Maintenance Strategy Reviews

Defining maintenance strategies and documenting Maintenance Plans

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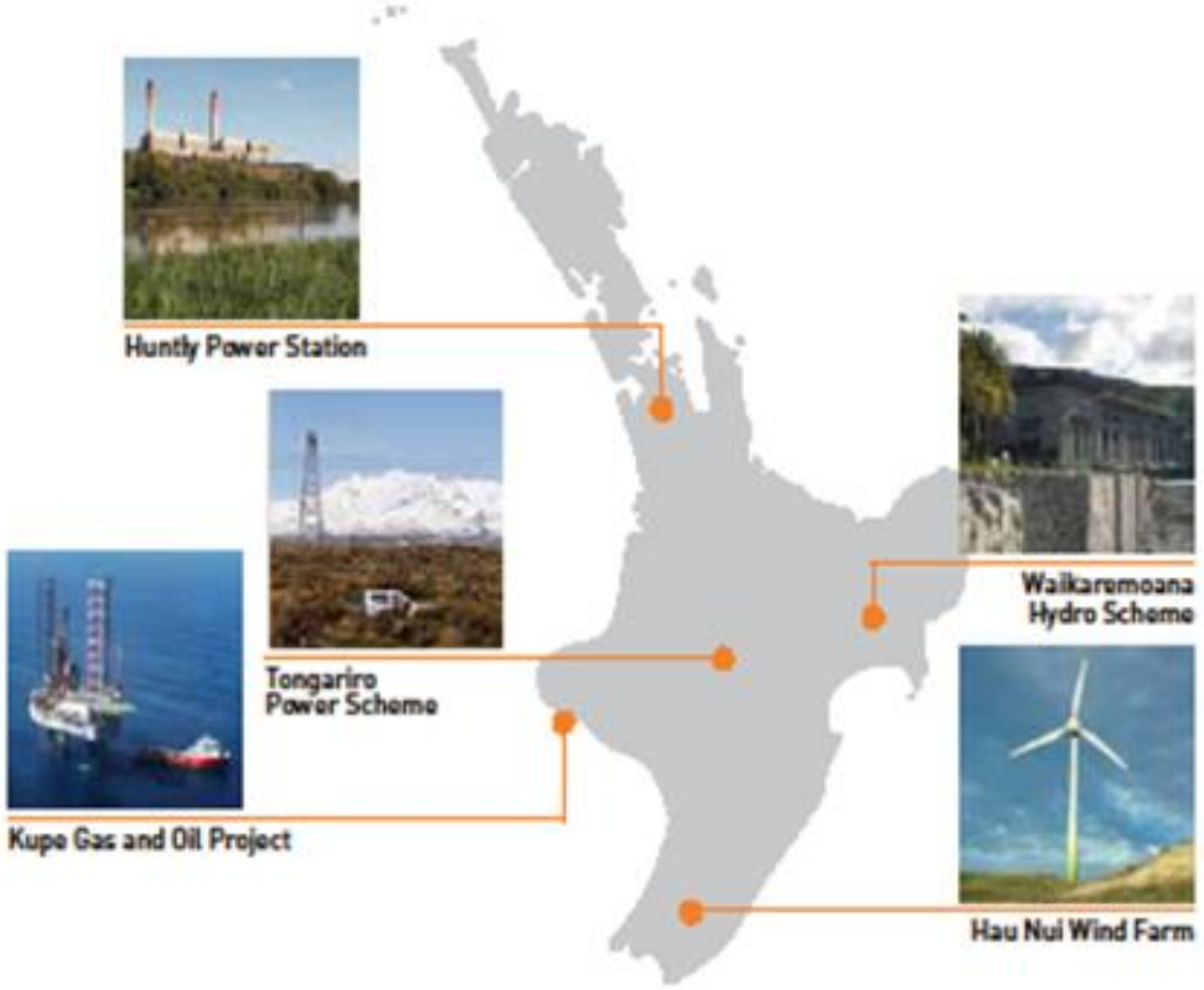
Introduction

— *“Doing the right things, on the right assets, at the right time”*

This presentation steps you through the journey that Genesis Energy is undertaking to review maintenance strategies across our Hydro and Thermal generating assets.

- **Background**
- **Problems / current state**
- **Framework and process**
- **Implementation and Progress**
- **Results and Benefits**
- **Questions**

North Island

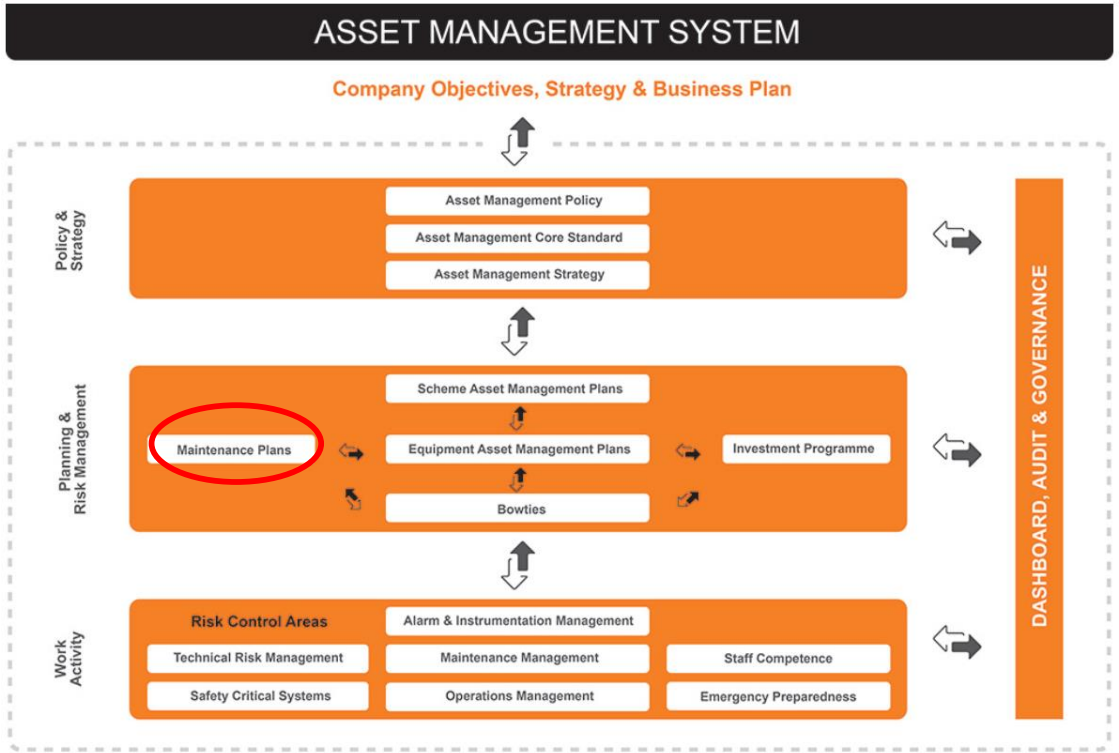


South Island

Asset Management System

— Progress to date…

- AMS Genesis Energy's Asset Management System (AMS) has progressed over the past 5 years, aligned to ISO 55000 and using process safety foundations.
- Bowties and Equipment Asset Management Plans (EAMPs) are in place, and are informing our Process Safety Dashboard, and asset investment programme
- This work has been developed based on current maintenance and operating practices (with some reviews and changes completed along the way)

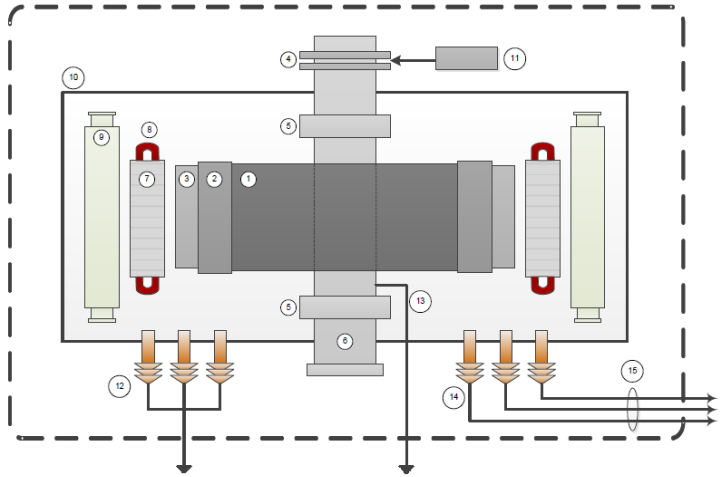


Asset Groups

— Boundaries are defined to align with technical accountability

Engineering Category	No.	Core Asset Group	EAMP Title
Electrical	1	Thermal Generators	Thermal Generators
	2	Hydro Generators	Hydro Generators
	3	Transformers	Transformers - Generator Transformers
			Transformers - Other Transformers
	4	Motors	Motors
	5	Cables & Earthing	Cables & Earthing
	6	EHV Distribution	EHV Distribution
			EHV Transmission Lines & Structures
	7	HV/LV Distribution & Protection	HV and LV Distribution
			Thermal & Hydro Generator Protection Systems
	8	DC Systems & UPS	DC Systems & UPS
Control Systems	9	Thermal Control Systems	Thermal Control Systems
	10	Hydro Control Systems	Hydro Control Systems
	11	Field Instrumentation	Field Instrumentation
	12	Systems Architecture and Applications	Systems Architecture and Applications
	13	Communication Systems	Communication Systems
Mechanical	14	Boilers & HRSG	Boilers
			High Energy Pipework
			HRSG
	15	Mechanical Auxiliary Plant	Condensate & Feedwater
			Compressed Air Systems
			Cooling Water (Hydro)
			Cooling Water (Thermal)
			Water Treatment Plant
			Screen cleaners
			Gas Systems - (non-fuel)
			Drainage & Dewatering
	16	Thermal Turbines	Gas Turbines
			Steam Turbines
	17	Hydro Turbines	Hydro Turbines
	18	Fuel Systems	Ash Plant
			Coal & PF Systems
			Fuel Gas System
			Liquid Fuels System
	19	Facilities	Ancillary Systems
			Diesel Generators & Pumps
			Fire Protection
			Water Services
	20	Cranes and Lifting Equipment	Cranes and Lifting Equipment
Civil	21	Hydraulic Structures	Dams
			Low Pressure Conveyance
			Penstocks
			Shafts & Tunnels
	22	Civil Structures	Buildings & Structures
			Roads, Bridges and Drainage
Other	-	Asset Systems & Information	Generation Systems & Information

- Boundary diagrams clarify what is included / excluded from each plan



	Item	Component	Scope / Terminal Points
	1	Rotor body (hub/spider)	All sections between the shaft and rim
	2	Rotor rim	Rotor section between the rotor body and poles, including female dove tail
	3	Rotor poles	Pole body, field winding, damper winding, male dove tail, wedges, keys and series connections (palms)
	4	Slip rings	Including brush gear assembly and dust extraction system
	6	Shaft	From the turbine coupling upwards
	7	Stator core	Laminated core, including through bolts, clamping plates and ventilation ducts
	8	Stator winding	HV winding bar or coil, including phase and neutral rings, leads, PD couplers and surge rings
	9	Coolers	Including filters, rotor fans, instrumentation and pipework
	10	Stator casing and frame	Core frame, outer casing, covers and hatches
	11	Excitation System / AVR	Including power supply, excitation transformer, and DC output at the slip rings
	12	Neutral terminals	Including busbars, links, star point and bushings
	13	Shaft Earthing	Brush and cabling
	14	Phase terminals	Including busbars, links, star point and bushings
Exclusions	15	HV Cables	Including, insulators, IPB, insulating oil, bus duct, bellows, seals, breathers and support structures Note: HV cables are covered under the Cables & Earthing EAMP
	5	Bearings	Upper and Lower – Guide and Thrust Note: Bearings and Lubrication Systems are covered under the turbine EAMP
		Main Earth	Main Earth circuits are covered under the Cables & Earthing EAMP

Current State / Problem

— Maintenance of our Generation Assets

- **What is done?**

  Captured in PMs, JPs and procedures in Maximo (information spread across multiple locations)

- **What should be done?**

  Not always defined well

How can we effectively review and optimise our maintenance when it is difficult to see everything we currently do, and without a basis defined for what should be done.

Maintenance Strategy Reviews

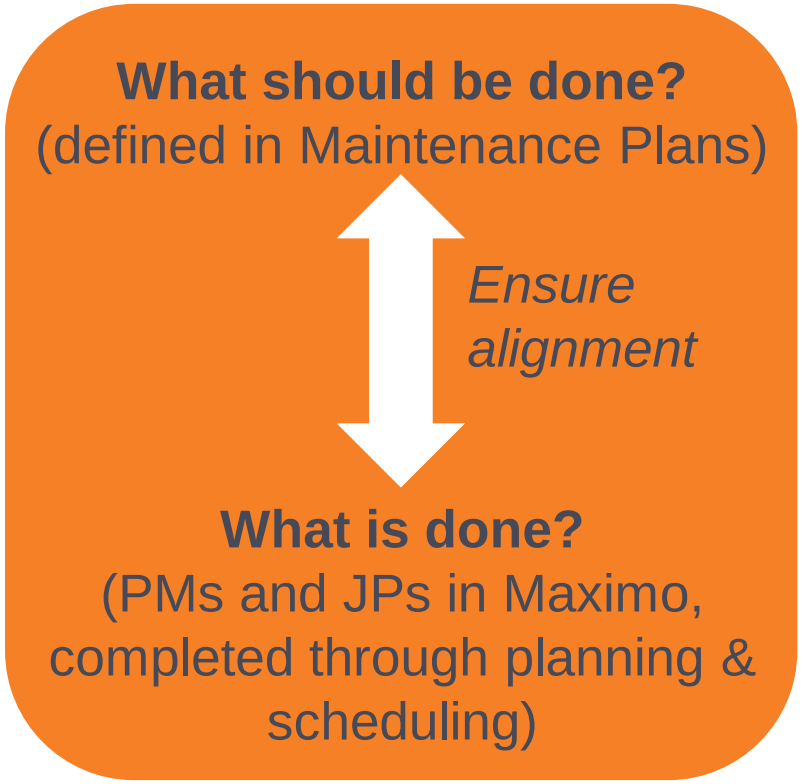
- **Step 1: Develop FMECAs for equipment types and publish Maintenance Plans for each EAMP area. These will define what should be carried out and justify why the tasks are required.**

  – what failure or risks are we mitigating by completing this maintenance?

- **Step 2: Review current maintenance practices (PMs and JPs in Maximo) and complete updates to align our scheduled maintenance to the maintenance plan requirements**

  – ensuring we are completing the right work on the right assets, at the right time.

MSR Process



What is a FMECA

— Failure Mode, Effects and Criticality Analysis

- Failure Modes and Effects and Criticality Analysis (FMECA) is used to identify potential failure modes and consequences of equipment failures. This helps identify appropriate Maintenance Tasks to eliminate / reduce the probability or consequence of failures.

- the FMECA process provides a method to:
  - Identify and assess generic and/or asset specific failure modes
  - Identify tasks to mitigate the effects or likelihood of the failure modes
  - Identify the risks of making changes to Planned Maintenance

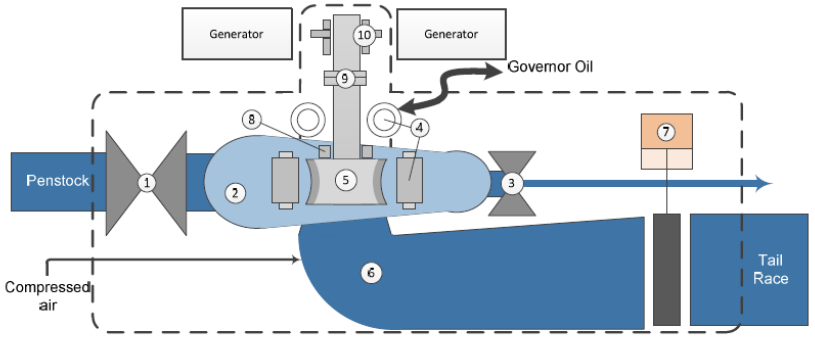
- The FMEA forms the basis of what, why and when we undertake maintenance on our assets.

How can it fail?

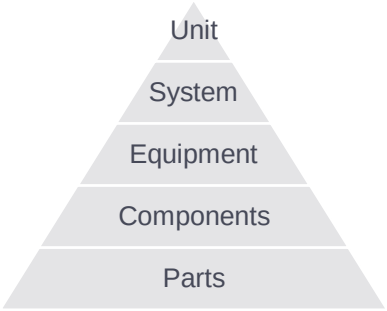
What is the impact?

How can we mitigate the failure?

FMECA Example



Item	Component	Scope / Terminal Points
1	Main Inlet Valve (MIV)	Including Main inlet valve, actuating gear/hydraulic power packs and bypass/priming valves, up to spiral case inlet. Tekapo head gates are covered under the hydraulic structures EAMP. The penstock section between the MIV and scroll case at TKU G1-G4 is excluded.
2	Scroll case and stationary assembly	Scroll case, stay vanes, top/bottom covers, cheek plates & stationary wear rings.
3	Relief valve (RV)	Includes the relief valve and valve actuating gear.
4	Wicket gates and actuation assembly	Includes wicket gates, wicket gate links, swing rings, swing ring links and governor servo motors up to oil inlet and outlet ports.
5	Runner	Includes runner, nose cone and shaft coupling bolts.
6	Draft tube and air admission	Main draft tube, relief valve draft tube, drain valves and air admission systems
7	Stop logs and lifting assembly	Includes removable draft tube stop logs and their associated lifting assemblies. Tokaanu features permanent installation draft tube gates.
8	Turbine bearing	Vertical guide bearing assembly, seals, packing and circulation/filtration system. Tuai G1 – G3 turbine bearings are horizontal combined thrust/guide bearings. Tekapo A turbine bearing is a water lubricated Thordon bearing.
9	Shafts and couplings	Includes turbine and generator shafts and shaft couplings.
10	Generator bearings	Includes complete vertical upper guide/thrust bearing assembly, lower guide bearing assembly, seals, packing and circulation/filtration systems. Tuai G1 – G3 generator bearings are horizontal guide bearings.
Exclusions	Penstocks	Refer to the EAMP for Penstocks
	Cooling water system	Cooling water supply to bearing heat exchangers and stator coolers is excluded. Refer to the EAMP for Hydro Cooling Water
	Compressed Air	Refer to the EAMP for Compressed Air Systems



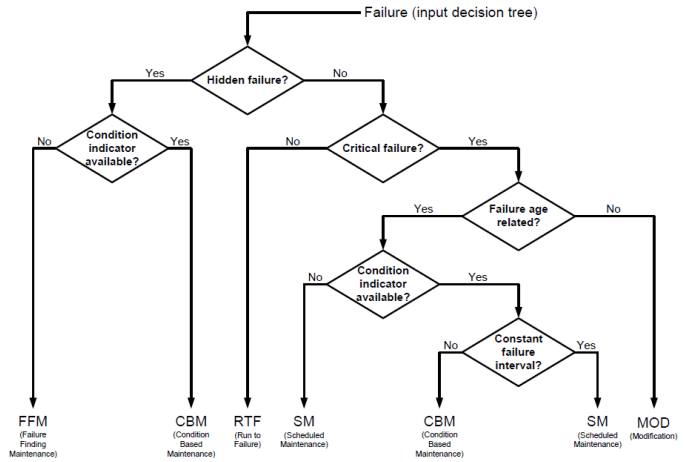
Component	Part	Failure mode	Maintenance task type	task description	Frequency
Spiral Casing		Cracked/Fractured/broken	Inspection Task (Physical CM)	UT inspection of spiral casing welds	5y
Spiral Casing		Leakage	Inspection Task (Physical CM)	inspect SC flanges for leaks, note amount and location	1y
Spiral Casing		Collapsed/Compressed/Deformed	Inspection Task (Physical CM)	Record depth, area and location of corrosion	4y
Top Cover		Cracked/Fractured/broken	Inspection Task (Physical CM)	Tap test top cover studs UT inspection of top cover studs	4y
Top Cover		Leakage	Inspection Task (Physical CM)	visual inspection and record location and amount of top cover leaks	1y
Bottom Cover		Leakage	Inspection Task (Physical CM)	visual inspection and record locationand amount of bottom cover leaks	1y
Runner		Cracked/Fractured/broken	Inspection Task (Physical CM)	visual inspection for cracks on runner vanes (possible UT)	4y
Runner		Surface deteriorated	Inspection Task (Physical CM)	visual inspection and record location and depth of cavitation on runner	4y
Runner	seals	Surface deteriorated	Inspection Task (Physical CM)	measure seal clearances of runner seals	4y
			Inspection Task (Physical	check unit alignemnt, measure runner seal	

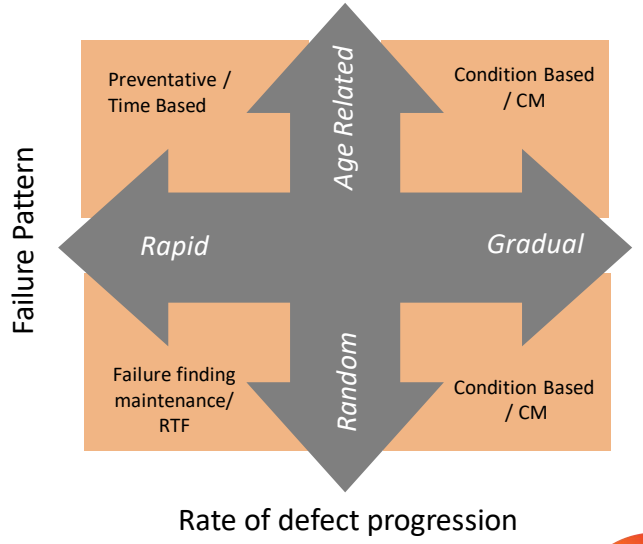
- Expand hierarchy and record FMECA.
  - More columns are added for additional details
  - Different frequency for different equipment classes/ health/ service factors

Determining Maintenance Tasks

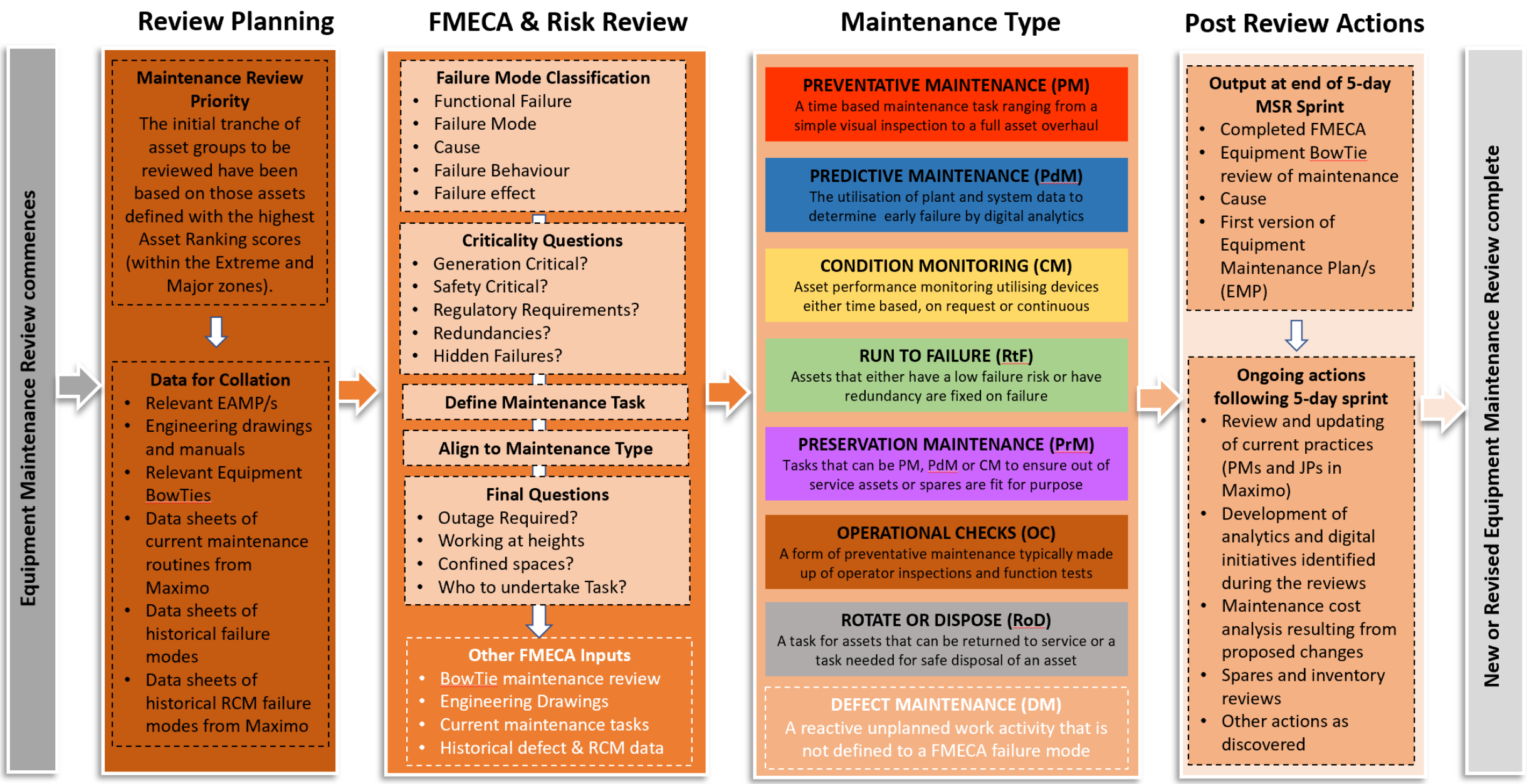
- Once a failure mode is identified and understood, tools can be used to help determine an appropriate and effective Maintenance Task / Type

- Assessment must also consider;
  - Regulatory / Statutory requirements
  - Impact of failure
  - Alternative methods or new technology (e.g. predictive analytics)
  - Spares holding/availability
  - Ease of defect identification
  - Cost of implementing condition monitoring





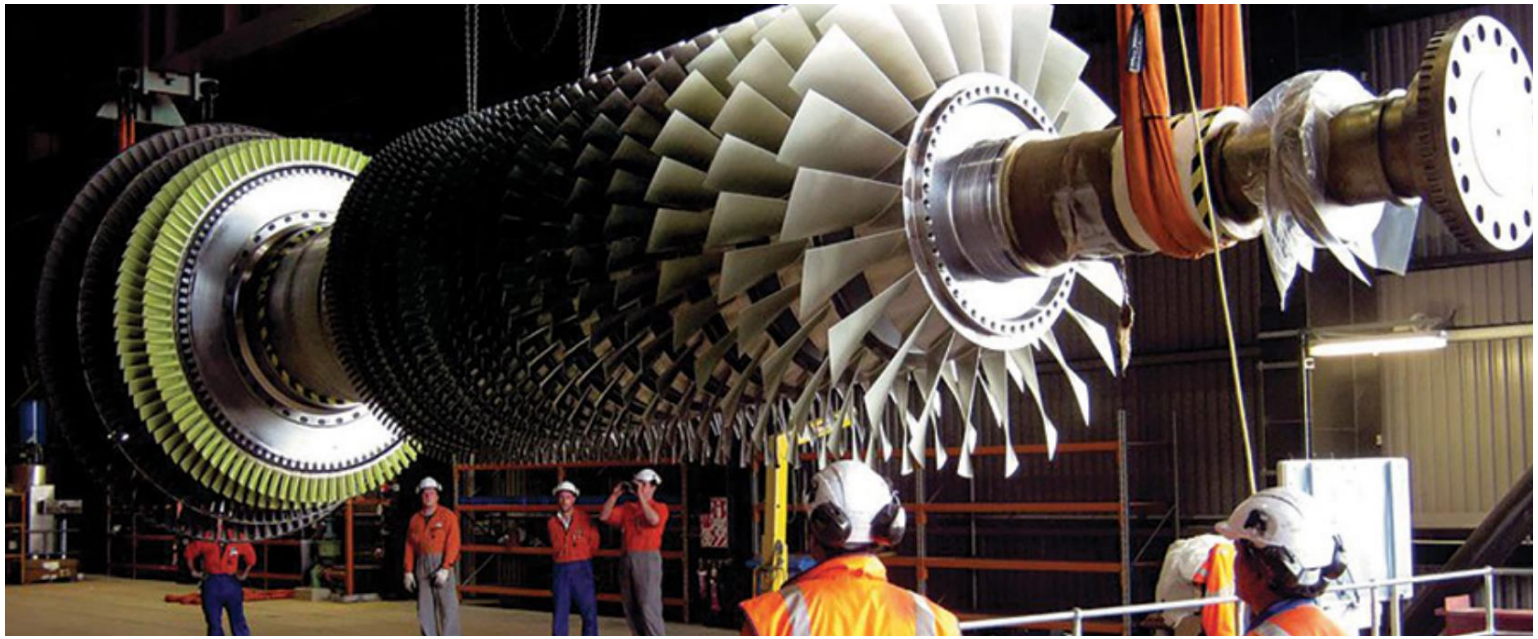
Development process diagram



Content of a Maintenance Plan

— Information included in an Equipment Maintenance Plan

- Asset Summary
- Strategy Overview
- Maintenance Types and Tasks
- Critical/ Emergency Spares
- Maintenance Data
- Maintenance Expenditure
- Support Contracts
- Improvement Actions
- links to FMECA and EAMP



Implementation and Progress

— 5 day dedicated workshops

Dedicated week blocks (sprints) for each asset group or combined asset groups. These follow the principles of an agile sprint and are customised to suit the needs of the MSR.

Commitment required from participants to assist in preparation and participate for 5 days with minimal interruption.

Actions recorded for ongoing work outside of the sprints.

15 Asset group MPs completed to date, work ongoing…

Who are involved

— Resource requirements

MSR Sprint (1 week)

Technical Authority + Site O&M Support

the knowledge, experience and participation from the Site Maintainers and Operators is a vital contribution to the MSR process as the outcomes will materially affect them too.

Asset Strategy team support

Support from the Asset Strategy team to define the process and tools, facilitate the sessions and help record results

Ongoing

Resource Planners, Technical Authority and site based O&M teams

Will be required to assist with review and update PMs and JPs to align with Maintenance Plan outcomes.

Asset Strategy team support

Support from the Asset Strategy team to track actions and clarify requirements

Outputs

— Outputs of the sprint, and ongoing actions

Outputs of the 1 week sprint:

- FMECA
- Maintenance Plans
- Bowtie maintenance reviews

Ongoing actions after completion of each sprint include:

- *The review and updating of current practices (PMs and JPs in Maximo)*
- *Development of analytics and digital initiatives identified during the reviews*
- *Maintenance cost analysis resulting from proposed changes*
- *Spares and inventory reviews*

Why is this important

— What we are getting for our effort

- Opportunity to challenge current maintenance practice, introduce more condition monitoring, condition based maintenance (predictive maintenance, data analytics)
- Clarity in approach to maintenance – consistency across portfolio
- Reduced defect spend through improved, accurate maintenance strategies and process
- Reduced risk of asset failure through detailed review and targeted maintenance plans
- A basis to improve ability to review maintenance practices in more detail, on a more frequent basis
- Risk awareness of each maintenance task - Identify risk associated to optimising PMs
- Enables improved defect/failure analysis


Questions
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