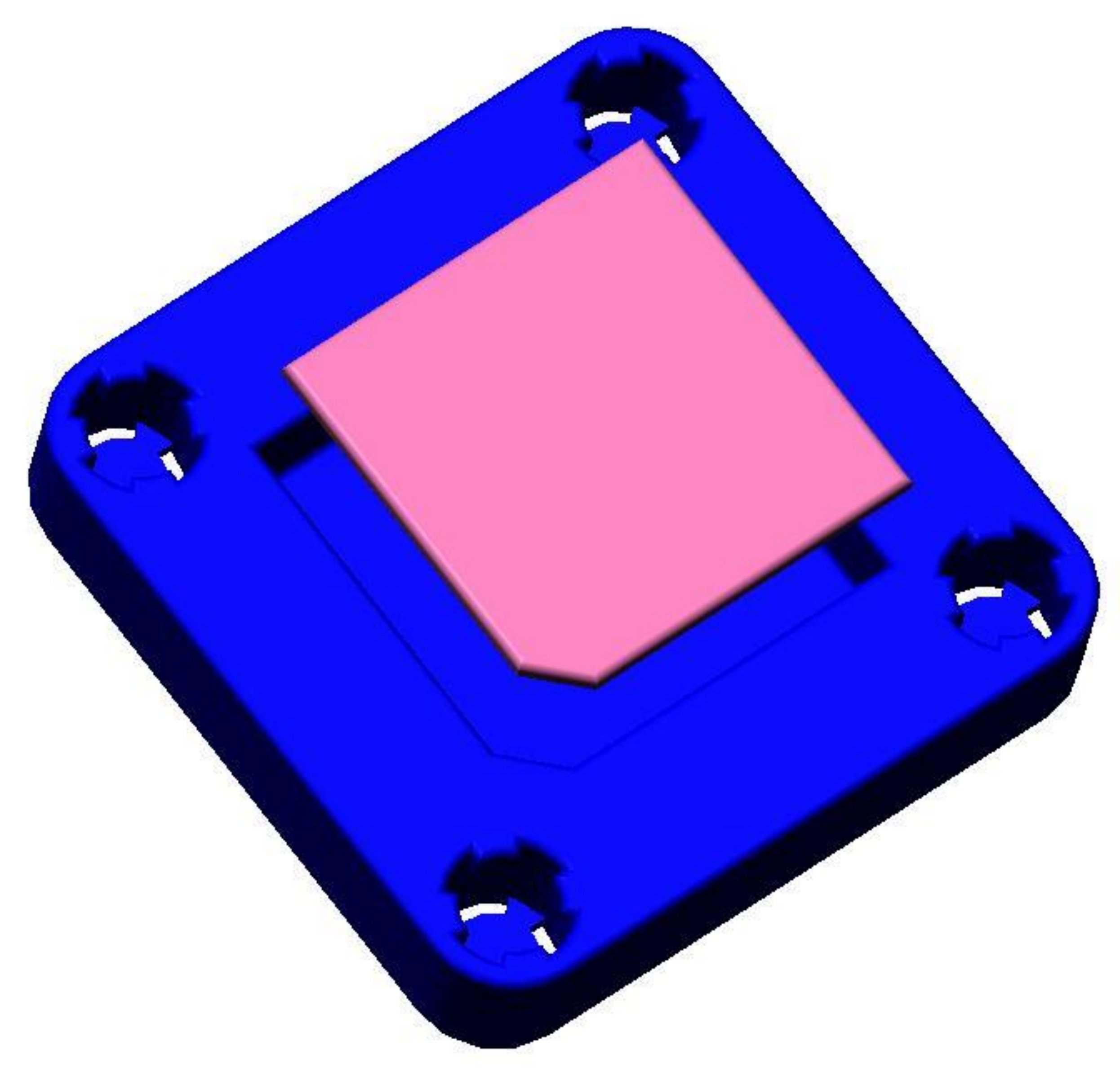
Socket Design 2

- "Square part" goes into "square pocket'.
- Chamfer corner limits insertion.
- Good Design.



How Do I Affect Symmetry Using SolidWorks?

- Want Symmetry? Use mirror and array commands at the end of your feature trees to make parts.
- Want Asymmetry? Add a single polarizing feature in both mating parts such as a pin and hole, tan and a slot, or matching chamfers.

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6 - Parts Handling / Mating / Nesting

- There are a lot of components of this concept:
  - Picking and holding parts
  - Placing parts into an assembly
  - Untangling parts
- All three are grouped into one area since they all involve ergonomics and part geometry.

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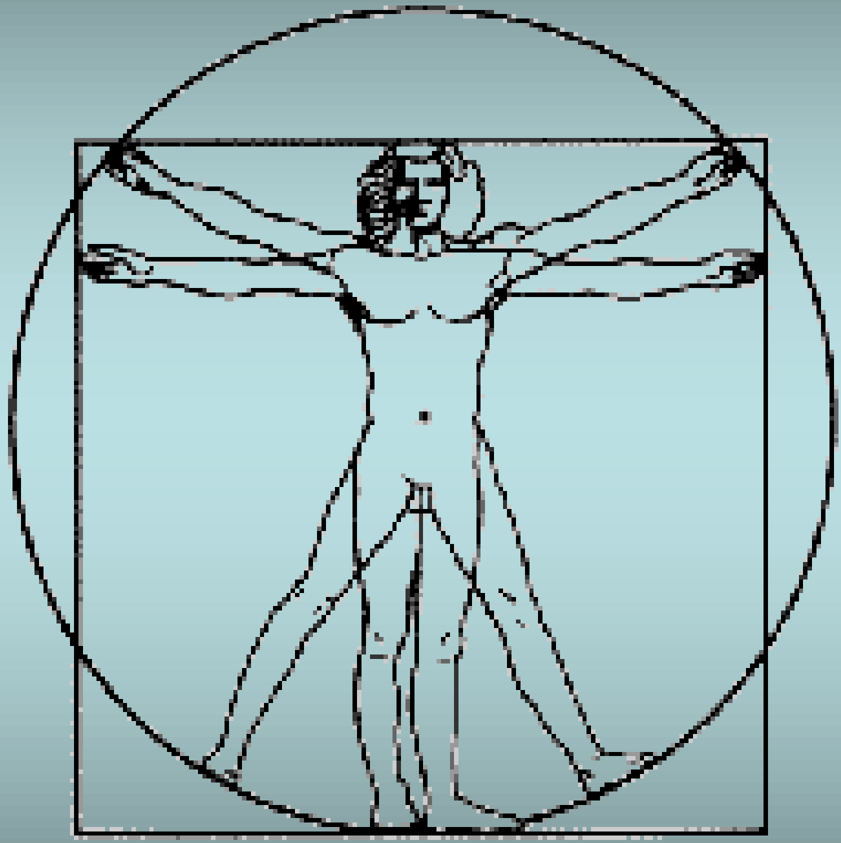
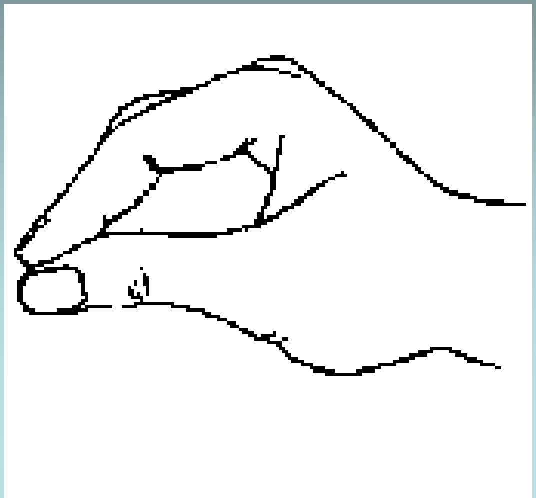
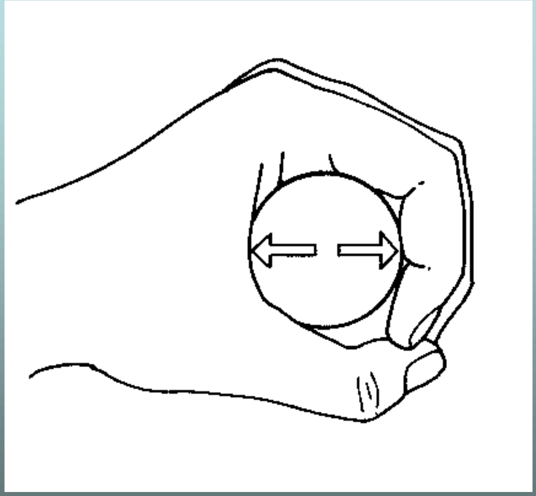
Ergonomics







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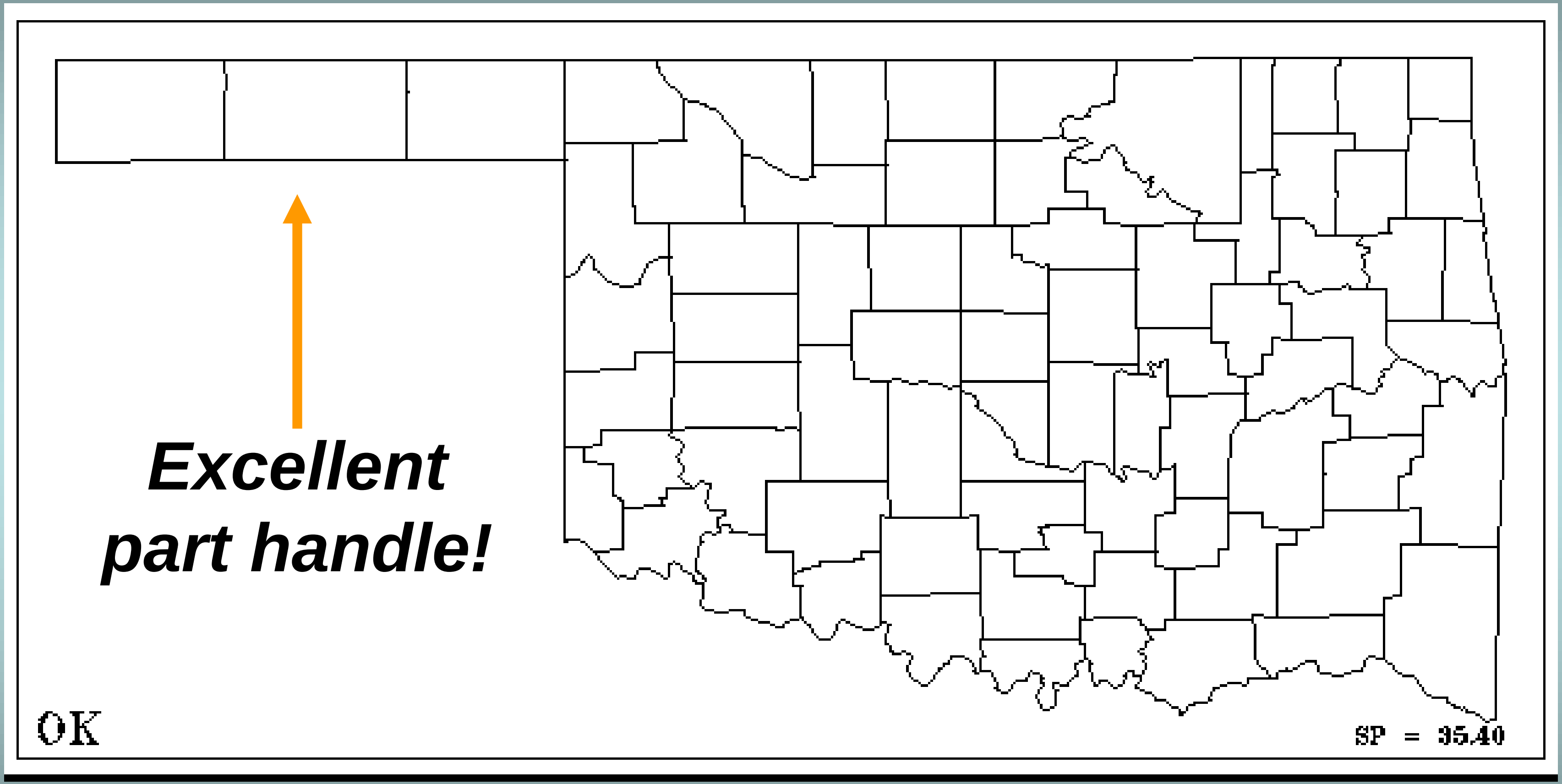
Oklahoma Panhandle



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The Ultimate Nesting

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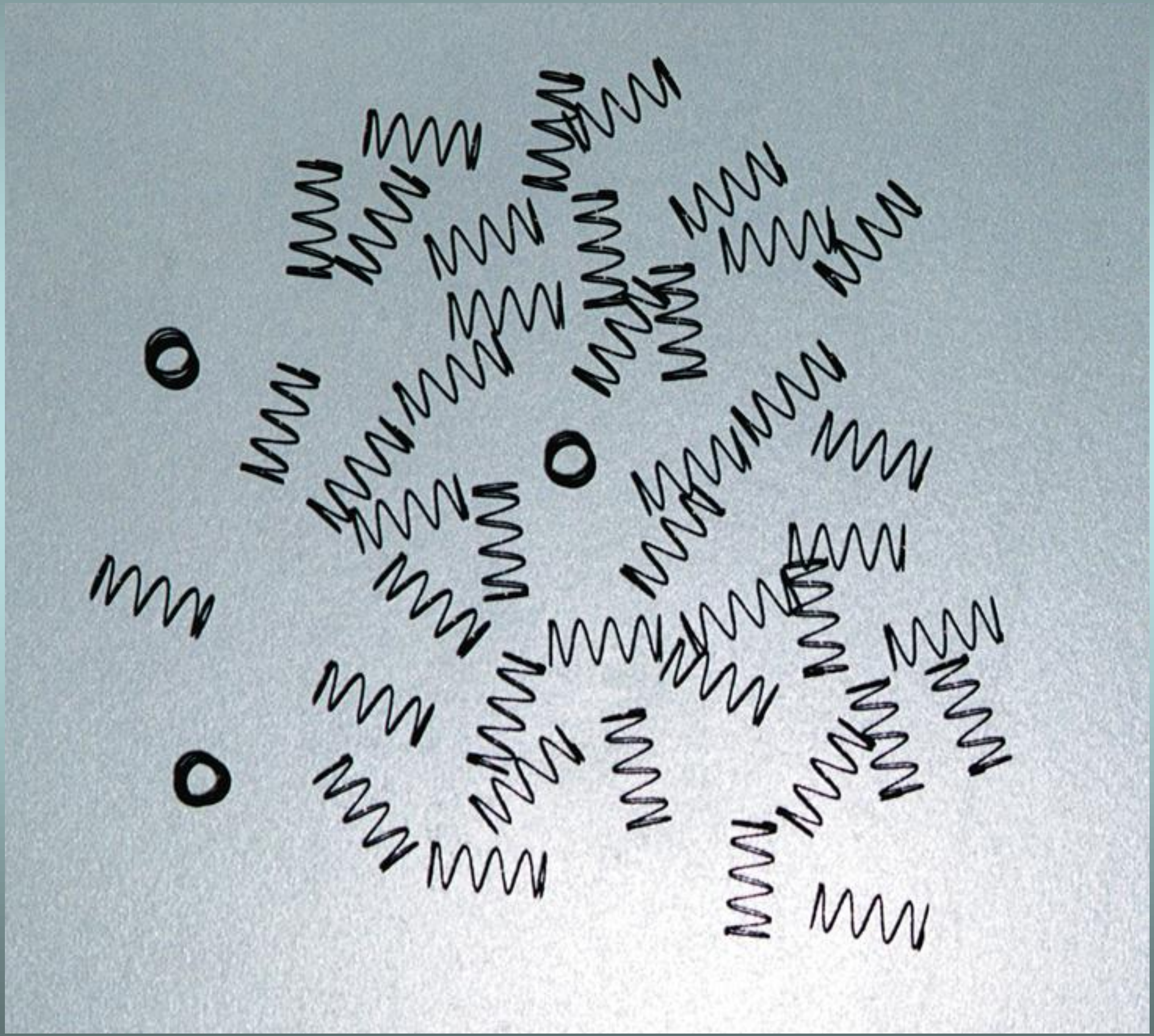
"Matryoshka"

Untangle Springs



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Untangle Springs, Please?

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How Do I Increase Parts Handling, Mating, and Nesting Using SolidWorks?

- Improve Parts Handling: Always note the size and centroid of parts (part properties).
- Increase Mating: Make sure parts don't just sit on other parts, make them nest.
- Decrease Nesting: Make a subassembly of the same parts and see if they will lock together.

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7 - Avoid Flexible Processes

- What's a flexible process?
  - Tubing
  - Wiring
  - Adhesives
- Easy to say, hard to do.
  - There's a lot of design opportunities that cannot be produced without flexible processes.
  - Still, look at the true "cost of ownership" to decide if you can really afford to use a flexible process.

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Tubing

- Flexible hoses are unpredictable.
- Rigid tubing is repeatable.

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Wiring

- "Flying leads" are the worst!
- PCB's are the best.

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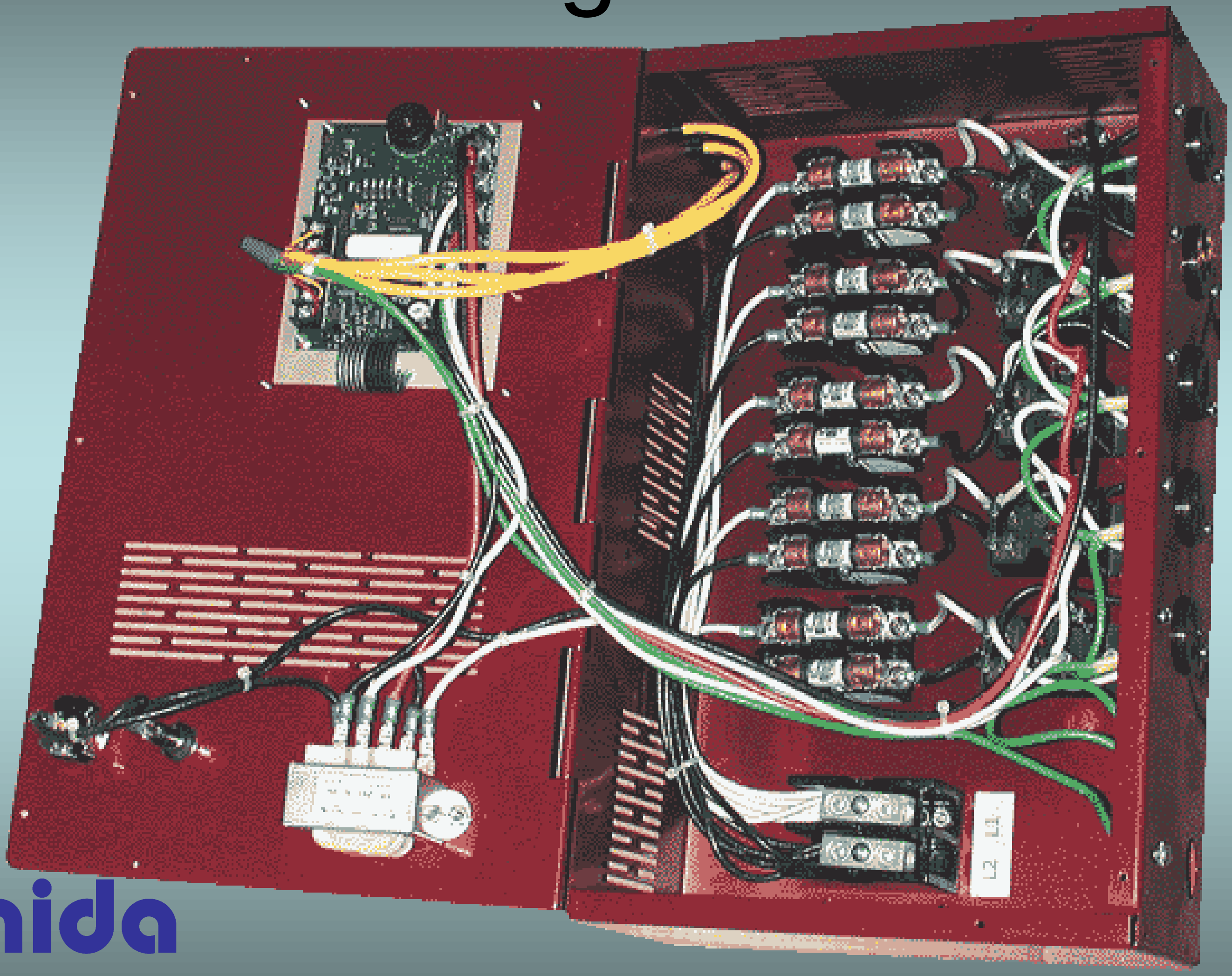
Wiring Panel



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Adhesives

- You would be proud if you built one of these in your garage.
- You should be ashamed to put this into production.

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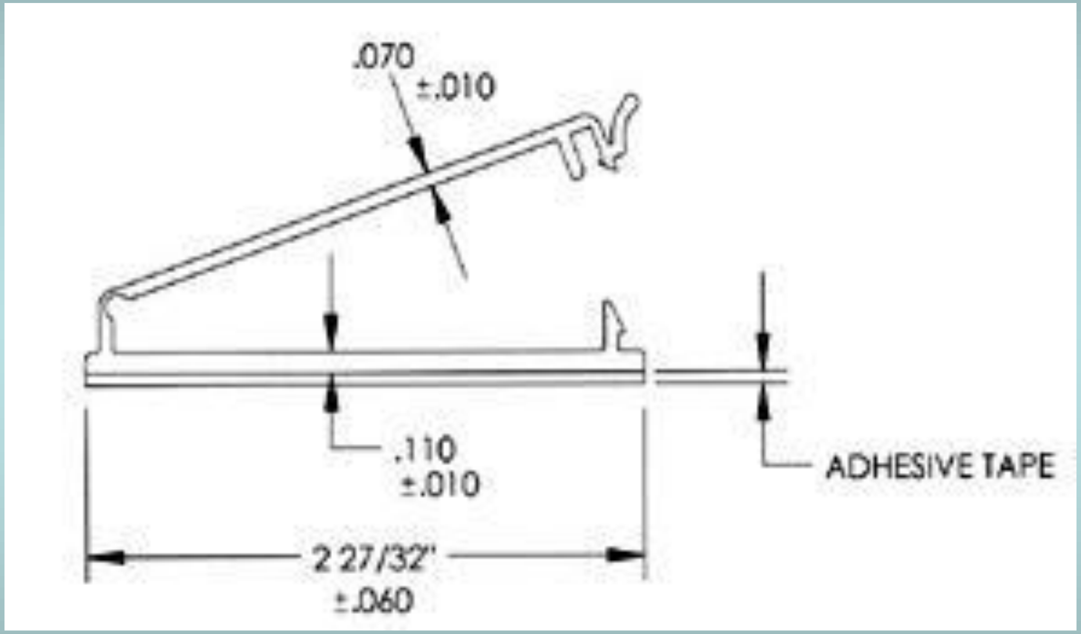
Adhesive

- What's wrong with a little strip of tape.
- Tape comes off.
- Tape needs to have the adhering surfaced prepped.
- Tape must be accurately placed.



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How Do I Avoid Flexible Processes Using SolidWorks?

- If you find yourself blazing new trails in “blob” construction or learning new ways to curse the words “3D Splines” then rethink the flexible process you are adding to your assembly.
- Watch for notes on assembly drawing saying things like “glue”, “adhesive”, or “as required”.

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Topic 4: Plastics

- There are a lot of plastics resins.
  - Polycarbonate (PC) - Lexan
  - Polyethylene (PE) - film, tubing, pipes, trash bins
  - Polyamide - Nylon
  - Polyvinyl Chloride (PVC) - pipe
  - Acrylonitrile - Butadiene - Styrene (ABS) - used everywhere
  - Polystyrene (PS) - cheap - egg cartons to jewel cases
- And many, many, many more…

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Plastic Container Identification Code

(found on the bottom of coded containers)

Code	1	2	3	4	5	6	7
Abbreviation	PET	HDPE	V or PVC	LDPE	PP	PS	Other
Full name	Polyethylene Terephthalate	High Density Polyethylene	Vinyl or Polyvinylchloride	Low Density Polyethylene	Polypropylene	Polystyrene	A mixture or combination of resins
Is it recyclable in Irving?	YES	YES	YES	YES	YES	No	YES
Can it be transparent?	Yes	Yes	Yes	No	Yes	Yes	Yes
Typical containers	soft drink, juice, water, peanut butter	milk, laundry detergent	shampoo	honey, mustard	syrup, sour cream, cream cheese	Foam cups, yogurt, egg cartons	Catsup, pudding, mayonnaise

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Recycling Codes

Polymer

- Plastics are made up of chains of molecules.
- A strand of this chain is known as a polymer.
  - “Poly” means “many”
  - “Mer” means sufficient
    - No that’s “mere”, I have no idea what “mer” means.
- Plastics are polymers of a carbon unit.

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“Co” <u>vs</u> “Homo”

- “Acetal is a linear thermoplastic polymer of oxymethylene units”.
  - From The Modern Plastics Encyclopedia.
  - We’ll talk about “thermoplastic” later.
- DuPont sells a homo-polymer of Acetal called **Delrin**.
  - Homo means it is a collection of the same polymers.
  - Very popular in the United States.
- Hoechst Celanese sells a co-polymer of Acetal called **Celcon**.
  - Co means it is a collection of similar but different polymers.
  - Not seen as much in the United States.

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Thermoset <u>vs</u> Thermoplastic

- A thermoset is a plastic that takes a permanent shape when exposed to a certain temperature.
  - The plastic will not change shape regardless of the exposure temperature.
    - Unless you count burning up as a shape.
- A thermoplastic is a plastic that takes a shape when exposed to a certain temperature and can be reformed whenever the plastic is exposed to that melting temperature again.

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Plastic Processing

- Thermosets are usually formed in a low pressure process like a transfer molding process.
  - These are not usually used in high precision components.
- Thermoplastics are usually formed in a high press process like an injection molding process.

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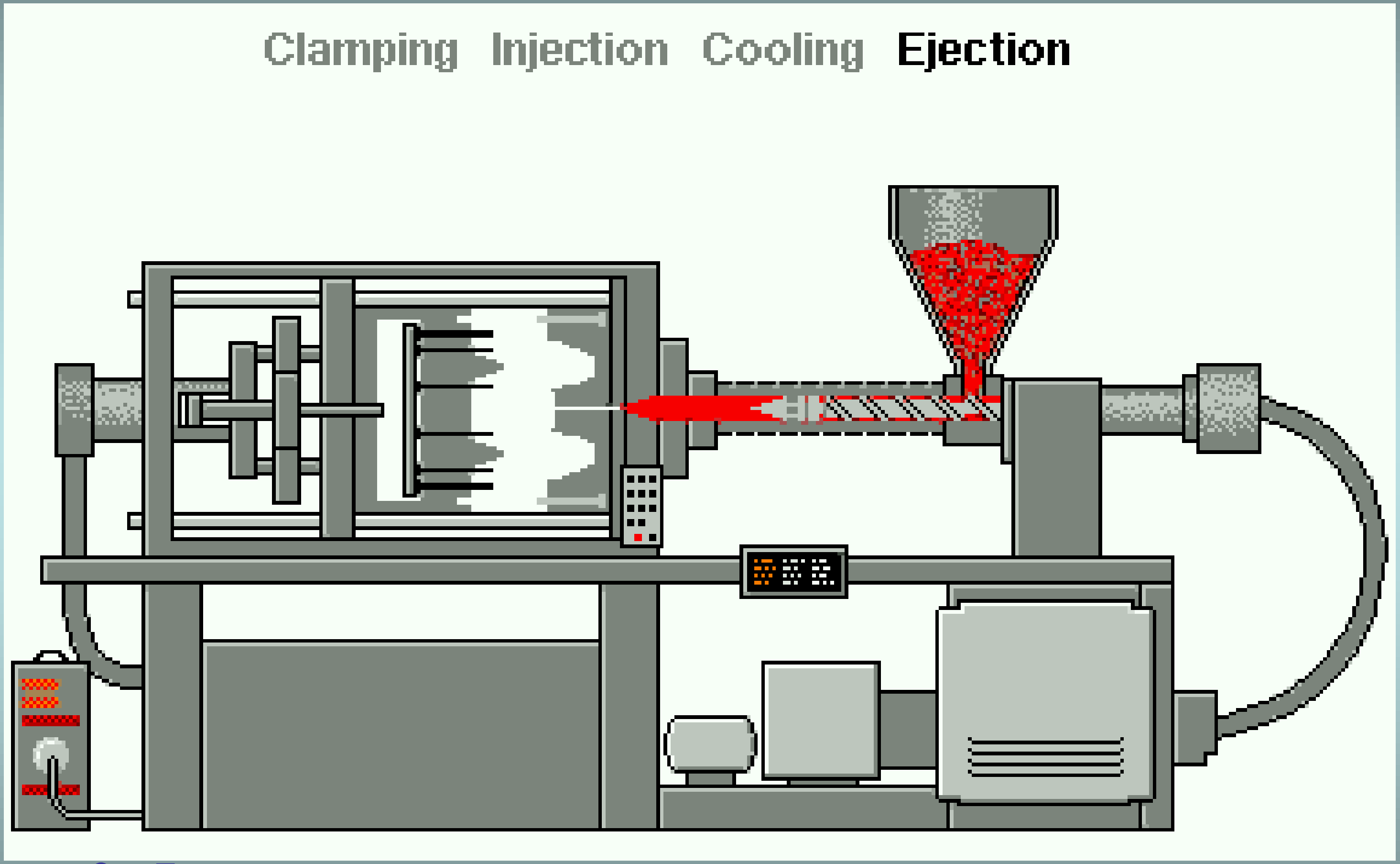
Injection Molding Animation



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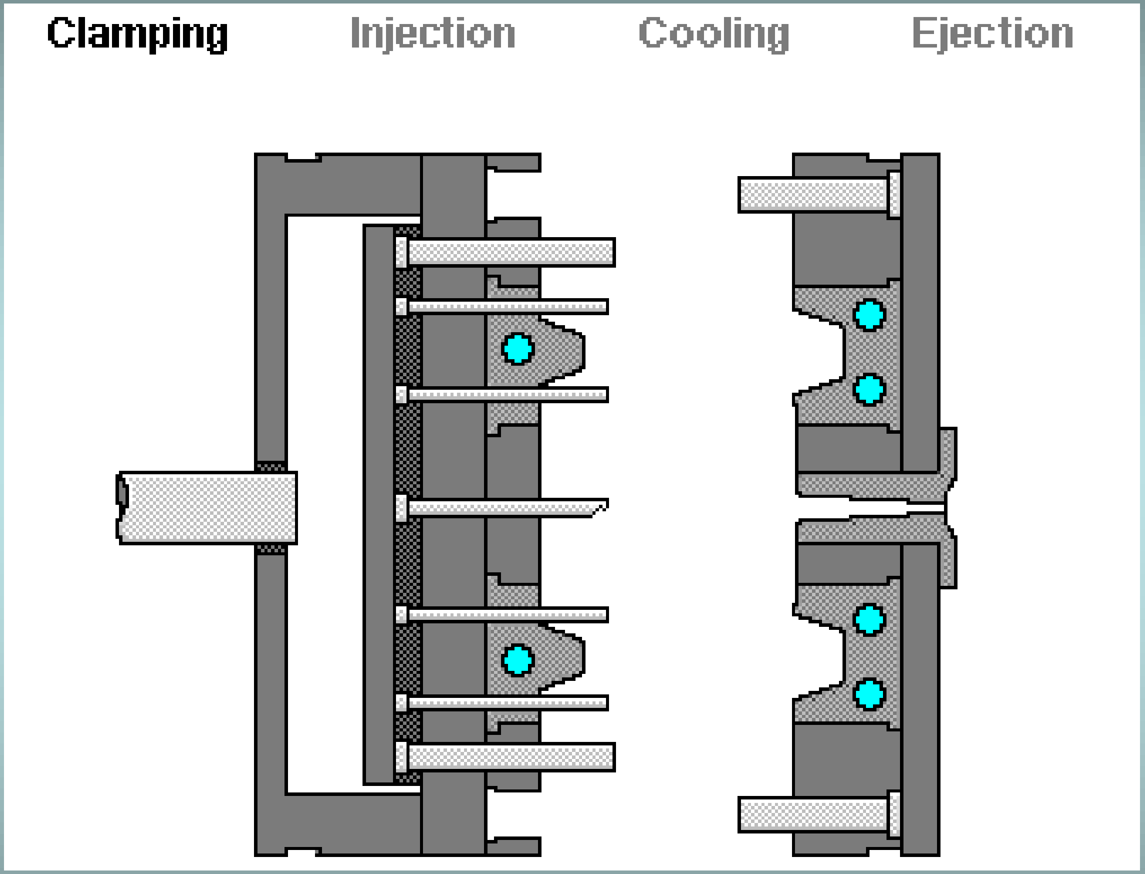
Courtesy of DME

Moldbase Animation



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Courtesy of DME

Slippery When Wet

- Some plastics change radically when exposed to moisture.
  - They don’t like water – hydrophobic.
  - Nylon is a common example of these plastics.
- Some plastics do not change dimensionally with the humidity level.
  - Acetal (Delrin) is hygroscopic.

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FEM Concepts

Many everyday problems are too large to solve by a single equation, inspection, or reason so you break a big problem into many smaller manageable problems and combine the results.

- Finite Element Methods break “continuum” problems down into a “finite” number of pieces, solve each little piece and add up the result.

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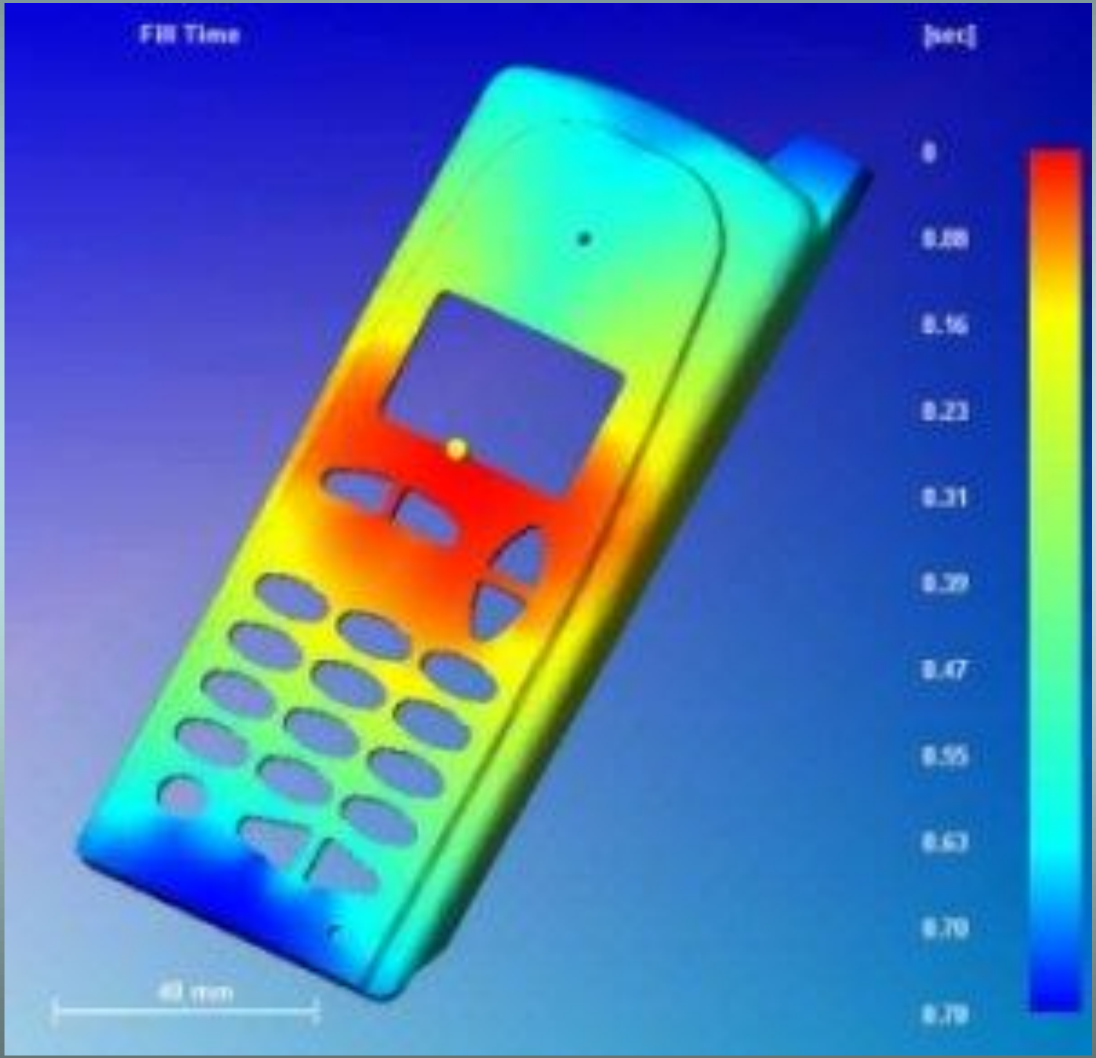
FEM Applications

- Stress Analysis
- Computational Flow Dynamics (CFD)
- Mold Flow Analysis



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Mathematical Background - Part 1

Everything's a spring

- For springs

  Force = Spring constant times deflection

  $F=kx$

- For bending beams

  $F=(AE/L)x$

- For pure heat conduction

  $q=(-k/L)(T_2-T_1)$

Ut tensio sie vis!

"As the extension so the force."

$\sigma=E\ \varepsilon$

Hooke's Law - 1670

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Mathematical Background - Part 2

Spring Rates are known as Moduli?

- The following equations are true:
  - $E=2G(1+\mu)$
  - $G=E/2(1+\mu)$
  - $\mu=(E-2G)/2G$
- Typical values for μ are .21 to .36 for metals and .3 to .5 for plastics.
- Therefore, G is always 2.42 to 3 times smaller than E.

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Mathematical Background - Part 3

Linear versus non-linear

- In FEM, linear takes on the strictest sense of the word:
  - proportional and ***passes through zero***
- Non-linearity's include:
  - stresses beyond the yield point
    - especially breaking!
  - material properties
  - fatigue
  - some geometry's

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Mathematical Background - Part 4

Stress representation

Stress may occur in six directions, but you only want to see a single value for the “combined” stress.

- Principal - uses the maximum value of all the stress components
- Von Mises - uses a combination of tension, compression, and shear stresses for the best practical “ductile” stress representation

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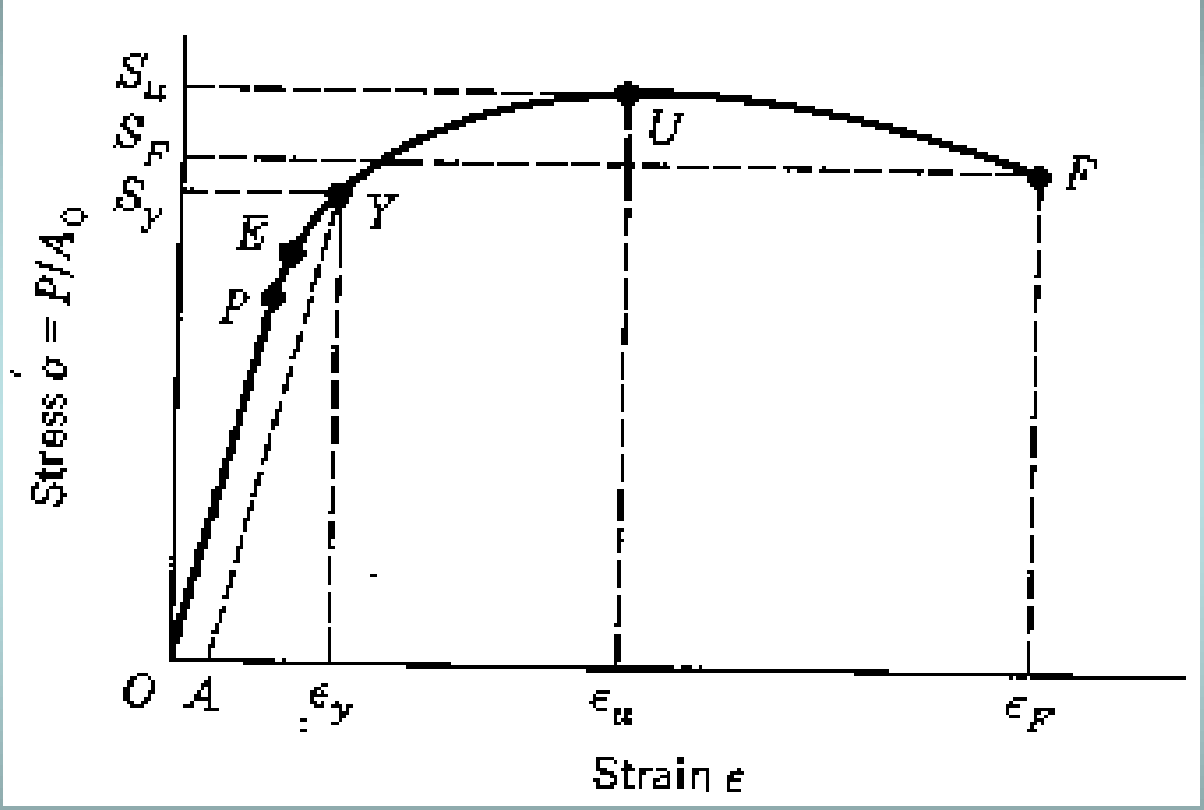
Mathematical Background - Part 5

Stress - strain diagram



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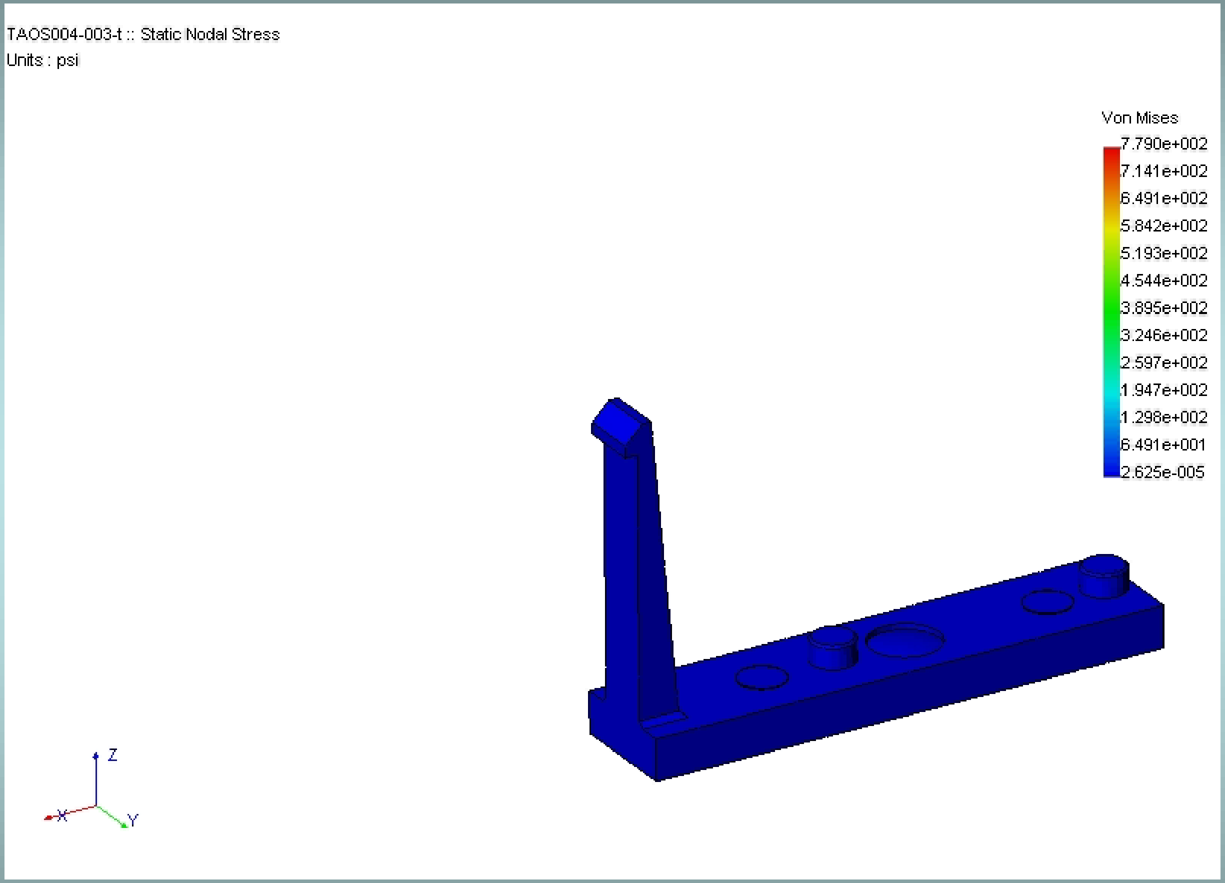
FEM Animation



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Pitfalls

- Use deflections to verify solution is reasonable.
- Make changes you know improve or worsen the problem to verify the solution is reasonable (especially "stress concentrations").
- Remesh with more elements in critical areas and verify the answer does not change significantly.

Computers don't lie
but sometimes
the truth is subjective.

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Other DFM Topics

The following topics don’t make the cut for tonight’s discussion but they all can improve the design for assembly and are discussed at length in my day long DFMA seminar:

- GD&T
- PFMEA ? DFMEA
- “Post Mortem”
- 3D Parametric CAD
- Communication
- “No Surprises” Management

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Farewell

If you have any questions about DFMA, please let me know.

Thanks

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