PROBABILISTIC FRACTURE MECHANICS CODE

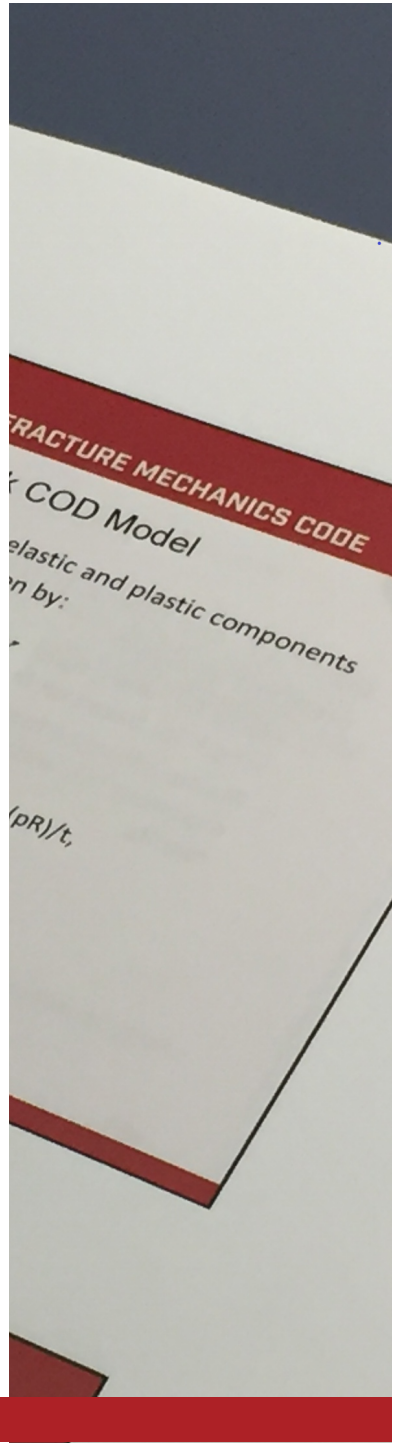
EVENTS

1. **Models Overview**
   June 3rd | 10-12 EDT

2. **Setting Up the Inputs**
   July 15th | 10-12 EDT

3. **Running the Simulation and Retrieving Results**
   July 29th | 10-12 EDT

4. **Advanced Methods**
   August 5th | 10-12 EDT



Seminar 3 Agenda
Running the Simulation and Retrieving Results

Introduction and Opening Remarks

File Structure Review

Running the Preprocessor

Setting Sampling Options and Controlling a Run

Viewing Results

Errors Display

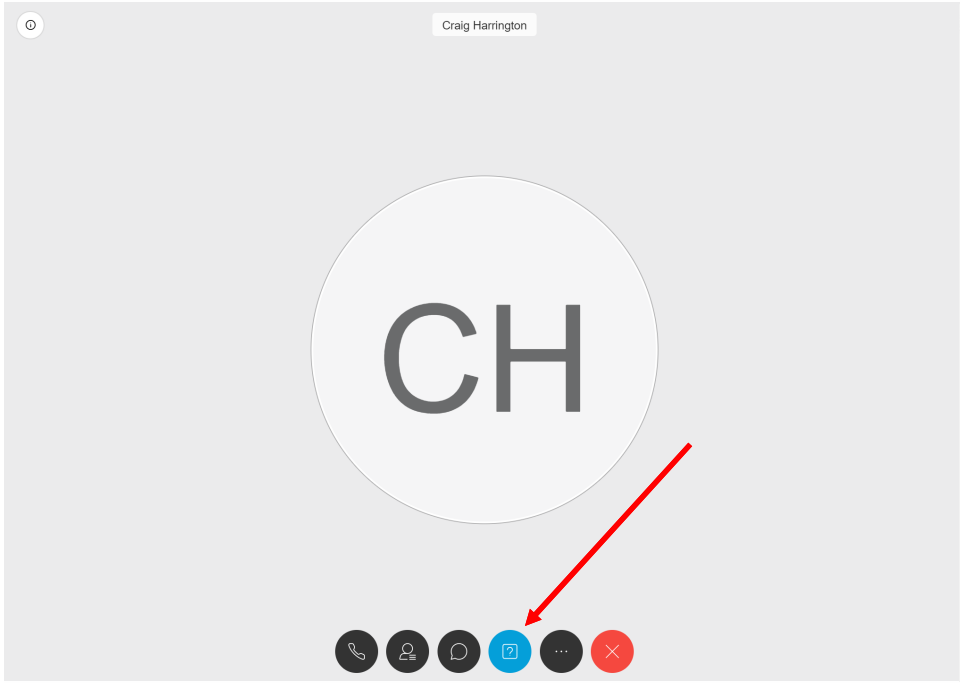
Navigating through the Framework

Break

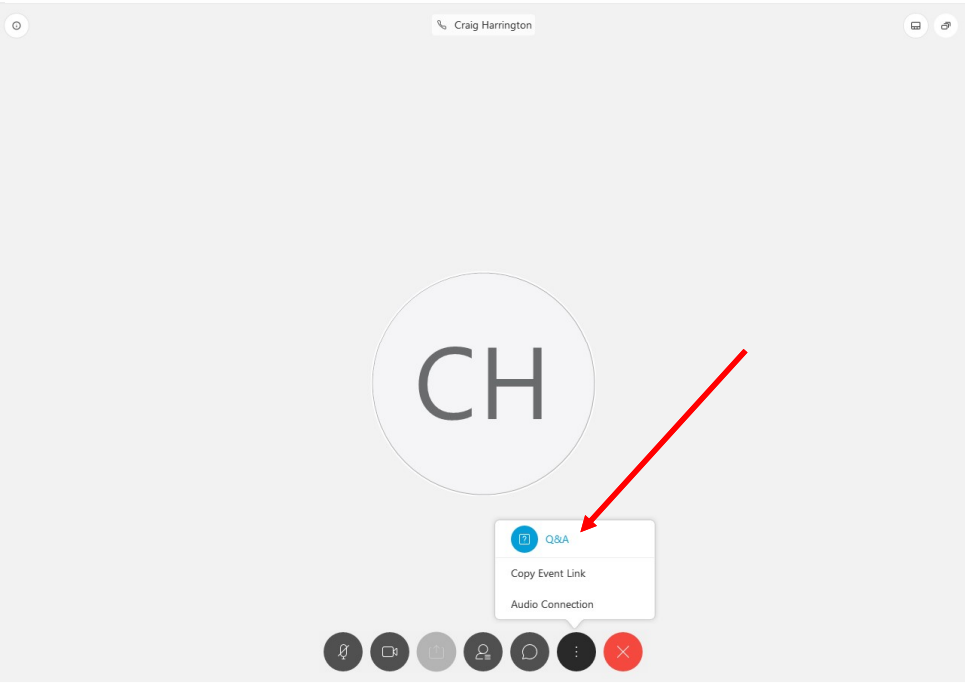
Questions and Answers

Closing Remarks

WEBEX Q+A



Webex Internet Browser



Webex Desktop Client

Resources

- User Manual Chapter 3
  - Section 3.3.2 (p. 59) to set up the sample size and random seed
  - Section 3.4 (p. 60-61) to run the code
  - Section 3.5.2 to inspect for errors (and Chapter 5 for the list of error codes)
  - Section 3.5.3 to look at the results
- xLPR-GR-FW, “Computational Framework Development, Testing, and Analysis”*

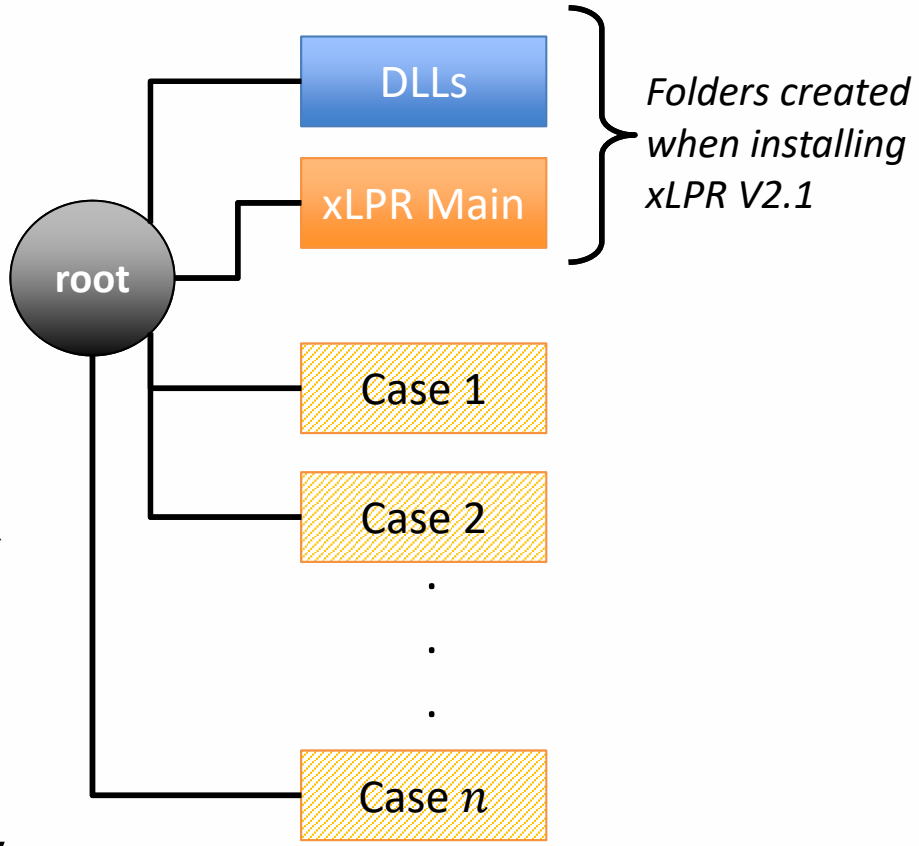
*To be released at a later date

File Structure

Navigate through xLPR file structure

Running the Code

- To run Extremely Low Probability of Rupture (xLPR) Version 2.1 (V2.1) code, the user needs:
  - One folder with a GoldSim player file (.gsp) or full version (.gsm) and the input Excel file
  - One folder named “DLLs” with all the dynamic link libraries (DLLs)
- It is thus possible to create a new folder at the root of xLPR v2.1 to separate runs and use only one DLLs folder
- Once xLPR V2.1 has been run, the GoldSim file can be saved and accessed from any location



File Names

- Excel input file name (*xLPR-2.1 Input Set.xlsx*) **cannot be changed.** GoldSim requires this name to read the inputs.
- GoldSim file name (*xLPR-2.1.gsm* / *xLPR-2.1.gsp*) can be changed. In theory, one can thus have multiple GoldSim files in the same folder. This is useful for replicate runs.
- DLLs folder name and DLL names cannot be changed

Steps for Running the Code

1. Set up input set file (presented in previous seminar)
2. Run preprocessors
3. Set up GoldSim parameters and output settings
4. Run GoldSim
5. Save once run is complete
6. Save and extract results

Preprocessors

What to run before running the code and when to run it

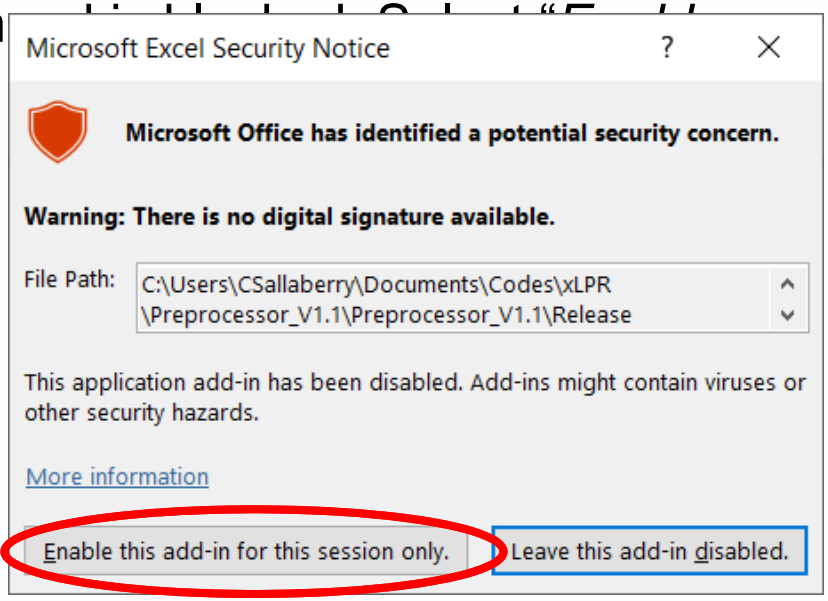
Preprocessing Parts

- To improve runtimes, two aspects of the calculations are done in the preprocessing stage
  - Calculate leak rates as a function of crack opening displacements and crack lengths (LEAPOR – Leak Analysis of Piping – Oak Ridge)
  - Calculate stress intensity factors and other information for all transients (TIFFANY - Thermal Stress Intensity Factors for ANY Coolant History)
- The preprocessors create lookup tables read by GoldSim. GoldSim linearly interpolates from these tables during the simulation.

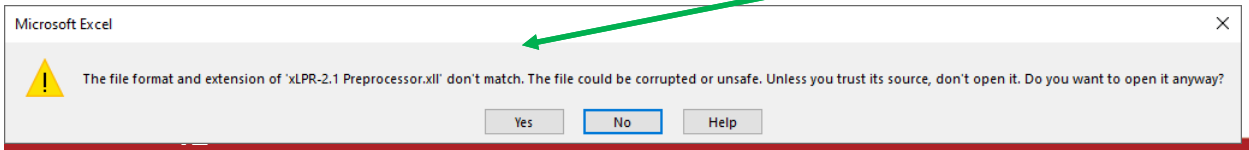
Running the Preprocessors (1/3)

- The preprocessors are run by double clicking on *xLPR-2.1 Preprocessor.xll*
- Currently the Excel add-in works only with the **32-bit** version of Excel. Any use with 64-bit versions will lead to an error.
- Since the file is an Excel add-in without a digital signature, a window will pop-up to inform the user that the comm… Select "*Enable this add-in for this session only*".

Note: it is possible that due to some companies' security protocols, any macro is disabled by default. Check with your information technology department if this is the case.

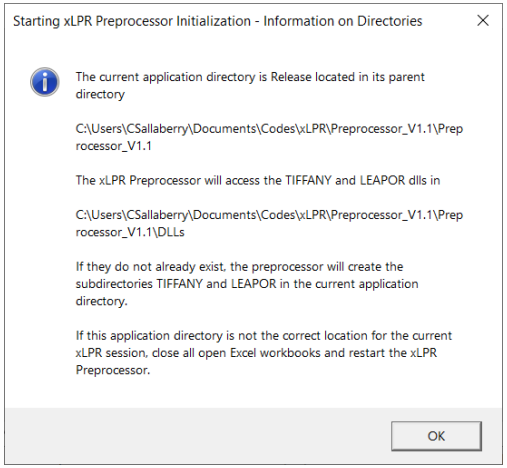


If run with the 64-bit version of Excel, an error window pops up

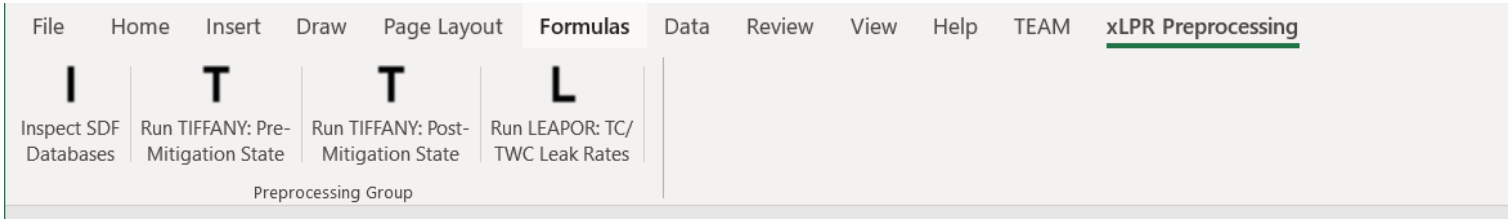


Running the Preprocessors (2/3)

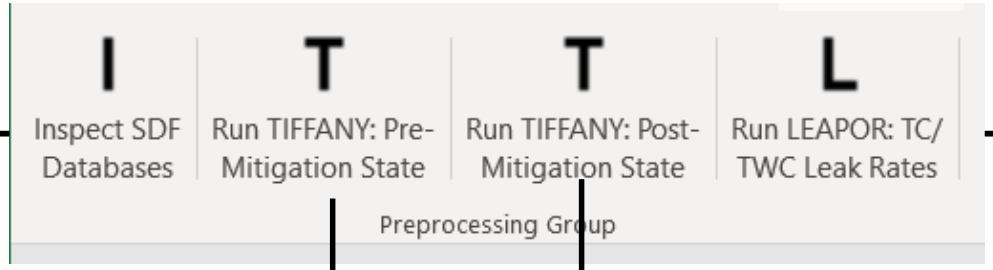
- Once activated, the xll file generates an information message on the file location. The preprocessor must be run where the Excel input set file and GoldSim file are located.



- After pressing “OK,” a new option (xLPR Preprocessing) is added to the main ribbon on top with the following buttons:



Running the Preprocessors (3/3)



Inspect Database
Used to look at tables created and compare them if needed

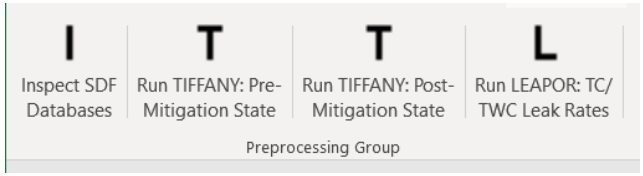
Run TIFFANY Pre-mitigation
Create tables for stress intensity factor solutions for surface cracks and through-wall cracks in both axial and circumferential directions for each transient

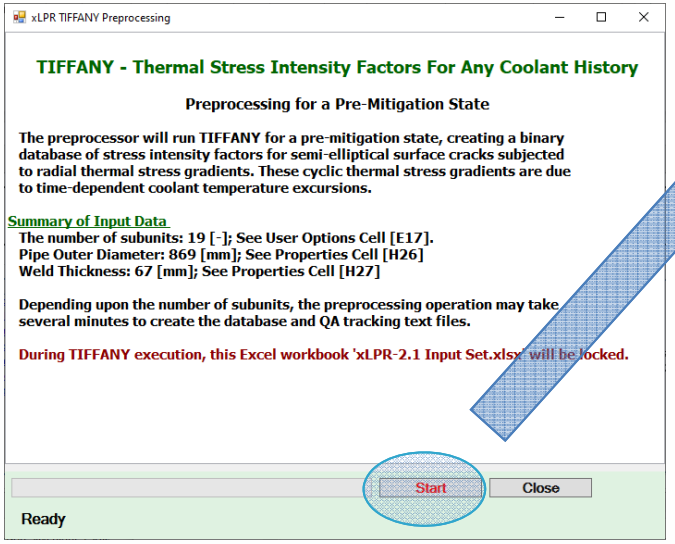
Run TIFFANY Post-mitigation
Create same tables as TIFFANY pre-mitigation using updated inputs from Post-mitigation

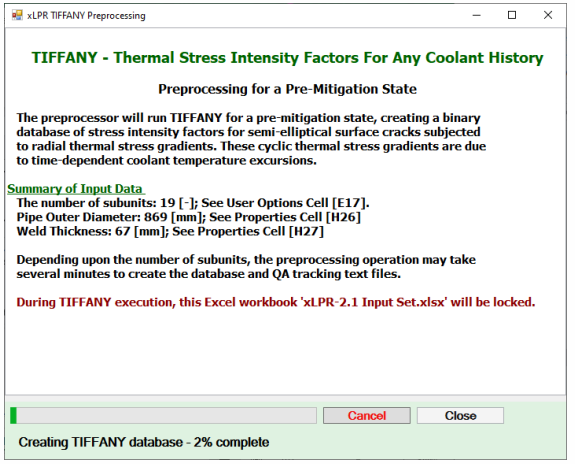
Run LEAPOR
Create tables estimating leak rates as a function of temperature, pressure, crack opening displacement, crack length, and pipe thickness

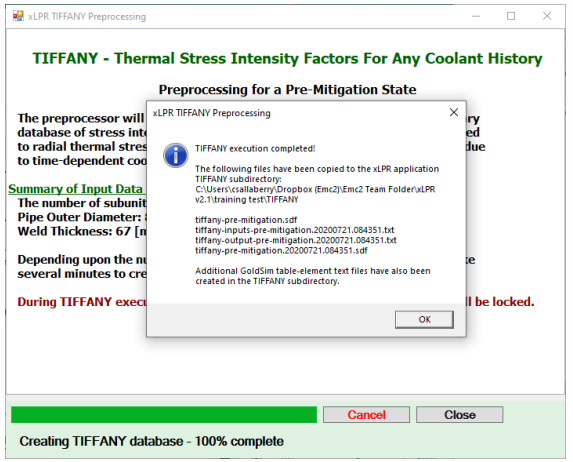
Demonstration

- Running the pre-processors









When Are the Preprocessors Needed ? (1/2)

If the preprocessors are not re-run, GoldSim uses the last text files generated. If no text files are available, GoldSim uses the values saved in the .gsm or .gsp file.

Modeling fatigue?

- **No:** No need to run TIFFANY
- **Yes:** Run TIFFANY pre-mitigation
  - Modeling mitigation?
    - **No:** No need to run TIFFANY post-mitigation
    - **Yes:** Run TIFFANY post-mitigation

Change in temperature range, pressure range, or pipe geometry?

- **No:** No need to run LEAPOR
- **Yes:** Run LEAPOR

The TIFFANY and LEAPOR inputs are identified by color-coding in the Excel inputs set file

COLOR CODING KEY*
Input that cannot be changed by the user
Property used by LEAPOR and TIFFANY
Property used by TIFFANY
Property used by LEAPOR

When Are the Preprocessors Needed? (2/2)

- If unsure, it is safer to re-run all preprocessors (date will coincide with the run date)
- LEAPOR and TIFFANY generate new folders of similar names to host the tables. Delete folders before running to confirm latest values are used.

PROBABILISTIC FRACTURE MECHANICS CODE

Global Settings Dashboard

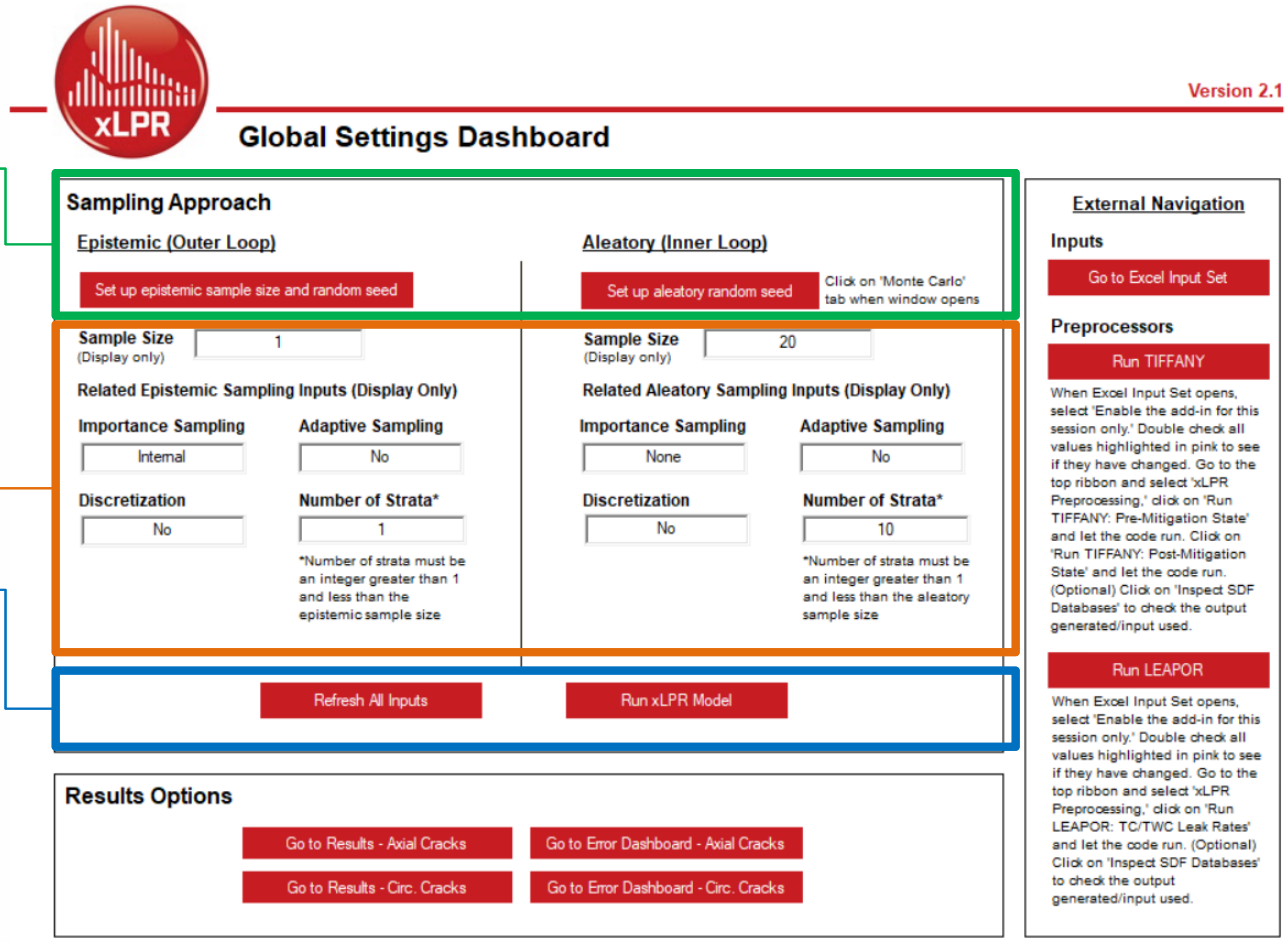
How to Run xLPR

GoldSim Dashboard Overview

Controls to set up epistemic sample size, random seed, and Latin hypercube sampling (LHS) options

Displays some of the sampling options

Controls to refresh input data and run the code

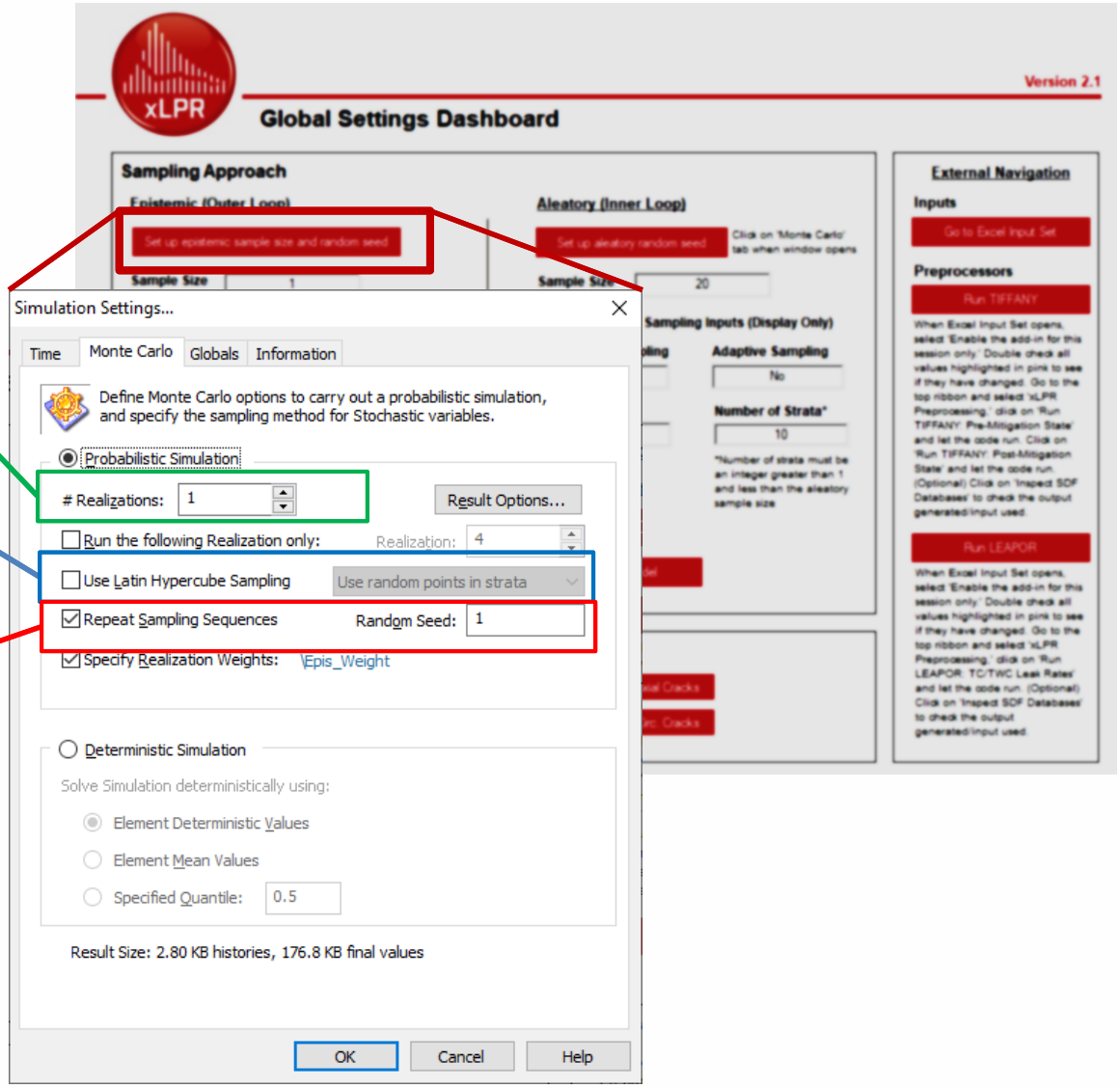


Options Set in GoldSim - Epistemic (Outer) Loop (Main Options)

Epistemic (outer) loop sample size

Use LHS or not

Use random number generated from random seed and set up random seed*



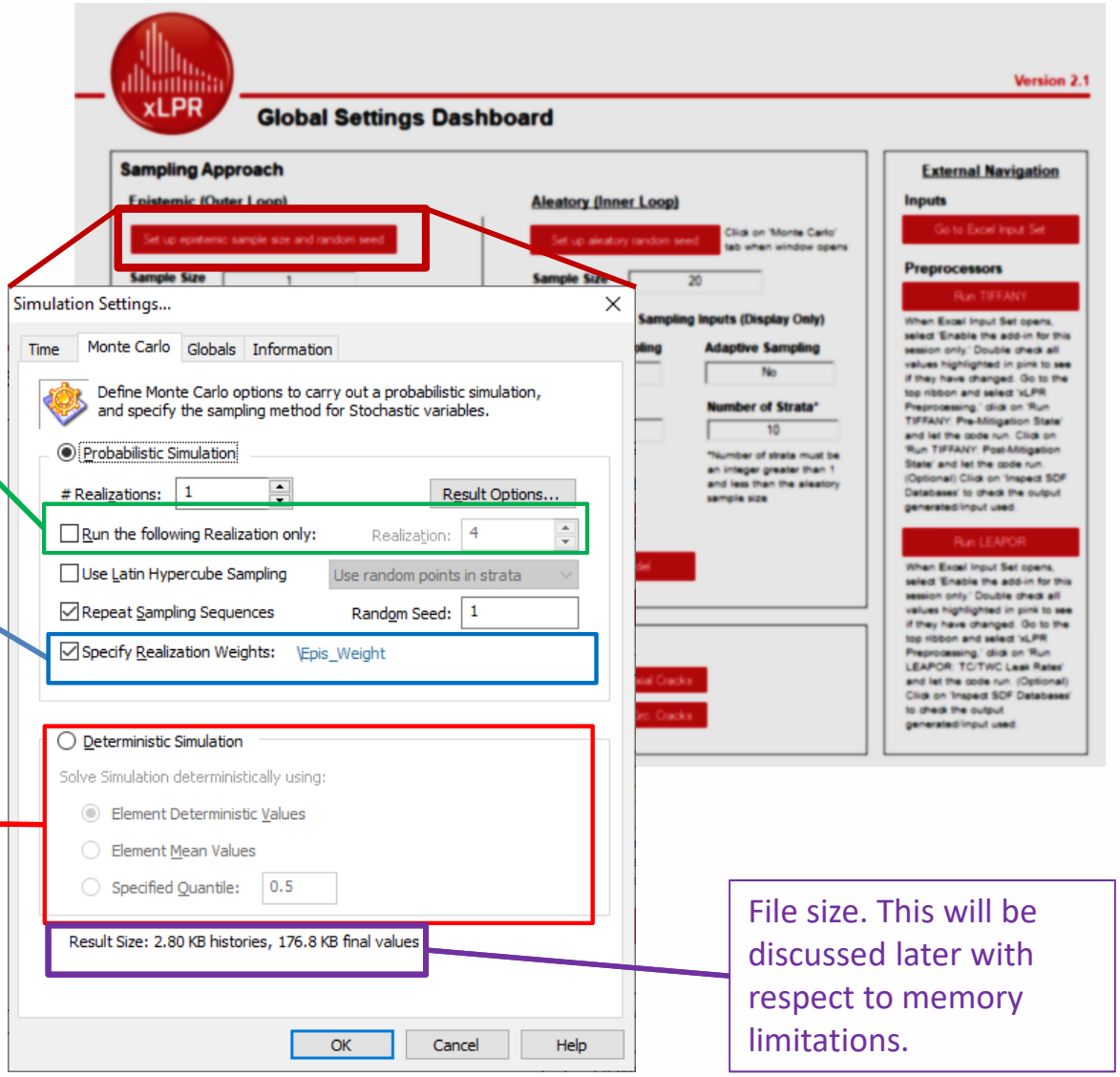
* If this box is unchecked, then a random seed is generated randomly, and the results are not reproducible

Options Set in GoldSim - Epistemic (Outer) Loop (Advanced Options)

Run a specific realization (will be described in next seminar)

Used by importance sampling. Should **always** be checked even when importance sampling is not used.

Option to run the outer loop deterministically. Can be used, but we recommend setting up a deterministic run differently.



File size. This will be discussed later with respect to memory limitations.

Options Set in GoldSim - Aleatory (Inner) Loop

By default, the window opens on the "Definition" tab. The user needs to click on the "Monte Carlo" tab.

Aleatory sample size is set in Excel inputs set file. **It should not be changed here.**

These options are the same as the ones for the epistemic (outer) loop

The aleatory (inner) loop can use the same sampled values for each new outer loop instance or change them. This option is checked by default.

File size. This will be discussed later with respect to memory limitations.

Sampling Options

Different sampling strategies are available:

- Use of one loop or two (separation between epistemic and aleatory uncertainties)
- Control of epistemic sample size and random seed
- Control of aleatory sample size and random seed
- LHS on either or both loops
- Application of importance sampling on selected values for either or both loops
- Use of discrete probability distribution for either or both loops
- Repeat random data or generate new data for the aleatory (inner) loop for each new sample of the outer loop

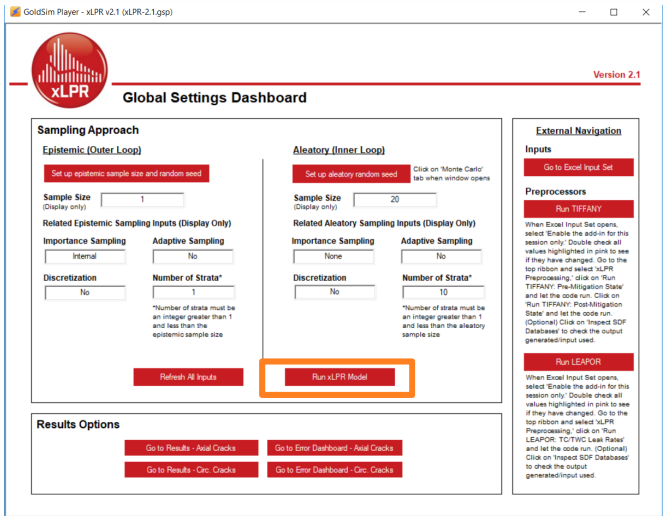
GoldSim

Excel

Both

Starting a Run

- Example with Challenge Problem 1 presented in previous seminar
- If the file structure is correct and all sampling options have been set, we are ready to run:



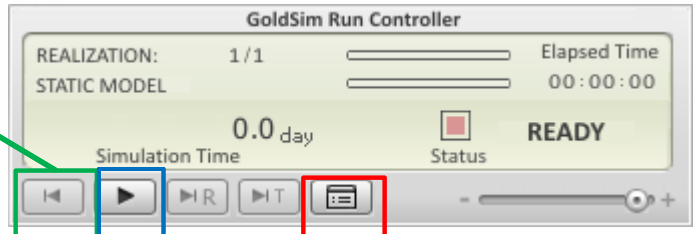
- **Three ways to start a run**:

1. Click on “Run xLPR Model” button on the Global Settings Dashboard
2. Click “Play” button on GoldSim Run Controller
3. Press F5 on the keyboard

Run Controller – Main Modes

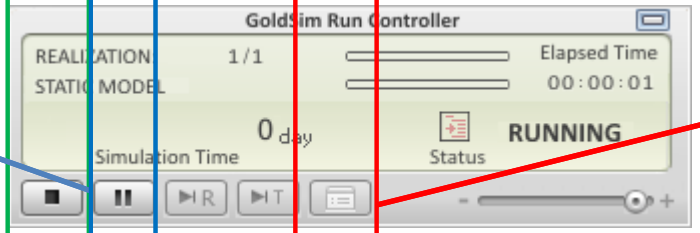
Edit mode
(before running)

Delete results or abort the simulation (not available in Edit mode)



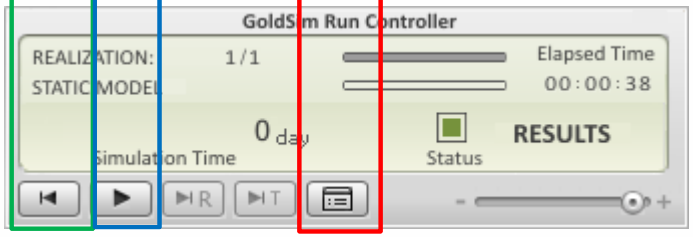
Running mode
(during running)

Run or rerun the simulation. Pause in Running mode.



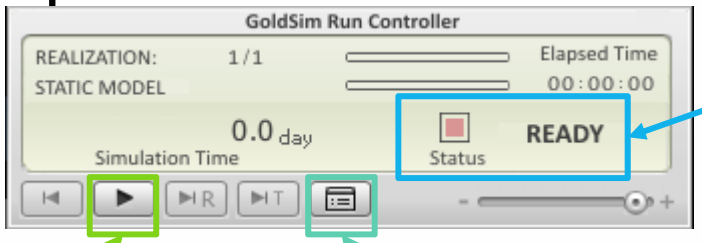
Menu: Access to file options and navigation controls (not available in Run mode).

Results mode
(after running)



Run Controller – Edit Mode

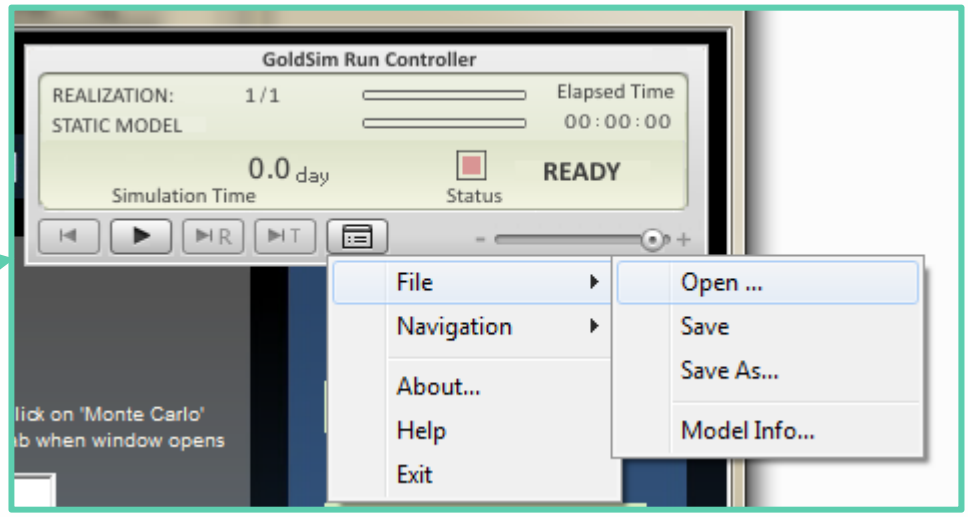
- GoldSim Run Controller in “Ready” state provides user run controls as well as access to common menu bar options.



“READY” indicates that simulation is ready to start but is not yet running

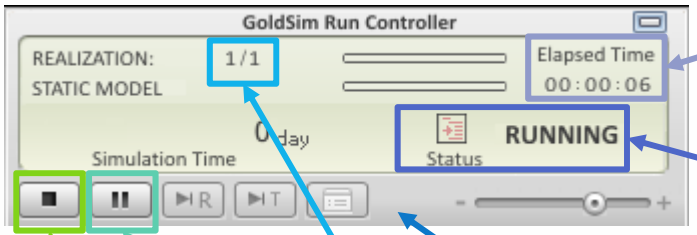
Play button starts a simulation

Menu button provides access to options and navigation controls



Run Controller – Run Mode

- GoldSim Run Controller in “Running” state provides user run controls and information about simulation status



Elapsed time shows the runtime for the simulation

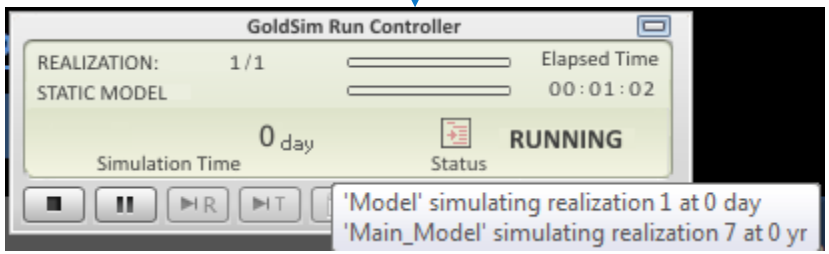
“RUNNING” indicates that simulation is running without error

Pause

Stop button aborts a simulation

Realization number shows the epistemic realization that is currently running

Hovering over the GoldSim Run Controller in “Running” state shows the current epistemic realization (top line) and current aleatory realization (bottom line) with operating time



What to Do when a Run is Finished

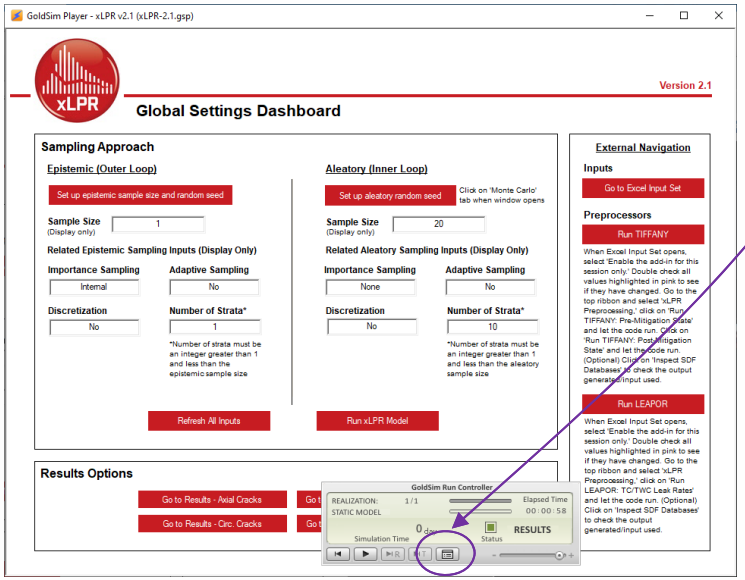
SAVE RUN (very important)

GoldSim saves a lot of data and displaying them may sometimes make the software crash. If the file has not been saved after completion of the run, all the results are lost.

Saving the GoldSim File

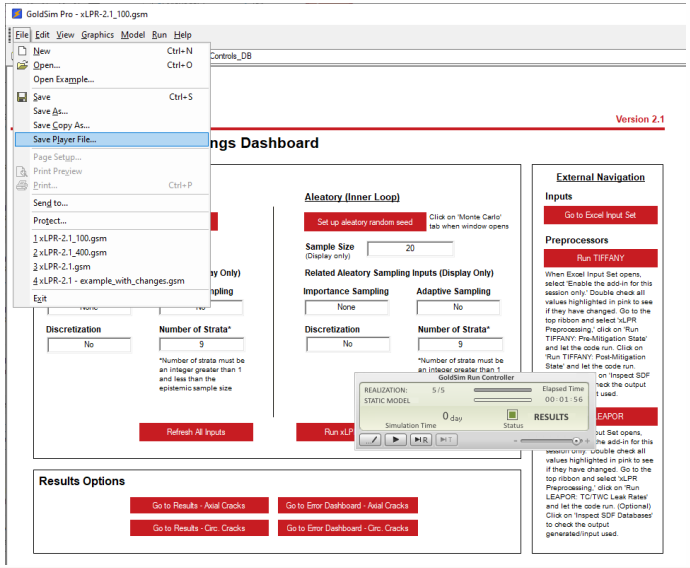
Player

- The option button in the Controller has a file section to save and open
- Shortcuts **Ctrl+S** (save) or **Alt+FA** (save as…) also work



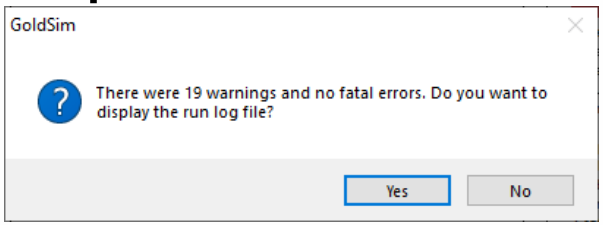
Full Version

- Same option as in the player
- In addition, a file menu is available at the top with the option to **Save Player file** which saves a player version that can be seen by anybody

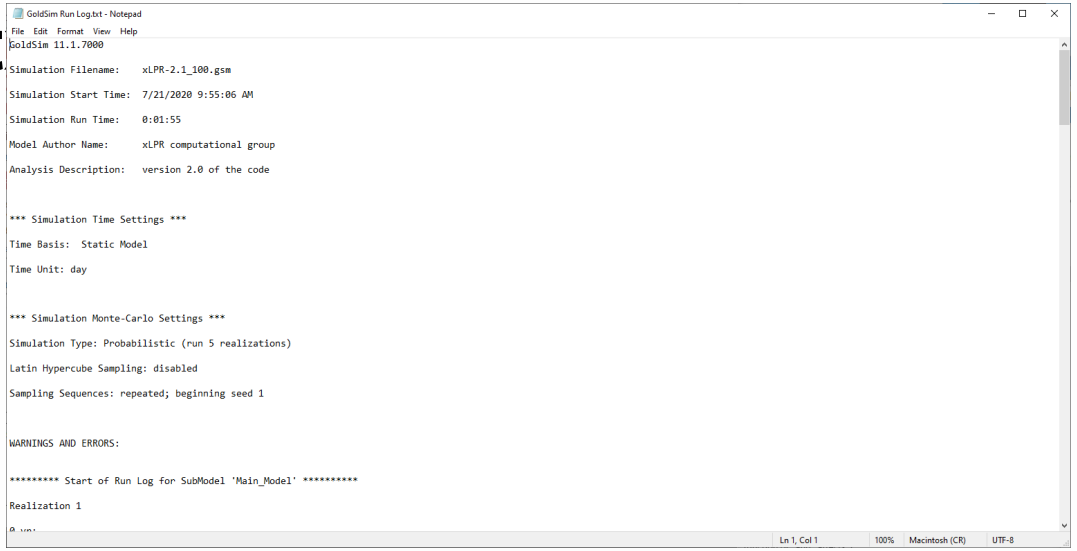


GoldSim Run Log

- A run log is generated for each simulation
  - GoldSim proposes to check it once a simulation is complete



  - It can also be looked at in the folder and is named **GoldSim Run log.t**



The file lists all the warnings and errors. It is an additional source in case of any issue.

Short Break for Questions

xlpr@nrc.gov

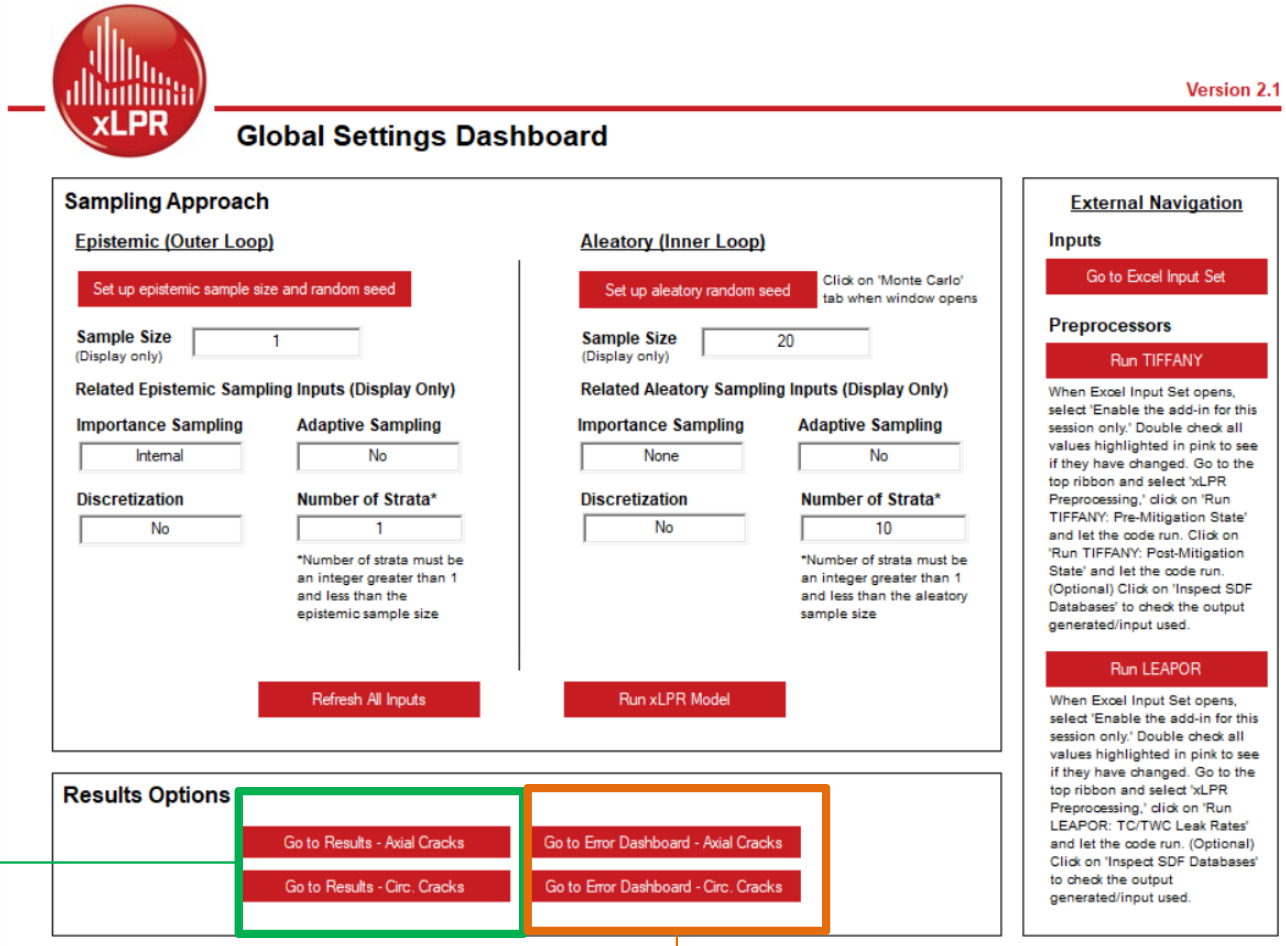
xlpr@epri.com

for Additional Information

Results

Looking at results of a run and exporting them

Access Results from the Dashboard



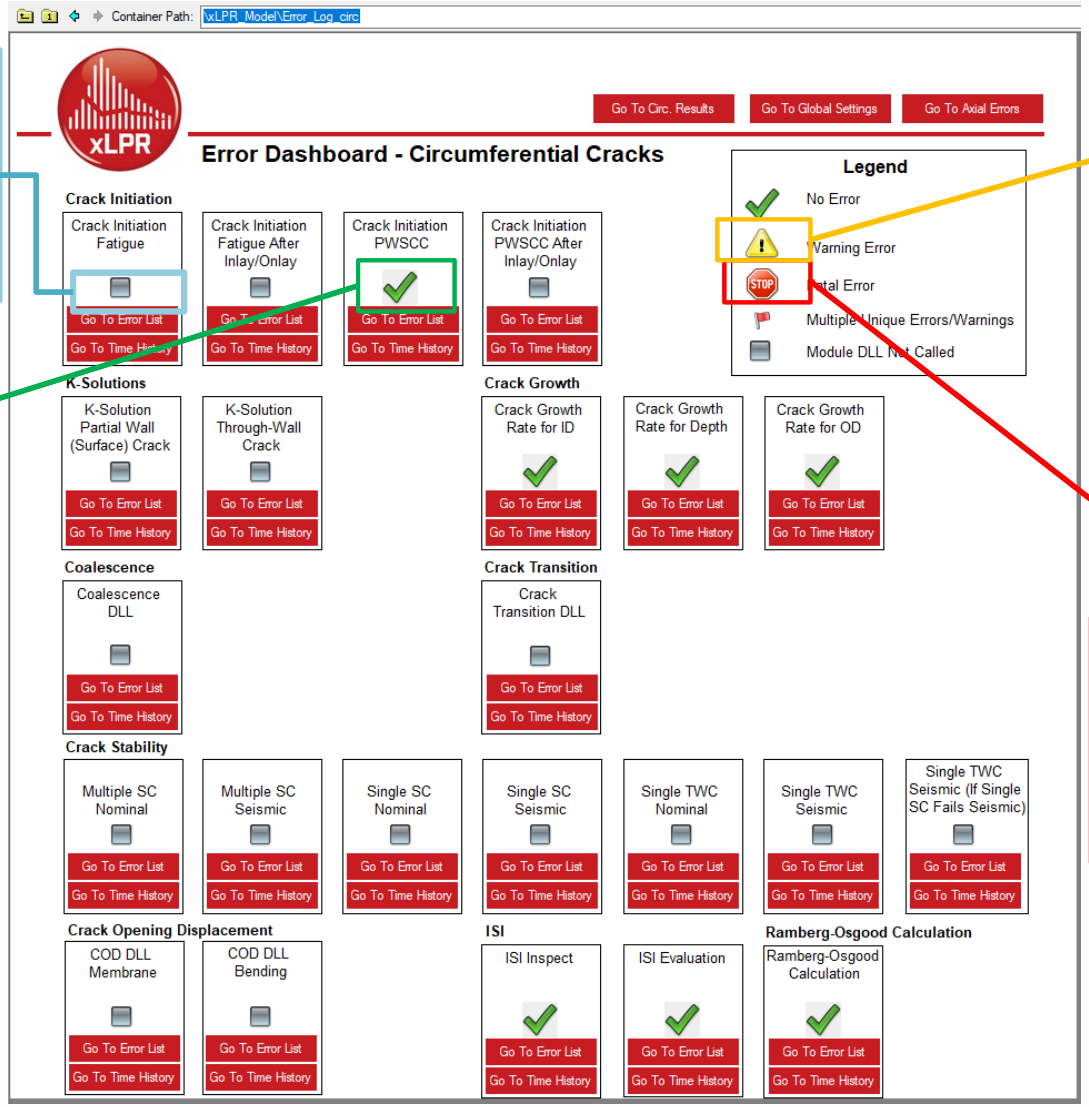
Access to results for circumferential and axial cracks

Access to error dashboards for circumferential and axial cracks

Checking for Potential Errors and Warnings

Gray square: module not used

Green check mark: module performed as expected



Warning sign: warning error – may not be serious but needs to be checked

Stop sign: fatal error - usually stops the code before the end of a simulation

Running a Large Sample Size

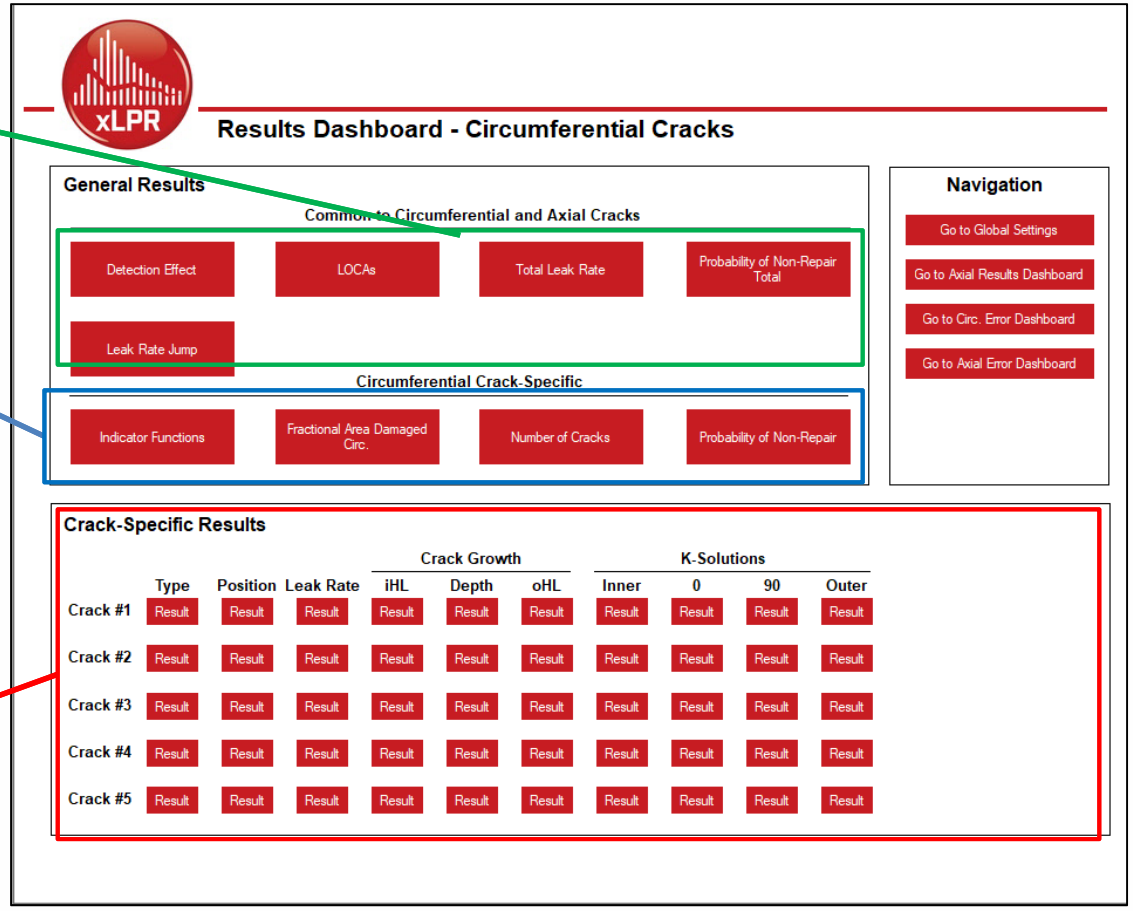
For a long simulation taking several hours, it is recommended to first run with a ***very small*** sample size (1-5 minute simulation duration) to confirm that no errors or warnings occur and that the results look “reasonable”

Standard Results

General results: Consider both axial and circumferential cracks

Direction-specific results: Summary results for either axial or circumferential cracks as applicable

Crack-specific results: Statistics for the first 5 cracks that occur



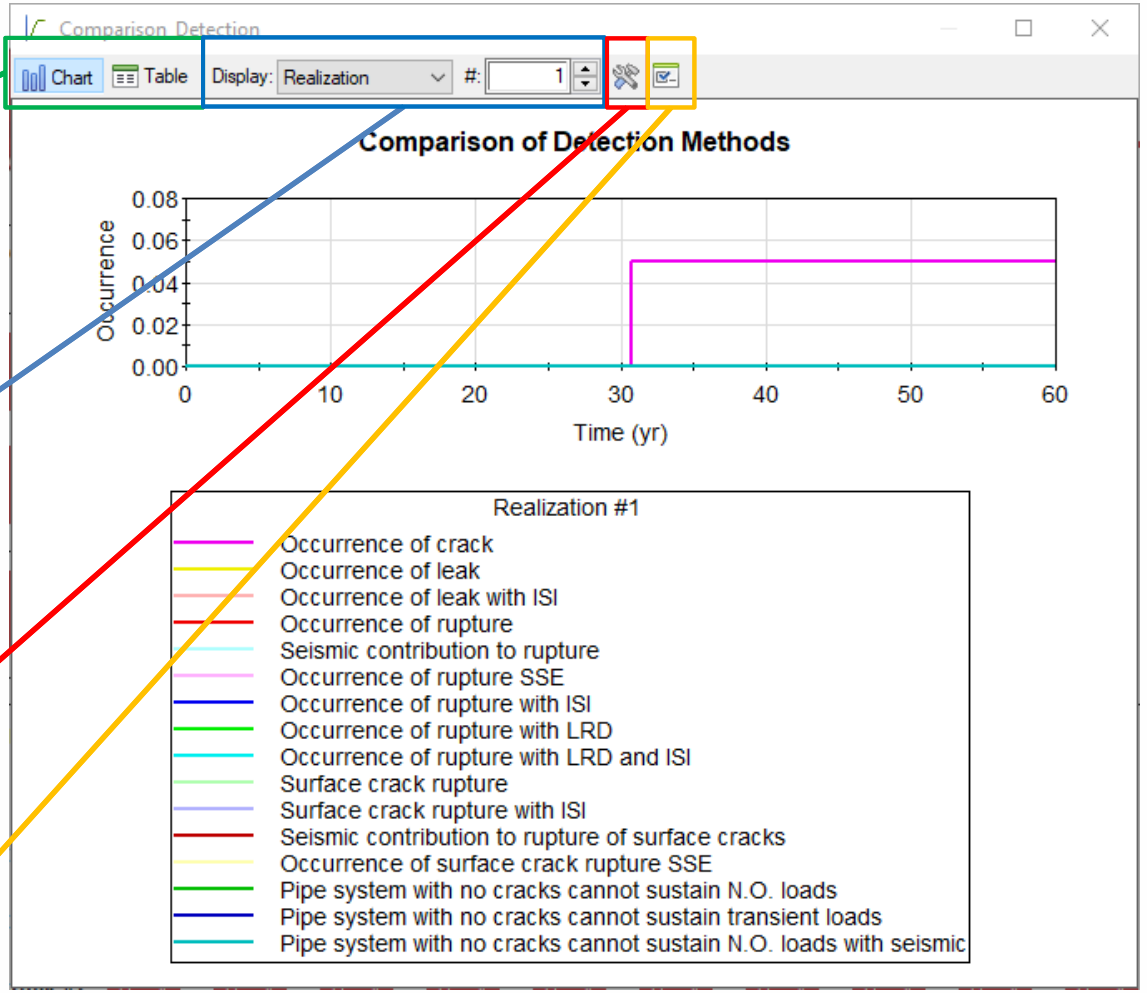
Results Options

Chart: Look at plot of results
Table: Table of results that can be copied and pasted to Excel or text file, for instance

Display:
Realization: *Only one (epistemic) realization, selected by the next box*
All realizations: *Display all realizations - /!\: DO NOT TRY THIS if large # of realizations (>2000)*
Probabilities: *Quantiles over realizations*
Statistics: *Selected statistic (selection in the next box)*

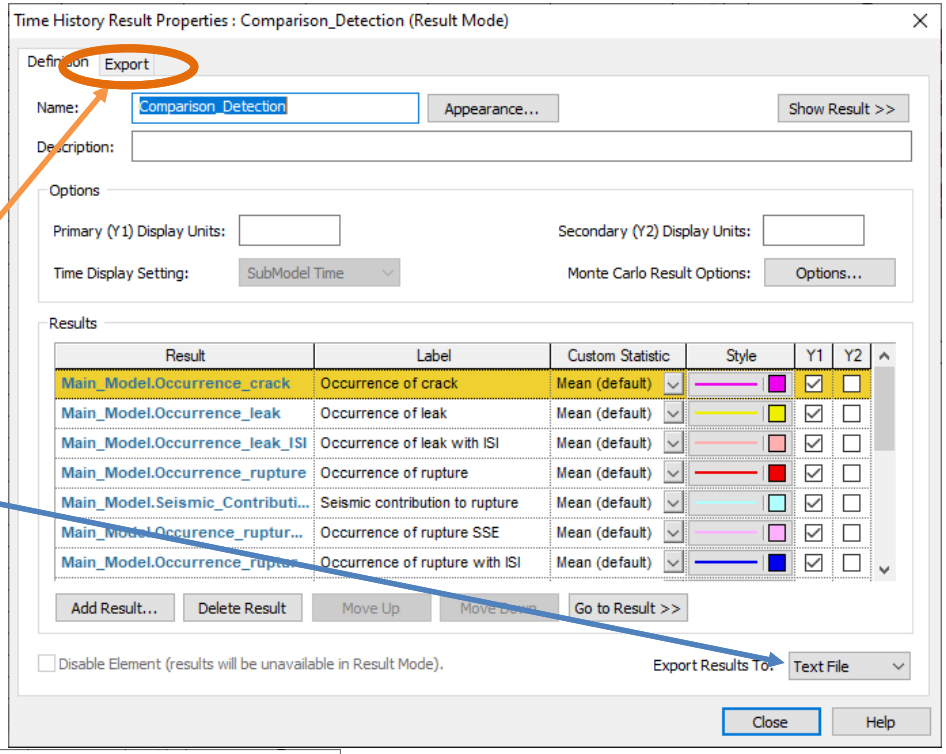
Chart Style (chart mode): Changing x-axis, y-axis …
Sorting (table mode):

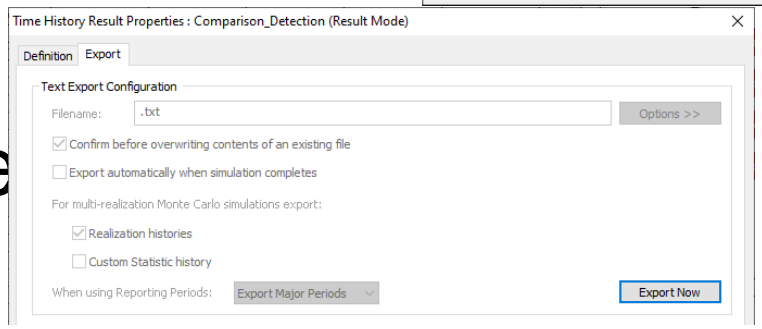
Access to result element (greyed-out in Player version)



Saving Results (Full Version of GoldSim)

- Needs to be done *before* running the code
- Access result element
- Select a type of results to export (text or Excel), opens a new tab
- New tab give
for exporting

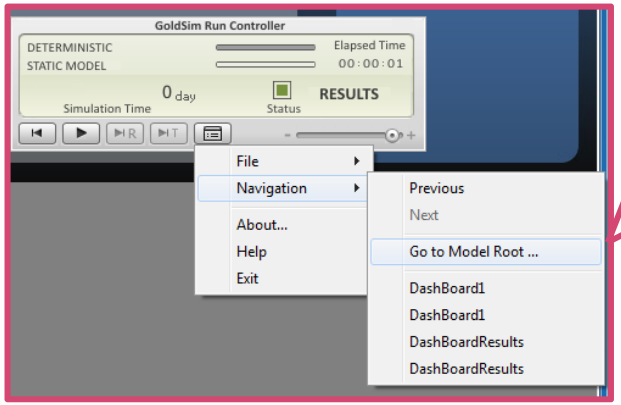


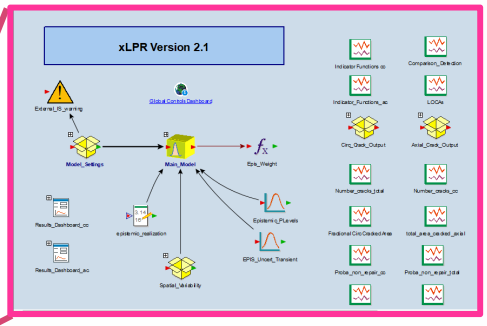


Saving Results (GoldSim Player Version)

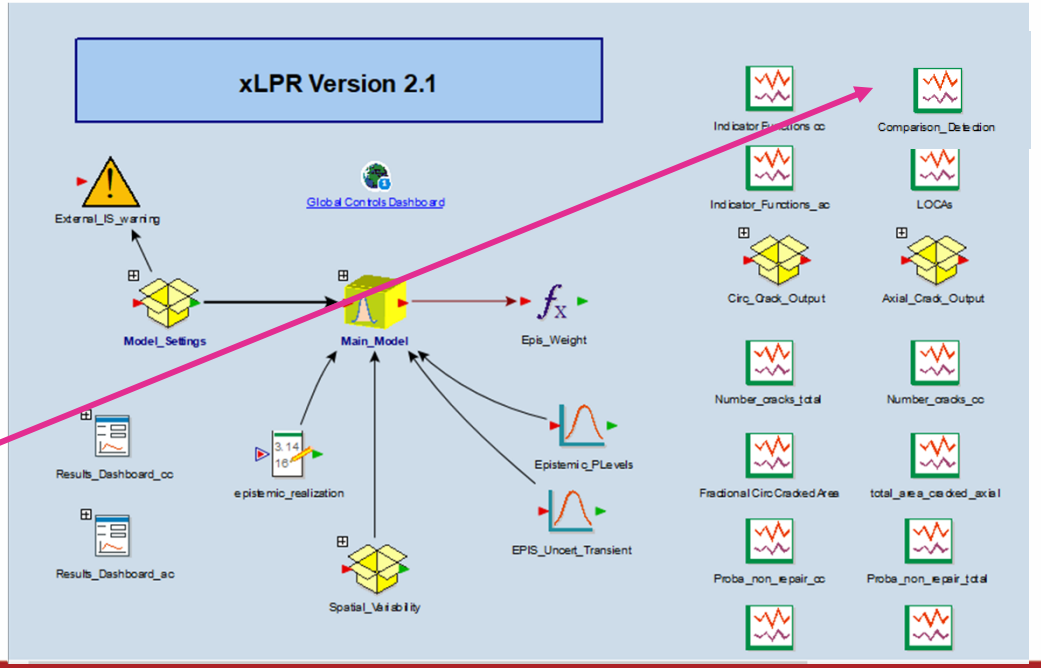
- Extra step to access the result element

Navigate to the model root





Right-click on a result element and click “Properties” to open a result properties window

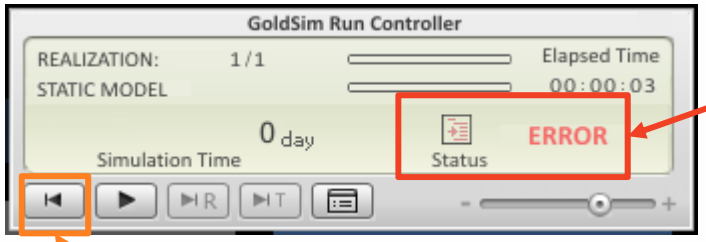


Runtime Errors

Most common issues and how to fix them

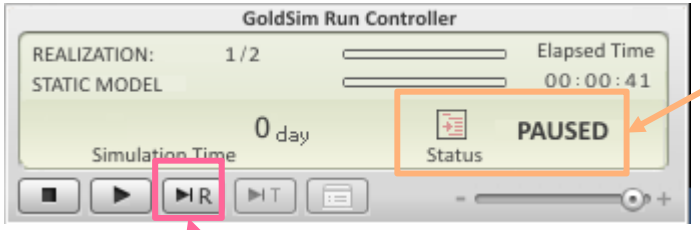
Runtime Error – Run Controller Message

- GoldSim Run Controller in “Error” and “Paused” states provides user run controls.



“ERROR” indicates that simulation has encountered an error and is stopped or paused

Reset simulation



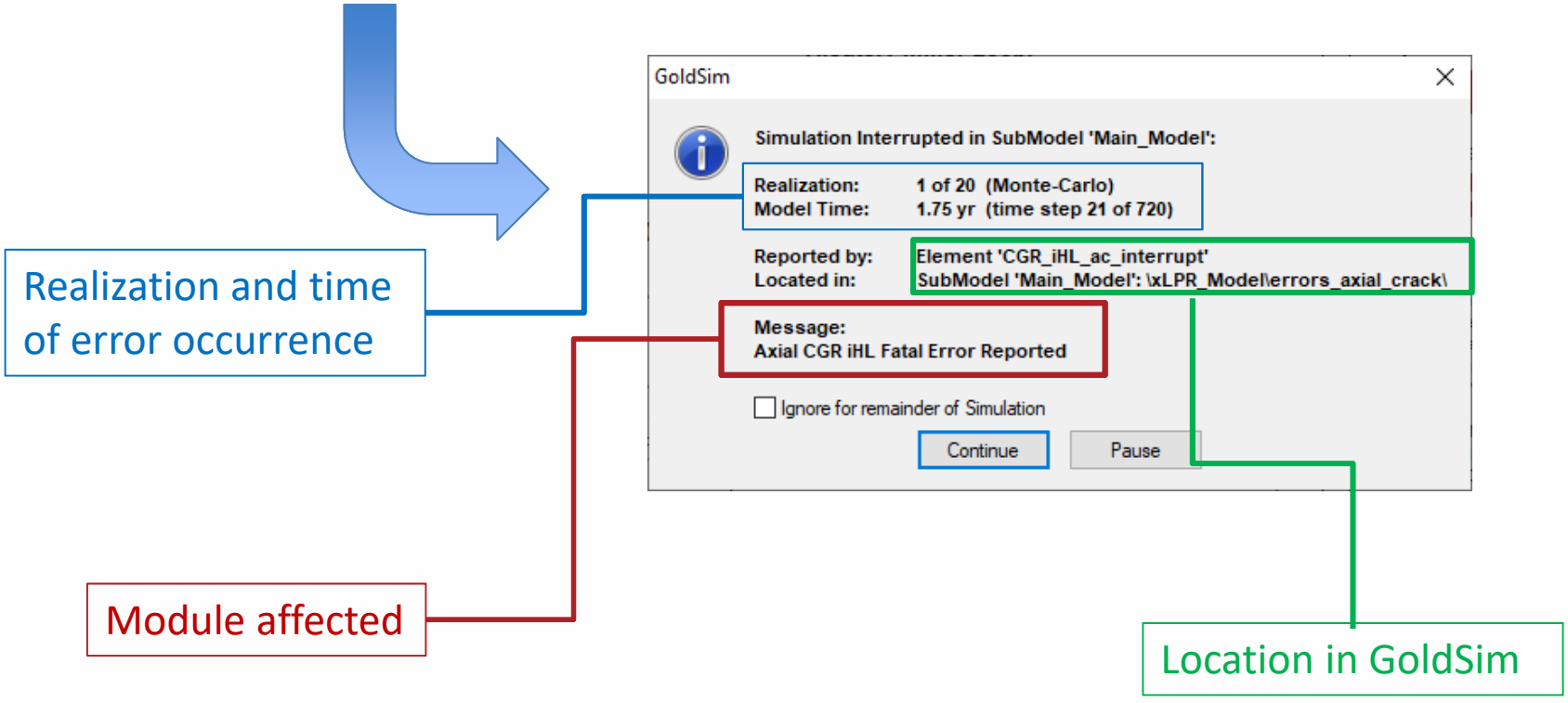
“PAUSED” indicates that simulation has been paused

Advance simulation by running one realization (epistemic)

Example of Error (1/3)

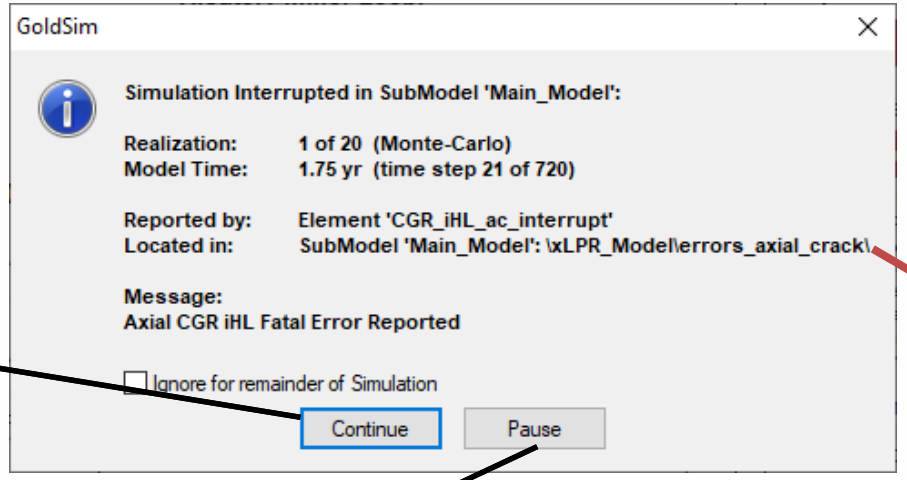
- Example with negative crack growth

[0, nomax)	2588	Power Law Constant, Alpha	(m/s)(Mpa-m1/2)^(-beta)	Constant	no	0.5	-3.00E+00	DISCRETE	1	1



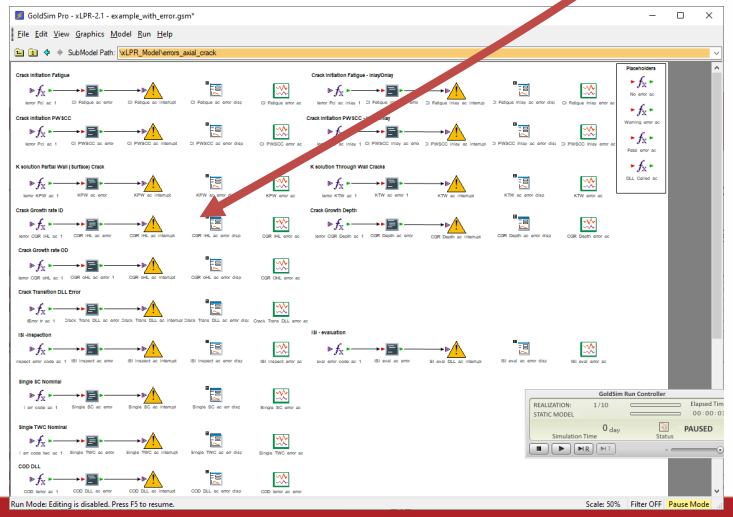
Example of Error (2/3)

- Tracking an error



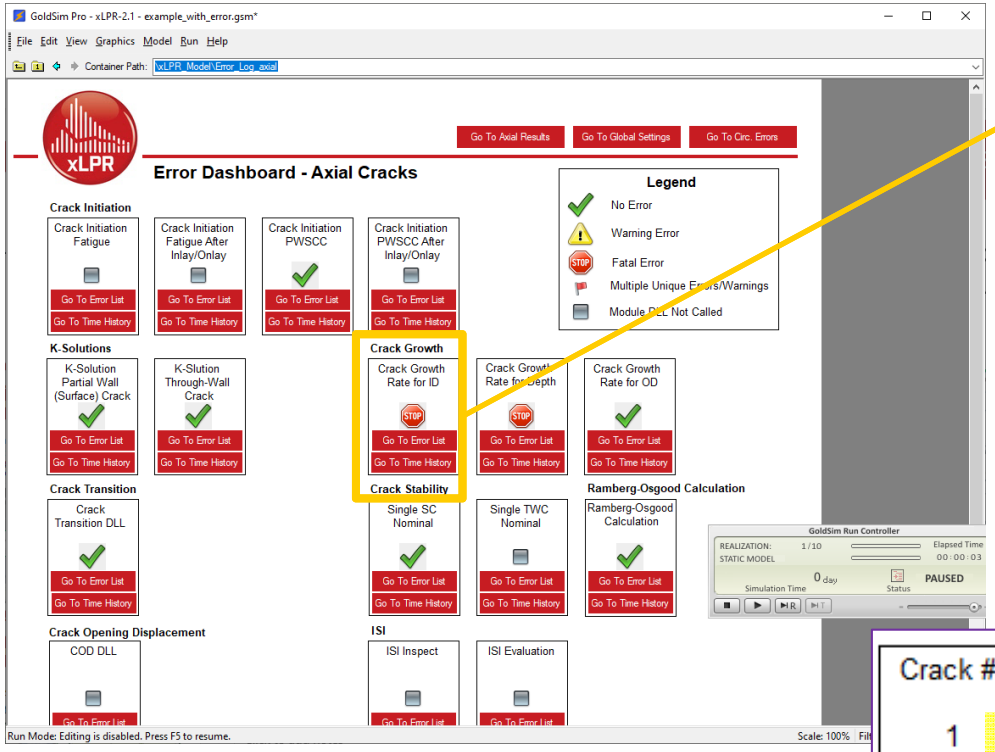
Continues the simulation

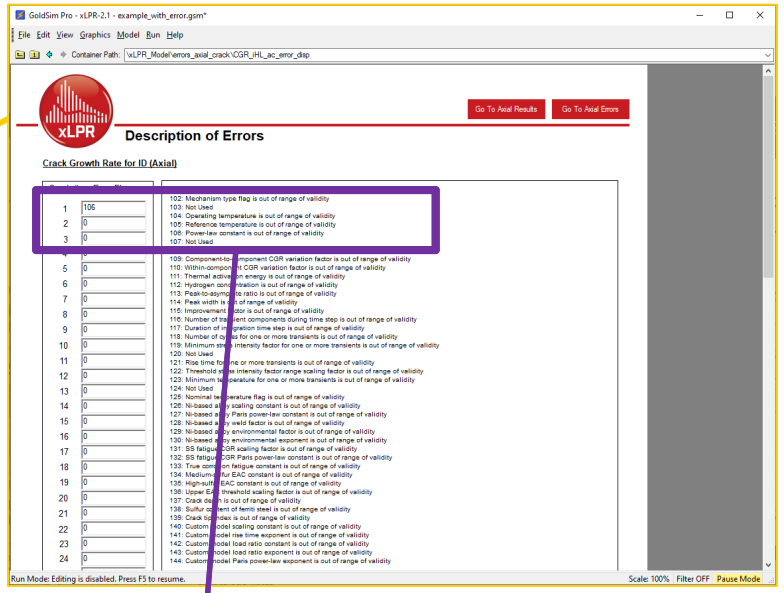
Pauses the simulation and brings to the GoldSim section where the error occurs

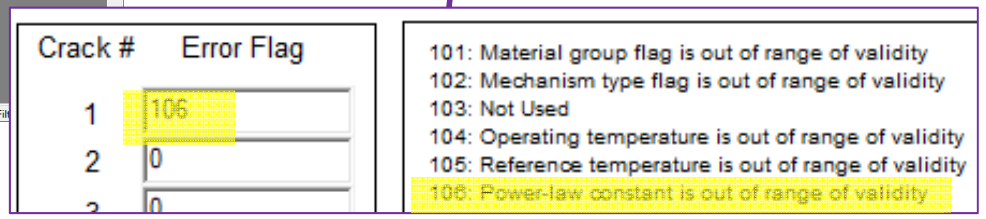


Example of Error (3/3)

- Debugging from the error dashboard





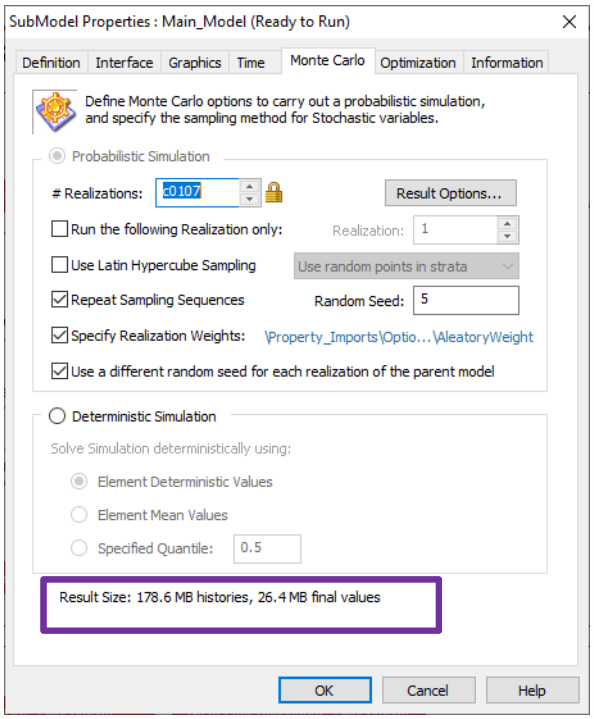


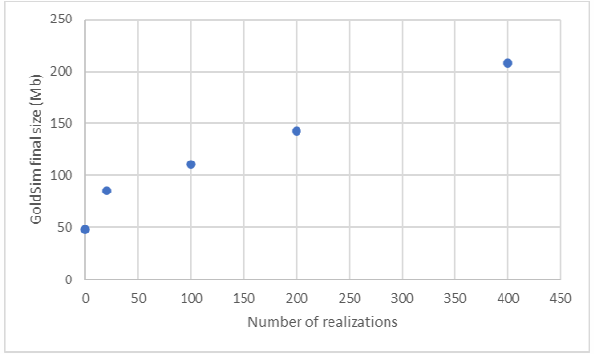
Memory Errors

- GoldSim V11.1 is a 32-bit program. It is limited to 3Gb of data.
- If the amount of data required is larger, GoldSim will crash and stop, then rerun. But **no results will be saved**. This is why it is important to always save when a run is complete.

Memory Requirements

- Memory requirement us reported in the Monte-Carlo tab for the aleatory (inner) loop
- The epistemic loop reports additional memory but is not of concern usually
- Experience is that aleatory loop is limited to 3k to 4k realizations
- Can be expanded to 8k using 80 epistemic x 100 aleatory, for instance
- With no changes, xLPR V2.1 requires 79 Mb of initial memory plus ~0.325 Mb per realization
  - Maximum size with original model ~8k realizations





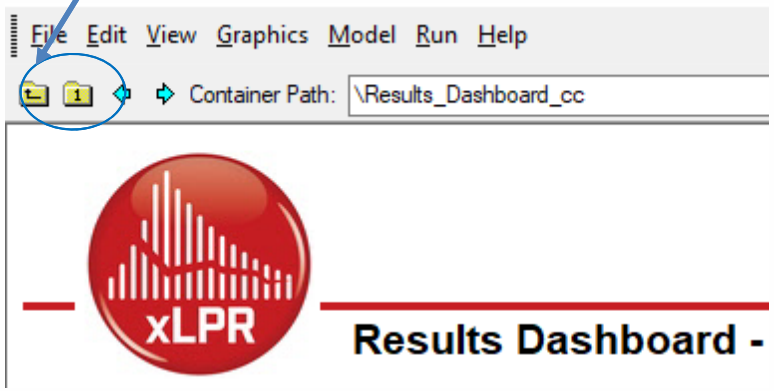
Framework

How to navigate through the GoldSim model

Accessing the model

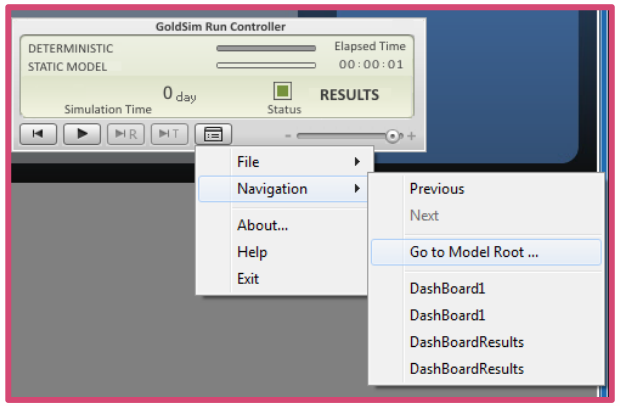
Full version of GoldSim

Click on the yellow icon with a "1" inside (second icon) on the top toolbar



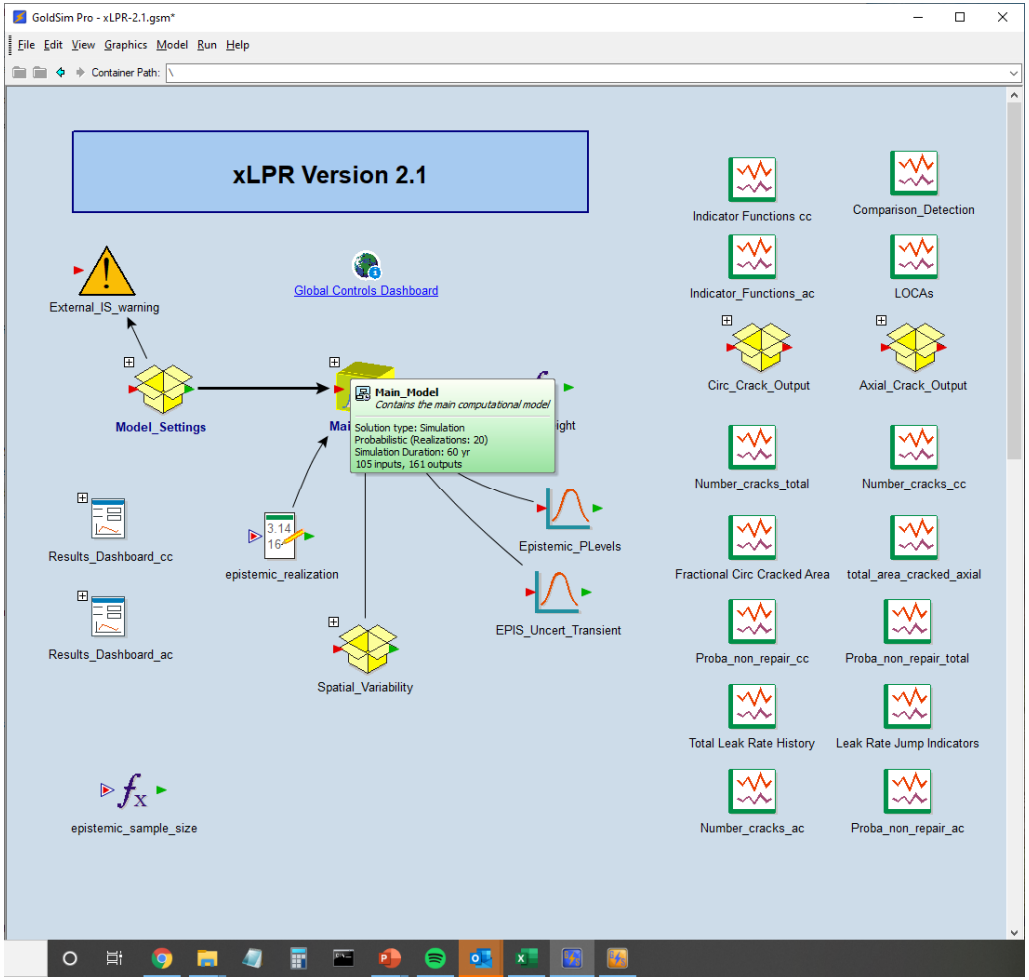
Player version

Select the last icon in the controller, then *Navigation* and *Go to model root…*

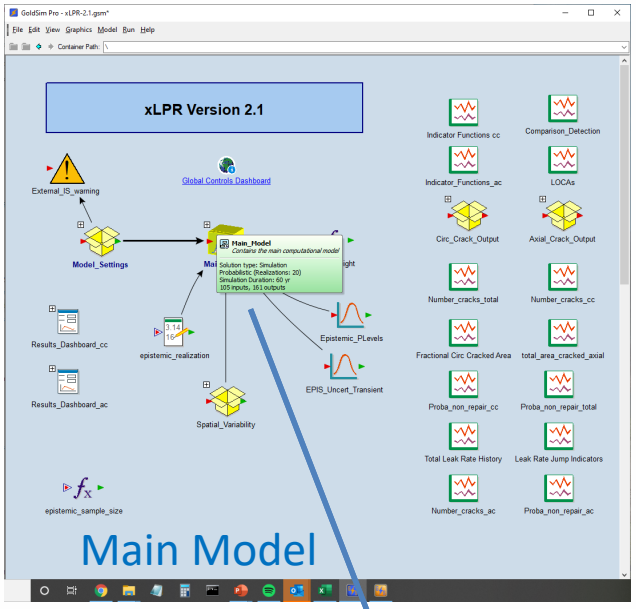


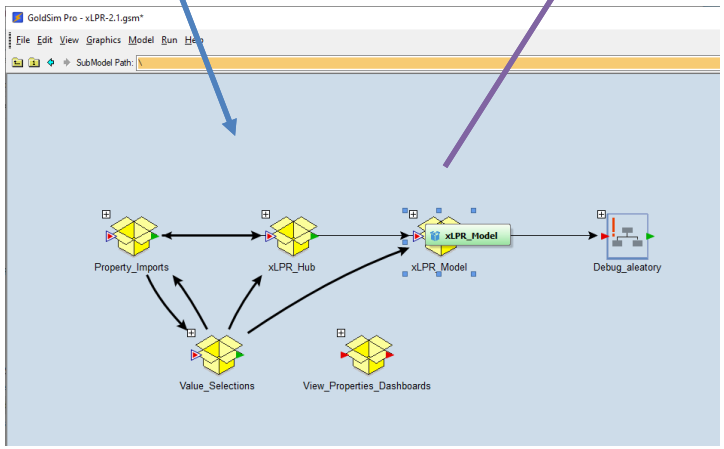
Navigating through the Model

- Containers are equivalent to folders
- Clicking on the “plus” sign in the upper left corner provides access to the container

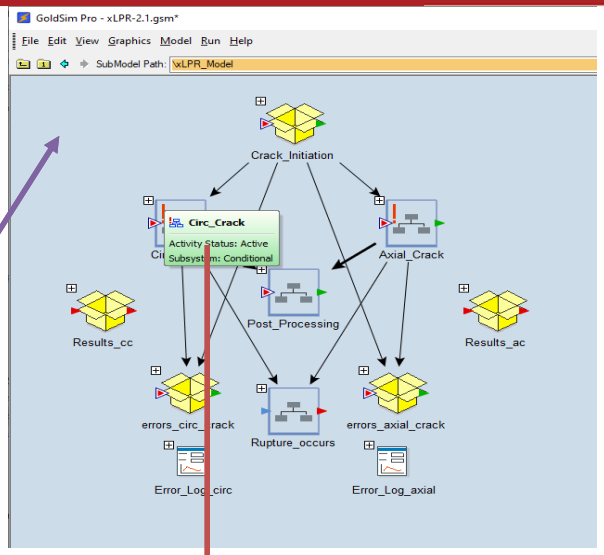


Important Containers

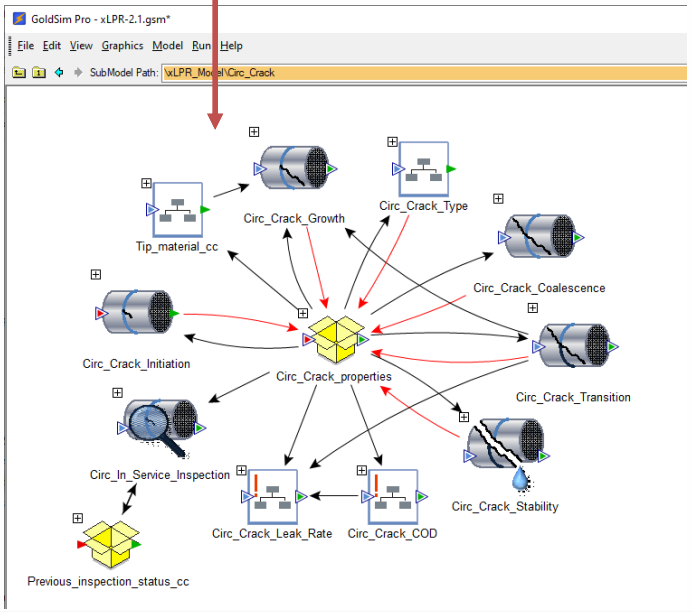




xLPR Model

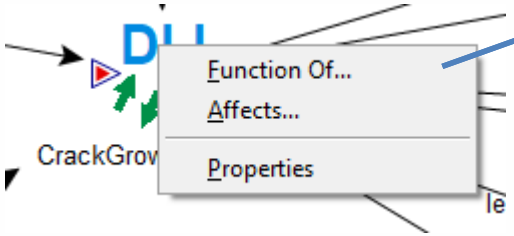


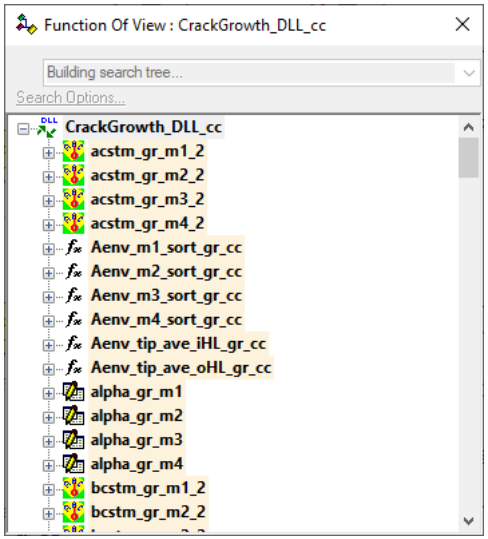
Circumferential Crack



Navigating through the Flow Path (1/2)

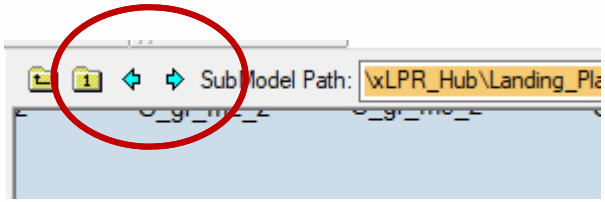
- Right clicking on each element gives access to the commands **Function Of**, **Affects**, or both:
  - **Function Of** gives the upstream information (which elements affect this one). A primary element does not have this function.
  - **Affects** gives the downstream information (which elements are influenced by this one). A final element does not have this function.

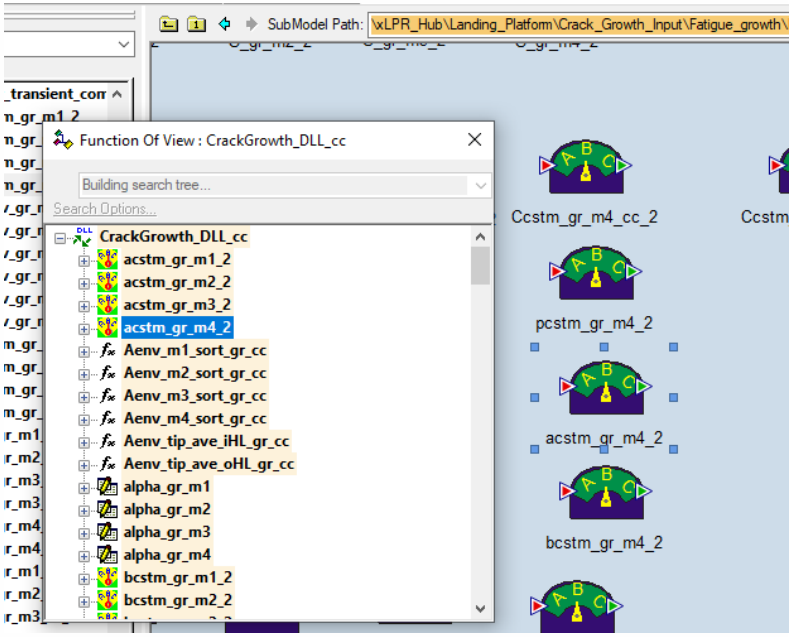




Navigating through the Flow Path (2/2)

- Clicking an element in the Function Of or Affects windows will navigate to the corresponding element
- Use the blue arrows to go back and forth between locations



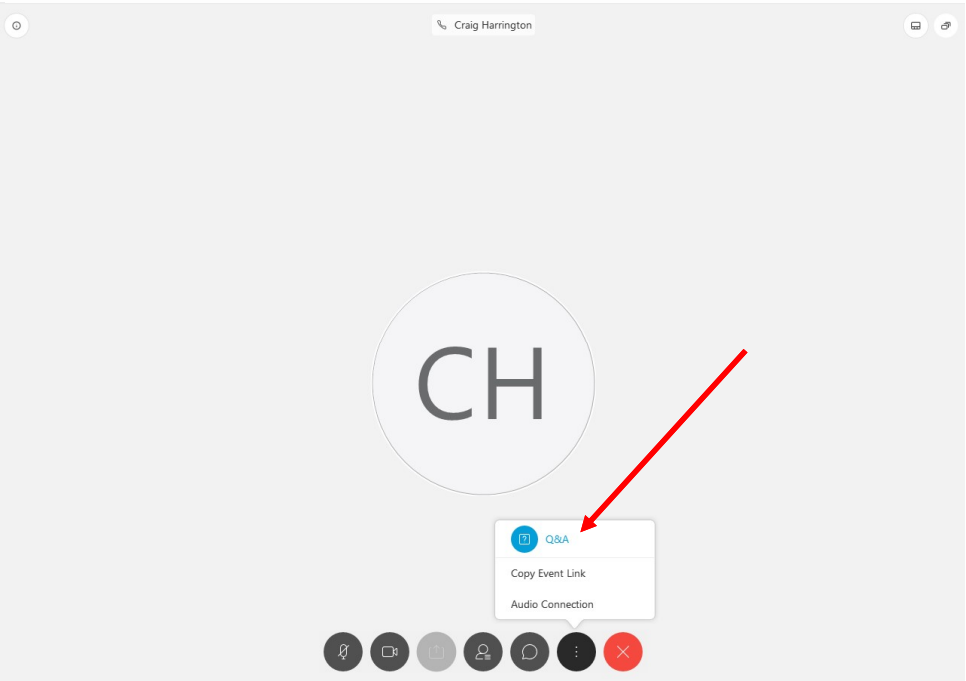


Break

Questions and Answers

WEBEX Q+A

Webex Internet Browser



Webex Desktop Client

Closing Remarks

Looking Forward

- Advanced Methods
  - **August 5th | 10-12 EDT**

Questions?

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