Reliability Issues From A Management Perspective

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Definitions

- **Reliability—**
  The probability that a component, device, system, or process will perform its intended function without failure for a given time when operated correctly under specified environmental conditions.
- **Life Cycle Costs—**
  All costs associated with the acquisition and ownership of a system over its full life. The usual figure of merit is net present value.
- **Reliability and Life Cycle Cost—**
  Business issues come together as a rational task.

Reliability?!—
Oh My--More Stuff To Learn!

- **New reliability tools are based on 60 years of experience —they are not a program of the month for new, "laser guided", techniques to solve costly old nagging problems we've attacked with "machetes"**
- **Reliability tools help reduce and eliminate future failures—plan improvements looking forward using failure data histories which look backward**
- **$Risk = (probability of failure)*$Consequence reduce $Risk to meet regulatory goals and cost containment--where pof = (1 – Reliability). Many problems get solved when converted to time and money issues.**

What's Your Reliability Policy?

- Your safety policy says **we will have an accident free work place.**
- Your quality policy says **we will ship products free from defects.**
- Does your reliability policy say **we will have no process failures?**
- Don't have a reliability policy? Then **get one.** Managers communicate with **policies**
- Policies drive procedures which drive detailed rules
- Policies are **strategic**, procedures and rules are **tactics**

Who Needs A Reliability Policy

- **If you think "everyone knows what to do" then "few know what to do" (and welcome back to the '50s)**
- **If you think API specs are you survival tool then welcome to an unhappy survival on minimum standards**
- **Individual professional organizations and their standards are not concerned with you business issues**
- **Tie specs and issues together with a reliability policy to**
  - ✓ **Make sure to do the right thing**
  - ✓ **Make sure things are done right**
  - ✓ **Make sure the policy is understandable to everyone**

Reliability Is A Business Issue

- Equipment failures cost money for repairs/claims
- System failures halt cash inflows plus incur repair costs
- Business needs equipment and processes that are
  - available ← ready for duty when needed
  - reliable ← free from system failures and high cost
  - affordable ← a life cycle cost issue of tradeoffs
- We speak of technology, safety, and reliability but the main issue is money which addresses life cycle costs!
- Use procedures to convert policy details into time and money so the entire organization can make business decisions

Procedures From Policies

- **Spell out top level details in procedure**
- **Address**
  - **Cost of spills**
  - **Violation costs for errors/events**
  - **Cost of accidents**
  - **Risk levels allowed and recommended**
  - **Applicable industry specifications**
- **Make top level details clear and specific**

Rules From Procedures

- The rules from policies are similar to your safety rules
- Address failure models
  - Stress-strength ←capacity to repel challenges
  - Damage-endurance ←capacity to repel cumulative challenges
  - Challenge-response ←failure not known until challenged
  - Tolerance-requirement ←performance outside of limits
- Address failure mechanisms
  - Mechanical and electrical/electronic
- Define what is a failure

Reliability vs Maintenance Engineering

- Changing the name of your maintenance organization to include the name reliability can give you style—but what about substance?
- Reliability engineering uses special tools to avoid failures—this means learning new engineering tools
- Maintenance engineering strives for fast repairs
- Reliability engineering is to the fire marshal as maintenance engineering is to fire fighters
- You'll need ~1 Reliability Engineer for every ~10 Maintenance Engineers (staff size is not increased)

Reliability Engineering Tools

Examples Follow

Table 1	
Short List Of Reliability Engineering Principles Tools	
• Mean time between failures indices • TPM and reliability principles • Preparing reliability data for analysis • Decision trees merging reliability and costs • Weibull, normal, & log-normal probability plots • Corrective action for Weibull failure • Models & Monte Carlo simulations • Pareto distributions for vital problems • Fault tree analysis • Design review • Load/strength interactions • Software reliability tools • Sudden death and simultaneous testing • Failure recording, analysis and corrective action • Failure mode effect analysis	• Bathtub curves for modes of failure • Availability, maintainability, capability • Critical items significantly affecting safety/costs • Quality function deployment • Mechanical components testing for interactions • Electronic device screening and de-rating • Quality function deployment • Reliability testing strategies • Accelerated testing • Contracting for reliability • Reliability growth models and displays • Cost of unreliability • Reliability policies and specifications • Reliability audits • Management’s role in reliability improvements

Start Your Numbers With Arithmetic

- Start with MTTF/MTBF = (Σ life)/(Σ failures)
- What are you mean times between failure for: Pumps? Heat exchangers? Valves? Etc.
- Understand MTTF/MTBF which begins with arithmetic and grows to statistics
- A key long term issue: mean time between maintenance actions--a durability issue

MTTF/MTBF--Arithmetic

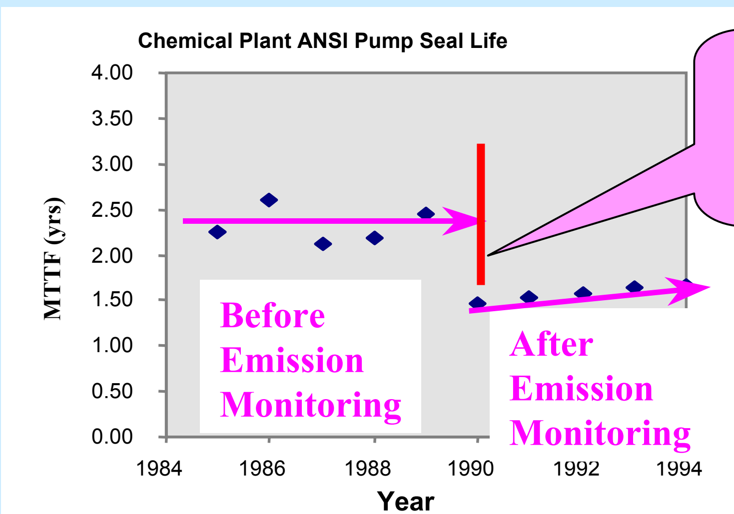
This MTTF data from production, maintenance, and purchasing records

Remember: MTTF is a meterstick—not a micrometer!!

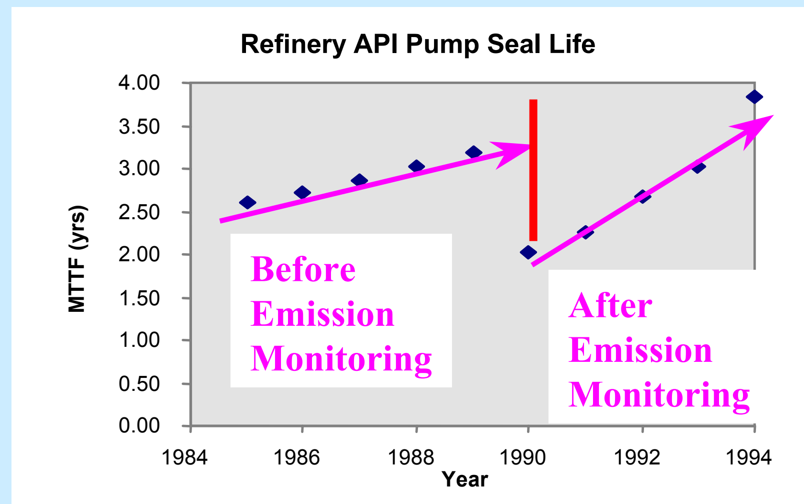
The Data

Chemical Plant ANSI Pump Life							
Year	Number Of Unspared Pumps	Number Of Spared Pumps	Total Hours Of Pump Operation	Number Of Seal Failures	Seal MTTF (yrs)	Seal Failure Rate (fail/hr)	Conditions
1985	937	2996	21,330,000	1083	2.25	50.8E-6	No
1986	943	2996	21,380,000	937	2.60	43.8E-6	Emission
1987	950	2998	21,450,000	1156	2.12	53.9E-6	Monitoring
1988	950	3008	21,500,000	1127	2.18	52.4E-6	
1989	953	3012	21,540,000	1003	2.45	46.6E-6	
1990	955	3028	21,630,000	1689	1.46	78.1E-6	
1991	957	3036	21,680,000	1628	1.52	75.1E-6	
1992	963	3048	21,790,000	1581	1.57	72.6E-6	
1993	955	3038	21,670,000	1517	1.63	70.0E-6	Emission
1994	951	3026	21,580,000	1487	1.66	68.9E-6	Monitoring

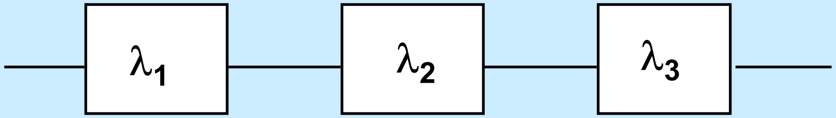
Refinery API Pump Life							
	Unspared Pumps	ber Of Spared Pumps	Total Hours Of Pump Operation	Number Of Seal Failures	Seal MTTF (yrs)	Seal Failure Rate (fail/hr)	Conditions
1985	313	1542	9,500,000	415	2.61	43.7E-6	No
1986	313	1542	9,500,000	398	2.72	41.9E-6	Emission
1987	313	1548	9,520,000	380	2.86	39.9E-6	Monitoring
1988	310	1560	9,550,000	361	3.02	37.8E-6	
1989	305	1580	9,590,000	343	3.19	35.8E-6	
1990	295	1580	9,500,000	535	2.03	56.3E-6	
1991	290	1590	9,500,000	481	2.25	50.6E-6	
1992	280	1598	9,450,000	403	2.68	42.6E-6	
1993	270	1602	9,380,000	354	3.02	37.7E-6	Emission
1994	265	1610	9,370,000	278	3.85	29.7E-6	Monitoring



Change In Failure Criteria



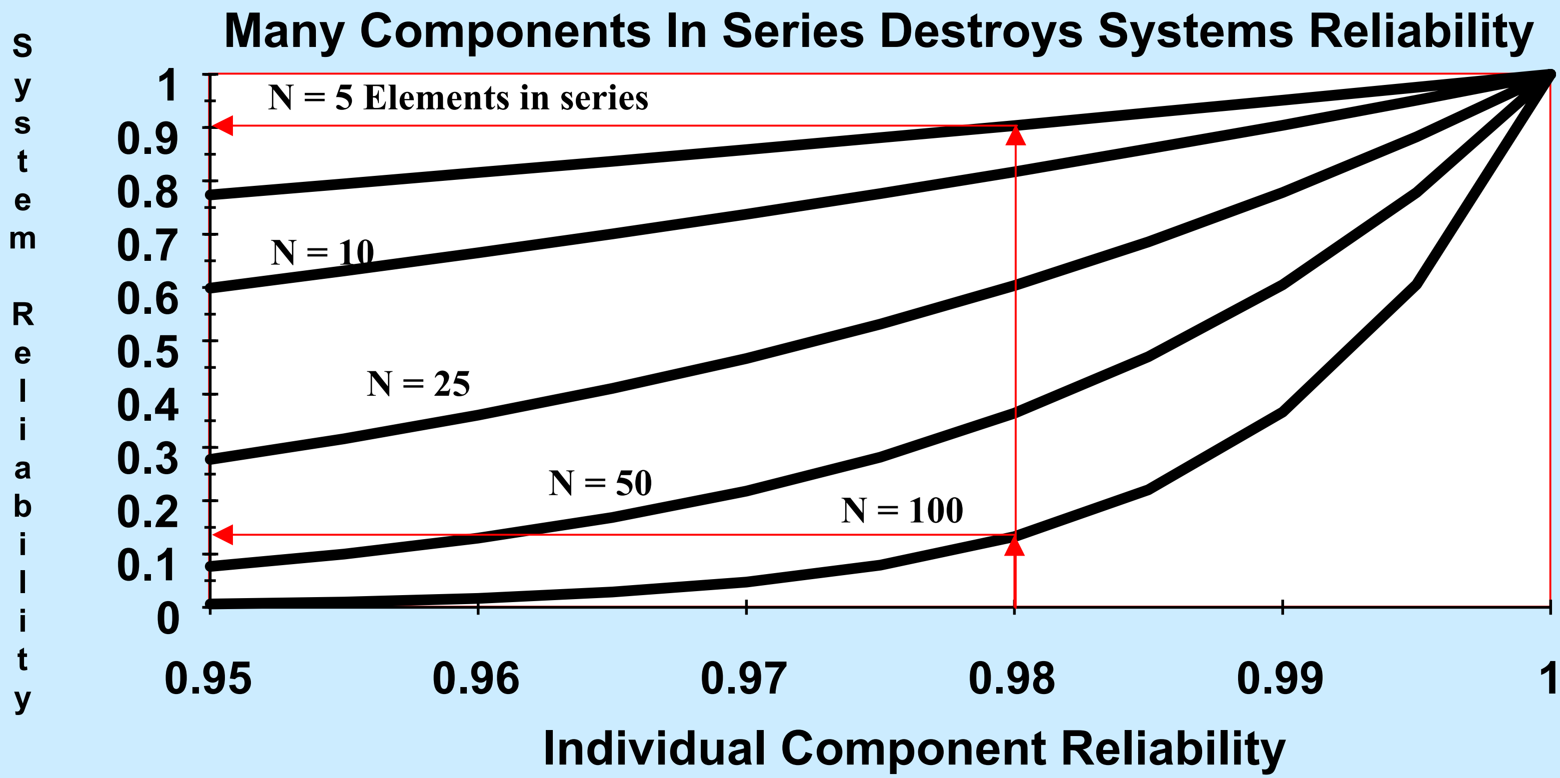
Series Reliability Models



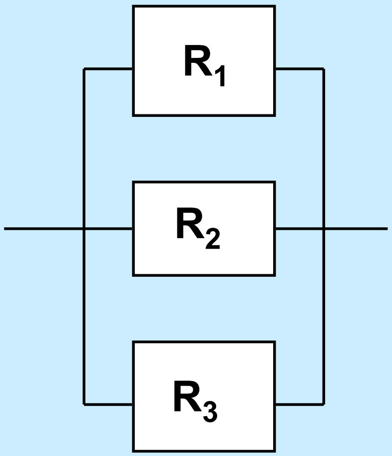
$R_1 = e^{(-\lambda_1 t)}$ $R_2 = e^{(-\lambda_2 t)}$ $R_3 = e^{(-\lambda_3 t)}$

$$\lambda_T = \Sigma\lambda_i = \lambda_1 + \lambda_2 + \lambda_3 \cdots$$

$$R_S = \prod_{i=1}^{i=n} R_i = R_1 * R_2 * R_3 = e^{(-\lambda_T t)}$$



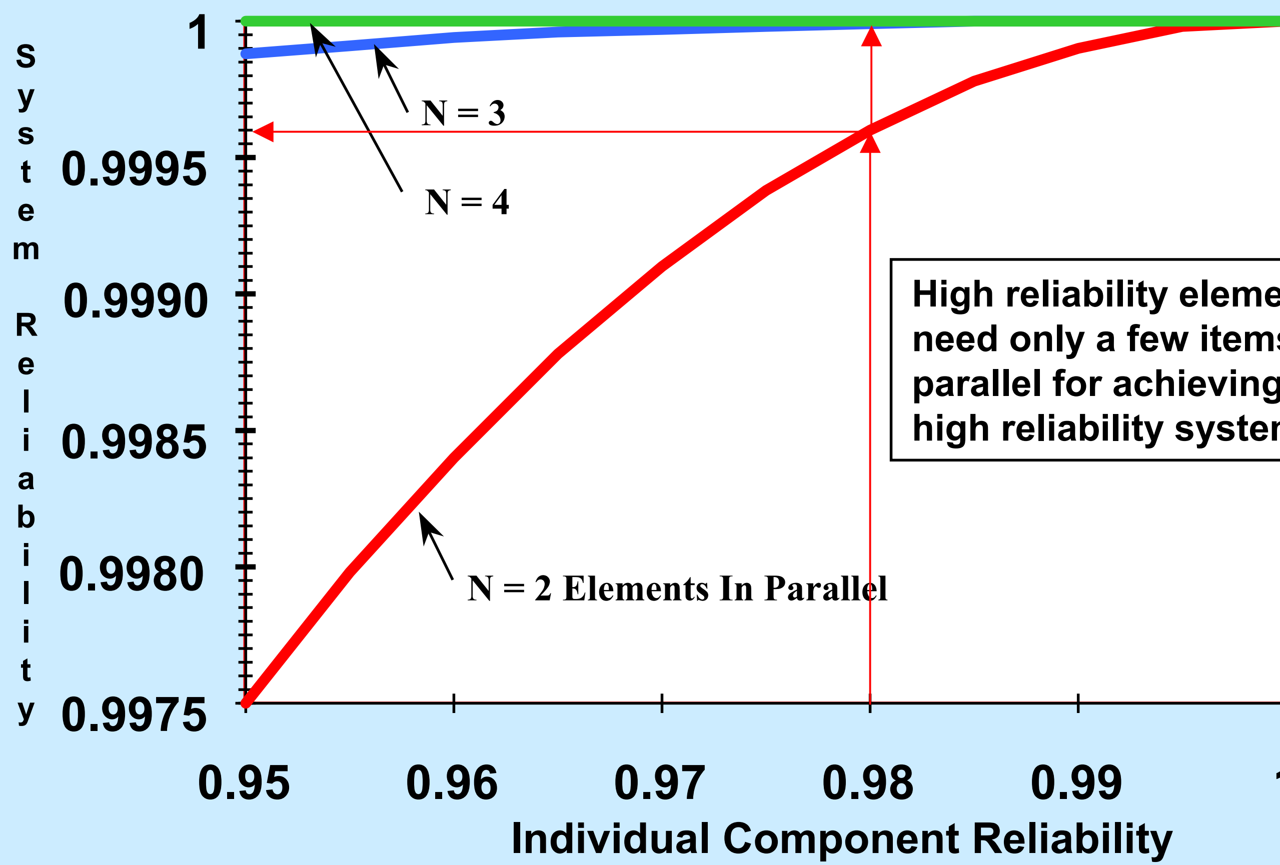
Parallel Reliability Models



Each element in parallel must be able to carry the full load

$$R_{overall} = 1 - (1 - R_1)*(1 - R_2)*(1 - R_3)*(\cdots)$$

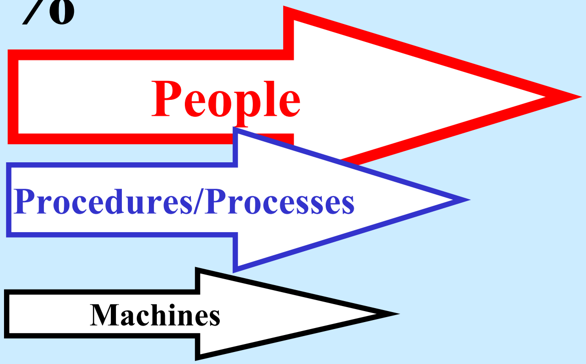
Components In Parallel Improve Systems Reliability



High reliability elements need only a few items in parallel for achieving a high reliability system.

Roots Of Reliability Failures

Mature Plants	Frequency %
• People	38
• Procedures + Processes	34
• Equipment	<u>28</u>
	100



- **Human reliability problems are opportunities for improvement by error proofing operations**
- **Some human failures are also tied to procedures and processes problems**

Human Models

Table 2 Time Available For Diagnosis Of An Abnormal Event After Control Room Annuciation	
Time (minutes)	**Probability Of Failure (%)**
1	~100
10	50
20	10
30	1
60	0.1
1500	0.01

← **If they don't forget!**

Reliability = (1 - pof)

Reliability & NPV Models

Table 3

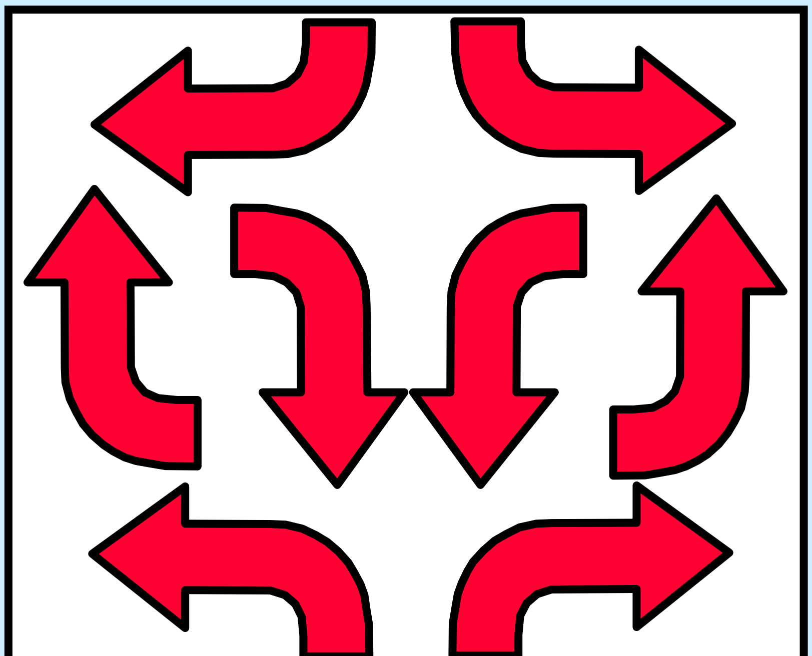
Device Reliability = 0.95 for 1 year mission, Failure Consequence = $20,000,000, Device Costs = $10,000/each

Number of Instruments	Reliability (%)	$Risk/yr	Capital Cost	NPV
1	0.95	$1,000,000	$10,000	-$4,639,636
2	0.9975	$50,000	$20,000	-$248,714
3	0.999875	$2,500	$30,000	-$37,320
4	**0.99999375**	**$125**	**$40,000**	**-$34,902**
5	0.999999688	$6	$50,000	-$42,932
6	0.999999984	$0.31	$60,000	-$51,485

Conflicting LCC Issues-- What To Do?

Project Engineers:
Minimize capital expenditures

Maintenance Engineers:
Minimize repair hours



Shareholders:
Maximize dividends and/or share price

Production:
Maximize uptime hours

Reliability Engineers And Regulators:
Maximize equipment reliability to avoid failures

Buy right? Or Buy Cheap?

Accounting:
Maximize project net present value

Engineers Must Quantify All Life Cycle Costs

Engineers Must Think Like MBA's

And

Act Like Engineers

To Get

Lowest Long Term Cost Of Ownership

Over The Entire Life Cycle

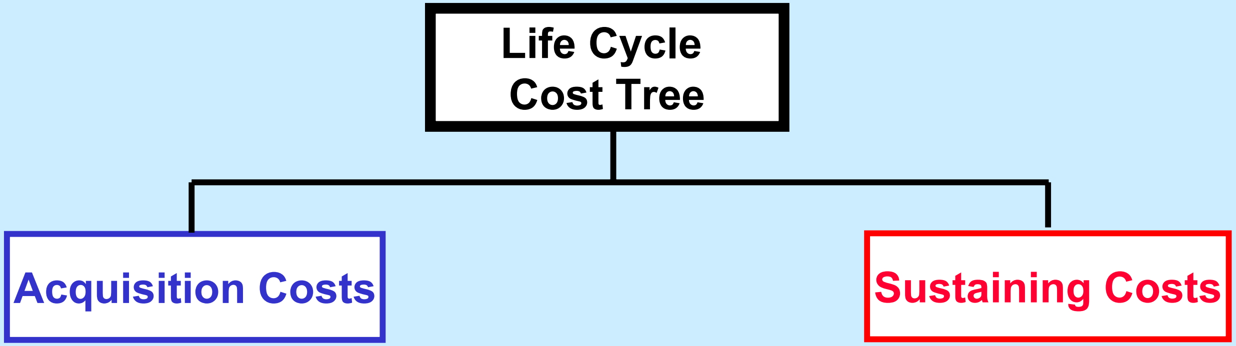
 Think NPV

Life Cycle Costs Are Fixed During Design

- **Often sustaining costs (including hidden costs) are 2-20 times acquisition costs (obvious costs)**
- **About 65% of total LCC are fixed by the time equipment is specified (but only a few percent of funds have been expended)**
- **Minimizing LCC pushes up NPV**
- **Finding the minimum LCC required details for both acquisition costs and sustaining costs**

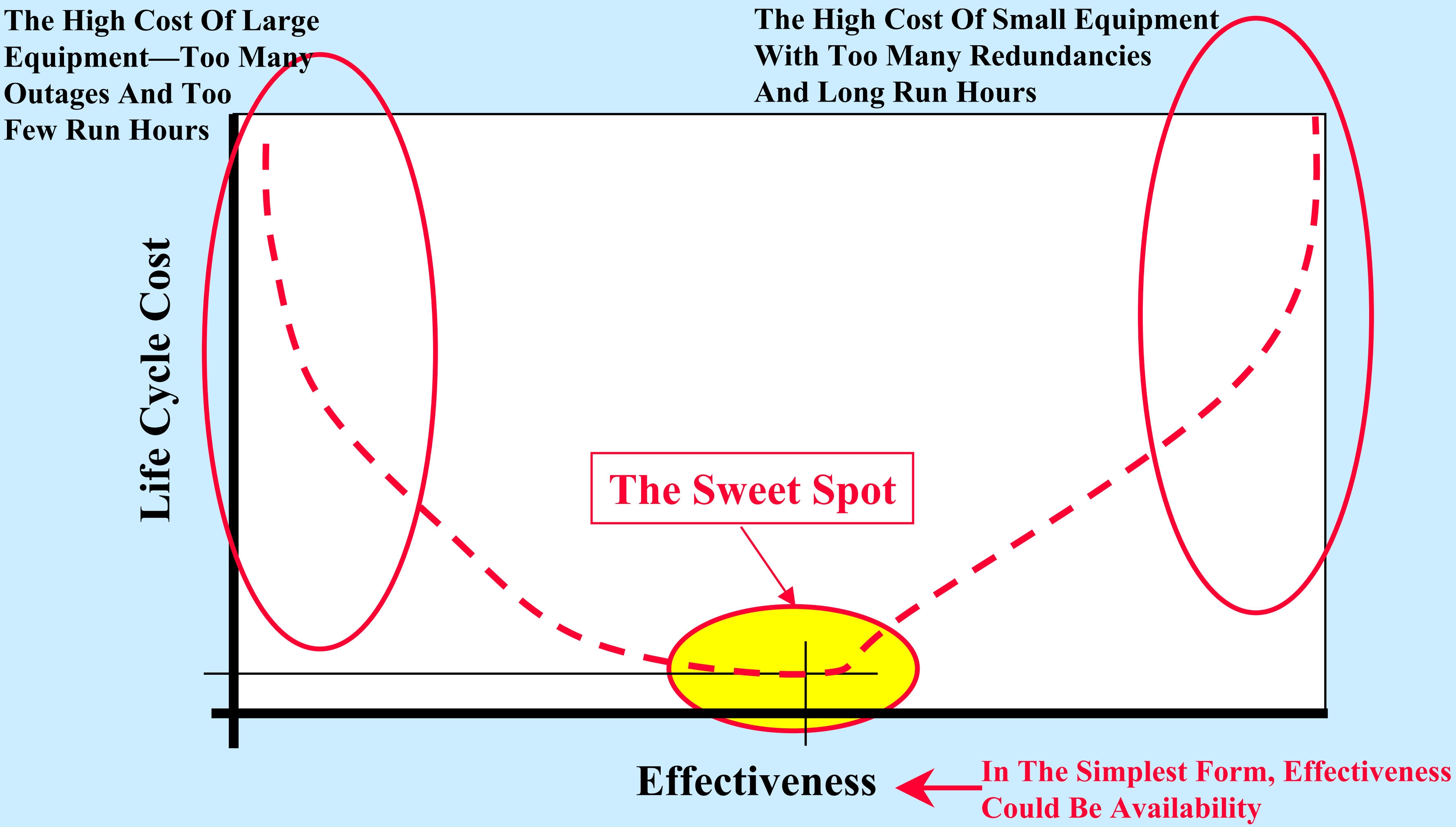
Top Levels Of LCC CostTree

- LCC = Acquisition Costs + Sustaining Costs



- Acquisition costs and sustaining costs are not mutually exclusive—find both by gathering the correct inputs and identifying cost drivers

Getting LCC Just Right!



LCC Thumbnail

- Life cycle costs include cradle to grave costs
- Including failures into LCC decisions permits engineering quantities of manpower, spare parts, and alternatives on a rational basis rather than use of rules of thumb or emotion
- LCC provides numbers for trade-off studies and uses NPV for sound, unemotional decisions
- Monte Carlo models add realism to numbers and help find trade-off values

RE Thumbnail

- **Reliability policies set the organization on a common course for a failure free environment**
- **Reliability engineering tools predict failures and risks for certain actions**
- **Show engineering details in terms of time and money for making correct trade offs**
- **If customers and the general public are unhappy with system reliability you need to make a change to get a change**

Summary

- Set a policy for a failure free environment
- Use data to predict problems and fix them
- Think time, money, and alternativeS
- Quantify unreliability and unreliability costs
- Plan for organized improvements
- Learn new tools for solving old problems
- Prevent system failures

Internet Downloads

- **Copies of the technical paper Reliability Issues From A Management Perspective and slides are available as down loadable PDF files**
- **http://www.barringer1.com/Papers.htm**
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Yes, that’s a capital “P”