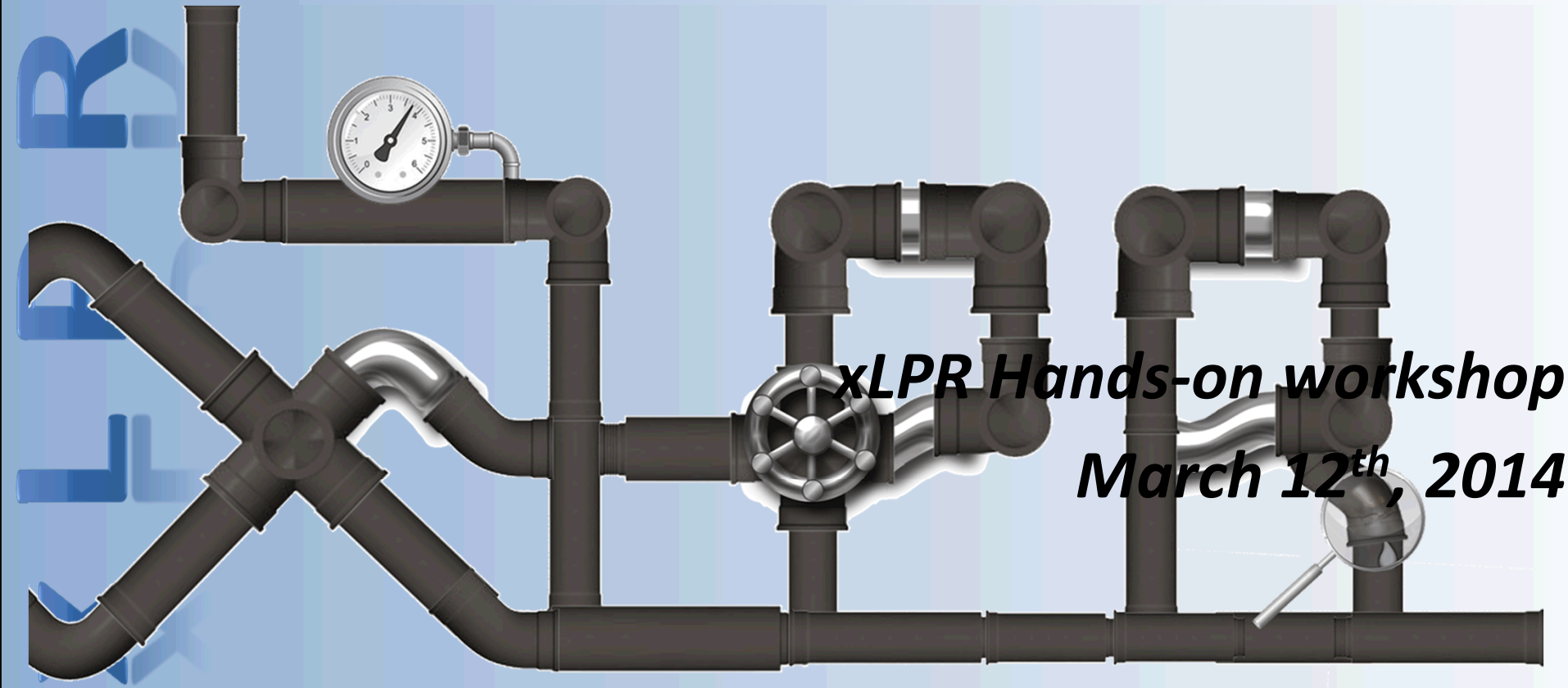
SAND2015-1856PE



xLPR Hands-on workshop March 12th, 2014

xLPR Hands-on workshop
March 12-13, 2015

Objectives

- **This workshop is about:**
  - Provide everybody in this room hands-on experience in setting-up and running the xLPR code.
  - Develop common "best practice" habits with performing simulations using xLPR.
- **What we want to get out of this workshop**
  - Hands-on experience from A-to-Z on how to setup and run the code.
  - **Interactive discussion and use of the code!**
  - Constructive feedback on workshop materials and examples used.
  - Address any question you may have with the USE of the code.
- **What this workshop is not about**
  - Review of the technical basis of the xLPR probabilistic fracture mechanic model.
  - Review of the implementation of the models.

Tentative schedule

Thursday March 12th: BASIC USE OF THE CODE

- **08:00 AM – 08:15 AM** Welcoming introduction (*R. Dingreville)*
- **08:15 AM – 09:00AM** GoldSim basics (*C. Sallaberry*)
- **09:00 AM – 09:30 AM** File structure (*C. Sallaberry*)
- **09:30 AM – 10:15 AM** Input Set Excel File structure (*C. Sallaberry*)
- **10:15 AM – 10:30 AM** **Break**
- **10:30 AM – 11:15 AM** xLPR simulation editor (*P. Mariner*)
- **11:15 AM – 12:00 PM** Input creation exercise (*P. Mariner*)
- **12:00 PM – 01:10 PM** **Lunch break**
- **01:00 PM – 01:45 PM** Internal structure of the code *(C. Sallaberry)*
- ***01:45 PM – 02:15 AM*** Sampling options / Running a simulation *(C. Sallaberry)*
- **02:15 PM – 03:00 PM** Error tracking and results visualization *(A. Eckert, C. Sallaberry)*
- **03:00 PM – 03:15 PM** **Break**
- **03:15 PM – 04:15 PM** Outputting results: Global output vs. local output (*S. Sanborn*)
- **04:00 PM – 04:30 PM** Questions

Friday March 13th: ADVANCED USE OF THE CODE

- **08:00 AM – 08:45 AM** Outstanding questions from Day 1 (*All*)
- **08:45 AM – 09:15 AM** Pre-processor: Fatigue and Leak Rate (*S. Sanborn*)
- **09:15 AM – 10:15 AM** Leveraging pre-existing input decks (*P. Mariner*)
- **10:15 AM – 10:30 AM** **Break**
- **10:30 AM – 12:00 PM** Scenario simulation / common errors – Hands-on (*P. Mariner*)
- **12:00 PM – 01:00PM** **Lunch break**
- **01:00 PM – 04:00PM** Hands-on session / Free format / open questions (*All*)

GoldSim Basics

What is GoldSim?

- GoldSim is a highly graphical, object-oriented program for carrying out dynamic, probabilistic simulations of complex systems.

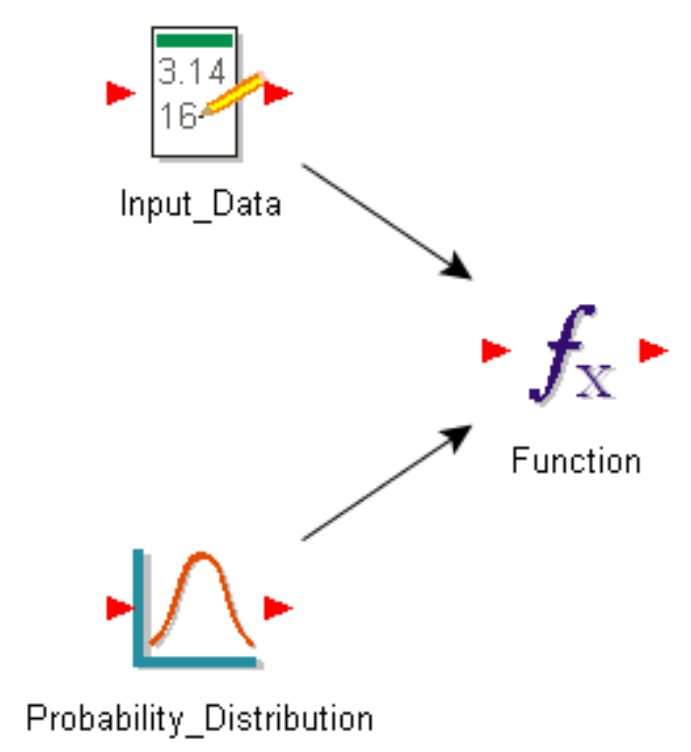
- A high-level programming language that requires no programming expertise.

- Similar to a spreadsheet, but:
  - Graphical so models are easier to maintain and explain to others
  - Understands concept of “time”
  - GoldSim models are much more realistic than anything that can be created using a spreadsheet

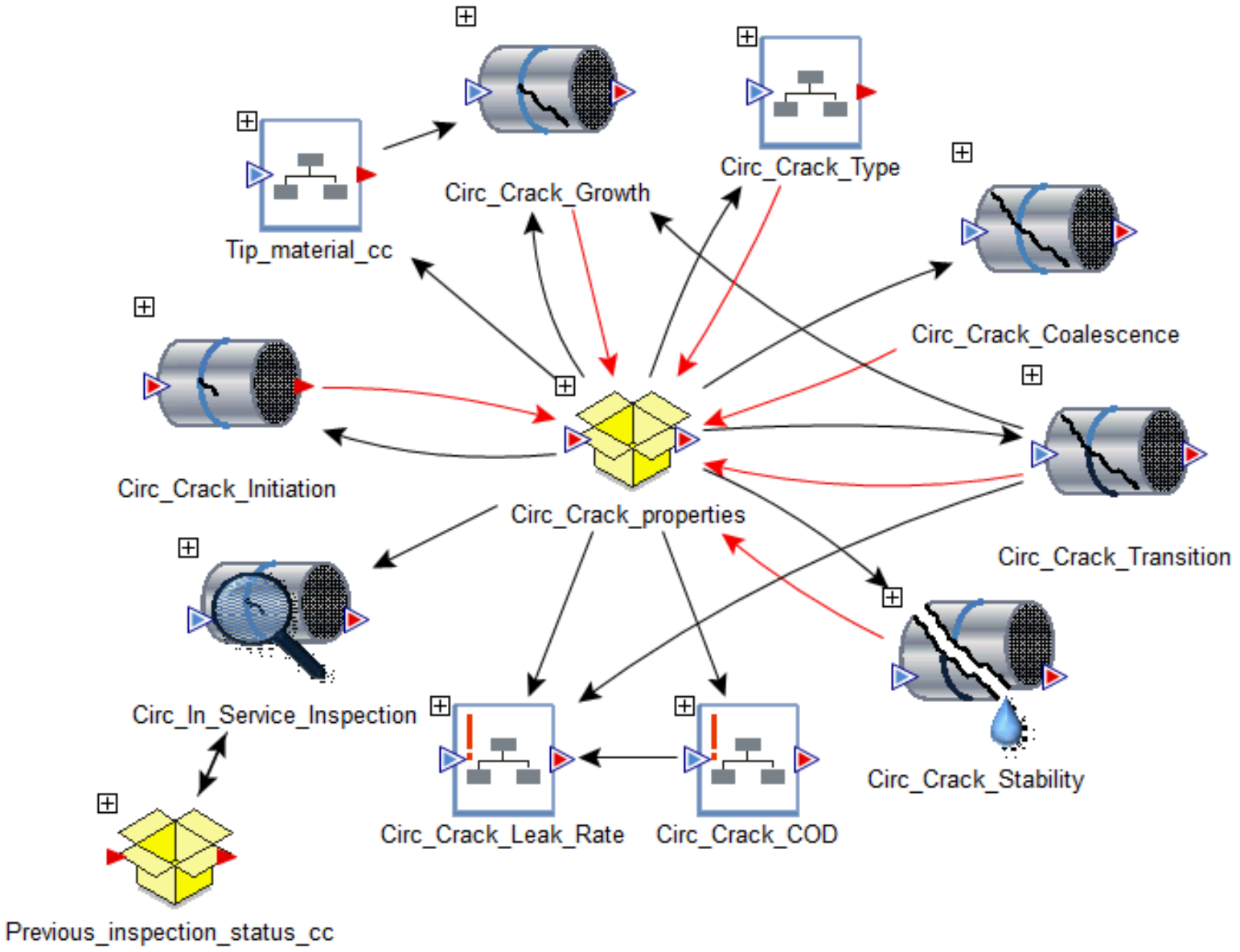
GoldSim Design Philosophy

- Models should be constructed in a "top-down" manner
  - Capture all key aspects and inter-relationships
  - Only add as much detail as required and justified
  - Keep focused on the "big picture"
- Must accurately and honestly express our uncertainty in all aspects of the system
  - parameters
  - processes
  - events
- A model that cannot be explained and understood is a model that will not be used
  - No black boxes!

Building Models with Objects



- Graphical objects (elements) used to create an influence diagram.
- Wide variety of specialized elements.
- Outputs of one or more elements are connected to the to the inputs of another element.


Circ_Crack_Growth
Circ_Crack_Type
Tip_material_cc
Circ_Crack_Coalescence
Circ_Crack_Initiation
Circ_Crack_properties
Circ_Crack_Transition
Circ_In_Service_Inspection
Circ_Crack_Stability
Circ_Crack_Leak_Rate
Circ_Crack_COD
Previous_inspection_status_cc

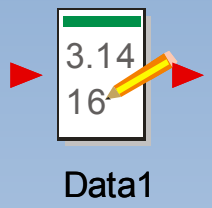
GoldSim Quick Tour: quick peak at xLPR

- GoldSim elements
- Linking elements and units
- Dynamic simulation
- Feedback
- Probabilistic simulation
- Discrete events
- Building Hierarchical models

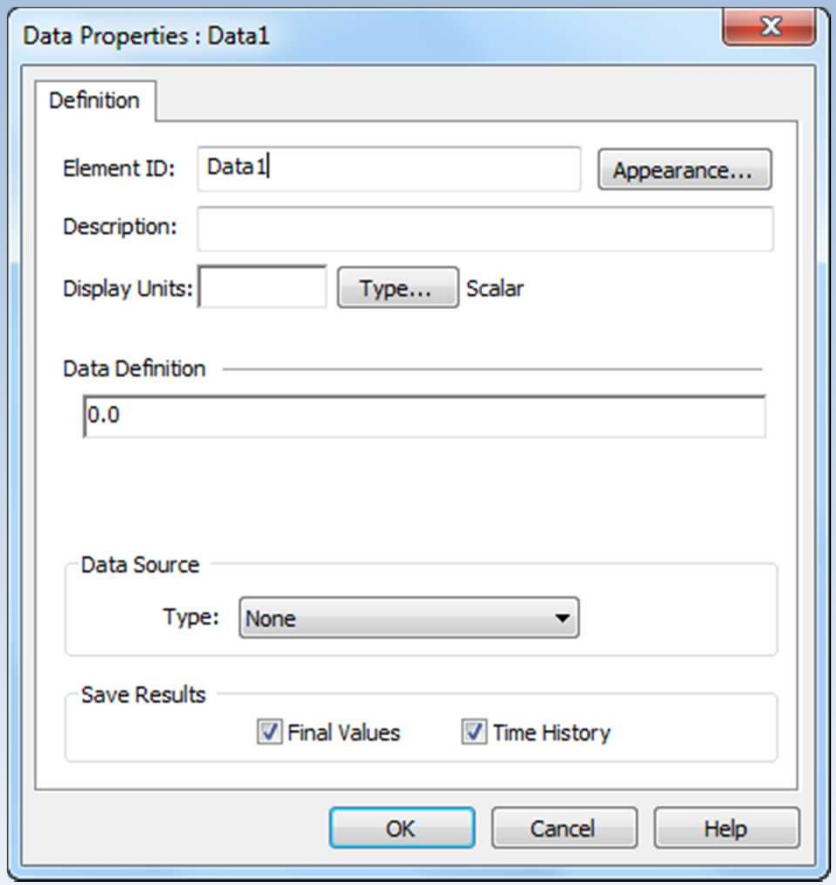
Creating Elements

- Use the context menu in graphics pane
  - (Right-click, then Insert Basic Element)
- GoldSim assigns a default name to each new element (type*nn*)
- You can change the element's name when it is first created or by double-clicking on the element in the graphics pane
- Elements in the same scope must have unique names (we will discuss scope later)
- Rules for element names

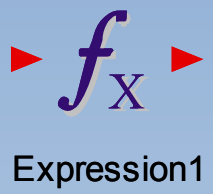
Data Element



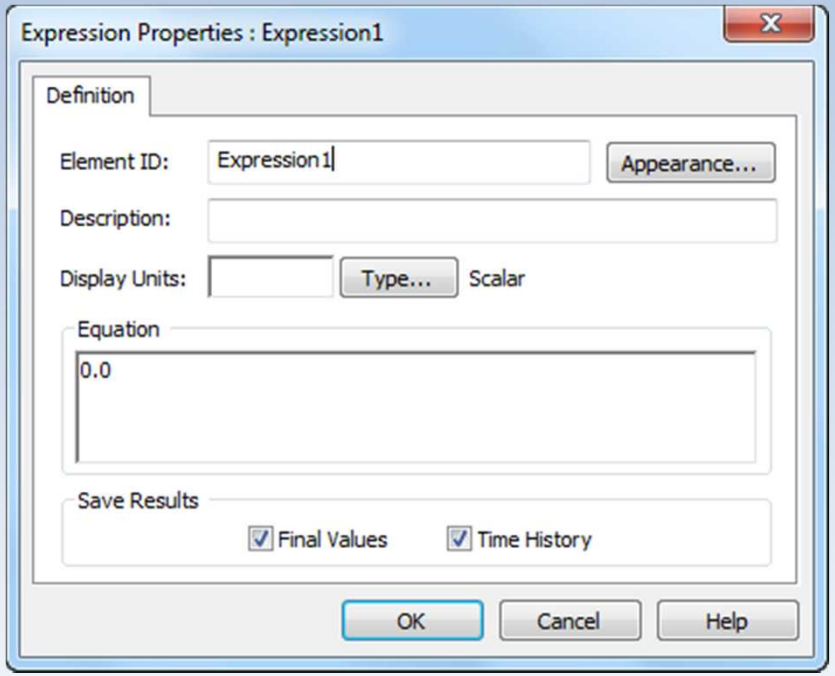
- ID and Description
- Data Type and Units
- Input fields
- Other
  - Appearance
  - Save flags



Expression Element



- The most basic element for writing expressions
- Similar to writing expressions in a Spreadsheet cell
- Create expressions using:
  - Standard operators (+ - * etc.)
  - Built-in functions
  - Built-in constants



Integrators

- Stock elements (such as Integrators) accumulate past events and provide systems with inertia and memory. Their outputs are determined by the previous value of their inputs. They are responsible for internally generating the dynamic behavior of most systems.

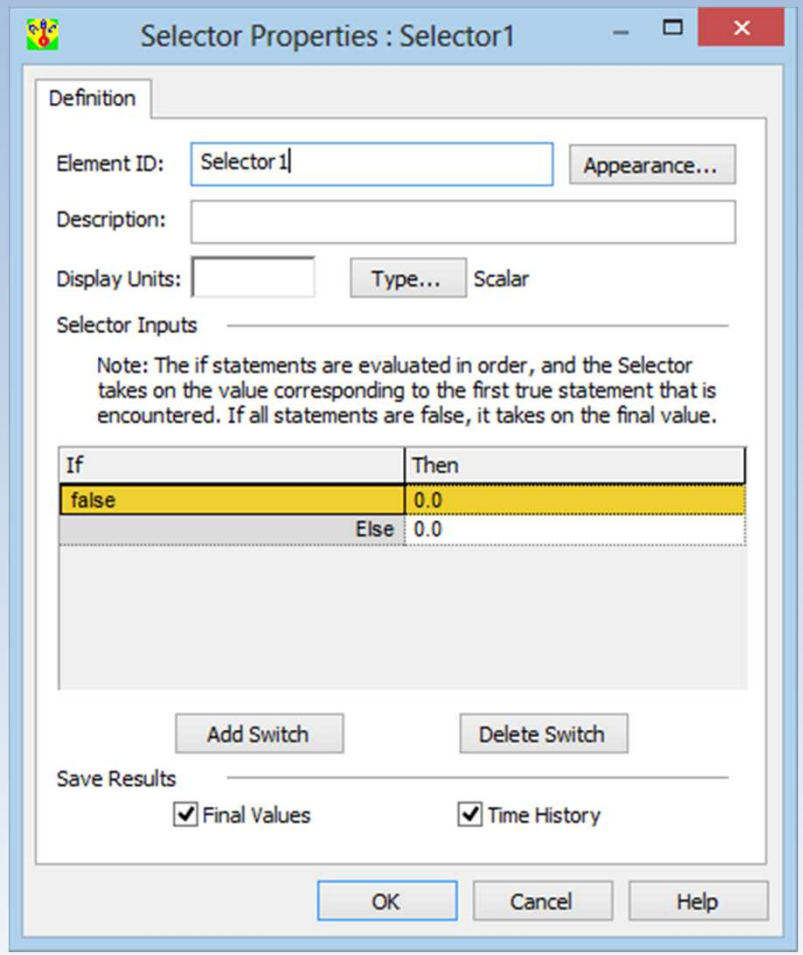
- **Integrators require an initial value and a Rate of Change as inputs, and output a Current Value:**

$$\text{Current Value} = \text{Initial Value} + \int \text{Rate of Change}$$

Selector Element

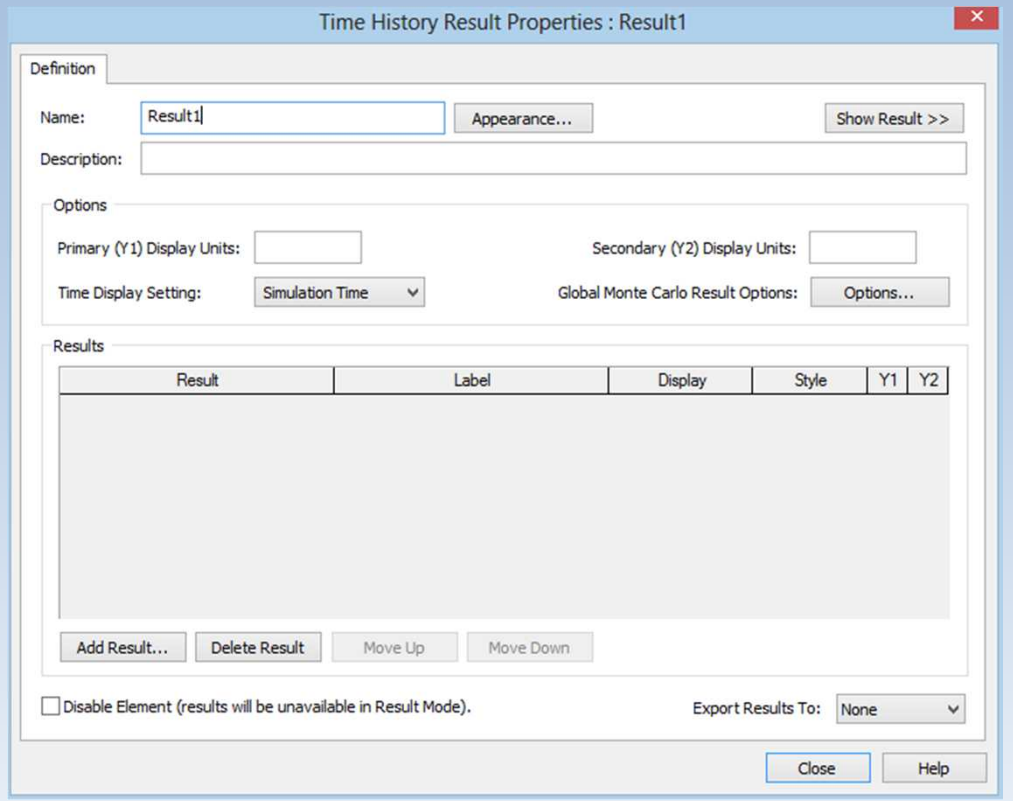
Selector1

- Provides clear way to define nested If, Then logic
- First column is a condition
- Second column is user-defined type

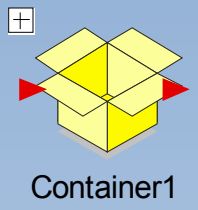


Time History Result Element

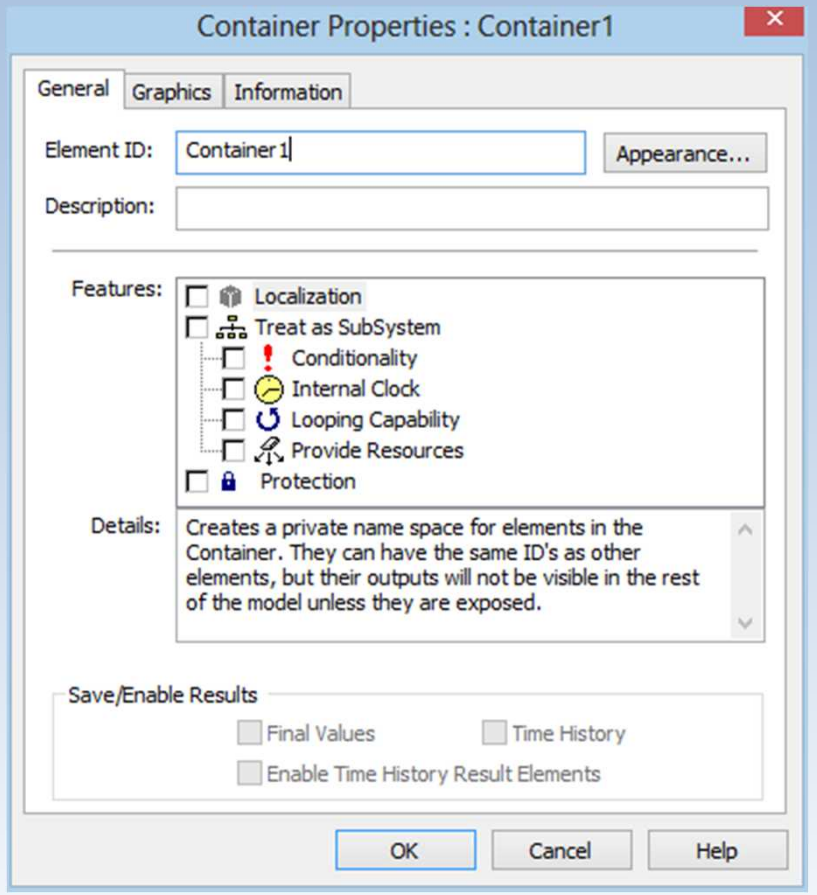
- Specify outputs
- User-defined labels
- Line styles
- Y1, Y2, and beyond (for tables)
- Display units
- Using Chart styles and Keywords



Container Element

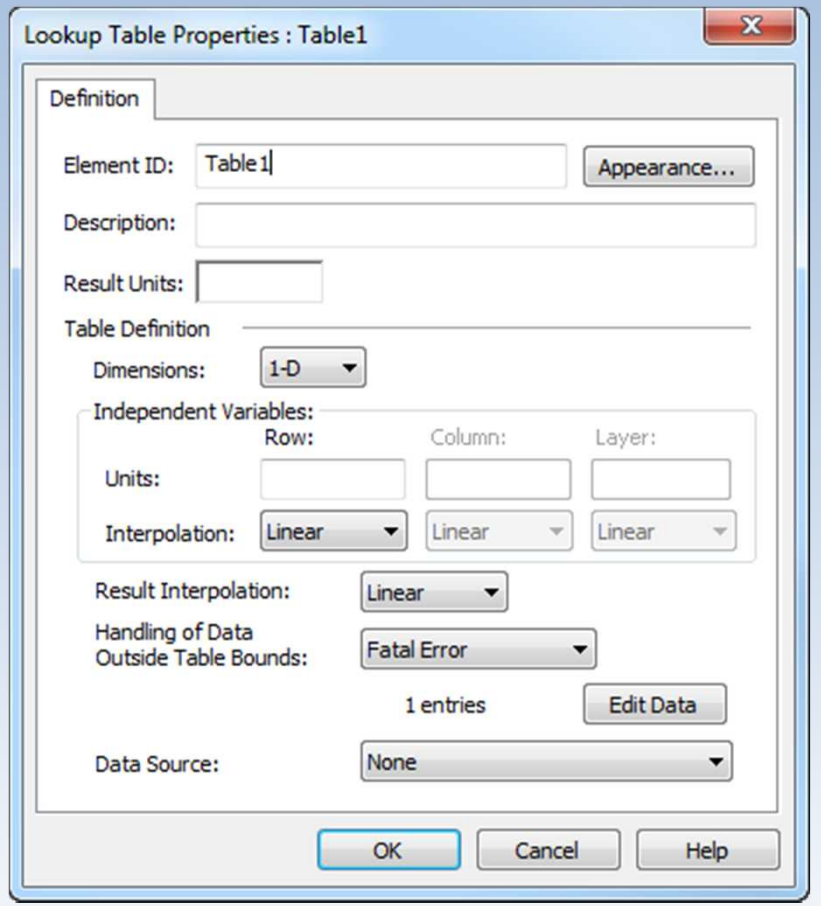


- Encapsulate portions of the model
- Move to…
- Links are maintained
- Name space

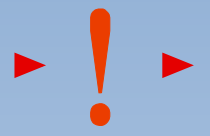


Lookup Table Element

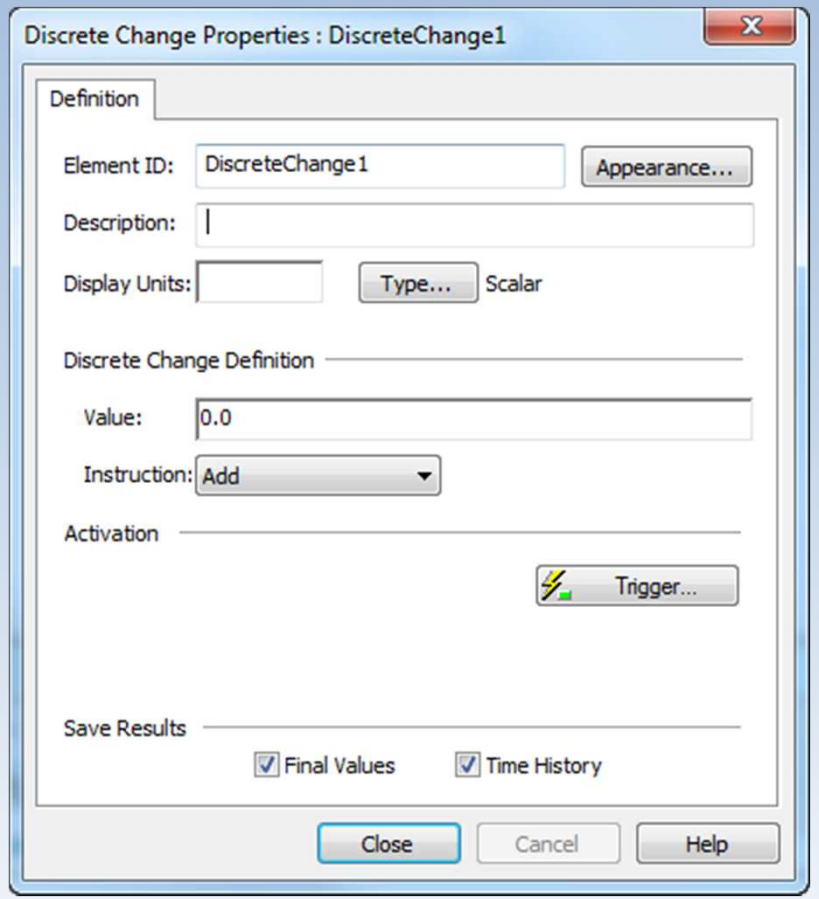
- Response surface
- 1D, 2D, 3D
- Global function
- Interpolation
- Optional lookup modifiers
  - For example, reverse lookup: Table(X, TBL_Inverse)
- External Data Source
  - Typically a spreadsheet



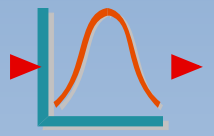
Discrete Change Element



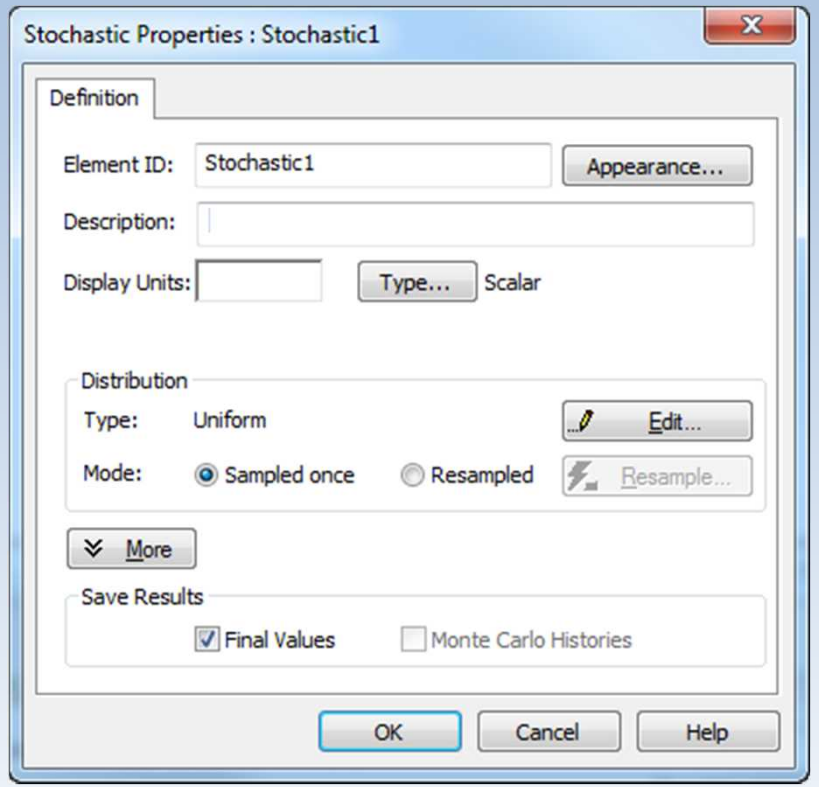
- Generates a discrete change signal
- Triggered by events
- Requires an input value
  - Add
  - Replace
- Main output is not a value



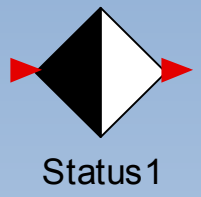
Stochastic Element



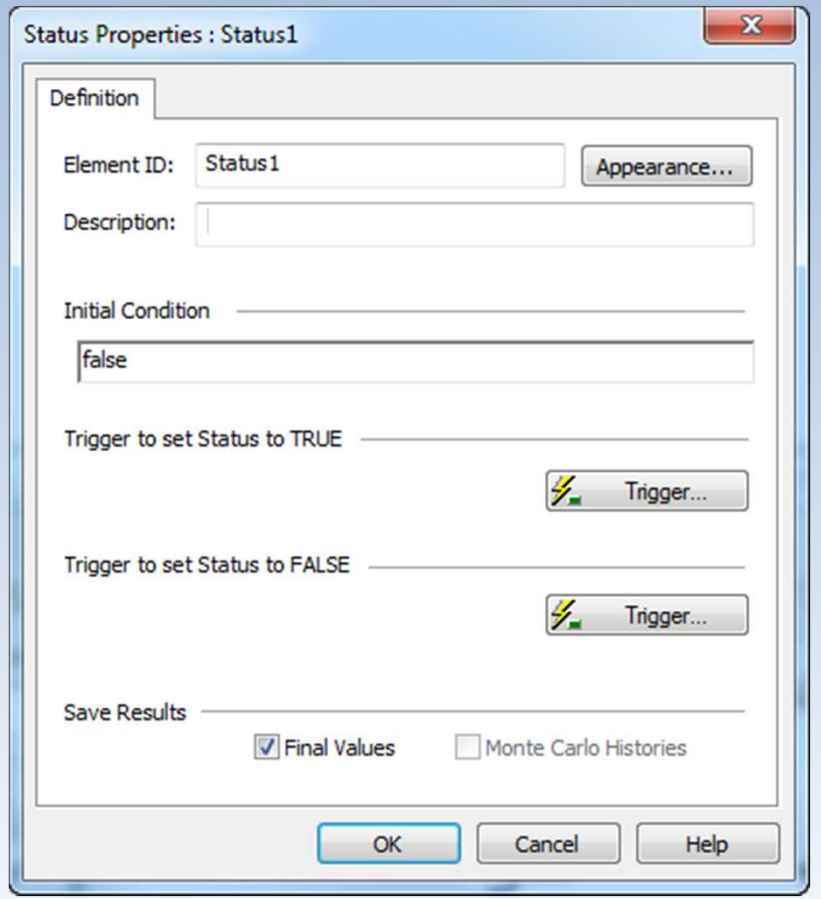
- Probability distribution to sample from
- Sampling mode
- Correlation
- Importance sampling



Status Element

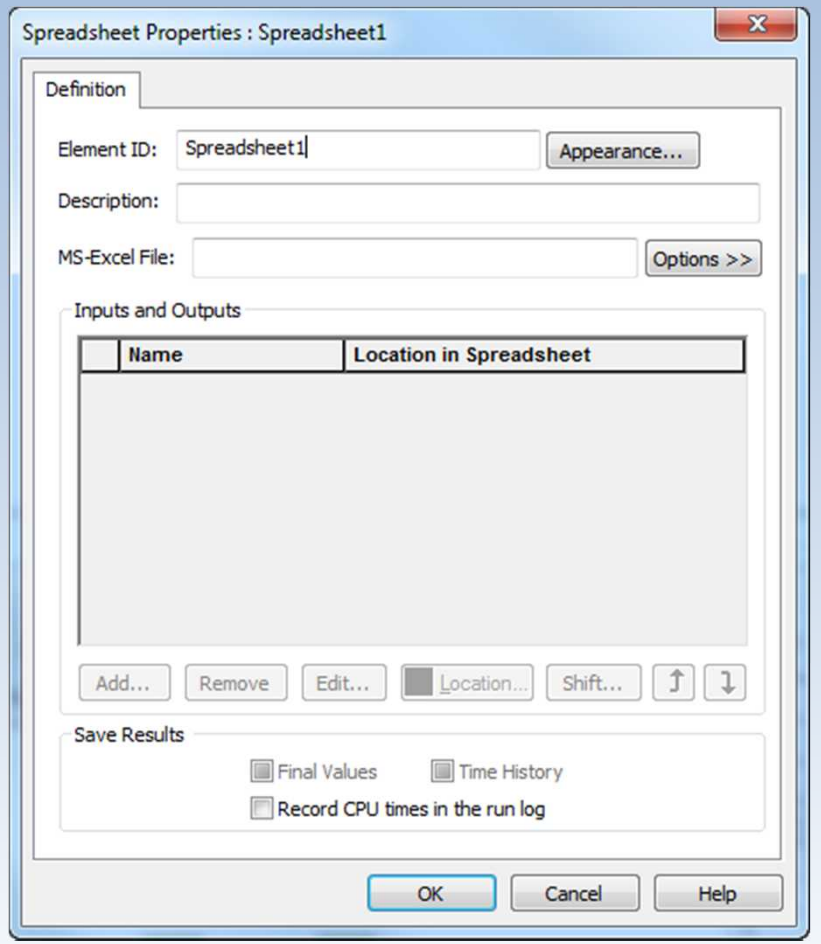


- Output is a Boolean (True/False)
- Three inputs:
  - Initial Value
  - Trigger(s) to set to True
  - Trigger(s) to set to False
- Very useful for tracking key state variables in a system (on/off)



Linking to Excel (Spreadsheet elements)

- Already have seen:
  - Importing from Excel to Lookup Table elements
  - Importing from Excel to Time Series elements
  - Exporting to Time History Result elements
- Spreadsheet element provides generic capability for importing from and exporting to Excel



How Does GoldSim Represent Time?

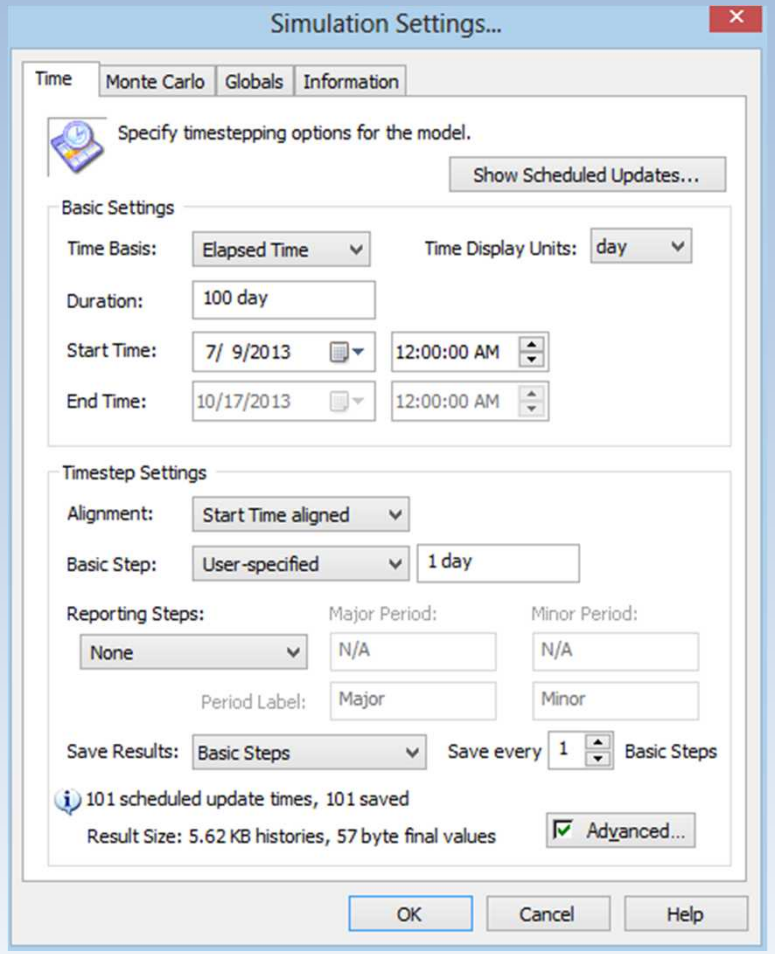
- GoldSim divides (discretizes) time into a series of (user-defined) timesteps
- Model calculations are carried out every timestep
- Key assumption of time stepping:
  - Variables are assumed constant over a timestep
  - In most models you will specify rates (e.g., flow rates, growth rates, spending rates) and GoldSim will integrate these rates over time to compute quantities (e.g., volumes, masses, number of items, lengths, amount of money)
  - These rates are assumed constant over a timestep

Carrying out a Dynamic Simulation

- The timestep length is defined by the user
  - Timestep length can vary during a simulation (e.g., monthly timesteps; telescoping timesteps)
  - GoldSim may override the user-defined timestep and insert additional (unscheduled) timesteps if necessary (not used by xLPR model)
  - NOTE: GoldSim's time stepping is fundamentally different from spreadsheet-based simulations in two key ways:
    - Spreadsheets have a fixed timestep (every row)
    - Spreadsheets deal with quantities, not rates
- After timesteps are defined, we "run the model" to produce results at every timestep

Simulation Settings

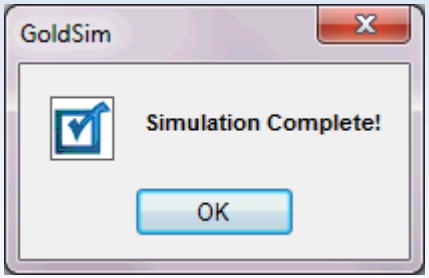
- Prior to running a simulation, you must specify the simulation settings
- Defined by:
  - Main menu (Model | Simulation Settings…)
  - Double-clicking on Simulation Settings button
  - Pressing F2



How Do I Run a Model?

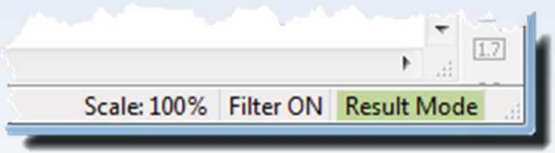
- Press F5 or the Run button
- The Run Controller will appear and the simulation will start

- After it completes, it will display a dialog:



Simulation Modes

- **Edit Mode:** Can edit model, contains no results. Press F5 to run the model.
- **Run Mode:** Model is running (or ready to run).
- **Pause Mode:** Model is paused in the middle of a run.
- **Result Mode:** Model has been run and contains simulation results. You can navigate the model and view results, but editing is limited. Press F4 to exit.
- **Scenario Mode:** Specialized type of Result Mode (not used by xLPR)



Code Status

Physical model implementation status

- Crack initiation ✓
- Stress intensity factor ✓
- Crack Growth ✓
- Transitioning Crack ✓
- Coalescence (only for circ. Crack) ✓
- Stability (different from SC and [TC, TWC]) ✓
- Crack Opening Displacement (only for TC and TWC) ✓
- Leak rate (only for TC and TWC) ✓
- In Service Inspection ✓
- WRS Importance Sampling ✗
- Fatigue Preprocessing ✗
- Inputs for Crack Initiation Direct Model 2 ✗
- Leak Rate COD Calculation ✗

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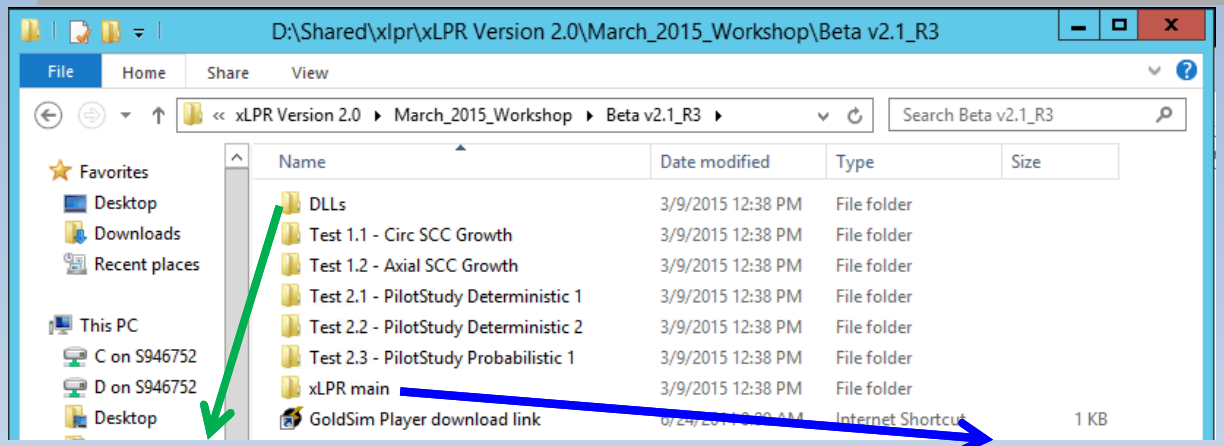
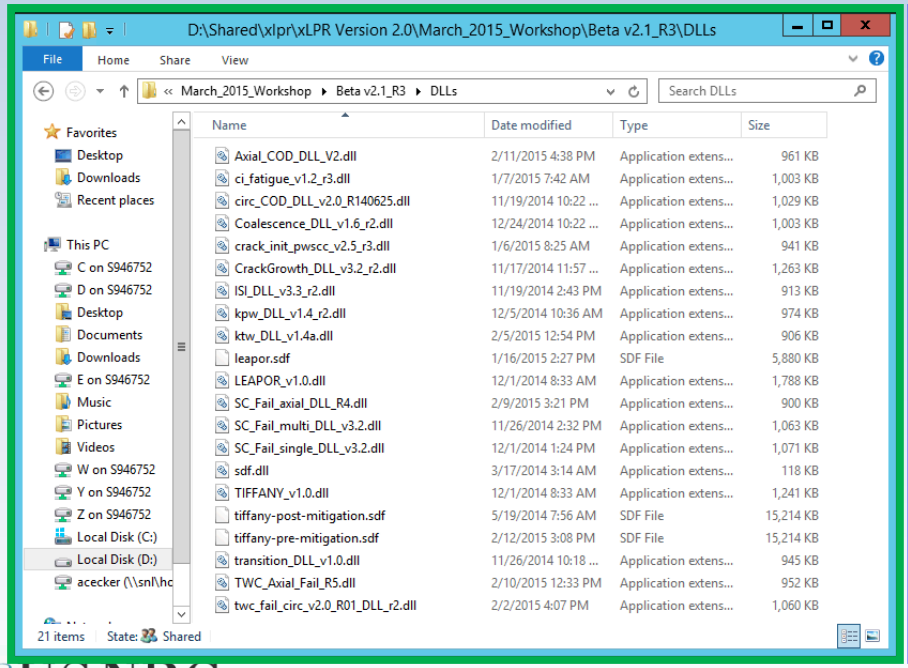
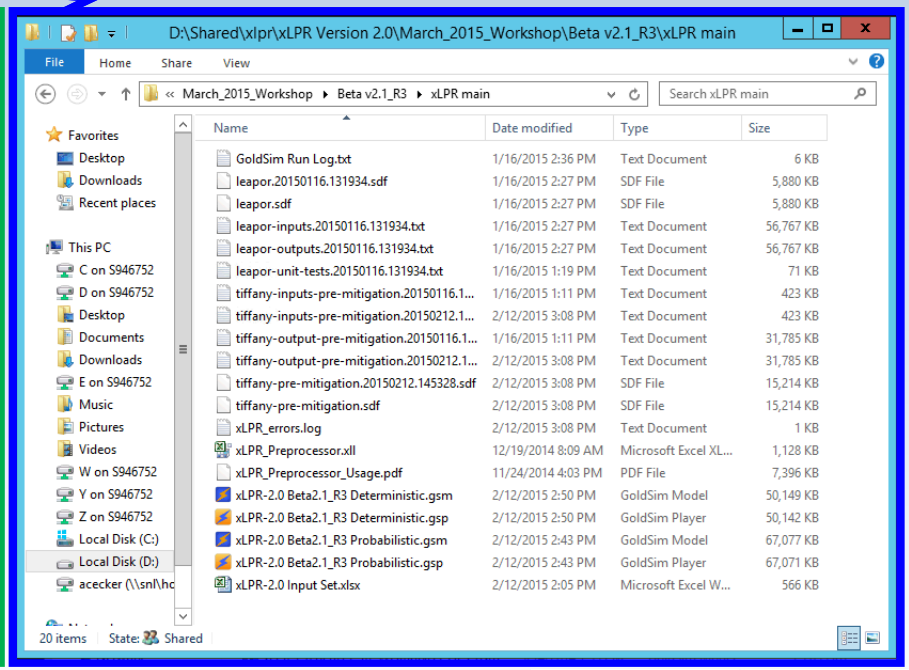
File Structure

File Structure







DLLs and xLPR main folder exist in one parent folder

Input set Excel file structure

Highlights

- Separation of database and input set
- Input set worksheet parts
- How to use the input set
- Formatting to help V&V
- Conclusion

Framework input spreadsheet overview

- Interface between user and global structure
  - Input parameters defined by category (including units)
  - Uncertainty distribution associated with each input (including uncertainty type)
- User change only input set now, except for GoldSim settings:
  - Epistemic sample size (in simulation settings) [can be copied into spreadsheet for record]
  - Epistemic random seed [can be copied into spreadsheet for record]
  - Aleatory random seed [can be copied into spreadsheet for record]
- GoldSim only runs the simulation. No more going back and forth between spreadsheet and GoldSim dashboards.
- GoldSim input dashboards solely used for viewing input for now. Will disappear in the future.
- Simulation editor (under development) will guide user into creating a reasonable input set.

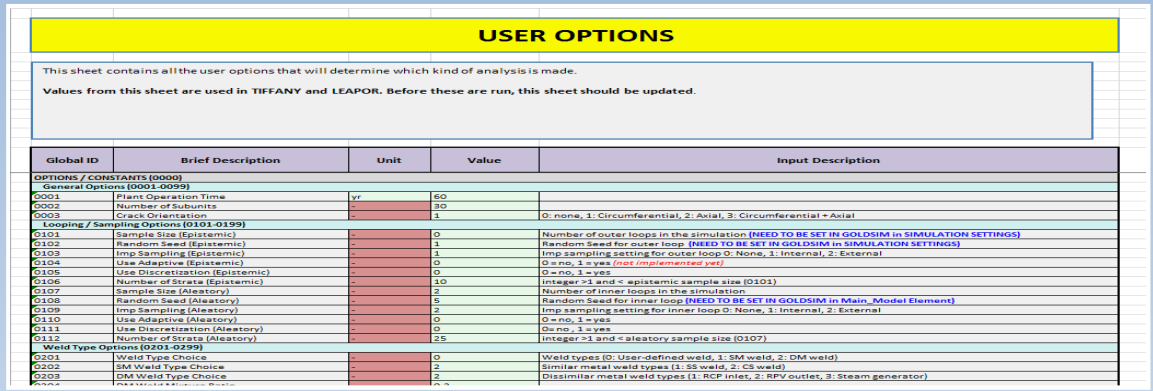
Database vs. input set

- **Input set** is set of data required for the run
- **Database** represents a list of pre-defined welds and material (as well as WRS) that can be used as a reference. It consists of separate Excel files (material, WRS, etc.) with one or more sheets of pre-defined inputs.
- Database uses same format as input set for tabs
- User can copy information from database to input set
- Simulation editor will simplify transfer from DB to input set

Structure of the input worksheet

- **User options:** plant operation time, coalescence flag, etc..
- **Properties:** input variables not specifically tied to a single material. E.g. pipe OD, weld width, operating conditions, loads, inspection and leak detection props.
- **Left/Right pipe**: materials properties associated with left/right pipe.
- **Weld:** input applied to weld material.
- **Mitigation:** input applied to post-mitigation weld material.
- **Hoop/axial WRS:** defines WRS profile through thickness for both pre/post-mitigation.
- **Transient definition:** Define transient type I. Up to 20.
- **TIFFANY inputs:** Define type II and II transients.
- **Options:** read-onlyused to communicate the spreadsheet file info in more convenient GoldSim format.
- **Drop list option:** List options available
- **Material flags:** list materials type flags used by various modules.

Input set worksheet: user options



USER OPTIONS

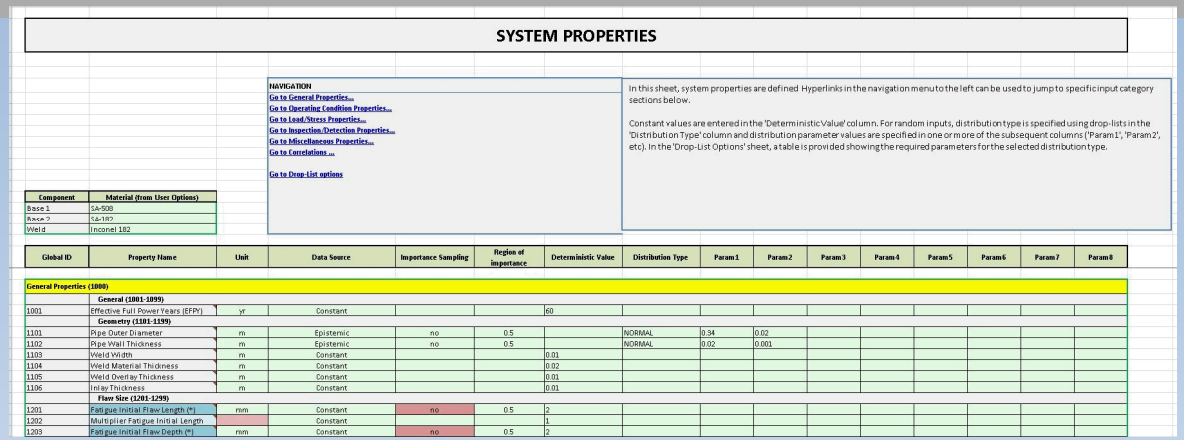
This sheet contains all the user options that will determine which kind of analysis is made.

Values from this sheet are used in TIFFANY and LEAPOR. Before these are run, this sheet should be updated.

Global ID	Brief Description	Unit	Value	Input Description
OPTIONS / CONSTANTS (0000)				
General Options (0001-0099)				
O001	Plant Operation Time	yr	60	
O002	Number of Subunits	-	30	
O003	Crack Orientation	-	1	0: none, 1: Circumferential, 2: Axial, 3: Circumferential + Axial
Looping / Sampling Options (0101-0199)				
O101	Sample Size (Epistemic)	-	0	Number of outer loops in the simulation (NEED TO BE SET IN GOLDSIM in SIMULATION SETTINGS)
O102	Random Seed (Epistemic)	-	1	Random Seed for outer loop (NEED TO BE SET IN GOLDSIM in SIMULATION SETTINGS)
O103	Imp Sampling (Epistemic)	-	1	Imp sampling setting for outer loop 0: None, 1: Internal, 2: External
O104	Use Adaptive (Epistemic)	-	0	0 = no, 1 = yes (not implemented yet)
O105	Use Discretization (Epistemic)	-	0	0 = no, 1 = yes
O106	Number of Strata (Epistemic)	-	10	integer >1 and < epistemic sample size (0101)
O107	Sample Size (Aleatory)	-	2	Number of inner loops in the simulation
O108	Random Seed (Aleatory)	-	5	Random Seed for inner loop (NEED TO BE SET IN GOLDSIM in Main_Model Element)
O109	Imp Sampling (Aleatory)	-	2	Imp sampling setting for inner loop 0: None, 1: Internal, 2: External
O110	Use Adaptive (Aleatory)	-	0	0 = no, 1 = yes
O111	Use Discretization (Aleatory)	-	0	0 = no , 1 = yes
O112	Number of Strata (Aleatory)	-	25	integer >1 and < aleatory sample size (0107)
Weld Type Options (0201-0299)				
O201	Weld Type Choice	-	0	Weld types (0: User-defined weld, 1: SM weld, 2: DM weld)
O202	SM Weld Type Choice	-	2	Similar metal weld types (1: SS weld, 2: CS weld)
O203	DM Weld Type Choice	-	2	Dissimilar metal weld types (1: RCP inlet, 2: RPV outlet, 3: Steam generator)

- All user options will be read from Excel into GoldSim with the exception of the epistemic sample size, epistemic random seed, and aleatory random seed.
- These controls were previously set by the user in the GoldSim dashboard.

Input set worksheet: System properties



SYSTEM PROPERTIES

NAVIGATION

Go to General Properties...
Go to Operating Condition Properties...
Go to Load/Stress Properties...
Go to Inspection/Detection Properties...
Go to Miscellaneous Properties...
Go to Correlations ...

Go to Drop-List options

In this sheet, system properties are defined. Hyperlinks in the navigation menu to the left can be used to jump to specific input category sections below.

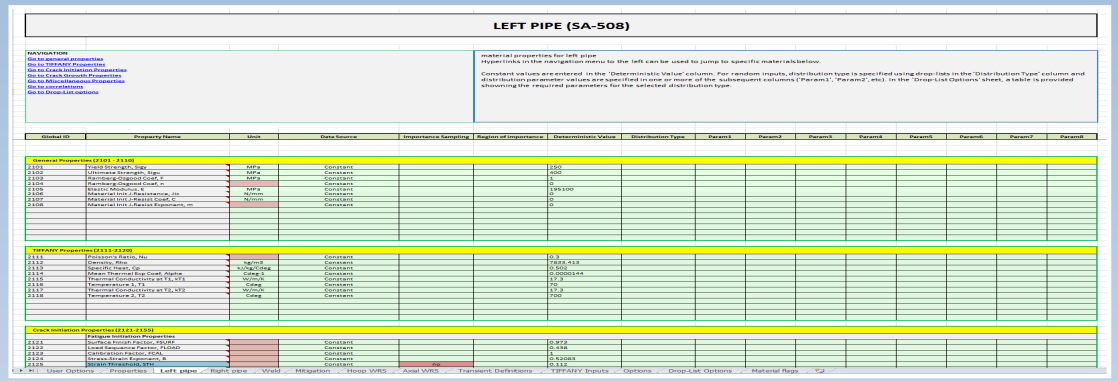
Constant values are entered in the 'Deterministic Value' column. For random inputs, distribution type is specified using drop-lists in the 'Distribution Type' column and distribution parameter values are specified in one or more of the subsequent columns ('Param1', 'Param2', etc). In the 'Drop-List Options' sheet, a table is provided showing the required parameters for the selected distribution type.

Component	Material (from User Options)
Base 1	SA-508
Base 2	SA-182
Weld	Inconel 182

Global ID	Property Name	Unit	Data Source	Importance Sampling	Region of Importance	Deterministic Value	Distribution Type	Param1	Param2	Param3	Param4	Param5	Param6	Param7	Param8
General Properties (1000)															
	General (1001-1099)														
1001	Effective Full Power Years (EFPY)	yr	Constant			60									
	Geometry (1101-1199)														
1101	Pipe Outer Diameter	m	Epistemic	no	0.5		NORMAL	0.34	0.02						
1102	Pipe Wall Thickness	m	Epistemic	no	0.5		NORMAL	0.02	0.001						
1103	Weld Width	m	Constant			0.01									
1104	Weld Material Thickness	m	Constant			0.02									
1105	Weld Overlay Thickness	m	Constant			0.01									
1106	Inlay Thickness	m	Constant			0.01									
	Flaw Size (1201-1299)														
1201	Fatigue Initial Flaw Length (*)	mm	Constant	no	0.5	2									
1202	Multiplier Fatigue Initial Length		Constant			1									
1203	Fatigue Initial Flaw Depth (*)	mm	Constant	no	0.5	2									

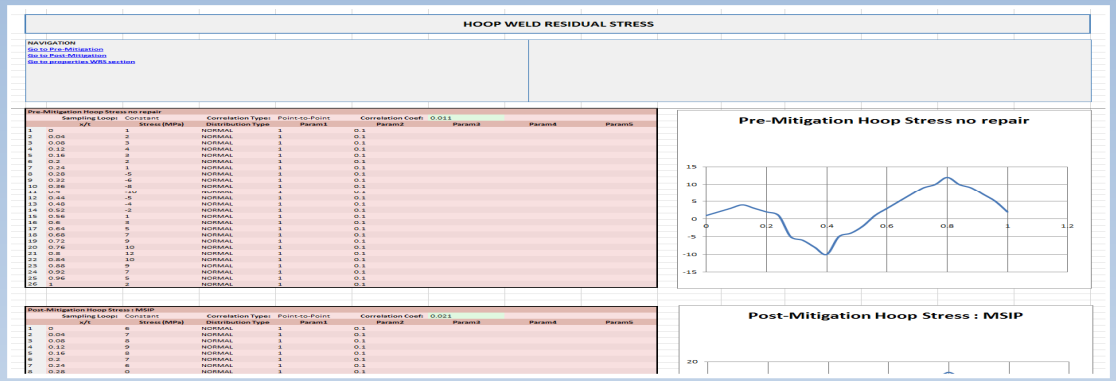
- Lists all the variables used in the model by category.
- Also lists the materials associated with a specific weld problem
- Defines variable units.
- Specifies the material types to be used (base 1, base 2, weld)
- **Now** selection of uncertainty type (alea./epis./constant) is **on the same sheet** as deterministic value or distribution
- Lists, depending on the choice
  - uncertainty type and associated distribution
  - deterministic value if constant is selected
- Part not used (distribution or constant) “hidden”
- Correlations for ISI parameters defined.

Input set worksheet: materials properties (4 tabs)



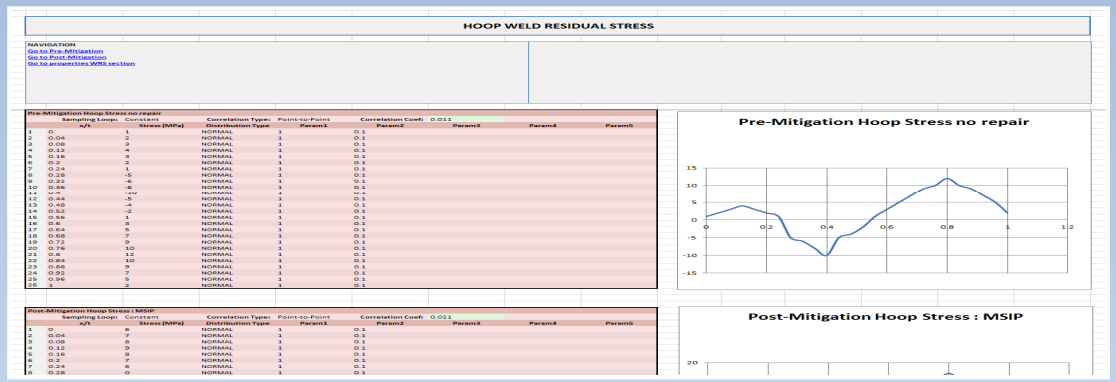
- Lists all materials properties for selected materials.
- Defines variable units.
- Defines materials flag: 2 initiation and 1 growth (in MISC rows) [c.f. Material flags tab].
- User selects which material is to be used for the left pipe / right pipe / weld / and mitigation (inlay or overlay). Assigned to individual tabs.
- Same uncertainty characterization as properties for input.
- Correlations for material properties defined.

Input set worksheet: WRS (2 tabs) (1/2)



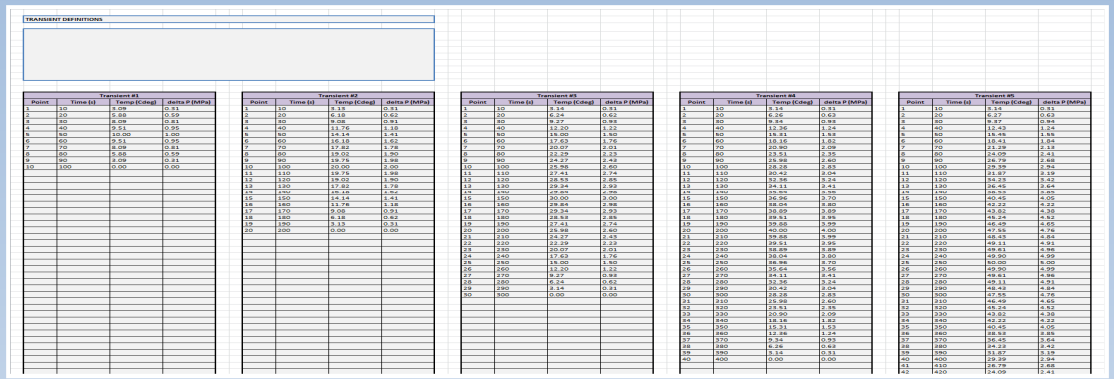
- One sheet for Hoop WRS and one for axial WRS.
- Universal weight function selected. Up to 26 locations can be used to represent the WRS profile.
- Stress can be entered as a constant or distribution (defined in the properties tab)
- Different distribution can be used for each of the 26 locations.
- Pre- and post- mitigation WRS defined for both Hoop and Axial.

Input set worksheet: WRS (2 tabs) (2/2)



- Weld type (DM, SM, or user option), weld properties, and weld repair state (0%, 15%, 50%) can be defined (in user options) to assign the appropriate geometry and material properties to the problem.
- Only **deterministic value** displayed in Excel.

Input set worksheet: transients



TRANSIENT DEFINITIONS

Transient #1

Point	Time (s)	Temp (Cdeg)	delta P (MPa)
1	10	5.09	0.31
2	20	5.88	0.59
3	80	6.09	0.81
4	40	9.51	0.95
5	60	10.40	1.00
6	80	14.19	1.76
7	70	8.09	0.91
8	80	5.88	0.59
9	90	5.09	0.31
10	100	0.00	0.00

Transient #2

Point	Time (s)	Temp (Cdeg)	delta P (MPa)
1	10	5.18	0.31
2	20	6.18	0.62
3	80	9.08	0.91
4	40	11.76	1.18
5	60	14.18	1.41
6	80	17.12	1.76
7	70	15.02	1.50
8	80	15.02	1.50
9	90	19.75	1.98
10	100	20.00	2.00
11	110	19.75	1.98
12	120	19.02	1.90
13	130	17.82	1.78
14	140	16.16	1.62
15	150	14.14	1.41
16	160	11.78	1.18
17	170	9.08	0.91
18	180	6.18	0.62
19	190	3.13	0.31
20	200	0.00	0.00

Transient #3

Point	Time (s)	Temp (Cdeg)	delta P (MPa)
1	10	5.18	0.31
2	20	6.24	0.62
3	80	8.27	0.83
4	40	12.20	1.22
5	60	15.60	1.56
6	80	20.07	2.01
7	70	17.63	1.76
8	80	15.00	1.50
9	90	12.20	1.22
10	100	8.27	0.83
11	110	6.24	0.62
12	120	5.14	0.51
13	130	0.00	0.00

Transient #4

Point	Time (s)	Temp (Cdeg)	delta P (MPa)
1	10	5.14	0.31
2	20	6.26	0.63
3	80	9.39	0.94
4	40	12.36	1.24
5	60	15.41	1.54
6	80	18.44	1.84
7	70	16.90	1.69
8	80	23.51	2.35
9	90	25.98	2.60
10	100	28.28	2.83
11	110	30.42	3.04
12	120	32.36	3.24
13	130	34.11	3.41
14	140	35.65	3.56
15	150	36.96	3.70
16	160	38.04	3.80
17	170	38.88	3.89
18	180	39.51	3.95
19	190	39.88	3.99
20	200	40.00	4.00
21	210	39.88	3.99
22	220	39.51	3.95
23	230	38.89	3.89
24	240	38.04	3.80
25	250	36.96	3.70
26	260	35.64	3.56
27	270	34.11	3.41
28	280	32.36	3.24
29	290	30.42	3.04
30	300	28.28	2.83
31	310	25.98	2.60
32	320	23.51	2.35
33	330	20.90	2.09
34	340	18.16	1.82
35	350	15.31	1.53
36	360	12.36	1.24
37	370	9.34	0.93
38	380	6.26	0.63
39	390	3.14	0.31
40	400	0.00	0.00

Transient #5

Point	Time (s)	Temp (Cdeg)	delta P (MPa)
1	10	5.14	0.31
2	20	6.27	0.63
3	80	9.37	0.94
4	40	12.43	1.24
5	60	15.41	1.54
6	80	18.44	1.84
7	70	16.89	1.69
8	80	23.51	2.35
9	90	26.09	2.61
10	100	28.79	2.88
11	110	31.87	3.19
12	120	34.29	3.43
13	130	36.45	3.64
14	140	38.34	3.83
15	150	40.45	4.05
16	160	42.22	4.22
17	170	43.64	4.36
18	180	44.74	4.47
19	190	45.49	4.55
20	200	47.56	4.76
21	210	48.43	4.84
22	220	49.11	4.91
23	230	49.61	4.96
24	240	49.90	4.99
25	250	50.00	5.00
26	260	49.90	4.99
27	270	49.61	4.96
28	280	49.11	4.91
29	290	48.43	4.84
30	300	47.56	4.76
31	310	46.49	4.65
32	320	45.24	4.52
33	330	43.82	4.38
34	340	42.22	4.22
35	350	40.45	4.05
36	360	38.53	3.85
37	370	36.45	3.64
38	380	34.22	3.42
39	390	31.87	3.19
40	400	29.39	2.94
41	410	26.79	2.68
42	420	24.09	2.41

- 20 transients defined.
- Copied in worksheet to be used by TIFFANY add-in.
- User will input transient definitions (up to 20) into one of the three transient types (type I only, type I and II, type III) in the **user options tab**
- This tab list all transient I inputs (up to 50 timesteps)

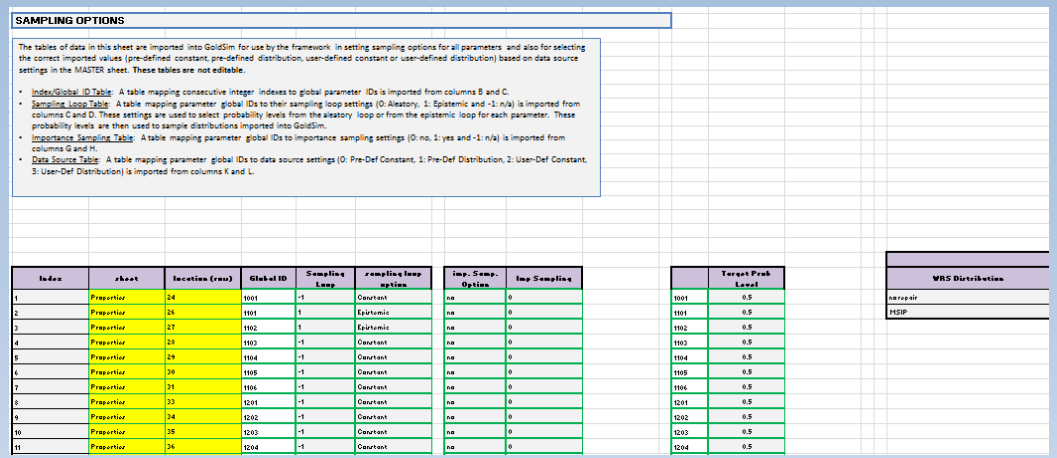
Input set worksheet: TIFFANY Inputs

Type II Transient Inputs (Thermal Stratification Stress)								
Transient #	Δ Membrane Stress (MPa)	Δ Bending Stress (MPa)	Start Month (mon)	End Month (mon)	Front-Back Loading	Frequency (yr-1)	# of Cycles per Event	Transient Uncertainty
1	1	2.00	0.00	720.00	0.5			
2	2	4.00	18.00	720.00	0.0			
3	3	6.00	18.00	360.00	0.0			
4	4	8.00	378.00	720.00	0.0			
5	5	10.00	0.00	720.00	1.0			
6	6	12.00	0.00	0.00	0.0			
7	7	14.00	0.00	0.00	0.0			
8	8	16.00	0.00	0.00	0.0			
9	9	18.00	0.00	0.00	0.0			
10	10	20.00	0.00	0.00	0.0			
11	11	22.00	0.00	0.00	0.0			
12	12	24.00	0.00	0.00	0.0			
13	13	26.00	0.00	0.00	0.0			
14	14	28.00	0.00	0.00	0.0			
15	15	30.00	0.00	0.00	0.0			
16	16	32.00	0.00	0.00	0.0			
17	17	34.00	0.00	0.00	0.0			
18	18	36.00	0.00	0.00	0.0			
19	19	38.00	0.00	0.00	0.0			
20	20	40	0	0	0			

Type III Transient Inputs (Additional Mechanical Stress)								
Transient #	Δ Membrane Stress (MPa)	Δ Bending Stress (MPa)	Start Month (mon)	End Month (mon)	Front-Back Loading	Frequency (yr-1)	# of Cycles per Event	Transient Uncertainty
1	10	20.00	0.00	720.00	0.50	0.10	10.00	50.00
2	20	40.00	18.00	720.00	0.00	0.67	1.00	100.00
3	30	60.00	18.00	360.00	0.00	0.67	4.00	150.00
4	40	80.00	378.00	720.00	0.00	0.67	2.00	200.00
5	50	100.00	0.00	720.00	1.00	12.00	8.00	250.00
6	60	120.00	0.00	0.00	0.00	180.00	240.00	300.00
7	70	140.00	0.00	0.00	0.00	210.00	280.00	350.00
8	80	160.00	0.00	0.00	0.00	240.00	320.00	400.00
9	90	180.00	0.00	0.00	0.00	270.00	360.00	450.00
10	100	200.00	0.00	0.00	0.00	300.00	400.00	500.00
11	110	220.00	0.00	0.00	0.00	330.00	440.00	550.00
12	120	240.00	0.00	0.00	0.00	360.00	480.00	600.00
13	130	260.00	0.00	0.00	0.00	390.00	520.00	650.00
14	140	280.00	0.00	0.00	0.00	420.00	560.00	700.00
15	150	300.00	0.00	0.00	0.00	450.00	600.00	750.00
16	160	320.00	0.00	0.00	0.00	480.00	640.00	800.00
17	170	340.00	0.00	0.00	0.00	510.00	680.00	850.00
18	180	360.00	0.00	0.00	0.00	540.00	720.00	900.00
19	190	380.00	0.00	0.00	0.00	570.00	760.00	950.00
20	200	400	0	0	0	600	800	1000.00

- List transients II and transients III inputs
  - Thermal stratification stresses
  - Additional mechanical stresses

Input set worksheet: options



SAMPLING OPTIONS

The tables of data in this sheet are imported into GoldSim for use by the framework in setting sampling options for all parameters and also for selecting the correct imported values (pre-defined constant, pre-defined distribution, user-defined constant or user-defined distribution) based on data source settings in the MASTER sheet. **These tables are not editable.**

- Index/Global ID Table: A table mapping consecutive integer indexes to global parameter IDs is imported from columns B and C.
- Sampling Loop Table: A table mapping parameter global IDs to their sampling loop settings (0: Aleatory, 1: Epistemic and -1: n/a) is imported from columns C and D. These settings are used to select probability levels from the aleatory loop or from the epistemic loop for each parameter. These probability levels are then used to sample distributions imported into GoldSim.
- Importance Sampling Table: A table mapping parameter global IDs to importance sampling settings (0: no, 1: yes and -1: n/a) is imported from columns G and H.
- Data Source Table: A table mapping parameter global IDs to data source settings (0: Pre-Def Constant, 1: Pre-Def Distribution, 2: User-Def Constant, 3: User-Def Distribution) is imported from columns K and L.

Index	sheet	location (row)	Global ID	Sampling Loop	sampling loop option
1	Properties	24	1001	-1	Constant
2	Properties	25	1101	1	Epistemic
3	Properties	27	1102	1	Epistemic
4	Properties	28	1103	-1	Constant
5	Properties	29	1104	-1	Constant
6	Properties	30	1105	-1	Constant
7	Properties	31	1106	-1	Constant
8	Properties	33	1201	-1	Constant
9	Properties	34	1202	-1	Constant
10	Properties	35	1203	-1	Constant
11	Properties	36	1204	-1	Constant

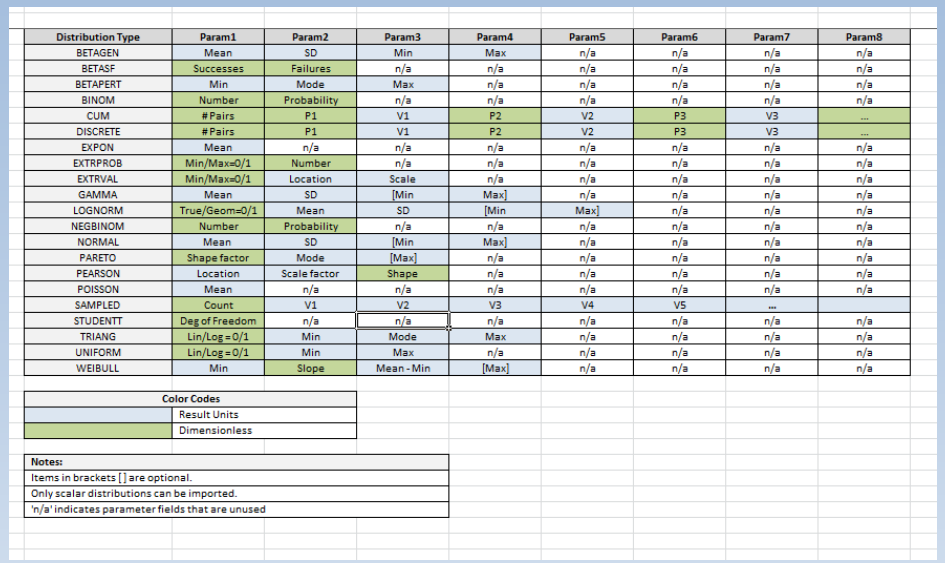
Imp. Samp. Option	Imp Sampling
na	0
na	0
na	0
na	0
na	0
na	0
na	0
na	0
na	0
na	0
na	0

	Target Prob Level
1001	0.5
1101	0.5
1102	0.5
1103	0.5
1104	0.5
1105	0.5
1106	0.5
1201	0.5
1202	0.5
1203	0.5
1204	0.5

WRS Distribution
narcpair
MSIP

- Transforms information relative to options into real numbers for GoldSim
- Will be hidden and protected in the released version – this should not be changed by the user

Input set worksheet: drop-list option



Distribution Type	Param1	Param2	Param3	Param4	Param5	Param6	Param7	Param8
BETAGEN	Mean	SD	Min	Max	n/a	n/a	n/a	n/a
BETASF	Successes	Failures	n/a	n/a	n/a	n/a	n/a	n/a
BETAPERT	Min	Mode	Max	n/a	n/a	n/a	n/a	n/a
BINOM	Number	Probability	n/a	n/a	n/a	n/a	n/a	n/a
CUM	#Pairs	P1	V1	P2	V2	P3	V3	...
DISCRETE	#Pairs	P1	V1	P2	V2	P3	V3	...
EXPON	Mean	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EXTRPROB	Min/Max=0/1	Number	n/a	n/a	n/a	n/a	n/a	n/a
EXTRVAL	Min/Max=0/1	Location	Scale	n/a	n/a	n/a	n/a	n/a
GAMMA	Mean	SD	[Min	Max]	n/a	n/a	n/a	n/a
LOGNORM	True/Geom=0/1	Mean	SD	[Min	Max]	n/a	n/a	n/a
NEGBINOM	Number	Probability	n/a	n/a	n/a	n/a	n/a	n/a
NORMAL	Mean	SD	[Min	Max]	n/a	n/a	n/a	n/a
PARETO	Shape factor	Mode	[Max]	n/a	n/a	n/a	n/a	n/a
PEARSON	Location	Scale factor	Shape	n/a	n/a	n/a	n/a	n/a
POISSON	Mean	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAMPLED	Count	V1	V2	V3	V4	V5	...	
STUDENTT	Deg of Freedom	n/a	n/a	n/a	n/a	n/a	n/a	n/a
TRIANG	Lin/Log=0/1	Min	Mode	Max	n/a	n/a	n/a	n/a
UNIFORM	Lin/Log=0/1	Min	Max	n/a	n/a	n/a	n/a	n/a
WEIBULL	Min	Slope	Mean - Min	[Max]	n/a	n/a	n/a	n/a

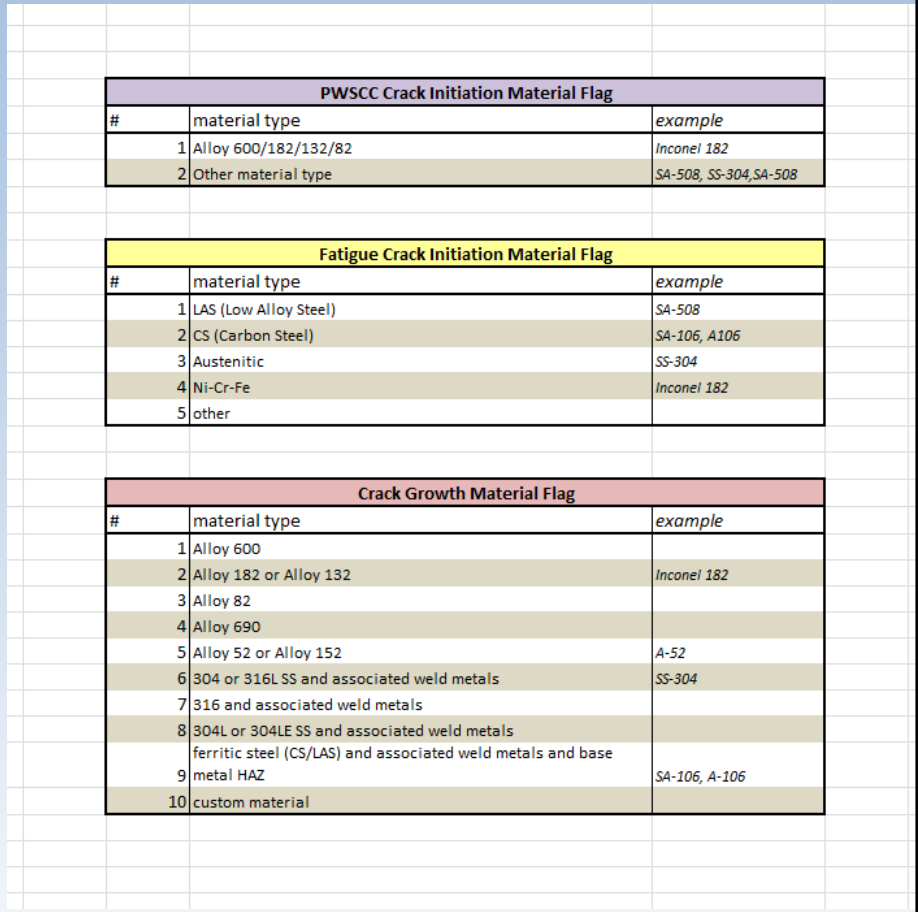
Color Codes	
	Result Units
	Dimensionless

Notes:
Items in brackets [ ] are optional.
Only scalar distributions can be imported.
'n/a' indicates parameter fields that are unused

- Informative spreadsheet on how the distributions are defined
- Should not be changed by user. Will be write-protected for released version

Input set worksheet: material flags

- Informative spreadsheet on the meaning of material flag in PWSCC CI, Fatigue CI and Crack Growth
- Information is used in the Materials tabs.
- Should not be changed by user. Will be write-protected for released version



PWSCC Crack Initiation Material Flag		
#	material type	*example*
1	Alloy 600/182/132/82	*Inconel 182*
2	Other material type	*SA-508, SS-304,SA-508*

Fatigue Crack Initiation Material Flag		
#	material type	*example*
1	LAS (Low Alloy Steel)	*SA-508*
2	CS (Carbon Steel)	*SA-106, A106*
3	Austenitic	*SS-304*
4	Ni-Cr-Fe	*Inconel 182*
5	other	

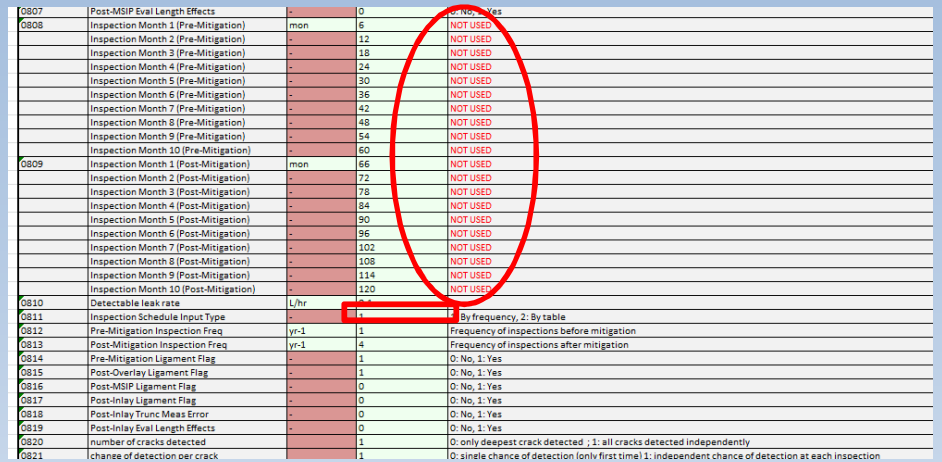
Crack Growth Material Flag		
#	material type	*example*
1	Alloy 600	
2	Alloy 182 or Alloy 132	*Inconel 182*
3	Alloy 82	
4	Alloy 690	
5	Alloy 52 or Alloy 152	*A-52*
6	304 or 316L SS and associated weld metals	*SS-304*
7	316 and associated weld metals	
8	304L or 304LE SS and associated weld metals	
9	ferritic steel (CS/LAS) and associated weld metals and base metal HAZ	*SA-106, A-106*
10	custom material	

Color coding conventions adopted

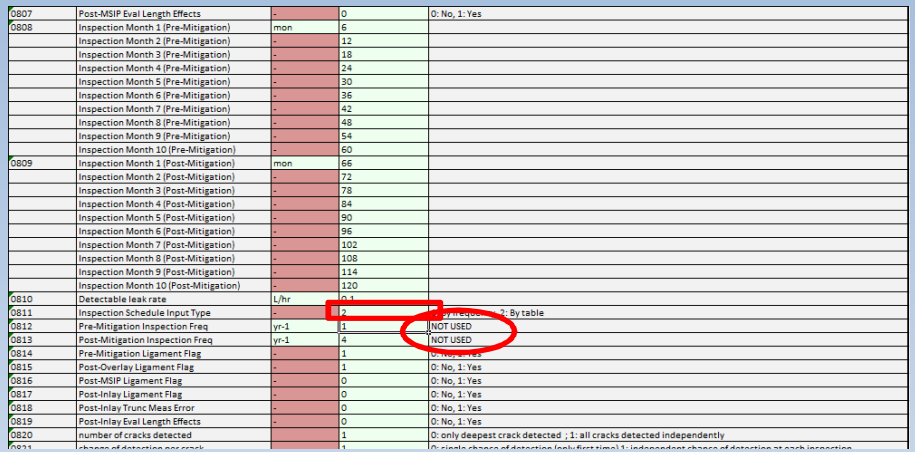
- User sets up the values in up to the first **7** spreadsheet
- Everything highlighted in green can be changed by the user
- Everything highlighted in red should not be changed (will be protected in final version of input set)
- Everything highlighted orange is for information

Global ID	Brief Description	Unit	Value	Input Description
OPTIONS / CONSTANTS (0000)				
General Options (0001-0099)				
0001	Plant Operation Time	yr	60	
0002	Number of Subunits	-	30	
0003	Crack Orientation	-	1	0: none, 1: Circumferential, 2: Axial, 3: Circumferential + Axial
Looping / Sampling Options (0101-0199)				
0101	Sample Size (Epistemic)	-	0	Number of outer loops in the simulation (NEED TO BE SET IN GOLDSIM in SIMULATION SETTINGS)
0102	Random Seed (Epistemic)	-	1	Random Seed for outer loop (NEED TO BE SET IN GOLDSIM in SIMULATION SETTINGS)
0103	Imp Sampling (Epistemic)	-	1	Imp sampling setting for outer loop 0: None, 1: Internal, 2: External
0104	Use Adaptive (Epistemic)	-	0	0 = no, 1 = yes *(not implemented yet)*
0105	Use Discretization (Epistemic)	-	0	0 = no, 1 = yes
0106	Number of Strata (Epistemic)	-	10	integer >1 and < epistemic sample size (0101)
0107	Sample Size (Aleatory)	-	2	Number of inner loops in the simulation
0108	Random Seed (Aleatory)	-	5	Random Seed for inner loop (NEED TO BE SET IN GOLDSIM in Main_Model Element)
0109	Imp Sampling (Aleatory)	-	2	Imp sampling setting for inner loop 0: None, 1: Internal, 2: External
0110	Use Adaptive (Aleatory)	-	0	0 = no, 1 = yes
0111	Use Discretization (Aleatory)	-	0	0= no , 1 = yes
0112	Number of Strata (Aleatory)	-	25	integer >1 and < aleatory sample size (0107)
Weld Type Options (0201-0299)				
0201	Weld Type Choice	-	DM - RPV	Weld type
0204	DM Weld Mixture Ratio	-	0.2	
0205	Base Material 1 (left pipe) Selection	-	SA-508	Base Material 1 Selection (entered in Properties tab)
0206	Base Material 2 (right pipe) Selection	-	SA-182	Base Material 2 Selection (entered in Properties tab)
0207	PWSCC Grow option in pipe (axial crack)	-	0	0: no PWSCC growth in pipe, 1:PWSCC growth in pipe
0208	Weld Material Selection	-	Inconel 182	Weld Material Selection (entered in Properties tab)
0209	Weld Repair State	-	1	Weld repair state choice (1: None, 2: 15% Inner Diam 360 Repair, 3: 50% Inner Diam 360 Repair)
Mitigation Options (0301-0399)				
0301	Mitigation Type Choice	-	0	0: None, 1: Stress-based only, 2: Chemistry-based, 3: Both
0302	Chem Mitigation Choice	-	3	0: None, 1: H2 mitigation, 2: Zn mitigation, 3: H2 and Zn mitigation

Conditional interpretation



0807	Post-MSIP Eval Length Effects	-	0	0: No, 1: Yes
0808	Inspection Month 1 (Pre-Mitigation)	mon	6	NOT USED
	Inspection Month 2 (Pre-Mitigation)	-	12	NOT USED
	Inspection Month 3 (Pre-Mitigation)	-	18	NOT USED
	Inspection Month 4 (Pre-Mitigation)	-	24	NOT USED
	Inspection Month 5 (Pre-Mitigation)	-	30	NOT USED
	Inspection Month 6 (Pre-Mitigation)	-	36	NOT USED
	Inspection Month 7 (Pre-Mitigation)	-	42	NOT USED
	Inspection Month 8 (Pre-Mitigation)	-	48	NOT USED
	Inspection Month 9 (Pre-Mitigation)	-	54	NOT USED
	Inspection Month 10 (Pre-Mitigation)	-	60	NOT USED
0809	Inspection Month 1 (Post-Mitigation)	mon	66	NOT USED
	Inspection Month 2 (Post-Mitigation)	-	72	NOT USED
	Inspection Month 3 (Post-Mitigation)	-	78	NOT USED
	Inspection Month 4 (Post-Mitigation)	-	84	NOT USED
	Inspection Month 5 (Post-Mitigation)	-	90	NOT USED
	Inspection Month 6 (Post-Mitigation)	-	96	NOT USED
	Inspection Month 7 (Post-Mitigation)	-	102	NOT USED
	Inspection Month 8 (Post-Mitigation)	-	108	NOT USED
	Inspection Month 9 (Post-Mitigation)	-	114	NOT USED
	Inspection Month 10 (Post-Mitigation)	-	120	NOT USED
0810	Detectable leak rate	L/hr	0.1	
0811	Inspection Schedule Input Type	-	1	By frequency, 2: By table
0812	Pre-Mitigation Inspection Freq	yr-1	1	Frequency of inspections before mitigation
0813	Post-Mitigation Inspection Freq	yr-1	4	Frequency of inspections after mitigation
0814	Pre-Mitigation Ligament Flag	-	1	0: No, 1: Yes
0815	Post-Overlay Ligament Flag	-	1	0: No, 1: Yes
0816	Post-MSIP Ligament Flag	-	0	0: No, 1: Yes
0817	Post-Inlay Ligament Flag	-	0	0: No, 1: Yes
0818	Post-Inlay Trunc Meas Error	-	0	0: No, 1: Yes
0819	Post-Inlay Eval Length Effects	-	0	0: No, 1: Yes
0820	number of cracks detected		1	0: only deepest crack detected ; 1: all cracks detected independently
0821	change of detection per crack		1	0: single chance of detection (only first time) 1: independent chance of detection at each inspection

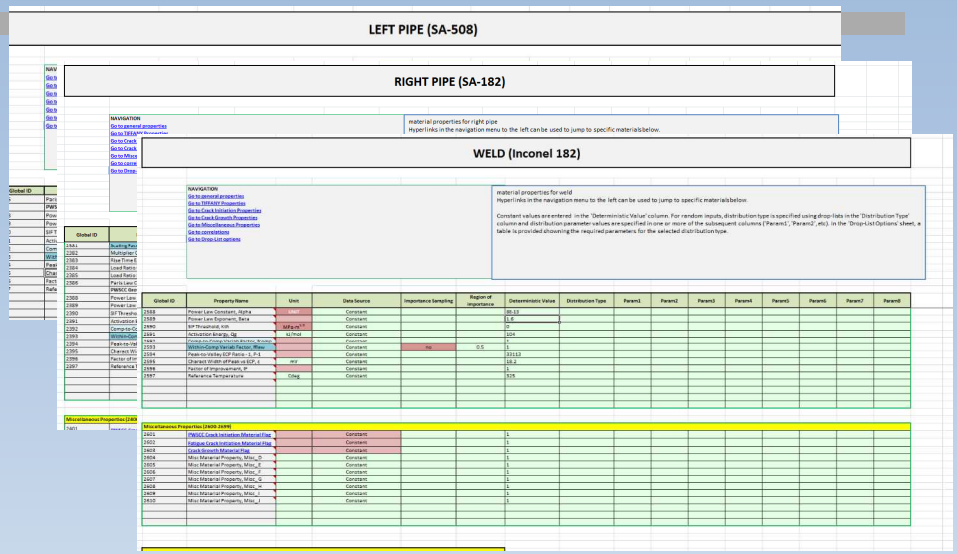


0807	Post-MSIP Eval Length Effects	-	0	0: No, 1: Yes
0808	Inspection Month 1 (Pre-Mitigation)	mon	6	
	Inspection Month 2 (Pre-Mitigation)	-	12	
	Inspection Month 3 (Pre-Mitigation)	-	18	
	Inspection Month 4 (Pre-Mitigation)	-	24	
	Inspection Month 5 (Pre-Mitigation)	-	30	
	Inspection Month 6 (Pre-Mitigation)	-	36	
	Inspection Month 7 (Pre-Mitigation)	-	42	
	Inspection Month 8 (Pre-Mitigation)	-	48	
	Inspection Month 9 (Pre-Mitigation)	-	54	
	Inspection Month 10 (Pre-Mitigation)	-	60	
0809	Inspection Month 1 (Post-Mitigation)	mon	66	
	Inspection Month 2 (Post-Mitigation)	-	72	
	Inspection Month 3 (Post-Mitigation)	-	78	
	Inspection Month 4 (Post-Mitigation)	-	84	
	Inspection Month 5 (Post-Mitigation)	-	90	
	Inspection Month 6 (Post-Mitigation)	-	96	
	Inspection Month 7 (Post-Mitigation)	-	102	
	Inspection Month 8 (Post-Mitigation)	-	108	
	Inspection Month 9 (Post-Mitigation)	-	114	
	Inspection Month 10 (Post-Mitigation)	-	120	
0810	Detectable leak rate	L/hr	0.1	
0811	Inspection Schedule Input Type	-	2	[illegible]: By table
0812	Pre-Mitigation Inspection Freq	yr-1	1	NOT USED
0813	Post-Mitigation Inspection Freq	yr-1	4	NOT USED
0814	Pre-Mitigation Ligament Flag	-	1	[illegible]
0815	Post-Overlay Ligament Flag	-	1	0: No, 1: Yes
0816	Post-MSIP Ligament Flag	-	0	0: No, 1: Yes
0817	Post-Inlay Ligament Flag	-	0	0: No, 1: Yes
0818	Post-Inlay Trunc Meas Error	-	0	0: No, 1: Yes
0819	Post-Inlay Eval Length Effects	-	0	0: No, 1: Yes
0820	number of cracks detected		1	0: only deepest crack detected ; 1: all cracks detected independently
0821	[illegible]		1	[illegible]

- When possible, logic has been added to indicate when a value is not used in the comment section
- Example: changing inspection schedule tag between frequency and table will indicate which inputs are used for the calculation in the description section

Tracking material used

0205	Base Material 1 (left pipe) Selection	-	SA-508
0206	Base Material 2 (right pipe) Selection	-	SA-182
0207	PWSCC Grow option in pipe (axial crack)	-	0
0208	Weld Material Selection	-	Inconel 182



- **Selected names for material are repeated in the top of the sheet related to the part of the system of interest (i.e., left pipe, right pipe, weld and mitigation)**

Conditional formatting on input characterization

Global ID	Property Name	Unit	Data Source	Importance Sampling	Region of importance	Deterministic Value	Distribution Type	Param1	Param2	Param3
Crack Initiation Properties (2121-2155)										
	Fatigue Initiation Properties									
2121	Surface Finish Factor, FSURF		Constant	no	0.5	0.973	NORMAL	100.1	1	
2122	Load Sequence Factor, FLOAD		Constant	no	0.5	0.438	NORMAL	100.1	1	
2123	Calibration Factor, FCAL		Constant	no	0.5	1	NORMAL	100.1	1	
2124	Stress-Strain Exponent, B		Constant	no	0.5	0.52083	NORMAL	100.1	1	
2125	Strain Threshold, STH		Constant	no	0.5	0.112	NORMAL	100.1	1	
2126	multiplier STH		Epistemic	no	0.5	1	NORMAL	100.1	1	
2127	Sulfur Content, SUL	%	Constant	no	0.5	0.015	NORMAL	100.1	1	
2128	C0		Constant	no	0.5	6.157	NORMAL	100.1	1	
2129	multiplier Co		Constant			1	NORMAL	100.1	1	
	PWSCC Initiation Properties									
2130	Zn Concentration Threshold, ZincTh	ppb	Constant	no	0.5	3	NORMAL	100.1	1	
2131	Zn Factor of Improvement - 1, FOIZn-1		Constant	no	0.5	0.5129	NORMAL	100.1	1	
2132	Activation Energy, Q	kJ/mol	Constant	no	0.5	184.2	NORMAL	100.1	1	
	PWSCC Initiation Cold Work Properties									

- When user selects the data source (constant or one of the type of uncertainty) **only** the relevant value set (either deterministic value or distribution) is shown in black text.
- **However** GoldSim reads **everything** so **placeholders** (greyed out) are required to be left **even** if they are not used.

Conclusion

- Separation of database and input set allowed simplifying the input set.
- Should be easier for the user to update and keep track of changes.
- Not all conditional formatting included. If some are found missing during V&V, please let us know and we will try to update in consequence.

xLPR SimEditor

xLPR SimEditor: Overview

- **Purpose:** Create an easy to use Graphical User Interface (GUI) for creating a simulation input set and for maintenance a database of material and weld properties.
- **2 modes:**
  - **Simulation mode** allows for creation of simulation input sets.
  - **Database mode** allows for creating pre-defined, password locked, data sets and user-defined data sets.

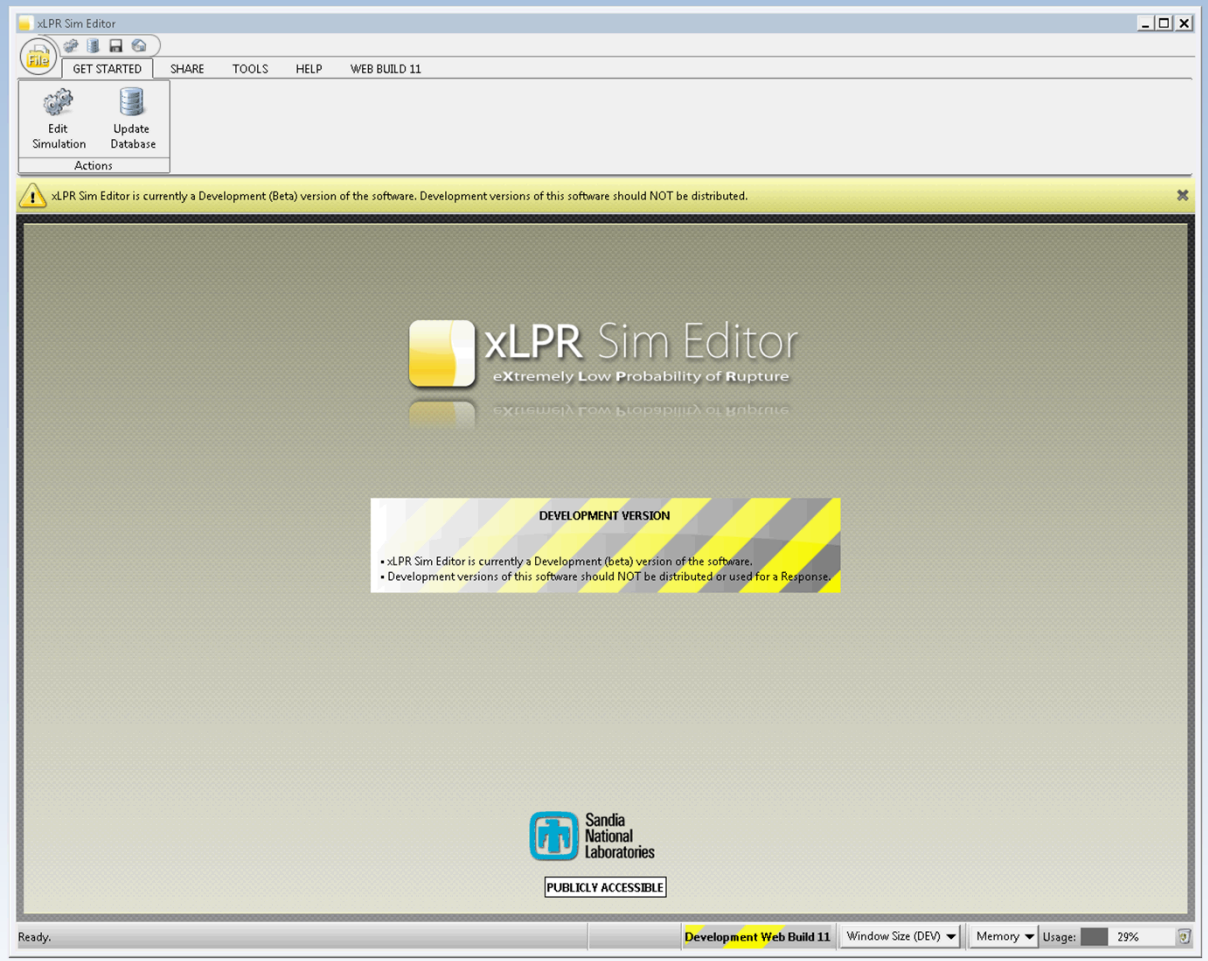
SimEditor Interactions

- SimEditor reads and writes to Excel files.
- More user friendly than Excel files
  - Hides input parameters that are not relevant to the simulation options chosen
  - Organizes inputs in a more user-friendly manner
  - Includes error-checking for input value ranges

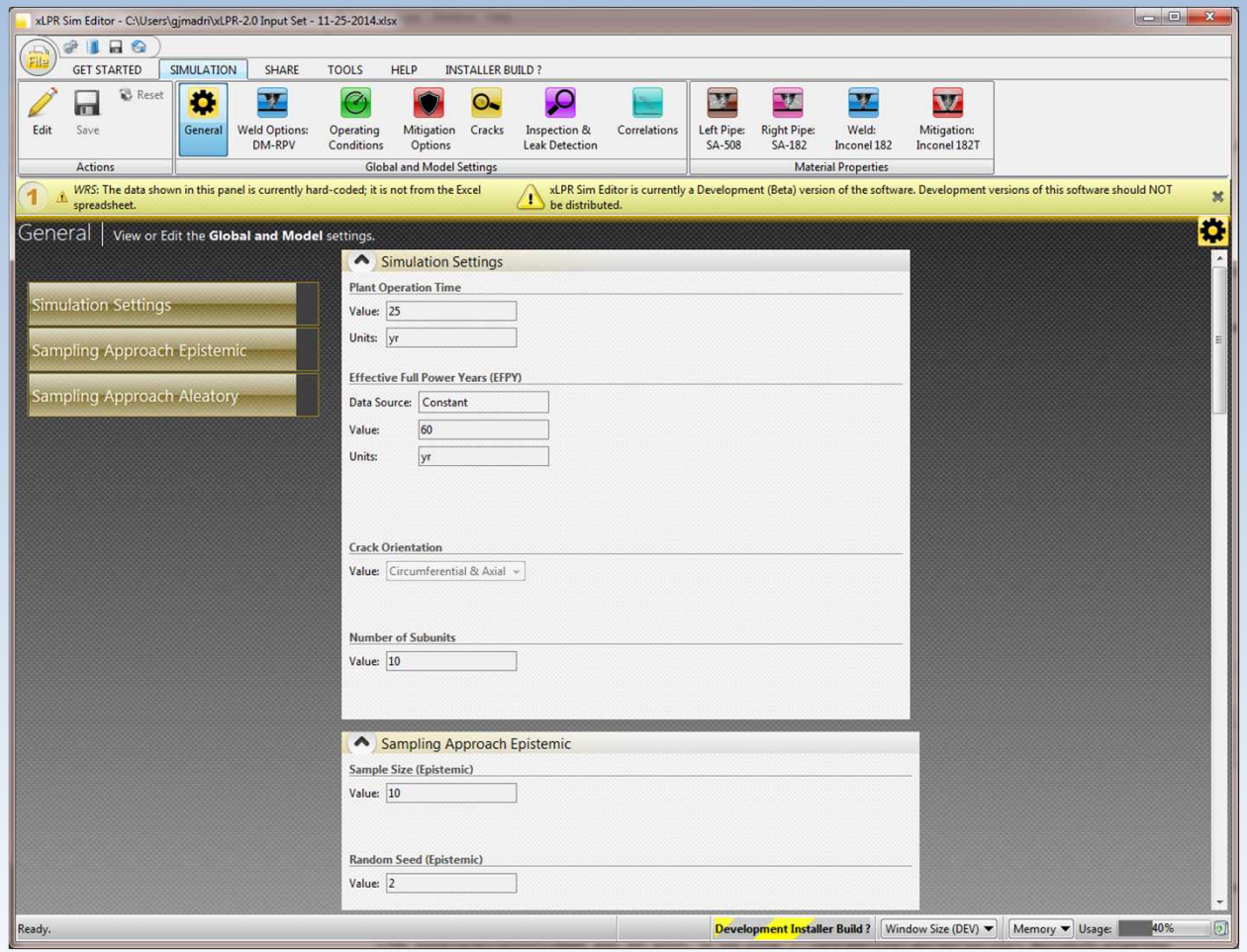
Status update

- **Current Status:**
  - Input mode finished.
- **What's Next:**
  - Develop database mode of SimEditor.
  - Error checking for input ranges.

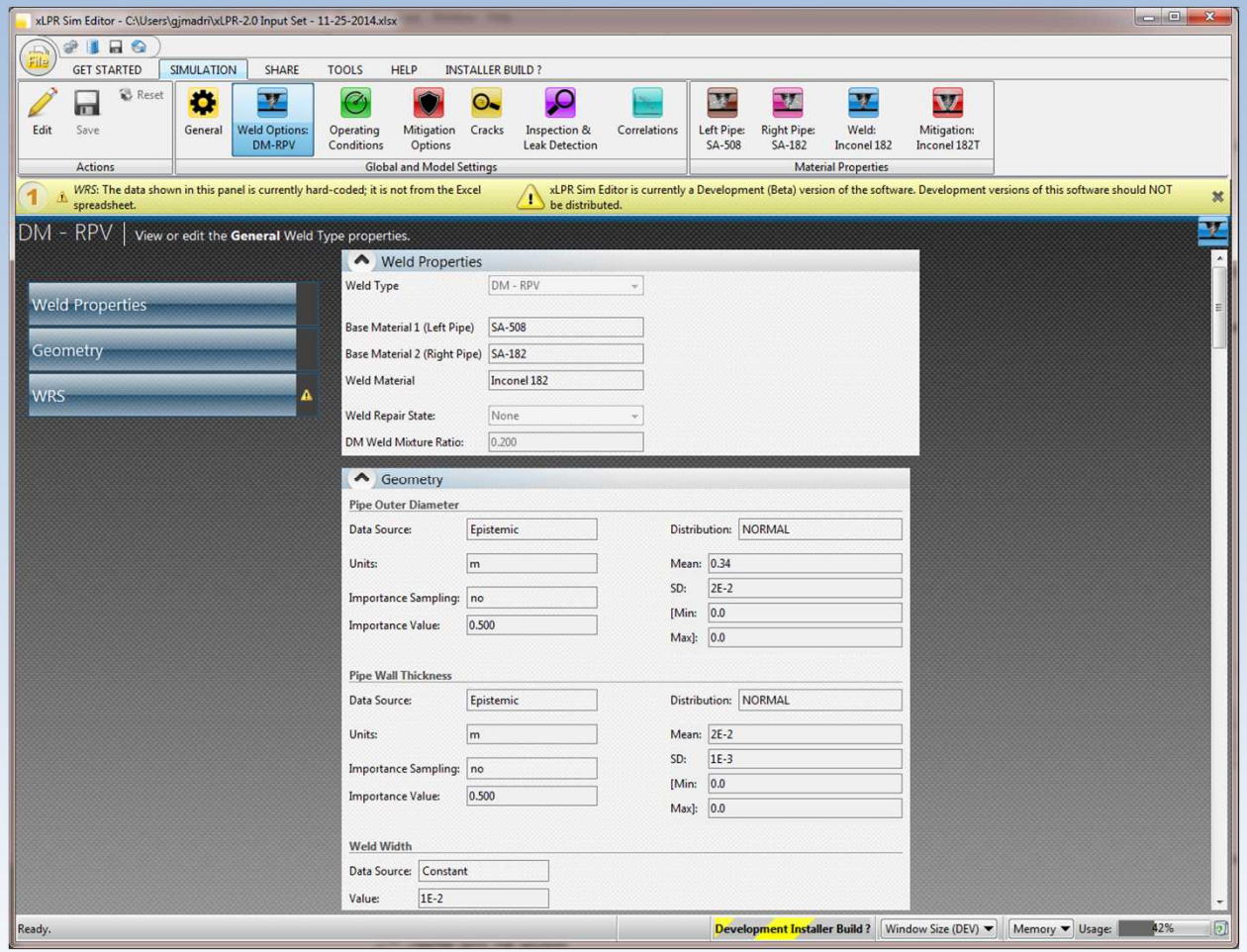
xLPR SimEditor: Overview (1/4) – Loading screen



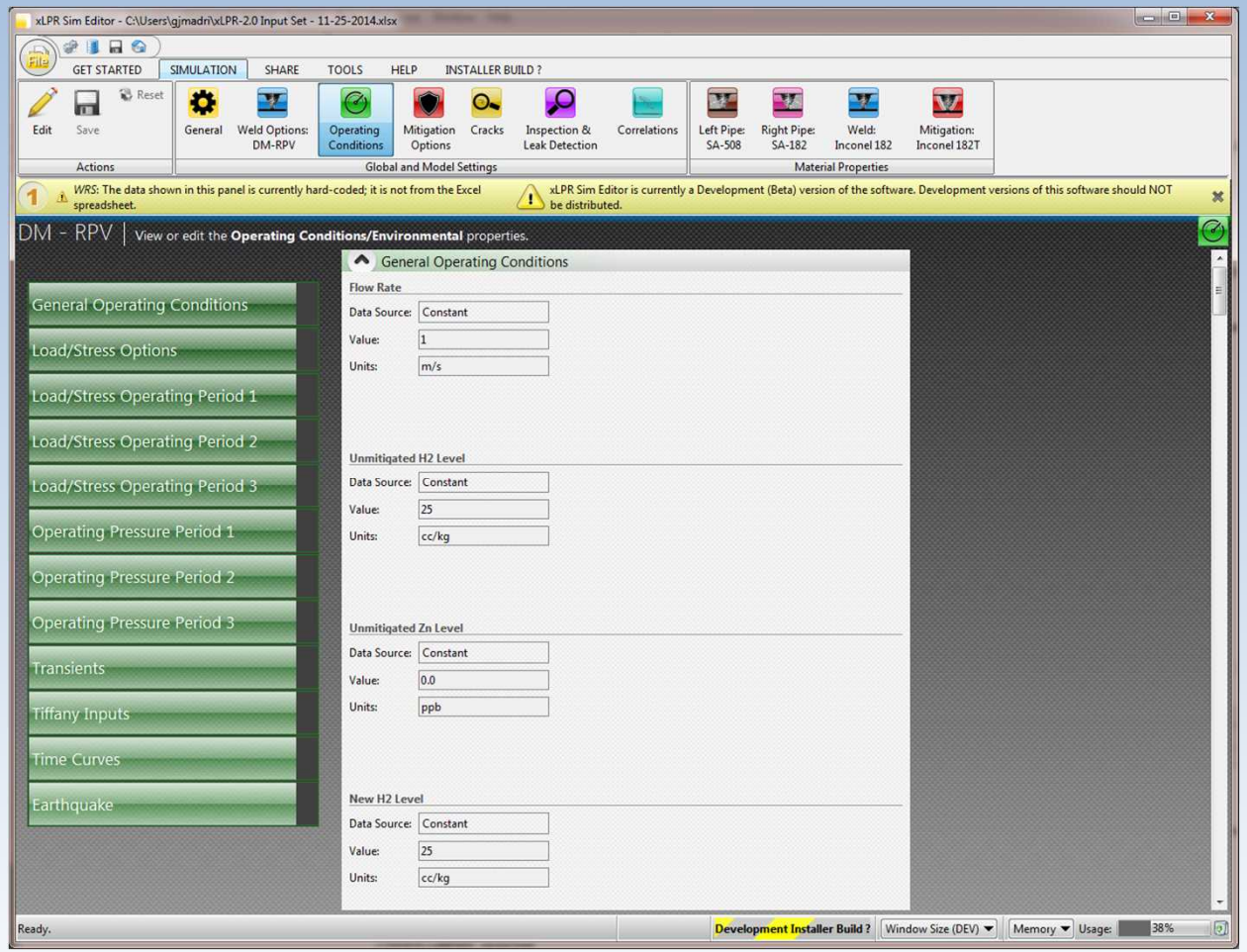
xLPR SimEditor: Overview (2/4) – General tab



xLPR SimEditor: Overview (3/4) – Weld options



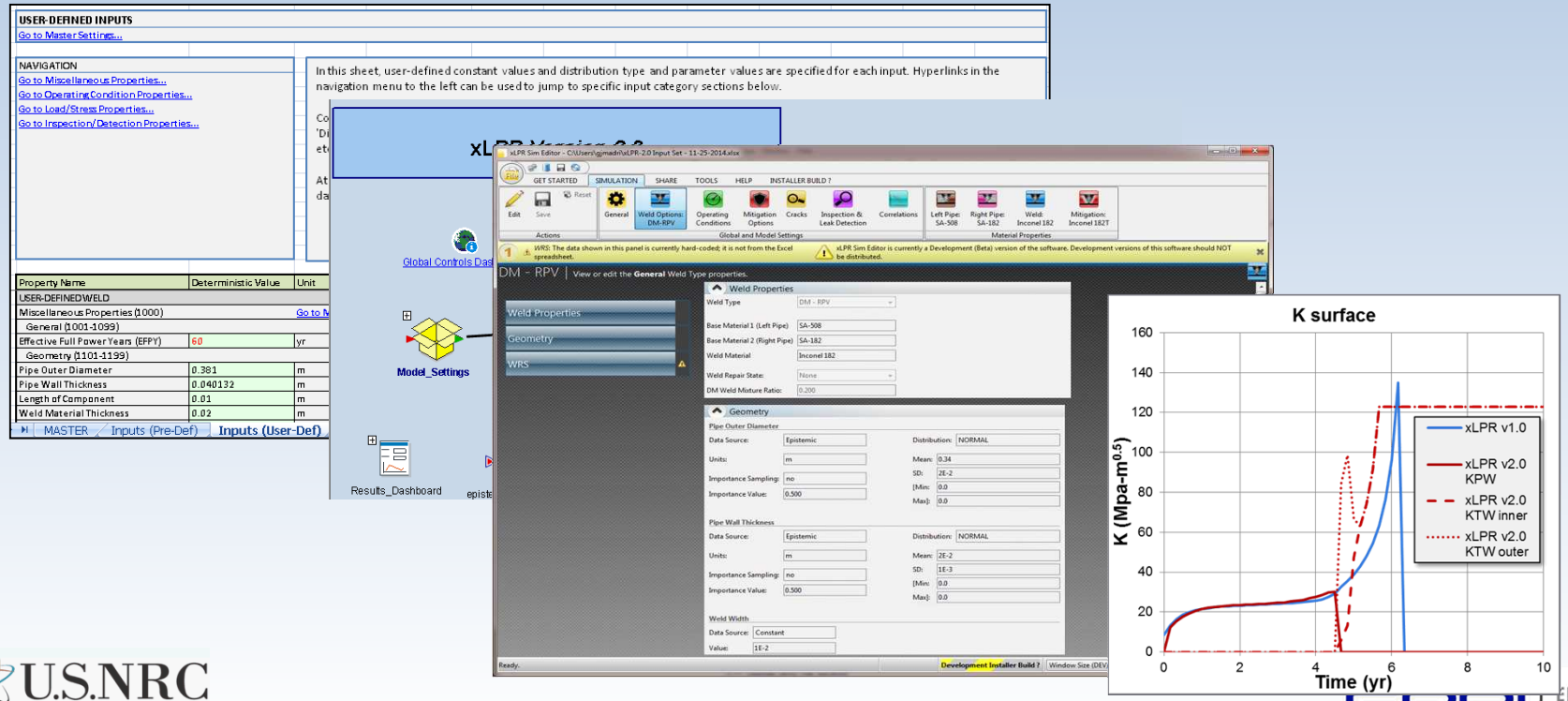
xLPR SimEditor: Overview (4/4) – Operating conditions



Input creation exercise

Steps for Test Case Creation

- Preparation of an Input Deck Using SimEditor
  - Open a working Input Set Excel file in SimEditor
    - **xLPR-2.0 Input Set.xlsx**
  - Save As new file to new simulation directory



Practice 1 - SimEditor

- PWSCC growth only with no mitigation
  - Similar to Scenario 3 of Scoping Analyses
- This test case considers:
  - SCC initiation (direct model 2)
  - SCC growth
  - Circumferential and axial cracks
  - No mitigation
  - Probabilistic

Practice 1
Steps for Input Deck Preparation

1. Open a new Simulation in SimEditor.
   - Open "xLPR-2.0 Input Set.xlsx" from "xLPR main" directory.
2. Save the opened Input Set into the Practice 1 directory with same name "xLPR-2.0 Input Set.xlsx".
3. Look at the entered parameter values in General and Weld Type.
4. Open the file in Excel and find the General and Weld Type inputs there.

Practice 1 Steps (cont.)

5. Change the following inputs in Operating Conditions and Cracks (may need to change from distributions to constants)

- UPDATE LIST
- Initial flaw length: 6 mm
- Initial flaw depth: 1.5 mm
- Unmitigated H2 level: 25 cc/kg
- Unmitigated Zn level: 0 ppb
- Operating pressure: 15.5132 MPa
- Operating temperature: 345 C
- Mx (Dead Weight): 1.31 kN-m
- My (Dead Weight): 0.21 kN-m
- Mz (Dead Weight): 1.02 kN-m
- Fx (Thermal Expansion): 3.87 kN
- Mx (Thermal Expansion): 65.3 kN-m
- My (Thermal Expansion): -57.54 kN-m
- Mz (Thermal Expansion): 52.99 kN-m

Practice 1 Final Steps

6. Look at other inputs. Compare to spreadsheet.
7. Save "xLPR-2.0 Input Set.xlsx"
8. Open the "xLPR-2.0 Beta2.1_R3 Probabilistic" GoldSim file in "xLPR main"
9. Save it in Practice 1 directory.
10. Run it.
11. Check results.
12. Check errors.

Practice 2 – Importance Sampling

- PWSCC growth, inlay at 40 years
  - Similar to Scenario 9 of Scoping Analyses
- This test case considers:
  - SCC initiation (direct model 2)
  - SCC growth
  - Circumferential and axial cracks
  - Inlay at 40 years
  - Probabilistic

Practice 2 Steps

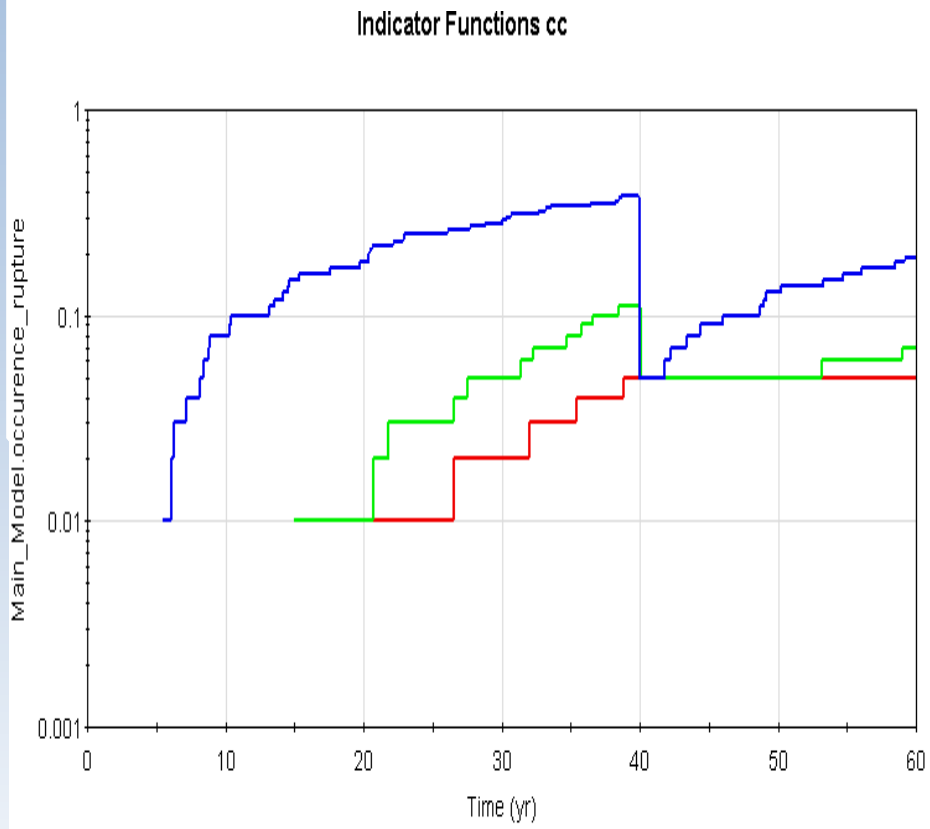
1. Copy the "xLPR-2.0 Beta2.1_R3 Probabilistic" GoldSim file and "xLPR-2.0 Input Set.xlsx" from "xLPR main" to the Practice 2 directory.
2. Open Input Set (SimEditor or Excel) and add inlay at 40 years (change user options, check Mitigation material, post-mitigation WRS, etc.)
3. Change number of aleatory realizations to 2.
4. Do importance sampling (epistemic) (option 0103). Importance sample on Comp-to-Comp Variab Factor, fcomp (Weld, 2592, region of importance 0.99).
5. Save Input Set.

Practice 2 Final Steps

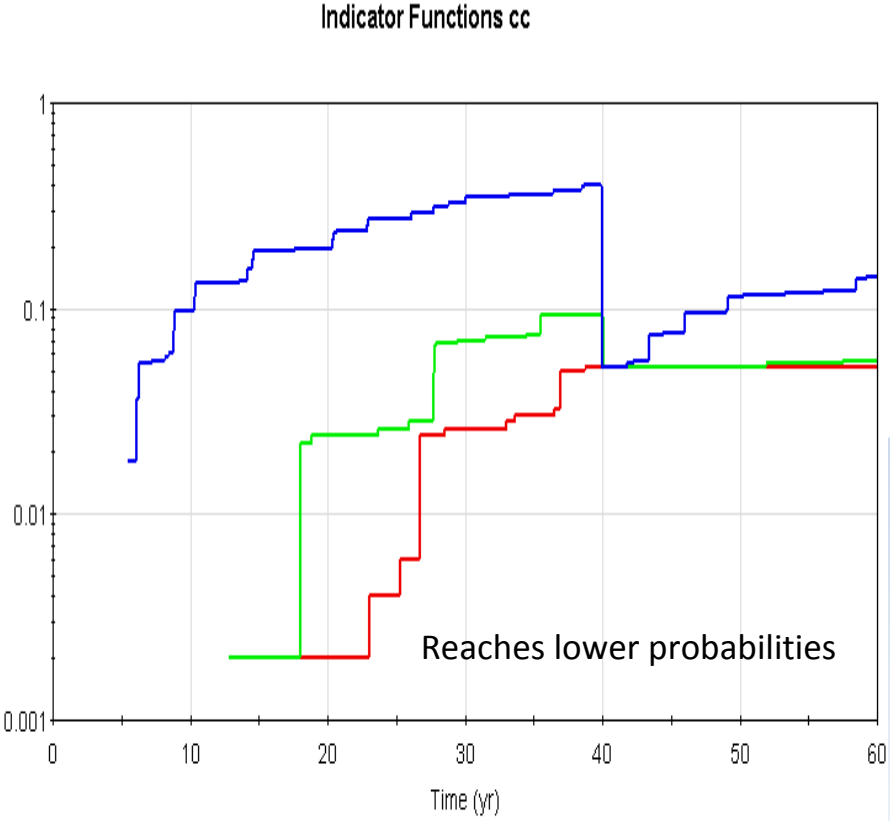
6. Open GoldSim file.
7. Change Simulation Settings (F2), Monte Carlo to 50 realizations.
8. Run GoldSim file. (4 minutes)
9. Check results.
10. Save GoldSim file as "Practice 2 with importance sampling"
11. Open Input Set (SimEditor or Excel) and de-select importance sampling. Save (and close if using Excel).
12. Run GoldSim file again and, when finished, save as "Practice 2 no importance sampling"

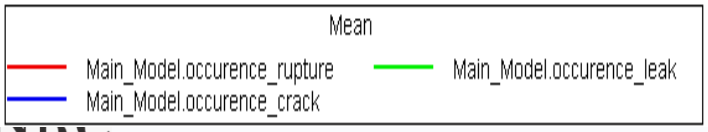
Practice 2 Results Comparison

No importance sampling



Importance sampling

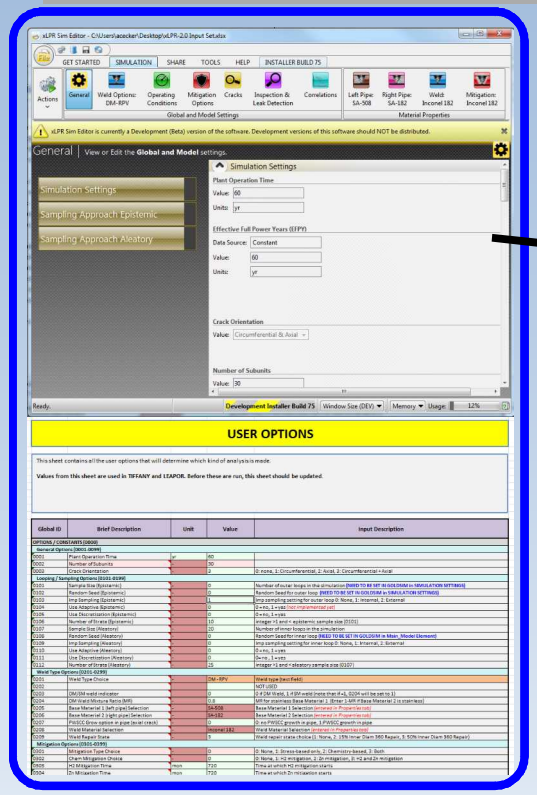


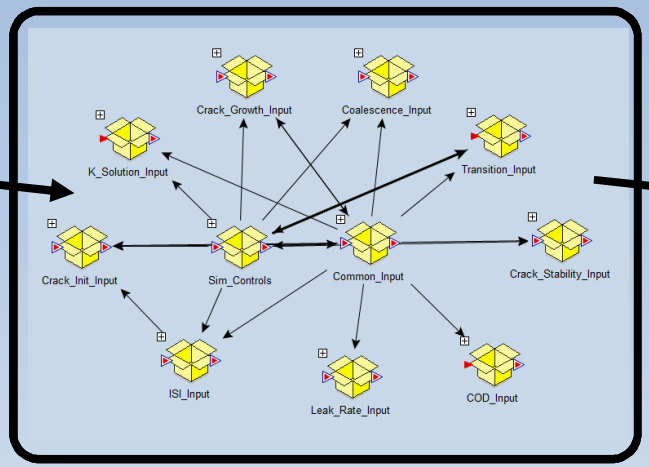


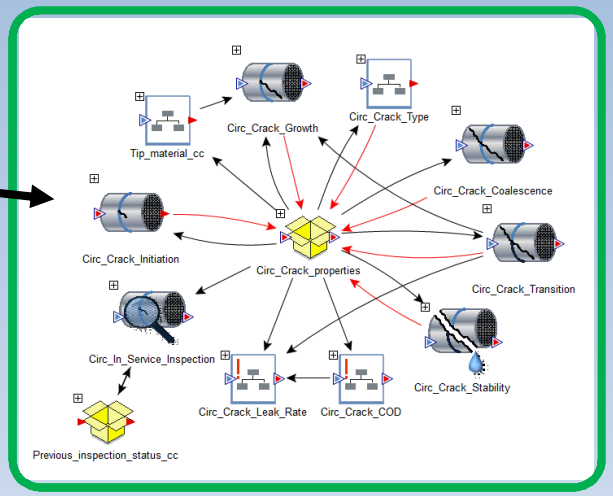
Curves will get smoother with more epistemic and aleatory sampling.

Internal structure of the code

Internal code structure







User interface
SimEditor and Excel workbook allow the user to define inputs.

Landing platform
Definition of all input variables as well as simulation controls.

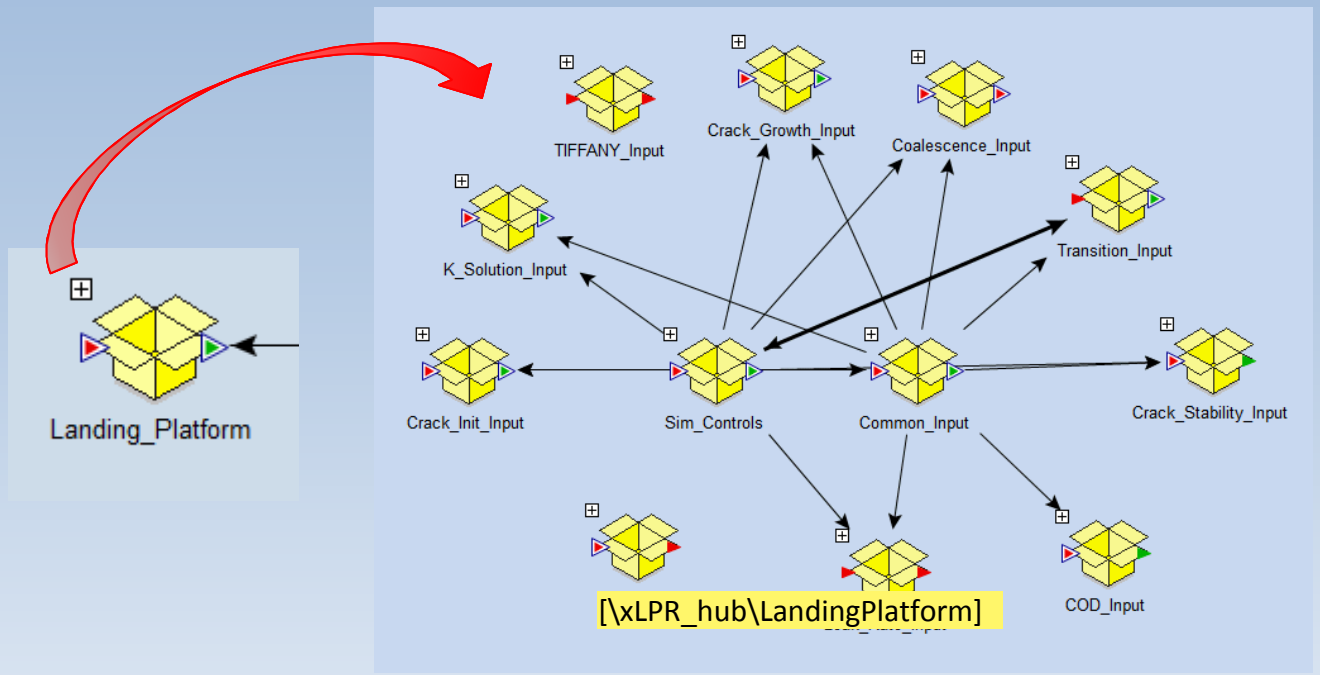
In collaboration with the **input group** (simulation settings) and the **model group** (input/output of each model).

Physical (deterministic) models
Definition of all input variables as well as simulation controls.

Each container host module developed by the **model group** and compiled as a DLL.

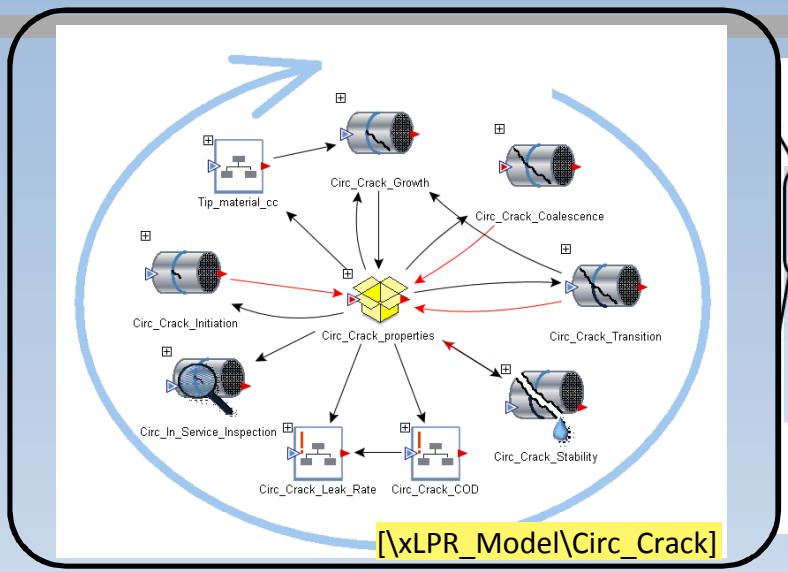
This strategy allows for multi-entities to share and work on the framework development in an efficient and parallel manner.

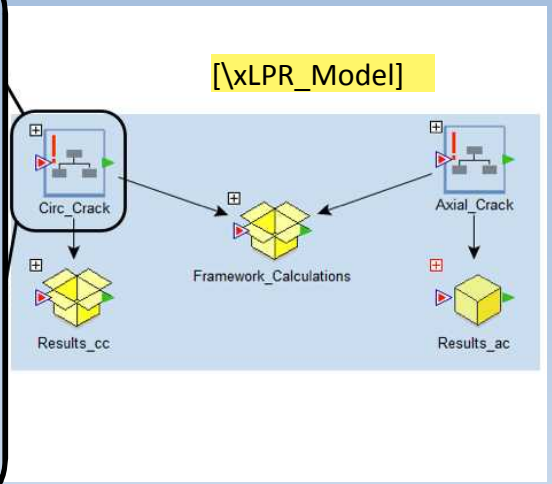
Landing platform: Imports inputs values from the GUI interface and Excel input spreadsheet into a common “hub”



- The landing platform lists and organizes the inputs used by each model.
- These containers only include data defined in the GUI and Excel input spreadsheet.
- Sim controls have model options such as circ and/or axial; model choices; fatigue and/or PWSCC…
- Common input are inputs from the GUI/Spreadsheet that are common to many of the modules.

Deterministic model: structure using on state variable integrator elements as vectors





- Circumferential and axial crack evolution have been implemented.
- Deterministic model linked to sampling scheme.
- **State variables** and **Integrator element** used to track crack properties (type, position, depth, inner/outer diam, half-length) changing over time.
  - Time histories saved and growth calculation using current props as input without recursive error.
  - Rate of change in variables, discrete changes.
- Vector structure for state variables:
  - Crack sorted by occurrence time.
  - Pipe subdivided in N regions (i.e. maximum 2N cracks possible for each realization in one sim.).
- Time loop starts at coalescence and finishes with crack growth. Crack growth rate for variable applied at the end of time step.

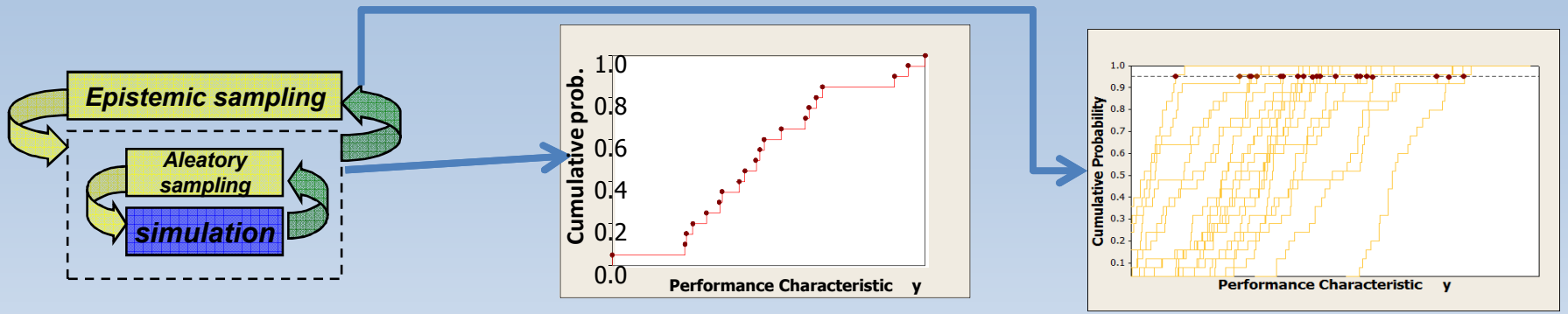
Sampling option and running the code

Difference between epistemic and aleatory uncertainty and spatial variability

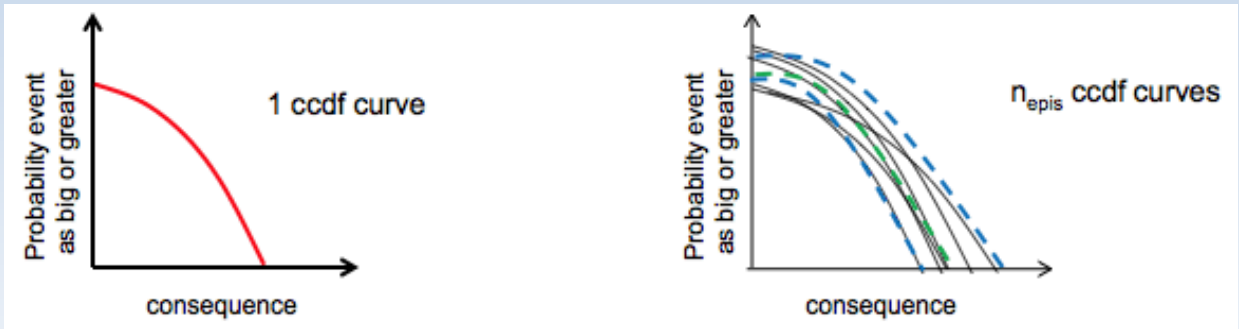
- **Aleatory uncertainty:** (Perceived) randomness in the occurrence of future events.
- **Epistemic uncertainty:** Lack of knowledge w.r.t. the appropriate value to use for a quantity that has a fixed, but poorly known, value in the context of a specific analysis.
- Treat questionable uncertainties as epistemic, and then determines the ones that dominate the epistemic output uncertainty. Only for those that are dominant, additional evaluation becomes necessary to justify their treatment as epistemic. All other uncertainties can then be allocated to the aleatory category.
- **Spatial variability:** inherent variability over space of a quantity, that usually cannot be measured precisely or at the expected scale. Spatial variability is NOT aleatory or epistemic uncertainty. Variability is linked to uncertainty.
- Probability usually used to characterize both aleatory and epistemic uncertainties and spatial variability.
- Alternatives to probability to the representation of epistemic exist, such as evidence theory, possibility theory, interval analysis and others.

Representation and interpretation of results

- Parameters selected either as aleatory or epistemic: Guidance needed
- Inner aleatory loop vs. outer epistemic loop



- Interpretation of the results:

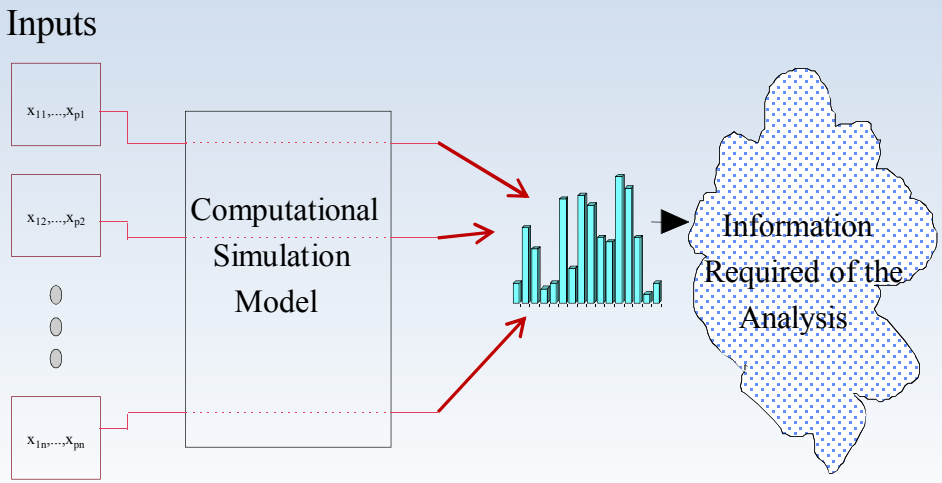


Aleatory uncertainty represents the **risk**. Not simply [probability]x[consequence] but probability and consequence

Epistemic uncertainty represent **the level of knowledge** we have with respect to this risk

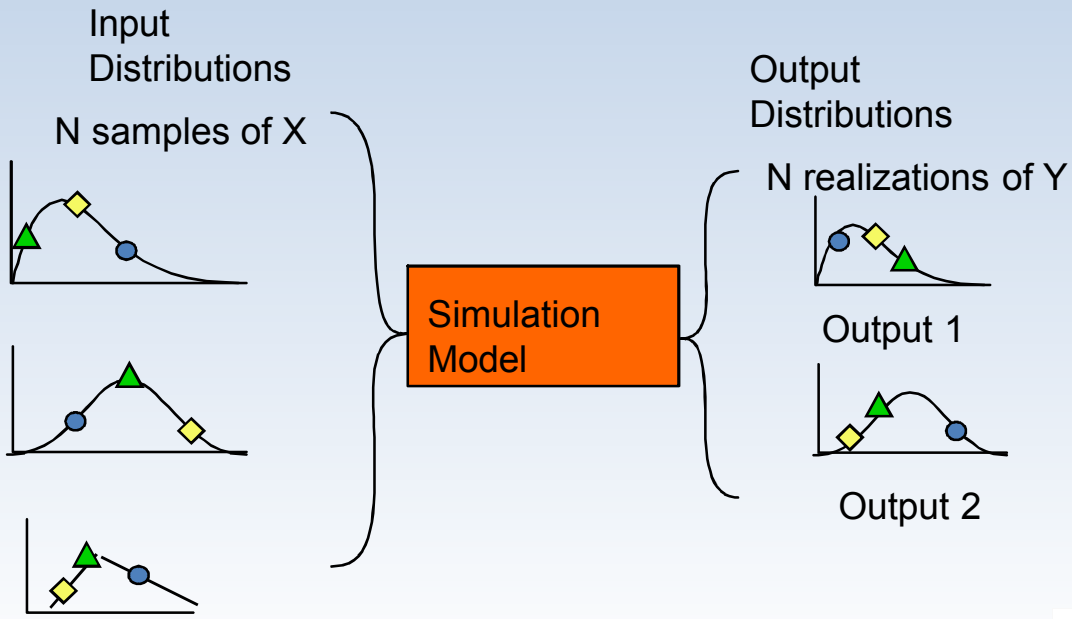
Sampling techniques

- Random sampling (Monte Carlo sampling)
- Latin Hypercube Sampling (LHS)
- Discrete Probability Distribution (DPD)
- Importance sampling
- Adaptive sampling

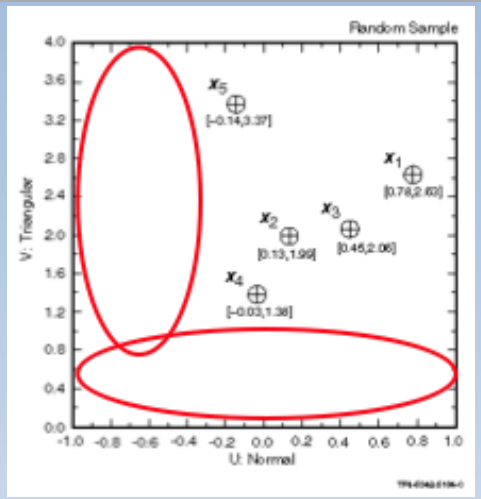


From mathematical characterization to implementation: Sampling approach

1. Characterization of distributions on the uncertain input values
2. Generation of sample from those distributions
3. Propagation of sample through analysis execution repeatedly
4. Presentation of uncertainty analysis results in the form of distributions of the outputs
5. Determination of sensitivity analysis results

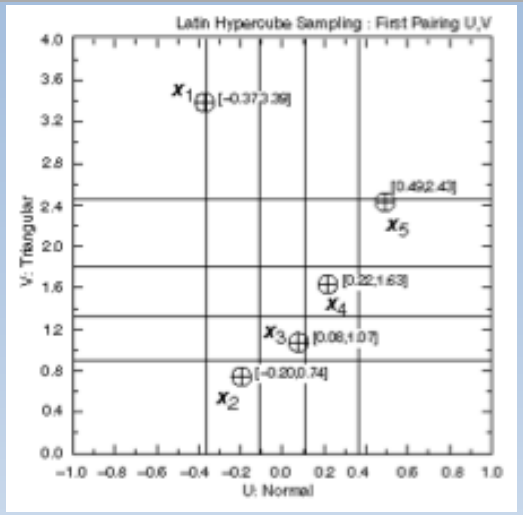


LHS vs. Monte Carlo sampling



Random sampling

- Preferred when sufficiently large samples are possible
- Easy to implement
- Easy to explain
- Unbiased estimates for means, variances and distribution functions
- Sufficiently large samples may not be possible

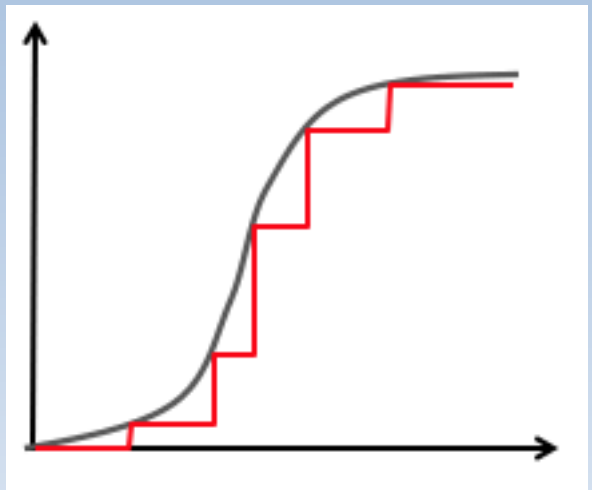


LHS

- Unbiased estimates for means and distribution functions
- "Force" samples to be spread out across domain of the input distributions
- Dense stratification across range of each variable
- Used when large samples not computationally practicable and estimation of high quantiles not required
- Uncertainty/sensitivity results robust with relatively small sample sizes (e.g., nLHS = 50 to 200)

Discrete Probability Distribution (DPD)

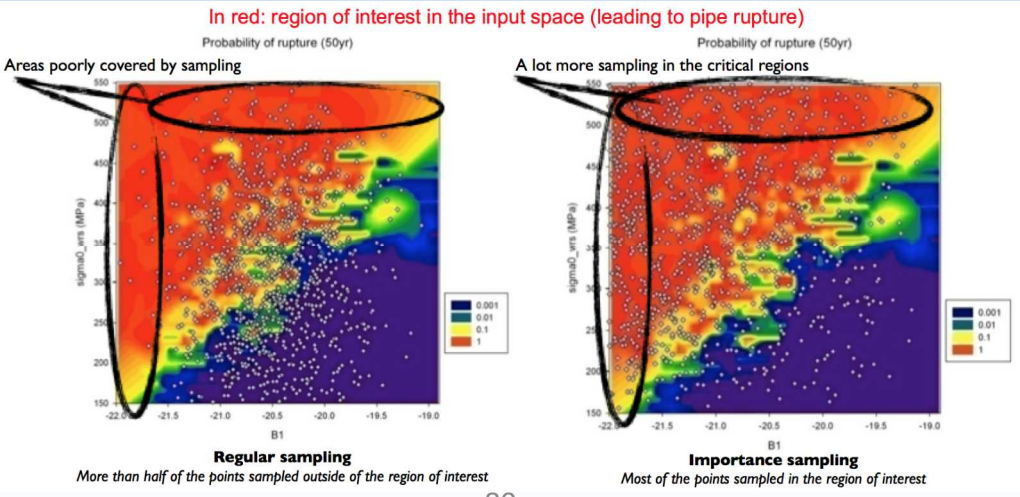
- DPD uses discrete values from probability distributions
  - Each value can be equally probable or of different likelihood



- Difference with LHS:
  - Less dense stratification. Worse than LHS if events of interest occur more for extreme values of inputs.
  - Higher combination (i.e. better multidimensional coverage). Better than LHS if events of interest occur more for combination of inputs.

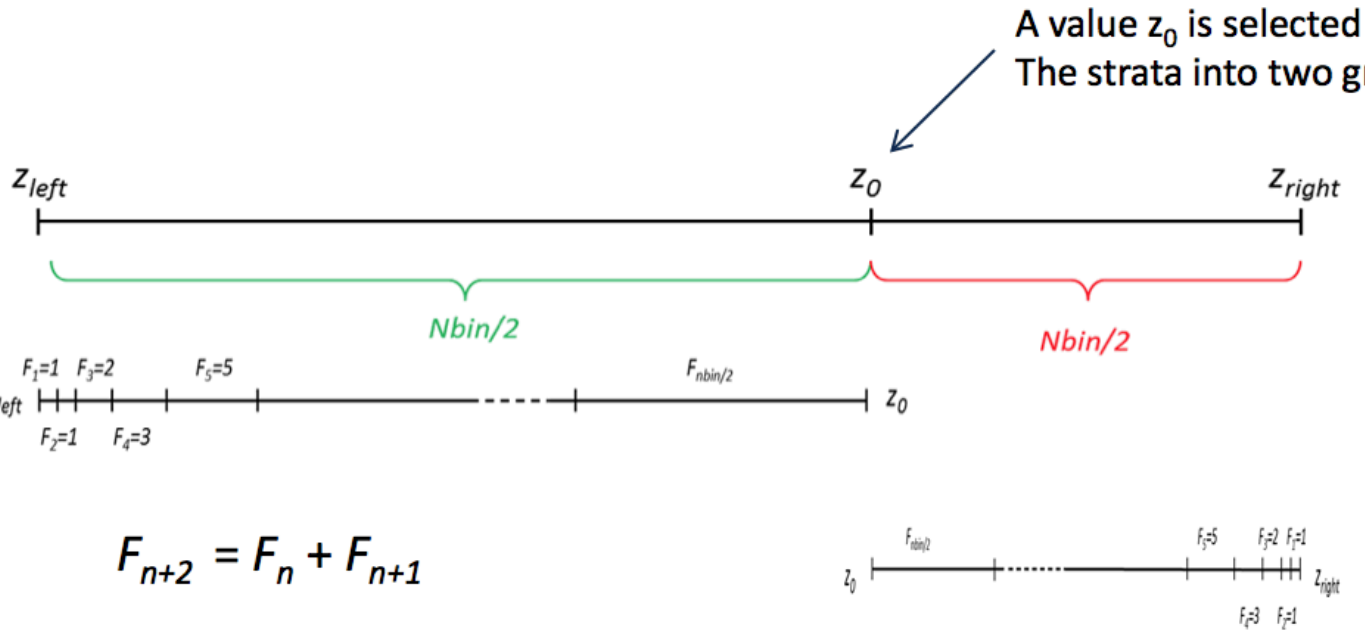
Importance sampling

- Importance sampling is a variance reduction technique that can be used in the Monte Carlo method
  - Certain values of the input random variables in a simulation have more impact on the parameter being estimated than others. If these "important" values are emphasized by sampling more frequently, then the estimator variance can be reduced.
  - Cannot be applied to all variables!
- The basic methodology in importance sampling is to choose a distribution which "encourages" the important values. The outputs are weighted to correct for the use of the biased distribution, and this ensures that the new importance sampling estimator is unbiased.



Example: DPD using importance sampling

- For example, a Fibonacci series works well for interrogating tails of distributions
- The strength of the Fibonacci series can be controlled by an exponent γ between 0 and 1 on the F value

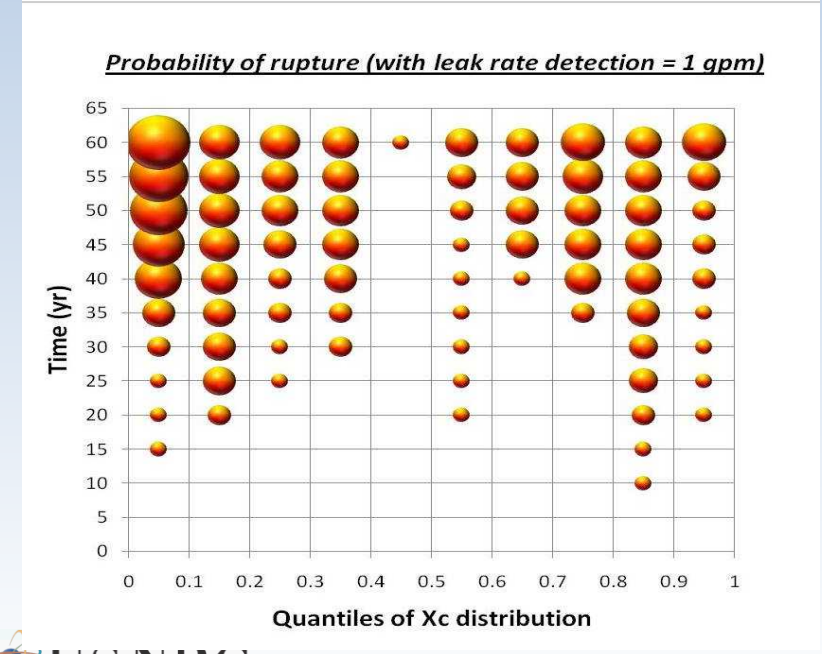


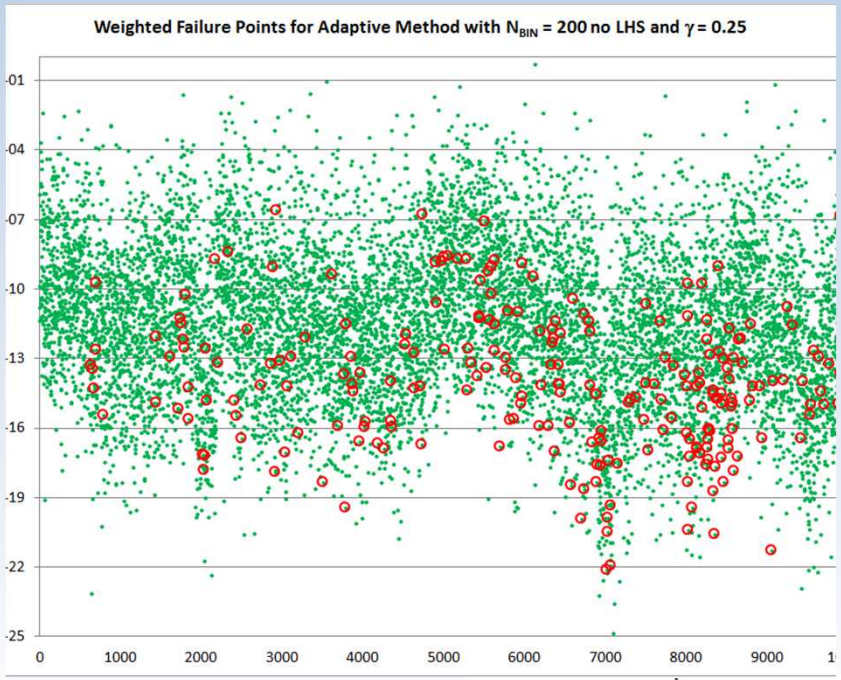
Fibonacci series is used to generate strata of unequal size with focus on the tail

Optimization method: Adaptive sampling

- Adaptive sampling promotes importance sampling by using model results to identify and focus on space of interest

- Adaptive sampling can cover more densely disparate regions in the input space, and reduces the number of samples needed to confidently estimate low probability (~10^{-6})

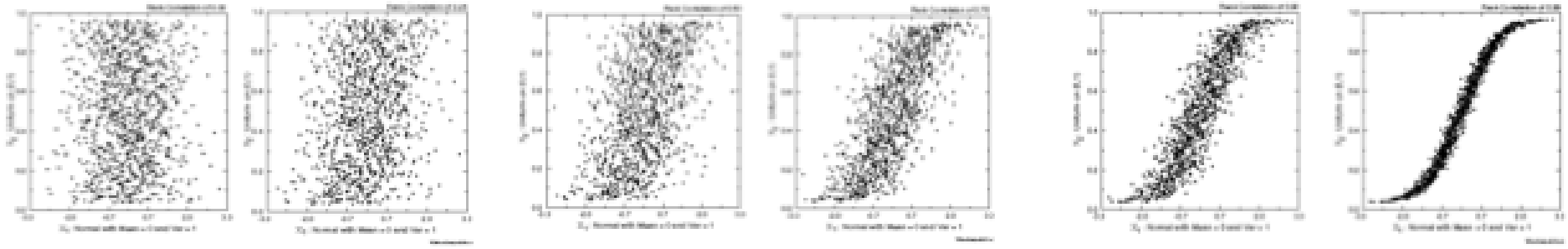




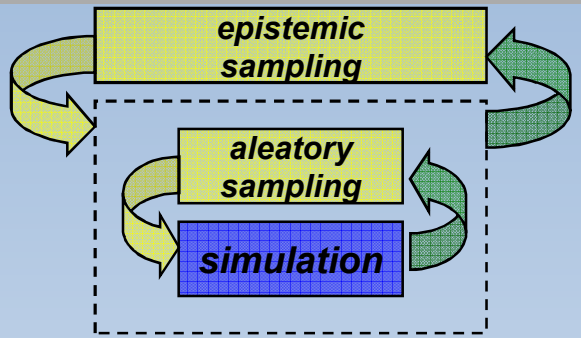
Sampling correlated inputs

- Correlation can be used to force behavior between two or more variables in order to remain in a physically acceptable input space
  - Individual inputs are not independent

- Correlation control should be done for a limited selected variables based on model/input recommendations



Sampling strategy

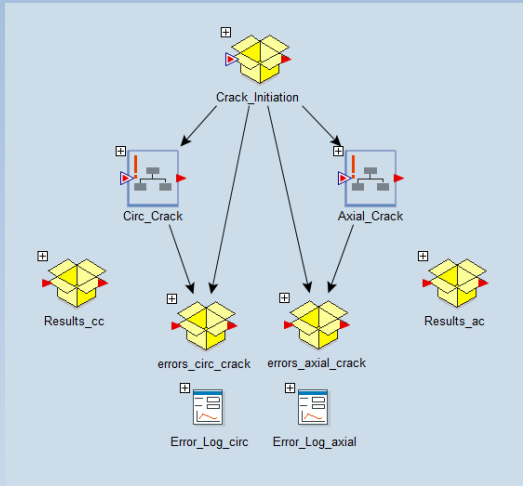


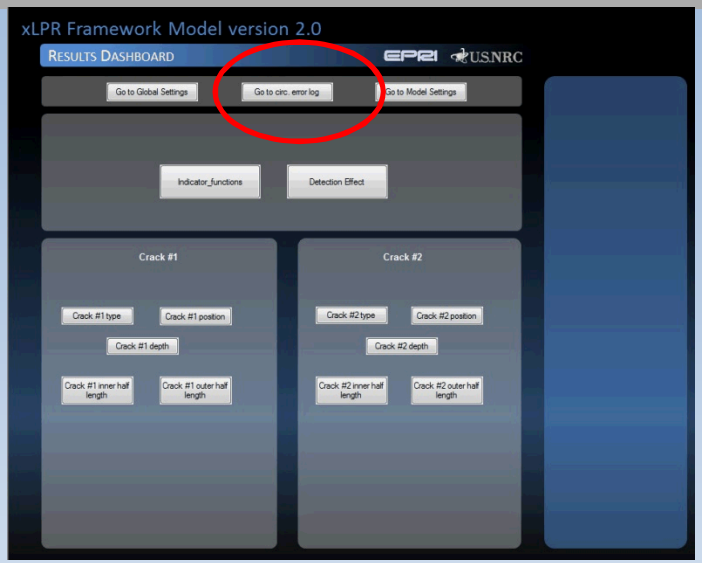
- Two loops can be considered (one can be ignored by setting the sampling size to 1). For each loop, on can select from the following options:
  - Simple random sampling or Latin Hypercube Sampling (LHS)
  - DPD
  - Importance sampling applied to selected values
  - Use of optimization instead of importance sampling for selected values

- **Example: Possibility of creating 12 sampling combination: [LHS vs. RS]x[DPD vs. no DPD] x[No importance vs. importance vs. adaptive] for each loop (totaling 12^2 combinations)**

Error tracking and results

Error Dashboard (1/3)





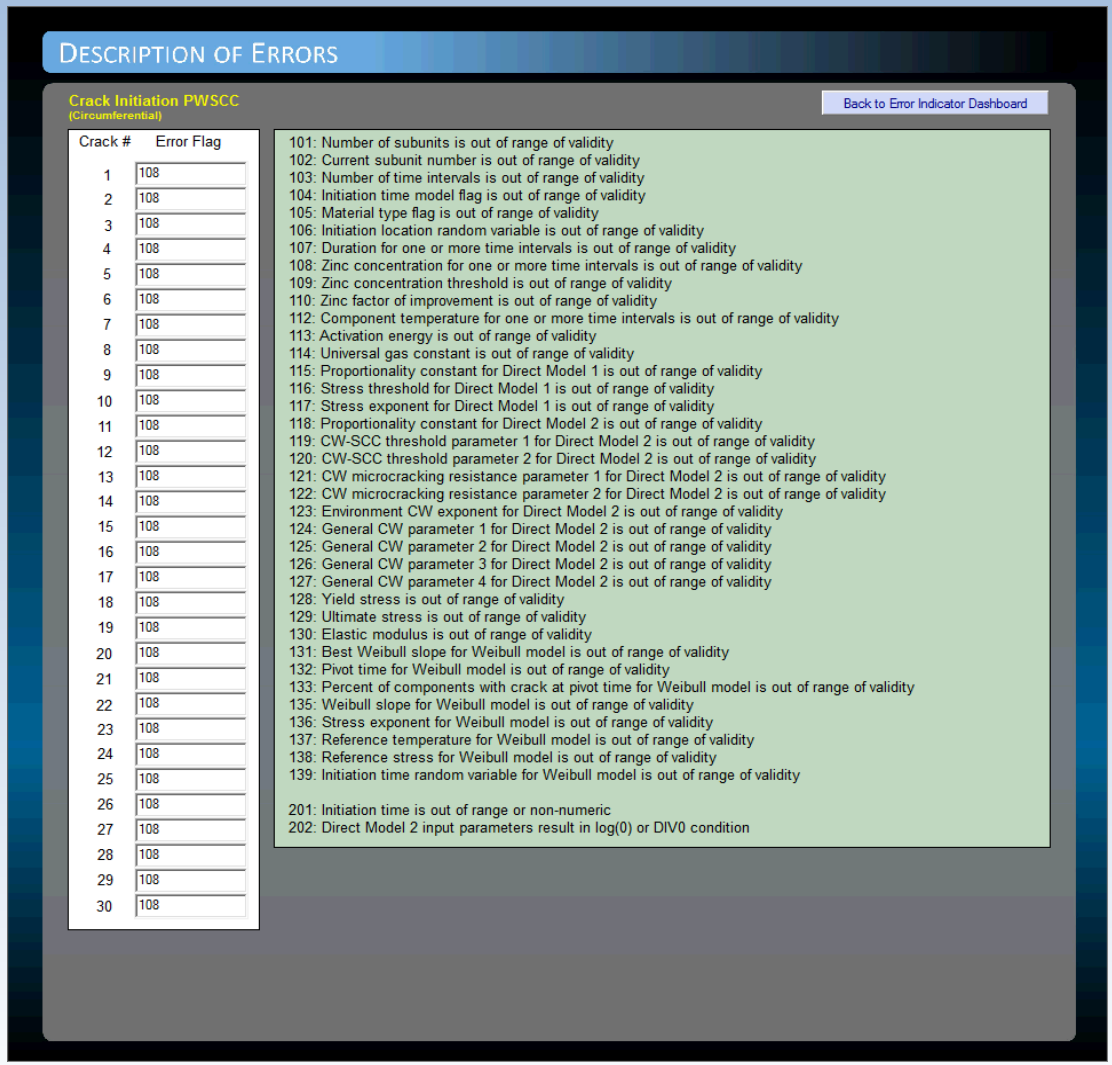
- Currently accessible from:
  \Main_model\xLPR_Model
- Link to Dashboard via result dashboard

Error Dashboard (2/3)

- Each dashboard lists status for each model
- Following symbols are used

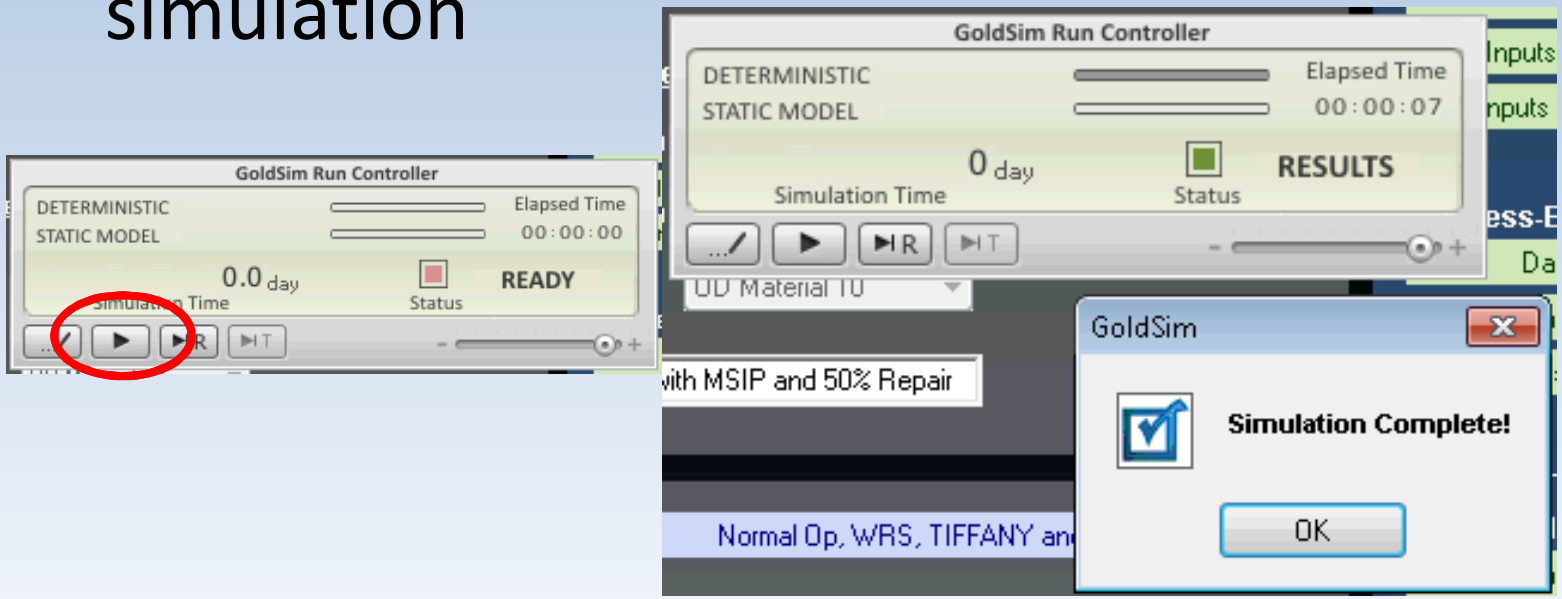
Error Dashboard (3/3)

- Error elements tracked per module per subunit
- List of error code meanings provided for each module
- Time history results available for each error element
- Additional development and debugging continuing with testing, including revising error codes for module updates

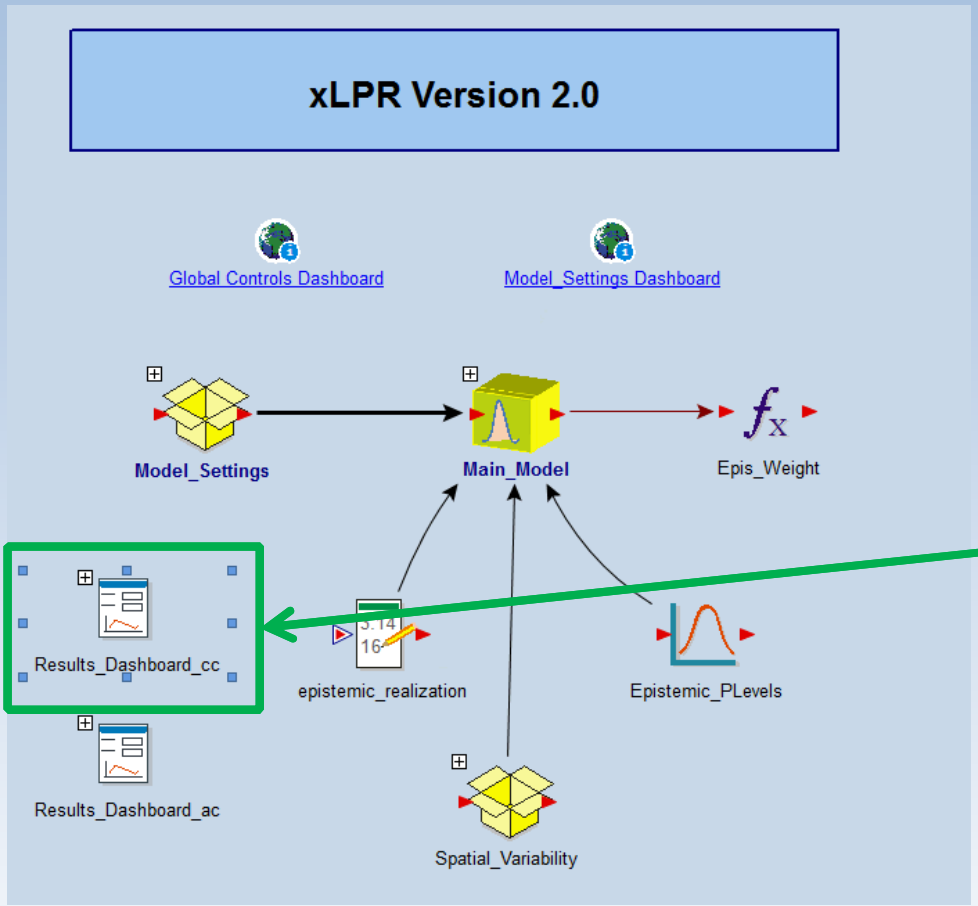


Running a Simulation

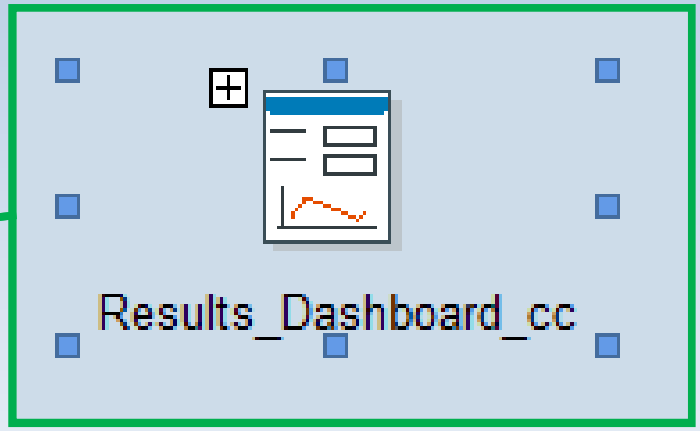
- Run a simulation by clicking the “Play” button in the GoldSim Run Controller
- Run Controller will display the status if the simulation



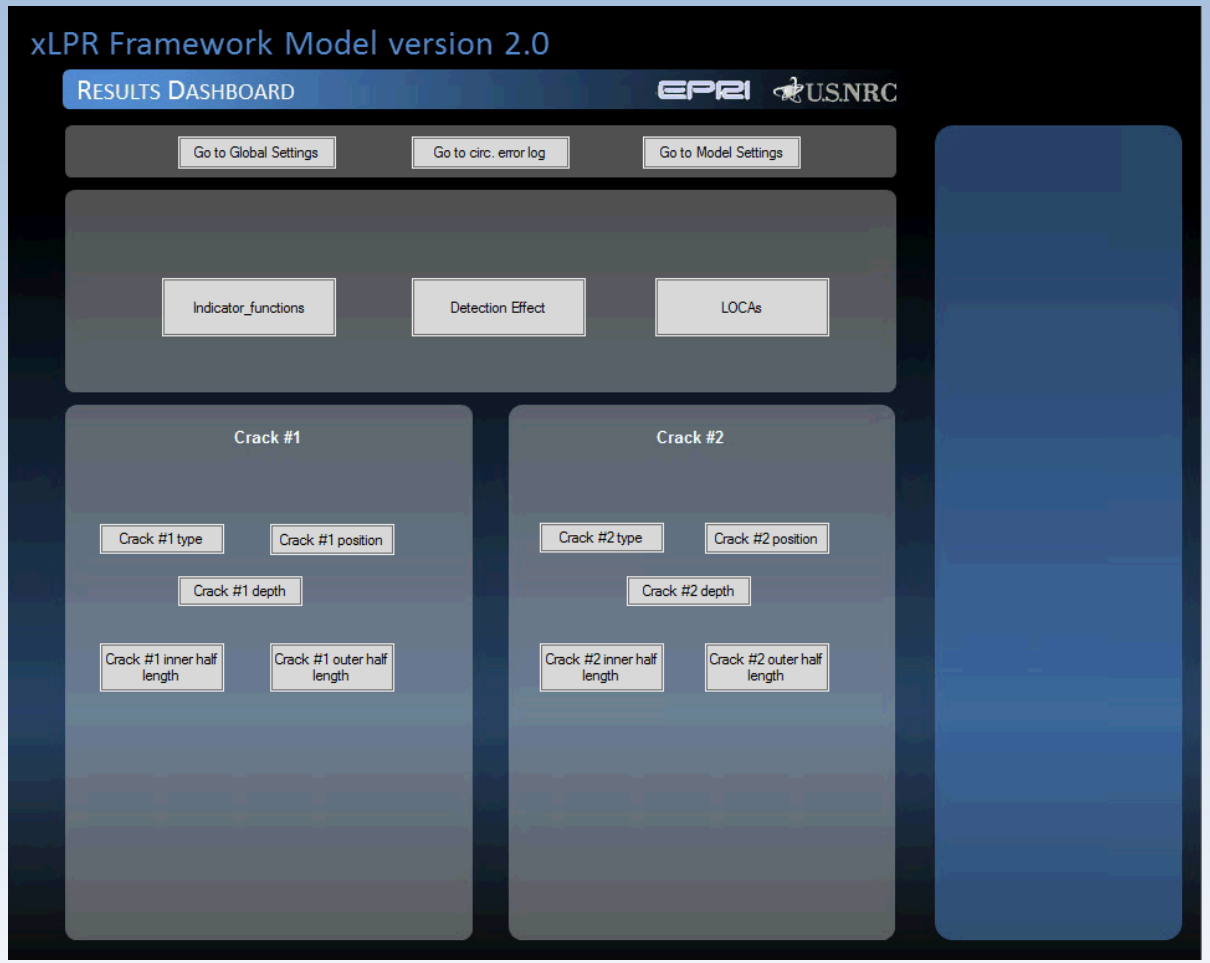
Results



- Navigate to results dashboard from the Main Model



Results

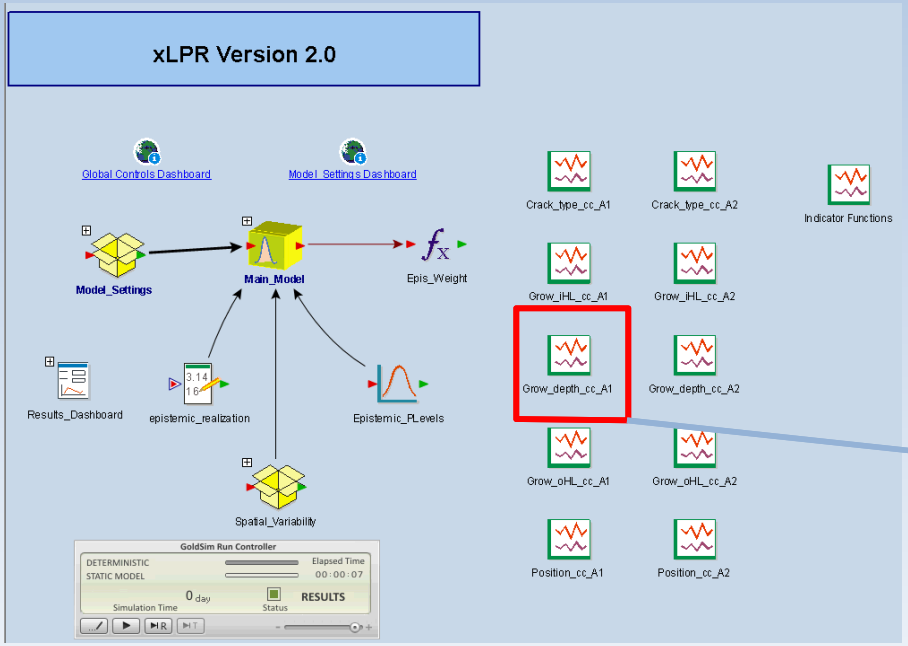


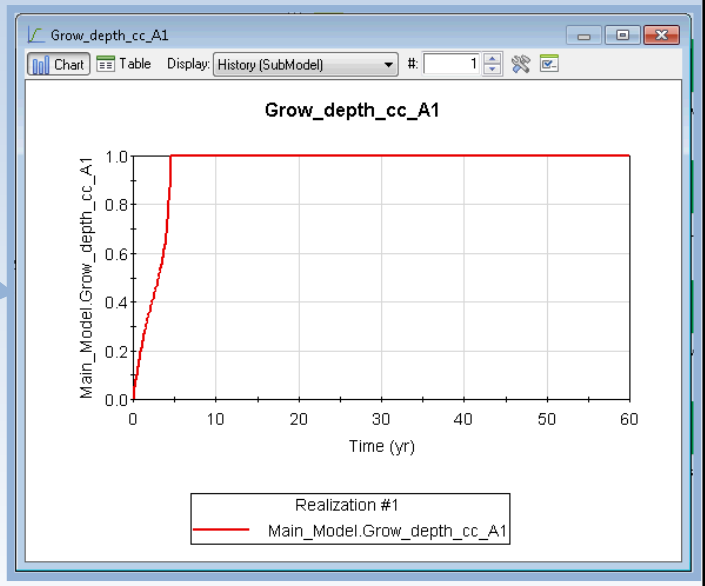
- Various results can be displayed from the results dashboard

Analysis of Simulation Results

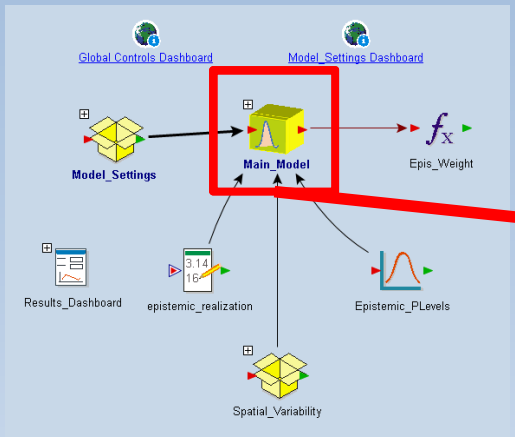
Finding Simulation Results

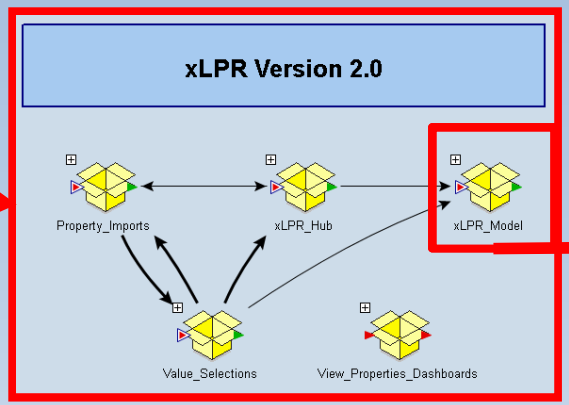
- Click on a result icon to view simulation results for a specified value

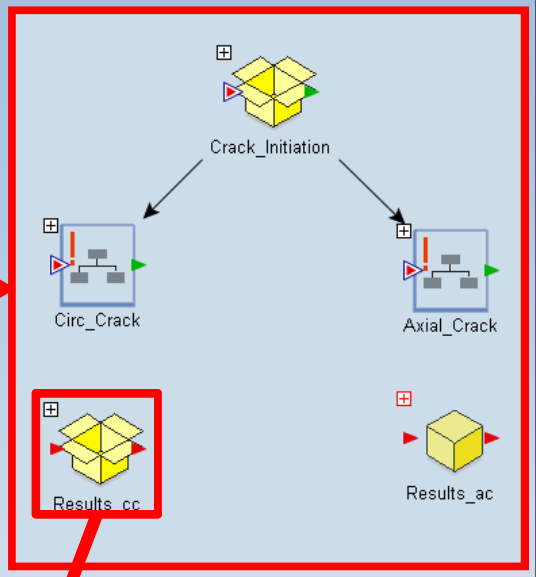




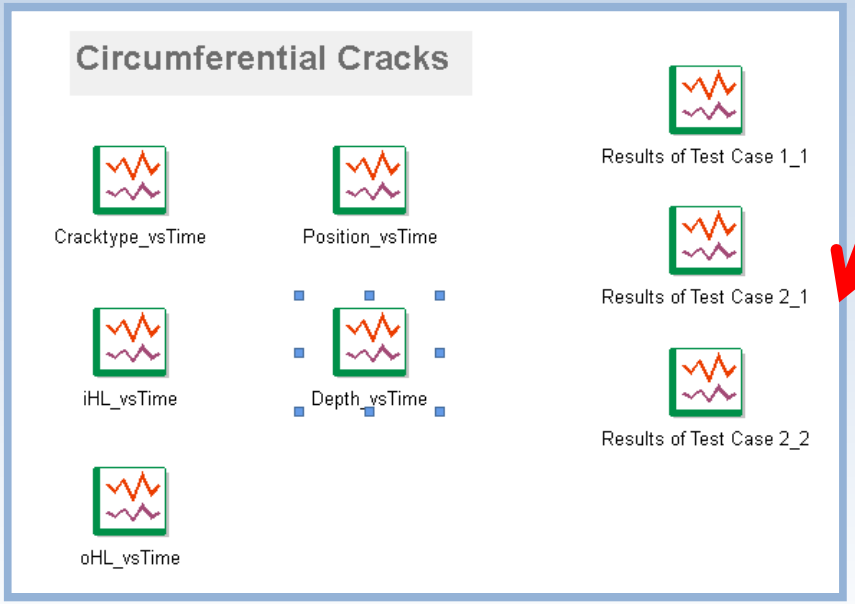
Simulation Results



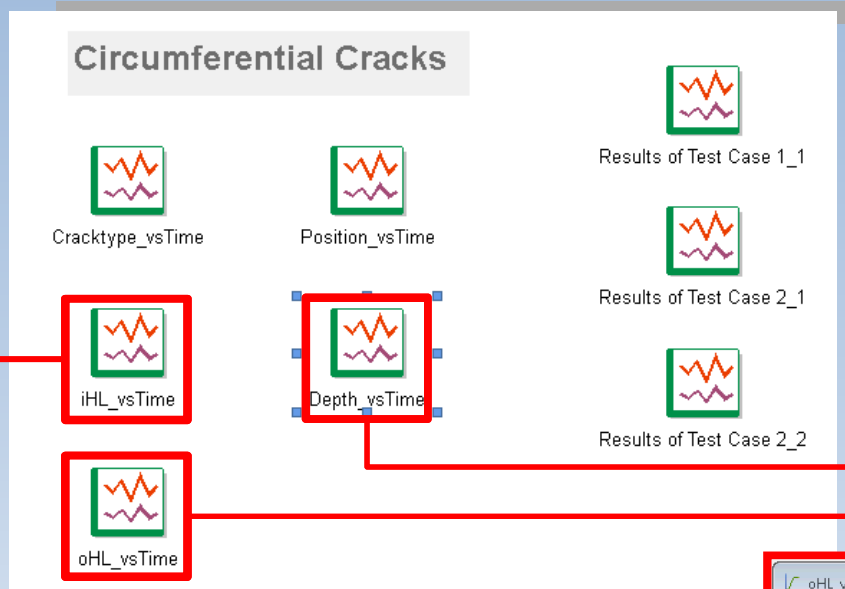


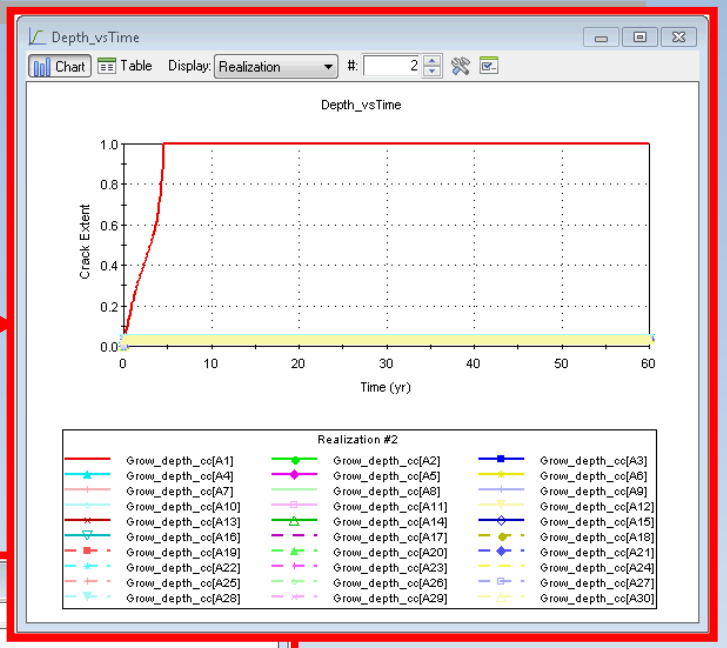


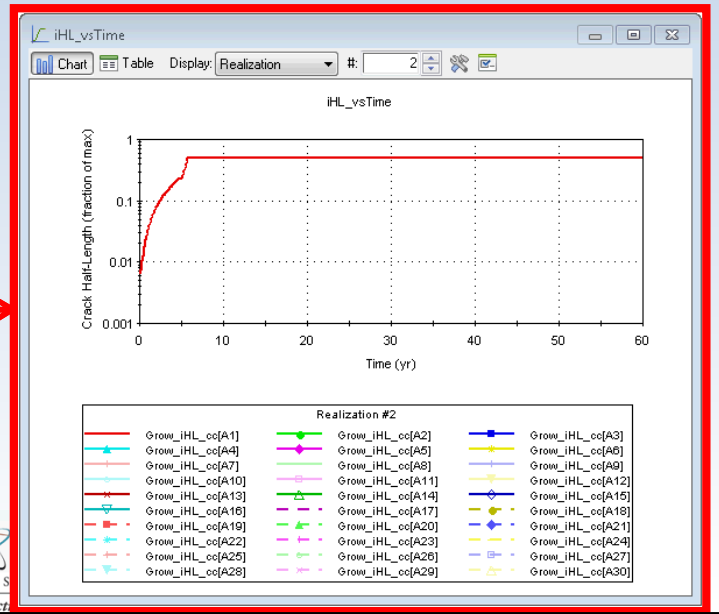
- From Main Model, navigate to the circumferential crack results container.

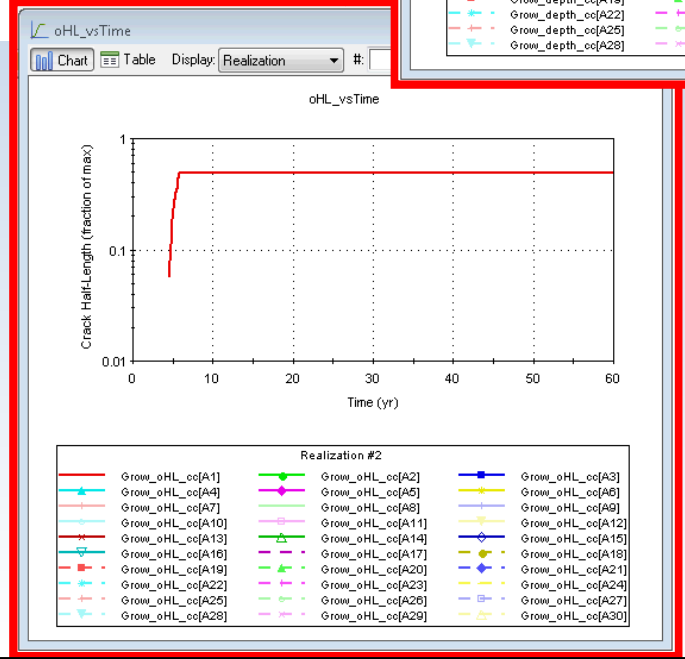


Simulation Results







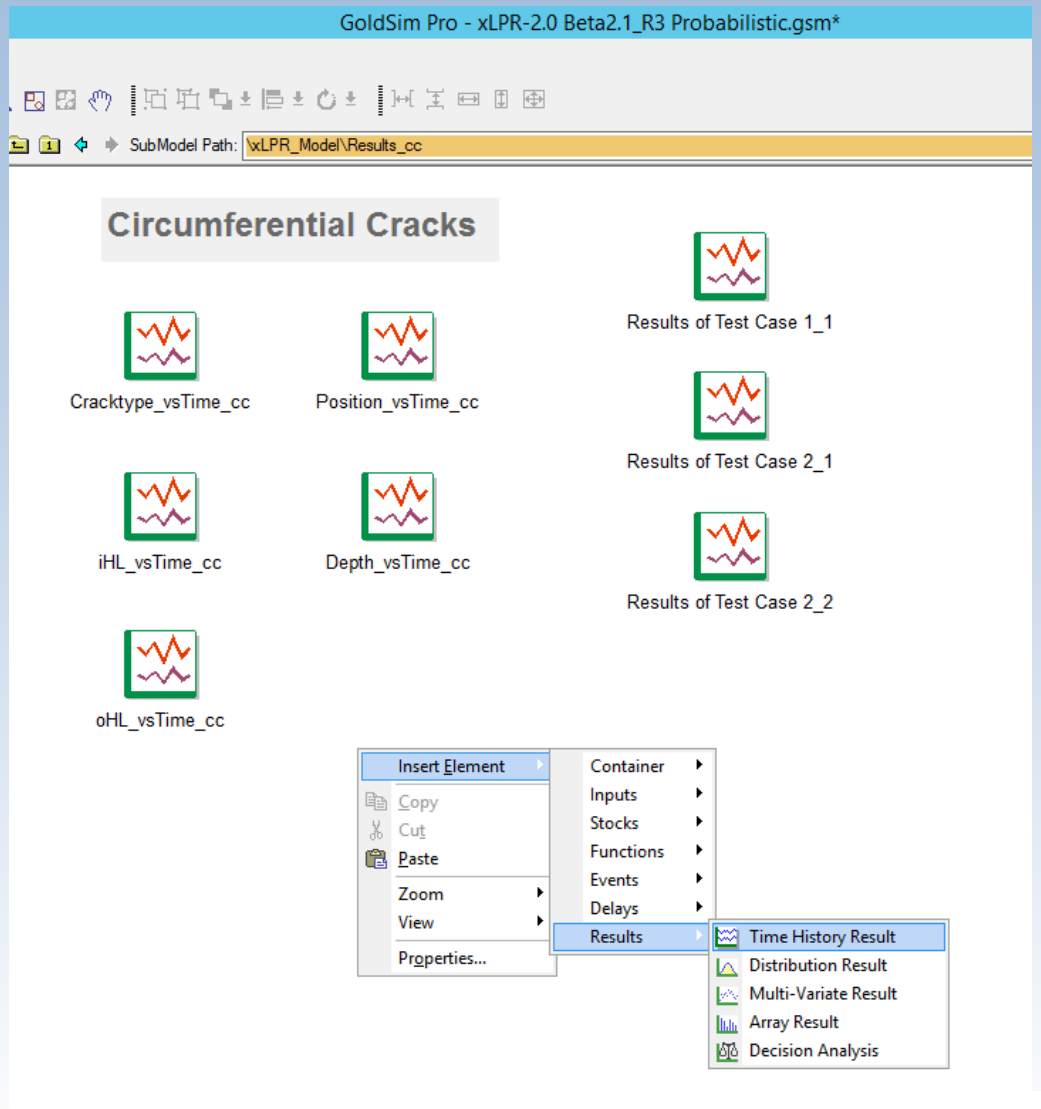


- Results can be viewed by clicking on results containers.

Adding additional outputs

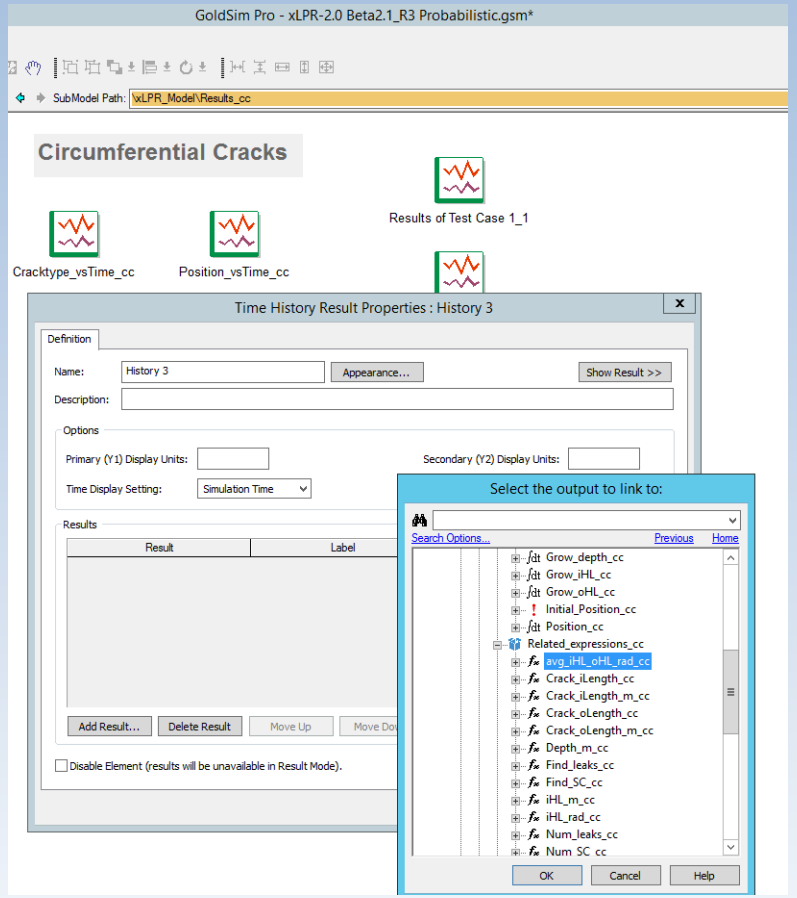
Global Results

- Can put results anywhere in model.
- Say we want average half-length vs. time.
- Insert Element -> Results -> Time History Result



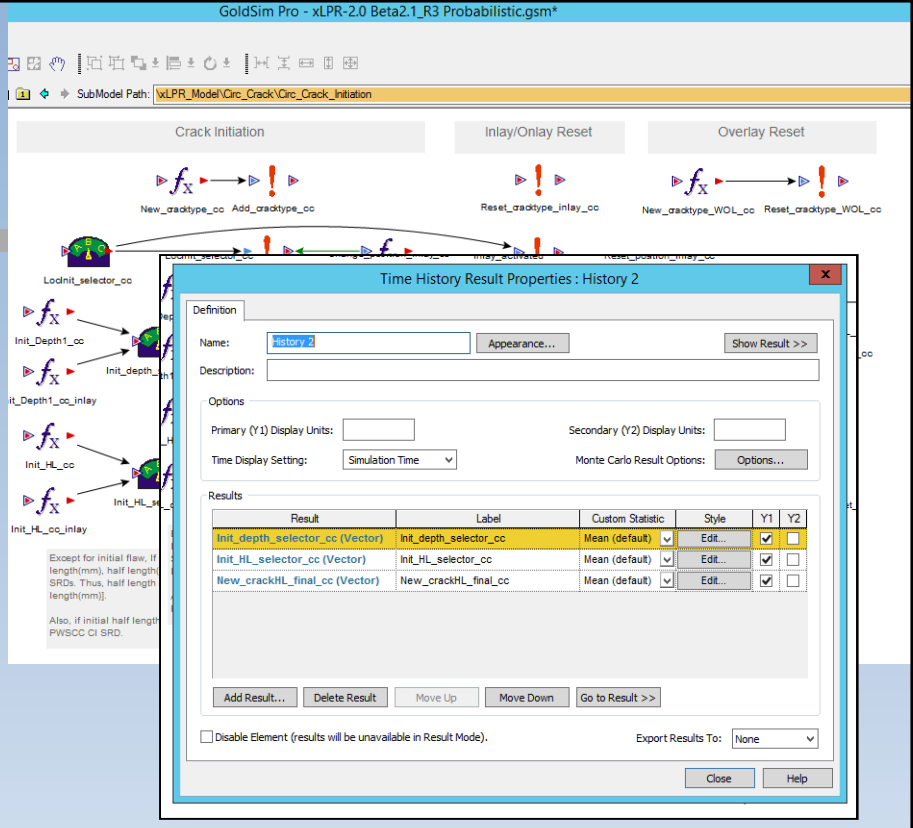
Global Results

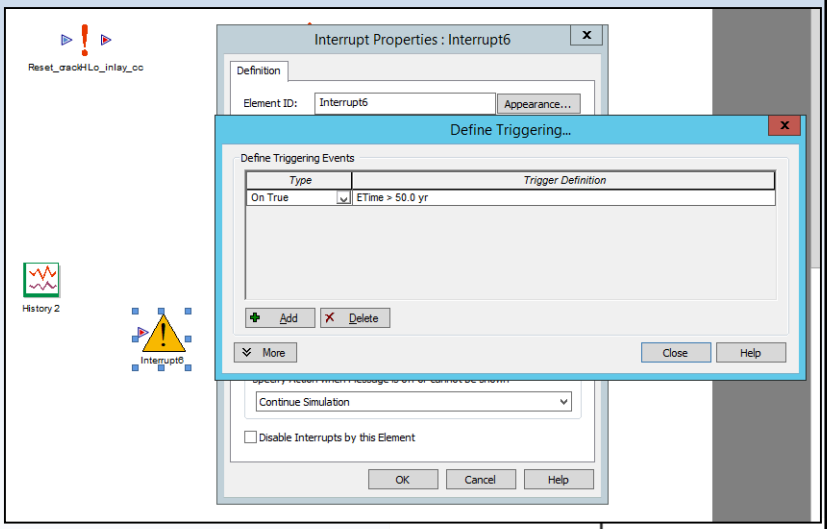
- Search or browse for output(s) needed.
- Add to results and set display settings as desired.



Module Result

- Say we want to check that the initial crack half-length is less than the depth.
- Can add result in relevant module.
- Insert -> Results -> Distribution Result
- Search or brows for outputs needed
- Can add interrupter to pause simulation when needed (e.g. Etime > 50 yr)



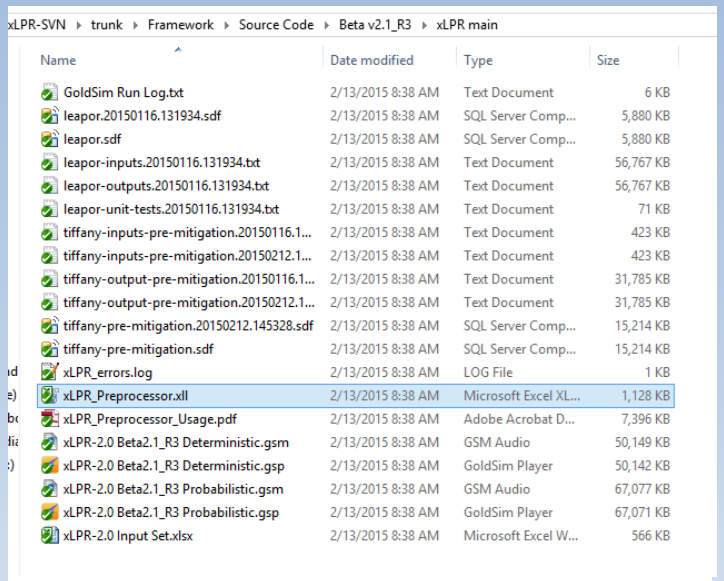


Questions?

Running preprocessors

Pre-processors: steps (1/3)

- Each pre-processor (TIFFANY pre-mitigation, TIFFANY post-mitigation, LEAPOR) creates a .sdf database for the Framework to read.
  - .txt files created for human readable QA purposes
- Steps to run preprocessors
  1. Ensure you have Microsoft .NET Framework 4 or later installed (one time and it may already be installed on your computer)
  2. Have required files in your directory (latest release has these already for you)
     - In run folder xLPR_Preprocessor.xll
     - In DLLs folder TIFFANY_v1.0.dll, LEAPOR_v1.0.dll, and sdf.dll

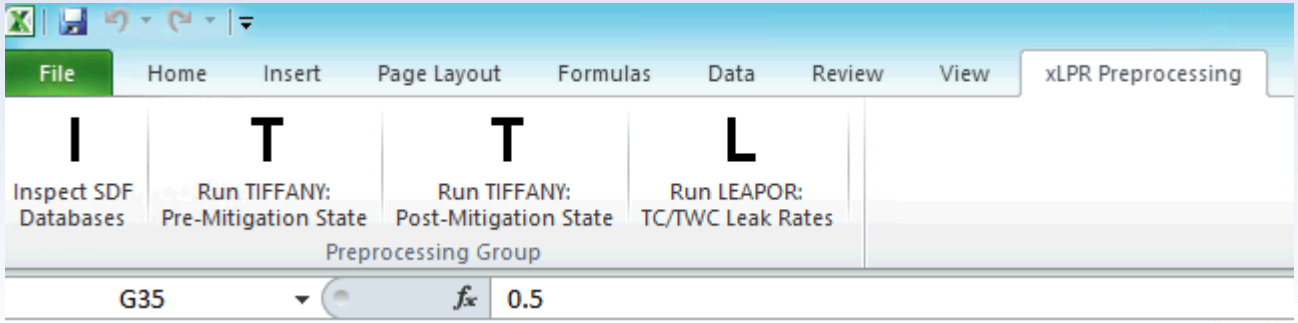


Pre-processors: steps (2/3)

- Steps to run preprocessors (cont.)
  3. Set-up TIFFANY and LEAPOR inputs in xLPR-2.0 Input Set.xlsx
     - Next release will have these color-coded (pastel pink and yellow) in the input file.

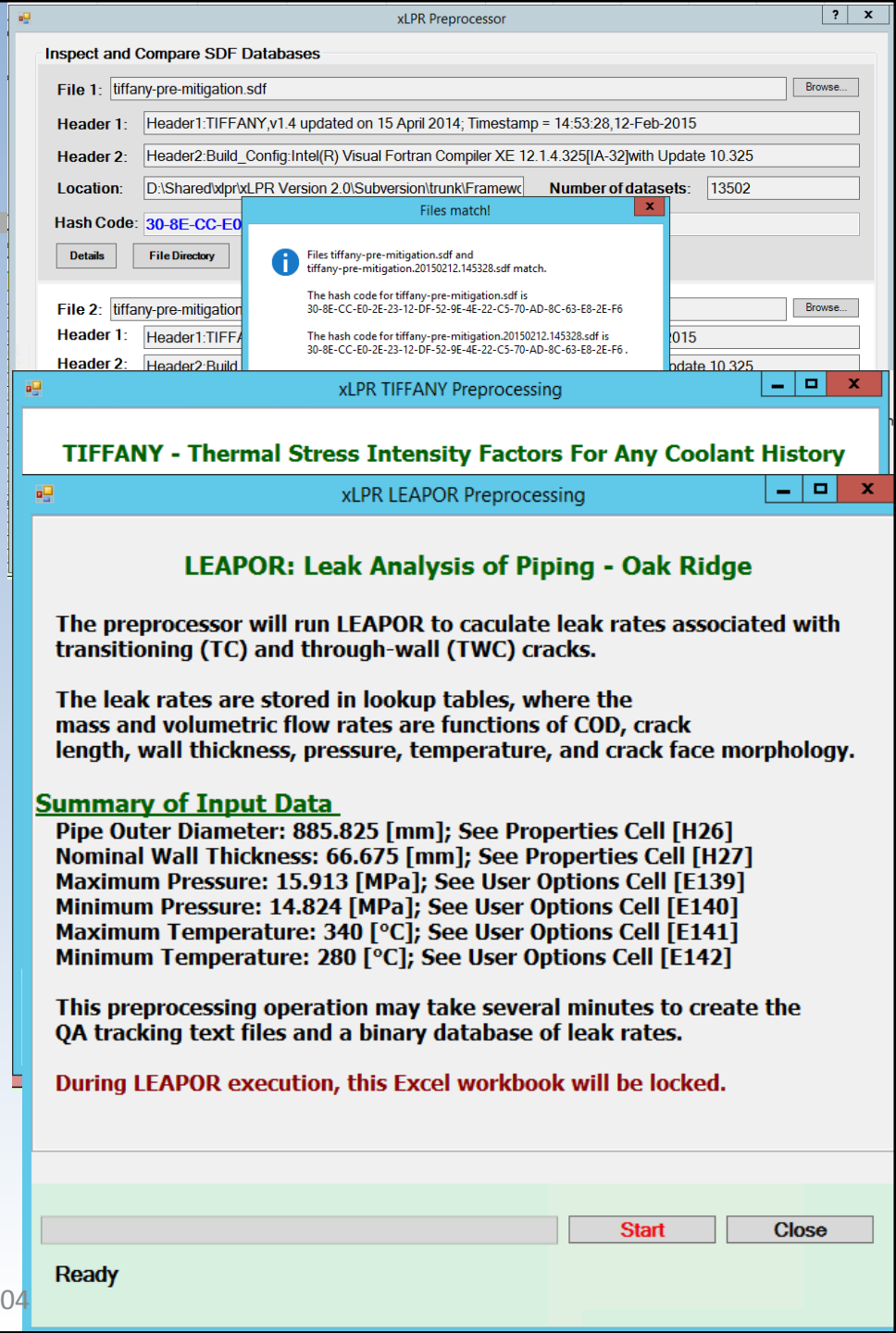
	Geometry (1101-1199)						
1101	Pipe Outer Diameter	m	Constant	no	0.5	0.885825	NO
1102	Pipe Wall Thickness	m	Constant	no	0.5	0.066675	NO
1103	Weld Width	m	Constant	no	0.5	0.025558	NO
1104	Weld Material Thickness	m	Constant	no	0.5	0.066675	NO
1105	Weld Overlay Thickness	m	Constant	no	0.5	0.02	NO
1106	Inlay Thickness	m	Constant	no	0.5	0.02	NO
	Flaw Size (1201-1299)						

  4. Open xLPR_Preprocessor.xll. Pop-up security window -> enable add-in.
  5. Use the xLPR Preprocessing tab in the ribbon.



Pre-processors: steps (3/3)

- Steps to run preprocessors (cont.)
  5. Use the xLPR Preprocessing tab in the ribbon.
     - Inspect database (not needed but can be helpful in determining if the pre-processors need to be rerun)
     - Run TIFFANY Pre- and Post-Mitigation
     - Run LEAPOR



Running pre-processing steps

- Running the pre-processors can take time (~10 mins)
- If the TIFFANY pre- or post-mitigation or LEAPOR inputs have not changed, and you have the databases already, you will not need to rerun that particular pre-processor.
- If you are not using fatigue then you won't need to run the TIFFANY pre-processors (you still need some dummy .sdf file in the directory)
- Caveat: Next (or the following) release will move from a .sdf to multiple .txt files for TIFFANY to speed up fatigue runs.
- Details installing and running preprocessors are on Subversion and Wiki:
  - TIFFANY preprocessor slides from Paul W.
  - LEAPOR preprocessor slides from Paul W.

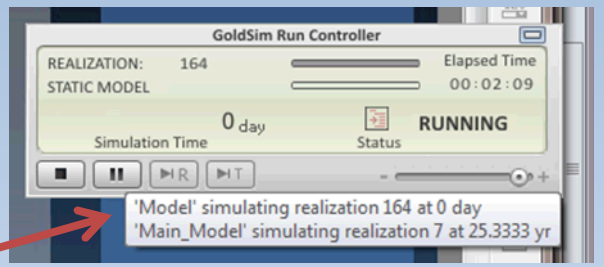
Common errors

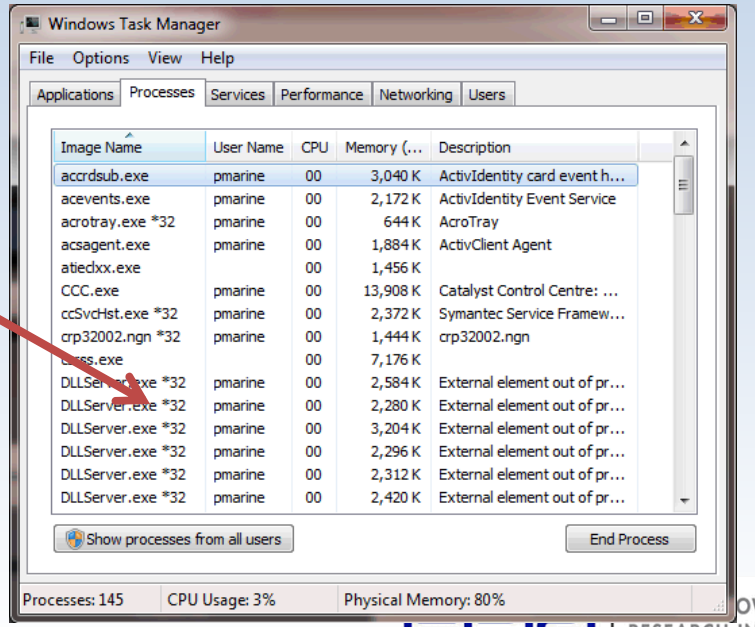
Running xLPR v2.0

- Excel (*xLPR-2.0 Input Set.xlsx*)
  - When copying and pasting, paste *values*
    - Otherwise, you can ruin conditional formatting, etc.
- Running xLPR v2.0
  - Error dashboard
    - Can watch during simulation
    - Saves error history for *current* realization
  - Interrupt warnings
    - Saves information to log file
    - Some may be false positives (e.g., *WARNING: Axial surface crack stability calculations were not run despite next test time being reached.*). These will be addressed.

Troubleshooting xLPR v2.0

- Runs that hang
  - Identify realization numbers (outer and inner loop) and time step
    - Found by hovering over Run Controller
  - To save results up to that point
    - Start killing DLL.exe processes in Task Manager
    - When you kill the right one, the run will issue an error and you can save the results





Troubleshooting xLPR v2.0

- Reporting bugs
  - Save the *xLPR-2.0 Input Set.xlsx* file
  - Create a Word file with the following info
    - Epistemic realization, aleatory realization, time step of stoppage
    - Total # of epistemic realizations sought (determines LHS quantiles)
    - Description
    - Snip or copy of error message
    - xLPR v2.0 beta release version
  - Zip the *xLPR-2.0 Input Set.xlsx* and Word file
  - Send or post the zip file

Common Errors

- User Errors
  - Lognormal input: Param1 is True/Geom (0/1) flag
  - Other input distributions (uniform, triangular, etc.): Check parameters needed in Drop-List Options sheet
  - A few cases of inputs are defined with a shift included. E.g. Peak to valley ratio is defined as P-1
  - GoldSim -4 value for lookup table: typically results from Fatigue initiation error code
  - GoldSim cannot find .dll file – appears at start of run. Make sure .dll files are the release version files and in the correct folder.
- Scenario Errors
  - Within-component variation factor. The upper limit on this factor had to be reduced from 2.04 to 1.6 so that the model could run. There appears to be a problem with how GoldSim assigns the upper quantile in this instance. (**Scenario 2**)
  - Axial cracks grow and leak on every realization but fatal COD error 112 occurs (p/pL > 0.6). Simulations are not stopped for this error. There are no axial ruptures. (**Scenario 3, 9**)
  - When 1000 epistemic realizations, this hangs at realization 164, aleatory realization 7 at 35.67 yrs. DLL error. (**Scenarios 4a MSIP and 5a MSIP**)
  - **Scenario 4b WOL and 5b WOL** will not run due to GoldSim floating point error. The run from Set 1 works ok, however.
    - Set 1
      - 100 epistemic, 20 aleatory; No importance sampling; ISI inputs not updated; All scenarios run
    - Set 2
      - 163 of 1000 epistemic, 20 aleatory; Runs crash at 164 due to DLL run error; Importance sampling on fcomp (SCC initiation variable); ISI inputs updated; WOL not run (GoldSim floating point error)

Hands-on session

Scenarios

Scenario	Flaw initiation	PWSCC Growth only	Fatigue Growth only	PWSCC and Fatigue Growth	Flaw orientation: circumferential	Flaw orientation: circumferential + axial	Stress Mitigation (WOL, MSIP)	Stress Mitigation (inlay)	Chemical mitigation: Zn	Chemical mitigation: H	Chemical mitigation: Zn and H	Mitigation timing: 20 yrs	Mitigation timing: 40 yrs	Probability of rupture
1. Risk analysis due to fatigue	Initial flaw as an input		✓		✓									L
2. Fully unmitigated PWSCC circ.	PWSCC initiation	✓			✓									H
3. Fully unmitigated PWSCC axial	PWSCC initiation	✓				✓								VH
4. Fully mitigated PWSCC 20yrs	PWSCC initiation	✓				✓	✓					✓		VL
5. Fully mitigated PWSCC 40yrs	PWSCC initiation	✓				✓	✓						✓	L
6. Chemical mitigation PWSCC, Zn	PWSCC initiation	✓				✓			✓			✓		M
7. Chemical mitigation PWSCC, H	PWSCC initiation	✓				✓				✓		✓		M
8. Chemical mitigation PWSCC, Zn&H	PWSCC initiation	✓				✓			✓	✓		✓		M
9. Inlay mitigation	PWSCC initiation	✓				✓		✓					✓	M
10. Full mitigation, fatigue, PWSCC	PWSCC and fatigue initiation			✓		✓	✓				✓	✓		VL
11 Fatigue initiation only	Fatigue initiation		✓			✓								VL