

wood.

Intelligent Operations
World Class Technical Consulting Services & Solutions





Intelligent Operations

Wood offers a global team of specialists experienced in applying advanced technology for the design and optimal operation of oil and gas production, pipeline and processing facilities. Our services and solutions provide clear value-added solutions for our customers in the upstream, midstream and downstream oil and gas industry as well as other process industries.

Our consultants are recognised as world-class experts in flow assurance and combining strong analytical capabilities and innovative technology in transient multiphase flow, thermodynamics, dynamic process simulation, production chemistry, computational fluid dynamics, multiphase metering and allocation, process optimisation & debottlenecking, data analytics and machine learning. We also provide solutions for advanced process control, environmental compliance management, training and competency, supply chain and manufacturing execution systems (MES).

Wood's know-how in engineering and operations of multiphase production systems is embedded in Virtuoso®, our field-proven simulation software suite. Through Virtuoso, we provide project-specific, turnkey, cost-effective real-time optimisation solutions for single-phase and multiphase production facilities and pipelines.

Our services ensure customers of the most complete solutions available. We provide value during the project through our cost effective execution, combined with a clear focus on operability from startup through the long term.

Our history and our legacy

Our technical consulting arm has been proudly serving the oil and gas industry over the last 20+ years. We continue to deliver innovative, cost-effective solutions for some of the world's toughest field development and production challenges. We have executed more than 4,000 technical consulting projects for 150 companies in over 50 countries. Wood offers unparalleled experience in vital upstream engineering disciplines including concept screening and field development, flow assurance, pre-FEED/FEED, field planning, well testing, fluid sampling and laboratory analysis and operations troubleshooting.

Today, we serve clients through numerous international offices and continue to invest aggressively in technology and people to expand our service and product line offering. Our goal is to provide value in every asset life cycle phase, from pioneering conceptual studies to deploying state-of-the-art production optimisation systems.

We perform as a standalone technical consulting team or part of a Wood multi-disciplinary engineering team supporting larger-scale engineering design studies. We also provide independent third-party verification services as owner's engineer.

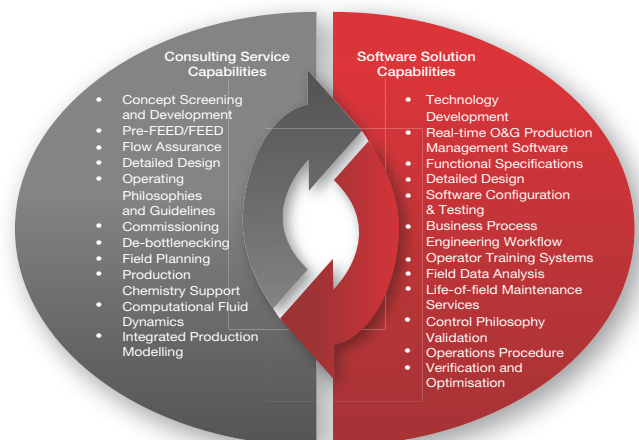
We offer:

- Independent project-specific tailored applications of field-proven technology
- Specialists combining strong analytical capabilities and innovative technologies with practical know-how

We are the largest globally-focused independent team of flow assurance and technical consulting experts and a world-class provider of field-proven digital tools and advanced technology.

to consult on flow assurance and develop turnkey applications.

- Experienced teams, with the depth & breadth of experience on a variety of operating environments, and committed to delivering excellence to our clients and their projects.
- Cost-effective solutions for real-time operations management, control and optimisation



We redefine Consulting Services through professional dedication and quality solutions!



Our Services

As an industry-recognised leader, Wood offers leading-edge technology, strong analytical capability and field-proven software systems. Our Virtuoso packages are used by our clients to manage 10% of the world's gas consumption.

We offer solutions in the following areas:

- Transient multiphase flow
- Computational Fluid Dynamics (CFD)
- Production chemistry & fluid phase thermodynamics
- Integrated production modeling & field development planning
- Process dynamics – topsides, subsea and plants
- Asset management and optimisation systems
- Operations support and troubleshooting
- Online monitoring systems & engineering simulators
- Operator training systems w/ fit-for-purpose fidelity
- Enhanced oil recovery (including steam-assisted/SAGD, chemical/ polymer flooding, CO₂ or water alternating gas/WAG)
- Carbon capture and storage, unconventional, shale and methane hydrate resources
- Environmental compliance management

Flow Assurance

Our consultants cover every aspect of the flow assurance field. Flow assurance is a diverse and often complex field covering the entire upstream process, from the reservoir to the production processing facilities. Our specialist flow assurance and process optimisation consultants have extensive experience in all project stages for offshore and onshore assets:

- Feasibility and conceptual studies
- Front-end engineering and detailed design
- Commissioning and start-up support
- Operations management and troubleshooting
- Life extension and decommissioning support

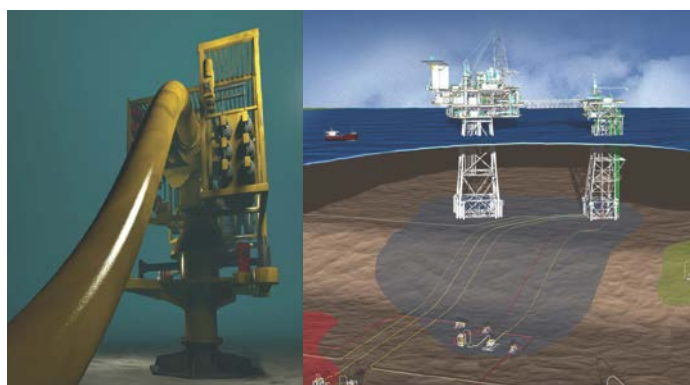
Wood's specialists are pioneers and leaders of flow assurance modeling methodologies. Transient multiphase flow modeling has become a standard technique for investigating system behaviour and operability of offshore, deepwater, arctic and desert production and transportation systems.

Our consultants use various techniques to understand multiphase pipelines and related facilities such as line sizing, line pack/unpack, safety-system analysis, slug-catcher analysis, corrosion-inhibitor transportation, hydrate/paraffin control. Transient multiphase flow modeling is achieved through multiple industry-standard tools.

We use state-of-the-art simulation tools including Olga, LedaFlow, Flowmaster2, PipeSim, PipeNet, Maximus, Hysys, Unisim, ChemCAD, DNV/Stoner SPS, Star CCM+, CFX and ScaleChem, plus Wood's own custom software, including Virtuoso, VPLink, GUTS, Maestro and the ProDyn/ProRPM/ProLearn/ProPlan/ProSched suite, providing cost-effective solutions to our clients.

Our dedicated team of consultants offer a broad knowledge and skill set devoted to providing the requisite understanding of the fluids and production chemistry issues to assist clients increase production, improve operability, and address operational issues that may come about. Whether integrated into an operator's multi-disciplinary team or our in-house Wood team, we can help investigate issues to handle a range of operational support services, including:

- Mitigating production chemistry issues
- Establishing operating procedures
- Tracking production performance and reporting of flow assurance KPI's
- Metering and production allocation
- Real-time support and operations troubleshooting
- Operations risk management and mitigation



Production Chemistry Support

Wood's production chemistry services enhance hydrocarbon recover by maintaining flow assurance integrity at all stages of production. We support plant integrity safety and apply cost-effective chemical solutions to production challenges. We help our customers gain a clearer understanding of fluid properties from the reservoir, pipelines and topside facilities, right through to the export system; providing the ability to predict and resolve potential issues.

Our highly experienced production chemists work alongside flow assurance and process optimisation engineers to provide integrated review and solution, underpinned with proprietary software technologies. Having implemented hundreds of projects, from small studies of large integrated inter-disciplinary projects, we offer a comprehensive and independent approach across all stages of field development and life cycle.

We manage fluids characterisation, conduct risk assessments of flow assurance issues, collaborate with laboratories for testing and develop solutions to mitigate production problems, including:

- Hydrates / wax / asphaltenes / naphthenates
- Microbiology / souring / corrosion / scale
- Emulsions / separation / fluid rheology / foaming
- Contaminants, e.g., mercury, H₂S
- Water injection – seawater, aquifer, river water, produced water reinjection and water alternating gas (WAG) injection plants
- Phase equilibrium and fluid property tuning for phase boundaries, liquid density and JT cooling & warming.

Focus Areas:

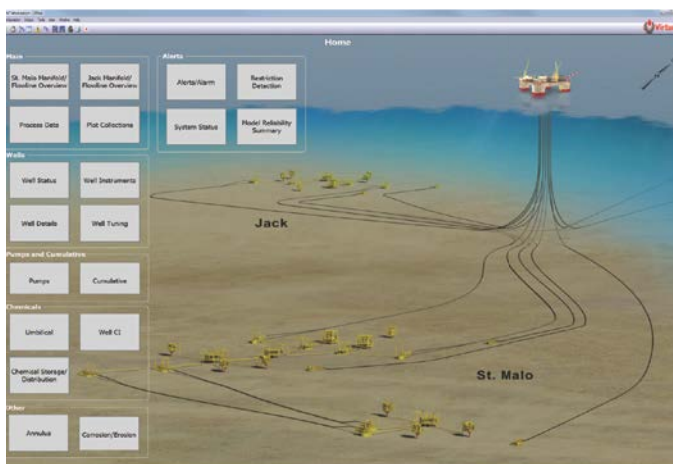
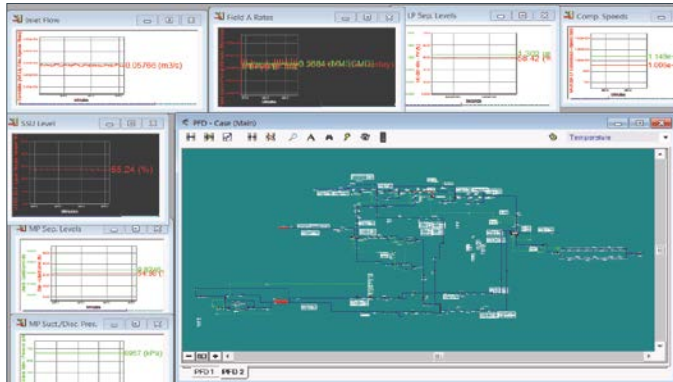
- Oil and gas field developments
- HPHT fields
- Acid gas sweetening
- Dehydration expertise
- Contaminant management

Services:

- Desktop review studies to define issues and recommend solutions
- Production system troubleshooting
- Chemical treatment facility design and application management
- General consultancy services
- Operations support (off-site and on-site, onshore and offshore)
- Provide training courses

Software used:

- GUTS™ (Grand Unified Thermodynamics Simulator)
- Electronic Corrosion Engineer (ECE)
- ScaleChem
- PVTsim
- KBC software (Multiflash & FloWax) for prediction of asphaltene and wax precipitation, wax deposition, hydrate formation and mercury partitioning



Dynamic Modeling & Simulations

Wood provides dynamic modeling and simulations consulting services. The typical deliverable in the development of detailed models include, but not limited to:

- Standalone dynamic process models
- Integrated models of production or gathering systems (e.g., wells, flowlines, including any subsea processes as well as topsides/downstream receiving facilities)

The benefits of using these models include:

- Facilitate process assessment and detailed analysis of robustness
- Integrated models to enable the evaluation of the performance of the topsides in response to the typical transient events of the production system, to establish a cause-effect-response matrix
- Perform operations planning and what-if analysis
- Provides a platform for operator training or deployment of operator training systems (OTS)
- Establish operating constraints and limits, including MAOPs/MAIPs, as in the case of pressure surge analysis.
- Conduct control system logic check-out and verify/validate control philosophy and troubleshoot issues and feasible solutions

Wood uses various tools for the services including:

- Process Modeling: Unisim, PetroSim, and Hysys, as well as Wood's Virtuoso suite, VP Link and ProDyn
- Pressure Surge Analysis: PipeNet, FlowMaster, Stoner SPS, AFT Fanthom Impulse, Olga and Virtuoso

Computational Fluid Dynamics (CFD) Analysis

CFD includes advanced numerical modeling of the flow of fluids in simple as well as complex three-dimensional (3D) geometries. Wood's team has extensive knowledge in all the leading CFD software packages and has been providing solutions for a wide variety of engineering problems for more than 20 years.

CFD modeling offers the following benefits:

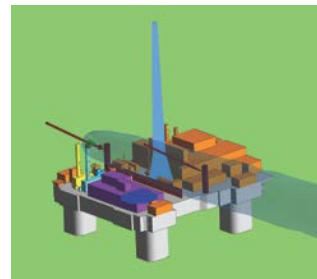
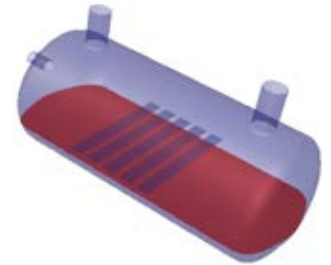
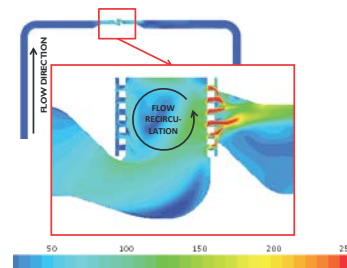
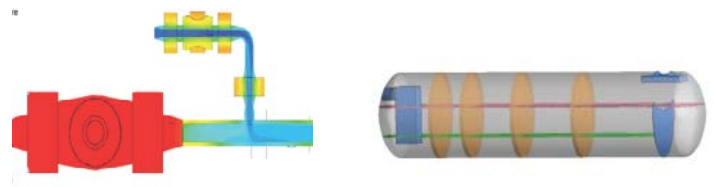
- Better understanding of fluid behaviour
- Safer operations through issue mitigation
- Improved design and advanced optimisation
- Reduction of conservatism and costs

CFD provides a platform to model the flow of fluids with a high-level of detail to get a better understanding of the flow dynamics. This valuable information would not normally be captured with other standard simulation tools used in the oil & gas industry. As such, CFD can be used to analyse unexpected flow behaviour and potential faults/flaws/issues that can be avoided and help redesign systems before failure occurs.

Given CFD's more accurate predictions, significant design cost savings can be achieved without sacrificing the safety of the asset, while making projects more economically viable. Wood has used CFD to investigate problems in areas such as flow assurance, separation performance assessment, gas dispersion studies, chemical injection studies, blast explosion & radiation assessment, and failure-consequence analysis, as well as projects involving Fluid-Structure Interaction (FSI) such as Flow-Induced Vibrations (FIV), and Vortex Induced Vibrations (VIV).



CFD tools are also used for heat transfer (conduction, convection and thermal radiation) modeling associated with fires (gas jet, spray and pool) and explosions. CFD provides the means to analyse/visualise the various aspects of the fluid flow in order to provide a better understanding of the corresponding thermal-fluid behaviour and evaluate associated structural interactions/effects. The results from the CFD simulations can serve as input to Finite Element Analysis (FEA) software to calculate the structural response to heat flux from fires or blast waves from explosions.



Services:

- Screening assessment
- Detailed evaluation, including dispersion, fire, thermal radiation, and blast
- Multiphase dynamic simulation
- Equipment & layout optimisation
- Quantitative Risk Assessment (QRA) – Exceedance
- Layout Optimisation
- Toxic/ exhaust dispersion, heli deck impact, wind chill, smoke, visibility and ventilation studies
- Escape, Evacuation and Rescue Analysis (EERA)
- Process safety relief systems

Asset Types:

- Offshore Deepwater, Shallow Water Fixed and Floating Facilities, Subsea & Subsurface
- Onshore Refineries, Chemical Plants, Liquefied Natural Gas (LNG) Facilities, Mining Assets and EOR Facilities
- Greenfield and brownfield

Available Software:

- STAR-CCM+
- ANSYS CFX
- FLACS and KFX

Metering & Allocation Services

From wellhead to processing facilities and further into midstream operations, Wood's experienced team is capable of supporting oil and gas operators worldwide to achieve optimum performance from their measurement system, both onshore and offshore.

Key Support Scenarios

- Measurement and allocation system assurance
- Multiphase meter sustainability in operations
- Capital projects measurement engineering

Wood has production measurement subject matter experts (SME) backed by a full staff of discipline engineers to address a variety of measurement- related areas including, but not limited to phase behaviour modeling, process engineering, flow assurance, CFD dynamic process simulation and process modifications & optimisation.

Measurement & Allocation Expertise

- Metering and analysers
- Sampling and laboratory analysis
- Flow calculations
- Phase behaviour and PVT applications
- Multiphase and wet gas metering
- Well test design and validation
- Uncertainty analysis
- Equipment testing and qualification
- Industry standards: API, AGA, GPA, ASTM, ISO, and EI
- Support for production agreements and regulatory permit

Applied Advanced Data Analytics & Machine Learning

Wood combines the latest methods in data analytics and machine learning with traditional physics based models. We facilitate improved design, gain better understanding of asset performance, enable predictive forecasting and manage proactive maintenance.

During design, Wood uses cutting-edge techniques to guide the performance of extensive parametric analysis commonly required. This facilitates streamlining and optimizing the number of cases and analysis to be considered and helps optimise the overall design. Our design can identify and capture key parameters material to addressing any flow assurance or process related issues. From managing slugging issues or operating at optimal conditions, these approaches lend significant added value to the overall assessment process.

During operations, Wood uses these techniques in our on-line Virtuoso digital tools, as part of the Virtuoso®/Data Analytics module, to better understand asset performance, behaviour of field instrument and equipment responses. These include, but are not limited to:

- Field-proven data analytics is part of our real-time, transient modeling, for detecting pipeline leaks. With our "finger-print" pattern-recognition technology, our systems have improved leak detection performance and location capability.

- Fit-for-purpose allocation system design including proportional, uncertainty-based, continuous / periodic mixed systems, by difference, and contingent allocation
- Independent input data analysis and assurance
- Allocation disputes investigation and reporting
- Process simulation modeling

Wood's team has a wealth of knowledge, backed by years of experience in developing production allocation systems with pre-defined contingency procedures for a variety of abnormal operating modes. Wood's multiphase metering team provides full life cycle support from start-up to ongoing performance verification.

Wood also deploys Virtuoso systems that provide an integrated platform for data handling, with surveillance and condition monitoring to HMI presentation or dashboarding.

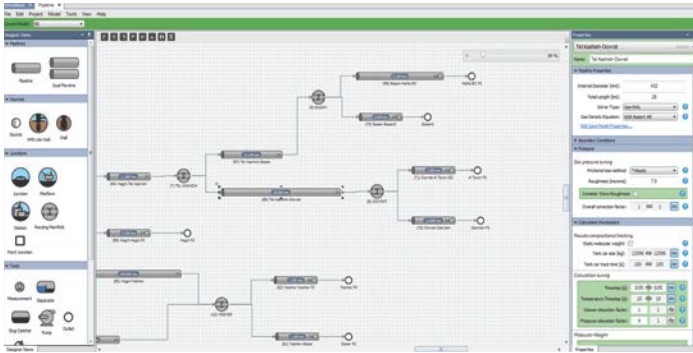


- These methodologies are used to improve water detection, as part of its Virtuoso®/VMS (Virtual Metering System®) packages. When deployed, improved accuracy in quantifying the presence of produced water is achieved, leading to economical application of hydrate inhibitors.
- Garbage in/garbage out. The idiom is very pertinent when it comes to field instrumentation and equipment performance. When dealing with real-time asset management and monitoring, improved data analysis of field instrumentation information helps identify valuable assets that may be under performing or potentially declining in sensitivity. Instruments and equipment that may be beginning to fail or have failed can be identified and isolated, so appropriate preventative or maintenance activities can be initiated.
- These techniques are also used to post-process field events and conditions to aid when conducting operational troubleshooting work. This approach provides another dimension in our ability to identify and quantify issues that impact our client's assets performance.

Integrated Production Modeling (IPM)

IPM considers the differences between individual engineering disciplines, as well as becoming a single unifying discipline to promote effective communication between sub-surface, subsea and topsides/process engineers. IPM captures the movement of oil and gas in a single integrated model with a detailed reservoir model through the wells, flowlines, risers, facilities and export pipelines.

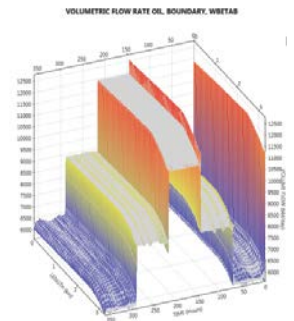
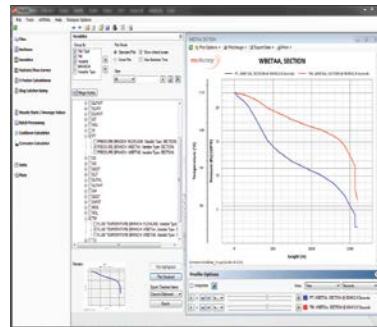
As part of a typical IPM project, Wood personnel works closely with the client's reservoir team to develop working models to forecast production, and benchmark against other independent reservoir models. Simultaneously, Wood's project team will work with a client's facilities team to understand the facility limitations and incorporate those constraints into the integrated model.



Wood has the ability to model the dynamic interactions between pipelines and plant/process facilities. This enables a more rigorous understanding of process control systems, safety systems, logic sequences and various other systems. We can accurately simulate fast transients and model response to system upsets, leading to a truly integrated system design.

Digital Tools for Workflow Optimisation

Wood offers digital tools to facilitate workflow optimisation. One of these is Maestro, a flow assurance software that enables the users to accurately visualise, analyse and interpret their simulation results. Taking information from steady state and transient flow simulators, the software provides better understanding of phase behaviour and potential operational limitations. Maestro offers comprehensive flow assurance calculations, which help improve user efficiency, providing them the necessary tools to pre and post-processing simulation results.



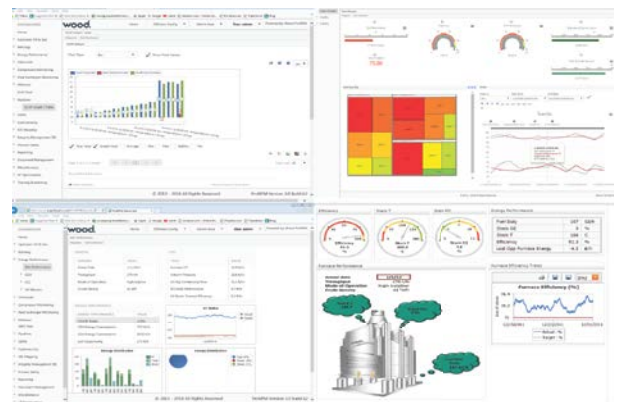
Operations Troubleshooting & Field Support

Wood offers technical consulting services for operations troubleshooting and other field-related issues. These services can include, but not limited to process optimisation & debottlenecking, process assessments, liquids management issues, product blending, unexpected operational issues, unwanted liquids or contaminants, flowline blockages, equipment failures and root-cause analysis.

Wood will deploy a team of specialists within our Intelligent Operations team or assemble a multi-disciplinary team of experts from the Company to assist our customers. We can also provide expert technical witnesses for various



Wood also offers ProPRM for data visualisation and performance monitoring. ProPRM is a highly configurable platform to enable the generation of informative dashboards. It provides key metrics, tracks and analyses indicators, monitors performance and adherence to KPIs and delivers vital business intelligence (BI).



Wood also offers environmental compliance management and reporting tools. Our ENVision and ProGHG helps streamline the monitoring and reporting requirements of our client's facilities. These tools ensure such assets are in compliance with regulatory requirements and flag users of any undue excursions that may necessitate immediate corrective actions.

To learn more about what Wood can offer, please visit us at www.woodplc.com/IntelligentOps, or contact us at IntelligentOps@woodplc.com.



Wood is a global leader delivering technical, engineering and project services across the entire asset life cycle. We operate in more than 60 countries, employing about 60,000 people. We provide performance-driven solutions from development to decommissioning for a broad range of industries including all energy sectors, process and refining, power and utilities, mining and manufacturing.

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