ABOUT ARMS RELIABILITY ENGINEERS

PROBLEMS WE SOLVE

Companies engage ARMS to:

- To build Reliability into their Design on major capital projects
- Reduce the high cost of unplanned maintenance, eliminate lost revenue caused by unplanned maintenance and escape a reactive maintenance culture.
- Evaluate existing plant performance and identify bottlenecks and improvement opportunities.
- Help them quantify whether their current maintenance strategy for new or existing equipment is able to deliver the required business results
- Eliminate recurring problems
- Escape a reactive maintenance culture

SOLUTIONS WE OFFER

ARMS provide complete Reliability solutions to:

- Perform RAMS analysis on major capital projects
- Perform RCM studies
- Perform System Availability Analysis
- Perform Maintainability Analysis
- Produce Maintenance documentation and load to Asset Management System
- Provide training in Proactive Reliability methods
- Empower our clients to develop, implement, sustain, and continuously improve asset management strategies
- Introduce Root Cause Analysis programs that are sustainable.
- Facilitate Incident Investigations.
- Develop new maintenance plans.
- Optimize existing maintenance plans.
- Document the work instructions with criticality, resource predictions, zero based budgets and implementation roadmap.
- Build the skills to perform reliability improvement studies
- Perform Data Analysis
- Facilitate Root Cause Analysis Investigations
- Integrate Reliability with Enterprise Asset Management.
- Provide training in SIL analysis
- Undertake SIL analysis studies
- Evaluate RBI application.
- Manage setting up RBI programs
- Our team of expert engineers are available for small one off jobs or large projects, and can provide an ongoing support service to ensure your in-house teams have expert coaching, mentoring and/or projection execution services at their finger tips.

RAMS Software:

ARMS Reliability Engineers sell a complete suite of Software tools to perform Reliability Prediction, conduct FMECA studies, build Reliability Block Diagrams, perform RCM, simulate System Availability, build Fault trees for Risk analyisis and SIL verification, perform HAZOPS, calculate Lifecycle Costs, perform Root Cause Analysis and implement effective Failure Reporting And Corrective Action System (FRACAS).

These tools are applicable for RAMS studies on new projects, Reliability studies on equipment, optimization studies of existing equipment, risk and hazard studies for risk mitigation studies, SIL verification, and to support establishing a proactive reliability culture in your asset management system.

As a full service provider ARMS Reliability Engineers will not only implement software but also train and provide expert project and call-off services.

Reliability Training

ARMS deliver practical, hands-on courses to help you learn how to implement a wide variety of RAMS methodologies into your organization. Our courses are interactive and our teaching style is to promote learning by experience. Students leave our training courses with valuable insights into how to be more effective in making decisions to reduce risk and maximize the reliability and availability of their assets.

We offer training courses either as public or in-house in the following subjects:

- Root Cause Analysis
- RAMS Analysis
- Reliability Centered Maintenance
- System Availability Analysis
- Faultree Analysis
- Reliability Methods
- Hazop Studies

Consulting Services available for new or existing projects

- RAMS Analysis for New Projects
- Maintenance Plan Development
- Asset Management Audits
- System Analysis
- Failure Data Analysis
- RCM Studies
- Master Data Loading
- Spares Optimization
- Reliability Of Design Evaluation
- Maintenance Requirement Analysis
- Reliability Prediction
- Evaluating RBI programs
- Manage set up of RBI system
- Lifecycle Cost Studies
- Fault tree studies
- SIL verification
- FMEA
- Zero Based Budgeting
- RCA Facilitation
- Evaluation Of Existing Maintenance Programs
- Criticality Analysis
- Opportunity Assessment
- Bottleneck Studies
- Implementing Enterprise portals with SAP, Maximo, Ellipse

CONTACT DETAILS

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Case Studies

A sample of recent and current projects, using RAMS to predict reliability and capacity:

- Anaconda Nickel Project (2001)
- Comalco Alumina Refinery Stage 1 Design (2001)
- Kennecot Utah Copper Refinery (2002)
- Queensland Alumina FFE Project (2002)
- Zinifex Century Mine (2003)
- Alcan Gove Stage 3 Expansion (2003)
- Comalco Weipa Bauxite Mine Expansion (2003)
- Orica Ammonia Storage – Gladstone (2003)
- Dalrymple Bay Coal Shipping Terminal (2003)
- QNI Yabulu Refinery (2004/5)
- Snowy Mountains Hydro-electric Scheme (2003/2004)
- Comalco Alumina Refinery Stage 2 Design (2004)
- BMA Blackwater, Coal Prep Plant. (2005)
- Qld Nickel existing plant and new expsnion (2004/5)
- SE Water (2001-5)
- US Coast Guard (2006)
- Australian Geoscience Early Warning Tsunami System model (2006)
- WaterCare Water network models (2006-9)
- Comalco Boyne Smelter (2001-5)
- Argyle Diamonds Crushing Plant (2006)
- Guinea Alumina Refinery Project (2007)
- BHP Olympic Dam Expansion (2007-2008)
- Wood Group Combined Cycle Power Plant(2008)
- BHP Cannington Proposed Expansion Project (2008)
- BHP Iron Ore “East Yard: Car Dumper 3 to Shiploader 3” reliability model (2009)
- Ravensthorpe Desalination plant (2008/9)

Why Use RAMS on Major Projects?

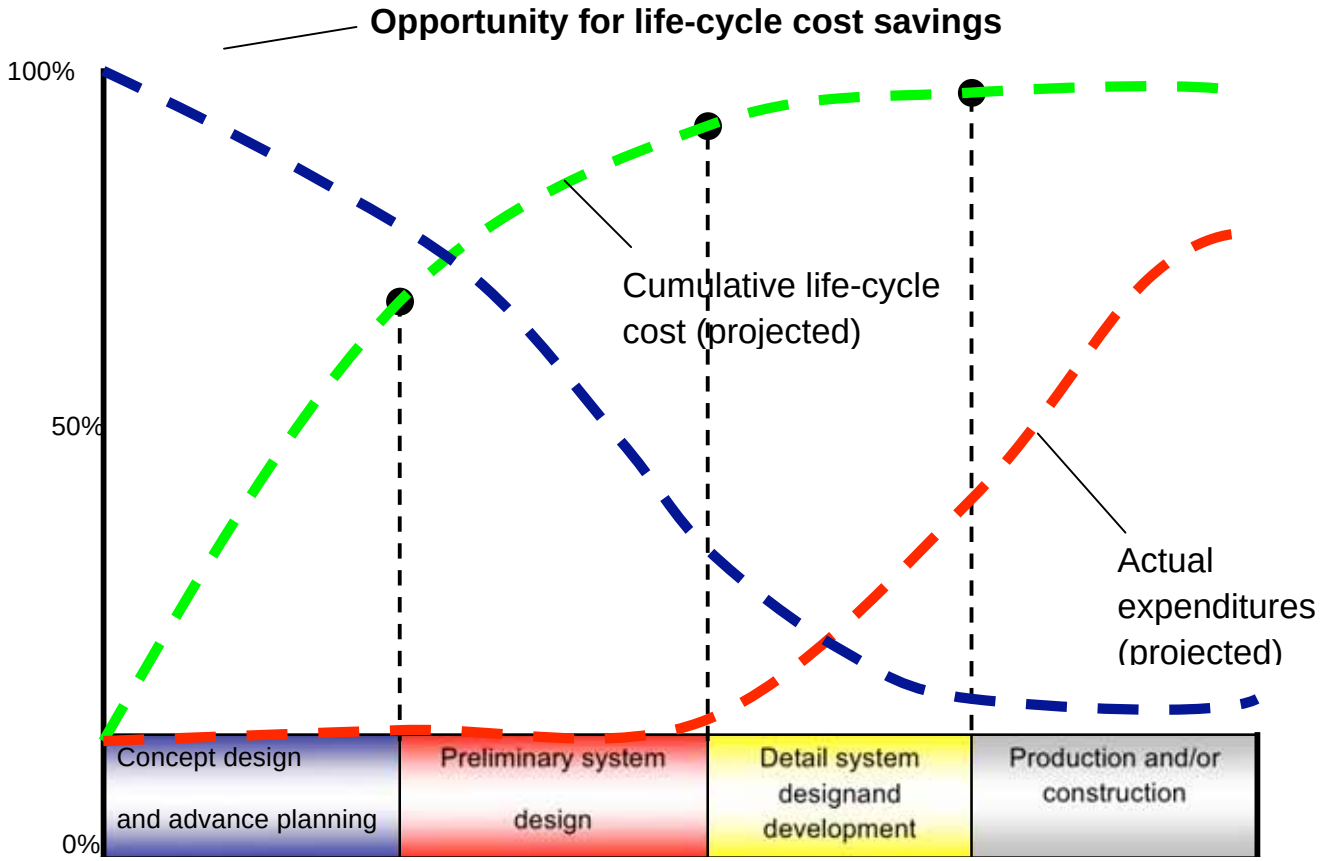
- RAMS for new projects in defence, aerospace and upstream oil industry has been common for past several decades.
- RAMS for new projects in mining, resource and energy sector is less common.
- Some companies with multibillion dollar projects are now specifying RAMS analysis within their major project schedules.
- This presentation looks at how and why it is done

Can you answer these Questions?

- Will the design meet the objectives over the lifetime?
  - Is there enough redundancy?
  - Are stockpiles, surge and buffers correctly sized?
  - Identify bottlenecks.
  - Will my maintenance strategy deliver what the design expects?
  - How many resources will be required and when?
  - How many spares will I need?
  - How do I develop a maintenance plan for new equipment?
  - How can I validate the OEM's recommendations?

RAMS As Early as Possible in Project Cycle

- IPA studies have shown that reliability analysis conducted early in project cycle saves 15% of total project costs.



RAMS Flows through to Operational Phase

Front End Engineering

Concept FEL1	Prefeasibility FEL2	Feasibility FEL3	Final Design EXECUTION	Construct^{n}	Start-Up OPERATION
RBD @ Outage	RBD @ Unit	RBD@ Equip Class	RBD @ Equip		
	FMECA@ Prediction	RCM @ Dom Mode	RCM@ Detail	Maint plan/ BOMS/WI's	
		HAZOP Prelim	HAZOP@P&ID		
			LCC		
			FTA		

The benefit of doing RAMS analysis early in a major capital project is that critical reliability issues can be addressed before expensive detailed design and procurement, and certainly making changes prior to construction and commissioning, saves a lot of valuable time and expense. Studies by IPA (Independent Project Analysis), show that better definition of requirements early in the project results in better cost performance overall because improving the project definition reduces the number of changes that occur during its execution, when changes cost more.

In most major capital projects there are many alternatives to achieve required reliability and availability and in many cases such decisions can impact on the financial viability of the project, but these decisions also need to be balanced against the capital cost of construction and the operational expense impact on profitability.

Design engineers need to consider the reliability of equipment under the proposed service conditions, and also the maintainability and supportability considering logistics of supply, access to resources and the available operational windows to repair failed equipment with minimal disruption. In more recent times, major projects need to consider availability of skilled resources to undertake necessary maintenance actions. For these reasons a reliability prediction is used in a reliability block diagram to represent how equipment interconnects in a logical manner and shows the failure logic of a system. Interdependencies between equipment, spares, resources, other equipment and events are clearly represented and allow the reliability engineer to simulate the likely behaviour of the system. Bottlenecks can be identified, equipment importance ranking provides focus to critical areas where design parameters such as redundancy, intermediate storage and equipment sizing can be reviewed and various alternatives evaluated to give the best predicted outcome.

Efficiency

The utilisation of RAMS tools for each phase of a capital project enables the final asset management plans to be created in a streamlined way consistent with the operational objectives of the project. In other projects where RAMS are not used the asset management plans are developed in silos with a lot of duplicated efforts and often biased towards the writer's previous experience. This can result in disjointed maintenance plans which soon lose support and the effort is wasted. In the worst cases no documentation efforts are made and maintenance/operational people come out of plant commissioning still looking for Asset registers, Bills of Materials, and reacting to failures causing them to develop repair procedures on the run. A rule of thumb is that a planned predictive maintenance regime costs 70% less than a reactive regime. This is a lot of expense money wasted, and unfortunately in most cases the cost of failure and associated risk of damage, lost production and safety far outweighs the maintenance costs.

Variables in Major Capital Projects

RAM modeling includes modeling the effect of:

- Labour availability,
- Spares availability,
- Maintenance strategies
- Equipment failure behaviour including infant mortality, random failures and aging.
- Production capacity,
- Size of intermediate buffers such as stockpiles or surge tanks,
- Standby equipment,
- Shutdown intervals,
- System configuration changes.
- Phased changes over time.

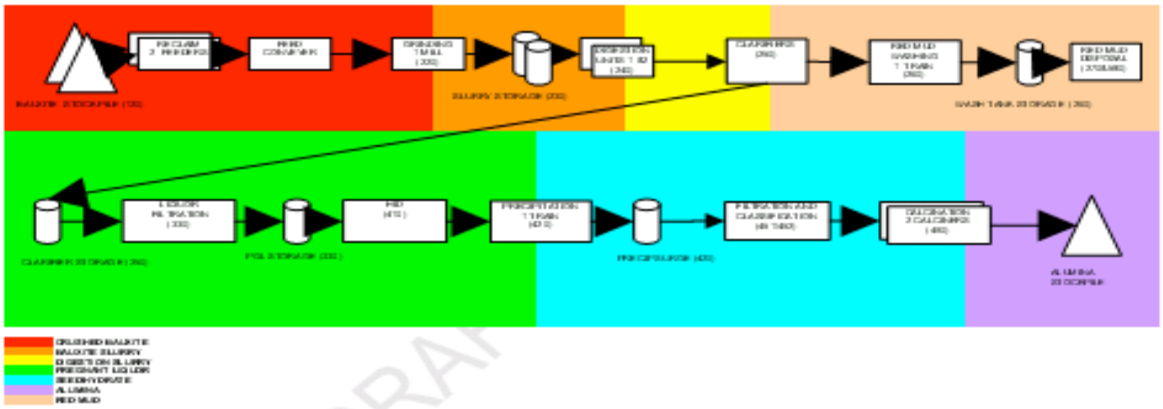
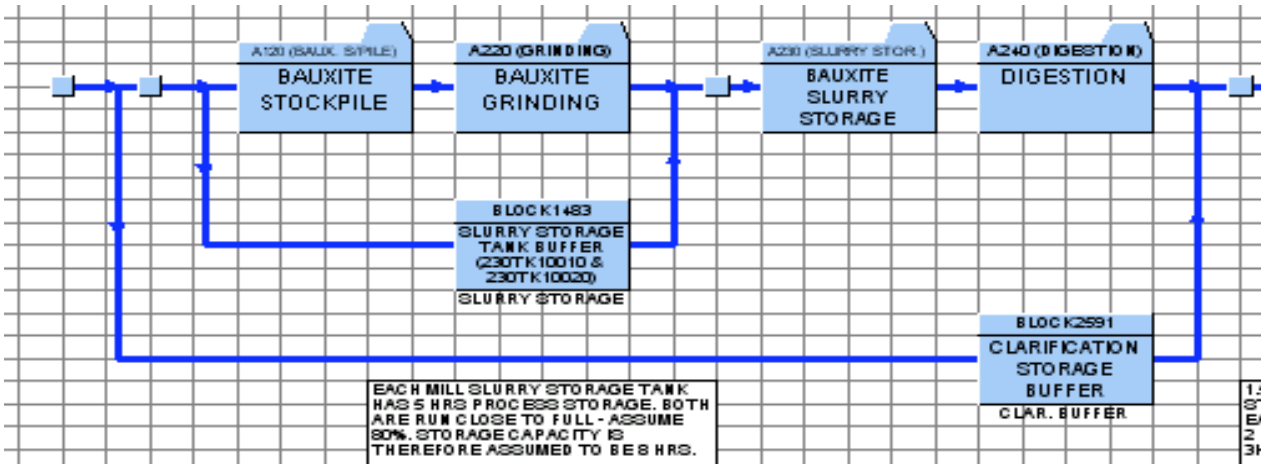
The Monte Carlo simulator engine enables the analyst to model complex redundancies, common failures and component dependencies that cannot be modeled using standard analytical techniques including those listed below.

- Warm and cold standby arrangements
- Queuing for labour
- Queuing for spares from site, depot and factory
- Hold for repair
- Opportunistic maintenance
- Changing failure rates over time

RAMS Outputs

- An early indication of a system's potential to meet the design availability and reliability requirements.
- Enables assessment of lifecycle costs to be carried out.
- An early indication of which components or areas contribute to the major portion of capacity loss.
- Enables trade offs to be made between reliability, maintainability, redundancy and buffer capacity.
- Provides early assessment of Safety and Environmental compliance.
- Identifies Critical items
- Predicts resource usage

Front-End Loading (FEL) 1: Business Planning/Concept Phase

- The primary objective of the Business Planning Phase is to define the opportunity or requirement. After the idea for a possible project has been identified, it must undergo a certain amount of definition. This includes a technical assessment, development of a milestone schedule, and development of an estimated cost range (typically a –25/+40 percent estimate). As the proposed project becomes better defined, a clearly formed business plan can be framed. Concurrently, economic models and business evaluations can assess the proposed project's strategic importance and its business, production, and financial potential.
- ARMS Reliability Engineers offers RBD Construction at a high level for projects in FEL 1, as described below:
- **RBD Construction**
- Build a high level Reliability Block Diagram showing system configuration and major equipment items. The initial concept for the project is broken down into a high level Process Flow Diagram.
- 
- A Reliability Block Diagram is built showing system configuration, redundancy, intermediate storage and outage assumptions.
- 

- The Reliability assumptions for each block or unit are assigned from benchmarking similar projects, vendor specifications for major equipment or reliability databases from industry such as OREDA in the Oil Industry**,** GADS Database from Nth American Electric Reliability Corporation, PERD from American Inst of Chem Engineers.

- The Reliability Block Diagram is used to assess the proposed concept and define the number of critical items used to determine what is required to achieve Availability assumptions in the business case.
- Outputs of interest
    - Confirms proposed design has ability to meet Availability Targets
    - Pinpoints Critical areas

Specialized Analysis

- Allocation of Reliability and Maintainability data to Equipment/Major Units.

Process

- Gather the necessary data and information from the design team and the Build Reliability Block Diagram. The ARMS Reliability Analyst will meet with each project team member and gather drawings, sketches, assumptions and information necessary to build a Reliability Block Diagram that represents the whole project from inputs to outputs. Further information is sought from major vendors, benchmark data from other projects, and specialists input to document reliability and maintainability data. The project is simulated using a monte carlo simulation engine and predicted levels of Availability determined. Availability predictions can be drilled down from the high level view through areas, systems and major items. Importance ranking lists provide guidance to the team as to where critical items are that need to be addressed. This first pass analysis is intended as a first pass validation of project viability.

Project Assistance

- RAMS Model workshop with Technical, and Engineering representatives to identify critical areas and to discuss alternative strategies to meet Availability Targets.

Deliverables

- ARMS Reliability Engineers will deliver a report that reports the overall predicted Availability. The critical areas are listed in order of importance and all major assumptions documented. The report will highlight major areas for improvement, and may also compare alternative scenarios.

Front-End Loading (FEL) 2: Scope Development

- The activities in the Scope Development Phase concentrate on selecting the right alternative and work scope by improving project definition and evaluating (thus, eliminating) alternatives; the emphasis has moved from business evaluation to technical evaluation.

- The major activities include conceptual process design, technology and site selection, and development of project execution strategies and a preliminary scope of work, which allows a more accurate cost estimate (–15/+25 percent) and schedule estimate to be made. Further, business objectives are clarified/revalidated, risks are identified, project objectives are created, and the business case is updated.

- ARMS Reliability Engineers offers several different products and services for projects that have entered or completed FEL 2, including Reliability Prediction, FMECA, Availability Simulation, Lifecycle Costs Calculations.

Reliability Prediction

- The level of project definition increases in FEL 2 whereby the emphasis moves from concept and unit/system assumptions to a lower level of definition at equipment level. Predicted Reliability at this level comes from Reliability Prediction Standards, Industry Libraries, similar projects.

Reliability Prediction provides early visibility of potential reliability issues.

Specialized Analyses

Reliability Data for Equipment

Reliability library and prediction data can be useful, however it is often not specific enough to provide a good guide to many industrial applications in mining, manufacturing, transport and utilities. Often more detailed assessment is required by a specialist who can not only assess failure rate data but also failure mode behaviour. An understanding of dominant failure behaviour such as creep and fatigue in fired components, or stress corrosion cracking and erosion corrosion in industrial liquors, or wear and abrasion for mills and liners. In order to perform a Reliability Prediction for this type of equipment, a reliability specialist is required. ARMS Reliability Engineers have experience in documenting dominant failure behaviour of major equipment in a wide cross section of industry.

Reliability Block Diagram

Equipment Reliability data is added to the Reliability Block Diagram down through units and systems to equipment level. Provides greater level of detail to design team regarding type of equipment required, level of redundancy, hot, cold or warm standby policies, consideration of outage windows for maintenance or process functions such as cleaning, regeneration, mandatory inspections, etc.

FMECA/RCM DESKTOP

The equipment data can be used in a FMECA study whereby dominant failure modes are considered, the effects of failures are assessed to identify any critical failures that require risk mitigation or redesign.

Lifecycle Cost Calculation

Identification of major equipment items often occurs early and it is usually desirable to investigate the selection process as early as possible for long lead time items. A Lifecycle cost evaluation to compare major equipment options will assist the team and procurement officers, what equipment has least cost over the assumed life of the project. A good lifecycle cost structure will consider sustaining and disposal costs – not just procurement costs. Maintenance requirements, sparing policies and cost of failure impacts all need to be factored into this study. ARMS Reliability Engineers can calculate and compare scenarios providing lifecycle cost comparisons using escalation rates and NPV.

Process

ARMS Reliability Engineers will work with design engineers, and discipline specialists, to document equipment requirements. The Reliability specialist will seek best available reliability data from databases, prediction standards, vendors, other industry users, industry bodies and perform literature searches where required. Where necessary he will facilitate a process with design engineers to document best assumptions.

Project Assistance

Provide specialist Reliability expertise to collect data, perform RCM Desktop study, Update Reliability Block Diagrams and facilitate FMECA and LCC studies.

Deliverables

ARMS Reliability Engineers will deliver a report that reports the overall predicted Availability. Major outages for maintenance periods will be documented and underlying assumptions described. Predicted Failure Effects will be established and can be compared to risk thresholds. List of critical items will be reported. Lifecycle cost Studies comparing whole of life comparison for major equipment items and critical assumptions will be reported.

Front-End Loading (FEL) 3: Project Planning

- The focus of the Project Planning Phase is on creating a detailed scope of work for the project and developing an execution plan that will support the safe and efficient design, construction, and commissioning of that scope of work. FEL 3 takes the basic design package that was put together in FEL 2 for the selected alternative and progresses that package to a point that will enable a control estimate to be developed. Typically, this degree of definition corresponds to 20 to 30 percent of engineering complete.

- In this phase often called feasibility or definition phase, the reliability estimates are drilled down to failure mode level. Failure parameters that reflect likely in-service behaviour are assigned and maintainability assessments are performed to provide detailed maintenance requirements. The RCM process is employed to develop the optimized maintenance requirements including, inspections, monitoring, periodic refurbishment or replacements, adjustment, cleaning and any mandatory requirements.

- Grouping of tasks are made to ensure resource efficiencies and minimal production impact through alignment of activities across the project so that shutdown requirements are optimized.

- The optimized maintenance plans are factored in the reliability block diagram along with individual equipment capacity, surge, and stockpile sizes, rundown rates etc. The resulting RBD can now simulate the maximum production capacity of the plant.

- The “Plant model” can now be used to verify design, identify bottlenecks, ensure appropriate sizing, produce detailed maintenance requirements and resource estimates, predict spares, and predict labour requirements.

- A One of the goals for capital projects nearing the end or at the end of the FEL 3 stage is to determine if a particular capital project is ready for full-funds authorization,

Project Validation

Availability and Plant Capacity Model

- Maximum plant capacity determination based on detailed reliability, maintenance and modelling of plant design. Used to validate project objectives.

Specialized Analyses

Equipment Reliability Review

- A study to pull together all inputs from designers, vendors, industry and other users and to assign reliability and maintenance parameters.

RCM Analysis

- Maintainability analysis, Sparing requirements are incorporated into RCM study to document equipment maintenance plans.

Hazop studies

- Helps project teams consider critical equipment, identify potential hazards and risk mitigation requirements to be reflected in the design or maintenance plans.

Execution

The execution phase is defined by IPA as the period from the start of detailed engineering to the end of construction (mechanical completion). During this phase, the project team is converting the process development package that was developed for the authorization estimate and schedule into detailed engineering drawings that will be used for construction of the project. The maintenance assumptions are an important part of the Project design and these need to now be reflected in the asset a management system ready for deployment in the operational

phase. The execution phase is considered complete when the project is mechanically complete and the project team is transitioning the project to the startup team members.

ARMS Reliability Engineers offers several products and services to teams that have entered the execution phase to guide them through execution or to assist them in the next phase of the project life cycle, as shown below:

Setting up the Asset Management System

Asset Hierarchy

An effective functional asset hierarchy that allows for efficient work planning and deployment, also ensures good historical data capture.

Failure Codes

A problem reporting and failure cause coding system that matches the RCM analysis will ensure optimal contribution to Continuous Improvement processes, and is an important driver of proactive system behaviour.

Bills of Material

Bills of Material at an equipment level provide for efficient maintenance definition. Bills of Material at a maintenance plan level provide for efficient maintenance execution.

Maintenance Plan

The maintenance plan documentation needs to include duration frequencies, resource requirements, types of resources, spares and any special tooling.

Maintenance Instructions

Detailed maintenance instructions include the steps to be completed, any threshold limits, refurbishment standards, special instructions. A maintainability study to identify any special job requirements, materials, tools or equipment. Accessibility needs to be considered, any special precautions or job safety requirements to be considered. A formal Job Safety Analysis assessment should be completed before final work instruction sign off. Work instructions need to be consistent with the maintenance plan, and documentation available to issue with each job to ensure clear understanding of requirements. Work instruction documents may refer to other detailed “how to “ procedures or Vendor manuals.

Asset Management System Assistance

ARMS Reliability Engineers can assist in defining the Master data to be input to the Asset Management System in a way that is consistent with the RAMS assumptions used in the Front End Engineering package, and that can provide for delivery of these in the operational phase.

Operation

Operation is defined by IPA as the period after mechanical completion. This phase includes project startup, which IPA measures from the end of mechanical completion (turnover of a

project to operations) to steady-state operation, regardless if design capacity is reached. It should be noted that IPA's Operability Index is based on the operational performance in months 7 to 12 after mechanical completion.

ARMS Reliability Engineers offers several products and services to teams that have entered the routine operation phase to assist them in maximizing the operability of the project.

Overall Assessments

Availability Model updates

Ensures visibility of any departures from original design intent or simply updates RAMS with any project modifications made. This ensures the reliability view across the whole project remains, will alert to any emerging critical issues and/or changes to bottlenecks.

Specalized Analyses

Root Cause Analysis Training

Provides a consistent methodology across all parts of the project team to define problems, understand causes and find effective solutions. ARMS Reliability Engineers can assist in institutionalizing root cause analysis and defect elimination.

RCM Workshops

The implementers of the maintenance strategy including planners, engineers and technicians need to understand why maintenance plans were put in place and how they can challenge and improve them.