Session # 7

Maintenance Plans
Engineered Maintenance Strategies,
Failure Analysis & Root Cause Analysis

Where does the Maintenance Plan fit in?

ASSET MANAGEMENT STRATEGY

Asset Management Plan

Strategy - Develop a robust program within strategic framework.

Business Review - Implement with respect to critical business needs and without impact to scheduled operations.

Technology Review - Implement technology that can support processes at the business unit level but that can also be supported at the enterprise level.

Implementation Planning - Identify an implementation schedule based on the program and corresponding costs.

The Purpose

ASSET MANAGEMENT PLAN

Asset Management Plan

Asset Operations Plan

Operating Parameters

Planned Utilization
Staffing Requirements
Raw/WIP Materials Requirements
Materials Handling Requirements
Energy/Utilities Requirements
Continuous Operating Hours
Production Schedule Variation
Incoming Materials Specifications
Finished Products Specifications
Production Minimum Lot Size
Planned Capital Life
Performance Variables (KPIs)
Performance Tracking Process
Business Risk Assessment

Asset Maintenance Plan

Maintenance Parameters

Asset Hierarchy
Criticality Ranking Index
Failure Modes and Effects
Maximum Continuous Operation
Mean-time-between-repair
Mean-time-between-maintenance
Mean-time-to –repair
Mean-time-to-rebuild
PM/PdM Requirements
Overhaul/Rebuild Requirements
Skills/Staffing Requirements
Anticipated Useful Life
Performance Variables (KPIs)
Reliability Risk Assessment

Asset Risk Plan

Risk Parameters

Risk strategy, tolerance
Risk definition and categorization
Loss data collection
Risk indicator data collection
Control self-assessment
Risk assessment and analysis
Expected/Unexpected
Loss Control Scores
Real exposures
Controls quality
Cost benefit analysis
Risk mitigation and transfer strategy

Standard Work

Asset Management Plan Key Components

THE OPERATING PLAN

The Operating Plan

- Standard operating procedures
- Start-up / Shut–down procedures
- Materials procedures
- Operator care procedures

Operating Envelope

- Boundary conditions, e.g. input-output
- Startup and shutdown cycles
- Permissible operating ranges and methods
- Operating campaigns
- Specific procedures for abnormal operating modes

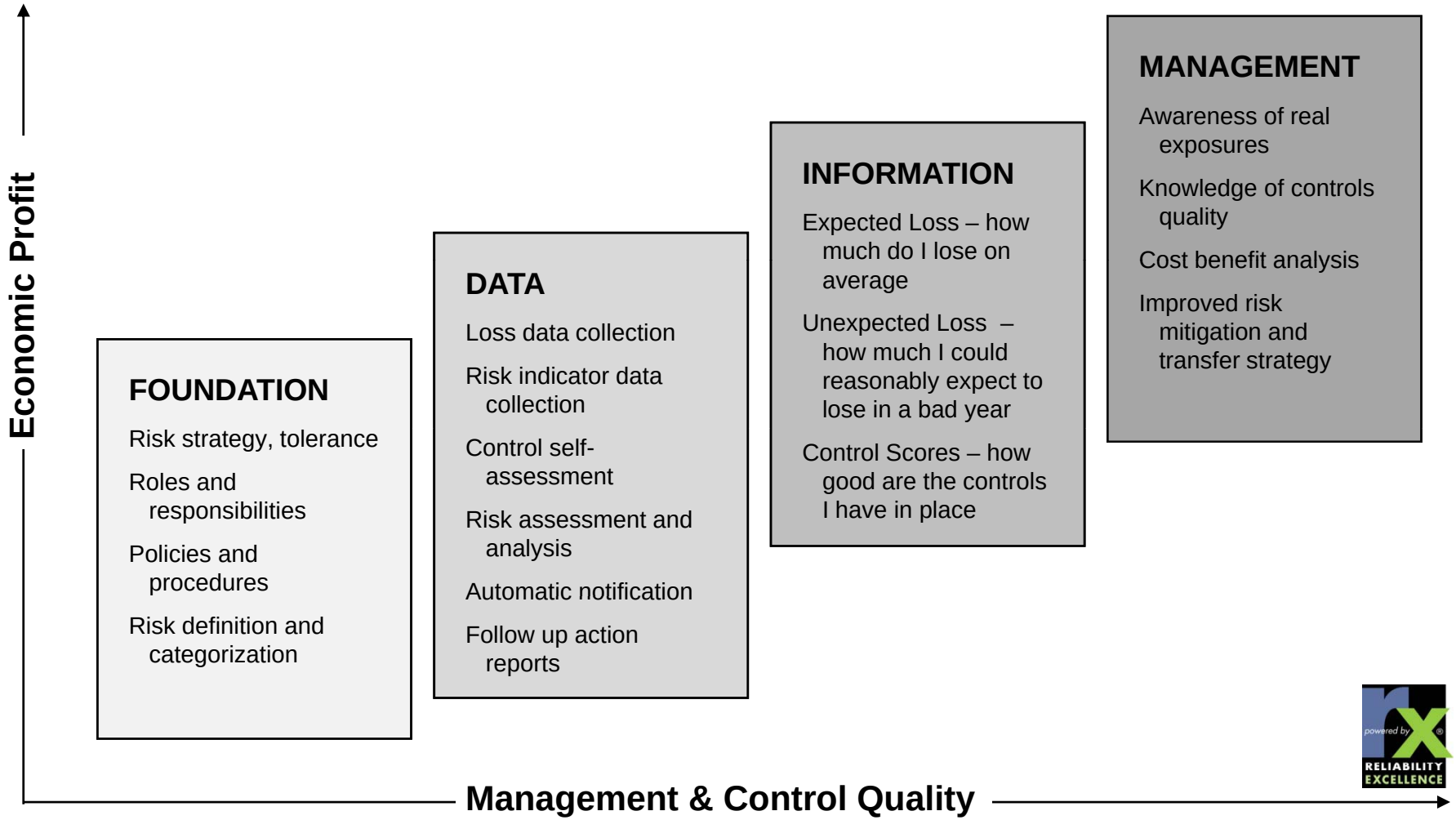
Asset Management Plan Key Components

THE RISK PLAN

The Risk Plan

- Risk identification
- Risk analysis
- Risk mitigation
- Communication plan
- Risk management table

The Benefit of Risk Management



Operational Risk Management

Asset Management Plan Key Components

THE MAINTENANCE PLAN

The Maintenance Plan

The infrastructure:

- Database development
- Asset definitions
- Required attributes
- Functional/Reliability block diagrams
- Hierarchy development
- Criticality analysis
- Failure mode and effect analysis

The Maintenance Plan

Task module creation

- Mapping failure modes to failure detection methods
- Rebuild / Refurbishment criteria
- Assigning crafts and trades
- Determining frequency
- Establishing durations
- Level loading tasks

Example of a Task Module

FACILITATOR ACTIVITY

EQUIPMENT MAINTENANCE PLAN

EQUIPMENT NUMBER	DESCRIPTION	LOCATION	DOCUMENTATION
305-2-1	Drawworks, Dreco SSGD-750-GE	Drill Floor	General Service Manual
305-2-1	Disc Brake System	Drill Floor	Maintenance Manual

ITEM #	MAINTENANCE TASK DESCRIPTION	FREQUENCY (Days)	CRAFT	CRAFTSMEN REQD	EQUIPMENT CONDITION	TYPE	PROCEDURE / TASK #	EST. TIME (Hrs)	SPECIAL TO RE
01	DAILY SERVICING ROUTINES	1	ENG/RM	1	RUNNING	PM			
02	WEEKLY SERVICING ROUTINES	7	ENG/RM	1	SHUTDOWN	PM			
03	CHECK DISC BRAKE FRICTION PADS, CHECK LUBE OIL PUMPS, CHECK HYDRAULIC OIL PUMPS AND ACCUMULATOR BOTTLES, LUBRICATE TORQUE ARM AND INSPECT WIRE ROPE	30	ENG/RM	1	SHUTDOWN	PM			
04	INSPECT INTEGRITY OF ELECTRICAL COMPONENTS	90	CE	1	SHUTDOWN	PM			
05	INSPECT LUBE OIL DISTRIBUTION LINES, CHECK GEAR OIL SPRAY NOZZLES, CHECK OPERATION OF HYDRAULIC PUMPS, INSPECT DRAWWORKS DRIVE GEARS, INSPECT THE TORQUE ARMS, OBTAIN LUBE OIL AND HYDRAULIC OIL SAMPLE, REMOVE AND REPLACE LUBE OIL FILTER ELEMENT, REMOVE AND REPLACE HYDRAULIC OIL FILTER ELEMENT	180	ENG/RM	1	SHUTDOWN	PM			
06	INSPECT GEARS, CHECK HIGH SPEED GEAR WOBBLE, CHECK PINION GEAR BACKLASH, CHECK PINION GEAR TOOTH CONTACT, INSPECT, DISASSEMBLE AND CLEAN LUBE OIL COOLING PLATE HEAT EXCHANGER, INSPECT PIPING, HOSES, CONNECTIONS AND FOUNDATION FASTENERS, DRAIN AND FLUSH HYDRAULIC POWER UNIT, CHECK BRAKE CALIPER DELAY SYSTEM, CHECK BRAKE DISK CONDITION AND NDE INSPECTION OF FOUNDATION BOLTS	360	ENG/RM	1	SHUTDOWN	PM			
07	VERIFY OPERATION OF ISOLATION BARRIERS, CHECK PRESSURE TRANSMITTERS, TEMPERATURE SWITCHES, LEVEL SWITCHES, DIFFERENTIAL PRESSURE SWITCH, VALVE ON/OFF SOLENOID, HAND OPERATED SWITCH, ENCODER AND DEADLINE ANCHOR PRESSURE TRANSMITTER	360	CE	1	SHUTDOWN	PM			
08	PERFORM CONDITION EVALUATION OF DRAWWORKS PRIOR TO SPS - TO DETERMINE OVERHAUL REQUIREMENTS	1800	ENG/RM	2	SHUTDOWN	PM			
09	PERFORM COMPLETE OVERHAUL AND NDE OF DRAWWORKS ASSEMBLY, REMOVE AND REPLACE HPU AND HYDRAULIC SYSTEM HOSES, REPLACE DRAWWORKS BRAKE CALIPER SPRING PACKS, NDE CALIPER PISTONS, NDE	1800	ENG/RM	5	SHUTDOWN	PM			

The Maintenance Plan

Developing preventive maintenance tasks

- Failure based
- Comprehensive procedure
- Organized structure
- Repeatable results
- Acceptance criteria

The Maintenance Plan

Predictive technologies – The Big 5

- Thermography
- Oil analysis
- Ultrasonic analysis
- Vibration analysis
- Motor analysis

The Maintenance Plan

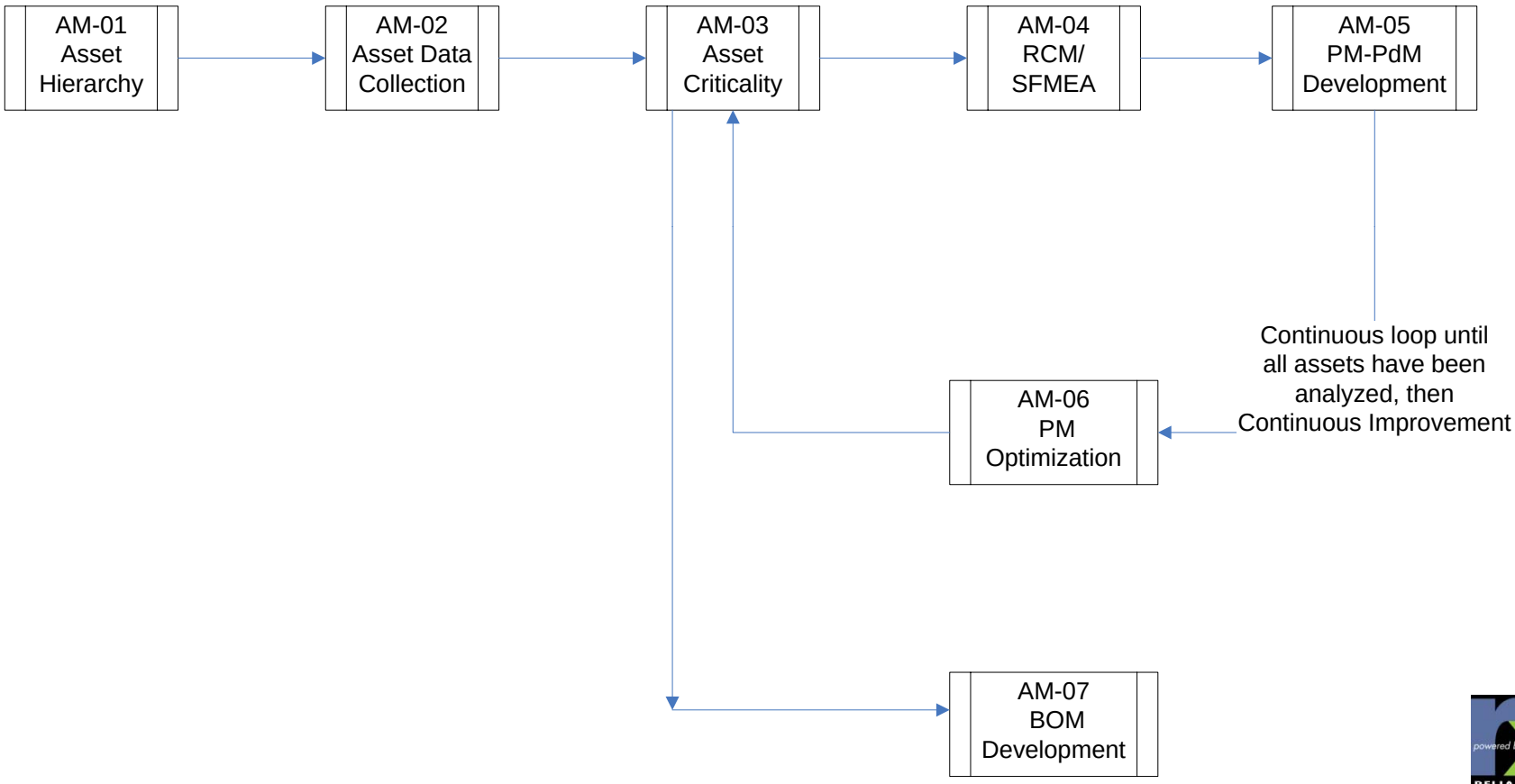
MRO support

- Developing bill of materials
- Determining critical spare part thresholds

Continuous improvement

- Value metrics
- Feedback process

Developing the Infrastructure



Block Diagrams

The precursor to developing a functional hierarchy and a maintenance *strategy is the functional and reliability block diagrams*

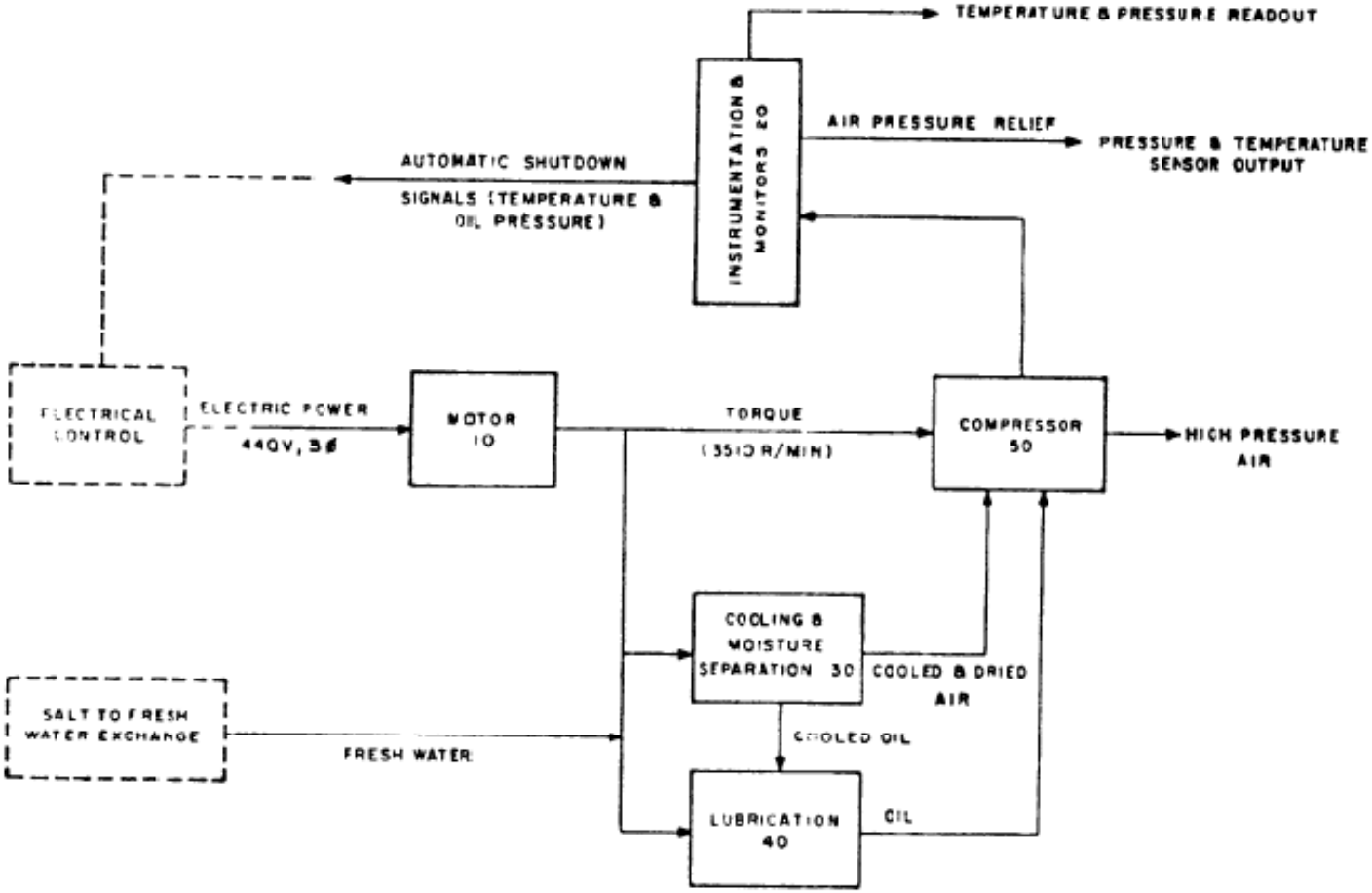
Block Diagrams

- *Functional* and *reliability block diagrams* illustrate the operation, interrelationships, and interdependencies of functional entities.
- More than one block diagram will usually be required to display alternative modes of operation, depending upon the definition established for the system.

Functional Block Diagram

- The primary purpose of the functional block diagram (FDB) is to ensure that the RE determines all of the functions provided by and within the asset and/or system so that functional failures can be determined and analyzed.
- Includes:
  - major system components
  - interfaces to distributive systems
  - interfaces between subsystems
  - power, data, and structural interfaces

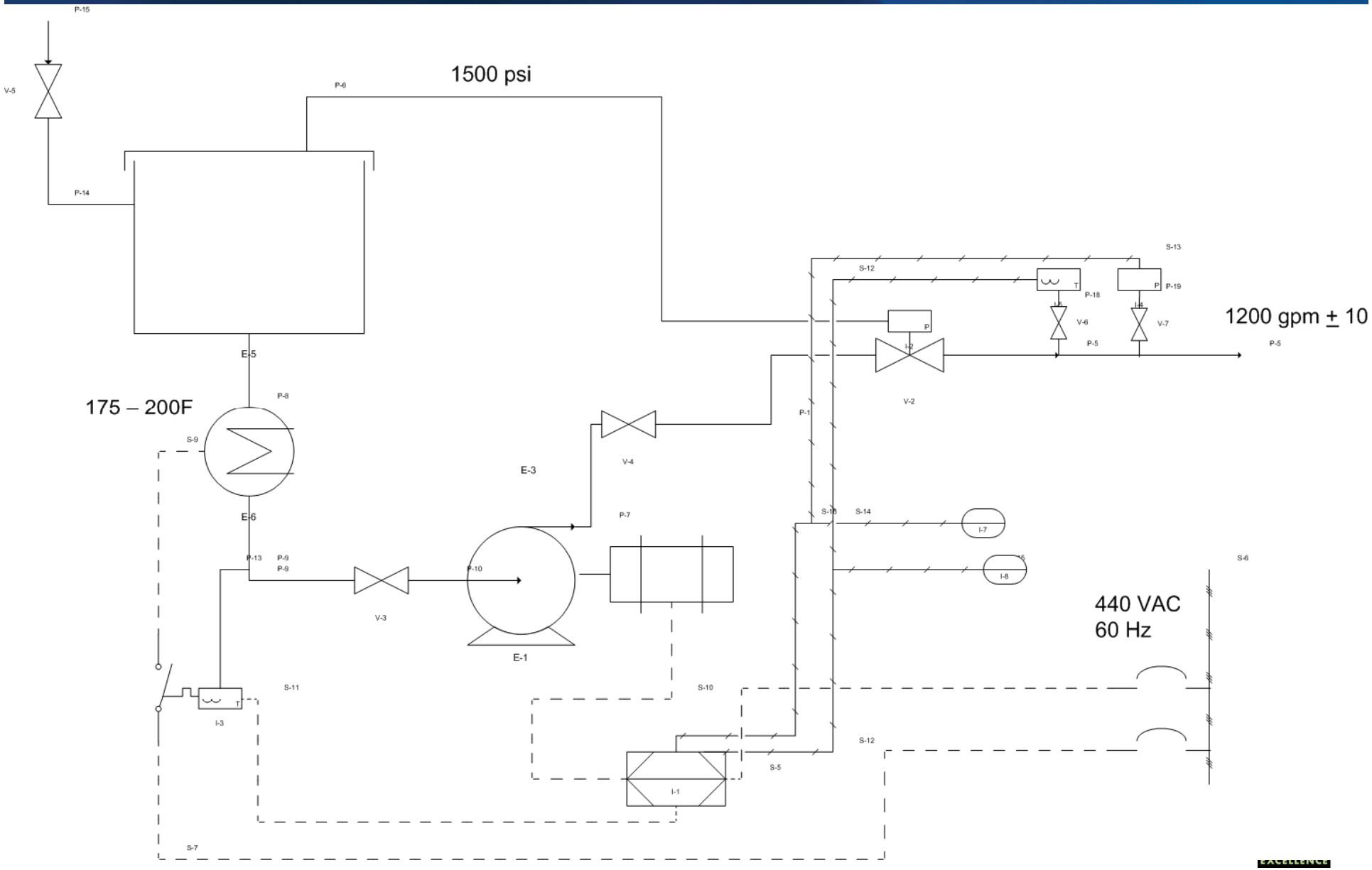
FBD Example



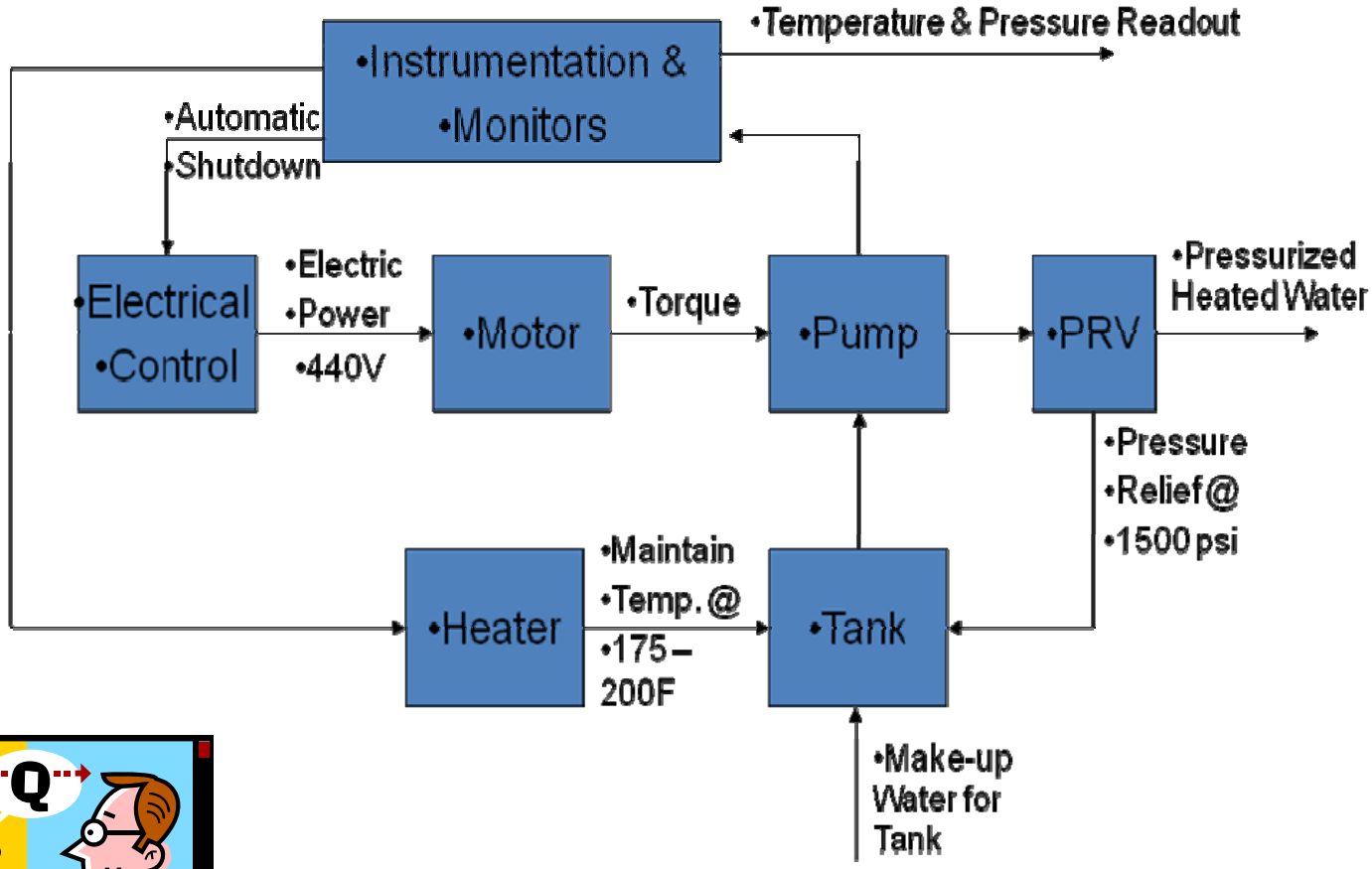
•From Mil-Std-1629, Fig. 101.1

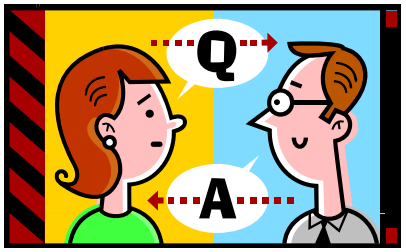
Functional Block Diagram Development

FACILITATOR ACTIVITY



Answer – FBD Activity

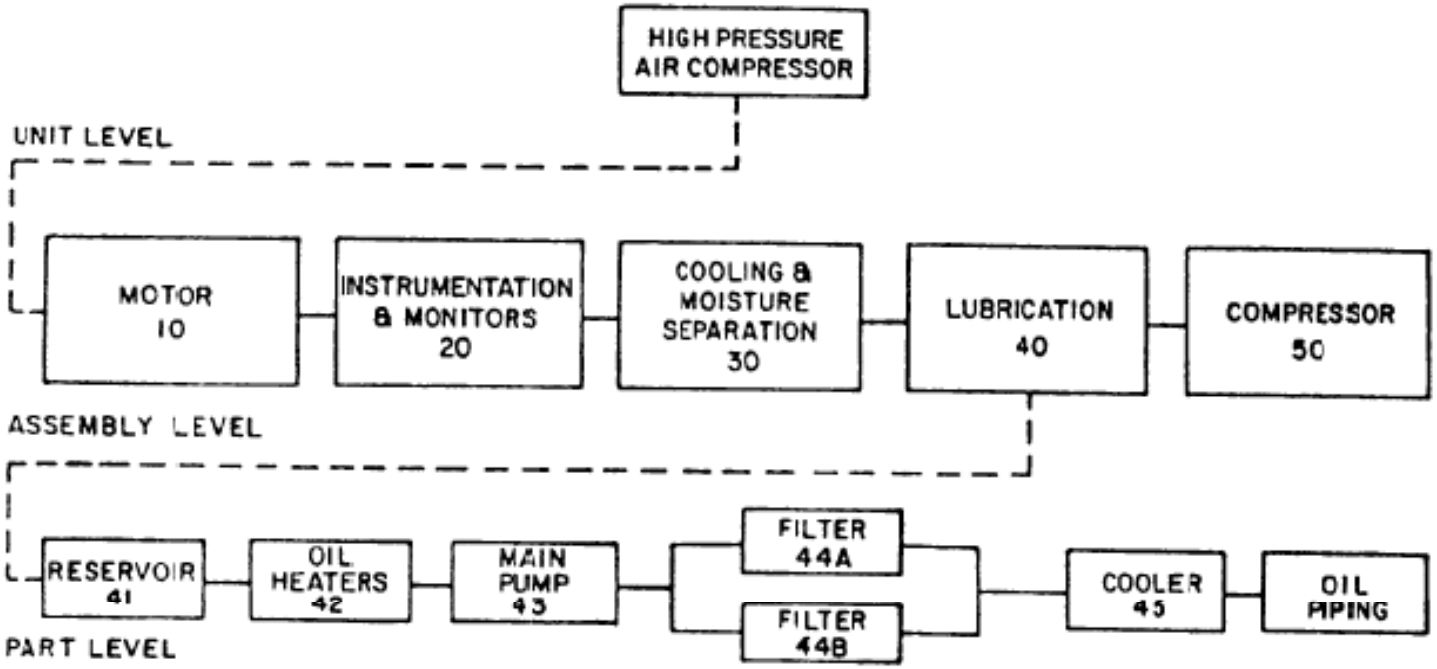




Reliability Block Diagram

- The primary purpose of the reliability block diagram (RBD) is to allow asset and/or system reliability and availability analyses using block diagrams to show network relationships.
- The structure of the reliability block diagram defines the logical interaction of failures within a system that are required to sustain system operation.

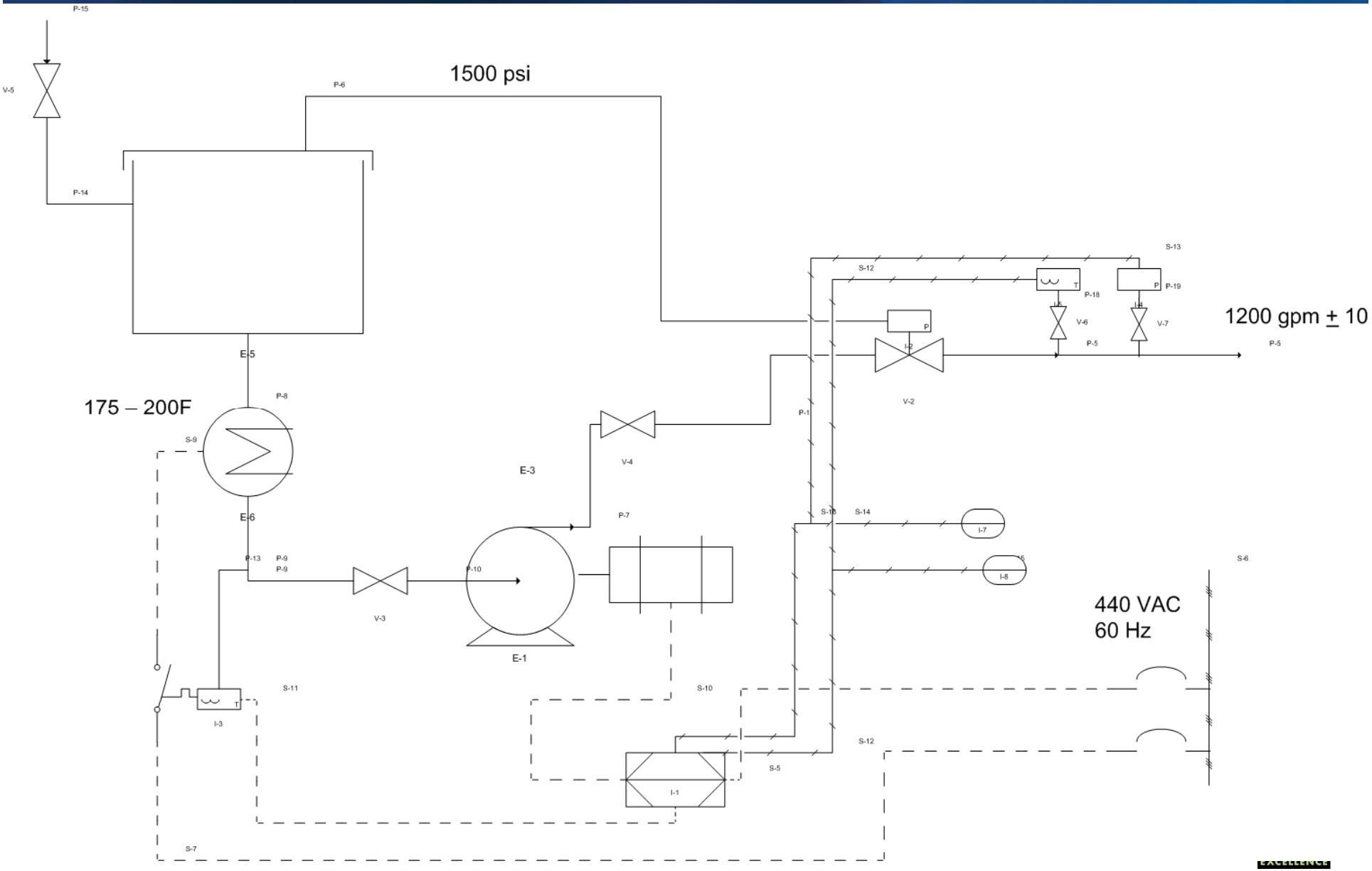
RBD Example



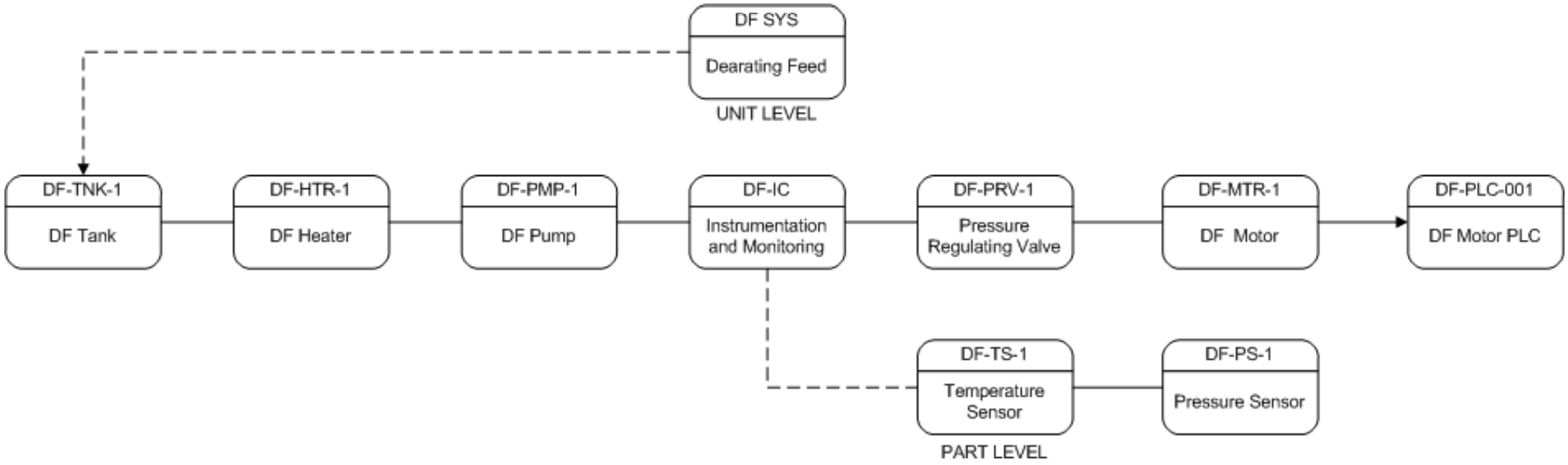
•From Mil-Std-1629, Fig. 101.2

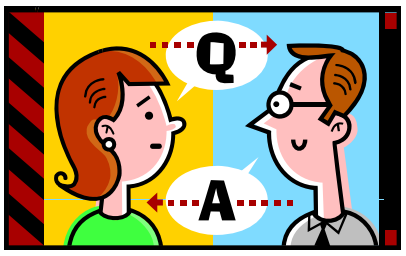
Reliability Block Diagram Development

FACILITATOR ACTIVITY



ANSWER – RBD Activity

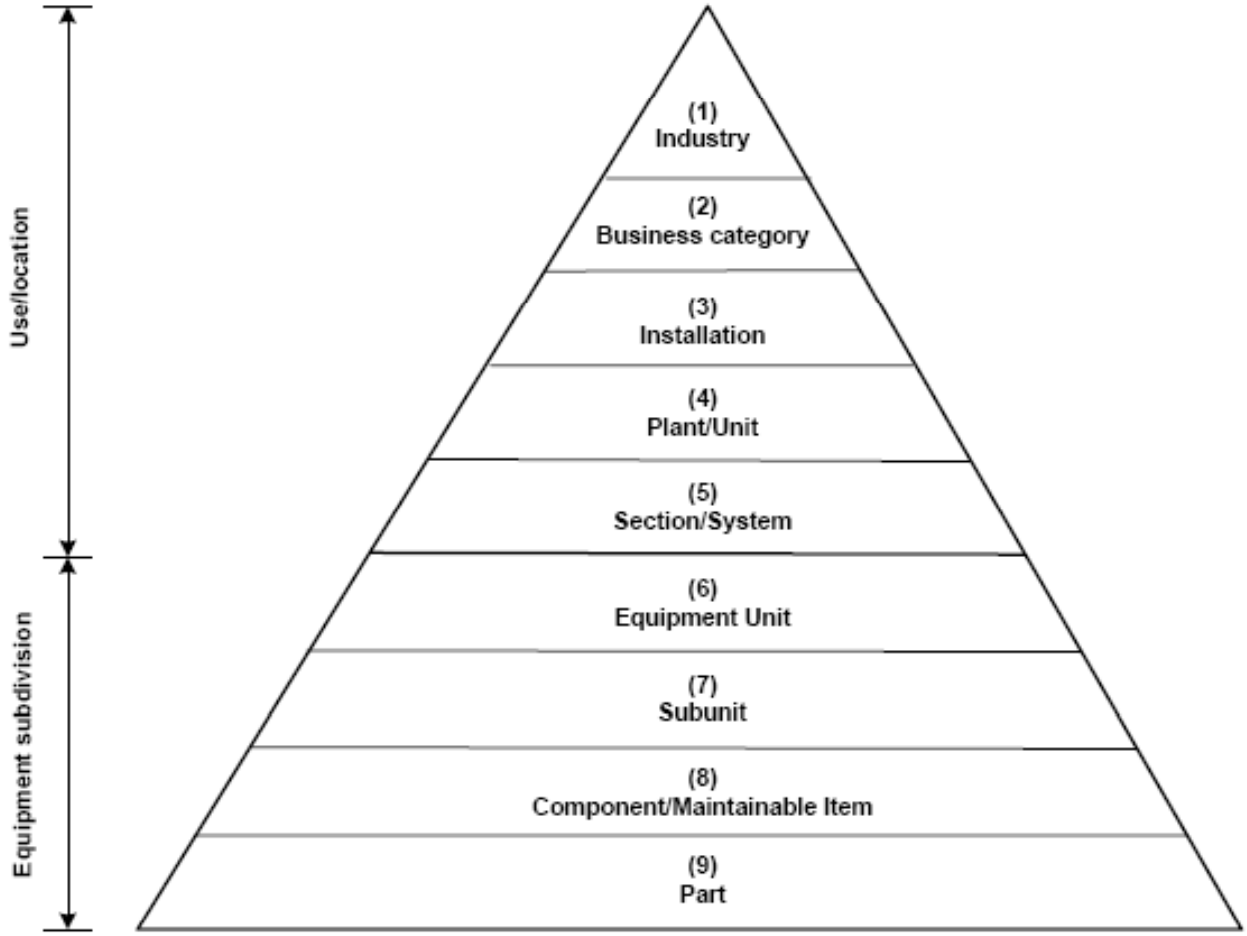




Hierarchy Development

Hierarchy is the systematic classification of items into generic groups based on factors possibly common to several of the items (location, use, equipment subdivision etc) in a parent – child relationship

Example of a Functional Hierarchy



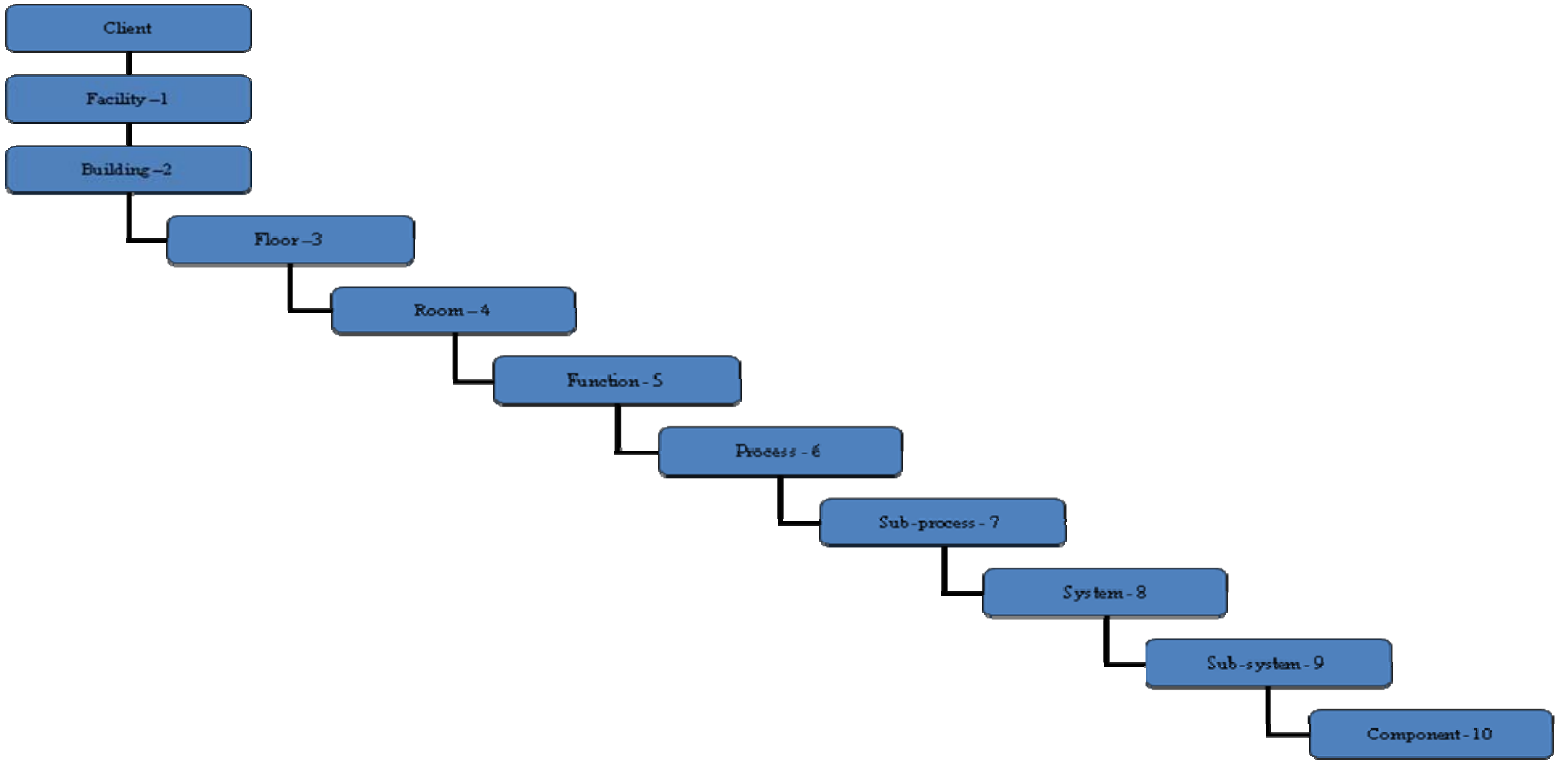
Create Functional Hierarchy

PARTICIPANT ACTIVITY

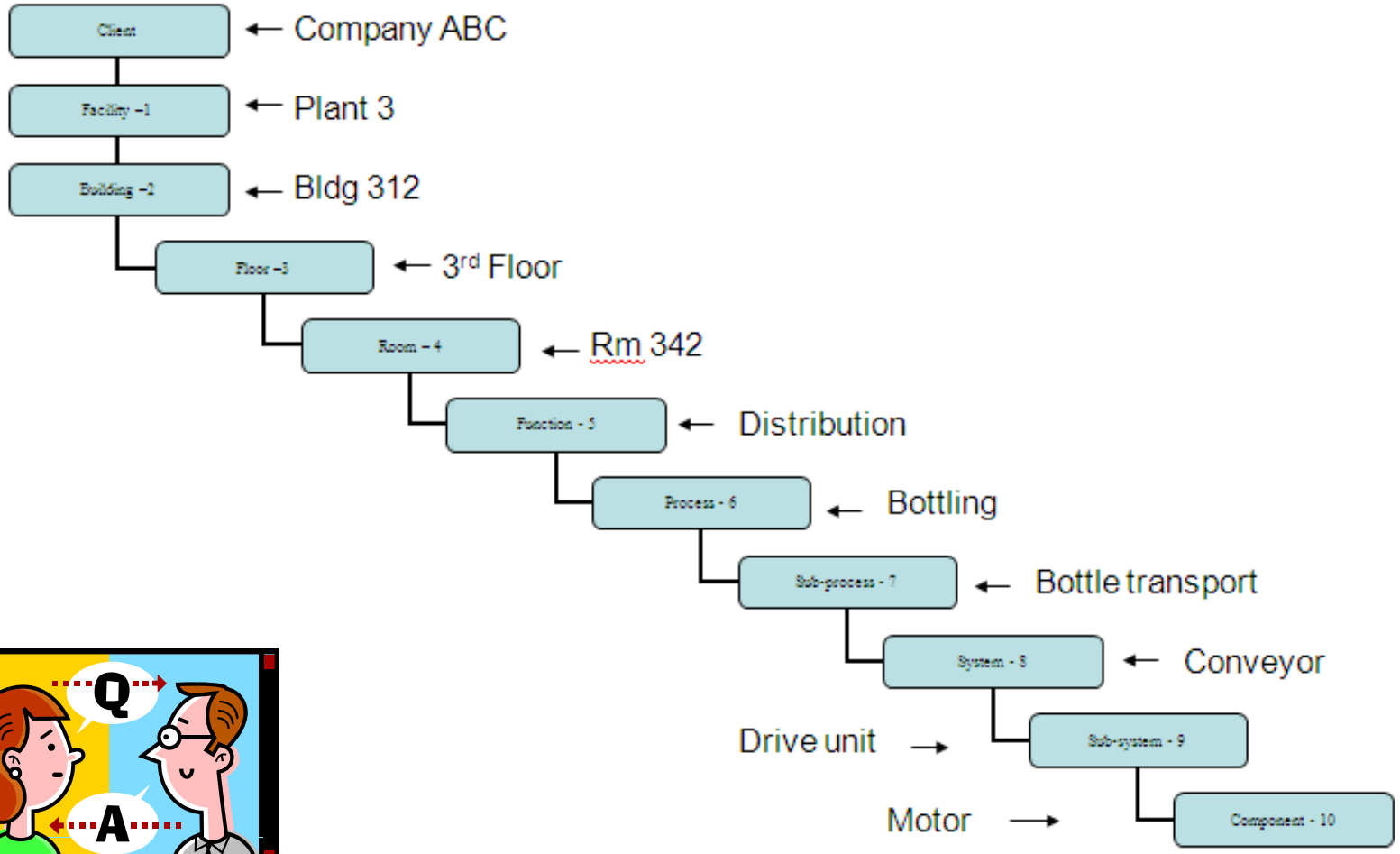
Exercise: Hierarchy Development

Description

Develop a functional hierarchy for a motor that drives a conveyor to transport bottles to be filled for distribution. The motor is located in room 342 of building 312 in 3 plant of the ABC Company.



Answer - Hierarchy



Hand out LCE Hierarchy Guidelines

FACILITATOR ACTIVITY

Main Category	Hierarchy level	Hierarchy	Definition	Examples
Use/ Location Data	1	Corporate Entity	Corporate body maintaining ownership over local body	ABC Incorporated
	2	Business unit	The individual plant or facility, which is in control of, or in possession of the asset	XYZ Plant
	3	Cost Center/ Operating unit[1]	Departments or production centers	Filtration, Pothouse, Casters, Barmill, Roll Forming, Infrastucture
	4	Function	Major process section within operating unit	Finish Grinding, Raw Grinding, Pots, Utilities
Equipment Subdivision	5	System	A combination of subsystems, assets and components forming a unit to support a process function.	Lubrication system, Cooling System, Process Control System,
	6	Subsystem/ Asset	Logical grouping of components that will perform a series of key functions required by a plant or facility.	Lubrication subsystem, Cooling subsystem, Control and Monitoring, Heating subsystem, Pelletising subsystem, Quenching subsystem, Refrigeration subsystem, Reflux subsystem, Distributed control subsystem
	7	Component/ Maintainable Item[2]	The group of parts of the subsystem that are commonly maintained (repaired/restored) as a whole.	Cooler, Gearbox, Pump, Motor, Fan, Valve, Cylinder.
	8	*Part/BOM*[3]	*The lowest level to which equipment can be disassembled without damage or destruction to the item involved*	*Seal, tube, shell, impeller, gasket, filter, plate, bolt, nut, etc*

[1]Cost Centers and Operating Units may alternatively be treated as separate levels

[2]For some types of equipment, there may not be a MI. E.g., if the subsystem class is Piping, there may be no MI, but the Part could be "Elbow".

[3]This level is placed in the standard for informational purposes only. Parts/BOM items are not expected to be captured on the functional hierarchy.

Asset Definition

Once the hierarchy is established, the level 7 components are standardized into asset types and minimum attributes are assigned to support:

- BOM development
- PM/PdM development
- Failure analysis

Asset Data

Detailed information such as:

- Asset criticality
- Nameplate data
- Engineering specification
- Property detail
- Other searchable characteristics

Criticality Analysis

Criticality is defined as a state of urgency.

As a measure, it represents the severity of a failure in relation to its consequences.

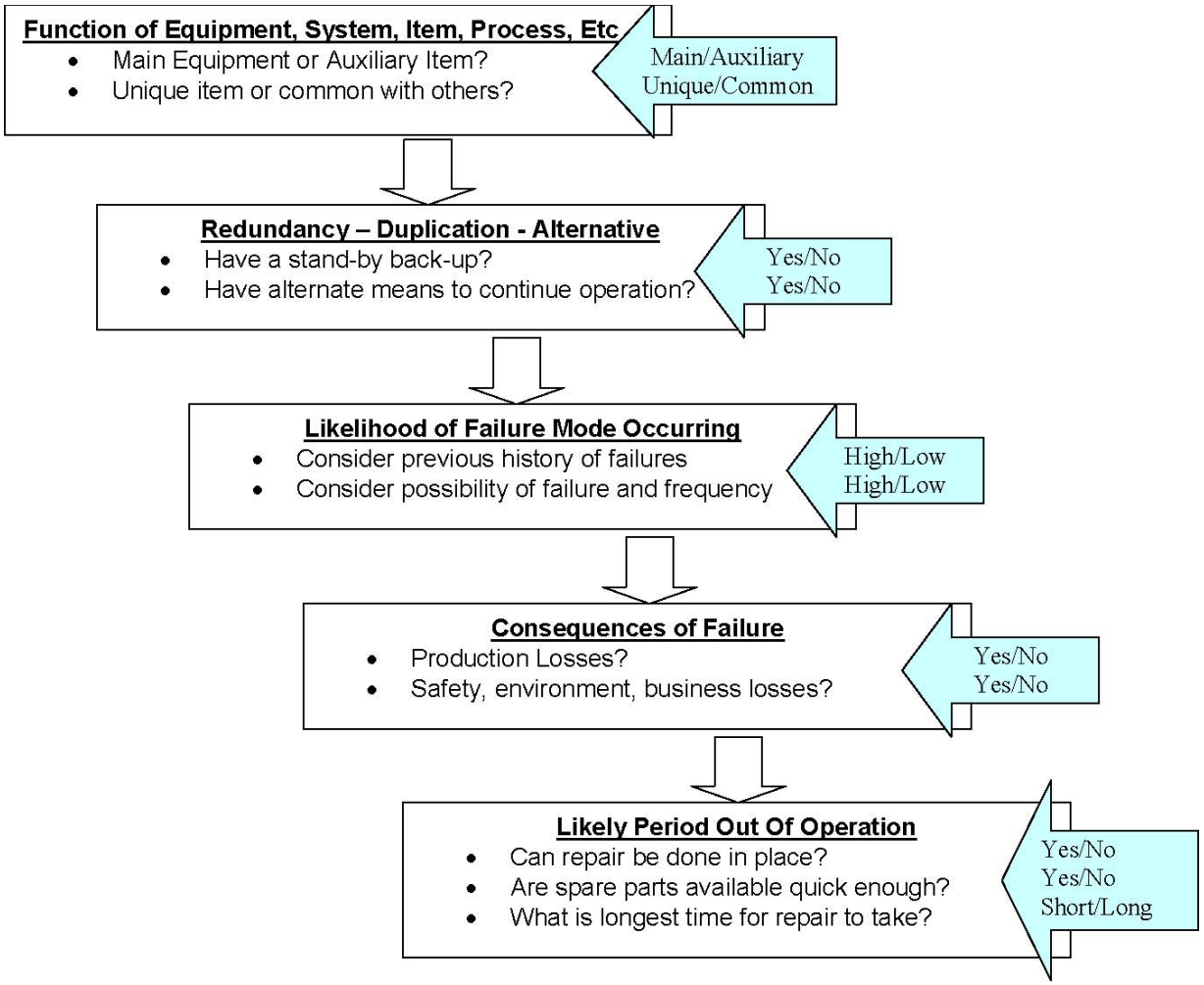
Equipment criticality is a ranking reflecting the magnitude of the consequences resulting from an equipment failure.

Contributors to Criticality

The consequences usually considered are the impact on:

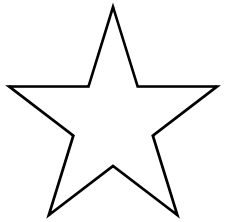
- Environment
- Health
- Safety
- Production or Value Stream
- Reputation

Example Criticality Review



Walk thru Asset Criticality Analysis Spread Sheet

FACILITATOR ACTIVITY



ROOT CAUSE ANALYSIS

Terminology

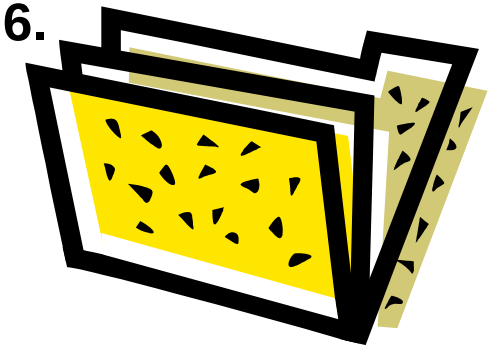
Root Cause Analysis (RCA)

- Logical, systematic means of resolving problems, limiting factors or issues.
- Done proactively, e.g. before a serious problem or failure occurs

Root Cause Failure Analysis (RCFA)

- Same
- Done reactively, e.g. after a serious problem or failure occurs

THE RCA PROCESS

1.  NOTIFICATION	2.  CLARIFICATION/ CLASSIFICATION	3.  ROOT CAUSE ANALYSIS
4.  CORRECTIVE ACTION EVALUATION	5.  VERIFICATION	6.  DOCUMENATION

Simplified FMEA

- Developed by US Military and standardized by automotive industry
- Top-down method
- Based on industrial and in-plant historical data
- Generally limited to major sub-systems

  Can include components, but failure modes, probability of failure, etc. Based on experience, not probability tables

Example Of SFMEA Analysis

Simplified Failure Modes and Effects Analysis Subsystem: 36-1A Pump					Severity		Probability		Detection	RPN		New RPN
Function	Functional Failure	Component	Failure Mode	Effect of Failure		Cause of Failure		Current Control			Improvements	
Provide 1000 gpm of Additive to process	No Flow	Motor	No rotation/torque	Shuts down process	10	Bearing seize due to Lubrication Issue	7	Lube Motor Bearings	3	70	Include on Vibration and IR route	

Terms

Occurrence ranking:

- A subjective estimate of the likelihood that if a defective part is installed it will cause the failure mode
- A subjective estimate of the probability that a failure mode will occur

Terms

Detection ranking:

- A subjective estimate of the probability that a cause of a potential failure will be detected and corrected before reaching the end user
- A subjective estimate of the probability that a cause of a potential failure will be detected and corrected before a failure can occur

Terms

Risk Priority Number (RPN):

- The product of severity, occurrence, and detection rankings
- Severity x Occurrence x Detection = RPN
- Sometime divided by 30 to give you a 100 scale

Uses of SFMEA

- Root-cause failure analysis
  - Methodology for understanding potential forcing functions that caused problem
- Drives preventive maintenance program
  - Identified forcing functions and failure modes determine the specific PM inspections that should be done to preserve the asset and prevent failures
- Drives Asset (Equipment) management program
  - Determines the fundamental requirements, e.g. operations and maintenance, for the asset
- Drives asset utilization plan

Uses of SFMEA

- Drives modifications and upgrades
  - Many of the identified forcing functions and failure modes can be eliminated by specific modifications or changes in design
- Drives Standard Work Practices (SWP) upgrades
  - Forcing functions or failures caused by setup or operating methods can be eliminated

Reliability Engineering SFMEA

- Engineer must understand the machine or production system
  - Machine or operating dynamics
  - Inherent design strengths and limitations
  - Failure modes of components, sub-assemblies and systems
- Requires homework and self-study to gain this knowledge

Reliability Engineering SFMEA

- Must be driven or supported by data
  - Focus Team SFMEA relies exclusively on “native knowledge”
  - Engineering SFMEA also uses, but all three criteria must be verified using existing historical data
- Level of detail must be as good as can be accomplished
  - Focus Team uses 80-20 rule
  - Engineering must strive for at least 90-10

Centrifugal Pump

- Operating requirements:
  - Flow 100 GPM+/-10
  - Temp 175-200 F
  - Pressure 58 +/-5 PSI
  - Must contain product

Develop Pump SFMEA

PARTICIPANT ACTIVITY

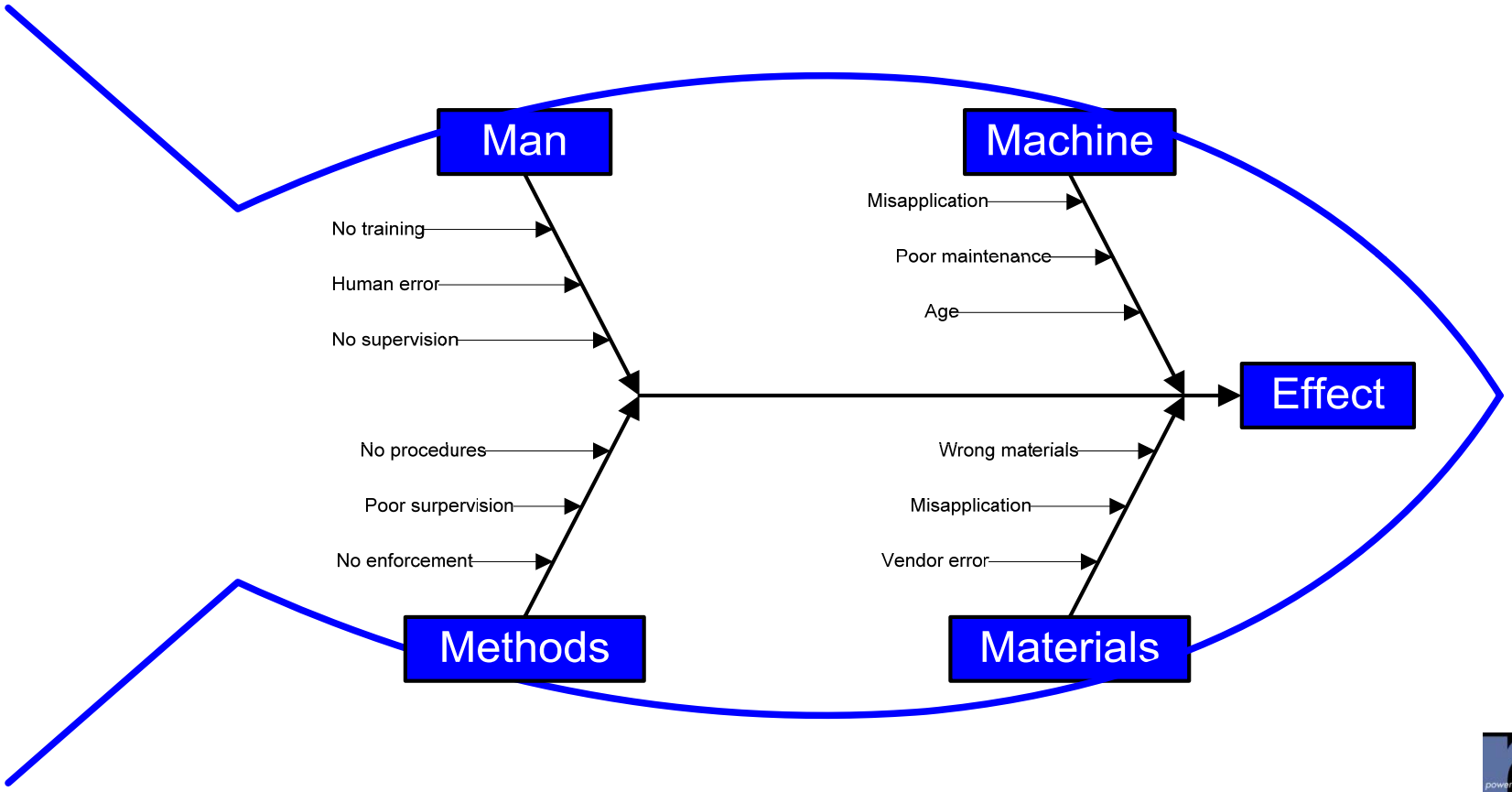
Cause-and-Effect Analysis

- Graphical approach to failure analysis (Ishakawa Diagram)
- Also called ***Fishbone*** or ***4M Analysis*** because of graphic pattern and classifications

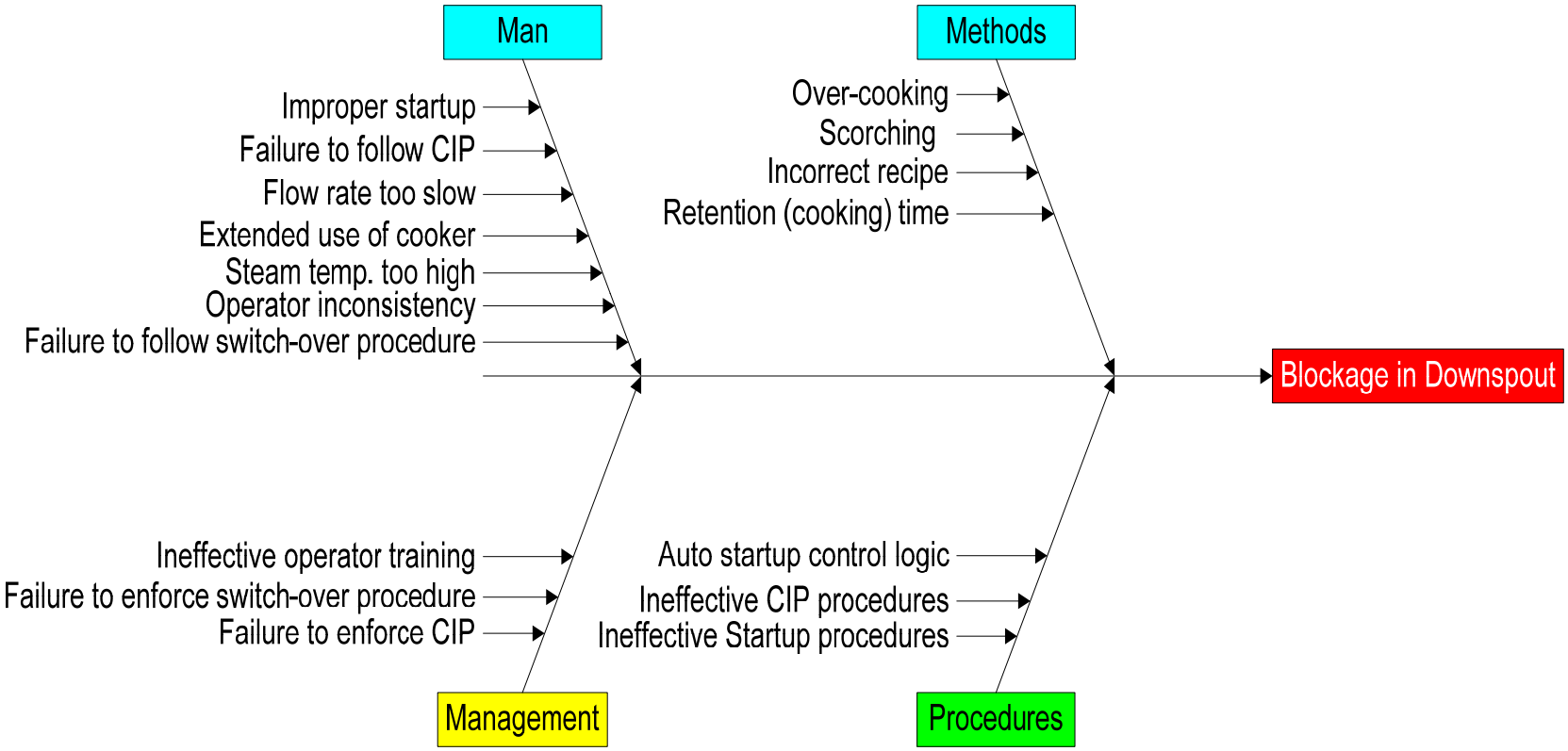
Cause-and-Effect Analysis

- Plots relationship between various factors that contribute to specific event
- Factors are grouped in sub-classifications to facilitate analysis

4M Cause-Effect Diagram



Example of Cause and Effect Diagram



Uses Of Cause-Effect

Process deviations

- Problems associated with capacity restrictions, product quality, abnormal costs

Regulatory compliance

- OSHA violations
- Environmental releases

Safety issues

•Most production problems require complete understanding of all probable variables that could contribute to a problem

Limitations

Cause-and-Effect Analysis has serious limitations:

- Does not provide a clear sequence-of-events that leads to failure
- Does not isolate specific cause or combination of forcing functions that result in problem
- It displays all of the possible causes

Cause and Effect Exercise

Problem:

A customer at your restaurant just complained that he was served a bad tasting cup of coffee. He asked for another cup and said the coffee was just as bad as the first cup he was served.

What are the possible causes?

Cause & Effect Analysis – Fishbone Diagram

Problem or “Effect”

Step 1 Identify the problem during one of your team’s brainstorming sessions. Draw a box around the problem. This is called the “effect”.

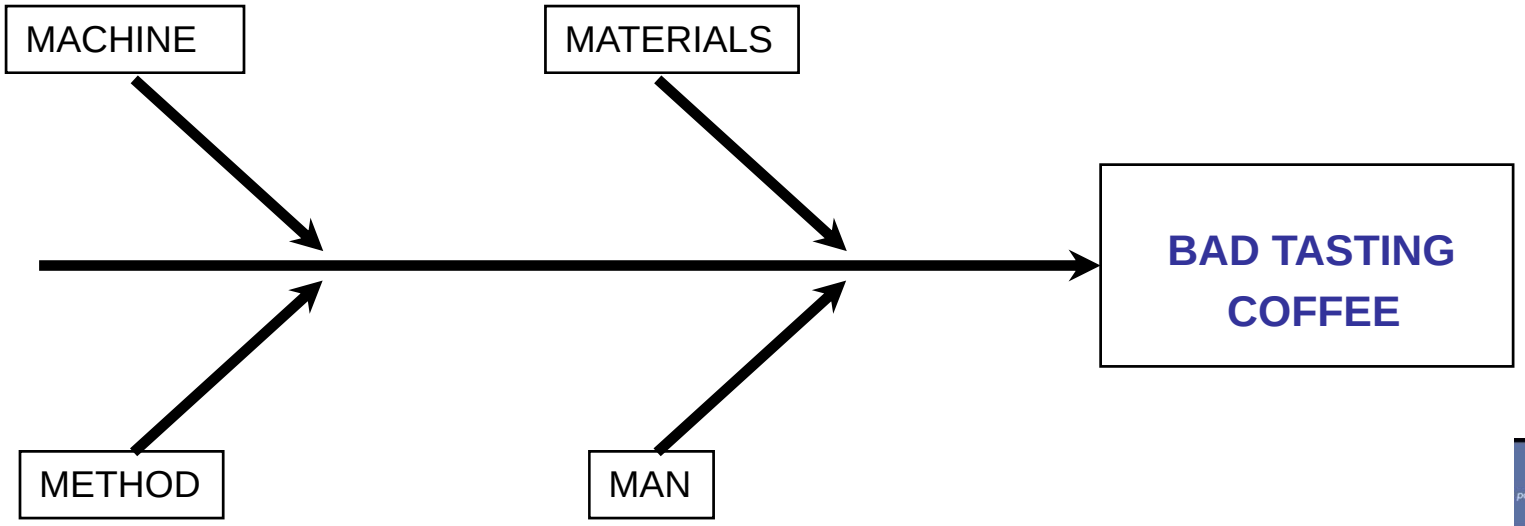
Bad Tasting Coffee

Step 2 Draw a long process arrow leading into the box. This arrow represents the direction of influence.

Bad Tasting Coffee

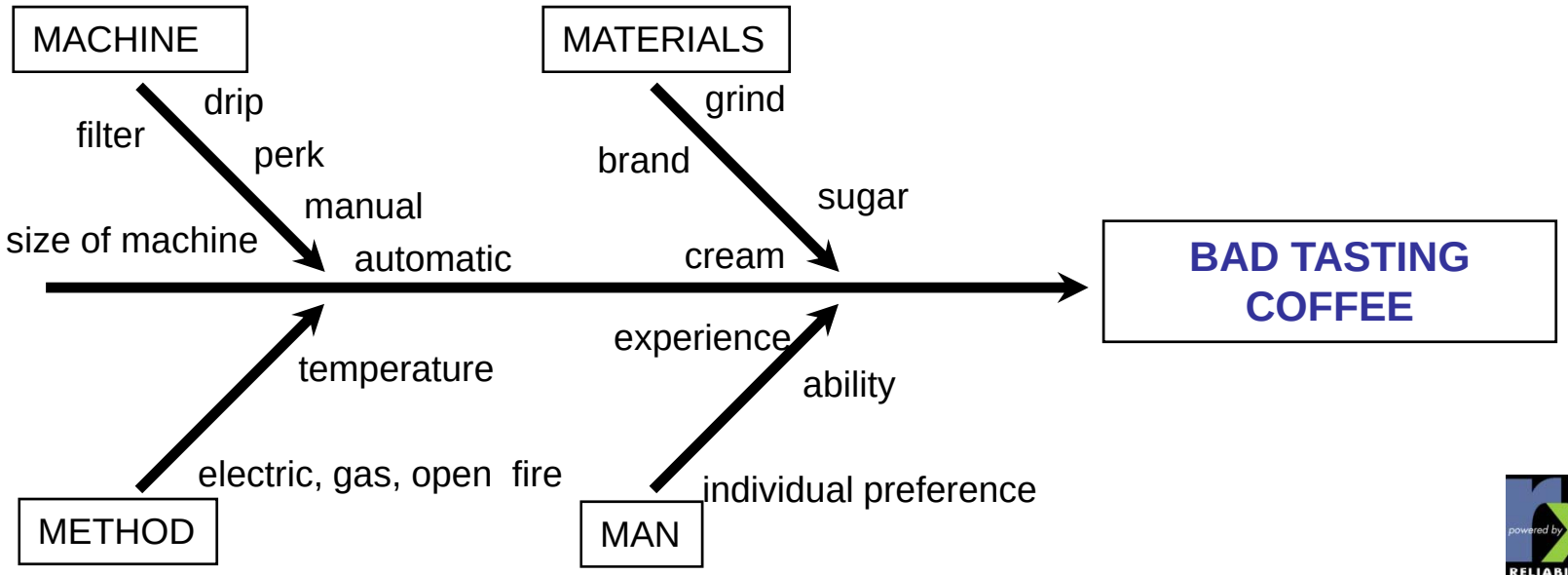
Cause & Effect Analysis – Fishbone Diagram (cont.)

Step 3 Decide the major categories of causes. Groups often start by using ***Machines***, ***Materials***, ***Methods***, and ***Man***. For some problems, different categories work better.



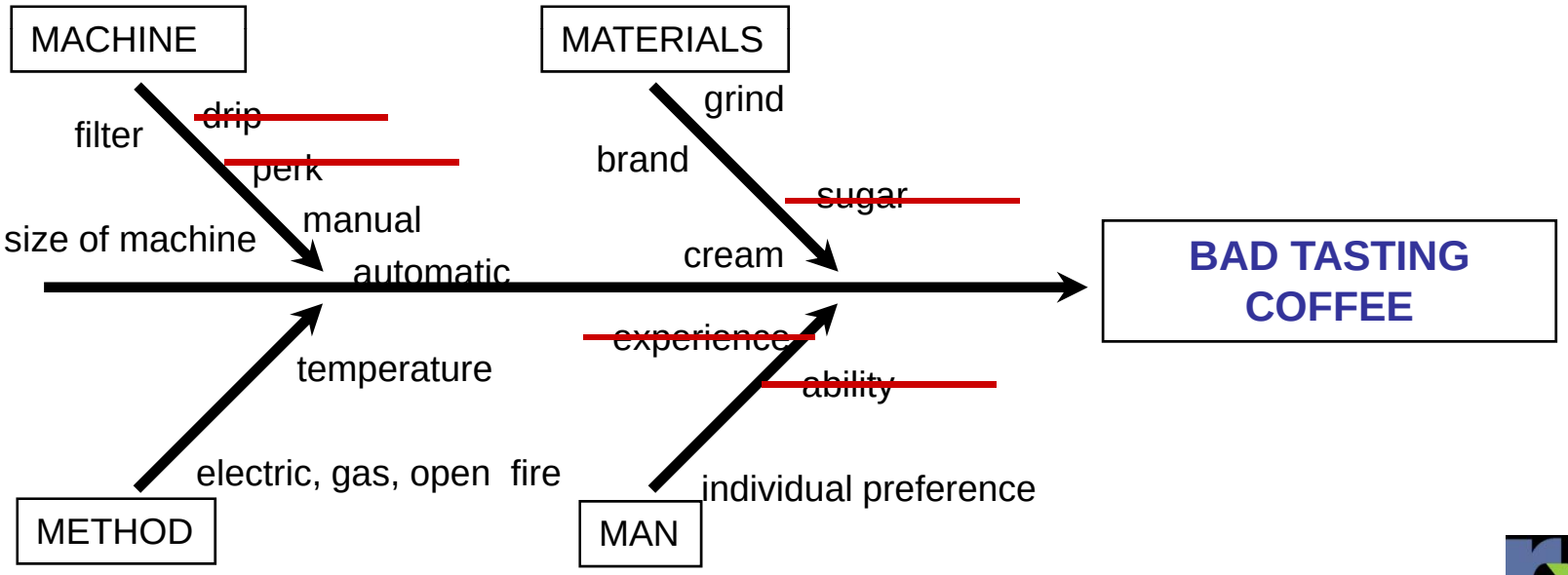
Cause & Effect Analysis – Fishbone Diagram (cont.)

STEP 4 Decide the possible causes related to each main category. For example, possible causes related to man are experience, ability and individual preference.



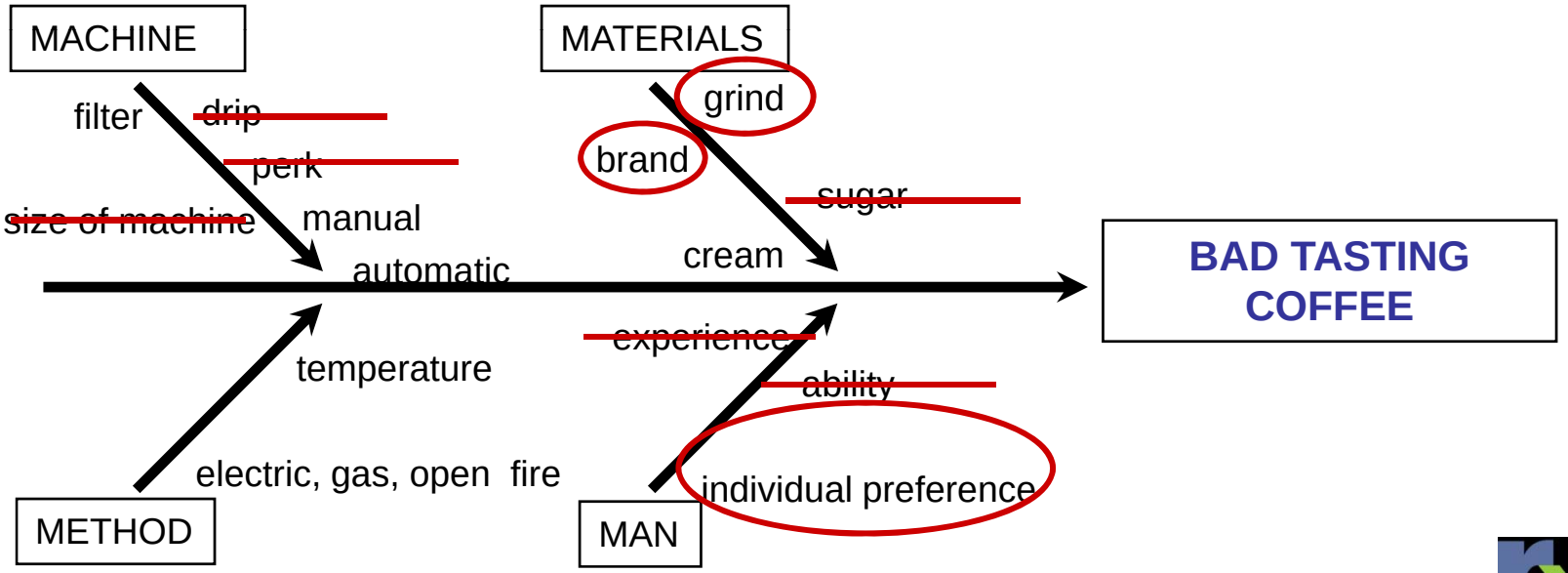
Cause & Effect Analysis – Fishbone Diagram (cont.)

Step 5 Eliminate the trivial, non-important causes.



Cause & Effect Analysis – Fishbone Diagram (cont.)

Step 6 Discuss the causes that remain and decide which are important. **Circle them.**



Questions?

Army Medicine Strategy Map

April 2008

Mission

- Promote, Sustain and Enhance Soldier Health
- Train, Develop and Equip a Medical Force that Supports Full Spectrum Operations
- Deliver Leading Edge Health Services to Our Warriors and Military Family to Optimize Outcomes

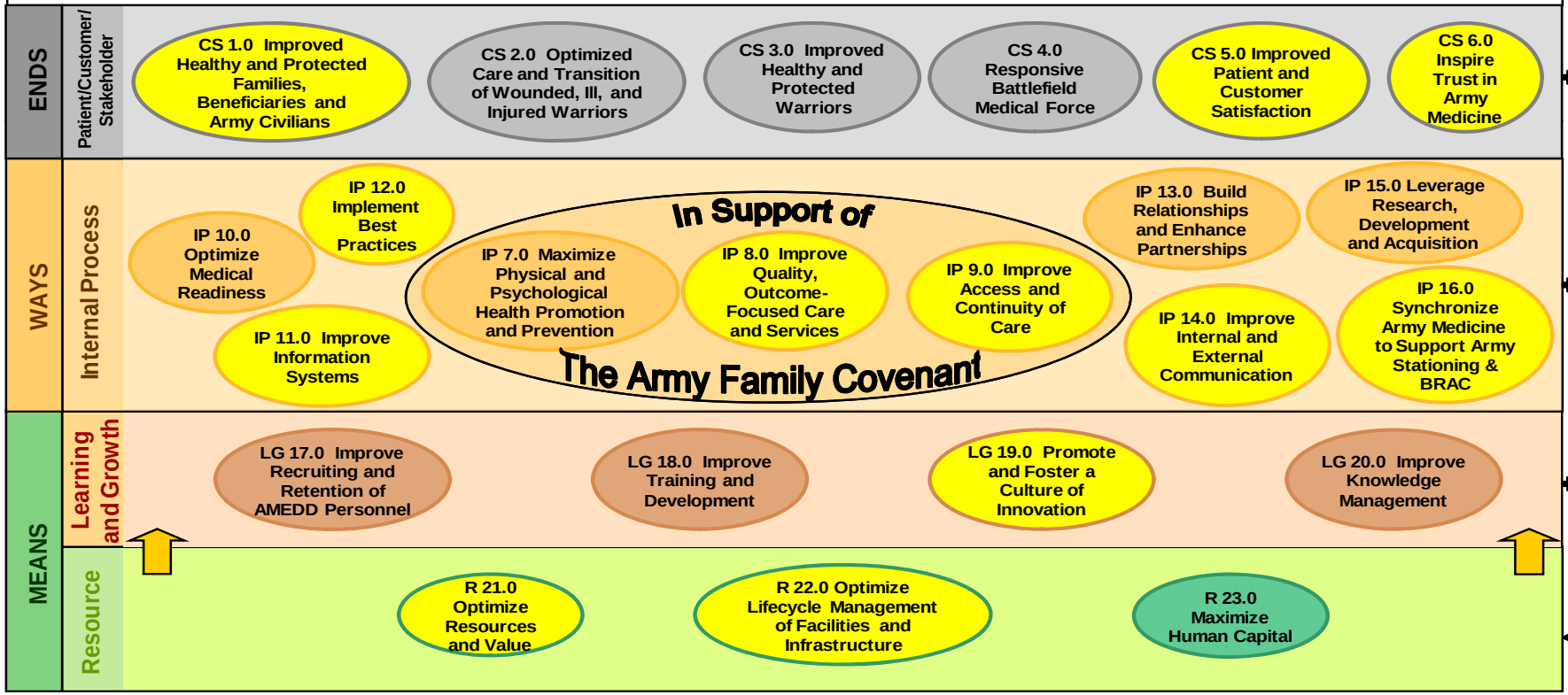
Vision

America's Premier Medical Team Saving Lives and Fostering Healthy and Resilient People
Army Medicine...Army Strong!

Strategic Themes

- Maximize Value in Health Services
- Provide Global Operational Forces
- Build the Team
- Balance Innovation with Standardization
- Optimize Communication and Knowledge Management

SUSTAIN PREPARE RESET TRANSFORM



This is a dynamic, living document

= CofS Accountability

For more information go to: https://ke2.army.mil/bsc