material handling logistics conference

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Reliability Centered Maintenance

Track 3 Session 7

SupplyChain Forward.

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Abstract

- In the warehouse or on a production line, Capacity Assurance is a product of equipment uptime. This session will examine the process and rewards of RCM, it's impact on uptime and the business case for investing in this popular methodology.

Agenda

- Provide a definition
- Describe evolution of RCM Methodology during its almost 50 year history
- Describe the overall process
- List steps of RCM analysis & why this differs from previous approaches to maintenance
- List motivations for and reasons why RCM should be applied in the field of Materials Handling
- Key Takeaways
- Acknowledgements
- Questions

RCM Definition

- **A systematic, disciplined process to ensure safety and mission accomplishment through assurance of continuity of system functions.**

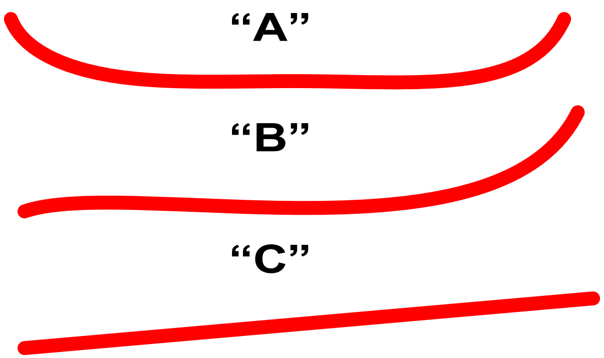
RCM History

- Developed in 1960's in anticipation of commercial introduction of jumbo jets
- Applied to military aircraft, nuclear subs & surface warships starting in 1970's
- Adopted for critical systems in commercial nuclear power plants in mid-1980's
- Applied to over 1000 commercial and industrial systems by late 1990's – worldwide
- Continues as the most effective and efficient way to determine what maintenance to perform as of 2009

Motivators to Adopt RCM

- **Primary Motivator – Economics**
- **Secondary Motivators –**
  - **Realization that "old" ideas concerning system and component failures were based on bad assumptions**
  - **Advent of Predictive Condition Monitoring Technologies and Analysis methods that obviated need for "intrusive maintenance"**

Profiles with Rising Failure Rates at End of Conditional Periods of Operations

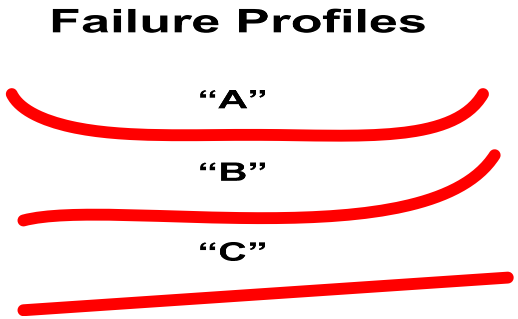


Failure Profiles	UAL 1968	Broberg 1973	MSP 1982	SUBMEPP 2001
"A"	4%	3%	3%	2%
"B"	2%	1%	17%	10%
"C"	5%	4%	3%	17%
	11%	8%	23%	29%

- **Totals (in red) reflect years of data collected on commercial aircraft , naval surface warships and nuclear submarines and analyzed using the same methodology and definitions**
- **Source: U.S. Navy Analysis of Submarine Maintenance Data and Development of Age and Reliability Profiles – Paper by Tim Allen 2001**

Basis for Time Directed Maintenance Tasking

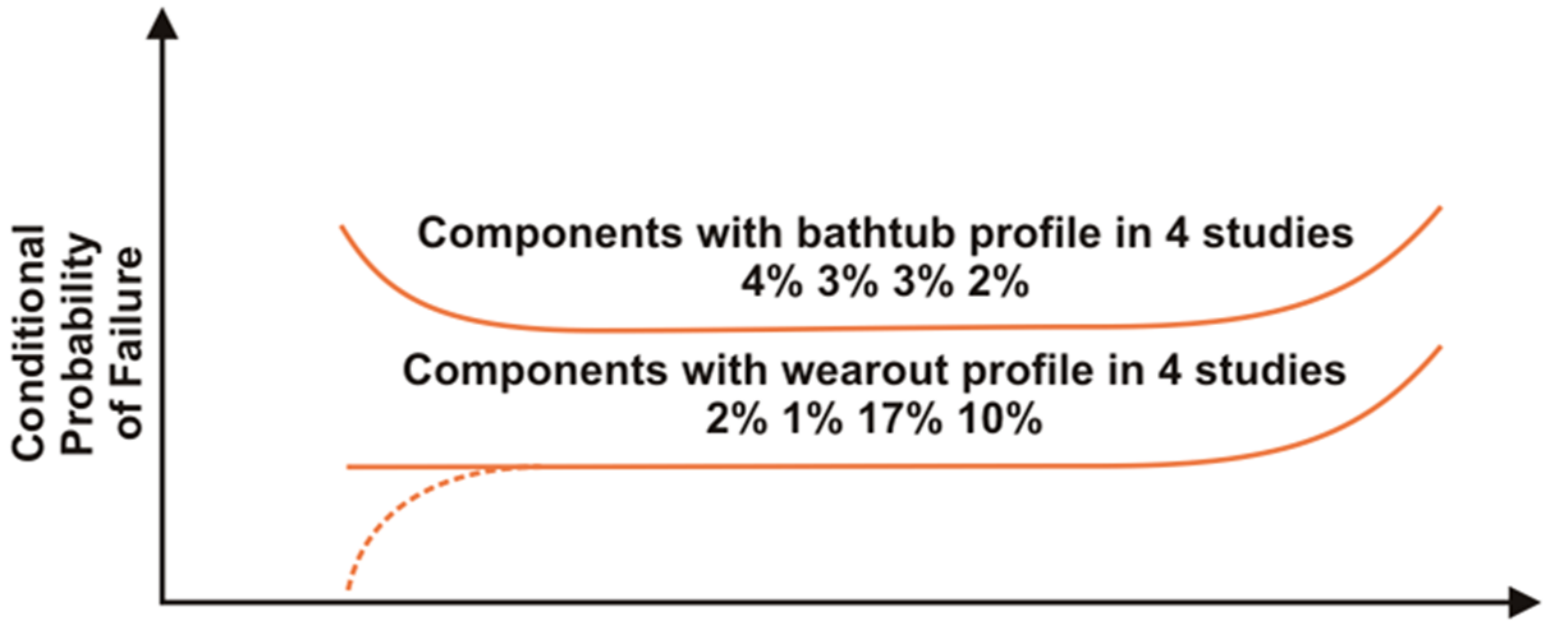
- **In the past shortest interval for time directed tasks was our *erroneous perception* that the vast majority of equipments possessed failure profiles "A", "B" or "C" with added allowance for "assurance"**
- **There was a constant hunt for the "right" interval for maintenance of production equipment which no one was able to get right**



- **The reason no one could guess right is because less than 20 to 30% of equipments or components of equipments had a failure profile that justified time directed tasking, (based on statistically significant studies done to date)**

Infant Failures and Planned, Time Directed Tasking

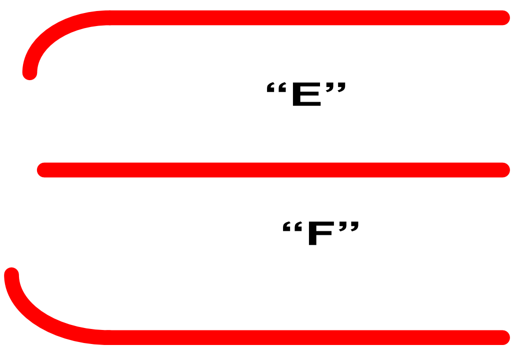
- **"It wasn't broke, but we fixed it anyway!"**



This point is illustrated in the combination profiles illustrated in the graph. Note that the totals for the only profiles showing a wearout characteristic are 6%, 4%, 20% and 12%, respectively

Profiles with No Wearout During Conditional Periods of Operation

Failure Profiles	UAL 1968	Broberg 1973	MSP 1982	SUBMEPP 2001
"D"	7%	11%	6%	9%
"E"	14%	15%	42%	56%
"F"	68%	66%	29%	6%
	89%	92%	77%	71%



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The Argument for Condition Directed Maintenance

- **"If it ain't broke, don't fix it"**
- **The summary numbers on the preceding slide are the best argument against time directed tasking and for condition directed tasking**
  - **89, 92, 77 & 71% of items with no wearout in four studies over 35 years**
- **That is, don't do any maintenance, except monitoring and non-intrusive sustaining actions, until condition directs intrusive corrective action**
- **Abnormal condition must be defined**
  - **May be based on throughput, quality, yield etc.,**

Typical Predictive Condition Monitoring Technologies

- Vibration Analysis
- Infra Red Thermography
- Lubricant, Hydraulic Fluids and Wear Particle Analysis
- Motor Current/Power Analysis
- Electrical Insulation Testing
- Transformer Predictive Analysis
- Electrical Circuit Analysis
- Ultrasonic Analysis
- Break Away & Coast Down Testing
- Filtration and Debris Analysis

RCM Process

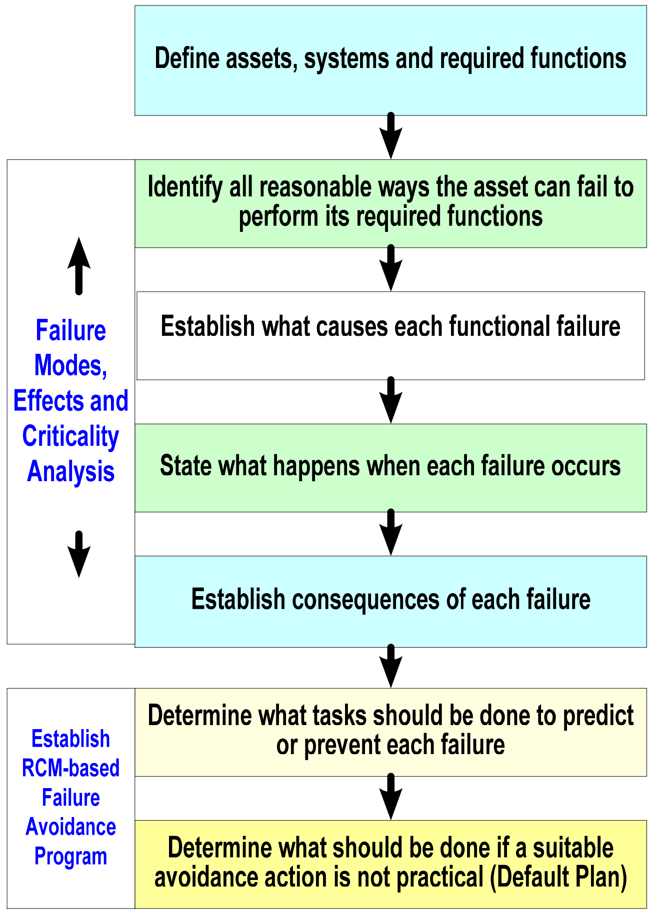
- Defines system boundaries
- Identifies system functions, functional failures, and likely failure modes for equipment and structures in a specific operating context.
- Develops a logical identification of the causes and effects (consequences) of system (and) functional failures
- Develops a set of applicable and effective tasks to mitigate or eliminate the consequences of these failures

RCM Analysis Basis

- **RCM analysis is used to extract the experience and knowledge of operating and maintenance experts who understand how the equipment works and are familiar with its operating and maintenance deficiencies in their context.**
- **It establishes a framework for anticipating, identifying, and developing proactive work tasks directed at maintaining system functions needed to assure safety and mission accomplishment**

Steps of RCM Analysis

Classical RCM



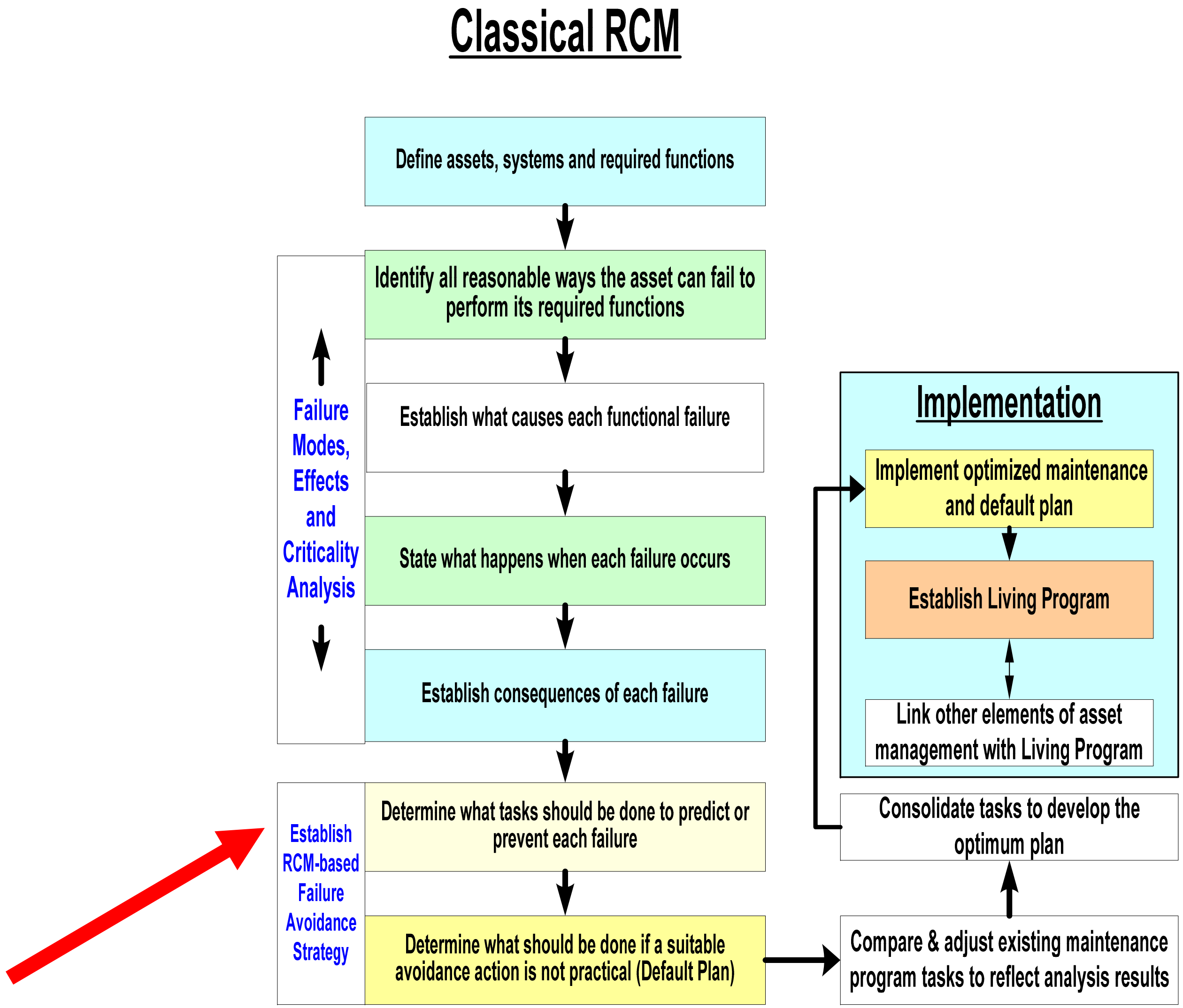
Elements for Success

- Elements that are needed or are highly desirable, if available, to assure a successful RCM outcome include:
  - Knowledge of RCM methodology and documentation techniques and tools
  - Organizational management support for the entire project
  - Availability of the best and brightest cognizant plant personnel for the project
  - Trained and disciplined RCM facilitators (or analysts)

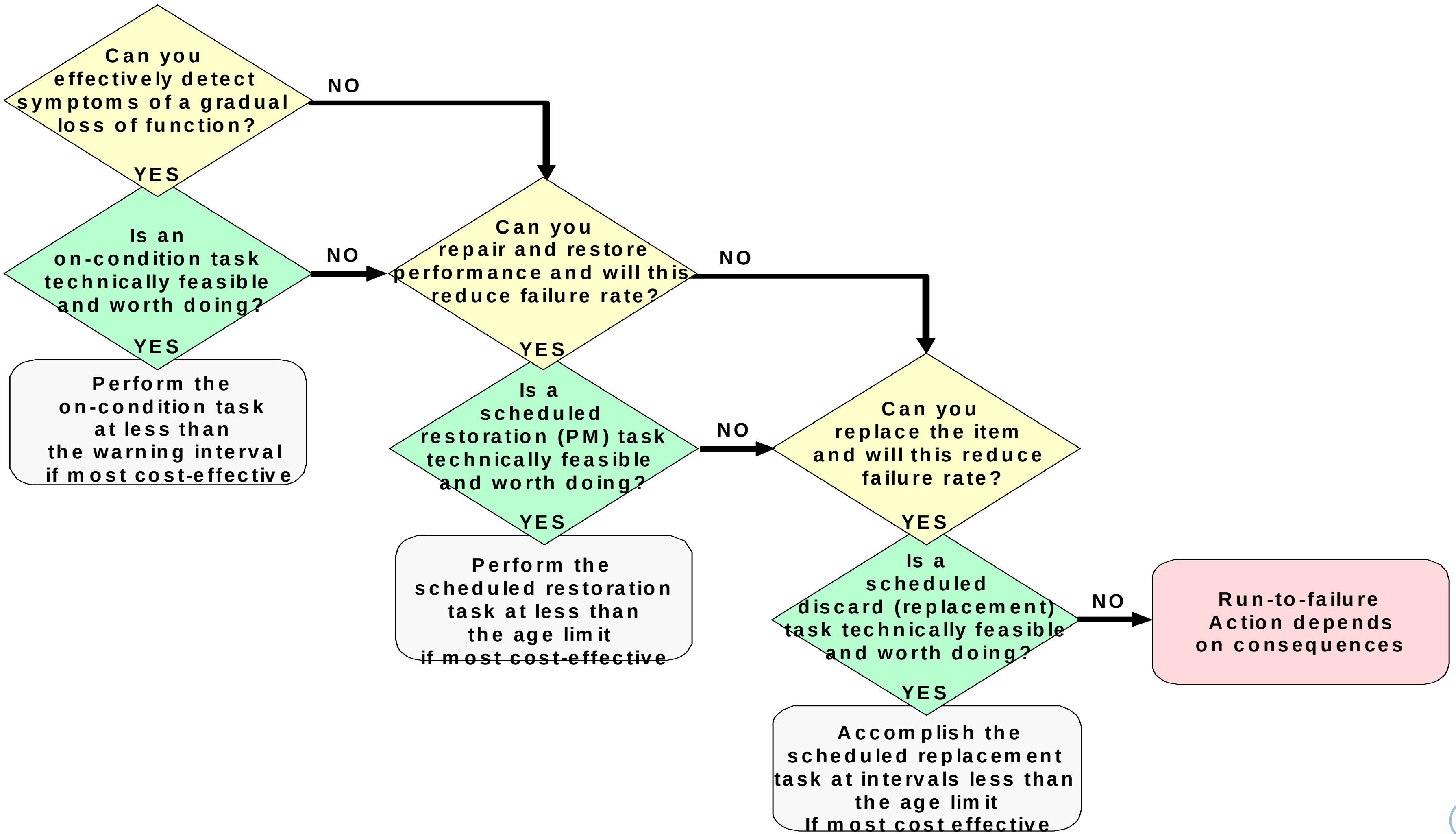
Elements for Success

- Cross-functional detailed equipment analyses
- Interaction with manufacturing or services systems Failure Modes, Effects and Criticality Analyses (FMECA's), if available – FMEA's if not
- Defined plans prepared (in advance of analysis) to implement recommendations
- Manpower and budgetary support for implementation
- Operator involvement with the project in as many ways as possible
- Periodic review of project progress and resulting benefits – Metrics to be discussed

RCM Task Selection



RCM Task Selection Logic



Task Applicability (i.e., It Works)

- **RCM has rules for “applicability” for each type of maintenance task - time directed, condition directed, and failure finding.**
- **Any task must be technically feasible - enabling a person to find, mitigate or prevent an actual failure or degrading condition leading to failure. For time-directed tasks to be applicable the interval between failures (by calendar or operating hours) must be known reasonably accurately.**

Condition Directed Task Applicability

- **The measured parameters must correlate to deterioration and related failure modes previously identified.**
- **The parameters must be measurable. be repeatable and sufficiently stable over time to serve as reliable triggers for corrective action.**
- **Measurements must be sufficiently consistent over every unit in a specific population to assure that a given measurement more or less represents equivalent condition and severity of a problem every time.**

Condition Directed Task Applicability

- There must be sufficient time between the discovery of a potential failure and the onset of actual functional failure to take appropriate corrective (condition-based) action.
- If condition-monitoring interval using periodic measurements is less than the minimum time between warning and functional failure for a critical (e.g., safety related failure mode), on-line, continuous monitoring may be the best solution

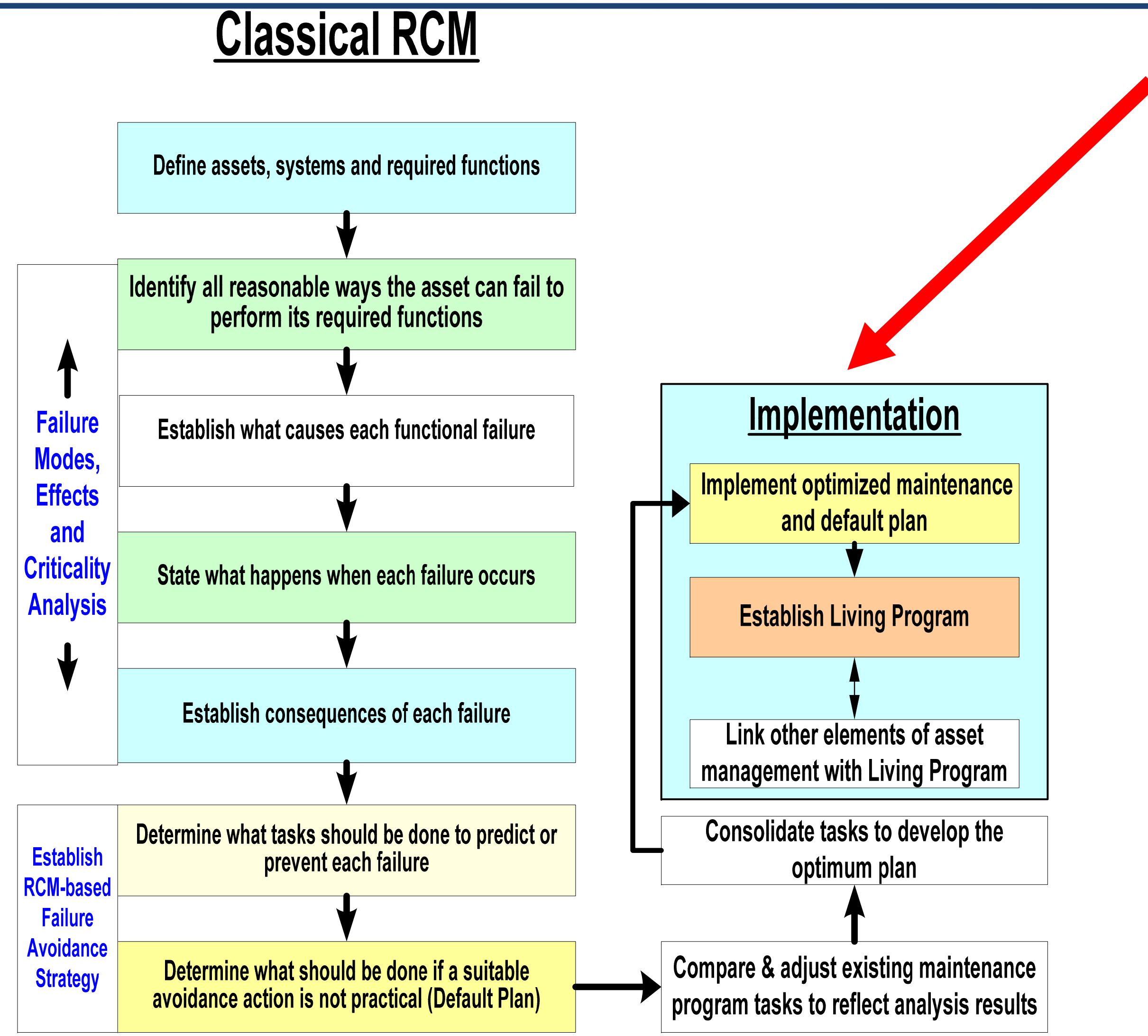
Task Effectiveness

- RCM's rules for "effectiveness" are based on the consequences of the failure that the task is intended to address:
  - For critical failures — the task must reduce the risk of failure to a tolerable level.
  - For all other failures — the task must be cost-effective (e.g., cost in lost production to find a hidden failure).
  - If mission or economics are involved — the investment required in executing the task (e.g., for capital and operating cost for a condition monitoring technology, including manhours, etc.,) should be less than the resources required to repair the failure after it has occurred.

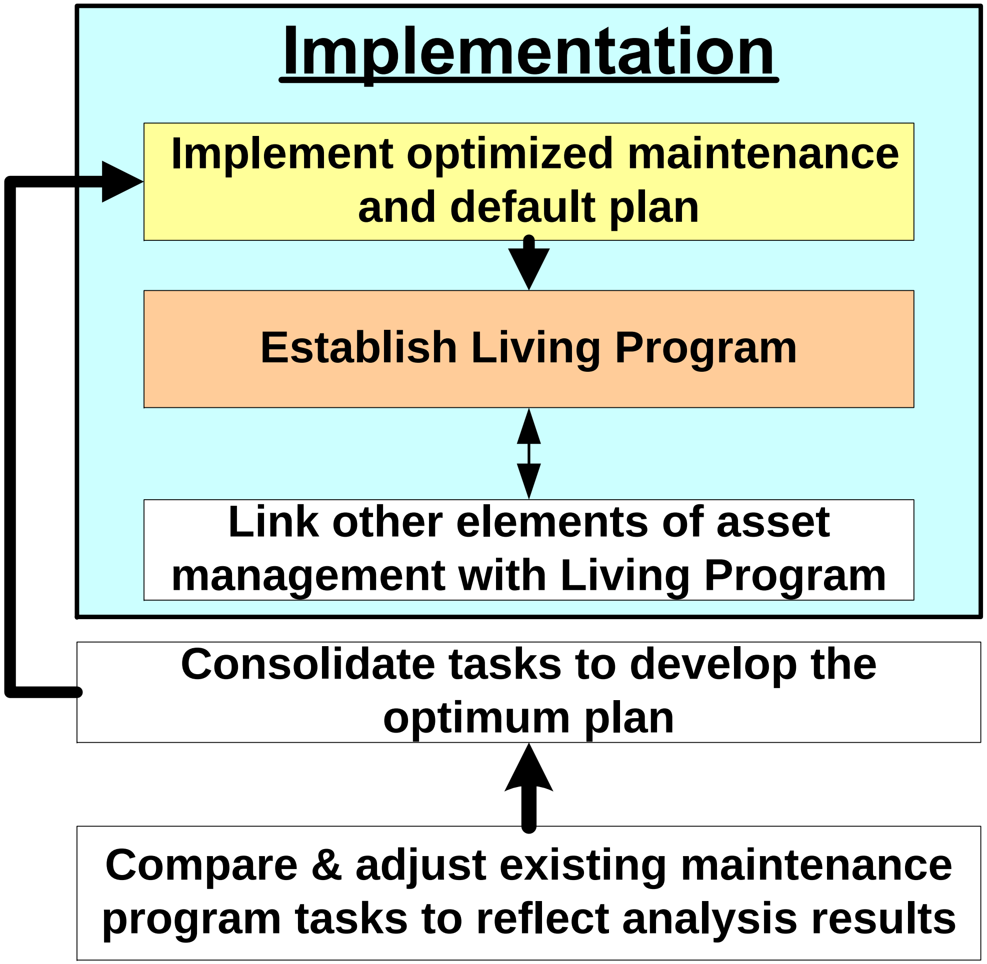
RCM Implementation

- **RCM Projects often fail because the results of analysis, while perfectly valid, are never implemented. There are many reasons for this including the two most important ones:**
  - **Support (budget, manpower, management interest) for implementation not provided or not provided soon enough to assure project continuity**
  - **No "buy-in" by personnel not involved with the RCM project analysis, but whose support is needed at time of implementation**

RCM Implementation



RCM Implementation



Streamlining RCM

- Streamlined RCM differs from Classical RCM in three principal areas:
  - The RCM process is preceded by a risk ranking
  - General templates are utilized
  - Analysis results are compared with existing maintenance tasks to arrive at an optimum strategy.
  - Existing maintenance tasks that do not clearly address a failure mode are abandoned if no other rationale for their application can be established.
    - Run-to-Failure becomes the strategy of choice

Streamlining RCM

- First used on nuclear submarines in late1970’s
- Applied to fossil powered generating plants in 1990’s using data from nuclear powered generating plants
- Applying the principles of risk management as early as possible in the conversion to an RCM-based program significantly reduced the time and resources necessary to gain real benefits.

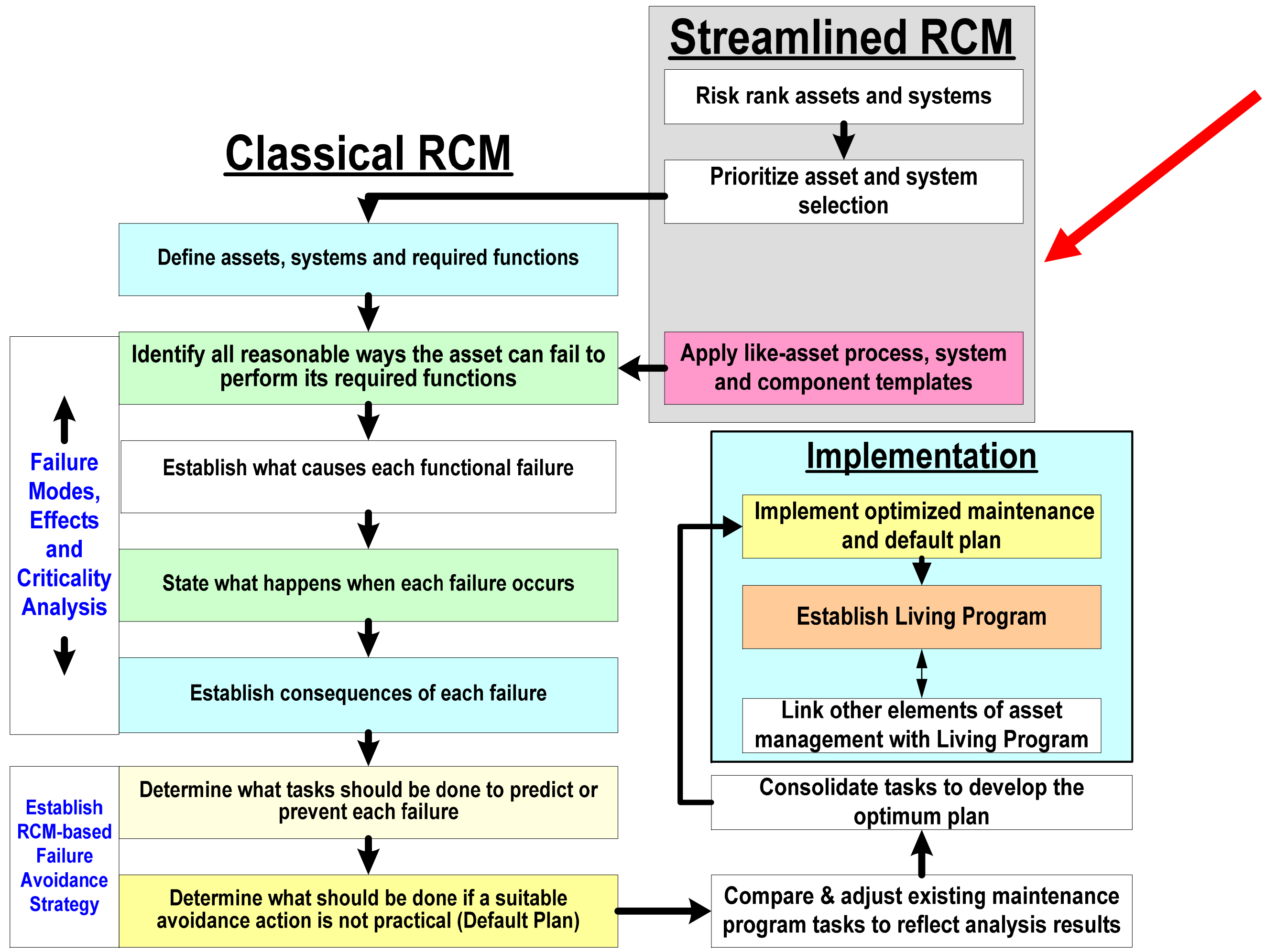
Streamlining RCM – Rationale

- Concentration on mitigating only a few highest probability failure modes in systems brought significant increases in projected and actual overall reliability and availability of subsystems.
- Maintenance costs were reduced.
- It was not cost effective to try to identify, or even possible to try to mitigate, all potential failure modes even in systems vital to mission – especially if redundancy provided

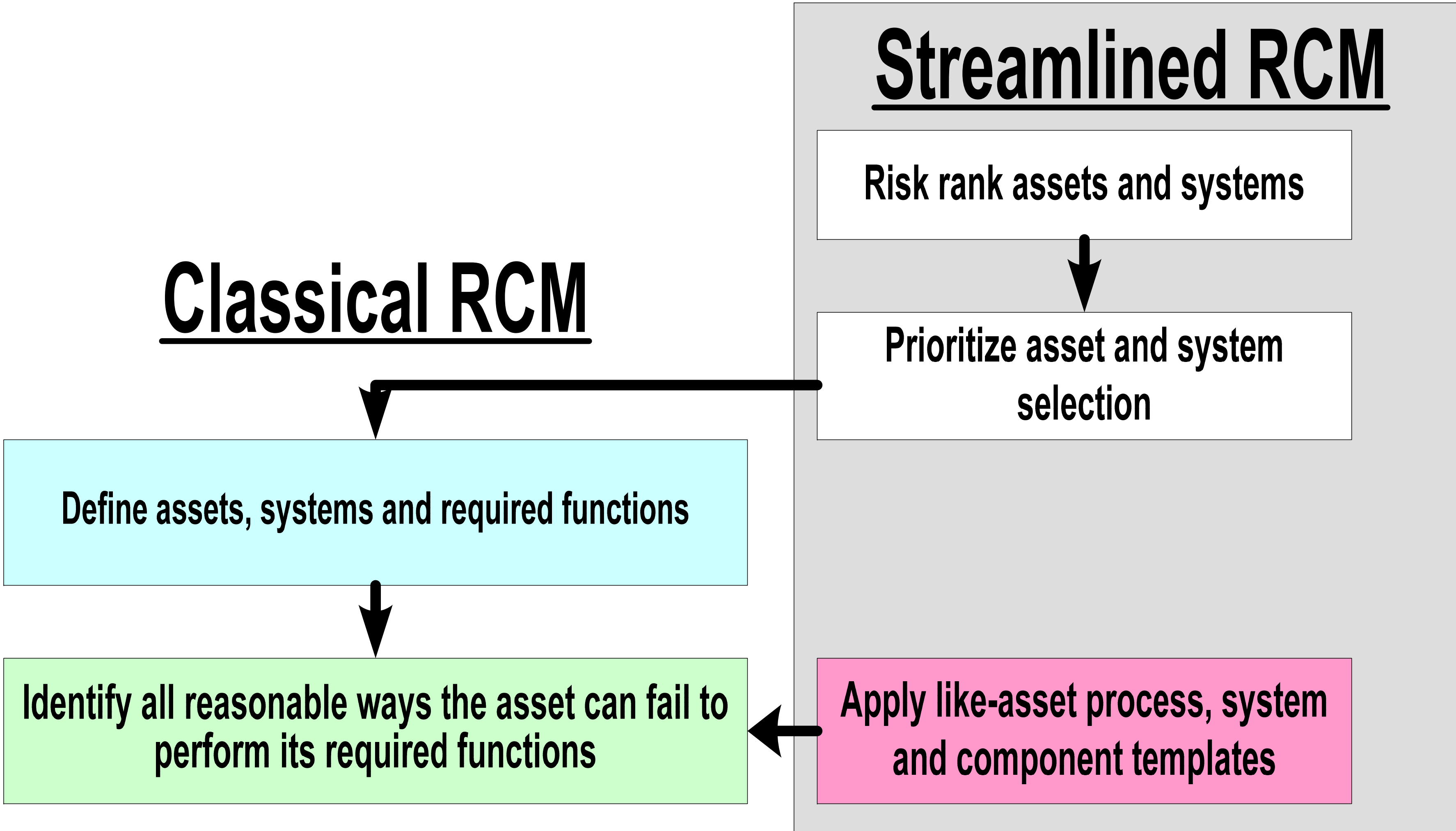
Streamlining RCM – Rationale

- There was extensive overlap in applicable functions, failures, and failure modes for similar pieces of equipment, even in different applications.
- The analysis phase of conversion to RCM is only a small part of the total effort required, particularly in a culture that is resistant to change.
- Even the most thorough RCM analysis often did not identify all potential failure modes.
    - Living Program needed for continuous improvement

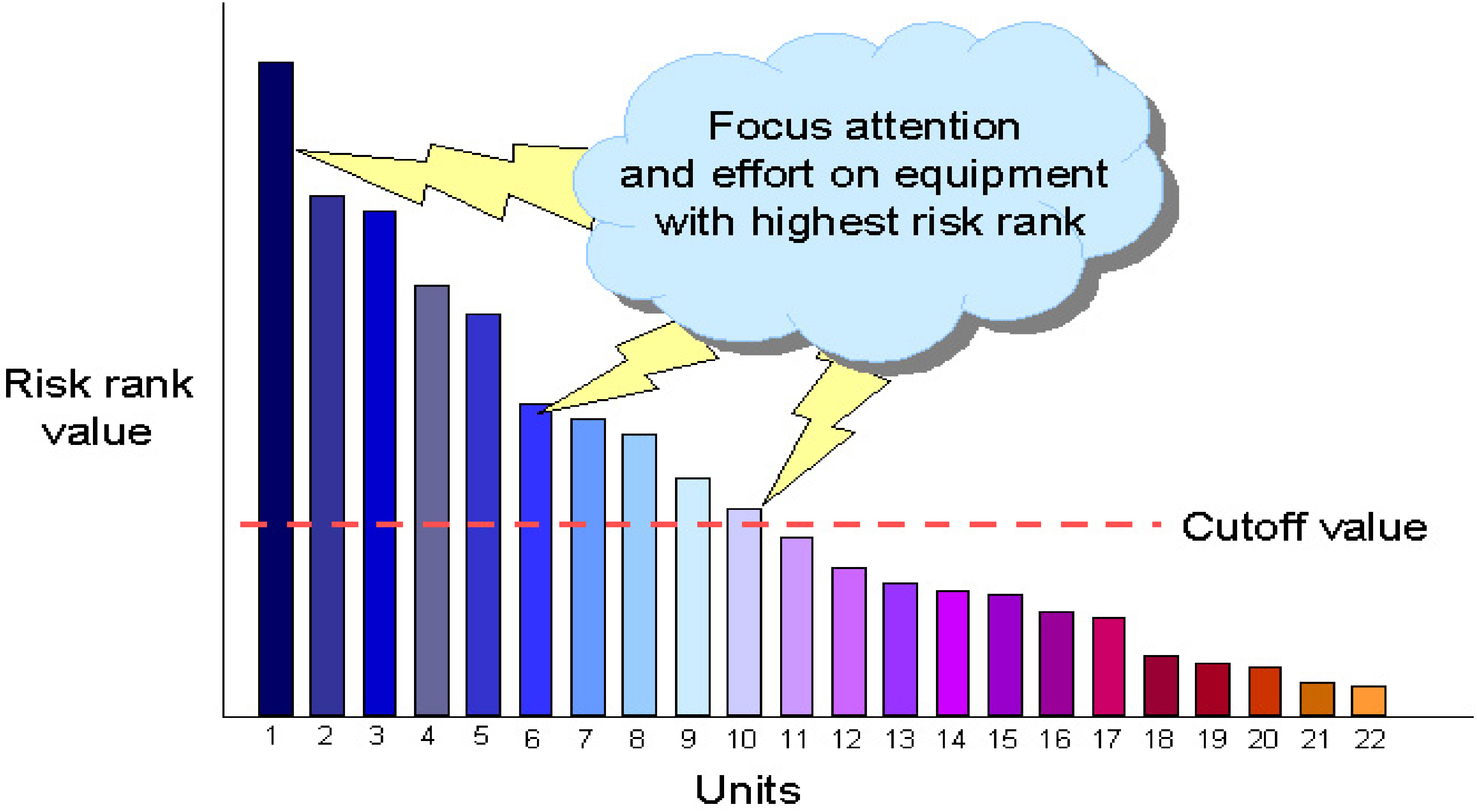
Streamlining RCM



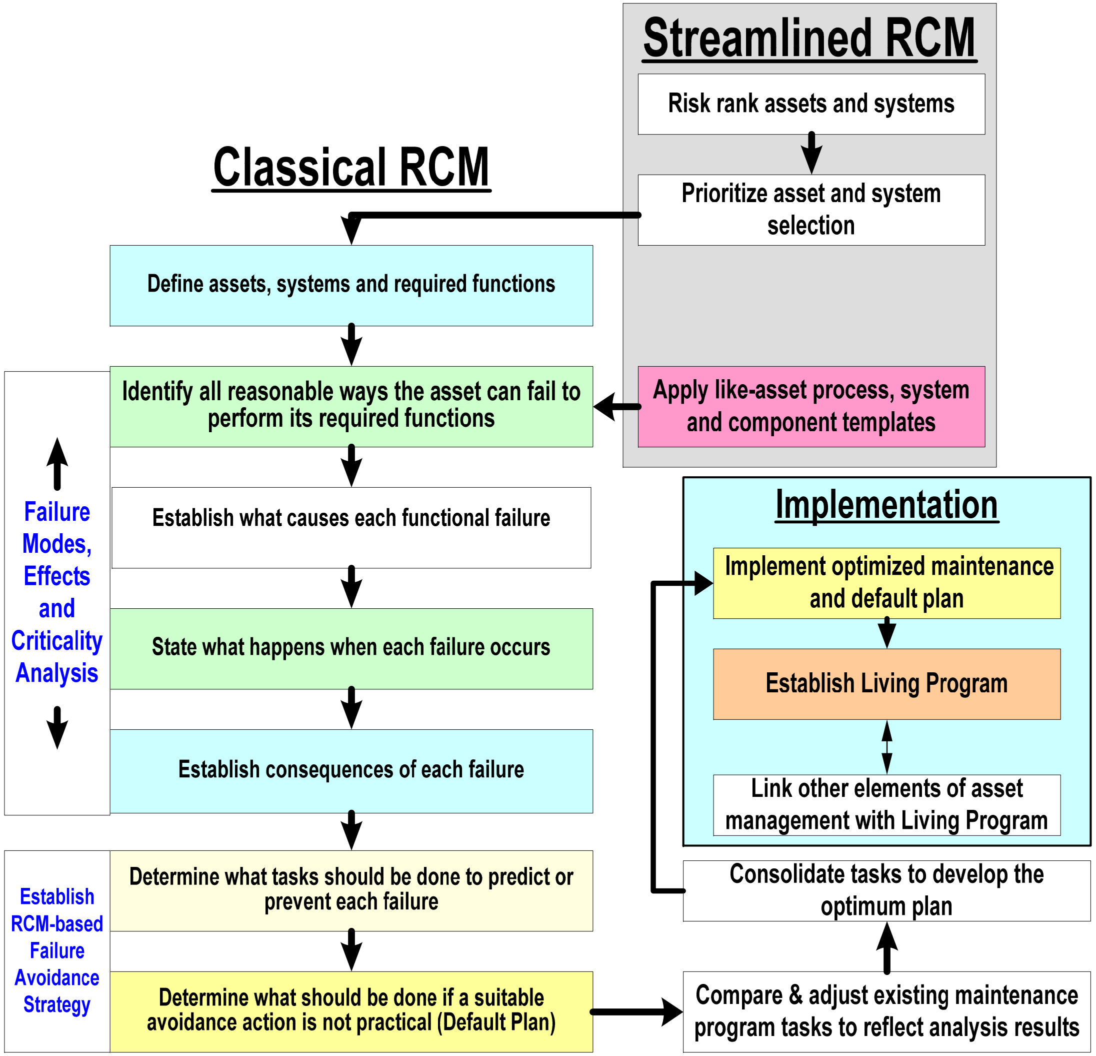
Streamlining RCM



Risk Ranking Systems for RCM Application



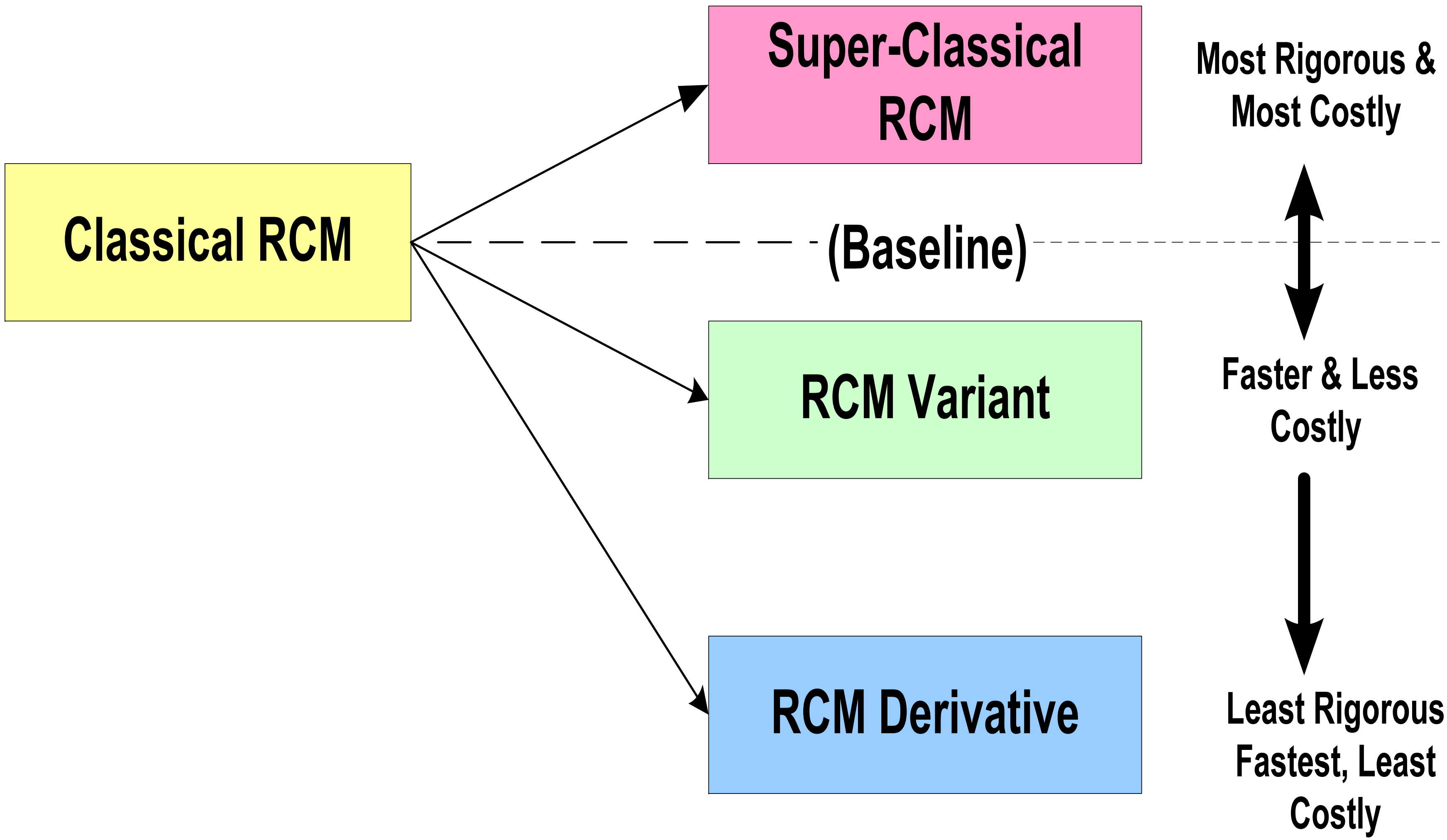
Streamlining RCM



Streamlining RCM with Templates

- **Templates or maintenance standards for specified components (motors, pumps, circuit breakers, transformers of specific design, manufacturer, application, capacity, etc.,) list:**
  - **Typical operating conditions**
  - **Common functions**
  - **Typical functional failures**
  - **Alternative functional failure mitigation strategies, tasks and other items (e.g., redesign, changed operating procedures, etc) resulting from previous RCM analyses**

RCM Evolution



RCM Variants and Derivatives

- Super-Classical RCM – a methodology that is more rigorous than the Classical RCM methodology described in the United Airlines report to DOD in 1978 specified by SAE RCM standard JA1011 (Year 2000)
- RCM Variant – An RCM methodology that skips or combines steps found in Classical RCM or incorporates substitutes for or supplements to Failure Mode and Effects Analysis in order to reduce the time and resources needed for a project
- RCM Derivative – an analysis methodology that produces a non-redundant, RCM-like set of tasks (Time Directed Intrusive and Non-intrusive, Condition Directed and, Failure Finding) derived from what is already in the Preventive Maintenance and/o, Predictive Maintenance (PdM) Program or within the capability of PdM technologies used.

Which RCM Approach to Use?

- **More rigorous RCM approaches provide best value for the most critical systems, processes or components of an asset – probably not more than 20% of the total.**
- **A variety of approaches (e.g., Super-classical, Variant and/or Derivative) should be considered for employment when one of the goals is to convert to an RCM basis for assets of a facility or vehicle.**

RCM Project Manager's Guide (RCM PMG) a.k.a. The RCM Scorecard

- Provides RCM users, participants & other interested parties with a "shopping list" from which metrics may be selected to help determine:
  - Whether or not to do RCM on a given system
  - Progress during analysis & implementation and to demonstrate how successful a given RCM Project is while it is in progress & during the period afterwards when benefits are realized
  - How successful project was in adjusting a maintenance program for a system after completion.

RCM PMG & Scorecard Uses

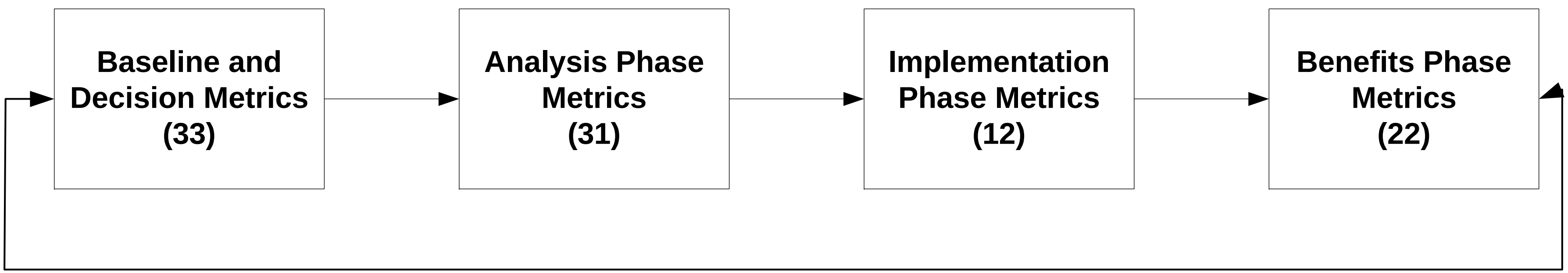
- Provide managers, supervisors or "champions" with a tool to measure:
  - RCM project progress on a given asset or set of assets during analysis and implementation phases of an RCM Project
  - Benefits derived from the RCM Project during and after it is complete
- Provides anyone with a basis for comparison of differing approaches to RCM methodology

RCM PMG Uses

- **Provides prospective RCM Project Managers with guidance on:**
  - **Readiness factors and steps to take when considering and executing an RCM effort**
  - **Factors that characterize successful efforts**
  - **Pitfalls to avoid when executing an RCM project**

RCM PMG & Scorecard Metrics

RCM Scorecard Metrics Relationships



Benefits Phase Compares "Before" and "After" Metrics

- **Provides a "menu" from which a selection of metrics, measures or Key Performance Indicators (KPI's) may be selected for evaluation at various periods before and during an RCM Project.**

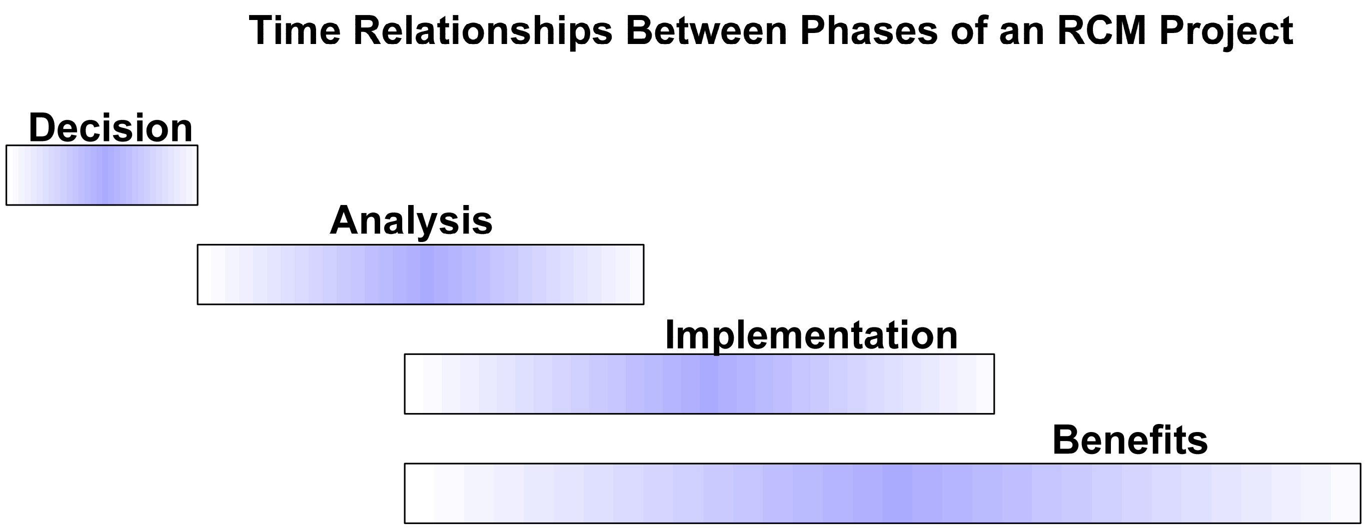
RCM Project Manager's Guide (RCM PMG) a.k.a. The RCM Scorecard

- **Developed in a series of events and actions between 2003 and 2007**
- **Contributed to by over 100 persons including some of the world's leading experts on RCM**
  - **From many different venues (government, manufacturing, services industry, consulting, etc.,)**
  - **From 16 different countries**
  - **Split into 4 working groups and then reconvened as a whole**
  - **Addressed every metric including definitions**
  - **Achieved consensus on how to be successful regardless of approach to RCM**
- **Result: Consensus achieved!**

RCM Project Manager's Guide (RCM PMG) a.k.a. The RCM Scorecard

- **Is completely neutral regarding approaches to RCM Methodology**
  - **Doesn't mention or recommend any proprietary or generic approach**
  - **Reliance on metrics makes each approach to RCM stand on its own in terms of cost vs. return gained from an improved, more directed maintenance program**
- **Made available for free download from Reliabilityweb.com**

Time Relationships Between Phases of an RCM Project



- **Phases of an RCM project (after the Decision Phase) should over lap for continuity within a project.**
- **One of the main reasons for RCM project failure is failure to plan for and begin implementing results of analysis – even before analysis is complete.**

RCM Applied to AGV at Copper Smelter

- Automated Guided Vehicles (AGV's) were used to move 44,000 pounds of copper anodes and blanks from anode preparation area to the tank house and back to the cathode stripping machines in a continuous loop.
- 2003 - AGV's had become the process bottleneck

RCM Applied to AGV's at Smelter

Source: Bill Keeter, CMRP, GPAllied, Inc.

- There were eight AGV's in the smelter, with six in use at any one time
- Within just a few months after implementation of an RCM-based program AGV downtime was reduced by 56%.
- As a result of the effort maintenance tasks were changed significantly, and the preventive maintenance interval for the AGV's was increased from two months to six months.
- AGV's were no longer the process bottleneck, and their performance was steady.

RCM Applied to Materials Handling at Eastman Kodak

Source: Doug Plucknette CMRP, Allied Reliability Inc.

- **Eastman Kodak performed RCM analysis on a materials handling system that started with inlet conveyors and included the case readers, sorters, holding conveyors, palletizers and wrappers.**
- **Following the analysis, implementation occurred over a period of 4 months**
- **Prior to the RCM the Overall Equipment Effectiveness (OEE = Availability X Quality Rate X Performance Efficiency) of this equipment was 78%,**
- **OEE increased to peak at 92% and with a sustained yearly average of 89%.**

RCM in a Hot Rolling Mill

- **In 1993, deciding to persevere in the face of aggressive overseas price competition in steel products, Dofasco Inc. of Hamilton Ontario started many initiatives including RCM application to its Hot Rolling Mill**
- **Systems included materials handling cranes, conveyors, advancing beam reheat furnaces and coilers**
- **By 2005 Mill throughput had increased from 60 to 125% of nominal design capacity**
  - **Wall Street Journal declared Dofasco the most profitable fully integrated steel producer in the world**
  - **2006 saw fierce international bidding war for Dofasco ultimately won by Mittel of India**

Key Takeaways

- RCM is very effective in determining what maintenance to perform to assure achievement of maximum design reliability at minimum cost
  - Overcomes past misconceptions concerning failure profiles
  - Nothing better for almost 50 years
- Getting better as Predictive Technologies and analysis methods evolve and streamlining templates are improved
- A variety of approaches (e.g., Super-classical, Variant and/or Derivative) should be considered for employment

Key Takeaways

- **Download (free) RCM Program Manager's Guide for metrics and guidance to help in deciding upon and execution of a project**
  - **www.Reliabilityweb.com**
- **A little RCM is better than no RCM**

Acknowledgements

- **Many of the images and content was taken from Mr. Nicholas' contributions to:**
  - **The Physical Asset Management Handbook 4th Edition - Clarion Technical Publishers**
  - **Advancing Reliability & Maintenance 3rd Edition - Reliabilityweb.com - Publisher**
- **Contributions from connections through the "Link-in" networking site during early July 2009 helped identify successful applications of RCM to Materials Handling Systems**

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Questions?