Facilitating On-Demand Risk and Actuarial Analysis in MATLAB

Timo Salminen, CFA, FRM
Model IT

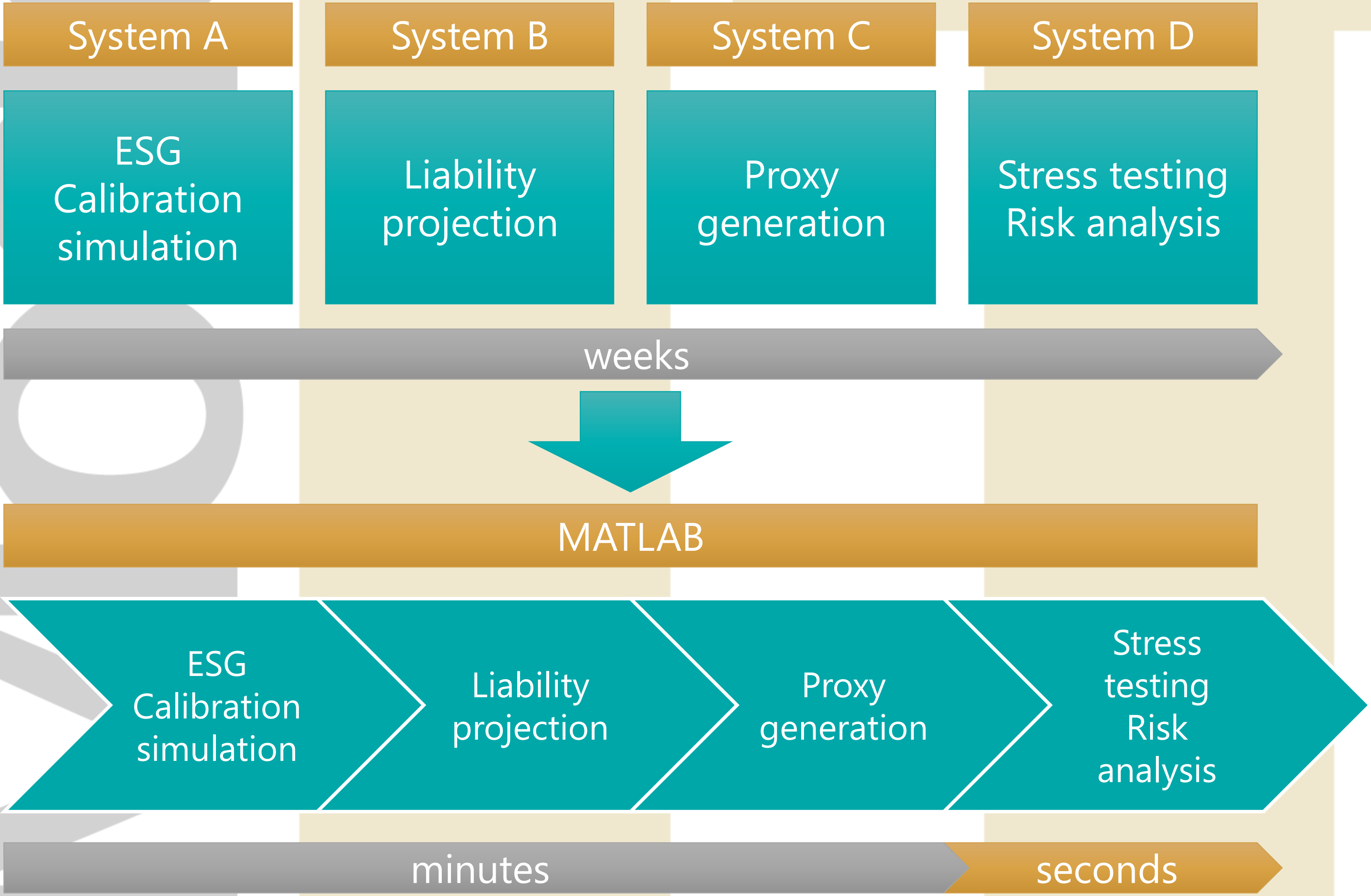
Introduction

- It is common that insurance companies can valuate their liabilities only quarterly
  - Sufficient for official valuation and capital calculations

- Market (consistent) value of liabilities can be quite volatile

- Need for
  1. knowing liability / equity value today
  2. risk analysis and stress testing
  3. hedge planning / re-balancing
  4. business forecasting

Facilitating on-demand calculations
Current challenges



System A

ESG Calibration simulation

System B

Liability projection

System C

Proxy generation

System D

Stress testing Risk analysis

weeks

MATLAB

ESG Calibration simulation

Liability projection

Proxy generation

Stress testing Risk analysis

minutes

seconds

Agenda
Building blocks for on-demand analysis

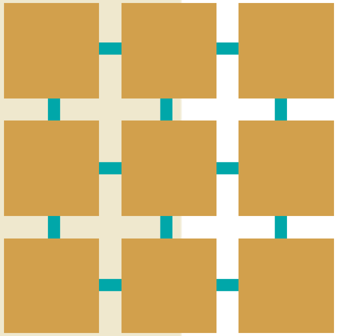
Building models with Business Language

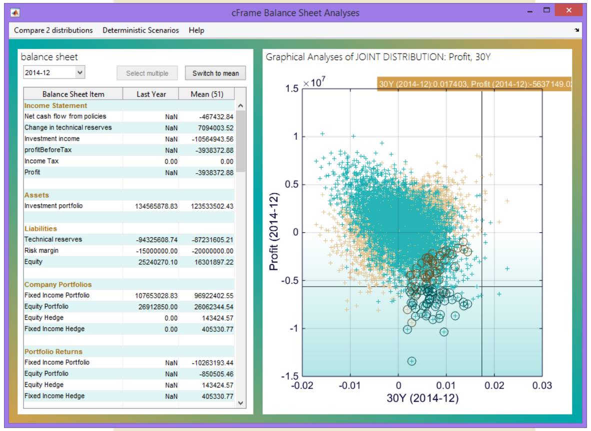
High-Performance Simulation of the model

Interactive visualization

```
%% Define Variable Annuity product terms
myVAProduct_2007 = ...
    cFrame.CashFlowEngine.ContractType(...
    'Name', 'VA Terms 2B/2007');

%% Add claim cash flow
life.AddCashFlow(...
    'Id',            'CLAIM_DEATH',...
    'Name',          'Death claim', ...
    'Payer',         'company', ...
    'Receiver',      'customer', ...
    'TriggerEvent',  'death_of_customer', ...
    'Amount',        @vaClaimAmountFcn
    );
```





Balance Sheet Item	Last Year	Mean (51)
Income Statement		
Net cash flow from policies	NaN	-467432.84
Change in technical reserves	NaN	7094003.52
Investment income	NaN	-10564943.56
profitBeforeTax	NaN	-3938372.88
Income Tax	0.00	0.00
Profit	NaN	-3938372.88
Assets		
Investment portfolio	134565878.83	123533502.43
Liabilities		
Technical reserves	-94325608.74	-87231605.21
Risk margin	-15000000.00	-20000000.00
Equity	25240270.10	16301897.22
Company Portfolios		
Fixed Income Portfolio	107653028.83	96922402.55
Equity Portfolio	26912850.00	26062344.54
Equity Hedge	0.00	143424.57
Fixed Income Hedge	0.00	405330.77
Portfolio Returns		
Fixed Income Portfolio	NaN	-10263193.44
Equity Portfolio	NaN	-850505.46
Equity Hedge	NaN	143424.57
Fixed Income Hedge	NaN	405330.77

Graphical Analyses of JOINT DISTRIBUTION: Profit, 30Y
30Y (2014-12):0.017403, Profit (2014-12):-5637149.0
×10^7
1.5
1
0.5
0
-0.5
-1
-1.5
Profit (2014-12)
-0.02
-0.01
0
0.01
0.02
0.03
30Y (2014-12)

Case: Life Insurance

Policy-by-policy simulation

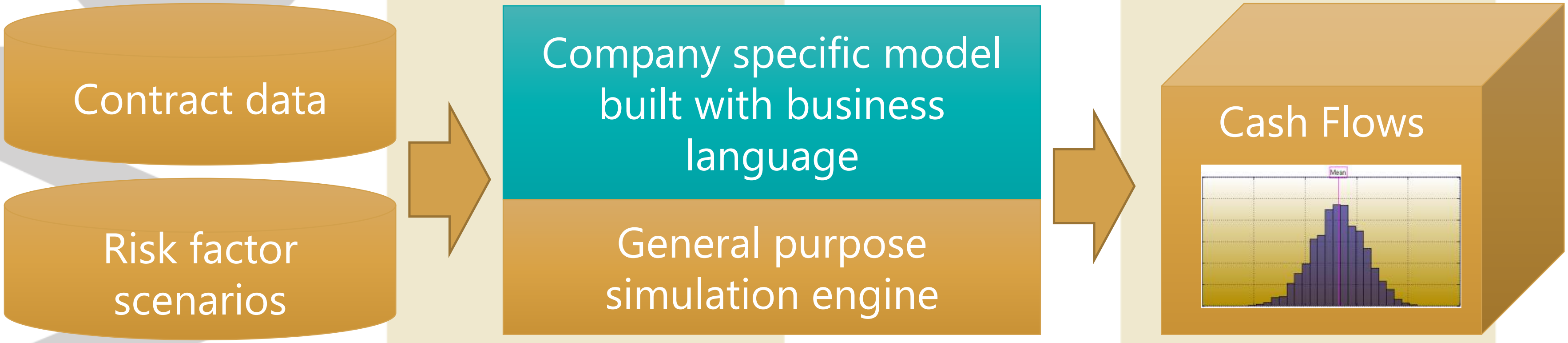
Proxy Modeling

Building models with “business language”

Business language

- Natural language designed to create realistic contract-by-contract cash flow simulation models
  - 100% replication of real-life contract terms
  - Ability to use real data

- Define all financial contracts as cash-flow exchange agreements
  - Cash flows depend on stochastic events



Contract data

Risk factor scenarios

Company specific model built with business language

General purpose simulation engine

Cash Flows

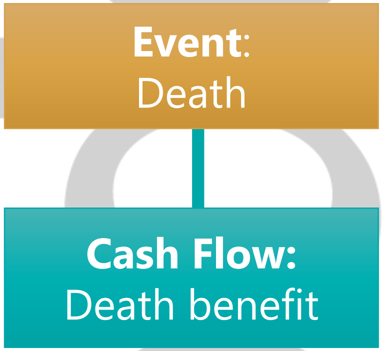
Example: Defining the death benefit

max(savings account, cumulative net payments)

Cash Flow:
Death benefit

```
myProduct.AddCashFlow(...
    ... Cash flow ID links cash flow to balance sheet
    'Id',           'DEATH_BENEFIT',...
    ... Long name makes analyzing results easier
    'Name',         'Death Benefit payment', ...
    ... Company pays the claim
    'Payer',        'company', ...
    ... Customer receives the claim
    'Receiver',     'customer', ...
    ... Cash flow is triggered when event 'death' occurs
    'TriggerEvent', 'death', ...
    ... The amount function can be any MATLAB function
    'Amount', @(model, customer, contract, eventdata)...
        max(eventdata.investmentFund, eventdata.cumNetPayments));
```

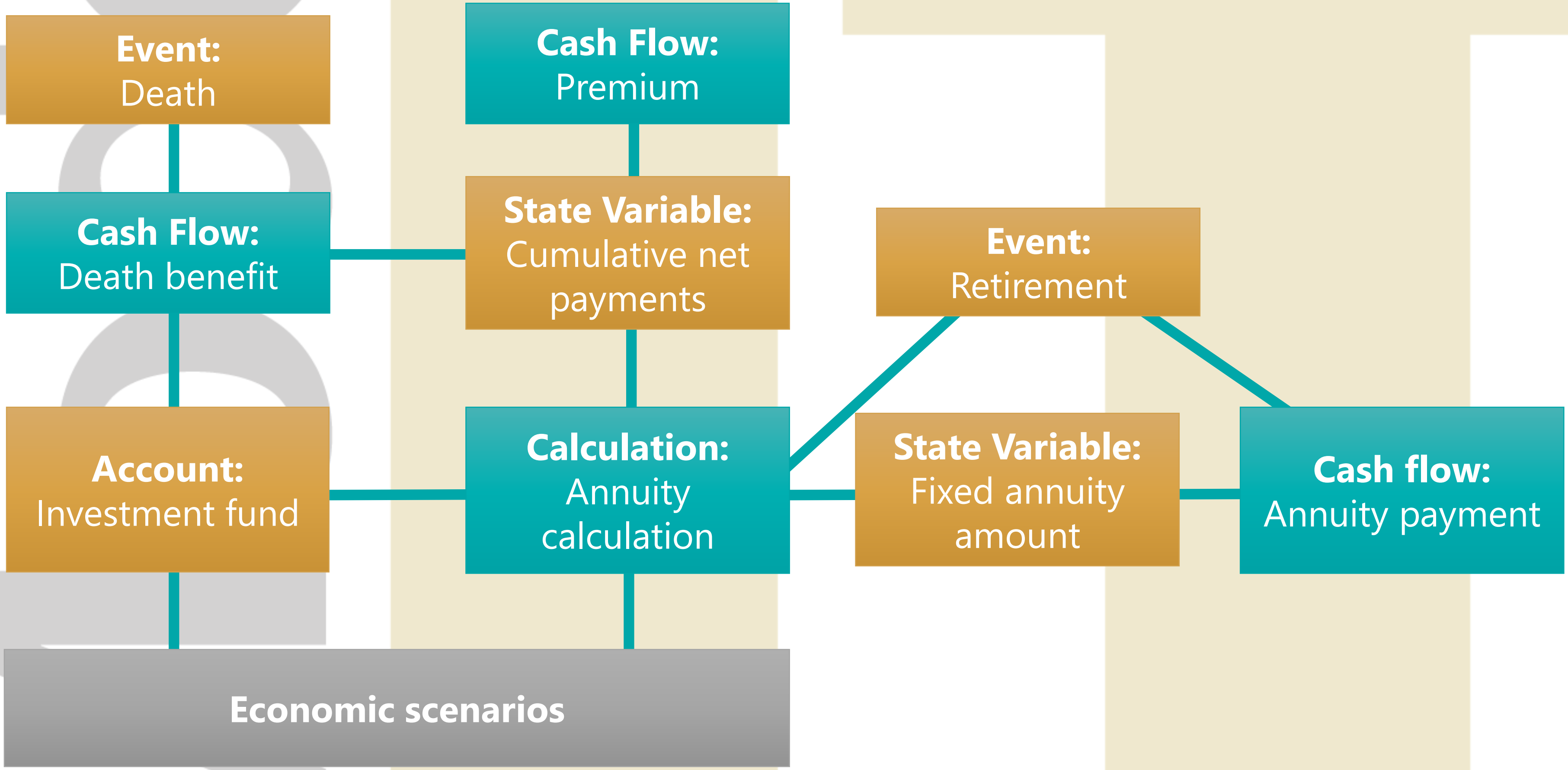
Example: Defining the death event



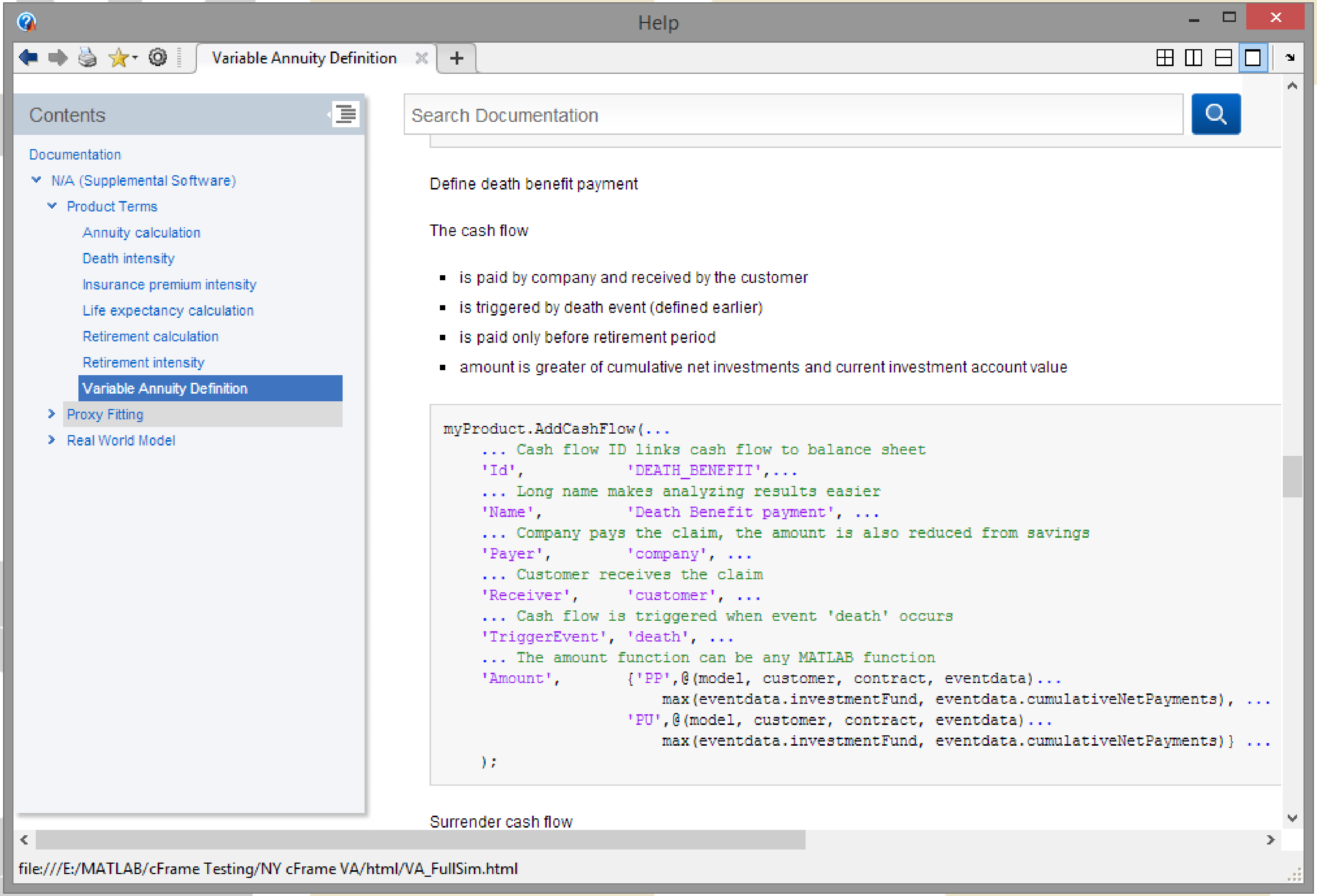
```
cfModel.DefineRandomVariable(...
    ... This links this random variable to product definitions<html>
    'Name',         'death', ...
    ... This event "happens" to customer and affects all customer's
contracts
    'Target',       'customer', ...
    ... This is a event (can also be a process)
    'Type',         'event', ...
    ... This event can happen only once
    'Occurence',    'single', ...
    ... A function that returns monthly intensities for this event
    'IntensityFun', @deathIntensity;
```

Completing the model

some example objects


Event: Death
Cash Flow: Premium
Cash Flow: Death benefit
State Variable: Cumulative net payments
Event: Retirement
Account: Investment fund
Calculation: Annuity calculation
State Variable: Fixed annuity amount
Cash flow: Annuity payment
Economic scenarios

Documentable


Help
Variable Annuity Definition
Contents
Documentation
N/A (Supplemental Software)
Product Terms
Annuity calculation
Death intensity
Insurance premium intensity
Life expectancy calculation
Retirement calculation
Retirement intensity
Variable Annuity Definition
Proxy Fitting
Real World Model
Search Documentation
file:///E:/MATLAB/cFrame Testing/NY cFrame VA/html/VA_FullSim.html

Define death benefit payment

The cash flow

- is paid by company and received by the customer
- is triggered by death event (defined earlier)
- is paid only before retirement period
- amount is greater of cumulative net investments and current investment account value

```
myProduct.AddCashFlow(...
    ... Cash flow ID links cash flow to balance sheet
    'Id',            'DEATH_BENEFIT',...
    ... Long name makes analyzing results easier
    'Name',          'Death Benefit payment', ...
    ... Company pays the claim, the amount is also reduced from savings
    'Payer',         'company', ...
    ... Customer receives the claim
    'Receiver',      'customer', ...
    ... Cash flow is triggered when event 'death' occurs
    'TriggerEvent', 'death', ...
    ... The amount function can be any MATLAB function
    'Amount',        {'PP',@(model, customer, contract, eventdata)...
                         max(eventdata.investmentFund, eventdata.cumulativeNetPayments), ...
                     'PU',@(model, customer, contract, eventdata)...
                         max(eventdata.investmentFund, eventdata.cumulativeNetPayments)} ...
    );
```

Surrender cash flow

Making contract-by-contract possible

Comparison using 10 000 scenarios, n computation nodes

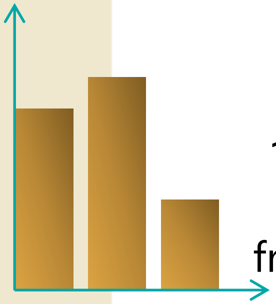
	Traditional systems **Designed for deterministic modelling**	Our approach **Designed for stochastic modelling**
Model is run	**10 000 times** With full overhead for each scenario	**1 time** Overhead from model logic and contract terms only once Stochastic items (accounts, state variables) are handled efficiently with matrix mathematics
One node handles	**All contracts** Close to impossible to use real data of millions of contracts	**1/n of policies** Any number of contracts can be handled with distributed computing

Parallel computing

- Distributable to clusters and Amazon EC2 cloud using MATLAB Distributed Computing Server
  - Accessible from MATLAB workspace
  - Close to linear speedup
- However, contracts may not be independent
  - e.g. company profit sharing to policies depends on performance of the total liability portfolio
  - need to synchronize all policies between company decision points (typically 60)
- MATLAB provided “synchronization” functions (gop) gather results very efficiently
  - Still each second spent increases total time by 60 seconds!
  - Usually not efficient to target simulation times of under 10 minutes.

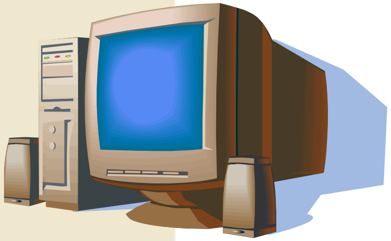
Use Case: Fennia Life

1 000 scenarios



60 years
150 Variable
time steps
from 1 month
to 1 year

60 000 policies
With profit annuity
30 cash flow and balance
sheet items



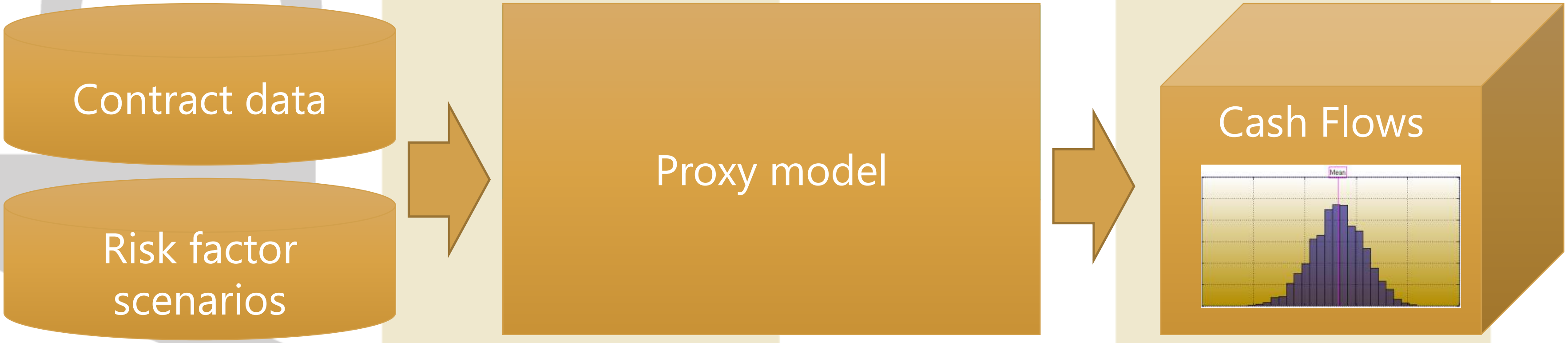
1 desktop computer
12 cores
24 GB RAM
~ EUR 3 000

30 minutes

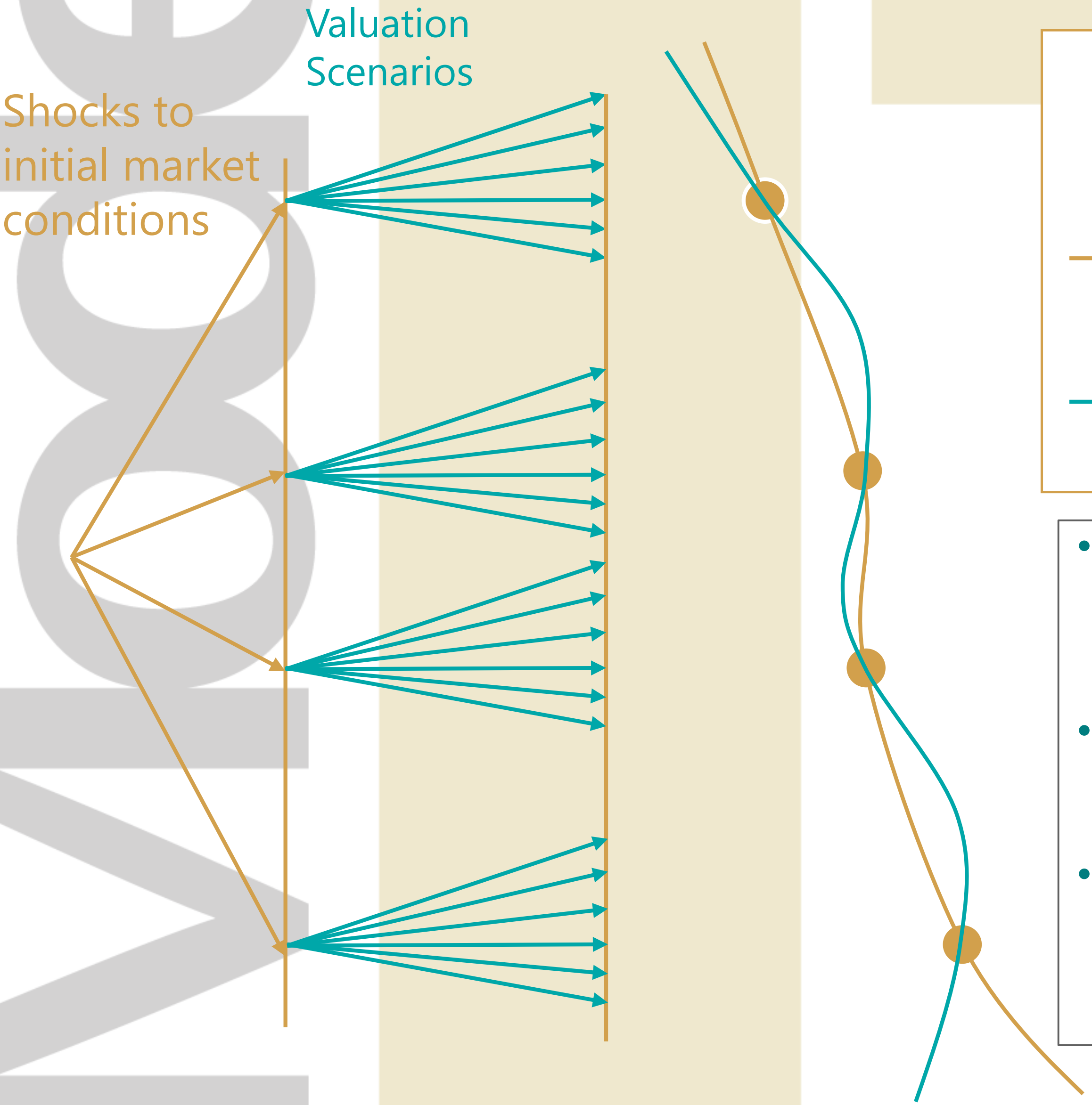
Proxy modeling

- Still calculating market (consistent) value for liabilities takes minutes or even hours

- For risk analysis, we need thousands of valuations in seconds ➔ Proxy modeling



Traditional way: Regression Analysis



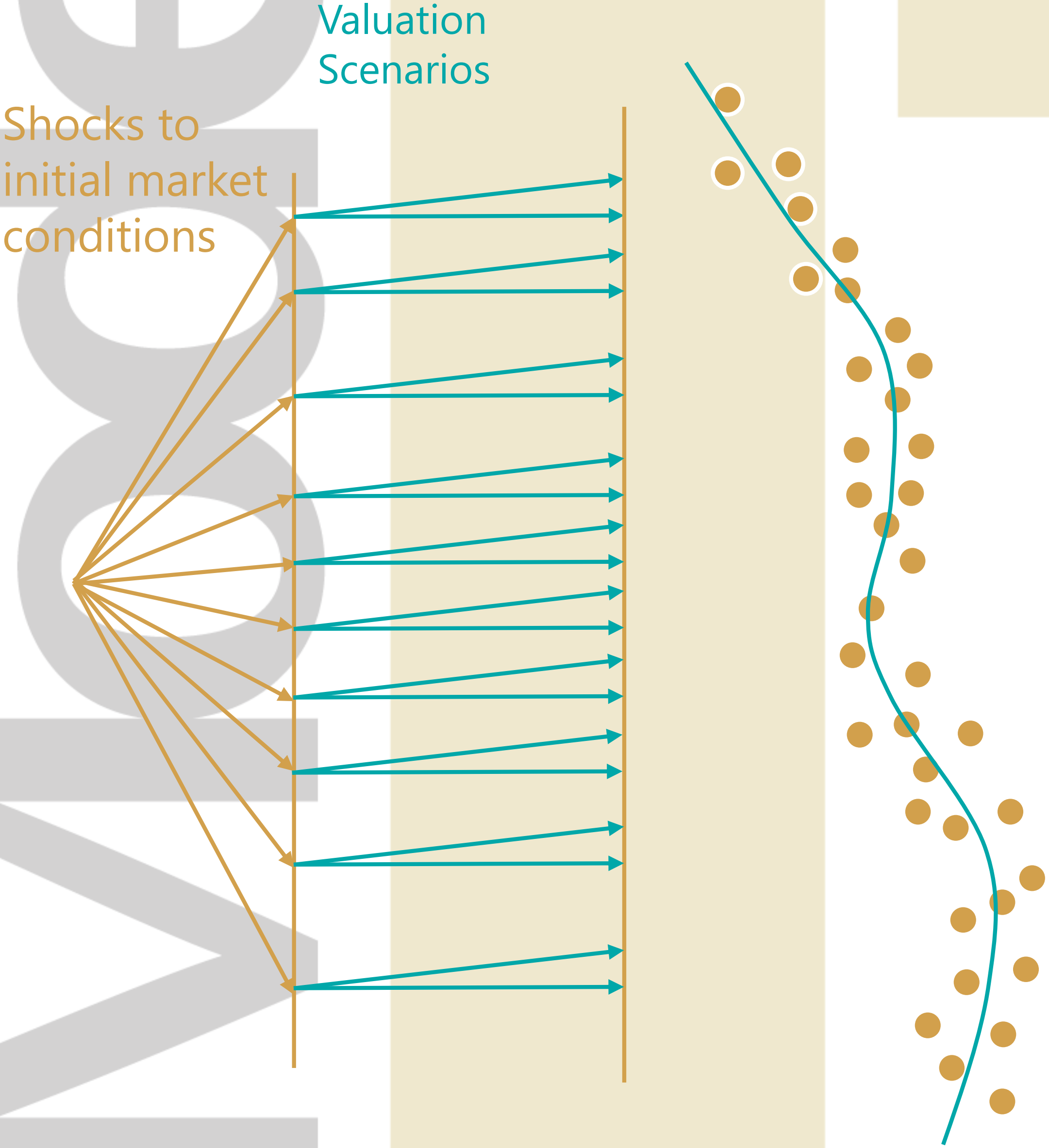
● Shocked liability values

— Fitted polynomial

— True liability value

- Lots of scenarios required (typically at least 50 000)
- Still only a fraction of space covered
- Fitting points and function form must be decided beforehand

Least Squares Monte Carlo



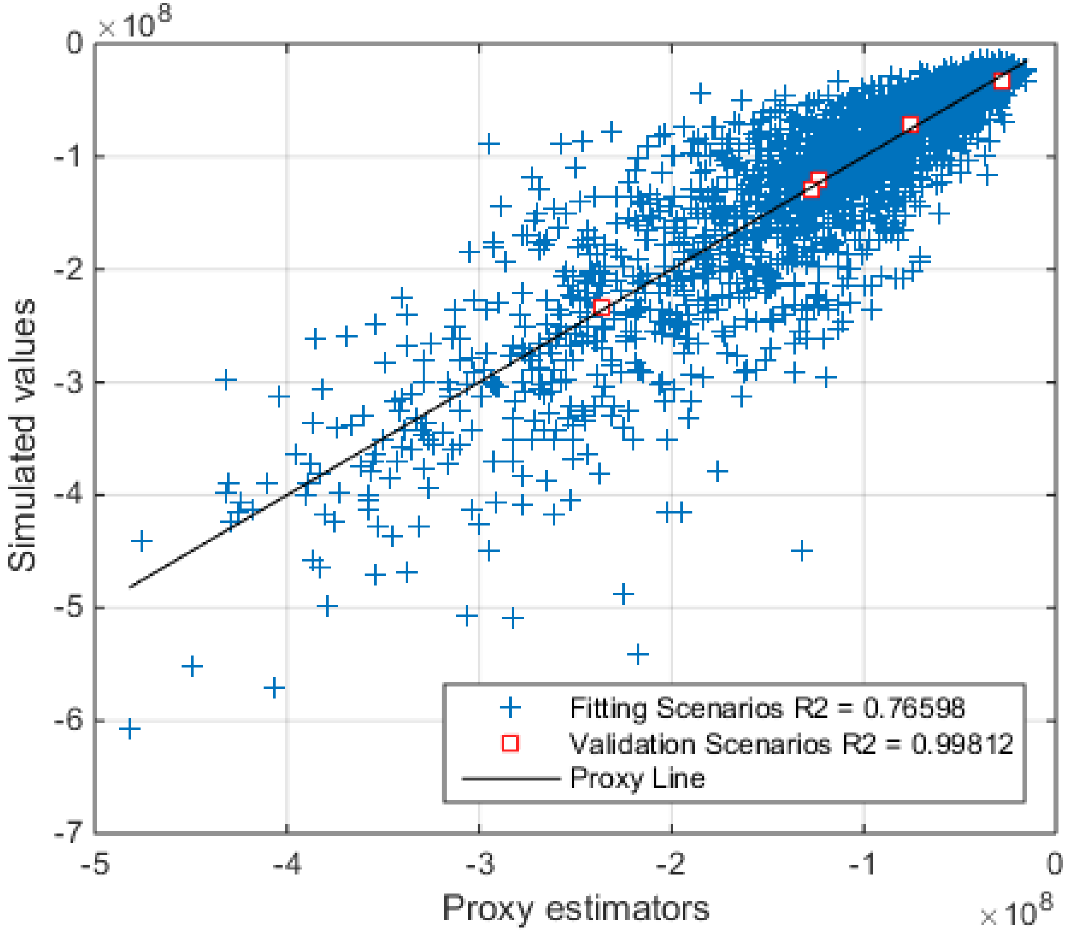
● Shocked liability values

— Fitted polynomial

- Independent error terms with zero expected value
- Much less scenarios required (typically 5 000)
- No need for selecting fitting points or function form beforehand

Validation

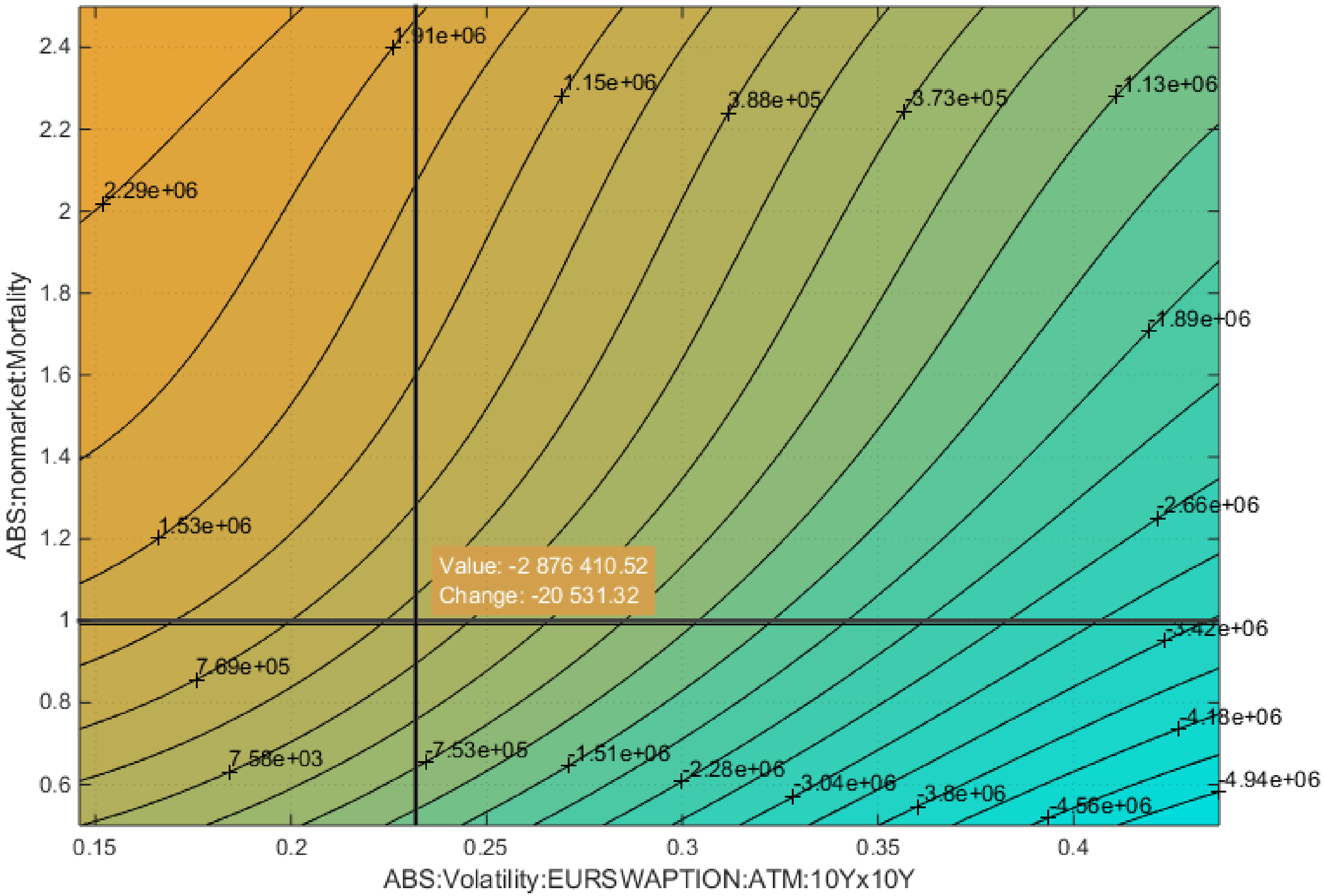
- Proxy model can be always validated by running full valuations at selected validation points and comparing results to proxy value



- 2500 shocks
- 5 validation points
- On proxy line, cash flow model and proxy model produce the same result

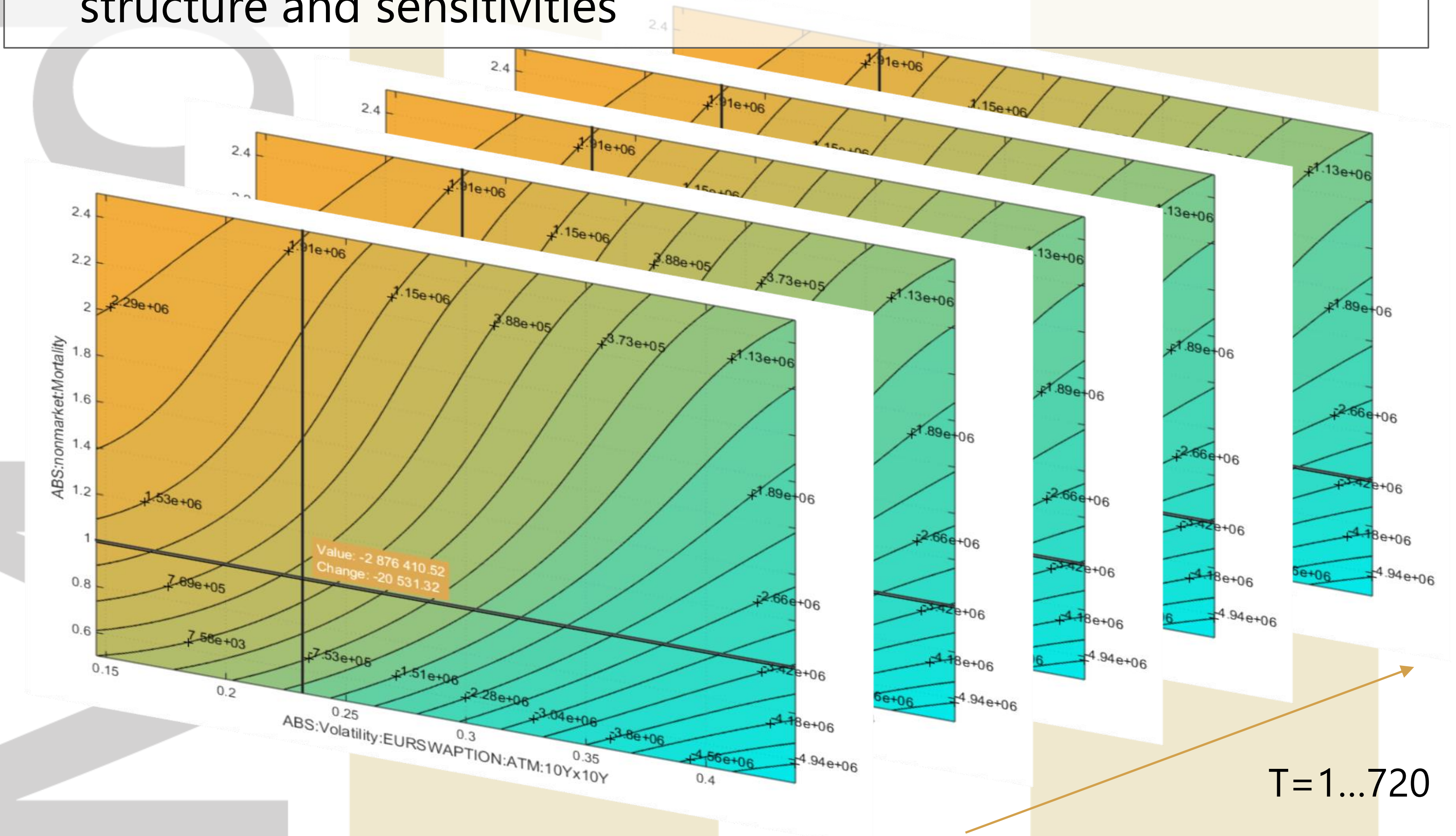
Result

- Liability value as a function of risk drivers



Time-decomposition

- Fitting an independent polynomial for each future time step provides a new level information about the liability time structure and sensitivities

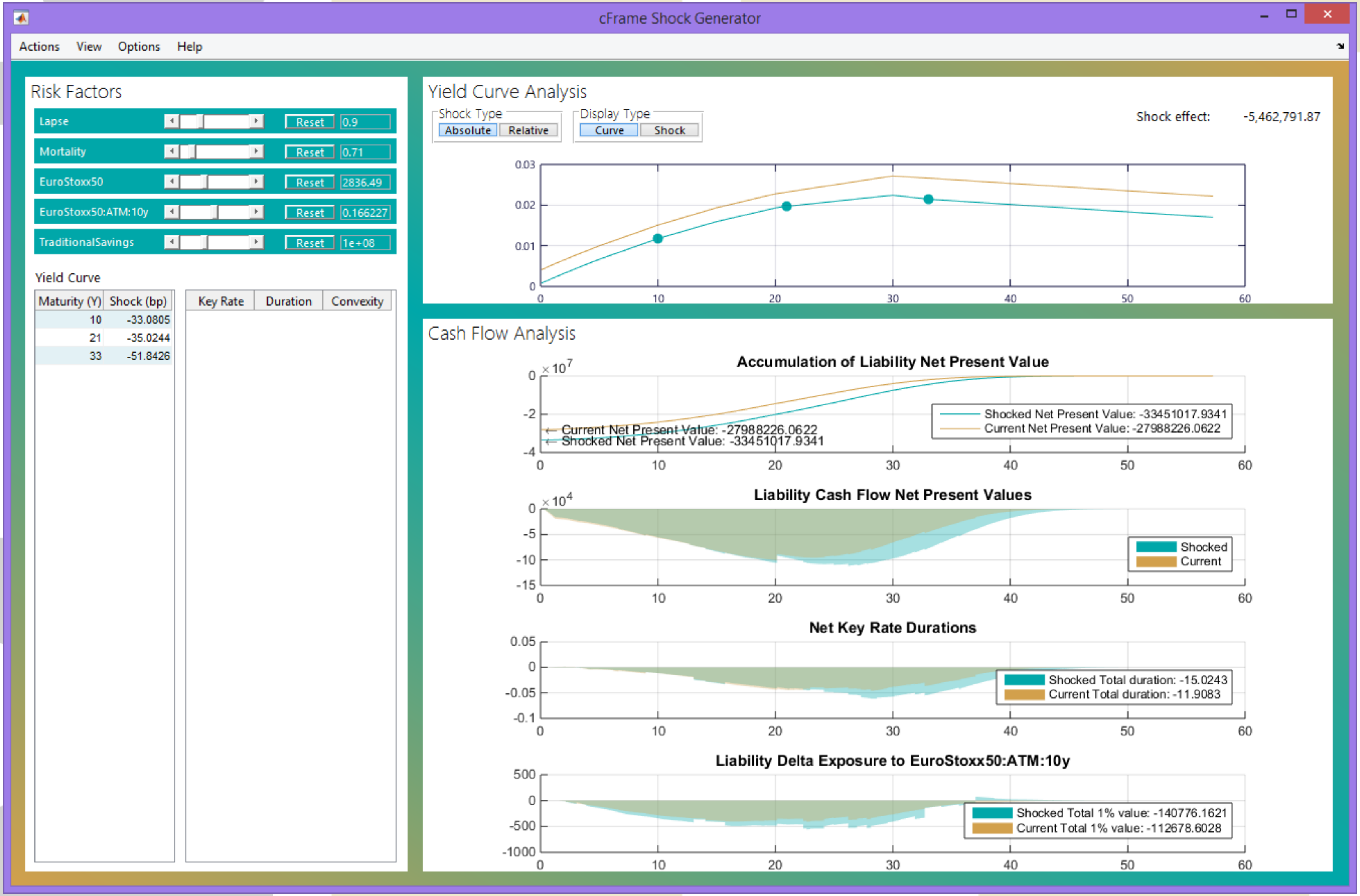


Shock Generation

DEMO

Stress generation

See how fully customizable interest rate shocks combined with other market and non-market shocks affect liability exposure (greeks) and profit



Risk Factors

Lapse	0.9
Mortality	0.71
EuroStoxx50	2836.49
EuroStoxx50:ATM:10y	0.166227
TraditionalSavings	1e+08

Yield Curve

Maturity (Y)	Shock (bp)
10	-33.0805
21	-35.0244
33	-51.8426

Yield Curve Analysis

Shock effect: -5,462,791.87

Cash Flow Analysis

Accumulation of Liability Net Present Value

Current Net Present Value: -27988226.0622
Shocked Net Present Value: -33451017.9341

Shocked Net Present Value: -33451017.9341
Current Net Present Value: -27988226.0622

Liability Cash Flow Net Present Values

Shocked
Current

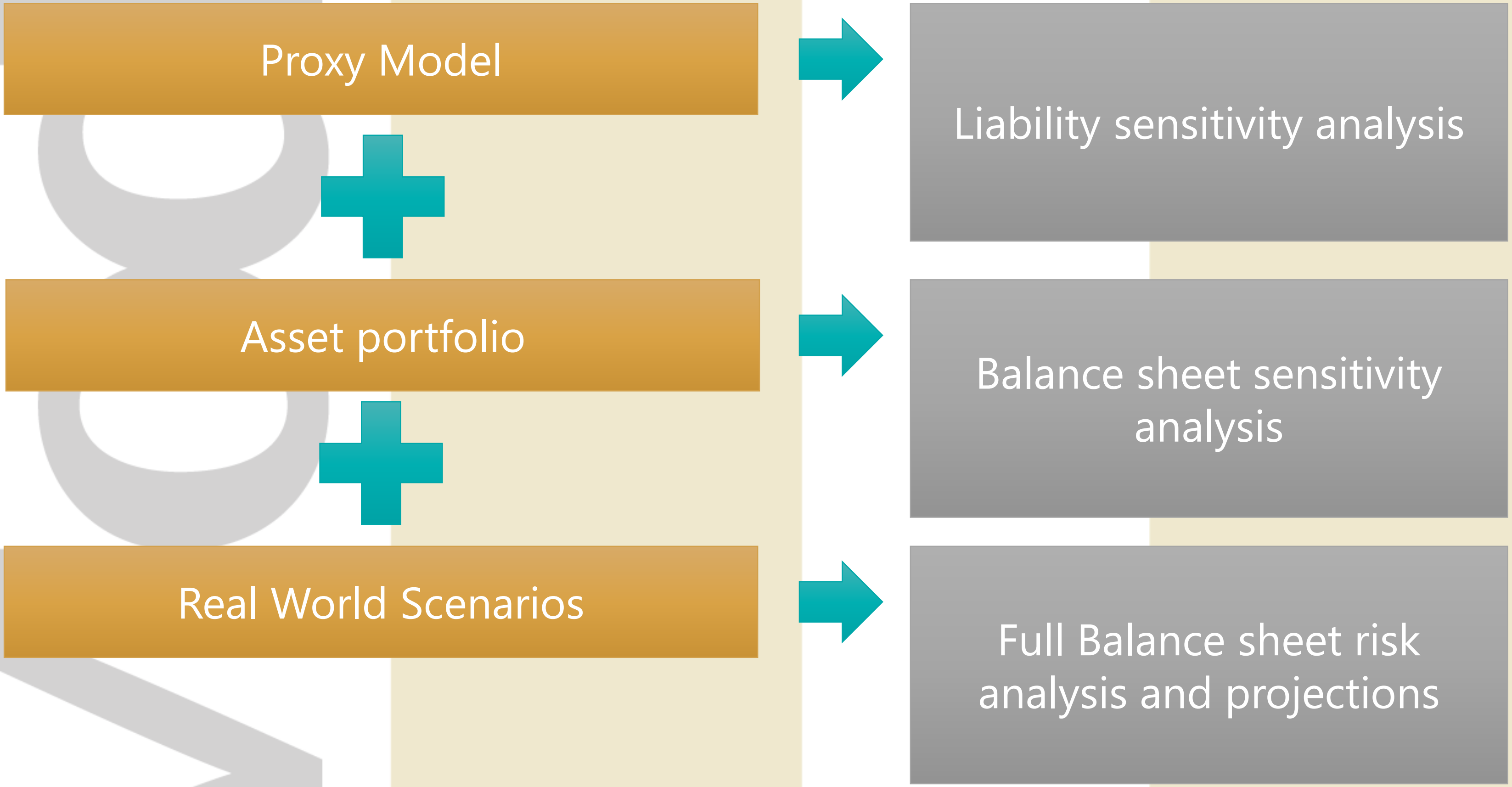
Net Key Rate Durations

Shocked Total duration: -15.0243
Current Total duration: -11.9083

Liability Delta Exposure to EuroStoxx50:ATM:10y

Shocked Total 1% value: -140776.1621
Current Total 1% value: -112678.6028

Combining pieces



Proxy Model

Asset portfolio

Real World Scenarios

Liability sensitivity analysis

Balance sheet sensitivity analysis

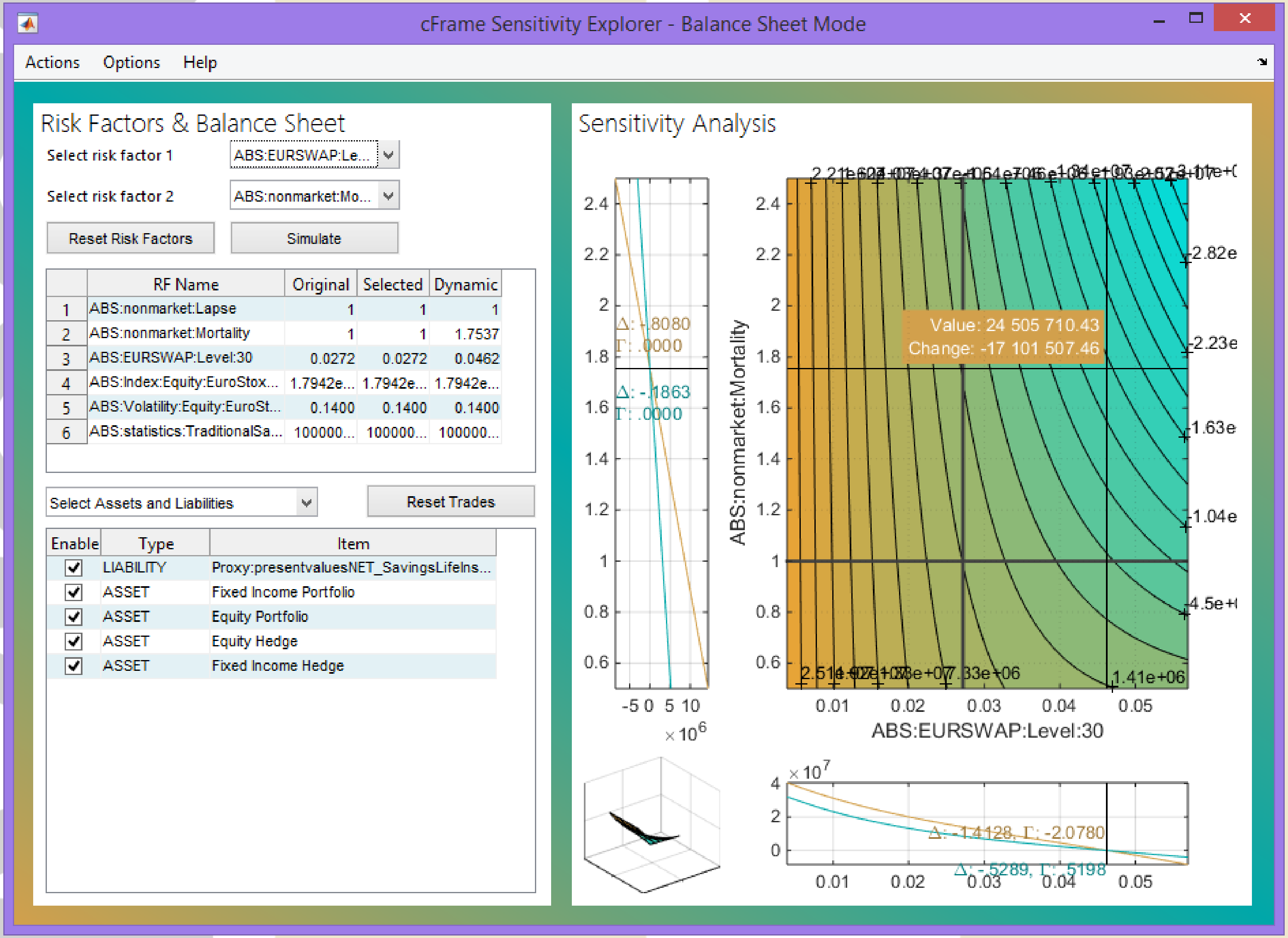
Full Balance sheet risk analysis and projections

Visualization

DEMO

Example: Balance Sheet sensitivities

Net exposure to joint shocks in mortality and interest rates



Select risk factor 1: ABS:EURSWAP:Le...

Select risk factor 2: ABS:nonmarket:Mo...

	RF Name	Original	Selected	Dynamic
1	ABS:nonmarket:Lapse	1	1	1
2	ABS:nonmarket:Mortality	1	1	1.7537
3	ABS:EURSWAP:Level:30	0.0272	0.0272	0.0462
4	ABS:Index:Equity:EuroStox...	1.7942e...	1.7942e...	1.7942e...
5	ABS:Volatility:Equity:EuroSt...	0.1400	0.1400	0.1400
6	ABS:statistics:TraditionalSa...	100000...	100000...	100000...

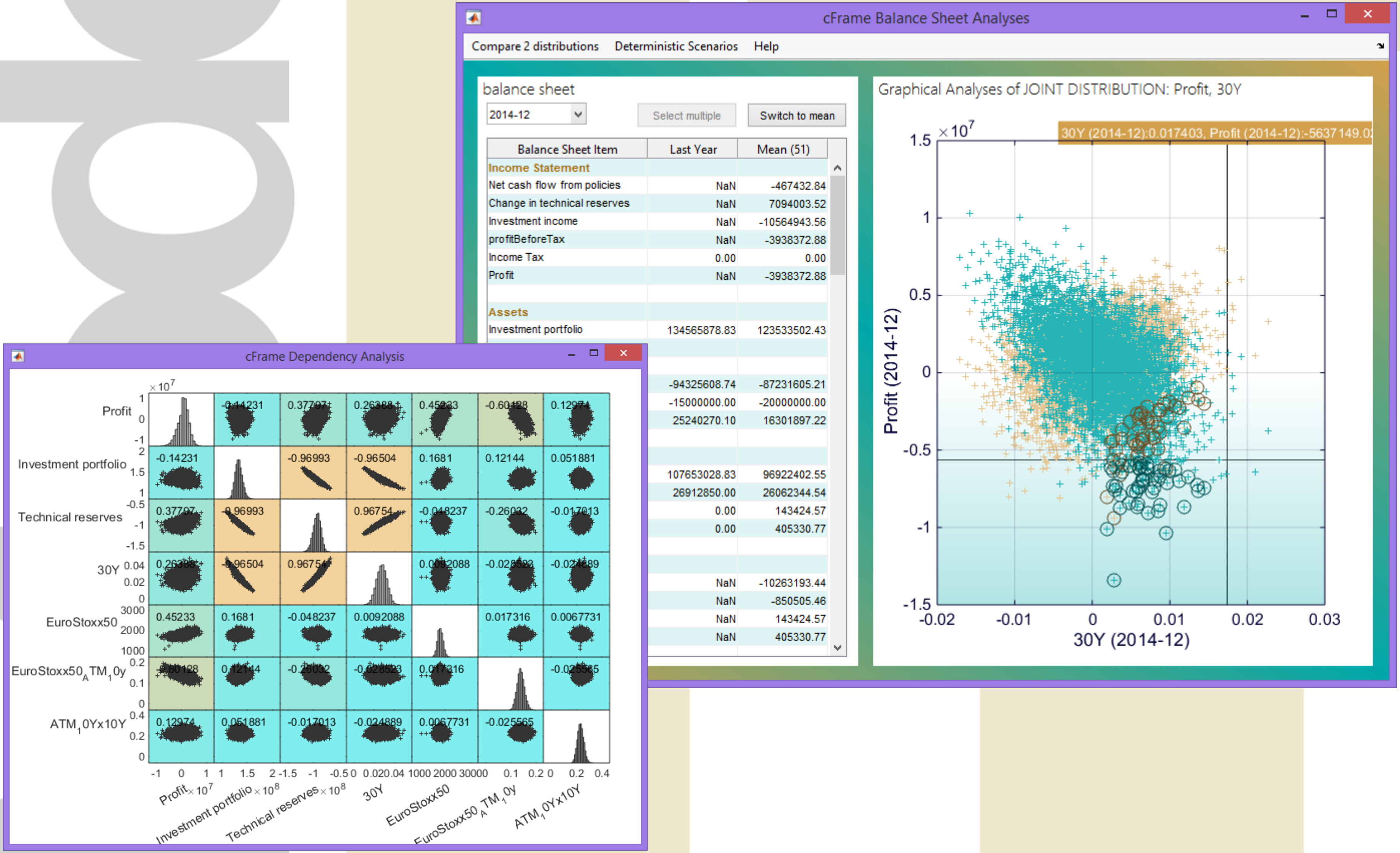
Select Assets and Liabilities

Enable	Type	Item
☑	LIABILITY	Proxy:presentvaluesNET_SavingsLifeIns...
☑	ASSET	Fixed Income Portfolio
☑	ASSET	Equity Portfolio
☑	ASSET	Equity Hedge
☑	ASSET	Fixed Income Hedge

Value: 24 505 710.43
Change: -17 101 507.46

Example: Balance Sheet Correlations

Net interest rate sensitivity with two different investment strategies



Balance Sheet Item	Last Year	Mean (51)
Income Statement		
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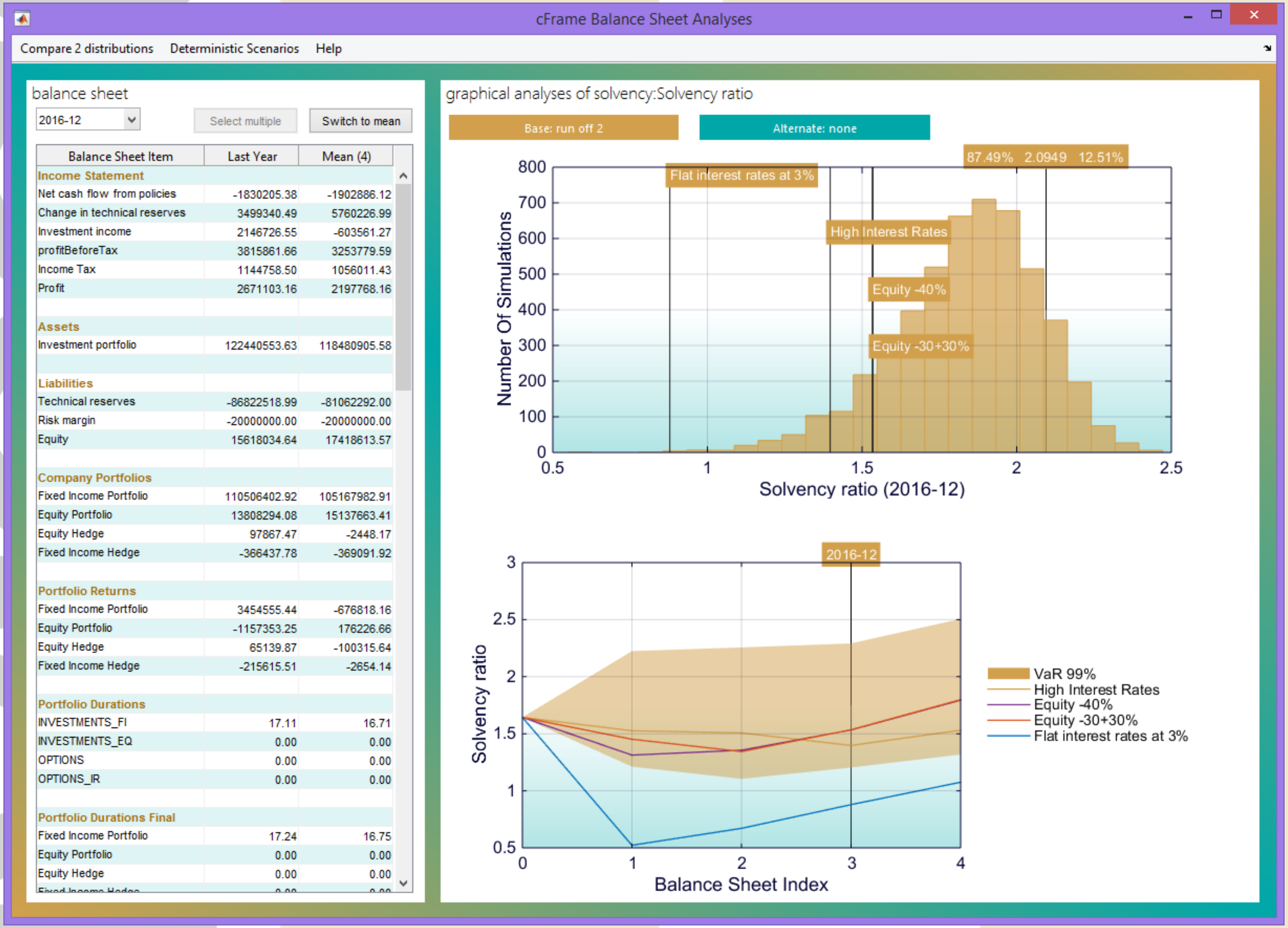
	-94325608.74	-87231605.21
	-15000000.00	-20000000.00
	25240270.10	16301897.22
	107653028.83	96922402.55
	26912850.00	26062344.54
	0.00	143424.57
	0.00	405330.77
	NaN	-10263193.44
	NaN	-850505.46
	NaN	143424.57
	NaN	405330.77

	Profit	Investment portfolio	Technical reserves	30Y	EuroStoxx50	EuroStoxx50_A TM_1 0y	ATM_1 0Yx10Y
Profit		-0.14231	0.37797	0.26388	0.45233	-0.60128	0.12974
Investment portfolio	-0.14231		-0.96993	-0.96504	0.1681	0.12144	0.051881
Technical reserves	0.37797	-0.96993		0.96754	-0.048237	-0.26032	-0.017013
30Y	0.26388	-0.96504	0.96754		0.0092088	-0.028523	-0.024889
EuroStoxx50	0.45233	0.1681	-0.048237	0.0092088		0.017316	0.0067731
EuroStoxx50_A TM_1 0y	-0.60128	0.12144	-0.26032	-0.028523	0.017316		-0.025565
ATM_1 0Yx10Y	0.12974	0.051881	-0.017013	-0.024889	0.0067731	-0.025565	

Example: Balance Sheet projections

Stochastic path dependent multi-year projection of solvency ratio including deterministic stress scenarios



balance sheet

2016-12

Balance Sheet Item	Last Year	Mean (4)
Income Statement		
Net cash flow from policies	-1830205.38	-1902886.12
Change in technical reserves	3499340.49	5760226.99
Investment income	2146726.55	-603561.27
profitBeforeTax	3815861.66	3253779.59
Income Tax	1144758.50	1056011.43
Profit	2671103.16	2197768.16
Assets		
Investment portfolio	122440553.63	118480905.58
Liabilities		
Technical reserves	-86822518.99	-81062292.00
Risk margin	-20000000.00	-20000000.00
Equity	15618034.64	17418613.57
Company Portfolios		
Fixed Income Portfolio	110506402.92	105167982.91
Equity Portfolio	13808294.08	15137663.41
Equity Hedge	97867.47	-2448.17
Fixed Income Hedge	-366437.78	-369091.92
Portfolio Returns		
Fixed Income Portfolio	3454555.44	-676818.16
Equity Portfolio	-1157353.25	176226.66
Equity Hedge	65139.87	-100315.64
Fixed Income Hedge	-215615.51	-2654.14
Portfolio Durations		
INVESTMENTS_FI	17.11	16.71
INVESTMENTS_EQ	0.00	0.00
OPTIONS	0.00	0.00
OPTIONS_IR	0.00	0.00
Portfolio Durations Final		
Fixed Income Portfolio	17.24	16.75
Equity Portfolio	0.00	0.00
Equity Hedge	0.00	0.00
Fixed Income Hedge	0.00	0.00

Summary

- Business Language
  - Rapid development, separate the model and the engine
  - Documentable, auditable
- High-Performance simulation
  - Use real contract data
  - Get results in minutes
- Proxy modeling
  - Run thousands of valuations in seconds
  - On-Demand risk analysis for complex balance sheets
- Visualization
  - Interactive drill down into results
  - Create stress tests, change asset allocation

Thank you!

QUESTIONS?

Contact details

- Timo Salminen, tel. +358 50 528 2359 timo.salminen@modelit.fi
- Model IT Ltd, Unioninkatu 13 3rd floor, 00130 Helsinki, Finland
- www.modelit.fi