



## tNavigator

### Release Notes



Rock Flow Dynamics

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## 1. tNavigator 19.2

The key new features in tNavigator 19.2 are:

- In Simulator: Multiple GPUs may be used for isothermal compositional models for vapor-liquid equilibrium, phase properties and their derivatives calculations.
- In Geology Designer:
  - Interpolation algorithms (Kriging, SGS, SIS) may be run on GPU (GPU is used in 3D grid properties calculation **Interpolation (Zones, Regions)** and **Facies Modelling (Zones, Regions)**).
  - The lithotypes prediction along wellbores using machine learning algorithms is available.
- In Model Designer: The new option is available for hydraulic fractures to switch between LGR approximation and virtual connection approximation.
- In PVT Designer black-oil delumping options have been implemented to provide conversion of black oil models to compositional models.
- In AHM and Uncertainty module new algorithms have been implemented: Ensemble and Box-Behnken.
- In VFP Designer new object is available – Electric Submersible Pump (ESP).
- In Network Designer new object is available – Python Object. The functions of this object may be set via Python code via application programming interface API.

### 1.1. tNavigator kernel

The tNavigator kernel 19.2 supports the following new functionality:

#### GPU calculations:

- Multiple GPUs may be used for isothermal compositional models for vapor-liquid equilibrium, phase properties and their derivatives calculations.

#### For models in E1 and E3 format:

- The multiplying factor for a control or limit value of a group may be used (keyword GTMULT).
- The option to define different settings of well block pressure averaging separately for each well is available (keyword WWPAVE).
- Different options may be used in coal bed methane model calculation (parameters 1, 5-9 of the keyword CBMOPTS).

**For models in E1 format:**

- An analytical model of foam effect on gas mobility was implemented (option FUNC of the keyword FOAMOPTS).
- The maximum surface gas concentration that will be used for Langmuir Isotherm scaling was implemented for coal bed methane models (keyword MLANG).

**For models in E3 format:**

- Transport coefficients may be used in isothermal compositional models (keywords ALPHA, TRCOEF, ALPHANUM).
- For isothermal compositional models a fully implicit scheme for polymer, surfactant and foam injection based on the use of multicomponent water has been implemented (keywords CWTYPE, FOAMFRM, FOAMFSC, FOAMFSW, FOAMFSO, FOAMFST, FOAMFCN).

**For models in IM, ST, GE format:**

- The range for permeability interpolation may be set in fracture zone (option FRAC\_CON of the keyword PLNRFRACT\_TEMPLATE).
- The option to disable or enable group cycling control has been implemented (keyword GCONCYCLE).
- For models in GE format the recycling (reinjection) control parameters may be set (options RECYCLE, RECFRC of the keyword GCONI).
- The multiplying factor for a group injection rate may be used (the keyword GCONIMULT).

**For models in MO format:**

- The option to turn on/off pinchouts is available (keyword PNSW).

**Special options:**

- The new option is available for hydraulic fractures (FRACTURE\_TEMPLATE etc.) to switch between LGR approximation and virtual connection approximation (keyword TNAVCTRL, option FRACTURE\_BUILD\_LOGIC parameter USE\_VIRTUAL\_CONNECTIONS).
- For models in E1 and E3 format the fault may be set in local grid (LGR) (keyword FAULTSL).
- For compositional models in E3 format water saturation may be modified in SCHEDULE section (keyword SWAT).

- The new option THRESHOLD of the keyword TNAVCTRL may be used to limit the number of virtual perforations created for hydraulic fractures via the keywords WFRA, WFRAC, WFRACP, WFRACPL.
- For compositional models in E3 format the gas source that will determine a gas composition for artificial gas lifting may be used (keyword WGASLIFT).

### Data input-output:

- At the end of the log-file the statistics table has been added (number of iterations, restart, size of results etc.).
- The format of Annual Summary Report allows to open it via open-source software like Libre Office.
- Annual Summary Report may be opened directly from tNavigator interface with pre-defined software.
- The new keyword PERFORMA is available to set simultaneously several parameters like CPU time (TCPU), total elapsed (ELAPSED) etc.
- The following SUMMARY mnemonics are supported:
  - Rates below and above contacts: FOPRA, FOPRB, FOPTA, FOPTB, FGPR A, FGPRB, FGPTA, FGPTB.
  - Parameters of numerical aquifers: ANQR, ANQT, ANQP, FNQT, FNQR.
  - Grid blocks parameters: BPRES (BPR), BOSAT (BSOIL), BWSAT (BSWAT).
  - Mass rates for connections: CWMR, CWMT, COMR, COMT, CGMR, CGMT.
  - Group control for production group: GMCTP.

## 1.2. Graphical User Interface

In tNavigator Graphical User Interface 19.2:

- The calculation and visualization of tracer parameters for fluid-in-place regions is available.
- Directional relative permeabilities may be visualized as 3D grid properties and as corresponding graphs for grid blocks.
- The option to extend start/end of the Multi Well Fence has been implemented (**Create Cross-Section** → **Multi Well Fence** → **Extend start/end of Cross-Section**).
- While the model is loaded previously calculated grid properties (in binary E1 format) may be loaded as well. Loaded grid properties are visualized in the tree **Grid Properties** as Results(model\_name).

- Loaded grid properties (in E1 binary format) may be visualized as graphs on the tabs **Graphs** → **Block Info** and **Profile Info**.
- In **Export all** graphs dialog the option to save and use the selected parameters is available (Button **Export all** on the right Graphs panel, options **Load Selection**, **Save Selection**).
- Previously created graphs may be used in **Graph Calculator**. If the graph was created in scripts via `export()` function it may be used later in other scripts via function `get_global_graph (name)`.
- In arithmetic operations (ARITHMETIC) the address to fracture zone/near fracture zone (FZ/NFZ) can be made via functions `BGFZ_<STAGE>`, `BGNFZ_<STAGE>`. This function should be used in User Maps in graphical interface to build this regions property.

### 1.3. Assisted History Matching and Uncertainty

In Assisted History Matching and Uncertainty 19.2:

- Specifying variables and algorithms:
  - New optimization algorithm is available – Ensemble method.
  - New experimental design algorithm is available – Box-Behnken.
  - Multi-objective Differential Evolution algorithm has been implemented.
  - Fast start of Sensitivity Analysis or history matching optimization is available from Model Designer and Geology Designer (extended dialogue to create AHM project from the Workflow).
- Objective function:
  - Well filter may be loaded from file and applied in objective function creation.
  - The option to hide cases outside objective function deviation range is available (button **Hide unmatched models**).
  - Visualization of objective function graph has been implemented (**Graphs** → **object Mismatches**).
- Other:
  - PCA (Principal component analysis) algorithm is available to visualize results on 2D view (**tab 2D** → **PCA**).
  - Visualization of quantiles graphs has been implemented (button **Show Quantile Graphs**).
  - Matching for 2D-Map parameters is available in Geology Designer (in matching process table may be used that is created via calculation **Tables** → **Create Table from Map**).

- **Create NPV Script** option is available to calculate NPV in Graph Calculator and use it in objective function for optimization.

## 1.4. Geology Designer

### GPU Calculations:

- Interpolation algorithms (Kriging, SGS, SIS) may be run on GPU (GPU is used in 3D grid properties calculation **Interpolation (Zones, Regions)** and **Facies Modelling (Zones, Regions)**).

### In Geology Designer 19.2:

- Machine learning, artificial intelligence:
  - The lithotypes prediction along wellbores using machine learning algorithms is available.
- Seismic:
  - 3D seismic data may be visualized in depth in Cross-Section tab (for example, it can be used to create geological bodies).
  - Spectral decomposition calculation is available (**Seismic** → **Seismic Surveys 3D** → **Calculate Attributes** → **Spectral Decomposition**).
- Import/Export:
  - Log data may be exported in the table text format (**Logs** → **Export** → **Table Format**).
  - Several logs may be exported to one file in the LAS format.
  - Several wells tables may be imported from one file (**Wells** → **Import** → **Multiple Well Tables from Text File**).
  - All data may be loaded from RESCUE file through workflow (check boxes **Load all properties, all wells, all faults, all horizons**).
- Well data, logs:
  - The option to create Discrete Log Statistics Table is available (**Tables** → **Create Discrete Log Statistics Table**).
  - Well Filter may be used in Well Log Calculator.
  - The following types of Log visualization may be used in 3D view: Cylinders, Lines, Curves, Solid Rectangles.
  - Tracks may be hidden for well logs display on 2D (Log signatures) to show only curves.

- Well Section tab:
  - Functionality to control the track of new log is available: add it to the first track or to a separate track (right click to enable the settings **Add logs to First track**).
  - The visualization settings of several markers may be changed simultaneously – select all markers and set the settings you need.
  - The Ghost Curve may be scaled vertically and horizontally, its vertical bounds may be modified. The corresponding hot keys are: **Ctrl+mouse wheel** and **Alt+mouse wheel**.
  - Button **Check All** is available to select all wells.
  - The synchronization is available for logs palette is available for Well Section and 3D view if palette bounds are set manually.
  - Markers position may be changed in the settings list.
  - Quick access to track settings, marker, log settings is available via mouse right click.
  - **Show Statistics** option is available on the right panel.
- Structural model:
  - Y/Lambda faults (truncated faults) may be used in structural model.
- Horizons and 2D-Maps:
  - Logical operations are available.
  - Interpolation mode type may be set via right click for 2D-Map visualization: Linear or Discrete.
  - Azimuth maps may be used in Kriging and SGS interpolation.
  - New algorithm is available for 2D-Maps Universal Interpolation – Amazonas.
- Grid:
  - The dip angle may be set in simple grid creation (**3D-Grids** → **Create Grid** → **Create Simple Grid** → **Dip angle** → **Azimuth, Dip**).
- Point Sets:
  - Point set may be created from fault's surface.
  - Points sets filters have been implemented (in **Settings** for Point Sets polygon may be selected as s filter for points visualization).
- Polygons:
  - Polygon may be created by horizon and faults intersection.



- The components of polygons may be saved as separate polygons (**Polygons** → **Polygons to Components**).
- Polygon's center may be autodetected to perform the polygon **Scale** operation to change its scale relative to the center.
- **Faults:**
  - The surface of fault may be extended to the specified depth, horizon or at length (**Faults** → **Extend Fault Surface**).
- **Grid Properties:**
  - A discrete property may be filtered according to the neighboring blocks values, the most common value of neighboring blocks is assigner to the block (**Properties** → **Auxiliary Calculations** → **Discrete Property Filtering**).
  - Standard statistics are available for connected components (count, sum, minimum, maximum, average) (**Properties** → **Connected Components** → **Calculate Over Components**).
  - The possibility to edit parameters simultaneously for multiple zones, regions (facies) is available in dialogues Facies Modelling (Zones, Regions), Property Interpolation (Zones, Regions) (check box **Apply changes to all zones/regions (facies)**).
  - **Property Interpolation by Property** may be used to fill missing data in geobodies construction process.
  - Grid quality check have been implemented (**Grid Properties** → **Grid Quality** → **Cell Deviation Angle, Cell Concavity Level**).
- **Cross-Sections tab:**
  - Contacts visualization is available.
  - Faulted horizons visualization is available.
  - Blocked Wells visualization is available.
- **Tabs, general visualization parameters:**
  - The position of camera may be saved and loaded in 3D view (button in the right panel **Views and Presentation params** choose **Save User View** and **Load User View**).
  - Grid layers filter is available to show selected range of layers for I, J, K, and also automatic scrolling mode, shifting the indexes by one for the sequential display of groups of layers (**Grid Settings** → **Filter** → **Slice**).
  - The display of points on the Crossplot in ranked form is available. Instead of points array XiYi we display the points array XkYk, where k - the rank of corresponding values (relation type – direct or inverse). The array of points is temporarily

reordered so that a smaller value of X corresponds to a smaller value of Y, and so on. Or for the case of inverse relation – the largest X corresponds to the smallest Y.

- Well, markers and attributes caption fonts may be modified.
- The option to extend start/end of the Multi Well Fence has been implemented (**Create Cross-Section** → **Multi Well Fence** → **Extend start/end of Cross-Section**).
- Markers on 2D may be visualized in the following modes: circle, outlined circle, ring.
- Several VPCs may be visualized simultaneously at one tab.
- Other:
  - New object is available – **Borehole Image**. It may be loaded from LAS files and visualized on the Well Section.
  - New objects are available – **Zone table** and well log **Zone Log**, that may be calculated via zones table (**Logs** → **Logs Calculation** → **Create Zone Log**).
  - Data declusterization is available for histograms calculation and performing stochastic modeling algorithms. Declustering Weights are created from point sets numerical attributes and Blocked Wells (calculation **Declustering Weights**). The resulting weight may be used in histograms, VPC, interpolation.
  - Volume weighting is available for histograms.

## 1.5. Model Designer

In **Model Designer** 19.2:

- Import/Export:
  - In **Import Data from Existing Model** process the previously calculated grid properties may be loaded as well (properties in E1 binary format). Loaded grid and properties are visualized in the object tree below the main\_grid as a separate object Results(main\_grid).
  - Grid with LGR (format EGRID) and corresponding grid properties (format UNRST) may be loaded to the project.
- Grids:
  - The option of automatic detection of the box boundaries (Lower/Upper I, J, K indexes) from the selected grid property filter is available to create logarithmic LGR (**3D-Grids** → **LGR Operations** → **Create Simple LGR** → **Autodetect parameters by filter property**).
- Tabs, general visualization parameters:

- The position of camera may be saved and loaded in 3D view (button in the right panel **Views and Presentation params** choose **Save User View** and **Load User View**).
  - Grid layers filter is available to show selected range of layers for I, J, K, and also automatic scrolling mode, shifting the indexes by one for the sequential display of groups of layers (**Grid Settings** → **Filter** → **Slice**).
  - The display of points on the Crossplot in ranked form is available. Instead of points array  $X_iY_i$  we display the points array  $X_kY_k$ , where  $k$  - the rank of corresponding values (relation type – direct or inverse). The array of points is temporarily reordered so that a smaller value of  $X$  corresponds to a smaller value of  $Y$ , and so on. Or for the case of inverse relation – the largest  $X$  corresponds to the smallest  $Y$ .
  - The option to extend start/end of the Multi Well Fence has been implemented (**Create Cross-Section** → **Multi Well Fence** → **Extend start/end of Cross-Section**).
- Workflow:
    - Fracture table may be edited in the workflow (**Workflow** → **Fractures** → **Adjust Fracture table**).
    - New functions for object visualization control is available: Palette (Show/Hide), Select Graph Model, Select Graph Object, Select Graph Template, Select Crossplot Axis, Create Screenshots Pack for selected range of time steps.
- Model Cases:
    - The state of each model case and its results is saved. In the **Cases** tree each variant can have different calculation results related to it (depending on included grid properties, RP, PVT, etc.). When you switch to each set of results, the state of the model (a set of files and settings) that was used in this calculation is displayed. When you switch to the case itself, it's current state is displayed (a set of files and settings).
    - Mnemonics of grid properties and graphs may be used to set the data output in the binary format **E1: Cases** → **Selective Writing of Results** → **Additional Data**. The new rule for time steps is available **Wells Data** → **Strategies** → **Add new rule** → **Results file control**.
- Graphs:
    - Previously created graphs may be used in **Graph Calculator**. If the graph was created in scripts via `export()` function it may be used later in other scripts via function `get_global_graph (name)`.
    - Visualization of graphs for tracers is available.

- Calculation results are grouped for cases on the Graphs tab.
- Other:
  - The new option is available for hydraulic fractures to switch between LGR approximation and virtual connection approximation: **Cases** → **Runspec** → **Tuning** → **Settings of model reading and calculation** → **Show table** → **Fracture\_Build\_Logic**.

## 1.6. PVT Designer

In **PVT Designer** 19.2:

- Black-oil delumping options have been implemented to provide conversion of black oil models to compositional models.
- A three-phase (vapor-liquid-solid phase) algorithm has been implemented for phase equilibrium calculation to model the precipitation of a solid phase (asphaltenes, paraffins).
- Split tables may be used for separator stages.
- Visualization of Hoffman Plot is available.
- New non-equilibrium flash models have been implemented, taking into account the three-phase nature of non-equilibrium phase transitions.

## 1.7. Network Designer

In **Network Designer** 19.2:

- New network object is available – Python Object. The functions of this object may be set via Python code via application programming interface API.
- Injection network may be constructed and calculated.
- IPR tables may be used to control the well via autochoke in the integrated model.
- The inflow model of the perforation interval of the well has been supported for the integrated surface-subsurface model (**Settings** → **Properties** → **Use Connections in Integration Wells**).
- The possibility to compare results of several cases is available.
- User actions may be set and started at the end of each calculation step. User may use all input parameters of all objects (pipe thickness, chokes etc.), all calculated parameters of all object's links (rates, pressure, velocity, etc.), lists of objects, steps, links, and also all input parameters of all objects may be modified (button **Open Python Actions Editor** on the top panel).

- The calculation of integrated model surface-subsurface (built in Network Designer) is available for Reservoir Coupling models.
- In **Events Editor**: parameters may be edited in the table form for time steps, object filters may be used.
- Advanced Mode is available to set pipe geometry in the table form.

## 1.8. VFP Designer

In **VFP Designer 19.2**:

- Well construction may be edited simultaneously in different projects.
- Sample data table may be set for several projects.
- New object is available – Electric Submersible Pump (ESP).
- Pressure loss from the top perforation to the tubing entrance is taken into account.
- Several VFP projects may be deleted simultaneously from Project Tree.

## 1.9. Documentation, Localization

**Localization:**

- Translated into Spanish: graphical interface of the Simulator and Model Designer.
- Translated into Chinese: graphical interface of Model Designer, PVT Designer, AHM and Uncertainty.

**tNavigator embedded help:**

- Embedded help has been added to PVT Designer, VFP Designer, Network Designer and AHM and Uncertainty module.

**New training tutorials are added for tNavigator 19.2:**

- New tutorials for module **Geology Designer**:
  - **GD3.5 How To Use MPS for Lithology Modeling**

In this tutorial we give an overview of the Multi-point facies simulation (MPS). This is a pixel-based algorithm which can be used to simulate object-like facies models. The supported property distributions for this method can be more complicated than the ones used for the Sequential Indicator Simulation (SIS). The principle is based on the definition of a training image which corresponds to the typical structures that can be found in the model. In this tutorial we perform the following steps: create a training image, perform a discrete property realization using the MPS algorithm, remove the noise using a filter, QC the filtering.

- New tutorials for modules **VFP Designer, Simulator:**

- **SIMVFP1.1 How To Use Multisegment Wells**

In this tutorial first we create a multilateral well in VFP Designer and import the created VFP project to the dynamic model using the keyword `IMPORT_PROJECT`. Second we create a multilateral multisegmented well using the VFP Designer and import this project to the dynamic model. Then we estimate the effect of multisegment well model by comparison with well model without segments in Simulator's graphical interface.

## 2. tNavigator 19.1

The key new features in tNavigator 19.1 are:

- In simulation kernel: The support of NVLink bus between GPU in multiple GPU runs is available. This provides the speed-up in data exchange between GPU and doesn't require PCI-E bus participation in this exchange.
- In Geology Designer:
  - 3D velocity model calculation is available. Conversions from time to depth and depth to time. Transfer of seismic horizons and faults from time to depth using velocity model.
  - Embedded help has been added to calculations of Geology Designer.
- In Model Designer: The possibility to customize page settings to print and create screenshots in workflow is available.
- In PVT Designer: A procedure of EOS blend is implemented. It creates a common compositional model for multiple different variants using the adaptive splitting of the original components into standard ones.
- In VFP Designer: New elements for well construction: a pull (keyword WSEGPULL) and a down-hole separator (keyword WSEGSEP) have been added.
- In AHM and Uncertainty: The possibility to create a Proxy model using a neural network is available.
- In Network Designer: New object – Autochoke has been added. It provides the pressure drop required for convergence of system of integrated equations.
- In license server: Cryptographic protection is supported for the license server access (HTTPS protocol).

### 2.1. tNavigator kernel

The tNavigator kernel 19.1 supports new functionality for the models in E1, E3, IM, ST, and GE format:

#### GPU Calculations:

- In simulation kernel: The support of NVLink bus between GPU in multiple GPU runs is available. This provides the speed-up in data exchange between GPU and doesn't require PCI-E bus participation in this exchange.

**For models in E1 and E3 formats:**

- For thermal models in E3 format the possibility to specify the position and parameters of heater connections in a local grid refinement (LGR) is available (keyword HEATERL).
- Tracer diffusion is available for black oil models in E1, E3 formats and isothermal compositional models in E3 format if tracer is connected to one-component water (keyword TRDIF).
- For compositional models in E3 format the possibility to specify the upper threshold of transmissibility between two cells in Z direction is available (keyword MAXTRANZ).
- The possibility to replace non-neighbor connections generated by faults in the grid is available (keyword EDITNNCR).
- The possibility to specify the target or limit value for wells using UDQ in the keyword WELTARG is available.
- The possibility to specify a well connection transmissibility factor (WPIMULT), a productivity (injectivity) index (PI) for wells (WELPI), well connection transmissibility factors in local grids (WPIMULTL) using UDQ is available.
- The possibility to specify recovery plant tables (keyword RECOVERY) in the SCHEDULE section is available.

**For models in IM, ST, GE formats:**

- For models in GE format gas diffusion between matrix and fracture (keyword DIFFUSION) can be included into molecular flux.
- The possibility to change a logic of action of consecutive transmissibility multipliers specified by keywords TRANSI/J/K, TRANLI/J/K (keyword TRANSMULT) is available.
- The possibility to specify well cutback limits for producers and injectors (keyword OPERATE WCUTBACK) is available.
- The possibility to specify the autodrilling sequence for wells (keyword DRILLQ ) is available.

**For models in MO format:**

- The possibility to specify the table of multipliers for permeability-related parameters as a function of the tracer concentration (keyword TFUN) is available.
- The limit type SHUT (all wells in the group will be shut when limit violation occurs) has been added to the keyword GLIM.
- The possibility to specify economic limits for wells and actions to wells when limit will be violated (keyword PLIM).



**Special options:**

- The possibility to specify the scaling of end points depending on the concentration of tracers has been added (keywords NPKTRC, ENPCTRC, ENPTRCM, ENPKTRCM, ENPCTRCM).
- The possibility to flexibly specify well cutback limits for producers and injectors is available (keyword WCUTBACX).
- Reinjection or voidage replacement control has been added to the keyword WWAG.
- Workover operations for well have been added (keyword WECONX): CON\_BOTTOM – close the bottom connection, CON\_TOP – close the top connection, CON\_WORST – close the worst connection.
- The possibility to normalize calculated VFP tables using the option VFP\_CURVES\_NORMALIZE of keyword TNAVCTRL is available.
- The option WELLEQUATIONS of keyword RUNCTRL is automatically turned on to accelerate calculation of models with very long wells or/and large number of fractures.
- Different arithmetic operators (“+ =”, “- =”, “\* =”, “/ =”) have been added for editing grid properties in fracture zone and fracture stimulated zone (keyword FRACTURE\_ARITHMETIC).
- The possibility to model the intersection of fractures.
- Default parameters of LGR construction for hydraulic fractures is changed. Unstructured grid with nested LGRs is created (In tNavigator 18.4 logarithmic refinement was constructed without nested LGRs). Settings can be changed via parameter FRACTURE\_BUILD\_LOGIC of the keyword TNAVCTRL.

**Data input-output:**

- Storage of calculation results is optimized in order to decrease the amount of occupied hard disk space. Additional keywords RPTRSTD, RPTRSTL, RPTRSTT for specifying restart steps have been added. For these steps all properties and graphs are saved, therefore a model can restart from them. For other steps calculation results will be recorded if keywords RPTMAP(D,L,T), RPTGRAPH(D,L,T) are specified.
- Option of calculation results thinning has been added. The possibility to specify time steps at which calculation results (graphs, properties) should be recorded or deleted is available in graphical interface. The recorded results are enough to view a model in **Results visualization** regime. **Main window of tNavigator** → **Modeling** → **Simulation Results** → **Thinning Results**.
- Mnemonics ICONN, SCONN, XCONN, IWELL, SWELL, XWELL, ZWELL for export to .UNRST file.
- The possibility to open a restart model using **Simulation Results** without base model.

## 2.2. Graphical User Interface

In tNavigator Graphical User Interface 19.1:

- In dual porosity models for single porosity area (DPNUM=0) visualization is added on the **Matrix** tab (visualization is not provided on the **Fracture** tab).
- The possibility to view results of integrated network model is available (A Network Designer license is needed for calculations, but the results can be viewed using the license of the Graphical User Interface only).
- Include files are grouped for sections in the **Files** menu (RUNSPEC, GRID etc).
- The possibility to scroll layers on the filter in 3D view is available (This filter is below 3D visualization panel).

## 2.3. Assisted History Matching and Uncertainty

In **Assisted History Matching and Uncertainty** 19.1:

- Specifying variables and algorithms:
  - The possibility to create a Proxy model using a neural network is available.
  - The estimation of Proxy model quality based on R2 coefficient has been added.
  - The possibility to use string variables for optimization algorithms (Differential evolution and Particle Swarm Optimization algorithm) is available.
- Objective function:
  - The possibility to transfer an objective function between projects is available.
  - The possibility to change absolute and relative deviations from historical values for each point of objective function (length of "segment") in a table is available.
- Workflow:
  - The possibility to run the workflow from the module interface is available. Creation of simple objective function, launch of Latin Hypercube and Optimization are available.
- Other options:
  - The possibility to edit groups of variants (add variants to groups, specify a group color for visualization) is available.
  - The possibility to specify weights of variables for MDS and clusterization is available (a weight of each variable is used in calculation of distance between pair of points; i.e. variables with lowest weights weakly affect the distance between pair of points and, hence, MDS plot).

- The possibility to color the selected variants according to user defined gradient (**Add Variants to Group** → **Call Groupset Manager** → **Add gradient**).
- A filter for model variables has been added.

## 2.4. Geology Designer

In **Geology Designer** 19.1:

- **Seismic:**
  - 3D velocity model calculation is available. Conversions from time to depth and depth to time. Transfer of seismic horizons and faults from time to depth using velocity model.
  - **Seismic** tab is synchronized with 2D and 3D tabs. Object and area selected in **Seismic** tab is visualized on 2D and 3D tab.
  - Visualization of seismic objects on 2D view: seismic data is visualized with captions and the possibility to customize visualization options.
  - Statistics for seismic is available. Right click on the seismic survey to see **Object Statistics**: samples informations, CMP, file information etc.
- **Import/Export:**
  - The possibility to import point sets with attributes in the format ASCII internal points is available. **Point Sets** → **Import With Attributes** → **Header format ASCII internal points**.
  - The possibility to export horizons and 2D-Maps in surfer .grd format.
  - The possibility to export polygons in surfer .bln format.
- **Well data, logs:**
  - **Linear Regression** calculation is available for Logs.
  - The possibility to create Log statistics table for each specific interval is available. **Tables** → **Create Log Statistics Table**.
  - The possibility to create Log by Blocked Wells is available. **Logs** → **Logs Calculation** → **Create Log by Blocked Wells**.
  - The following new options are available (**Logs** → **Logs Calculation**):
    - \* Spline interpolation using user-defined points;
    - \* Rescaling (min-max normalization);
    - \* Mute (with three sigmas correction).
  - The possibility to do log normalization by well is available. (**Logs** → **Logs Calculation** → **Log normalization**).

- The possibility to filter logs by top and bottom marker (or depth) is available for Histogram and Crossplot to analyze data in the specific depth range.
- Well Section tab:
  - The possibility to edit new log interactively is available. **Well Section** → **Button "Edit Well Logs"** → **Add Log Points**.
  - The possibility to align logs is available (depth alignment). **Well Section** → **Button "Edit Well Logs"** → **Shift Log Vertically**.
- Structural modeling:
  - The possibility to create horizon from faulted horizon is available. **Horizons** → **Auxiliary Calculations** → **Create Horizon by Faulted (Multivalued) Horizon**.
  - The possibility to create point set from faulted horizon is available. **Point sets** → **Create Point Set by Faulted (Multivalued) Horizon**.
  - The possibility to update horizon locally is available.
  - The possibility to create multivalued (faulted) horizon by grid layer is available.
  - The possibility to create multivalued (faulted) horizon by grid filter is available (filter is specified via filter property).
  - The possibility to create bottom/roof horizon by grid is available.
- Structural model:
  - New options for taking into account isochores and proportional partitioning are available.
  - The possibility to create structural model with faults is available.
- Interpolation:
  - Facies Modelling: the additional parameters are available to adjust 3D property on 2D-Maps:
    - \* on trend set via 2D-Map and(or) VPC;
    - \* thickness map (above and below contact).
  - The distribution source for MPS is added: initial data or Training Map.
  - For 3D interpolation algorithms the new option is available to interpolate only in the area and merge with "old values" on the boundary (local update of 3D properties).
  - For universal interpolation of horizons and 2D-Maps Discrepancies elimination may be used in Least Squares algorithm. **Universal Interpolation** → **Least Squares** → **Advanced Settings** → **Discrepancies elimination**. Option is enabled by default.

- Fluid in place Estimation:
  - **Reservoir type** parameter is added to control all dialogue settings (active and inactive boxes).
  - The possibility to create statistics table for output properties directly from this dialogue. **Properties** → **Volumetric properties** → **tab "Table Creation Settings"**.
  - Reservoir area may be calculated and added to the table.
  - Effective thickness may be calculated and added to the table.
- Polygons:
  - Point Set calculation via polygon is available.
  - The possibility to visualize and edit polygons in table form is available. (Switch to the **Table** tab and select polygon).
  - Two new options are available while creating polygons in 2D: **Put into folder** and **Use generic name**.
- 2D-Maps:
  - The calculation of the map – 2D distance (in horizontal direction) to the specified object – is available.
- Grid properties:
  - The possibility to create property by 2D-Maps is available. **Properties** → **Auxiliary Calculations** → **Property by 2D-Map**.
  - The possibility to create property via contact is available (for each block: below, above the contact or intersection with the contact). **Properties** → **Auxiliary Calculations** → **Property by Contact**.
  - The possibility to use Mode filter type is available in moving average filter. **Properties** → **Moving Window Filter**.
  - The possibility to calculate an intersection of fence polygons with grid is available. **Properties** → **Auxiliary Calculations** → **Grid&Fence Polygons Intersection Property**.
  - The possibility to create Blocked Wells by property is available. **Blocked Wells** → **Create Blocked Wells by Property**.
  - The new calculation is available to calculate the distance from selected object or several objects:
    - \* Height above the horizon (contact);
    - \* Distance to Pointset;
    - \* Distance to Wells;
    - \* Distance to Blocked Wells;

- \* Distance to Grid Blocks that have the selected range of values or index.
- Arithmetic expressions are added to edit grid property locally – **Block, Cylinder**.
- Workflow:
  - The possibility to create/edit wells in the workflow is available.
  - The possibility to create screenshots in workflow is available. **Workflows** → **GUI** → **Create Screenshot, Add Page to Print**.
- Cross-Sections tab:
  - For polygons’ projection and fence polygons visualization on the **Cross-Section** tab the following options are available:
    - \* points of intersection with plane;
    - \* depth limit;
    - \* different colors for polygons’ parts (projections) lying on opposite sides of **Cross-Section**;
    - \* polygons’ names;
    - \* synchronized visualization settings for all polygons together or each one separately.
- Tabs, general visualization parameters:
  - The possibility to create multiple filters is available for grid properties. Filters may be synchronized between tabs. Filters are available on the panel **Settings**, tab **Grids**.
  - Visualization of markers’ names is available in 3D.
  - Zoom in via rectangle selection is available on 2D, holding **Alt** button.
  - Filters may be applied to statistics dialogues. Right mouse click on the object to see **Object Statistics**, then use **Wells Filter** (for logs) or **Use filter from active window** (for grid properties).
  - Filters for grid blocks may be used for grid properties and Blocked Wells visualization on the **Histogram** tab.
  - The possibility to move filters between windows is available.
  - The possibility to delete tabs is available.
  - The possibility to rename objects according to the specified template is available. **Right mouse click on the object** → **Show rename dialogue**.
  - The possibility to center the palette to zero is available. Additional default palettes have been added: **Delta Palette, Delta Hard Palette, Delta Soft Palette**.
  - Statistics for properties in the grid block is available via right click and selecting **Block Statistics**.

- On the Crossplot tab polygons and trend lines may be created, edited and rotated.
- The possibility to apply filters for VPC, Histogram and Crossplot is available.
- Other:
  - Calculator for Blocked Wells is available.
  - The possibility to visualize and edit points sets and their attributes in table form is available. (Switch to the **Table** tab and select point set).
  - Coordinate system library is updated (up to EPSG Version 9.5.5).
  - The possibility to record history with objects is available.

## 2.5. Model Designer

In **Model Designer** 19.1:

- Import/Export:
  - The possibility to import and export grid and properties in the .gslib format is available.
  - The possibility to import and export grid and properties in the .EGRID format is available.
- Grid:
  - New type of coarse grid creation (upscaling) is available. **3D-Grids** → **Create Grid** → **Create Coarse Grid (Upscaling)** → **Check the box "Flow Based Permeability Upscaling"**.
  - The possibility to create fine grid (downscaling) is available preserving the properties of parental blocks. **3D-Grids** → **Create Grid** → **Create Fine Grid (Downscaling)**.
  - The possibility to create LGR via CARFINBG is available for selected grid property. Additional mask should be set selecting blocks for LGR. **3D-Grids** → **LGR Operations** → **Create LGRs by Filter Property** → **Create LGR With Mask**.
  - The possibility to create LGR via CARFINBG is available for wells, one LGR for well with mask. **3D-Grids** → **LGR Operations** → **Create LGRs by Wells** → **Create LGR With Mask**.
  - The possibility to create multiple filters is available for grid properties. Filters may be synchronized between tabs. Filters are available on the panel **Settings**, tab **Grids**.
  - The possibility to apply filters for VPC, Histogram and Crossplot is available.
- Tabs, general visualization parameters:

- Zoom in via rectangle selection is available on 2D, holding **Alt** button.
- The possibility to delete tabs is available.
- On the Crossplot tab polygons and trend lines may be created, edited and rotated.
- Arithmetic expressions are added to edit grid property locally – **Block, Cylinder**.
- Statistics for properties in the grid block is available via right click and selecting **Block Statistics**.
- The possibility to rename objects according to the specified template is available. **Right mouse click on the object** → **Show rename dialogue**.
- The possibility to center the palette to zero is available. Additional default palettes have been added: Delta Palette, Delta Hard Palette, Delta Soft Palette.
- PVT, relative permeabilities:
  - Calculation of scaled relative permeabilities is available via right mouse click on the grid block to choose **SPR oil-water, SPR gas-oil, SPR gas-water**.
  - The possibility to set thermal properties is available using PVT Designer.
- Workflow:
  - The possibility to create/edit wells in the workflow is available.
  - The possibility to create screenshots in workflow is available. **Workflows** → **GUI** → **Create Screenshot, Add Page to Print**.
- Well data. Well Rules, Strategies:
  - New rules are available to set the keywords WCYCLE and WELLWAG.
  - The possibility to delete user keywords via well filter is available.
  - Perforation interval in MD may be created while importing the model in the formats IM/ST/GM (the keyword COMPDATMD).

## 2.6. PVT Designer

In **PVT Designer** 19.1:

- Automatic grouping of components for lumping based on their K-values, acting on light and heavy components independently, is implemented.
- A procedure of EOS blend is implemented. It creates a common compositional model for multiple different variants using the adaptive splitting of the original components into standard ones.
- The possibility to use GOM (Dindoruk and Christman) correlation is available to calculate oil properties.



- The possibility to import compositional variants and black-oil variants from NE/VI format.
- The possibility to import data from PVCDO table is available.

## 2.7. Network Designer

In **Network Designer** 19.1:

- Visualization of formation of gas hydrates in pipes in surface network has been added.
- In the tab **Pipe** visualization of pipe segments that have gas hydrates formation at specified composition and inhibitor concentration has been added. The option is turned on by **Settings** → **Parameters** → **Properties** → **Identify Pipe Segments With Hydrates**.
- New object – Autochoke has been added. It provides the pressure drop required for convergence of system of integrated equations.
- Hydrostatic Correction Factor and Friction Correction Factor have been added to pipe parameters.

## 2.8. VFP Designer

In **VFP Designer** 19.1:

- The possibility to calculate VFP tables for injector is available.
- New elements for well construction: a pull (keyword WSEGPULL) and a down-hole separator (keyword WSEGSEP) have been added.

## 2.9. Licenses and license server

In tNavigator 19.1:

- Cryptographic protection is supported for the license server access (HTTPS protocol).

## 2.10. Documentation, Localization

**Localization:**

- Graphical user interface of simulator was translated to Chinese version.

**tNavigator embedded help:**

- Embedded help has been added to calculations of Geology Designer.

## New training tutorials are added for tNavigator 19.1:

- New tutorials for module **Network Designer**, showing the functionality of integrated modeling:
  - **ND1.2. How To Do Integrated Model**

In this tutorial we use several tNavigator modules to create integrated model surface-subsurface starting from dynamic model .data file. In Network Designer we define objects parameters: pipes, chokes, etc., specify time steps in agreement with the SCHEDULE section of the dynamic model, set fluid properties the same as in the dynamic model. To use existing wells from dynamic model in the integrated project we replace keywords WELSPECS, WELLTRACK and COMPDATMD by VFP projects, however a VFP table for these wells will be imported. For new wells we create projects in VFP Designer: specify well geometry, well construction, fluid composition (using PVT Designer) and then calculate VFP tables. The keyword IMPORT\_PROJECT in the .data file integrates the subsurface and surface parts. At the end we run integrated model and see results in simulator interface and in Network Designer interface.
- New tutorials for module **Geology Designer**:
  - **GD4.4. How To Generate Attributes**

In this tutorial the following options are presented: seismic attribute cube computation (instantaneous amplitude, instantaneous phase, instantaneous frequency, coherence), seismic attribute interpretation, fault interpretation on seismic.
  - **GD5.2. How To Create Trends**

In this tutorial: we load a satellite image (analogue), digitize a main channel represented on the satellite image, create a porosity gradient map will be created (using the point set attributes), digitize a secondary channel, use the boolean operations on polygons to merge channels and create a new 2D porosity map taking into account the new channel system.
- New tutorials for module **Model Designer**:
  - **MD2.6. How To Find The Best Perforation Interval**

Problem statement: The most common way of selecting the perforation is based on well KH and HC saturation along the well. The manual way of selecting perforation depths based on visual inspection in well section is very tedious especially if there are multiple wells and is also subject to human error. Solution provided: In this tutorial we provide a workflow example (Python code) of automated way of selecting best perforation intervals for multiple wells in one go. This workflow scans through the well log (Perm and Oil Saturation (So)) and selects the interval with best  $Kh \cdot So$ . At the end of the workflow it generates COMPDATMD keyword for all the wells under consideration. This can be directly included within the simulation file.

- New tutorials for module **Assisted History Matching and Uncertainty**:

- **AHM1.10. How To Use Proxy Models**

In the case that the full calculation of model variant is time and computer resource intensive, the use of a Proxy model allows users to rapidly generate an arbitrary number of model variants using the Monte Carlo method. In graphical interface it is possible to construct and see the formula of quadratic Proxy model. This expression can be further used to generate model variants using Monte Carlo sampling method. The Proxy model provides a quadratic approximation of the parameter over the selected variants of the model.

- **AHM1.11. How To Use Multi Objective Optimization**

In this tutorial we perform AHM via Multi-Objective Particle Swarm Optimization (MOPSO) algorithm. We analyze results and display the best variants via Pareto Front representation on the cross plot. Multi-objective optimization allows to do history matching via optimizing two objective functions (or more) simultaneously. In this example first objective function is oil, water and gas rates mismatch. Second objective function is RFT mismatch. Comparing to the Single-Objective Optimization algorithm, MPSO can yield a more diverse set of solutions.

- New tutorials for modules **PVT Designer, Simulator**:

- **SIMPVT1.2. How To QC and Improve PVT Tables**

In this tutorial we show the example of dynamic model with the following messages on initialization and simulation. "Negative oil compressibility", "Extrapolation of PVT table was the cause of the negative value of gas viscosity in the block, it has been reset to small value", etc. We explain the origin of these messages and then how PVT tables may be corrected in PVT Designer via approximation by correlation and extension of pressure range. After corrections the model is loaded and calculated without warnings and errors.

### 3. tNavigator 18.4

The key new features in 18.4 are:

- In tNavigator kernel:
  - Local grid refinements getting progressively finer in the vicinity of the fracture are introduced for XYZ fractures.
  - Default setting of results saving was changed. For models in E1/E3 format, if none of the command line options or keywords (RPTRST, etc.) related to selective writing of the results are specified, the grid properties will be recorded only on the first and last step. Previously in this case all grid properties got recorded on all steps. For models in IM, ST, GE formats the grid properties are still recorded on all steps.
- In Geology Designer:
  - Grid coarsening with corresponding property upscaling is introduced.
  - The Multi Point Simulation computation is available, which allows to perform the interpolation by using multi point statistics method.
  - The possibility to perform a fluid in place estimation for a 2D surface is available.
  - The possibility to compute seismic attributes and transfer them on geological grids is available.
- In Model Designer:
  - Import of hydraulic fracture data in GOHFER format.
  - Entering of hydraulic fracture parameters in tabular form.
- In PVT Designer: thermal variants are supported.
- In VFP Designer: Integration with Model Designer is supported. Each well in the Model Designer corresponds to a project in VFP Designer.
- In Assisted History Matching and Uncertainty: multitarget optimization by particle swarm method is supported.
- In Network Designer: Integration with Model Designer is supported. When a dynamic model is loaded to Model Designer, a corresponding Network Designer project is created automatically.

#### 3.1. tNavigator kernel

The tNavigator kernel 18.4 supports new functionality for the models in E1, E3, IM, ST, and GE format:

**GPU Calculations:**

- Multiple GPUs on a single node can be used for the solution of system of linear equations.

**For models in E1 and E3 formats:**

- The possibility to connect analytic aquifers to LGR is available (keyword AQANCONL).
- Modification of pore volume is available for models with keywords ROCKTAB/ROCKTABH (keywords HMRREF, HMMROCKT).
- Depth correction flag RES of the keyword WPAVE is available (the hydrostatic head is calculated using a representative density for the fluid in the reservoir).

**For models in IM, ST, GE formats:**

- For models in GE/IM formats surface tensions can be specified as properties when using the J function option (keywords SRFTNW, SRFTNG).
- For models in GE/IM formats initial reservoir pressure can be used as reference one when calculating pore volume (keyword DEPLETION).
- For models in ST format the default initial component composition is available.
- For models in GE/IM formats the option DAMP-PCOW-TROIL is available for hysteresis of capillary pressure .
- For models in ST format the option allowing to adjust initial water and oil saturations is available to improve a robustness of calculations (keyword SAT\_ADJUST).
- The possibility to add a list of well groups under the group control that performs a fluid recycling injection (keyword GPRODGROUP).

**For models in MO format:**

- The vertical scaling of relative phase permeabilities is available (keywords YKOG, YKOW, YKRG, YKRW).

**Special options:**

- A grid refinement around fracture zone for XYZ fractures is available.
- For thermal and compositional models in E1 and E3 formats the component composition can be specified in each block for the option NEI (keyword TNAVCTRL NEI).
- For compositional models in E3 format there is a possibility to define a method of transition of hydrocarbon phases (oil, gas, NGL) to standard conditions after separator (keywords SEPDEN, DENSTRMIX).

- For models in tNav format new options specifying aquifer's connection type for Dual Porosity/Dual Permeability models (options BOUNDARYM/RESBNDM, BOUNDARYF/RESBNDF, DEPTHM/DEPTHF of the keyword AQUGP).
- A modification of Carter-Tracy's aquifer has been added for more accurate modelling of bottom water (option BD of the keyword AQUGP).
- For models in E3 format the temperature scaling of relative phase permeabilities and capillary pressure in compositional isothermal models.
- Options providing solver settings for segmented wells are available (options MAXSEGWELLIT, TOLSEGWELL of keyword RUNCTRL).
- The option STRICT\_CONST\_FRACTURE\_THICKNESS of the keyword TNAVCTRL providing a conservation of central layer width under grid refinement using the keyword PLNRFRACT\_TEMPLATE and INNERWIDTH has been added.
- Options controlling the logic of properties initialization in the inactive blocks that transfers to active ones when penetrating by hydraulic fracture have been added (The option FRACTURE\_INACTIVE\_BLOCK\_PROPERTIES\_LOGIC of the keyword TNAVCTRL should be set as NEAREST\_IJK\_ACTIVE\_BLOCK).
- Keyword IMPORT\_PROJECT is available to create integrated model.

#### Data input-output:

- Default setting of results saving was changed. For models in E1/E3 format, if none of the command line options or keywords (RPTRST, etc.) related to selective writing of the results are specified, the grid properties will be recorded only on the first and last step. Previously in this case all grid properties got recorded on all steps. For models in IM, ST, GE formats the grid properties are still recorded on all steps.
- An option of recording the last computed step is introduced, so that a crashed calculation could be resumed smoothly afterwards. It is activated in console version by the command line switch `--dump-res-last` and in GUI via **Settings** → **Options** → **Advanced** → **Dump last calculated step** (simulator) or **Settings** → **Options** → **Calculation options for new jobs** (queue manager).
- SUMMARY mnemonics for multisegment wells are supported: SOFRE, SOFRS, SOFT, SOFTA, SWFT, SWFTA, SGFRE, SGFT, SGFTA.
- SUMMARY mnemonics for phase potentials of shut/stopped wells are supported: WGPP2, WOPP2, WWPP2.
- RPTRST mnemonics for phase velocities are supported: VELOIL, VELWAT, VELGAS.
- Output of well names to .SMSPEC file (WGNAMES) is supported.

## 3.2. Graphical User Interface

In tNavigator GUI 18.4:

- 3D grid properties can now be visualized with partial transparency.
- Interface of importing arbitrary graphs for visualization has been modified: now the imported graph can be assigned any type and units.
- User graphs created in the Graph Calculator can now be used in Bubble Maps. For example, you may visualize cumulative production over a certain period.
- For remote GUI the possibility to see the number of nodes in queues has been added in manager settings.
- Output of indexes of LGR blocks into log-file was improved. In 2D and 3D views indexes of all parent blocks have been added.
- The visualization of the following data has been added:
  - User properties WORKxxx, IWORKxxx in the category Initial.
  - Thermal conductivities.
  - Biot constant in geomechanical model.

## 3.3. Assisted History Matching and Uncertainty

In Assisted History Matching and Uncertainty 18.4:

- Specifying variables and algorithms:
  - Multi-objective Particle Swarm Optimization algorithm has been added.
  - Monte Carlo experimental design has been added.
  - The possibility to visualize the Pareto front in the Crossplot has been added.
  - The possibility to calculate the multiple number of model variants using the proxy formula by substituting variables distributed by Monte Carlo method in it.
  - Discrete distribution of variables is available.
- Objective function:
  - The possibility to create a list of objective functions is available. Objective functions are on the separate tab in GUI.
  - The possibility to calculate linear history matching along with quadratic.
  - In the objective function configuration the filter for producers/injectors has been added.

- Integration with Model Designer and Geology Designer:
  - To work with fractures new features have been added in workflow: **Fractures** → **Adjust** → **Adjust Fracture Template, Adjust Fracture Stage, Adjust Fracture Arithmetic**.
  - Matching by target function in Geology Designer is introduced. It can be used, for example, to match reserves with the approved figure.

### 3.4. Geology Designer

In Geology Designer 18.4:

- Seismic:
  - The possibility to interpret a horizon using several loaded SEG-Y files is added.
  - In Seismic tab, the possibility to move the orthogonal section to the visualized section (inline or crossline) and to switch to this section is added.
  - The possibility to select the data by depth, time, line or CMP is now available (**Delay in Z axis, Min Z, Max Z Import** → **Type && Geometry**).
  - The possibility to work with data in depth is added: import, visualization and interpretation (horizons and faults) are now available.
  - Velocity cubes from checkshot data can be computed.
  - Basic seismic attributes can be computed: coherence, instantaneous amplitude, instantaneous frequency, instantaneous phase (Seismic Survey 3D → Calculate Attributes).
  - The possibility to transfer seismic attributes on geological grids is added (for seismic data in depth).
  - The possibility to convert seismic faults to depth is added. Faults can be created by seismic faults (**Faults** → **Create Fault by Seismic Fault**).
- Import/Export:
  - The possibility to import/export grids in Cornerpoint Grid (CORP) in NE/VI format is added.
  - The possibility to import/export grids in CORNERS format.
  - The possibility to load faults and polygons in Z-Map Plus format is added.
  - The possibility to load well data (markers, well logs...) for areas without well trajectories is added. The possibility to elongate the well trajectory if needed is also added to the markers and well logs import windows (**Logs or Markers** → **Import** → **Elongate Well Trajectory if necessary**).
  - The possibility to load the wells production history from a database using Python scripts in workflows is added.



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- The export of markers in table format is added (**Markers** → **Export** → **Well/-Markers Table**).
  - Well data, logs:
    - UWI is supported when loading and working with wells and well logs.
    - The angle, depth and azimuth of well trajectories can now be displayed in the Wells Tables.
    - The possibility to cut the trajectory by depth and by markers for the visualization is available for 2D, 3D, and Sections tabs.
    - The following calculations for dealing with logs were added:
      - \* Smoothing with moving median filter.
      - \* Smoothing with moving average filter.
      - \* Gaussian smoothing.
      - \* Normalization by Min and Max values.
      - \* Normalization by average and RMS.
  - Well Section tab:
    - The possibility to hide tracks without data is added (option **Hide Empty Track**)
    - A compact version of depth TVDSS/MD scale is added (the size of serifs is reduced, for depths values the number of decimals, the font size is reduced and the numbers switch to a vertical location when the scale width is minimal which allows a better visualization).
    - Settings for markers and horizons are added to templates.
  - Grids:
    - The possibility to upscale the entire grid and its properties to a coarser one (**3D-Grids** → **Create Grids** → **Create Coarse Grid**) is added.
    - The possibility to resample properties from one grid to another is added. The grids can have different global and block sizes, different azimuth angles and everything.
    - The possibility to set a layering horizon during the grid building is added.
  - Structural model:
    - The Structural Model object is added for building a consistent structural framework, taking into account all available input data for the construction, and for calculating the thicknesses of the created formations.
  - Interpolation:
    - The Multi Point Simulation computation is available, which allows to perform the interpolation by using multi point statistics method.

- The possibility to populate the grid from an assumed probability distribution (normal, log-normal etc...) as input data is added.
- Fluid in place Estimation:
  - The possibility to perform a fluid in place estimation for a 2D surface is available (**2D-Maps** → **Calculate Volumetric Map**).
  - A statistics table of fluid in place estimation can be generated for a 2D surface fluid-in-place estimation and can be used for the uncertainty analysis (**Table** → **Create Table from Map**).
- Polygons:
  - Boolean operations on polygons (Subtractions, Unions and Intersections of polygons) are available (**Polygons** → **Perform boolean operations on polygons**).
  - 2D- Maps and horizons can be merged in order to build a surface using polygons, 2D-Maps or horizons and constant depth values as input data **Horizons** → **Auxiliary computations** → **Horizons Merging, 2D-Maps** → **Auxiliary computations** → **2D-Maps Merging**
- 2D-Maps:
  - The point sets attributes are taken into account during the Universal Interpolation for 2D-Maps.
  - 2D-Maps can be cut by polygons.
- Workflows:
  - The possibility to launch an external program from workflows is added.
  - The possibility to launch a workflow from another workflow is added.
  - The possibility to open a dynamic model from a workflow is added (**Workflows** → **Export** → **Open or reload dynamic model**).
- Cross-Sections tab:
  - The well names can be displayed in the Cross-Section window. The associated settings are also added.
  - The possibility to enter the numerical value of the scale in the settings window is added. The hot keys for zooming: up and down is available.
- Tabs, general visualization parameters:
  - Synchronization of certain properties of visualization tabs is supported (selected objects, camera position, filters).
  - Restoration of closed visualization tabs is supported (**View** → **Windows** → **Restore**).

- Global rotation points for 3D are introduced. They can be shown on all 2D and 3D views.
  - 3D grid properties can now be visualized with partial transparency.
  - Statistics on every objects can now be called from the object tree, regardless of the currently active visualization window.
- Other options:
    - Undefined value can now be explicitly specified in the calculator and used in the expressions.

### 3.5. Model Designer

In **Model Designer** 18.4:

- Hydraulic fracture:
  - Import of hydraulic fracture data in GOHFER format.
  - Entering of hydraulic fracture parameters in tabular form.
- Integrated modeling:
  - Integration of VFP Designer with Model Designer is supported. Each well in the Model Designer corresponds to a project in VFP Designer.
  - Integration of Network Designer with Model Designer is supported. When a dynamic model is loaded to Model Designer, a corresponding Network Designer project is created automatically.
- Grids:
  - Creation of unstructured grids is supported (CARFINBG + INNERWIDTH).
  - Loading and exporting models using the COARSEN option is supported.
- Tabs and visualization options:
  - Synchronization of certain properties of visualization tabs is supported (selected objects, camera position, filters).
  - Restoration of closed visualization tabs is supported (**View** → **Windows** → **Restore**).
  - Global rotation points for 3D are introduced. They are shown on all 2D and 3D views.
  - 3D grid properties can now be visualized with partial transparency.
  - Statistics on every objects can now be called from the object tree, regardless of the currently active visualization window.

- Relative permeabilities:
  - RP tables can now be grouped by folders.
  - Export of RP tables in NE/VI format is now supported.
- Miscellaneous:
  - Interface for creating rules that specify the frequency of time step recording is introduced.
  - Many model parameters are now supported in workflow.
  - Double porosity for aquifers is now supported.
  - Many development rules can now be specified in tabular form.
  - Vector fields can now be visualized.
  - Trends in crossplots are made geometry objects. It is possible to create, edit, and selectively visualize them.

### 3.6. PVT Designer

In **PVT Designer** 18.4:

- A tree of thermal variants is added, similar to those of compositional and black oil variants.
- For black oil variants, new way of defining PVT data is supported (tN-compatible keywords BOT, VOT, COT, BGUST, VGUST).

### 3.7. Network Designer

In **Network Designer** 18.4:

- The Network Designer integrates with Model Designer. When importing the existed model into the Model Designer the project of Network Designer will be automatically created with a possibility of its further modification.
- New object – Automatic Choke has been added, in order to specify upper limits of phase rates and pressure for wells and groups of wells.
- New object – Injector has been added.
- New object – Limits, used for group control options, has been added.
- New object – Automatic Pump has been added, in order to specify lower limit of pressure for wells and groups of wells.
- The automatic update of results of network calculation when running the integrated network–reservoir model.
- The possibility to disconnect any end of pipe from the connected object has been added.

### 3.8. VFP Designer

In VFP Designer 18.4:

- The VFP Designer integrates with Model Designer. In the Model Designer each well corresponds to a project of VFP Designer.
- New construction elements of multisegment well has been added: sub-critical valve (keyword WSEGVALV), autonomous inflow control device (keyword WSEGAICD), spiral inflow control device (keyword WSEGSICD).
- The possibility to calculate solely a hydrostatic pressure drop is available (When calculating a VFP table select the Correlation type – **Hydrostatic only**).
- Import of VFP tables in NE/VI format is available.

### 3.9. Compatibility with previous versions

In tNavigator 18.4:

- Default setting of results saving was changed. For models in E1/E3 format, if none of the command line options or keywords (RPTRST, etc.) related to selective writing of the results are specified, the grid properties will be recorded only on the first and last step. Previously in this case all grid properties got recorded on all steps. For models in IM, ST, GE formats the grid properties are still recorded on all steps.
- The logic of calculation for API groups has been changed, the previous logic may be switched on via the keyword TNAVCTRL option API\_GROUP\_LOGIC\_PRE182.

### 3.10. Licenses and license server

In tNavigator 18.4:

- Usage of one or two GPUs on one node calculation is included to the Black oil license. For every two additional GPUs one more Black Oil license is required.
- Licensing in the presence of keywords IMPORT\_NETWORK and IMPORT\_WELL. One license per model is required, even if the keywords are used in it multiple times:
  - With IMPORT\_NETWORK: Network Designer license;
  - With IMPORT\_WELL: similar to using VFP Designer, the first available of Model Designer, Network Designer, and Geology Designer licenses is used.
  - With both IMPORT\_NETWORK and IMPORT\_WELL: Network Designer license;
  - With IMPORT\_PROJECT → license depending on projects types that are included via this keyword.

### 3.11. Documentation

New training tutorials are added for tNavigator 18.4:

- Introductory overview presentations on all modules:
  - **SIM0.1. Simulator Overview.**
  - **AHM0.1. AHMUncertainty Overview.**
  - **GD0.1. Geology Designer Overview.**
  - **MD0.1. Model Designer Overview.**
  - **PVT0.1. PVTDesigner Overview.**
  - **PVT0.2. PVTDesigner Experiments.**
  - **ND0.1. Integrated Modeling.**
  - **VFP0.1. VFPDesigner Overview.**
- New tutorials on **Model Designer**:
  - **MD1.1. How To Analyze Model in Model Designer.**

In this training tutorial we load and analyze existing dynamic model: 3D, grid properties, statistics, 2D, contour lines, Histogram, Filters to calculate fluid-in-place for FIP regions, Crossplots, graphic filters for Crossplots, Cross Sections horizontal and vertical. Settings and Visualization options, Wells and Properties Filters. Run dynamic model and analyze Rates, Totals, etc on Graph Templates for FIELD and wells. Check the quality of history matching (Hist vs Calc crossplots).
  - **MD1.5. Voronoi Diagrams.**

This is a method of dividing a 3D property into regions (as many regions as there are wells) in such a way that the boundary between two "neighboring" regions is perpendicular to the straight line connecting the wells (region centers) and runs halfway between two wells. Voronoi diagrams are used for a rough estimation of fluid-in-place in the well's regions (the well's fluid-in-place in its Voronoi region). Voronoi diagrams are also used for estimating a well's drainage area.
  - **MD2.1. How To Add Wells.**

In this training tutorial we will: add vertical and horizontal wells in GUI, perforate well and edit a well trajectory with a mouse, visualize DLS (Dog leg severity), specify well controls and limits for the development strategy, add a branch for the horizontal well, run model and see results on graphs, export well trajectories as WELLTRACK (X, Y, Z, Measured Depth).
  - **MD2.2. Local Grid Refinement.**

In this tutorial we provide an overview of all tools to create LGR: Create LGRs around the wells, Create LGRs within the defined box, Create LGRs via Property Filter.

- **MD2.4. How To Update Schedule.**

In this tutorial we consider an example of adding new historic data to the model (production data, new well trajectories, perforations).

## 4. tNavigator 18.3

The key improvements in 18.3 are:

- In tNavigator kernel:
  - End-point scaling for relative permeabilities is available for models with low salinity option LOWSALT and for models with surfactant injection SURFACT.
  - Default settings for the amount of results output have been changed. Instead of previously used "all data at all time steps" now grid properties are saved at the time steps according to model input deck (RPTRST), graphs are saved at all time steps.
- In Geology Designer:
  - The first implementation of the tool to provide the collective work of several users with one project through the mechanism of transferring objects between projects has been added.
  - Collocated Cokriging algorithm and Kriging Variance calculation is available in 3D interpolation.
- In PVT Designer: non-equilibrium phase state may be modeled for compositional models (different rate of gas liberation from liquid and its dissolution).
- Assisted History Matching and Uncertainty: quadratic Proxy model may be built from selected model's variants. Resulting formula of Proxy model is available to the user and may be used by third-party tools for additional analysis by Monte Carlo sampling methods and others.

### 4.1. tNavigator kernel

The tNavigator kernel 18.3 supports new functionality for the models in E1, E3, IM, ST, and GE format:

#### For models in E1 and E3 formats:

- End-point scaling for relative permeabilities is available for models with low salinity option LOWSALT (keywords LSWL, LSWLPC, LSWU, LPCW, LSOGCR, LSOWCR, LSWCR, LKRW, LKRWR, LKRO, LKRORW, LKRORG).
- End-point scaling for relative permeabilities is available for models with surfactant injection SURFACT (keywords SSWL, SSWCR, SSWU, SSOWCR, SKRW, SKRWR, SKRO, SKRORW).
- For multisegment wells the possibility to choose rules for scaling the interpolated pressure drop according to the length or depth span of each segment is available (parameter 7 of the keyword WSEGTABLE).



- The possibility to set well control mode via UDQ in the 2-nd parameter of the keyword WTMULT is available.
- The possibility to specify the number of Newton method iterations for a time step, for which well targets will be updated (for wells working under group control or with limits on the amount of pressure drop) is available in the SCHEDULE section (keyword NUPCOL).
- Various methods of averaging the density in the wellbore are available (parameter 145 of the keyword OPTIONS, parameter 44 of the keyword OPTIONS3 and new parameters of the keyword RUNCTRL (WELLDENWEIGHTOPEN and WELLDENWEIGHTSTOP)).
- The possibility to use wild card '?' as a well name in the keyword WELSPECS inside ACTIONW is available.

#### For models in E3 format:

- For compositional models the modified LBC correlation may be used to calculate viscosity of the hydrocarbon phase (keyword VCOMPACT).
- For thermal models non-equilibrium initialization is available (keyword NEI).
- For compositional models the option of H2S solution is available (keyword H2SSOL).

#### For models in IM, ST, GE formats:

- For compositional models in GE format the possibility to set temperature gradients for volume shifts is available (keywords VSHIF1, TREFVS).
- For thermal models in ST format the possibility to model chemical reaction that deviate from equilibrium is available (keywords RXEQFOR, RXEQBAK, RXEQBASE).
- For thermal models in ST format COMPLEX method of block thermal conductivity calculation is available for models with solid phase.
- Additional possibilities are available to set hydraulic fractures via LGR (keywords INNERWIDTH, BLOCKGROUP).

#### Special options:

- For compositional models in E3 format the possibility to set temperature gradients for volume shifts is available (keywords VSHIF1, TREFVS).
- The possibility to control the logic of properties calculation for inactive blocks that are in the area of hydraulic fracture (for the keyword TNAVCTRL option FRACTURE\_INACTIVE\_BLOCK\_PROPERTIES\_LOGIC).
- For models in E1, E3 format additional possibilities are available to set hydraulic fractures via LGR (keywords CARFIN\_BG, INNERWIDTH, BG\_XXX).

**Data input-output:**

- In SUMMARY section a new mnemonic WBP0 is available (1-point pressure average recalculated to reference depth).
- New mnemonics have been added to the keyword RPTRST: ZMF, ALLPROPS, SURFCNM, SURFBLK, SURFACT, SURFMAX, SURFST.
- New mnemonics are available in SUMMARY section: FEIR, FEIT, FEPR, FEPT, GEIR, GEIT, GEPR, GEPT, WEPR, WEPT, WEIR, WEIT, FOIRP, FHMPT, FHMIT, FHMPR, FHMIR, FRPV, WGPP2, WODN and WGDN.

**4.2. Graphical User Interface**

In tNavigator GUI 18.3:

- The possibility to open in Model Designer is available from simulator's graphical interface. A new project is created when the button **Open in Model Designer** is pressed and all data from the current model is imported to that project.
- The possibility to set global options to dump results binary files by default is available. In tNavigator main window → Options → Models → **Save graphs and properties binaries**.
- The possibility to set Z-scaling as a number is available in the settings of 3D window. Hot keys to change the scale are: up and down.
- Functionality of palette has been extended: Use Local Precision, Show Histogram and Max Histogram Value.
- Graphs:
  - Visualization of the new graph WBP0 is available (1-point pressure average recalculated to reference depth).
  - Graph Calculator: access to external Python modules is simplified. In tNavigator main window → Options → Path → **Use external Python library, Check Python3.dll, Manually set path to Python modules**.
  - The possibility to create folders in Graph Templates is available.
  - In Graph Templates the possibility to create arbitrary crossplot is available (Template Settings → Axes options → Choose parameters for X and Y axis).

**4.3. Assisted History Matching and Uncertainty**

In Assisted History Matching and Uncertainty 18.3:

- Pareto Chart may be built via Spearman correlation.

- Quadratic Proxy model may be built from selected model's variants. Tools for quality check and the resulting formula of Proxy model is available.
- In graphical interface the following tabs are combined in one tab (tab Results Table in the version 18.3 is a combination of tabs from 18.2: Results Table, Mismatches Table, Model Variables). Visualization of data for objects (groups, wells) has been added.
- HM module may be used for models with reservoir coupling option (no backward compatibility).
- Integration with modules Model Designer and Geology Designer:
  - The following tools are available when AHM module is started from Geology Designer: histograms, crossplots, CDF graphs and MDS tab.
  - The following tools are available when AHM module is started from Model Designer: new interface for RP tables, optimization for the case with many saturation regions.

#### 4.4. Geology Designer

In **Geology Designer 18.3**:

- Grids:
  - Option **Import All Properties** has been added to the calculation **Import. Load Grid**.
- Interpolation:
  - A new interpolation algorithm is available for 2D Maps and horizons that allows to use different data simultaneously as a source data: well markers, point sets, polygons and horizons. **Calculations** → **Universal Interpolation**.
  - Collocated Cokriging is available in 3D interpolation: **Property Interpolations (Zones, Regions), Facies Modelling (Zones, Regions)**.
  - Kriging Variance may be calculated for 3D interpolation: **Property Interpolations (Zones, Regions), Facies Modelling (Zones, Regions)**.
- Wells data, Logs, Well Section:
  - New well attribute "symbol" and global table of "symbols" may be used (list of svg files). Wells may be displayed with their symbols on 2D.
  - The possibility to merge logs and to load logs with the same name without overwriting is available. Calculation **Merge Logs** with merge types: Ignore, Merge, Overwrite.
  - Discrete log labels may be used to color logs on the Well Section (set template and use option **Show Discrete Log Labels**).

- Well logs may be displayed on the Well Section with defined range of uncertainty (option **Show Uncertainty Range**).
- Well logs and trajectories may be loaded from the data base.
- Functionality of **Well Selection** on 2D is extended: wells may be selected for correlation profile one by one, via brush or inside selected area.
- Volumetric Properties, Connected Components:
  - Geometrical Volume, Net Volume, Pore Volume and HCPV may be calculated separately for oil zone, gas zone, oil+gas zone and for entire grid. **Properties** → **Calculations** → **Calculate Volumetric Properties**.
  - The possibility to calculate the number of blocks in each component is available. Parameter **Component Counts Property** in **Properties** → **Calculations** → **Connected Components**.
  - **Filter Small Connected Components** is available in Connected Components tab.
- Faults:
  - Faults visualization is available on 2D views.
  - The possibility to export all faults is available.
  - The possibility to create fault from point set is available **Approximate Pointsets by Surface**.
- **Cross-Section** tab for cross-section visualization:
  - Visualization of faults, perforations and well logs is available.
- Polygons:
  - The possibility to calculate area inside polygon is available (**Calculate Polygon Area**).
  - The possibility to create polygon via intersection of two horizons or horizon and depth is available (**Polygon by Horizon Intersection**).
  - The possibility to load polygon from file defining columns that should be used is available.
- Other options:
  - The possibility to transfer objects between projects is available. **Document** → **Project Data Exchanger**.
  - Thickness Map may be calculated between horizons. **2D-Maps** → **Auxiliary Calculations** → **Thickness Map by Horizons**.
  - Loaded User Map Images may be visualized in 3D.

- The possibility to set Z-scaling as a number is available in the settings of 3D window. Hot keys to change the scale are: up and down.
- Functionality of palette has been extended: Use Local Precision, Show Histogram and Max Histogram Value.

## 4.5. Model Designer

In **Model Designer** 18.3:

- Cases tab:
  - The possibility to add to dynamic model only selected faults is available in Cases → Properties → Faults. Transmissibility multiplier, diffusivity multiplier and threshold pressure may be set.
- Grid properties tools:
  - Regions may be visualized in dynamic model after it's initialization.
  - Grid properties may be changed on time steps (in SCHEDULE).
  - The possibility to set Z-scaling as a number is available in the settings of 3D window. Hot keys to change the scale are: up and down.
  - Functionality of palette has been extended: Use Local Precision, Show Histogram and Max Histogram Value.
- Wells data and Well Rules:
  - The possibility to load parameters of hydraulic fractures in a table form is available.
  - Functionality of **Well Selection** on 2D is extended: wells may be selected for correlation profile one by one, via brush or inside selected area.
  - Group hierarchy may be exported from the rule **Create Group Hierarchy** in the form of the keyword GRUPTREE or lists well-group, group-well etc.
  - The following keywords may be recognized as a separate rules (group hierarchy and wells' parameters) when data is loaded from existing model: WELSPECS, WELSPECL, WELLSPEC, GRUPTREE.
- Other options:
  - In the tab **Fluid Properties** Equilibration Data and Rock compressibility may be set by default via grid. This option is available via right mouse click **Create Default by Grid**.

## 4.6. PVT Designer

In **PVT Designer** 18.3:

- 3-phase VLW flash is available in CCE experiment.
- Non-equilibrium flash may be used. The following experiments are available: NCCE, RELAXATION, NCVD. Nonequilibrium parameters may be matched to sample measured data.
- Fingerprint plot may be visualized.
- Parameter of Chueh-Prausnitz correlation may be changed in BIC calculation.
- Critical point may be used as a control parameter to make objective function in matching weights for lumping.
- Comments may be added to the variants.

## 4.7. Network Designer

In **Network Designer** 18.3:

- Several variants of network may created, calculated and compared via graphs and tables.
- The possibility to create Group of Elements is available.
- Input of well production in the total node production may be visualized in a form of Bubble Maps.

## 4.8. Compatibility with previous versions

In tNavigator 18.3:

- Default settings for the amount of results output has been changed. Instead of previously used "all data at all time steps" now grid properties are saved at the time steps according to model input deck (RPTRST), graphs are saved at all time steps.
- In simulator INIT keyword must be specified in GRID section to export initial properties in binary format E1/E3.
- In Graph Calculator the syntax of aggregation and retrieval of individual values from graphs has been altered (no backward compatibility).
- AHM module may be used for models with reservoir coupling option (no backward compatibility).

## 4.9. Documentation

New training tutorials are added for tNavigator 18.3:

- For module **Simulator**:
  - **SIM6.6. How To Use VLWFlash CO2** – Modeling of oil displacement with alternating injection of water and CO2 for enhanced oil recovery. Compared to pure CO2 injection, the alternating water/CO2 variant is cheaper, since much of the cost is due to CO2. Alternating injection of water and CO2 in varying ratio may be efficient for heterogeneous reservoirs. In this tutorial there is a comparison for two models: with CO2 solubility in water phase and without its dissolution. To calculate the phase equilibrium in gas-water-oil system, we use the VLW\_FLASH option of the FLASHCTRL keyword.
- For modules **Simulator, Model Designer, Assisted History Matching and Uncertainty**:
  - **COMMON1.4. How To Use Graph Calculator Python** – Graph Calculator is designed to create additional user graphs and is available in Simulator Graphical Interface, AHM and Uncertainty module, Model Designer. In this tutorial we provide description of Python's syntax and logic, special functions for working with model objects, libraries import. There are examples of objective function creation for AHM and Uncertainty module via Python scripts to solve the following tasks:
    - \* Matching the displacement characteristic of a model against the reference data.
    - \* Match model on tracer analysis.
- For module **Geology Designer**:
  - **GD1.5 How To Work With Logs** – In this tutorial we provide a detailed description how to work with log data and use Calculator, for example:
    - \* Move digital log data or digitized logs to the log interpreting environment
    - \* Display all logging data
    - \* Edit logs to eliminate invalid data
    - \* Calculate a new log (corresponding to the volume of shales) using a formula
    - \* Depth shift all log curves not recorded with the base log
    - \* Calculate the average value of a log between 2 markers and visualize it on 2D
- For modules **Model Designer, Assisted History Matching and Uncertainty**:
  - **MDAHM1.1 How To Use Molar Rates In AHM** – Back-allocation method described in this tutorial is based on total mass (molar) historical rates at a field level as well as historical bottom hole pressures (BHP), tubing head pressures (THP) and phase water rates at well level. Wells are controlled by group historical total molar rates at field level. Total Molar rate is calculated based on well potential. The following tasks are solved in this tutorial:

- \* Load historical molar rates at the field level (Model Designer)
  - \* Create Group Controls by historical data, set group control by historical molar rates for wells (Model Designer)
  - \* Back-allocation and history match (AHM)
- **MDAHM1.2 How To Use 3D Cos Transf Workflow AHM** – This tutorial shows accelerated Model Designer to AHM workflow based on Discrete Cosine Transform (DCT) of permeability property:
- \* DCT Algorithm overview (theory)
  - \* Building in MD workflow for permeability amplitude parametrization
  - \* Sensitivity analysis
  - \* Automatic history matching
  - \* Analysis of history matching results in MD



## 5. tNavigator 18.2

The key improvements in 18.2 are:

- Integration of modules Simulator, Network Designer, VFP Designer to build integrated models of reservoir-surface network.
- In simulator: speed up in compositional model calculation by using vector instructions of CPU+GPU processors.
- In simulator: the possibility to run restart models on different grid is available (with a set of LGRs different from those in the base model).
- In Geology Designer: the possibility to create an experiment for Geology Designer tables without building a complete hydrodynamic model is supported. This allows to perform a complete uncertainty analysis for geological parameters.
- In Geology Designer: the possibility to create several grids in the same project is supported: create, display and edit additional grids.
- In PVT Designer: the calculation of gas hydrates formation is implemented; visualization of the hydrates curve is available on the Phase Envelope tab.
- In Model Designer: Cases Manager, that provides the possibilities to add comments to cases, group cases, create folders with cases, set in cases arbitrary properties of RUNSPEC, GRID, PROPS, SOLUTION sections, add development strategies.

### 5.1. tNavigator kernel

The tNavigator kernel 18.2 supports new functionality for the models in E1, E3, IM, ST, and GE format:

#### **CPU+GPU calculation**

- The option to calculate a vectorized compositional flash on GPU is enabled by default (if GPU is used in simulation).

#### **For models in E1 and E3 formats:**

- The possibility to switch on/off LGR on calculation time steps and the possibility to use them in ACTION keywords is available (keywords LGRON/LGROFF).
- The possibility to set well temperature cutback tables is available (keywords WELLTCB, WELLTCBT, TCBDIMS).
- The possibility to set parameters of Palmer-Mansoori rock compaction for coal bed methane model is available (keyword ROCKPAMA).

- The possibility to set a sigma factor multiplier as a function of pressure to take into account a modification of the matrix-fracture coupling caused by rock compaction for dual porosity models (keyword ROCKTSIG).
- The possibility to create a new scanning drainage curve if an imbibition process on a scanning imbibition curve is reversed into a drainage process (Killough model) (option NEW of the 6-th parameter of the keyword EHYSTR).
- The possibility to set ALQ as user defined quantity UDQ is available (parameter 12 of the keyword WCONPROD).
- The possibility to set constant gas fuel usage rate as user defined quantity UDQ is available (parameter 2 of the keyword GRUPFUEL).

**For models in E3 format:**

- For thermal models the possibility to use correlations for all viscosity models is available (option CORRELATION of the keyword OILVISC).

**For models in IM, ST, GE formats:**

- RP and Capillary pressure hysteresis is implemented. The following keywords may be used:
  - Format **IM**: HYSKRO (\*CARLSON, \*KILLOUGH \*HYEXO), \*HYSKRW (\*KILLOUGH/\*KILLOUGH\_MOD \*HYEXW), \*HYSKRG, \*SWTI, \*SORMAX. Capillary pressure hysteresis: \*SWT, \*SLT, \*SGT (5-th column), \*EPSPC, \*EPSPCG.
  - Format **GE**: \*HYSKROW (\*CARLSON, \*KILLOUGH \*HYEXO \*SWTI), \*HYSKROG, \*HYSKRG. Capillary pressure hysteresis: \*SWT, \*SLT, \*SGT (5-th column), \*EPSPC.
  - Format **ST**: \*HYS\_KRO (\*CARLSON \*SOTMAX, \*HYEXO \*HYEXW \*SWTI, \*KILLOUGH, \*KILLOUGH\_MOD ), \*HYS\_KRG (\*CARLSON \*SGTMAX, \*KILLOUGH \*HYEXG \*SLTI), \*HYS\_PCO $\bar{W}$ , \*HYS\_PCOG, SWT, \*SLT (5-th column), \*HYS\_LEVEL.
- The possibility to use restart models is available (keywords RESTART, RESDATE).

**For models in GE format:**

- Rowe-Chou correlation for water density calculation with dissolved salt NaCl (keywords \*AQUEOUS-DENSITY \*ROWE-CHOU, \*SALINITY).

**For models in IM format:**

- API tracking option is implemented (keywords \*MODEL \*API-INT, \*PVTAPI, \*API-GRAD, \*BOTAPI, \*VOTAPI, \*API, \*APIT).

- The possibility to use grid properties PERMI/PERMJ/PERMK in the Well section is available.
- The possibility to use hysteresis rock compaction is available (keyword CROCKTABH).

**For models in MO format:**

- The possibility to modify parameters of correlation used for calculation of critical Z-factors in an equation-of-state simulation is available (keyword ZCOR).

**Special options:**

- The flexible hysteresis settings are available for E1, E3 format models: for each region its own hysteresis model can be set, hysteresis parameters can be set for each phase curve of two-phase system, Carlson's analytical model (keywords HYSTOPTS/HYSTOPTSR, HYSTKRW/HYSTKRWR, HYSTKROW/HYSTKROWR, HYSTKRG/HYSTKRGR, HYSTKROG/HYSTKROGR).
- The possibility to change porosity and permeability in SCHEDULE section is available (PORO, PERMX, PERMY, PERMZ).
- For compositional models in E3 format, for carbon dioxide dissolution option CO2SOL three-phase flash water-gas-oil is implemented (parameter VLW\_FLASH of the keyword FLASHCTRL).
- For compositional models in E3 format, nonequilibrium thermodynamic processes are taken into account (keyword NEFLASH).
- The possibility to use restart model with a set of LGRs different from base model is available.
- The possibility of equilibration of initial water saturation SWATINIT via capillary pressure shift is available (6-th parameter of the keyword ENDSCALE).
- Automatic transition of perforations set via COMPDATMD to local/global grid blocks when LGR is activated/deactivated.
- In the keyword COMPDATMD perforations may be set in fracture area defined via FRACTURE\_WELL.
- In the keyword FRACTURE\_TEMPLATE a new parameter REFINEMENT may be used to set the type of local grid refinement.
- In the keyword FRACTURE\_ARITHMETIC the possibility to change the following grid properties is available: PORO, NTG, MULTPV, PVTNUM.
- For black-oil model in the keyword FRACTURE\_ARITHMETIC the following grid properties may be modified: SWAT, SOIL, SGAS.

- Hydraulic fractures (FRACTURE\_WELL) may be added in restart models.
- New parameters for WAG cycling are available to set well cycling mode defining injection rate in surface or reservoir conditions (RATE, RESV, SWITCH, SINGLE of the keyword WWAG).
- The possibility to set type of the initial approximation of pressure in well segments is available (parameter 6 of the keyword WSEGCNTL).
- The possibility to set total molar rate control or limit for group is implemented (option TM of the keyword GRUPTARG).
- The possibility to set well control mode as fraction of group rate specified via GRUPTARG (TGRUP in the 3-rd parameter of the keyword WCONHIST).
- The possibility to set economical limits of any type for groups is available (keyword GECONX).
- The automatic correction of VFP curves in case if the pressure difference at the bottom and at the wellhead increases as the flow rate decreases (option VFP\_NORMALIZE of the keyword TNAVCTRL).

**Integration with other modules:**

- Integration with VFP Designer via the keyword IMPORT\_VFP.
- Integration with Network Designer via the keyword IMPORT\_NDP.

**Data input-output:**

- The possibility to export SCON in UNRST file is available.
- In the keyword RPTRST the following mnemonics have been added to polymer viscosity model: POLYVM and options SHWVISI, SHWVISJ, SHWVISK for mnemonic VISC.

## 5.2. Graphical User Interface

In tNavigator GUI 18.2:

- Multi-touch interface for 2D and 3D is available.
- The support of High DPI displays is improved.
- In the drop-down list of time step selection, each step is marked with a symbol depending on which calculation results are saved at this step (grid properties, only graphs, or nothing).
- Palettes and objects' templates:

- The possibility to assign to each object a template and a palette is available.
- Palettes templates are available for grid properties.
- Graphs:
  - Visualization of new graphs is available: Molar Production Rate, Molar Production Rate [WEFAC], Molar Production Rate Target, Molar Production Total, Molar Production Target Total, Water Production Target Total.
  - In Graph Calculator, multiple user graphs may be produced from one script.
  - New predefined graph templates are available: Matching, Matching (Oil), Matching (Gas), Matching (Presentation), Total, Total (Presentation).
- Grid Properties:
  - The possibility to choose LGRs that are going to be visualized on 2D/3D is available: show all, active on the current time step, don't show.
  - The possibility to use non-Latin characters and spaces in the names of user grid properties (User Maps) is available.
  - For models with geomechanical option visualization of roof deformation and elements of stress matrix is available.
  - For coal bed methane model visualization of initial coal gas concentration is available (specified by the keyword GASCONC).

### 5.3. Assisted History Matching and Uncertainty

#### In Assisted History Matching and Uncertainty 18.2:

- The new type of variable can be used in DEFINES keyword – STRING, External Grid Search may be used to search through included (in the .data files) file names.
- Visualization of CDF graph is implemented (CDF – cumulative distribution function). Using this option, for instance, quantiles P10, P50, P90 can be analyzed on a graph for selected parameters.
- The possibility to utilize user graphs for wells and groups in objective function is available.
- Visualization of reporting parameters for fluid-in-place regions is available.
- Integration with Geology Designer and Model Designer Module:
  - The possibility to create an experiment for Geology Designer tables without building a complete hydrodynamic model is supported. This allows to perform a complete uncertainty analysis for geological parameters.
  - Discrete cosine transform (DCT) algorithm is implemented in Model Designer to use the Discrete Fourier transform algorithm for history matching.

## 5.4. Geology Designer

The following changes occurred in the version 18.2 of **Geology Designer**:

- Seismic:
  - The possibility to open several SEGY files, by selecting it from the seismic tab are available. 2 options of file opening are supported: **Open seismic** (without any additional settings, if the data parameters are automatically detected), **Open Seismic with Customize** (the parameters are checked and edited manually).
  - The possibility to interpret one horizon on several seismic cubes or 2D lines is added (there is no need to create a separate horizon for each loaded SEGY file).
  - The possibility to display velocities on the loaded seismic 2D or 3D data after the loading of the corresponding time to depth relation. The time to depth relationship can be defined and is stored in the seismic object tree available in the **Seismic** tab.
- Grid construction:
  - The possibility to create several grids in the same project is supported. The possibility to create, display and edit additional grids is added.
  - The calculation of **Fault Lines** during the grid construction is added. The fault lines can be edited and can then be used to rebuild the grid.
  - The possibility to compute faults by polygon sets is added.
  - The possibility to edit a point set is added.
  - In the fault edit menu, the possibility to select several fault sticks (horizontal and vertical) is added, the multiple selection is supported.
- Interpolation:
  - The possibility of setting the input data separately for each zones and regions is added. 2 new computations are added: **Interpolation (zones, regions)**, **Facies Analysis (zones, regions)**.
  - The tab **Data Analysis** is added. This tab allows to compute variograms by blocked wells for the chosen zones and regions and to display the VPC.
  - If a discrete template is assigned to the BlockedWells, the variogram and the VPC are computed for each category. The variogram parameters and the VPC can be edited.
- Integration with Assisted History Matching and Uncertainty Analysis module:
  - The possibility to create an experiment for Geology Designer tables without building a complete hydrodynamic model is supported. This allows to perform a complete uncertainty analysis for geological parameters.

- The calculator for logs is available, it includes the possibility to use the defined terms as variables in workflows.
- **Cross-Section** tab for cross-section visualization:
  - The possibility to create cross-sections in 2D, 3D and on horizons is added (the presence of a grid in the model is not mandatory). During the cross-section creation by Points Selection, the option **Use Horizons** must be used.
  - The possibility to visualize logs and faults on cross-sections is added.
  - The possibility to build and edit polygons on cross-sections.
- Other options:
  - The computation of polygons by horizons and 2D contour lines is added. This option allows to visualize contour lines of a horizon on a chosen property (i.e. for example structure contour lines can be superimposed on any 2D map or any 2D view of any property).
  - In the Well Section tab, the possibility to color the gap (difference) between two displayed curves is available.
  - The possibility to work with raster images: loading and visualization. For example, digitized maps of seismic attributes, facies and other geological maps (object **User Map Images** in objects' tree).
  - The possibility to build a contact by horizons or depth, taking the zones and other discrete properties into account (Calculation **Contact. Create Contact by Horizon**).
  - Accurate computation of volumes and reserves taking the contacts into account (Calculation **Properties. Auxiliary Calculations**). If a contact crosses the middle of a block, the parts situated below and above the contact will be taken into account.
  - The possibility to export project in rescue format is available.

## 5.5. Model Designer

In **Model Designer** 18.2:

- Model Cases:
  - The possibility to add comments to model cases is available.
  - The possibility to add a new case from a particular time step is available.
  - Cases are now organized in a tree structure according to their origin.
  - The possibility to add arbitrary properties of RUNSPEC section in model case is available.

- Grid properties:
  - Visualization of LGR on 2D is implemented.
  - Visualization of transmissibilities and flows between blocks in current dynamic model is available (tab **Interblock Flows**).
  - Dynamic grid properties may be used in Calculator.
- Fluid and Rock properties:
  - Several RP curves may be visualized on graphs simultaneously.
  - Leverett J-Function option for capillary pressure may be set (JFUNC).
  - Directional transmissibility multipliers of rock may be added (ROCKTAB).
- Aquifers:
  - The possibility to change aquifers' properties in workflow is available; also aquifers' properties may be used as variables for assisted history matching.
  - Assignment of aquifers to the model cases is available in Cases tab.
- Wells Data and Rules:
  - The possibility to recalculate production tables to other time dates is available (tab **Wells Data. Tables**, option **Rebuild table for other time steps**).
  - The possibility to calculate rates from cumulative values is available (tab **Wells Data. Tables**, option **Calculate Rate from Cumulative**).
  - **Date Filter** in Strategies is implemented and may be used to show data only for selected dates range.
  - A new Rule to set well connection factor multiplier is implemented (WPIMULT).
  - In forecast creation dialog parameters to set injected water and vapor composition are added (WINJTEMP).
  - ALQ parameter has been added in the rule to create well controls by table.
  - **Group production tables** are available with the possibility to create group control rules from them (GCONPROD, GCONINJE).
  - New rule **Reset Group Target** is available (GRUPTARG).
  - The possibility to set control from group molar rates is available.
  - Filter for rules' types is implemented (option **Use Rule Filter**).
- Streamlines visualization for current dynamic model is available.
- Visualization of graphs for connections, fluid-in-place regions and aquifers is available for current dynamic model.



- Pictures and diagrams have been added to the dialogs of hydraulic fracture creation to illustrate all parameters (Fracture Path, Fracture Plane, Fracture Template, Fracture Stage, Fracture Arithmetic).
- The possibility to load VFP tables in MO format is available (keyword TUBI).

## 5.6. PVT Designer

In PVT Designer 18.2:

- For compositional variant K-values calculation is available as function of pressure and temperature (K-values are exported as keywords KVTEMP, KVTABTn).
- For compositional variant new Component Properties are available: specific gravity, boiling point, specific heat (TBOIL, SPECHA, SPECHB, SPECHG, SPECHH). The possibility to calculate specific gravity and boiling point via correlations is implemented.
- When exporting a compositional variant, the component properties may be selected for export independently one by one.
- In Saturation Pressure experiment the calculation of pressure in the lower dew point is available and the complete boundary of the two-phase area is visualized.
- The calculation of gas hydrates formation is implemented; visualization of the hydrates curve is available on the Phase Envelope tab.
- For compositional variant selected properties may be recalculated using correlations.
- New parameters can be calculated and visualized on graphs for experiments CCE/CVD: Liquid Dropout (Psat Vol.) (fraction), Gas Deviation Z factor, Two Phase Z Factor, Oil Z Factor (EOS), Gas Z Factor (EOS).
- Depth visualization is available in Grading test Y-axis.
- For black-oil variant PVT Calculator is implemented to calculate properties: mass fraction of oil, mass fraction of gas, oil formation volume factor and other.
- For black-oil variant parameters of PVT correlation may be adjusted to match sample data (**Matching Samples** option).
- For black-oil variant existing PVT table may be approximated with correlations (**Matching PVT Tables** option).

## 5.7. Network Designer

In **Network Designer** 18.2:

- The integration of Network Designer and Simulator is provided via the keyword **IMPORT\_NETWORK**.
- The possibility to create workflows is available.
- The possibility to create multiple visualization tabs is available.
- Temperature option is taken into account in calculation if tables **OILVISCT** and **WATVISCT** are set in PVT Designer project.
- Turner criterion is implemented: calculation of liquid loading velocity ratio for the well.
- Calculation of heat loss through pipe walls is implemented, the following parameters are taken into account: thermal conductivity of walls, pipe burial depth, method how pipe burial depth is taken into account.

## 5.8. VFP Designer

In **VFP Designer** 18.2:

- The integration of VFP Designer and Simulator is provided via the keyword **IMPORT\_WELL**.
- The possibility to create multilateral wells is available (option **Branches** in Geometry tab).
- The possibility to load VFP tables in **MO** format is available (keyword **TUBI**).
- A new object is available for Well Construction: **Gas Lift Valve**.
- In the tab **Basic data** the list of created object's settings has been extended: name, group name, object (well or pipe), well type (injector or producer), current VFP, preferred phase, inflow equation, instructions for automatic shut-in, density type, drainage radius, crossflow ability and segment model flag.
- The visualization of ALQ axis is available when lifting table is loaded.
- The possibility to take ALQ in account in VFP table calculation (only for black-oil models).

## 5.9. Compatibility with previous versions

In tNavigator 18.2:

- Results storage for geomechanical calculations (initiated by the keyword GEOMECH) is optimized.



*The new method of results storage for geomechanical calculations is **not** backward compatible. An attempt to view the results calculated in previous versions will return an error. To view the results, rerun the calculations in the current version of tNavigator.*

## 5.10. Licenses and license server

In tNavigator 18.2:

- The installation on a system with SELinux enabled is available for the license server.

## 5.11. Documentation

New **training tutorials** are added for tNavigator 18.2:

- For Module **Simulator**:
  - **HowToCreateFracsViaLGR** – Hydraulic fracture modeling via LGR and properties editing in fracture zone and SRV (Stimulated Rock Volume). Arbitrary fracture template can be created via polylines. Fracture (or a series of fractures) are tied to the well trajectory at the specific depth MD. Uniform and logarithmic LGR;
  - **HowToUseGeomechanics** – In tNavigator joint system of coupled equations is used describing filtration processes in reservoir and geomechanical effects on unified grid. This tutorial contains the following test models:
    - \* ModelGeoMech.data (option GEOMECH FE) – Young’s modulus, Poisson constant, boundary condition for stress, boundary condition for displacement.
    - \* ModelRocktabh.data (ROCKTABH) – modeling of geomechanical effects via hysteresis rock compaction data tables.
    - \* ModelMohrCoulomb.data (COHESION, THETA) – Mohr-Coulomb failure criterion is used to analysis of wellbore stress state and predict the potential rock fault. Possible fracture directions.
- For Module **Geology Designer**:
  - **HowToUseTemplatesPalette** – In this tutorial we give an overview of objects templates for discrete and continuous properties. Discrete and continuous palette, ternary palette. Templates import and export;

- **HowToUseFilters** – In this tutorial we give an overview of the following filters to visualize data and analyse properties: Cut, Discrete Property Cut, IJK Filter, Property Filter, Zone Filter;
  - **HowToUseIntegratedUncertainty** – In this tutorial we perform the integrated uncertainty study for gas in place using variables of static and dynamic model. Model is built using workflow as Python script. In static model 3 facies categories are modeled (fluvial channel, crevasse splay, flood plain) and 5 lithology categories (sands, silts, tight, shales, coal). Grid is built taking S-shape fault into account. Variables are: uncertainty in horizon depth, fault transmissibility multiplier, variogramms' ranges, coefficients in permeability formulae, GWC, minimum water saturation. P10, P50, P90 for gas in place are calculated. Pareto charts are used to estimate the correlation between variables and gas in place. Also gas production for wells can be analyzed;
  - **HowToUseCoreSamplesImages** – In this tutorial we load core samples images and analyze them on the Well Section together with well logs.
- For Module **Model Designer**:
    - **HowToCreateAndCompareCases** – In this tutorial we load to Model Designer existing model in E1 format. To improve the quality of history matching and modify BHP values we create several cases for this model:
      - \* Case 1 – original case
      - \* Case 2 – edit relative permeabilities in table form
      - \* Case 3 – convert RP to Corey correlation and edit end-points
      - \* Case 4 – use new schedule strategy: reset well target BHP
      - \* Case 5 – edit 3D permeability property near wells

All cases are saved in cases tree and can be calculated and compared on Graphs in one window.
  - For Module **AHM and Uncertainty**:
    - **HowToAnalyzeUncertainty** – In this tutorial we make sensitivity test on various model's parameters: Permeability values (coefficient in porosity function formula), Vertical permeability ( $K_v/K_h$ ), RP in 2 saturation regions (critical water saturation and curvature of oil RP), Fault transmissibility, Hydraulic fracture geometry (azimuth, half-length). Analyze Uncertainty of wells' performance and Production Forecast, chosen variables don't affect the initial FIP. Tables, Graphs, Histograms, Stacked Plot, Pareto Chart (Pearson correlation) and Quantiles P10-P50-P90. Model variants corresponding to quantiles.

## 6. tNavigator 18.1

The key improvements in 18.1 are:

- For models in E1 and E3 formats, hydraulic fracture model based on grid refinements and changing rock properties in SRV (Stimulated Rock Volume) zone and fracture zone is implemented (keywords FRACTURE\_PATH, FRACTURE\_PLANE, FRACTURE\_TEMPLATE, FRACTURE\_WELL, FRACTURE\_ARITHMETIC, FRACTURE\_STAGE).
- In CPU+GPU calculation NVidia® Volta® video cards are supported.



*For all video cards (including NVidia® Pascal® and NVidia® Volta®) user **must update** device drivers to the latest version with Volta® support.*

- OpenGL version 2.0 is supported.



*Compatibility issues may be encountered when using tNavigator together with software that relies upon older versions of OpenGL.*

- *Microsoft® Remote Desktop® does not support OpenGL 2.0. Please use other software for remote access.*
- *Oracle® VirtualBox® does not support OpenGL 2.0. Please use other software for virtualization.*

- According to the active development of module Model Designer functionality all pre-processing options will be moved from simulator graphical interface to Model Designer. Simulator graphical interface will be used for post-processing results. In 18.1 the following functionality of the tab Fluid Properties has been moved from graphical interface to Model Designer:

- RP editing with mouse holding Shift button and manual editing of RP table on the right;
- Introducing of proppant properties table;
- Introducing of flow function.

### 6.1. tNavigator kernel

The tNavigator kernel 18.1 supports new functionality for the models in E1, E3, IM, ST, and GE format.

**For models in E1 and E3 formats:**

- Dynamic toggling of local grid refinements in SCHEDULE via LGRON / LGROFF is available.

- The possibility to set rock regions numbers (keyword ROCKNUM) in SCHEDULE section is available.
- For geomechanical models, permeability multiplier can now be specified as a tabulated function of stress (PERMSTAB keyword).

**For models in E3 format:**

- Types of components in standard conditions are supported (keyword CVTYPES).

**For models in IM, ST, GE formats:**

- Coal bed methane modeling is supported (keywords ADGMAXC, ADGCSTC, COAL-DIF-COMP, COAL-DIF-TIME).

**For models in IM, GE formats:**

- Simultaneous specification of CCPOR (rock compressibility by region) and CROCK-TAB (table of porosity and transmissibility as functions of pressure) for different regions is supported.
- The possibility to specify initial water saturation at given gravity capillary equilibrium (VERTICAL DEPTH\_AVE) using SWINIT keyword.
- SWNEQ keyword for initial fluid distribution is supported.
- For IM models, SONEQ keyword is supported.
- Pseudopressure option is available (keyword PSEUDOP).
- The possibility to set relative permeabilities scaling for wells' connections to calculate phase mobility (keyword KRPERF).

**Special options:**

- For models in E1 and E3 formats, hydraulic fracture model based on grid refinements and changing rock properties in SRV (Stimulated Rock Volume) zone and fracture zone is implemented (keywords FRACTURE\_PATH, FRACTURE\_PLANE, FRACTURE\_TEMPLATE, FRACTURE\_WELL, FRACTURE\_ARITHMETIC, FRACTURE\_STAGE).
- For models in E1 and E3 formats, keywords related to finite elements method in geomechanical modeling are supported: ROCKAXES, COHESION, THETA.
- For models in E1 and E3 formats the possibility to turn off hysteresis is available (option NONE parameter 5 of the keyword EHISTR, option NONE parameter 4 of the keyword EHISTR).
- tNavigator TNAVCTRL settings:

- Faster and more efficient vectorized code for compositional flash and phase properties calculation is turned on by default (TNAVCTRL VEC\_FLASH YES).
- GPU calculation of vectorized compositional flash is supported (TNAVCTRL GPU\_FLASH).
- NVIDIA Volta video cards are now supported for GPU calculations.



*For all video cards (including NVidia® Pascal® and NVidia® Volta®) user **must update** device drivers to the latest version with Volta® support.*

## 6.2. Graphical User Interface

In tNavigator GUI 18.1:

- According to the active development of module Model Designer functionality all pre-processing options will be moved from simulator graphical interface to Model Designer. Simulator graphical interface will be used for post-processing results. In 18.1 the following functionality of the tab Fluid Properties has been moved from graphical interface to Model Designer:
  - RP editing with mouse holding Shift button and manual editing of RP table on the right;
  - Introducing of proppant properties table;
  - Introducing of flow function.

its format (E1, E3, MO, IM, ST, GE) does not have to be specified.

- In the Graph Calculator:
  - Usage of external Python libraries is supported (compatible with Python version 3.6.4 or higher).
  - Usage of UDQ is supported.
  - Function of aggregation over time intervals is introduced (aggregate\_by\_time\_interval).
- In Bubble Maps:
  - Legend display is added.
  - Option of viewing bubble maps without viewing the wells is added.
- In the graphs:
  - Option of exporting multiple screenshots by wells is added in **Graph templates**. To unload multiple graphs with the same parameters on multiple wells, create a Well Filter and then enable it when saving the screenshot in **Graph templates**.

- Option of User Selection of graphs is added (check multiple graphs, right-click and select **Add All Checked to User Selection.**)
- In Remote GUI, integration with Windows HPC is supported.

### 6.3. Assisted History Matching

In the **Assisted History Matching** 18.1:

- Automatic weight assignment based on historic data is introduced in objective function specification.
- Filter by groups of variants is added.
- Display of calculated UDQ's for model variants is added.
- Calculation of objective function by user graphs is redesigned. If possible, a historic value is automatically calculated and is taken into account in the objective function.

### 6.4. Geology Designer

The following changes occurred in the version 18.1 of **Geology Designer**:

- Seismic:
  - Display of wells, markers, and logs on the 2D seismic lines and arbitrary seismic lines.
  - Interpretation of arbitrary seismic lines.
  - Calculation for transforming a seismic fault into fault in depth.
  - Window of seismic filter for 3D, 2D, arbitrary lines. Customizable range and geometry.
  - Visualization of seismic lines intersection.
- Interpolation:
  - Azimuth map calculation is available.
  - Variograms for Blocked Wells are available (for discrete Blocked Wells, per facies).
- Grid creation:
  - Possibility to edit faults is available.
- Import:
  - Loading of Shape files is available (polygons, point sets).



- New object **Contact** is introduced.
  - Creating a contact by horizon or by depth is available (without zone separation, etc).
  - Contacts WOC-GOC are taken into account in Calculate Volumetric Properties (volumes and fluid-in-place).
- New object **Core Sample Images** is introduced. It can be loaded and displayed on Well Section.
- Other visualization options:
  - In 3D, a filter by values of discrete property is introduced.
  - Crosshair pointer on Well Section is added.
  - Editing of comment logs on Well Section is introduced.

## 6.5. Model Designer

In **Model Designer** 18.1:

- Enhancements in the **Fluid properties** tab that specifies the properties of fluids, rock, proppants:
  - The possibility to convert table RP to Corey / LET correlations is available.
  - The possibility to load tables of capillary pressures from other tables when specifying RP.
  - The possibility to load laboratory data on phase permeabilities and match the model parameters against them by varying the end points and curvature parameters.
  - Different keywords for PROPS and SOLUTION sections can now be specified in graphical interface in keyword form.
  - Creation and editing of proppant properties and flow function (exported as FLOW-FUNC and PROPPANT) is introduced.
- Working with well data:
  - In Well rules, the possibility to specify multiple development strategies for a model is available. Each strategy may contain Global rules and rules by time steps of its own. When assembling a model (**Definitions** → **Schedule**), any strategy can be attached.
- Working with grid properties:
  - Interface for grid properties is reorganized. All grid properties are initially created in a common project tree **Properties**. Then a model is assembled, and a grid property is assigned for each particular property needed for the hydrodynamic model.

- Grid properties that are assigned for usage in the hydrodynamic model are highlighted with bold in the **Properties** tree.
- The possibility to control the amount of RAM used for quick access to project data (**Settings** → **Options** → **Designer** in the main window of tNavigator).
- Ternary palette is added as an option to Object Settings.

## 6.6. PVT Designer

In **PVT Designer** 18.1:

- Splitting of heavy fraction into components is introduced. Whitson and Pedersen correlations are implemented.
- The possibility to specify black oil phases viscosity as temperature dependent (keywords WATVISCT, OILVISCT, VISCREF).
- The possibility to export depth-dependent temperature (keyword TEMPVD) from Grading test.
- Temperature is considered for calculating water properties.
- Quality Check for mixing of compositional variants is introduced.
- The possibility to specify component concentrations in mass percent.
- New library components are added (ethanol  $C_2H_5OH$ , propylene glycol  $C_3H_8O_2$ , diethylene glycol  $C_4H_{10}O_3$ , triethylene glycol  $C_6H_{14}O_4$ ).
- Parachors are now calculated for library and user components, and can be exported (keyword PARACHOR).

## 6.7. Network Designer

In **Network Designer** 18.1:

- **Project Management** is introduced. The following workflows are supported:
  - **PVT** → **Network Designer** allows the usage of a previously created PVT Designer project in Network Designer.
  - **PVT** → **VFP** allows the usage of a previously created PVT Designer projects in VFP Designer projects, with the option of mass editing of the PVT tables used in VFP.
  - **VFP** → **Objects** allows the usage of a previously created VFP Designer projects for objects (wells, pipes, etc.) with the option of mass editing of the used VFP tables.

- Object filter is added.
- Legend for sector diagrams is added.
- Heat loss in the pipe is taken into account.

## 6.8. VFP Designer

In **VFP Designer** 18.1:

- **Project Management** is introduced. It is now possible to use the previously created PVT Designer project in VFP Designer, in particular, when opened from Network Designer.
- Interface for creation of pipes and casings is redesigned.
- New IPR models are added: Jones, Fetkovich, Back pressure, Vogel.
- Import of VFP projects into simulator is enabled (keyword `IMPORT_VFP`, model format E1).

## 6.9. Licenses and license server

In tNavigator 18.1:

- The possibility to install the file license and file for USB key directly from a \*.zip archive.
- New versions of license server (18.1) can now run on active license with expired support (with tNavigator versions 17.4 and earlier).
- Limitation of 300 000 blocks for academic licenses is introduced.

## 6.10. Documentation

New **training tutorials** are added for tNavigator 18.1:

- For Module **Simulator**:
  - 3.1 How To Use WELLTRACK+COMPDATMD.
- For Module **Geology Designer**:
  - 9.3 How To Create Grid With Y-Faults;
  - 9.5 How To Upscale Log Data;
  - 9.6 How To Do Facies Modeling;
  - 9.7 How To Do Porosity Modeling;
  - 9.9 How To Start With Seismic;

- 9.10 How To Interpret Horizons On Seismic;
  - 9.11 How To Do The Time To Depth Conversion;
  - 9.12 How To Do Volume Estimation.
- For Module **PVT Designer**:
    - 11.2 How To Use Blackoil Variants;
    - 11.3 How To Create Condensate Model.

## 7. tNavigator 17.4

The key improvements in 17.4 are:

- The geomechanical modeling is supported. The solution of the elasticity problem by finite elements method is fully coupled with the calculation of filtration problem.
- In Model Designer, the first implementation of **Model Composer** is available to manage multiple variants of hydrodynamic model (realizations). For each variant grid properties, PVT, RP and other properties can be selected independently.
- In Geology Designer, the geological reserve estimation is available (without hydrodynamic model initialization).
- In Geology Designer, tables generation for fluid-in-place and source data is available.
- In Model Designer, dual porosity models can be built in Model Composer.

### 7.1. tNavigator kernel

The tNavigator kernel 17.4 supports new functionality for the models in E1, E3, MO, IM, ST, and GE format.

#### **GPU calculations:**

- GPU calculation of phase properties and their derivatives is supported for isothermal compositional models.

#### **For models in E1 and E3 format:**

- The geomechanical modeling is available. The solution of the elasticity problem by finite elements method is fully coupled with the calculation of filtration problem. Young modulus, Poisson coefficient, boundary conditions can be specified (keywords GEOMECH, GMDISBC, GMPSTBC, YOUNGMOD, POISSONR). The following grid properties are visualized: displacements, stress tensor, porosity.
- The possibility to use the hysteresis model of rock compaction (keyword ROCKTABH) is available.
- The possibility to set the name of the well group or a satellite group for the source or sink nodes is available (parameter 6 of the keyword NODEPROP).
- The possibility to use residual resistance factors for polymer flood model is available (keyword PLYKRRF).

#### **For models in E1 format:**

- The possibility to set water viscosity as a function of concentrations of polymers and salts, and also of temperature is available (keyword PLYVSCST).

- For the models with TEMP option, rock heat conductivity can be specified with the keywords THCOIL, THCGAS, THCWATER, THCROCK, THCONSF.
- For the models with gas containing vaporized oil (keyword VAPOIL), non-equilibrium phase transitions are supported (keyword VAPPARS).
- Options that decide the application of group control operations are supported (second record of the keyword PRORDER).
- The possibility to use well segments representing pullthrough pumps is available (keyword WSEGPULL).
- The possibility to use well segments representing down-hole separators is available (keyword WSEGSEP).

**For models in E3 format:**

- For the models with solid phase, the possibility to simulate the lowering of phase mobility as a result of adsorption of solid phase on the rock is available (keywords SOLIDMMS, SOLIDMMC, SOLIDADS).
- For thermal models, the following keywords related to oil density calculations are supported: CCTYPE, CCTYPES, PREFS, DREFS, TREFS.
- For thermal models, the new options of chemical reactions modeling are available (keywords EQLDREAC, EQLDKVCR).
- The possibility to check the VFP tables (VFPPROD and VFPINJ) correctness against the specified PVT properties is available (keyword VFPCHECK).

**For models in IM, ST, GE format:**

- The possibility to specify and use templates for hydraulic fractures (keywords PLNRFRAC\_TEMPLATE, PLNRFRAC).
- The possibility to change the grid block parameters (volume and face area) is available (keywords VAMOD, VATYPE).
- GASZONE OIL can now be specified for the calculation of initial fluid distribution.
- LINEAR\_ISOPERM model is available (LININTERP for ST format) to calculate oil relative permeability.
- For models in IM format, OILWATER model type is supported.
- For models in ST format, the parameters controlling pressure loss and heat exchange in the wellbore can be specified (keyword PHWELLBORE).

**Data input/output:**

- RPTRST keyword now supports the options WMF, XMF, YMF controlling the export of grid properties of the initial component composition of oil, water and gas to binary files.
- SUMMARY section now supports the option DATE for the formatting of .RSM file.

### Special options:

- The possibility to set THP well control mode for the wells working in history matching mode is available. For producers, this corresponds to the THP option in the 3rd parameter of the keyword WCONHIST, for injectors it is the THP option in the 12th parameter of the keyword WCONINJH.
- Flow speed limitations at bottom hole are supported (keyword WELTARG, options FLOWWH, FLOWOH, FLOWLH, FLOWGH, FLOWVH, FLOWW, FLOWO, FLOWL, FLOWG, FLOWV).
- The possibility to set temperature in the wellbore is available (TEMPERATURE option of the keyword WELLDATA).
- The following calculation control options are available (keyword TNAVCTRL):
  - Option controlling the D-factor calculation for multilateral wells (DFACTORSCALING).
  - Option that enhances numeric stability of calculations in models containing wells with very high rate, producers and injectors alike (parameter TEST\_WELL\_FOR\_MAX\_RATE). When enabled, it limits the maximum rate with the estimated maximum rate of fluid flow to/from neighboring blocks considering the given BHP.

## 7.2. Graphical User Interface

In tNavigator GUI 17.4:

- The capabilities of Graph Calculator on the Graph Templates tab are enhanced. The following options are introduced:
  - Cycling through models, time steps, and objects (groups, wells, perforations).
  - Vector function if\_then\_else (operates on graphs).
  - Tables linearly interpolating the given values vs time (i.e. function create\_table\_vs\_time). May be used, in particular, to estimate oil prices.
  - Functions to translate cumulative rates to average rates per step and vice versa (diff, diff\_t, cum\_sum, cum\_sum\_t).
- The possibility to use User Cut (filter by blocks) when exporting 3D properties in xyz format is available.

- New type of cross-sections by vertical wells is implemented. It is specified by radius and azimuth angle with respect to the well.
- The possibility to set the composition of the injected water and steam is available for thermal models in the well edit dialog (keyword WINJTEMP will be exported to the user file).
- The possibility to set the fixed scale for printing is available.

### 7.3. Assisted History Matching

In the **Assisted History Matching** 17.4:

- Triangular distribution for Latin hypercube is available.
- Extended variants of Plackett-Burman experiment are available: **Standard**, **Folded (symmetric)**, and **Including the line with minimal values**.
- On the Stacked plot, the absolute values mode is added. This way, the **Mismatch** mode lets the user estimate the contribution of wells to the objective function, while **Absolute** mode allows the selection of high-rate producers for the adjustment of weights in the objective function.
- Table with values is added to the Stacked plot.

### 7.4. Geology Designer

The following changes occurred in the version 17.4 of **Geology Designer**:

- Volumetric properties and fluid-in-place computation is available (HCPV, STOIP, GIIP, etc).
- Report generation and export in table format is now available for fluid-in-place and source data, with an indication of the layer, the fluid-in-place type, the zone, the geometric volume of fluid-in-place, etc.
- Algorithms of grid construction are extended and optimized. The following options are available:
  - Algorithms: Create Grid by Horizons and Create Grid by Point Sets and Faults.
  - Grid construction in CORNERS format.
  - Use of arbitrary surfaces as structural faults.
  - Management of non structural faults (in particular Y-fault models).
  - Different types of horizons and point sets can be defined, which allows to manage horizon contacts. The following types are available: Conformable, Discontinuous, Erosional and Basement.



- The following options are now available to work with seismic data:
  - Visualization of several seismic cubes and 2D lines in 3D.
  - Data visualization along polylines for several seismic cubes at the same time.
  - 2D visualization of seismic data flattening along a seismic horizon.
  - Use of cash memory for SEG Y cubes in order to accelerate the working process.
  - Interpretation of seismic faults on seismic profiles.
- The following options are now available to work with well log data:
  - Log curves editing: remove equals (repeated values), remove spikes, resample logs (modify the discretization step), change the type of the curve for continuous curves.
  - Facies names are displayed on the Well Section tab.
  - Visualize well logs on 2D for wells (Log Signature).
- The following options are now available for interpolation computation:
  - In order to prepare the well data to the property modeling by upscaling the well logs to the grid, **Blocked Wells** computation is added. 9 blocking methods are available.
  - Computed Blocked Wells can be visualized in 3D, on the well section tab and as a histogram.
  - Compute a variogram per facies and select it for the modeling.
  - Setting of the facies proportion (defined as fractions) for each facies corresponding to the output facies. The fractions can be numerically defined or can be taken from the trend, the well logs or the blocked data.
  - New algorithms for discrete interpolation (Facies Analysis) are added: 3D Kriging and 3D SGS.
- A new tab **Cross Section** is available. It allows to visualize user-defined cross-section and gathers the following options:
  - Properties and well trajectories visualization.
  - Construction of cross-sections using wells, polygons and grids.

## 7.5. Model Designer

In **Model Designer** 17.4:

- The first implementation of **Model Composer** is available to manage multiple variants of hydrodynamic model (realizations). The following options are available:
  - Manage different hydrodynamic models realizations.

- Selection of petrophysical, relative permeabilities, and PVT properties for each variant.
- Easy model editing and copying.
- The possibility to build dual porosity models.
- The following options are now available in Well Rules tab:
  - Implementation of the rule which allows to add a comment in the beginning of a time step.
  - Implementation of the rule which allows the gas-lift optimization (the keywords LIFTOPT and WLIFTOPT are added to the schedule).
  - Display only the time steps for which the rules are defined.
  - Creation of tables with limits and history during the import of models in Model Designer.
  - Implementation of the option **Check the Rules** to check the coherence of the rules, to find contradictory inputs and lack of data. The detailed information is displayed on the log panel.
- The following options are now available in Fluid and rock properties tab:
  - A totally new design for the **Fluid Properties** tab is implemented.
  - Definition of parameters for salt, polymers, surfactants (ASP), and temperature modeling.
  - Improved menu for the mapping of the properties to the regions.

## 7.6. PVT Designer

In **PVT Designer 17.4**:

- For compositional models, there is now an option to specify multiple compositions within one variant, and to run simultaneous matching of multiple experiments against different compositions.
- Variants with different components can now be blended. If some components are declared as having different properties in original variants, their resulting properties are adjusted so as to reproduce the phase properties of original variants as close as possible.
- Grading test can now export keywords that specify the content of dissolved gas in oil or vaporized oil in gas as a function of depth (RSVD/RVVD).
- After a pseudocomponent is created, it is possible to run Grading test to specify the contents of the initial components before lumping (keyword DETAILMF).
- The possibility to import depth-dependent composition (keywords ZMFVD/COMPVD) is available.
- Water salinity can now be considered when generating PVT tables for black oil variants.

## 7.7. Network Designer

In **Network Designer** 17.4:

- Printing of the boundary conditions to the log file before the calculation is added.
- Second equation system to calculate flows in the surface network is added.
- Representation of surface network calculation results in GUI after model reload is added.
- Visualization of calculation results along the well is added.

## 7.8. VFP Designer

In **VFP Designer** 17.4:

- New objects are available: Bottom Hole, Open Hole, Filter.
- 3D well geometry can now be visualized with coloring according to correlation type or DLS.
- Well logs can now be loaded and visualized in 3D.
- Correlations for IPR are added (Vogel (for liquids only), Fetkovitch (for liquids only), Well-PI, Well test Data).
- Events on given dates can now be specified.
- VFPPROD tables checking is introduced. THP is assumed to be  $10^{10}$  if:
  - properties of unspecified phase are referred to;
  - phase properties are physically unrealistic;
  - pressure calculation fails to converge for any other reason.

## 7.9. Licenses and license server

In **tNavigator** 17.4:

- The combination of several sets of licenses on one USB key (for standalone and network licenses) is supported.

## 7.10. Documentation

New documents are added in tNavigator 17.4:

- VFP Designer Guide.

New training tutorials are added for tNavigator v.17.4:

- Modules **Geology Designer, Model Designer, Assisted History Matching:**
  - How To Use Integrated Workflow AHM (Workflow and integrated assisted history matching).
- **Model Designer** module:
  - How To Add Aquifer All Possibilities (All practical ways to create an aquifer).
  - How To Build Big Model Use Well Rules (Creating a model with numerous wells, setting well rules).
- **VFP Designer** module:
  - How to use VFP Designer (Using VFP Designer).

## 8. tNavigator 17.3

The key improvements in 17.3 are:

- New module **VFP Designer** is available. It is intended to model well geometry and construction, load the pressure drop measurements, create lifting tables from correlations, and adjust them with the measurements.

### 8.1. tNavigator kernel

In tNavigator 17.3 kernel new options are supported for the following model formats: E1, E3, MO, IM, ST, GE.

#### For models in E1 and E3 format:

- The possibility to define chord segment links required to occur looped flow paths in multisegment wells is available (keyword WSEGLINK).
- The possibility to define well segment as influx control device ICD is available (keyword WSEGSICD).
- The possibility to specify diffusion coefficients for block faces is available (keywords DIFFX, DIFFY, DIFFZ).
- The possibility to specify multipliers for diffusion coefficients is available (keywords DIFFMX, DIFFMY, DIFFMZ, DIFFMX-, DIFFMY-, DIFFMZ).
- The possibility to specify diffusion coefficients for non-neighbor connections is available (keywords NNC, NNCGEN).
- The possibility to scale the pressure used for calculation of the adsorption capacity in the block when modeling the coal bed methane is available (keyword LANGMPL).
- The possibility to specify the artificial lift quantity via UDQ is available (4th parameter of the keyword BRANPROP) and fixed pressure for the terminal node (2nd parameter of the keyword NODEPROP) for extended network model.
- The possibility to modify the location of relative permeability scanning curve for the wetting phase is available in order to decrease the deviation of scanning curve from the region bounded by the drainage and imbibition curves (parameter 13 of the keyword EHSTR).
- The possibility to remove gas from a node of the extended network is available (keyword NGASREM).

#### For models in E3 format:

- Reinjection options can be set via parameters 12-15 and 17-19 of the keyword WELLINJE.
- The possibility to define the composition of the oil or gas injected or produced by a satellite group is available (parameters 1-3 of the keyword GSATCOMP).
- For compositional models, support of tracing of the detailed composition in pseudocomponents produced by lumping is available (keywords LUMPING, DETAILVD, DETAILMF).
- For thermal models, support of the options CGVTYPE/COVTYPE for density calculations of oil and gas is available.

**For models in MO format:**

- The possibility to define viscosity dependence upon pressure gradient is available (keyword OVPG).

**In MPI version:**

- Keyword ARITHMETIC now supports the usage of grids with properties from previous sections.
- Keyword ARITHMETIC now supports the operations BLOCK, CYLINDER, X, Y, Z.

**Special options:**

- The following options of calculation control TNAVCTRL can be used:
  - COARSEN\_BLOCK\_DATA\_LOGIC defines coarsening of the grid. Possible values: CENTRAL or NEAREST\_ACTIVE\_TO\_CENTRAL. In the latter case, the nearest active block (according to I,J,K coordinates) to the inactive central block is selected as its representative.
- Keyword ARITHMETIC now supports the CYLINDER option, which creates a grid with value 1 assigned to the blocks inside the specified cylinder.
- The possibility to remove oil from a node of the extended network is available (keyword NOILREM).
- The possibility to define viscosity dependence upon pressure gradient is available (keyword OVPG).

## 8.2. Graphical User Interface

In Graphical User Interface 17.3:

- Visualization of the rock compaction transmissibility multipliers (specified by ROCK-TAB) at current time step. The property is available at **Grid Properties** → **Calculated** → **Rock compaction Trans. Mult.**
- Visualization of the Transmissibility multipliers along X, Y, Z, X-, Y-, Z-. The properties are available at:
  - **Grid Properties** → **Initial** → **Trans. Mult. along X** (also Y, Z, X-, Y-, Z-). This property is the product of the transmissibility multiplier along X (MULTX), additional transmissibility multiplier along X (HMMULTX, HMMLTXY), and fault transmissibility multiplier along X (MULTFLT).
  - **Grid Properties** → **Calculated** → **Trans. Mult. along X** (also Y, Z, X-, Y-, Z-). This property is the product of the transmissibility multiplier along X (MULTX) and fault transmissibility multiplier along X (MULTFLT) from the start till the current time step.
- The dialog **Load well data** now contains the following options:
  - **Replace missing values with zero.** If this option is used, the parameters for the well that are missing in the file on the specific date will be replaced with zeros.
  - **Assign zero values to model dates missing in historical data.** If selected, the values for missing dates will be replaced with zeros. Otherwise the values from the previous time step are used.

## 8.3. Remote GUI

In the remote graphical user interface 17.3:

- Queues Filter is available.

## 8.4. Assisted History Matching

In Assisted History Matching 17.3:

- The possibility to create user's custom vectors (vector calculator) is available.
- The possibility to use the user's vectors as objective function is available (the graph must be named objf).
- The possibility to create forecast variants with user's SCHEDULE section is available. Variables can be set in user SCHEDULE.

## 8.5. Geology Designer

In Geology Designer 17.3:

- Editing of 2D surfaces using contour lines (available for horizons and 2D Maps).
- Grid building:
  - The possibility to specify the parameters of logarithmic local grid refinement (LGR).
- Working with seismic data:
  - 3D editor of seismic horizons on the 3D tab.
  - Display of wells, well logs and markers on the Seismic tab (2D).
  - The possibility to create a synthetic velocity curve, synthetic acoustic impedance, reflection coefficient and interval velocity curves to compare it with the seismic data.
- Option of filtering the trajectories by depth in 3D (option **Cut Trajectory by Depth**).
- Third coordinate for polygons can be used (Z).
- The possibility to use Ghost curve on the Well Section is available to compare the form of log of one well with its form on other wells when correlation is performed.
- Check for simultaneous opening of a project by multiple users (.lock file).

## 8.6. Model Designer

In Model Designer 17.3:

- **Date Filter** for importing and exporting of events and history is available.
- Choice of measurement units in the export dialog of events and history is available.
- The possibility to specify main control mode for wells in the Rules.
- The possibility to use **Filter by wells** in the tables of events and history is available.
- The possibility to use the Well Filter in the Well Table is available.
- The possibility to select fonts for contour lines marks is available.
- Visualization of legend for crossplots is available.
- Check for simultaneous opening of a project by multiple users (.lock file).



## 8.7. PVT Designer

In PVT Designer 17.3:

- Creation of PVT tables by correlations for black oil variants is available.
- Comparison of the graphs of most important properties before and after matching, and also before and after lumping.
- Binary interaction coefficients of components can now be used as variables for matching.
- Export of multiple variants as multiple EOS/PVT regions is available.
- Export of pseudocomponent's composition (keyword LUMPING) is available.
- The number of compounds in the component library has been extended.

## 8.8. Network Designer

In Network Designer 17.3:

- Integration with VFP Designer.
- New types of network objects can be used:
  - 2-phase separators;
  - 3-phase separators.
- The possibility to load existing VFP tables or create them in VFP Designer for pipes, wells, compressors, pumps, chokes.
- The possibility of simultaneous editing of multiple objects is available.
- Undo/redo functionality is available.
- The possibility to turn objects off at different steps is available.

## 8.9. VFP Designer

In tNavigator 17.3 the first implementation of **VFP Designer** is available:

- Integration with PVT Designer, Network Designer is provided.
- Well geometry specification:
  - Loading of well trajectory in standard formats (Well Path/Deviation, LAS, GWTD, etc.);
  - Copying of trajectory points from a text file or a spreadsheet;

- Manual editing of a trajectory;
- Well geometry visualization (TVD and Deviation Survey).
- Well construction specification:
  - Casing, tubing, perforation, squeeze, packer;
  - Visualization of construction along well trajectory;
  - Manual drag-and-drop addition and editing of properties of well construction objects;
  - Creation and import of custom object catalogs;
  - Selection of parameters of well construction objects as variables for matching experimental data (pressure drop measurements).
- Fluid composition specification:
  - Loading of properties or usage of PVT Designer to specify black oil or compositional properties.
- Entering the experimental data (pressure drop measurements).
- Creation of lifting tables (VFP):
  - Creation of tables by correlations (Beggs-Brill, Hagedorn-Brown, Orkiszewski, Gray, etc.);
  - Usage of different correlations for vertical, deviated and horizontal parts of the wellbore;
  - Setting of Friction multiplier and Hydrostatic component of the correlation;
  - Specification of points to calculate correlations in the table form;
  - Visualization of the experimental measurement along with the created VFP tables;
  - Normalization of VFP tables;
  - Matching of tables by selected measured parameters and variables (construction elements' settings, Friction and Hydrostatic components);
  - Application of the construction elements' settings found by matching;
  - Export of VFP tables to a file or to Network Designer.

## 8.10. Licenses and license server

In tNavigator v.17.3:

- **Licensing of VFP Designer.**

This module is included in Geology Designer, Model Designer, and Network Designer. When starting the VFP Designer from these modules, a separate license is not required. When starting the VFP Designer as a standalone program, it searches for available license in this order: Model Designer, Network Designer, Geology Designer.

## 8.11. Documentation

New documents are added in tNavigator 17.3:

- Network Designer Guide;
- PVT Designer Guide.

New training tutorials are added in tNavigator v.17.3:

- Module **Geology Designer**:
  - 9-0\_HowToGetStartedGeologyDesigner (Introduction to Geology Designer). This tutorial shows the process how to create Geology Designer project. Working with Settings, Calculations and Visualization panel. Set coordinate reference system. Directions of coordinate axes. Floating tabs. Visualization settings.
- Module **Network Designer**:
  - 12-1\_HowToUseNetworkDesigner. This tutorial shows how to build surface network from wells to sinks. Different surface equipment is used: pipes, links, chokes, pumps, compressors, separators. Integration with PVT Designer and VFP Designer. PVT Designer is used to set fluid properties. VFP Designer is used to set well construction, geometry and create VFP tables for wells via correlations.

## 9. tNavigator 17.2

The key improvements in 17.2 are:

- The first implementation of module **Network Designer** is available. Production and injection networks can be created in graphical interface and calculated.
- Tools for seismic interpretation are available in Geology Designer: Manual interpretation, Guided Autotracking, Seeded 2D autotracking, Seeded 3D autotracking, time to depth conversion.
- Assisted History Matching module is integrated with Model Designer and Geology Designer. Variables can be added to the workflow.
- The first implementation of **Geosteering** is available in module Geology Designer, that allows to display horizontally logs of planned and drilled well, 2D visualization and calculate synthetic log using reference well.

### 9.1. tNavigator kernel

In tNavigator 17.2 kernel new options are supported for the following model formats: E1, E3, MO, IM, ST, GE.

#### **CPU+GPU calculation:**

- Calculation of compositional models via CPU+GPU is available. The only GPUs starting from Pascal architecture are supported (and latest CUDA drivers).

#### **For models in E1 and E3 format:**

- The possibility to open wells closed due to priorities is available (option POPN in the 2-nd parameter of the keyword WELOPEN).
- The possibility to assign for well drilling unit number is available, so that all wells with the same unit number are drilled simultaneously (3-rd parameter of the keyword WDRILPRI).
- The possibility to use water molar fraction in VFP tables is available (option WTF in the 4-th parameter of the 1-st line of the keyword VFPPROD).
- The possibility to set guide rate at the beginning of each time step equal to the value of group's production rate in reservoir conditions is available (option VOID in the 10-th parameter of the keyword GCONINJE).
- The possibility to inject several passive tracers in one well is available (injection is set via the keyword WTRACER).

- For dual porosity models multiplier for matrix-fracture transmissibility can be set as one value for all grid (keyword MULTSIG) or for each grid block (keyword MULTSIGV).

**For models in E1 format:**

- Option SHRATE is available for a polymer shear thinning/thickening in logarithmic form.
- Option MISCIBLE is available (keywords PMISC, MSFN, SDENSITY, SGCWMIS, SORWMIS, TLMIXPAR).

**For models in E3 format:**

- The possibility to set oil injection rate and gas injection rate limits (options HCOIL, HCGAS in the 2-nd parameter of the keyword WCONINJE).
- For thermal models in E3 format options CGDTYPE/CODTYPE are available to calculate gas/oil phase densities.

**For models in IM format:**

- The possibility to use quadratic inflow relationship for gas inflow/outflow from a well is available (option QUAD of the keyword PERF).

**For models in GE format:**

- Correlations can be used to set component properties (keywords PVC3, CRIT).

**For models in MO format:**

- For compositional models CO<sub>2</sub> solution in water can be taken into account (keywords SOLU, RHAQ).
- The possibility to inject several passive tracers in one well is available (injection is set via the keyword TRAC).

**Data input-output. Reports:**

- The following parameters can be requested in SUMMARY:
  - Water component molar injection rate (FWMIR, GWMIR, WWMIR);
  - Water component molar injection total (FWMIT, GWMIT, WWMIT);
  - Water component molar production rate (FWMPR, GWMPR, WWMPR);
  - Water component molar production total (FWMPT, GWMPPT, WWMPPT);
  - Component Hydrocarbon as Moles (FCMIP).
- Well control mode (WMCTL) can be requested while exporting UNRST/UNSMRY binaries and RSM file from graphical interface.

- Well Filter can be used to export UNRST/UNSMRY binaries and RSM file from graphical interface.
- The possibility to save reporting parameters for wells (groups) on calculation time steps in UNRST/UNSMRY binaries export is available in console calculation (keywords RP-ONLY and RPTONLYO can be used in sections SUMMARY and SCHEDULE).

### Special options:

- The following options to set tNavigator calculation are available in TNAVCTRL:
  - AQUCON\_LGR – allows to build links for numerical aquifer-grid when local grid refinement LGR is used in the area of aquifer connection.
  - USEGASLIFTFROMSHUTWELLS – allows to include or ignore the value of gas-lift for shut wells in network.
  - RECOMPUTE GPMAINT – sets the logic of cumulative pressure error recalculation (integral of pressure error) when the wells are not on GPMAINT control (keywords GPMAINT, GPMAINT3).
  - WELLPRESTOL – sets tolerance, used to calculate bottom hole pressure for the well which is not on bottom hole pressure control.
- For models in E1 format the possibility to use quadratic inflow relationship for gas inflow/outflow from a well is available (option QUAD in the 8-th parameter of the keyword WELSPECS).
- User defined quantities (UDQ) can be used in gas-lift optimization options (3-rd parameter of the keyword WLIFTOPT; parameters 2,3 of the keyword GLIFTOPT).
- The possibility to set THP limit for wells working in history matching mode (option THPTARG of the keyword WELTARG).

## 9.2. Graphical User Interface

In Graphical User Interface 17.2:

- Create a screenshot option has been updated for 2D, 3D visualization, graphs. A screenshot can be saved in vector or raster format, copied to clipboard or printed.

## 9.3. Geology Designer

In Geology Designer 17.2:

- Floating tabs are available (2D, 3D, Histogram, Seismic, Wells Table, Well Section, VPC, Crossplot, Geosteering) with the possibility to place them in separate windows or next to each other through splitters.

- Multiple tabs with individual settings for each one can be created. For example, several 2D views with different settings can be created via menu **View. Windows**.
- Create a screenshot option has been updated for 2D, 3D visualization, graphs. A screenshot can be saved in vector or raster format, copied to clipboard or printed.
- Workflow:
  - The possibility to create workflow automatically according to user's actions is available (**Document. Record actions to user workflow**).
  - The possibility to uncheck temporary selected actions in workflow is available.
  - The possibility to check consistency of the workflow before running it (button **Test** in Workflow dialogue).
  - Integration with Assisted History Matching module is available: variables can be added to the workflow. Variables can be used in the following calculations: Horizon Calculator, Property Calculator, Adjust Variogram parameters, Property Interpolation, Create RP Tables, Create Equil tables.
- Work with seismic data:
  - Tools for seismic horizons interpretation are available on **Seismic** tab. Manual interpretation, Guided Autotracking, Seeded 2D autotracking, Seeded 3D autotracking. Interpreted horizon is visualized in time axis (time in milliseconds).
  - 3D Correlation is available to create seismic 3D horizon according to picking.
  - Time-depth law can be loaded as a Log for wells.
  - The possibility to create horizon via seismic horizon and time-depth law is available (**Create Horizon by Seismic Horizon** in Auxiliary Calculations).
- Well correlation (**Well Section** tab):
  - The possibility to Show Distance Between Wells is available.
  - The possibility to load and visualize **Comment Log** is available. Values of Comment Log are text rows assigned to depth. Comment Log can be edited in **Wells Table**.
  - The possibility to edit marker visualization settings is available (color, width, line type).
  - The possibility to **Show Marker Label** on Well Section is available. Label color, font and position can be set.
  - The possibility to set common vertical scale for all wells is available.
  - The possibility to set individual scale for each well is available.
  - The possibility to edit discrete logs is available.
  - The following hot keys are available:

- \* E – Edit/Create Well Markers;
  - \* A – Edit Discrete Log;
  - \* 2 – Decrease vertical scale;
  - \* 1 – Increase vertical scale;
  - \* T – Edit Logs Limits;
  - \* Q – Find Well/Conn.
- The possibility to display Well Section horizontally is available.
- A new tab **Geosteering** is available:
    - Configure geosteering: reference well, planned well, drilled well.
    - Create synthetic log using reference well.
    - Simultaneous display of two correlation profiles (planned well and drilled well) and 2D view.
  - Object Settings (Option is available via right mouse click on the object and choosing **Object Settings**):
    - The possibility to change object settings (property, horizon, log and other) is available: name, color, template that specifies object's units and palette.
    - The possibility to use standard templates or set user's template is available.
    - Discrete palette can be set for object templates. For templates one can set for each value it's name and color.
  - The possibility to visualize properties according to zones is available (**Zones Filter**).
  - The possibility to load horizons from RESCUE files is available.

## 9.4. Model Designer

In Model Designer 17.2:

- Floating tabs are available (2D, 3D, Histogram, Seismic, Wells Table, Well Section, VPC, Crossplot, Geosteering) with the possibility to place them in separate windows or next to each other through splitters.
- Multiple tabs with individual settings for each one can be created. For example, several 2D views with different settings can be created via menu **View. Windows**.
- Create a screenshot option has been updated for 2D, 3D visualization, graphs. A screenshot can be saved in vector or raster format, copied to clipboard or printed.
- The possibility to create models with hysteresis is available (check **Hysteresis** in **Definitions** tab).



- Workflow:
  - The possibility to create workflow automatically according to user's actions is available (**Document. Record actions to user workflow**).
  - The possibility to uncheck temporary selected actions in workflow is available.
  - The possibility to check consistency of the workflow before running it (button **Test** in Workflow dialogue).
  - Integration with Assisted History Matching module is available: variables can be added to the workflow. Variables can be used in the following calculations: Property Calculator, Adjust Variogram parameters, Property Interpolation, Create RP Tables, Create Equil tables.
- Object Settings (Option is available via right mouse click on the object and choosing **Object Settings**):
  - The possibility to change object settings (property, horizon, log and other) is available: name, color, template that specifies object's units and palette.
  - The possibility to use standard templates or set user's template is available.
  - Discrete palette can be set for object templates. For templates one can set for each value it's name and color.
- Working with models in IM, ST, GE formats:
  - The possibility to add keywords in formats ST, GE, IM is available (**Create new rule. User Keywords**).
  - The possibility to edit keywords in formats ST, GE, IM is available.
  - The possibility to export keywords in formats ST, GE, IM is available (**Document. Export model** in corresponding format).
  - So model in ST, GE, IM can be loaded to Model Designer, edited and exported in its initial format.
- Rules for wells:
  - The possibility to set additional options in the rule **Well Specification Parameters** is available: reference depth, drainage radius, crossflow flag and other.
  - The possibility to load time in formats HH:MM:SS, HH,MM,SS, HH.MM.SS is available in event and history loading dialogues. Also dates with hours can be created in Schedule section.
  - For thermal models historical data for steam injection can be loaded. Then it can be used in WINJTEMP creation.
- The possibility to visualize properties according to zones is available (**Zones Filter**).

## 9.5. PVT Designer

In PVT Designer 17.2:

- Visualization of Phase Envelope has been updated. Vapour fraction is visualized via color and (or) contour lines and filling.
- The possibility to work with Black Oil Variants is available. Black Oil Variants can be created from Compositional Variants or loaded from file with standard keywords in E1 format. Data can be visualized and edited. Phase compressibility is calculated to analyze consistency of PVT tables.
- PVT tables PVTO-PVTG can be created for subcritical area.

## 9.6. Network Designer

In tNavigator 17.2 the first implementation of **Network Designer** is available:

- The possibility to create and calculate the surface network is available (find network characteristics in the internal points based on data specified at the boundary objects of the network). Steady-state problem is considered.
- Fluid composition: compositional properties or black oil can be used.
- Integration with PVT Designer is provided.
- The following objects can be used to create network:
  - Boundary network objects:
    - \* Source;
    - \* Sink.
  - Inner network objects:
    - \* Pipe;
    - \* Link;
    - \* Joint;
    - \* Choke;
    - \* Pump;
    - \* Choke.
- The following options of pressure drop calculations are available:
  - Pipe:
    - \* One phase Moody's correlation with Haaland's correlation are used for calculation of the turbulent friction coefficient;
    - \* Beggs&Brill multiphase correlation.

- Choke:
  - \* Mechanistic correlation for subcritical/critical flow regimes;
  - \* Ashford&Pierce correlation for subcritical/critical flow regimes.
- Pump/Compressor, the calculation can be based on:
  - \* Pressure ratio;
  - \* Pressure difference;
  - \* Pressure after equipment;
  - \* Equipment power.
- Graphical user interface to analyze results:
  - Bubble Maps (pressure, mass flow rate) or 2D network visualization.
  - Graph of pressure distribution along selected network branch.
- Control of network correctness:
  - Detection of network's parts, where a flow is absent, (active/non-active elements) before running calculation.
  - Detection inconsistency of heights of pipe end-points at pipe joints.
  - Control of sufficiency of the number of boundary conditions (pressure, mass flow rate).
  - Control of setting equipment characteristics required for calculations.

## 9.7. Assisted History Matching

In Assisted History Matching 17.2:

- The contribution of each individual measurement to objective function can be adjusted.
- Table with R2 coefficients is available to analyze quality of history matching.

## 9.8. Compatibility with previous versions

In tNavigator 17.2:

- To run AHM or uncertainty from Model Designer and Geology Designer variables can be added only in workflows (compatibility with previous versions is not provided).

## 9.9. Licenses and License server

In tNavigator 17.2:

- New license module is supported: **Network Designer**.

## 9.10. Manuals

In tNavigator 17.2 the following **technical documentation** is available:

- tNavigator Library;
- User Manual;
- User Guide;
- Assisted History Matching User Guide;
- PVT Designer User Guide;
- Designer User Guide (Geology Designer, Model Designer);
- Batch Jobs User Guide;
- Remote GUI User Guide;
- Installation and License Guide;
- Release Notes.

In tNavigator 17.2 the following **new training tutorials** are available:

- Module Assisted History Matching:
  - 8-8\_HowToGoFromAHMtoForecast.
- Module Geology Designer:
  - 9-3\_HowToUsePetrophysicalModeling;
  - 9-4\_HowToUseSeismicInterpretation;
  - 9-5\_HowToUseCorrelation.

## 10. tNavigator 17.1

In 2017 tNavigator version enumeration is updated. Now the version number consists in two last digits of the year and the number of release in this year, separated via a dot. For example, 4 tNavigator versions in 2017 will have the following numeration: 17.1, 17.2, 17.3, 17.4, corresponding to the numbers of quarters when these versions are released. Update of enumeration system has a goal to make it easier for users to identify current and out-of-date versions.

The key improvements in 17.1 are:

- **Geology** module is split in **Geology Designer** and **Model Designer**, licensed separately. **Geology Designer** – building geological model from scratch. **Model Designer** – pre-processor to build dynamic model. **PVT Designer** is included in both licenses **Geology Designer** and **Model Designer**.
- In **Geology Designer** there is a first implementation of tools to load and work with 3D seismic data.
- In this release there is a first implementation of CPU+GPU simulation engine: calculation speed-up can be obtained due to solving systems of linear equations using graphics accelerators NVidia. The only GPUs starting Pascal architecture are supported (and latest CUDA drivers) to utilize GPU functionality.
- The algorithm of solving linear systems is enhanced.
- The following default parameters are modified:
  - For the keyword RUNCTRL, the option MAXLINIT (which is the maximum number of iterations used for solving linear systems) is set to 400 by default;
  - For the keyword RUNCTRL the option TMAXMULT (which is the maximum multiplier used to multiply the current time step length during the next time step calculation) is set to 3 by default;
  - For the keyword TNAVCTRL the option SCALE\_MATRIX is used by default: it is set to 1 (or YES).
- The design of the main window is modified in order to allow a more comfortable access to all the modules.
- The access to the **Manuals** is available from the main window. To read the **Manuals** any pdf reader is needed.
- 32-bit versions on all platforms are not supported anymore.
- For Windows Platform Windows 7 (SP1) operating systems or newer are supported.

## 10.1. tNavigator kernel

In tNavigator 17.1 kernel new options are supported for the following model formats: E1, E3, MO, IM, ST, GE.

### Reservoir Coupling:

- Dynamic restarts are available in graphical interface, options --continue, --restart are available for console, automatic restarts. Restart MASTER and SLAVE models can be used.

### For models in E1 and E3 formats:

- The possibility to set the salt concentration in the injection stream via user defined quantity UDQ (2-nd parameter of the keyword WSALT).
- The possibility to set group name, whose produced polymer (salt) concentration will be used in the injection stream for the well (4-th and 5-th parameters of the keyword WPOLYMER).
- Artificial lift quantity (ALQ) value can be set and used in the pressure loss calculations for the group's pipeline (4-th parameter of the keyword GRUPNET).
- CIRR mode is available to set injectivity multiplier for injectors. Injectivity increase is not reversed for all connections. Connections continue working with its maximum attained injectivity multiplier (4-th parameter of the keyword WINJMULT).
- The possibility to set the grid block pressure limit for well rate cutback or for reversing the cutback process (8-th and 9-th parameters of the keyword WCUTBACK).
- The algorithm of surface network calculation has been updated.

### For models in E1 format:

- Temperature effects can be taken into account using polymer option (keywords PLYVISCT, TEMPNODE).
- The possibility to use temperature option with API is available (3-th parameter of the keyword VISCREF).

### For models in E3 format:

- TRACK option is supported for compositional models (keywords TRACK, TRACK-REG).
- Molecular diffusion can be used in compositional models (keywords DIFFCGO, DIF-FCOG).
- Separator's stage can be set to defined composition of injected fluid (5-th parameter of the keyword WINJGAS).

**For models in ST format:**

- Thermal conductivity options COMPLEX and TEMPER are available (keyword THCONMIX COMPLEX, TEMPER).

**Data input-output. Reports:**

- The following parameters are available in SUMMARY section: ANQP, ANQT, ANQR, FNQT, FNQR, FOPV, FWPV, FGPV, ROPV, RWPV, RGPV.
- The possibility to save AQUIFERA, AQUIFERL and AQUIFERN properties in the INIT file.
- The possibility to save tracers' concentrations in .UNRST file.
- The possibility to load history from files in fhf format (Field History File format).

**Special options:**

- For models in E1 and E3 formats D-factor correlation coefficients can be set for certain block with connections (in global grid and LGR) (the keyword WDFACCORL).
- For models in E1 and E3 formats average pressure can be calculated taking into account virtual perforations of hydraulic fractures (options FALL and FOPEN of the 4-th parameter of the keyword WPAVE).

## 10.2. Model Designer

In **Model Designer** 17.1:

- The following possibilities has been added to the option **Import Data From Existing Model**:
  - Models in **ST**, **GE**, **IM**, **MO** can be loaded and analyzed (editing and export is supported only partly).
  - Compositional models in **E3** format can be loaded. Fluid properties can be visualized in the tab **Fluid Properties. Compositional Properties**.
- The data defined via the keywords PRVD, ROCKTAB can be loaded to the tab **Fluid Properties** and visualized.
- The possibility to visualize projections of wells trajectories on the Cross-Section if they are not far that defined distance from it (**2D. Cross-Section. Advanced Settings. Use distance to Trajectory**).
- The possibility to create **Property Filter** setting the ranges or several 3D properties is available.

- **Crossplots** can be created for 3D properties. Property Filter can be used for Crossplots and trend lines can be visualized.
- Several tables **Well Production Table** and **Well Structure Table** can be created. In the tab **Wells Data. Rules** the name of production (structure) table should be specified when a new rule is added.
- The possibility to create new rules is available (in accordance with the corresponding keywords):
  - Drawdown Limit for Well (WELDRAW).
  - Group Efficiency Factor (GEFAC).
  - Economic Limits for Production Group (GECON).
  - Gas Lift Optimization for Groups (GLIFTOPT).
- The possibility to apply a Rule to wells from the Well Filter. Each Rule can be applied to one well, all wells or wells from the Well Filter.
- The possibility to create Wells and Groups Filter, which affects on SCHEDULE section export. This filter can be set on specific date. When the model is exported only the data from Rules for wells and groups from this filter is saved in the SCHEDULE section.
- Well Filter can be used to visualize Rules. Rules will be visualized only for selected wells and groups.

### 10.3. Geology Designer

In **Geology Designer** 17.1:

- Polygons can be imported in the formats CPS-3 lines and Polygon lines.
- Point sets can be imported in the formats CPS-3 lines and Point set lines.
- Point sets can be exported in the format xyz.
- **Adjust to Source Distribution** option can be used in SGS property interpolation.
- The possibility to visualize projections of wells trajectories on the Cross-Section if they are not far that defined distance from it (**2D. Cross-Section. Advanced Settings. Use distance to Trajectory**).
- The possibility to create **Property Filter** setting the ranges or several 3D properties is available.
- **Crossplots** can be created for 3D properties. Property Filter can be used for Crossplots and trend lines can be visualized.



- There is a first implementation of tools to load and work with 3D seismic data:
  - Loading of 3D seismic data in SEG-Y format is available.
  - The possibility to create and visualize (2D and 3D) Inlines, Crosslines and time-slices.
  - The possibility to create horizon manually via seismic 3D data is available.

## 10.4. PVT Designer

In **PVT Designer 17.1**:

- The possibility to match automatically chosen parameters with defined laboratory data (Samples) obtained in several different experiments. The possibility to set weight of experiment and weight of measured sample is available.
- The possibility to mix two compositions is available (Blend experiment).

## 10.5. Assisted History Matching

In **Assisted History Matching 17.1**:

- The possibility to use Assisted History Matching module for model in the formats **ST**, **GE**, **IM** (scenarios from graphical interface can be started or **DEFINES** keywords can be set in the **DATA**-file).
- The possibility to add variables to the base model is available. New variables can be added in the **DATA**-file or defined in History Matching Variables Manager in graphical interface.
- Multidimensional scaling is available to visualize variants on 2D (tab **MDS**).
- Variants Clusterization can be created for variables values.
- The possibility to group model variants and set visualization properties for each group independently on Graphs and Crossplots (**Create Group Set From Selected Variants**).
- The possibility to set user variants – experimental design matrix (**Experimental Design. Custom**).
- The following scenarios started from graphical interface are available: Multiply Poro Volume by Regions, Multiply Transmissibility by Regions.
- The possibility to visualize the allowable mismatch range on Graphs (the range for each parameter is defined in Objective Function dialogue as **Deviation**).
- The possibility to create forecasts from selected variants.

## 10.6. Graphical User Interface

In Graphical User Interface 17.1:

- In **Schedule** table the following features has been added:
  - Separate tabs for keywords specifying **Group operations** and **Network operations**.
  - The column with Group name. Keywords in the list can be sorted via this name.
  - The possibility to choose the columns to visualize.

## 10.7. Compatibility with previous versions

In tNavigator 17.1:

- Obsolete commands of command line have been removed -t, --report-tables.
- If you have a functioning network license with **Geology** module on license server below 4.2.6 it is necessary to update license server to 17.1 to continue using geological tools in tNavigator 17.1.
- 32-bit versions on all platforms are not supported anymore.
- For Windows Platform Windows 7 (SP1) operating systems or newer are supported.

## 10.8. Licenses and License server

In tNavigator 17.1:

- New license modules are supported: **Geology Designer**, **Model Designer**, **Network Designer**.
- **Geology** module is split by **Geology Designer** and **Model Designer**. For network licenses and local usb-licenses, that contain **Geology** module, tNavigator and license server 17.1 convert automatically each license of **Geology** module to the pair **Geology Designer** and **Model Designer**.

## 10.9. Manuals

In tNavigator 17.1:

- The following technical descriptions are available:
  - User Manual;
  - User Guide;
  - Modules Geology Designer, Model Designer User Guide;

- tNavigator Arithmetic Manual;
- tNavigator Release Description.
- Clicking on the button **Export** in the menu **Manuals** will lead to the export of all the available technical descriptions in the language corresponding to the current language of the interface.

## 11. tNavigator 4.2.6

In tNavigator 4.2.6 a new module of tNavigator PVT Designer is available. In PVT Designer it is possible to choose components, conduct experiments, load laboratory measurement data, execute an automatic matching of chosen parameters in accordance with measured data (regression) and create PVT tables.

### 11.1. tNavigator kernel

In tNavigator 4.2.6 kernel new options are supported for models in E1, E3, MO, IM, ST, GE formats.

**For models in E1 and E3 formats the following options are supported:**

- For the group control mode it is possible to limit the surface water and gas production rate by the fraction of the corresponding phase injection rate (18 and 19 parameters of the keyword GCONPROD, and PBWS, PBGS values in parameter 2 of the keyword GCONPROD).
- The possibility to take into account the dependence of polymer adsorption on salt concentration (keywords ADSALNOD, PLYADSS).
- The possibility to take into account a passive tracer absorption (keywords TRROCK, TRADS).
- The possibility to generate horizontal pinchout connections via defining the pinchout threshold widths in X and Y direction, respectively (keyword PINCHXY).
- The use of keyword MULTREGT in SCHEDULE section is supported (multipliers are accumulated, i.e. the resultant multiplier is the product of previous dates multipliers).
- The compatibility setting to coarse grid calculations is supported (value 1 should be set for the parameter 141 of the keyword OPTIONS).
- The possibility to use the option of velocity dependent relative permeability in pseudo-pressure calculation (parameter 4 of the keyword PICOND).

**For models in MO format:**

- For the well gas inflow simulation the Russell-Goodrich (R-G) equation and pseudo-pressure (P-P) option are available (keywords GPP, MPGP, WGPP, WMPG, RG, WRG).
- The option AREA allowing to calculate the analytical aquifer productivity index is available (keyword AQWO).
- For the black-oil model the temperature expansion is supported (keywords THER, UOIL, UGAS, UWAT, UROC, THCO, THCG, THCW, THCR, OVVT, GVVT, TEMP).

**For models in E3 format:**

- The possibility to define the target or limit of the total molar rate is available (parameter 20 of the keyword WELLINJE).
- For simulations of isothermal compositional models several water components can be chosen (keywords WNAMEs, COMPW, PREFW, DREFW, VREFW, CREFW, WI, WMF, WMFVD, AQSTREAW).
- For isothermal compositional models three components asphaltene model is available. This model allows to simulate the variation of "mobile" pore volume caused by asphaltene deposition process (keywords ASPDEPO).

**Data input-output. Reports:**

- The possibility to save Maps in UNRST/UNSMRY binary format (the keyword RP-TRST with parameters FOAMMOB, VELOCITY, VISC).
- The possibility to save binary SUMMARY files either separately for each reporting time step, or as a unified one (keywords UNIFOUTS, MULTOUTS).

**Special options:**

- The choke can be set and the fluid flow pressure through the choke using correlation formulas can be computed (the keyword NETCHOKE).
- For water-gas two phase model (E1 format) it is possible to define phase relative permeability using Corey and Let correlations (keywords COREYWG, LETWG).
- The well geometry is taken into account when calculating a bottom hole pressure via a wellhead pressure using VFP correlations (keywords WELLINCL, WELLDATA, WELLBRANCH).
- The geometry of analytical aquifer connection to the reservoir can be detailed defining a connection on specified depth, to the reservoir bottom, to the reservoir boundary and different ways of productivity index calculation (the keyword AQUGP).
- The possibility to deactivate blocks by their depth value is available (the keyword DEACDEPT).
- For hydraulic fracturing simulations it is possible to create User Maps and User Cuts using virtual perforations (wmvc function) allowing to visualize blocks with virtual perforations generated by hydraulic fractures.
- The possibility to create User Maps and User Cuts picking out all blocks which a well trajectory passes through (function wmtc).

**MPI version:**

- IDW interpolation method can be used.

## 11.2. Model Designer

In tNavigator 4.2.6 Model Designer the following features are added:

- The possibility to save and run WorkFlows, i.e. to create, copy, modify and start a calculation sequence.
- Templates are available for Well correlation profile (Well Section): it is possible to create, copy and edit templates (it is possible to move the objects on panels and change their settings).
- It is possible to load objects in the following formats:
  - Well trajectory, wellhead, markers, events, Well Logs: Landmark OWX files \*.asc;
  - Horizons: Surfer 7 GRD (Bin) Format, Z-Map Plus Format, GXF-3 Format;
  - Faults: Surfer 7 GRD (Bin), Surfer BLN file, Landmark Fault 3d;
  - Polygons: Surfer BLN files, TKS Polygons.
- It is possible to interpolate 2D Maps via Wells Attributes using the following methods: IDW, Kriging, Gauss Simulation, Least Squares.
- For Well Section the scale can be defined manually.
- Cross-Sections can be visualized in 3D mode as planes.
- Well Logs, Horizons, Markers, Maps, Points Sets and Wells Attributes can be presented via Histograms.
- The Statistics table for Histograms is available.
- Advanced properties are available for Histograms and VPC.
- User section SCHEDULE can be loaded into Model Designer (data are visualized in Well Data. Rules).
- The possibility to rearrange rules in the Rules tree is available (date and rule execution order can be changed).
- The possibility to define well control on THP and VFP tables for injection wells is available.
- The possibility to choose oil as injected fluid for injection group control is available.
- The well construction on Well Section can be visualized and modified.
- The possibility to load measurement data for VFP tables is available, after that matching for VFP tables on measured data can be done.
- The possibility to create VFP tables taking into account the well trajectory is available.

### 11.3. PVT Designer

In tNavigator 4.2.6 PVT Designer:

- The Graphical user interface was optimized.
- New experiments are available (Separator Test, Swelling Test, Compositional Grading).
- The phase phase envelope can be plotted and the critical mixture point can be determined.
- For all experiments it is possible to define measurement data and automatically match chosen parameters according to defined laboratory data.
- New component grouping algorithms (lumping) automatically computing component weight coefficients in pseudo-components are available.
- The obtained results can be exported in E1 and E3 format files.

### 11.4. Assisted History Matching

In tNavigator 4.2.6 Assisted History Matching module the following features are added::

- The Plackett-Burman experimental design method is implemented.
- The optimization algorithm can be started from the initial population defined by the user.
- The algorithm may be set up to terminate when the objective function does not improve during the defined number of iterations.
- Automatic restrictions are added to scenario calculating possible relative permeability end points values (e.g.,  $SWL \leq SWCR$ ).
- For optimization algorithms in assisted history matching it is possible to choose historical data that will be taken (or not) into account. I.e. the possibility to choose the historical points for objective function calculation is available.
- PLT measurements can be used in Assisted History Matching.

### 11.5. Graphical User Interface

In tNavigator 4.2.6 Graphical User Interface:

- Logarithmic scale can be used for Crossplots Graph Templates.
- Arbitrary icons for wells on 2D maps can be loaded (Preferences. Well and connection icons).

- Fonts and Units can be set in Bubble Maps.
- In the Schedule table new tabs with keywords defining Multisegment Wells, Economic Limits, Drilling and Workovers are available.
- ALQ graph for network is visualized (Analysis Tab).
- Visualization of Flow graphs for numerical Aquifers is available.

## **11.6. Compatibility with previous versions**

In tNavigator 4.2.6:

- The option allowing pressure to increase going up the network is not supported anymore (option INCREASENETWORKP of the keyword TNAVCTRL).



## 12. tNavigator 4.2.5

### 12.1. tNavigator kernel

In tNavigator 4.2.5 new kernel options are supported for the following model formats: E1, E3, IM, ST, GE.

**For models in E1 and E3 format the following options are supported:**

- The possibility to use INSTANT option for Coal Bed Methane Model (parameter INSTANT of the keyword CBMOPTS).
- The possibility to set the control mode for injectors that work in the history matching mode: injection rate control or BHP control (parameter 12 of the keyword WCONINJH).
- The possibility to control the inheriting process of the threshold pore volumes (MINPV or MINPVV) for LGR blocks (46-th parameter of the keyword OPTIONS).
- The possibility to set tracer decay half-life (the keyword TRDCY).

**For models in E1 format the following options are supported:**

- Foam modeling option (keywords FOAM, FOAMOPTS, FOAMADS, FOAMROCK, FOAMDCYW, FOAMDCYO, FOAMMOB, FOAMMOBS, FOAMMOBP, SFOAM, WFOAM).
- The possibility to set several gas producers, that are opening from the drilling queue when the sales gas production rate falls below the minimum limit (the keyword WGASPROD).

**For models in E3 format the following options are supported:**

- For isothermal compositional models Residual oil modeling option is available (keywords SOR, SOILR, ROMF, SOROPTS).
- For isothermal compositional models 2-component Asphaltene option is available (keywords ASPHALTE, ASPP1P, ASPREWG, ASPP2P, ASPPW2D, ASPFLRT, ASPVISO, CATYPE).

**For models in IM format the following options are supported:**

- The possibility to set bubble points pressure as a map for models with equilibrium (VERTICAL DEPTH\_AVE) initialization (PB ALL).

**For models in GE format the following options are supported:**

- The possibility to set model geometry via specifying blocks tops (the keyword CORNERS).

**Data input-output. Reports:**

- The possibility to dump RSM-file with simulation results is available for all model formats (E1, E3, IM, ST, GE, MO).  
The keywords SEPARATE and RUNSUM are supported for models in formats E1, E3. For console version the command `--ecl-rsm` can be used. Dump of the RSM-file can be requested from graphical user interface (File. Reports) and from remote graphical user interface (in Model Queue).
- The possibility to create a template to dump graphs in E1 binary format and RSM-file is available. These templates can be saved and used in several models (also for models in not E1 input syntax). The template can be used in Model Queue for cluster calculations.

**Special options:**

- The possibility to generate PVT tables automatically via the input component properties is available for black oil models in format E1 (the keyword PVTGEN). PVT tables are created and used in simulation. In this case in the PROPS section component properties should be specified in E3 format instead of PVT-tables.
- The possibility to set model geometry via specifying blocks tops is available for model in formats E1, E3 (the keyword CORNERS). The GRID files is dumped automatically for models with the keyword CORNERS.
- The possibility to control foam/tracer participation in decay process (option DECAY\_MODEL of the keyword TNAVCTRL).

**12.2. Model Designer**

In tNavigator 4.2.5 the following features are added to Model Designer:

- The possibility to create several Correlation profiles for Well Section is available. Use Well Selector to pick wells on 2D view.
- The possibility to "put" horizon on markers is available (Calculations. Interpolation. Discrepancies Elimination).
- The possibility to load horizons and faults in the format Surfer 7GRD is available.
- The possibility to load polygons and faults in the binary format SurferBln is available.
- The possibility to choose and delete objects from the object list is available, the possibility to delete all objects from the folder (use Shift to choose several objects).
- The possibility to calculate Residuals for horizon interpolation. Residuals are calculated automatically as Wells Attributes (difference between marker depth and the point where well trajectory intersects a new horizon). Visualization is available on 2D Maps, Wells Table and Statistics.

- The possibility to add wells on 2D Maps has been added. The following drawing options are available:
  - Drawing on the selected depth.
  - Intersection with horizon.
  - Well head.
  - Bottom hole.
- The possibility to calculate geometric volume in a specified polygon between two surfaces (User Maps. Auxiliary Calculations. Assign between surfaces).
- The possibility to average log-data for wells between markers is available: netpay, porosity, permeability, NTG and other (Well Attributes. Average Log Between Markers).
- The possibility to create special 2D Maps is available: top and bottom of the collector, netpay, porosity, permeability, NTG and other (2D Maps. Auxiliary Calculations. 2D Map by 3D Map).
- The possibility to replace PVT and RP correlations by generated tables. Then tables can be edited manually (Replace by generated tables button).
- The possibility to load capillary pressure to existing RP correlations (Import. Load Pcap tables. Load the file with keywords SWOF, SGOF).
- The possibility to load RP data defined by Corey correlation (COREYWO, COREYGO) and capillary pressure in table form (SWOF, SGOF).
- New operator is available in arithmetics: IF-THEN-ELSE-ENDIF. if operator with brackets {} is not supported in this version and further.
- In the table with User Keywords (Well Data. Rules. User Keywords) the following options are available:
  - the possibility to move lines (data of the event is changed according to the new position);
  - copy the line with keyword (Right mouse click. Duplicate Keywords);
  - Keyword Editing. The pop-up hint for all parameters is available in all editing modes;
  - the possibility to switch between Table and Text form for keyword Adding and Editing.
- New options are available to create Assisted History Matching project from Model Designer:
  - A scenario to create variables for relative permeabilities defined via Corey correlation is available.

- The possibility to use interpolation parameters as variables is available.
- Variables can be used in Calculator.

### 12.3. Assisted History Matching

In tNavigator 4.2.5 Assisted History Matching module the following features are added:

- The new approach to create variables to edit relative permeabilities for models with many saturation regions is implemented.
- In the scenario to create variables from graphical user interface (for end-point scaling and relative permeabilities defined via Corey correlations): the possibility to set one variable for several regions is available.
- The possibility to combine different type of objects in the objective function is available (add terms in objective function dialogue).
- The possibility to change the ranges of several variables at the same time.

### 12.4. Graphical User Interface

In tNavigator 4.2.5 Graphical User Interface the following features are added:

- New operator is available in arithmetics: IF-THEN-ELSE-ENDIF (can be used in User Maps, User Cuts, ARITHMETIC keyword in the .data-file).
- Visualization of the Cross-Sections is available in 3D view (3D Map). A Cross-Section can be visualized as a plane in 3D view (Check Show Cross-Section).
- The possibility to create templates for Bubble Maps is available. Bubble Maps can be visualized for wells, groups, network nodes. These templates can be exported and used in other models.
- Well Filter has been improved. Filter to choose group of wells or network nodes is available. Groups and nodes that are selected are visualized on 2D Maps.
- The possibility to manage the visualization of group structure and surface network is available. Press right mouse click on the object to add or remove it itself (of with subordinate objects) from visualization filter.
- Well Selection option has been improved. Wells can be selected on 2D Map: one by one, by rectangle in inside the curve of any arbitrary shape (use Shift, Ctrl to select wells in several zones, one by one mode). The selected wells can be used in the Well Filter.
- The possibility to smooth well trajectories on 3D Maps and 2D maps is available (Document. Preferences. Well Options).

- The visualization of the map of linear solver residual is available (Calculated Maps. Number of Convergence problems). This map should be requested via the option CONVERGENCE\_PROBLEM\_NUM of the keyword TNAVCTRL.

## 12.5. Licenses and License server

In tNavigator 4.2.5:

- The licensing module has been modified to optimize the resources consumption and reduce delays.
- The statistics about current license utilization is available in the format Open iT LicPoll.
- New license type is available – Large Data Set. This license can replace any number of Black Oil licenses (more than 8) for corresponding tasks.

## 13. tNavigator 4.2.4

### 13.1. tNavigator kernel

In tNavigator 4.2.4 new kernel options are supported for the following model formats: E1, E3, IM, ST, GE.

#### **Reservoir Coupling support:**

- The possibility to couple models with different physics is available: black oil, compositional, thermal. Models can be in different formats: E1, E3, IM, ST, GE.
- The possibility to couple models with common surface network is available (keywords for Standard network option are available).

#### **For models in E1 and E3 format the following options are supported:**

- The possibility to update skin-factor for connections (the keyword CSKIN).
- The possibility to use an operation MAXR when a maximum rate limit is violated – maximization of the future production rate by setting the reinjection fraction limit to 1 (parameter 5 of the keyword GCONSALE).
- The possibility to set the value of gas consumption for extended network nodes (the keyword NCONSUMP).
- The possibility to activate pressure modifications to achieve initial equilibration (option QUIESC the keyword EQLOPTS).
- The possibility to use automatic compressors for standard network option (parameters 1-3 of the keyword GASFCOMP).
- The possibility to use the following group control mode – production balancing fraction (parameter PRBL of the keyword GCONPROD).
- The possibility to prevent the well changing from rate control to THP control when it is constrained to operate on the unstable side of its VFP curve (parameter 4 of the keyword WVFPEXP).
- The possibility to set minimum interval between gas lift optimizations (parameter 3 of the keyword LIFTOPT).

#### **For models in E3 format the following options are supported:**

- The possibility to set the distribution of CO<sub>2</sub> component between water and hydrocarbon phases via the table data as a function on pressure (keywords CO<sub>2</sub>SOL, SOLUBILI, RSWVD, RSW).

- For thermal models the control by water saturation pressure and temperature can be used (options SATT and SATP of the keywords WCONPROD, WELLPROD).

**For models in IM, ST, GE format the following options are supported:**

- The possibility to use analytical Fetkovich aquifer (the keyword AQMETHOD (\*FETKOVITCH)).
- The possibility to connect analytical aquifer to the reservoir boundary (the keyword AQUIFER (\*BOUNDARY, \*RESBND)).

**For models in IM format the following options are supported:**

- The possibility to use the model of polymer flood (keywords MODEL POLYMER, PADSORP, PPERM, PMIX LINEAR, NONLINEAR, TABLE, VELTABLE, PREFCONC, PVISC).
- The possibility to set block and direction dependent pressure gradient thresholds (keywords PTHRESHI, PTHRESHJ, PTHRESHK).
- The possibility to set grid corner point geometry (the keyword CORNERS).

**For models in GE format the following options are supported:**

- The possibility to set different ways to calculate the density of the stock-tank oil and gas after separator (the option STREAM-DEN in the keyword SEPARATOR (\*EOS, \*GASLAW)).

**Special options:**

- The possibility to use modified Corey correlations to set relative permeabilities (COREYWOMOD, COREYGOMOD).
- For models in E1 and E3 formats the new operation can be used when the group limit is exceeded (option TARG in the 7-th parameter of the keyword GCONPROD). The option works analogously to the RATE option with the following difference. When RATE option is specified, then the corresponding limit is always checked, when TARG option is specified, then the group limit is removed when it can't be performed.
- The fully implicit option can be used to calculate analytical aquifers (the keyword AQUOPTS (FI, FI\_ELIM\_AQ\_VAR)).
- The possibility to set model initialization and calculation logic compatibility with different versions of other simulators (option COMPATIBILITY of the keyword TNAVC-TRL).
- The possibility to use the model with zero number of time steps as a base model for restart (forecast).

## 13.2. Model Designer

In tNavigator 4.2.4 the following features are added to Model Designer:

- New options are available to create Assisted History Matching project from Model Designer:
  - A scenario to create variables is available – equilibration parameters (contacts' depths).
  - The visualization of analytical data is available (crossplots, Pearson correlation, Tornado chart).
- The possibility to use separators in PVT experiments option is available.
- The visualization of the keywords loaded from SCHEDULE section is available for E1 format. User can edit existing keywords and add new keywords.
- The possibility to add arbitrary time steps (Time step editor).
- The possibility to set the coordinate reference system (Datum). The system can be set in Document, Settings. Coordinate reference system can be found using its name, country or EPSG code. In the tab Detailed Information the datum information and the ellipsoid is provided.
- This visualization of Contour lines is available on 2D Maps (check Show Contour lines, Color by Contour lines).
- The following options are available for data loading:
  - load grid in gridecl format (in the current version the grid can be loaded without LGR);
  - the possibility to merge curves with the same names when curves are loaded.
- Facial Analysis is available (User Maps. Facial Analysis can be used to create facies, then reservoir properties maps can be created using facies. Different interpolation parameters can be set in different zones).
- The following options are available on Well Section tab:
  - The date of measurement can be visualized for LOG curves (LAS, RFT/MDT) (can be unchecked in Properties).
  - One LOG curve (LAS, RFT/MDT) can be visualized at the same time at different dates and with different visualization settings. Duplicate the curve and set in its Properties the number of date you need and other visualization parameters.
  - The scale with block numbers is available.
- The possibility to edit maps on 2D view via Brush button is available.



### 13.3. Assisted History Matching

In tNavigator 4.2.4 Assisted History Matching module the following features are added:

- A new scenario is available to create variables from graphical user interface – Multiply Permeability by Layers.

### 13.4. Graphical User Interface

In tNavigator 4.2.4 Graphical User Interface the following features are added:

- The possibility to move the points of well trajectory using mouse is available.
- The visualization of Bubble maps for groups and network nodes is available.
- In the option Schedule (tabs Well Definition, Well Production, Other operations, All operations) the pop-up tips for keywords are available.
- The possibility to reload model and start calculations immediately is available (Document. Reload model and Run Calculations).
- The possibility to cut wells' trajectories by depth (Z direction) is available (for visualization) (Document. Settings. Well Options. Check the box Cut Trajectory by Depth).
- The following options are available on Well Section tab:
  - The date of measurement can be visualized for LOG curve (LAS, RFT/MDT) (can be unchecked in Properties).
  - One LOG curve (LAS, RFT/MDT) can be visualized at the same time at different dates and with different visualization settings. Duplicate the curve and set in its Properties the number of date you need and other visualization parameters.
  - The scale with block numbers is available.

### 13.5. Licenses and License server

In tNavigator 4.2.4:

- The possibility to use multiple licenses on a local dongle is available. Thus, it is possible to have more than one for each type of the license on the dongle. So if you have multiple licenses then the corresponding number of models can be calculated at the same time.

## 14. tNavigator 4.2.3

### 14.1. tNavigator kernel

In tNavigator 4.2.3 new kernel options are supported for the following model formats: E1, E3, IM, ST.

In this release there is a first implementation of Reservoir Coupling option for integrated calculation of several models using common group controls.

Also in this release there is a first implementation of compositional models in GE format.

#### **Reservoir Coupling support:**

- Option is set via the keywords SLAVES, GRUPMAST, GRUPSLAV.
- Several SLAVE models are integrated via one MASTER model.
- In this release only black oil models can be used in coupling in all supported data formats: E1, MO or IM.
- MASTER model must be in E1 format. It can be full-featured model or simple fake model with one active grid block.
- There is fully implicit model calculation. Equations from all models are combined to one common system of equations that describes the whole integrated reservoir.

#### **For models in GE format the following options are supported:**

- The possibility to use cubic equation of state: Soave-Redlich-Kwong equation or Peng-Robinson equation (the keyword MODEL).
- The possibility to set multiple equations of state is available (EOS) (the keywords EOS-SET, EOSTYPE). In each region component properties can be set (the keywords MW, PCRIT, VCRIT, TCRIT, ZCRIT, BIN, PCHOR), coefficients of equations of state (the keywords AC, OMEGA, OMEGB), and the volume shift (the keyword VSHIFT).
- HZYT and PEDERSEN correlations can be used for hydrocarbon phases viscosity simulation (the keywords VISCOR, VISVC, MIXVC, VISCOEFF).
- Separators can be set for resources calculation (the keyword SEPARATOR) and for wells (the keyword WELSEP).
- Fully implicit and adaptive implicit (the keyword AIM) methods can be used.

#### **For models in E1 and E3 format the following options are supported:**

- The possibility to set maximum allowed number of open wells subordinate to the group for which economic limits are set (parameter 9 of the keyword GECON).

- The possibility to set an interpolation method for Artificial Lift Quantity ALQ in VFP tables (the keyword VFPTABL).
- Autonomous inflow control devices (ICD) can be used in multisegment wells (the keyword WSEGAICD).
- The possibility to set the time limits taken for well automatic workovers when group economic limits are violated (the keyword WORKLIM).
- The possibility to set Artificial Lift Quantity (ALQ) that is used in the pressure loss calculations for the branch in extended network (parameter 4 of the keyword BRANPROP).
- The possibility to set well cutback limits (the keyword GCUTBACK).
- The possibility to set the phase for which group's guide rate is calculated (parameter 10 of the keyword GCONPROD).
- The possibility to set the decrement for contract gas rate and conditions to cut group's rate in DCQ option – Gas Field Model (the keywords GASFTARG, GASFDECR).
- The possibility to set guide rate wells' values (the keyword WELLGR).
- The possibility to set the way to extrapolate VFP table values for water fraction, gas fraction and ALQ (parameter 5 of the keyword WVFPEXP).
- The possibility to set the multiplier which is used to calculate the matrix-fracture flows in dual porosity models (the keyword MULTMF).
- The possibility to set transmissibility multipliers for all cells in specified faults in schedule section (the keyword MULTFLT).

**For models in E1 format the following options are supported:**

- The possibility to use polymer shear thinning/thickening logarithmic model (the keyword PLYSHLOG).

**For models in E3 format the following options are supported:**

- The possibility to set the oil viscosity dependence on pressure via PVCO table for thermal models.
- The possibility to set temperature, pressure, specific enthalpy rate and steam quality of the injected fluid for thermal models (parameters 21-24 of the keyword WELLINJE).

**For models in IM, ST, GE format the following options are supported:**

- The possibility to smooth relative permeabilities (parameters LINEAR, QUAD, CUBIC of the keyword SMOOTHEND).

- The possibility to set water saturation below water-oil contact (the keyword WOC\_SW).
- The possibility to set reference pressure for pore volume calculation the first block of the region (option REFFIRST of the keyword ROCKOPTS).

**For models in ST format the following options are supported:**

- IDEALGAS option is available.

**Special options:**

- A new tNavigator data format is implemented. This format is an extension of E1, E3 formats that provides more convenient definition of well data (to set trajectories in X, Y, Z, MD and perforations in measured depth) (the keywords WELLTRACK, COMP-DATMD).
- The possibility to smooth relative permeabilities for models in E1 and E3 (the keyword KRSMOOTH).
- The new keyword AQUOPTS is implemented to set parameters for analytic aquifers calculation for models in format E1 and E3.

**Data input output:**

- A new option KEYWORDS\_SPACE is added to the keyword TNAVCTRL for models in format E1 and E3. If this setting is set to 1 the keywords that are written after the space symbol at the beginning of the line are read. By default this option is not used, these keywords are ignored, and the corresponding message will be visualized.
- A new option LONGNAMES is added to the keyword TNAVCTRL for models in format E1 and E3. If this setting is set to 1 then tNavigator will read well names that are longer than 8 symbols. For default without this setting there is a cut for names that are longer than 8 symbols.
- The possibility to save the reporting parameters for wells, groups in binary files in UNRST/UNSMRY format export at calculation time steps when the model is calculated by tNavigator console version. Option is used for default. It can be switched off using the keyword RPTONLY. If UNRST/UNSMRY binary files are saved from graphical user interface they will be saved at reporting (not calculation) steps.
- The output of the threshold pressure between equilibration THPRES to .log-file is available.

## 14.2. Model Designer

In tNavigator 4.2.3 the following features are added to Model Designer:

- The possibility to save model in a new tNavigator data format is implemented. This format is an extension of E1, E3 formats that provides more convenient definition of well data (to set trajectories in X, Y, Z, MD and perforations in measured depth) (the keywords WELLTRACK, COMPDATMD).
- The possibility to visualize and edit well trajectories, markers and Wells Logs in table form.
- The possibility to create PVT tables for oil and gas (black oil models) using input compositional properties. The following options are supported:
  - Component sets can be created using the standard list or can be imported as a text file.
  - CCE, DLE, CVD experiments can be simulated for a component set; the critical point of the mixture can be calculated; bubble point pressure dependence on temperature can be build.
  - The results of experiments are visualized as graphs and tables.
  - PVT tables for oil and gas can be calculated via a component set and chosen parameters.
  - PVT tables are visualized as graphs and tables.
  - PVT tables can be added to the model, or exported to a text file.
- The possibility to analyze component properties: compositional calculator (phase envelope) and graphs (viscosity, mass density, molar density). When component lumping (group components) is used you can compare results on phase envelope and graphs before and after lumping.
- The possibility to find wells on 2D, 3D maps and Well Section is available.
- The possibility to create sub folders in object tree is available.
- The possibility to sort and manually change the order of objects in the tree is available.
- The possibility to set Well Logs loading settings (including units, palette type etc).
- Statistics is available for Well Log visualization on 3D Map.
- The possibility to add markers where the wells' trajectories intersect a horizon.
- The possibility to do local horizon editing: pull up the horizon to the selected markers on selected wells.
- The possibility to create grids via faults and horizons and taking into account the impact of faults.

### 14.3. Assisted History Matching

In tNavigator 4.2.3 Assisted History Matching module the following features are added:

- Response surfaces method is implemented (Proxy models).
- Modified Particle Swarm Optimization method is implemented (FlexiPSO).

### 14.4. Graphical User Interface

In tNavigator 4.2.3 Graphical User Interface the following features are added:

- The RFT/MDT Mismatch Table is visualized for wells and zones (layers' groups). The table is available in Graphs. If zones (reservoirs) are set via the keyword ZONES then mismatches for each zone (reservoir) will be available on this tab as well.
- The possibility to save a zip-archive with a model (available in Document menu). Model .data file and all included files will be saved in separate zip-archive. This functionality can be used to zip the model with a lot of included folders with data and a lot of included files.
- The visualization of OILVISCT, GASVISCT is available.
- The visualization of group hierarchy on 2D maps is available.
- The possibility to save loaded well data to tNavigator format (the keywords WELL-TRACK, COMPDATMD).
- The new mode for time axis visualization is available for models with very small time steps. Choose in Graphs Settings the data format – HH:MM:SS.xxx.

### 14.5. Compatibility with previous versions

- The format of results files has been changed. tNavigator version 4.2.2 and earlier are not visualizing results of 4.2.3 calculation.

### 14.6. Licenses and License server

In tNavigator 4.2.3:

- Licensing for Reservoir Coupling option is supported (to do integrated simulation of several models using a common group controls).
- License server can be installed with password protection.

## 15. tNavigator 4.2.2

### 15.1. tNavigator kernel

In tNavigator 4.2.2 kernel new options are supported for the following model formats: E1, E3, ST.

#### Calculations speed-up, accuracy settings:

- The new speed-up option WELLDENWEIGHT of the keyword RUNCTRL is available. It reduces oscillations of wellbore mixture density, thus reducing well oscillations and improving convergence and calculation speed. This option may be used for all models formats.

#### For models in E1 and E3 format the following options are supported:

- Grid coarsening option is available (the keyword COARSEN).
- The possibility to prevent well connection pressures from falling below atmospheric pressure is available (parameter 47 of the keyword OPTIONS).
- The actions for wells can take place after a defined time period has passed (the keyword DELAYACT).
- Reference depth can be specified independently for each region in FIP family (the keyword DATUMRX).
- The surface tension can be set as a function of salt and surfactant concentration in models with salts and surfactants (keywords ESSNODE, SURFSTES).
- Special inflow equations for wells are available: Russell-Goodrich equation (R-G option) and P-P (generalized pseudo-pressure equation) (parameter 8 of the keyword WEL-SPECS).

#### For models in E1 format the following options are supported:

- Total molar rate target can be used as a well control or a limit (option TMRA of the keywords WCONPROD, WELTARG).
- Capillary pressure in systems water-oil and gas-oil can be set as functions of surface tension (option SURFTENS of the keyword SATOPTS; keywords STOW, STOG).

#### For models in E3 format the following options are supported:

- Generalized pseudo pressure option is available (option GPP, parameter 5 and 6 of the keyword PICOND).
- For compositional models Pedersen viscosity correlation is supported (keywords PED-ERSEN, PEDTUNE, PEDTUNER).

**For models in ST format the following options are supported:**

- Aquifer can be connected to the reservoir using the keyword BOTTOM.

**Special options:**

- VFP tables can be generated for producers via correlations (the keyword VFPCORR) in compositional models.
- The fully implicit calculation of API is implemented (the keyword TRACEROPTS). In the version 4.2.2 for salts and API fully implicit calculation is used by default. To use semi-implicit calculation (default in previous versions) one need to use flag EXP in the keyword TRACEROPTS.
- Well lists can be used (WLIST) in the second parameter of the keyword ACTIONC.
- BLOCK(x,y,z) function can be used in the keyword ARITHMETIC in sections PROPSOLUTION.
- MAPAXES is taken into account when coordinates X, Y, Z are defined in BLOCK (X, Y, Z are set in the global coordinate system).
- ARRXXX maps from previous sections can be used in the keyword ARITHMETIC.

**MPI version:**

- Grid coarsening option is available (the keyword COARSEN).
- Blocks from LGR can inherit rock property automatically from global grid (the keyword LGRCOPY).
- Non-neighbor connection transmissibility values between blocks in any two grids can be set (the keyword NNCGEN).

## 15.2. Model Designer

In tNavigator 4.2.2 the following features are added to Model Designer:

- Several model variants can be created.
- Calculation results of different model variants can be loaded automatically.
- Forecast model can be created; the possibility to edit forecast period and wells' control modes on the first forecast time step is available.
- Economical limits can be edited in the Well Properties dialogue.
- A compass and a scale are available on the visualization panel.
- Bubble maps are available on 2D maps.



- The local grid editing is available using selected markers and radius.
- Statistics for horizons is available.
- The possibility to select the length units separately for XY and for Z is available in data loading (RESCUE, well data).
- Polygon union operation is available.
- Filter for horizon can be used using polygon.
- Interpolation for 3D maps using VPC and selected map is available.
- 3D permeability map can be interpolated using porosity map and permeability distribution.
- Trends can be used in different interpolations of 3D maps: any property (trend property), VPC (2D-map + trend), core data (porosity Log, porosity precision).
- The result of interpolation can be cropped using the bounds of input data.
- In Well Section logarithmic scale is available.

### 15.3. Assisted History Matching

In tNavigator 4.2.2 Assisted History Matching module the following features are added:

- Particle Swarm Optimization method is implemented (PSO).
- Differential Evolution method is optimized for a small amount of simulation launches. Select Local to use this option. If you can launch simulator a lot of times Global can be used.
- Optimization for NPV is available (net present value).
- Typical HM scenario is available from GUI to vary end-points arrays (SWCR, KRO etc.). Experiments are created automatically.
- Typical HM scenario is available from GUI to vary faults' transmissibility multipliers (MULTFLT). Experiments are created automatically.
- The possibility to assign variable values from specific number of values (defined manually) is available.
- The series of experiments can be created for different geological realizations.

## 15.4. Model Queue. Remote GUI

In tNavigator 4.2.2 Model Queue and Remote GUI module the following features are added:

- Model Queue is integrated with Model Designer. Calculations can run on cluster.
- The possibility to start calculation from the selected time step is available.

## 15.5. Graphical User Interface

In tNavigator 4.2.2 Graphical User Interface the following features are added:

- The visualization of surface network is available (NETWORK). Use Show Network nodes on 2D map.
- The possibility to create Templates for Cross plots is available; for example for Hist. vs. Calculated graphs. On Graphs Templates switch from Graphs to Crossplots.
- The regions maps (FIPNUM, SATNUM etc.) can be used as a Cut for visualization.
- The histogram for palette is available (shows the distribution of selected parameter).
- The possibility to group virtual and real well connections is available (for hydraulic fractures). These groups are visualized in objects list and in Well Filters.
- The multipliers for units can be fixed on Graph Templates (thousands/millions).
- User defined arrays ARR can be visualized in View Results mode and they can be used in map arithmetic command line (User Maps and User Cuts).
- Maps PINCHNUM and ENDNUM can be used in map arithmetic command line (User Maps and User Cuts).
- In Load Well Data dialogue the date can be set in the format of number of days from the starting date (select this option in the corresponding box).
- In Load Well Data dialogue the historical data can be applied to the previous time step (select this option in the Units Settings tab).
- The possibility to expand/collapse all child objects in the object tree for Graphs is available via the right mouse click on the object.
- Transmissibilities TRANX (Y,Z) are visualized and saved in the INIT file with transmissibility multipliers applied – MULTX(Y,Z), MULTX-(Y,Z), HMMULTX(Y,Z), HMMULTX-(Y,Z), HMMLTXY.

## 15.6. Compatibility with previous versions

- The format of results files has been changed. tNavigator version 4.2.1 and earlier are not visualizing results of 4.2.2 calculation.
- To save and split the model it is necessary to check in the Settings. Models. Write Initial Maps). Recording of initial maps is not done for default now to speed-up models' opening on slow shared disks and to reduce the size of the folder with calculation results.

## 15.7. Licenses and License server

In tNavigator 4.2.2:

- Histograms of the licenses usage are available in the web interface of the license server. For each module there is a separate histogram. It shows the percentages of time during the indicated time period when certain number of licenses was used. 0 Licenses were occupied during this percentage of time, 1 license – during this the percentage of time, etc. up to N – the number of licenses of this type.

## 16. tNavigator 4.2.1

### 16.1. tNavigator kernel

In tNavigator 4.2.1 kernel new options are supported for the following model formats: E1, E3, ST. New option is available – VFP table generation according to the selected correlation.

#### Calculations speed-up, accuracy settings:

- Adaptive implicit method AIM is supported for thermal models in E3, ST format.

#### For models in E1 and E3 format the following options are supported:

- User defined tables UDT can be used to assign values to user defined quantities (the following interpolation types can be used: NV, LC, LL).
- User defined quantities can be specified for well segments in UDQ keyword (for example, SOFR etc.).
- A control or limit value for the well can be increased or decreased for the specified value (the keyword WTADD).
- Scale deposition model: the cumulative effects of scale deposited around the well connections and the resulting degradation of the productivity index due to sea water injection (keywords SCDPDIMS, SCDATAB, SCDPTAB, WSCTAB (parameters 1-3)).
- Segmented model of density calculations can be used in BRINE option (parameter 12 SEG of the keyword WELSPECS).
- The threshold pressures for flow in each direction between equilibration regions can be different (option IRREVER of the keyword EQLOPTS).
- Non-neighbor connections across cells deactivated by MINPV can be created even if thickness exceeds threshold value (option GAP of the 2-nd parameter of the keyword PINCH).

#### For models in E1 format the following options are supported:

- Gas consumption rate and gas import rate can be specified via UDQ (parameters 2 and 3 of the keyword GCONSUMP).
- The possibility to apply maximum rate at which the solution gas-oil ratio is allowed only in blocks with free gas (option FREE 2-nd parameter of the keyword DRSDT).

#### For models in E3 format the following options are supported:

- The possibility to modify the Stone I three-phase oil relative permeability (the keyword STONEPAR).

- The possibility to define each component fraction to sale or fuel (4-the parameter of the keyword GRUPSALE, GRUPFUEL).

**For models in ST format the following options are supported:**

- Option ISOTHERMAL can be used (energy conservation equation is not imposed in model. As a conclusion, grid cell temperatures will not change from their specified initial values).

**Special options:**

- New option is available – VFP table generation for producers according to the selected correlation (the keyword VFPCORR). The following correlations can be used:
  - PA - Petalaz & Aziz,
  - HB – Hagedorn & Brown,
  - O – Orkiszewski,
  - G – Gray,
  - AGF – Aziz,
  - Govier & Fogarasi,
  - MB – Mukherjee & Brill.
- An implicit calculation of passive tracer is available for black oil and compositional models and for waters with different salinities simulation (the keyword TRACEROPTS).
- Each block can have its own primary variable for thermal models in E3 and ST format (option MIX of the keyword TFORM). Variables are chosen automatically by tNavigator
- A new option of console version is available: --restart, it continues calculation from input step or last calculated step if input step is not calculated.

**MPI version:**

- Splitting of hybrid models is available.

## 16.2. Model Designer

In tNavigator 4.2.1 the following features are added to Model Designer:

- Local grid refinement LGRs can be added: refinement along well trajectory, connections, in the specified box.
- Wells' perforations can be edited (Ctrl+click on the well or Edit Perforations on the Well Section).
- New wells and sidetracks can be added (Alt+click on the map).

- The possibility to create aquifers is available (set geometry and properties to Fetkovich or Carter-Tracy aquifer).
- Historical data is visualized on Graph Templates immediately when it is loaded to the project.
- The possibility to add well controls is available.
- The possibility to add group controls is available.
- The possibility to add economic limits for wells is available.

### 16.3. Assisted History Matching

In tNavigator 4.2.1 Assisted History Matching module the following features are added:

- An objective function can be set manually using UDQ.
- RFT measurements made before zero time step are assigned to zero time step and compared with the initial reservoir pressure.
- A comment can be added to each new experiment in the corresponding box.

### 16.4. Model Queue. Remote GUI

In tNavigator 4.2.1 Model Queue and Remote GUI module the following features are added:

- For LSF queuing system the number of nodes requested by the waiting tasks is displayed.
- Cluster calculations are not stopped when the queue that was created in tNavigator is closed.

### 16.5. Graphical User Interface

In tNavigator 4.2.1 Graphical User Interface the following features are added:

- The possibility to navigate quickly to the line in the model's file in which an error or warning occurred while reading. The transition is performed by double-clicking on the line with the message on the panel report.
- User Cut concept have been extended. The possibility to create a cut for grid blocks with specified map value is available.
- Visualization of parameters that are specified via the keywords ZMFVD and TEMPVD is available in Properties option.

- The possibility to build the vertical cross sections of the model by planes parallel to the XZ plane and YZ.
- The possibility to continue down the well trajectory in the Add well dialogue is available via Add Point button.
- Well's transmissibility factor can be edited in Wells Properties dialogue.
- Any graph for well and for group can be loaded to Graphs Templates using Load graphs button.

## **16.6. Licenses and License server**

In tNavigator 4.2.1 the following features are added to work with license::

- The possibility to use a license server for Windows (without the virtual machine). Only the following systems are supported: 64-bit version of Windows 7, 8, 8.1, 10, Vista.

## 17. tNavigator 4.2.0

This version is released as tNavigator 4.2.0 due to significant improvements in the GUI and integration of simulator with the preprocessor. The Geology module was renamed as Model Designer due to the fact that at the moment the main it's application is creation of simulation models for tNavigator (preprocessor). All the functionality of Geology module is available in Model Designer now.

### 17.1. tNavigator kernel

In tNavigator 4.2.0 kernel new options are supported for the following model formats: E1, E3, ST.

#### Calculations speed-up, accuracy settings:

- Speed-up of black oil and compositional models calculations using AIM method. For compositional models AIM is used by default.

#### For models in E1 and E3 format the following options are supported:

- Coal Bed Methane Model can be used (keywords COAL, COALNUM, DIFF-COAL, LANGMUIR, ROCKDEN, GASCONC, LANGMEXT, DIFFCBM, RESORB, GASSATC).
- Relative permeability of the injected phase can be defaulted (parameter 6 of the keyword COMPINJK).
- Minimum time interval between well priority calculations can be specified (parameter 1 of the keyword PRIORITY).
- The possibility to choose if the time steps are controlled to coincide exactly with the on/off cycling times of the well (parameter 6 of the keyword WCYCLE).
- Rescaling of saturations at wells connections can be used (keyword COMPRP).
- Segment number to allocate to all connections within the specified range can be set (parameter 11 of the keyword COMPSEGS, COMPSEGL).
- A segment of multi-segment well can be defined to represent a flow limiting valve (keyword WSEGFLIM).
- Low salinity option can be used: the oil and water RP and the water-oil capillary pressure are functions of the salt concentration (keywords LOWSALT, LSALTFNC, LWSLTNUM).
- The cubes can be imported to the global grid via the keyword IMPORT (option UNFORMATTED).



- Speed-up in opening models with a large number of local grid refinements (>10000).
- Well's connections can be specified via the keyword WELLCOMP (parameters 1-9, 11-12). This keyword is analogue of the keyword COMPDAT.
- Producer's control mode can be specified via the keyword WELLPROD (parameters 1-14). This keyword is analogue of the keyword WCONPROD.
- Group limits and targets can be specified via the keyword GRUPPROD (parameters 1-8). This keyword is analogue of the keyword GCONPROD.

**For models in E1 format the following options are supported:**

- Mixing of waters with different salinities BRINE can be used with ASP option (injection of polymer-alkaline-surfactant) (keywords SALTNODE, PLYVISC).

**For models in E3 format the following options are supported:**

- An injection mixture by order can be specified (keyword WINJORD).
- The data to maintain the average pressure in a particular pressure maintenance region at a specified target can be specified (keyword GPMINT3).
- Drainage option can be used in hysteresis (keyword DRAINAGE).
- Equation of state number can be specified for each separator stage (8-th parameter of FIELDSEP, 9-th parameter of FIPSEP, 10-th parameter of SEPCOND).
- An alternative model for capillary number calculations is supported in velocity dependent RP (5-th parameter of VELDEP).
- Forchheimer model for connection D-factor calculations is supported in velocity dependent RP (4-th parameter of VELDEP).
- Recovery plant table can be specified for compositional models (keyword RECOVERY).
- Minimal and maximal reservoir temperature can be specified for thermal models (keyword TRANGE).
- Numerical model for heat loss can be used in thermal models (option N in 6-th parameter of the keyword ROCKPROP).
- The molar composition of the injected fluid can be defined as a mixture (option MIX of the keyword WELLINJE).

**For models in ST format the following options are supported:**

- Minimal and maximal reservoir temperature can be specified (keywords MINTEMP, MAXTEMP).

**Special options:**

- Maximum rate of increase of solution gas-oil ratio as a function of pressure can be specified (only in black-oil models) (keyword DRSDTVP).
- An alternative model of gas dissolution that takes into account the exponential nature of the system relaxation can be used (only in black-oil models) (keyword DRSDTVPE).
- Possibility to use Corey (LET) correlation only for RP and define capillary pressure via table (in this case one should enter 0 in parameter 12 (power) of the keyword COREYWO, COREYGO (LETWO, LETGO) and define tables SWOF, SGOF or other. Values for capillary pressure will be taken from tables and RP will be calculated using Corey (LET) correlation.
- Possibility to define EGRID for grid visualization (keyword VISGRID). This option is used for models with unstructured grids.

**In MPI version:**

- Hybrid models are supported (model in E1 or E3 format, well data in MO format).

**Input output data, Export Results:**

- in SUMMARY section the following parameters can be used:
  1. output of fluids-in-place at surface (separator) conditions or reservoir conditions SFIP, RFIP (.UNRST-file);
  2. liquid and vapor mole fractions for wells, groups, field: FXMF, FYMF, FZMF, GXMF, GYMF, GZMF (.UNSMRY-file).

## 17.2. Model Designer

In tNavigator 4.2.0 the following features are added to Model Designer:

- Integration of the simulator with Model Designer.
- Option Definitions is available.
- The possibility to open additional windows with the functionality of the main window.
- The possibility to load well data (events and history) in schedule format.
- The detailed information of component grouping (lumping) for compositional models is available.
- Well filter is available.
- The possibility to create well groups.

- The possibility to add the following cubes:
  1. RP end-point scaling (swcr, sgcr, sower, sogcr, swu, sgu, swl, sgl, swlpc, kro, krw, krg, krwr, krgr, krorg, pcw, pcg);
  2. new fluid-in-place (FIP) regions FIPXXX;
  3. cubes to work with the pore volume (MINPVV, MULTPV).

### 17.3. Assisted History Matching

In tNavigator 4.2.0 Assisted History Matching module the following features are added:

- Integration with Model Designer: the possibility to create automatically basic variables (RP end-points specified via Corey correlation (COREYWO, COREYGO) and contact depths (EQUIL)).

### 17.4. Model Queue. Remote GUI

In tNavigator 4.2.0 Model Queue and Remote GUI module the following features are added:

- Queuing system SLURM is supported.
- Visualization of cluster queues load (output of the number of occupied nodes).
- The possibility to reassign job to another cluster queue (if the job has not started yet).
- The possibility to send jobs automatically to multiple cluster queues.
- The possibility to close tNavigator when the local queue is completed.

### 17.5. Graphical User Interface

In tNavigator 4.2.0 Graphical User Interface the following features are added:

- The possibility to hide some of the options.
- The possibility to choose the map visualization type: 3D, 2D, Histogram.
- The possibility to use the grid size up to 10x10 windows in Graphs Templates.
- In Load Well Data dialogue the column preview of selected files is available (for history and perforations).
- Visualization for multi-segment wells is available: segments structure in the form of a tree and graphs of total parameters for segments.
- For compositional models graphs are grouped by components, component injection graphs for wells and groups are available.

- The possibility to view and modify the parameters of the simulator's iteration process (keyword RUNCTRL) from the GUI in Document. Simulator options dialogue. Changes may be done in sections RUNSPEC (global settings) and SCHEDULE (settings for the individual time steps).

## 17.6. Licenses and License server

In tNavigator 4.2.0 the following features are added to work with license:

- The possibility to reinstall the license during the calculation in the GUI version.
- The possibility to use a new format of license: a hybrid license based on usb-device and file with the license information that allows to change the number and the duration time of license without changing the USB key, just changing the file.
- Simplified reference to the license can be used:  
`http://<license>/tNavigator<group_id>` or `http://<license>/navigator<group_id>`, where <license> – IP address of the license server or DNS name, and <group\_id> – number of license group.

In tNavigator 4.2.0 the license server can be administered using the web-interface:

- The license file can be loaded using the web-interface.
- Server log-file can be viewed using the web-interface.
- Web-interface is available via the simplified license references:  
`http://<license>/tNavigator` or `http://<license>/navigator`, where <license> – IP address of the license server or DNS name.

## 18. tNavigator 4.1.3

### 18.1. tNavigator kernel

In tNavigator 4.1.3 kernel new options are supported for the following model formats: E1, E3, IM, ST, MO.

#### Calculations speed-up, accuracy settings:

- Speed-up in calculations of thermal models having a water zone (option WATERZONE in the keyword RUNCTRL is used for default for compositional and thermal models).
- The water molar concentration in water zone can be excluded for compositional models if WATERZONE option is used (is used by default).
- The possibility to switch on/off WATERZONE option in the SCHEDULE section via the keyword RUNCTRL.
- The main variable (the last hydrocarbon component) can be excluded for thermal models via the option INCVCE 0 in the keyword RUNCTRL (is used by default).

#### For models in E1 and E3 format the following options are supported:

- Well friction can be taken into account in the well bore (keywords WFRICTN, WFRICTNL, WFRICSEG, WFRICSGL).
- The method (implicit or explicit) of VFP table interpolation for the well can be chosen (2-nd parameter of the keyword WVFPEXP).
- The minimum group potential rates for a new drilling can be specified (GDRILPOT).
- Minimum and maximum permitted sales gas production rate can be specified (parameter 3-5 of the keyword GCONSALE).
- The possibility to stop the run at the next report time step in case if the well is shut or stopped for any reason after being opened (parameter 8 of the keyword WECON).
- The fixed pressure drops between network node and well's THP can be specified (WNETDP).
- Grid block permeabilities can be averaged when the interblock transmissibilities are calculated (PERMAVE).
- Block center method can be used in transmissibility calculations (OLDTRAN).
- The depths of the middle of each grid block can be specified (MIDS).
- The surface tension can be defined as a function of pressure (STVP) for the MISCIBLE option.

**For models in E3 format the following options are supported:**

- Water wet hysteresis models are supported (Jargon model) (values 8 and 9 in the 2-nd parameter of the keyword EHYSTR).
- WAG hysteresis model can be used (parameters 1-3, 5-8 of the keyword WAGHYSTR).

**For models in MO format the following options are supported:**

- Lower watercut, gas-oil ratio and other lower limits can be used for wells (PLIM).

**For models in ST format the following options are supported:**

- Heater wells can be specified (HTWELL, HTWRATE, HTWRATEPL, HTWTEMP, HTWI).
- The reaction rate temperature-dependence factor with multiple activation energy values can be specified (EACT\_TAB).

**For models in IM and ST format the following options are supported:**

- Fracture volume fraction and the rock-in-fracture fraction can be specified for dual porosity models (FRFRAC, FORMINFRAC).
- The multipliers for geometric grid block volume can be specified (VOLMOD).

**In MPI version:**

- The hydraulic fractures can be specified using the keyword COMPFRAC.
- Models with geometry DX/DY/DZ can be used.

**Special options:**

- LET correlation can be used for relative permeabilities in E1 and E3 format models (keywords LETWO, LETGO)
- The length of perforated interval can be set in specified grid block in E1 and E3 format models (COMPVAL).
- Lower economic limits can be set for watercut, gas-oil ration, water-gas ratio and gas-liquid ratio in E1 and E3 format models (negative values should be specified in the keyword WECON parameters 4-6, 13).

**Input output data, Export Results:**

- in SUMMARY section the following parameters can be used:
  1. inter-region phase flow total (ROFT, RGFT, RWFT);
  2. salt, polymer, alkaline and other tracer concentrations (WTIC, WTPC, WTIR, WTPR, WTIT, WTPT, WCIC, WSIC, WTICALK, WTICSUR);
  3. data for well segments (SOFR, SGFR, SWFR, SPR, SPRD, SPRDH, SPRDF, SPRDA, SWFV, SOFV, SGFV, SWHF, SOHF, SGHF, SLPR, SWCT, SGOR, SOGR, SGWR, SWGR, SOWR, SWOR, SLGR, SGLR).

## 18.2. Geology

In tNavigator 4.1.3 the following features are added to Geology module:

- the possibility to load grids, faults and wells from rescue files;
- dual porosity support;
- calculations of resources for black oil models;
- the possibility to load PVT and RP data in E1 syntax;
- the possibility to load well data in SCHEDULE format;
- the possibility to load component properties for compositional models in E3 syntax;
- component grouping (lumping) for compositional models;
- maps visualization on Well Section;
- the possibility to edit fault transmissibility in GUI;
- 2D map visualization;
- possibility to run simulation model directly from Geology without opening it in separate window in tNavigator, with maps and graphs available in Geology;
- visualization of contour lines on 2D maps;
- Statistics button for 2D maps;
- the possibility to measure distances on 2D and 3D maps;
- the possibility to create and edit sections;
- streamlines visualization.

## 18.3. Assisted History Matching

In tNavigator 4.1.3 Assisted History Matching module the following features are added:

- the possibility to use RFT data in history matching;
- the possibility to normalize objective function by object (wells, groups) number and parameter (rates, totals, pressure) number;
- calculation of P10-P50-P90 and any other P-quantiles for parameters that are selected by user;
- the possibility to merge several history matching projects, created for the same model with the same set of variables but with different calculated experiments.

## 18.4. Graphical User Interface

In tNavigator 4.1.3 Graphical User Interface the following features are added:

- visualization of LET correlation data for relative permeabilities;
- new interface for visualization of Corey correlation (RP) and Standing correlation (PVT);
- the possibility to cancel the last action in Map Editing (Ctrl+Z);
- visualization of resources maps for compositional models;
- visualization of resources calculation progress;
- visualization of VFP tables;
- visualization of hysteresis;
- the possibility to import several User Maps simultaneously;
- visualization of component number in Information option;
- visualization of graphs for well segments;
- new arithmetic functions for maps are available in User Maps and User Graphs: column operations (min\_2d (minimum), max\_2d (maximum), avg\_2d (average), sum\_2d (sum));
- in Graph Templates:
  1. the possibility to visualize graphs for months and years;
  2. the possibility to select the range (for time steps) of graph visualization.

## 18.5. Licenses and License server

In tNavigator 4.1.3 the following features are added:

- visualization of the license server status and usb-key data in the "License details".



## 19. tNavigator 4.1.2

### 19.1. tNavigator kernel

In tNavigator 4.1.2 kernel new options are supported for the following model formats: E1, E3, IM, ST, MO.

#### Calculations speed-up, accuracy settings:

- Speed-up of compositional models calculations. For black oil and compositional models AIM option is supported (beta version).  
By default the fully implicit method is used; the adaptive implicit method may be included as an option AIM of the keyword RUNCTRL.
- Speed-up in calculations of models having a water zone (water saturation in the grid block is equal to 1). The option can be included as WATERZONE in the keyword RUNCTRL (is used by default for compositional models).

#### For models in E1 and E3 format the following options are supported:

- The well can be closed during drilling and workovers in case of automatic drilling of new wells. It will be opened in a specified number of days taken to drill it (parameter 3 of the keyword WDRILTIM).
- The iteration parameters for multi-segment wells can be specified (parameter 1 of the keyword WSEGITER).
- The well can be opened if it was closed because of GROUP or FIELD limits violation (option G in the keyword WTEST).
- The number of FIP region can be specified, that will be used in the calculations of the well rate in reservoir conditions (parameter 13 of the keyword WELSPECS).
- Well rate can be controlled by the gas-oil ratio (keyword WGORPEN).
- The well startup time and maximum timestep length, at which the well is turned on by automatic cycling (parameters 4 and 5 of the keyword WCYCLE).
- Maximum number of wells on artificial lift (ALQ) in the group can be specified (parameter 3 of the keyword GLIFTLIM).
- Parameters for reinjection or voidage replacement can be specified (parameters 7-8 of the keyword WCONINJ).
- The dynamic changing of fixed pressures can be used (keyword GNETDP).
- In the keywords OPERATE, OPERATER operations ABS, MULTIPLY can be used.

- In the keyword OPTIONS the 117-th option can be used:  
**Value 1** – the map MULTNUM should be specified both for matrix and fracture;  
**Value >= 2** – maps MULTNUM, FLUXNUM, PINCHNUM, OPERNUM should be specified both for matrix and fracture.
- If NTG is used in the arithmetic (ADD, MULTIPLY, ...) non-specified values are replaced by 1.

**For models in E3 format the following options are supported:**

- The availability of injection fluids can be taken into account in injection rate calculations (keyword WAVAILIM).
- Economic limits for production wells can be specified for component mole fractions (keyword WECONCMF).
- For compositional models hysteresis of RP and capillary pressures can be used with the option MISCIBLE.
- The makeup gas can be used for injection (parameter 4 of the keywords WINJGAS and GINJGAS).
- Modifications of the map MULTPV in EDIT section via arithmetic (ADD, MULTIPLY, ...) is ignored to reproduce the behavior of E3.

**For models in E1 format the following options are supported:**

- For multisegment wells the segment external source or sink can be specified (keyword WSEGEXSS).
- Sales gas production rate target can be specified for groups (parameters 1 and 2 of the keyword GCONSALE).

**For models in MO format the following options are supported:**

- Parameters for reinjection or voidage replacement can be specified: GVRT, GWRT, GGRT, VREP, RECYcle.

**For models in ST format the following options are supported:**

- The option SEGREGATED can be used to calculate phase resources and phase rates in surface conditions (keyword SURFLASH)
- The bubble point pressure at initial temperature at each block for specified component can be specified (keyword PBC).
- The following models are supported: Linear Elastic, Nonlinear Elastic, Dilation-Recompaction (keywords PORMAX, CPORPD, PBASE, PRPOR, POR, CPEPAC, PDILA, CRD, PORRATMAX, PPACT, FR).

**For models in IM and ST format the following options are supported:**

- Fracture blocks of global grid can be deactivated if any one of the following conditions is satisfied:  
 $DIFRAC = DJFRAC = DKFRAC = 0$   
 $PINCHOUTARRAY = 0$   
 $PERMI = PERMJ = PERMK = 0$

**In MPI version:**

- The possibility of streamlines calculation is added.
- The keyword MINP (Minimal Pore Volume Tolerance) is supported for MO format models.
- Full support of the keyword COPYBOX. Input and output BOXes can be used with different Z-coordinates.

**Special options:**

- For models in format E1 and E3 economic limits can be specified in user-defined way for wells (WECONX) and for groups (GECONX), also UDQ can be used.
- The following options of the keyword TNAVCTRL are added:  
**DPGRID\_PRE2014 > 0** – switch off the copying of NTG values from matrix to fracture blocks (if the values are not specified) in dual porosity models for E3 format;  
**SWCR\_CORR: 1, 2 or 3** – adjustment of SWCR in blocks using SWU, SWL.
- The special permeability value used for JFUNC computation can be specified for E1 and E3 format models (the keyword JFPERM). If this value is specified for block, than the 6-th parameter of JFUNC (JFUNCR) is ignored).

## 19.2. Geology

In tNavigator 4.1.2 the following features are added to Geology module:

- operations with maps and horizons: rotation and movement;
- the possibility to load horizons in binary format (GRDB);
- the possibility to create horizons via point set;
- the possibility to construct Vertical Proportional Curves for cubes;
- histograms;
- the possibility to create a grid with unstructured faults.

### 19.3. Assisted History Matching

In tNavigator 4.1.2 Assisted History Matching module the following features are added:

- calculation of P10-P50-P90 for parameters that are selected by user;
- the possibility to set the periods of recorded map and graph data when the job is added to queue.

### 19.4. Graphical User Interface

In tNavigator 4.1.2 Graphical User Interface the following features are added:

- the possibility to load RFT pressures, automatic calculation of corresponding reservoir pressure;
- visualizations of graphs for surface network (if the keyword NETWORK is used);
- visualizations of graphs for SEMI-ANALYTICAL aquifers;
- visualizations of Drainage Network on 2D maps (connection between producers and injectors);
- the possibility to fill contour lines with different colors (2D maps);
- In Graph Templates:
  1. visualization of user-defined UDQ;
  2. the possibility to sum graphs for components;
  3. the possibility to rename the axis.

### 19.5. Compatibility with previous versions

Extended possibilities of calculation results storage. To view the calculations results of version 4.1.2 use only the GUI version 4.1.2.

### 19.6. License server

In tNavigator 4.1.2 licence server:

- The support of systemd for RHEL 7 compatible with Linux-distributive is added.
- The support of Apache 2.3/2.4 is added.
- The possibility to reserve licenses for cluster version with the utility tNavigator License Status is added.
- Settings for automatic rotation of server logs are added.

- All kinds of statistics take into account the setting of output IP/Hostname.
- Exterior JavaScript libraries (jQuery and plug-ins) that are used in the web-interface have been updated.

## 20. tNavigator 4.1.1

### 20.1. tNavigator kernel

In tNavigator 4.1.1 kernel new options are supported for the following model formats: E1, E3, IM, ST.

**For models in E1 and E3 format the following options are supported:**

- Maximum gas-liquid ratio (GLR) can be specified as an economic limit (parameter 13 of the keyword WECON).
- The guide rate can be set at the beginning of each timestep equal to the group's net voidage rate (net voidage rate is equal to the voidage production rate minus the reservoir volume injection rate of any other phases) – option NETV of the keyword GCONINJE (parameter 10).
- Maximum rate of change of guide rate for wells under group control can be specified (the keyword DGRDT).
- A group can be set whose rate target the automatic choke attempts to match by adjusting the pressure drop across it (parameter 5 of the keyword NODEPROP).
- The well can be closed if it is found to be operating on the stabilized part of its VFP curve (parameter 3 of the keyword WVFPEXP).
- Voidage mobility for injectors can be set (keywords COMPMOBI, COMPMBIL).
- Well priority numbers can be set for the wells under group control (keyword WELPRI).
- A segment of multi-segment well that represents a sub-critical valve can be defined (keyword WSEGVALV).
- Pore volume multipliers (MULTPV) can be used in SCHEDULE section.

**For models in E3 format the following options are supported:**

- Advance import gas can be assigned to a group supplying gas for reinjection (keyword GADVANCE).
- Mixture injection can be used (keyword WINJMIX and MIX option of the keywords WINJGAS, GINJGAS).
- WAG (water and gas) cycle types can be used: M – months and Y – years in the keyword WELLWAG.
- Pressure maintenance regions can be specified (keyword PMANUM).

- The availability of injection fluids can be taken into account when calculating injection rates (keyword WAVAILIM).

**For models in E1 format the following options are supported:**

- Maximum rate of increase of vapor oil-gas ratio (OGR) can be set (keyword DRVDT).

**For models in ST format the following options are supported:**

- Initial distribution can be set from the conditions of hydrostatic equilibrium (VERTICAL) in conjunction with initial phase saturations (SW, SO, SG).
- Default parameter values are supported for analytical aquifers (AQPROP).
- Default parameter values are supported for injection enthalpy calculations.
- The SEMI-ANALYTICAL aquifer model can be used.
- Multiple viscosity regions can be set (keywords VISCTYPE, VSTYPE).
- Multiplies for a well operating targets or limits can be used (keyword WTMULT).

**For models in IM, ST format the following options are supported:**

- Unweighted injectors. Injected fluid mobility should be part of a well index (keyword \*UNWEIGHTED INJECTOR).

**Input output data, Export Results**

- Multout mode is supported for export results in E1/E3 format.
- The size of file with calculated maps has been optimized.
- Parameter ALLPROPS of the keyword RPTRST is supported.

## 20.2. Geology

In tNavigator 4.1.1 the following features are added to Geology module:

- Discrete interpolation in arithmetic is available.
- New objects are available: a point set and multi-valued horizons. For them the following features are supported:
  1. The point set can be loaded from a text file.
  2. The point set can be created via horizons.
- New tools can be used to navigate through operations with objects.
- A new object "selector" is available for the convenience of working with the well section.

- A step-by-step update of calculated objects has been implemented that is convenient for long calculations: horizon interpolation and automatic markers correlation.
- A creation of new objects from the object tree is available.
- The calculation cancellation can be used.
- The area of grid editing can be calculated via a single point with a radius.
- Construction of geological grid with faults:
  1. An algorithm to "pull" grid lines to the fault has been optimized: the method of "dual" grid.
  2. An integration of faults of arbitrary shape, which don't violate a system of generators of the grid, has been implemented. The method of "draft-horizon" is used. The establishment of correspondence between the connected components is used for fault intersections with core horizon and horizons of each connected component.
- Tools for working with faults:
  1. A group of faults can be built with the addition of structural and non-structural faults.
  2. Faults can be limited in height.
  3. Faults can be constructed from the set of points or from the several surfaces.
  4. Automatic processing of faults intersection is available.
- Horizons interpolation by markers or point sets, taking into account the faults of arbitrary shape, is available.

### 20.3. Assisted History Matching

In tNavigator 4.1.1 Assisted History Matching module the following features were added:

- the ability to specify manually the values of the variables;
- the ability to remove the experiment;
- the log-normal distribution of parameter.

### 20.4. Remote GUI

In tNavigator 4.1.1 Remote GUI module the following features were added:

- the possibility to run different versions of tNavigator from GUI;
- the possibility to do forced-ending of dangling tasks;
- the messages on the log panel are sorted by their type.



## 20.5. Graphical User Interface

In tNavigator 4.1.1 Graphical User Interface the following features are added:

- Axis are available in the compositional calculator.
- Visualization of the time of flight of fluid particle on streamlines on 2D and 3D maps (uncheck "Show mesh" to see the streamlines).
- In Graphs Templates:
  1. The possibility to synchronize time axes is available;
  2. The possibility to create a screen shot is available;
  3. The possibility to print to the printer is available;
  4. The possibility to save in the vector format is available;
  5. Automatic check for not saved template is performed.
- In Create Forecast dialogue:
  1. The possibility to set THP control mode for producers is available;
  2. The possibility to set Drawdown control mode for producers is available;
  3. The possibility to set different control modes for water and gas injectors is available.
- In Well properties dialogue:
  1. The possibility to set Drawdown control mode for producers is available;
  2. Maximum gas-liquid ratio can be set as economic limit.
- Well trajectories can be loaded (Load Well Data dialogue) in the units different from the model units.
- Drawdown graph is visualized.
- The current connection status (open, closed, not specified) is visualized.
- Virtual connections created via hydraulic fracture are visualized in the connection list.
- The thickness of the contour lines and the size of the text can be set.
- In the mode "View Large Model":
  1. The possibility to see Initial maps is available;
  2. User Cuts are available;
  3. Well filters are available;
  4. Automatic model coarsening is done for viewing speed-up.

## 20.6. Compatibility with previous versions

Support for 32-bit Linux systems is no longer available (including the license server).

## 20.7. License server

In tNavigator 4.1.1 license server:

- Only 64-bit Linux-systems are supported.
- tNavigator versions below 4.0 are no longer supported.
- A new format of licenses is available: a hybrid license based on usb-devices and file with the license information that allows to change the number and the duration time of licenses without changing the USB key, just changing the file.
- For hybrid license a "hot-swap" of file with the license information is available.
- A fault-tolerance has been improved: tNavigator access keys are provided for 24 hours in case of errors in interaction with usb-device (assuming the smooth operation for 48 hours before the error).
- E-mail notifications of the licencing-period termination or of error interaction with the usb-device can be configured.
- A page with information about the version of the server and the connected usb license device is available.
- The basic Apache authentication has been supported, which allows to set the input username and password for access to the license server.
- On the page with the licenses that are currently being used, information about tNavigator versions is available.
- In the log files the time periods have been added.
- The spaces in the module names in the files of Open IT Statistics have been removed.

## 21. tNavigator 4.1.0

### 21.1. tNavigator kernel

In tNavigator 4.1.0 kernel compositional thermal models in ST format are supported. New options are supported for formats: IM, E1 and E3.

**For models in ST format the following options were supported:**

- K-values for hydrocarbon components in the GAS-OIL system can be set via tables (keywords GASLIQKV, KVTABLIM, KVTABLE) or via five coefficients in the correlation formula (keywords KV1, KV2, KV3, KV4, KV5). Optional specification of K-values for hydrocarbon component for calculating phase equilibrium in surface conditions (K\_SURF) is available. For water component the internal correlation is used to calculate the equilibrium in the GAS-WATER system.
- Liquid phases individual component densities (in WATER, OIL) can be set as a functions of pressure and temperature (keywords MOLDEN, MASSDEN, MOLVOL, CP, CT1, CT2, CPT). The inner correlation formula is used if for water component if all parameters specified via the keywords MOLDEN/MOLVOL CP, CT1, CT2, CPT, are zero. Gas Z-factor is used to calculate GAS phase density. This factor is calculated from the cubic Redlich-Kwong equation of state with zero Binary interaction coefficients. The re-calculation of gas Z-factor is done at each Newton iteration (GASD-ZCOEF (IMPLICIT)). The densities of the individual solid components are set as functions of pressure and temperature (SOLID\_DEN).
- Liquid phases individual component viscosities (in WATER, OIL) can be set as functions of temperature (or temperature and pressure) via the tables (keywords VISCTABLE, ATPRES), or via the correlation formula (AVIS, BVISC). The option of non-linear mixing is supported for OIL viscosity (keywords VSMIXCOMP, VSMIXENDP, VSMIXFUNC). Component individual viscosities in the GAS phase can be set via the correlation formula (AVG, BVG).
- Enthalpies of hydrocarbon components in the OIL and GAS phases can be set as functions of temperature (keywords CPG1, CPG2, CPG3, CPG4, CPL1, CPL2, CPL3, CPL4, HVAPR). The possibility to set the enthalpy of vaporization for the hydrocarbon components as a function of temperature (HVR, EV). The internal tables are used to calculate the enthalpy of the water component in the GAS and WATER phases, in this case the enthalpies of the water component are the functions of both temperature and pressure. The enthalpies of solid components in the solid phase can be set as functions of temperature (SOLID\_CP). The rock enthalpy can be set as a function of temperature (ROCKCP).
- The SIMPLE model of thermal conductivity has been added (THCONMIX), which allows to take into account thermal conductivity of the mobile phases (THCONW, THCONO, THCONG), the thermal conductivity of the solid phase (THCONS), and the rock conductivity (THCONR).

- Porosity dependence on temperature and pressure can be defined (keywords PRPOR, CPOR, CTPOR, CPTPOR).
- The analytical model of heat loss between the reservoir and surroundings is now available (keywords HLOSSPROP, HLOSST, HLOSSTDIFF).
- Fetkovich and Carter-Tracy aquifers are supported (keywords AQUIFER, AQMETHOD, AQPROP, AQLEAK).
- Two heater models are supported in Heater simulation: Heater with constant energy injection rate and Heater with energy injection rate that depends on temperature difference between the block and the heater (keywords HEATR, TMPSET, UHTR).
- Chemical reactions simulation is now available (keywords EACT, O2PP, STOREAC, STOPROD, FREQFAC, FREQFACP, RENTH, RPHASE, RORDER, RTEMUPR, RTEMLOWR, RXCRITCON).
- Initial conditions: initial conditions can be either calculated from hydrostatic equilibrium conditions or set explicitly (keywords PRES, TEMP, SW, SO, SG, MFRAC\_OIL, MFRAC\_GAS).
- It is possible to define different thermal primary variables of the filtration problem (energy density or temperature) (TFORM (ZH | ZT)).
- Dual porosity/dual permeability models have been added (keywords DUALPOR, DUALPERM).

**For models in E3 format the following options are supported:**

- Heater simulation: Heater with constant energy injection rate, Heater with energy density dependent injection rate and Heater with energy injection rate that depends on temperature difference between the block and the heater (HEATER).
- Matrix to fracture thermal conductivity for dual porosity models can be set explicitly (THCONMF).
- Liquid and solid phases thermal conductivities can be defined now (THCROCK, THCOIL, THCGAS, THCWATER, THCSOLID).
- The logics of single-porosity regions support in dual porosity models has been changed (keyword DPNUM). In single porosity blocks the data specified for matrix blocks is used.
- Wet gas rate limit is now available (parameter WGRA in the keywords GCONPROD, GCONPRI, GRUPTARG).
- The stage of the separator which defines the fluid composition and limit for injection can be set (5-th parameter of GINJGAS).

- The order in which fuel, sales and re-injection gas are taken from production gas steam can be provided now (WTAKEGAS).
- Molecular diffusion option has been added (keywords DIFFUSE, DIFFCGAS, DIFF-COIL).
- The coefficients for LBC correlation and reference surface tension in MISCIBLE option now can be set for each region (LBCCOEFR, MISCSTRR).
- Velocity dependent relative permeabilities have been added (keywords VELDEP, VD-KRO, VDKRO).
- The supply of advance import gas can be assigned to a group that provides gas for re-injection (GADVANCE).

**For models in E1 and E3 format the following options are supported:**

- Injection network is now available (GNETINJE) as well as convergence parameters specification for network option (parameters 2-4 of the keyword NETBALAN);
- Gas Field Model. The calculation of the gas Daily Contracted Quantity has been added (DCQ): keywords DCQDEFN, GASBEGIN, GASEND, GASFIELD, GASMONT, GASPERIO, GASYEAR, GDCQ, GDCQECON, GSWINGF, SWINGFAC;
- Killough's Hysteresis Model used for the non-wetting gas and water phases and the wetting oil phase is now available (value 7 in the 2-nd parameter of the keyword EHISTR);
- The reading of CORNERS format grid geometry from the GRID file is improved for the case when inactive block data is absent;
- The compatibility for the names of groups and wells is improved (the first 8 significant characters are supported).

**For models in MO format the following options are supported:**

- keywords X-DI, Y-DI, TUBI, LONG and PACK formats (VFPPROD);
- improvement of FIELD units support.

**In MPI version:**

- loading giant models: requirements for RAM are reduced;
- models in IM and ST formats can be calculated in MPI version.

## 21.2. Geology

In tNavigator 4.1.0 the following features are added to Geology module kernel:

- construction of three-dimensional geological grids with faults (the faults, specified via ruled surfaces, are supported);
- automatic correlation of well data (selection of markers from curves), a simple option;
- faulted model export: the keywords THPRES, FAULTS, MULTFLT, THPRESFT;
- in the BLOCK function in arithmetic the dual porosity is supported;
- option of discrete cubes interpolation;
- option of loading cubes.

In tNavigator 4.1.0 the following features are added to Geology module GUI:

- acceleration of 2d-maps visualization;
- dual porosity model manual 3d-map editing (GUI);
- the 3d-visualization of connections that are specified on trajectories (without considering the time).

## 21.3. Assisted History Matching

In tNavigator 4.1.0 Assisted History Matching module the following features were added:

- parallel run of multiple versions of the differential evolution algorithm;
- a quick comparison of several similar models without adding variables to the model;
- loading history of average reservoir pressure;
- the possibility to use arithmetic expressions with variables instead of variables in MO models (and in hybrid models in the RECU section);
- analysis for any set of parameters;
- the possibility to use the constants  $e$  and  $\pi$  to set variable value and limits.

For model queue the following features were added:

- an external API is made to run the simulator;
- the possibility of limiting the number of tasks on the cluster;
- saving of job queues to files that can be transferred between computers;
- view log of model calculation (monitor job) after completing the task in a normal queue (similarly, as Show Log in Remote GUI manager);
- the possibility to limit task calculation time in the queue.

## 21.4. Graphical User Interface

In tNavigator 4.1.0 Graphical User Interface the following features were added:

- The compositional calculator that provides the phase analysis of fluids, allows to find bubble point pressure and the dew points pressure.
- Graph Templates:
  1. The graph may be pinned (the pinned graph doesn't change when the selected objects are changed).
  2. It's possible to distribute different objects graphs automatically to different panels.
  3. The undo option (Ctrl+Z)
  4. Graphs Templates Options dialogue is improved (You can edit the settings of all graphs and template settings in one dialog.)
  5. Well lists are available in templates.
  6. Sum and average are available for graphs of various objects.
  7. It's possible to set the difference with the base model (Right mouse click on the model name and select "Set as reference model").
  8. Search option for objects, graphs and templates is improved (search now finds everything that contains as substring all words typed by the user).
  9. Possibility to reorder templates by dragging them with the mouse.
  10. Back lighting of current panel graph names during editing.
  11. The support of compositional models is improved (the list of components and separator stages is added).
  12. The parameter list can be displayed as a tree for quick search when editing.
- GUI:
  1. Each model is run in a separate process to increase the stability in case of the emergency termination of one of the calculation processes.
  2. The Log panel is improved (the possibility to hide the Log panel and to display information about the number of messages in different categories).
  3. Export of the well trajectories to a file via the keyword WELLTRACK (columns: X, Y, Z, Measured Depth) on the "Well Profile".
  4. An option "Draw Trajectories Projections" is added on 2d maps. If you choose this option the well trajectory projection to the selected map will be shown (if the trajectory is set).
  5. The well efficiency factor can be edited in "Well properties" dialogue (Economic Limits tab).

6. In "Load Well Data" option the possibility to upload files with a hierarchy of well groups is supported. Reload the model to apply the changes.
- Large models. For models, calculated on a cluster with full results export, it is possible to see 3D maps on computers with limited RAM. Open the model via "View Large Model" option (in the main tNavigator window). Features:
    1. Visualization of cubes exported using the keyword RPTRST.
    2. Visualization of wells: the current status is shown.
    3. Visualization of streamlines exported using an option of the command line `-ecl-sln`.
    4. Possibility to show I, J, K sections.
    5. Loading data progress bar.

## **21.5. Compatibility with previous versions**

It's impossible to create a forecast in the current version 4.1.0 for models with hydraulic fractures (keywords WFRACP, COMPFRAC) if the calculation of base model was made in the previous version 4.0.4 or earlier. For correct results, please recalculate the base model in 4.1.0.



## 22. tNavigator 4.0.4

### 22.1. tNavigator kernel

In tNavigator 4.0.4 kernel the following options are supported:

1. For models in E1 and E3 format alkaline injection is supported. The following keywords can be used: ALKALINE, ALKADS, ALSURFAD, ALPOLADS, ALSURFST, WALKALIN.
2. For models in E1 and E3 format surfactant injection is supported. The following keywords can be used: SURFACT, SURF, SURFADS, SURFROCK, SURFST, SURFCAPD, SURFVISC, WSURFACT.
3. For models in E1 and E3 format polymer injection is supported. The following keywords can be used: POLYMER, SPOLY, PLYADS, PLYROCK, PLYVISC, PLYMAX, PLMIXPAR, PLYSHEAR, WPOLYMER.
4. For models in E1 and E3 the following options are supported
  - an option TRANPORV of the keyword PETOPTS;
  - operations CON, CON+, WELL for group productions limits in the keywords GCONPROD, GCONPRI;
  - the keyword WELLOPEN;
  - the keyword COMPLMPL;
  - well limits on bottom hole gas liquid ratio (keyword WBHGLR);
  - group reservoir volume injection rate control mode (keyword GCONINJE, parameter RESV);
  - specification of well PVT region (11-th parameter of the keyword WELSPECS);
  - calorific rate limit and natural gas liquid limit (NGL and CVAL) – parameters 18 and 20 of WCONPROD, parameter 12 of WCONHIST, WELTARG NGL, WELTARG CVAL;
  - recording of \*.end-file, which contains the number of all errors/problems/warnings in the model;
  - editing of ROCKV keyword in EDIT section via arithmetic operations;
  - the keyword MULTREGT in dual porosity models.
5. In MPI version the following options are supported:
  - the keyword WCONINJP;
  - the keyword GRUPNET;
  - usage of maps MULTNUM, FLUXNUM, OPERNUM from previous sections in arithmetic operations.

## 22.2. Geology

In tNavigator 4.0.4 the following features are added to Geology module kernel:

- option of preparatory curve interpolation in multi-layer interpolation;
- 3D interpolation;
- calculations of Voronoi regions with radius specification (multi-layer and 3D);
- calculation of Cut (cube with values 0 and 1) according to well trajectories with radius specification;
- calculation of Cut (cube with values 0 and 1) according to well perforations with radius specification;
- calculation of SATNUM regions according to well data;
- calculation of connected components (via ACTNUM);
- export of "USER files" for GRID section
- possibility to create a geological project "tied" to existing hydrodynamic model; after objects editing the changes are saved in "USER files";
- function "block" for GRID section (in user arithmetic);
- the possibility to remove the calculation form the list in WORKFLOW.

In tNavigator 4.0.4 the following features are added to Geology module GUI:

- units visualization;
- optimization of maps and horizons visualization on 2D;
- an option "show mesh" for maps and horizons;
- smoothing option for contour lines;
- rulers with scale in 2D;
- a possibility to align the wells according to markers and depth on Well Section;
- an option to create and edit markers on Well Section; undo option;
- navigation buttons on 3D: a top view, side, bottom, etc.;
- translucency option for horizons on 3D;
- filters for 3D-meshes (I,J,K – filter and Cube Value Filter);
- a possibility to see the change of parameters for interactive 2D mesh modification;
- interactive cube editing in 3D (a brush);
- information windows with statistics for some objects.

### 22.3. Assisted History Matching

In tNavigator 4.0.4 Assisted History Matching module the following features are added:

- Automatic conversion of relative permeabilities tables SWFN, SGFN and SOF3 to Corey correlation (at user selection in GUI).

### 22.4. Remote GUI

In tNavigator 4.0.4 Remote Graphical User Interface the following features are added:

- An option to see only the results on graphs without loading all model results.

### 22.5. Graphical User Interface

In tNavigator 4.0.4 Graphical User Interface the following features are added:

- User-customizable Graph Templates that allow:
  - to make a quick selection of a set of graphs on the screen;
  - to adjust color, thickness, and the names of the graph icons;
  - to configure the type and color of the fonts;
  - to configure the captions and units for graphs;
  - to show several sets of graphs in one window;
  - to export and import Graph Templates from the file.
- The possibility to compare graphs of any two models results (from all graphs loaded) in the "Hist. vs Calc." Graph tab, and a more convenient menu.
- The possibility to use unique streamlines colors for different wells.
- Quick selection of displayed grid blocks on 3D map (selection of X, Y, Z layer numbers).
- An option to load only graphs from model results without loading maps.

## 23. tNavigator 4.0.3

### 23.1. tNavigator kernel

In tNavigator 4.0.3 kernel the following options are supported:

1. For thermal compositional models in E3 format:
  - New Well control mode – Control by total molar rate target (parameter 14 of the keyword WCONPROD).
  - New Well control mode – Control by wet gas rate target (parameter 13 of the keyword WCONPROD, parameter 11 of WCONHIST, option WGRA of the keyword WELTARG).
  - Calculation of friction for multisegment wells via correlation formulas (corresponding parameters of keywords WELSEGS, COMPSEGS).
2. For thermal models in E3 format:
  - New Well control mode – Control by steam rate target (parameter 15 of the keyword WCONPROD, option STRA of the keyword WELTARG).
  - Steam production rate limit for producers (parameter 15 of the keyword WCONPROD).
  - Multicomponent gas injection.
3. For E1 format models the following options are supported:
  - Calculation of friction for multisegment wells via correlation formulas (corresponding parameters of keywords WELSEGS, COMPSEGS).
  - Special formulas of inflow of gas from the completed grid blocks and the well completions: R-G, P-P, GPP (parameter 8 of the keyword WELSPECS).
  - Output of streamlines to binary files SLNSPEC, SLNxxxx (option `-ecl-sln` (for console version) or from graphical interface).
  - Secondary water cut limit for wells (parameters 11–12 of the keyword WECON).
  - Switch off automatic compressors (the keyword COMPOFF).
  - Removing and moving the wells in the well lists (keyword WLIST, operations DEL and MOVE).
  - ALQ specification in the keywords WCONHIST and WCONPROD.
  - Specification of dependence of relative permeabilities end-points from temperature (keywords ENPTVT, ENKRVT, ENPCVT).
4. For MO format models the following options are supported:
  - Direct calculation in MPI version (without intermediate data conversion).

- Recalculation of well bottom hole pressure at equivalent radius (keywords and events PREX, P-RE).

5. In MPI version the following options are supported:

- MO-format models.
- Calculation of flows FLOWW, FLOWO, FLOWG, FLOWWZ, FLOWOZ, FLOWGZ.
- Usage of COPYBOX in case in the copied blocks are equal.
- For GDFILE an amount of required RAM is reduced.

## 23.2. Geology

In tNavigator 4.0.3 Geology module the following features are added:

- Local interactive editing of 3D mesh.
- Local interactive editing of horizons.
- Local interpolation of cubes.
- Contour lines visualization for maps and horizons.
- Creation and editing of objects for PVT, RP, equilibrium.
- Creation of maps with Voronoi regions via markers.
- New arithmetic functions: INTERPOLATE\_ML\_TRIVIAL, INTERPOLATE\_ML\_IDW, INTERPOLATE\_ML\_SGS, INTERPOLATE\_ML\_KRIGING.
- Logs visualization with cylinders in 3D.
- Creation and editing of palettes.
- Well section was improved.
- Geological project can be created form hydrodynamic model. The following functions were added:
  - Loading of Inactive blocks.
  - Loading of regions FIPNUM, SATNUM, EQLNUM, PVTNUM, ACTNUM.
  - Loading of PVT, RP, equilibrium.

### 23.3. Assisted History Matching

In tNavigator 4.0.3 Assisted History Matching module the following features are added:

- Automatic conversion of RP tables to Corey correlation (from GUI).
- Forecast objective function.
- An option to match BHP, THP and reservoir pressure.
- An option to load in history matching project models from another project.

Model queue was improved (calculations are started in separate processes, files backup on timer was added).

### 23.4. Remote GUI

In tNavigator 4.0.3 Remote Graphical User Interface the following features are added:

- Queue type can be specified in installation time. The following options are supported:
  - LSF
  - PBS/torque
  - SGE (Sun Grid Engine)
- Old versions of PBS/torque are supported (below 2.3).

### 23.5. Graphical User Interface

In tNavigator 4.0.3 Graphical User Interface the following features are added:

- Export of gas field development data in tabular form.
- Support of FIPOWG keyword (E1/E3 – data format) in viewing results mode.
- An option to save and load model visualization settings templates (graph colors etc.).
- An option to use different colors instead of markers for loaded calculation results of other models.
- An option of scaling for only one axis in the graphs.
- Dependence of 2D map scaling of the mouse position.
- For dual permeability models. An option to choose porosity system for connections in Well properties dialogue.
- An option to export 2D maps including well trajectories data.

## 24. tNavigator 4.0.2

### 24.1. tNavigator kernel

In tNavigator 4.0.2 kernel the following options are supported:

1. For compositional models in E3 format:

- Compositional properties and EOS type for production system (surface conditions) may be specified (keywords ACFS, BICS, EOSS, OMEGAAS, OMEGABS, MWS, PCRITS, SSHIFTS, TCRITS, VCRITS, ZCRITS).
- Relative permeabilities and capillary pressure may depend on surface tension (keywords PARACHOR, MISCIBLE, MISCNUM, MISCSTR, MISCEXP).
- The options for gas-oil capillary pressure treatment (keyword FORMOPTS) are added.
- Relative permeabilities scaling with respect to composition (keywords ENKRVC, ENPCVC, ENPTVC, EPSCOMP) is added.
- Resources for fluid-in-place regions may be calculated by taking into account the separators (keywords FIELDSEP, FIPSEP).
- Model initialization by option NEI (keyword NEI) and 11-th parameter of keyword EQUIL is supported. Also, the support for 10-th parameter EQUIL with values 2 and 3 is improved.
- LI critical temperature correlation is supported (keywords FACTLI, LILIM).
- The option NOMIX for oil and gas relative permeabilities near the critical point added.
- The keyword WELLINJE is added to provide injection control data for a well.
- The keyword GRUPFUEL is added to specify the amount of gas produced from a group that is burnt as a fuel, and thus cannot be used for re-injection.
- Gas plants are supported (keywords GPTABLE, GPTABLE3, 7-th parameter of keyword FIELDSEP, 8-th parameter of keyword FIPSEP, 9-th parameter of keyword SEPCOND).
- Load and save for compositional properties specified in the section SUMMARY are supported.
- Flash calculations are significantly accelerated for single-phase hydrocarbon regions, load balancing for compositional property calculations is added.
- The support for multiple EOS and EQUIL regions is improved.
- Compositional models in MO format are supported.

2. For thermal compositional models in E3 format:

- Relative permeability scaling with respect to composition (or temperature) can be combined with the scaling specified in each grid block (5-th parameter of keyword ENDSCALE).
  - K-values may be specified by the tables (keyword KVTABTn).
3. For E1 format models the following options are supported:
- Directional relative permeabilities including dual porosity case (parameters DIRECT and IRREVERS of keyword SATOPTS, keywords KRXNUMX, KRXNUMX-, KRXNUMY, KRXNUMY-, KRXNUMZ, KRXNUMZ-, KRXNUMMF, IMBNUMX, IMBNUMX-, IMBNUMY, IMBNUMY-, IMBNUMZ, IMBNUMZ-, IMBNUMMF).
  - Gravity drainage options for dual porosity (keywords GRAVDR, SIGMAGD, SIGMAGDV, GRAVDRM, DZMTRX, DZMTRXV).
  - WAG process (keywords WCYCLE, WELLWAG).
  - Gas lift optimization (keywords LIFTOPT, GLIFTOPT, WLIFTOPT, GLIFTLIM).
  - Well prioritization option (keywords PRIORITY, GCONPRI).
  - Assigning separators to groups (keywords GSEPCOND, SEPVALS).
  - Economical limits for liquid (the 14th parameter of keyword WECON).
  - The option to decrease guide rates oscillations due to rate-dependent conning phenomena (9-th parameter of keyword GUIDERAT) is supported.
  - Automatic initialization of multiple FIP regions representing the original GAS, OIL and WATER zones (keyword FIPOWG).
  - Wettability alternation due to the accumulation of surfactant (keywords SURFWNUM, SURFADDW, SURFADS, SURFROCK).
  - The option to limit permeability multiplier increase for bright-water nano-polymer models.
4. For MO format models the following options are supported:
- Compositional models including  $CO_2$  injection option.
  - WAG process (keyword and event WWAG).
  - The target limits for accumulated values (parameters COIL, CWAT, CGAS, CLIQ, CWIN, CGIN).
  - Well efficiency factor set by a keyword (keyword WWEF).
5. In MPI version the following options are supported:
- Numerical aquifers (keywords AQUNUM, AQUCON).
  - TEMPerature option.
  - API tracking option.



- BRINE option (keywords SALT, SALTVD etc).
- TRACER option (keywords TRACERS, AQANTRC etc.).
- SURFACT option.
- The keyword ADDZCORN.
- The keyword WELSOMIN.
- HYSteresis option.
- The parameter IRREVERS of keyword ROCKCOMP.
- Average pressures WBP4, WBP5, WBP9 calculation in case pattern split between nodes.
- The keyword ARITHMETIC.
- Non-neighbour connections (keyword NNC) between blocks located on different nodes.
- The keywords SATNUM, PVTNUM in SCHEDULE section.
- The keyword WFRA.
- The export of FIPXXX maps into binary INIT file.
- The keyword PCSH (MO).
- Creation of files listed in option –touch-after in case of job termination.
- Well production and injection reports may be outputted on each computational time step by log level set WELL LOW of keyword REPORTFILE.
- Per-node thread load balancing for properties computation.

## 24.2. Geology

In tNavigator 4.0.2 Geology module the following features are introduced:

- New window "tables" for view, edit, filter well objects in table form (markers, wells profiles, perforations, production data, etc).
- "Workspace" save.
- Interpolation algorithms for maps and horizons:
  - Simple, usual, universal kriging.
  - Simple, usual, universal kriging with anisotropy support.
  - Sequential Gauss simulation with anisotropy support.
  - Least squares method.
- Layer by layer interpolation for 3D data:
  - Simple, usual, universal kriging.

- Simple, usual, universal kriging with anisotropy support.
- Sequential Gauss simulation with anisotropy support.
- Least squares method.
- SCHEDULE section creation for hydrodynamic model.
- Well profile averaging for 3D grid blocks.
- Well profile creation by geology 3D data.
- Grid creation by several different properties layers.
- Arbitrary object delete is supported (markers, well profiles, perforations, well production data, etc).
- Object loading from text files with table data with column selection (markers, well survey, perforations, production data, etc).
- Edit and save parameters for object drawing.
- Windows management and navigation improved.
- Geology project may be created by existing hydrodynamic model.

### 24.3. Assisted History Matching

In tNavigator 4.0.2 Assisted History Matching module the following features are introduced:

- Job ordering for local job queue can be changed.
- Local PC may be switch off after all jobs in local queue are finished (for Windows only).
- Background data loading (very important for large number of variants).
- Well production target functions.
- The target function for sum of parameters.
- Well water or gas injection target functions.
- The support of Nelder-Mead algorithm.
- Well and group data is visualized in graphs, cross-plots, and histograms.
- History matching variables improved:
  - Arithmetic expressions may be used as a variable definition as for variable usage.
  - The variable type (floating point or integer) may be specified in data file.

- The cross-plots are improved:
  - Arbitrary parameter may be used as X.
  - Model data shown in cross-plots is coloured as corresponding experiment.
  - The variables can be visualized on cross-plots.
- "Tornado" plots are improved.

## 24.4. Remote GUI

In tNavigator 4.0.2 Remote Graphical User Interface the following features are introduced:

- The default settings for client may be specified on a server. The settings are:
  - default number of threads;
  - default number of slots used in job queue;
  - default queue name.

## 24.5. Graphical User Interface

In tNavigator 4.0.2 Graphical User Interface the following features are introduced:

- Conditional "if" statement is supported in arithmetic expressions for map editing.
- Dual porosity model support is improved (edit for maps in matrix and fracture, histograms for maps in matrix and fracture, etc).
- PDF viewer for documentation may be specified in settings.

## 25. tNavigator 4.0.1

### 25.1. tNavigator kernel

In tNavigator 4.0.1 kernel the following options are supported:

1. For compositional models E3 format the following functionality is added:
  - Restart both the console and GUI versions.
  - View the calculation results of compositional models during computation on a cluster.
  - Multiple EOS regions.
  - Speed of compositional calculation was increased.
  - Algorithms for determining the phase composition near the critical point was improved.
  - Compatibility with other simulators in flash calculations and phase identification was improved.
  - Parameters of VFP tables specific for compositional models.
  - D-factor in the formula of inflow to well for compositional models.
2. For E1 format models the following options are supported:
  - Hysteresis of relative permeabilities.
  - The API Tracking option: mixing of different types of oil, having different surface densities and PVT.
  - Multiphase injection (option MULTI for the 3-rd parameter of the keywords WCONINJE, WCONINJH, WCONINJP).
  - Option UDQ in the keyword ACTIONW.
  - Options LIFT and GUID for 2-nd parameter of the keywords WTMULT and WELTARG.
  - "Standard" network (keywords GNETPUMP, GRUPNET; previously only "Extended" NETWORK option was supported).
  - Reference depth for well block average pressure calculation (WPAVEDEP).
  - The dependence between well PI multiplier versus maximum water cut (keywords PIMULTAB and WPITAB).
  - Group controls for different phases for one well group (parameters 3, 4, 5 of the keyword WGRUPCON).
  - LGR models: geometry inside local grid refinement (via COORD/ZCORN and TOPS/DX/DY/DZ).

- Options for calculation of the transmissibility between the regions (5-th parameter of the keyword MULTREGT).
  - Grid in binary format for models with LGR (keyword GDFILE for models with LGR).
  - Keyword NNCGEN.
  - The calculation of transmissibility for the value ALL 5-th parameter of the keyword PINCH was improved.
  - Options of the command line `-touch-before`, `-touch-after` to create files (specified by user) before of after calculation.
3. For MO format models the following options are supported:
- VFP tables specification.
  - User-files in E1 format are possible in MO format models (for example, to set the proppant properties tables or automatic hydraulic fracture).
  - FIELD units.
4. In MPI version the following options are supported:
- Restart for compositional models.
  - Hysteresis of relative permeabilities.
  - Output of PLT binary files (keywords WRFT, WRFTPLT).
  - Output of binary files, managed via the keyword OUTSOL in SCHEDULE section.
  - Output of a set of vectors for the keyword ALL in section SUMMARY.
  - Option STORE of the keyword ROCKOPTS.
  - Option SMARTMB of the keyword RUNCTRL.
  - An automatic restart from the beginning of reporting step with the minimum initial time step, if the calculation for one reason or another has not converged.

## 25.2. Geology

In Geology module the following new functionality was added:

- Calculator of all objects.
- The history of the objects. Tool to recalculate objects with different parameters.
- The well profile with an ability to edit markers.
- A tool for creating and editing of the coordinate system (is used for the grid construction).
- Taking into account a polygon (for example, the license block) in the grid construction.

- A tool for creating and editing of polygons.
- A tool for creating and starting the model (sections RUNSPEC, GRID, PROPS (with correlation), SOLUTION).
- Information window (calculation details).

### 25.3. Assisted History Matching

In Assisted History Matching module the following new functionality was added:

- An ability to work with integer variables in history matching.
- An algorithm of relative permeabilities history matching (Corey correlation).
- Option "Connect to the model" (view results for models that are calculating at this time).
- For any variant of history matching project the table "Variant Info" is enable (double click on the variant in the option Project Info). Table can be exported to html.

### 25.4. Remote GUI

In Remote Graphical User Interface the following options were added:

- The design of the main window was modified: an ability to configure location and form of tools.
- Now one can add a variety of models, including specification of the directory where tNavigator searches all data files.
- An ability to load configuration of running processes from the server.

### 25.5. Graphical User Interface

In Graphical User Interface the following options were added:

- Graphs of component production for compositional models.
- An ability to load results of the model that in calculated at this moment.
- LGR blocks are displayed via grey color at the map of roof.
- 2D maps of sum, average, rms, ... : LGR blocks borders are displayed as dotted line.
- An ability to display the time steps with a precision better than days (hours, minutes).
- An ability to customize the accuracy of the numbers in the tables for graphs.
- The symmetric logarithmic palette for maps with positive and negative values.
- An ability to visualize crossplots for regions for historical and calculated graphs simultaneously.

## 26. tNavigator 4.0.0

### 26.1. tNavigator kernel

In tNavigator 4.0.0 kernel the following functionality is supported:

1. Compositional models in E3 format are supported:
  - the standard set of options for compositional modeling is supported (except for an injection of CO<sub>2</sub>);
  - calculation of compositional models is supported in the cluster (MPI) version;
  - for compositional models in the GUI all visualization options are added.
2. "Black oil" models calculation in IM format is supported.
3. New module – geology modeling – is added:
  - loading trajectories, markers, LOGs, horizons;
  - creation of horizons by markers;
  - creation of mesh by horizons;
  - interpolation of cubes from LOGs (via the formula) (creation of cubes: net-to-gross ratio, porosity, permeability);
  - export of mesh and cubes into a corner point geometry format (COORD/ZCORN);
  - saving of log of all data operations;
  - 2D and 3D visualization of all data.

This module allows to create a geological and hydrodynamic model using a primary processed information in a single interface.

4. New module – Assisted History Matching module – is added (this module is based on Experiment designer):
  - Optimization algorithm (differential evolution) was added. This algorithm allows to minimize the mismatch in the adaptation in automatic mode, via changing of parameter values.
  - Construction of user-defined objective function (weighted sum of residuals) in GUI. The objective function can be constructed for any group of wells in basic model. Oil, water, liquid, gas (rate or total), watercut or gas-oil ratio can be used.
  - New algorithm (creation of model variants) can be run from previously created initial approximation (model variant) in the History Matching window. Variants generated by different algorithms are compared in a single window.
  - A new algorithm for estimating the sensitivity is added – tornado experiment, which allows to make a tornado diagram.

- Assisted History Matching for **E1** and **MO** data models. "Manual" specification of variables for **E1** format models (the keyword **DEFINES**) and **MO** format model (the keyword **VDEF**).
  - Variables for history matching can be specified in GUI (history matching of **WOC**, **GOC**).
  - Saving of History Matching Project (the state of History Matching data) to the file which is portable between computers and operating systems.
  - The integration of the model queue to a remote task queue on the cluster.
5. Remote GUI (graphical interface) module is added. This module allows the user to do the following things from his workstation (running under Windows or Linux):
- put a model in a queue for the calculation on remote cluster;
  - delete a model from the queue;
  - view the status of the queue;
  - view the status of the calculation (progress and calculation log);
  - connect to the current calculation and visualize the calculation results.
- In fact, this module makes the calculation on the remote cluster the same convenient, as well as the calculation on the local computer.
6. For models in **E1** format the following keywords are supported: **JFUNCR**, **GSATPROD**, **GSATINJE**, **GCONSUMP**, **WELPI**, **RPTRST** (options **FREQ** and **BASIC**).
7. For models in **MO** format the following keywords are supported: **DPOR**, **DPER**, **DPSS**, **LOCATION**, **ZONE**. Dual porosity is supported for models in **MO** format. Splitting and merging of **MO** format models is supported.
8. For models in **MO** format the new possibility to add a hydraulic fracture is added: a table with events (new tNavigator keyword – **WFRP** – is analogous to the keyword **WFRACP** for models in **MO** format).
9. A possibility to specify the relative permeabilities tables with Corey correlations via the keywords **COREYWO** and **COREYGO**.
10. Support of options in MPI version is improved:
- dual porosity and dual permeability models are supported;
  - restart is supported;
  - saving of **UNRST/UNSMRY** binary files is supported;
  - the continuation of the calculation from the last calculated step is supported;
  - compositional and temperature models are supported.



11. The possibility to open on another computer the results of calculation, that goes on the cluster, if the model is calculated on the shared disk.
12. The GUI can be used to view the results of calculated models without a full license (GUI may have it separate licensing).

## 26.2. Graphical User Interface

The GUI version of tNavigator 4.0.0 has the visualization of new physical models and new modules:

- Compositional model;
- Geology;
- Assisted History Matching;
- Remote GUI.

The following functions are added:

1. For User maps and User Cuts: the calculator is added. Calculator buttons are names of available maps and available operations with them. For 2D map Layer selection of any area with "brush" can be used. Calculator simplifies the work with User Arithmetic.
2. A possibility to enter the injected tracer name and its concentration in the GUI in the Well Properties dialogue.
3. A possibility to enter the economic limits for wells in GUI in the Well Properties dialogue.
4. The interface for perforating the well along it's trajectory is improved.
5. The interface for tracer graphs is improved.
6. A possibility to use the economic parameters (enter in GUI tax values, cost of operation, new drilling, geological and technological procedures).
7. A possibility to create a well trajectory on Cross-Section.
8. Dynamic creation of WELL LIST in GUI. Visualization in GUI of WELL LIST that are specified in model files and in GUI.
9. Binaries converter (from binary files to text files) is added.

## 27. tNavigator 3.3.4

### 27.1. tNavigator kernel

In tNavigator 3.3.4 kernel the following functionality is supported:

1. Work with dual porosity models has been improved:
  - local grid refinement (LGR) for dual porosity models is supported;
  - arrays in EDIT-section can be changed for dual porosity models.
2. Work with models with a large number of inactive blocks has been improved:
  - Loading models with a large number of inactive blocks is accelerated;
  - Restart models with a large number of inactive blocks is supported.
3. Splitting a large model into small sectors has been improved:
  - Splitting models with a large number of inactive blocks is supported;
  - Splitting models with group control is supported.
4. MPI version options are upgraded:
  - keyword ACTION can be used with a limited amount of stored information;
  - option CHECKSAT of the keyword RUNCTRL;
  - a single run of calculations provides splitting of a large model into sectors and calculation of the boundary conditions;
  - restart of regular version with the calculation of MPI version.
5. Support for numerical aquifers has been improved.
6. The second parameter of the keyword GRIDUNIT (E1).
7. New Interpolation method has been added – multilayer and 3-dimensional Sequential Gauss Simulation.
8. Protection from damage of result files was added in the case when one model is opened simultaneously by multiple instances of tNavigator, including on the shared disk.
9. New elements of the automatic adaptation:
  - Experiments designer. Creation of the different model variants with different variable values modified by one of the following algorithms: Grid Search or Latin hypercube.
  - Sensitivity analysis tool: Pearson correlation between the model variables and the values of parameter mismatch.
10. The model queue. The opportunity to send a notice to e-mail when the model calculation is finished.

## 27.2. Graphical User Interface

In tNavigator 3.3.4 Graphical User Interface the following functionality is supported:

1. To support the functions of Experiments designer the list of functions to compare the results for the queue models is enlarged. The following features were added:
  - Graph of difference between the calculated and historical values.
  - Values Crossplot for selected calculated models.
  - Export to a text file for histograms, graphs and tables.
  - Sorting of the selected models.
  - Deleting of non-selected models.
  - Mark the selected models in the table of values and residuals for copying to the clipboard.
  - Selecting displayed columns in tables of values and residuals.
  - Hiding parameters with the same values in the tables and histograms.
  - Ability to set the historical values from the selected model to calculate the residuals and compare results.
2. The functionality of cross-sections has been upgraded:
  - Cross-sections can be made through a fence, specified via individual points, horizontal well or several wells.
  - Map Editing. the possibility to edit map inside or outside the cross-section (analogously to the profiles).
  - Cross-section through the well can be made: through the centers of blocks with connections or through the trajectory branch. Smoothing (reducing the number of trajectory points) with the selected precision can be done.
  - Cross-section through the several wells. Wells can be chosen from the Well filter or Well selection. Wells order can be changed in the list. Cross-section can be made through well top, bottom or middle part.

## 28. tNavigator 3.3.3

### 28.1. tNavigator kernel

In tNavigator 3.3.3 kernel the following functionality is supported:

1. Calculation of dual porosity (and dual permeability) model is modified, working with these models is accelerated.
2. Artificial Lift Quantity (ALQ) is supported in lifting-tables and in well control modes (E1).
3. 3-rd parameter of WEFAC (E1).
4. Cross-flow blockage (ALLX) in MO models.
5. LGR in MO models.
6. LGR in values interpolation into crosshole space.
7. Values interpolation into crosshole space is accelerated (for Multilayer Geostatistical (Kriging) interpolation Type).
8. Map Editing. In Multilayer Determined interpolation a new parameter "Radius" is added. Radius has influence on smoothing near well.
9. Map Editing. Connected Components and Voronoi Diagrams are added.

### 28.2. Graphical User Interface

In tNavigator 3.3.3 Graphical User Interface the following functionality is supported:

1. Calculation of historical data is done when model is open, so model loading is accelerated.
2. Graphs. Well list. Historical or calculated well status is shown.
3. Playback results function is added.
4. Automatic creation of screenshots for several time steps.
5. Acceleration of 2D and 3D maps for large models.
6. User Interface for dual porosity and dual permeability models is updated.
7. Automatic selecting of integer layers for Contour lines. Previous behaviour (uniform partition of the range of values into intervals) can be chosen in Preferences. Visualization.

8. Loading of User contours for profiles.
9. Improved navigation of logs (Option "Find" is added).
10. User Arithmetic description is updated. Option "Find" is added.
11. Models queue is changed:
  - models queue is in the new window (queue status is saved);
  - one can make several models queues and choose one to work with;
  - historical values visualization for models from queue and residual histograms for calculated models;
  - visualization of values for calculated models at any time step.

## **29. tNavigator 3.3.2**

### **29.1. tNavigator kernel**

In tNavigator 3.3.2 kernel the following functionality is supported:

1. Option NETWORK is enlarged (E1): compressors, booster compressor station, water discharge at the network nodes.
2. Separators are supported (E1).
3. Boundary conditions record for model splitting have been updated.
4. ROFF format for initial grid data is supported.

### **29.2. Graphical User Interface**

In tNavigator 3.3.2 Graphical User Interface the following functionality is supported:

1. Adding well is via Alt+Click (earlier – Ctrl+Click). Commands "Show Block Info (graphs)" and "Add well" have different control sequences.
2. Selecting of nearest to the mouse well on 2D map.
3. Visualization of well groups and wells in these groups (for all graphs).

## 30. tNavigator 3.3.1

### 30.1. tNavigator kernel

In tNavigator 3.3.1 kernel the following functionality is supported:

1. Increased support for open models with a large number of inactive blocks: multireservoir models are supported, splitting of such models is supported and boundary conditions creation.
2. Saving and splitting of multireservoir models.
3. Calculations of the split patterns in MPI-version.
4. The ability to write the boundary conditions without opening .patterns-model.
5. The drawdown limit can be taken into account when calculating the well's production potential (WELDRAW, item 4) (E1).
6. The maximum drawdown within the set of connection grid blocks (WELDRAW, item 5) (E1).
7. Group reservoir fluid volume production rate control (GCONPROD RESV) (E1).
8. The keyword GEFAC (E1).
9. **COMPDAT AUTO** – connection is initially closed. It will be opened automatically when another well connection is closed during an automatic workover. A connection on AUTO is opened each time the well is worked over, in the order in which the connections are first defined in COMPDAT. (E1).
10. Prioritized drilling queue. Sequential drilling queue (keywords WDRILTIM (item 1-2), WDRILPRI (item 1-2), DRILPRI (item 1-9)) (E1).
11. Removed the generation of files EGRID, INIT, UNRST when using the option-d (E1).
12. Algorithm of evenly balancing the allocated memory between the NUMA nodes was improved, calculations on systems with NUMA architecture was accelerated.
13. Added a section of a hybrid time-dependent data in the hybrid model. (model E1 + MO time-dependent data + additional time-dependent data E1).
14. Models MO with temperature option.

## 30.2. Graphical User Interface

In tNavigator 3.3.1 Graphical User Interface the following functionality is supported:

1. New visualization of Well section (Well profile) and LAS files.
2. Interpolation on 3D maps:
  - 2.1. geostatistical interpolation (kriging)
  - 2.2. determined method (least square method)
3. A simplified way to create perforations filters in layers is added.
4. A possibility to create compact window with graphs for selected parameters.
5. A possibility to create a well filter via selecting wells on a 2D map.
6. Synchronization of well filters for all windows.
7. A possibility to delete well filter.
8. In model statistics, the model values are now written with the factors (thousand, million).
9. An acceleration of the interface with large models.
10. A possibility to create a filter (cut) for faults.



## 31. tNavigator 3.3.0

### 31.1. tNavigator kernel

In tNavigator 3.3.0 kernel the following functionality is supported:

1. Dual porosity and dual permeability (E1) is supported in calculations and in graphical interface (in tracers calculations, salts, polymers, temperature option).
2. Option to limit the rate of inverse gas dissolution is supported (DRSDT).
3. Number of supported parameters in the following keywords increased (E1): WELDRAW, WECON, WECONINJ, GECON, PPCWMAX, GPMAINT, WCUTBACK, GCONINJE, GCONPROD.
4. Multiple group controls is supported (E1, MO).
5. The keyword WFRAC is supported for MO models; and its expansions (for example FLOWFUNC) that was supported earlier only for E1 models.
6. Restart for MO models is supported.
7. Support of unit systems has been improved (FIELD, METRIC), also in user arithmetic (E1, MO).
8. Section SUMMARY for E1 models is supported: when one orders export of results to binary files E1 (UNRSMRY) they are saved in accordance with the specified in the section SUMMARY fields. Graphical interface to choose export fields has been added.
9. The keywords OUTSOL and RPTRST for E1 models are supported: when one orders export of results to binary files E1 (UNRST) they are saved in accordance with the specified in the keywords fields. Graphical interface to choose export maps has been added.
10. In the keyword GDFILE in addition to the binary grid format EGRID mesh GRID (E1) are supported.
11. Hybrid model mode: up to section of non-stationary data it has the format E1, the section describing the trajectories, events, well data has the format MO.
12. In Surfactant model adsorption is taken into account (E1).
13. In polymer model Bright Water temperature option is taken into account.
14. Faster calculation of the historical data while loading model (E1, MO).
15. Temperature option is expanded beyond E1: a) heat capacity of blocks with non active blocks can taken into account in temperature calculations, b) one can set the heat exchange with the environment (top and bottom layer).

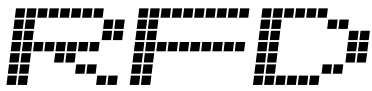
16. The ability to write concise event of perforation, while saving the model (in demand by splitting-merging the model and the desire to further manual editing) (E1).
17. Dates to 1900 year are supported (E1, MO).
18. To reduce the amount of data (written to disk) the file containing flows between the FIP regions is generated only by user request (E1, MO).
19. First implementation of geomechanical option.
20. Default values in the input maps are supported.
21. For the cluster version: support for **GDFILE**, multi-reservoir models, all types of group control, an optional recording of the entire set of results files (E1).
22. For the console version (including cluster version): an explicit entering from the command line a set of results files that will be generated. For example, one can specify a record of results for groups and wells to reduce the amount of required disk space and to reduce time. Generated graphics then can be viewed in a graphical interface.
23. For the console version (including cluster version): command line option `-thread-bind-to-cpu` to explicitly specify the binding of threads to logical processors.
24. Improvements in balancing between the **NUMA** nodes used by the program RAM.
25. Improvements in the use of CPU cache.
26. Speed of calculation of sector models with boundary conditions was significantly increased (FLUX).
27. Different options in calculating the local grid refinement (**LGR**) were supported (nested **LGR**, options **PINCH**, streamlines).
28. Improvements in the calculation of the initial equilibrium (a significant acceleration in some cases; transit zone and the accuracy of equilibrium are supported, etc.).

### 31.2. Graphical User Interface

In tNavigator 3.3.0 Graphical User Interface the following functionality is supported:

1. An ability to read only the time-dependent model data (schedule data) for **E1**, **MO** models, hybrid format. This can highly speed up adaptation work, if only wells and perforations data was changed.
2. Local mesh refinement (**LGR**) is supported in all parts of the GUI: 2D and 3D maps, contour lines, in user arithmetic, editing maps, adding new wells.
3. Adding perforations dialog can use the trajectories. Now, if the well trajectory is loaded, the perforations can be added in format "from – to" in **TVD** or **MD** (E1, MO).

4. An ability to additional loading well data and storing it in a table-text format (similar to MO format).
5. A map of the ternary diagram for saturations.
6. If the map Cut is enable, then by selecting the "Wells" shows the sum of all perforations, selected by this Cut.
7. An ability to rename profiles and well filters. So profile name is used now instead of profile number.
8. In User Arithmetic expressions one can use relative permeabilities scaling, even if they have not been explicitly defined (E1, MO), and maps of aquifers connections.
9. Setting to control the accuracy of signatures to the isolines.
10. Loading cubes from files .grdecl format was improved (now one can download the data inside the BOX / ENDBOX structure).
11. Maps of minimum and maximum for 2D maps.
12. Creation of well filter, taking into account the Unified Adaptation Results table.
13. An ability to sort the wells using Unified Adaptation Results table data.
14. An ability to assign a name for the Annual Summary Report.
15. Visualization of ROCKTAB (E1), KVSP (MO) data.
16. Visualization of vector fields for the geomechanical option.
17. An ability to save a picture of map or graph to the clipboard by pressing the camera button.
18. An ability to import well filters from the clipboard.
19. Factors (thousand, million) in tables and graphs are now the same for the graphs on the same axis.



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