Manufacturing Reliability

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Ron’s Background

- BS Systems Engineering, US Naval Academy
- MBA, City University of Seattle
- Ph.D. Candidate for Industrial Engineering, UAH
- Nuclear submarine officer (12 years active duty; 22 years reserve duty)
- Pharmaceutical Manufacturing (30 years)
    - Maintenance Manager
    - Engineering Director
    - Global Maintenance and Reliability Leader
- Selected as the 2017 Certified Maintenance
and Reliability Professional of the Year

What is Reliability?

- Reliability is the probability that a system will perform its intended function within the mission timeframe.
- Systems Engineering and Reliability grew from the military requiring complex equipment from WWII. Very much focused on a weapon system performing correctly.
- Typically, reliability has had a product focus: a jet engine, a rocket, a weapon system, a pump. We can call this Product Reliability.

But there is a different type of Reliability out there in the industry…

- Not product reliability focus but reliability focused on the ability to reliably manufacture product.
- Pharmaceutical Industry, for example
  - Product reliability (the medicine) is determined by scientists and medical doctors-not reliability engineers.
  - Reliability engineers focus on the manufacturing processes used to make the medicine.
- Very much aligned with Industrial Engineering

Product Reliability vs Manufacturing Reliability

- Product Reliability-the probability that the product will perform its function correctly within the mission period

- Manufacturing Reliability-the probability that the product will be manufactured correctly within the mission period

American Society for Quality--Certified Reliability Engineer (CRE) Body of Knowledge

- Reliability Fundamentals (85% applies to Manufacturing Reliability)
  - Leadership foundations
  - Reliability Foundations
- Risk Management (60% applies to Manufacturing Reliability)
  - Identification
  - Analysis
  - Mitigation
- Probability and Statistics for Reliability (90% applies to Manufacturing Reliability)
  - Basic concepts
  - Data Management
- Reliability Planning, Testing, and Modeling (50% applies to Manufacturing Reliability)
- Life-Cycle Reliability (70% applies to Manufacturing Reliability)
  - Reliability Design techniques
  - Parts and Systems Development
  - Maintainability

The Birth of the Manufacturing Reliability Model

Conversation with VP of Engineering:

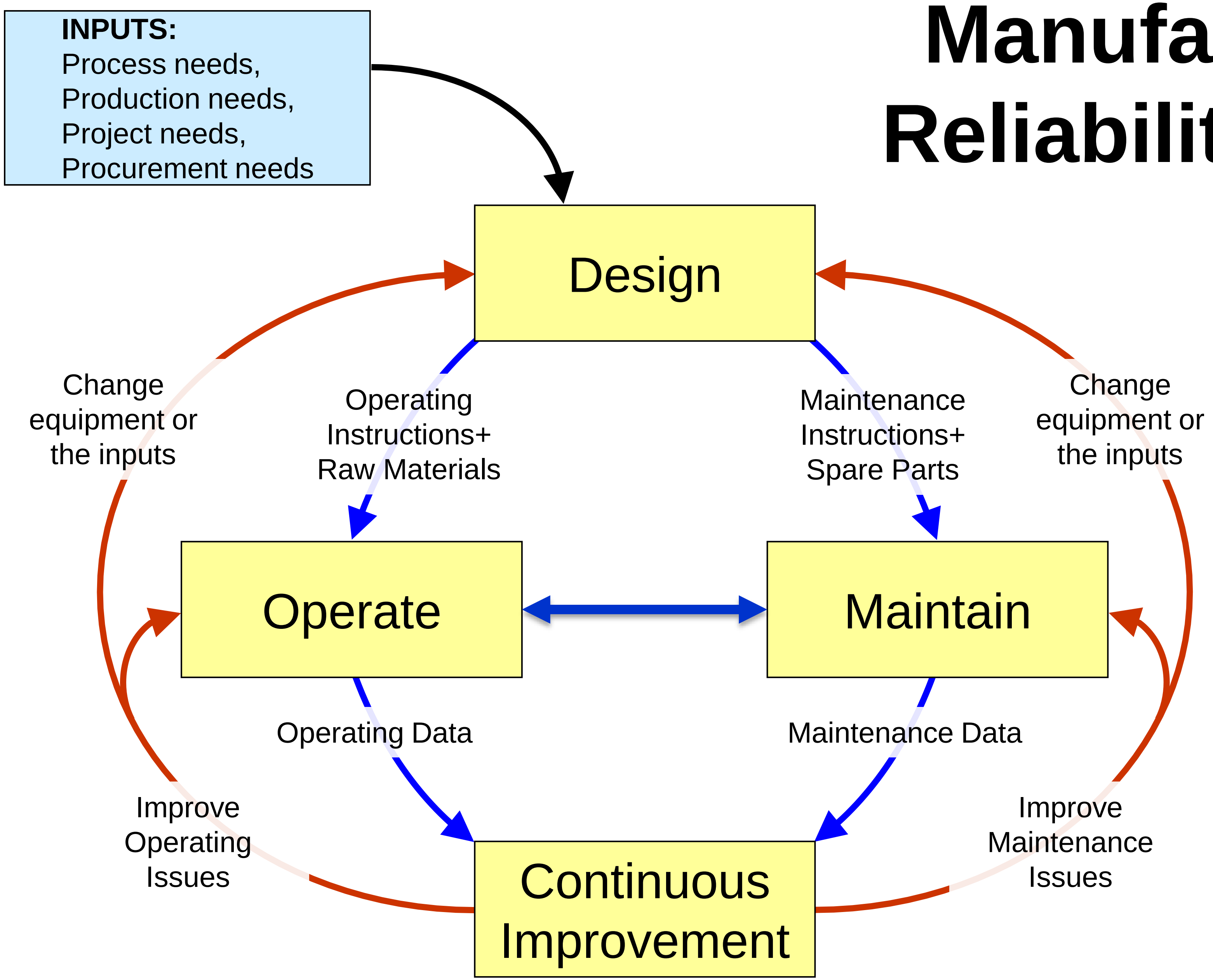
- VP: We need more reliability!
- Me: What is your definition of reliability?
- VP: Equipment does what it is supposed to do!
- Me: Why doesn't equipment do what it is supposed to do?
- VP: Because we have bad maintenance!
- Me: Could it be more things than just maintenance? Could Operations run the equipment incorrectly, for example?
- VP: Hmmm. You're right. Make me a reliability model!

Manufacturing Reliability Model-Four Domains

- **Manufacturing Reliability is a result** of how well we design our manufacturing processes as well as how we operate and maintain it.

- **Design**-The selection and installation of manufacturing equipment
- **Operate**-How the installed equipment is operated along with materials being used for production
- **Maintain**-How the installed equipment is maintained along with the spare parts and lubricants used for maintenance
- **Continuous Improvement**-Looking at Operating and Maintenance data for areas of improvement. Downtime metrics, RCFA, FMEA…

Manufacturing Reliability Model



A Design Issue

Two homogenizers designed to operate at 8000 psi to break open cells.

Issue: The installed heat exchangers could not cool the output of the homogenizers to specifications.

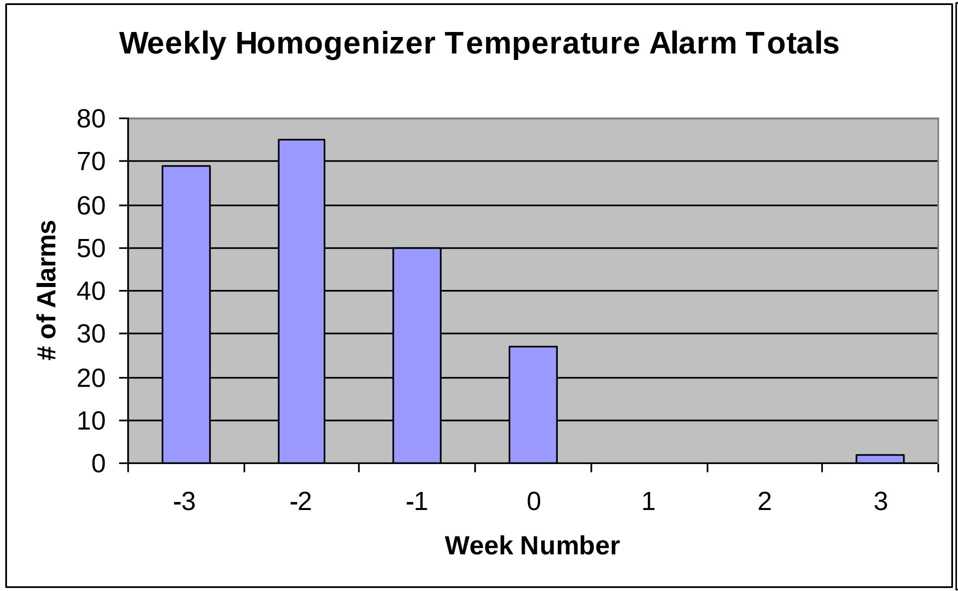
•Numerous temperature alarms
•Manual reduction of homogenizer pressure to reduce heat input
•Increased cycle times
•Deviations

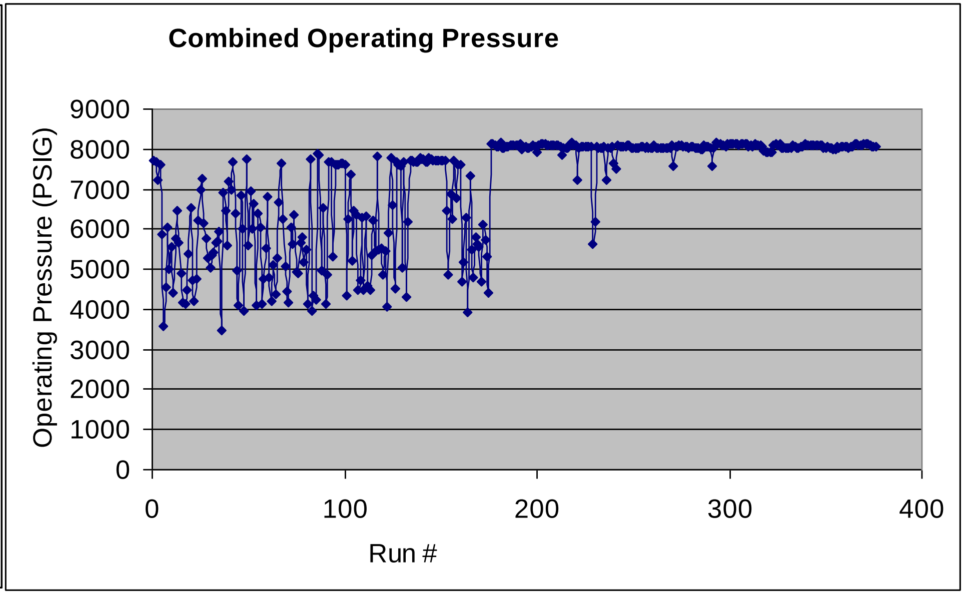
Equipment operated correctly
Equipment maintained correctly

→Heat exchangers too small for load

A Design Issue (con't)

After changing process requirements and modifying the cooling system, the following results were achieved:





The reliability of the homogenizer system improved. Equipment can now perform its intended functions. Benefits are far beyond M&R costs…

An Operate Issue

Magnetic drive pumps issue. Installed many pumps to reduce emissions. Lubricated via process fluid: Cannot be operated dry. Temperature alarms installed.

- After installations, MTBF≈3 weeks
- Operation technique was to run the pumps dry when transferring from one tank to another.
- Changed operation technique to allow the last 2% of the tank to be drained instead of pumped.

→Pump MTBF improved to multiple years.

A Maintenance Issue

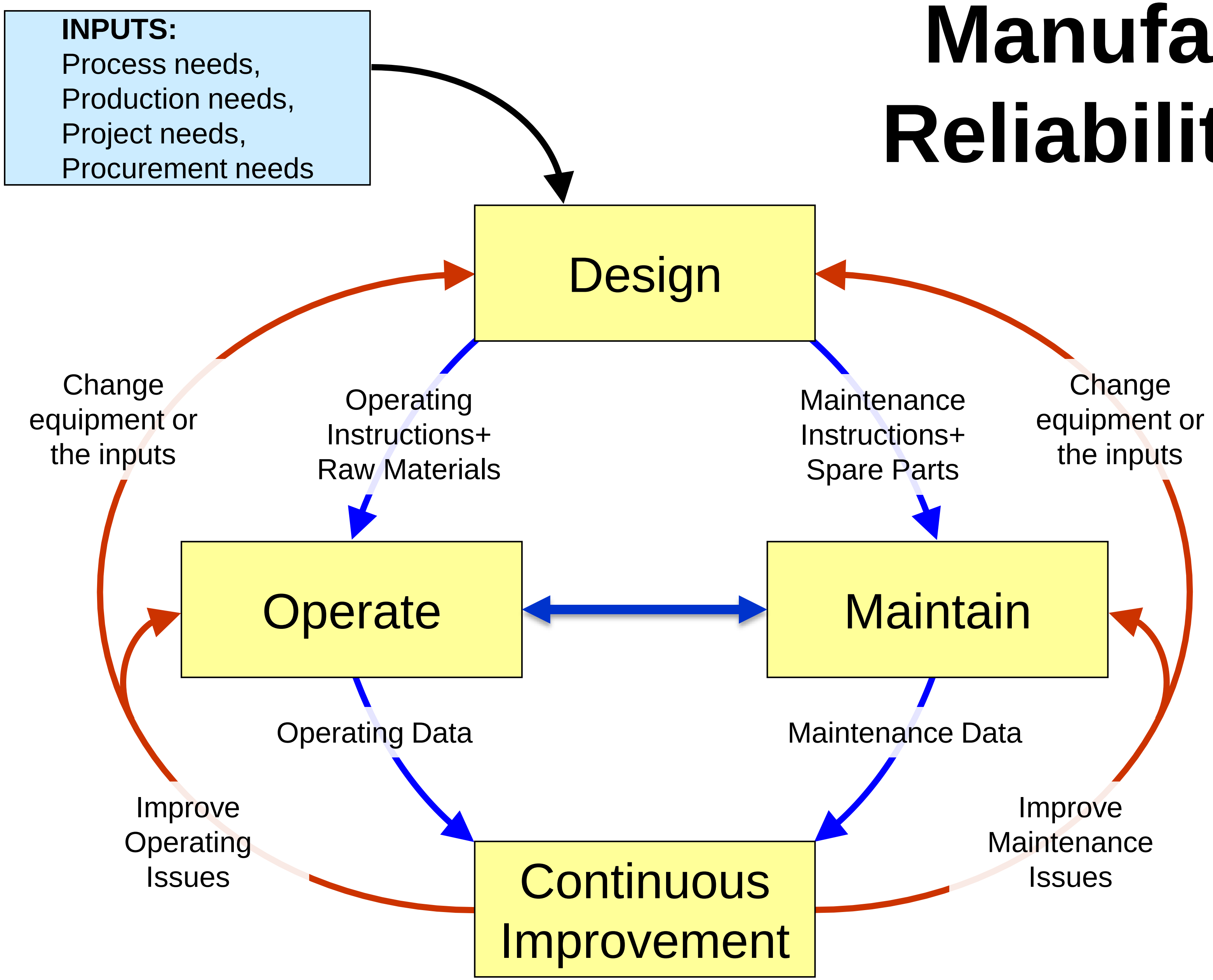
Mechanical Shaft Seal on Critical Reaction Tank

- Seal failed after tank replaced (initial seal installed by tank manuf.)
- Maintenance replaced the seal.
- New seal failed within two weeks.
- This work was repeated several times, in conjunction with the seal manufacturer.

- Finally, it was discovered that the seal needed to be placed one quarter of an inch higher on the shaft due to the glass coating on the shaft.

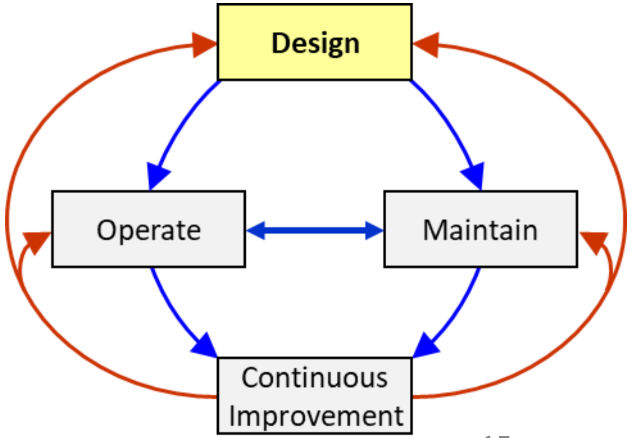
→Maintenance work procedure updated

Manufacturing Reliability Model



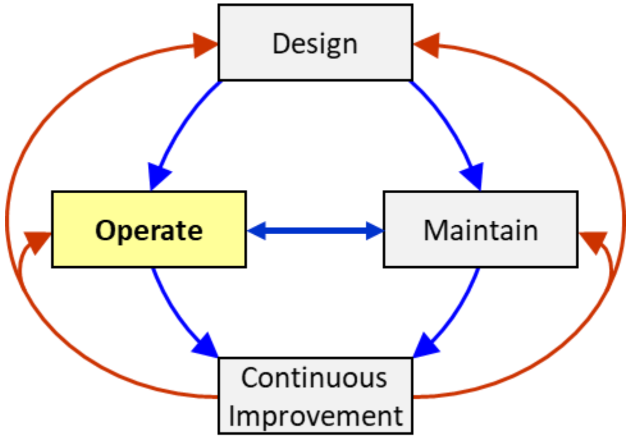
Good <u>**Design**</u> Practices and Behaviors

- Equipment capability > Process requirements
- Ensure capacity, reliability, and downtime are included in user requirements
- Ensure good Operability and Maintainability functionality
- Base purchase decisions on life cycle costs instead of purchase costs
- Ensure proper storage before installation
- Ensure proper installation-avoid pipe strain
- Ensure good knowledge transfer on training, SOPs, maintenance strategies, and spare parts.



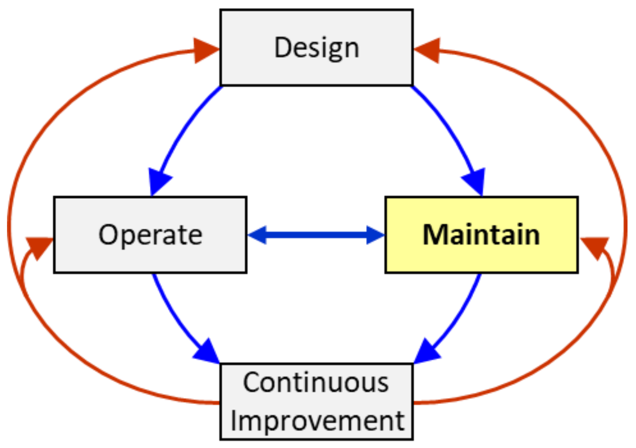
Good **<u>Operate</u>** Practices and Behaviors

- Operate equipment with its design space
- Develop robust SOPs which cover all modes of operation
- Develop an effective alarm program
- Practice precision operations
- Have a well-trained workforce
- Keep area clean
- Immediately report any abnormalities
- Record downtime and other data
- Save failure components



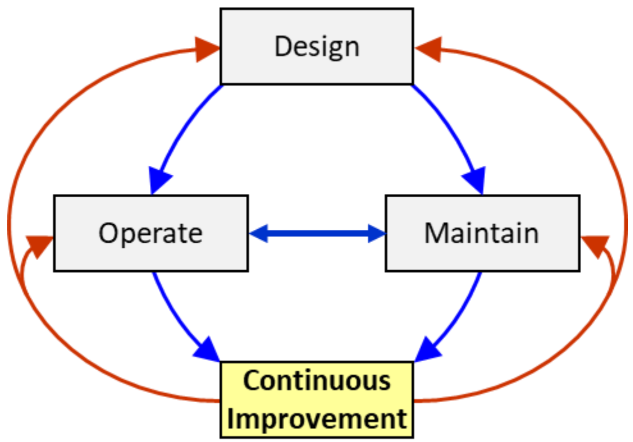
Good **Maintenance** Practices and Behaviors

- Build a proactive maintenance organization (equipment reliability, planning and scheduling)
- Minimize invasive maintenance
- Practice precision maintenance
- Use robust work instructions (job plans)
- Do predictive maintenance (vibration analysis , thermography, oil analysis, etc.)
- Do world class lubrication
- Keep CMMS data current
- Store and use spare parts correctly
- Save failed components for analysis



Good **Continuous Improvement** Practices and Behaviors

- Identify problem equipment (downtime, MTBF, $$, # of work orders)
- Gather data-data from Design, Operate, Maintain, OEM
- Analyze data-Use multi-functional team if appropriate
- Develop countermeasures
- Implement countermeasures
- Check for effectiveness



Manufacturing Reliability-Beyond the Model

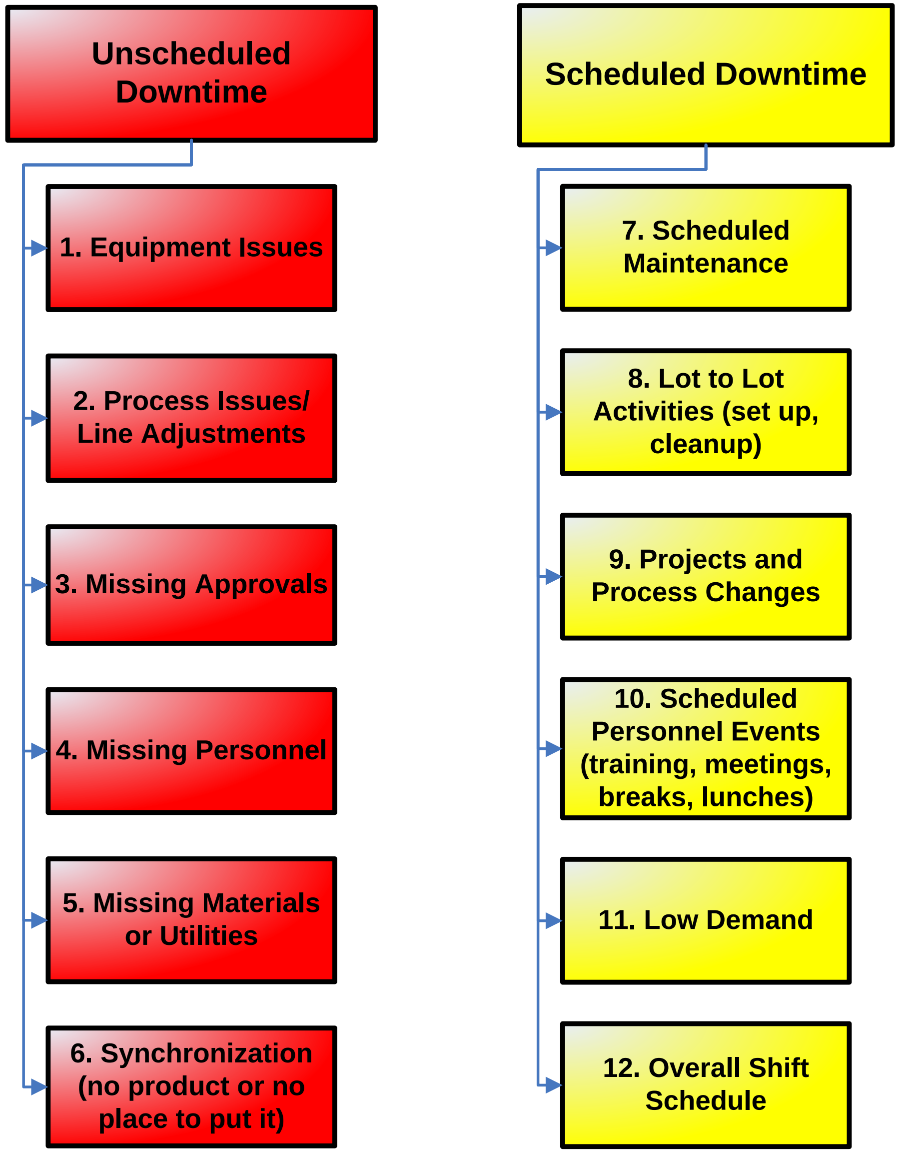
Reliability Metrics-Downtime tracking, MTBF, OEE…

Reliability Knowledge-Bathtub curve, P-F, Precision…

Proactive Culture-Management energy needed

Key Reliability Metric: Downtime

Uptime (Equipment Running)



Downtime Tracker: Keep track of all times the equipment/process/line is NOT running. Select a reason for each block of time.

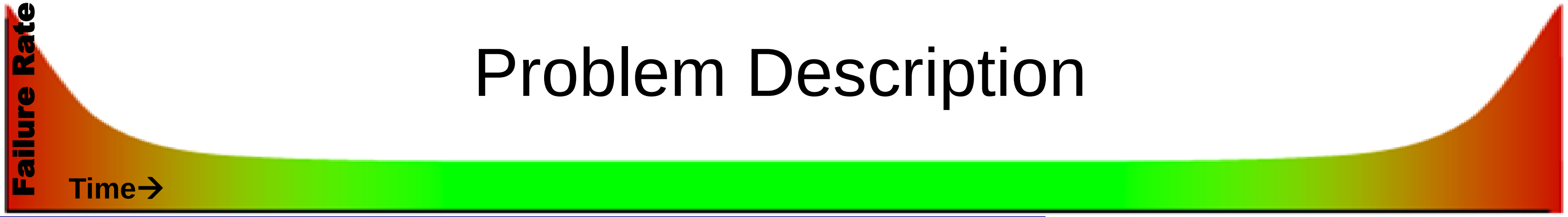
Manufacturing Goal: Maximize Uptime by eliminating the Red and managing the Yellow

-All time is based on 24/7

-There are “double clicks” or subheadings under each of the 12 categories which can be customized for each Process Team.

Bathtub Curve: *Most equipment does not wear out*

Problem Description



80% of Failures	20% of Failures

INFANT MORTALITY

- High failure rate after invasive work: repairs, PMs, setups, and adjustments
- Decreasing failure rate
- No probability predictions can be made.

Sources of Failures

- Set-up errors
- Operating errors
- Repair errors
- Installation errors
- Software/control errors
- Raw material variability

Dominant Failure Mechanism

- Overload

USEFUL LIFE

- Failure is unpredictable but often can be detected early.
- Constant failure rate
- Reliability probability predictions can be made with MTBF data

Sources of Failures

- Unknown stresses during design
- Acceptable risk stresses
- Equipment/Process mismatch
- Unplanned for stresses caused by process variability, raw material variability, operating & service variability.

Dominant Failure Mechanism

- Fatigue
- Corrosion

END OF LIFE

- Equipment is wearing out
- Increasing failure rate
- Probability predictions can be made with data.

Sources of Failures

- Wear out
- Calibration drift
- Filters dirty
- Loss of lubrication quantity and quality

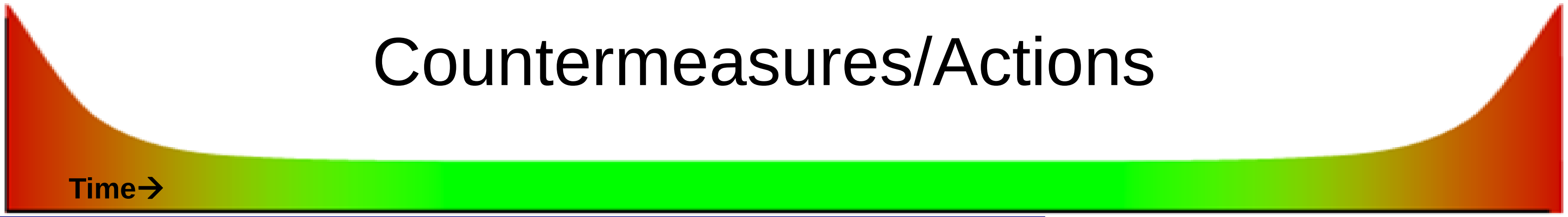
Dominant Failure Mechanism

- Wear

Countermeasures Depend on the Root Cause

Adding a PM is not always the right countermeasure!

Countermeasures/Actions



80% of Failures | **20% of Failures**

<u>INFANT MORTALITY</u>

•High failure rate after invasive work.

<u>Failure Management Actions</u>

•Training
•Experience and knowledge
•Robust work instructions

<u>Failure Elimination Actions</u>

•Reduce/eliminate the need to intervene or change the equipment and process
•Improve the accuracy and repeatability of required interventions

<u>USEFUL LIFE</u>

•Failure is unpredictable but often can be detected early.

<u>Failure Management Actions</u>

•Early Detection – Predictive Maintenance and PM inspections
•Operator based inspections

<u>Failure Elimination Actions</u>

•Increase design robustness to decrease failure rate
•Reduce process variability
•Reduce raw material variability
•Reduce operating variability

<u>END OF LIFE</u>

•Equipment is wearing out

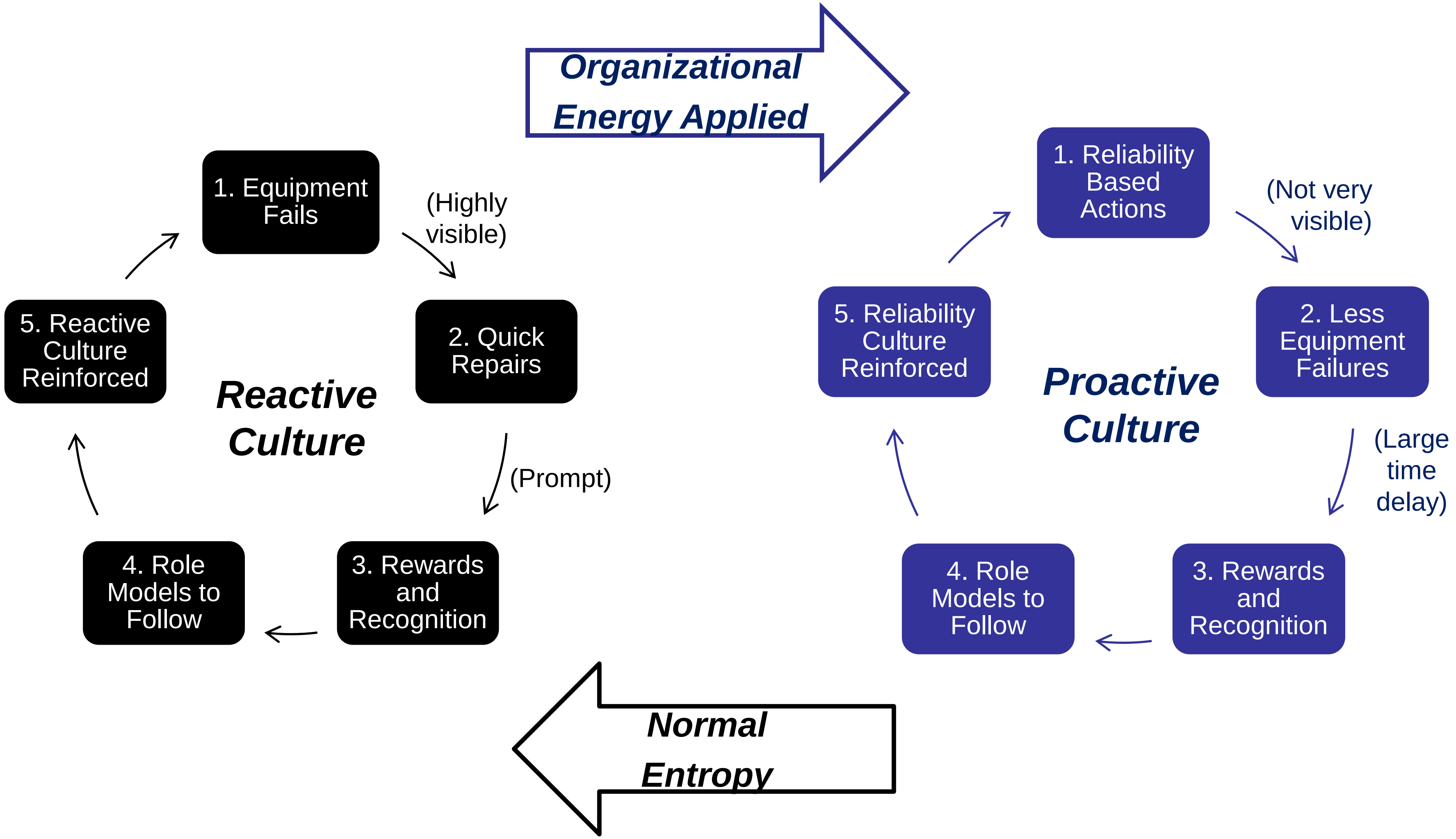
<u>Failure Management Actions</u>

•Calibration PM
•Rebuild PM
•Replacement PM

<u>Failure Elimination Actions</u>

•Add actions to delay wear out.
•Modify service frequencies to increase time to wear out.
•Select longer life components
•Modify process to better match the equipment capabilities

Why Culture Naturally Defaults to Reactive

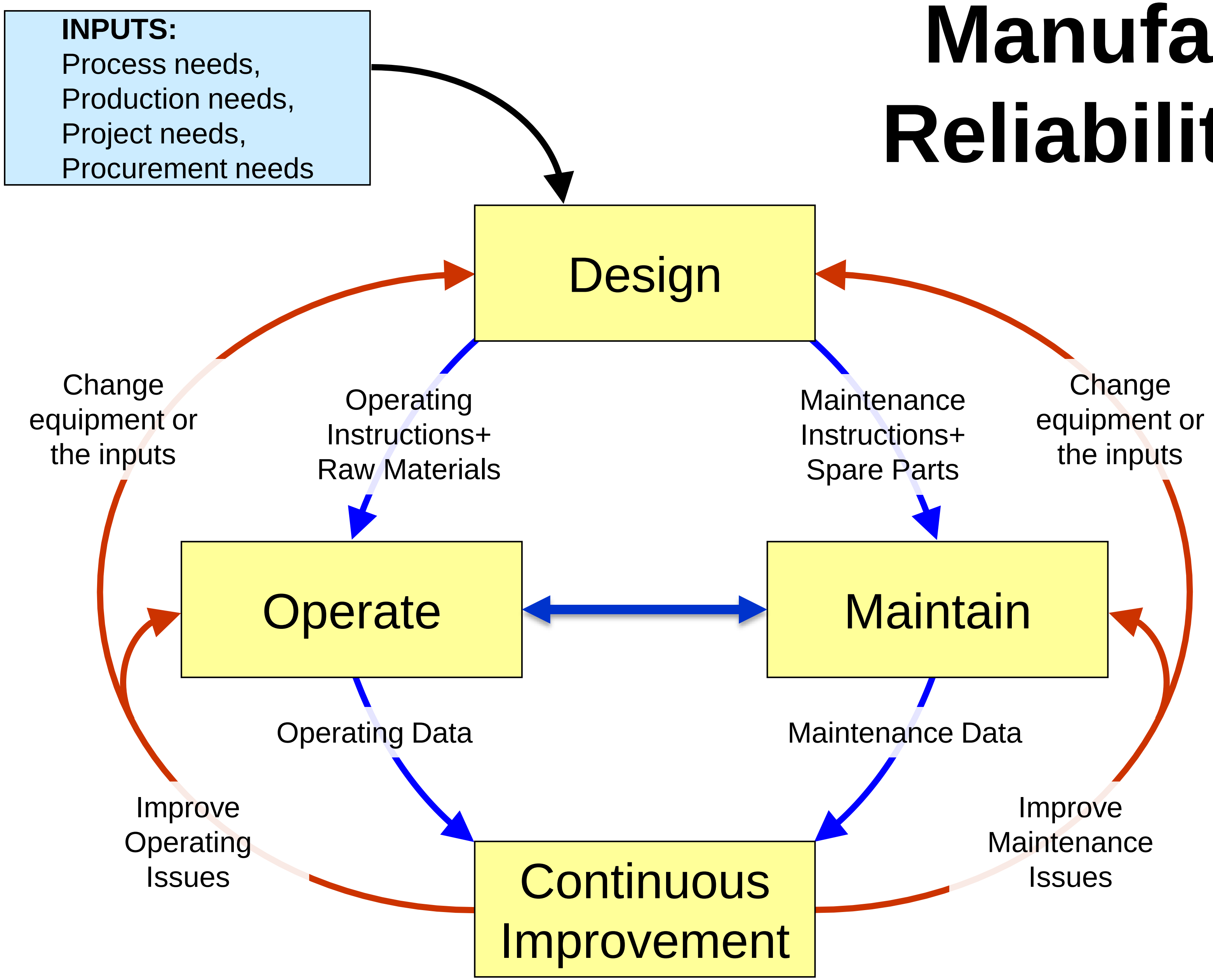


Stephen J. Thomas, *Improving Maintenance & Reliability Through Cultural Change*, Industrial Press, 2005

Safety & Reliability Cultures

Old Safety Beliefs	New Safety Beliefs	Old Reliability Beliefs	New Reliability Beliefs
Accidents just happen	Accidents are preventable	Equipment just breaks	Equipment failures are preventable
Safety is the Safety Department’s concern	Safety is everyone’s concern	Reliability is Maintenance’s concern	Reliability is everyone’s concern
Using PPE is optional	We wear the correct PPE	Use tools and parts that are available	We use the correct tools and parts
We only report lost time injuries	We report and investigate all injuries, including minor injures	Report only major production stoppages	We report and investigate minor equipment issues: leaks, noises, vibrations, heat
Safety issues are never resolved	Safety issues are resolved	Reliability issues are never resolved	Reliability issues are resolved

Manufacturing Reliability Model



Paper Mill Improvement

A paper mill, built in 1937 with last capital expansion in 1985, experienced ***significant cost pressures*** due competition, raw materials and environmental regulations.

In 1995, they made fundamental changes to their manufacturing and reliability culture. Without adding any additional equipment, they saw tremendous improvement over the next eight years:

Area	**1989**	**2003**	**Change**
Manufacturing Output	1900 tons/day	2700 tons/day	**+ 42%**
M&R Expense	$70mm	$40mm	**- 43%**

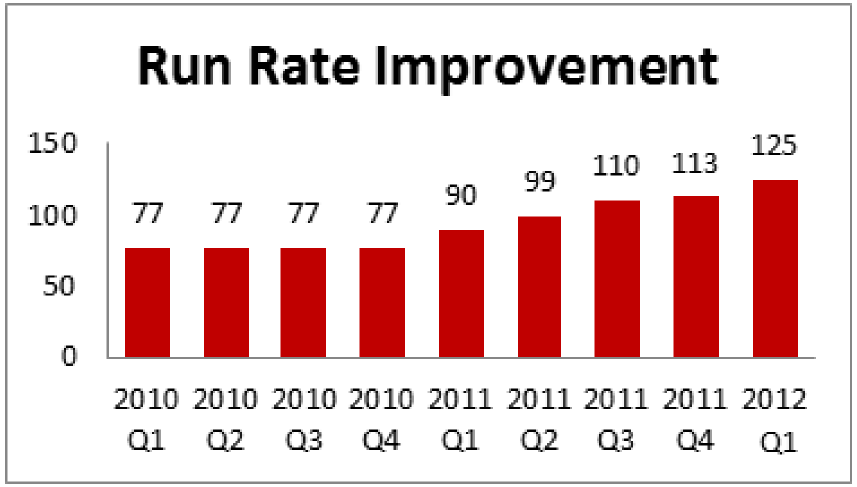
Production Line Improvement

In 2010, a production line standard rate was 77 units per minute.

The same production line improved to a standard rate of 125 units per minute by the second quarter of 2012—a 60% increase in a little over a year's time!

Examples of projects that impacted the essential elements of reliability include:

- **Design**: Redesigned the glue system
- **Operations**: Improved changeover time from 4.3 hours to 3.5 hours
- **Maintenance**: Improved maintenance practices of the glue system and robot head (moves units into the cartoner)



	2010	2012
Standard	77 units/min	125 units/min
Yearly Capacity	30.8 million units	50.2 million units

Summary

- There is significant value in improving Manufacturing Reliability: capacity, safety, environmental, financial
- There is about a 75% overlap between Product Reliability and Manufacturing Reliability
- Manufacturing Reliability includes the Design, Operation, and Maintenance of manufacturing systems
- Manufacturing Reliability involves much more than engineering-it also involves Procurement, Operations, Management, and organizational cultural changes

Thank you!

Any questions?

Proactive Maintenance Model