Simulation and optimisation technologies supporting Refinery operation Planning and Scheduling

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WHERE DO WE COME FROM ?

DR. ALBERTO FERRUCCI

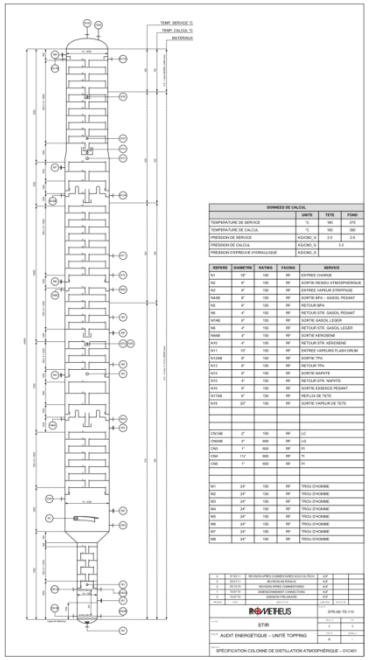
- Genoa ERG Refinery (late 60'): as shift operator improves CDU train with 50°C Furnace Inlet increase.
- Priolo ISAB Refinery
  - ✓ (1972-1976) feasibility, project planning, engineering, procurement, construction, start-up, management.
  - ✓ (1977) appointed CEO of ISAB.
  - ✓ (1979) oil crisis, crude price skyrockets: "wrong refinery in the wrong place in the wrong moment"
  - ✓ (1981) 1st Mild Hydro Cracker of the world
  - ✓ (1983) 1st Real Vacuum Pitch Visbreaking
- Genoa Refinery: (1980) saves it from Bankruptcy
- 1985 with ISAB profits buys Chevron's Italian Assets and becomes the first Italian private downstream operator.
- 1985 appointed ERG Group VP and ISAOIL (ex Chevron Italy) President
- 1986 Starts Prometheus

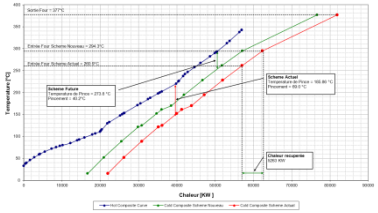
2011: Lukoil buys ISAB refinery for 2.0 Billions USD

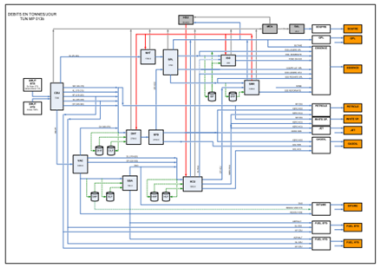
PROMETHEUS

- We help various operators worldwide
  - ✓ Italy (IPLOM, IES, API)
  - ✓ Former Soviet Union (UFA and Odessa Refineries)
  - ✓ Mediterranean Area (Egypt, Libya, Tunisia)
  - ✓ India (HMEL)
- Providing Consulting Services
  - ✓ Strategic consulting, feasibility studies
  - ✓ Technical assistance
  - ✓ Process design studies
- and Software solutions: Prometheus DSS
  - ✓ Crude oil characterisation
  - ✓ LP Refinery Optimisation
  - ✓ Blending Optimisation
  - ✓ Operation Scheduling
  - ✓ Plant simulation / monitoring

SPECIALISED CONSULTING







- **Surveys**
  assess current Performance and highlight minor modifications permitting to overcome production bottlenecks and to improve global profitability
- **Feasibility Studies**
  highlight solutions to cope with operational changes or evaluate process modifications
- **Conceptual Engineering**
  process design of modifications of existing units aimed to reach new operational targets (heat & material balances, thermodynamic calculations, equipment sizing, issue of datasheets, PFDs & P&IDs)
- **Energy Audits**
  improve Energy Performance Fuels optimisation, heat transfer and heaters efficiency, utilities and fuels balances, emissions control
- **LP Audits**
  assess the reliability of the existing LP model, verify its capability to model in a satisfactory way the specific operative flexibilities

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DECISION SUPPORT SYSTEM TOOLS

Designed specifically for refinery professionals trigger the diffusion of a common "techno-economic mentality" in refinery services.

A framework of integrated technologies to support Supply Chain Management tasks.

… Oil Characterisation

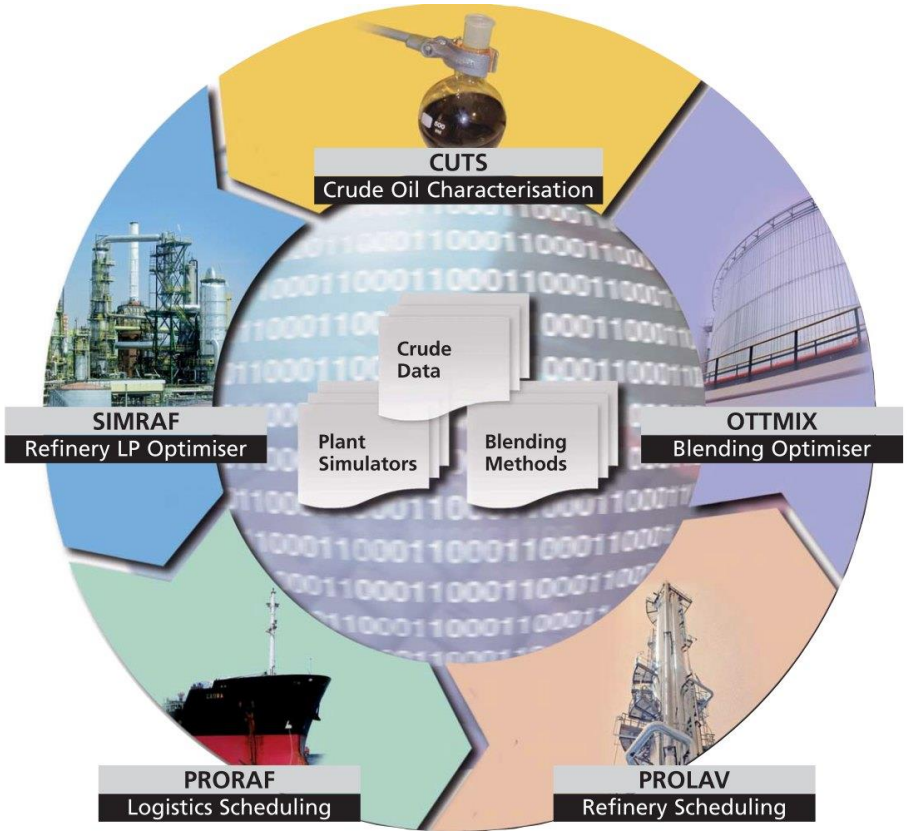
… LP Optimisation

… Scheduling

… Logistics

… Processing

… Blending

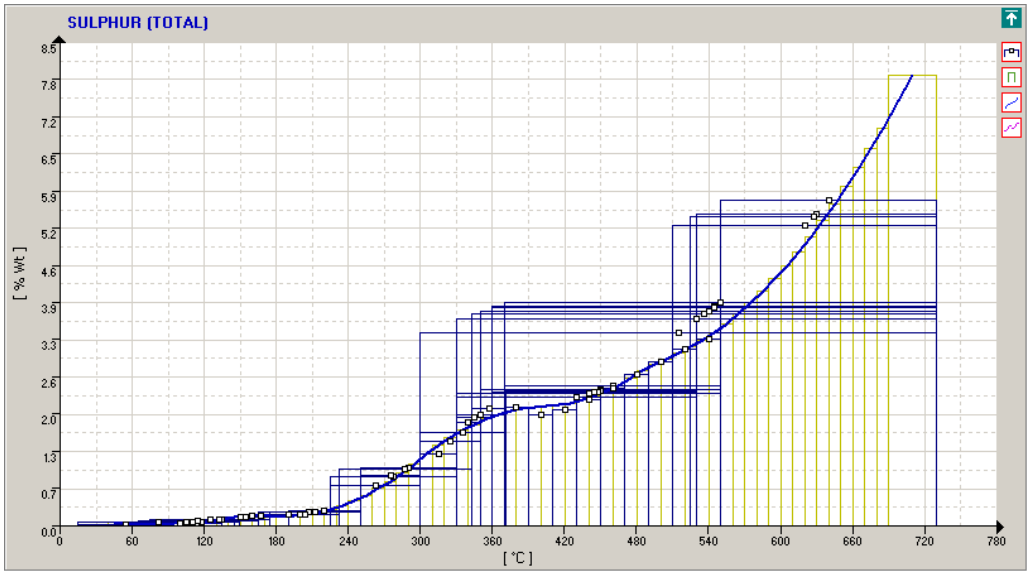


CUTS™: CRUDE ASSAY DATA REGRESSION

"Multi-dimensional regression" characterises crude oils by pseudo - components (narrow cuts) generating information required by processing simulation.

Crude Assay data are not independent: the regression considers at the same time fractions quality balances and distribution shapes.

The system predicts well all characterisation data required for operation Planning and Scheduling activities (~30 fundamental properties plus derived).



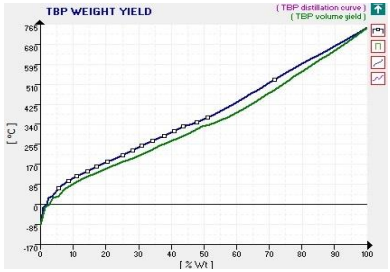
Results Data Check

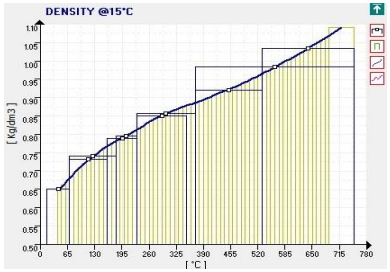
Check for property : **SULPHUR (TOTAL)**

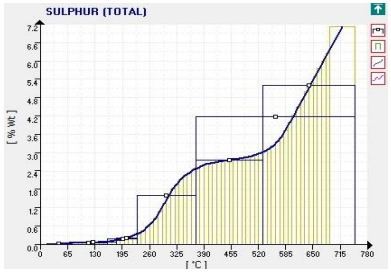
CUTS	Initial Temp. [°C]	Final Temp. [°C]	Input [% Wt]	Calculated [% Wt]	Difference Input-Calc.	Difference [%]
BULK	-88.6	730.0	1.880	1.892	-0.012	-0.64 %
C01	15.0	95.0	0.023	0.023	0.000	0.00 %
C06	15.0	149.0	0.056	0.056	0.000	0.00 %
C02	65.0	135.0	0.050	0.050	0.000	0.00 %
C03	65.0	145.0	0.062	0.062	0.000	0.00 %
C04	75.0	145.0	0.069	0.067	0.002	2.90 %
C07	65.0	165.0	0.085	0.086	-0.001	-1.18 %
C05	90.0	145.0	0.073	0.073	0.000	0.00 %
C09	75.0	175.0	0.106	0.104	0.002	1.89 %
C10	90.0	175.0	0.111	0.111	0.000	0.00 %
C11	95.0	175.0	0.120	0.119	0.001	0.83 %
C08	135.0	165.0	0.150	0.150	0.000	0.00 %
C12	135.0	175.0	0.160	0.162	-0.002	-1.25 %
C13	145.0	175.0	0.175	0.175	0.000	0.00 %
C14	145.0	190.0	0.180	0.180	0.000	0.00 %
C16	149.0	232.0	0.190	0.194	-0.004	-2.11 %
C15	175.0	225.0	0.195	0.192	0.003	1.54 %
C17	175.0	232.0	0.200	0.200	0.000	0.00 %
C18	165.0	250.0	0.240	0.239	0.001	0.42 %
C19	175.0	250.0	0.245	0.246	-0.001	-0.41 %
C20	190.0	250.0	0.260	0.260	0.000	0.00 %
C21	225.0	300.0	0.710	0.695	0.015	2.11 %
C22	250.0	300.0	0.880	0.858	0.022	2.50 %

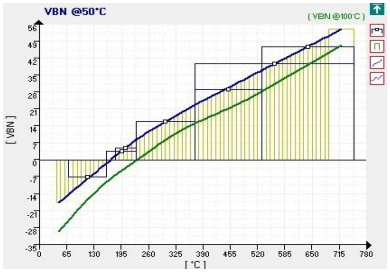
CUTS™: PROPERTIES

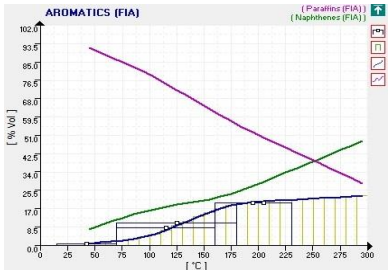
- Properties
  - TBP weight yield
  - Density @15°C
  - Sulphur (Total)
  - Sulphur (Mercaptans)
  - Viscosity @50°C
  - Viscosity @100°C
  - Viscosity Index
  - Acidity
  - Aromatics (FIA)
  - Naphthenes (FIA)
  - Paraffins (FIA)
  - Aromatics (GC)
  - Naphthenes (GC)
  - Paraffins (GC)
  - Clear MON
  - Clear RON
  - TEL 0.5 RON
  - TML 0.5 RON
  - RVP
  - Freezing Point
  - Cloud Point
  - Pour Point
  - Refraction Index @20°C
  - Refraction Index @70°C
  - Aniline Point
  - Total Nitrogen
  - Basic Nitrogen
  - Ash
  - Asphaltenes
  - Conradson Carbon
  - Nickel
  - Vanadium
  - Waxes
  - Cyclopentane content
  - C6 Isoparaffins content
  - N-hexane content
  - Methylcyclopentane content
  - Benzene content
  - Cyclohexane content

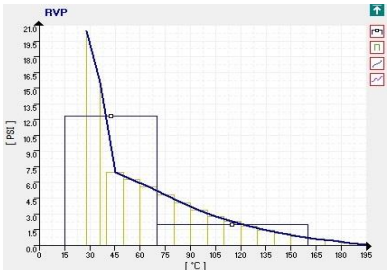


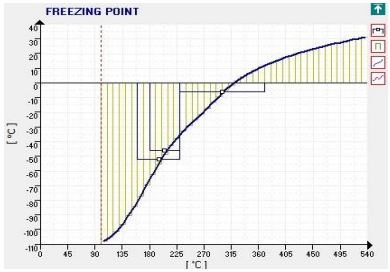


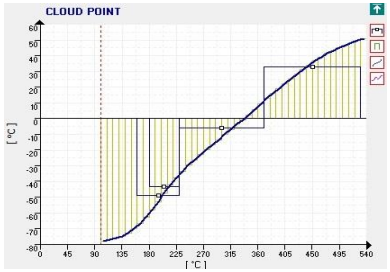


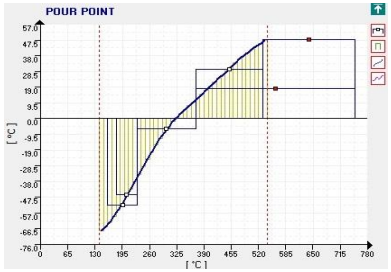


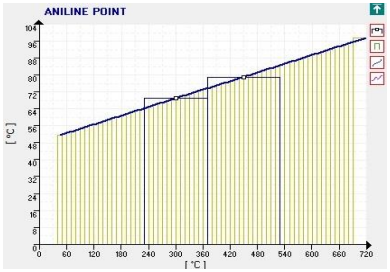


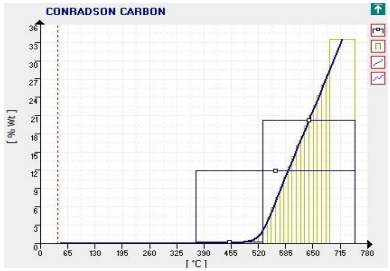


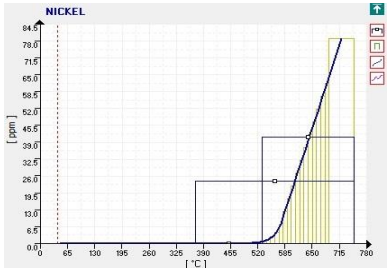


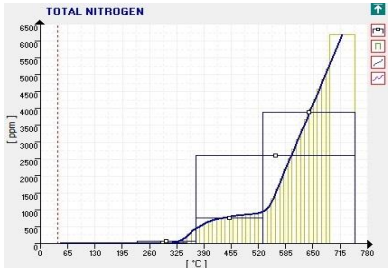


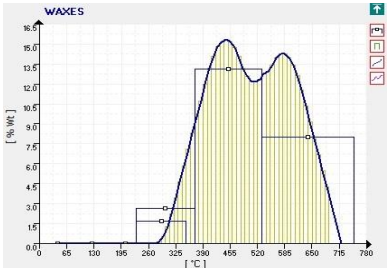












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CUTS™: SOURCE DATA

Tab. 1b: ASTM D2892

TBP CUT POINT °C	DISTILLATE % ON CRUDE m/m	CU %
Gas+Gpl	0.4	
80	3.5	
100	3.6	
120	3.9	
140	4.0	
160	2.4	
160	2.1	
180	4.4	
210	5.2	
230	4.5	
250	4.1	
270	4.2	
290	3.8	
320	5.3	
350	5.7	
370	4.2	
400	4.5	
400+	34.2	

Tab. 4: GASOILS

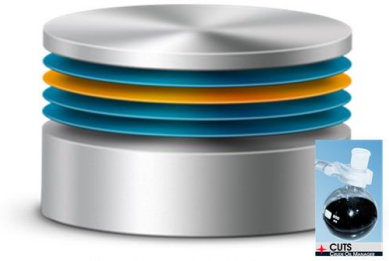
TBP RANGE	°C	230-320	320-370	370-400	
YIELD % ON CRUDE	% m/m	21.63	9.21	4.66	ASTM D 2892
	% v/v	21.41	8.66	4.29	✓
DENSITY @ 15°C	Kg/l	0.8397	0.8843	0.9024	ASTM D 4052
SPECIFIC GRAVITY @ 60/60°F		0.8401	0.8848	0.9029	" "
API GRAVITY @ 60/60°F		36.9	28.4	25.2	" "
✓ SULPHUR (Total)	%m/m	0.04	0.18	0.21	ASTM D 4294
✓ NITROGEN (Total)	ppm			970	ASTM D 4629
✓ BASIC NITROGEN	ppm			384	UOP 313
✓ ACIDITY (Total)	mg KOH/g	0.04	0.18	0.30	ASTM D 974
✓ WAX	%m/m			7.29	BP 237
✓ CLOUD POINT	°C	-24	+3	+21	ASTM D 2500
✓ POUR POINT	°C	-24	+3	+18	ASTM D 97
✓ CETANE INDEX by four var. equations		53.6	55.6	58.4	ASTM D 4737
✓ ANILINE POINT	°C	77.0	81.6	84.4	ASTM D 611
✓ AROMATICS					IP 391
Monocyclic	%v/v	16.6	19.3	20.3	" "
Bicyclic	%v/v	5.3	10.0	11.3	" "
Tri + Tetracyclic	%v/v	0.1	0.4	0.5	" "
Total	%v/v	21.9	29.6	32.1	" "
✓ REFRACTIVITY INDEX @70°C		1.4464	1.4700	1.4809	ASTM D 1747
✓ CARBON RESIDUE (Conradson)	%m/m				ASTM D 4530
✓ KINEMATIC VISCOSITY @ 40 °C	mm²/s	4.383			ASTM D 445
✓ " " 50 °C	mm²/s	3.966	3.97	15.78	" "
✓ " " 50 °C	VBN	16.60	16.60	25.98	ASTM D 341
✓ " " 60 °C	mm²/s		3.560	11.320	ASTM D 445

STANDARD CRUDE ASSAY

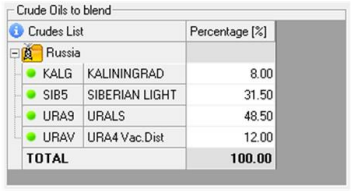
TEST RUN RESULTS

		Stabilised Naphtha	Light Kerosene	Kerosene	Light Gasoil	Heavy Gasoil	Residue
Density	Kg/m3	711.30	787.60	812.60	840.00	866.60	905.20
Yield	% m/m	24.30	15.47	7.50	16.22	5.31	26.50
Distillation		D86	D86	D86	D86	D1160	D1160
IBP		36.5	150.9	156.9	225.5	252.0	235
10 %v	°C	62.7	167.3	212.8	280	354	385
30 %v	°C	81.6	180	236.1	293	400	465
50 %v	°C	99.5	190.5	248.2	313	425	518
70 %v	°C	116	203	257	330	450	568
90 %v	°C	137	212	269	360	475	
EBP		160	238	286	>371,0	504	

FIELD DATA



Crude oil database



Blend composition

STANDARD BLEND

Crude oil database

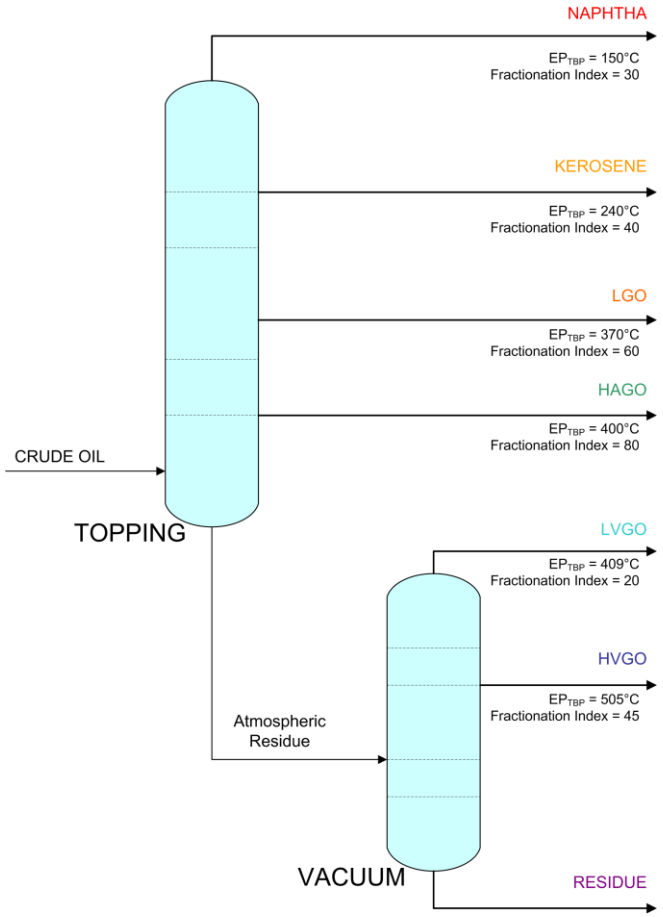
Type	Property	Temperature [°C]	Unit	Initial temperature [°C]	Final temperature [°C]	Specified Value	Calculated Value
Bulk	Density @15°C		Kg/dm3			0.8580	0.8610
Bulk	Pure Component Yield		% Wt	-88.6	-0.5	1.200	1.162
Bulk	Sulphur (Total)		% Wt			1.770	1.814
Bulk	TBP Recovered@	70.0	% Wt			3.90	4.60
Bulk	TBP Recovered@	190.0	% Wt			21.90	22.07
Bulk	TBP Recovered@	235.0	% Wt			30.00	29.97
Bulk	TBP Recovered@	280.0	% Wt			38.20	38.10
Bulk	TBP Recovered@	343.0	% Wt			49.30	49.20
Bulk	TBP Recovered@	565.0	% Wt			81.30	81.40
Cut	Viscosity @100°C		Cst	343.0	+	25.00	25.72

Target Specifications

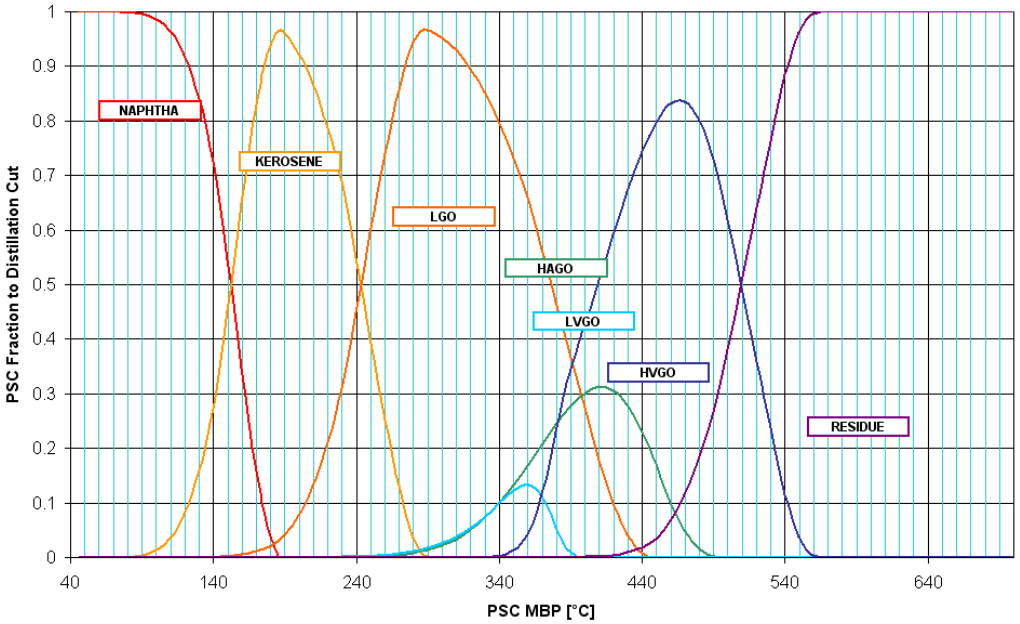
OPTIMIZED BLEND (DATA MINING)

ACCOUNTING FOR REAL FRACTIONATION

Detailed crude characterisation permits to embed directly in the LP model processes and activities usually realised externally like:



- Calculate oil mixes and fractions
- Simulate distillation units (with efficiency)
- Characterise Process units feedstock and effluents.



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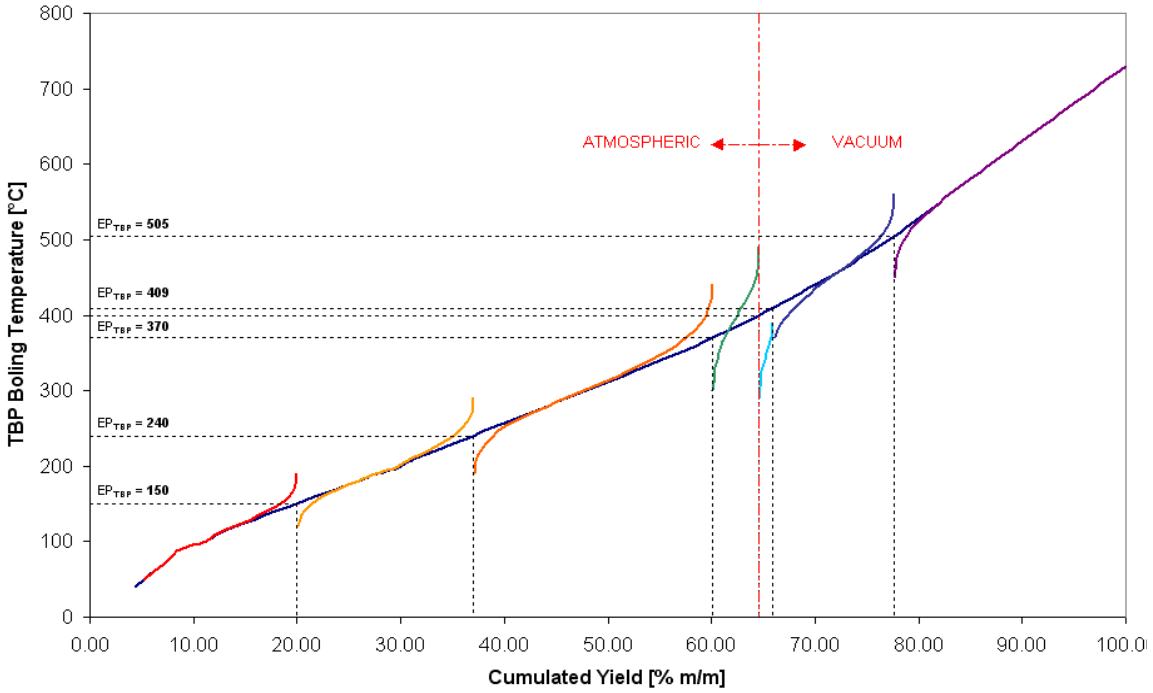
ACTUAL DISTILLATION RESULTS

Ignoring this effect introduces quality estimations errors affecting the optimal solution (overestimating refinery result).

The bigger impact is on viscosity, cold properties and distillation values.



RECUTTING WITHOUT FRACTIONATION INDEXES		NAPHTHA	KERO	LGO	HAGO	LVGO	HVGO	RESIDUE
Yield	% m/m	19.55	17.12	23.05	4.53	1.30	11.72	22.37
Density 15/4	Kg/dm^3	0.695	0.792	0.850	0.892	0.899	0.917	1.013
Sulphur	% m/m	0.053	0.208	1.244	2.057	1.982	2.371	5.189
Viscosity@50°C	cst	0.41	1.04	3.33	10.2	14.6	35.6	33229
Freezing	°C		-51.9	-8.1				
Cloud	°C		-49.1	-3.6	21.2	25.8	34.2	
Pour	°C		-51	-6.4	16.5	20.4	32	
Rec.@100	% v/v	56						
Rec.@250	% v/v		100	0	0	0		
Rec.@360	% v/v			100	0	0		

RECUTTING WITH FRACTIONATION INDEXES		NAPHTHA	KERO	LGO	HAGO	LVGO	HVGO	RESIDUE
Yield	% m/m	19.55	17.12	23.05	4.53	1.30	11.72	22.37
Density 15/4	Kg/dm^3	0.696	0.792	0.851	0.893	0.872	0.916	1.012
Sulphur	% m/m	0.059	0.242	1.247	2.005	1.746	2.395	5.166
Viscosity@50°C	cst	0.41	1.05	3.4	11.8	5.5	32.6	29931
Freezing	°C		-48	-7.2				
Cloud	°C		-45.1	-0.6	23.7	8.2	33.8	
Pour	°C		-48.6	-5.3	18.8	6.6	31.4	
Rec.@100	% v/v	52						
Rec.@250	% v/v		99	4	0	0		
Rec.@360	% v/v			93	21	96		

Changes in the range 10-20 %
Changes beyond 20 %

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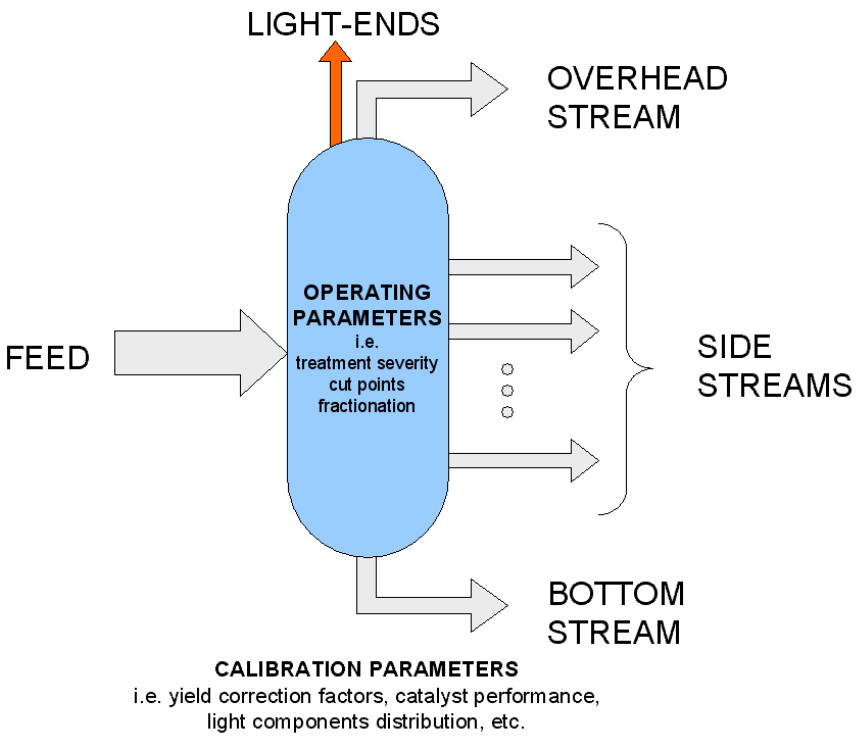
PLANT SIMULATION MODELS

Plant simulation models are integrated in the models and calculate effluents yields and quality as function of feedstock and of meaningful operating variables.



- Fine-tuneable to predict actual performance.
- Need for few input data
- Available processes are:
  - ✓ Distillation (primary and successive)
  - ✓ Hydrogenation and Desulphurisation.
  - ✓ Thermal Conversions (Coking, VB, THC)
  - ✓ Catalytic Conversions (Reforming, FCC, Hydrocracking)
  - ✓ Lubricant (Solvent Dearomatisation and Dewaxing, Catalytic Dewaxing).
- The same algorithms are applied both in SIMRAF and in PROLAV

SIMULATION MODELS – CATALYTIC PROCESSES

PROCESS	VARIABLE	DESCRIPTION
CATALYTIC REFORMING	Feedstock	Density, Distillation, PNA, RVP
	Severity	Reformate C5 PLUS RON
	Pressure	Average reactor Pressure
	Fractionation	Light Ends Distribution
	Cycle advancement	H2 and Reformate EOR Yield Correction
	Model tuning	Hydrogen and Reformate Yield Correction
FLUID CATALYTIC CRACKING	Feedstock	Characterisation Factor (VABP, Sulphur, AP, SG)
	Severity	Gasoline 204°C Vol Conversion
	Feed Type	Hydrotreated or not
	Fractionation	Light Ends Distribution, TBP Cuts and Fractionation Efficiency
	Model tuning	Catalyst performance, C3-204 and Coke yield correction
MILD HYDROCRACKING	Feedstock	Density, Sulphur, Nitrogen, Bromine, Viscosity, Distillation
	Conversion Severity	Wt. Conversion of 375°C Plus fraction
	HDS Severity	% of Feedstock sulphur removed
	H2 Consumption	Detailed HDS, HDN, HDBr, Conversion, Downgrade
	Fractionation	Light Ends Distribution, TBP Cuts and Fractionation Efficiency
HYDROTREATMENT	Feedstock	Density, Sulphur, Nitrogen, Bromine, Distillation, Cold Properties
	HDS Severity	% of Feedstock Sulphur removed or ppm Sulphur out
	HDN Severity	% of Feedstock Nitrogen removed
	HDBr Severity	% of Feedstock Bromine number removed
	Yields	Fuel Gas and Wild Naphtha
	H2 Consumption	Detailed HDS, HDN, HDBr, Conversion, Downgrade

SIMULATION MODELS – THERMAL PROCESSES

PROCESS	VARIABLE	DESCRIPTION
VISBREAKING	Feedstock	Density, Sulphur, Nitrogen, Cold Properties, Viscosity, Conradson, Metals, Asphaltenes, Distillation
	Severity	Wt. Conversion of 371°C Plus fraction
	Feed Type	Atmospheric / Vacuum Residue
	Fractionation	Light Ends Distribution, TBP Cuts and Fractionation Efficiency
	Model tuning	Residue Viscosity Calculation parameters
THERMAL CRACKING	Feedstock	Density, Sulphur, Nitrogen, Cold Properties, Viscosity, Conradson, Metals, Asphaltenes, Distillation
	Severity	Wt. Conversion of 371°C Plus fraction
	Feed Type	Percentage of Recycled VGO
	Fractionation	Light Ends Distribution, TBP Cuts and Fractionation Efficiency
	Model tuning	Residue Viscosity Calculation parameters
COKING	Feedstock	Density, Sulphur, Nitrogen, Cold Properties, Viscosity, Conradson, Metals, Asphaltenes, Distillation
	Feed Type	Atmospheric / Vacuum Residue
	Fractionation	Light Ends Distribution, TBP Cuts and Fractionation Efficiency
	Model tuning	Coke yield correction

SIMULATION MODELS – LUBRICANTS

PROCESS	VARIABLE	DESCRIPTION
SOLVENT DEAROMATISATION	Feedstock	Density, Sulphur, Cold Properties, Viscosity, Viscosity Index Refraction Index, Wax Content, Distillation
	Solvent	Solvent Feed Ratio
	Temperature	Extraction Temperature
	Model tuning	PNA distribution over products for max/min operating variables values (fine tuning for actual unit performance)
SOLVENT DEWAXING	Feedstock	Density, Sulphur, Cold Properties, Viscosity, Viscosity Index Refraction Index, Wax Content, Distillation
	Separation	Hard / Soft wax ratio
	Model tuning	Hard wax oil content / soft wax oil content
CATALYTIC DEWAXING	Feedstock	Density, Sulphur, Cold Properties, Viscosity, Viscosity Index Refraction Index, Wax Content, Distillation
	Severity	Product Pour Point
	HDS Severity	% of Feedstock sulphur removed
	Cycle	Cycle advancement
	Fractionation	Light Ends Distribution.
	Model tuning	SOR/EOR Light Ends and Naphtha Yields, Min/Max/Design LHSV, SOR/Min/Max Reactor Temperature, Hydrogen consumption (Detailed HDS, HDN, HDBr, Conversion, Downgrade)

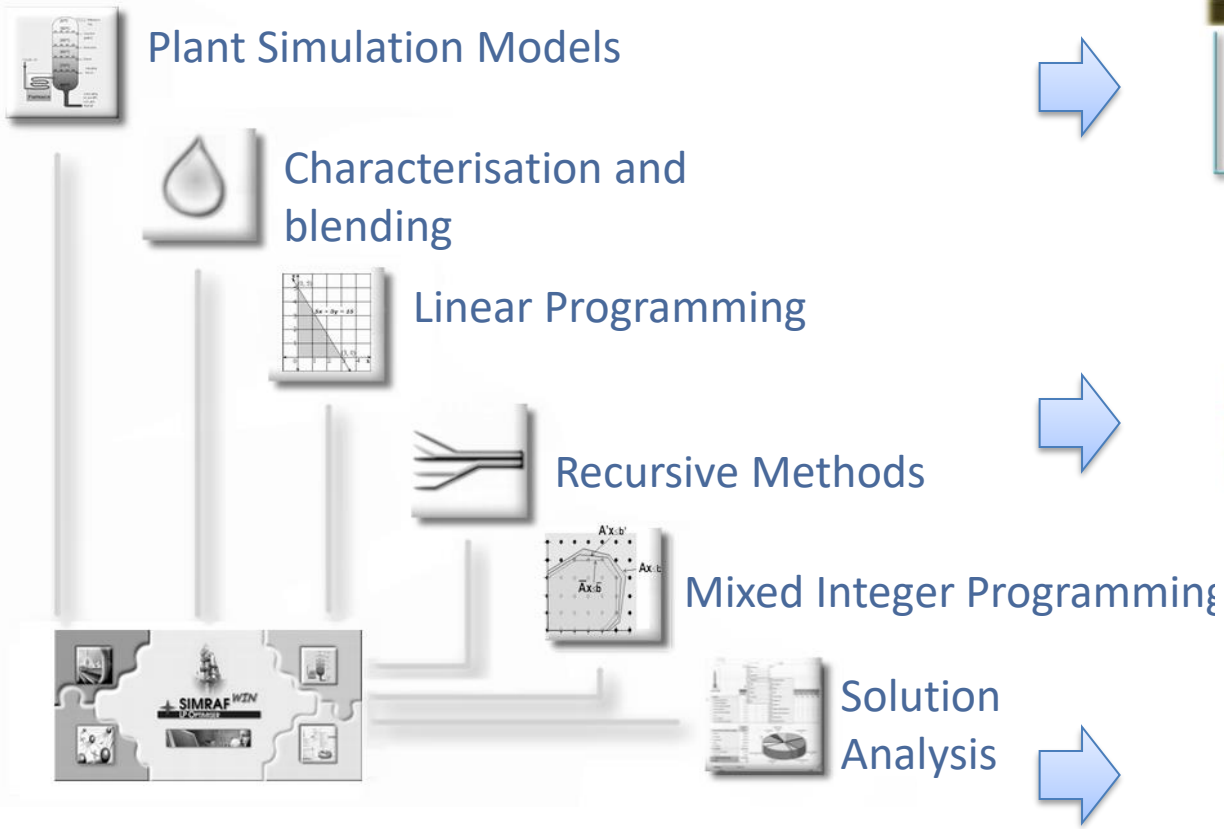
SIMRAF – LP PLANNING TOOL: APPLICATIONS

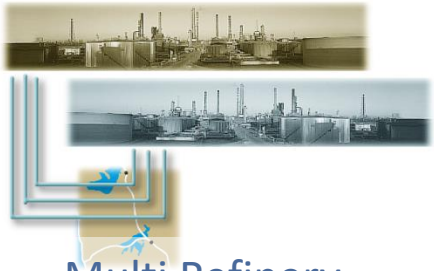
Conceived by refinery experts it an "industry oriented" LP tool.

Intuitive for oil downstream professionals supports the addressing of strategic and ordinary planning problems:

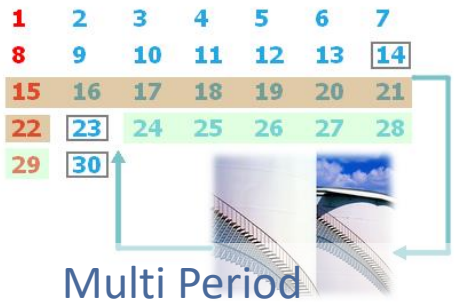
SIMRAF TECHNOLOGIES

The competitive advantage results from the availability in the same environment of simulation and optimisation technologies:

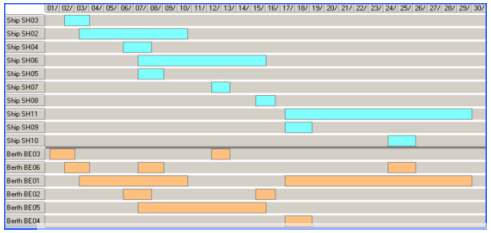




Multi Refinery



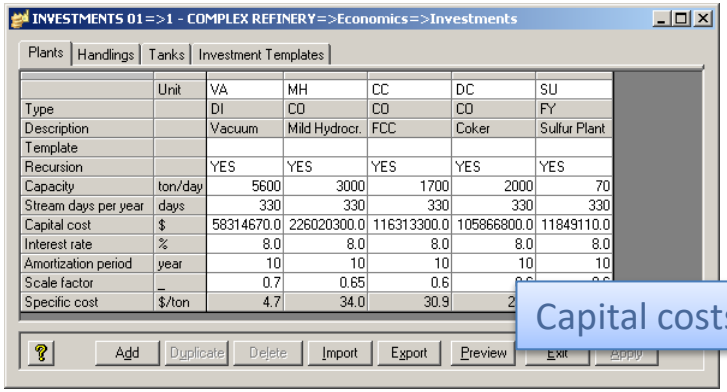
Multi Period



Optimised Scheduling

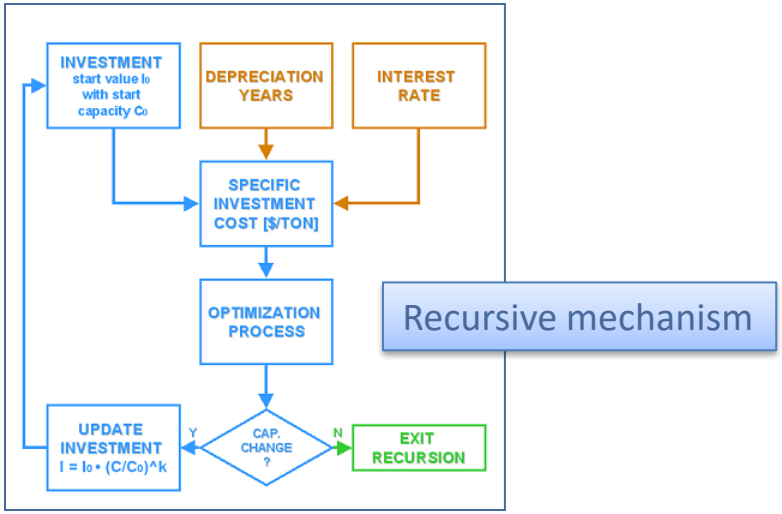
STRATEGIC PLANNING STUDIES

SIMRAF disposes of particular features useful in case of strategic Planning studies for new investments.



	Unit	VA	MH	CC	DC	SU
Type		DI	CO	CO	CO	FY
Description		Vacuum	Mild Hydrocr.	FCC	Coker	Sulfur Plant
Template						
Recursion		YES	YES	YES	YES	YES
Capacity	ton/day	5600	3000	1700	2000	70
Stream days per year	days	330	330	330	330	330
Capital cost	$	58314670.0	226020300.0	116313300.0	105866800.0	11849110.0
Interest rate	%	8.0	8.0	8.0	8.0	8.0
Amortization period	year	10	10	10	10	10
Scale factor	_	0.7	0.65	0.6		
Specific cost	$/ton	4.7	34.0	30.9	2	

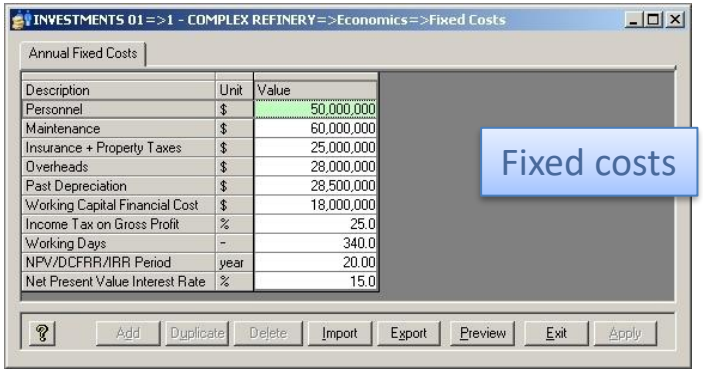
Capital costs



Recursive mechanism

ECONOMIC RESULTS	UNIT	VALUE
Sales	$	3,426,333,174
Purchases	$	2,767,892,727
Variable Costs	$	11,698,200
Personnel	$	52,058,822
Maintenance	$	62,470,586
Insurance + Property Taxes	$	26,029,411
Overheads	$	29,152,940
Total Production Costs	$	2,949,302,686
Interest on Investments Debt	$	27,560,640
Interest on working capital	$	18,741,176
Fixed Depreciation		673,528
Valued Depreciatic		471,322
Total Costs		749,352
Taxable income	$	349,583,821
Income Tax	$	87,395,955
Net Income	$	262,187,866
Capital Costs	$	494,357,343
Cash Flow	$	329,754,597
Pay Out Period	year	1.50
DCFRR - IRR	%	66.7

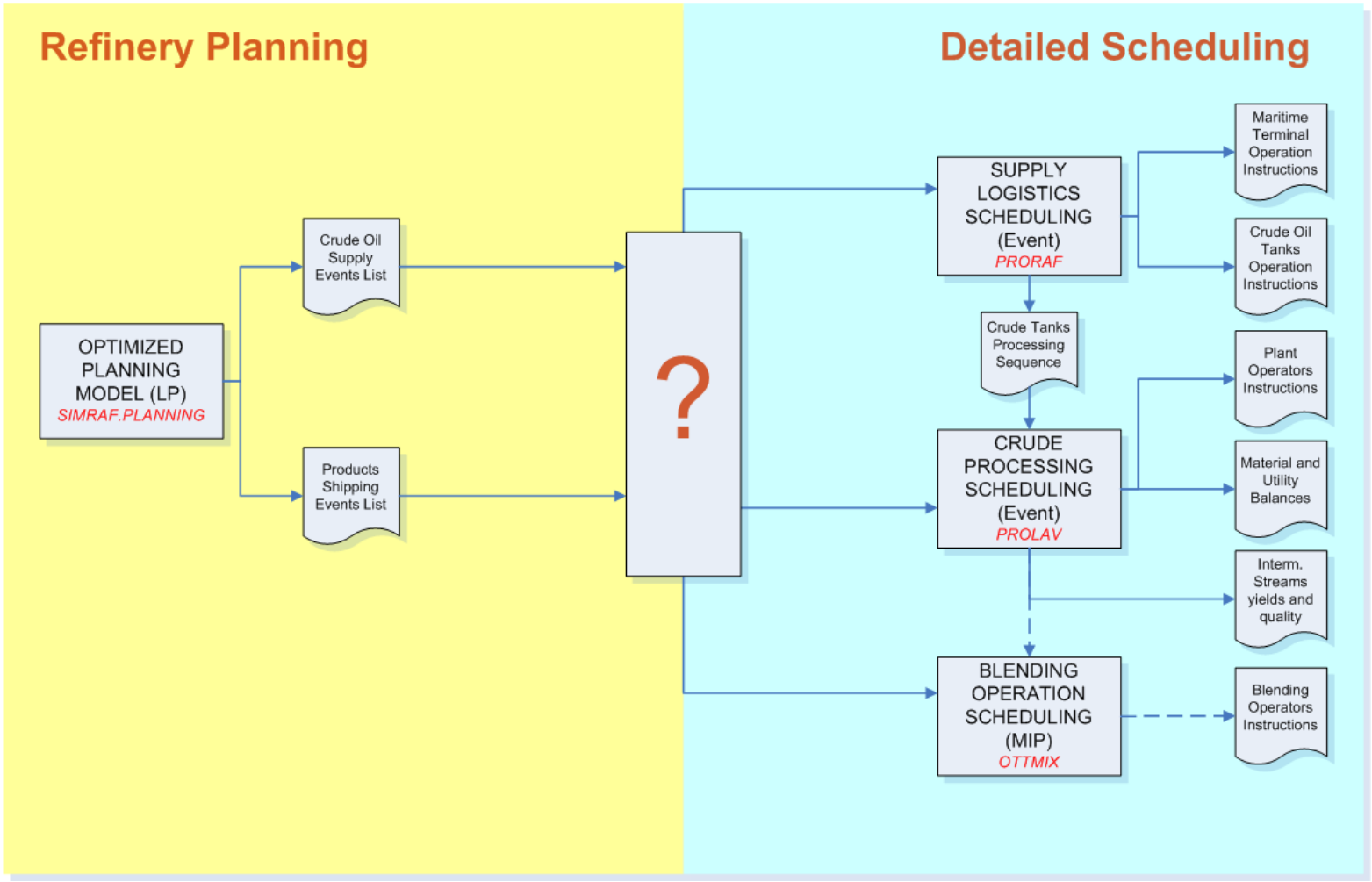
Financial result



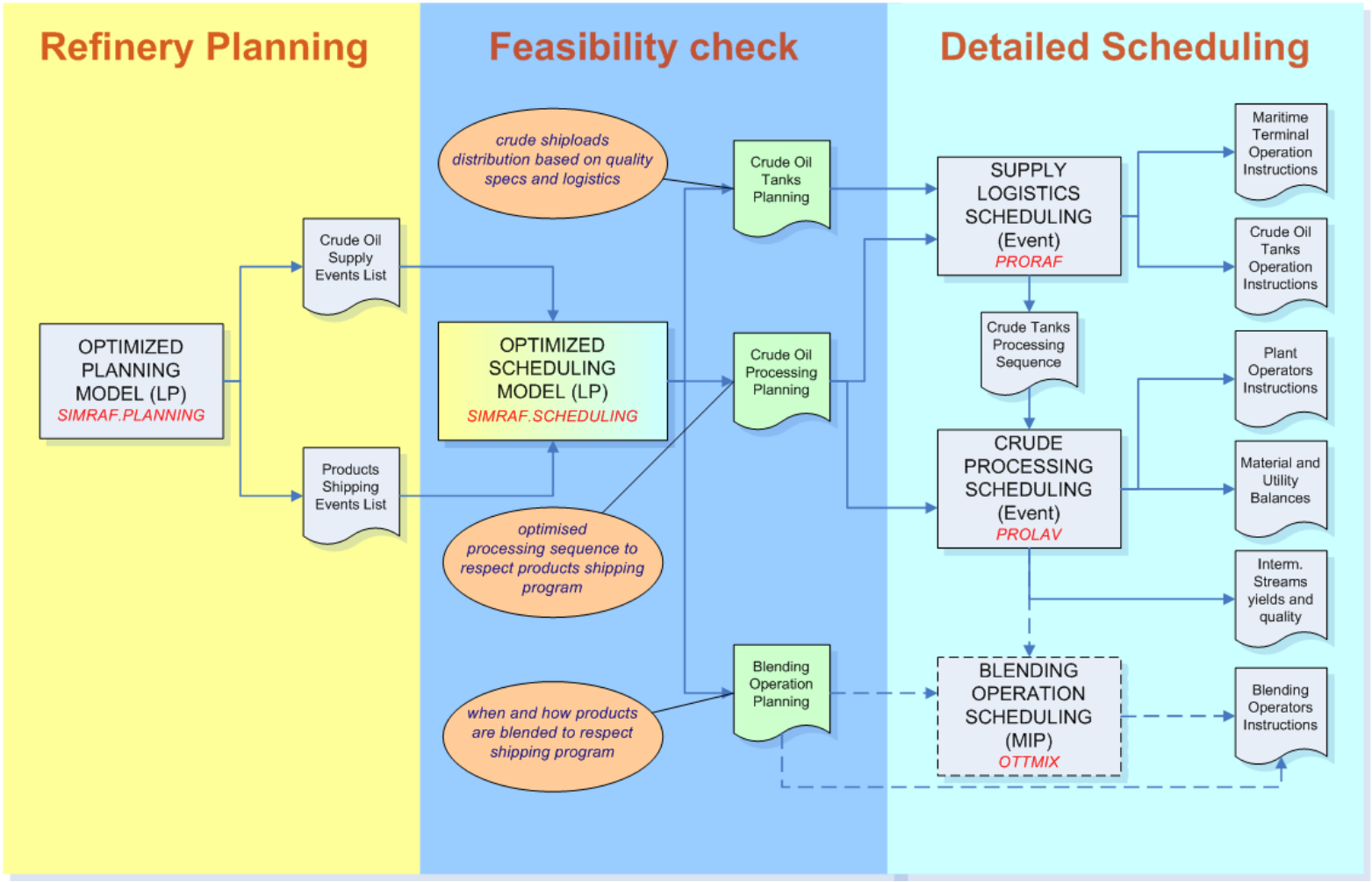
Description	Unit	Value
Personnel	$	50,000,000
Maintenance	$	60,000,000
Insurance + Property Taxes	$	25,000,000
Overheads	$	28,000,000
Past Depreciation	$	28,500,000
Working Capital Financial Cost	$	18,000,000
Income Tax on Gross Profit	%	25.0
Working Days	-	340.0
NPV/DCFRR/IRR Period	year	20.00
Net Present Value Interest Rate	%	15.0

Fixed costs

TURNING PLANNING INTO REALITY…

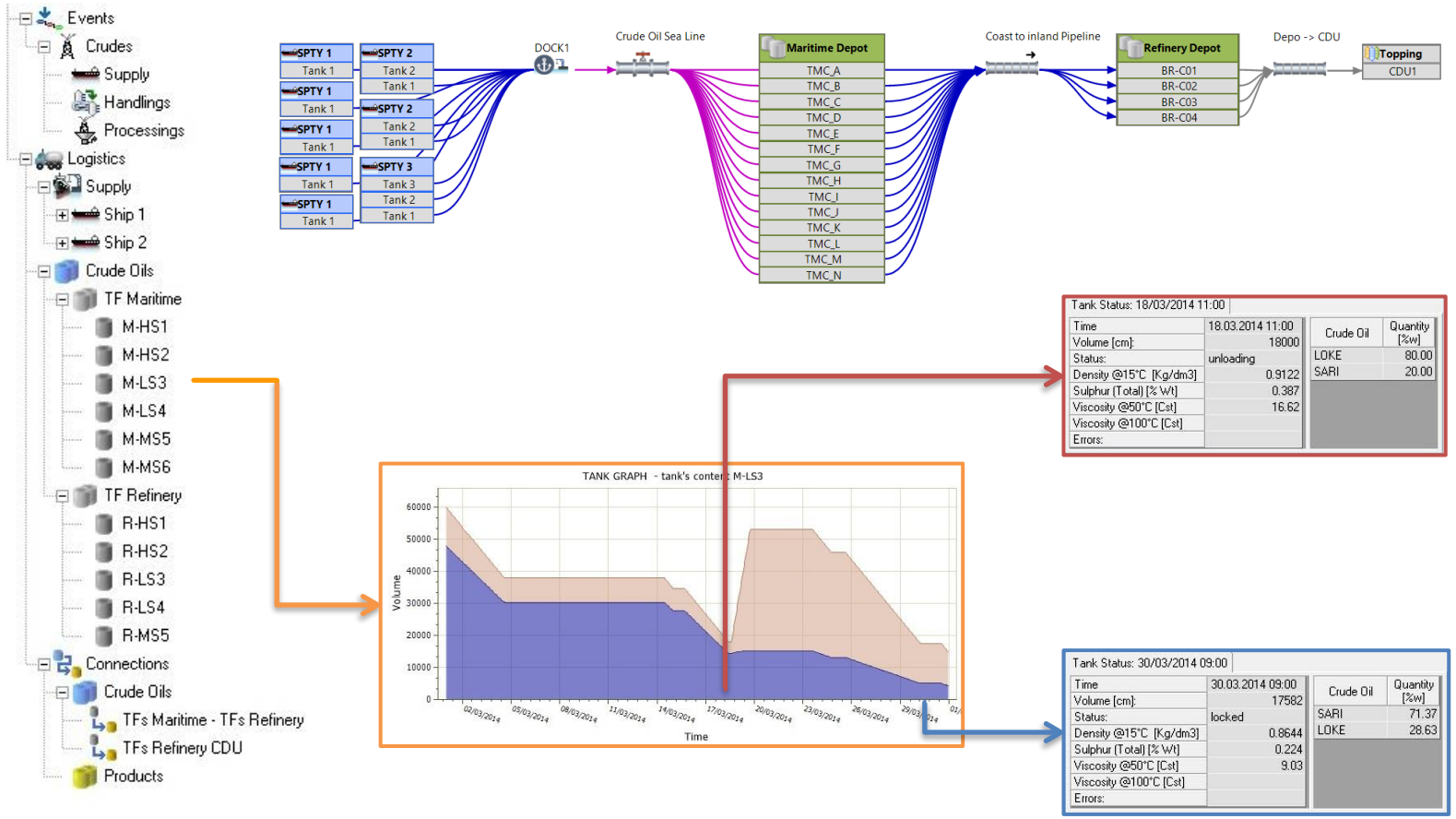


PLANNING FEASIBILITY CHECK



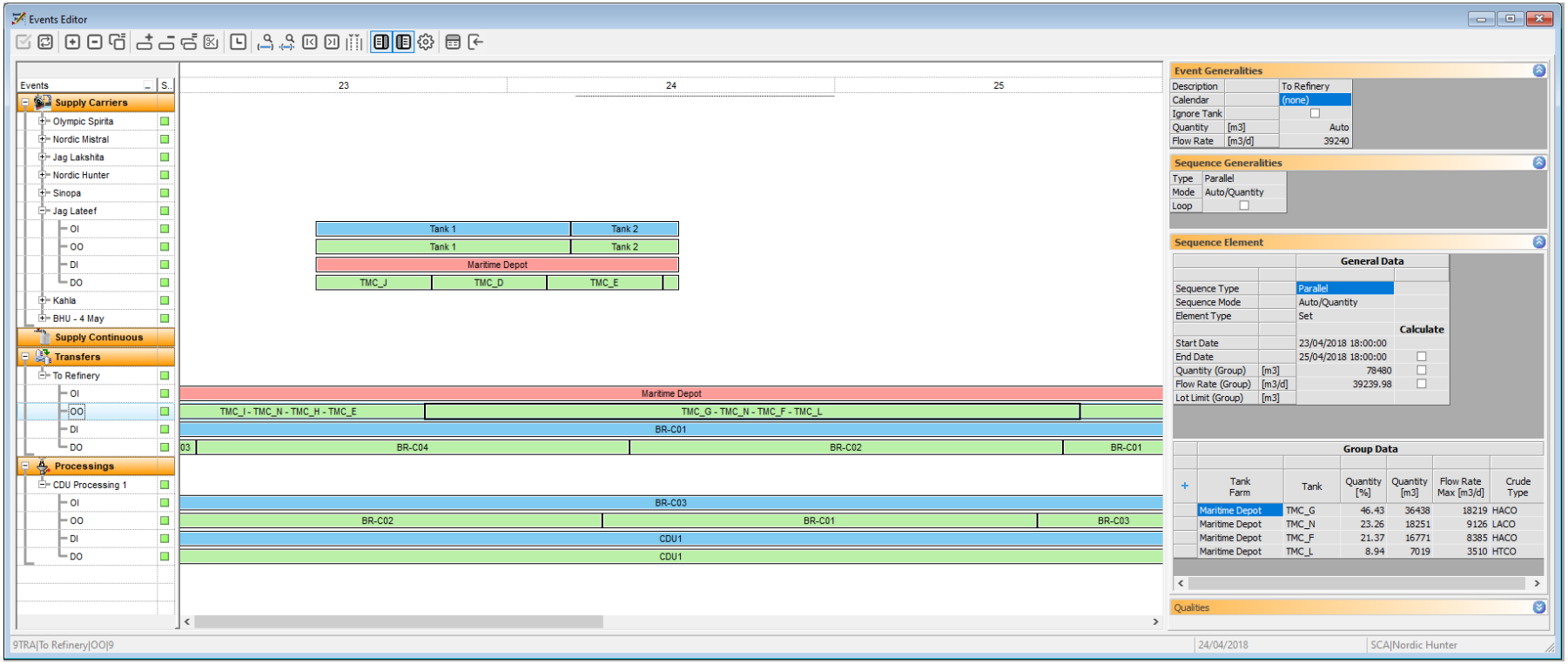
PRORAF: LOGISTICS SIMULATION

Considering supply, handling and processing events calculates the hourly evolution of each tank status, returning volume and composition for each tank to be processed.



PRORAF: EVENTS EDITOR

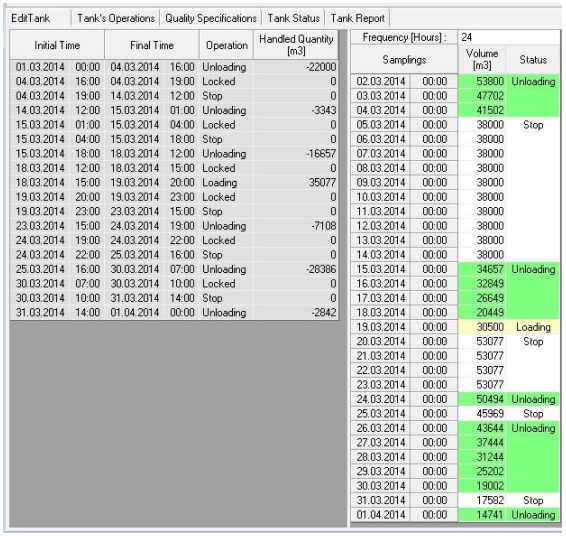
This environment enables the definition of transfer events and the setting of related parameters (type, calculation mode, origin, destination, volume, flow rate and quality constraints).

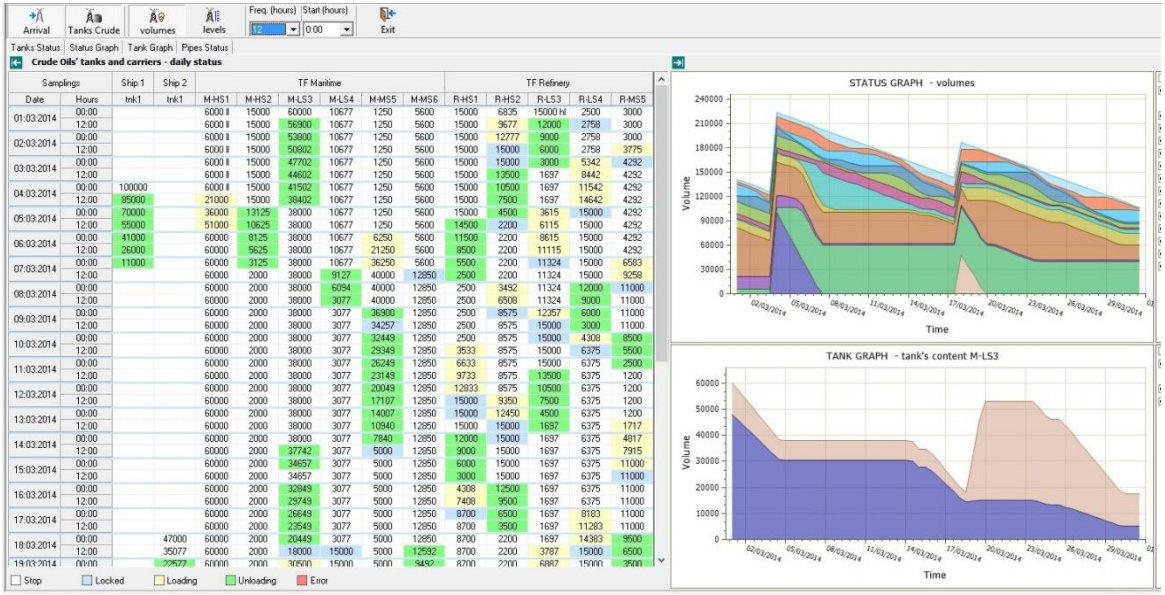


PRORAF: CALCULATION ENGINE

Manages the service requests for supply, handling and processing events to produce an operative plan considering:

- Volume and pumping (Load/Unload) constraints
- Status (volume and content) and availability
- Handling operations (Drainage, Measurements)
- Quality specifications
- Pipeline quality tracking
- Tank selection logics



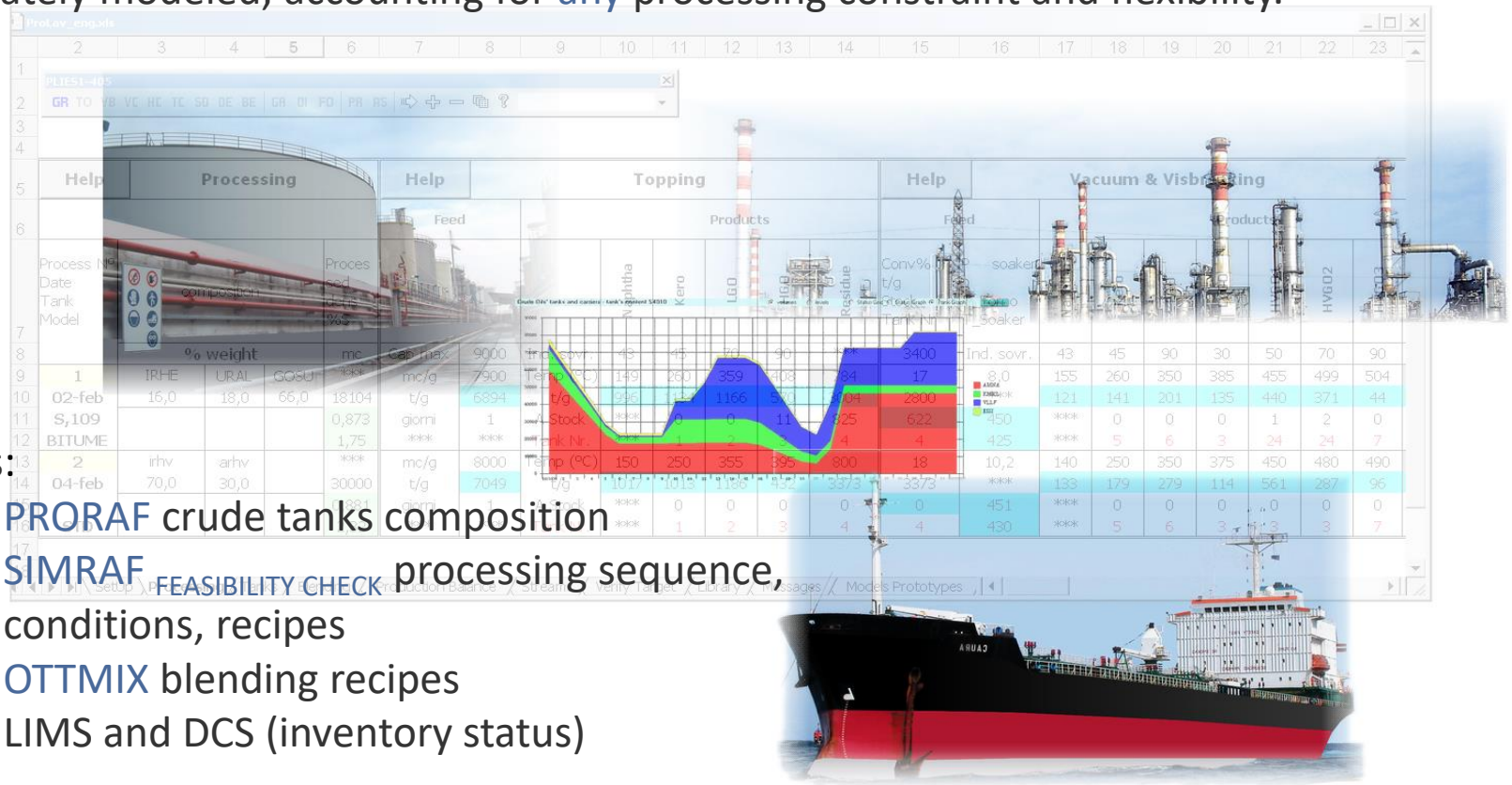


PROMETHEUS

PROLAV: WIDE REFINERY MODEL

PROLAV finds the best scheduling program considering supply, logistics and processing constraints:

- Simulates the processing of a sequence of crude tanks. Refinery operation is accurately modeled, accounting for any processing constraint and flexibility.

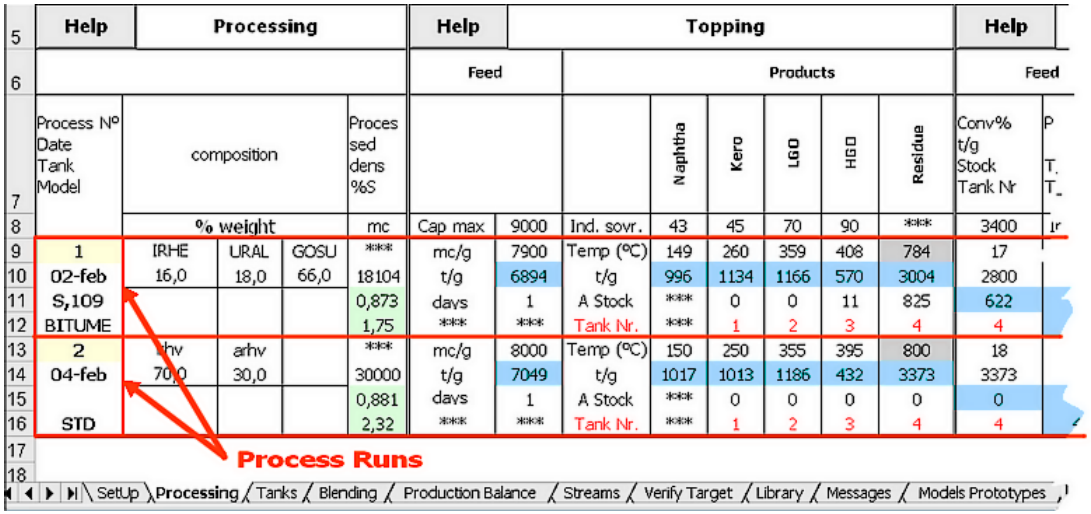


- Links:
  - ✓ PRORAF crude tanks composition
  - ✓ SIMRAF processing sequence, conditions, recipes
  - ✓ OTTMIX blending recipes
  - ✓ LIMS and DCS (inventory status)

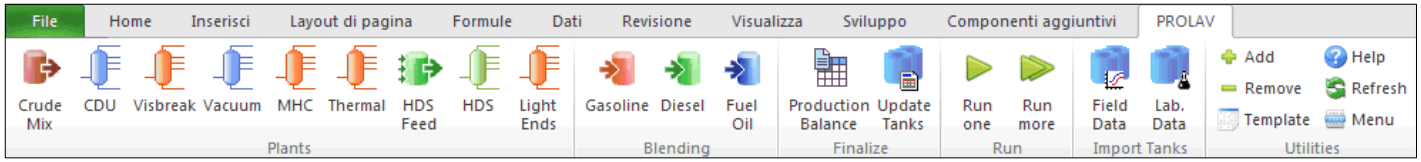
PROLAV: FEATURES

PROLAV applies crude characterization database and plant simulation models to simulate refinery daily operation calculating:

- Yields and refinery material balance
- Fuels and utilities
- Hydrogen balance
- Inventories
- Operative instructions
- KPIs
- Production control
- Energy performance
- Blending



The model is built to follow and reproduce client's consolidated operative flexibilities and is operated through an Excel interface.



THANK YOU!

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