What Have We Done Lately?

The Current Status of the SAPHIRE Risk Analysis Software

Authors :

S. Ted Wood, James K. Knudsen, and Kellie J. Kvarfordt

www.inl.gov

INL
Idaho National Laboratory

SAPHIRE – What is it?

SAPHIRE - Systems Analysis Programs for Hands-on Integrated Reliability Evaluations

SAPHIRE is an integrated PRA software tool that gives a user the ability to create and analyze fault trees and event trees using a personal computer using Windows operating system developed by Idaho National Laboratory (INL) for US Nuclear Regulatory Commission (NRC).

INL has been a principal developer of Probabilistic Risk Analysis (PRA) tools for over 45 years, supporting risk activities at government agencies that include the U.S. Nuclear Regulatory Commission (NRC), National Aeronautics and Space Administration (NASA), and Department of Energy (DOE).

SAPHIRE - History

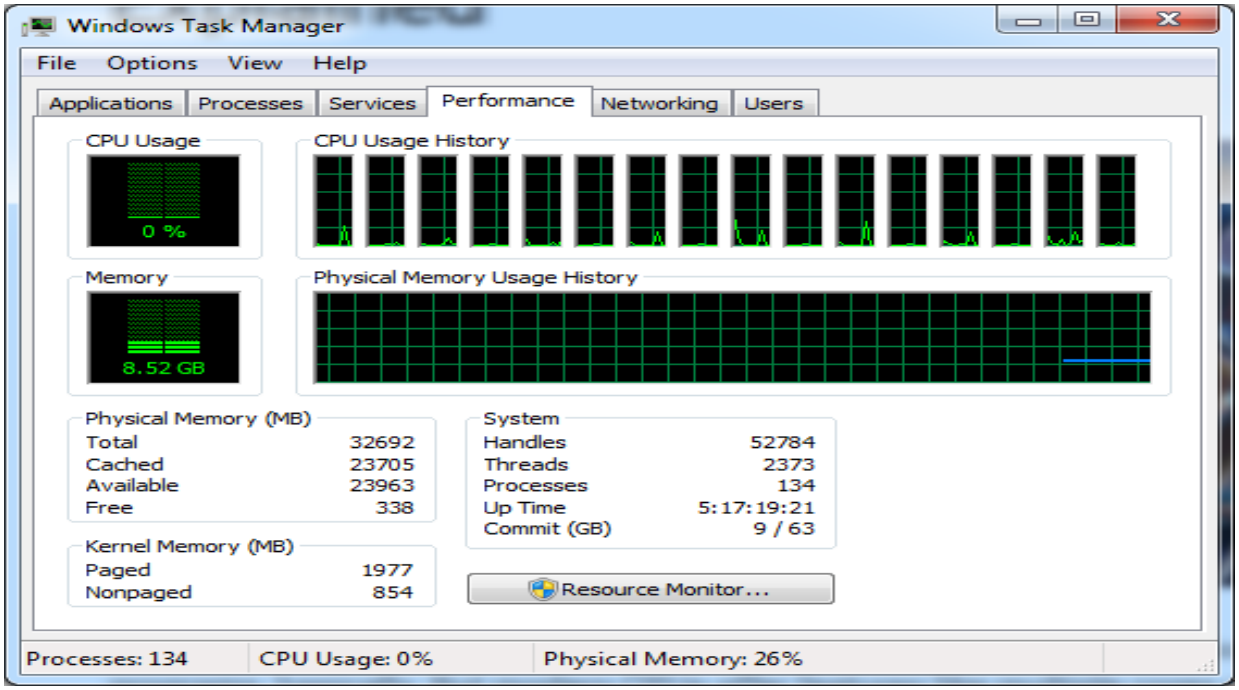
- 1987 – Integrated Reliability and Risk Analysis System (IRRAS) 1.0
- 1989 – IRRAS 2.0
- 1990 – IRRAS 4.0
- 1992 – IRRAS 5.0 (32-Bit) resulted in an order of magnitude decrease in analysis time.
- 1997 – SAPHIRE for Windows version 6.0.
- 1999 – SAPHIRE for Windows version 7.0
- 2010 – SAPHIRE for Windows version 8.0
- 2018 – SAPHIRE for Windows version 8.1.8 (Current Release)

SAPHIRE – Fundamental Capabilities

- Cut set generation and quantification
- PC-based fault tree and event tree graphical editors
- Importance measures and uncertainty modules
- Relational database with cross-referencing features
- External events analysis (e.g., seismic)
- Rule-based recovery and end-state analysis
- Common Cause Failure (CCF) basic event capabilities

SAPHIRE – Make it faster!!

How to use more of our desktop power?

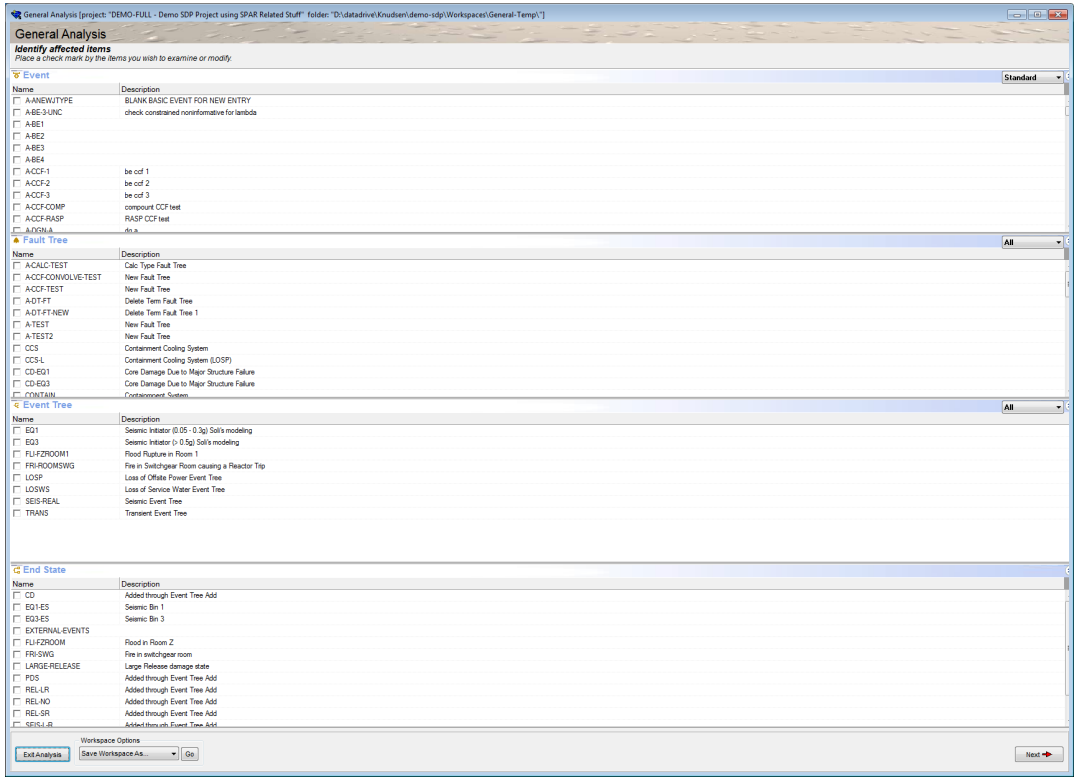


SAPHIRE – Workspace Concept

- Workspace
  - A snapshot or copy of the original model
    - Can be modified and analyzed to determine the impact of possible changes
    - Doesn't change original model
    - Can be saved and examined in more detail

SAPHIRE - Workspace Examples

- General Analysis
- Events and Conditions Analysis (ECA)
- Significance Determination Process (SDP)



SAPHIRE – Sandbox Concept

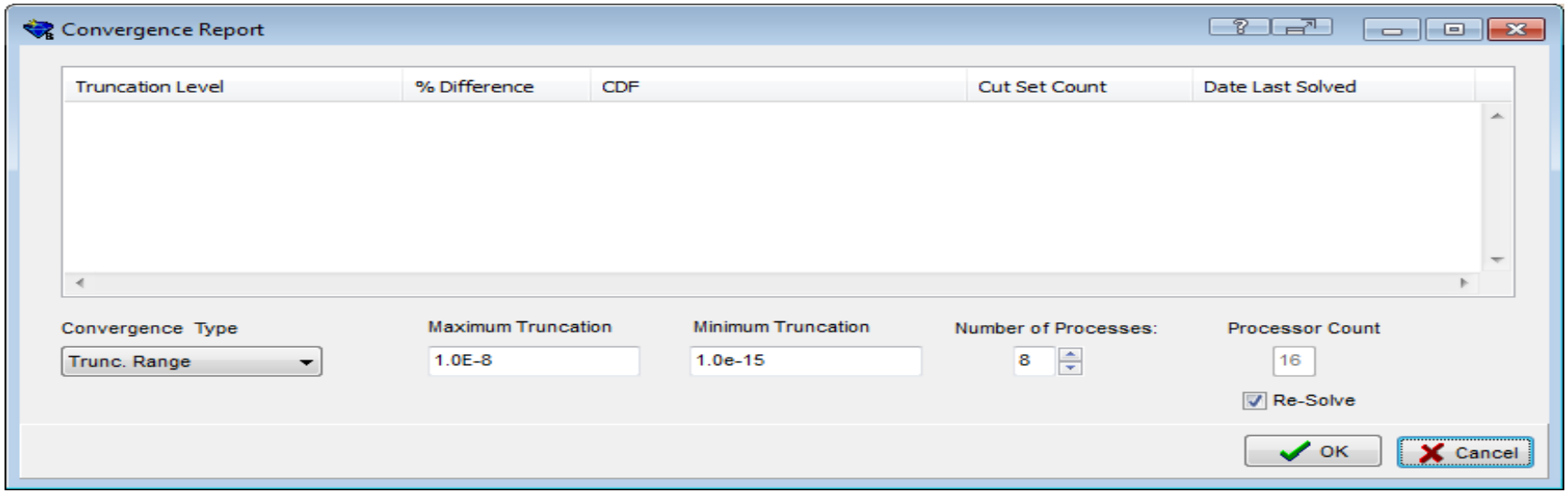
- **Sandbox almost = Workspace**
- Differences –
  - Not saved for future analysis
  - Specific answers from sandbox are used to get values for reports in the parent project
  - Each sandbox has its own SAPHIRE executable driven by a SAPHIRE instruction set or macro

SAPHIRE – Sandbox Examples

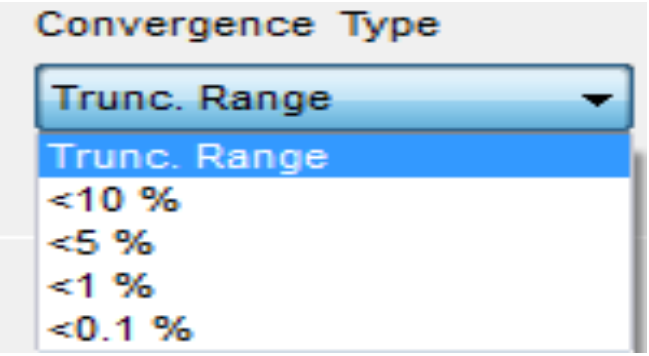
- **Two examples of Sandboxes**
  - **Convergence Report** – Calculate and display the Core Damage Frequency (CDF) at various truncation levels.
  - **Plant Information e-Book (PRIB) Report** – Calculate and display System and Component Level Importance.

SAPHIRE – Convergence Report

- **Convergence Form**



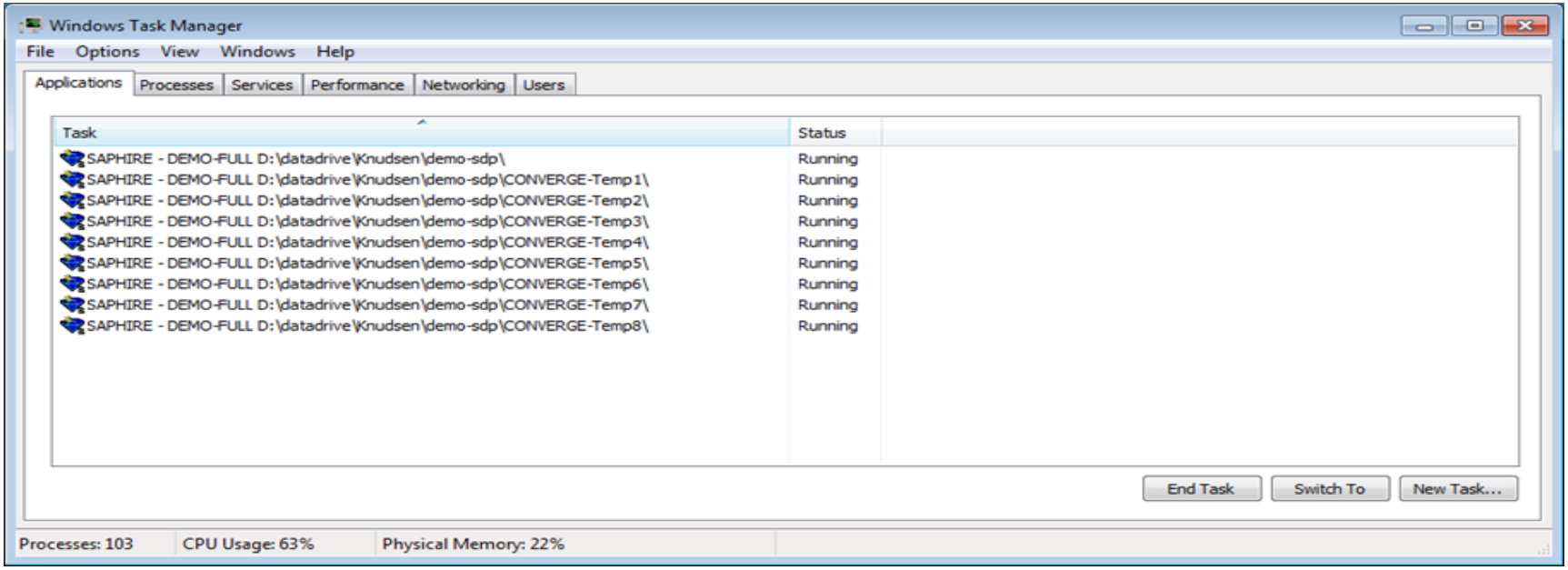
SAPHIRE – Convergence Options



- The default option is “Trunc. Range”, or truncation range, which allows the user to select the maximum and minimum truncation values.
- Other options – Stop the convergence when levels of % Difference floors are achieved
  - <10 %
  - < 5%
  - < 1%
  - < 0.1%
- % Difference = $(CDF_n / CDF_{n-1}) * 100.0$
  - where
    - CDF_n is the overall CDF for the current truncation level and
    - CDF_{n-1} is the overall CDF for the previous truncation level.

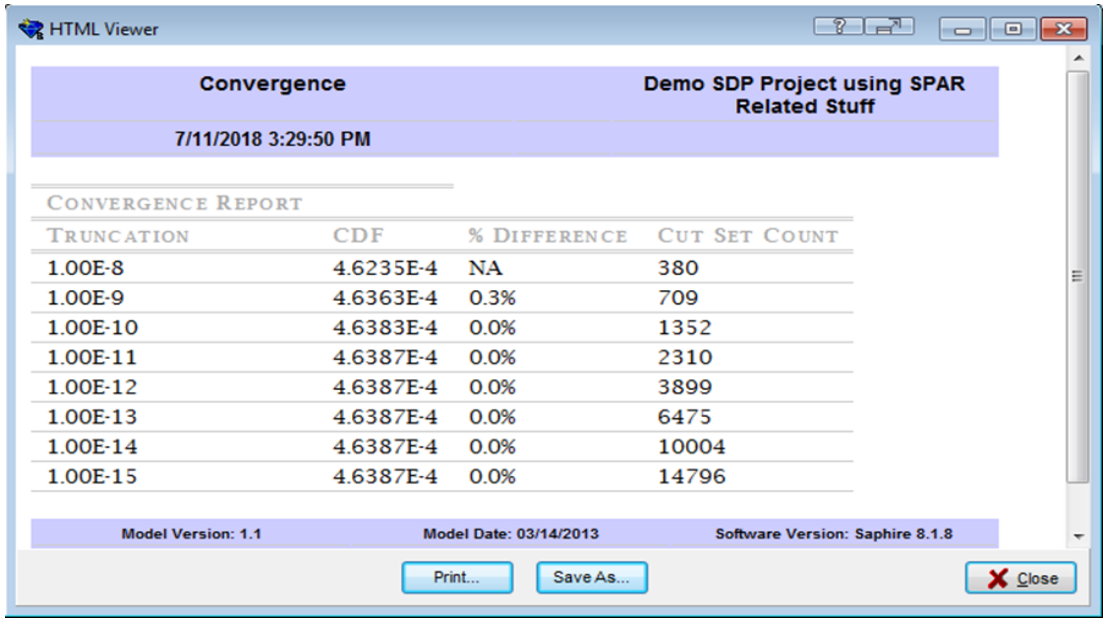
SAPHIRE – Convergence Process

- Each SAPHIRE sandbox sub-instances is started with an assigned project sub-directory
- Each SAPHIRE sandbox sub-instance is running a macro (SAPHIRE defined command language)



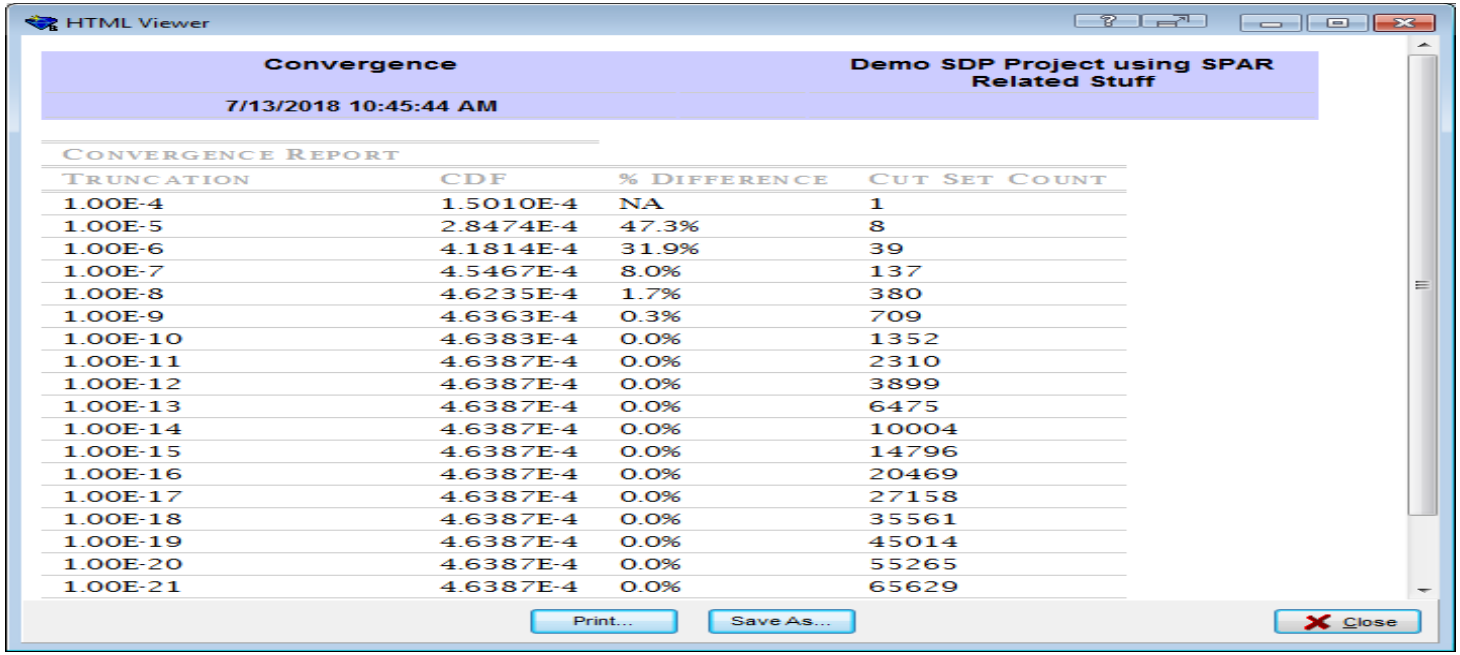
SAPHIRE – Convergence Report

- Convergence Report for maximum of 1.0E-8 to minimum of 1.0E-15 truncation



SAPHIRE – Another Convergence Report

- Convergence Report for maximum of 1.0E-4 to minimum of 1.0E-21 truncation



CONVERGENCE REPORT

TRUNCATION	CDF	% DIFFERENCE	CUT SET COUNT
1.00E-4	1.5010E-4	NA	1
1.00E-5	2.8474E-4	47.3%	8
1.00E-6	4.1814E-4	31.9%	39
1.00E-7	4.5467E-4	8.0%	137
1.00E-8	4.6235E-4	1.7%	380
1.00E-9	4.6363E-4	0.3%	709
1.00E-10	4.6383E-4	0.0%	1352
1.00E-11	4.6387E-4	0.0%	2310
1.00E-12	4.6387E-4	0.0%	3899
1.00E-13	4.6387E-4	0.0%	6475
1.00E-14	4.6387E-4	0.0%	10004
1.00E-15	4.6387E-4	0.0%	14796
1.00E-16	4.6387E-4	0.0%	20469
1.00E-17	4.6387E-4	0.0%	27158
1.00E-18	4.6387E-4	0.0%	35561
1.00E-19	4.6387E-4	0.0%	45014
1.00E-20	4.6387E-4	0.0%	55265
1.00E-21	4.6387E-4	0.0%	65629

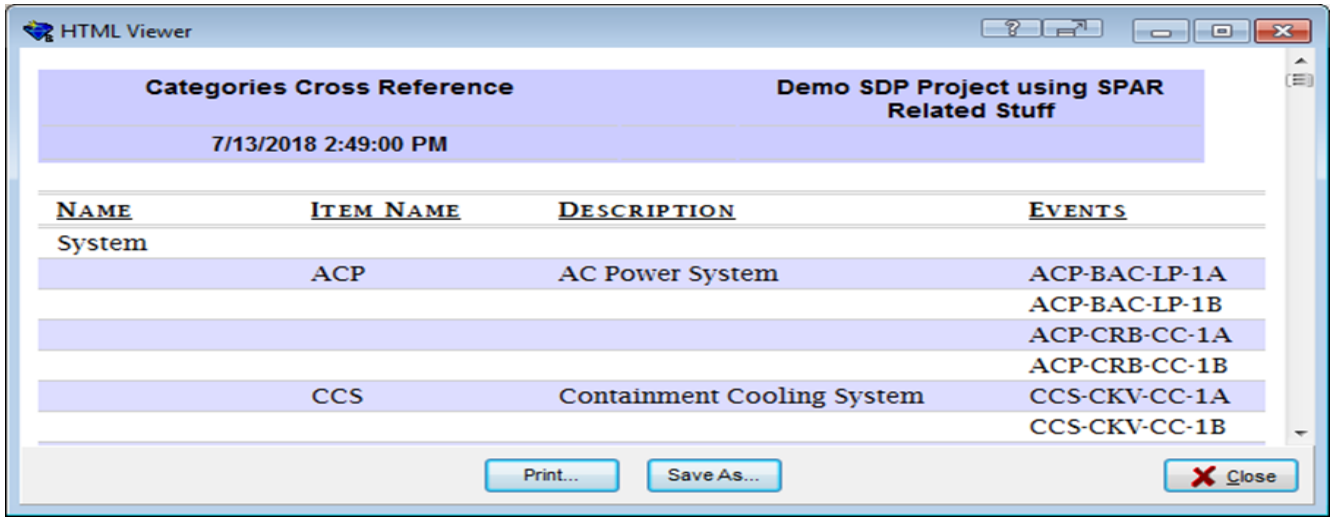
SAPHIRE – Convergence Report Timing Results

Sandbox Count	Setup Time (mm:ss)	Total Time (mm:ss)
1	0:03	4:01
2	0:05	1:25
3	0:08	1:09
4	0:10	1:30
5	0:12	0:50
6	0:15	1:03
7	0:17	0:51
8	0:20	0:54
12	0:30	1:05
16	0:39	1:20

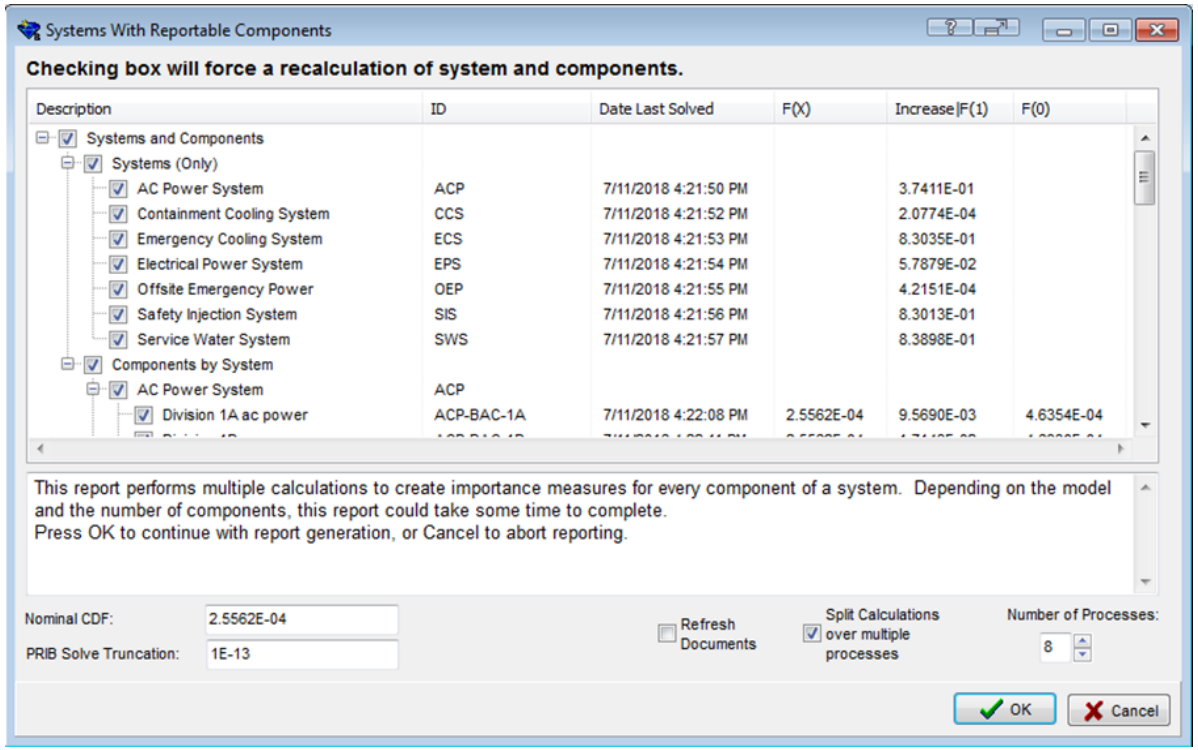
- Convergence Report - Hand timed calculation times for various numbers of sandboxes

SAPHIRE – PRIB Example

- **Plant Information e-Book (PRIB) Report**
  - Performed on Standardized Plant Analysis Risk (SPAR) models
  - Works like Convergence Report with multiple sandboxes of SAPHIRE
  - Calculates system and component type importance measures

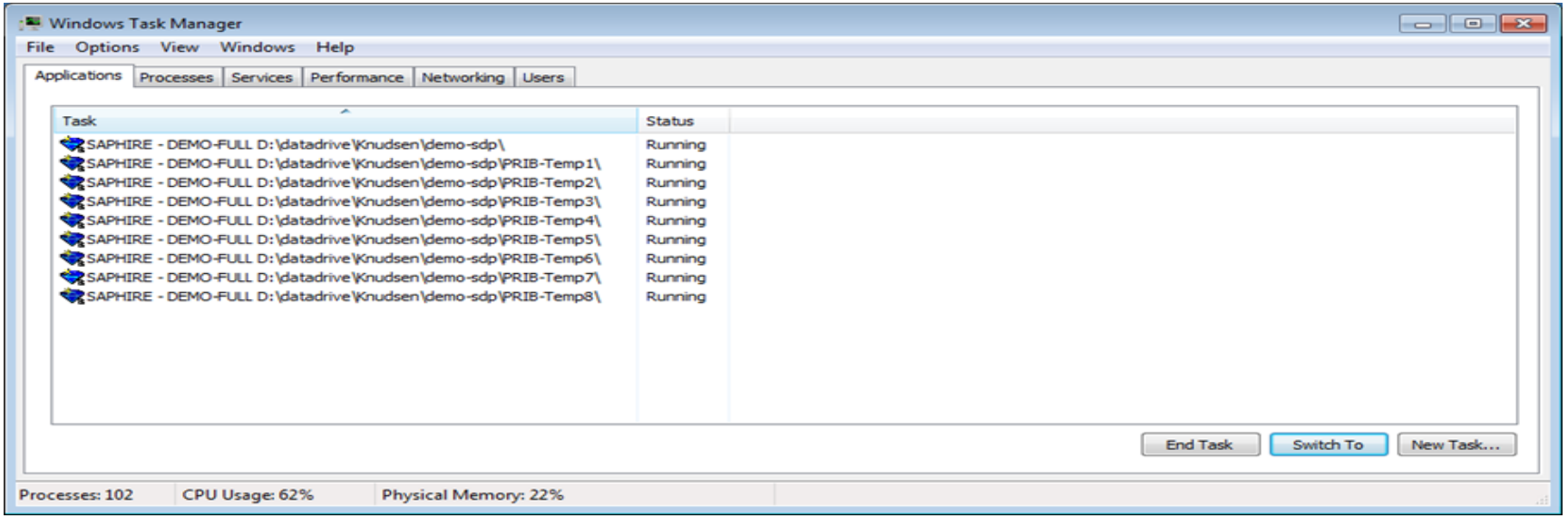


SAPHIRE – PRIB Report Setup Form



SAPHIRE – PRIB Process

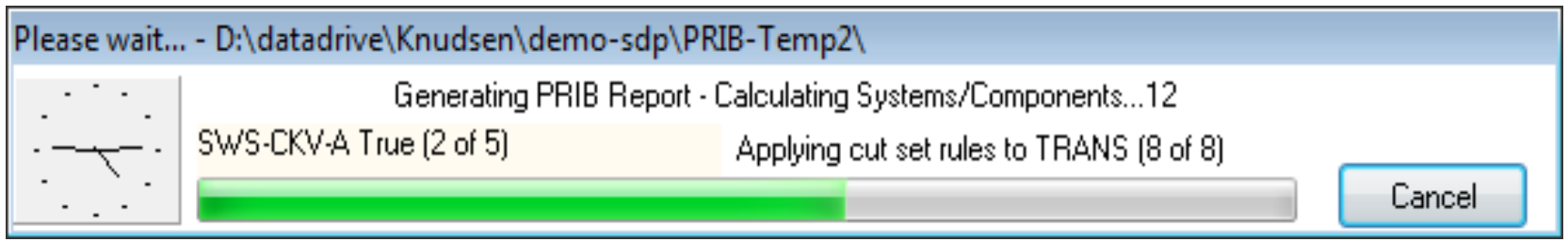
- Each SAPHIRE sandbox sub-instances is started with an assigned project sub-directory
- Each SAPHIRE sandbox sub-instance is running a macro (SAPHIRE defined command language)



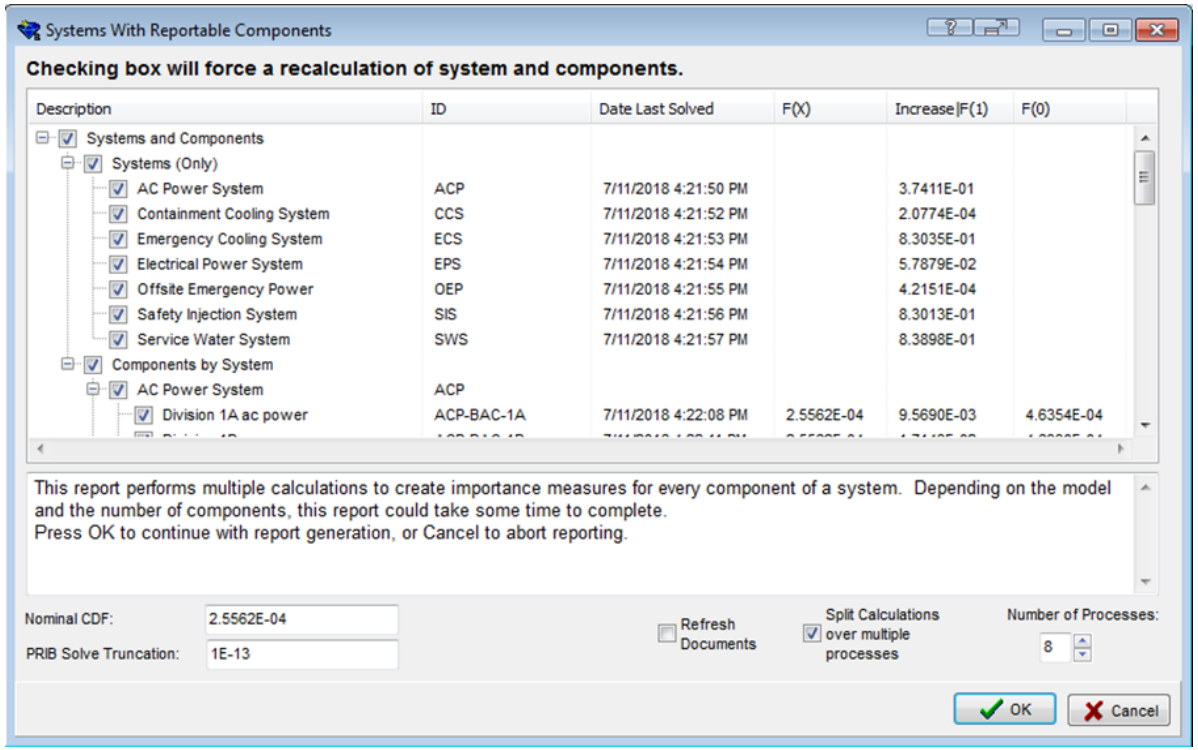
SAPHIRE – PRIB Process (Continued)

Each instance of SAPHIRE displays a status dialog.

- The caption displays the sandbox directory.
- Text just beneath the caption indicates the overall solve process and how many times this sandbox has been used.
- Text to the right of the clock shows the system/component type pair being processed along with the counter of which component it is of the total components for the system.
- Text to the right of the system/component pair name shows the state of the solve process.



SAPHIRE – PRIB Report Results



SAPHIRE - PRIB Report Timing Results

Sandbox Count	Setup Time (mm:ss)	Total Time (mm:ss)
1	0:02	14:00
2	0:08	7:20
3	0:11	4:50
4	0:14	3:30
5	0:18	3:02
6	0:21	2:51
7	0:24	2:53
8	0:29	3:13
12	0:43	3:42
16	1:00	4:10

- PRIB Report - Hand timed calculation times for various numbers of sandboxes

SAPHIRE – Conclusion and Future Work

Possible sandbox uses in the future:

- Sensitivity studies where each sandbox is assigned a change set
- Dividing a solve process for multiple event trees/sequences
- Performing uncertainty analysis for multiple event trees/sequences

This report was prepared as an account of work sponsored by an agency of the U.S. Government. Neither the U.S. Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use, or the results of such use, of any information, apparatus, product, or process disclosed in this report, or represents that its use by such third party would not infringe privately owned rights. The views expressed in this paper are not necessarily those of the U.S. Nuclear Regulatory Commission.

SAPHIRE – Credits

Core INL development team

- James Knudsen (project manager)
- Curtis Smith (technical advisor)
- Ted Wood (lead developer)
- Kellie Kvarfordt (developer)
- Steve Prescott (developer)

NRC

Jeffery Wood (current technical manager), Walter Leschek (current project manager), Erasmia Lois, Richard Robinson, Jr., Dale Rasmuson, Harold Vandermolen, Patrick O'Reilly, Dan O'Neal.

SAPHIRE – Credits (Continued)

INL

Kenneth D. Russell, Martin Sattison, John Schroeder, William Galyean, Scott Beck, Robert Buell, John Biersdorf, Michael Calley, Dana Kelly, Doug Zeek, Dan Jensen, Rae Nims, Dan Kurkowski, Charity Follett, Howard Stewart, Douglas Brownson, Dick Fowler, Tami Thatcher, Leon Wolfram, Kevin Quick, Dale Snider, Kurt Wagner, Robin Van Horn, Scott Matthews, Cory Atwood, Carol English, Nancy Skinner, Melinda Cebull, Wendell Richardson, and K.A. Branham-Haar.

INL
Idaho National Laboratory