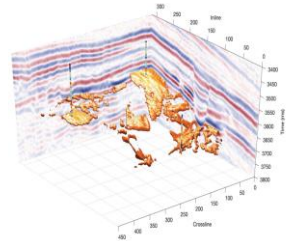
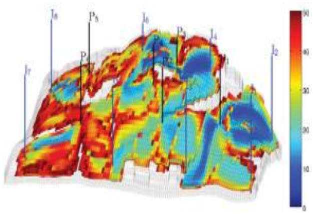
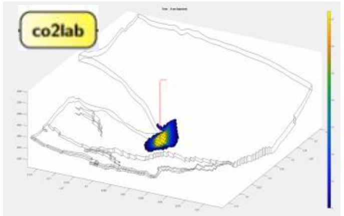
# Industrial Solutions for Energy Resources in MATLAB & SIMULINK®

(v. 4Q24)

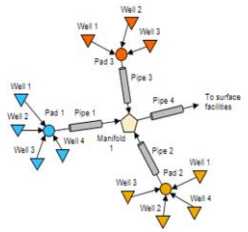
**Subsurface**

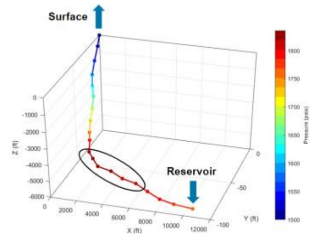


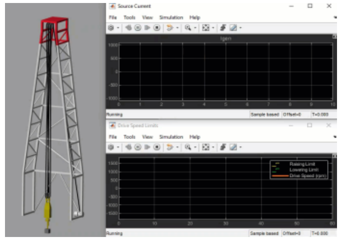




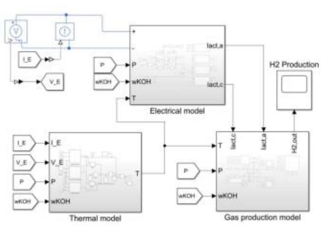

**Oilfield**

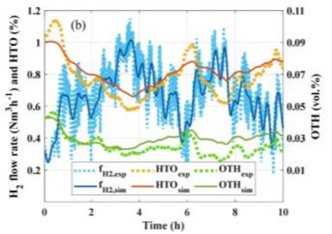


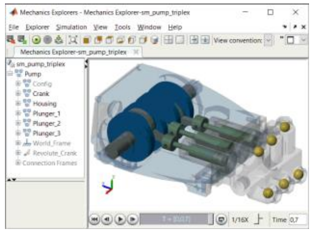



**Plant**



- Artificial Intelligence
- Big Data Analysis
- Deep Learning
- Machine Learning
- Reinforced Learning
- Predictive Analytics
- Internet of Things
- Process Optimization
- Model-Based Design
- Process Automation
- New Process Integration

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MATLAB® & SIMULINK®


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for STEM applications

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and profitable every year

# Our Customers by Industry


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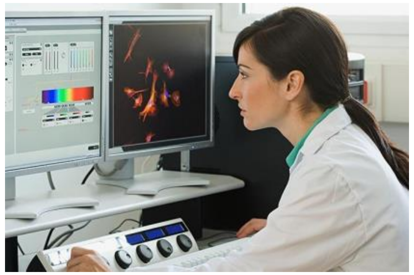
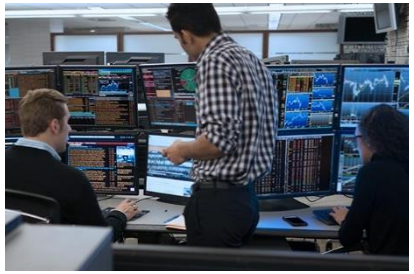

Biological Sciences


Biotech and Pharmaceutical


Communications


Electronics


Energy


Financial Services

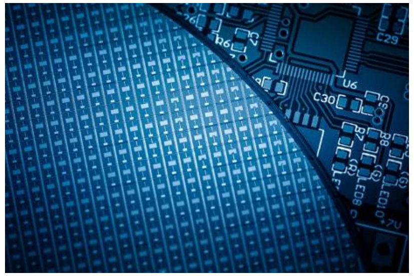

Industrial Machinery


Medical Devices


Process Industries

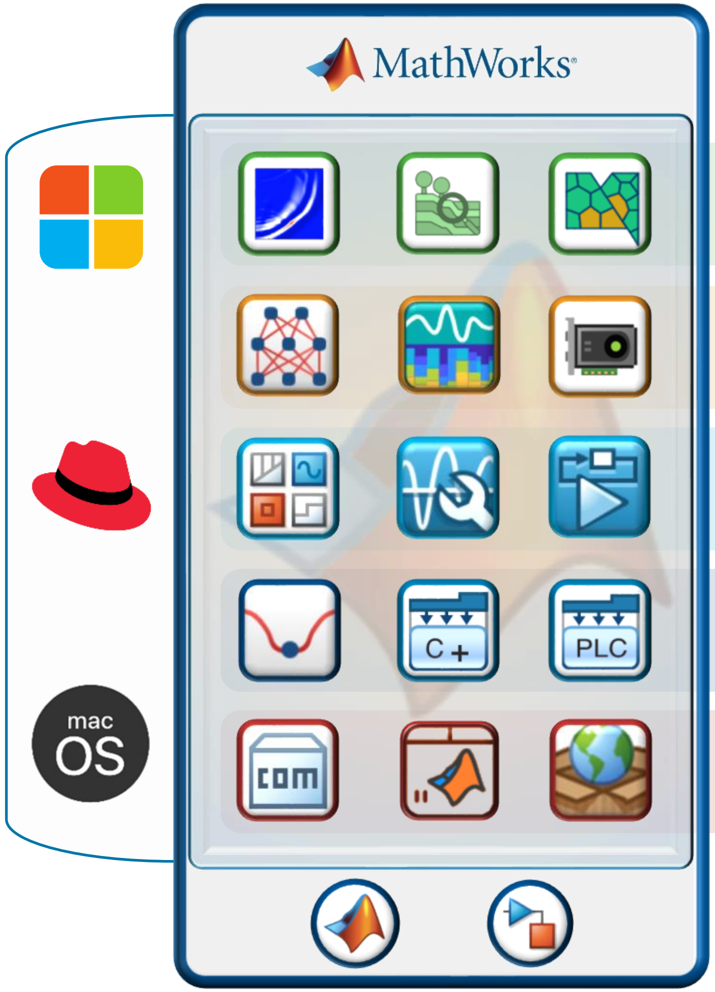

Neuroscience

Railway Systems


Semiconductors


Software and Internet

# How to Accelerate Scientific & Engineering Processes with MATLAB® & SIMULINK®



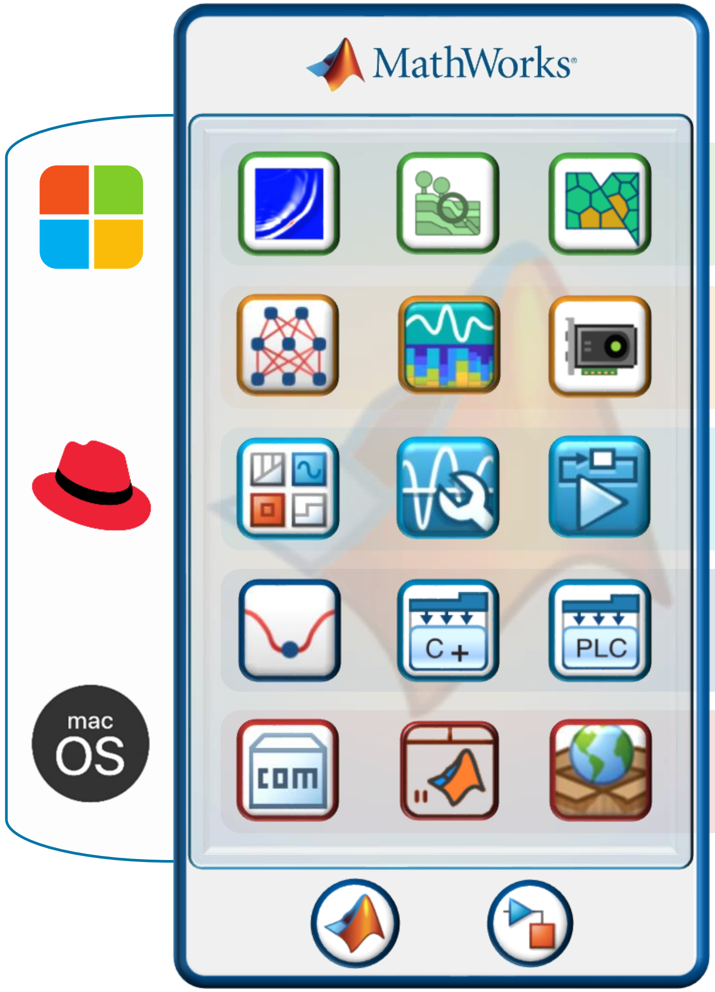
**Streamlined Asset Production Management**

- (Geo)Sciences & Engineering
- Big Data & Image Analysis
- Simulation & Control
- Optimization & Automation
- Interconnectivity & Deployment

**Industry-compliant, adaptive, cost-effective Scientific & Engineering solutions**

- **User-Friendly Interface for Non-Programmers** with intuitive IDE for applied engineering & scientific tasks
- **Streamlined Complex Computing** for predictive real-time analysis of large and frequent datasets
- **Graphical Model-Based Design** to simulate, test, validate, and control complex physical systems
- **Built-in Domain-Specific Toolboxes** for control systems, signal processing, AI, and automation
- **Direct Software & Hardware links** to accelerate workflows and data analysis on IT/OT infrastructure

# How to Accelerate Big Data & Image Analysis with MATLAB & SIMULINK

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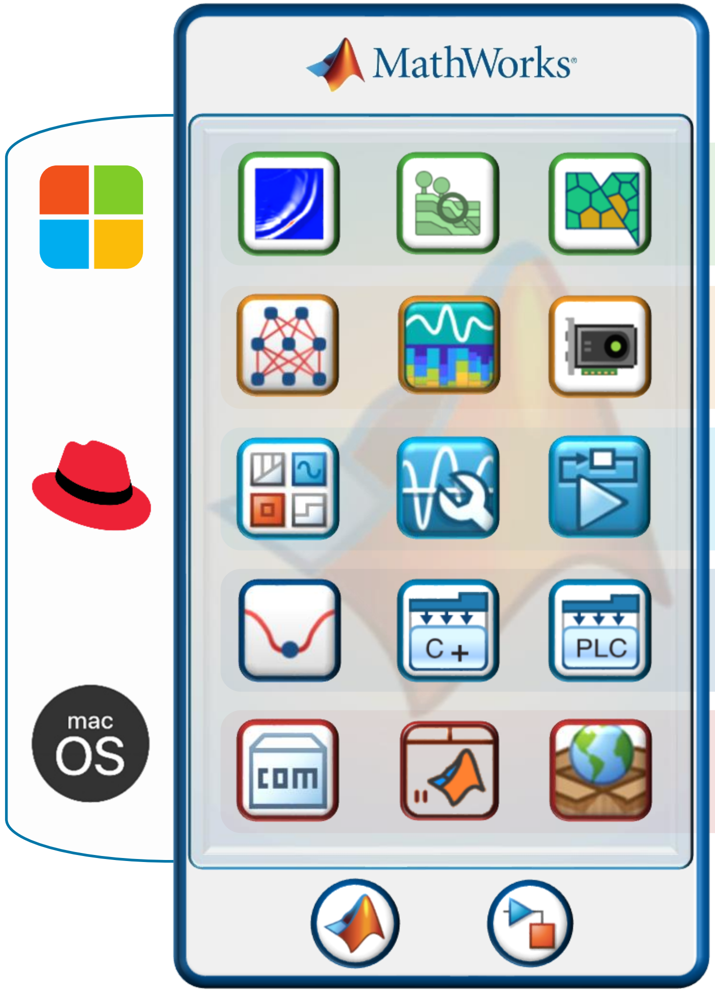
- Interconnectivity & Deployment

**Industry-compliant, adaptive, cost-effective Scientific & Engineering solutions**

- **Built-in big data scalability** using tall arrays and integration with Hadoop and Spark datastores
- **Advanced toolboxes** to rapidly process, analyze, and visualize large-scale data, signals, and images
- **Automated code generation** to integrate software and hardware systems for enhanced performance
- **Just-in-time (JIT) compilation** with optimized numerical analysis and matrix-based performance
- **Built-in parallel computing** using on-prem or cloud-based CPU or GPU cluster infrastructures

# How to Streamline Real-Time Data Analysis with MATLAB® & SIMULINK®




**Streamlined Asset Production Management**

- (Geo)Sciences & Engineering
- Big Data & Image Analysis
- Simulation & Control
- Optimization & Automation
- Interconnectivity & Deployment

**Industry-compliant, adaptive, cost-effective Scientific & Engineering solutions**

- **Easy-to-use and scalable platform** with high-level language, intuitive syntax, and low coding
- **Engineering workflows** to optimize & accelerate signal processing, control systems, and AI tasks
- **Specialized toolboxes** for real-time analysis, testing & validation of mission-critical operations
- **Automatic C/C++ code generation** to deploy on embedded systems and real-time platforms
- **Supports OPC, MODBUS & CAN protocols** for real-time analysis using OT and IIoT devices

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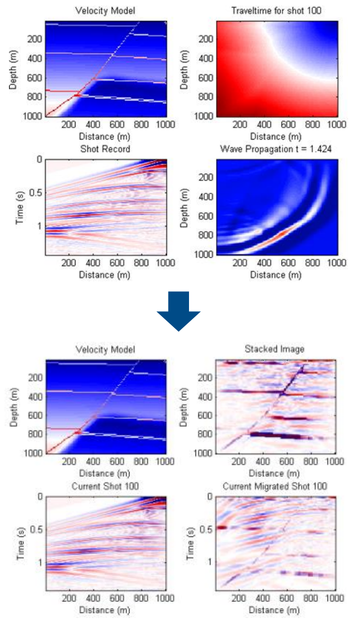
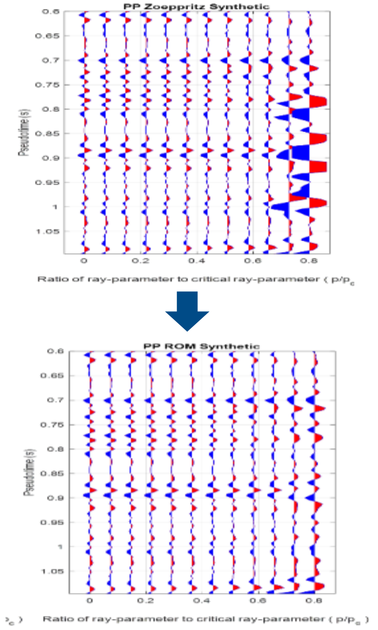
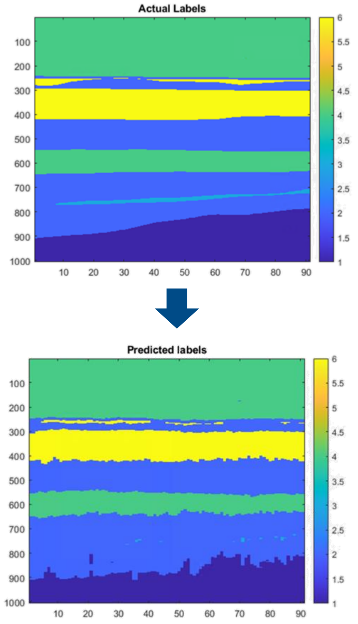
# Upstream Geosciences | Big Data Science Workflows

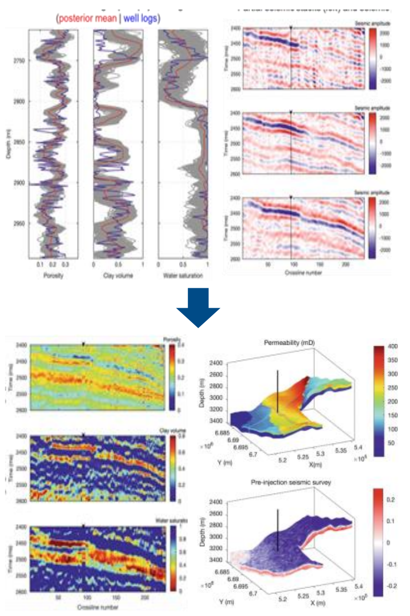
| Workflow | Imaging | Conditioning | Classifying | Inverting | Predicting |
|---|---|---|---|---|---|
| **Inputs** | Prestack seismic gathers<br>Seismic velocity model | Prestack migrated gathers<br>(after NMO or NHMO) | Seismic migrated stacks<br>Seismic inversion volumes | Prestack conditioned<br>AVO-compliant gathers | Seismic inversion volumes<br>Subsurface property vols. |
| **Key features** | **Prestack imaging**<br>(RTM, LSM, FWI)<br>Parallel computing<br>(CPU, GPU) | **Reduced order modeling**<br>(AVO, AVA, AVAz)<br>Gather flattening<br>Spectral balancing | **Structural / Stratigraphic classification**<br>Spectral decomposition<br>PINNs (CNN, RNN) | **Rock physics modeling**<br>**Petroelastic inversion**<br>Geostatistical modeling<br>Bayesian classification | **Sweet spot classification**<br>**Petroelastic/Geomechanical**<br>Petroelastic classification<br>PINNs (CNN, RNN) |
| **Toolboxes** | S3I (MCT)<br>Mapping<br>Parallel Computing | CMSL (MCT)<br>Signal Processing<br>Parallel Computing | Deep Learning<br>Wavelet<br>Parallel Computing | SeReM (MCT)<br>MRPI (MCT)<br>Parallel Computing | Deep Learning<br>Wavelet<br>Parallel Computing |
| **Outputs** | Prestack migrated gathers<br>Prestack migrated stacks | Prestack conditioned<br>AVO-compliant gathers | Structural class. volume<br>Stratigraphic class. volume | Seismic inversion volumes<br>Subsurface property vols. | Sweet spot geobodies<br>Property class. volumes |

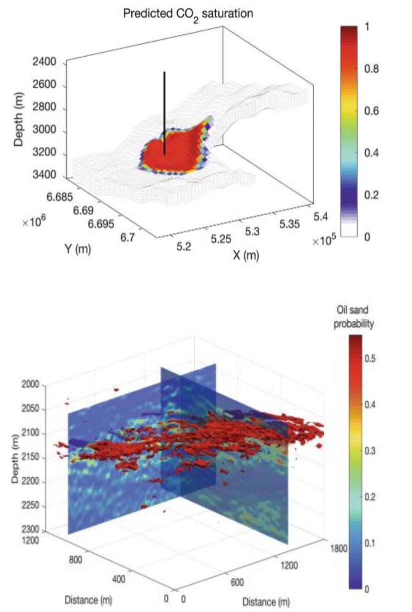
**Examples**



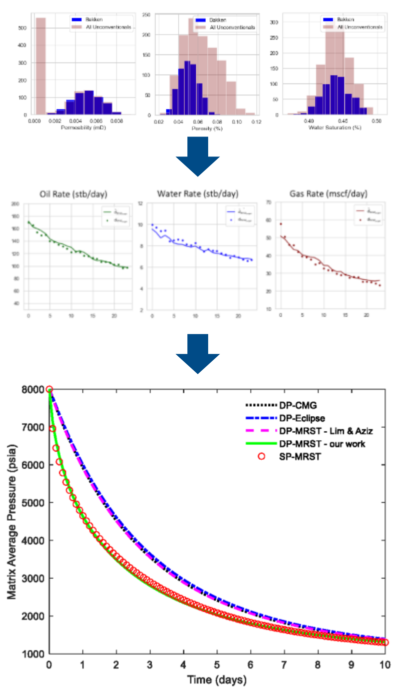



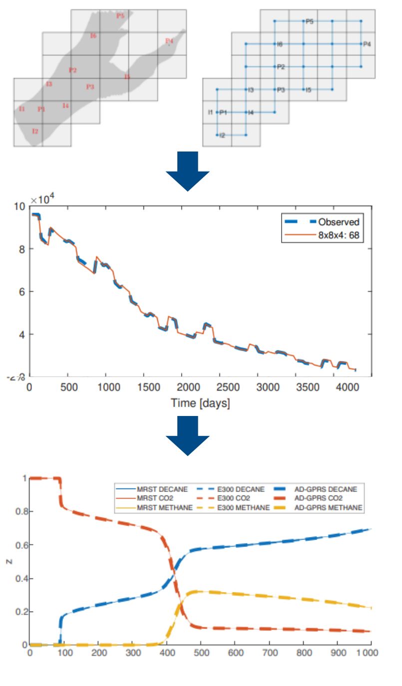


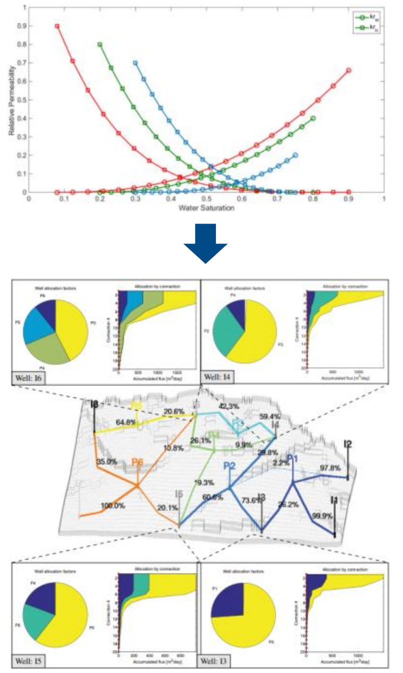
# Upstream Engineering | Production Optimization Workflows

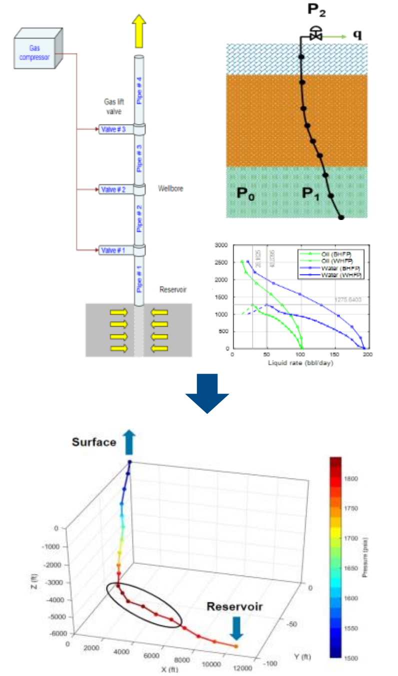
| Workflow | Modeling | Simulating | Automating | Monitoring | Optimizing |
|---|---|---|---|---|---|
| **Inputs** | Reservoir property grids<br>Production history data | Reduced order models<br>Dynamic model decks | Production history data<br>Reservoir model updates | Borehole and surface pipeline sensor data | Production history data<br>IPR & VLP data |
| **Key features** | **Reduced order modeling**<br>**CRM modeling**<br>**Dual-porosity modeling** | **Geomechanical simulation**<br>**Compositional fluids**<br>**Sensitivity analysis** | **Automatic history matching (AHM)**<br>Machine learning model | **Subsurface-to-surface nodal analysis**<br>Steady-state analysis | **Multi-pad, multi-well production optimization**<br>Steady-state analysis |
| **Toolboxes** | MRST (MCT)<br>Deep Learning<br>Parallel Computing | MRST (MCT)<br>Optimization<br>Parallel Computing | MRST (MCT)<br>Machine Learning<br>Parallel Computing | MRST (MCT)<br>Simscape<br>Parallel Computing | Optimization<br>Computational Finance<br>Parallel Computing |
| **Outputs** | History matching outputs<br>Reservoir model updates | History matching outputs<br>Reservoir model updates | History matching outputs<br>Reservoir model updates | Borehole and surface dynamic properties | Production history outputs |

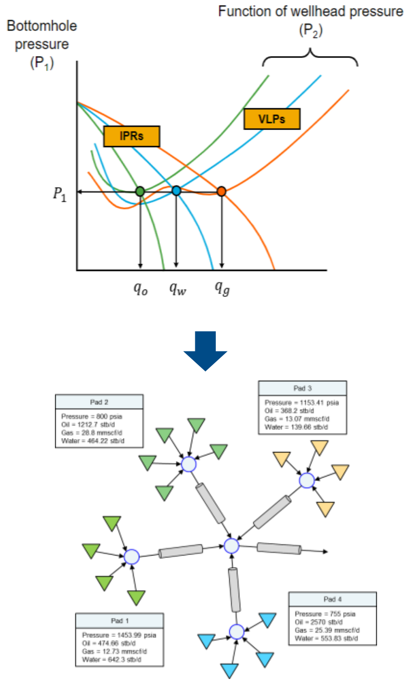
**Examples**



# MathWorks solutions for Midstream Asset Management

| Workflow | Key Solutions | Main Objectives | Major Applications | Examples |
|---|---|---|---|---|
| **System Design & Simulation** | **Simulink & Simscape** | • **Design and model** digital twins of complex multi-domain LNG infrastructure<br>• **Simulate and optimize** LNG facilities design before construction<br>• **Visualize and analyze** dynamic interactions between LNG subsystems | ➢ Fluid dynamics, thermodynamics, control systems<br>➢ Predictive, real-time operational optimization<br>➢ Gas processing and compression, LNG cooling | • Optimize and Automate Energy Assets with Digital Twins in MATLAB and Simulink<br>• Optimize Oil & Gas Production Assets with Simscape - MATLAB & Simulink |
| **Control System Development** | **MPC, Control Systems & PLC Coder** | • **Design** advanced control systems essential for LNG processes<br>• **Generate** structured text to deploy on PLCs and embedded controllers | ➢ Gas liquefaction, storage, and transportation<br>➢ Safe and efficient temperature & pressure control<br>➢ LNG facility process automation | • Digital Twins for Industrial IoT - MATLAB & Simulink<br>• Developing Energy Systems from Tank to Fuel Cell - MATLAB & Simulink |
| **Predictive Maintenance & Reliability Analysis** | **Pred. Maintenance, Machine & Deep Learning** | • **Design** predictive algorithms using sensor data from LNG facility equipment<br>• **Predict** operational performance using data-driven models and data analytics | ➢ Proactive maintenance to avoid unplanned downtime<br>➢ Optimize maintenance schedules (compressors, pipelines, tanks)<br>➢ Predict equipment degradation | • Introduction to Predictive Maintenance with MATLAB<br>• Digital Twins for Predictive Maintenance of Oil & Gas Processes - MATLAB & Simulink |
| **Process Optimization & Safety Assessment** | **Optimization & Planning** | • **Optimize** facility layouts, pipeline routing and LNG processing parameters<br>• **Quantify** risks in complex LNG operations<br>• **Model** safety-critical LNG systems | ➢ Enhanced operational efficiency, safety, and cost effectiveness<br>➢ Assess potential failures in pipelines, tanks, or processes | • Optimizing Operational Processes with Reinforcement Learning in MATLAB |
| **Scalability & Enterprise Systems Integration** | **App Deployment Servers & Industrial Communications** | • **Process** historical and real-time data from PI systems to fine-tune operations<br>• **Integrate** SCADA, ERP, and PI historians to analyze and optimize operational data<br>• **Deploy** enterprise-wide applications | ➢ Advanced process analytics to improve energy efficiency<br>➢ Run complex analysis, visualize data trends, and make data-driven decisions in real time | • MATLAB Production Server – MATLAB<br>• MATLAB Web App Server – MATLAB<br>• Industrial Communication Toolbox - MATLAB |

# MathWorks solutions for Downstream Process Optimization

- Flexible and scalable simulation of large-scale plant designs and unit-specific optimizations
- Advanced predictive analytics using data science and AI to optimize process operations
- Industry-compliant tools to ensure safe and sustainable production processes

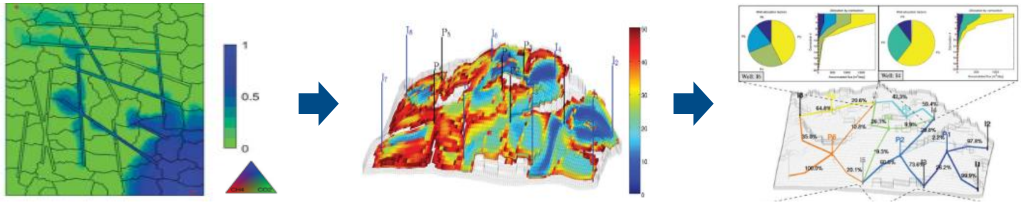
| Workflow | Key Solutions | Main Objectives | Major Applications | Examples |
|---|---|---|---|---|
| **Process Modeling & Simulation** | **MATLAB, Simulink & Simscape** | • **Build** dynamic models of chemical reactors, distillation columns, and heat exchangers<br>• **Simulate and optimize** nonlinear and time-dependent petrochemical processes<br>• **Visualize and analyze** dynamic interactions between petrochemical subsystems | ➢ **Optimize** process design and operations<br>➢ **Analyze** energy and mass balances<br>➢ **Troubleshoot** processing and production bottlenecks | • Chemicals and Materials - MATLAB & Simulink<br>• Selection of Optimum Chemical Reactor Design<br>• Controller for Distillation Column<br>• Heat Exchangers |
| **Process Control & Automation** | **MPC, Control Systems & Simulink Real-Time** | • **Design and tune** advanced controllers (MPC, PID) for distillation towers, compressors, and polymerization reactors<br>• **Develop and integrate** real-time models for predictive analytics using control systems<br>• **Implement** closed-loop control systems | ➢ **Enhance** process safety and reliability<br>➢ **Automate** fault-tolerant processes and operations<br>➢ **Integrate** DCS and SCADA systems and PI historians | • Nonlinear Model Predictive Control of Exothermic Chemical Reactor<br>• Adaptive MPC Control of Nonlinear Chemical Reactor<br>• Use OPC UA Data to Test Binary Distillation Column Plant Model |
| **Process Safety & Reliability** | **Pred. Maintenance, Machine & Deep Learning** | • **Develop** risk assessment models (HAZOP) supported by software-in-the-loop (SIL) tests<br>• **Simulate** critical process scenarios<br>• **Create** logical alarm management frameworks<br>• **Monitor** equipment health in real time using machine learning | ➢ **Simulate** and mitigate hazardous scenarios for critical process units<br>➢ **Analyze** historical alarm data to identify nuisances<br>➢ **Predict** and prevent equipment failure and anomalies | • Digital Twins for Predictive Maintenance of Oil & Gas Processes - MATLAB & Simulink<br>• Optimizing Operational Processes with Reinforcement Learning in MATLAB |
| **Process Design & Optimization** | **Optimization & Planning** | • **Optimize** feedstock blending and reaction conditions<br>• **Improve** throughput and reduce waste using data-driven modeling<br>• **Evaluate** economic and environmental performance of alternative processes | ➢ **Enhance** operational efficiency, safety, and cost effectiveness<br>➢ **Assess** potential failures in petrochemical facilities | • Multivariate Analysis for Process Monitoring \| Fault Detection and Diagnosis in Petrochemical Processes, Part 1<br>• HYSYS-MATLAB LINK - File Exchange - MATLAB Central |

# Subsurface Geosciences & Engineering

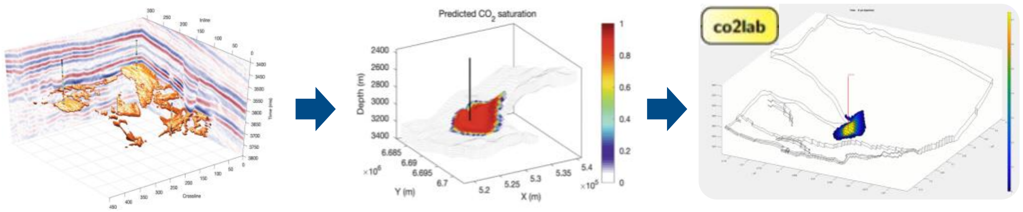
● Customize & optimize subsurface processes with integrated solutions developed in MATLAB & Simulink to maximize asset value ●

## Key Applications

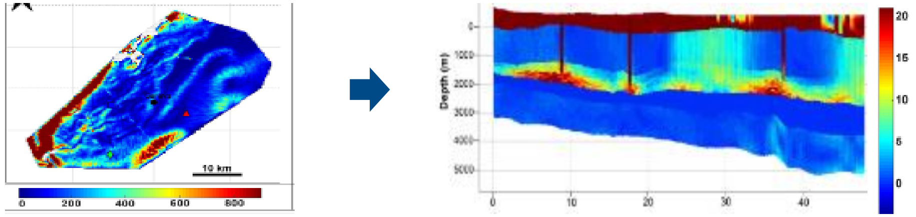
### Enhanced Recovery (EOR | IOR)



### Carbon Capture & Storage (CCS | GCS)




### New Energies (Hydrogen | Geothermal)




| Solution | | Key Features |
|---|---|---|
| S3I | Seismic Migration & Imaging | • 3D prestack migration (Kirchhoff, RTM, LSM)<br>• 3D elastic full waveform inversion (FWI)<br>• Multi-CPU and multi-GPU parallel processing |
| SeReM | Seismic Modeling & Inversion | • Seismic convolutional and geostatistical modeling<br>• Rock-physics-informed Bayesian facies inversion<br>• Elastic, mechanical, and petrophysical properties |
| MRST | Reservoir Modeling & Simulation | • 3D reservoir modeling and fluid flow simulation<br>• Multi-fluid, multi-physics geodynamics<br>• Automatic differentiation & reduced order models |

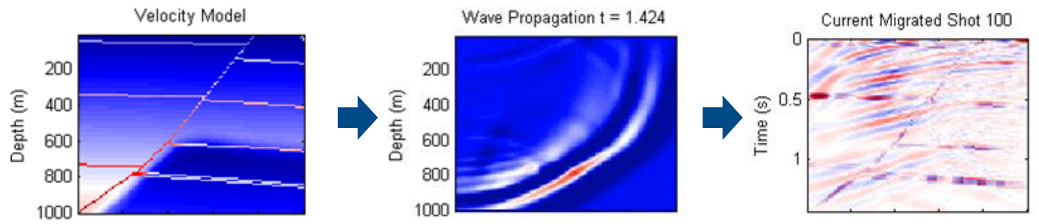
# Upstream Big Data & Image Analysis

MATLAB & SIMULINK

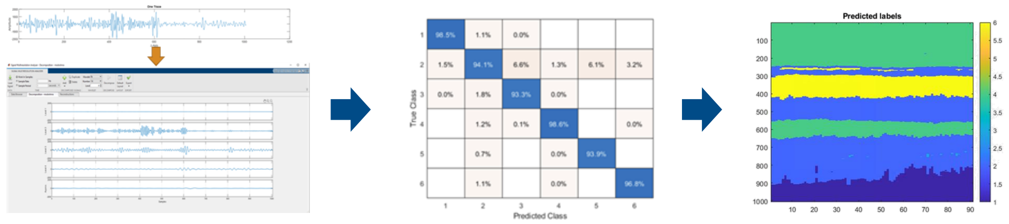
**● Accelerate processing and analysis of large-scale and real-time data and images to make prompt and informed asset decisions ●**

## Key Applications

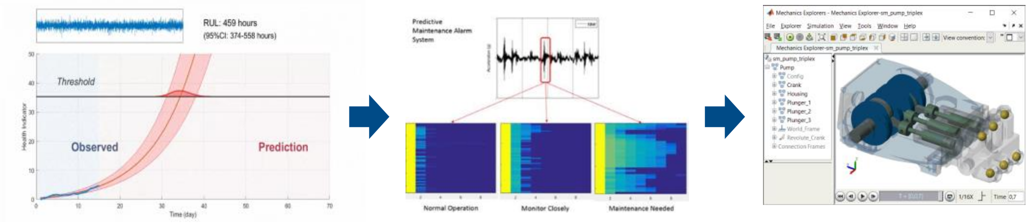
### Seismic Migration & GPU Computing




### Image Classification using PINNs (RNN | CNN)




### Predictive Maintenance & Anomaly Detection



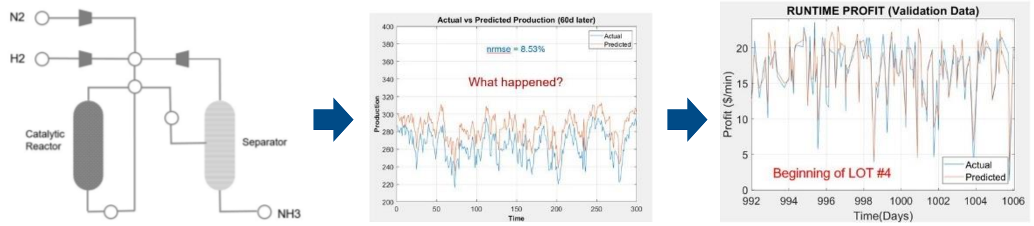

| Solution | Key Features |
|---|---|
| Machine & Deep Learning | • Classification, regression & clustering algorithms<br>• Deep neural networks (NN) & transfer learning<br>• Reduced order modeling & physics-informed NNs |
| Signal & Wavelet Processing | • Signal and wavelet analysis (time, space, freq.)<br>• Time series analysis and wavelet decomposition<br>• Multi-scale analysis for physics-informed NNs |
| High Performance Computing | • Multi-CPU, multi-GPU cluster & cloud computing<br>• GPU CUDA code generation & cloud deployment<br>• Run real-time analytics for process automation |

# Midstream & Downstream Data & Image Analysis

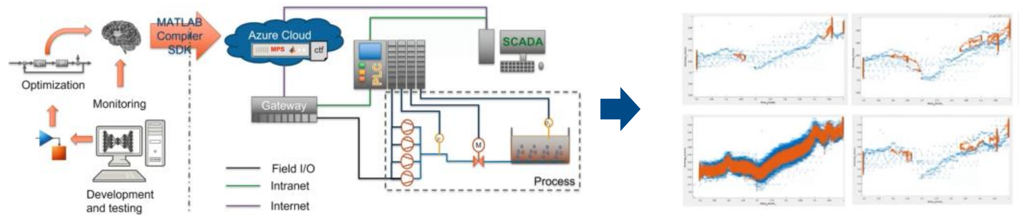
● Accelerate processing and analysis of large-scale and real-time data and images to make prompt and informed asset decisions ●

## Key Applications

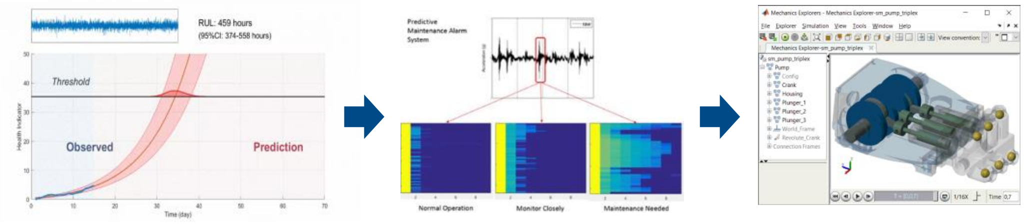
### Chemical Production Data Analytics




### Plant Production Monitoring and Optimization




### Predictive Maintenance & Anomaly Detection

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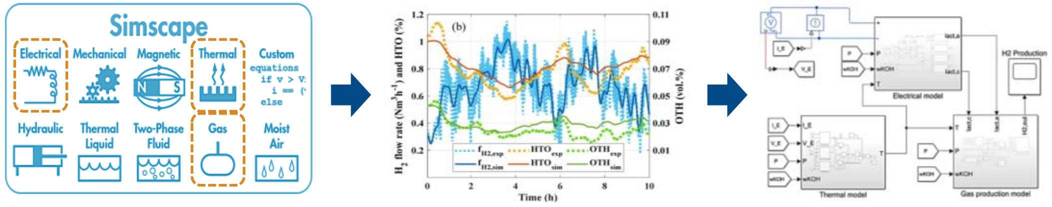
| Signal & Wavelet Processing | • Signal and wavelet analysis (time, space, freq.)<br>• Time series analysis and wavelet decomposition<br>• Multi-scale analysis for physics-informed NNs |
| High Performance Computing | • Multi-CPU, multi-GPU cluster & cloud computing<br>• GPU CUDA code generation & cloud deployment<br>• Run real-time analytics for process automation |

# Process Simulation & Control

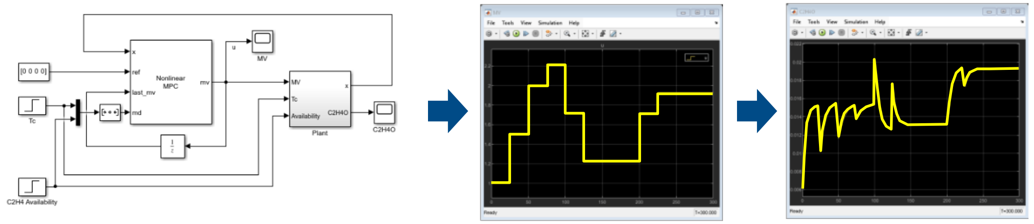
● Model, simulate, and monitor production processes using Simscape and Control Systems for cost-effective asset performance ●

## Key Applications

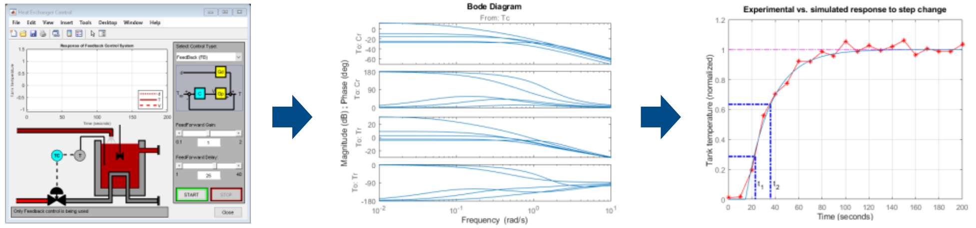
### Green Hydrogen Production Digital Twin




### MPC for Nonlinear Chemical Process Simulation




### Thermal/Fluid Process Predictive Control




| Solution | Key Features |
|---|---|
| Simscape Process Simulation | • Multi-domain process modeling and simulation<br>• Fluid, chemical, thermal, electromechanical model<br>• Model-based Design (MBD) of digital twins |
| Control Systems Design | • Design dynamic systems and controller response<br>• Tune PID controller & SISO/MIMO compensators<br>• Detect anomalies & diagnose feedback controls |
| Model Predictive Control | • Design advanced process controls (ACS \| DCS)<br>• Linear & nonlinear MPC design and optimization<br>• Control production process & remote surveillance |

# Upstream Process Optimization & Automation

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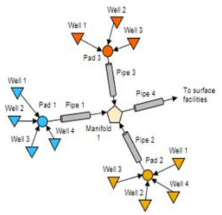
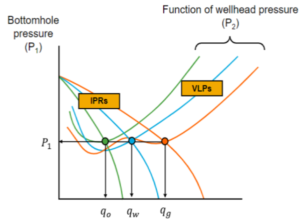
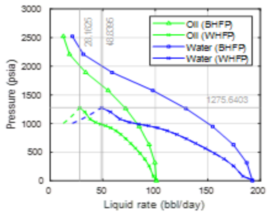
**● Perform techno-economic assessments and generate embedded code to optimize and automate reliable production processes ●**

## Key Applications

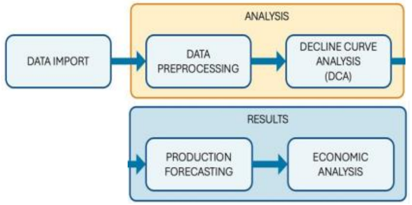
### Multi-pad, multi-well production optimization

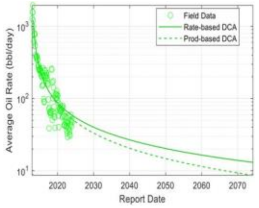


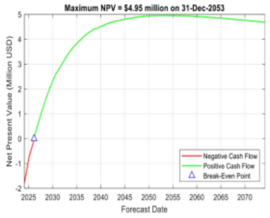



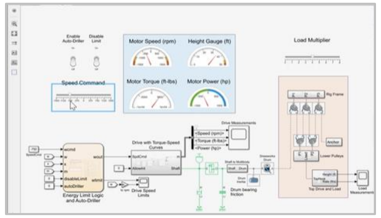

### Oil & gas production forecasting & economics

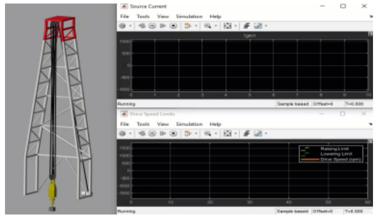



### Drilling rig system simulation & automation





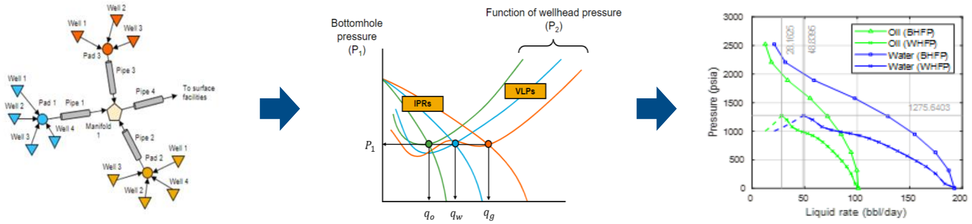
| Toolbox | Key Features |
| --- | --- |
| Optimization & Financial Computing | • Multi-variate process optimization and forecasting<br>• Technical and economic production optimization<br>• New energy risk and investment management |
| MATLAB Coder & Compiler | • C/C++ embedded code generation from MATLAB<br>• Customize, optimize, trace SIL & PIL processes<br>• Deploy on control systems for process automation |
| Simulink PLC Coder | • PLC & PAC structured text and ladder diagrams<br>• Support code generation for third-party IDEs<br>• Agnostic production surveillance with IIoT devices |

# Mid/Downstream Process Optimization & Automation

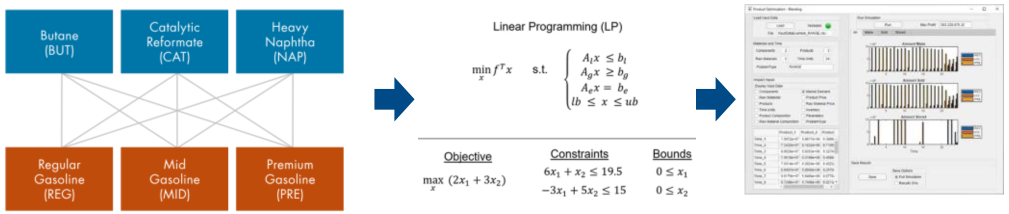
**● Perform techno-economic assessments and generate embedded code to optimize and automate reliable production processes ●**

## Key Applications

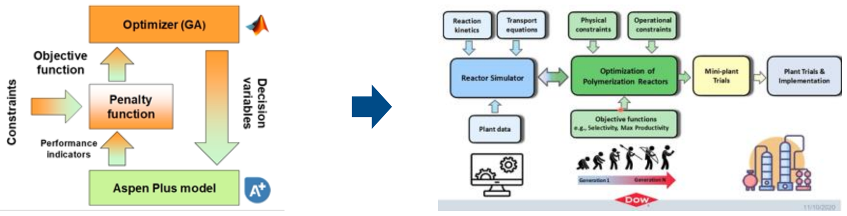
### Multi-pad, multi-well production optimization




### Supply chain optimization & economics




### Chemical process optimization & co-simulation

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# App Interconnectivity & Deployment

● Create, interconnect, and deploy software and hardware applications across asset's IT, OT, and IIoT infrastructure ●

## Key Applications

### Interconnectors with 3rd-party software

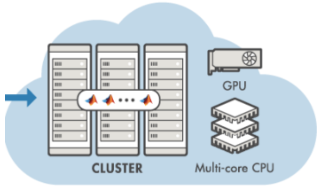
*Upstream*: Petrel, Eclipse, Vista

*Downstream*: Ansys, Honeywell, AVEVA, COMSOL

### Interconnectors with IIoT devices (PLC | DCS | RTU)

SIEMENS, YOKOGAWA, BECKHOFF, OMRON, EMERSON, Schneider Electric, MITSUBISHI ELECTRIC

### App & Microservice Deployment in the Cloud


Amazon SNS, Azure HDInsight, Amazon SQS, Databricks, Apache Spark, Google BigQuery, Amazon RDS, Google Storage, AWS Athena, Hadoop, Amazon S3, Azure Data Lake, Azure Blob Storage, AWS DynamoDB, Azure Cosmos DB

| Solution | Key Features |
|---|---|
| Industrial Comms | • Exchange data with OPC UA, MQTT protocols<br>• Interconnect IIoT devices (PLC, DCS, RTU)<br>• Support distributed control systems (SCADA) |
| MATLAB Compiler SDK | • Build standalone and web apps from MATLAB<br>• Build Python, .NET, C++, and Docker packages<br>• Deploy in OT & edge devices for IIoT surveillance |
| MATLAB Web App Server | • Use MATLAB App Designer to create Web GUIs<br>• Deploy and host MATLAB & Simulink web apps<br>• Control access using OpenID Connect & LDAP |

# MathWorks solutions for Digital Twin Modeling of Oilfield Processes

| | Product | Objective | Functions | Applications | Examples |
|---|---|---|---|---|---|
| Process Simulation | Simulink | Model dynamic systems with block diagrams to represent physical processes and control systems | • Model thermal flow systems<br>• Model oilfield infrastructure<br>• Model control systems | Oilfield assets:<br>• Borehole sensors<br>• Pipelines<br>• Oilfield equipment<br>• Processing facilities<br>• Storage facilities | Optimize and Automate Energy Assets with Digital Twins in MATLAB and Simulink |
| Process Simulation | Simscape | Model multi-physics processes | • Model gas and fluid flow dynamics<br>• Model condensation / evaporation<br>• Model liquefaction / regasification | | Optimize Oil & Gas Production Assets with Simscape - MATLAB & Simulink |
| Process Simulation | Sim. Real-Time | Test and deployment of models in real-time environments | • Hardware-in-the-loop (HIL) testing<br>• Testing digital twins in real-time<br>• Process safety and reliability | | Electro-Mechanical System Optimization using Simulation - MATLAB & Simulink |
| Process Control | Pred. Maintenance | Analyze equipment data from sensors, predict performance, and forecast maintenance | • Detect process anomalies<br>• Predict equipment failure<br>• Optimize maintenance schedule | • Pressure control<br>• Temperature control<br>• Flow rate regulation<br>• Faulty conditions<br>• Healthy conditions | Digital Twins for Predictive Maintenance of Oil & Gas Processes - MATLAB & Simulink |
| Process Control | Control Systems | Design, analyze, and implement process controls in digital twins | • Model Predictive Controls (MPC)<br>• Advanced Control Systems (APC)<br>• Distributed Control Systems (DCS) | | Digital Twins for Industrial IoT - MATLAB & Simulink |
| Process Control | PLC Coder | Deploy control algorithms onto field devices including PLCs and embedded controllers | • Automatic PLC code generation<br>• Automatic C/C++ code from Simulink model for hardware | • Multi-brand PLCs<br>• Multi-brand RTUs<br>• Embedded controllers | Developing Hydrogen Systems from Tank to Fuel Cell - MATLAB & Simulink |
| Data Analytics | MATLAB | Develop scripts, algorithms, and predictive models to perform real-time data analysis from sensors | • Data preprocessing and analysis<br>• Real-time signal processing<br>• Data postprocessing | S&H Integration with:<br>• Big data stores<br>• PI historians<br>• CaaS and SaaS<br>• RT dashboards<br>• 3rd-party applications<br>• Control systems | Digital Twins for New Energy Processes – MATLAB & Simulink |
| Data Analytics | Machine Learning | Develop predictive models using machine learning algorithms | • Process optimization, anomaly detection, and data analysis<br>• Real-time predictive analytics | | Optimizing Operational Processes with Reinforcement Learning in MATLAB |

# What energy customers have achieved using MathWorks products

| Customer | Objective | Outcome | MathWorks solutions |
|---|---|---|---|
| ExxonMobil | Drilling Modeling, Simulation, and Control | **Improved drilling performance and automation** | **MATLAB & Simulink** |
| | Model drill string dynamics for operational surveillance, diagnosis, and automation | • Continuously improve drilling automation process<br>• Save time selection and optimizing drilling systems | • Simscape + Stateflow<br>• Control Systems |
| aramco | Natural Fracture Prediction and Analysis | **Efficient geomechanical modeling & simulation** | **MATLAB** |
| | Perform key structural geomechanics analysis in a computational and cost-efficient manner | • Accelerated reservoir geomechanics workflow for elastic dislocation and fracture prediction analysis | • Math & Optimization<br>• App Deployment |
| Chevron | Reduced-Order Reservoir Simulation | **Accelerated reservoir management decisions** | **MATLAB** |
| | Simulate reservoir and surface conditions in a mature oilfield to optimize production recovery | • Integrated LSTM-CRM reservoir models<br>• Supported real-time decision making | • Reservoir Modeling & Simulation<br>• Optimization & App Deployment |
| Shell | Microseismic Monitoring of Carbon Storage | **Accelerated CCS surveillance decisions** | **MATLAB** |
| | Design measuring-monitoring-verifying (MMV) plan for CO2 storage using microseismic data | • Developed a risk-based MMV app for microseismic analytics to assess containment at CCS complex | • Image & Signal Processing<br>• Data Analytics +App Deployment |
| BR PETROBRAS | Oil Production Modeling and Control | **Integrated process control theory and practice** | **MATLAB & Simulink** |
| | Model oil production processes, dynamic responses, and advanced control structures | • Production methods for data processing, modeling, and simulation of oilfield control systems | • Math & Optimization<br>• Control Systems |
| HALLIBURTON | Borehole Image Processing and Analysis | **Enhanced DAS survey modeling & VSP imaging** | **MATLAB** |
| | Model and process distributed acoustic sensor (DAS) datasets to enhance borehole images | • Integrated seismic models to design DAS surveys<br>• Design migration algorithms for VSP images | • Image & Signal Processing<br>• Math & Optimization |
| slb | Adaptive Multi-Domain Controller Design | **Improved wireline logging operations** | **MATLAB + Simulink** |
| | Model, simulate, and deploy multi-domain controller systems for operational optimization | • Customized control system model, generated embedded code, and test automation in DevOps | • Simscape + Stateflow<br>• Control Systems + Simulink Test |

MathWorks®

*Accelerating the pace of engineering and science*

INITIATE

INNOVATE

INSPIRE

MATLAB® & SIMULINK®