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Digital Twin Technology for Enhancing GOSP Performance and Oil Production Efficiency

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Abstract- Gas-oil separation plants (GOSPs) are tightly coupled production systems in which well behaviour, multiphase flow, separator performance, rotating equipment, instrumentation, pipelines, utilities and environmental constraints interact continuously. A digital twin can create operational value only when it connects these physical dependencies to traceable measurements, validated engineering models and accountable field decisions. This paper presents a practice-informed technical review and an implementation framework for applying digital-twin technology to GOSP performance and oil production efficiency. The work is informed by the author's current involvement in a digital-twin initiative and by AVEVA-oriented digital training, while deliberately excluding confidential project information. The proposed reference architecture integrates field and control-system data, AVEVA PI System for operational data management and contextualisation, AVEVA Process Simulation for online first-principles modelling, equipment-performance analytics, engineering information, and controlled operator or maintenance workflows. Technical depth is developed around three high-value use cases: three-phase separator stability, pump and compressor reliability, and production-deferment diagnosis. The paper defines the minimum model logic required for these applications, including phase mass balances, residence time, equipment-curve residuals, uncertainty-weighted data reconciliation, anomaly thresholds and constrained production optimisation. It also proposes a validation workflow based on historical events, shadow-mode operation, prediction error, false-alarm rate, missed-event rate and engineering acceptance. The review uses only sources that were traceable through a working DOI or an official institutional or vendor page at the time of preparation. The resulting framework positions the digital twin as a governed engineering decision system rather than a visual dashboard, and provides a technically defensible route for staged deployment in Saudi smart oil-field projects without overstating unverified benefits.

Keywords: digital twin; GOSP; AVEVA PI System; process simulation; data reconciliation; separator performance; predictive maintenance; production optimisation; Saudi oil fields.

I. INTRODUCTION

GOSPs receive unstable multiphase production from wells and gathering systems, separate oil, gas and produced water, maintain crude-handling conditions, support compression and liquid evacuation, and protect downstream pipelines and processing facilities. A disturbance rarely remains confined to one item of equipment. Changes in well water cut or gas-oil ratio can affect separator residence time; separator pressure can affect compressor loading; a pump limitation can cause high levels and production restriction; and instrument drift can make an apparently stable operation misleading. The plant therefore has to be understood as an interacting production network rather than as a collection of independent assets.

Conventional historian trends, alarm lists and dashboards are essential, but they usually describe what has happened rather than testing why it happened or what will happen after a proposed intervention. A technically useful digital twin adds a continuously maintained model of expected behaviour. It compares measured and modelled states, evaluates uncertainty, forecasts developing constraints, and supports controlled what-if analysis. This distinction is important: a three-dimensional model, a dashboard or an isolated machine-learning predictor may be valuable digital tools, but they do not constitute an operational twin unless the physical asset, data, model and decision process are kept connected for a defined purpose [1]-[6].

The author is currently involved in digital-twin work within an oil and gas project and has undertaken multiple digital training activities associated with AVEVA solutions. That experience motivates the practical focus of this paper. However, the paper does not disclose proprietary project configuration, tag names, process capacities, control settings or company documents. AVEVA PI System, AVEVA Process

Simulation, PI Vision and Unified Engineering are used as a documented reference technology stack because their official product documentation supports real-time data integration, online simulation and engineering-information connectivity [19], [20]. This reference architecture should not be interpreted as confirmation that every listed module is deployed in the current project.

The technical problem addressed is the gap between broad digital-twin claims and the engineering evidence required for safe GOSP decisions. Many publications identify predictive maintenance, optimisation and emissions reduction as potential benefits, but fewer explain the measurement traceability, model equations, calibration evidence, confidence limits and approval workflow needed before an operator can rely on a recommendation. Recent reviews of oil and gas production systems similarly identify model fidelity, interoperability, cybersecurity, human trust and lifecycle maintenance as persistent requirements [9]-[13].

This paper therefore treats the digital twin as a governed decision layer. Its value is judged by whether it can answer a specific operational question with traceable inputs, an explainable model, a quantified confidence level and a measurable outcome. The central examples are: detecting deterioration in three-phase separation before a major upset; separating equipment degradation from changing process conditions for pumps and compressors; and reconstructing production deferment across wells, flowlines, separators and downstream constraints. These use cases are directly relevant to GOSP performance and can be validated without claiming unverified production gains.

II. AIM, OBJECTIVES AND CONTRIBUTION

This study aims to develop a technically detailed, practice-informed framework for a GOSP digital twin that integrates live operational data, first-principles process models, equipment-performance analytics, engineering information and accountable field execution. The framework is intended to support monitoring and diagnosis first, prediction second, and prescriptive optimisation only after the required validation and governance controls have been demonstrated.

The objectives are to: define the minimum functional architecture of a GOSP digital twin; identify traceable data and modelling requirements for separators, pumps, compressors and production networks; show how an AVEVA-based reference stack can connect historian data to online process simulation and engineering context; define equations and residuals that make model behaviour auditable; map each use case to specific validation metrics and decision owners; and establish a staged deployment method that protects safety, cybersecurity and management-of-change requirements.

The paper makes four contributions. First, it narrows the digital-twin discussion to GOSP decisions that have measurable operational significance rather than presenting a generic catalogue of Industry 4.0 technologies. Second, it places measurement uncertainty and data reconciliation at the centre of the architecture. Third, it links process simulation to equipment-performance and deferment analysis, allowing cross-system causes to be examined instead of treating each asset in isolation. Fourth, it provides a controlled validation and deployment workflow informed by current project involvement and AVEVA training, but without presenting confidential data or unsupported numerical benefits.

The framework is not an empirical claim that a particular site has already achieved the described outcomes. It is an implementation-ready technical design that can be populated and validated using authorised project data. Where site evidence is unavailable for publication, the paper distinguishes proposed calculations and expected decision value from achieved performance.

III. METHODOLOGY

A practice-informed structured technical review was used rather than a formal meta-analysis. Sources were searched through IEEE Xplore, ScienceDirect, MDPI, publisher DOI landing pages and official institutional or vendor websites. The principal search expressions combined terms such as "digital twin", "online simulation", "oil and gas", "processing plant", "production system", "data reconciliation", "process simulation", "predictive maintenance", "PI System" and "GOSP". The review prioritised material published from 2020 to July 2026, while retaining

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standards and official product information where required to describe architecture or governance.

A source was included only when it met three conditions: it was directly relevant to oil and gas production, process engineering, model validation or the selected technology architecture; its bibliographic identity could be confirmed; and it was reachable through a working DOI or an official publisher, standards-body, NIST, AVEVA or Saudi Aramco page. References that could not be located by exact title and author, or that were only weakly related manufacturing examples, were excluded. The final reference list contains 22 traceable sources. URLs and DOIs were checked during preparation; continued accessibility remains subject to publisher and website changes.

Evidence was extracted against the engineering questions that control implementation: What physical decision is supported? Which measurements are required? What model type is used? How is the model calibrated? Which validation metrics are reported? How is uncertainty handled? What action is produced, and who is accountable for accepting it? Table 1 summarises representative evidence. The table is intentionally selective; its purpose is to show how each source supports a specific element of the proposed GOSP framework rather than to maximise the number of citations.

The author's current project involvement was used only to identify practical workflow requirements such as tag mapping, model configuration, engineering review, information continuity, operator trust and confidentiality. No proprietary measurements or project results were used. AVEVA product documents were treated as primary evidence for software capability, not as proof of operational benefit. Academic publications were used for digital-twin definitions, oil and gas requirements, process modelling, data reconciliation, validation and operational resilience.

Table 1. Traceable evidence base and contribution to the GOSP digital-twin framework.

Source	Application domain	Framework contribution	Main limitation	Traceable identifier
Wanasinghe et al. (2020) [1]	Oil and gas digital-twin review	Industry use cases, opportunities and barriers	Broad review; limited plant-level validation	10.1109/ACCESS.2020.2998723
Rasheed et al. (2020) [2]	Modelling perspective	Value, uncertainty and model maintenance	General, not GOSP-specific	10.1109/ACCESS.2020.2970143
Shen et al. (2021) [7]	Oil and gas production	Optimisation and prediction architecture	Site transferability requires validation	10.1155/2021/3062841
Seman et al. (2021) [15]	Oil-well production models	Data reconciliation and parameter tuning	Focuses wells rather than complete GOSP	10.1016/j.compchemeng.2020.107179
Knebel et al. (2023) [9]	Oil and gas cloud/edge review	Deployment architecture and security trade-offs	Many implementations remain partial	10.1016/j.cie.2023.109363
Belo et al. (2025) [10]	Oil and gas production systems	Functional and non-functional twin requirements	Requirements need site-specific prioritisation	10.1016/j.infsof.2025.107742

Peterson et al. (2025) [11]	Process engineering	First-principles, reduced and data-driven models	Computational choices depend on use case	10.1016/j.compchemeng.2024.108917
Hamidishad et al. (2025) [12]	Oil and gas processing plants	Processing-plant frameworks and lifecycle gaps	Few long-duration plant validations	10.3390/pr13113488
Mazzuto et al. (2025) [13]	Experimental oil and gas plant	Integrated model, PID behaviour and predictive analysis	Experimental scale; further data required	10.1016/j.array.2025.100443
AVEVA / Saudi Aramco (2025) [22]	Process Simulation Twin	Automated data collection, reconciliation and calibration	Conference implementation summary	Official AVEVA World page

IV. DIGITAL TWIN FOUNDATIONS FOR GOSP SYSTEMS

A digital twin should begin with a decision definition, not with software selection. For a separator, the decision may be whether an unstable interface level is caused by inlet slugging, incorrect control response, changing fluid properties or downstream evacuation restriction. For a pump, the decision may be whether reduced flow is caused by hydraulic system change, valve position, cavitation, fouling or internal degradation. A model is useful only when its inputs, assumptions, output confidence and required action are explicit.

The proposed architecture contains five connected functions. The physical function comprises wells, manifolds, flowlines, separators, pumps, compressors, valves, pipelines and utilities. The measurement function includes DCS and SCADA signals, flow, pressure, level, temperature, vibration, power, laboratory data, inspections and maintenance events. The operational-data function stores and contextualises time-series data, aligns units and timestamps, applies quality flags and maps tags to the correct equipment hierarchy. AVEVA PI System is suitable for this role because it captures and enriches operational data, while PI Vision can present time-aligned plant and model information [19], [20].

The modelling function combines first-principles and data-driven elements. AVEVA Process Simulation supports steady-state, rating/fluid-flow and dynamic modes and can integrate operations data from PI System. Its official documentation also identifies integration with Unified Engineering for PFDs, P&IDs, datasheets and three-dimensional plant information [19]. In a GOSP twin, the first-principles model should represent phase equilibrium, mass balance, separator holdup, pressure drop and equipment performance. Data-driven models should be limited to behaviours that are difficult to represent reliably from physics alone, such as valve stiction signatures, fouling, vibration patterns or residual relationships. A grey-box approach is preferable to an opaque predictor where safety or production actions are involved.

The decision function converts model residuals and scenarios into operational language. A recommendation should identify the affected asset, the observed deviation, the probable causes, the variables that most influenced the conclusion, the confidence level, the production and safety consequences, the verification action, and the accountable engineer or operator. Recommendations must remain advisory until operating procedures, HAZOP and SIL constraints, cybersecurity controls and management-of-change requirements have been checked.

The architecture also requires configuration discipline. Equipment replacement, instrument reranging, pipeline rerouting, control tuning and operating-strategy changes can make a previously accurate twin obsolete. Each model should therefore have an owner, version, calibration date, validity range and documented relationship to the physical configuration. A digital twin that is not maintained is only a historical simulation.

4.1 Materials Procurement, Inspection and Asset-Lifecycle Information Integration

The digital-twin architecture should also incorporate materials procurement, inspection and technical-documentation data for every component installed or used within the GOSP. The objective is to establish a complete and traceable digital record that follows each material and equipment item from engineering specification and procurement through inspection, installation, commissioning, operation and maintenance.

Each component should be assigned a unique asset or material identifier linked to the plant equipment hierarchy. The associated digital record should include engineering datasheets, material requisitions, purchase-order references, vendor documents, technical bid evaluations, approved technical deviations, NMRs, inspection and test plans, manufacturing records, test certificates, inspection release notes, material receiving reports and preservation or storage requirements.

During construction and installation, the same record should be updated with receiving-inspection results, material traceability information, installation location, equipment tag number, inspection checklists, test reports, punch-list status, pre-commissioning records and commissioning acceptance data. This creates continuity between the material originally specified by engineering, the item purchased from the vendor, the item received at site and the component finally installed in the operating plant.

The information should be contextualised within the digital-twin database and made accessible through an integrated dashboard. By selecting an equipment tag or plant component, authorised users should be able to retrieve its engineering specifications, procurement status, vendor information, inspection history, material certificates, installation details, commissioning baseline and current operating or maintenance condition in a single view.

After commissioning, the material and inspection record should be linked to the operations and maintenance database, including preventive-maintenance plans, inspection intervals, work orders, failure records, replacement history, corrosion or integrity findings, spare-parts information and condition-monitoring results. This lifecycle connection enables engineers to determine whether equipment deterioration, repeated failures or performance deviations may be associated with material selection, vendor quality, manufacturing history, installation condition or subsequent operating exposure.

Appropriate data governance is essential. Document ownership, approval status, revision number, inspection authority, confidentiality classification and retention requirements should be defined. Only approved and verified technical records should be presented as authoritative information within the digital twin.

Additional implementation updates

Data readiness should also include verification of approved datasheets, material requisitions, vendor documents, technical evaluations, NMRs, inspection records, receiving reports, installation evidence and commissioning baselines before incorporation into the operational digital twin. Engineering drawings, datasheets, material requisitions, vendor documents, inspection and test records, material receiving reports, installation records, commissioning baselines and vendor performance curves should remain linked through controlled information management and subsequently connect with the operations and maintenance database so users can retrieve the complete lifecycle history of each installed component from a single asset-centred dashboard.

4.2 Integrated Project Construction, Operations, Security and Enterprise Management

The Digital Twin platform shall be extended beyond engineering and asset information to support the complete project construction lifecycle, operations, maintenance, enterprise management and security monitoring through a unified database and dashboard.

Project Construction Management

The platform shall integrate engineering, procurement, construction, inspection, installation and commissioning data to provide complete lifecycle visibility for every plant component. All engineering datasheets, material requisitions, technical evaluations, NMRs, inspection reports, receiving records, installation records and commissioning documents shall be linked to each equipment tag.

Integrated Asset Lifecycle

After commissioning, all project records shall automatically connect to the Operations and Maintenance database, including preventive maintenance, work orders, inspection history, integrity records, equipment performance, failures, spare parts and replacement history.

Unified Dashboard

A single-click dashboard shall enable engineers and management to retrieve engineering, procurement, construction, commissioning, operational and maintenance information for every installed asset from one interface.

Project Controls Integration

The Digital Twin shall connect with project schedules, progress measurement, forecasting, earned value, construction status and milestone tracking. KPI dashboards shall display engineering, procurement, construction, commissioning and operational performance in real time.

Automated Progress Reporting

Construction progress reports shall be generated automatically using field data, photographs, videos, inspection records and mobile updates, providing instant project status at any required time.

Security Command Centre Integration

The system shall integrate with security command centres to monitor personnel movements, equipment movement, site access, CCTV images, photographs, safety observations, incidents and emergency information, enabling automated reporting and real-time tracking.

Corporate Management Connectivity

The platform shall connect to the corporate network and executive dashboards, enabling management to monitor project execution, operational performance, production status, safety KPIs and asset health online from any authorized location.

Enterprise Decision Support

The integrated Digital Twin shall provide management with real-time KPIs, forecasts, productivity trends, construction progress, operational readiness, maintenance performance and safety indicators, supporting faster and data-driven decision making throughout the asset lifecycle.

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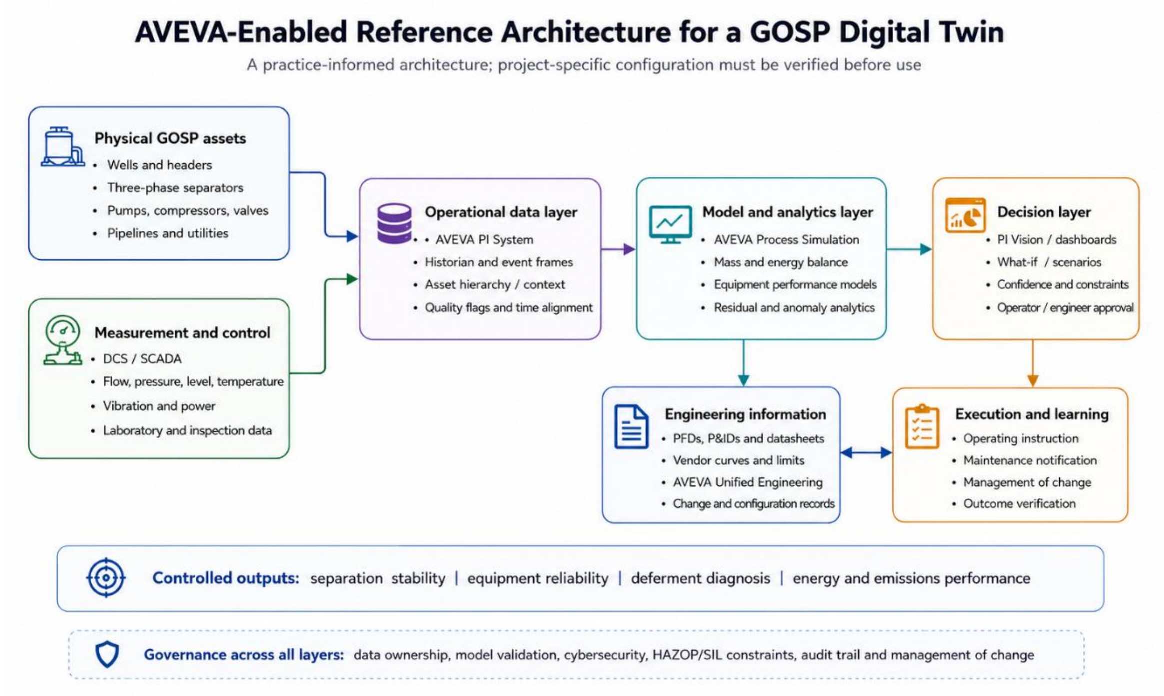

Figure 1. AVEVA-enabled reference architecture for GOSP performance and oil production efficiency.

Figure 1 is a reference architecture rather than a declaration of the exact software configuration used in the author's current project. Project-specific modules, interfaces and data routes must be confirmed from authorised engineering documentation.

V. GOSP PERFORMANCE PRIORITIES AND DIGITAL TWIN USE CASES

The strongest starting use cases are those with a clear operational loss, reliable measurements and an identifiable decision owner. For GOSPs, three-phase separation, critical rotating equipment and production deferment meet these conditions. Energy, flaring, produced-water handling and integrity should be included as constraints and consequences rather than treated as independent optimisation targets.

For separator stability, the twin should receive inlet and outlet flow estimates, separator pressure and temperature, oil level, oil-water interface level, gas flow, produced-water flow, water cut or basic sediment and water, control-valve position, alarm state and downstream pump condition. The model should calculate phase inventories, expected residence time and the consistency of measured inlet and outlet streams. A high-level alarm alone does not identify cause. The twin should test whether the event is consistent with an inlet liquid surge, reduced oil evacuation, reduced water evacuation, level-transmitter drift, valve stiction, pressure disturbance or changing emulsion behaviour. The output should be a ranked diagnosis and a verification sequence, not an automatic set-point change.

For pumps and compressors, process conditions must be separated from equipment condition. Vibration or power cannot be interpreted without flow, suction pressure, discharge pressure, fluid properties, speed, recycle position and vendor performance information. A pump may appear inefficient because the system curve has changed, while a compressor may move toward an operating limit because separator pressure or gas composition has changed. The digital twin should calculate expected head or pressure ratio at the current condition, compare it with measured performance, and trend the residual after correcting for process variation. Maintenance priority should reflect both degradation likelihood and the production consequence of failure.

Production-deferment diagnosis requires a network view. The twin should maintain event relationships among well availability, routing, flowline pressure, separator constraints, compressor loading, pump availability, downstream pipeline limits and planned work. When production falls, the system should preserve the sequence of constraints and estimate the contribution of each cause. This prevents reservoir limitations, facility bottlenecks, equipment failures and planning restrictions from being grouped under one generic deferment category. The result can support daily production meetings, root-cause closure and prioritisation of engineering work.

The author's current digital-twin involvement is most appropriately reflected through this decision-centred structure. Project details can be added after internal approval by identifying the asset, data sources, modelling tool, validation event and user workflow. Until those items are authorised, the paper should remain explicit that the examples are anonymised and implementation-oriented.

Table 2. GOSP digital-twin use cases, model logic, validation and operational decisions.

Use case	Minimum data	Model or calculation	Validation evidence	Decision output
Three-phase separator stability	Flow, pressure, temperature, oil and interface levels, water cut, valve positions	Phase balance, holdup, residence time, reconciled residuals	Mass-balance closure, level prediction RMSE, alarm lead time	Inspect instrument/valve, manage inlet routing, verify evacuation constraint
Pump performance and reliability	Flow, suction/discharge pressure, power, vibration, temperature, speed	Pump curve, system curve, efficiency and health residual	Head residual, false alarms, detection lead time, post-maintenance recovery	Verify process cause, schedule inspection or maintenance, protect production window
Compressor performance and reliability	Suction/discharge conditions, flow, speed, recycle, vibration, power	Performance map, pressure ratio, operating margin, anomaly residual	Map deviation, trip-event replay, missed-event rate	Adjust loading within limits, inspect recycle/control, plan maintenance
Production deferment diagnosis	Well routing, flowline pressure, equipment status, alarms, maintenance and downstream limits	Network constraint model and event-causality graph	Attributed versus reported deferment, closure time, recurrence	Assign root cause and accountable corrective action
Energy, flaring and environmental constraint	Power, fuel, flare events, produced water, operating envelopes	Constrained scenario evaluation	Energy per barrel, flare-event prediction, compliance exceptions	Reject production scenario that violates environmental or integrity limits

VI. PRODUCTION OPTIMISATION AND DECISION MODELLING

Production optimisation in a GOSP digital twin should not be reduced to maximum throughput. The highest instantaneous output may increase energy intensity, stress rotating equipment, reduce separation quality or increase the risk of upset. The stronger objective is constrained optimisation: maximising reliable production within safety, environmental, equipment and integrity limits. A digital twin provides the computational environment for this balance because it can compare scenarios before field action is taken. It can test how changes in well routing, separator pressure, compressor loading, pump operation or maintenance timing may affect the overall facility.

The optimisation model should include both physical and data-driven components. Physical models are useful where engineering relationships are well understood, such as pressure drop, pump curves, compressor envelopes, separator residence time and basic material balance. Data-driven models are useful where behaviour is complex, nonlinear or not fully captured by first-principles equations, such as fouling, intermittent slugging, valve stiction, sensor drift and maintenance-related degradation. Hybrid modelling is especially suitable for GOSPs because it preserves engineering interpretability while using operational data to update uncertainty and detect deviations [3], [5], [6].

Decision quality depends on model fidelity, but fidelity must be matched to the decision. A high-fidelity dynamic simulator may be justified for compressor surge analysis or separator upset investigation. A simpler soft sensor may be enough for early warning of pump degradation. A statistical anomaly detector may be useful for tag-level surveillance but insufficient for maintenance planning unless connected to equipment context. Therefore, a GOSP digital twin should be built as a portfolio of models rather than a single monolithic model. Each model should have a declared purpose, input data, confidence range, validation method and escalation rule.

Figure 2 presents the proposed closed-loop operating cycle. The cycle begins with sensing, where real-time field data and historical records are collected. It moves to validation, where data quality, sensor reliability and context are checked. Simulation then compares observed behaviour with expected behaviour. Prediction estimates the likely effect of current trends on production, safety and equipment health. Optimisation ranks feasible interventions. Action requires operating approval and management of change where necessary. Learning occurs after the result is measured and fed back into the model. Governance surrounds the whole cycle because unsafe automation or undocumented decision-making is unacceptable in high-risk facilities.

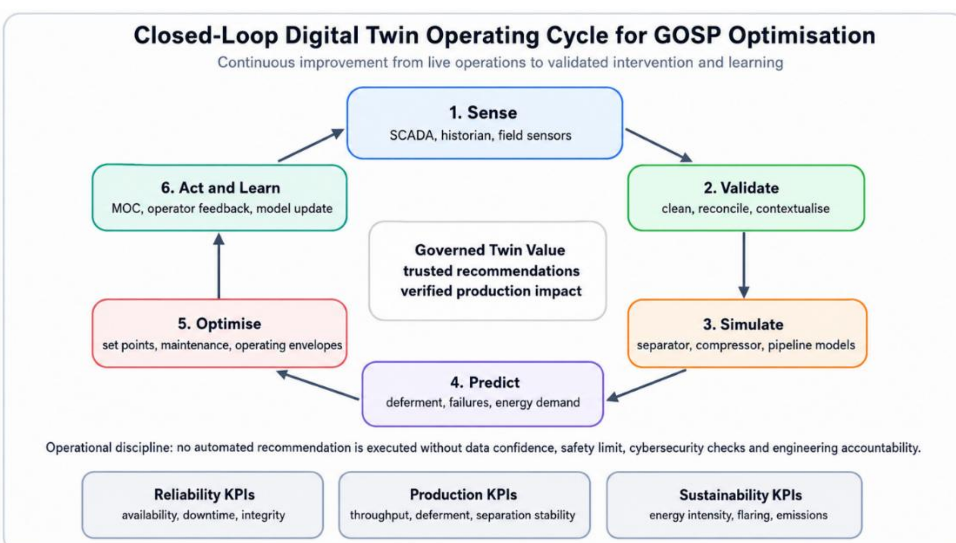

Figure 2. Development, validation and controlled deployment workflow for a GOSP digital twin.

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VII. SAUDI SMART OIL FIELD CONTEXT AND VISION 2030 ALIGNMENT

Saudi oil-field operations combine large production networks, remote facilities, mature and new infrastructure, high-value rotating equipment, extensive pipelines and demanding environmental conditions. These characteristics increase the value of reliable remote visibility and scenario analysis, but they also increase the consequence of poor data, an invalid model or an unauthorised recommendation. The technical case for a digital twin is therefore strongest when it reduces uncertainty in a defined engineering decision.

The author's background in major GOSP-related projects, flow measurement, pumps, compressors, project engineering, environmental auditing and current digital-twin work provides relevant practice context. It supports a lifecycle view in which design information, vendor data, commissioning baselines and operating measurements remain connected. This is particularly important for brownfield modifications, equipment replacement, pipeline rerouting and changes to operating philosophy, because the twin must reflect the as-operated facility rather than the original design model.

Alignment with Saudi Vision 2030 should be demonstrated through measurable engineering capability: improved use of operational data, local model ownership, faster diagnosis, reduced repeated failures, more efficient energy use, stronger environmental evidence and structured transfer of expert knowledge. General statements about digital transformation are insufficient. Each deployment should define a baseline, a responsible owner and an auditable benefit measure.

The Saudi Aramco Process Simulation Twin presented at AVEVA World in 2025 illustrates the relevance of automated data collection, reconciliation, model calibration and up-to-date simulation for decision support [22]. The example is from refining rather than a GOSP, but the underlying discipline is directly applicable: models must be continuously refreshed, reconciled and connected to high-value troubleshooting and opportunity identification.

VIII. IMPLEMENTATION READINESS AND GOVERNANCE REQUIREMENTS

Data readiness is the first gate. Each required tag should have a defined source, engineering unit, sampling behaviour, quality flag, calibration status, expected range and asset relationship. Duplicate tags, incorrect timestamps, unit conversion errors and manual entries must be resolved before model calibration. Historian completeness alone is not sufficient; the data must be fit for the decision.

Model readiness is the second gate. Every model should document purpose, equations, assumptions, parameters, valid operating range, calibration dataset, validation dataset, confidence limits and failure modes. A separator model validated only at stable conditions should not be used to diagnose severe slugging. A pump model based on a clean-water curve should not be used without correction where fluid properties or gas entrainment materially affect performance.

Organisational ownership is the third gate. The asset owner should approve the use case and benefit measure. The data owner should maintain tag quality and context. The model owner should control versioning, calibration and drift assessment. The cybersecurity owner should approve interfaces and access. Operations should own the final field decision. Maintenance and reliability teams should confirm how recommendations enter inspection, notification or work-order processes.

Training must cover more than software navigation. Engineers and operators should understand model assumptions, uncertainty, residuals, confidence levels, override criteria and the difference between correlation and physical cause. The author's AVEVA training can be documented in the final manuscript through exact course titles and certificates once those records are available. Until then, the paper should refer generally to AVEVA-oriented digital training and should not claim certification in a named module.

Cybersecurity and safety controls must be designed with the architecture. Operational technology and information technology connections should use approved network segmentation, authentication, secure data transfer, logging, backup and change control. Model inputs and parameters should be protected against unauthorised modification. Recommendations that influence critical operations must be screened against safe operating limits, alarm and trip logic, HAZOP safeguards and SIL functions. NIST CSF 2.0 provides a current risk-management framework, while ISO 23247 provides useful digital-twin lifecycle and architecture principles [17], [18].

Deployment should proceed from offline analysis to historical replay, shadow-mode online operation and controlled advisory use. Benefits should be measured against an agreed baseline. Model performance should be reviewed after equipment maintenance, process modification, instrumentation change or sustained drift. If data confidence or model validity falls below the approved threshold, the twin should clearly declare that it is unavailable for decision support.

IX. CHALLENGES AND RESEARCH GAPS

The first challenge is incomplete evidence of long-term operational value. Many oil and gas studies remain conceptual, pilot-scale or limited to one asset. Recent systematic reviews confirm that requirements are increasingly well described, but fewer publications report sustained plant-level accuracy, model-maintenance effort and realised value [10], [12]. Future GOSP studies should publish anonymised before-and-after evidence, including model errors and unsuccessful cases, rather than only potential benefits.

The second challenge is measurement credibility. Oil, gas and water flows are affected by calibration, pressure, temperature, fluid properties, multiphase conditions and time alignment. A digital twin can amplify poor measurements if reconciliation and uncertainty are omitted. Research should compare alternative reconciliation strategies and quantify how measurement uncertainty propagates into deferment, equipment-health and optimisation decisions.

The third challenge is model lifecycle management. Process conditions, wells, equipment, control logic and facility configuration change. Model drift may be gradual and difficult to distinguish from developing equipment degradation. Practical research is needed on automated drift detection, controlled recalibration and retention of engineering interpretability. A model that is frequently retrained but cannot explain why its recommendation changed may be unsuitable for high-consequence operations.

The fourth challenge is integration. Engineering documents, real-time data, maintenance history, inspection findings and operator knowledge often exist in separate systems with inconsistent asset identifiers. The reference AVEVA architecture can reduce this fragmentation, but successful integration still depends on data ownership, naming standards and project-to-operations information handover. Vendor capability does not remove the need for engineering governance.

The fifth challenge is human trust. Operators may ignore alerts that are frequent, unexplained or disconnected from available actions. Future work should measure the quality of explanations, investigation time, operator acceptance, false-alarm burden and learning from rejected recommendations. The most valuable twin may be one that improves the quality and speed of human judgement rather than one that attempts autonomous control.

The final challenge is confidentiality. Real GOSP case studies are difficult to publish because process data, equipment configuration and operating limits may be restricted. Anonymised case structures, dimensionless variables, normalised residuals and approved event descriptions can provide technical evidence without exposing sensitive details. The current paper adopts that approach and should be updated with authorised project evidence when available.

X. IMPLEMENTATION SYNTHESIS

Implementation should begin with one asset and one decision. A suitable first case is a separator or critical pump with repeated disturbances, measurable production consequence and adequate instrumentation. The project team should define the decision, baseline KPI, required lead time, safe operating limits and responsible user before collecting additional data or building a model.

The second step is data qualification. Tags should be mapped to the asset hierarchy, units and timestamps harmonised, calibration and uncertainty reviewed, and relevant alarms, laboratory values, maintenance events and operating modes aligned. Historical normal operation and known disturbances should be separated into calibration and validation datasets. Data that cannot support the required decision should be identified openly rather than concealed through interpolation.

The third step is model construction. First-principles relationships should represent mass balance, holdup, pressure drop and equipment performance. Data-driven components should model residual behaviour only where justified. The AVEVA reference stack can connect PI System data to Process Simulation, contextualise assets and present results through operational dashboards [19], [20]. Engineering drawings, datasheets and vendor curves should remain linked through controlled information management.

The fourth step is validation. The model should reproduce historical normal periods and known events, and its error, false-alarm rate, missed-event rate and detection lead time should be documented. Validation should include different production rates, fluid conditions, equipment line-ups and post-maintenance states. The model should then operate in shadow mode so that predictions are compared with actual behaviour without affecting operations.

The fifth step is controlled use. Recommendations should be advisory, explainable and linked to a verification action. Operations and engineering should review the affected asset, probable cause, confidence, production impact, safety constraints and proposed response. Any change to operating limits, control logic or maintenance strategy should follow approved procedures and management of change.

The final step is benefit verification and expansion. The project should compare outcomes with the baseline: earlier detection, shorter diagnosis, fewer repeated events, lower deferment, improved availability, reduced energy intensity or stronger environmental evidence. Benefits should not be assumed from software deployment. Once one-use case demonstrates sustained value and acceptable maintenance effort, the architecture can be extended to connected assets and eventually to integrated GOSP optimisation.

XI. CONCLUSION

This paper has replaced a broad digital-transformation discussion with a technically specific, practice-informed framework for GOSP digital twins. The core contribution is an auditable architecture that connects traceable measurements, AVEVA-based operational data management, online process simulation, equipment-performance analytics, engineering information and controlled field decisions. The framework is developed around separator stability, rotating-equipment reliability and production-deferment diagnosis because these use cases have clear data requirements, measurable consequences and identifiable decision owners.

The analysis shows that technical credibility depends on measurement uncertainty, data reconciliation, explicit equations, model validity ranges and event-based validation. RMSE or model fit alone is insufficient; false alarms, missed events, detection lead time, process-mode robustness and post-maintenance behaviour must also be demonstrated. Optimisation should remain constrained by equipment envelopes, environmental obligations, HAZOP and SIL safeguards, cybersecurity and management-of-change requirements.

The author's current involvement in digital-twin work and AVEVA-oriented training provides practical relevance, but this paper deliberately avoids claims that cannot be supported by authorised evidence. The AVEVA technology stack is presented as a traceable reference architecture, not as a declaration of the exact current-project configuration. No confidential project data, tag names, process capacities or proprietary operating limits are disclosed.

A professional GOSP digital twin should therefore be judged not by visual sophistication or the number of connected tags, but by whether it produces a trusted, explainable and measurable improvement in an engineering decision. The recommended route is narrow deployment, rigorous validation, shadow-mode use, accountable advisory decisions and evidence-based expansion.

REFERENCES

[1] T. R. Wanasinghe et al., "Digital Twin for the Oil and Gas Industry: Overview, Research Trends, Opportunities, and Challenges," IEEE Access, vol. 8, pp. 104175-104197, 2020. https://doi.org/10.1109/ACCESS.2020.2998723

[2] A. Rasheed, O. San, and T. Kvamsdal, "Digital Twin: Values, Challenges and Enablers from a

Modeling Perspective," IEEE Access, vol. 8, pp. 21980-22012, 2020. https://doi.org/10.1109/ACCESS.2020.2970143

[3] A. Fuller, Z. Fan, C. Day, and C. Barlow, "Digital Twin: Enabling Technologies, Challenges and Open Research," IEEE Access, vol. 8, pp. 108952-108971, 2020. https://doi.org/10.1109/ACCESS.2020.2998358

[4] M. Liu, S. Fang, H. Dong, and C. Xu, "Review of Digital Twin about Concepts, Technologies, and Industrial Applications," Journal of Manufacturing Systems, vol. 58, pp. 346-361, 2021. https://doi.org/10.1016/j.jmsy.2020.06.017

[5] E. VanDerHorn and S. Mahadevan, "Digital Twin: Generalization, Characterization and Implementation," Decision Support Systems, vol. 145, 113524, 2021. https://doi.org/10.1016/j.dss.2021.113524

[6] D. M. Botin-Sanabria et al., "Digital Twin Technology Challenges and Applications: A Comprehensive Review," Remote Sensing, vol. 14, no. 6, 1335, 2022. https://doi.org/10.3390/rs14061335

[7] F. Shen, S. S. Ren, X. Y. Zhang, H. W. Luo, and C. M. Feng, "A Digital Twin-Based Approach for Optimization and Prediction of Oil and Gas Production," Mathematical Problems in Engineering, 2021, 3062841. https://doi.org/10.1155/2021/3062841

[8] O. Elijah, P. A. Ling, S. K. A. Rahim, T. K. Geok, A. Arsad, E. A. Kadir, M. Abdurrahman, R. Junin, A. Agi, and M. Y. Abdulfatah, "A Survey on Industry 4.0 for the Oil and Gas Industry: Upstream Sector," *IEEE Access*, vol. 9, pp. 144438–144468, 2021, doi: 10.1109/ACCESS.2021.3121302.

[9] F. P. Knebel, R. Trevisan, G. S. do Nascimento, M. Abel, and J. A. Wickboldt, "A Study on Cloud and Edge Computing for the Implementation of Digital Twins in the Oil & Gas Industries," Computers & Industrial Engineering, vol. 182, 109363, 2023. https://doi.org/10.1016/j.cie.2023.109363

[10] R. C. Belo, M. S. Pimenta, T. T. Salvador, R. H. Petry, and M. Abel, "Fundamental Requirements of Digital Twins for Production System in Oil and Gas Industry: A Systematic Literature Review," Information and Software Technology, vol. 184, 107742, 2025. https://doi.org/10.1016/j.infsof.2025.107742

[11] L. Peterson, I. V. Gosea, P. Benner, and K. Sundmacher, "Digital Twins in Process Engineering: An Overview on Computational and Numerical Methods," Computers & Chemical Engineering, vol. 193, 108917, 2025. https://doi.org/10.1016/j.compchemeng.2024.108917

[12] N. Hamidishad, R. S. Barbosa, A. Allahyarzadeh-Bidgoli, and J. I. Yanagihara, "Digital Twin Frameworks for Oil and Gas Processing Plants: A Comprehensive Literature Review," Processes, vol. 13, no. 11, 3488, 2025. https://doi.org/10.3390/pr13113488

[13] G. Mazzuto, I. Pietrangeli, M. Ortenzi, F. E. Ciarapica, and M. Bevilacqua, "Leveraging Digital Twin for Operational Resilience in the Oil and Gas Industry," Array, vol. 27, 100443, 2025. https://doi.org/10.1016/j.array.2025.100443

[14] E. Jahanshahi, D. Krishnamoorthy, A. Codas, B. Foss, and S. Skogestad, "Plantwide Control of an Oil Production Network," Computers & Chemical Engineering, vol. 136, 106765, 2020. https://doi.org/10.1016/j.compchemeng.2020.106765

[15] L. O. Seman et al., "Tuning of Oil Well Models with Production Data Reconciliation," Computers & Chemical Engineering, vol. 145, 107179, 2021. https://doi.org/10.1016/j.compchemeng.2020.107179

[16] A. Sircar, K. Yadav, K. Rayavarapu, N. Bist, and H. Oza, "Application of Machine Learning and Artificial Intelligence in Oil and Gas Industry," Petroleum Research, vol. 6, no. 4, pp. 379-391, 2021. https://doi.org/10.1016/j.ptlrs.2021.05.009

[17] International Organization for Standardization, "ISO 23247-1:2021 - Automation Systems and Integration - Digital Twin Framework for Manufacturing - Part 1: Overview and General Principles," 2021. https://www.iso.org/standard/75066.html

[18] National Institute of Standards and Technology, "The NIST Cybersecurity Framework (CSF) 2.0," NIST CSWP 29, 2024. https://doi.org/10.6028/NIST.CSWP.29

[19] AVEVA, "AVEVA Process Simulation," official product documentation, accessed 29 July 2026. https://www.aveva.com/en/products/process-simulation/

[20] AVEVA, "Integrating AVEVA PI System with AVEVA Process Simulation," 23 June 2025, accessed 29 July 2026. https://www.aveva.com/en/perspectives/blog/unlocking-operational-excellence/

[21] AVEVA, "Eni: Deploying a Digital Twin to Maximize Upstream Assets," official success story, accessed 29 July 2026. https://www.aveva.com/en/perspectives/success-stories/eni/

[22] AVEVA and Saudi Aramco, "Accelerating Corporate Decision-Making with the Process Simulation Twin," AVEVA World 2025, accessed 29 July 2026. https://www.aveva.com/en/perspectives/presentations/2025/accelerating-corporate-decision-making-with-the-process-simulation-twin/