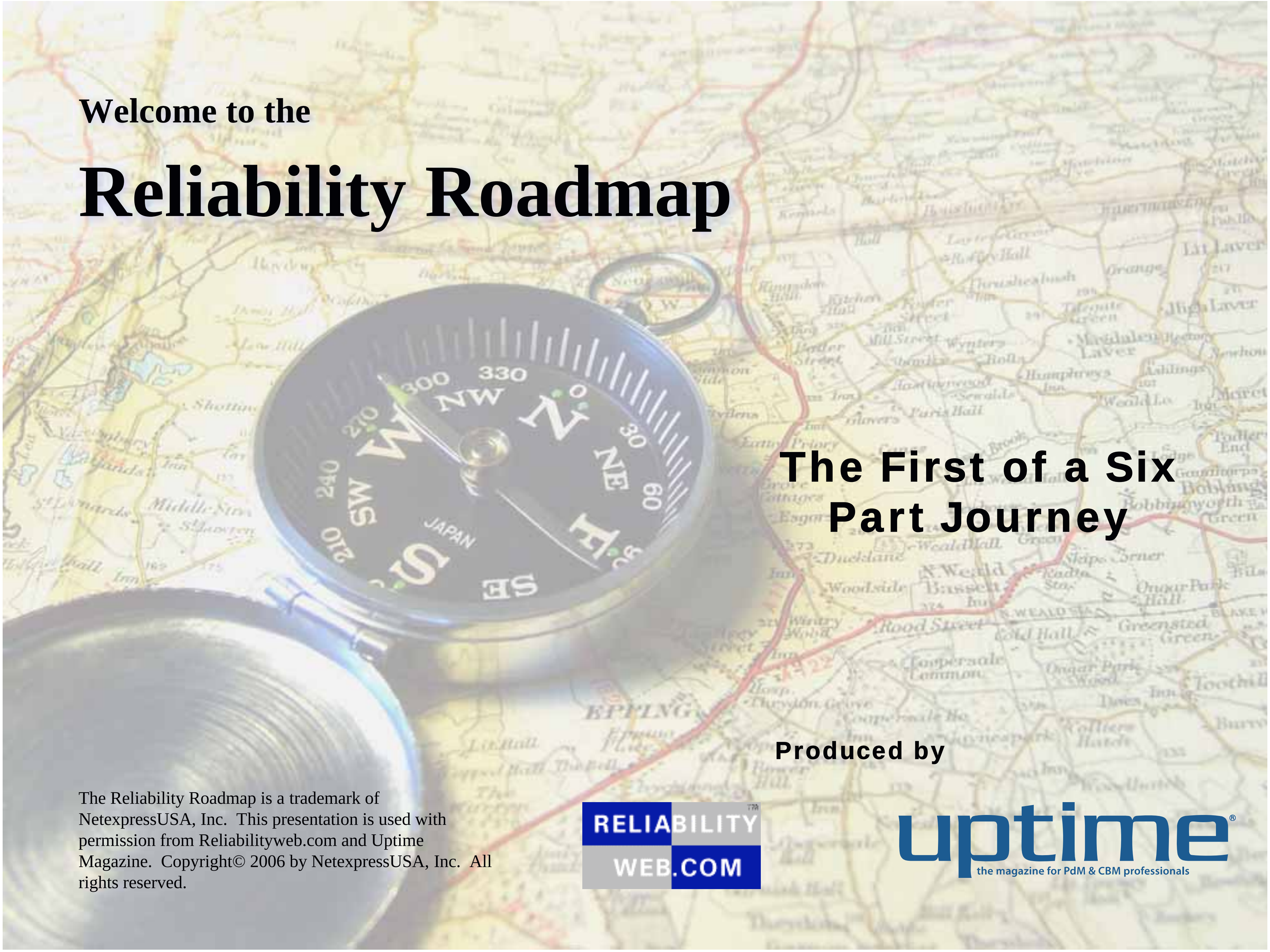

Welcome to the

Reliability Roadmap

The First of a Six Part Journey

Produced by

RELIABILITYWEB.COM

uptime
the magazine for PdM & CBM professionals

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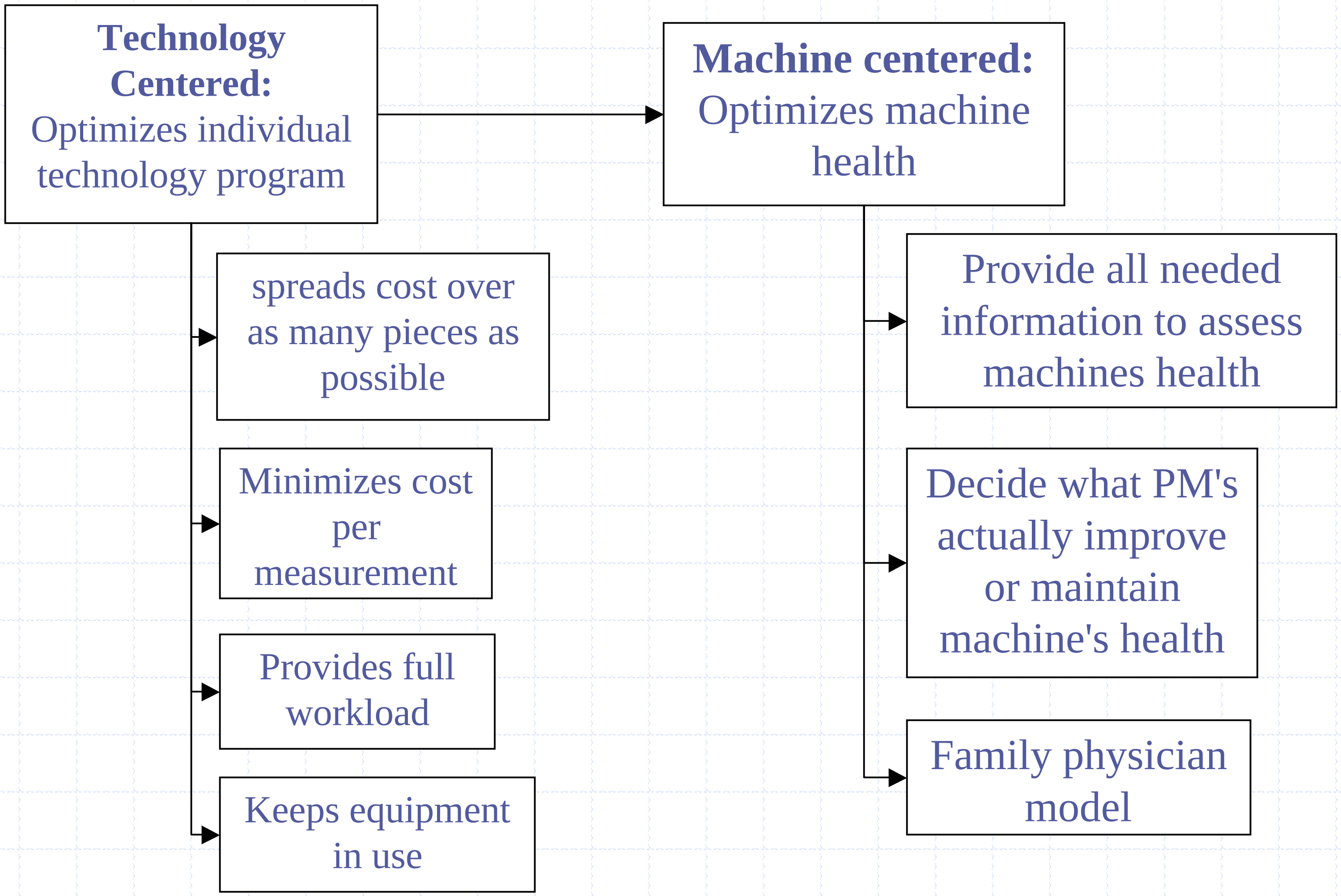
Machine Centered Condition Assessment

An Alternative to Technology Centered Condition Assessment

Background


Technology Centered: Optimizes individual technology program
spreads cost over as many pieces as possible
Minimizes cost per measurement
Provides full workload
Keeps equipment in use
Machine centered: Optimizes machine health
Provide all needed information to assess machines health
Decide what PM's actually improve or maintain machine's health
Family physician model

Each Technology Is Optimized

Spreads cost over as many machines as possible

Minimizes cost per data point

Maximizes utilization of test equipment

Provides evidence of full work load to supervision

Machine Healthcare is sub-optimized

Is This the Best Way?

Would you be happy with your doctor if on your annual physical he only tested your pulse rate?

And then sent you out to contract your own blood work and interpret the results?

Then based on that limited information, he makes the decision to do surgery.

A pump overhaul is surgery!

Application to Machinery Healthcare

To get a complete picture of machine health, you need to run a number of tests.

You're more likely to catch something early.

And when that PM for overhaul (surgery) comes up, you can make an informed decision on whether to perform or defer it.

Advantages of a Machine Centered Approach

Collect complete data on each trip to machine

Less machines per day

More valuable information

Manage failure

Defer routine overhauls

Optimize Machines Healthcare

Machine Centered Process

It's nothing new

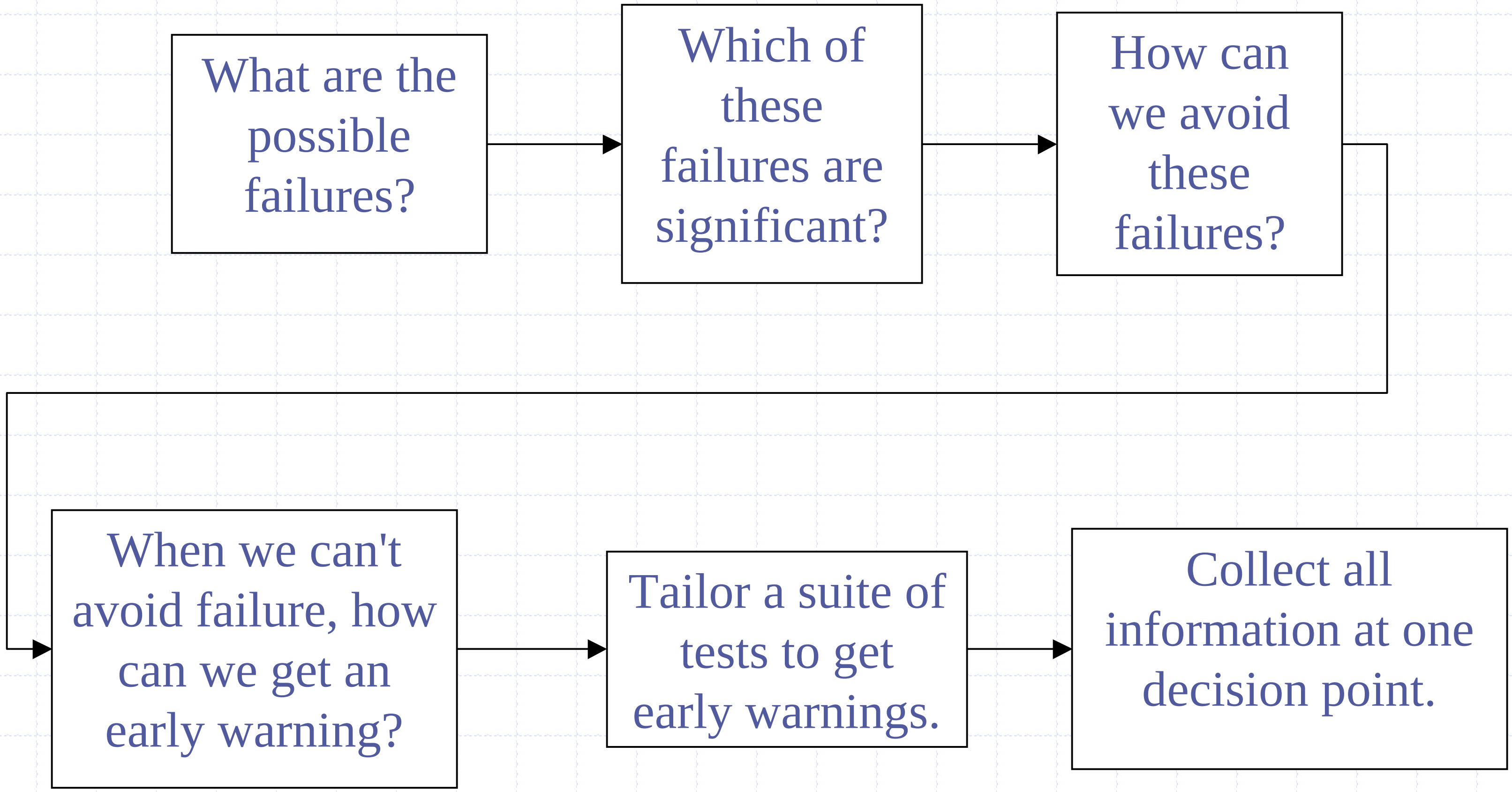
Reliability Centered Maintenance formalizes it

But the fact is not everyone can do RCM

- They can't afford it
- They don't have the manpower
- They can't get approval

But they still have to maintain the machine

Machine Centered Thought Process



First ask:

What are the possible failures

Think about the function of the machine

How can it fail to meet that function?

Motor-Drive System Functions

Function
Downstream (Load side)
Start motor
Stop motor
Deliver specified torque at specified RPM
Specified speed ramp rate up
Specified speed ramp rate down
accelerate load from stop to operating speed
adjust torque and speed on demand

Functional Failure of a Motor Drive System

Function	Functional Failure	Failure Mode
Start motor	Motor will not turn	winding failure (stator) Insulation Failure (stator) Rotor failure Bearing Seized Contactor Failed Loss of Power VFD Malfunction (Start)
Stop motor	Motor will not stop	Contactor Failed VFD Malfunction (STOP)
Deliver specified torque at specified RPM	Motor turns at wrong speed.	VFD Malfunction (Speed control) Motor fault load fault
Specified speed ramp rate up	Motor ramps up at wrong rate	VFD Malfunction (ramp up) winding failure (stator) Insulation Failure (stator) Rotor failure Bearing Seized

Next ask:

Which of these failures are significant?

How often it happens - frequency

What's the impact when it does - consequence

Risk = frequency times consequence

Criticality Survey

Score	Frequency	Effect
1	1/10 yrs	None
2	1/ yr	A little
3	1/ month	Some
4	1/ week	A lot
5	1/ day	Complete

Then ask:

How can we avoid these failures?

Adjust, lubricate, ...

Preventive replacement

Design changes

When we can't avoid failure, ask:

How can we get an early warning?

- Process parameters
- Inspections
- Technology

Then:

Tailor a suite of tests to get early warnings?

- Only do the tests needed

Motor Failure

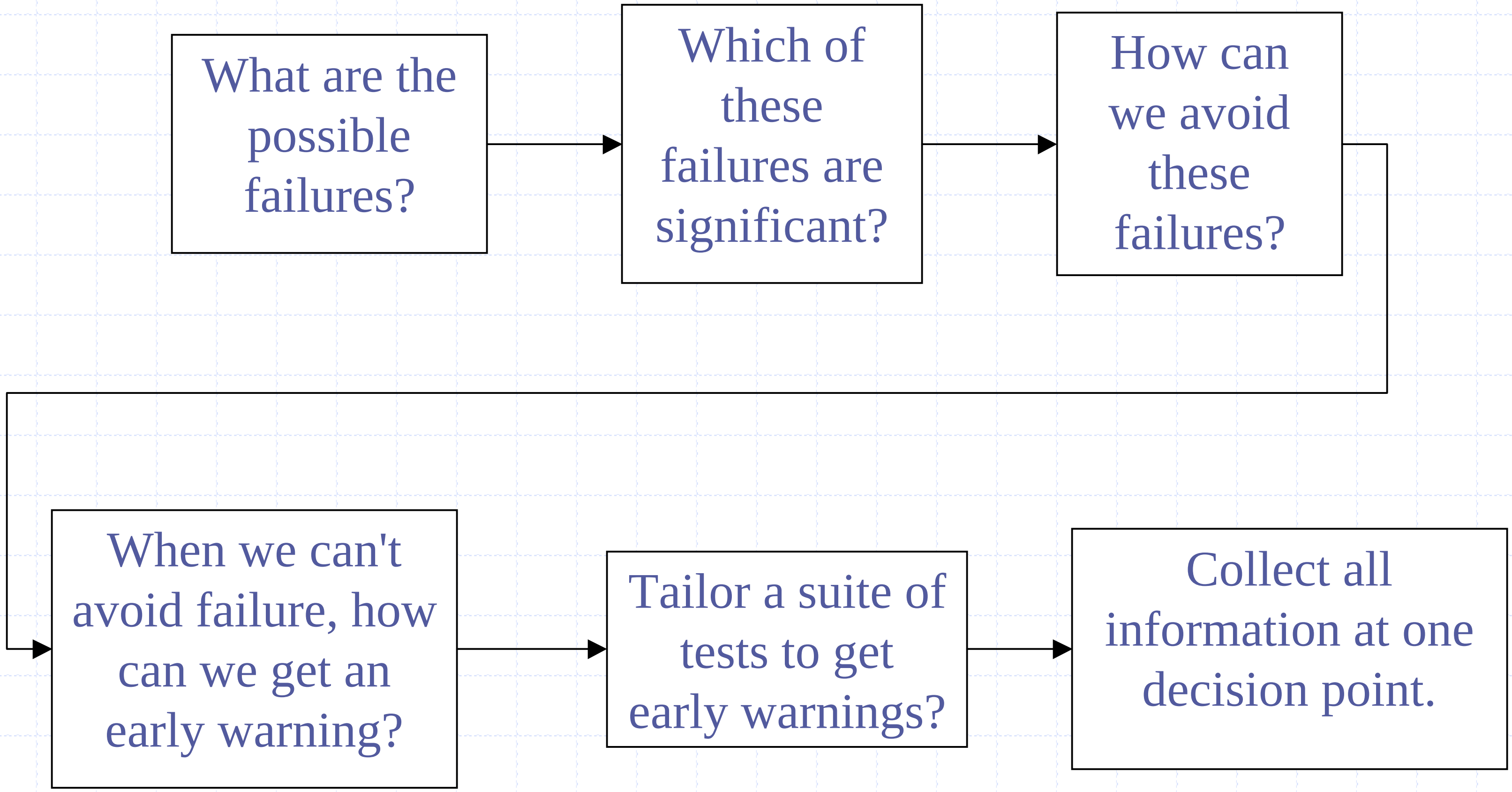
Failure Mode	Failure Causes	Symptoms	Measurement
winding failure (stator)	Conductor failure	vibration > ips	vibration monitoring
		Various	MCSA
		Various	MCE
	excessive vibration	vibration > ips	vibration monitoring
Insulation Failure (Stator)	Breakdown		Polarization index
		R to gnd < ohms	Megger
	excessive current	temperature > °F	thermometer
		amperes > A	ammeter
	voltage spike		power quality monitor
	excessive temperature	Motor temperature > °F	thermometer
		Ambient temperature > °F	thermometer
			thermography
	excessive vibration	vibration > ips	vibration monitoring
	phase imbalance	phase angle >± °	power quality monitor
			MCSA
			MCE
		temperature > °F	thermometer
Rotor failure	broken rotor bars	vibration > ips	vibration monitoring
Bearing Seized	Fatigue	vibration > ips	vibration monitoring
		shock pulse > db	Shock pulse meter
	improper lubrication	shock pulse > db	Shock pulse meter
		Lube deterioration	lube monitoring

Finally:

Collect all information at one decision point.

Most important step!

Machine Centered Thought Process



Optimize the Machine's Healthcare

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Failure Finding Task Intervals

By V. Narayan
Effective Maintenance Ltd.

Why do we need FFTs

- Hidden Functions
- Protective Devices
- Complexity and cost of modern equipment
- Safety and how protective devices help
- How will we know if we can trust them to work?

Hidden Functions

Not obvious to operator during normal duties

A second event or failure is necessary for him to know of the failure; hence called Hidden function

Examples

- Start up of standby pump
- Smoke detector or PRV condition
- Ejector seat of fighter plane
- Brake light of your car ....etc.

Protective Functions

Device or system whose only role is to protect other equipment/systems - over-speed, axial displacement trips, relief & blowdown, emergency depressurizing or shutdown, deluge, Tanker release etc.

These devices can fail in one of two ways

- Fail to protect when required
- Operate when not required, i.e. - spuriously

  Spurious trips are a major source of loss

The Litmus Test

- Did the consequence occur at the same time as the failure?
- If it did, the function is evident
- If not, i.e., another event or failure is required before you experience the consequence, it is a hidden function

Equipment Complexity

- Machinery becoming more complex and costly
- Driven by demand for productivity & quality
- Damage can cause large losses
- So they need protection, from mal-operation, unbalance, loose bolts, worn thrust bearings, reverse current etc.
- Protective devices have hidden functions
- If protection is lost *and* protected equipment needs it (i.e. multiple failure), serious damage can result

Hidden Function, Sleeping Tiger

A Feature of Hidden Functions

We will only know if an item is working when

- We use it due to a real need, or
- We test it

Availability with Hidden Functions

At any given time,

- the expected value of its being in a working state is equal to its survival probability or reliability
- so its availability on demand has the same numerical value as its reliability

Hence, for a hidden function,

Availability = Reliability

Availability

In the case of hidden functions, we make two assumptions

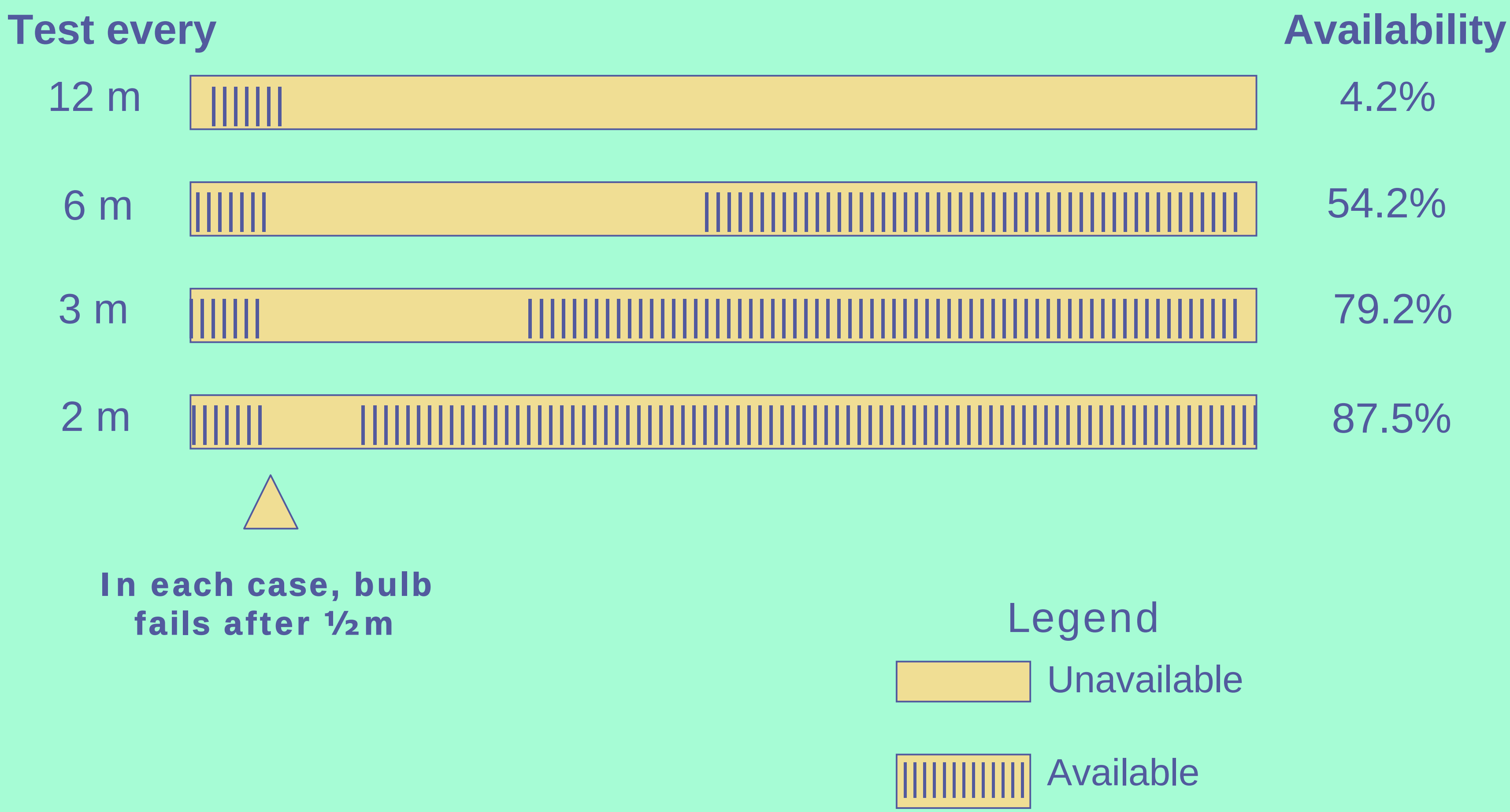
1. Any failed item is replaced as soon as we know of it
2. The failures are exponentially distributed

Exercise

Your car brake light bulb MTBF = 5 years.
One bulb fails randomly, ½ m after annual vehicle inspection.

- What is the availability of the light ?
- If you test the brake light after 6m, 3m, 2m, will its availability be different?

Testing and Availability



Some assumptions

With hidden functions, reliability of item is

- 100% when newly installed
- The test interval is much smaller than the MTBF

typically T/MTBF < 5

where T is the test interval

FFT intervals

It can be shown that

$$-T / MTBF = \ln(2 \bar{A} - 1)$$

Where **T** is the FFT or test interval

MTBF is that of the protective device

ln is the natural or napieran logarithm

Ā is the required mean availability

Application of formula

- We need to know the risk level and demand rate. From this we can assess the required mean availability for the hidden function
- The higher the risk, the higher the required availability

Summary

- Hidden Functions are important for Health, Safety, Environment and Profitability ($)
- Protective devices/systems have hidden functions
- High risk situations need high availability protective systems
- For a given MTBF we can always get the required availability by selecting the right test interval

Get this book! – Terry O

EFFECTIVE MAINTENANCE MANAGEMENT: Risk and Reliability Strategies for Optimizing Performance

By V. Narayan

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