ARTIS Live application

as part of an ISO 55000 Asset Management System

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EXECUTIVE SUMMARY

The ISO 55000-2 series is the international standard, published in 2014, for asset management, that is the coordinated set of activities of an organisation to realise maximum value from their assets in the delivery of its objectives, and it applies to all industries. It is set up around the familiar 'Do – Check – Improve' learning cycle, involving all disciplines, and it outlines the requirements for an asset management system for continual improvement. Other key concepts include risk based decision making and the 'line of sight', providing a shared understanding of how the company strategy and objectives cascade from the top down to targets for all levels of the organisation.

In any business, there is an expectation that every asset will deliver on its promises by achieving its objectives, and a requirement that each asset provide assurance regarding its ability to meet this expectation. A risk based approach to internal control can be the basis for such assurance.

This guideline outlines what it means to develop and sustain a risk based approach, for the dimension of production availability and mission reliability, with the ARTIS Live application as one of the asset management plans, in line with the requirements of the ISO standard. The ARTIS Live application enables the organisation to optimise its responses to the risks to and opportunities for the production availability and mission reliability and maximise the lifetime value of their assets.

ARTIS Live takes a scientific and integrated approach through risk modelling, data collection, optimisation and reporting, with a mathematical background based on probability theory and statistical modelling. Its key advantage is that it provides a corporate model, fully quantified and validated, accessible and understandable for all, up-to-date with the current condition status, for reviewing and optimising the responses to the opportunities and the risks. Assurance is built into every business process and ARTIS Live provides an agreed platform for that.

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Introduction

The ISO 55001 standard sets requirements for an asset management system as part of a risk based internal control system.

For the petroleum, petrochemical and natural gas industries, the ISO 20815 standard provides guidance for production assurance and reliability management during project development. This standard is also risk based and aims to meet the long term supply commitments made and maximise the net present value of the project through the careful selection and definition of design alternatives, taking account of the opportunities and risks through their impact on the production availability.

For the space industry, the ESA standards ECSS-Q-ST-30C – Dependability (6 March 2009), ECSS-Q-ST-30-09C, Availability analysis (31 July 2008) and provide a comparable basis. It defines the dependability assurance programme and the dependability requirements for space systems. In that standard, dependability assurance is a continuous and iterative process throughout the project life cycle.

The Availability Assurance Charter builds on these standards to provide a bridge between the project development and the asset management.

The Availability Tracking and Reporting Information System (ARTIS) is an IT platform that supports the application of the charter, in line with the ISO 55001 requirements.

An ARTIS Live application meets these requirements for the dimension of production availability and mission reliability by implementing the Availability Assurance Charter. It is a risk based management system designed to provide reasonable assurance of achieving the organisation's production availability and mission reliability targets, address opportunities, protect company assets, facilitate effective and efficient operations, and help to ensure transparent reporting and compliance with applicable laws and regulations.

ARTIS Live takes a scientific and integrated approach through risk modelling, data collection, optimisation and reporting, with a mathematical background based on probability theory and statistical modelling. ARTIS can take the current condition of the assets on board to produce short to medium term forecasts of the production availability and mission reliability of the integrated system.

A fundamental difference between an ARTIS Live application and the ISO 55000 standard is that the application aims to optimise the alternative risk responses, based on modelling the net risks and their impact, whereas the standard not necessarily requires a fully quantitative approach nor any integrated optimisation.

In contrast to the ARTIS Live application, traditional risk management approaches are typically based on isolated and qualitative analyses and may have the dangers of fragmented and possibly opinion-based decision making.

1 Scope

This document provides guidance for the application of ARTIS Live, meeting the ISO 55001 requirements and consistent with the guidance provided in ISO 55002, with a single focus on the production availability and mission reliability. It describes how an ARTIS Live application, as part of an asset management system that meets the ISO 55001 requirements, can provide a complete risk management platform, implement the line of sight and close the learning cycle.

It provides a transparent and powerful abstraction of the physical assets that can be used at any scale and with any continuous production system. It can be used by all sizes of organisations.

2 Normative reference

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application.

ISO 55000:2014, Asset management — Overview, principles and terminology

ISO 55001:2014, Asset management — Management systems — Requirements

ISO 55002:2014, Asset management — Management systems —Guidelines for the application of ISO 55001

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 55000 apply.

4 Context of the organisation

4.1 Understanding the organisation and its context

The design of the ARTIS Live application will vary according to the characteristics of the organisation and the context and boundaries within which it operates. A good understanding of these characteristics is key:

- the nature of the business (products and services, asset base, size, customer and supplier factors, industry conditions, competition, market position and condition, ...)

- the culture and operating style within the business (believes and values, 'tone at the top', organisational structures, attitudes, ways of working, management/staff norms and expectations, risk appetite, ...)

- the culture and operating style surrounding the business (beliefs and values, the ways in which society operates, clarity and consistency of legal framework, the expectations of shareholders and other stakeholders, ...)

It is also important to describe the boundaries which exist for the organisation, including:

- the external constraints (the license to operate, laws and regulations, mandatory standards, stakeholder requirements or demands, …)

- the internal constraints which limit freedom of action or choice (values, business principles, mandates, policies, structures, 'givens', …)

Internal boundaries are generally cascaded down through the organisation. The further down in the organisational tree, the more likely a business unit is to sense these expectations as limits, and possibly feel constrained by them. However, these boundaries are an essential part of aligning the organisation's activities and ensuring focus. Establishing boundaries also facilitates empowerment throughout the organisation, because empowerment is only possible when the 'comfort zones' within which each action or decision may be taken are clear and agreed. This is the line of sight.

The ARTIS Live application provides a platform for optimising the organization's production availability and mission reliability targets, cascading these targets down and managing their risks. One possible

use of the line of sight is to raise these targets, for example, this might include a strategic 5-year plan to achieve 'first quartile', 'pacesetting', or 'best in class' performance.

The organisational context may harbour various risks to and opportunities for the application itself, they are not part of it's scope:

- Operations: continuity

- People: commitment, expertise, human error

- Technology: access to new technologies, product development

- Systems: compatibility, interfaces

- Stakeholders: conflict of interest, ability to influence

- Authorisation: ownership, responsibility

- Management: alignment, risk attitude, acceptance

- Confusion: conflicting objectives, internal politics

Depending on the organisational context, there may be additional risks and opportunities. Although not part of the ARTIS Live scope, its application does support opportunity realisation and risk treatment in the wider uncertainty context by providing transparency and that line of sight. In that respect, it fits seamlessly into the asset management processes for continual improvement and enables the organisation to grasp cost effective opportunities in the supply chain. This is commonly referred to as 'sweating the assets', taking advantage of the improved control for reducing both CAPEX and OPEX.

4.2 Understanding the needs and expectations of stakeholders

The stakeholders that are relevant to the ARTIS Live application may include national and local governments, resource holders, joint venture partners, and buyers. In case the application is used for setting supply commitments, the approach may be agreed with the buyers and all stakeholders that have a financial interest in the assets as a quantitative basis for confirmation.

The application provides reporting of the realised performance, which can be used as the basis for balanced scorecard input and external reporting to the stakeholders.

4.3 Determining the scope of the ARTIS Live application

Risks are those factors which could influence the achievement of business objectives. This definition covers both the 'upside' opportunity and the 'downside' hazard – in essence both the helps and the hurts which could move you either towards or drive you away from achievement of your objectives. It is important to identify, assess and determine appropriate ways of responding both to upside risks in pursuit of opportunity and value and to downside risks which could hinder performance or result in losses.

The ARTIS Live application enables the organisation to adopt production availability and mission reliability as a risk based decision making criterion. It covers all assets that are critical to production and all uncertainties that could be of influence, either positively, through opportunities, or negatively, through risks:

- Operations: capacity profiles and fluctuations, reliability, unplanned shut downs

- People: human error

- Asset integrity: breakdowns, maintenance and inspection, safety, damage

- Information: usability, accuracy, accessibility

- Natural events: weather, seasonal effects

- Decision making: investment evaluation, planning

- Knowledge: corporate memory, hidden or false assumptions, knowledge sharing

- HSE: equipment failures, leaks

- Markets: long term contracts, trading, supply, demand

For example, the uncertainties may harbour opportunities for optimising long term development plans and for trading on the short term.

Some of the risks may originate from outside the organisation. The system boundaries of the application lie on the feed import and product export interfaces of the assets. Details on the supply risks on the import interfaces are required as input. The risks on the export interfaces are quantified by the application itself.

The application includes common cause failures.

ARTIS Live considers the full life of the assets,

- the past: for performance reporting and capacity loss accounting,

- the present time to three years ahead: for target setting and maintenance and inspection planning

- and the future: for availability studies that support long term planning and design optimisation for project development.
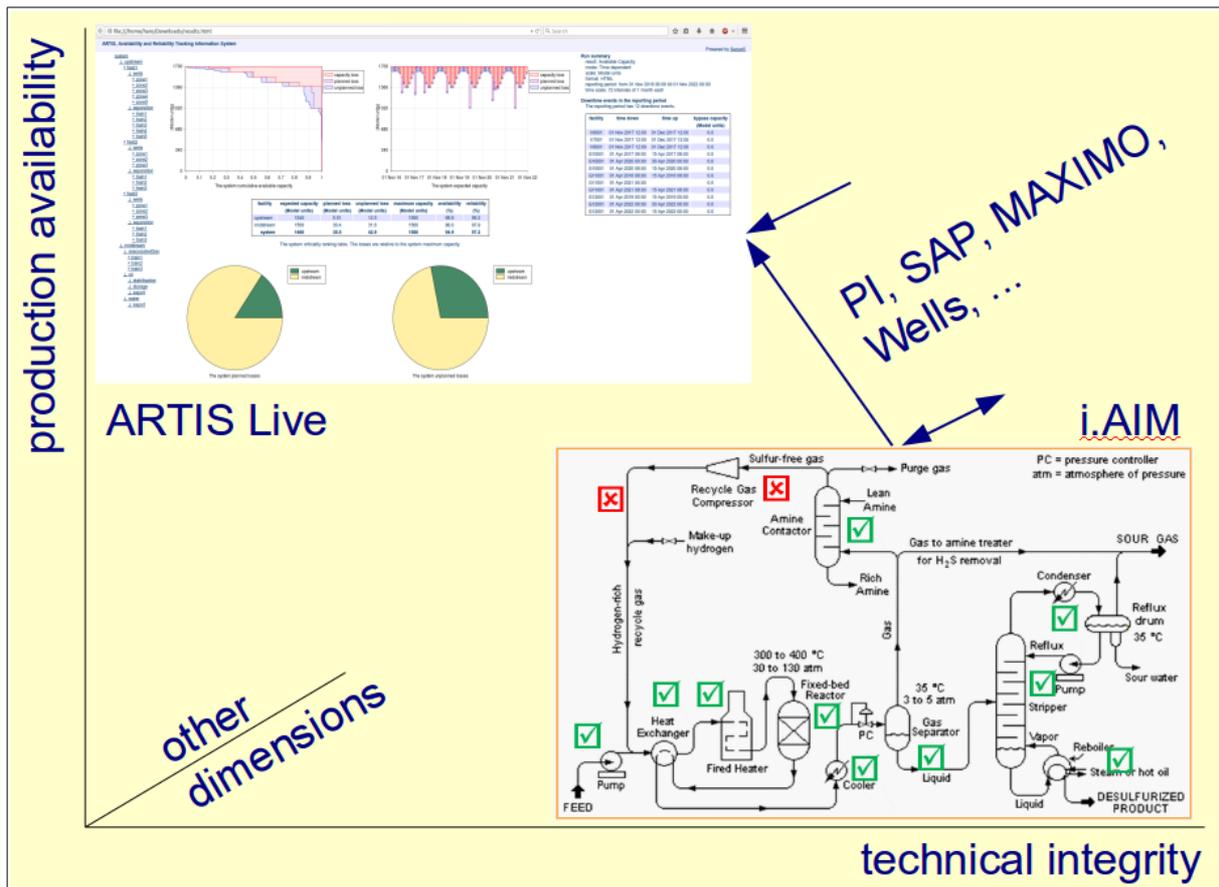
Figure 1: two dimensions of the asset management system

It may interface with the management systems of other organisational functions, including:

- long term planning, also known as strategy planning or asset reference planning: to support concept selection, optimising capacities and timing of possible future developments, and optimising the lifetime value

- project development: for the selection of alternative concepts and design optimisation

- asset integrity management and the other asset management dimensions, see Figure 1: providing the line of sight and a platform for the learning cycle

- production: for production availability and mission reliability target setting, performance reporting and loss accounting

- trading: for identifying and quantifying opportunities on the short to medium term market

- maintenance and inspection: for for maintenance and inspection optimisation and planning

For a company has long term supply commitments, the interface of the ARTIS Live application with the strategic planning and project development planning is especially key since it enables balancing the capacity margin with the level of supply commitments, as these may change over time. The application covers a somewhat wider area than what ISO 55001 requires because it also addresses parts of the long term (strategic asset management) planning and the project development processes.

The ARTIS Live approach to managing risks is quantitative, it is based on the collection of historical unplanned downtime data and on the mathematical modelling of the risks and their impact. Although

most risks, including possible equipment failures, technical integrity issues, common mode failures, human error, external events and other factors, can be taken on board, some non-technical types of risk can be difficult to quantify or may have insufficient relevant historical data. The application ignores the risks that cannot be quantified, hence these must be addressed elsewhere in the organisation's management systems.

The organisation may be subject to a range of risks that are unrelated to the production availability and mission reliability. Those risks are not part of the scope of the application either and they must be covered by other risk management processes.

4.4 The ARTIS Live application

4.4.1 The application

The ARTIS Live application is one of the asset management plans and it covers the risks to production availability and mission reliability. Although this is only a single dimension, it does provide a uniform yardstick and captures all planned and unplanned downtime and all capacity changes and changes to the operating envelope, as might arise from project expansions and de-bottlenecking, maintenance and inspection, capacity swings and capacity declines, and other sources. With it, the organization can control the link between the production availability and mission reliability targets and the alternative risk responses and ensure that, over time, its assets are capable of delivering its targets.

The intent of the ARTIS Live application is for the organisation to optimise its responses to the risks and opportunities identified in section 4.3 and maximise the lifetime value of their assets.

It builds around a transparent and quantitative computer model of the assets and provides the means to take on board all risks to production availability and mission reliability, tie together the many elements of asset improvement programs that make the system work cohesively, provide the line of sight, and close the learning cycle, for all levels of management and all disciplines.

Its key advantage is that it provides a corporate model, quantified and validated, accessible and understandable for all, up-to-date with the current condition status, for reviewing and optimising the risk responses. Assurance is built into every business process and ARTIS Live provides an agreed platform for that.

ARTIS Live takes a scientific and integrated approach through risk modelling, optimisation and reporting, with a mathematical background based on probability theory and statistical modelling, see section 4.4.4.

The risk assessment criteria for all the assets' facilities are:

- the consequences of downtime, that is the loss of production availability and mission reliability of the system
- the likelihood of downtime, that is the frequency and duration of the system capacity losses

Its results include a hierarchical breakdown of these criteria, after accounting for possible backup alternatives and contingency plans. ARTIS Live uses a single decision making criterion, that is either the loss of production availability or the loss of mission reliability, with the definitions as provided in https;//wiki.artis.la.
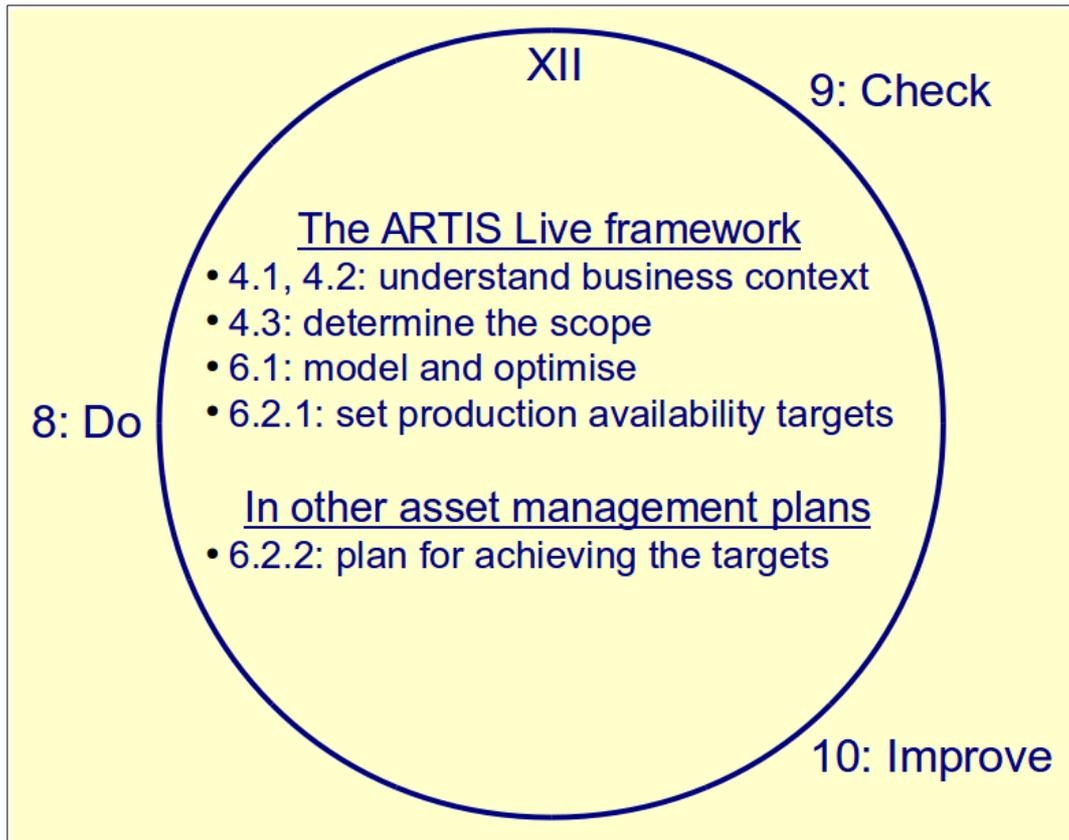
Figure 2: The ARTIS Live learning cycle around the modelling and optimisation framework, with the relevant ISO 55001 section numbers

These guidelines describe a framework for modelling and optimisation and a 'Do – Check – Improve' learning cycle, shown in Figure 2. The ARTIS Live application delivers the ARTIS Live framework, that is the risk management framework. The learning cycle is the process by which the framework is established and sustained. Together, the framework and the cycle provide the controls that are required for managing the risks to production availability and mission reliability.

In an environment with resource and budget limitations, the establishment of the ARTIS Live application can be phased, starting with a limited number of facilities and adding the other assets and facilities in later phases. For ensuring management alignment and acceptance, a phased commitment and introduction is recommended. This might start with a pilot on one asset, followed by subsequent introduction for all assets.

Once the establishment has been completed, there will be a limited requirement for application maintenance, for example in case of updates of the database interfaces or the web reporting format. The project development and asset management plans need to cover these development and maintenance budgets.

Starting the initial steps during the project development phase, or during project expansions, is most efficient because all the required engineering knowledge, from all disciplines, is readily accessible in the project development team. This also enables use of the same model for capturing early value by design optimisation and confirming the completeness and consistency of the assets' database systems. The model, data and documentation should then be part of the project documentation and the hand-over from the project development to the operations.

Alternatively, the initial data collection and modelling can be done in a once-off multi-disciplinary exercise during the operational phase. Regardless of the timing, the model needs to be developed to 'as built' status and the databases must be made complete and consistent.

Under the assumption of high demand, the loss of production availability and mission reliability is a proxy for the loss of revenue. The ARTIS Live application does not include a full economic model of the assets.

The application covers all time scales from the short term, for tracking and reporting, up to the time horizon of the strategic plan, for long term planning support. It must be kept consistent with any changes in the assets, as and when they happen, to maintain it's 'as built' status and it must include all future development plans.

4.4.2 The framework

The ARTIS Live framework is a risk based internal control framework. It may be applied to the whole of a business, or to any part of a business (asset, field, project, etc.). The framework is developed in five steps, see Figure 2, to allow for optimisation these may be interrelated and iterative:

1. clarify the business and its context, see sections 4.1 and 4.2.

2. determine the scope, see section 4.3

3. address the risks associated with the production availability and mission reliability, through modelling and optimisation of alternative risk responses, see section 6.1

4. provide the line of sight by setting the production availability and mission reliability targets, see section 6.2.1

5. plan for achieving the targets, see section 6.2.2

The framework comprises the ARTIS Live model, the report, the database interfaces, the reporting website and the line of sight, that is the set of production availability and mission reliability targets. The framework is like a fingerprint in that it is unique to a particular business operating in a particular set of circumstances. While frameworks for similar businesses will have many elements in common, and it is certainly possible to use another framework as a template or starting point, there will generally be a need customise the framework for each business.

There are many processes, often under different names in different industries, that cover one or more of the steps of the framework development. Provided that the decision making criterion is the loss of production availability and mission reliability, on a continuous scale, or the loss of mission, on the binary scale, this includes:

- Probabilistic Risk Assessment (PRA), Fault Tree Analysis (FTA), Reliability, Availability and Maintainability (RAM) studies: these may cover several steps of the framework

- Failure Mode, Effects, and Criticality Analysis (FMECA), Reliability Centered Maintenance (RCM), Risk Based Inspection (RBI): these may be part of other asset management plans but cover part of addressing the risks, see section 10.1

4.4.3 The learning cycle

The purpose of the learning cycle is to sustain optimum control over the risks and opportunities and manage them, maintain alignment with the production availability and mission reliability targets, ensure continual improvement, and maximise the expected lifetime value. This requires a full understanding of the root causes of downtime, the operating flexibility, including backup, bypass and other ways to

avoid production losses, and the impact of the downtime events, taking account of both their frequencies and durations.

The actions for sustaining the application make up this learning cycle are:

1. apply ('Do') it, by providing support to project development, maintenance and inspection optimisation, trading opportunity identification, performance reporting, etc., see section 8

2. appraise ('Check') it, by reviewing the model and data, updating the criticality ranking, etc., see section 9

3. and adapt ('Improve') it, see section 6.2.2 for the establishment of the application and section 10 for its subsequent improvements.

The first 'Improve' step is the establishment of the application, starting from scratch or adapting from an existing framework. If an organisation already operates a framework for managing the risks to production availability and mission reliability, there's no need to 'start from nothing' and the first steps are to describe what's already in place and plan to take full advantage of the existing processes and interfaces.

If an organisation were to decide against adoption of the ARTIS Live application, it is still recommended to adopt the modelling approach outlined in section 6.1 for the identification, analyses and evaluation of the risks.

4.4.4 The software

ARTIS, the Availability and Reliability Tracking Information System, is a web based modelling, reporting and training tool for computing the available capacity of a continuous production system that is subject to maintenance, inspection, testing, failure and repair. For example, it can be applied to oil and gas projects, gas liquefaction plants and refineries. Whereas process flow simulations can determine the maximum operating capacities, ARTIS calculates the available capacity levels of a system, their frequency and duration and the integrated production availability and mission reliability.

ARTIS can take as input the current state of the equipment items and then calculate the available capacity levels, availability and reliability of the system, conditioned on the current state. This is the 'Live' aspect and it may include data uploads from the plant information, computerised maintenance management system, condition monitoring and other databases. ARTIS Live represents the assets in a model one layer above the individual databases and can show the production availability and mission reliability in real time on the intranet to achieve transparent and up-to-date reporting to all staff.

ARTIS has two components:

- the user interface running in your favourite web browser

- the Cloud service for making the runs

The ARTIS user interface has some unique strengths:

- a clean and hierarchical user interface that is easily accessible by a wide audience, with a low learning curve that does not does not require 'specialist tool expertise', offering full access and transparency for management and all disciplines

- a single focus on production availability and mission reliability, supported by a complete and consistent set of definitions, in line with common intuition and ISO standards

- a model can have all equipment items that are critical to the production, arranged in hierarchical groups according to the design plans and the impact on system availability. ARTIS

enables a bird's eye overview of the model and the user can zoom in on the critical parts of the model that require detailed attention

- superior model management and version control, avoiding the need for model duplication, with full parameterisation so that a single model can cover many alternative scenarios and sensitivity cases and full flexibility to run parts of the model without having to update the model

- light and flexible database interfaces, using open source components, with 'single click' search from the model into the databases, including Oracle, MySQL, SQLite and others

- web based reporting, with the full model hierarchy, criticality rankings and automatically generated plots

- zero IT overhead, the user interface runs in the web browsers and there is no installation on the clients' devices

- future compatibility

The ARTIS engine has some unique strengths too; is based on robust and efficient analytical and numerical mathematical methods and does not rely on Monte Carlo simulations. Even for models with thousands of equipment items, the ARTIS runs are quick and free of statistical noise. For large models, where Monte Carlo based tools may take hours or more, the typical ARTIS run times remain below 1 minute. Using one and the same model, the ARTIS engine can cover all different scenarios:

- on the past, for performance tracking and reporting

- on the current period, for vulnerability monitoring and scheduling

- on the future: for evaluation of project development alternatives and identification of bottlenecks, maintenance optimisation and target setting

5 Leadership

5.1 Leadership and commitment

Visible and consistent top-down support, evidenced by both behaviour and actions, is essential. In addition to regular management review and discussion of the framework, examples of support include communicating the importance of fit-for-purpose risk responses, frequent attention to the way significant risks are managed and commitment of resources. Actions can then be taken on a timely basis in the event of a failure, weakness or significant change to the appropriateness of the framework.

Top management shall ensure that the ARTIS Live application is covered in the asset management system.

Top management shall authorise the ARTIS Live policy.

5.2 Policy

This policy describes the risk based approach for providing reasonable assurance of achieving the organisation's production availability and mission reliability targets. The policy governs the development and implementation of the production availability and mission reliability strategy, objectives and plans.

The organisation is expected to:

- identify and evaluate the significant risks to production availability and mission reliability, set boundaries for risk taking, and apply fit-for-purpose risk responses and establish production availability and mission reliability targets , that take these factors on board. The targets must be covered in the strategic plan, including possible improvement plans.

- incorporate risk responses into the ARTIS Live application

- monitor its effectiveness

- follow relevant organisational guidelines and standards which relate to particular types of risk

- provide an annual assurance regarding the extent of its compliance with this policy.

Line management is expected to:

- design, resource, operate and monitor the ARTIS Live application

- ensure that the application is communicated to staff, embedded in business processes, and responsive to evolving risks

- assign accountability for managing risks within agreed boundaries

- report the results of balanced assessments regarding the effectiveness of the application, including identified weaknesses or incidents, to executive management.

5.3 Organisational roles, responsibilities and authorities

Top management shall ensure that the responsibilities and authorities for the production availability and mission reliability are covered with the respective asset management responsibilities and authorities.

Top management signs of on the production availability and mission reliability targets for the integrated system and at all other levels the managers sign off on the targets of the assets or facilities under their respective responsibilities.

6 Planning

The planning initiates the 'Do – Check – Improve' learning cycle by making the first 'Improve' step and it establishes the ARTIS Live framework, see Figure 2. It is the first step, possibly during the project development, of setting up the ARTIS Live application. Subsequent 'Improve' steps should result in updates of the framework.

The initial development can be arranged as a multi-disciplinary study, with the objectives to prioritise the risks regarding their impact on the integrated system and optimise the risk responses, through design choices, through optimisation of the maintenance and inspection strategies, and other possible risk responses, see section 6.1.

The two planning processes are:

1. pilot study and field visits to install ARTIS, enable tracking and reporting, and provide training

2. road shows and management presentations to obtain upfront buy-in

The planning may also include any number of improvement processes from the 'Improve' step in section 10 and must set the production availability and mission reliability targets, see section 6.2.1.

6.1 Actions to address risks and opportunities for the ARTIS Live application

The actions that are necessary for addressing the risks and opportunities are to identify these risks, assess them, and develop responses to them. These actions can be taken together in the form of a modelling and optimisation study, both during the establishment of the application and during its subsequent learning cycle improvements, as updates to the framework.

6.1.1 Identify risks

The owner of the production availability and mission reliability targets is responsible for the 'Identify risks' step, that is the identification and understanding of the risks and the collection of the downtime data. For this step, previous experience with similar projects is usually a good starting point.

For the classification of downtime data, existing standards might be used as a starting point. For example, for the Oil & Gas industry, the ISO 14224 standard might be used. For the space industry, the ESA standard ECSS-Q-HB-30-08A might be used.

6.1.2 Assess risks

The 'Assess risks' step aims to analyse the risks and quantify their impact by developing the availability model, including the classification and collection of the downtime data, and the documentation. This step can be integrated across all assets, to enable the hierarchical view, from the top level overview all the way down to the individual assets, other layers in the asset hierarchy, the individual equipment items, and the downtime modes (aka basic events in fault tree terminology) at the bottom. The availability model takes the place of the risk register and risk matrices; the register and matrices can be produced by, or derived from, the availability model.

6.1.3 Respond to risks

The 'Respond to risks' step aims to find the optimum responses to the risks with one, or more, of the four 'T's (Take, Treat, Transfer, Terminate). This optimisation may comprise the selection from project development alternatives, the development of condition monitoring and inspection plans and the development of an optimised maintenance reference plan. In order to turn them into reality, the plans that are developed in the optimisation framework must then be integrated and implemented in the organisation's processes.

Less may be more, if the responses selected are well suited to both nature/culture of the business and the type of risk. Excessive layers of control, especially for lower level risks, may slow down business processes and increase costs.

The evaluation of the effectiveness of these actions and their optimisation are part of the study.

6.2 production availability and mission reliability targets and planning to achieve them

6.2.1 production availability and mission reliability targets

A large organisation may have many layers and types of inter-related asset management objectives. Whether for the organisation as a whole or one of its business units, it must be clear what these

objectives are, what expectations haven been set, what promised have been made and what must be delivered.

A balanced set of objectives is likely to reflect all three elements of sustainable development: economic, social and environmental. Of those three, ARTIS Live addresses the economic element explicitly and the other two are considered only to the extent that they may impact on the production availability and mission reliability. Since the ARTIS Live application does not include a full economic model of the assets; the implicit assumptions for the optimisation of lifetime value are twofold:

- In economic terms, the loss of production capacity translates, through product price, to lost revenues,

- For projects that involve capital expenditure, there is an established working interface with the organisation's cost estimation and economic modelling function.

The organisation's economic objectives should take account of the production availability and mission reliability targets.

The application provides a quantitative basis for setting the targets at all levels of the organisation. It also provides the confirmation that the targets are mutually consistent by showing how the target at one level cascades down to the targets at the next lower level. The ARTIS Live web reporting makes this visible for everybody, thereby providing the line of sight:

- a transparent connection to the bottom line, with the corporate production availability and mission reliability performance indicators linking directly to the volumes sold

- a full and top down hierarchical breakdown of these indicators, consistent with the corporate targets

- clear and consistent reporting of the indicators, visible for everyone, complete with break downs and the impact of each event on the system

- full traceability of the underlying data

- an explicit connection between project development and operations and maintenance improvement initiatives with their impact, at all levels, on the indicators as a solid basis for evaluating and ranking and measuring the value captured, consistently throughout time and with their impact on the bottom line

- a clear and agreed basis, throughout the organisation, for linking individual performance metrics and employee development plans to the indicators.

production availability and mission reliability targets are SMART:

- **S**pecific: they are intuitive, easily understood and based on well accepted mathematics, with clearly defined alternatives. They apply at all levels and include the availability, reliability, uptime and related measures of the individual equipment items.

- **M**easurable: they can be reported on the intranet, from the highest level down, including all levels, to the individual equipment items, components and failure modes.

- **A**ligned: the impact of downtime on the production availability and mission reliability at the next higher level is always clear

- **R**ealistic: with a single model for historical reporting, analysing the current status and assessing the future, the targets can be based on the historical performance and any ongoing and planned improvement initiatives. This allows a transparent and quantitative route to setting stretched targets.

- **T**imely: the targets can be set to match the organisations' reporting time frame, whether it is annual, quarterly or otherwise. This enables updates as circumstances change, to ensure continued validity and desirability. Deviations in performance might be used as inputs to revise the objectives.

6.2.2 Planning to achieve production availability and mission reliability targets

6.2.2.1 Asset management plans

The asset management plans must include the strategic asset management plan (aka the strategic plan or the asset reference plan) and the maintenance and inspection reference plan. In case the strategic plan and the maintenance and inspection reference plan, or their equivalents, do not yet exist, the organisation should draft the missing plans during the establishment of the ARTIS Live application.

The application includes processes for target setting and reporting, maintenance optimisation, the identification of trading opportunities, and a host of other value adding processes. These processes address the 'who/what/when/where/why/how questions and the resource requirements. They may be developed as part of the application or as part of other asset management plans, provided that they all use the loss of production availability and mission reliability as the criterion for decision making. The processes are executed in the individual steps of the learning cycle and a number of them are listed in the respective sections 6, 8.1, 9.1, and 10.3.

The ARTIS Live application has a review period of one year, see section 9.3.

6.2.2.2 Ownership and continuity

Achievement of objectives doesn't 'just happen', *People* must act to achieve objectives, which means they need to know what is expected, and who is responsible for what. Every objective must be assigned to someone (whether it is an individual or a team); that 'someone' must agree to accept ownership of the objective.

The asset managers are responsible for identifying and understanding the risks to production availability and mission reliability for their respective assets. For assigning ownership and responsibility, the asset managers must sign off on their respective targets.

For ensuring continuity, an Availability Assurance Team must be set up, with a mix of engineering, long term planning, system optimisation, operations, maintenance and inspection expertise. As backup, an external consultant might be required to provide general experience and continuity.

The ARTIS Live model runs in most of the common web browsers and has a very low learning curve. For general awareness, with all disciplines and management, it's recommended to provide full access on the intranet.

6.2.2.3 Risk management

The management of the risks to production availability and mission reliability is fully covered in section 6.1.

6.2.2.4 Documentation

The availability model is documented in the report. The report must be self contained, meaning that it must be possible to fully reconstruct the model on the basis of the report and it's referenced sources only. In order to ensure that all modelling assumptions are firmly anchored in the engineering and

other relevant documentation, the report and all its referenced sources, along with any future updates, must be controlled documents and subject to version control in the sense of ISO 9001, see section 7.6.1.

7 Support

7.1 Resources

The development and maintenance of the ARTIS Live application must be part of the annual budget and resource planning process.

7.2 Competence

The competences necessary for developing and sustaining the ARTIS Live application include:

- first degree in mathematics, physics or an engineering discipline (mechanical, process, …)
- experience with plant design, long term planning, or maintenance / inspection optimisation
- capable to lead multi-disciplinary study teams
- ability to actively develop the overall view and lead towards consensus

7.3 Awareness

People need to become familiar with the ARTIS Live application as a risk based control framework. Communicating the framework will promote understanding of what level of risk is acceptable, guide day-to-day decisions, explain why particular controls are in place, and clarify what is expected of whom. Widely communicating the framework is also an effective means of enhancing it, provided that individuals are given the opportunity to offer diverse risk ideas, and to add details whether assumed responses are actually in place. Brief awareness/training sessions may be an appropriate way of introducing groups to the concepts and inviting contributions.

The application addresses these points directly by making transparent for everybody what the impact of their activities are. This includes, for all staff and contractors:

- the ARTIS Live policy
- why production availability and mission reliability is important throughout the organization
- the implications of changes in the production availability and mission reliability targets or the operations, as far as they may impact on their respective areas of accountability
- their contribution to the effectiveness of the application, including the benefits of improved production availability and mission reliability
- the risk consequences (actual or potential) of their work activities, their behaviour, and the production availability and mission reliability benefits of improved personal performance and how they relate to each other
- their roles, responsibilities and authorities as well as the importance of their contribution in meeting the requirements of the policy and the application

- how well the organization is performing in meeting its targets.

The specific awareness needs of any stakeholder should be determined by their role and its relationship to the organization meeting its production availability and mission reliability targets. The need for awareness of some areas can apply to only a limited group of individuals, for example those directly involved in a particular function, such as plant maintenance.

The level of organizational awareness can be improved, for example, by the following:

- a programme of road shows and workshops with staff throughout the organization concerning the application

- discussion of production availability and mission reliability in the organization's newsletters, briefings, introduction programme or journals (including new employee orientation)

- publications on relevant websites

- inclusion in staff and management team meetings

- briefings for top management;

7.4 Communication

The main communication channels are:

1. the ARTIS Live website

2. the management reporting

The ARTIS Live application allows daily monitoring of the progress towards the targest, transparent for everyone throughout the organisation. It also provides web based reporting, with the full asset hierarchy, criticality rankings and automatically generated plots, see Figure 3.

Figure 3: the ARTIS Live reporting website

The application tracks the production availability and mission reliability of the integrated system, aimed at giving operations an improved and faster response capability in case of any unfolding risks to production and keep the organisation informed on a continuous basis, enabling a pro-active risk management approach. ARTIS Live provides a full platform for defining, measuring and testing the acceptable risks, maximising production availability and mission reliability and managing the vulnerability to possible capacity shortfalls.

ARTIS Live can monitor the impact of planned and unplanned downtime, capacity changes, other changes to the operating envelope and all other critical events on the integrated system, in real time. With ARTIS Live, the failure, maintenance, process upset and other critical events are tracked as time develops and these events are loaded automatically into the availability model. The availability model is then run to produce the results website, complete with hierarchical breakdowns and automatically generated charts.

For short term planning, the analysis takes on board the current state of the system and applies conditional probability methods to provide:

- a look-ahead of the quantified risks to the production availability and mission reliability

- an estimate of the vulnerability, at system level, to impending capacity and downtime losses

- a platform for optimising the maintenance and inspection scheduling

- a basis for immediate decisions and actions at the time that the events unfold, on mobilisation of backups and alternative supplies, mobilisation or rescheduling of maintenance and other mitigating short term measures

- identification of loss of availability / capacity and sources, avoiding "grey losses" and tracking the accumulation of small losses

- a platform for comparing different operator shifts, management scenarios and maintenance strategies as well as changes in availability targets over the life of the asset

Vulnerability monitoring serves to enable expedient decisions and actions, for example on mobilisation of backups, mobilisation of maintenance, delay of planned maintenance and inspection, and other mitigating short term measures on an objective and quantified basis of the immediate exposure to losses in production availability and mission reliability.

7.5 Information requirements

ARTIS Live requires the availability model, that contains all information on maximum operating capacities of the facilities, their configuration and the operational flexibility and an updating process for the planned and unplanned downtime events, see Figure 4. The state of the equipment is extracted in real time or at given time intervals (for example every hour or per shift) from the plant information database. The updates of the maintenance plans and maintenance completion predictions are loaded from the maintenance and inspection management database. Root cause analysis and data quality processes must ensure that the data is accurate. Manual inclusion of additional or alternative maintenance plans into the model is also possible, for example to enable sensitivity studies on the timing of condition based maintenance.
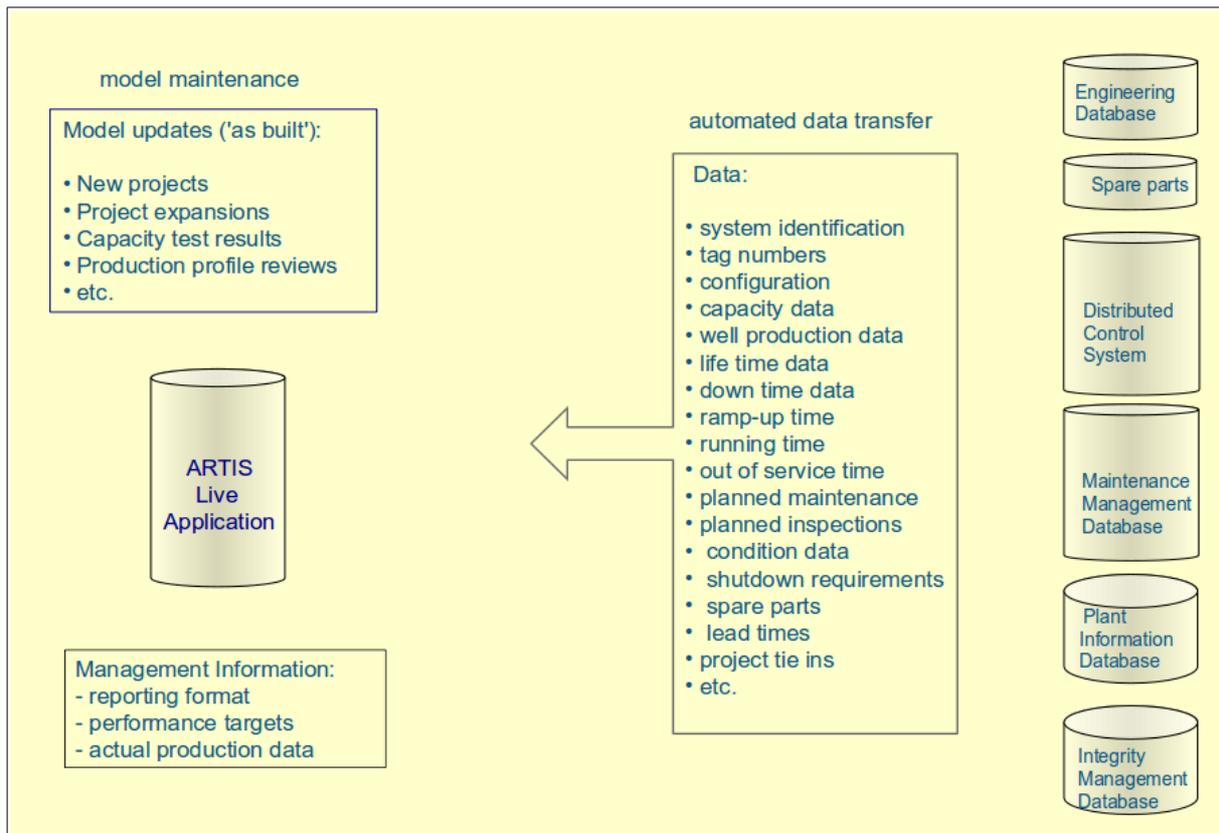
Figure 4: the ARTIS Live data model

The ARTIS Live application can be made accessible from the assets to facilitate the collection of planned and unplanned downtime data.

For the purpose of tracking and reporting, the control room operators may be given access to a copy of the model so that they can enter the downtime events as they happen. The maintenance staff and support staff also have access to check the data quality and make any corrections to the events.

ISO 14224 provides the standard for the collection and exchange of reliability and maintenance data for equipment.

7.6 Documented information

In establishing its documented information needs, the organization should consider the identification and definition of documented information that will be managed and maintained over the lifetime, taking into account its period of responsibility for the assets. The organization should also consider the requirement to maintain this documented information for any defined period beyond the disposal of the assets, in accordance with its business, legal and regulatory requirements. The controls put in place should be adequate for the type of information in supporting the asset management activity.

The organization should determine the documented information required to ensure effectiveness of its ARTIS Live application. When creating and updating documented information, an organization should determine if appropriate controls are in place to ensure that the information is appropriate; these controls are necessary to ensure that the personnel supporting the asset management activity are using the approved, accurate, most up to date information.

7.6.1 General

The documentation of the ARTIS model should be clear and complete, allowing the ARTIS model to be fully reconstructed, from scratch, on the basis of the report and its references only. All data must be traceable. The report and its references are controlled documents in the sense of ISO 9001. For maintaining clarity and efficiency, the model and its documentation should be produced and updated hand in hand.

The register of the risks to production availability and mission reliability is (being developed as) part of the ARTIS Live automatic reporting and hence that part of the risk register does not require a separate effort.

For project development, the ARTIS model and its documentation should be part of the project documentation and hence the standard requirements of the project management system apply.

7.6.2 Creating and updating

The requirements of the organisation's asset management system apply with no exceptions.

7.6.3 Control of documented information

The requirements of the organisation's asset management system apply with no exceptions.

8 Operation

8.1 Operational planning and control

The ARTIS Live application offers many opportunities for including lower level processes that implement the risk responses from section 6.1, achieving the production availability and mission reliability targets from section 6.2.1 and implementing the corrective and preventive actions from section 10, not limited to:

1. sales contracts optimisation
2. target setting and tracking
3. planned shutdown timing optimisation
4. optimise spare parts holding for the critical equipment items
5. ensuring data quality for collecting the planned and unplanned downtime events
6. model management
7. tracking, website updating
8. daily, monthly, quarterly, annual reporting

Improvement processes from other management systems might be included:

9. maintenance and inspection strategy optimisation
10. root cause analysis of all unplanned events, as they occur, by multidisciplinary teams
11. loss accounting

For all these processes, the (expected gain or loss of) production availability and mission reliability is the risk assessment criterion. Hence, the implementation requires that each process has an interface with the ARTIS Live framework for modelling and evaluation.

8.2 Management of change

The ARTIS Live framework needs to be kept up to date with the 'as built' status of the existing equipment and the current and future development plans. This requires buy-in from all stakeholders and hence a model change process must be followed to ensure that the framework maintains its status at all times.

To facilitate the model management and ensure the completeness and consistency, the ARTIS Live framework has only a single model that contains all past, present and planned future facilities and the relevant capacity and downtime data and that model is used for all purposes.

Project development studies can be done with the model itself or with an new model which then can be imported into the integrated model after completion of the study.

Update requirements of the model can arise from many different sides:

- Project developments, both new facilities and expansion projects. Previous plans may get updated as the development work progresses.

- The ARTIS Live model assumes that the databases have complete and accurate information but adding and removing equipment items needs to be done manually in ARTIS. The consistency checks and possible updates may be part of the tracking and data quality processes.

- The completion of small projects and debottlenecking work may require an update of the capacity of the assets.

- Expansion projects on feed projects, utilities and other assets that are outside the scope of the ARTIS Live application but that are still relevant to the production availability and mission reliability need to be kept up to date.

- Capacity test, the reporting process and other studies (such as hydraulic study updates) may provide new information on the capacity of the assets.

- Analysis of the actual downtime data as collected during the Availability Tracking and Reporting process may justify an update of the planned and unplanned downtime assumptions.

- From time to time, possible improvements to the model can be suggested, modelling preferences may change or other corrections may be identified.

All capacity changes and changes to the operating envelope need to be reviewed in the availability assurance and capacity margin workshop, or elsewhere in the management review process, see section 9.3, for authorisation by the asset managers.

For maintaining control of the model, all changes must be recorded in the change log file and documented in the study reports, see section 7.6.

	Update requirement	Initiation	Coordination	Review	Approval
1	project development	project manager	ARTIS Live focal point	project team	project manager
2	Database consistency	ARTIS Live team	ARTIS Live focal point	database manager	asset manager
3	Small projects and debottlenecking	Field Staff	ARTIS Live focal point	asset engineering staff	asset manager
4	relevant changes outside	ARTIS Live	ARTIS Live	asset engineering	ARTIS Live

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	the ARTIS Live scope	team	focal point	staff	manager
5	capacity tests and other new information	asset manager, ARTIS Live team	ARTIS Live focal point	asset engineering team	asset manager
6	Failure data updates	ARTIS Live manager	ARTIS Live focal point	ARTIS Live team	ARTIS Live Manager
7	Improvements and corrections	ARTIS Live team	ARTIS Live focal point	ARTIS Live team	ARTIS Live manager

Table 1: Overview of the change management process

As owner of the model, the ARTIS Live focal point coordinates all changes. In addition to the above process, it is recommended to have an internal review inside ARTIS Live team before the external review takes place. This internal review includes a technical review of the model updates and reporting and a full reproduction of all updated results by a second party.

8.3 Outsourcing

It is recommended that the ARTIS Live manager and the ARTIS Live focal point are own staff. Other roles can be outsourced using the normal processes. This includes all of the initial planning and all of the learning cycle steps.

9 Performance evaluation

9.1 Monitoring, measurement, analysis and evaluation

Ensuring that the framework is robust, 'fit-for-purpose' and functioning as expected requires that the framework and its performance be appraised from time to time. Appraisal actually begins with the various forms of monitoring which are already built into the ARTIS Live application, see section 8.1.

The appraisal in this section is focussed on the ARTIS Live framework, not it's operation. Appraisal activities are mechanisms for stepping back to review, evaluate an consider the *entirety* of a risk based control framework. These are generally performed on a periodic basis, either by people within the business (self-appraisal) or by people outside the business (independent appraisal). Both self and independent appraisals typically review and place reliance upon the results of the built-in monitoring activities.

The performance evaluation processes of the 'Check' step may include:

1. the availability assurance and capacity margin workshop, see section 9.3

2. model and documentation review

3. validation of the model against historical production data

9.2 Internal audit

The ARTIS Live application internal audits must be part of the organisation's asset management system internal audits, with no special requirements and no exceptions.

9.3 Management review

The ARTIS Live application management reviews must be part of the organisation's asset management system management reviews, with no special requirements and no exceptions.

It is recommended to organise these reviews as an availability assurance and capacity margin workshop in which the owner of the ARTIS Live application, the ARTIS Live team and all assets take part. The workshop provides an effective and efficient way to review and approve the large majority of the model changes. However, if the frequency of the workshop is once per year only then the ARTIS Live manager is responsible to ensure that written (minutes, emails) traces are kept as a reference for each change.

10 Improvement

10.1 Nonconformity and corrective action

Technical failures do not classify as nonconformities. Breakdown repairs do not classify as corrective action. Technical failures result from the optimised risk treatments that have been selected and updated in the 'Plan' and 'Improve' steps. The fact that they do happen doesn't change the optimisation in any way, provided the assumptions in the ARTIS Live framework of the frequency and duration of the downtimes are correct..

In the ARTIS Live application, examples of possible nonconformities include:

- the occurrence of previously unrecognised failure modes

- process upsets and spurious trips

- missed production availability and mission reliability targets

- modelling and data inconsistencies

- missing or incorrect downtime events

Corrective actions need to be taken at the source of the nonconformity, wherever that is.

The corrective actions are fully part of the learning cycle, see section Table 1, and section 10.3.

10.2 Preventive action

Condition monitoring and inspection are planned as per the optimised risk treatments that have been selected and updated in the 'Plan' and 'Improve' steps. In the ARTIS Live application, they do not classify as preventive action in any other way.

Instead, examples of possible preventive actions include:

- periodic studies aimed at identifying previously unrecognised failure modes

- periodic process control reviews aimed at reducing process upsets and spurious trips

- increased attention to assets where production availability and mission reliability targets that are likely to be missed
- periodic framework reviews
- provide training on entering downtime events

The corrective actions are fully part of the learning cycle, see section Table 1, and section 10.3.

10.3 Continual improvement

There are two areas of possible improvements: the production availability and mission reliability of the assets and the ARTIS Live application itself. Both are covered.

The improvement processes are:

1. project development support, availability studies
2. align with plant operations, maintenance, integrity and other management systems:
   - database interface specifications
   - implementation (asset hierarchy, tag numbers, downtime coding, …)
3. capacity margin optimisation
4. fault tree analysis (FTA)
5. critical equipment items identification and ranking
6. setting production availability and mission reliability targets
7. preparing life and repair time estimates from own historical downtime data

Improvement processes from other management systems might be included:

8. long term planning
9. failure mode effects and criticality analysis (FMEA / FMECA)
10. reliability centered maintenance (RCM) studies
11. risk based inspection (RBI) studies

The learning cycle can have any selection of these improvement processes. That selection may change over time, for example when starting with a small set and then gradually expanding it. Hence, the learning cycle may get reviewed and updated as part of the continual improvement.

All improvement processes use the same ARTIS Live framework for determining, assessing and prioritising opportunities and for measuring the effectiveness of the improvement implementations.

The ARTIS Live application supports the continual improvement. It is driven top down, starting from the production availability and mission reliability of the integrated assets, down to the individual downtime modes, for example:

- The opportunities for increasing the production availability and mission reliability are the capacity and availability bottlenecks. They are identified on the ARTIS Live results website.
- The opportunities for reducing the impact of the availability bottlenecks may include faster mobilisation, optimised maintenance contracts, optimised spare parts holding and other ways to treat the risk of unplanned downtime. A reliability centered maintenance (RCM) study or failure

mode and effect (FMEA/FMECA) study may be required to establish which treatment, or which combination, is best.

- In a number of countries and industries, a periodic update of the reliability centered maintenance (RCM) studies is mandatory. The ARTIS Live application provides focus for these updates.

- production availability and mission reliability increases may be driven by setting, over time, increasingly challenging but realistic targets. For example, this can provide the drive for working towards top quartile performance within 5 years time.

- For selected critical facilities, the organisation (or the asset manager) might prefer to take a proactive approach, and plan (with budget and resources) a series of capacity tests to confirm the assumptions made in the ARTIS model. The timing and scheduling of the capacity tests needs to take into account any possible capacity fluctuations (for example, well profiles, fluids composition and effects of ambient temperature), and the production planning requirements. The capacity tests might be complemented with (an update of) the reservoir, network, process and hydraulic simulations, including their validation.

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