SKUA-GOCAD™

Integrated
Earth Modeling

SKUA-GOCAD

Towards High Definition Earth Modeling

Higher-definition reservoir modeling improves the accuracy of production forecasts with geologic models that are closer to reality. This results in lower-risk reservoir management decisions.

How?

1. **Geologically consistent seismic interpretation:** Use SKUA Volumetric Interpretation for a full 3D interpretation of all faults and stratigraphic horizons in the entire seismic volume.

2. **Enhanced geologic accuracy**: Extract stratigraphic features from seismic data that were undetectable until now, using 3D paleo-flattening, and honor all data for a more geologically realistic earth model.

3. **Improved forecasting through comprehensive uncertainty assessment**: Use SKUA to quantify the impact of fault position and structural uncertainty on in-place hydrocarbon estimates and production forecasts.

Paradigm™ GOCAD™ has led the industry for over 20 years in providing the most advanced capabilities for seismic, geological and reservoir modeling. In 2013, GOCAD merged with Paradigm SKUA™, to create the most technologically advanced modeling application on the market.

SKUA-GOCAD is a huge leap forward in geologic characterization. Geoscientists can use it to incorporate difficult model structures, multi-z surfaces, and complex faults such as salt dome, overthrust and reverse faults. With a simple-to-use, workflow-based interface, users can obtain results quickly. And when the modeling gets tough, SKUA-GOCAD handles complexities that other solutions cannot.

A Shared Earth Model to Meet Your Team's Common Goals

From seismic to flow simulation, the SKUA-GOCAD common earth model provides consistent, discipline-specific views of the subsurface. Well, seismic, micro-seismic, production, geology, and trend data are all integrated with the earth model.

The SKUA-GOCAD collaborative environment ensures that everyone involved has access to the full interpretation of the earth, with no unwarranted simplification. Your team can investigate multiple, traceable scenarios and create a historical data trail that will allow them to trace models back through different iterations. They can then view and manipulate data anywhere along the path while creating highly accurate models of the subsurface.

You shouldn't have to sacrifice years of acquired knowledge to adopt new technology.

Take your GOCAD expertise to a higher level of effectiveness. No more worrying about losing current work. No more tedious workflow re-creation. No work disruption. You can now run all your GOCAD workflows in SKUA-GOCAD, without modification. It's that simple.

You shouldn't have to model one surface at a time, when you can model the entire subsurface volume.

The unique SKUA-GOCAD 3D volume modeling approach automates all fault network and stratigraphic horizon construction. All faults at once. All horizons at once. You save time by completing reservoir models in days or weeks instead of months or years.

You shouldn't have to change the geology to fit the software. Change the software to fit the geology.

SKUA-GOCAD uses a volume-based 3D modeling approach that removes all limitations and deformations caused by conventional methods. This unique technology uses all available data and honors basic geologic rules to build more accurate, simple-to-complex subsurface models. Any fault structure. Any stratigraphic system. Nothing is too complicated!

▲ Integrated display of data in the Barnett shale (seismic, horizons, geobodies, karsts, wells and microseismic)

A Better Geological Foundation Means a Better Production Result

From well correlation to structural framework construction, 2D and 3D restoration, and fault seal analysis, the SKUA-GOCAD product suite offers geologic interpretation and validation combined with unparalleled structural and stratigraphic modeling. Given the correct structural and depositional context, SKUA-GOCAD can help create property models that match geological concepts and honor all available data. Uncertainties are accounted for every step of the way.

Accurate Interpretation as a Crucial First Step

The unique SKUA-GOCAD modeling platform is based on the proprietary UVT Transform™ algorithm, which automatically creates sealed structural and stratigraphic models during the interpretation process and enables the consistent use of all interpretation data throughout the geoscience and engineering workflows. UVT Transform is a mathematically derived 3D methodology that generates a volume description of the subsurface, including the structure, stratigraphy, geological grid, flow simulation grid, and geomechanical grid. It uses ALL of the data, without simplification.

UVT Transform removes the constraints of traditional (pillar-based) technology. Without pillars, SKUA-GOCAD users are able to create more accurate models of the subsurface. The algorithm delivers a consistent representation without "dumbing down" the data, which means your team will no longer need to simplify their interpretations. In addition, UVT Transform brings a wealth of new opportunities to all of your E&P workflows.

A Broad Solution Suite

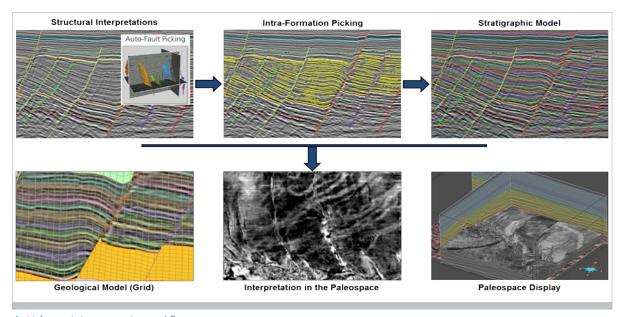The SKUA-GOCAD product suite consists of numerous modules that can be used either as standalone applications or connected to the Epos™ database. Start with the core module, then add discipline and process-specific modules to create a customized solution that meets your specific needs.

SKUA-GOCAD for Geophysics

SKUA-GOCAD Velocity Modeling

The range of powerful yet easy-to-use velocity modeling methods offered by SKUA-GOCAD enables accurate, efficient, and productive time-to-depth conversion. Unlike other solutions where structural complexity is quickly a limiting factor and where the approach incorporates simple layering, SKUA structural and stratigraphic modeling enables accurate time-to-depth conversion in salt and structurally complex environments, using 3D operations that honor the stratigraphy and faults.

The SKUA-GOCAD velocity modeling technology allows users to:

- Construct salt bags or salt sheets from picks, and insert salt inside a sediment velocity background
- Construct layer-based velocity models interpolating interval velocities in SKUA paleo-space
- Apply structural smoothing of velocity volumes honoring fault displacement and subsurface stratigraphy
- Integrate complex structures such as salt, reverse faults and overthrust
- Manipulate and rework any velocity model to make time-to-depth conversion fit the horizons of the matching well markers
- Through tight integration with GeoDepth®, use velocity volumes, geological formation volumes, and dip/azimuth volumes created in SKUA-GOCAD for illumination, grid tomography and migrations, and RTM modeling workflows

▲ Volumetric interpretation workflow

Volumetric Interpretation

An enhanced interpretation modeling workflow includes tools for performing volumetric (global) interpretation. Faults can be semi-automatically interpreted by using a fault autopicker on fault attributes (e.g. fault likelihood attribute). The resulting SKUA model can be used to accurately flatten the seismic volume and enable advanced stratigraphic interpretation in paleo-space. 3D grids with seismically constrained layering are then produced, for accurate velocity and property modeling.

SKUA-GOCAD for Geology

SKUA Structure and Stratigraphy

The ability to rapidly create a fully sealed structural model, whatever the geologic complexity, is the most important piece of any seismic-to-simulation workflow. The unique technology in SKUA provides structure and stratigraphy capabilities in a user-friendly, highly advanced computing environment.

SKUA structure and stratigraphy provide automatic construction of the structural framework, and a fully sealed structural model, yielding the most accurate models. There is no limitation to the complexity of the models, ensuring that none of the data is left out.

SKUA Structural Analysis

Given a structural framework constructed in SKUA, geologists can look at fracture probability, as well as stress and strain information. The stress/strain information can be computed from the SKUA UVT Transform or from 3D kinematic restoration. In addition, a geomechanical mesh can be constructed from a SKUA-GOCAD model, initialized with properties directly in SKUA-GOCAD, exported to Abaqus® for deformation analysis, and re-imported in SKUA-GOCAD to transpose properties to other objects like reservoir simulation grids.

SKUA Fault Seal

Given a structural framework constructed in SKUA, fault displacement maps, fault juxtaposition maps, and fault SGR properties can be computed. A weighted SGR attribute takes into account the smearing potential of a facies.

SKUA-GOCAD Basin Modeling

SKUA-GOCAD Basin Modeling allows users to construct structural models, from the overburden to the basement. SKUA-GOCAD enables the construction of 4D basin models for transfer to basin model simulation software by:

- Simplifying the creation of a consistent structural model
- Empowering the construction of special grids for basin modeling
- Sequential 3D restoration of the 3D volume
- Sequential restoration of the basin grids from the present date to the depositional time

SKUA-GOCAD Well Correlation

Well correlation tools allow the geologist to create well sections showing many different types of tracks, digitize markers in different domains (TVT, TST, flatten), and correlate markers with ghosting. Elevation and thickness maps are updated automatically, and everything communicates with the 3D viewer. Correlations can also be done inside geological cross sections, with additional tools to digitize and paint conceptual geological models.

SKUA-GOCAD Facies Interpretation

Given a stratigraphic framework constructed in SKUA, geologists can perform paleo-facies interpretation on any chrono-stratigraphic time slice from well facies. Vertical facies trends and stratigraphic trend maps can be interpreted and manipulated to create a full 3D facies volume for later use by the reservoir engineer.

SKUA-GOCAD 2D/3D Restoration (Kine3D™)

The SKUA-GOCAD Kine3D structural analysis tool restores 3D basin and reservoir models in complex areas where seismic data is scarce or of poor quality. As part of the SKUA-GOCAD toolset, Kine3D dramatically simplifies and accelerates the 3D restoration process by applying geologic, lithologic and geomechanical parameters to restore models to their undeformed state in both 2D and 3D. The process validates structural interpretations and geometries with embedded geologic constraints.

SKUA-GOCAD for Reservoir Modeling
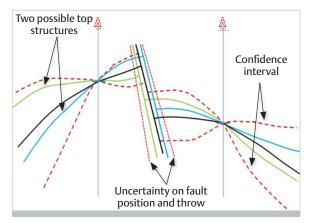
SKUA-GOCAD Data and Trend Analysis

The Data and Trend Analysis module offers tools to organize, validate, analyze, interpret and model reservoir data. It is designed to guide users through all steps required to establish reliable input statistics for constructing robust reservoir property models. It focuses on de-clustering, histogram identification, and trend modeling for both facies and continuous petrophysical properties, with or without seismic data.

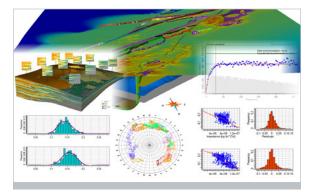### SKUA-GOCAD Reservoir Properties

The SKUA-GOCAD Reservoir Properties application contains a flexible and dynamic workflow for populating reservoir grids. It offers an extensive suite of geostatistical algorithms for spatially interpolating (mapping), and stochastically simulating geological facies (or any discrete variables) and petrophysical properties, such as porosity and permeability (or any continuous variables). A post-processing workflow provides tools for summarizing and analyzing simulation results, together with decision-making support tools such as volumetric map computation and connectivity analysis.

SKUA-GOCAD Facies Modeling

Facies Modeling offers tools and algorithms to develop geologically realistic 3D models of depositional facies and post-depositional features. Integrated with SKUA-GOCAD Reservoir Properties and used in combination with SKUA-GOCAD Data and Trend Analysis, Facies Modeling includes a flexible object-based stochastic simulation algorithm (Boolx) and an efficient multiple-point simulation (MPS) algorithm (IMPALA, developed in collaboration with Ephesia Consult).

▲ A rich toolbox for accurate and systematic structural and reservoir data analysis
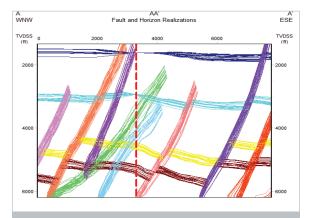
SKUA-GOCAD Reservoir Uncertainty

The SKUA-GOCAD Reservoir Uncertainty system (Jacta®, developed in collaboration with Total) is the industry's leading tool for quantifying uncertainty in the position and volume of hydrocarbon plays. Designed to integrate all sources of uncertainty, the system guides users through the construction of 3D reservoir models. The results are multiple valid alternatives that can be ranked and exported to commercial flow simulators, summarized for optimal appraisal or infill target identifications, or used to reliably inform traditional Monte Carlo-based economic assessment applications.
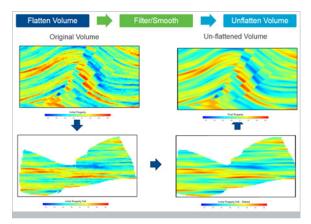
SKUA Structural Uncertainty

The structural uncertainty workflow in this module enables users to assess the impact of fault and horizon uncertainties on reservoir volumes and production. Uncertainty can be defined for faults, horizons, and fluid contacts to assess the hydrocarbon rock volume uncertainty range. This module also connects to the Reservoir Uncertainty module to enable full reservoir volume uncertainty assessment on geologic grids.

SKUA-GOCAD Fracture Modeling

Fracture Modeling (FracMV, developed by Midland Valley) uses fracture density and orientation information to generate geologically constrained discrete fracture networks (DFN) and compute effective fracture flow properties.

▲ Principles of structural uncertainties

▲ Apply fault and horizon uncertainties while maintaining a consistent model

▲ Structural smoothing using SKUA paleospace

FracMV is part of a complete set of tools for characterizing, modeling, and dynamically simulating fractured reservoirs. It facilitates the rapid investigation of the impact of natural fractures on production and field development decisions. Fracture density constraints result from structural analysis using SKUA-GOCAD Structural Analysis and Kine3D, from seismic analysis using Probe™, Vanguard™, Stratimagic™ and EarthStudy 360™, and well analysis from Geolog™. All of these can be calibrated and combined using SKUA-GOCAD Data and Trend Analysis and SKUA-GOCAD Reservoir Properties.

SKUA-GOCAD Saturation Modeling

The SKUA-GOCAD fluid saturation workflow provides a guided process for building 3D models of initial water saturation, taking into account reservoir heterogeneities and compartmentalization.

Many advanced methods are provided to define transition zones. Multiple methods can be combined for a single model by defining a different method for each compartment and/or lithology. The same functions applied to the reservoir model can be applied to wells, to create saturation curves at well resolution that can be compared to the available saturation logs or core data.

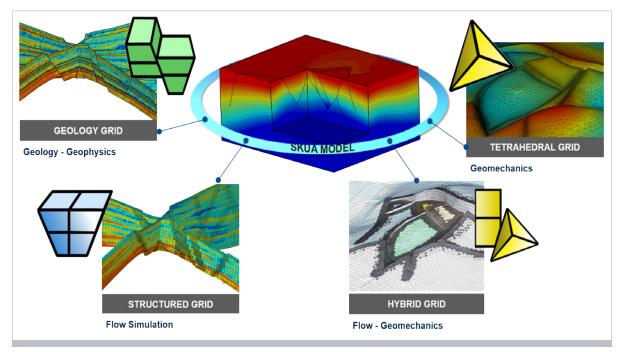### SKUA-GOCAD for Reservoir Engineering

SKUA Simulation Grids

The SKUA Simulation Grid workflow enables geoscientists and engineers to construct robust, fit-for-purpose, 3D reservoir grids that are optimal for numerical simulations. These grids are true to the interpreted geology in terms of both structure and stratigraphy. No simplification is required. The fault blocks observed on seismic volumes are accurately captured.

For flow simulation, the SKUA stair-step grid has orthogonal cells with minimal deformation to improve numerical accuracy. For geomechanical simulation, the SKUA hybrid grid has a mix of structured hexahedral cells for computational efficiency and unstructured tetrahedral cells along faults to capture geometrical and geomechanical detail needed for finite element calculations.

SKUA-GOCAD LGR and Upscaling

The LGR and upscaling workflow provides a systematic yet flexible approach to grid coarsening, grid refining (including local grid refinement/LGR) and property upscaling. Blocks of cells to be refined or coarsened are automatically identified using key features of the model, such as faults, wells and fluid contacts.

▲ Fit-for-purpose 3D reservoir grids created from SKUA structural model

A wide range of upscaling methods is offered to upscale discrete (e.g. facies), static (e.g. porosity) and dynamic (permeability) properties from the geological model to the simulation model.

SKUA-GOCAD and Flow Simulation

The SKUA-GOCAD Production Data Analysis and Reservoir Simulation Link modules provide direct connections to reservoir simulators from SKUA-GOCAD. The application enables the creation of input parameter files for commercially available reservoir flow simulators, the launch of simulation runs, and the loading, visualization, analysis and manipulation of flow simulation results as well as historical production data.

The SKUA-GOCAD Reservoir Simulation Link is an innovative workflow that guides users through all the steps in the construction of a flow simulation model. It is available for ECLIPSE® 100 and 3DSL, but can be used to launch any simulator that functions with an ASCII parameter file.
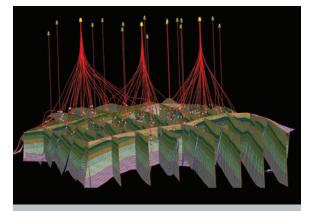
SKUA-GOCAD Well Planning

The SKUA-GOCAD Well Planning tool is used to plan both onshore multi-lateral wells and offshore wells or platforms. Integrated with reservoir Emerson E&P software engineering tools, it provides complete well planning and reservoir optimization capabilities in one package.

SKUA-GOCAD for Geomechanics

SKUA-GOCAD offers robust tools for creating grids for geomechanical simulations. These grids include structured and unstructured meshes, both of which conform to faults and stratigraphic horizons. The grids can then be exported to the Abaqus® geomechanical simulator from Dassault Systémes.

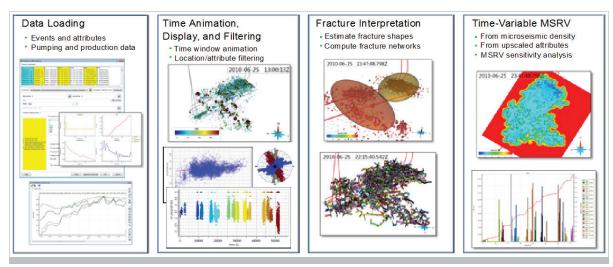### Microseismic Analysis Tools for Unconventional Reservoirs

SKUA-GOCAD includes integrated tools for loading, visualizing and analyzing microseismic data, to better understand the propagation of fractures, estimate stimulated volumes, and optimize well spacing in hydraulically stimulated reservoirs. Features include:

▲ SKUA-GOCAD delivers a comprehensive seismic-to-simulation workflow

- Flexible data loader to import microseismic events, stages, attributes, well treatment and production data

- Integrated time-animated display

- Advanced event filtering tools based on event locations, attributes, time, and well treatment data

- Advanced data plotting, including frequency plots, rose diagrams, crossplots, production and treatment plots

- Advanced connected fracture network created from events, with realistic shapes and growth patterns

- Stimulated volume estimation from fracture distance volumes and upscaled event attributes

SKUA-GOCAD for IT and Developers

Whether your company is large or small, the SKUA-GOCAD Software Development Kit enables your developers to create the exact plug-in, program, or solution you need. Add custom functionalities or use the underlying SKUA-GOCAD algorithms in a different user interface or application. SKUA-GOCAD runs inside or outside of the Epos framework, allowing you to select the exact configuration to meet your company's unique modeling goals.

▲ Example of a microseismic analysis workflow

Interoperability

All Epos-based applications enable interoperability with third-party data stores, including:

- RESQML 2.0.1
- OpenWorks® R5000.10
- GeoFrame® 2012
- Petrel* 2019 & 2018
- Recall™ 5.4.2

(a mark of Schlumberger)*

System Specifications

- Microsoft® Windows® 7, 8.1, 10
- 64-bit Red Hat® Enterprise Linux® 6.8 and subsequent minor releases, and 7.1 and subsequent minor releases

The Emerson E&P Software Advantage

Work smarter

- Leverage a single, comprehensive, seismic-to-simulation workflow solution.
- Model any type of simple-to-complex fault system.
- Honor all available data and retain full subsurface complexity, without compromise.
- Allow both experts and beginners to produce fast, simple, accurate reservoir models.
- QC your interpretation in unique SKUA paleo-stratigraphic space.

Work faster

- Complete reservoir models in days or weeks, not months or years.
- Use a single model for velocity modeling, structural analysis and restoration, fault seal, reservoir modeling and reservoir simulation; save time in prospect generation and seismic-to-simulation workflows.
- Deploy a cost-efficient, open and customizable modular solution that integrates all data types and works seamlessly with other software.
- Create a unique, detailed, stratigraphic model using all seismic signals with SKUA global interpretation.

Improve quality

- Enhance the speed and accuracy of prospect mapping and interpretation, giving you more confidence in prospective wells.
- Reduce risk by seamlessly incorporating uncertainty into data and interpretations.
- Create more realistic subsurface geology representations using our unique QC tools.
- Make better decisions, reduce uncertainty, and increase recovery.

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