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Mistake Proofing

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Introduction

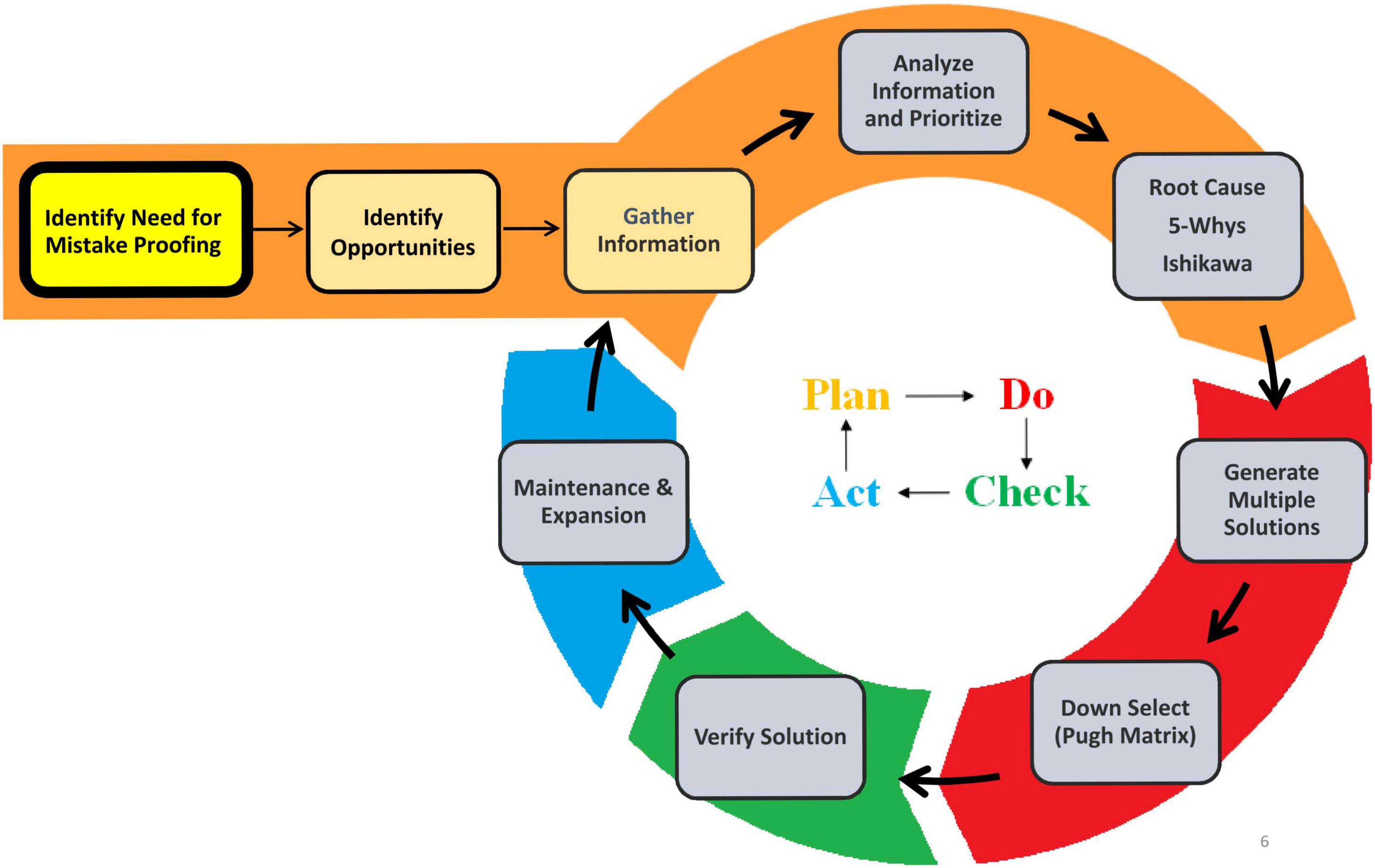
- Safety: Exits
- Bathrooms
- Who we are
- Who you are
  - Name
  - Organization
  - What do you want to learn today?

Agenda; *and a framework for Mistake Proofing activities*

- **Introduction**, what is mistake proofing and why should we care?
- **Plan**
  - How to prioritize Mistake Proofing opportunities.
- **Do**
  - Developing a toolkit of Mistake Proofing techniques, developing multiple solutions.
  - Choosing the best Mistake Proofing solution.
- **Check**
  - Verify the solution works.
- **Act**
  - Ensure permanence, look for opportunities to deploy broadly.

The Design Engineer's role

- But wait, if I'm a Design Engineer…why do I need to know about manufacturing mistakes and how to prevent them?
- *Answer:* Nearly every single manufacturing mistake has its roots in a design decision; if you are thoughtful enough, and not overly constrained, your product can achieve zero defects with minimum effort from the production floor.
- By understanding the source of defects, before you design your next product, you can incorporate Mistake Proofing from the beginning.
- By understanding the methods of preventing mistakes from becoming defects, you can design-in features to enhance mistake proofing.


Identify Need for Mistake Proofing
Identify Opportunities
Gather Information
Analyze Information and Prioritize
Root Cause
5-Whys
Ishikawa
Generate Multiple Solutions
Down Select (Pugh Matrix)
Verify Solution
Maintenance & Expansion
Plan
Do
Check
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Introduction to Mistake Proofing

- This course will address methods to prevent manufacturing ***mistakes*** from becoming product ***defects***.

  - A ***mistake*** is when a person or process:
    - Performs an impermissible action
    - Does not perform a required action
    - Falls out of required specifications

  - A ***defect*** is when a mistake is allowed to be passed on to the next operation or final product.

Mistakes

- Manufacturing mistakes are impossible to prevent with 100% certainty
  - For Example:
    - Operators may be tired, inexperienced, or inattentive
    - An operator may lack required information
    - Tools can wear, or break unexpectedly
    - Machines can wear or perform erratically
    - Environmental factors may influence quality

To err is human, to allow the error to become a defect is bad management

Sources of Mistakes

- Mistakes (not conforming to requirements) can be categorized into two main types:

- **Common-Cause:** Predictable, anticipated sources of variation
  - Quantifiably predicable based on History
    - Tool wear
    - Machine MTBF
    - Predictable responses to environmental changes; etc.

SPC

- **Special-Cause:** Unpredictable, erratic sources of variation
  - Non-quantifiable, unanticipated, not predicted by history
    - Improperly assembled, or missing part
    - Void in material
    - Tool breakage; etc.

This Course

Mistake Proofing

- Preventing Special-Cause mistakes from generating defects.
- Has several names: Poka-Yoke; Mistake Proofing; Fool Proofing; etc.
- Using an AUTOMATIC design control or device or method that prevents a mistake from occurring, prevents it from being presented to the next operation, or informs the system of the error in an immediately obvious way.
- Making sure passing along a defect requires more energy into the system than keeping the mistake at the point of origination.

Guiding principle: Make it easiest to do the right thing

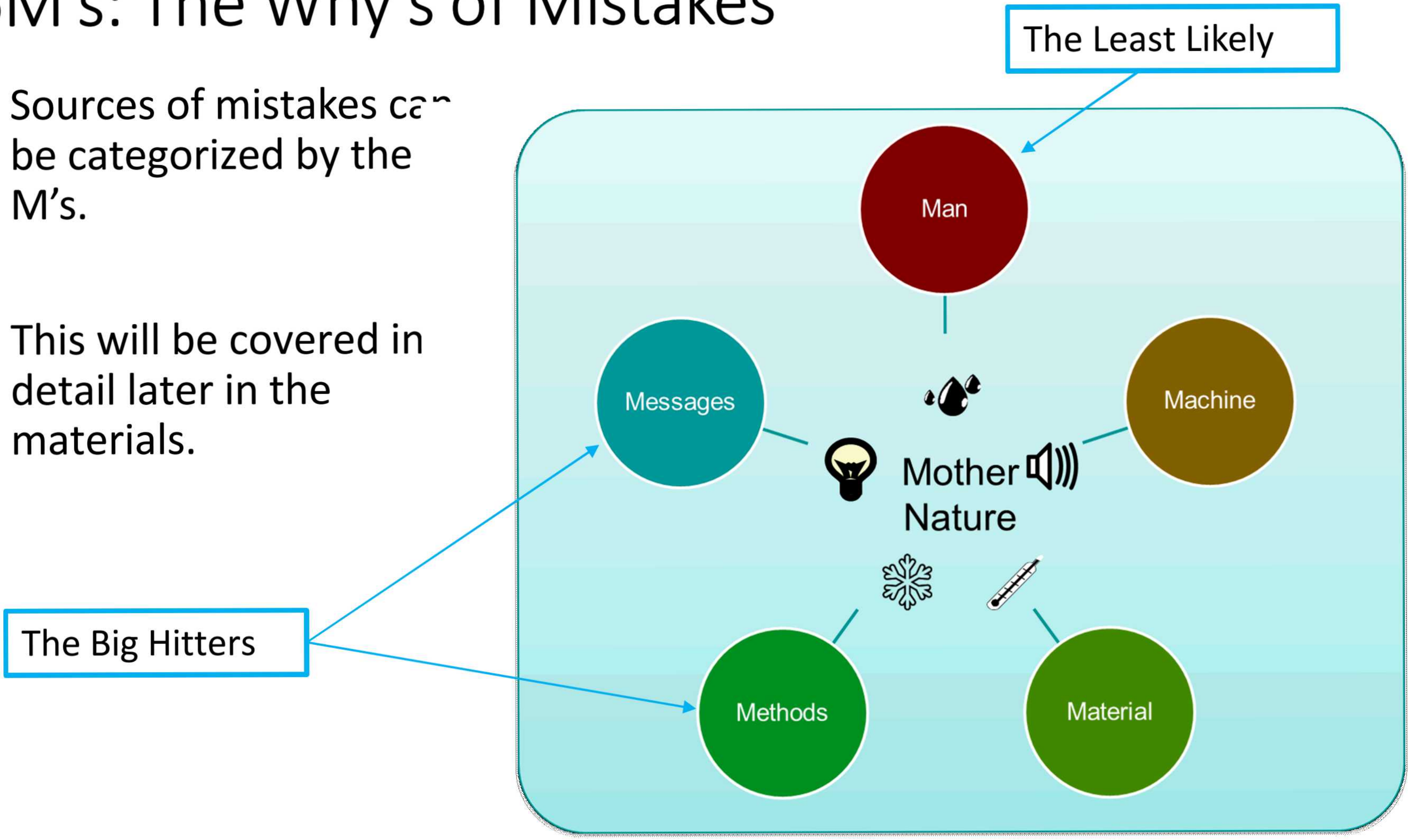
Why? Isn't 99.9% good enough?

- 99.9% Defect-Free:
  - You will spend 9 hours in cardiac arrest each year.
  - One hour of unsafe drinking water every 7 weeks.
  - 2.5 unsafe landings in Atlanta every day.
  - 353 babies accidentally dropped each day.
  - 500,000 lost pieces of mail each day.
  - 4 hours per year staring at your computer while it displays the Blue Screen of Death.
  - Nine missspeld werds on evry paage of every magzine.

6M's: The Why's of Mistakes

- Sources of mistakes can be categorized by the M's.

- This will be covered in detail later in the materials.



Examples:

Identify the M category

Why do we need to prevent defects?

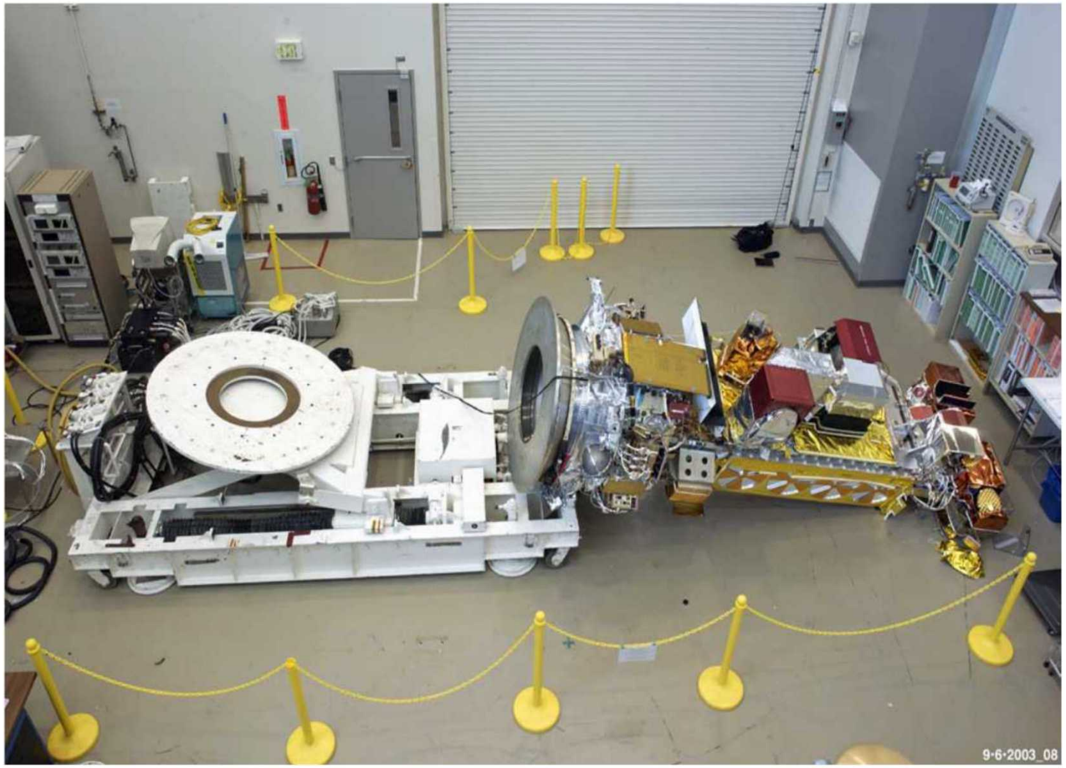
Examples of Defects and Mistake Proofing in Society and at Sandia

Omitted Parts

- WWII: missing pin during manufacturing of Hand Grenades.
- Manufacturer implemented two inspectors for each operator to prevent this defect (300% inspection!).
- Even still, a grenade was sent down the line without a pin, killing a worker.
- Solution: new rack system which requires the grenade to be hung by the pin before it can be sent down the line, and a drop box to contain dropped grenades.
  - 0% inspection, 100% certainty.
- Using Machine to prevent missing parts reaching the next operation.

Omitted Parts

- Missing mounting bolts caused a satellite to be damaged
- Official NASA mishap report missed the most important part: Missing bolts were not obvious!



Omitted Parts

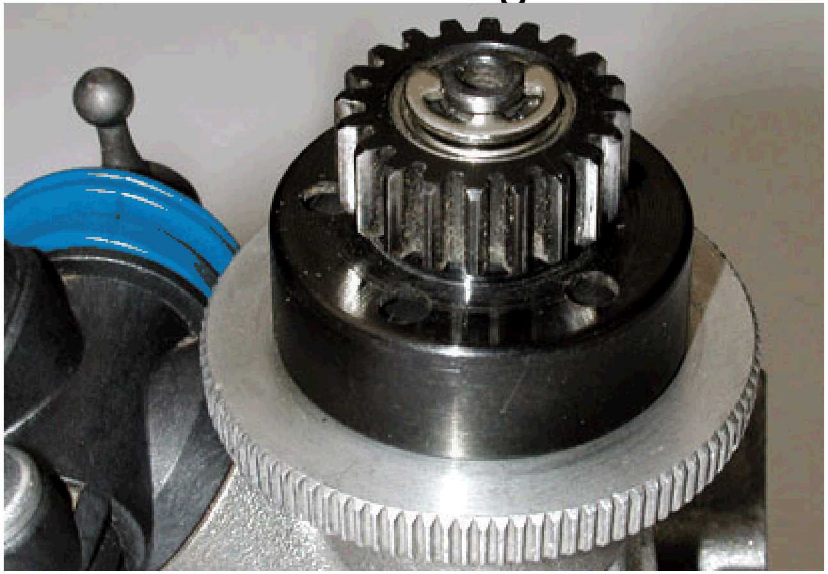
- Missing/Loose bolts is a problem long-since solved in the trucking industry.
  - Are there any bolts missing below?
  - Once again information can prevent defects.

Omitted Parts

- Shaft retaining clips/O-rings/springs that are missing can allow for disassembly.
  - Missing because operation was missed.
  - Missing because it wasn't fully inserted.
- Difficult to verify.
  - Can you clearly see if the circlip is installed correctly?

Using Messaging to Prevent Omitted Parts

- Color can be used to make mistakes obvious.
  - Metallic plating on e-clips
  - Colored O-Rings

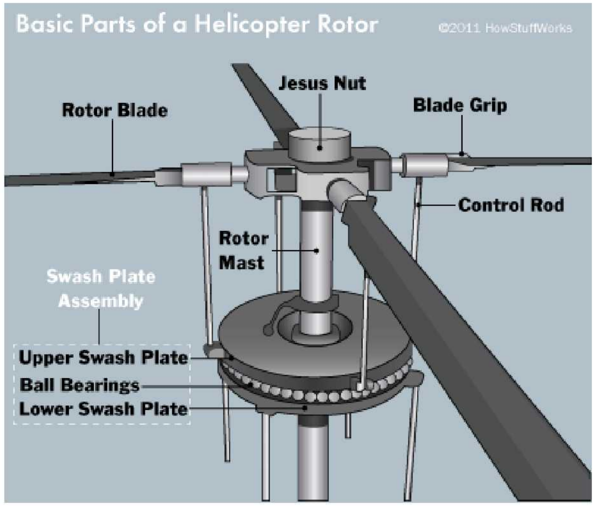


Omitted Action

- Sometimes people forget to flush public toilets.
- Automatic flush is an example of mistake-proofing.

Single Point Failure

- Helicopter Main Rotor Assembly: A collection of single point failure opportunities

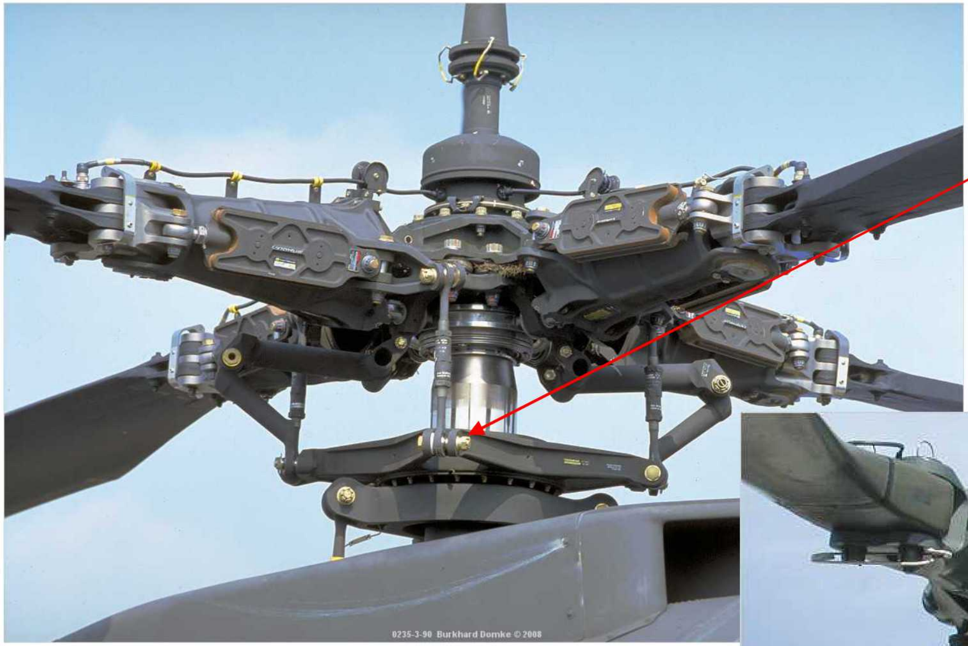


200% inspection; results
Mechanics' fatigue and lack of clear steps on a "work card" or "checklist" also contributed to an inadequate post-maintenance inspection
(NTSB finding)

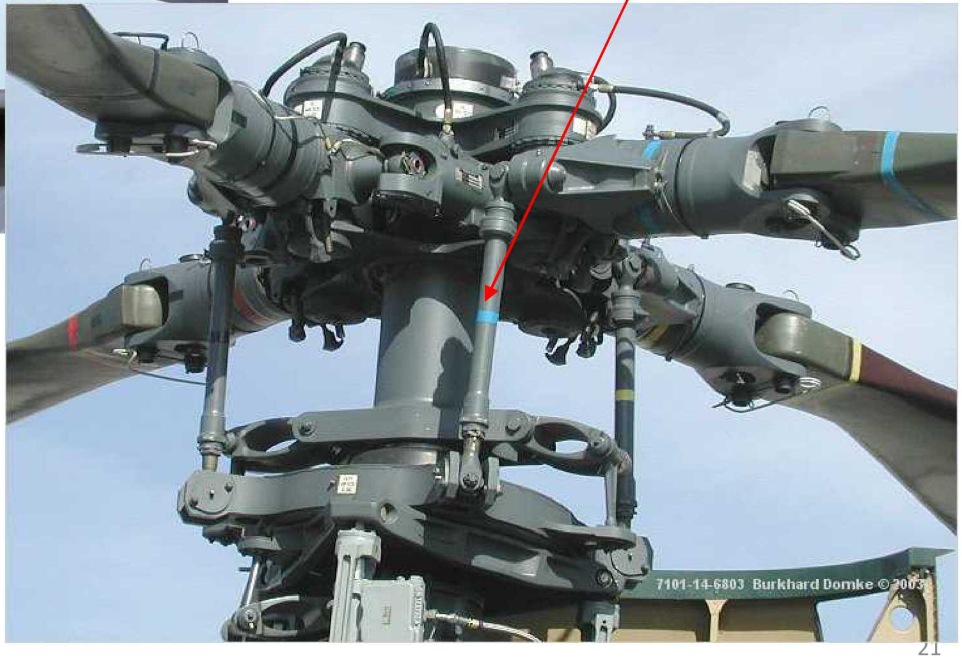
LOOSE NUTS ARE NOT OBVIOUS!

A little color can help

It is more obvious these bolts are installed



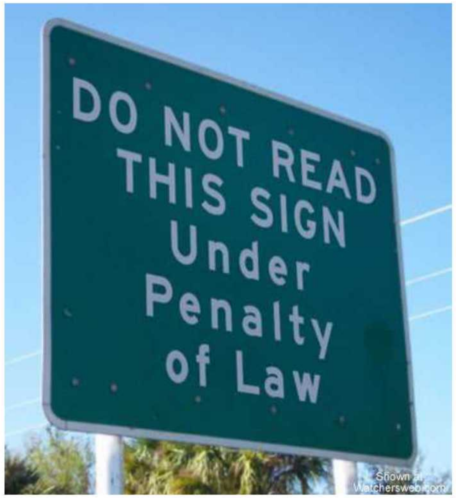
This one matches rotors to actuators



Wrong Orientation

- Wrong orientation is a big problem with power and data.

Wrong Information



Using Information to Prevent Defects

Apparently this road was a shortcut

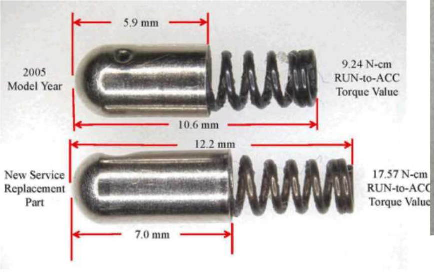
Not Good Enough

Better

Bad Requirements

- GM Designed the ignition switch in some models to turn with too-low of a torque, having forgotten many of its customers use heavy keychains which can turn off ignition (and disable airbags) during driving.
  - 153 deaths
  - 29 million cars recalled
- Temporary fix: Remove everything from your keyring.
- Permanent fix: New plunger design with sufficient torque capacity; Key redesigned to reduce applied torque.

A critical part of the design process is making sure the requirements are correct, and traced to credible real-use cases



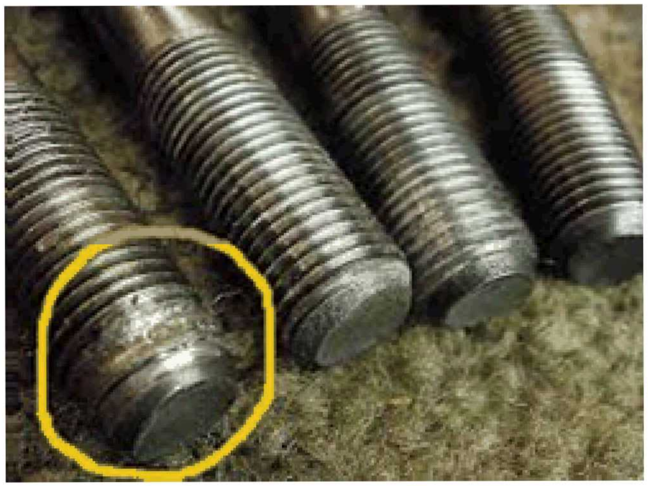
Intentional Defects

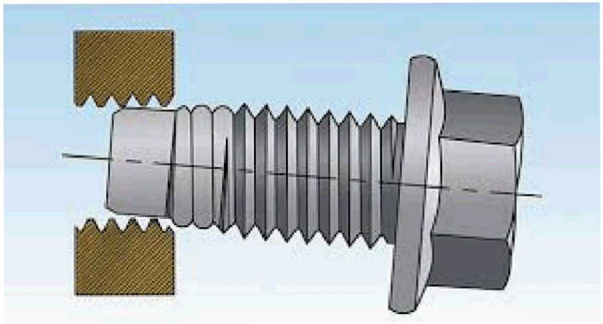
- In 1982, Tylenol was discovered intentionally laced with potassium cyanide.
- There was no system in place to warn the consumer of the tampering.
- This led to the development of tamper-evident seals (and the elimination of Tylenol capsules).

A design solution to an impermissible (hostile) action

Damaged Part

- Bolt threads are commonly damaged at installation.
- Dog-point bolts are a design solution to an “operator error.”
  - Prevents cross threading.





Prohibited Action

- Need prohibited action example

Prohibited Action - Example

Allow Impermissible Action

- In 2007, Hasbro recalled a new Easy-Bake oven model that used a heating element instead of the traditional lightbulb:

- Children were getting their fingers caught in the opening and burned.

FROM WWW.CPSC.GOV

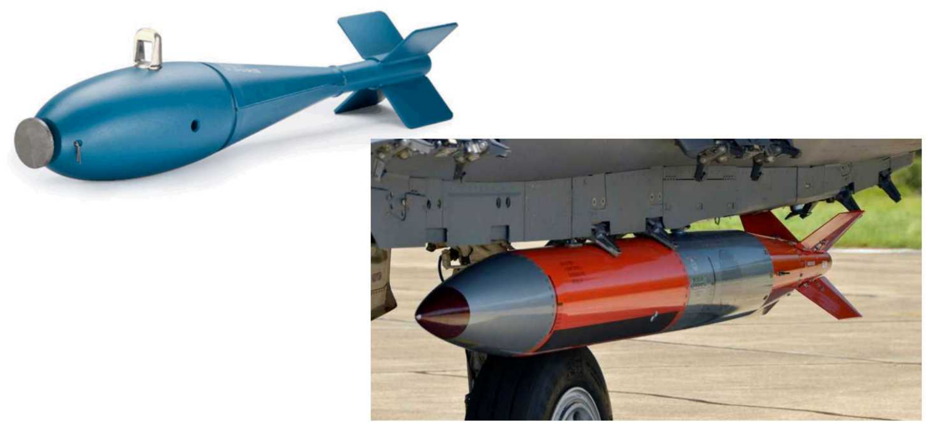
This is 100% a failure to design the product correctly. Always assume credible human mistakes WILL HAPPEN.

Other common, everyday examples

Skateboard Prevention

Take card before cash

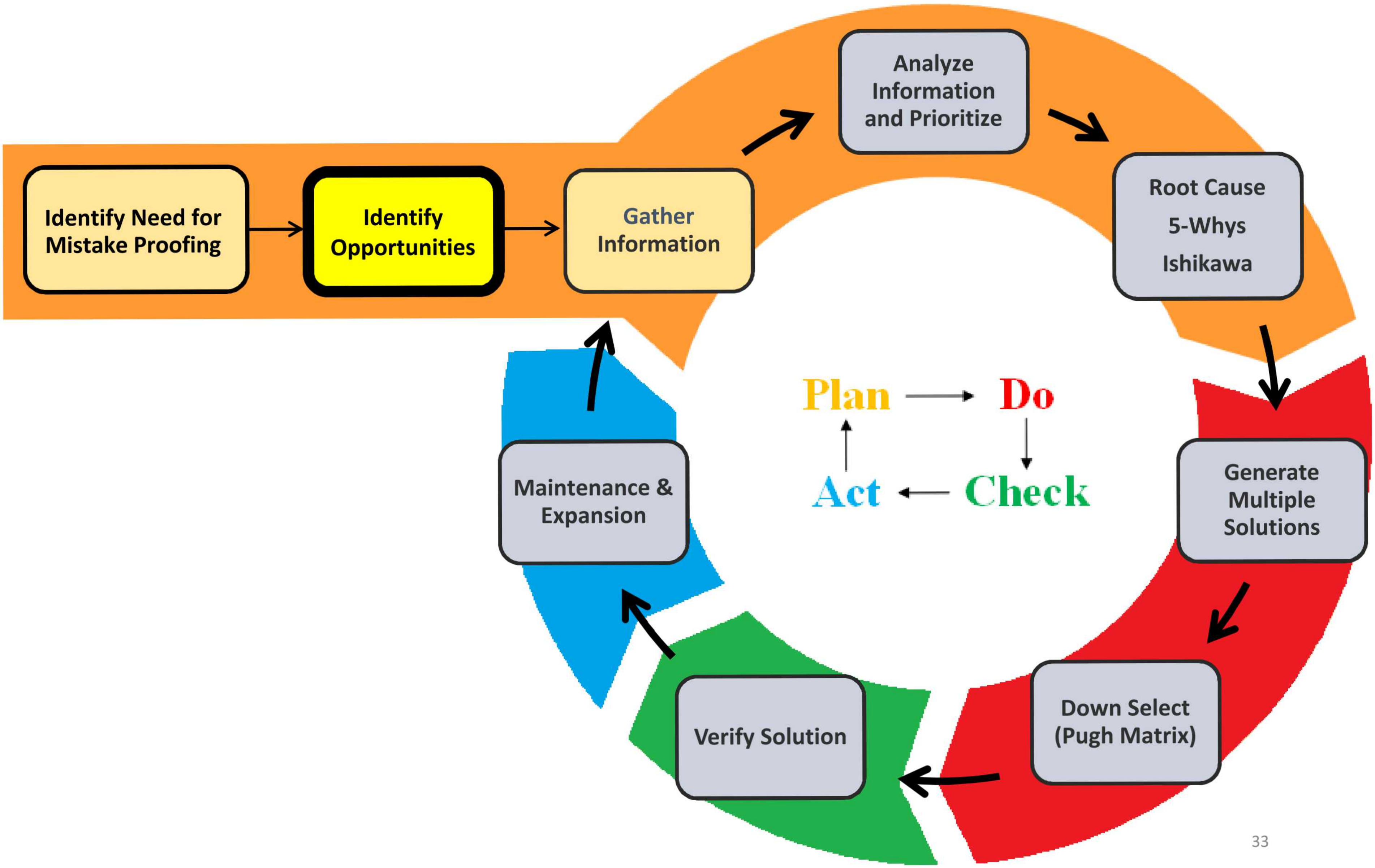
Breakaway hose
(didn't work this time!)



Training Bombs are painted differently

Exercise

- Shout it out, give examples of mistakes which have resulted in defects:
  - Work related
  - Personal Life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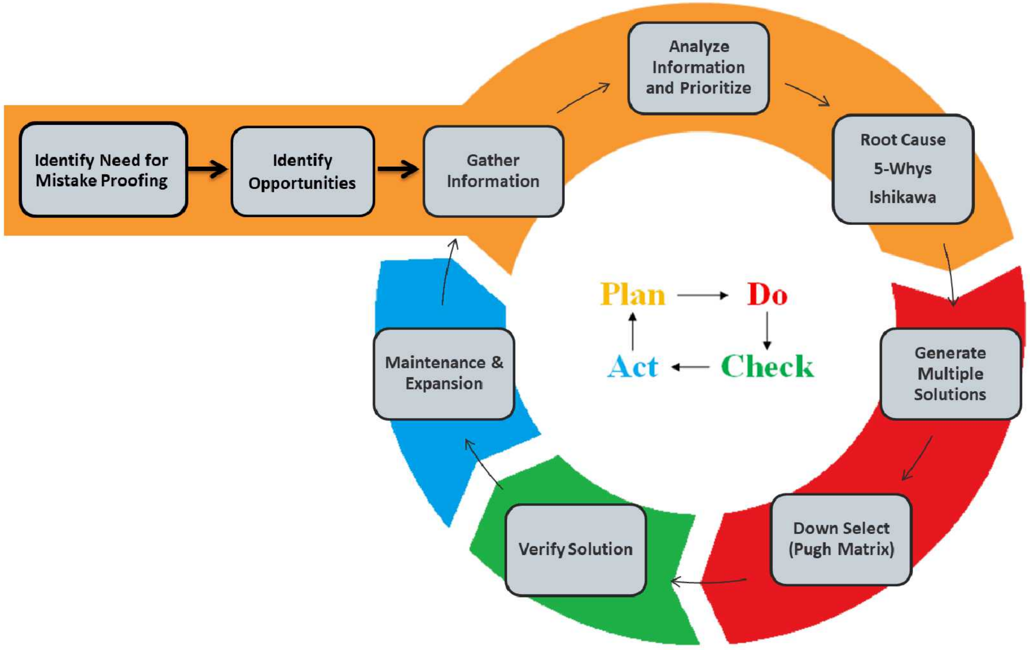
Exercise (5 min)

- Group activity (4-6 people)
- Think about a issue or problem within your area. Discuss with your group.
  - Can be a design or process based issue
  - Present some examples to the class
- Example(s) will be used throughout the class activities



How?

- **Deming:** “85% of the reasons for failure to meet customer expectation are related to deficiencies in the Systems and Processes, rather than the employees. The role of leadership is to change the process rather than badger the individuals to do it better. “ (W.E. Deming, *Out of the Crisis*, 1982)

How?

- In corrective action reports, we observe the converse, the majority of "corrective actions" are items like:
  - Train or Retrain operators.
  - Have inspectors inspect the operator.
  - Have inspectors inspect the inspectors inspecting the operator.
  - Rewrites to operating instructions that aren't any more informative.

THIS APPROACH IS <u>UN</u>LIKELY TO SUCCEED

Don't confuse inspectors, training and operating instructions with mistake proofing!

You CANNOT train mistakes out of existence

How?

- Best: Prevent defects from occurring in the first place.
  - Control to prevent the mistake from being generated.
  - Change design to be immune to likely defects (robust).
- Better: Detect the mistake while in process.
- Good: Detect mistake before proceeding to next step.
- Mediocre: Detect defect at the next step.
- Weak: Train the operators better, hire better operators, make OI’s better, add inspectors, etc.
  - There are times where these methods are appropriate to fix a specific deficiency – beware of using these by default.
- Too Late: Customer finds the defect.

Video

- https://www.nbc.com/saturday-night-live/video/assembly-line/2834510?snl=1

Video

- Even this operator could have been more successful with better information.

- What other mistake proofing opportunities were there?

100% Inspection to the Rescue!

- 100% traditional inspection is not 100% effective:
  - Juran observed that 100% inspection is 87% effective.
  - Further, as the defect rate goes down, the inspection accuracy gets worse!
- 4:1 TAR, some parts 25% out-of-tolerance can be accepted; potential ~2% of total population is non-conforming.
- 200% inspection isn't much better.
- Quality is not the responsibility of the quality department.
  - Quality is the responsibility of the entire manufacturing system, from design through production.
  - Quality Assurance vs. Quality Control.

Quality Cannot Be Inspected In!

How? (overview)

Instead of blaming operators, try these
(in order of effectiveness):

1. Redesign the product or process so that the opportunity for, or effect of, the mistake is completely eliminated. (Simplify or Make Robust).

2. Redesign the product or process so that the mistake is impossible, or cannot be propagated to a defect; add source inspection, Poka-Yoke. (Control).

3. Add defect detection to prevent mistakes from continuing to the next operations. (Shutdown, Warn, etc.).

BREAK

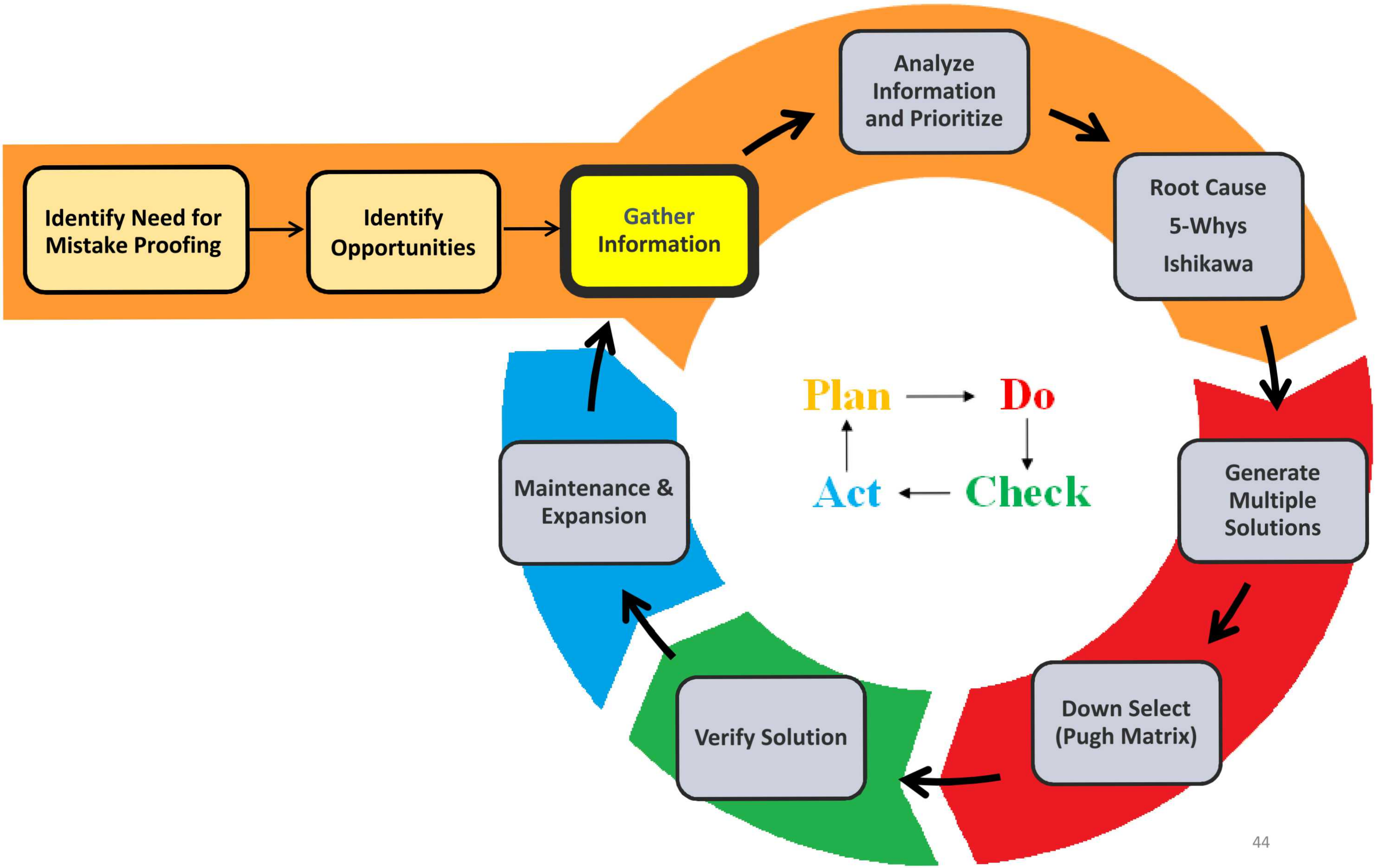
- Break (10 minutes)

- Exercise, 4 volunteers (15 minutes);
  - Using “management” to reduce defects.

Managing Defects

- Video

- https://www.youtube.com/watch?v=NkQ58I53mjk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Mistakes and potential mistakes

- Mistake proofing comes in two forms:
  - **Pro-active mistake proofing -** seeks to identify potential mistakes before they happen and prevent them from becoming realized.
  - **Responsive mistake proofing -** takes place after the mistake has been realized and corrective action is needed.
- Both are used throughout design, development and production.
- The Complexity of a product, process has significant impact on mistakes.
- Mistake proofing early in the product lifecycle will be more impactful.

The Goal of this class is to give you the tools to imagine how mistakes can happen and prevent them.

Gather Information:
Pro-Active data sources (examples)

- Identification of potential mistakes that have not be realized
  - Will be identified through the use of analysis tools.
  - Data and information will be presented as hypotheticals.
- Examples of sources and tools used for pro-active mistake proofing.

- **Flowchart identifying Critical processing/inspection points**
- Product/Process tact time analysis
- **Input from production floor personnel**
- Process walkthroughs
- Product design reviews
- Historical product Lessons Learned
- Design reviews
- **Operator insight**
- Formal Engineering Drawing Inspection
- Peer Review Findings
- Lessons learned (leverage mistakes from other products)
- Educated guess from other product mistakes
- Design for manufacturability reviews
- Statistical Process Control Charts (SPC)
- Fagan
- HALT

Attempt to identify all potential mistakes no matter how unlikely. If there is potential for a mistake, it will happen and become a reality.

Gather Information:
Reactive Data Sources (examples)

- Identification for realized defect sources.
  - Will come from the errors that have happened.

- Examples of data sources used for reactive mistake proofing.
  - Production floor defect codes/Non-conformances
  - Part/Piece part inspection data
  - Functional, Environmental test results
  - Lessons Learned
  - Production Scrap
  - **Operator insight**
  - HASS

Once a mistake has happened it is critical to identify it and prevent it from happening again.

Mistake Proofing procedure with flowchart

- A flowchart is a generic tool that can be adapted for a wide variety of purposes
  - Manufacturing processes
  - Administrative processes
  - Project planning
  - Etc…

- Flowcharts provide a visual representation of your process that can be used to:
  - Communicate with other how a process is performed.
  - Review process and contemplate where mistakes are likely to occur.
  - Identify the types of mistakes or defects can/did happen based on processing method.
  - Identify critical processing/inspection points.

Examples of Common Mistakes

- Incorrect Processing:
  - Omission– Forgetting a process step, operation, etc.
  - Commission – Adding an unexpected process, operation, etc.
  - Positioning Error – Orientation and/or location
- Incorrect Parts:
  - Missing part (Omission), extra parts (Commission)
  - Defective/damaged parts, wrong parts
- Material Defects:
  - Wrong material specified
  - Material defective
- Information:
  - Defective information
  - Insufficient information
  - Excess of information

Complexity & Opportunity for Mistakes

- Task and part complexity is a powerful indicator for mistake opportunities.
- Complexity can be measured in many different ways.
  - Time needed to complete task.
    - Complex tasks naturally take longer than simple tasks
    - Process time is not always an indication of complexity. (i.e. Oven bake outs, epoxy cures).
  - Quantity of parts or assemblies.
    - Assemblies with many parts increases complexity and opportunity for mistakes.
  - Size of Parts and Handling requirements.
    - Large parts can be cumbersome and hard to handle.
    - Small Parts require delicate handling and often times need additional tools.
  - Number of operation steps.
    - The more steps that are needed to complete a task the more opportunity for mistakes.
  - Orientation of parts.
    - The orientation in which a part is installed can have a large impact on the complexity and difficulty of a task.
  - Measurement Complexity.
    - Automated measurement or complex gages or devices?

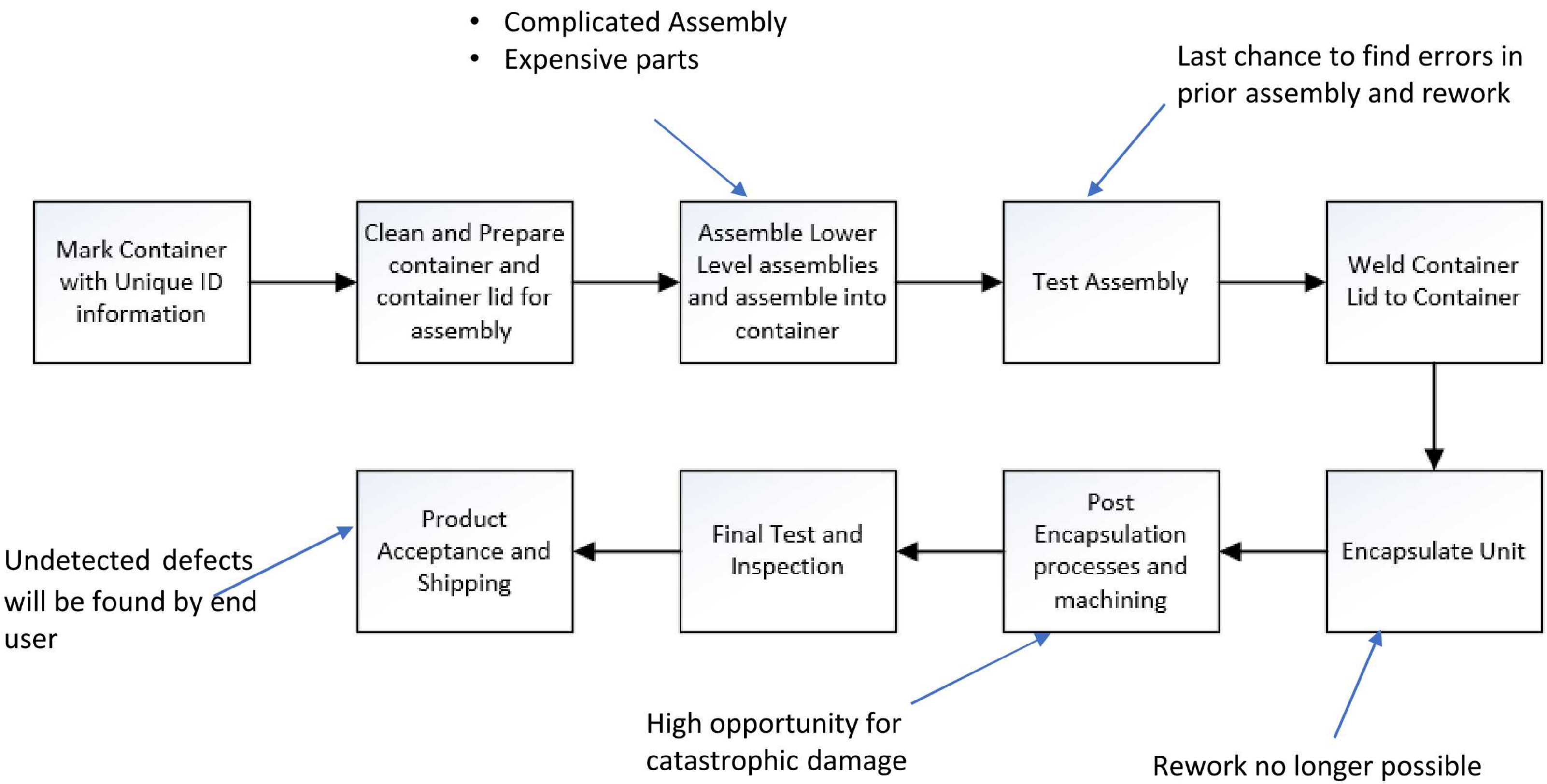
Can the 6Ms be attributed to each of these?

Complexity & Opportunity of Mistakes

Critical Processing/Inspection Points

- Where a minor error early in the process causes major problems later in the process.
- When the consequences of an error are expensive or dangerous or irreversible
    - Examples
        - Where raw material is received
        - Costly operations
        - Where potential damage can occur
        - Prior to Point of no return (unit can't be re-worked)
            - Encapsulation
            - Welding
            - Painting
            - Overmolding
            - Assembly process
        - When stocking
        - Changing from development to production
        - When quality responsibility changes hands

Example of Simple Flowchart



Assign cause where mistake becomes a defect

Exercise (20 min)

- Group activity (4-6 people)
- Pick an issue you discussed earlier.
  - Can be a design or process based issue
  - Can be pro-active or responsive
- Activity for Flow chart/information gathering
- Use information sources that are available to you to come up with 3-4 possible areas to apply mistake proofing.

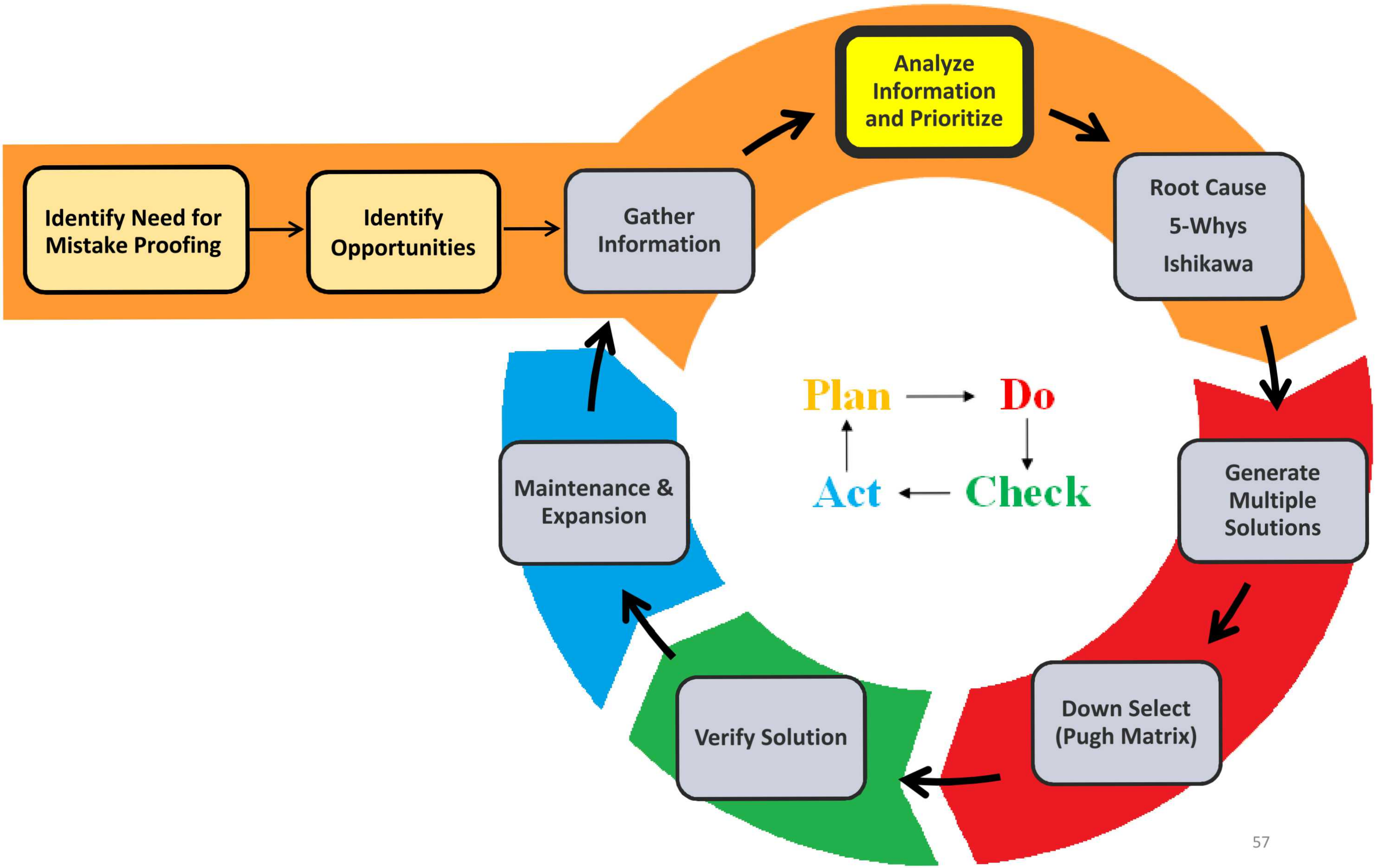
- Identify steps where mistakes are likely to happen
- Identify type of possible mistakes
- Identify critical processing/inspection points

Go to the source (operators, users) - *Gemba*

- Operators/Users Know the Process/Product the best.
  - What takes the most time?
  - What is the most difficult?
  - What is the most common mistake?
  - What would make the process easier?
  - What is the best way to complete the task?
  - Can you complete the work as written?
  - Are there undocumented steps or procedures?
  - What mistakes do new people make?

a.k.a. process walkthroughs

Example of Gemba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Analyze and Prioritize the data and information gathered

- After the mistakes or potential mistakes have been identified the data must be analyzed in order to determine prioritization.
  - Need to select and understand the appropriate data sources listed above in order to determine the frequency, impact and detectability of a mistake or potential mistake.
- Things to keep in mind:
  - High Frequency problems do not always constitute significant problems.
  - High severity mistakes should be solved first.
  - Also look for low detectability.
  - Not all problems can be solved immediately.

Analyzing Information using FMEA techniques

- Failure Modes Effects Analysis (FMEA)
  - RPN score non-realized defect sources:
    - Severity of the potential mistake (R)
    - Likelihood of the potential mistake (P)
    - Detectability of the potential mistake (N)
  - RPN score for realized defect sources:
    - Severity/Impact to the product and production floor (R)
    - Occurrence of the mistake (P)
    - Detectability of the mistake (N)
- Risk Priority Number Score (RPN)
  - Severity x Occurrence x Detectability = RPN
  - RPN Score should be used to rank the order in which problem are solved.
  - Regardless of the RPN score, problems with a high severity should be addressed sooner than later.

Severity (R)

- How bad is the mistake and what how bad is the impact of the mistake?

Severity	SEV	Criteria
Minor	1	Unreasonable to expect that the minor nature of this mistake will cause any noticeable effect on item of system performance or subsequent process or assembly operation. Customer will most likely not be able to detect the failure.
Low	2, 3	Due to the nature of this mistake, the customer experiences only slight annoyance. Customer will probably notice slight deterioration of the item or system performance or a slight inconvenience with a subsequent process or assembly operation, i.e. minor rework
Moderate	4, 5, 6	Mistake causes some customer dissatisfaction which may include discomfort or annoyance. Customer will notice item or system performance deterioration. This may result in unscheduled rework/repair and/or damage to equipment.
High	7, 8	High degree of customer dissatisfaction due to the nature of the mistake, such as inoperable item or system. Mistake does not involve safety or government regulations. May result in serious disruption to subsequent processing or assembly operations and/or require major rework.
Very High	9, 10	Mistake affects safety or involves noncompliance to government regulations. May endanger machine or assembly operator (9 with warning, 10 without warning).

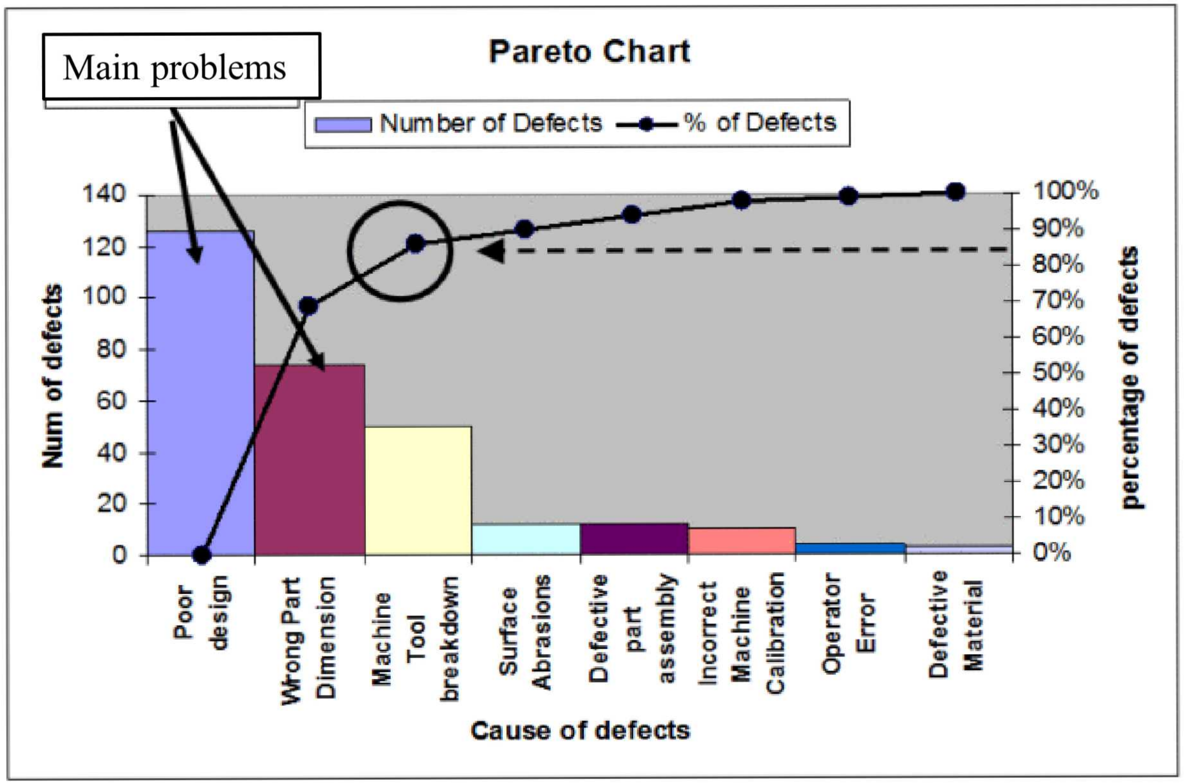
Occurrence/Likelihood (P)

- For Pro-Active mistake proofing the Occurrence will be the Likelihood of the mistake being realized.
- For realized mistakes a Pareto chart is a good tool.

Occurrence	Criteria	OCC	Failure Rate
Remote	Mistake is unlikely	1	< 0.0001%
		2	0.0007%
Low	Relatively few mistakes	3	0.0067%
		4	0.05%
		5	0.25%
Moderate	Occasional mistakes	6	1.25%
		7	5.0%
High	Repeated mistakes	8	12.5%
Very High	Mistake is almost inevitable	9	33.3%
		10	> 50%

Occurrence using Pareto chart

- Used to analyze the frequency of a problem.
- Easily compare many types of defects within a process.
- Does not indicate the severity of the issue.



80% of mistakes in 20% of population

Detectability (N)

- How easy is it to detect the mistake using current process controls?
- The higher the score the harder it is to detect.

Detection Rank	DET	Criteria
Very High	1, 2	Current control(s) almost certain to detect the mistake. Reliable detection controls are known with similar processes. Process automatically prevents further processing.
High	3, 4	Controls have a good chance of detecting mistake. Process automatically detects mistake.
Moderate	5, 6	Controls may detect the existence of a mistake.
Low	7, 8	Controls have a poor chance of detecting the existence of mistake.
Very Low	9	Controls probably will not detect the existence of mistake.
None	10	Controls will not or cannot detect the existence of a mistake. No known controls available to detect mistake.

Exercise (20 min) FMEA Activity

- Same Groups
- Using the mistake proofing opportunities that you gathered earlier.
  - Determine the RPN score using the FMEA Severity, Occurrence/Likelihood and Detectability.
  - Prioritize mistake proofing opportunities based on RPN Score.
  - Out brief top two.

Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detec	RPN
Drill Blind Hole	Hole too deep	Break through bottom of plate	7	Improper machine set up	3	Operator training and instructions	3	63
	Hole not deep enough	Incomplete thread form	5	Improper machine set up	3	Operator training and instructions	3	45
			5	Broken Drill	5	None	9	225
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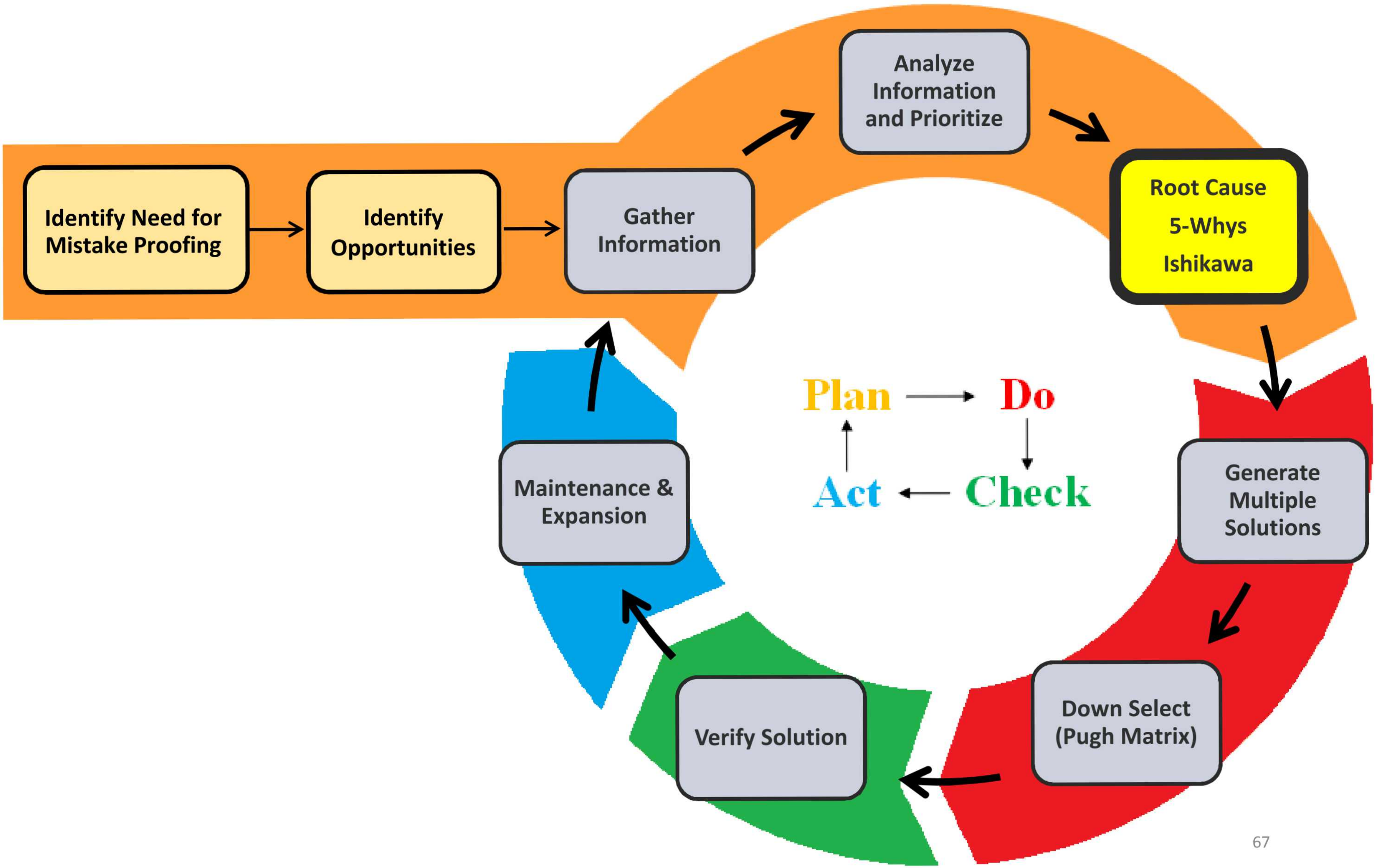
Providing training on the fundamentals of product realization quality.
NQT
National Security Quality Training Program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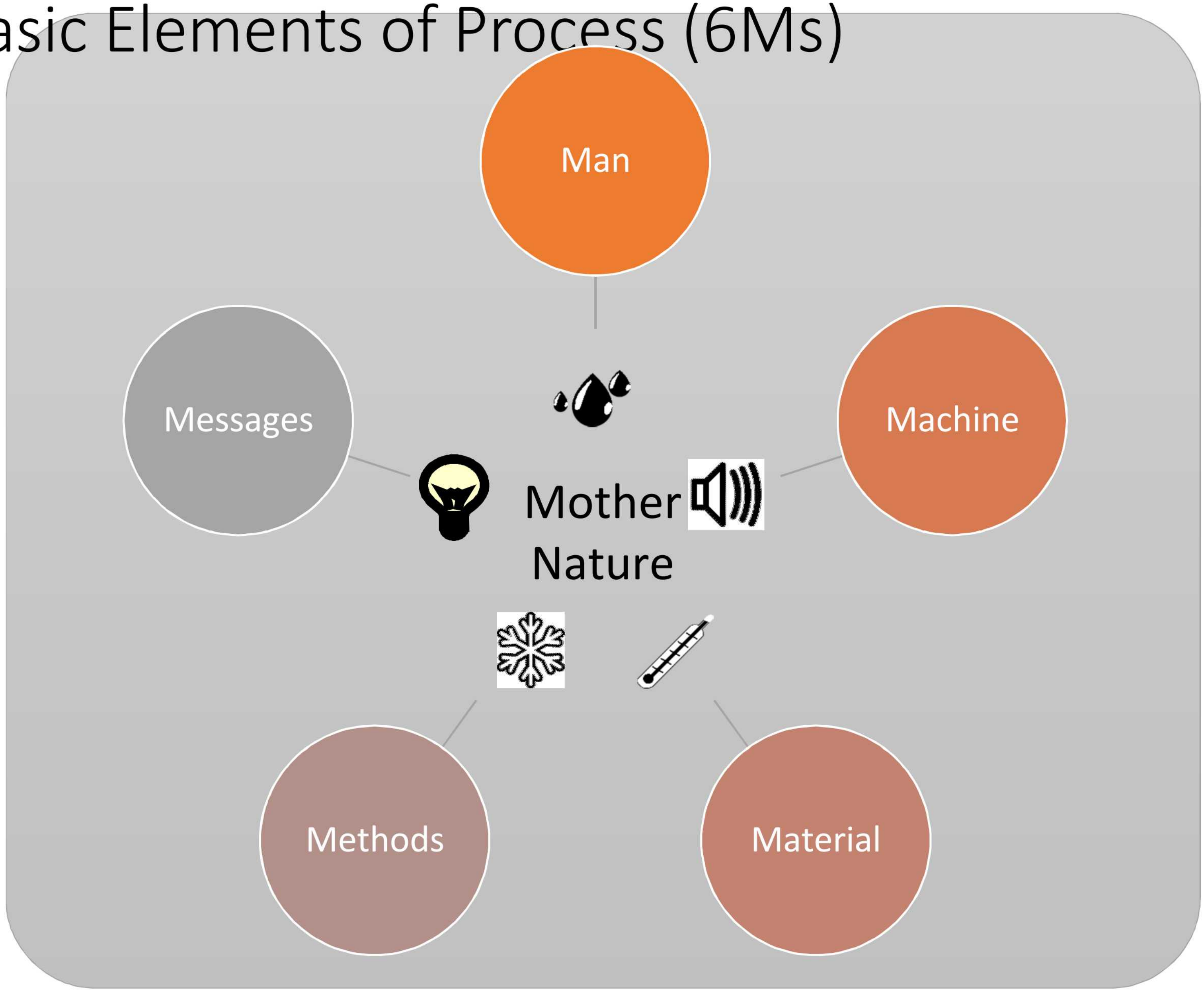
Act

Basic Elements of Process (6Ms)

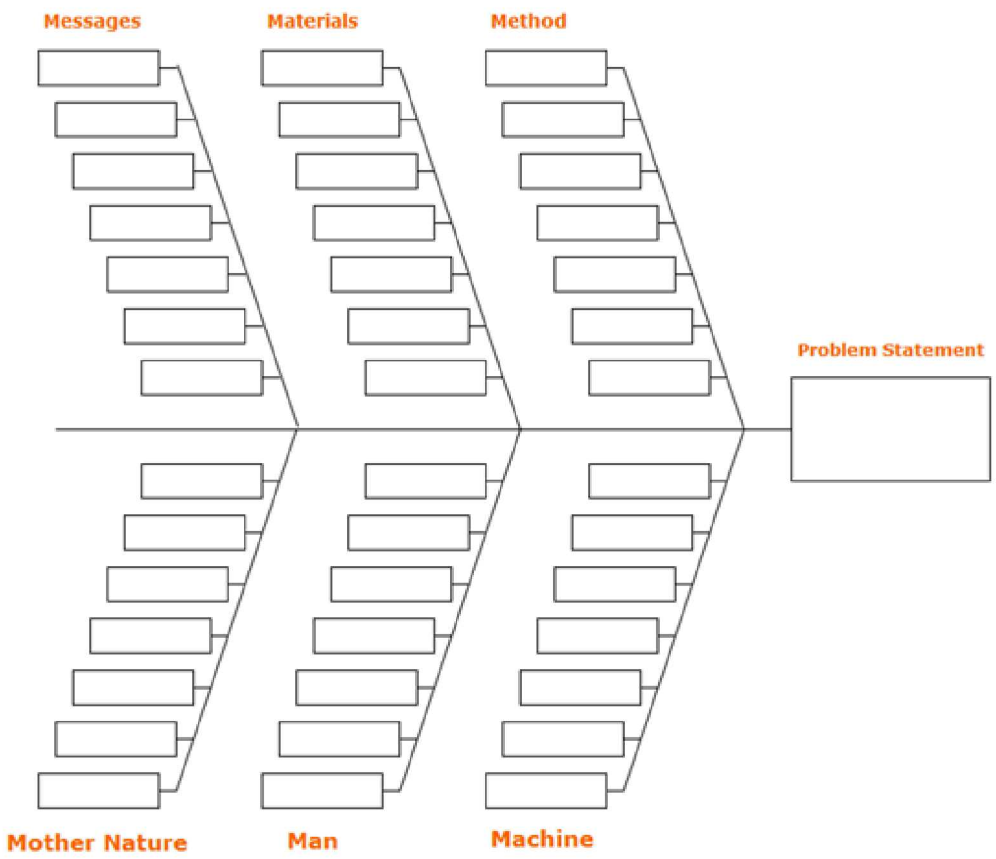


Finding the root cause of a mistake using the “5 Whys” method

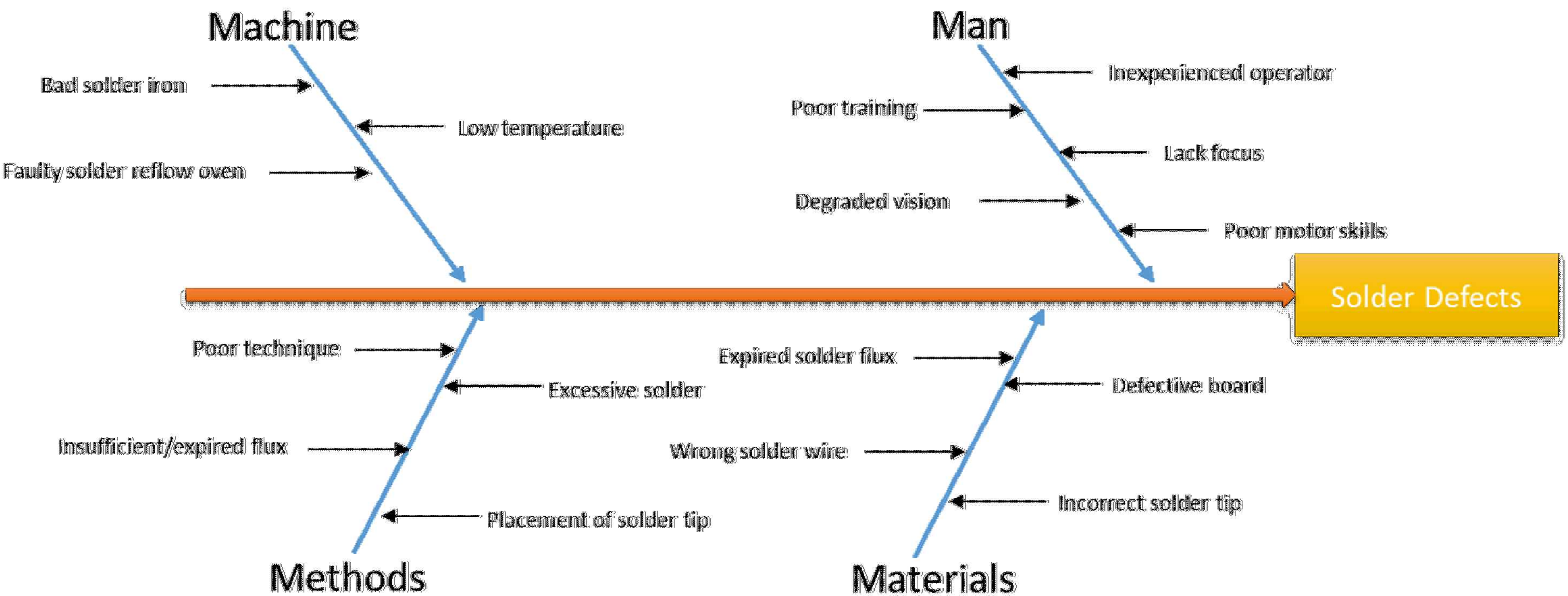
- The 5 Whys method is a way to drill down to the root cause of a problem.
- Originally developed by Sakichi Toyoda.
  - “by repeating why five times, the nature of the problem as well as its solution becomes clear.”
- Start with a clearly defined problem statement and ask “Why?”
  - Answer why. Ask Why (2) again
    - Answer why. Ask Why (3) again
      - Answer why. Ask Why (4) again
        - Answer why. Ask Why (5) again
- Keep asking why until the root cause of the problem is identified
  - May take more than 5, may take less than 5.

Fishbone (Ishikawa) Diagram

- Insert the Problem statement.
- Brainstorm possible causes asking “Why does this happen?”. Write the causes in the correct section (causes can go in multiple sections).
- Each section may not be applicable
- 5-Whys can be used for each cause



Fishbone Example: Soldering Defects



Lincoln Memorial 5 Whys example

- The Lincoln Memorial was deteriorating faster than expected.

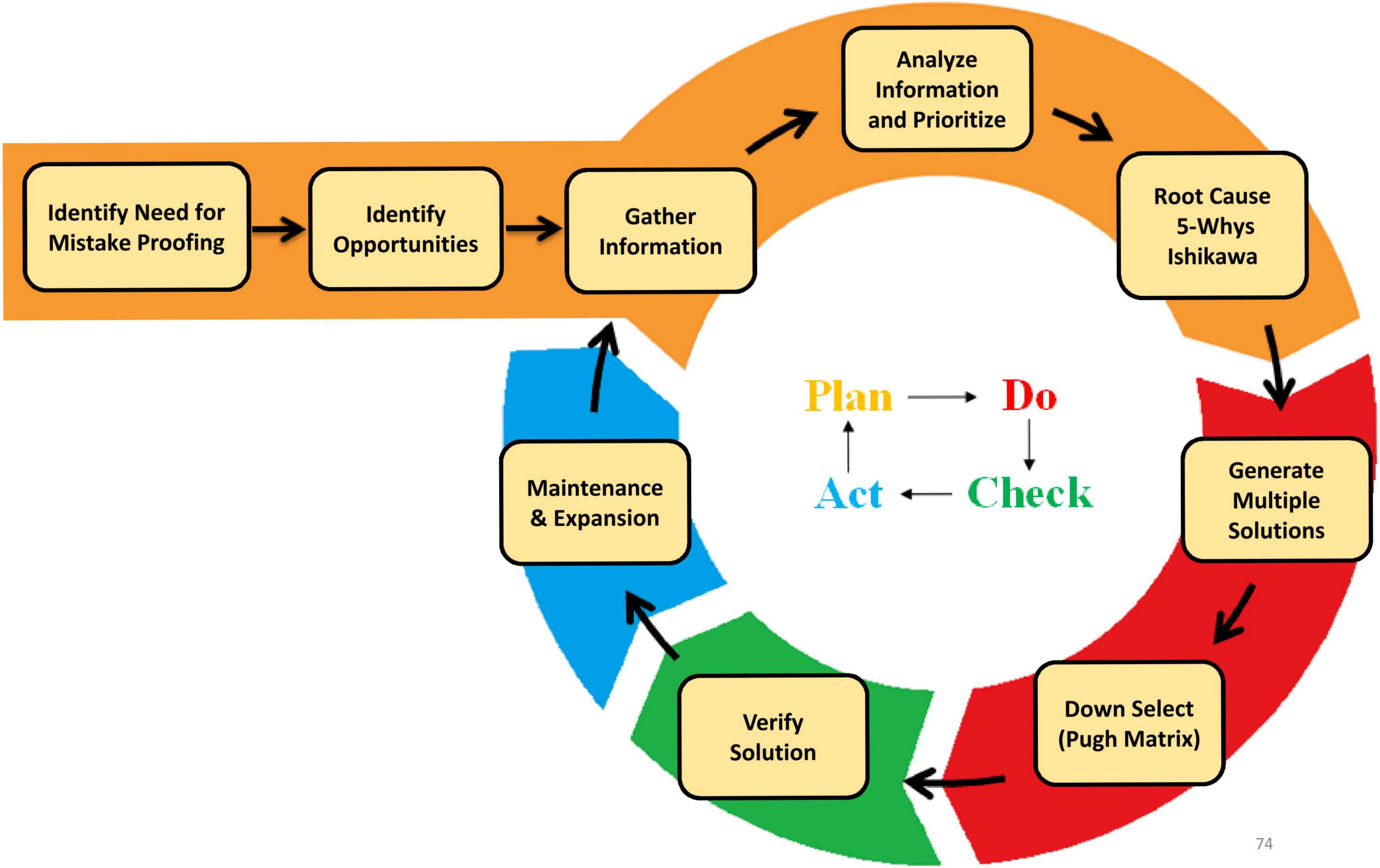
1. Why is the Memorial Deteriorating?
    - Harsh Chemical are being used to clean the memorial. (Material)
2. Why are Harsh Chemicals needed?
    - To clean off large number of bird dropping on the memorial. (Mother Nature)
3. Why are there a large number of bird dropping?
    - There is a large Population of bugs around the memorial that is a large source of food for the birds. (Mother Nature)
4. Why is there a large population of bugs?
    - Insects are drawn to the memorial at dusk. (Mother Nature)
5. Why are the bugs drawn to the memorial at dusk?
    - The lighting of the memorial at night attracts the bugs. (Method/Message)

- By changing the way the memorial was lit up at night they were able to minimize the bug population, reducing the birds, reducing the bird droppings, reducing the need for excessive cleaning.

Exercise (10 min)

- Find the Root cause of your top priority problem.
- Assign a 6M category to each “Why”.

Review


Identify Need for Mistake Proofing
Identify Opportunities
Gather Information
Analyze Information and Prioritize
Root Cause 5-Whys Ishikawa
Generate Multiple Solutions
Down Select (Pugh Matrix)
Verify Solution
Maintenance & Expansion
Plan
Do
Check
Act

Exercise (15 min)

- Complexity and Mistakes (Ball Toss)
  - Timed activity
- Objective
  - Beat the other team(s)
- Class Split into 2-3 groups
  - Each group form a circle (facing in)
- Rules
  - Item must start and end with the same person
  - You must always pass the item to the same person (i.e. order must stay the same)
  - Everyone in the circle must touch the item being passed one time (no more, no less)
  - Cannot pass the item to the person standing next to you
  - If Item is dropped it must start again from the beginning

Traditional Inspection

- 100% inspection is expensive
- Inspection occurs downstream of the process
    - Generate scrap or rework
- Inspection is imperfect, can result in defects going to the customer

Traditional Inspection

- Either significant rework or scrap
  - Inspection process is tedious.
  - Have added a lot of value to a part before errors are detected.
    - You are inspecting a completed part.. Error could have happened in step 1 of process.
  - Error prone → errors could reach the customer.
    - Errors are not always caught during inspection.
  - You cannot inspect quality into the product.

Successive Inspection

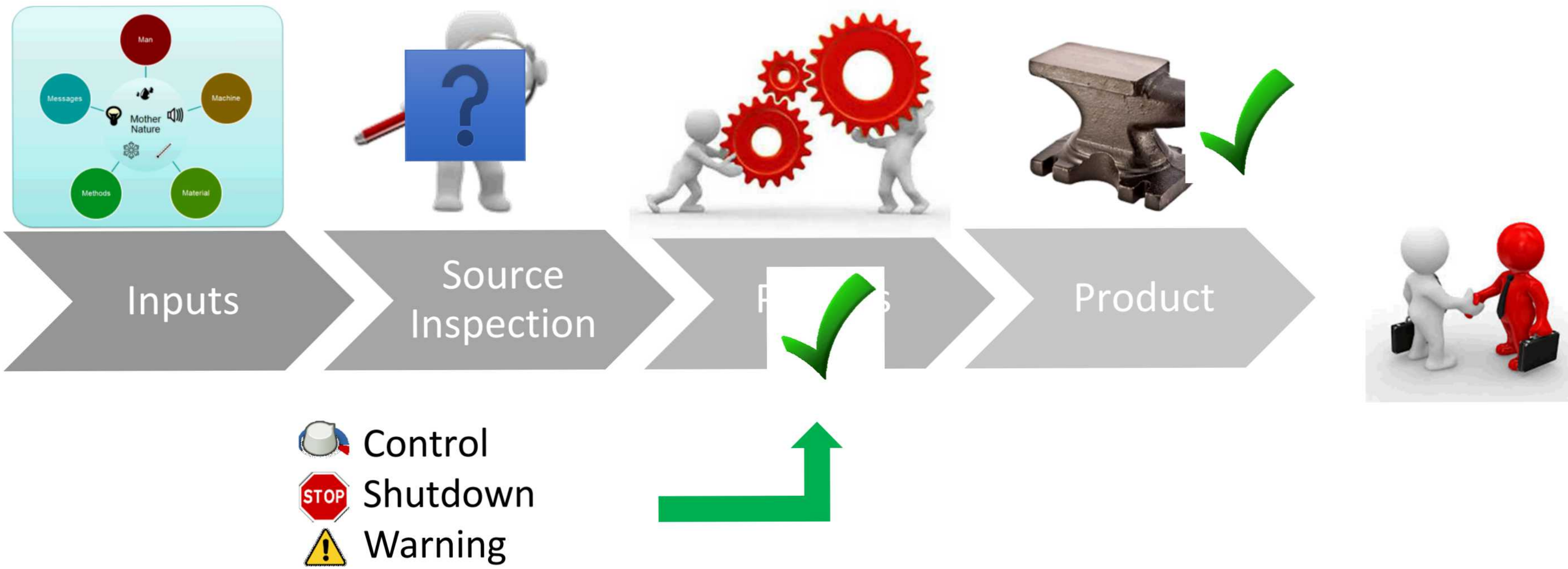
- Inspection is done at the next step of the process
- Plastic "flags" used on heavy trucks/busses can be used as a quick check for proper torque.
  - Visual go/no-go gage
  - Saves time (particularly if everything is good)
  - Very cheap solution to a problem with significant consequence

Self Inspection

- Workers check their own work immediately after doing it.
- Car can't drive a car off the line without tires.
- OR, can't send the grenade down the line without a pin.

Source Inspection

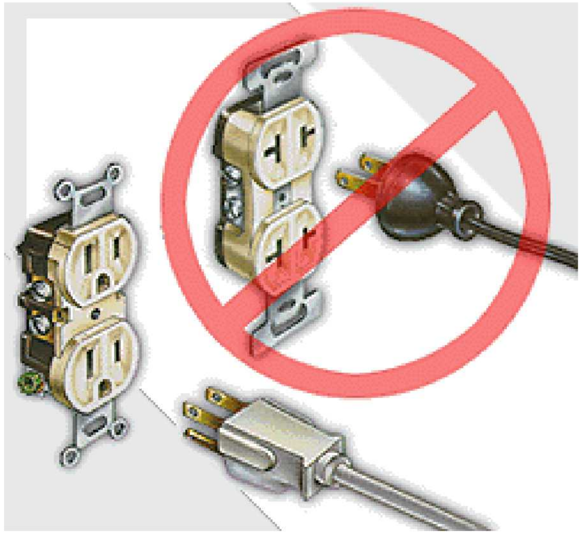
This "source inspection" is not the KCNSC definition, but the traditional definition from Shigeo Shingo



Prevents mistakes from turning into defects by:
- 100% source inspection
- Immediate feedback and corrective action
- Check for root errors, rather than resulting defects

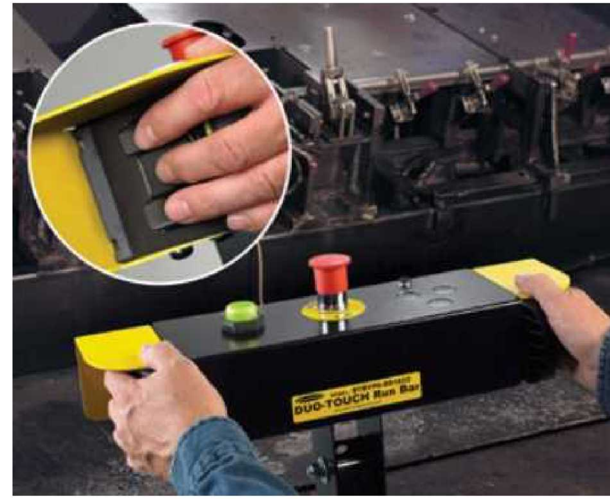
Source Inspection

- Can't perform the operation unless it is ok.
  - 3 prong plug (obvious asymmetry)
  - Lightning connector (perfect symmetry)

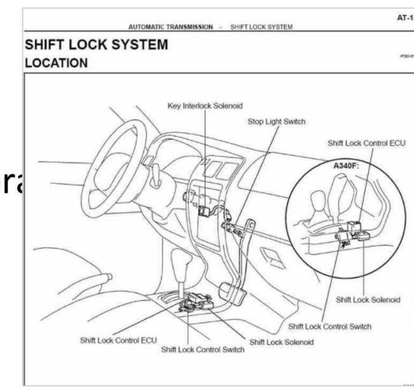


Source Inspection

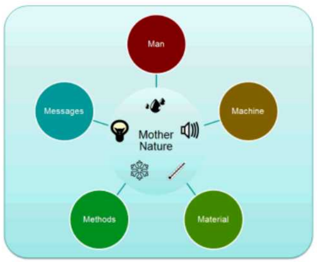
- 2 Hand check for machines



- Brake-Transmission Shift Interlock
  - Prevents shifting out of park unless bra
    applied
  - Prevents unintended acceleration



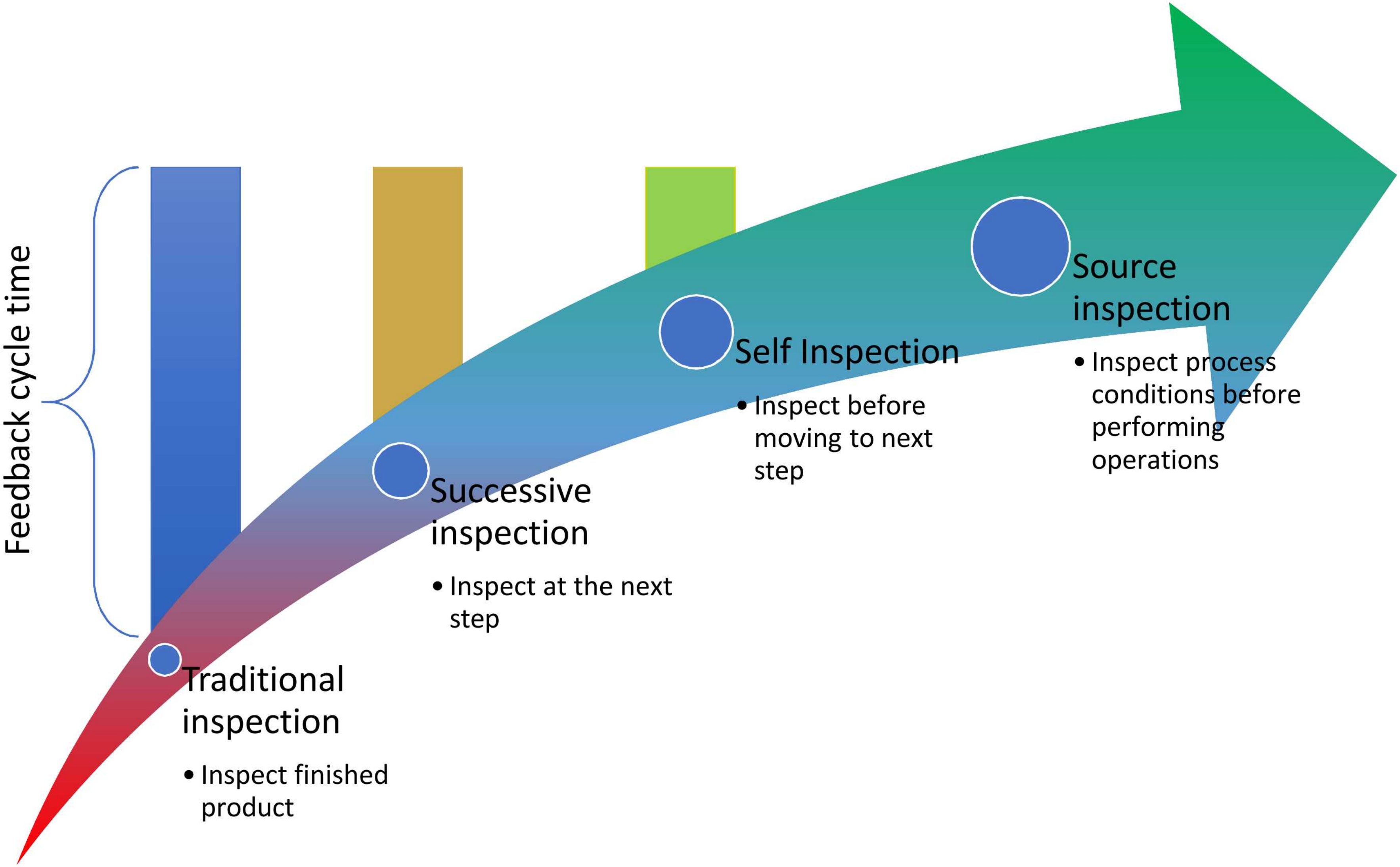
Information Inspection
(Fagan inspections During requirements)



Inputs → Source Inspection → Process → Product

- Control
- Shutdown
- Warning

Mistake Proofing and Inspection



Achieve Zero Defects

Design Simplification
- Remove sources of mistakes

+

Design Robustness
- Make design immune to mistakes

+

More Simplification
- For good measure

+

In Process Source inspection
- Prevent mistakes

+

Poka-Yoke devices
- Prevent mistakes from becoming defects

=

Zero Defect Quality Control

Review of Common Mistake Sources

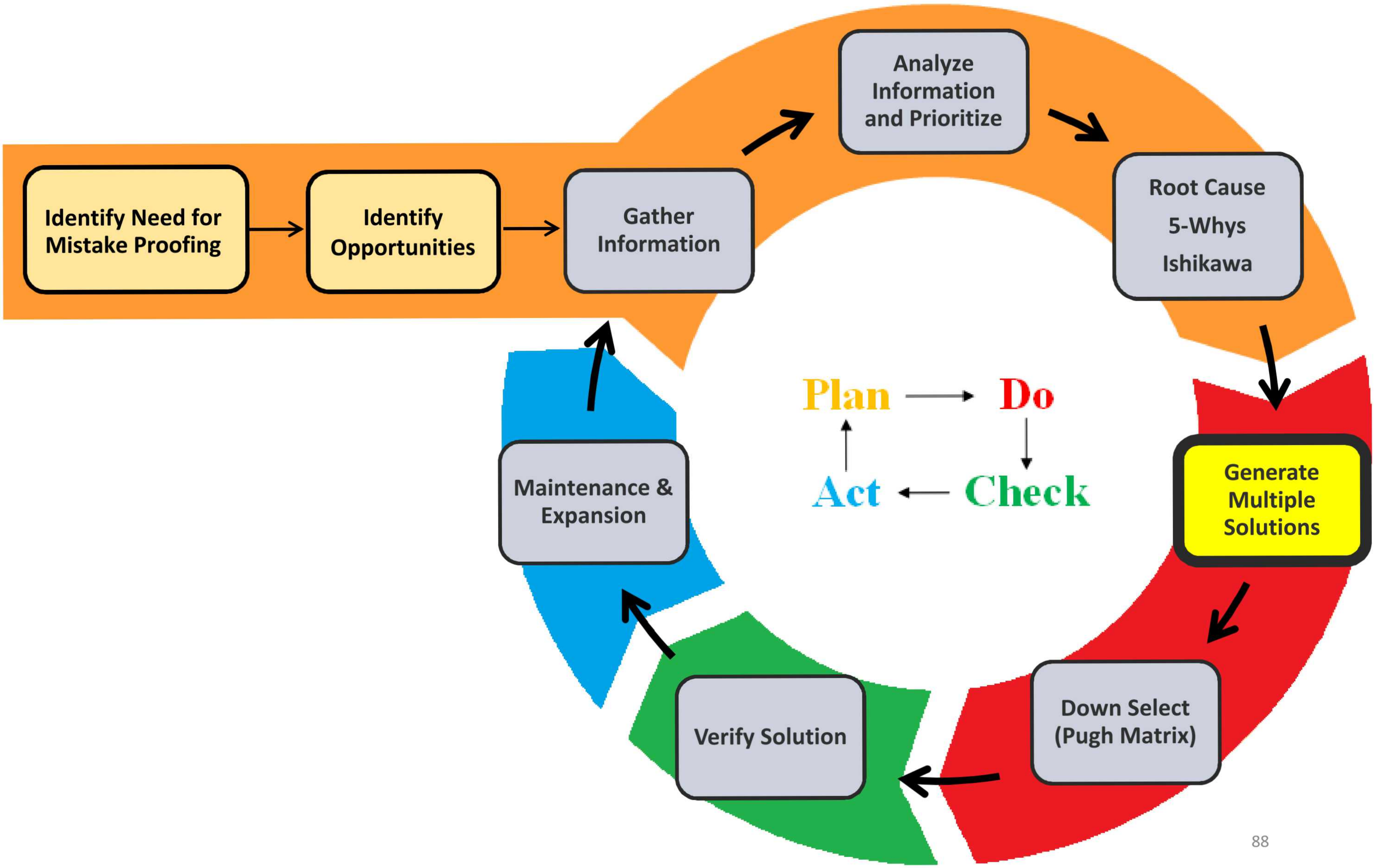
- Incorrect Processing:
  - Omission– Forgetting a process step, operation, etc.
  - Commission – Adding an unexpected process, operation, etc.
  - Positioning Error – Orientation and/or location
- Incorrect Parts:
  - Missing part (Omission), extra parts (Commission)
  - Defective/damaged parts, wrong parts
- Material Defects:
  - Wrong material specified
  - Material defective
- Information:
  - Defective information
  - Insufficient information
  - Excess of information

Common Defects - Examples

Here's some of the things I've seen:

- Omission of operation – Cap left installed
- Operation Error – Test series out of order, cross-thread
- Omitted parts: E Clips, screws, etc.
- Wrong part – Bolt thread pitch/type , glues/sealants, sandwich?

New example photos



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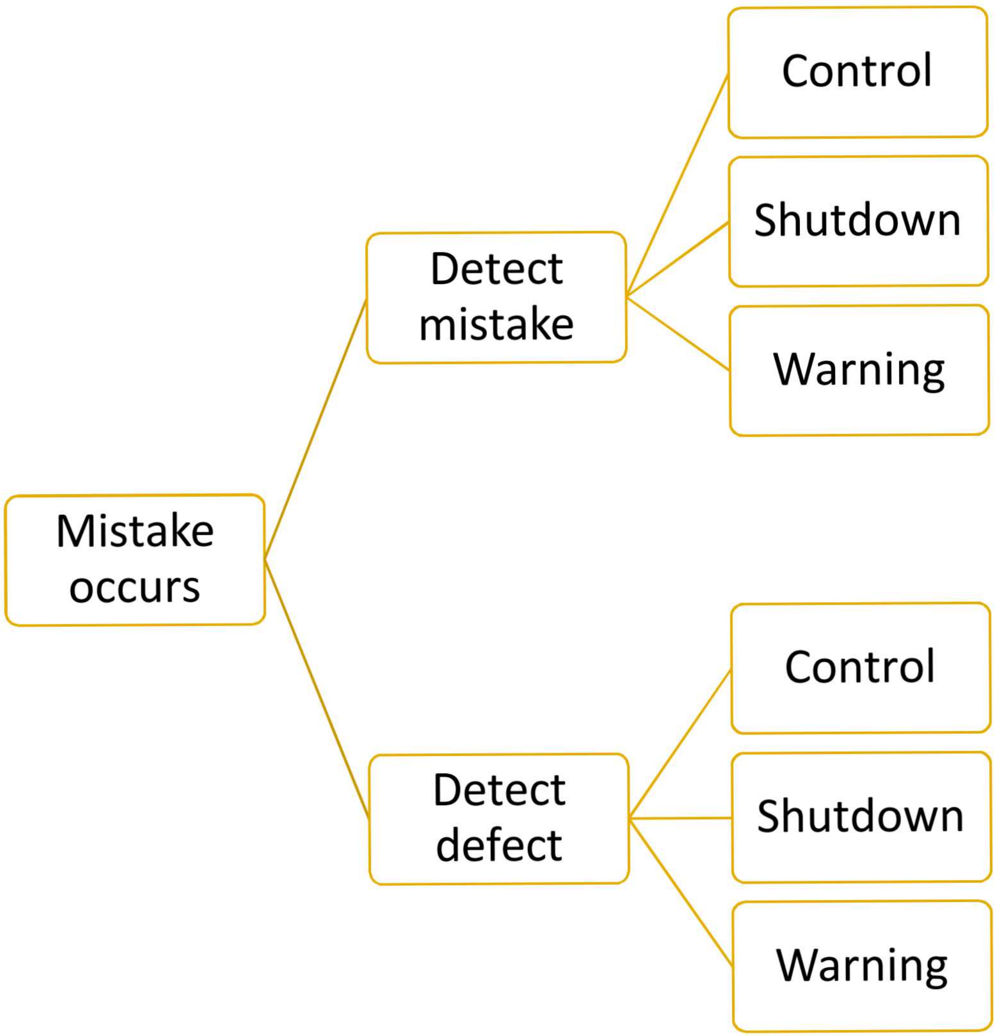
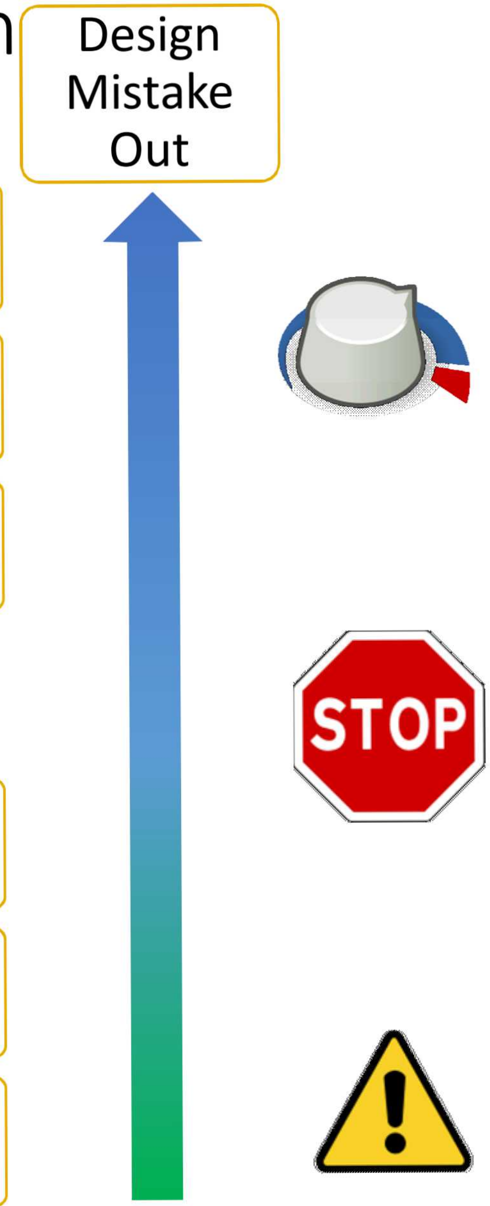
Basic mistake-proofing function





Existing mistake-proofing concepts

- Guides
  - Wrong orientation
  - Wrong parts
  - Misalignment
- Switches (limits)
  - Wrong parts
  - Wrong orientation
  - Creates interference
- Counters
  - Omitted parts
  - Omitted operations
- Alarms
- Checklists
  - Omitted parts
  - Omitted operations

How to become effective at mistake proofing

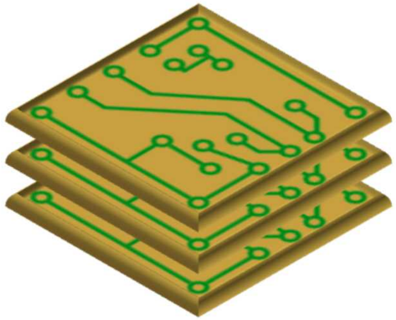
- A very effective way to learn and become proficient at mistake proofing is by studying previous examples.
  - There are many sources in which you can find examples.
    - Documented solutions for your work space
    - Industry examples (automotive, tech, medical)
    - Literature
      - Poka-Yoke (book handed out during class)

- The most effective way to become proficient at mistake proofing is by doing.
  - Write down all solutions no matter how “crazy” or “unrealistic”
    - May lead to innovative realistic solutions
  - Often times the best solution is a mix and match of many solutions

> If you cannot make it impossible for the error to occur, think of ways to detect the error and minimize its effects

Example: Wrong Orientation Problem

New example



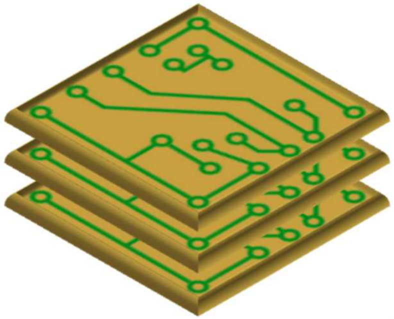
Circuit Board Assembly

Encapsulate

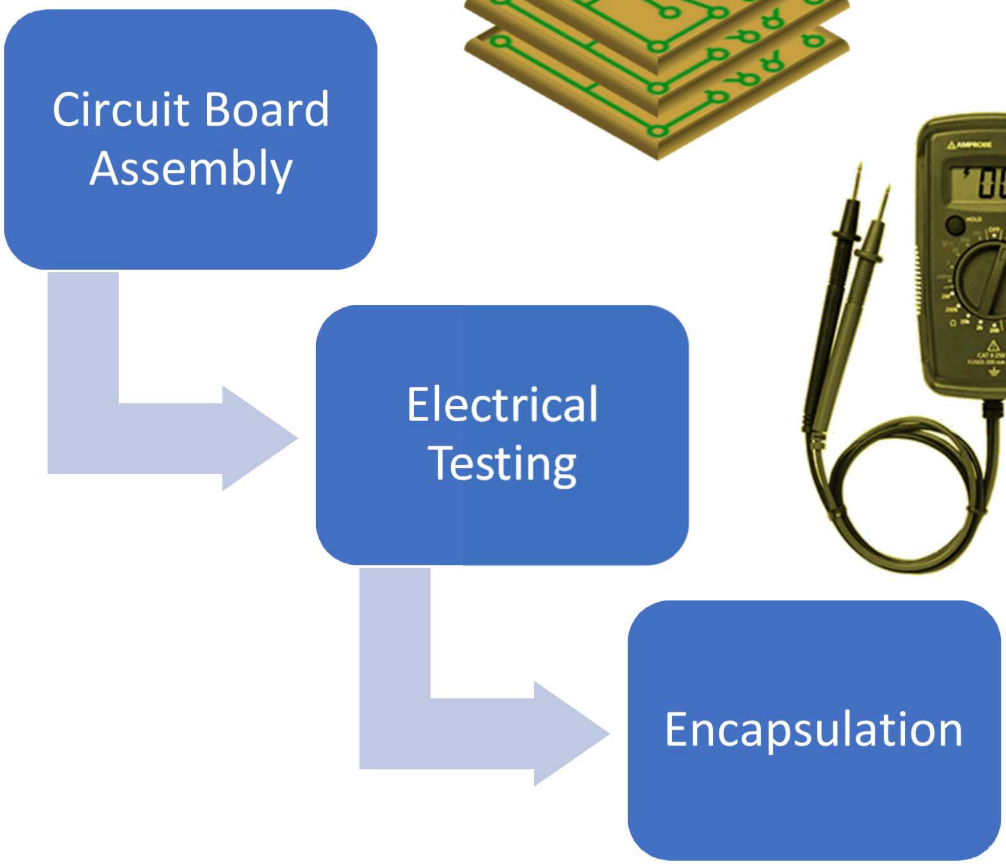
Electrical testing

Electrical testing after encapsulation is too late

Example: Wrong Orientation
Catching the mistake (production)

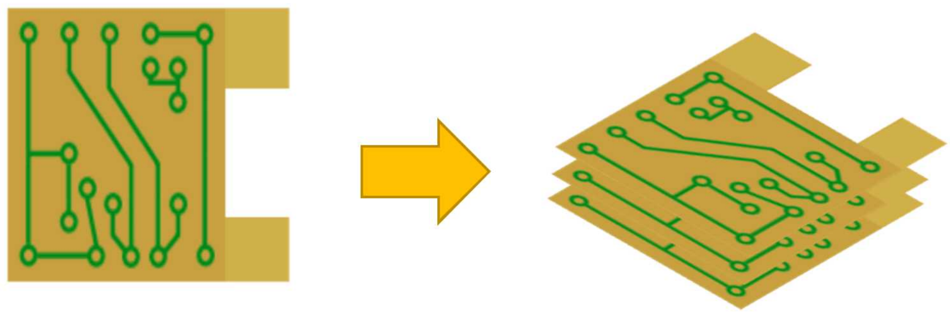


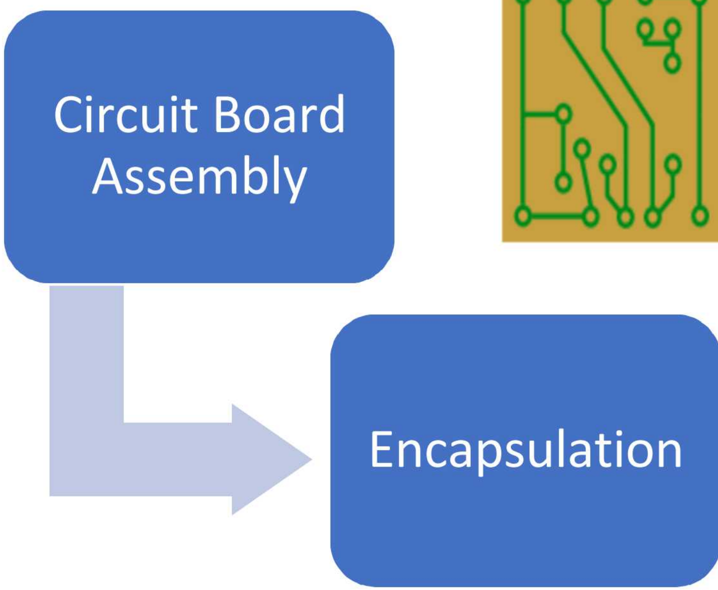
A simple change in process flow switches electrical testing to before encapsulation. Catching any wrong orientation mistake



Example: Wrong Orientation
Preventing the mistake (Design)

Making Unique features for each layer of PWA board ensures that there is only one way to assemble them. This also eliminates the need for electrical inspection.





Example: Wire Cutting

- Wires were similar color combinations.
- The length of the wire was dependent on where the operator held the ruler.
- Was difficult to hold the wire, hold the ruler and cut at the same time.
- No visual help on where wires are to be soldered.
- Operator had to constantly check which wire length he was cutting and remember values.
- Wire bundle came out of the side of connector and made it hard to route inside the unit.

Example: Wire Cutting Solution

- Connector is placed in next level assembly position
- Wires are a solid color, with no multiples
- Wires are routed in a fixture to correct location. Operator can verify wire has been correctly routed based an fixture as well as next level assembly picture.
- Once wire routing is verified all wires are cut at once, operator does not have to remember values.
- High voltage and non High voltage are clearly marked and are separated by shrink tubing sleeves.
- Parts are placed in oven to heat treat the shrink tubing and to pre-orient the wires for next level assembly.
- Wires only route to a single location

Using Information to Prevent Defects

Fixture Assembly

Before

- Using torque sequence 6, 5, 3, 1 and 2, 7, 8, 4 (shown below) torque each bolt to approximately 35 inch-lbs.
- Fixture was marked with random number order.

After

- Torque each standoff bolt to correct torque in order (1-8).
- Re-mark bolts following torqueing order .

Using information to prevent defects

- Torque Pattern is numbered on the part.

Using Symmetry to Prevent Defects

- Perfect symmetry
  - Cable connectors:
    - Where possible, design cables with the same connector on each side.
      - If cable is installed backwards, an SXR can be done stating that cable was designed to work in either orientation.

Using Asymmetry to Prevent Defects

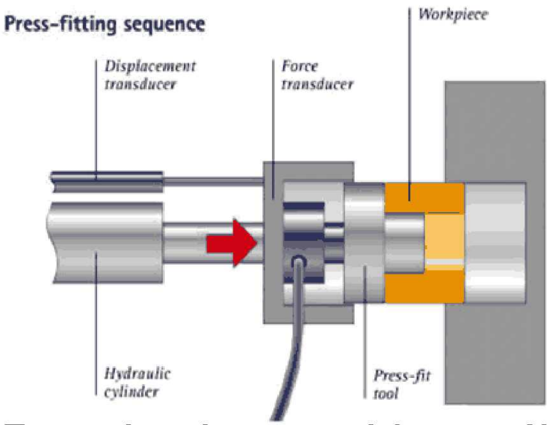
- Use asymmetry to force correct assembly.

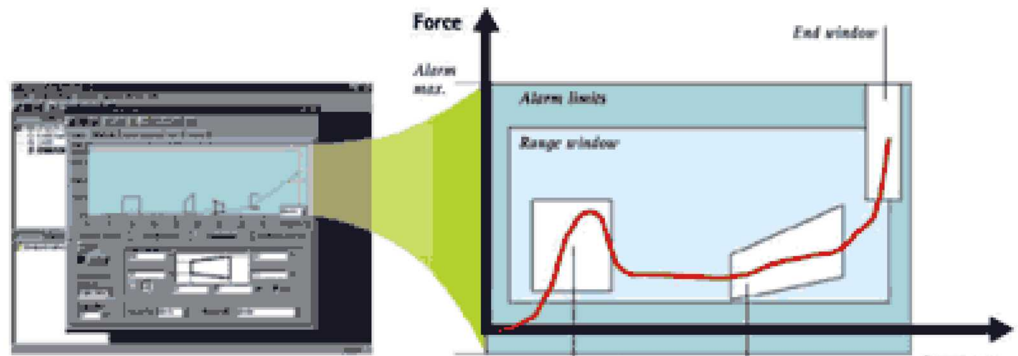
Example

- Asymmetry

Example

- Pressing operations – Monitor force vs. displacement to ensure correct assembly.





Applications-oriented graphical user interface: easy to use "windowing technique" for monitoring

- Can also be used to verify presence of wire in a crimp.

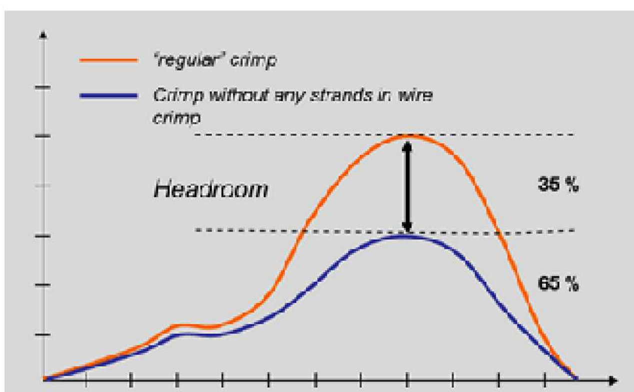
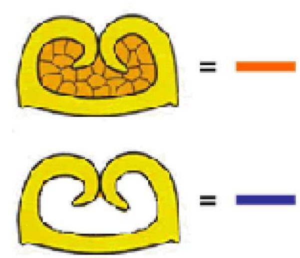
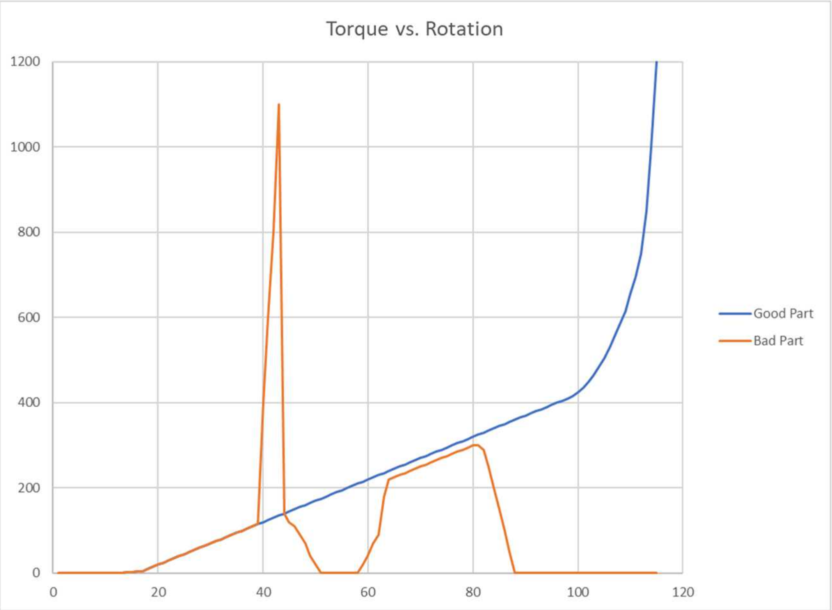


Figure 1

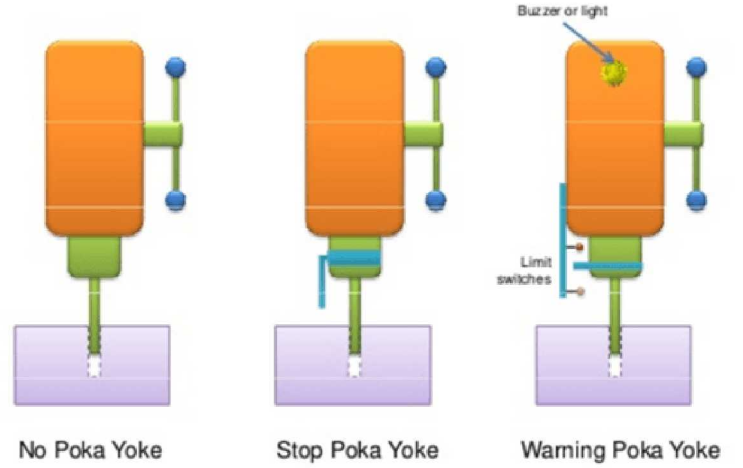


Example

- Torque monitoring
  - Just going "to torque" is insufficient.



- Control depth of drilling.



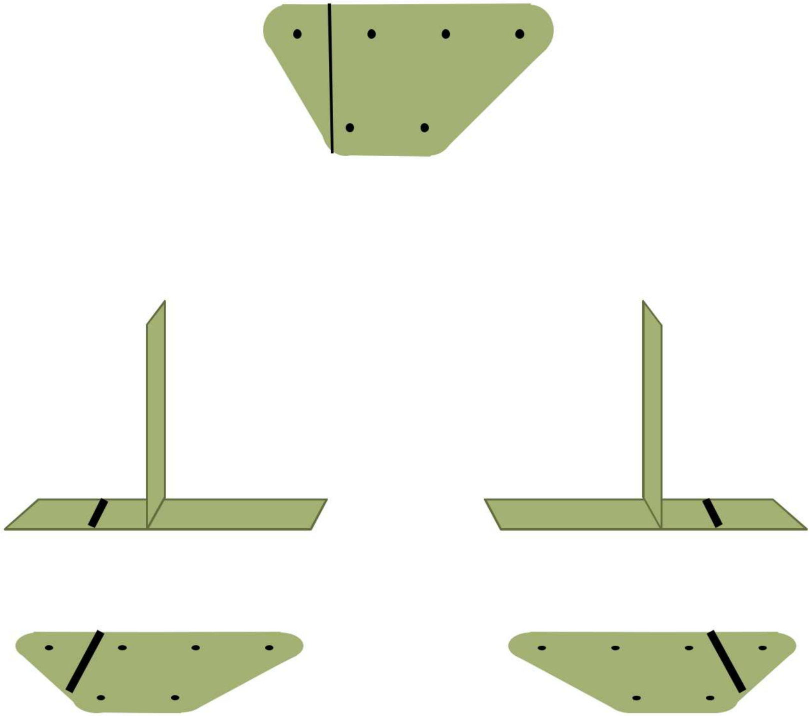
Exercise

- Shout it out
    - Do any of these examples match a mistakes that you are aware of?
    - After seeing multiple examples have you identified any quick solution you can implement in your defect?

Asymmetric Plate Installation

Two identical asymmetric plates are installed to mount the pilot and copilot pedals. "Bottom" is marked on one side of the plate, but for correct assembly, the plate must be put on with "bottom" up on the pilot side, or the console will not fit. The error is found late in the production.

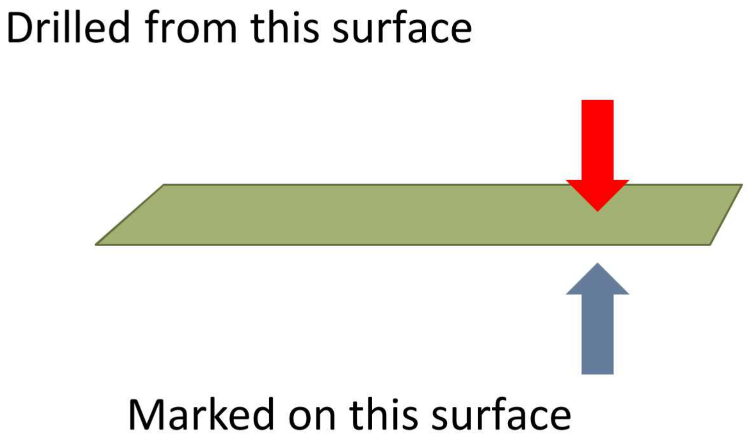
"Bottom" text is covered. Asymmetric part and mount are marked so that correct orientation is obvious.

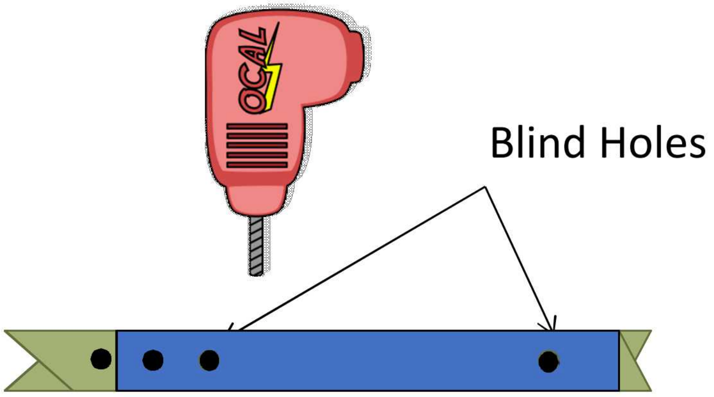


Blind Drilled Holes

For drilling access, assemblers must drill holes from the opposite surface from where the position of the hole is defined. Holes may be misaligned or oversized when drilled.

Use smaller marking fixture for the side with blind holes, using pilot hole as a reference hole.



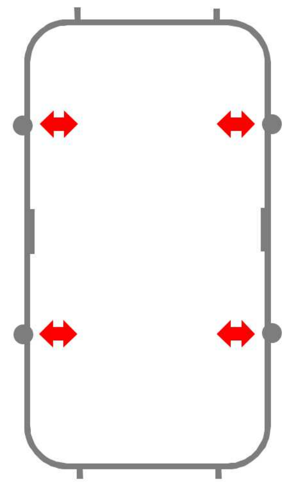


Clam Shell Door Mounts

Hinge mounts for the top and bottom of a clam shell door are installed in an aircraft. Side holes must be accurately drilled in plates at midheight to assure that the door is secured when closed. These holes often are misaligned with door segments when the door is installed.

A single fixture holds top & bottom hinge plates for alignment during assembly, centers the doors side to side in opening, and guides side hole drilling.

Misaligned hole must be repaired

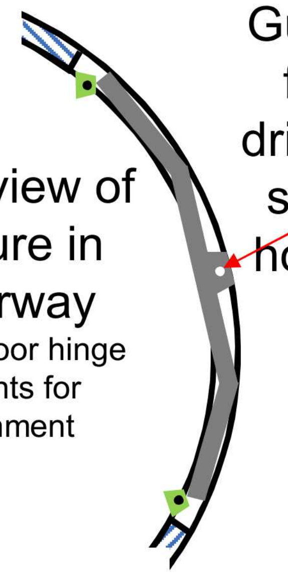


Door Mount Fixture

w/ retractable centering elements

Side view of Fixture in doorway

Holds door hinge mounts for alignment



Guide for drilling side holes

Clam Shell Door Mounts

Hinge mounts for the top and bottom of a clam shell door are installed in an aircraft. Side holes must be accurately drilled in plates at midheight to assure that the door is secured when closed. These holes often are misaligned with door segments when the door is installed.

Change the order of operations, to drill the side hole after the door is installed.

Misaligned hole must be repaired

Aircraft Fasteners Insertion

Fasteners that appear to be identical visually are installed in the wrong location and are easily confused because identifiers are similar. Some rivets are hardened and difficult to remove.

Each fastener type is identified by a symbol on the templates and aircraft that match the unique symbols on the fastener storage bins. Symbols may be color coded for strength.

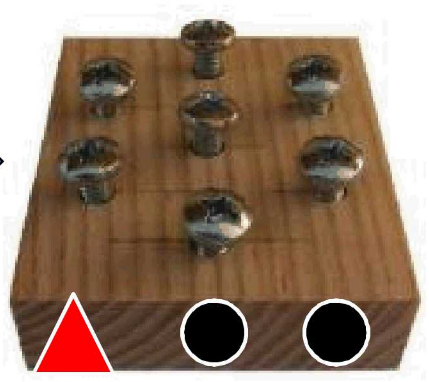
Aircraft Fasteners Insertion

Fasteners that appear to be identical visually are installed in the wrong location. Some rivets are hardened and difficult to remove.

Unique fasteners used in a few locations are assembled using matrix blocks to assure the count is correct and all fasteners are inserted.

Matrix Box

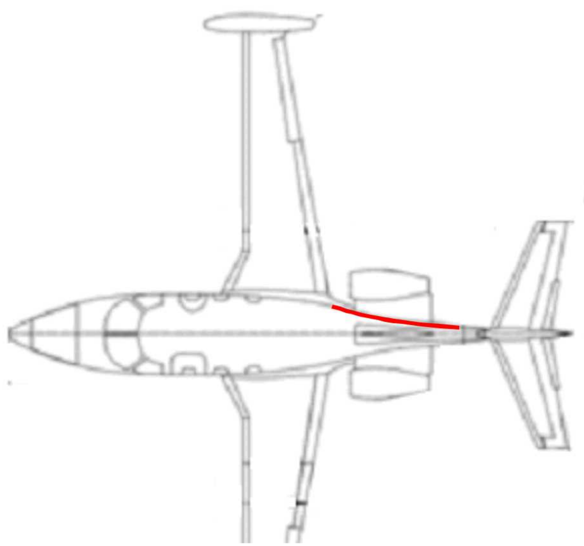
Pre-Sorted
Pre-Counted
Pre-Oriented
Easy to pick up
Finger clearance

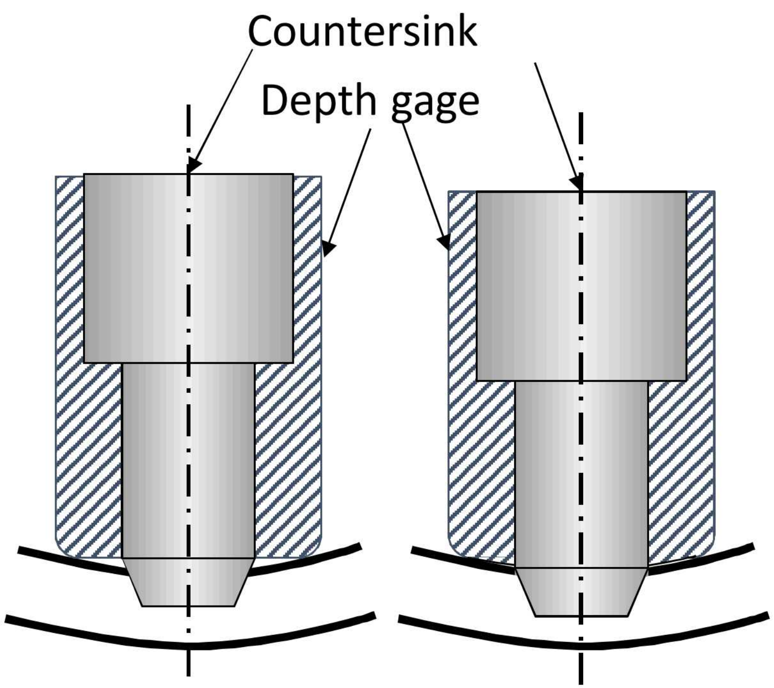


Countersunk Holes

Fasteners on the external skin of an aircraft must be flush within 0.002". 60% of the fasteners on one section of the aircraft are not set deep enough and must be replaced. These fasteners are on a concave surface of the aircraft.

A special tool with a saddle shape depth control face sets countersink depth on concave surfaces.

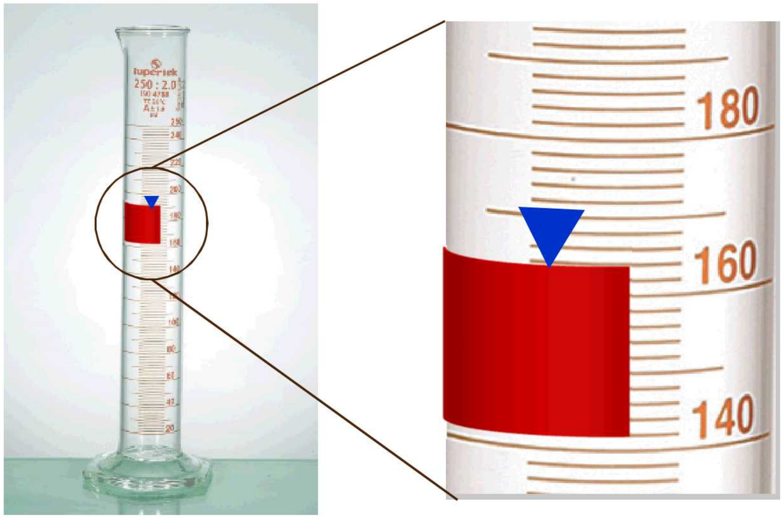




Fluid Measurement

Graduated cylinders are used for measuring cleaning solutions, but the graduated cylinder doesn't have adequate or obvious markings to measure the fluid correctly.

Even with precision markings the fill quantities can easily be misread. A level with a pointer is permanently bonded to the cylinder when the cylinder is only used to measure one fluid quantity.



Expiration Date Marking

Critical operations may apply a more conservative expiration date than manufacturers for certain materials, but the containers now have 2 expiration dates. Both are visible, confusing operators.

The manufacturers expiration date is covered with the new expiration sticker on the box ***and every container inside the box***.

Hot Plate Control

The fluid being heated needs to reach a defined temperature. Using a simple hot plate was time consuming and finding the correct temperature was a trial and error series of manual adjustments.

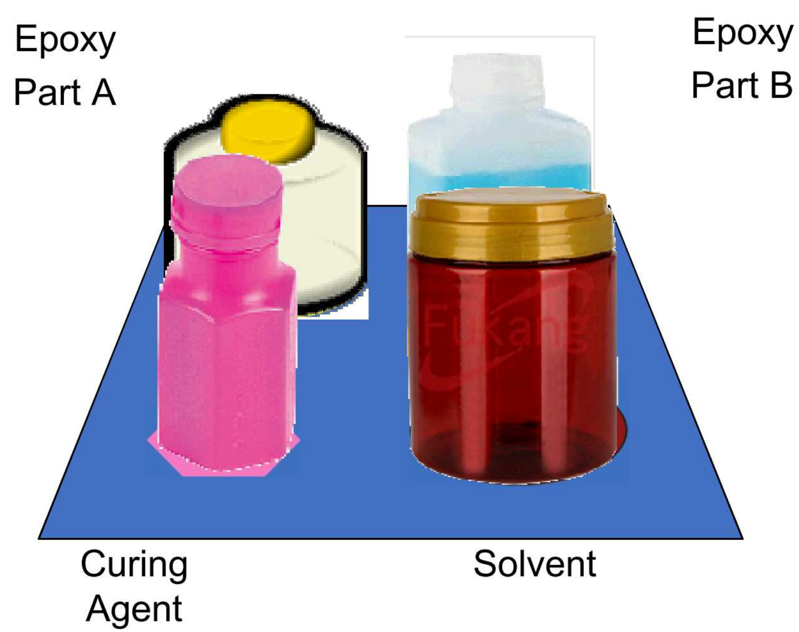
The target temperature is set, and the liquid is heated to the set temperature using a sensor. A magnetic stirrer assures the temperatures are uniform in the liquid.

Complex Encapsulation Process

Encapsulation uses several fluids that are weighed, mixed, heated for curing. Many weighing steps are done in a time-limited process.

- The wrong materials have been used
- Weighing errors have occurred,
- Materials have been left out.

Materials for each encapsulation process are pre-weighed and placed in a kit, where it is obvious if the right number and quantity of fluids are prepared.



Encapsulation Fluid Weighing

Encapsulation uses several fluids that are weighed, mixed, heated for curing. Many weighing steps are done in a time-limited process.

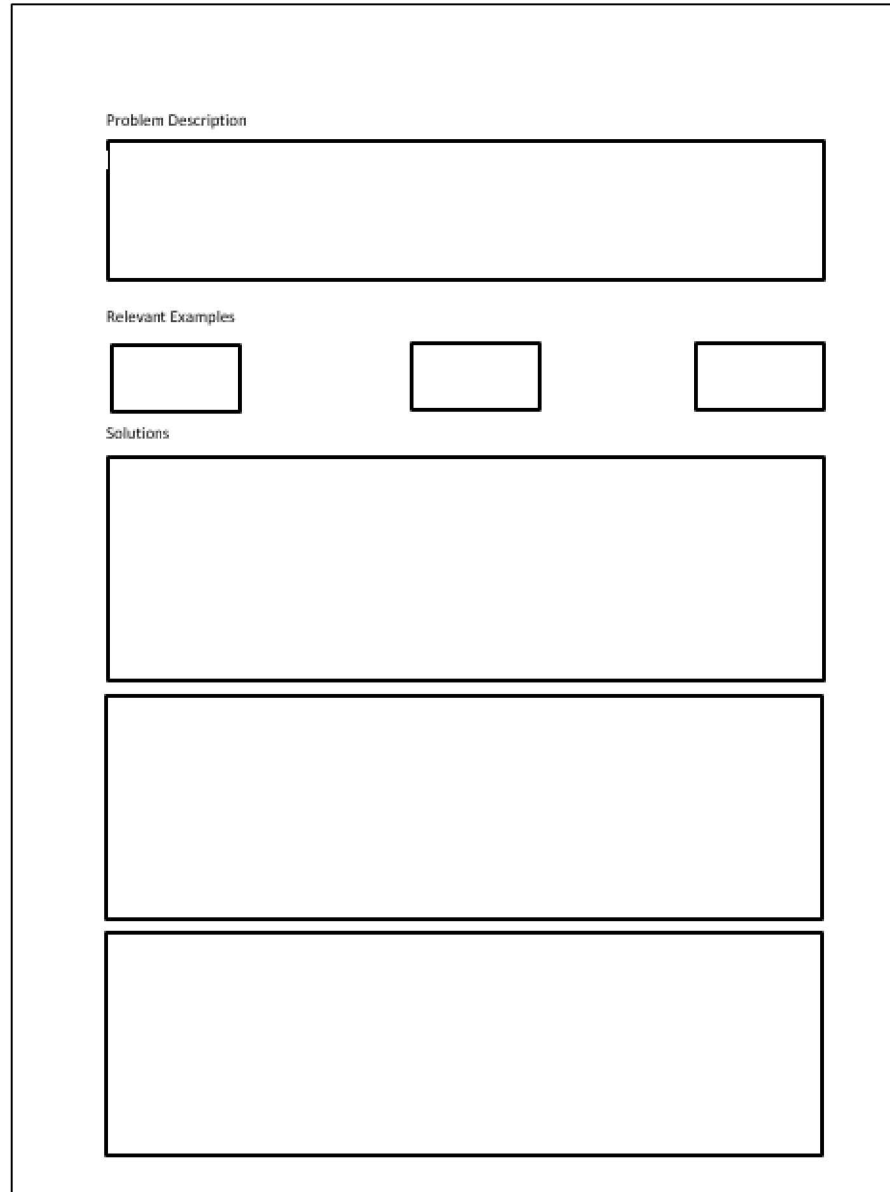
- Weighing errors have occurred
- Material weights have been switched
- Operator must reference or remember all material weights

- The weight of measuring containers are all 1000 gm.
- A fixed master weight is made for each material measured.

Example: for Epoxy A a master weight of 46 grams is made. When weighing Epoxy A, tare with 46 gm weight, replace weight with container, and weigh to 1000 gm.

EXERCISE (30 minutes)

- Draft 3 solutions specific to your problem.
- Use your book as a resource to find examples that are relevant to your problem.
  - Index of improvement categories – 275
  - Index of operations, processes, and problems – 276
- Find 3 relevant examples.
  - Note: for real problems, it is recommended that you develop as many potential solutions as you can.
- Try to have at least 1 "crazy" idea.

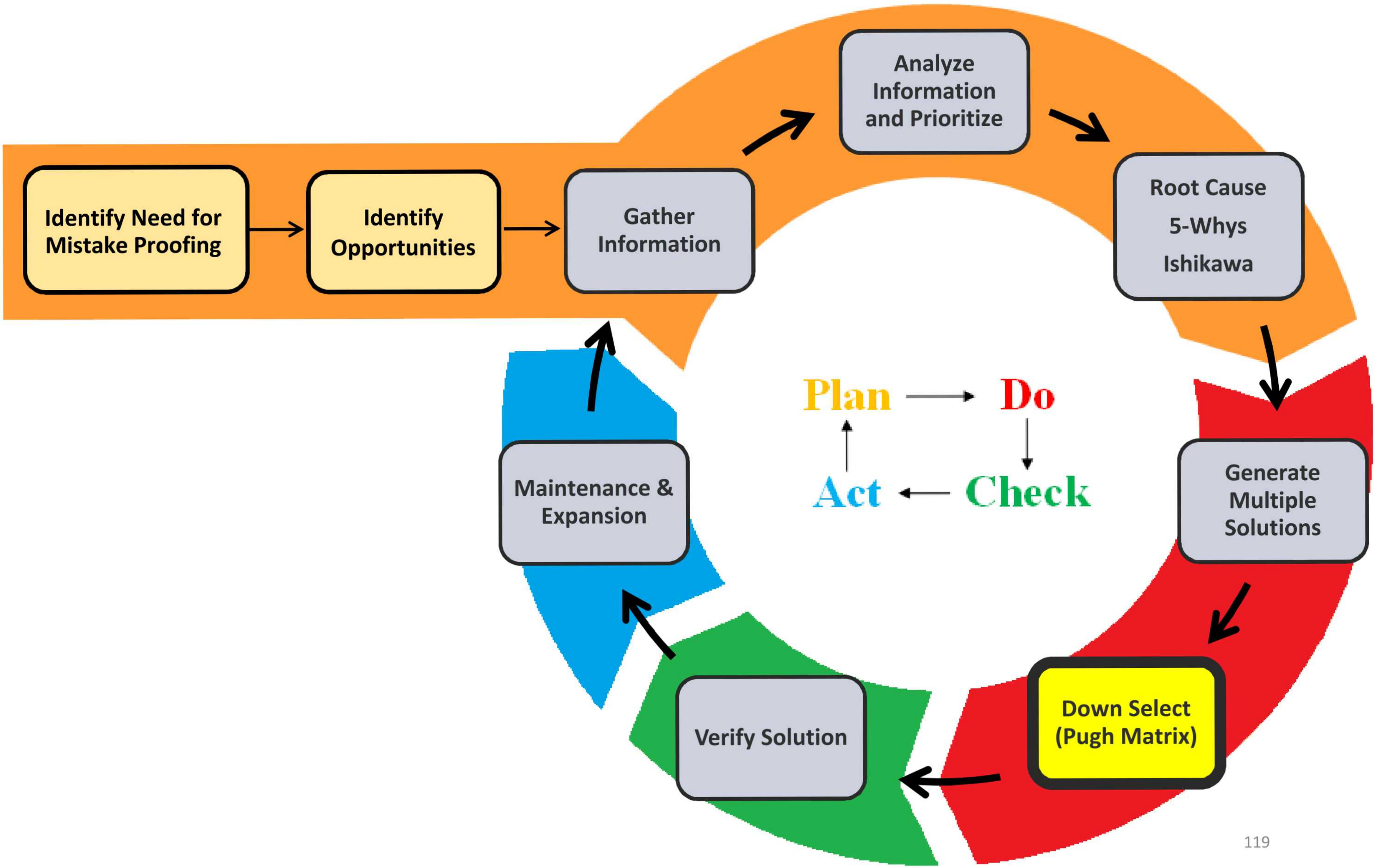

Problem Description

Relevant Examples

Solutions

References for Exercise

- Slides references:
  - Shigeo Shingo, The Poka-yoke System, Part I, Theory, Productivity Press, Portland Oregon, 1987.
  - Red Poka Yoke book.
  - Designing errors out.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Ishikawa
Generate Multiple Solutions
Down Select (Pugh Matrix)
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Maintenance & Expansion
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Check
Act

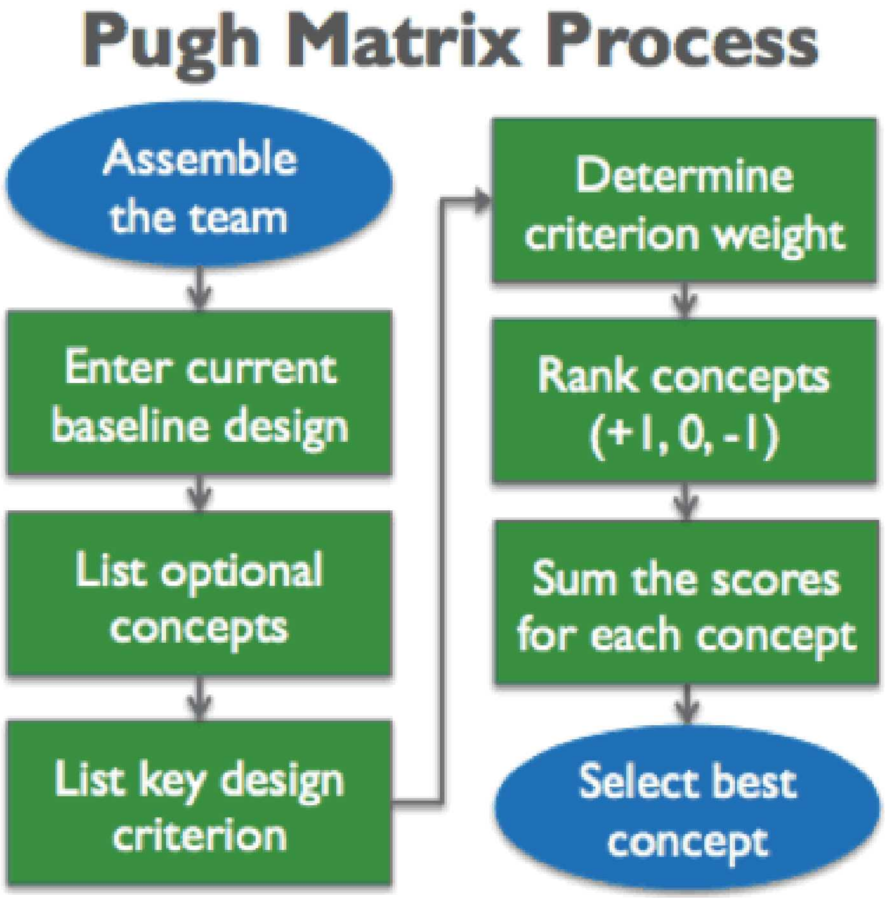
Compare Solutions and Down Select

- Comparing many solutions can be difficult.
  - Which is the “best” solution?
  - Personality clashes.
  - Potential unintended effects.
- Decisions should have requirements as focus.
  - Include the customer in the decision making process, if possible.

Pugh Matrix for Decisions

- A Pugh matrix is a great way to compare many solutions
  - Scores solutions by attributes rather than entire system
  - Attributes can be customer desire or requirement derived.
- Assign a "rank" to each attribute based on attribute importance
  - This will contribute to the "weighted score."
- Select a baseline design.
  - Can use the existing design, if applicable.
- Score each attribute against the baseline, not each other.

Pugh Matrix for Decisions



IMPORTANCE/WEIGHT	
0	Not important
1	Lowest Importance
2	…
3	…
4	…
5	Highest Importance

LEGEND	
2	much better
1	better
0	same as baseline
-1	worse
-2	much worse

EXERCISE – Pugh Matrix (20 min)

Selection Criteria / Attributes	***Importance (5 is HIGH)***	***Baseline Option***		***Option 1***		***Option 2***		***Option 3***	
		U	***W***	***U***	***W***	***U***	***W***	***U***	***W***
Cost to implement	3	0	0	1	3	-2	-6	2	6
Time to implement	4	0	0	-1	-4	1	4	1	4
Ease of implementation	1	0	0	-1	-1	-1	-1	1	1
Effective/Accurate	5	0	0	1	5	0	0	2	10
Support/Maintenance	3	0	0	2	6	-2	-6	-1	-3
Reliability	5	0	0	2	10	1	5	0	0
Unweighted Score		0		4		-3		5	
Weighted Score		0		19		-4		18	

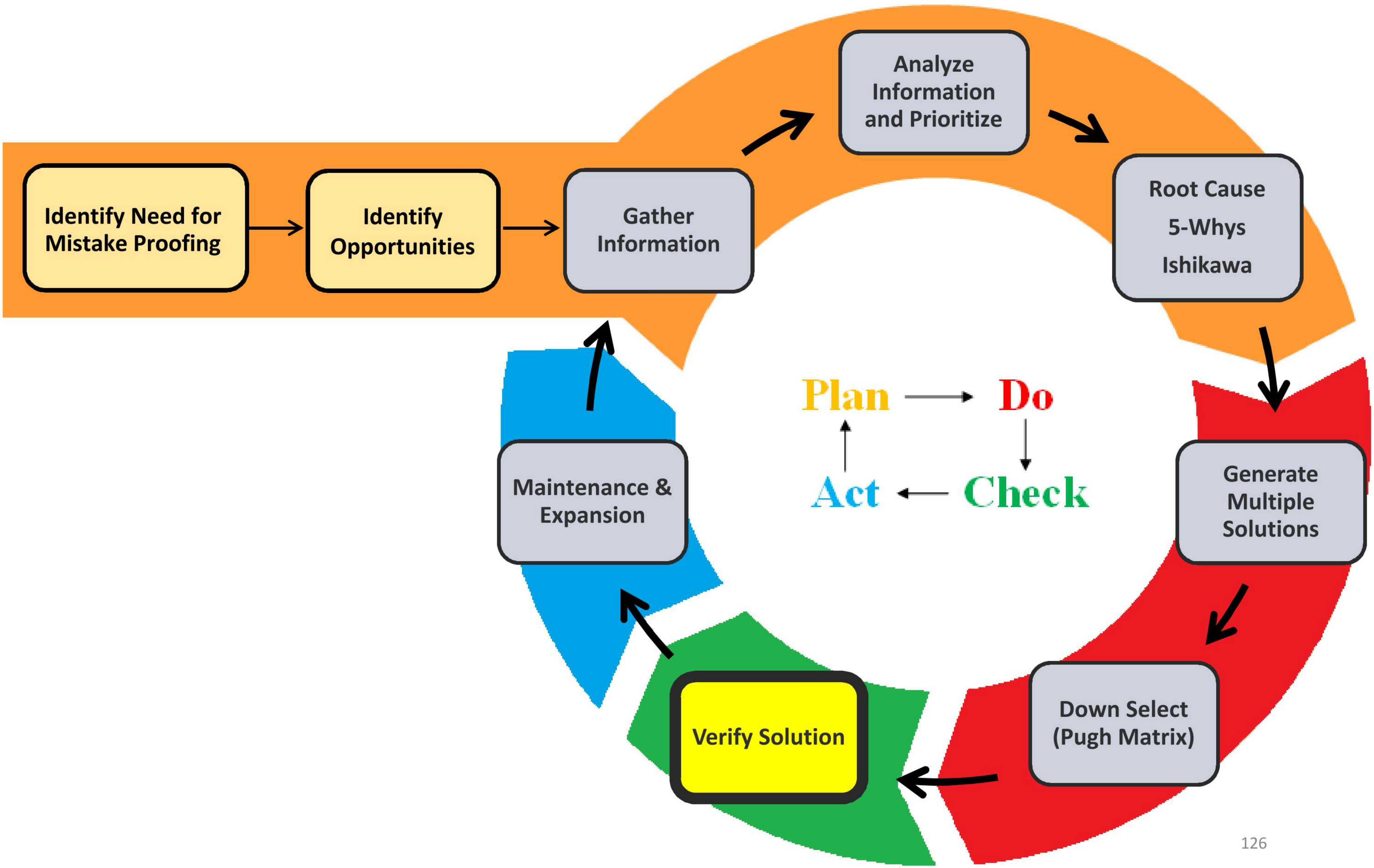
Maximum Unweighted Score	5	Option 3
Maximum Weighted Score	19	Option 1

EXERCISE – Pugh Matrix (20 min)

- What was your prevailing solution? Review with class.
- Did the weighted scores change the outcome?
- Can attributes of multiple solutions be combined to create an even better solution?

Solution Deployment

- Define metrics for success.
  - Cost
  - Schedule
  - Performance
  - Always/Never
- Come up with a “surveillance” plan.
  - Collect data
- Plan the deployment of the solution.
  - Training
  - Equipment
  - How long will it take to implement the solution?
  - Maintenance


Identify Need for Mistake Proofing
Identify Opportunities
Gather Information
Analyze Information and Prioritize
Root Cause
5-Whys
Ishikawa
Generate Multiple Solutions
Down Select (Pugh Matrix)
Verify Solution
Maintenance & Expansion
Plan
Do
Check
Act

Collect Data

- Use Metrics defined previously (Gather Information).
    - Cost
    - Schedule
    - Performance

- Compare this information to what was done before mistake proofing.

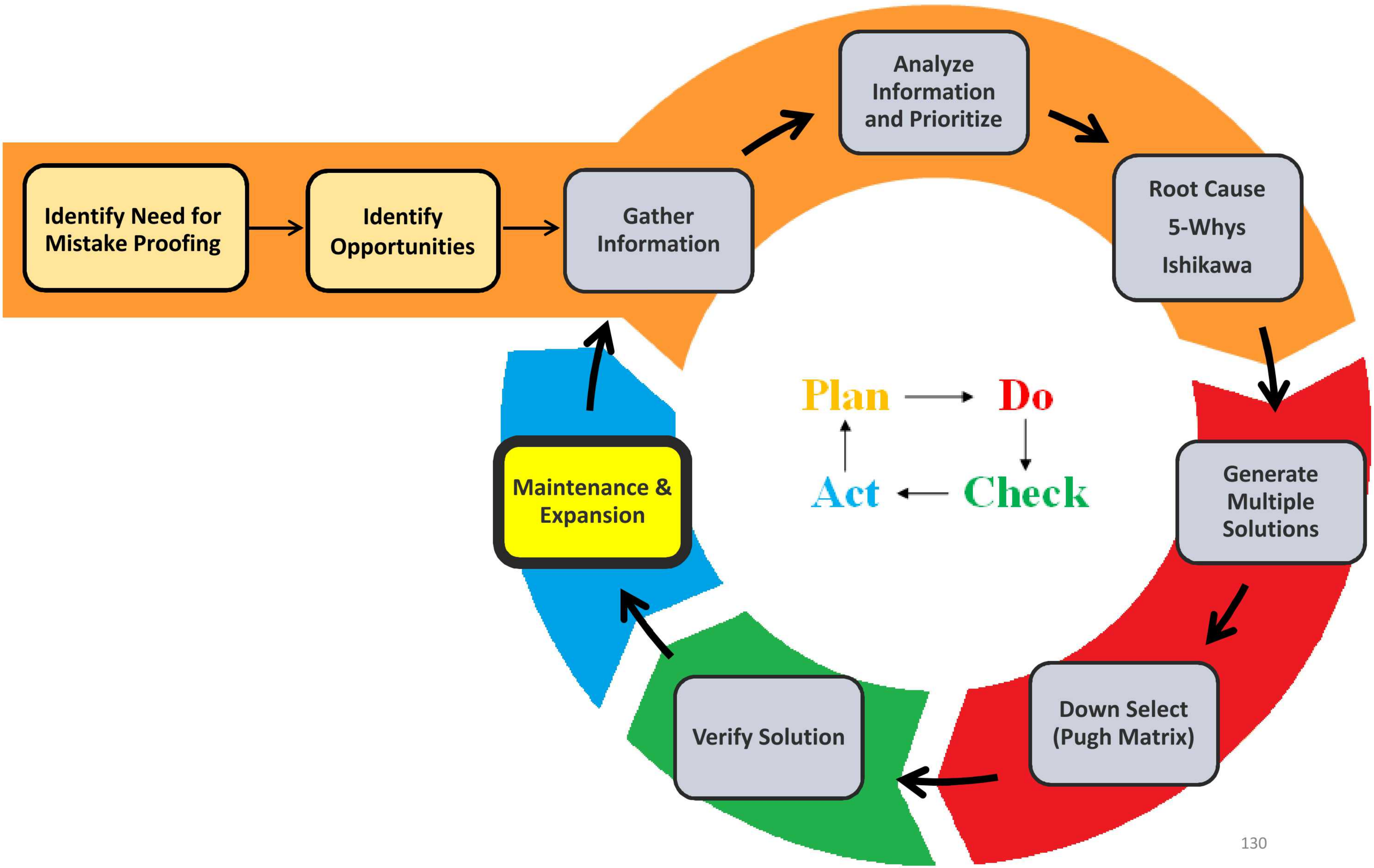
Collect Data

- Assure defect would not repeat in the future.
  - Use data to identify possible future problems.
    - Trend data
  - Does the solution need to be maintained?
  - What could change and cause defects again (unknown unknowns).

- If there are problems, think about revisiting the Pugh Matrix
  - Change ranks?
  - Change scores?

Verify Solution

- Does the solution solve the correct problem?
- Does it introduce new problems?
- Test the solution
  - Introduce “intentional” defect to test if the solution worked.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Document the Solution

- Document everything.
  - Proposed solutions and reasons they did/did not work.
  - Pugh Matrix (even if it’s just scanned)
  - Explain clearly.
- Use configuration control.
  - Lessons Learned (LL) or Product Realization Report (RR) document.
  - Information Engineering Release (IER in Prime).
  - If possible, include reasoning in other documents (work instructions).
- Share
  - Deploy wherever applicable.
  - Who/what else could benefit from this?

Why do we need to document?

- All the examples we've gone over came from previous experiences.
  - Adding to these gives future employees a resource that may solve one of their problems.
  - Help others learn from previous mistakes before making their own.

Wrap Up

- Summary
  - We learned the differences between mistakes and defects.
  - We learned to identify and prioritize opportunities for mistake proofing both proactively and reactively.
  - We learned about a wide variety of solutions as examples to put us into a mistake proofing mindset.
  - We learned how to develop many solutions to a problem and choose the best option.
  - We learned we need to evaluate our solution to make sure it works the way we intended.
  - We learned we need to document our solution so it can be used in the future.
  - We learned that the best approach to prevent manufacturing mistakes is to design them out in the first place, or design in features to make mistakes obvious.

Wrap Up

- End of class questions