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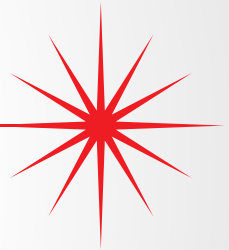

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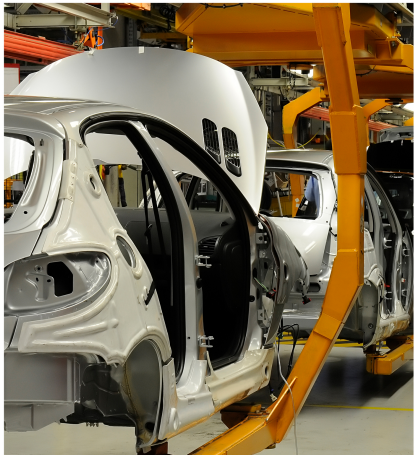

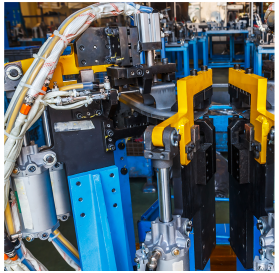

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Keynote

Balancing in Resonance

by Greg Lee, Senior Project Manager, PRÜFTECHNIK

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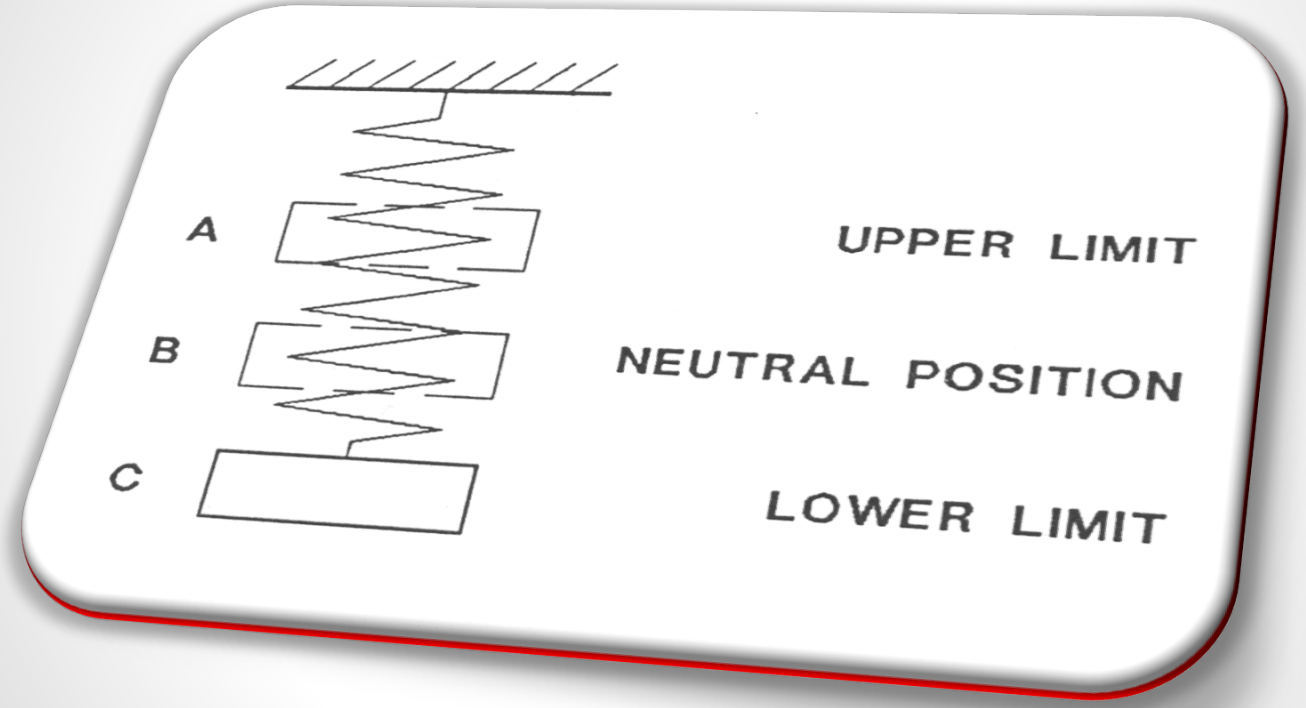
What is Resonance and Why Does it Effect Balancing?



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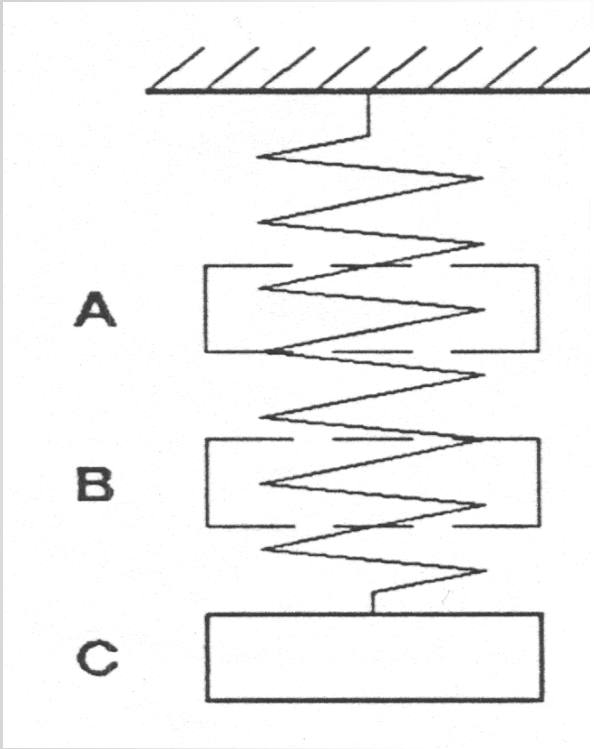
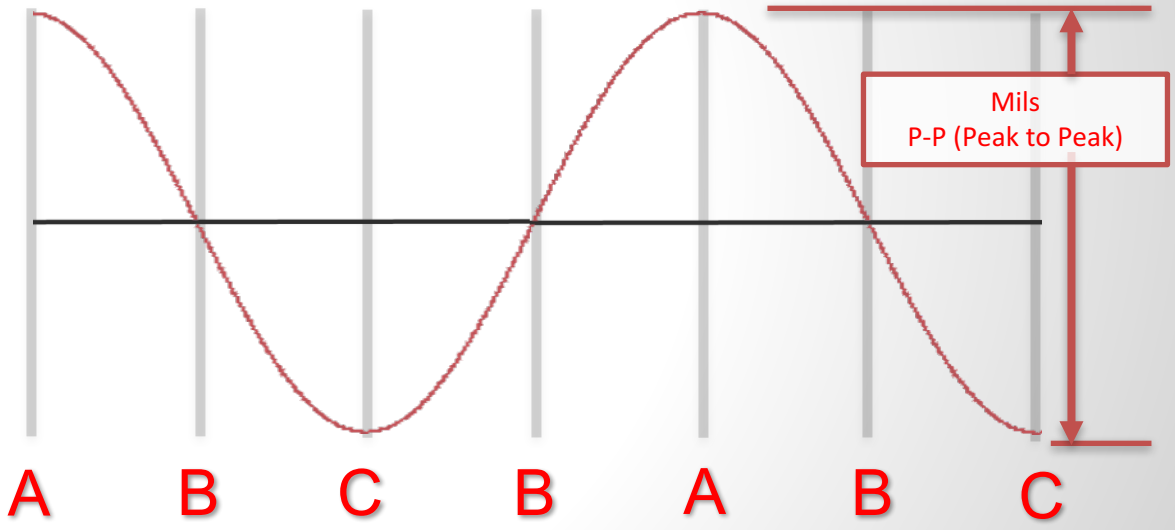
Displacement Waveform



Displacement



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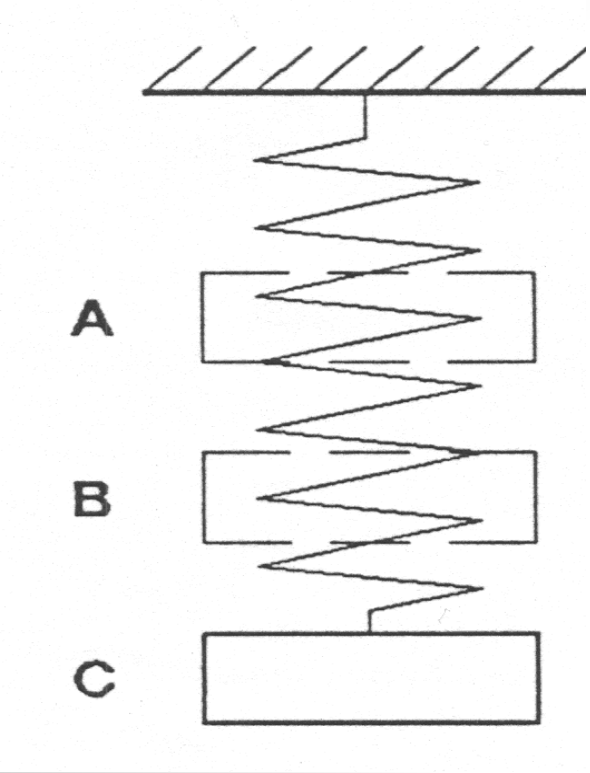
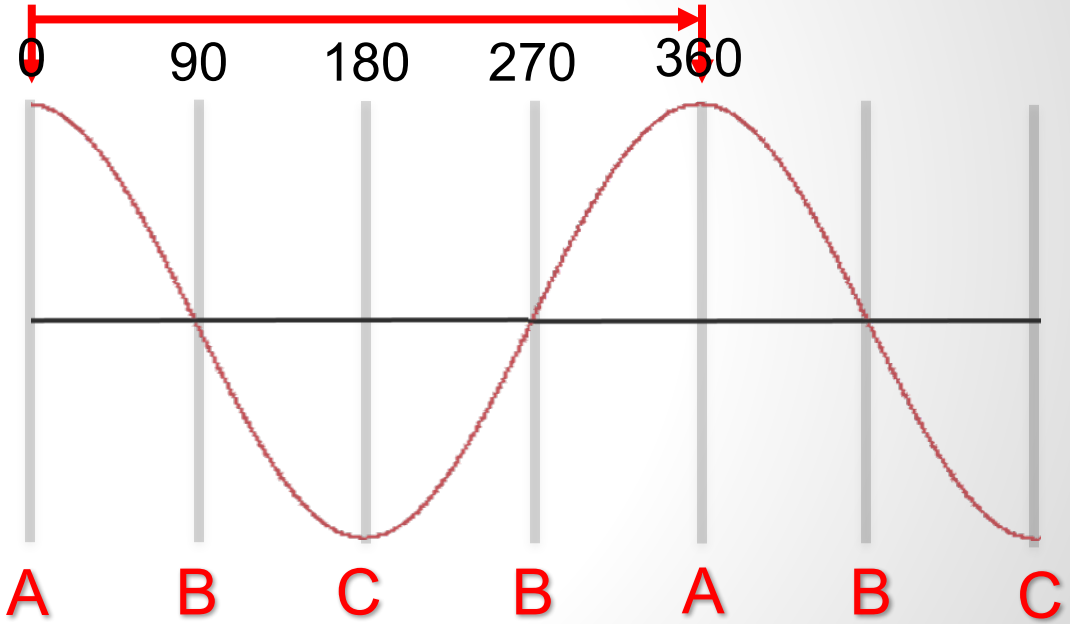
Displacement Waveform Phase





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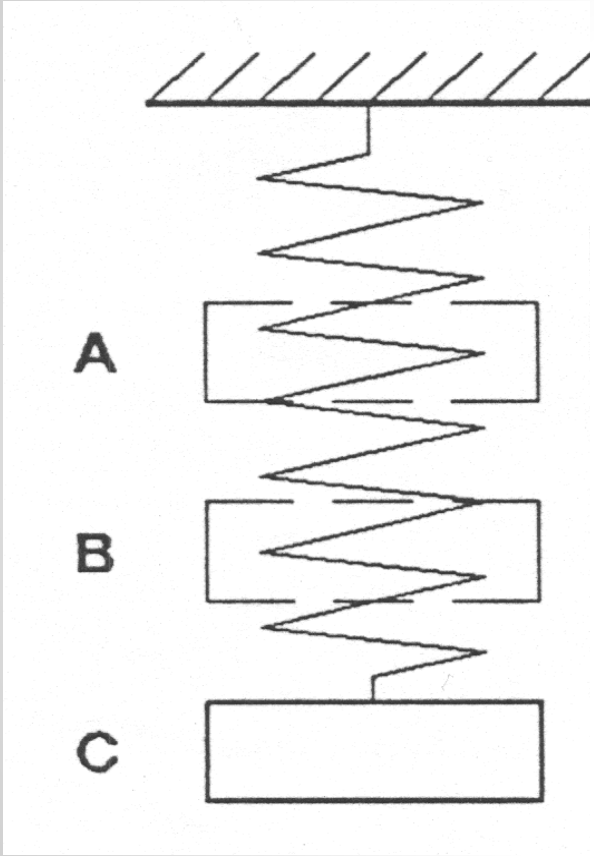
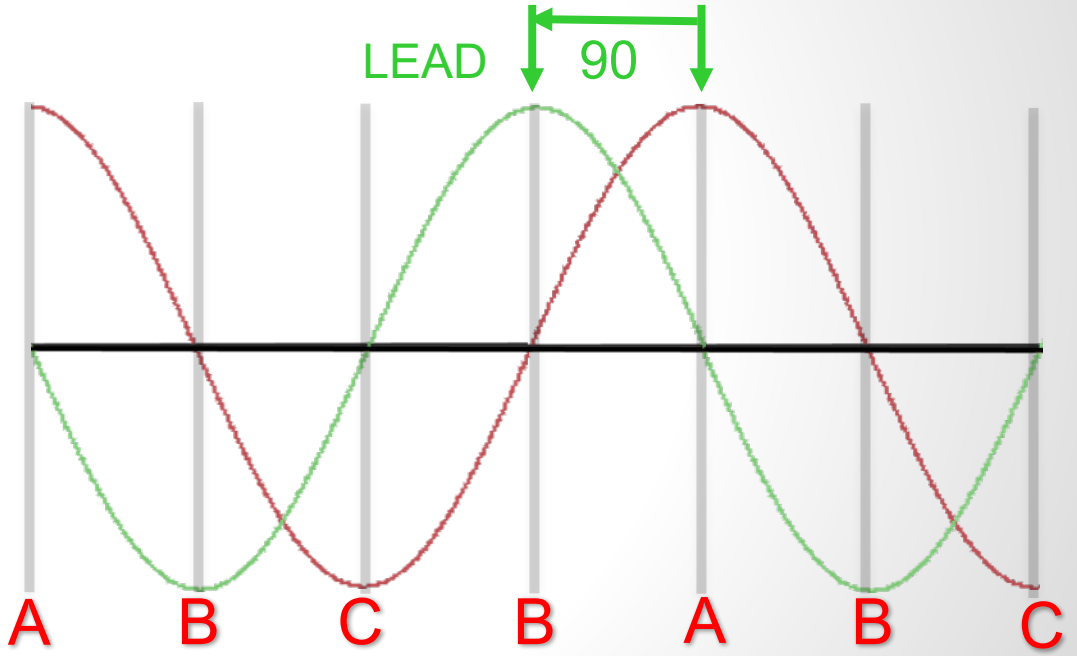
Velocity Phase Shift – 90 Degrees Lead





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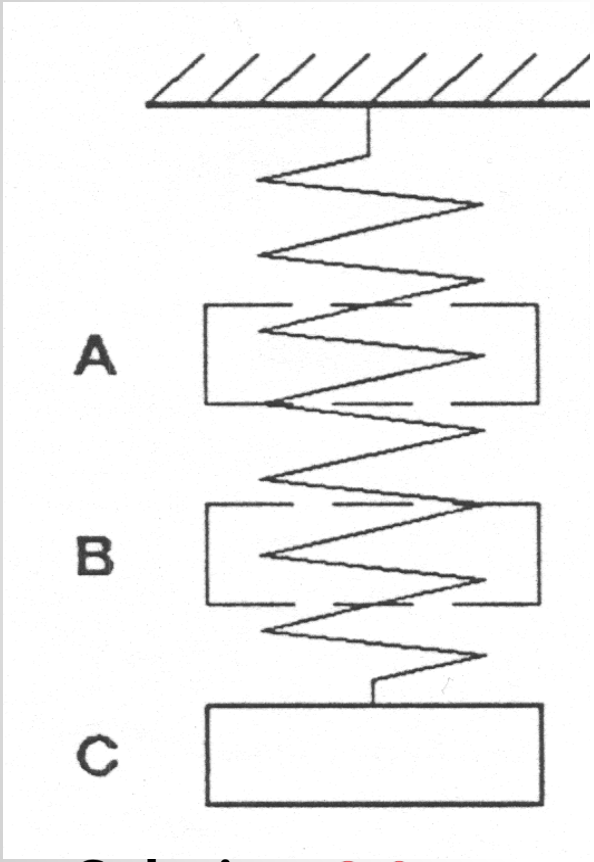
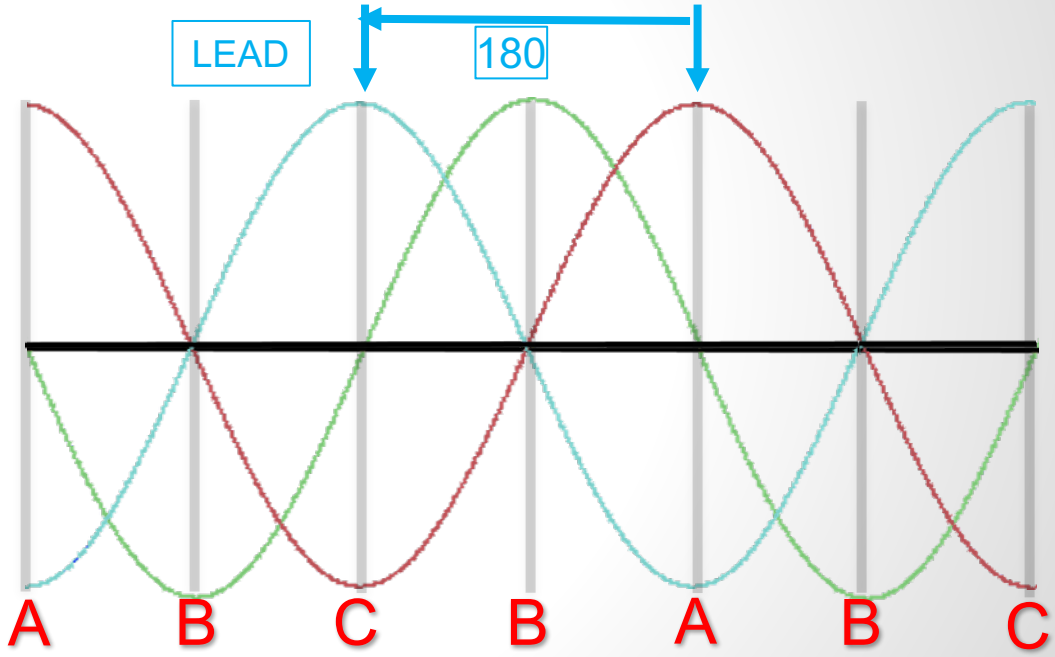
Acceleration Phase Shift – 180 Degrees Lead





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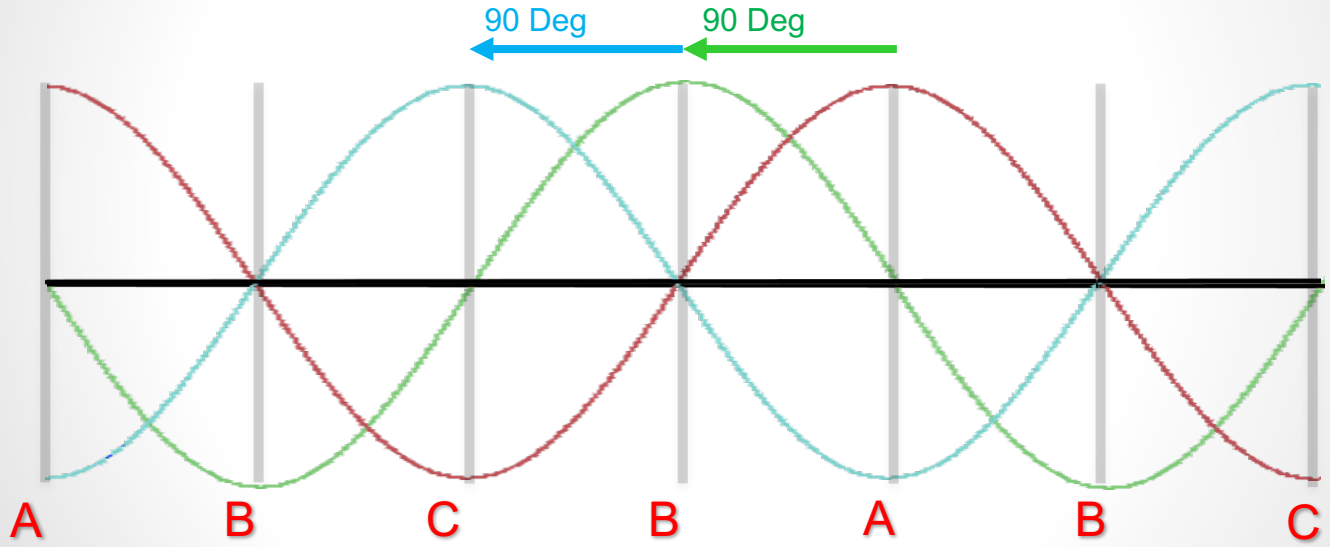
Resonance

K(Stability)
= (Displacement * Stiffness)
+ (Velocity * Dampening)
+ (Acceleration * Mass)



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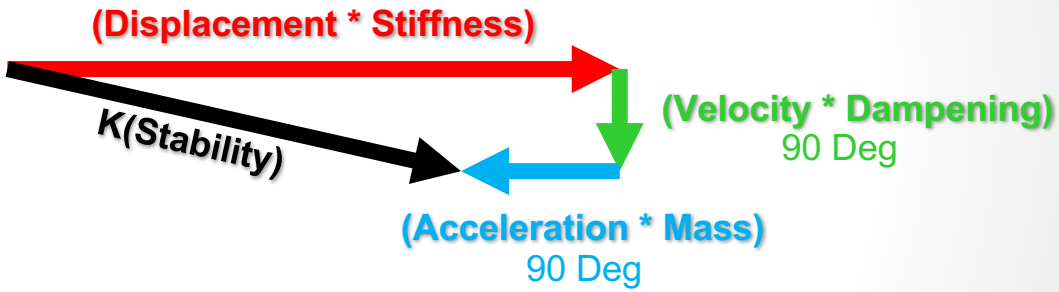
The Vectors of Resonance

K(Stability)
= (Displacement * Stiffness)
+ (Velocity * Dampening)
+ (Acceleration * Mass)



Below Resonance
Stiffness Stabilizes System

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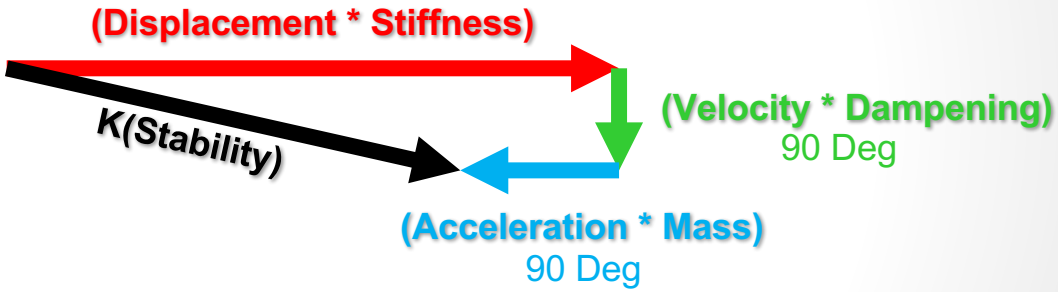
Below Resonance

Machine Increases in RPM



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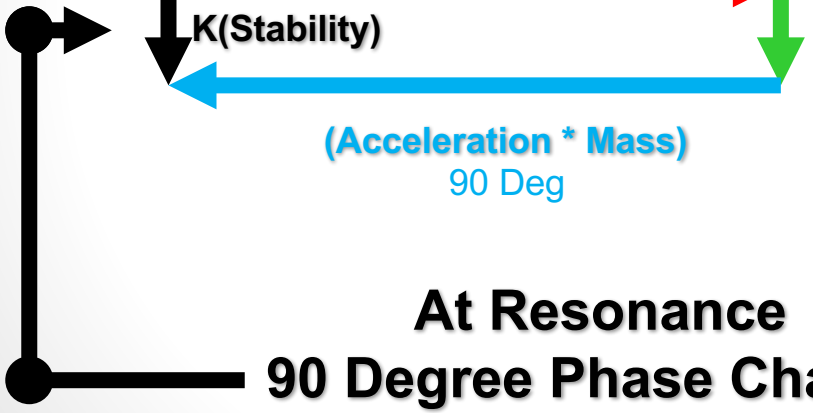
At Resonance

Machine Increases in RPM



(Displacement * Stiffness)

K(Stability)

(Velocity * Dampening)
90 Deg

(Acceleration * Mass)
90 Deg

At Resonance the
Acceleration Term
Cancels the
Displacement Term

The Only Thing
Stabilizing the
System is
Dampening

At Resonance
90 Degree Phase Change

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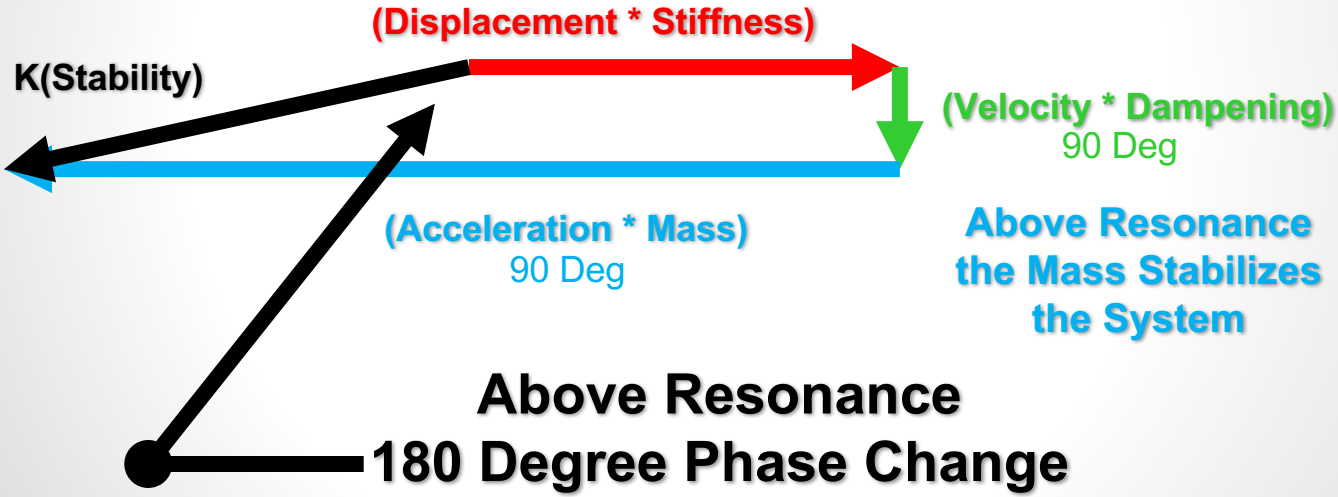
Above Resonance

Machine Increases in RPM



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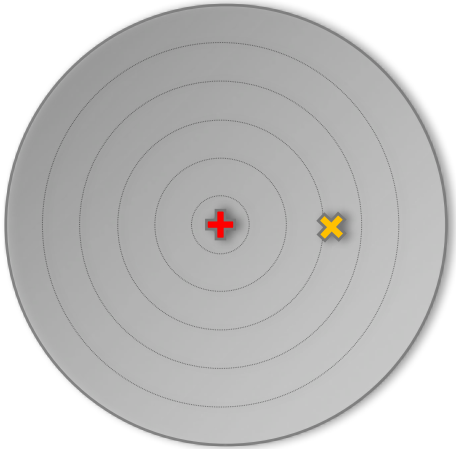
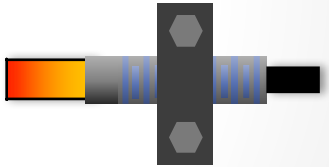
How Does Resonance Impact Balancing?

Below Resonance the Rotor Try's to Rotate Around it's Machined Center





The High Spot Equals the Heavy Spot

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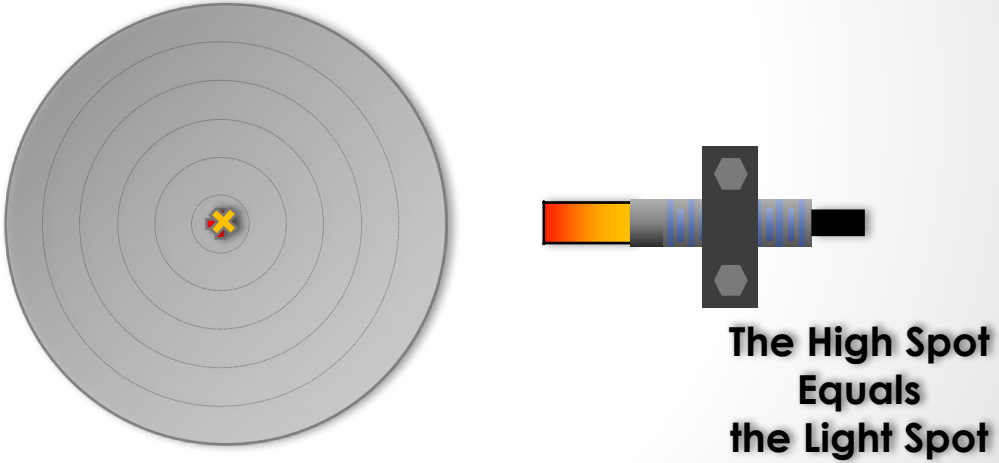
How Does Resonance Impact Balancing?

Above Resonance the Rotor Try's to Rotate Around it's Mass Center



The High Spot Equals the Light Spot

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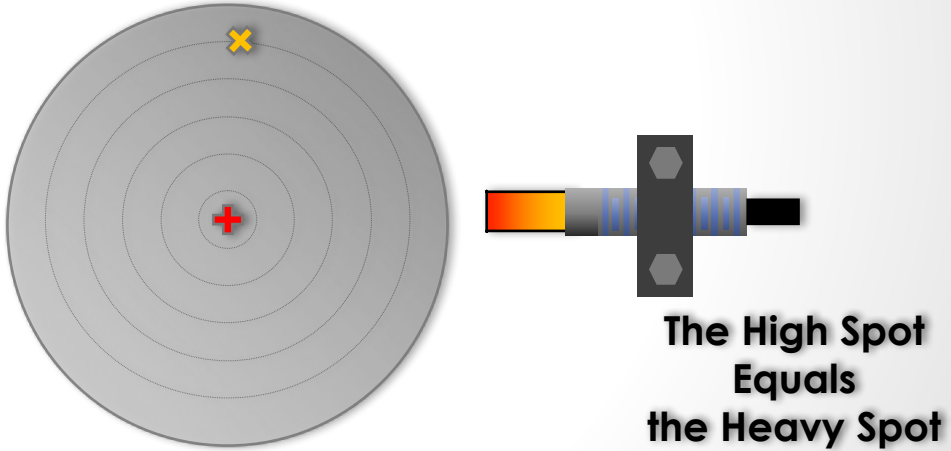
How Does Resonance Impact Balancing?

In Resonance the Shaft is Unstable.

- **The Amplitude Increases**
- **The Phase Changes by 90 Degrees**



The High Spot Equals the Heavy Spot

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Are you in Resonance?

Bump Test

- Machine Off
- Machine On with Negative Averaging
- Machine Off with Calibrated Impact Hammer

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Are you in Resonance?

Startup / Coast down

- Cascade Plot of Spectrums
- Indicates at what speed range the unbalance excites the resonate Frequency

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Are you in Resonance?

Startup / Coast down

- Bode Plot
  Phase and Amplitude
  at RPM
- 90 Degree Phase
  Change at Resonance

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Zone of Phase Roll

The Bode Plot is an excellent method of viewing shaft resonant frequency. One can easily identify the phase roll that creates unreliable results from traditional field balancing methods.

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How Can One Balance In or Near Resonance?

Speed Change

- Change the speed of the machine so that it runs of the "Zone of Phase Roll".
- Above or Below the Resonance will work as Field Balancing is a ratio method. One just needs to know the effect on phase and amplitude a trial weight has on vibration amplitude and phase angle at running speed.

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How Can One Balance In or Near Resonance?

Can't Change Speed?

Trial Weight and Repeat Method

When one must balance in the "Zone of Phase Roll":

1. Initial Run
2. Trial Weight Run
3. Correction Weight Run (Reduction is Typically is Small)
4. Leave Correction Weight and Start Over at step 1.

Each time the process is repeated the vibration typically reduces in increasing increments. Repeat Until Vibration is in Tolerance. Note that the Resonance peak will narrow and reduce in amplitude.

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How Can One Balance In or Near Resonance?

Can't Change Speed?
Trial Weight and Repeat Method

This method is extremely effective but does require repeated runs. Each time the excitation force is reduced (unbalance) the resulting Bode Plot will have a lower amplitude and the phase roll or shift will happen over a narrower speed range. This method is often faster, requiring less machine stops and starts than the no phase method mentioned below.

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How Can One Balance In or Near Resonance?

Want to Reduce Stops and Starts?
Try the Recalculate Coefficient Method:

Some of the most modern field balancing / analyzer instruments use a method of balancing called the Recalculate Coefficient Method. This is a fantastic method to balance a single plane rotor that is running in the "Zone of Phase Roll".

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How Can One Balance In or Near Resonance?

Recalculate Coefficient Method:

1. Initial Run
2. Trial Weight Run
3. Correction Weight Run
4. Trim Weight Run (Balancing Coefficients are Recalculated)

The Trim Weight is used to recalculate the balancing coefficients. The effect is like starting over with a new initial run and trial weight but without the extra runs.

5. Trim Weight Run (Balancing Coefficients are Recalculated using step 3 and 4)

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How Can One Balance In or Near Resonance?

Recalculate Coefficient Method:

This method is only available for Single Plane Balancing. It is extremely effective at reducing the influence of resonance for each trim run.

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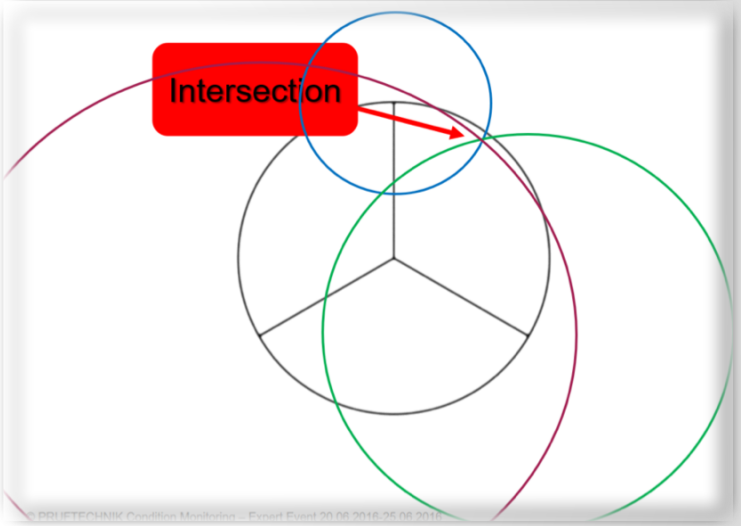
How Can One Balance In or Near Resonance?

PHASE BALANCING

You may have heard of this method of balancing , also called 4 run balancing, but one can balance without a tachometer or strobe light. This method requires 4 stops and runs but one only hast to measure the amplitude.

It happens that this method is extremely effective if the rotor you are balancing is in resonance! It does this by affixing the trial weights to fixed angle locations that do not change with resonance.



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No Phase Balancing

Initial Measurement = O

1. Do not place any weight on the rotor
2. Start the rotor and run at a fixed RPM that will be used for each of the following measurements.
3. Locate a vibration transducer on the bearing housing in a radial position that results in close to maximum amplitude reading.
4. Record the amplitude of the vibration.
5. Stop the rotor
6. This measurement is designated as O, which stands for the original measurement.
7. Keep the vibration transducer at this same measurement location for the remaining 3 readings.

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No Phase Balancing

Second Measurement = T^1

8. Prepare a trial weight that is less than 10% of the rotor weight. This trial weight will be used for the next three measurements.
9. Attach the trial weight to the rotor. This becomes 0 (Zero) degrees.
10. Start the rotor and run at the fixed RPM.
11. Record the amplitude of the vibration.
12. Stop the rotor.
13. Remove the trial weight
14. This measurement is designated as T^1 at 0 degrees which stands for the first trial measurement.

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No Phase Balancing

Third Measurement = T^2

15. Move the position of the trial weight either clockwise or counter clockwise 120 degrees. 120 degrees is the ideal location but can be as little as 90 degrees.
16. Attach the weight to the rotor in the new T^2 position but at the same radius as the original weight. We will again assume the ideal position which is now 120 degrees for this example.
17. Start the rotor and run at the fixed RPM.
18. Record the amplitude of the vibration.
19. Stop the rotor.
20. Remove the trial weight
21. This measurement is designated as T^2 at 120 degrees which stands for the second trial measurement.

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No Phase Balancing

Forth Measurement = T^3

22. Move the position of the trial weight in the same clockwise or counter clockwise direction as you did for T^2. Adding an additional 120 degrees to the T^2 position is the ideal location but again this can be as little as 90 degrees.
23. Attach the weight to the rotor in the new T^3 position but at the same radius as the original weight. We will assume the ideal position of 240 degrees for this example.
24. Start the rotor and run at the fixed RPM.
25. Record the amplitude of the vibration.
26. Stop the rotor.
27. Remove the trial weight
28. This measurement is designated as T^3 at 240 degrees which stands for the third trial measurement.

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No Phase Balancing

Graphing Results Example

- Original Unbalance (O) = 10 mils
- Trial Weight - TW = 50 g
- First Trial - T^1 = 7.0 mils @ 0 degrees
- Second Trial - T^2 = 12.0 mils @ 120 degrees
- Third Trial - T^3 = 18.0 mils @ 240 degrees

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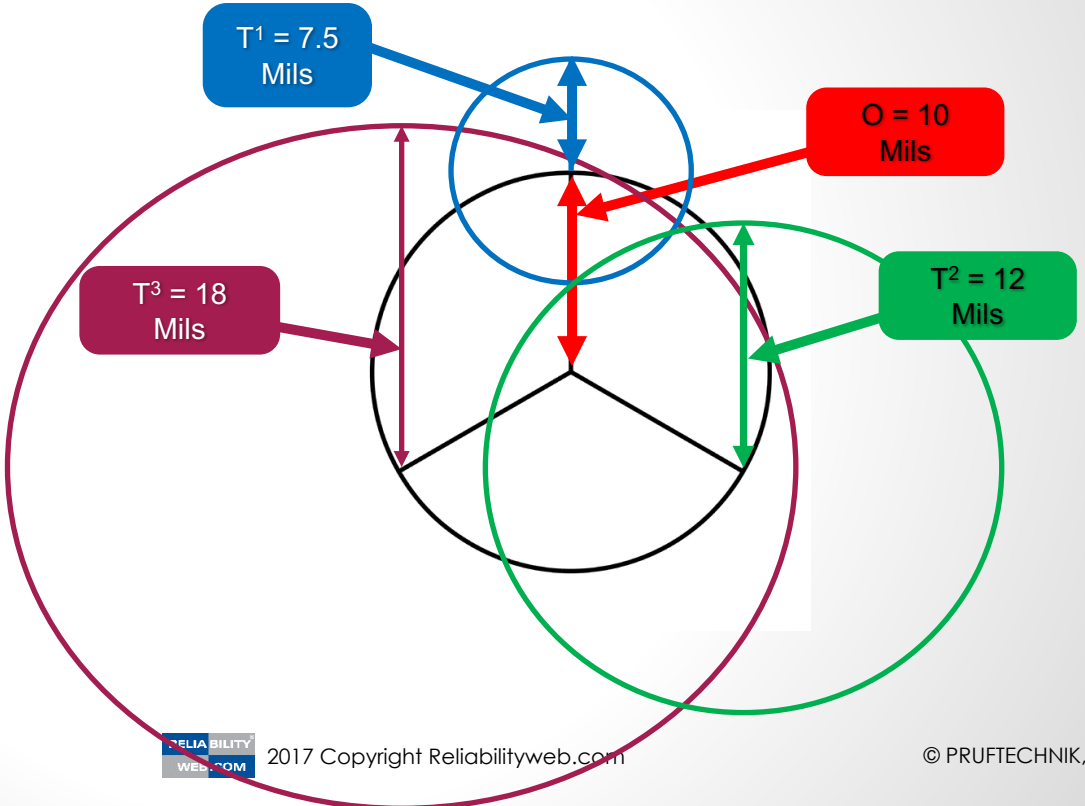
No Phase Balancing

Graphing Results



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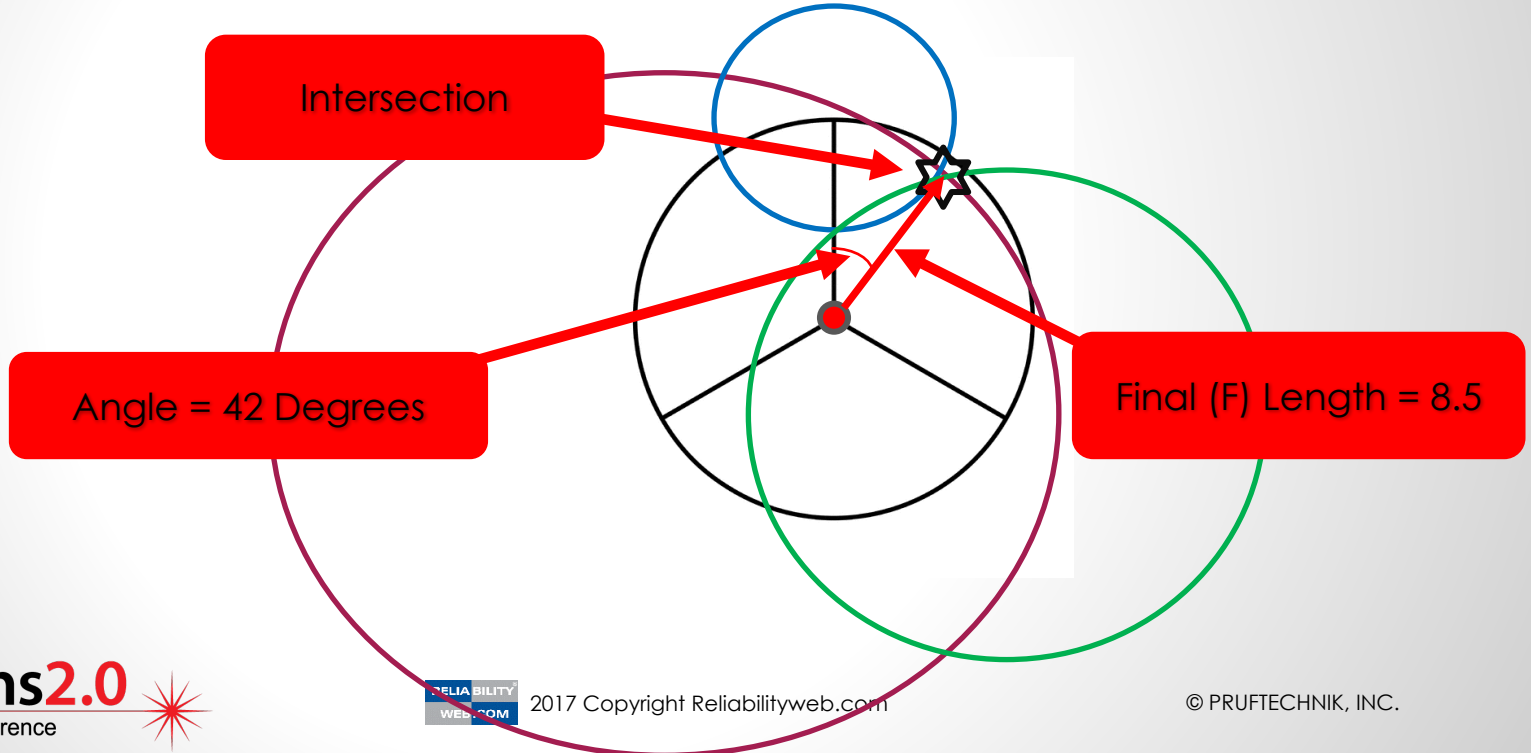
No Phase Balancing

Graphing Results



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No Phase Balancing

Ratio Calculation

Formula for the Amount of Correction Weight:

Trial Weight (TW) x Original (O)/ Final (F) = Correction Weight

Where:
TW = 50 g
O = 10
F = 8.5

Correction = TW x (O)/(F) = 50 x 10/8.5 = ***59.0 g at 42 Degrees***

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Thank You for Attending Balancing in Resonance

Presented by: Greg Lee
Senior Project Manager
PRUFTECHNIK, Inc.

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Philadelphia, PA 19153
Tel: (844) 242-6296
email: greg,lee@pruftechnik.com

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P2Insight's The Order Hub

E-Commerce for EAM

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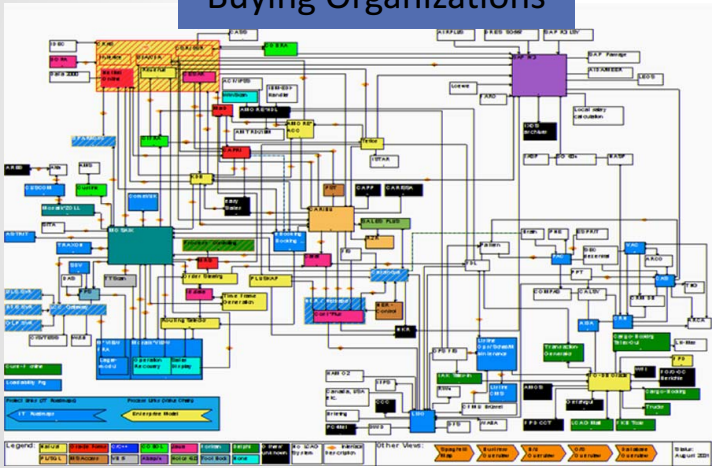
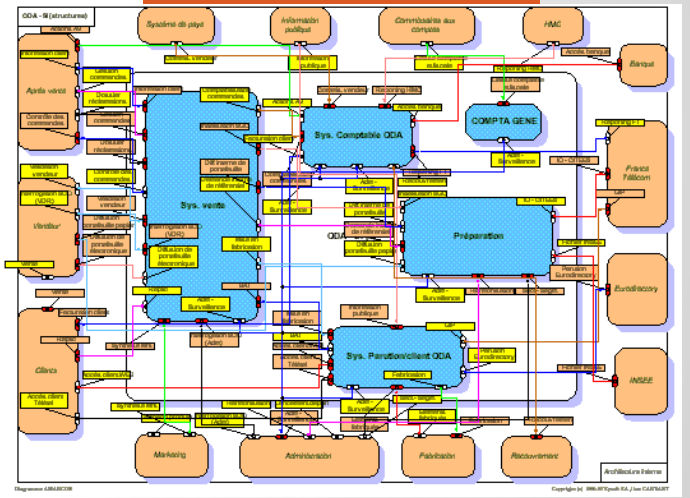
Communication between buyer / seller systems

Buying Organizations



Selling Organizations



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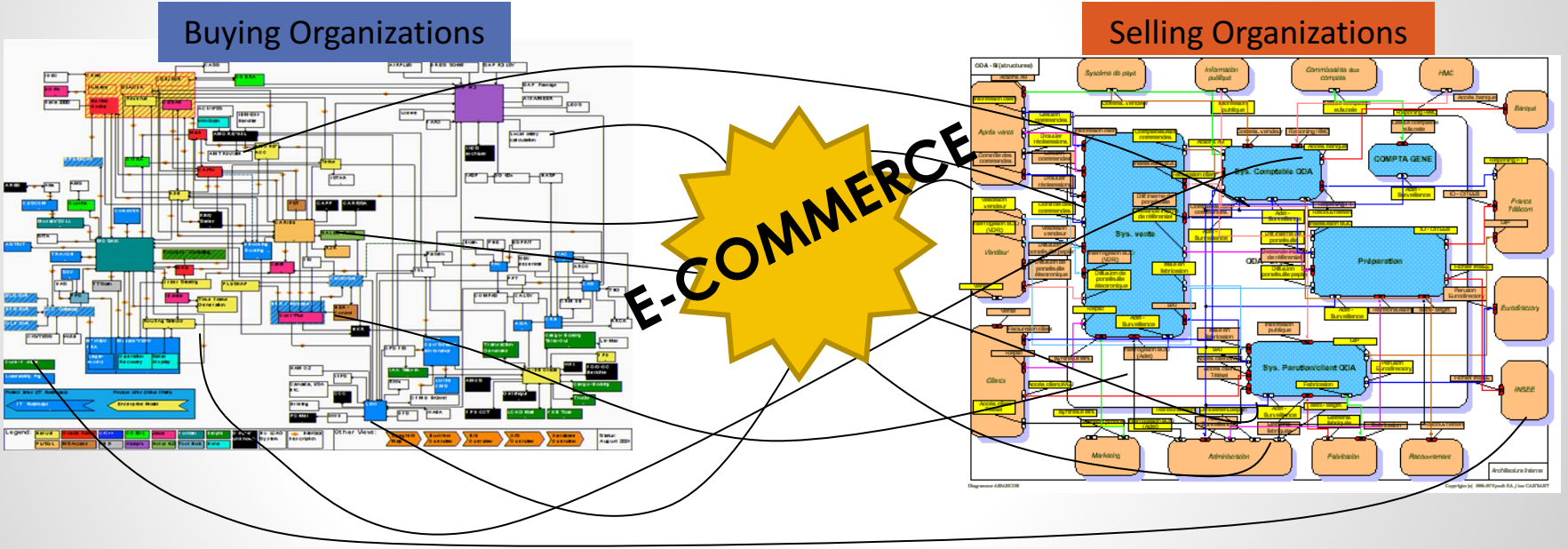
Communication between buyer / seller systems



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What are the benefits of E-Commerce?

Faster Transaction Processing – instant

Better and more Communication – easier to communicate, so more communications takes place

More Accurate Data – no data entry, no double entry

Self Service Capabilities – provides transparency to third parties… no more phone tag

Increased visibility and trust within the supply chain - Increase Reliability! Your supply chain is part of your Reliability Capability

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We give Maximo full "E-Commerce" Capabilities

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- Vendor/Contractor Portal for Dispatching and Negotiating
- Full Procure to Pay, from order placement to Invoice payment
- Online RFPs and Quotes
- Online transaction management
- External contractor engagement

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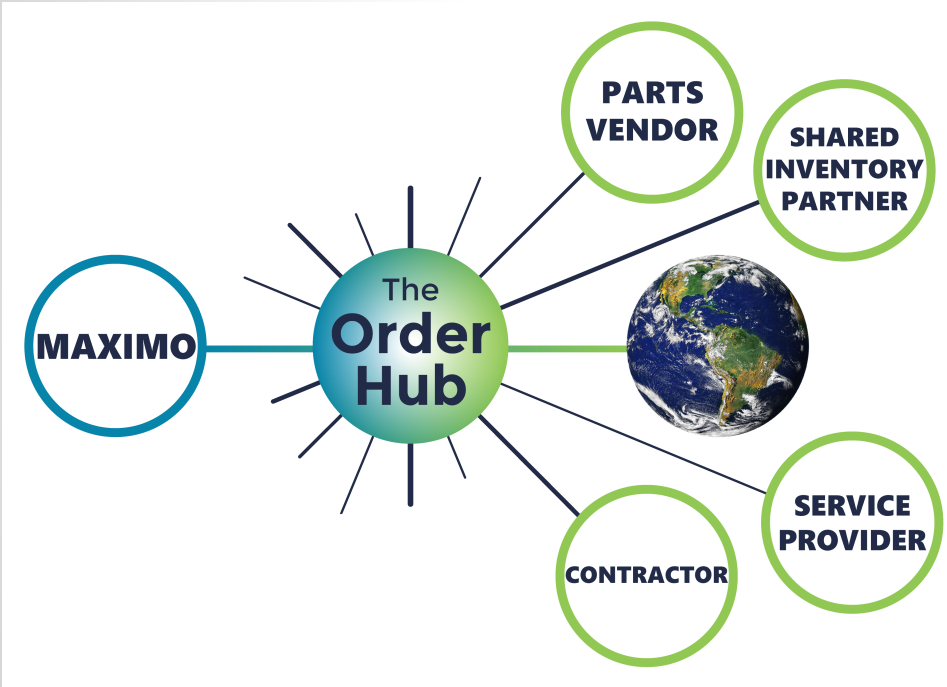
P2Insight's The Order Hub



- Purchase Order
- Work Orders
- RFQ
- Purchase Price Contracts
- Receipts
- Invoices
- Time Cards
- WO Closing
- WO Scheduling
- Shared Inventory
  - Dispatching
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  - Negotiating
  - Expediting

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P2Insight's The Order Hub

The Purchase Order Hub

- Transactions and vendor engagement for purchasing goods
- Shared high value inventory management

The Service Order Hub

- Transactions and contractor engagement for purchasing services
- Contractor time entry & approval

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Contact P2Insight

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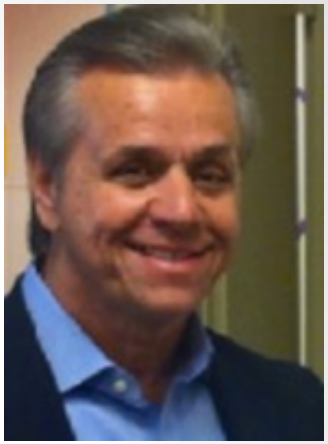

Jim Hall, CRL, Executive Director
The Ultrasound Institute, LLC
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- Energy Audits

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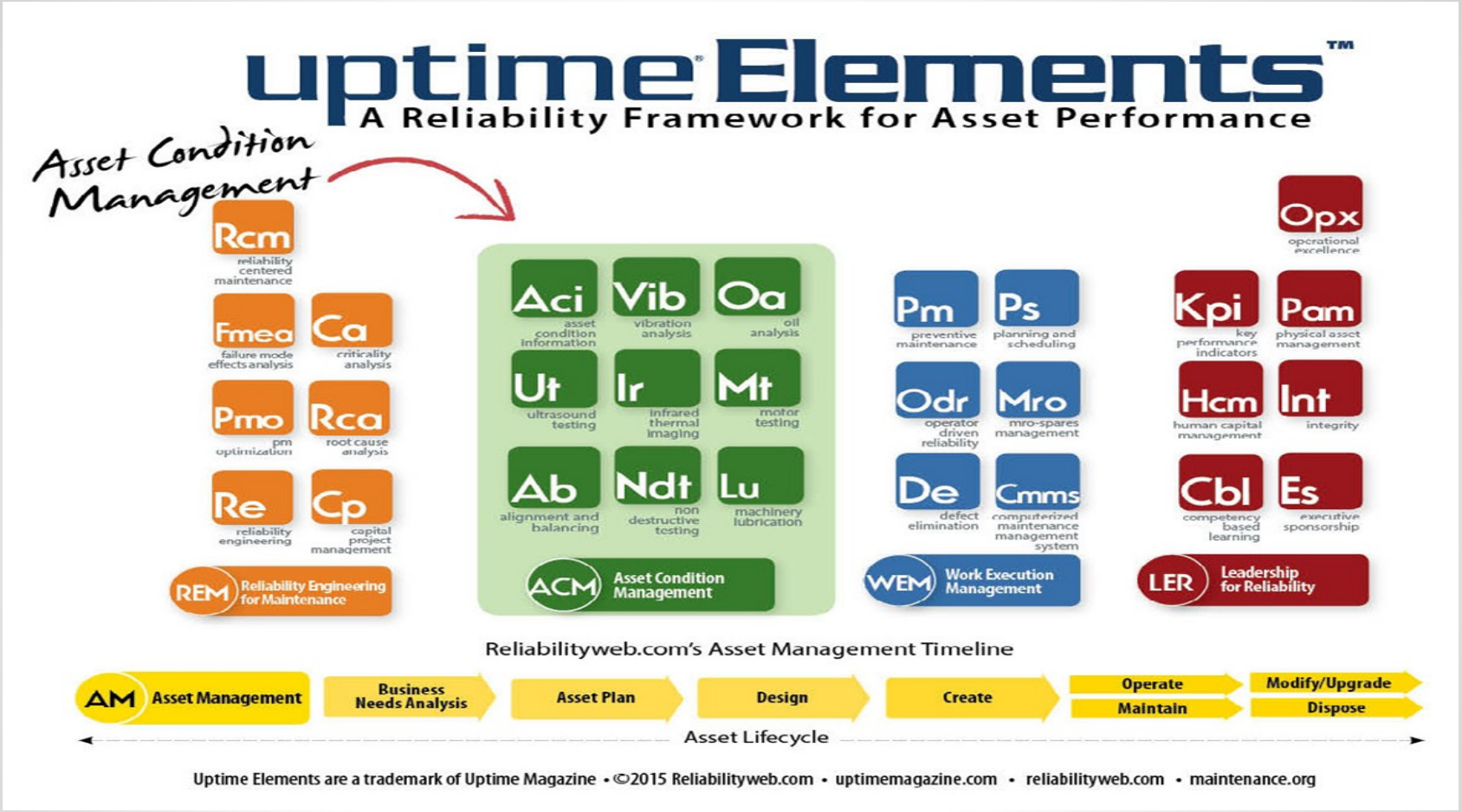

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ULTRASOUND and the ACM-UPTIME®Elements™ Framework

ACM: Asset Condition Management

- **UT: Ultrasound**
- **IR: Infrared**
- **Vib: Vibration**
- Ab: Alignment Balancing
- Ndt: The other Ut

Lu: Machinery Lubrication
Fa: Fluid Analysis
ACI: (Asset Conditions Information)
MT: Motor Testing

All are part of the Framework…However, few understand ultrasound theory or know the many applications and saving potentials.

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ULTRASOUND and the ACM-UPTIME®Elements™ Framework

Ultrasound within the UPTIME® Elements™ is simply to present an understanding of the technology to better equip you as a Reliability Leader.

At TUI we take a step deeper into the technology and

- Instrument Familiarization
- Dealing with background noise or competing sounds
- A multitude of different applications
- How to deliver energy savings or a Return-On-Investment

And…We provide an understanding of how the three-technologies (IR, Vib, UT) compliment each other.

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ARE YOU A CRL?

If your already a CRL, you were introduced to the technology through the CRL Passports.

- Now's the time to "step-up" and build or take your ultrasound program to the next level.
- **Your BEST ROI applications**, Acoustic Lubrication, Ultrasonic Electrical Inspection and Energy Savings…*You cannot have a "World Class Maintenance Program" without Ultrasound!*

Call for that Quote Today!

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The Ultrasound Institute

Call for a quote or to schedule a Level I or II

Ultrasound Certification Course or a Kick Starter

Program…

Email: Jim@TheUltrasoundInstitute.com

Phone: (770) 517-8747

No Matter Whose Instrument You Are Using, We Can Train You…

Solutions2.0 Virtual Conference

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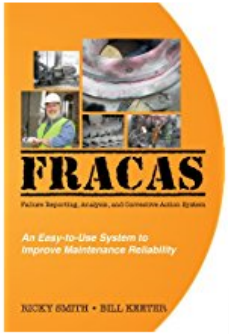
Educational Session

Learning to See with FRACAS

by Chad Williams, Maintenance and Reliability Manager, Merz North America



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Introduction

Chad Williams

- CMRP
- CRL
- MLT I
- Ultrasound Level I

Worked in Maintenance and Reliability Industry since 1996

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What Is FRACAS

Failure **R**eporting, **A**nalysis, and **C**orrective **A**ction **S**ystem

Provides a process for which failures can be reported (in a timely manner), analyzed, and a corrective action put into place in order to eliminate or mitigate the recurrence of a failure.

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The Problem

Culture of the Industry

Information goes in, but does not come out.

We keep having the same failures, over and over.

Why should I spend my time documenting what I do/did?

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Why Is This Important?

Establish the WHY

Need to understand the terminology

- Beginning of understanding
- Develop a common language

Establishes a process

- Proactive Workflow

Enables Communication

- Feedback Loop

Creates Value

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New Terminology

- Failure Reporting
- Potential Failure
- Functional Failure
- Performance Standard
- Failure Modes
- Infant Mortality
- Reactive Maintenance
- Proactive Maintenance
- P-F Curve
- Mean Time Between Failure
- Asset Criticality
- Defect Elimination
- Reliability
- Maintenance Strategies
- Planning and Scheduling
- Failure Patterns

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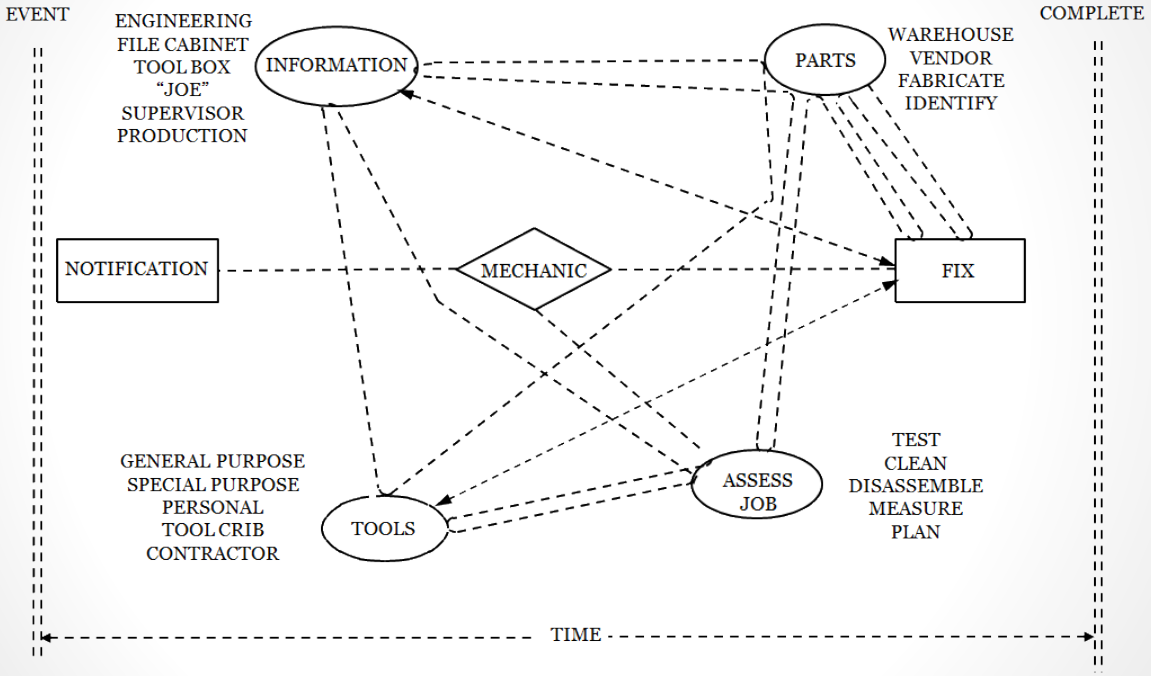
Traditional Maintenance



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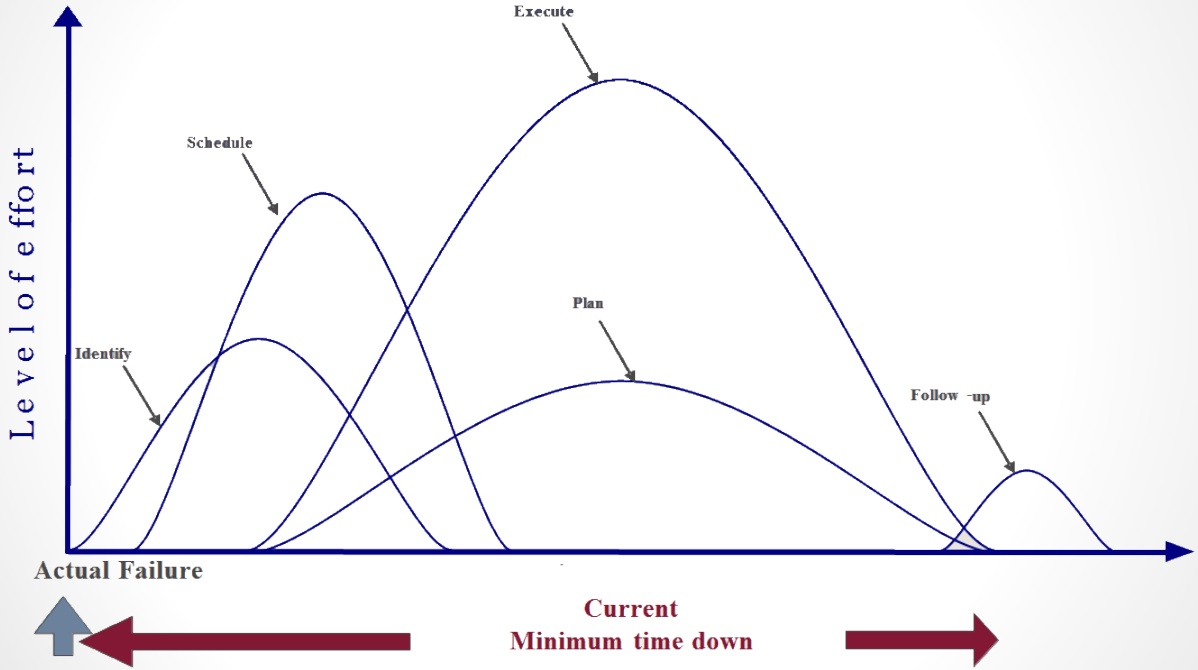
Reactive Maintenance



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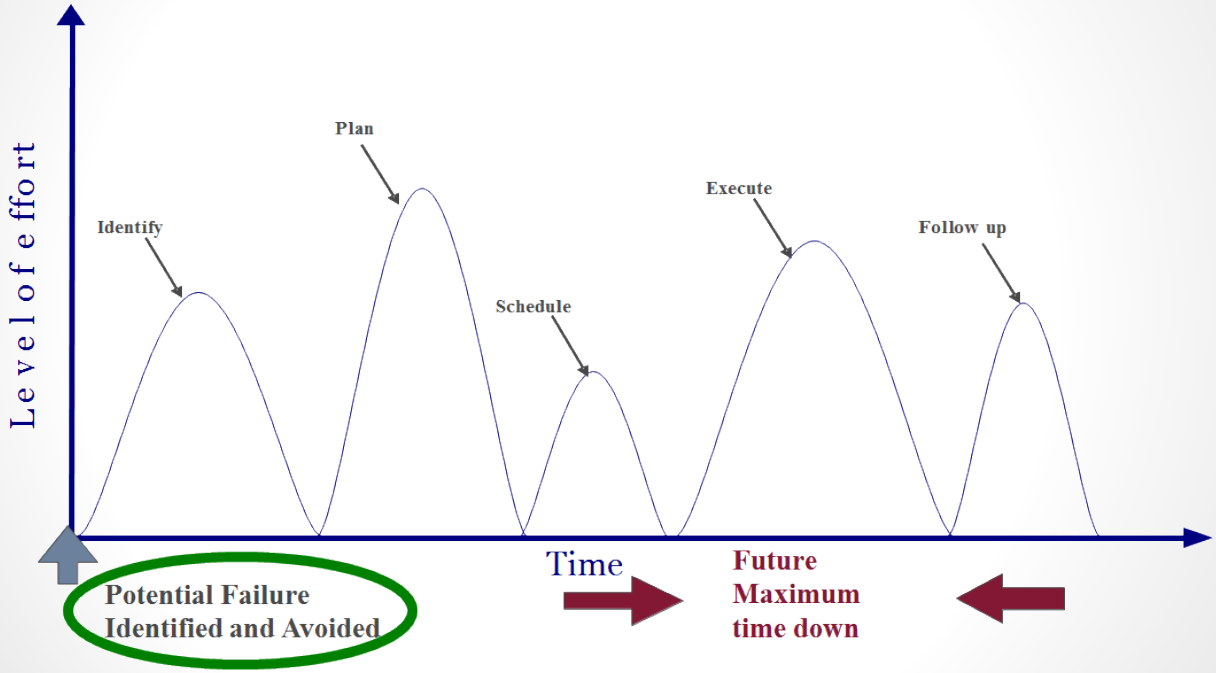
Proactive Maintenance



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FRACAS Loop

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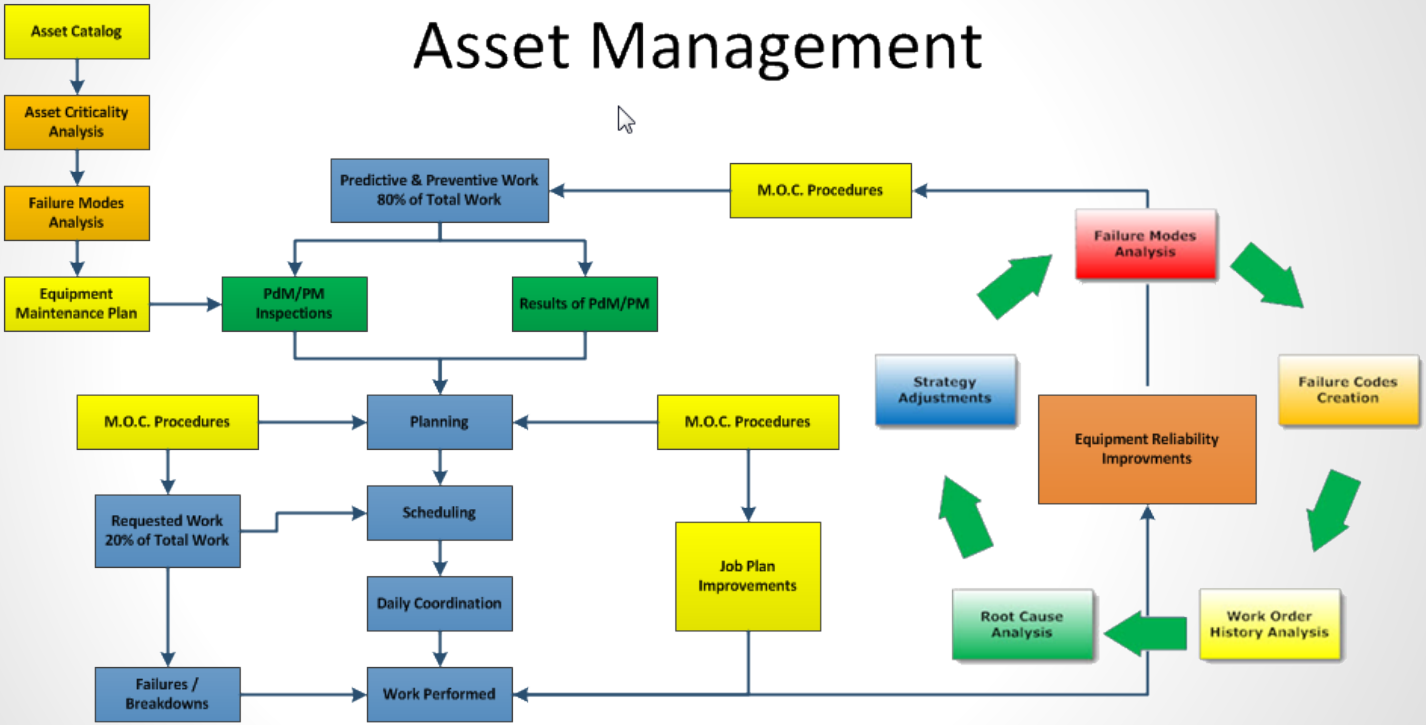
Communication



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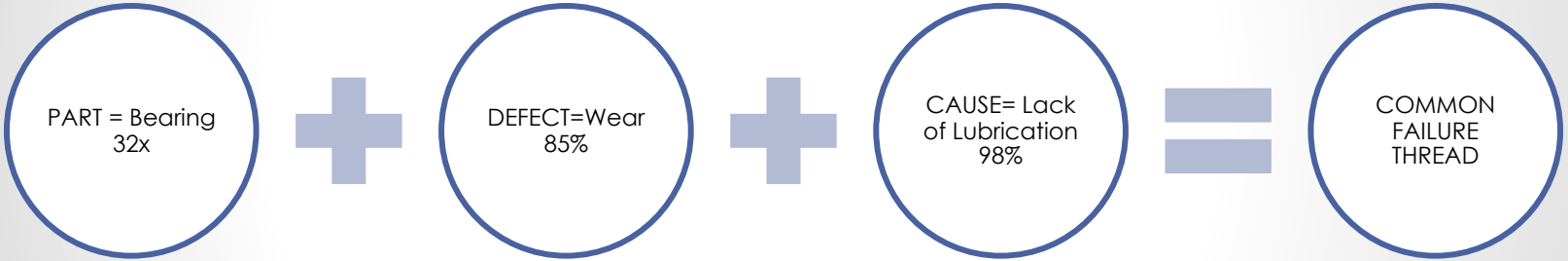
Part-Defect-Cause Report

32 Bearing Failures Across the Plant
Wear Defect for 85% of Bearing Failures
98% of Defects Caused by Lack of Lubrication



What is the Solution to Defect Elimination?

Resolve the Lack of Lubrication Problem

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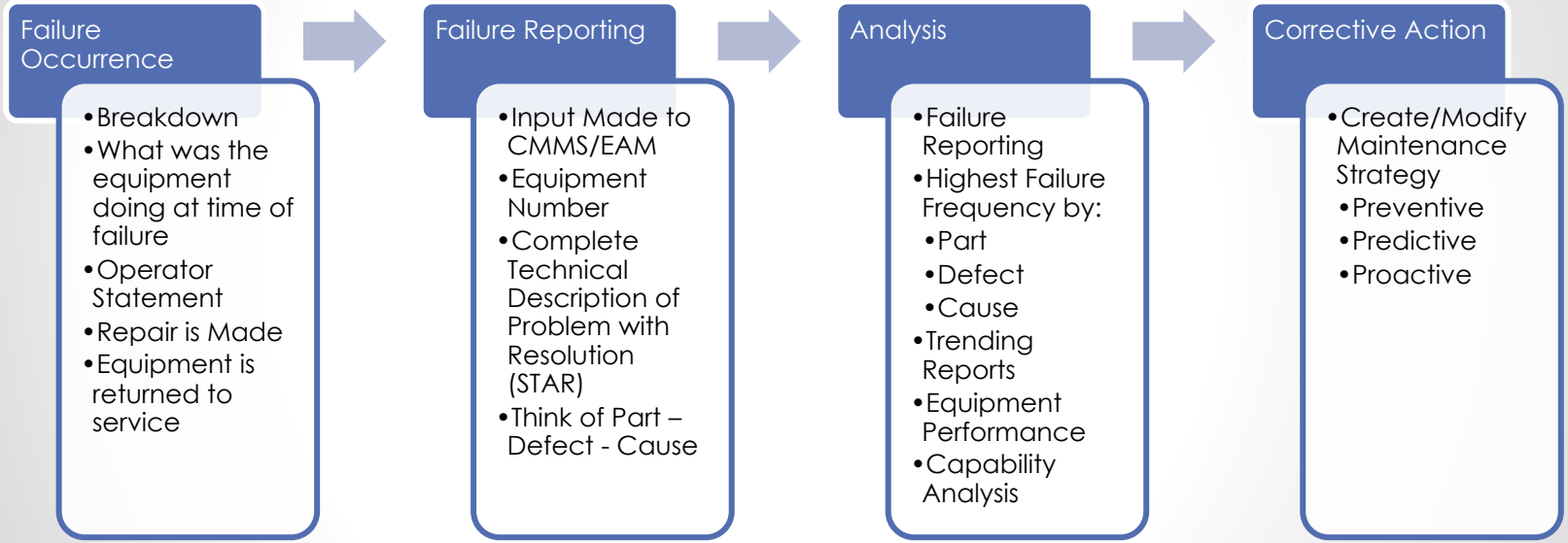
The FRACAS Process



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Added Value

Knowledge and Understand of Reliability for Technicians

Reduction in Downtime Events

Cost of Maintenance will be reduced

Sustainable Change

The WHY is explained

Build a common language and a common purpose

Sets a standard of accountability

Propagate communication at all levels

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Conclusion

Establish the WHY

Need to understand the terminology

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Establish a process

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Creates Value

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Questions & Answers

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Next Webinar

Date: Wednesday, May 31

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Keynote

Essential Components of a World-Class Ultrasound Program

by Adrian Messer, Manager of US Operations, UE Systems Inc.

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Educational Session

To Be Announced

by Oli Hakansson, Nexus Global

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