Digital Risk Twin-Enabled Operational Readiness (OR) Lifecycle Transforming Reliability for Mining, Oil & Gas, and Energy Projects

*A unified DRT framework delivering **risk-aware design**, readiness tracking, and predictive operations across asset-intensive industries.*

The Digital Risk Twin (DRT) transforms Operational Readiness (OR) by integrating design, risk, and operational data into a single digital model. This enables real-time, risk-based decision-making from concept through operations, ensuring that readiness, reliability, and performance targets are met across the full project lifecycle.

Lifecycle Coverage:

Concept → Feasibility → FEED → Detailed Design → Construction → Commissioning → Operations

Each stage includes risk quantification, design validation, and readiness verification; providing early visibility and control over project reliability performance.

Execution Guide for Operation Readiness (OR) Lifecycle with Digital Risk Twin (DRT) (Mining, Oil & Gas, and Energy projects)

START

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Stage 1: Conceptual / Pre-Feasibility

Investors/Executive Sponsors

Board of Directors: Establish Business Case:
Define project purpose, investment criteria, and key readiness objectives.

High-level technical and economic viability

Resources: Discipline Engineers, Geologists, Economists, Business Analysts, RAM Engineer, etc.
Tools: Panning Software, Economic Models, RAM Simulation Platform

INPUT:
- Operational Readiness is a parallel workstream (not just a late activity). Define readiness milestones at each stage gate.
- Responsible Persons: Project director, OR program lead, governance SME.

DRT Value:
Serves as the single source of truth for OR KPIs and risks, ensuring early visibility and governance.

Define OR Framework in Project Charter

DRT Execution:
-Create a simplified RAM with assumed uptime values (e.g., 85% vs. 90%).
-Demonstrate early how reliability and availability impact financial viability, preventing over-optimistic assumptions.

INPUT:
- Develop block diagrams for main system/process/major equipment item.
- Assign generic MTBF/MTTR values based on benchmark data.
- Responsible Persons: RAM engineer, process engineer, reliability SME.

Why DRT:
Replaces theoretical output with probabilistic uptime to calculate realistic production and financial performance

Develop high-level DRT with RAM/ availability assumptions

DRT Execution:
-Quantify regulatory and HSE risks early within the same twin used for financial and reliability analysis.
-Update the model with risk probabilities and potential downtime impacts.
-Load early RBDs into the DRT and link them to the TCO/LCC (NPV) model to calculate and compare lifecycle costs for different concept options.

Early HSE and regulatory identification

INPUT:
- Map environmental permits needed. Identify community impacts. Develop preliminary HSE risk register.
- Responsible Persons: HSE advisor, permitting specialist, legal counsel.

DRT Value:
Integrates risk, reliability, and cost to create a complete readiness view for decision-making.

Update DRT with HSE Risk factors and Financial Data

Pre-Feasibility OR Gate Output:
-Validated business case with quantified availability, HSE, and financial risks that translate into a realistic financial projections for board review.

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Stage 2: Feasibility

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INPUT:
- Develop Class 3 cost estimate.
- Vendors provide preliminary quotes for major equipment items/ packages/systems.
- Engineers refine process flows.
- Responsible Persons: Discipline engineers, EPC estimators, cost engineers, RAM engineer.

DRT Value:
Selects the most resilient technical solution, not just the cheapest.

Confirm technical solution and costs

Update DRT with process flow

Define target operating model (org structure, headcount)

DRT Execution:
- Add process flow to the DRT. Compare design alternatives (sensitivities) by simulating uptime, costs, and risk.

INPUT:
- Draft full operational org chart: Ops, processing, maintenance, logistics, HSE, support, etc. Decide contractor vs. in-house.
- Develop skeleton SOPs (safe start-up, shutdown, lock-out).
- Maintenance strategy: decide condition-based vs. time-based.
- Responsible Persons: HR planners, operations managers, benchmarking consultants, Maintenance engineers, OEM reps, OR consultants.

DRT Value:
Aligns workforce and strategies to sustain uptime targets

Draft preliminary SOP framework and maintenance strategy

DRT Execution:
- Workforce availability modeled. Simulate downtime impact if insufficient maintainers/operators.
- Upload preliminary PM tasks into DRT. Simulate if strategy meets reliability goals.

Update DRT by adding PM tasks, assess impact on manpower

INPUT:
- Conduct HAZOP/HAZID to identify design and operational risks affecting reliability and maintainability.
- Record identified hazards, causes, and mitigations for integration into the DRT risk register.
- Responsible Persons: OR Lead, Process Engineers, HSE Specialists, Maintenance SMEs.

DRT Value:
Turns qualitative risk into quantitative performance impact.

Risk register: operability/ maintainability risks

DRT Execution:
- Each risk quantified in DRT (probability × downtime impact). Model effects on production.

Update DRT with production-impacting risk mitigations.

Feasibility OR Gate Output:
- Preferred technical concept confirmed with risk-adjusted reliability and cost basis for investment approval (Bankable feasibility report).

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Stage 3: Front-End Engineering Design (FEED)

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Update DRT with FEED Design (PFD Level)

INPUT:
- Document production rate, product specs, utility needs, reliability targets.
- Prepare execution plan
- Responsible Persons: EPCM engineers, project controls, OR team.

Develop Basis Of Design (BOD) and execution plan

DRT Value:
Confirms design matches RAM and financial expectations.

Update DRT with detailed RBD and FMEA analysis

DRT Execution:
- Upload FEED design into DRT
- Identify and eliminate design related failure risks early
- Refine uptime model with real capacities and redundancies.
- Simulations run in DRT with vendor MTBF/ MTTR or industry standard or historical values or as specified by the experienced engineers.
- DRT integrates Failure Modes and Effects Analysis (FMEA) data to simulate and optimize system reliability, maintainability, and readiness before the design is locked.

INPUT:
- Identify high-risk systems (pressure vessels, piping, tanks). Define corrosion loops, degradation mechanisms, and inspection boundaries. Develop preliminary Corrosion Management Program (CMP) and RBI philosophy.
- Responsible Persons: Integrity engineers, corrosion specialists, materials engineers.

Develop RBI and CMP basis for critical assets

DRT Value:
Integrates integrity management early in design to reduce lifecycle risk and maintenance cost.

DRT Execution:
- Add spare list for the critical system
- Add preventive task / turnaround activities to validate the design per BOD.
-Model corrosion and inspection risks within DRT as time-based degradation functions linked to uptime and availability.
- DRT configured to report integrity and readiness KPIs from RBI/CMP and RAM inputs.

INPUT:
- Develop asset hierarchy; align with ISO 14224 coding and RAM model structure..
- Push failure codes and preventive maintenance tasks derived from DRT analysis into CMMS.
- Use DRT simulations to display readiness progress by area (Design, People, Systems, Spares, Risk).
- Responsible Persons: Maintenance planners, IT/CMMS specialists, OR program manager, HR, training specialists.

Define CMMS structure and asset hierarchy

DRT Value:
Ensures data continuity between design, commissioning, and operations.

Update DRT with RBI/ CMP/RAM data and readiness KPIs.

Front-End Engineering Design (FEED) OR Gate Output:
- Design verified against RAM, RBI, and CMP targets, establishing readiness baseline for detailed engineering.

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Stage 4: Detailed Design & Procurement

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INPUT:
- Detailed engineering drawings complete. Vendor specs finalized. Procurement issues POs.
- Responsible Persons: EPCM, procurement, vendors.

DRT Value:
Procurement decisions reflect real lifecycle risk.

Finalize design and procurement

Update DRT with detailed Design (PFD and P&ID)

Develop SOPs and maintenance procedures

DRT Execution:
-Update the model in PFD and P&ID level
-Feed the most realistic reliability data based on material spec as provided by the vendors,
-Make sure the proper failure curves and MTTR are addressed for each equipment item

INPUT:
- Translate OEM manuals into site-specific SOPs. Add local safety context.
- Quantify corrosion risk, optimize inspection frequency.
- Asset data, PM tasks, and spares loaded into CMMS.
- Conduct full HAZOP; confirm that safety instrumented systems meet target integrity levels.
- Responsible Persons: Design and Ops engineers, vendor reps, Maintenance planners, IT admins.

DRT Value:
Develops CMMS by validating SOPs and optimizing PM that mirrors live CMMS data.

Populate CMMS with equipment, maintenance tasks, RBI plan and CMP

DRT Execution:
-Test procedures in DRT for maintainability; simulate downtime for maintenance execution.
-Generate equipment criticality, System bottleneck that impact the production (normally 20% equipment contribute 80% production loss)
-PM optimization based on the equipment criticality and update CMMS data accordingly

Update DRT with optimized PM tasks, RBI and Inspection Plan

INPUT:
- Identify critical spares. Procure and stage in warehouse.
- Prepare BOM for the critical parts
- Responsible Persons: Supply chain managers, warehouse.

DRT Value:
Ensures critical spares availability at startup and prioritizes procurement based on risk impact.

Order spares, consumables, and tools

DRT Execution:
-Add the critical spare (commissioning/ operational).
- Simulate downtime risk of spare unavailability.
- Do spare optimization.

Update DRT with critical equipment spare configuration

Detailed Design & Procurement OR Gate Output:
- Design integrity, maintainability, and spare-part readiness confirmed with residual risk quantified before construction.

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Stage 5: Construction

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Update DRT with schedule deviations (if any) and progress data

INPUT:
- Civil, mechanical, electrical works executed.
- Equipment installed.
- Responsible Persons: EPC contractors, inspectors.

Construct facilities and install equipment

DRT Value:
Provides risk-adjusted schedule forecasts.
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OR team mobilized on site for reviews

DRT Execution:
-Simulates schedule deviations (delays, rework, late deliveries) and their impact on OR milestones.
-Recalculates effects on downstream activities — commissioning, reliability testing, and OR gates.
-Quantifies production readiness risk and startup slippage.
-Enables proactive recovery actions (e.g., fast-tracking commissioning or adding resources).

INPUT:
- OR staff check for safe access, tag alignment, maintainability. Punch-listing issues.
- Warehouse operational. Inventory and barcode systems tested.
- Responsible Persons: OR engineers, maintenance SMEs, Logistics managers, IT team.

Confirm warehousing, logistics, and monitoring systems

DRT Value:
Resolves issues before commissioning and mitigates supply chain risks.

DRT Execution:
- DRT simulates as-installed systems to verify functionality and performance.
- Identifies readiness gaps and validates system behavior before commissioning.
- Update in real time to reflect actual installation and ensure a smooth transition to start-up.

Update DRT with as-built installation data and verified functionality

INPUT:
- OEMs deliver classroom, simulator, and field training. Competency assessments completed.
- Responsible Persons: OEM trainers, training coordinators, workforce.

Begin operator/ maintainer training with OEMs

DRT Value:
Ensures staff are job-ready before start-up.

DRT Execution:
-Models human reliability and competency gaps by simulating operator performance, training levels, and human error probabilities to assess their impact on overall system availability and safety

Update DRT with human reliability analysis (HRA) parameters

Construction OR Gate Output:
- Installed systems verified for operability and logistics readiness; risks resolved before commissioning handover.

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Stage 6: Commissioning & Start-Up

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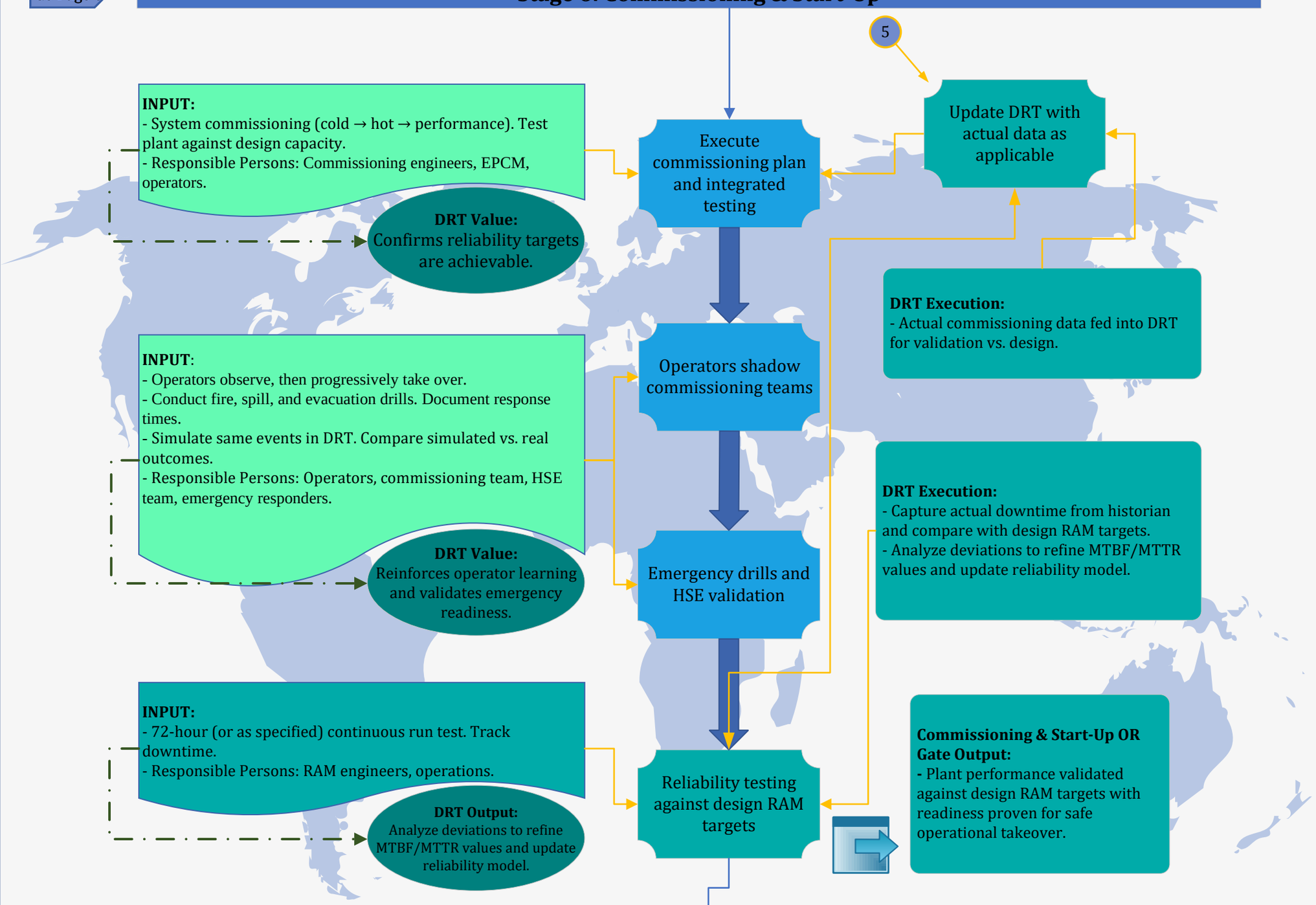

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Stage 7: Operations / Handover

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Stage 7: Operations / Handover

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INPUT:
- Deliver O&M manuals and redline drawings
- Responsible Persons: EPCM, document control.

DRT Value:
Establishes operational twin.

Formal handover of as-built and vendor data

Update baseline DRT

Establish KPIs and performance monitoring

DRT Execution:
-Feed live KPIs from CMMS
- Data streams are established from the CMMS and historian systems.
- Failures, downtime, and repair logs automatically populate reliability databases.
- Dashboards show live KPI trends for equipment, system, and plant levels.
- Thresholds are defined (e.g., MTBF < 500 hr = critical asset review), triggering alerts or maintenance strategy updates.

INPUT:
- Implement MTBF, MTTR, OEE (Overall Equipment Effectiveness) tracking issues.
- Analyze failures and adjust PM
- Responsible Persons: Reliability engineers, data analysts, and Maintenance engineers.

DRT Value:
Enables predictive insights and improves maintenance efficiency.

Optimize maintenance strategies post start-up

Update FMEA and reliability models

DRT Execution:
- Integrate early operational data.
- Refine model continuously.
- It sustains continuous performance improvement.

INPUT:
- Transition from EPCM/commissioning staff to permanent operations team; verify full shift coverage and competency.
- Responsible Persons: Operations, HR, HSE, OR program manager.

DRT Value:
Ensures sustained, competent and safe operations from day one.

Ensure full workforce transition and coverage

DRT Execution:
-Track workforce readiness, coverage, and human reliability factors
- Continuously feeds and visualizes live KPIs, updating reliability models

Continuous improvement and OR gate closure

Operations / Handover OR Gate Output:
- Seamless transition to operations with predictive and proactive reliability control.

END