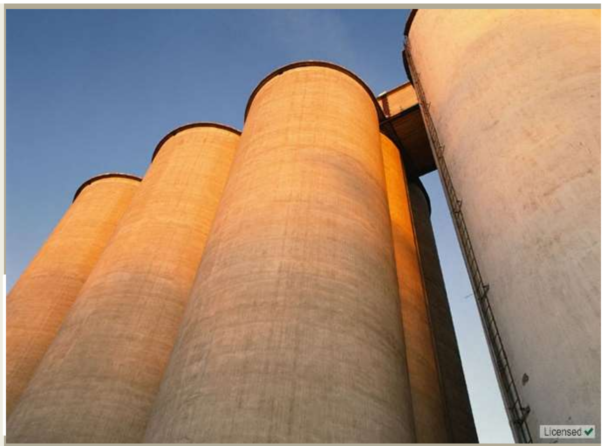
THE RELIABILITY ENGINEER'S ROLE IN THE STO

Managing and Reducing Risk in the Shutdown, Turnaround or Outage



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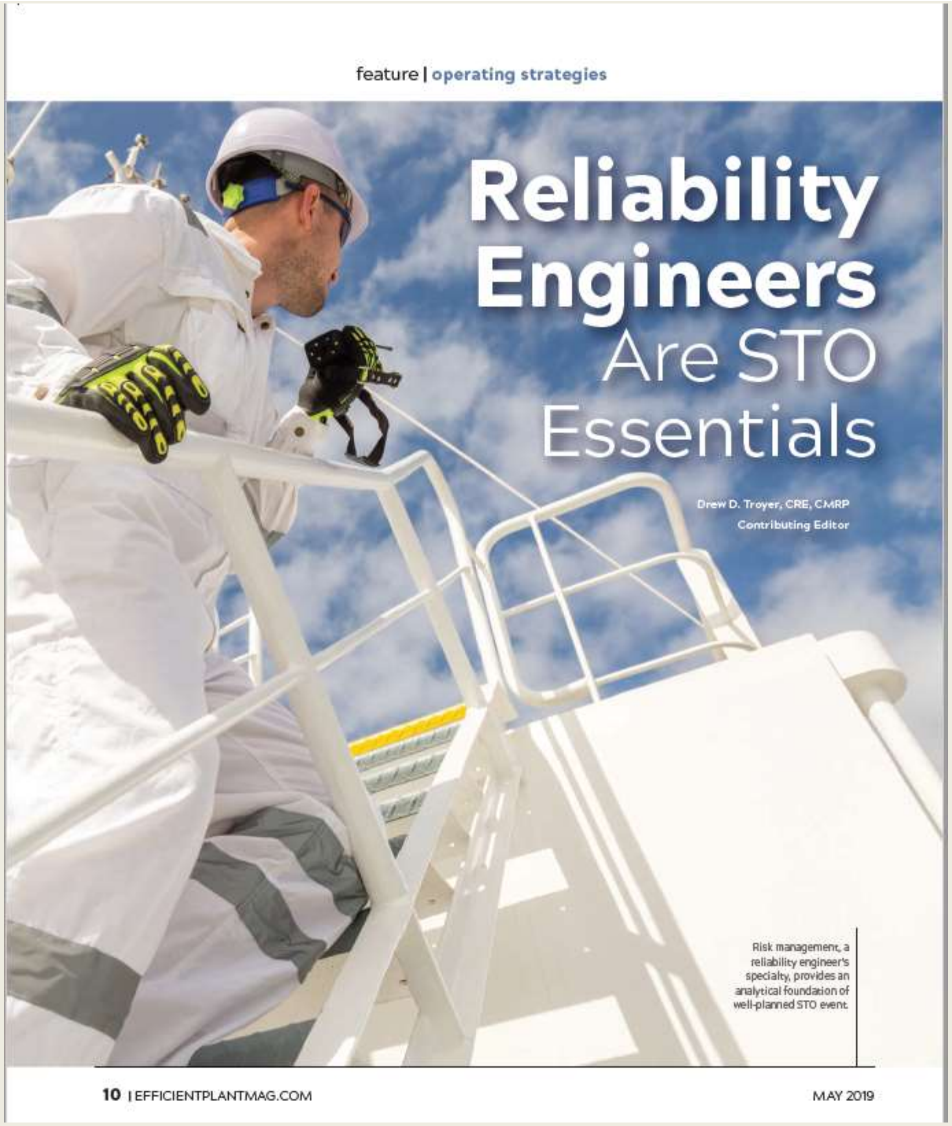
AGENDA

1. **Reliability engineers are your risk analysts – use them to de-risk your STO**
2. **Proactively reducing jobs demanded**
3. **End to end risk management with pre-STO PFMEA and post-STO RCA – a closed loop**
4. **Risk-based Job Priority Analysis (JPA)**
5. **Reducing "discovery" work in the STO**


feature | operating strategies

Reliability Engineers Are STO Essentials

Drew D. Troyer, CRE, CMRP
Contributing Editor

Risk management, a reliability engineer's specialty, provides an analytical foundation of well-planned STO event.

10 | EFFICIENTPLANTMAG.COM MAY 2019

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Subscribe (free) at:

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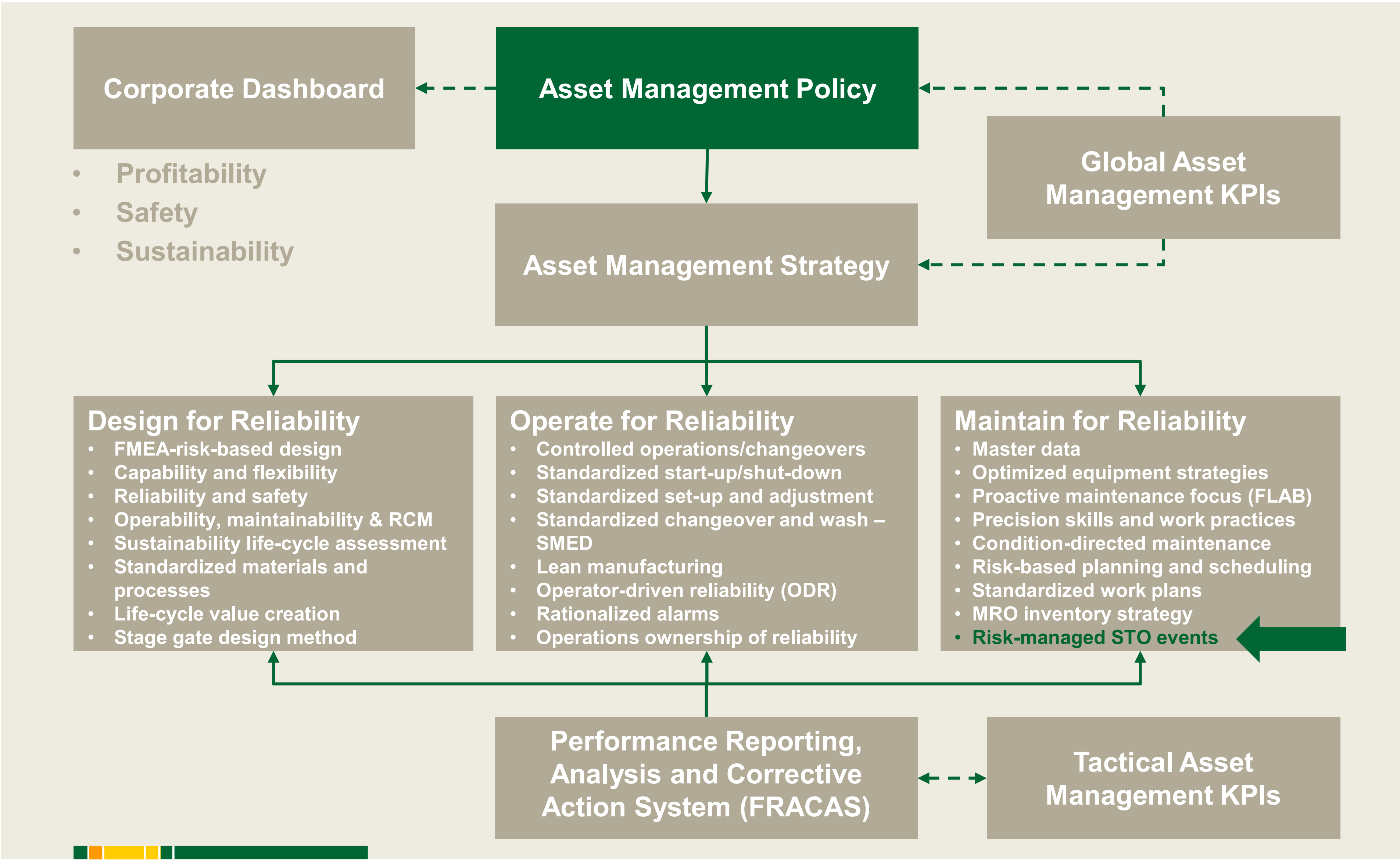
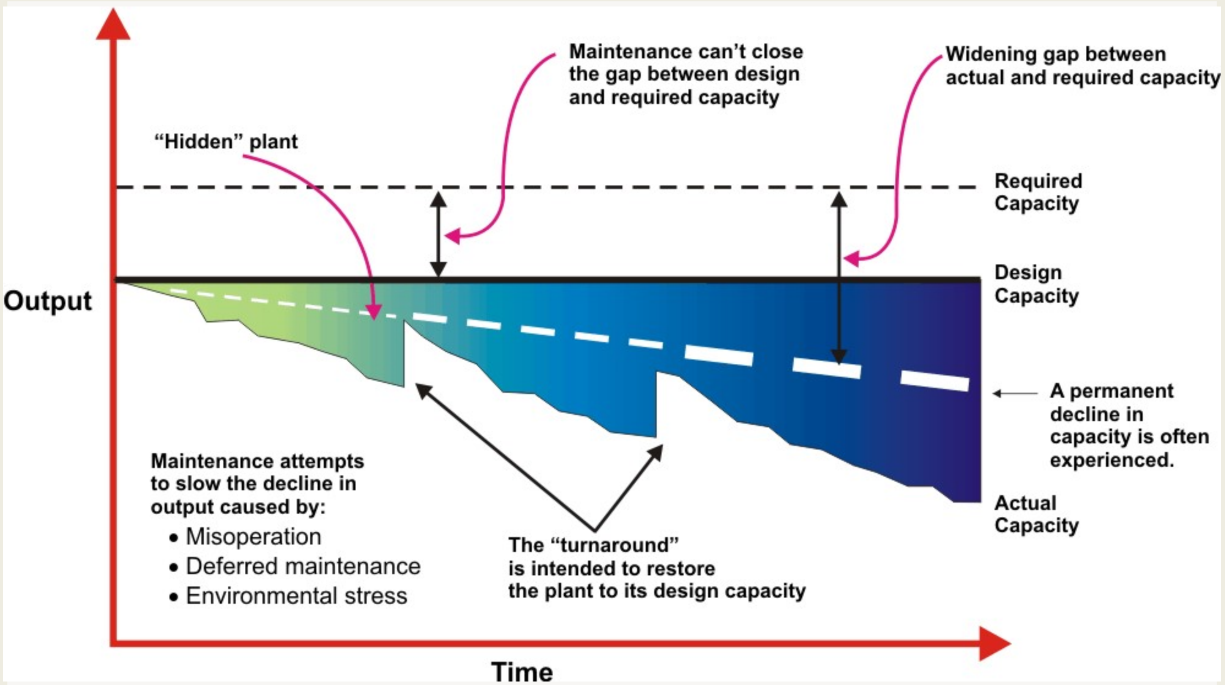
Also look for my monthly column called "*Seeking Reliability.*" Find it on the inside back cover of Efficient Plant Magazine.

THE RE ROLE IN THE STO



The Anatomy of the STO

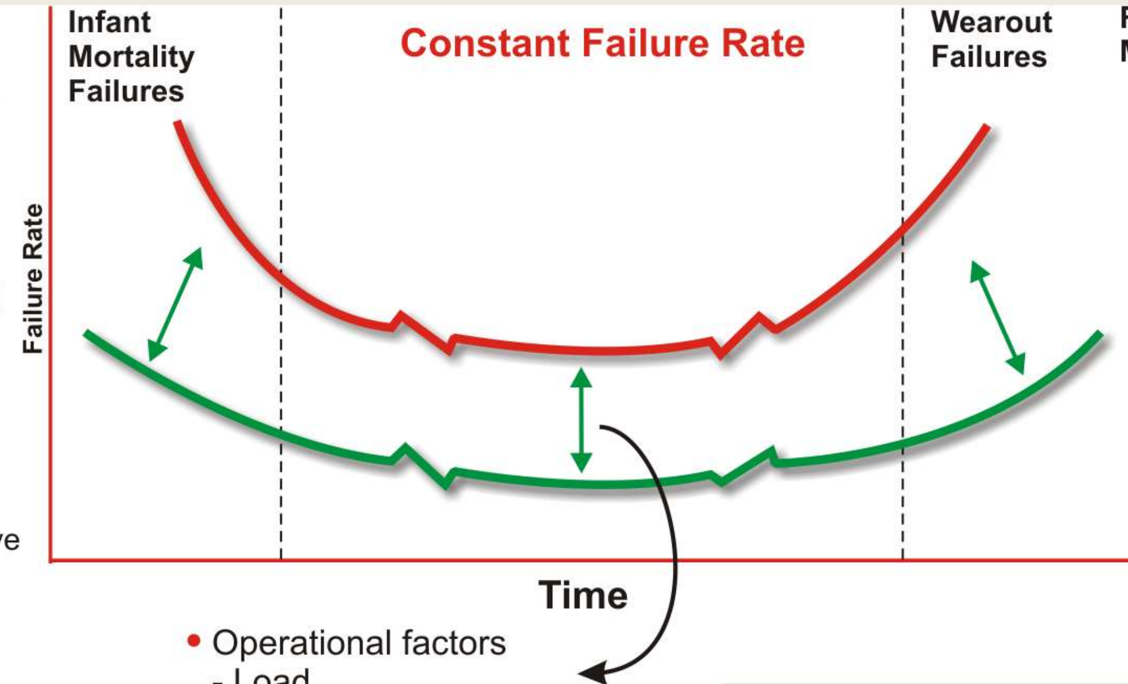
The STO Cycle	RE Role
	Decrease the rate at which capacity declines Increase the Interval between STO events Increase the extent to which capacity is restored Decrease the STO, scope duration and cost Maximize STO quality and minimize STO rework – minimize the permanent decline

Ref: D. Troyer (2006) Sigma Reliability

RELIABILITY ENGINEERING BASICS

KEEP YOUR BATHTUB CLEAN

Reduce by Eliminating:
- Design defects
- Manufacturing defects
- Assembly, installation and commissioning defects.
- Operating defects
- Reduce invasive maintenance actions

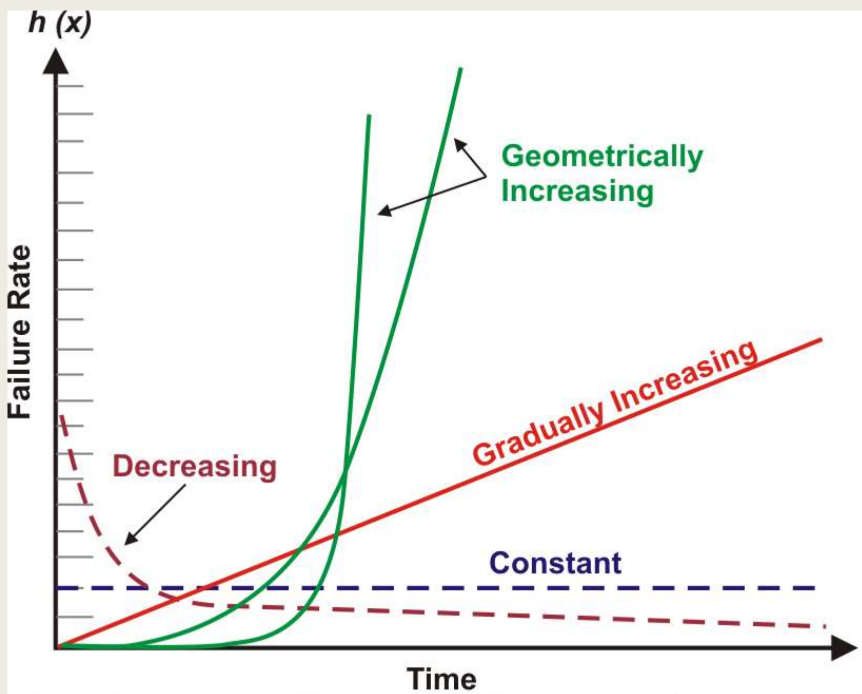


Reduce by Managing:
- Overload conditions
- Material deterioration
- Fastener looseness
- Equipment/ system design

Reduce rate and extend service life by controlling:
- Operational factors
  - Load
  - Speed
- Environmental factors
  - Lubrication
  - Contamination
  - Vibration
  - Heat
  - Etc.

Bathtub Curve:
An equipment failure-rate with an initial sharply declining failure rate, followed by a prolonged constant-average failure rate, after which the failure rate again increases sharply.

Ref: DT, E.C.Fitch



Depending upon machine type, the failure rate may decrease, remain constant, gradually increase or geometrically increase as a function of time

Reciprocal Relationship for Exponential Distribution

Failure Rate:

$$\lambda = r / T$$

Mean Time Between/ To Failure:

$$\theta = T / r$$

Where:

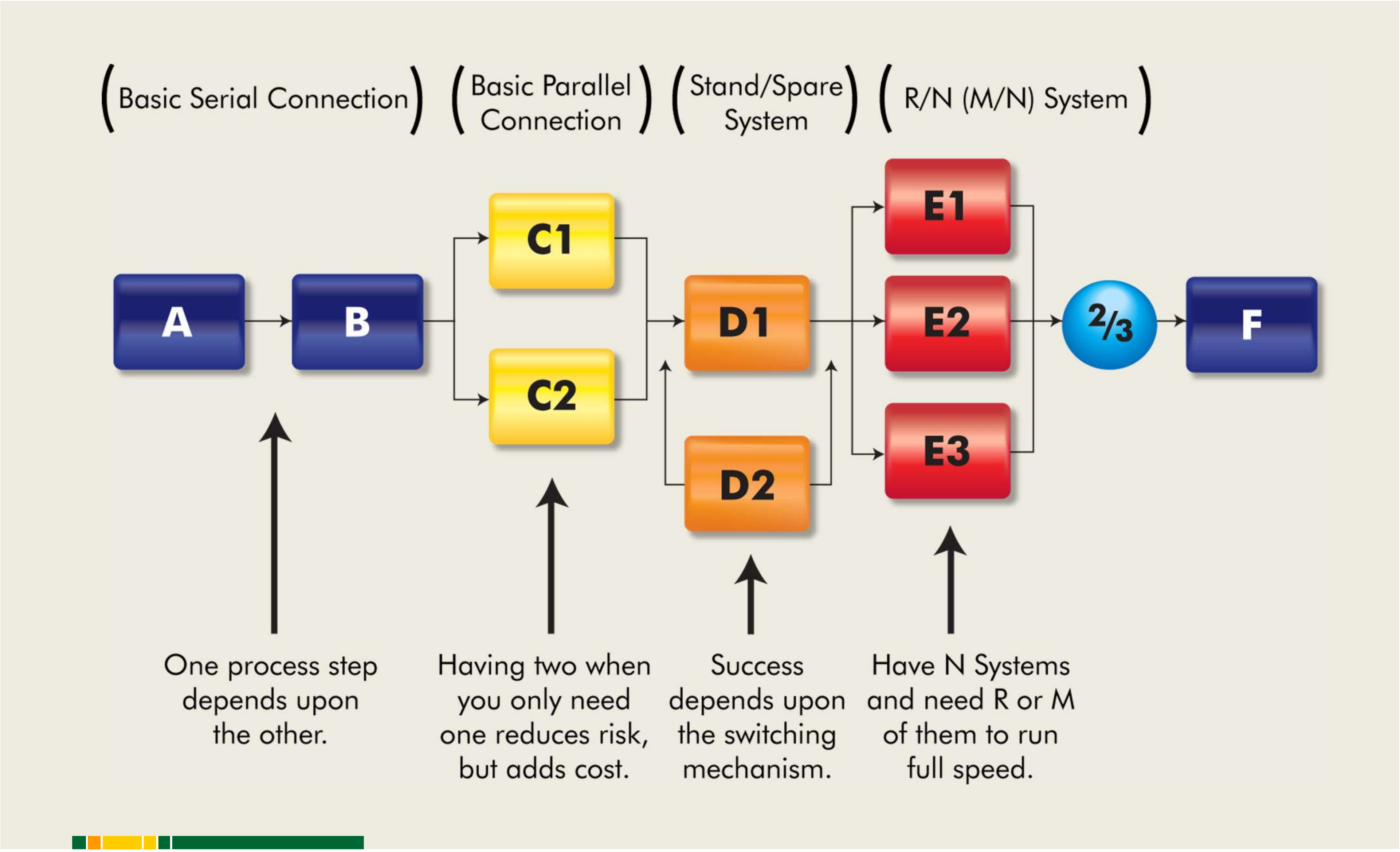
- λ = Failure Rate
- θ = Mean time between (Repairable/to (Unrepairable) Failure - MTBF/MTTF
- T = Total running time/ Cycles/miles/etc. For both failed and unfailed items
- r = The total number of failures

Example:

If five electric motors are run for a collective period of fifty years with five functional failures, the failure rate (λ) is 0.10 failures per year and the MTBF (θ) is 10 years

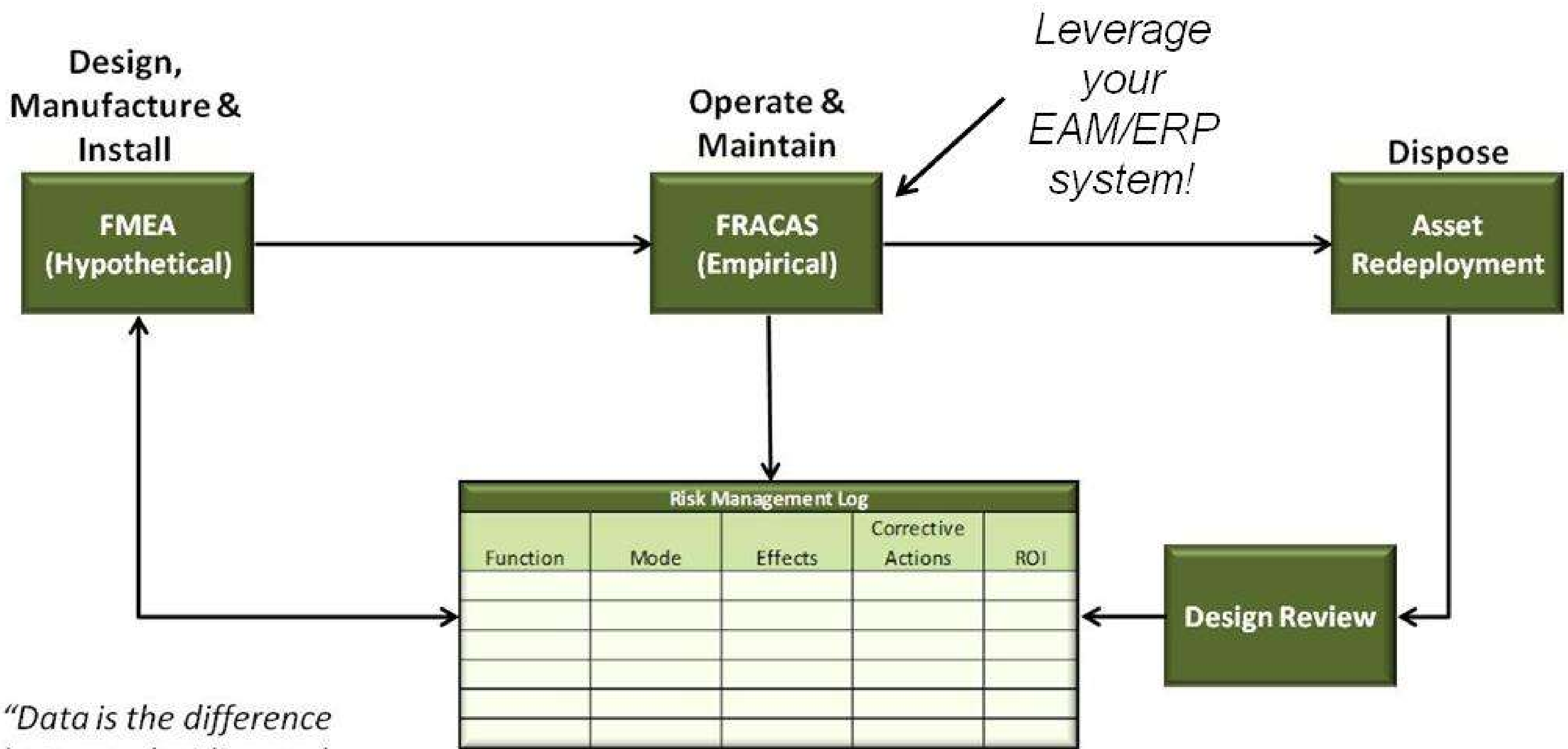
 Ref: Dovich, DT

RELIABILITY BLOCK DIAGRAMS



Ref: DT 4198

RISK MANAGEMENT OVER THE MANUFACTURING LIFE CYCLE



"Data is the difference between deciding and guessing!"™

Drew D. Troyer, CRE

Ref: DT

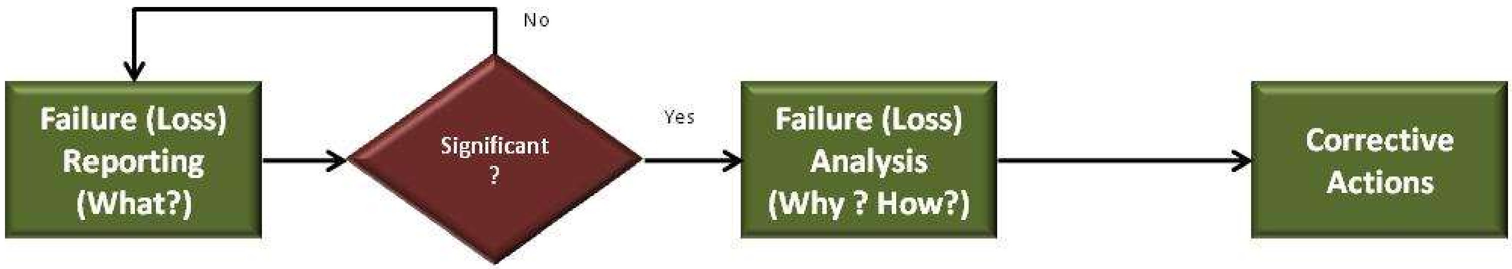
START WITH GENERIC FAILURE MODES AND CUSTOMIZE AS REQUIRED – IEC 60812

1	Structural failure (rupture)
2	Physical binding or jamming
3	Vibration
4	Fails to remain (in position)
5	Fails to open
6	Fails to close
7	Fails open
8	Fails closed
9	Internal leakage
10	External leakage
11	Fails out of tolerance (high)
12	Fails out of tolerance (low)
13	Inadvertent operation
14	Intermittent operation
15	Erratic operation
16	Erroneous indication
17	Restricted flow

18	False actuation
19	Fails to stop
20	Fails to start
21	Fails to switch
22	Premature operation
23	Delayed operation
24	Erroneous input (increased)
25	Erroneous input (decreased)
26	Erroneous output (increased)
27	Erroneous output (decreased)
28	Loss of input
29	Loss of output
30	Shorted (electrical)
31	Open (electrical)
32	Leakage (electrical)
33	Other unique failure conditions as applicable to the system characteristics, requirements and operational constraints.

Ref: IEC standard 812

FRACAS – AN OVERVIEW



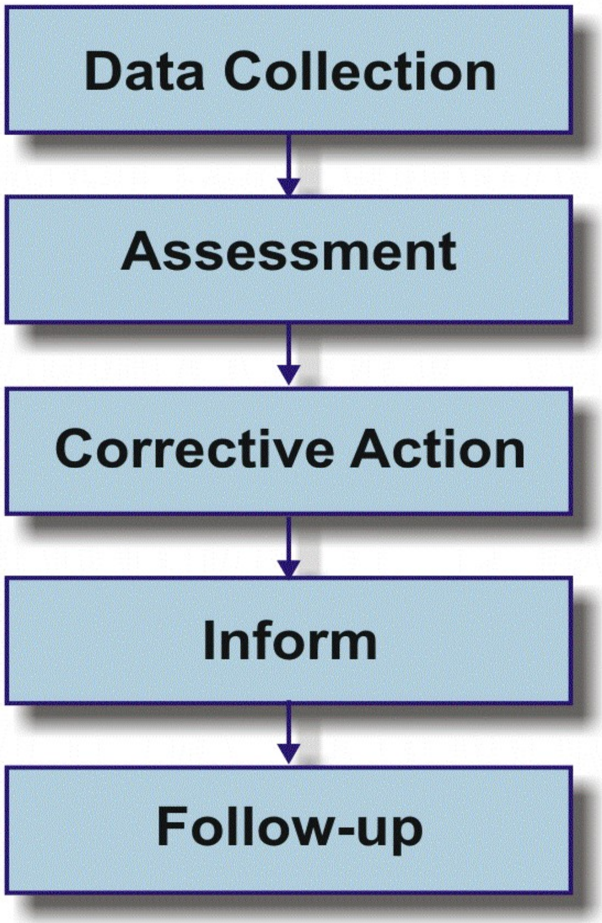
- Failure (Loss) Mode from Standard Taxonomy
- Effects
  - Annualized costs
  - HS&E Impact

- Apparent/Root Cause Analysis (ACA/RCA)
- Standard Taxonomy of Failure Causes
- Description of Mechanism(s)

- Hardware
- Software
- Peopleware
  - Procedures
  - Training
  - Enforcement
- Risk Mitigation
  - Redundancy
  - Critical Spares
  - Inventory Buffer

Ref: DT

THE FIVE PHASES OF RCA PER DOE-NE-1004-92



DOE-NE-1004-92 provides a clear and easy-to-follow and implement five step methodology for performing root cause analysis (RCA).

The standard is a free document developed by the United States Department of Energy, it is public domain information.

It can be obtained for free as a PDF download. To find it, simply search using the standard name and number.

Ref: DOE-NE-1004-92

FAILURE ROOT CAUSE CODING CATEGORIES

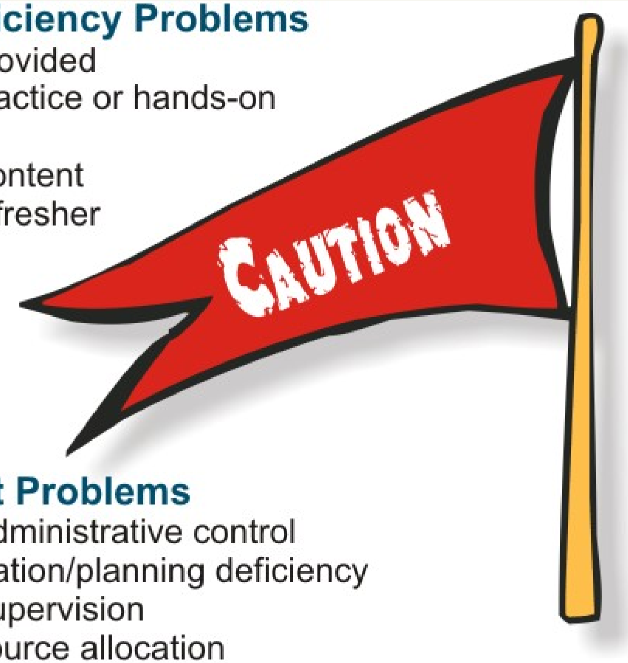
Equipment / Material Problems
- Defective or failed part
- Defective or failed material
- Defective weld, braze or soldered joint
- Manufacturer shipping error
- Electrical or instrument noise
- Contamination

Procedure Problems
- Defective or inadequate procedure
- Lack of procedure

Personnel Problems
- Inadequate work environment
- Inattention to detail
- Violation of requirement or procedure
- Verbal communication problem
- Other human error

Design Problems
- Inadequate man-machine interface
- Inadequate or defective design
- Equipment material selection error
- Drawing, specification or date errors

Training Deficiency Problems
- No training provided
- Insufficient practice or hands-on experience
- Inadequate content
- Insufficient refresher training
- Inadequate presentation of materials



Management Problems
- Inadequate administrative control
- Work organization/planning deficiency
- Inadequate supervision
- Improper resource allocation
- Policy not adequately defined, disseminated or enforced
- Other

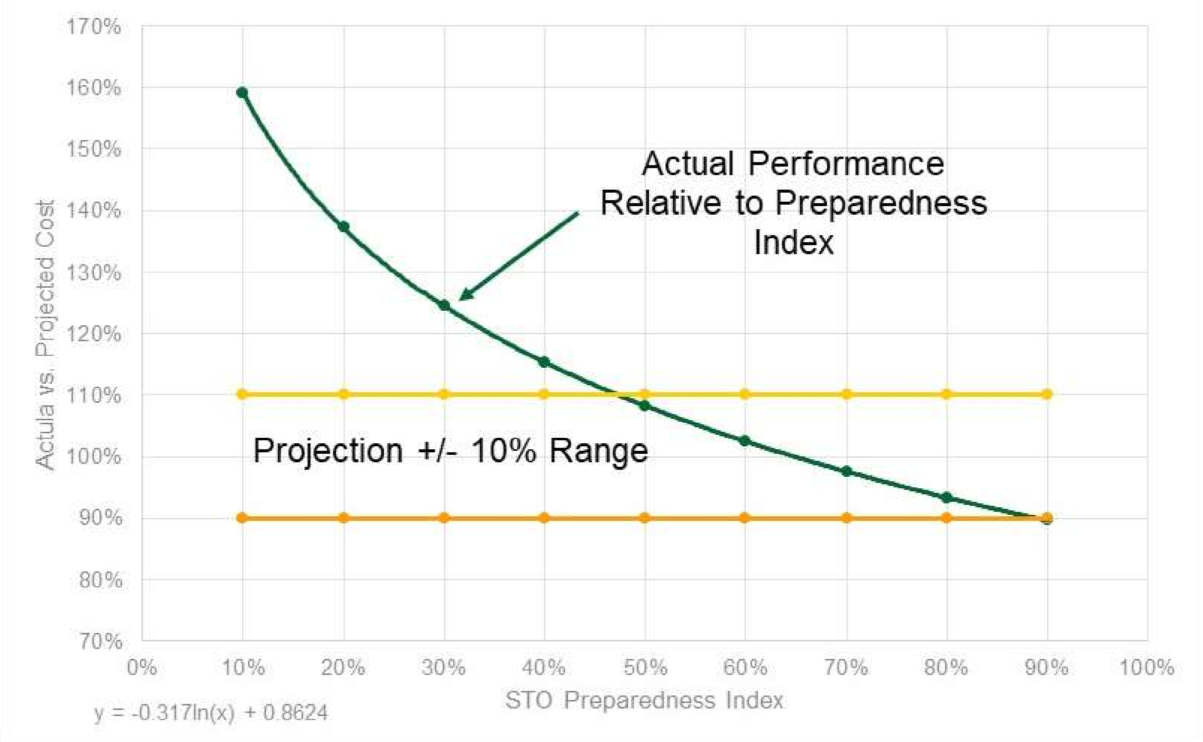
External Phenomena
- Weather or Ambient Condition
- Power Failure or Transient
- External Fire or Explosion
- Theft, Tampering, Sabotage, Vandalism

Ref: DT, DOE-NE-1004-92

THE RELIABILITY ENGINEER'S ROLE

The average STO event runs about 20% over budget. The worst run as much as 60% over. The best come in on or under budget.

STO Preparedness Is Key to Cost and Schedule Control



Ref: G. Lawrence (2012) Oil & Gas Journal

RE Drivers

Poor control over the forcing functions that lead to failure

Poor understanding of the actual condition of the plant

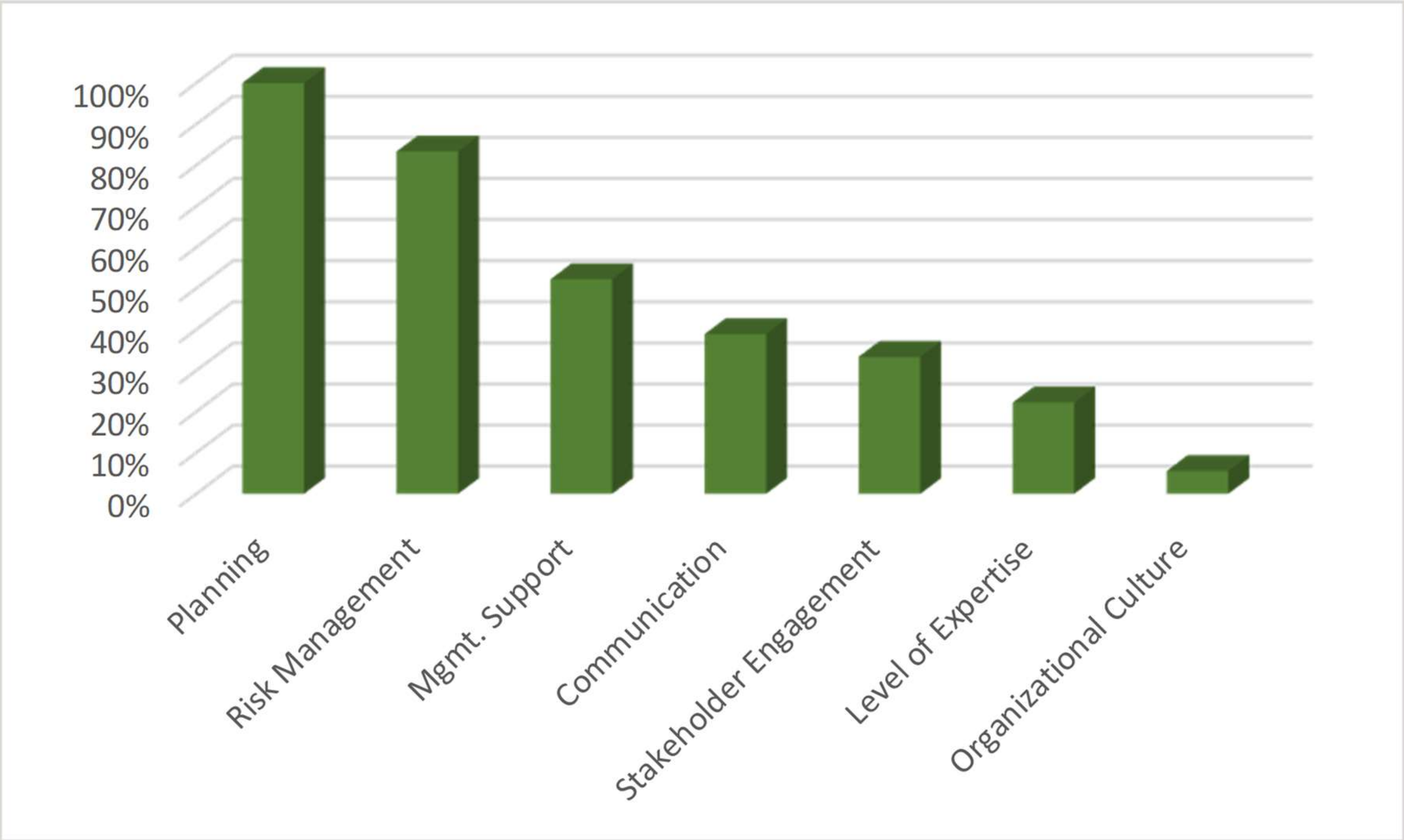
Failure to create a comprehensive risk management plan

Poor job of prioritization and scope management.

Poor anticipation of emergent and contingency work

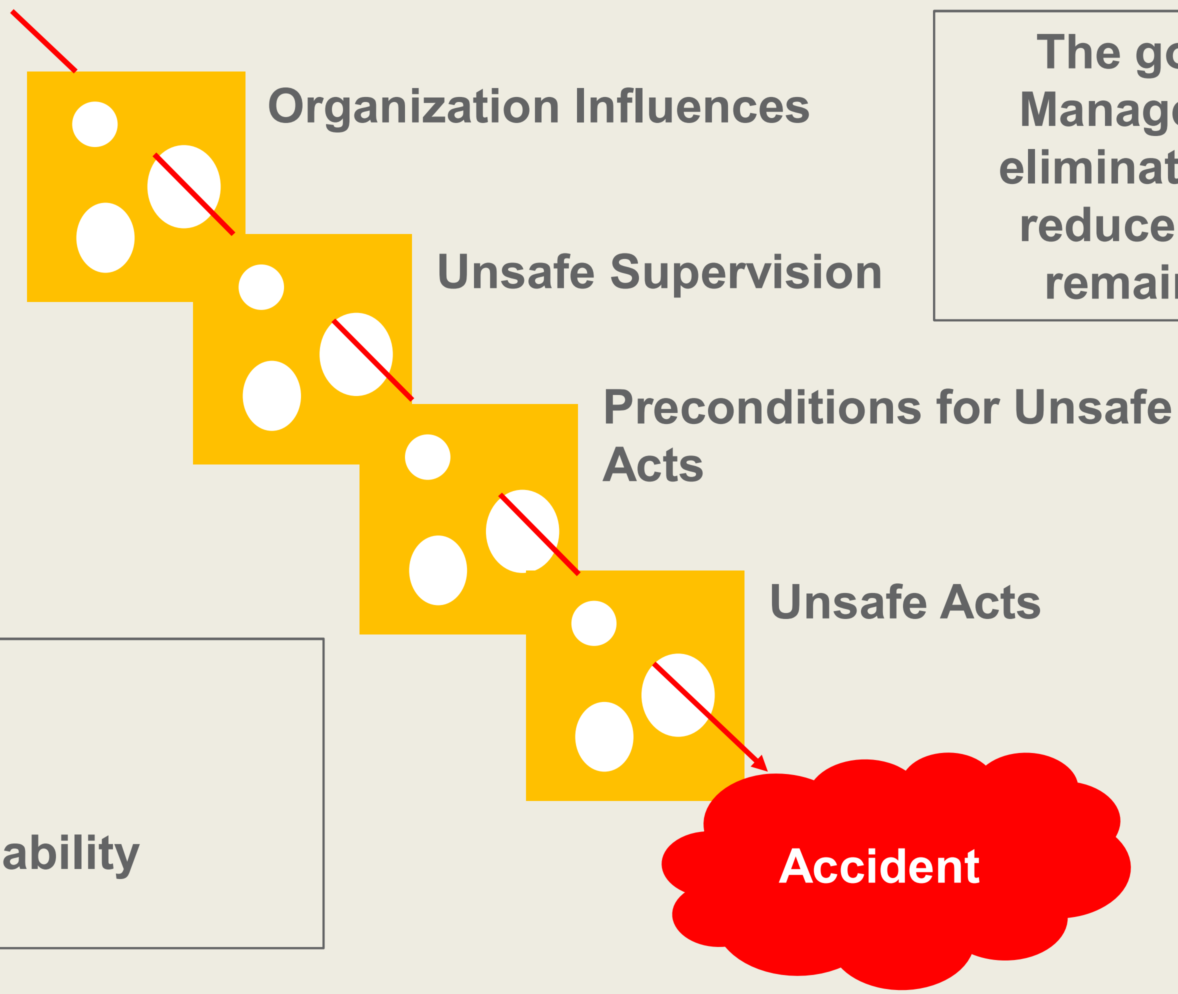
Rework

STO success Factors – Relative Importance



Ref: S.C. Hlophe & J.K. Visser

REASON'S SWISS CHEESE MODEL

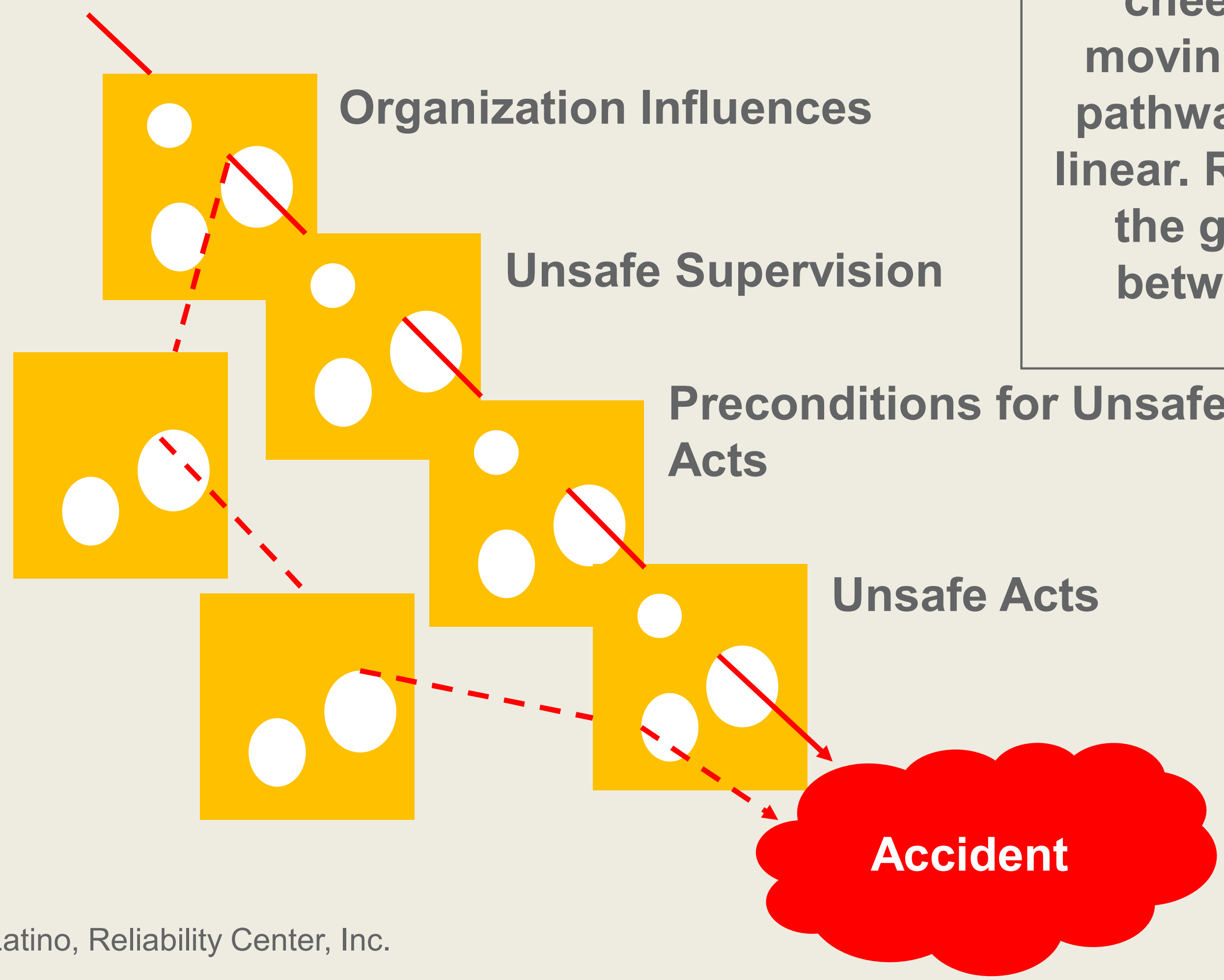


The goal of Risk Management is to eliminate holes and reduce the size of remaining ones

Impacts:

- **Safety**
- **Profit**
- **Sustainability**
- **Cost**

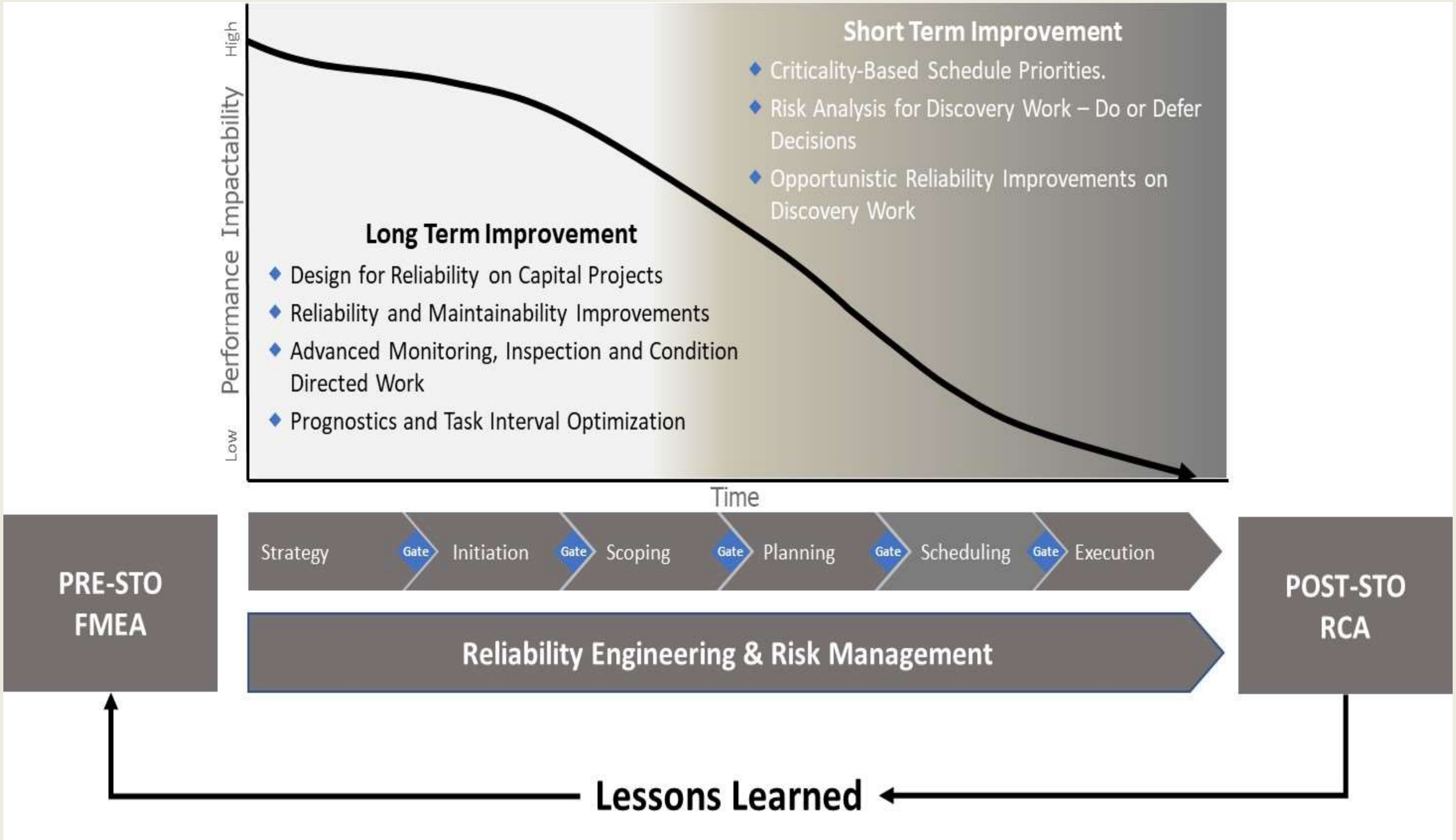
LATINO'S DYNAMIC SWISS CHEESE MODEL



During an STO, the cheese slices are a moving target and risk pathways aren't always linear. Risks can occur in the gaps that reside between the normal controls.

Ref: Bob Latino, Reliability Center, Inc.

THE RE ROLE IN THE STO



STO Process FMEA/FRACAS

Identify STO Risks →	Quantify STO Risks →	Harmonize Site-Wide STO Risk Register →	Prioritize STO Risks →	Act Upon STO Risks
-Safety	-Magnitude	-Across Units	-RPN	-Mitigate
-Environmental	-Likelihood	-Across Functions	-Qualitative analysis	-Eliminate
-Timeline	-Current controls	-Contractors		-Accept
-Budget	-Risk priority number (RPN)	-Support		-Review and revise
		-One register		

Primary STO risk categories – Start with lessons learned from the last STO

High volume of unknown supplemental scope post-freeze (number of scope items)

Insufficient qualification / experience

No scope freeze model

Delay in scope definition

Insufficient scope quality

Role distribution unclear

Scope risk assessment missing

Delayed pre-TA inspection program

Important fluctuation of key personnel

Unclear definition of process, roles and responsibilities, and of acceptance

Inadequate management of permissions by persons in authority

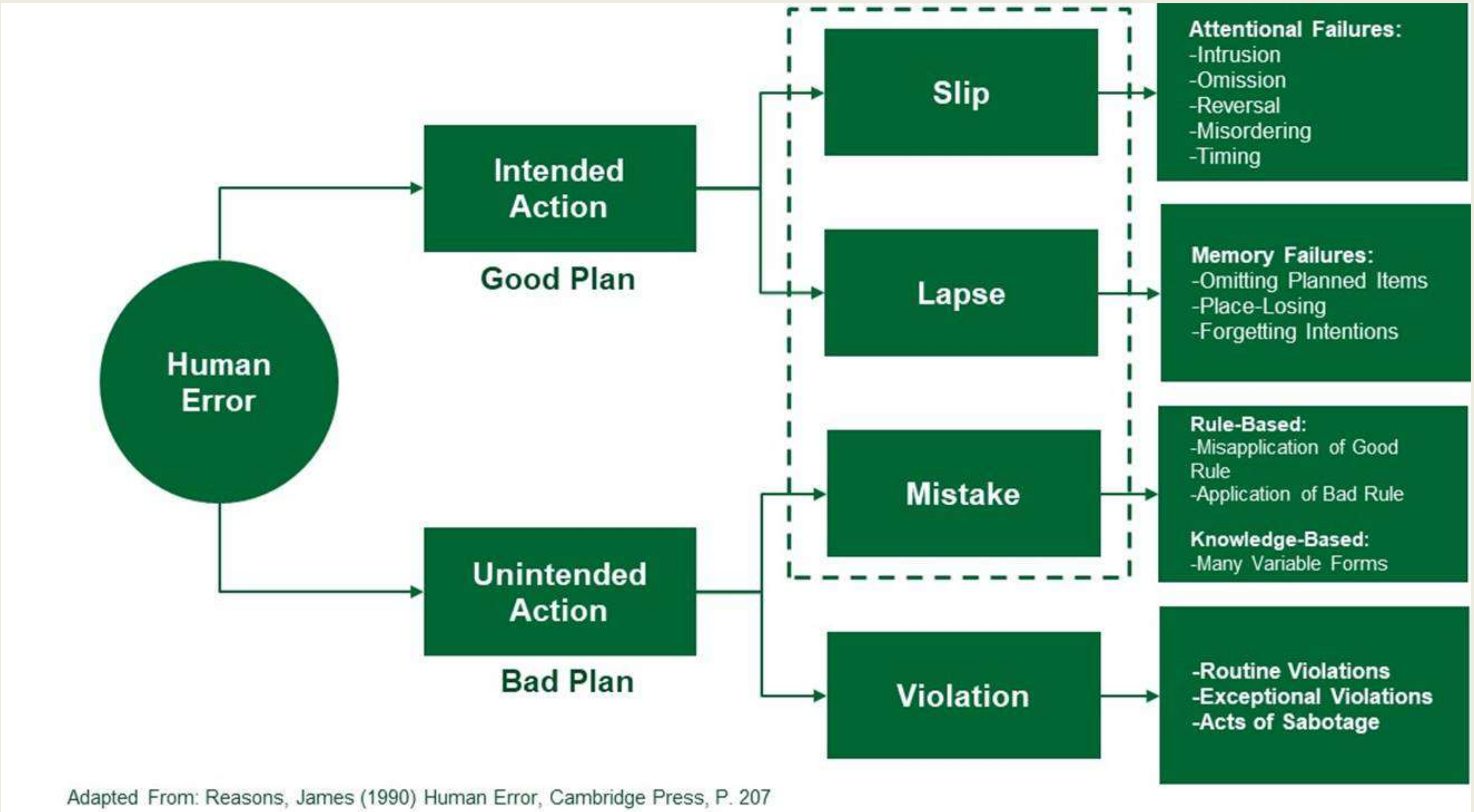
Insufficient resources during preparation

Missing transparency on scope changes

Inadequate communication / interface management

Scope evaluation with regard to expected discovery work missing

Be familiar with the human factors of failure.



Example FMEA/FRACAS – Analyze success in addition to failure!

Logic Method	Method	Process Step	Failure/ Opportunity Mode	Effect	Severity	Cause(s)	Occurrence	Controls	Detection	RPN	Action Taken	Severity	Occurrence	Detection	New RPN
Inductive	FMEA/OMEA	What is the process being investigated?	What COULD go wrong with the process?	How COULD the Failure or Opportunity Affect the Organization?	A	What COULD cause the Failure or Opportunity	A	What COULD be done to prevent failure or insure the opportunity?	A	B	Specify	A	A	A	B
Abductive/ Deductive	FRACAS/DCACAS	What is the process being investigated?	What DID go wrong or right with the process?	How DID the Failure or Success Affect the Organization?	C	What DID cause the failure or success?	D	What DID cause the failure or the success?	E	F	Specify	C	D	E	F

Notes:

A. For FMEA/OMEA - Use 1-10 scale, one being lowest and 10 being highest. Note, for detection, 1 is undetectable.

B. For FMEA/OMEA - Multiply Severity X Occurrence X Detection - produces a score of 1-1000.

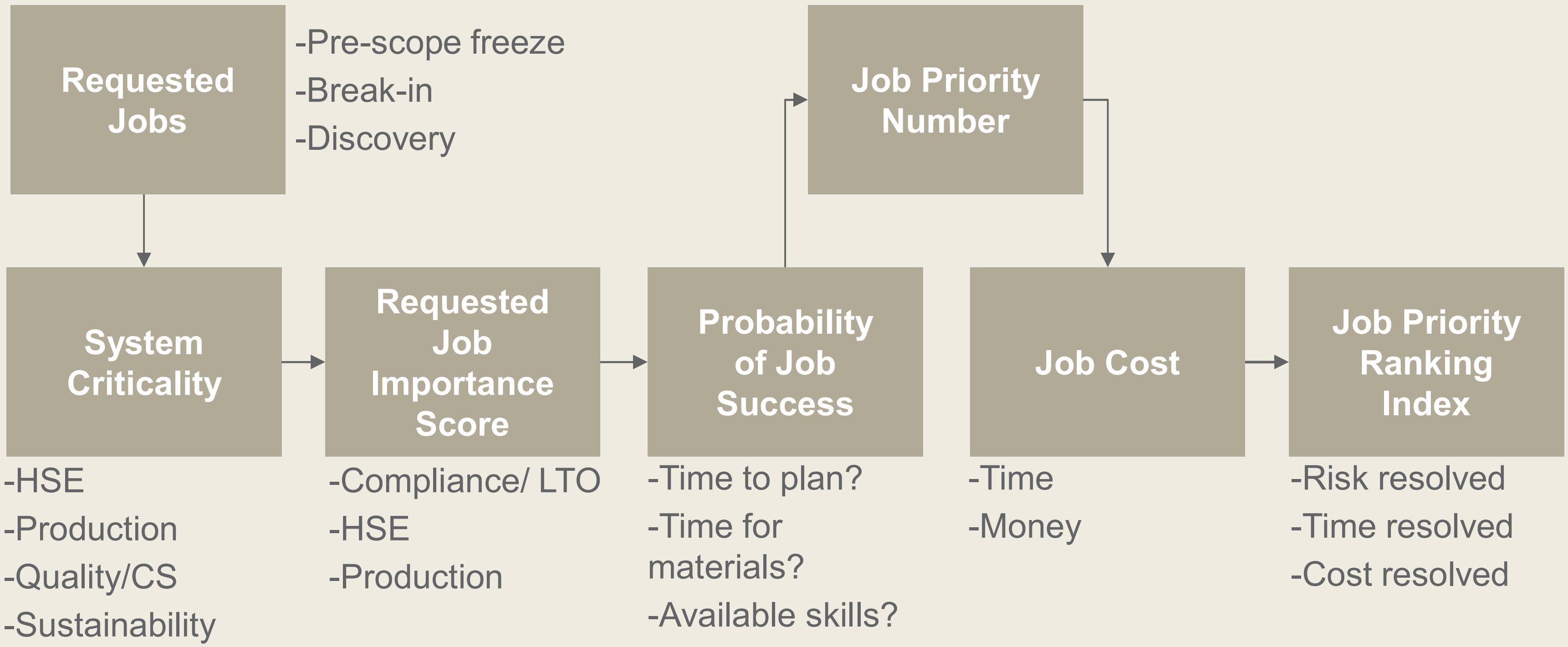
C. For FRACAS/DCACAS - Input value of failure or opportunity in objective terms (e.g. dollars, injury/death, environmental impacts, etc.).

D. For FRACAS/DCACAS - Input number of occurrences per year (may be fractional).

E. For FRACAS/DCACAS - Input the percentage likelihood that the failure or success can be detected in time to assure control.

F. For FRACAS/DCACAS - Multiply Severity X Occurrence X (1 - Detection Percent) = Annualized Risk/Opportunity.

Job Priority Analysis and the Hurdle – Rank the Jobs Based on Risk Eliminated, Required Time and Cost

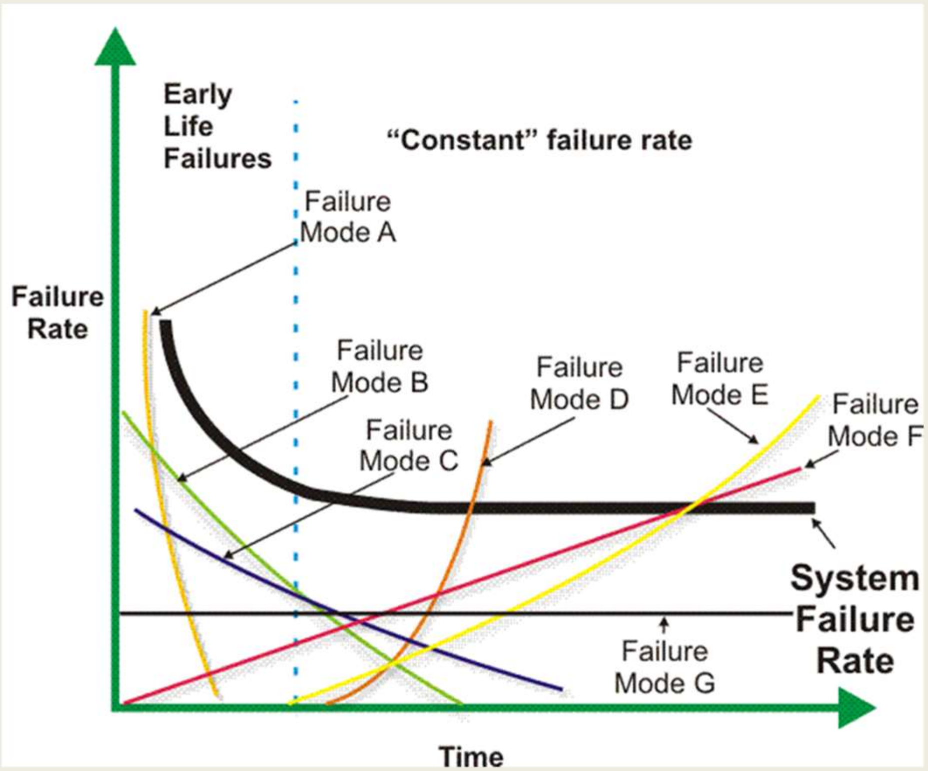


Risk Managed STO Scope

Reduces subjectivity in deciding what jobs are in and what jobs are out!

Reliability analytics improves predictions of where discovery work will be found

REDUCE DISCOVERY WORK



IMPROVED PROGNOSTICS

Process data analytics

Improved risk-based inspection (RBI) activities

Predictive monitoring

Pre-STO inspections

Historical failure data analytics (MTBF/MTTR/Weibull)

Physics of failure analytics

Improved coordination

Your next steps…

1. Get your reliability engineers off of the STO sideline and into the game
2. Engage REs to perform a pre-STO PFMEA and create and integrated risk register – start with lessons learned from the last STO.
3. Perform a risk-based job priority analysis resolved in terms of risk, time and cost.
4. Involve reliability engineers in capital projects to drive design for reliability, operability, maintainability and safety to drive life-cycle asset value.
5. Involve reliability engineers in the planning process with asset condition assessment to effectively scope work (including spare parts).
6. Perform reliability analytics to reduce discovery work during the STO.
7. Engage your REs to conduct the post-STO lessons learned using the RCA process.

SINCE 1994

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350+ PROJECTS

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