

Software Platform Evaluation

Verifiable Fuel Cycle Simulation (VISION)
Model

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November 2005



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Acronyms

AFC	Advanced Fuel Cycle
AFCI	Advanced Fuel Cycle Initiative
ANL	Argonne National Laboratory
BCC	Base Construction Cost
CH	Contact Handled
COA	Code of Accounts
D&D	Decontamination and Decommissioning
DDS	Design description for software
DOE	U.S. Department of Energy
DYMOND	Dynamic Model of Nuclear Development
EMWG	Economic Modeling Working Group
FICA	Federal Insurance Contribution Act
FOAK	First-of-a-Kind
HLW	High-level Waste
IAEA	International Atomic Energy Agency
IDC	Interest During Construction
INEEL	Idaho National Engineering and Environmental Laboratory
INL	Idaho National Laboratory (formerly the INEEL)
LFR	Lead-Cooled Fast Reactor
LLW	Low-level Waste
LUEC	Levelized Unit of Electricity Cost
MRS	Monitored Retrievable Storage
MSR	Molten Salt Reactor
NOAK	Nth-Of-A-Kind
NRC	Nuclear Regulatory Commission
O & M	Operations and Maintenance
OCRWM	Office of Civilian Radioactive Waste Management
RAD	Rapid Application Development
R&D	Research and Development
RD&D	Research, Development, and Demonstration
RH	Remote Handled
RTM	Requirements traceability matrix
SNL	Sandia National Laboratory
SCMP	Software configuration management plan
SCWR	Supercritical-Water-Cooled Reactor
SFR	Sodium-Cooled-Fast Reactor
SMP	Software management plan
SNF	Spent Nuclear Fuel
SNL	Sandia National Lab
SPE	Software Platform Evaluation
SQAP	Software quality assurance plan
SRS	Software Requirements Specification
STP	Software test plan
SWU	Separative Work Unit
TCIC	Total Capital Investment Cost
TOC	Total Overnight Cost
TSLCC	Total System Life Cycle Cost
V&V	Verification and Validation
VHTR	Very-High Temperature Reactor
VISION	Verifiable Fuel Cycle Simulation Model
WBS	Work Breakdown Structure
WIT	What-It-Takes
WU	Weapons Useable

Introduction

The purpose of this Software Platform Evaluation (SPE) is to document the top-level evaluation of potential software platforms on which to construct a simulation model that satisfies the requirements for a Verifiable Fuel Cycle Simulation Model (VISION) of the Advanced Fuel Cycle (AFC). See the *Software Requirements Specification for Verifiable Fuel Cycle Simulation (VISION) Model* (INEEL/EXT-05-02643, Rev. 0) for a discussion of the objective and scope of the VISION model. VISION is intended to serve as a broad systems analysis and study tool applicable to work conducted as part of the AFCI (including costs estimates) and Generation IV reactor development studies. This document will serve as a guide for selecting the most appropriate software platform for VISION. This is a “living document” that will be modified over the course of the execution of this work.

This SPE compares three potential classes of software platforms for satisfying the requirements for a simulation model supporting the AFCI Program. Within each platform classification there are a variety of specific platforms that qualify for consideration. In order to expedite the process the number of platforms considered was limited to those that are currently supported by the modeling team. Supported means the software is available and that at least one member of the team has experience using that particular platform.

The model development will likely include the partnership of the Argonne National Laboratory (ANL), the Idaho National Laboratory (INL), Sandia National Laboratory (SNL), and Los Alamos National Laboratory (LANL). These four development partners along with the Department of Energy, Nuclear Energy (DOE-NE) and the Department of Energy, Radioactive Waste (DOE-RW) would be the primary customers for the model.

ANL has developed a preliminary model, Dynamic Model of Nuclear Development – US (DYMOND), that could be used as the initial platform from which to begin developing a more extensive and comprehensive model. ANL used Stella/Ithink for their development platform. Their choice was based on modeling criteria and resident expertise using Stella/Ithink.

The Idaho National Laboratory (INL) has reviewed the DYMOND model and is knowledgeable about the model’s structure and functionality and has added to the models functionality. With this in mind, the first thought is that Stella/Ithink would be the platform of choice. However, during the review and subsequent model development, some limitations of Stella/Ithink were readily apparent. Some of those limitations are 1) limited array structures; 2) limited data analysis tools; 3) cumbersome equation editor; 4) limited graphics tools and 5) limited model size. Some of these limitations could be worked around but the limited model size has restricted adding new features to the current model and therefore has expedited the need to move to a new platform. The purpose of this SPE is to compare the potential software platforms that could be used for developing VISION.

DYMOND was used to generate a range of output data for the Simulation, Evaluation, and Trade Study (SETS) working group FY05 Year End Report, *Fuel Cycle Scenario Definitions, Evaluation, and Trade-off*¹. In the process of generating those reports it quickly became evident that Stella/Ithink software would not support the next set of upgrades to the model. We reached the limit of the number of elements that Stella/Ithink could have in one model. VISION will have all the complexity of the current DYMOND model plus the economic data as well as other upgrades. Taking that into consideration, Stella/Ithink will not be able to support those new additions.

In addition to comparing the capabilities of software platforms other important considerations need to be included in the selection process. One consideration is that SNL has developed several dynamic system models on the nuclear fuel demand cycle. These models were developed using Powersim Studio. Leveraging off these fuel demand models would be advantageous. Therefore, linking in to these models as well as other models that could be identified in the future will be important. The ability to link to other models and data sets is an important criterion from which to judge the competency of development platforms.

It is important to emphasize what VISION is being tasked to do and evaluate the packages against that purpose. VISION is designed to help develop insights into the nuclear fuel cycle. What effects in terms of economics, long-term storage and electricity supply the combination and timing of reactors, recycling and storage have on the big picture. The model is not being designed to track individual fuel bundles through the system and understand process flow. The overall picture of process flow will be captured but not at a detailed discrete level.

This SPE will not make any decisions but simply outline the advantages and disadvantages of each of the platforms that are under consideration in order to support the selection of the modeling platform.

Definitions

It is important that some of the concepts that are being considered in this evaluation be defined.

Unlimited Flow – this concept means that the only capacity restriction is the number of reactors. Under this scheme all other resources are available when needed. There is enough uranium to fill the demand; there is plenty of reprocessing, etc.

Limited Flow – this concept means that throughput can be restricted by limitations in reprocessing capacity, uranium supply, etc.

Continuous Processing – this concept means that material flows through a facility in a continuous smooth process.

¹ Fuel Cycle Scenario Definition, Evaluation, and Trade-offs, INL/EXT-05-xxxxx, September 2005 (DRAFT).

Batch Processing – this concept means that while facilities are discrete, flow through these facilities are in batch modes. A batch enters the facility and after the designated process period the batch exits the facility.

Discrete Processing – this concept means that discrete packages are tracked throughout the flow series. A batch may consist of more than one package.

Object Oriented Programming – The idea behind object-oriented programming is that a computer program is composed of a collection of individual units, or *objects*, as opposed to a traditional view in which a program is a list of instructions to the computer. Each object is capable of receiving messages, processing data, and sending messages to other objects.

Feedback – the idea behind feedback is that a process causes a change the system that in turn causes a change to the original process.

Platform Classes/Specific Software Platforms Evaluated

Three classes of platforms were considered appropriate based on the requirements identified in the *Software Requirements Specification for Verifiable Fuel Cycle Simulation (VISION) Model* (INEEL/EXT-05-02643, Rev. 0). The three classes of platforms considered were: Programming Languages, Business Application, and Systems Simulation Models. Within each of the classes were several specific software platforms that were evaluated.

Programming Languages

The following were considered in this evaluation:

- FORTRAN
- C++
- C#
- Delphi
- Visual Basic

Programming languages contain a complete set of development tools for building Web applications, XML Web services, desktop applications, and mobile applications. The newest generation of software development languages such as, FORTRAN, C++, C#, Delphi and Visual Basic all use an integrated development environment (IDE), which allows them to quickly develop software applications. Although FORTRAN 95 was specifically evaluated in this SPE, any of the aforementioned programs could be substituted for FORTRAN 95 without radically changing the evaluation results. Specifically, these programming languages offer graphical user interfaces, object oriented programming, scientific libraries and comprehensive compilers. There are specific

differences between the various languages but those differences are narrowing as each advances with new versions.

Business Applications

The following business applications were considered in this evaluation:

- Microsoft Excel Spreadsheet
- Quattro Pro

This class of platforms is basically spreadsheet applications. Most spreadsheet software platforms such as Excel and Quattro Pro contain a large set of functions and analysis tools that can be used to analyze data. Data can be quickly entered either through special linking or manual data entry. Charts and graphs can be developed to assist in the data analysis. Although Excel was specifically evaluated in this SPE, Quattro Pro could be substituted for Excel without radically changing the evaluation results.

Systems Simulation Models:

The following simulation modeling software was considered in this evaluation:

- Stella/Ithink
- Vensim
- Studio 2005
- SimCad

System simulation software is used for developing, analyzing, and packaging dynamic non-linear feedback models. Models are usually constructed through a graphical interface or in a text editor. The models are typically built around a system of differential equations that track behavior of system elements through time.

Within each class there are many possibilities for individual software platforms than those listed above. Evaluation of every possible platform within the three classes is beyond the scope and funding of this evaluation. As a first screen, only software platforms on which members of the AFCI Economic Benefits and Systems Analysis Team had first hand experience or software platforms identified as possible interfaces or conversion (e.g. SimCad), were considered (see Table 1).

Platform	Office	Experience Level
FORTRAN	Idaho National Lab	Some
	Sandia National Lab	Some
	Argonne National Lab	Some
C++/C#	Idaho National Lab	Considerable
	Sandia National Lab	Considerable
	Argonne National Lab	Considerable
Delphi	Idaho National Lab	Considerable
	Sandia National Lab	None
	Argonne National Lab	None
Microsoft Excel Spreadsheet	Idaho National Lab	Considerable
	Sandia National Lab	Considerable

	Argonne National Lab	Considerable
Quattro Pro	Idaho National Lab	Considerable
	Sandia National Lab	Considerable
	Argonne National Lab	Considerable
Stella/Ithink	Idaho National Lab	Considerable
	Sandia National Lab	Some
	Argonne National Lab	Considerable
Vensim	Idaho National Lab	Considerable
	Sandia National Lab	Considerable
	Argonne National Lab	Some
Studio 2005	Idaho National Lab	Some
	Sandia National Lab	Considerable
	Argonne National Lab	None
SimCad	Idaho National Lab	None
	Sandia National Lab	None
	Argonne National Lab	None

Table 1. Partner Lab experience with software platform.

The six software platforms plus a hybrid system considered for detailed evaluation were:

1. Microsoft Excel Spreadsheet

Description: Excel is a well known and extensively used data analysis package. The programming package includes a wide variety of data analysis function and packages including statistical analysis routines and graphical output tools. In addition, there are a variety of add-on packages that make Excel a good tool for complex analysis.

Established Experience: General knowledge of using Excel is available at all the partner locations. However, using Excel to emulate a dynamic system has not been done at any site.

2. FORTRAN

Description: While FORTRAN is directly referenced this discussion could easily encompass any of the advanced rapid application development software packages currently available such as: Borland's Delphi, Microsoft's C#, C++ and Visual Basic. The advantages of a programming tool are that everything can be custom designed and developed. The new packages can be designed to run on a desktop system or as a web application. The disadvantage would be the time to program everything from scratch. In essence, using a programming language to develop a dynamic model would be to develop a Vensim or Powersim environment from scratch. It would be better to take advantage of the development that has already been done.

Established Experience: All three sites have experienced programmers although none are currently on the team.

3. Stella/Ithink

Description: Stella is a system dynamic's based development package that has been historically used by educators. Stella/Ithink has an extensive set of tools for developing a user interface, sometimes referred to as a cockpit. Stella is easy to learn and as such is the reason for its extensive use by educators in the classroom. It should be noted that ISEE Systems have designed their product to support small, easy to develop, quick learning models. They are particularly interested in the education side of the market. As such, they have designed Stella/Ithink for quick easy entrance into the modeling world. They have made the interface fun and easy to develop user interfaces.

However, this product lacks extensive model analysis tools, causal tracing, in depth units' analysis; it has limited array structures; a limited equation editor; and most importantly it has a limited model size. The modeling software is **not** designed for large complex system modeling but for small relatively simple systems. Many of the issues can be worked around but it would require longer development time to work around some of the limitations. It would also require longer time to verify and validate the model performance. **However, the model size limitation has made it essential that the model be ported to a new platform.**

Established Experience: The INL, ANL and SNL have extensive experience using Stella/Ithink. All three partners have used Stella/Ithink for other projects and have had good success.

(ISEE Systems, Inc. 46 Centerra Parkway, Suite 200, Lebanon, NH 03766. Phone: 603 643 9636. Toll Free: 800 987 6758. Fax: 603 643 9502. (URL: <http://www.iseesystems.com/index.aspx>). Current Version: 8.0)

4. Vensim

Description: Vensim is used for constructing models of business, scientific, environmental, and social systems. Vensim has an extensive set of analysis tools such as causal tracing, sensitivity analysis and optimization that make is a good choice for complex modeling. Ventana Systems market their product for businesses and research environments. Unlike Stella/Ithink, Vensim has a limited set of tools for building a user interface. Vensim has an extensive set of tools for analyzing model behavior, able to handle larger array structures, a highly advanced equation editor and a variety of tools for advance modeling. Vensim can also link to external functions developed through C, C# and Visual Basic.

Established Experience: The INL has extensive experience using Vensim for modeling. SNL has only recently begun to use Vensim but have already become proficient using the product. ANL has not used Vensim to date.

(Ventana Systems, Inc. 60 Jacob Gates Road, Harvard, MA 01451.
Phone: 508 651 0432. Fax: 508 650 5422 (URL:
<http://www.vensim.com>). Current Version: 5.4b)

5. **Powersim Studio 2005**

Description: Powersim Studio 2005, formerly called Powersim, has the characteristics of a combination of Stella/Ithink and Vensim. It includes an extensive set of user interface components and also an extensive set of model analysis tools. Powersim Studio has a steeper learning curve than either of the other System Dynamics software packages but also offers more usability. This usability and functionality comes at a cost: It is also more expensive than either of the other two packages.

Studio 2005 is trying to be the comprehensive system dynamic modeling software. Powersim Studio has both a powerful user interface (rival to Stella) and also a very comprehensive set of analysis tools. Powersim Studio 2005 is a very powerful system dynamic modeling program. The negative side is that the package is more expensive than Vensim and Stella/Ithink and a steeper learning curve (due to the more powerful and comprehensive set of tools) to become proficient using the software.

Powersim Studio also has the added ability to use Visual Basic script function to handle complex equations. The function allows you to write your own functions for specific tasks that are not covered by the available functions in Powersim Studio.

Established Experience: SNL is the only partner that has significant experience using the newer versions of Powersim Software. The INL has experience with some of the original versions of Powersim (Versions 1 and 2) but has not used the newer versions. ANL has no experience using any Powersim products.

(Powersim Solutions, Inc., 585 Grove Street, Suite 130, Herndon, VA 20170. Phone: 703 467 0910. Fax: 703 467 0912. (URL: <http://www.powersimsolutions.com/default.asp>). Current Version: Studio 2005)

6. **SimCad**

Description: SimCad is a discrete event simulation package that has been used by the Department of Energy, Radioactive Waste Department to track the waste packages from the reactor to long-term storage. This software package is able to model each component of the waste management system for each unique waste package. It is designed for tracking individual discrete items throughout the lifecycle process.

SimCad is notably a discrete event simulation modeling tool. It is a process modeling tool designed to model business and process systems. While SimCad designed to track flow of material through a system it is not, however, designed to

handle feedback control. The AFCI modeling project has some discrete elements but overall the project is centered on a continuous, non-linear feedback system. SimCad is not designed for this type of analysis but like other products listed here can be adapted to this type of analysis but it adds difficulty to using the product.

It should be noted that DYMOND as it currently stands is a process model. There is very little in terms of feedback control. But future versions of VISION are intended to have quite a variety of feedback in areas such as economics and constrictive flows. So as it is SimCad could do a good job of mimicking the processes currently modeled in DYMOND but would have difficulty with feedback control.

Established Experience: None of the three partners (INL, SNL, or ANL) have experience using SimCad. The INL has reviewed SimCad and evaluated its components against the project requirements but otherwise there is no experience with this product.

(CreateASoft, 1212 S.Naper Blvd Ste 119, Naperville,IL 60540. Phone: (630) 428 – 2850. Fax: (630) 357 – 2590 (URL: <http://www.createasoft.com>). Current Version: Simcad Pro 6.3)

7. **Vensim/Delphi hybrid**

Description: The last platform to examine is a cross between Vensim and a programming language. Vensim contains its own components for developing a user interface but it is limited and difficult to customize. However, to offset this shortcoming, Vensim does have all the components available to allow the program to be controlled through available *dynamic link library* (DLL) external functions. A DLL is a module that contains functions and data that can be used by another module, program or DLL. FORTRAN, Delphi or any of the other programming languages could be used to develop the user interface that would then use the DLL functionality to operate the Vensim model.

The INL has used this technique on a variety of projects and the outcome has been excellent. The user interface can be very powerful because of the tools available in the programming environment. The model is also very powerful because of the tools available in Vensim. Stella does not have the capability to be accessed and run through an external user interface while Powersim Studio has the capability but has a powerful enough user interface that it would exclude using this technique.

The down side of this option is that it takes considerable effort to develop and link a user interface with a programming language. Vensim has the components available to allow linking to a programming language but it still takes time. Any changes to the model that affect variable names require that the interface be changed to align with the model changes. Another minus is that this technique requires that someone be familiar with both the modeling environment as well as the programming language.

Established Experience: The INL has extensive experience combining Vensim models with a program interface. None of the other two partners has experience in this area.

The software platform capabilities are summarized in Table 2.

Task	Excel	FORTRAN	Stella	Vensim	Studio 2005	SimCad
Cost	\$229.00 as new license	\$500.00 to \$1,400.00	\$1900.00 \$1200.00 for GUI Software	Versions: 1) Professional \$1,200 2) DSS \$2,000	Versions: 1) Expert \$2,550 2) Executive \$6,800	Simcad Pro- Lean \$1,995.00
Free Reader	No	Yes	No (~\$100)	Yes	Yes	No
Causal Tracing	No	No	No	Good	Fair	No
Units Checking	No	No	Fair	Good	Good	No
User Interface	Visual Basic	Yes	Good	Fair	Excellent	Yes
Ease of Model Development	Difficult	Difficult	Good	Good	Excellent	Okay
Exchange Data with Excel	N/A	Yes	Good	Fair	Excellent	Yes
Model Sheets ²	Yes	Yes	No	Yes	Yes	No
DLL Configuration ³	No	Yes	No	Yes	No	Yes
Arrays	Yes (2-D only)	Yes	Yes (2-D only)	Yes	Yes	Yes
Interactive Graphs ⁴	Yes	Yes	Yes	No	Yes	Yes
Model Calibration	No	No	No	Yes	Yes	No
Sensitivity Analysis	Yes (Not a standard utility and requires additional programming)	Yes (Not a standard utility and requires additional programming)	Yes	Yes	Yes	No
Optimization	Yes (Not a standard utility and requires additional programming)	Yes (Not a standard utility and requires additional programming)	No	Yes	Yes	No
Causal Loop	No	No	No	Yes	Yes	No

² Model Sheets are separate worksheets that can contain one particular section of the model. It makes viewing and printing a model much simpler.

³ DLL – Dynamic Link Library, is a module that contains functions and data that can be used by another module, program or DLL. It allows other programs to access and control the simulation model.

⁴ Interactive graphs allow the user to click in a chart and read the data at different points along the axis.

Task	Excel	FORTRAN	Stella	Vensim	Studio 2005	SimCad
Diagrams						
Variable Analysis ⁵	No	No	Fair	Good	Fair	Yes
Built-in Reality Checks ⁶	No	No	No	Yes	No	No
Customer Support	Self help	Self help	Normal Business Hours	Normal Business Hours	Normal Business Hours	Normal Business Hours

Table 2. Miscellaneous platform considerations.

⁵ Variable analysis refers to the ability to trace a variable and view the results in a chart and/or table.

⁶ Reality checks are checks that can be built into a model that will check that certain limits are not exceeded when the model runs. The checks are established as the model is being developed so when the model is changed the model meets the reality checks established.

Evaluation Process

Each platform's capabilities were compared to each of the VISION requirements specified in the *Software Requirements Specification for Verifiable Fuel Cycle Simulation (VISION) Model* (INEEL/EXT-05-02643, Rev. 0). Each platform was placed in one of three levels of support for each requirement:

1. Supports: The platform supports the requirement without modification.
2. Supports with Mods: The platform supports the requirement with some modification. (modifications include extensive programming, linking with additional software or models, etc.)
3. Does Not Support: The platform will not support the requirement even with modifications.

Evaluations were reviewed by the entire AFCI Economic Benefits and Systems Analysis Team.

Evaluation Results

There are a total of 45 required, 27 desired and 8 optional specifications that each platform was evaluated against. Figure 1 shows the number of specifications supported by a software platform without any modifications needed to the platform. Figure 2 shows the number of specifications supported by a platform if modifications are made to the platform. Individual specifications/platform results can be found in Appendix B of this document.

Stella/Ithink meets 39 of the 45 required elements but does not support multidimensional arrays (>2D) and also does not let you save data results except by a cumbersome process of saving the program under a different name or using windows copy feature to copy data to a spreadsheet. Vensim meets 43 of the 45 required elements but does not meet the requirement for a good user interface. Studio 2005 is the only package that meets all 45 of the required elements.

The programming languages were found to support all of the requirements but would require extensive programming that would in essence require building a platform similar to the simulation programs in order to support all the required features. In other words, anything is possible with a programming language given enough time and resources. In actuality, all the simulation packages are written in a programming language therefore, using one of them is in essence short cutting the development time.

The cost of using a particular platform is dependent on how many licenses and how much training is needed. It was assumed that each partner Lab would require one copy of the advanced version of a platform for the lead developer and two copies of the next advanced version for assistant developers. The general users would use free readers (if available) or minimal versions needed to run the model. The availability of platform versions and other miscellaneous cost considerations can be found in Table 3.

To fairly assess each platform, an estimate was made of the time to develop, verify and validate (V&V) a known application as if the application were being developed for the first time. The DYMOND model was used for this comparison. The time estimated to develop DYMOND for the first time using each of the software platforms is shown in Table 4.

The overall cost of using a platform and developing the VISION model in that platform can be found in Table 5.

In general, a dynamic simulation software package needs to be assessed according to⁷

- its basis in fundamental system dynamics theory;
- the ease with which it can be used;
- the support it gives to model building;
- the extent to which models can be documented and explained to a customer;
- the facilities it has for debugging a model;
- the ease of making experiments and producing output;
- the scope of its facilities for policy design.

The three system dynamics packages under evaluation are based on fundamental system dynamics theory. Many of the parameters considered in this evaluation could be viewed as subjective based on experience and preferences of the developer.

In consideration of the subjective nature of such an evaluation, a quick survey was distributed to seven modelers at SNL and INL who have experience in at least 2 of the 3 packages. In a pair wise format (e.g. Vensim vs. Stella, Vensim vs. Studio 2005, and Stella vs. Studio 2005) the developers were asked to rate if the first platform of a pair would take more-, same-, less-time to develop a model; more-, same-, less-time to verify and validate a model; and good/same/not-as-good for development of a user interface. If a respondent did not have experience with a particular package they refrained from comparing that package against the other two.

The survey results (see Table 6) suggest that development time is basically the same for the three packages. Not surprising, the bias seems to be toward the software that developer has the most experience using. Verification and validation definitely show that Studio 2005 and Vensim are superior to Stella/Ithink but not much discrimination between Studio 2005 and Vensim. For development of a “User Interface”, Vensim was viewed as the weakest package followed by Stella/Ithink and leading this category was Studio 2005.

Task	Powersim	SimCad	FORTTRAN
Unlimited Flow	Yes	Yes	Yes
Limited Flow	Yes	Yes	Yes
Batch Flow	Yes	Yes	Yes

⁷ Coyle, R.G.; “System Dynamics Modelling – A practical approach”, Chapman & Hall/CRC; Book&Disk edition, May 1, 1996;

Discrete Tracking	No	Yes	Yes
Feedback Control	Yes	No	Yes
Object Oriented	No	No	Yes

Note: Object Oriented is a programming feature. Although objects can be defined and reused it is necessary to develop the objects first.

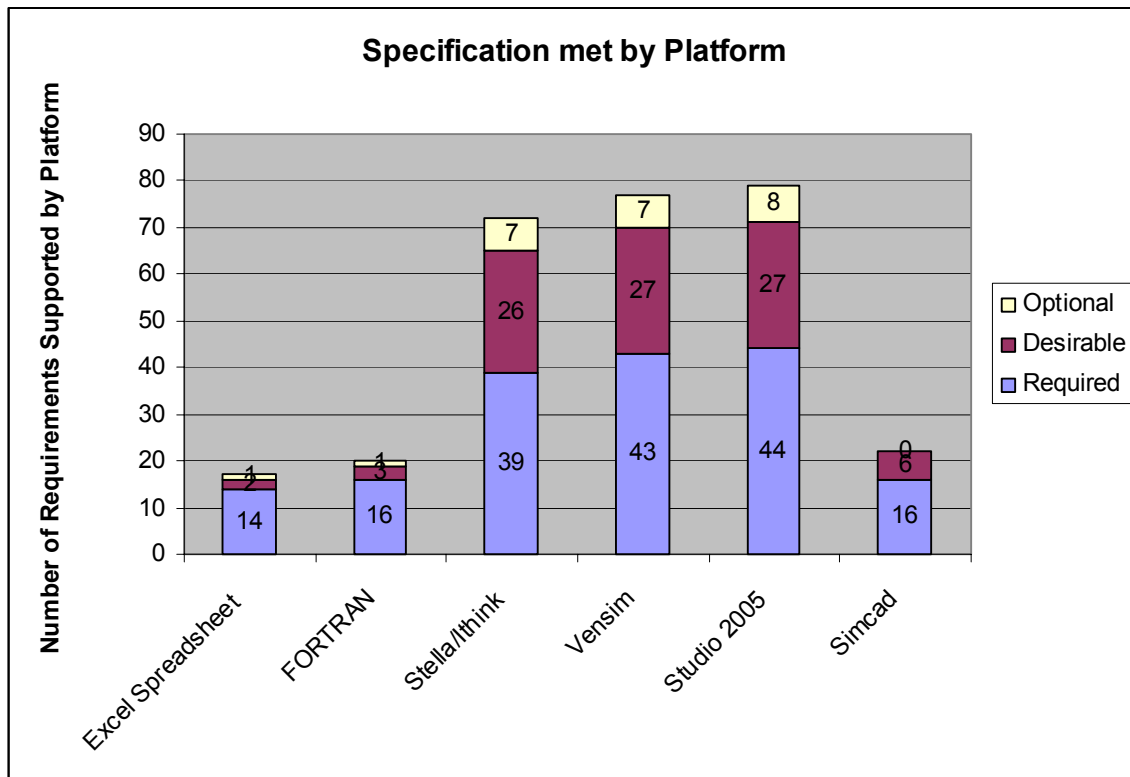


Figure 1. Number of specifications supported by a platform without platform modification.

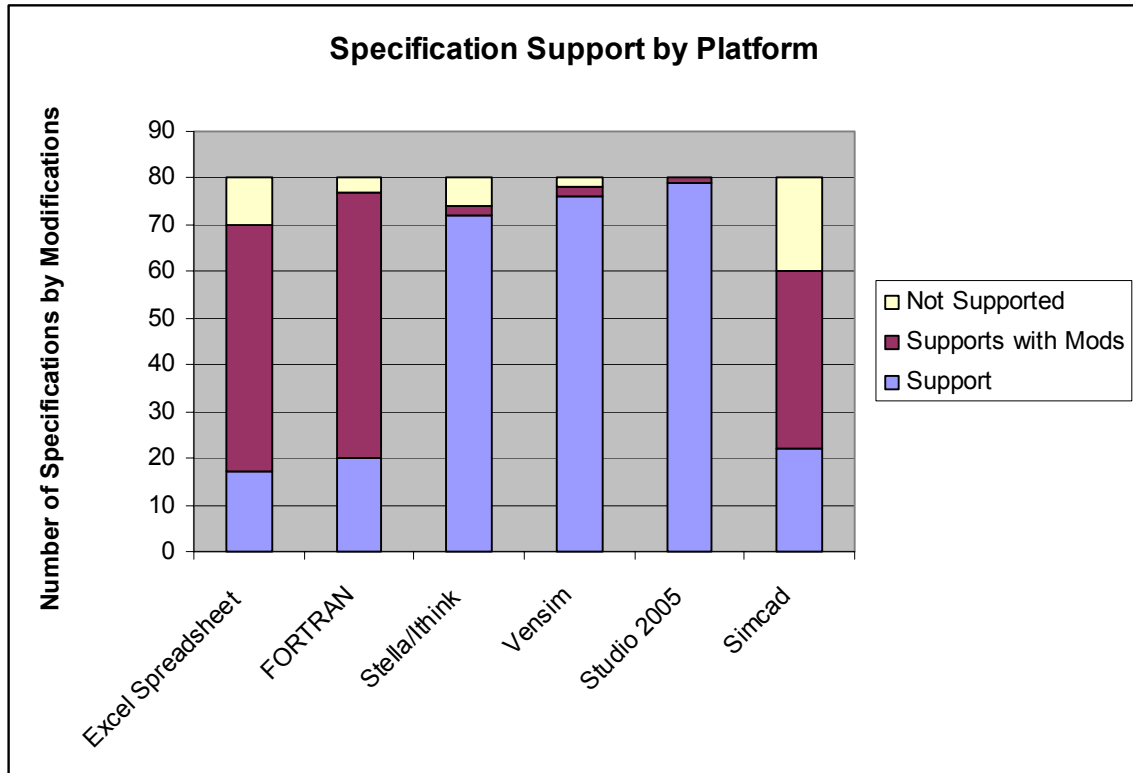


Figure 2. Number of specifications supported without and with a platform modification.

	Developer Licenses			Graphical User Interface			User Licenses (free reader or basic version)		Basic Training	Unlimited live Tech support
	Type	\$/license	# Needed for partner Labs	\$/GUI license	# Needed for partner Labs		\$/license	# Needed in the DOE complex		
Excel Spreadsheet	Lead		0	0	0				As available	Unavailable
	Assistant		0	0	0					
Programming Languages⁸	Lead	~\$1,000	0	0	0		0	0	As available	NA
	Assistant	~\$1,000	0	0	0					
Stella/Ithink	Lead	\$1,900	0	0	0		\$100	8 ⁹	3 days @\$1200 (3rd party training)	\$300
	Assistant	\$1,900	4	0	0					
Vensim¹⁰	Lead	\$2,000	1	\$1,200	2		\$0	1	2 days @\$1000	\$300
	Assistant	\$1,200	5	0	0					
Studio 2005¹¹	Lead	\$6,800	0	0	0		\$0	3	2 days @\$1000	\$500
	Assistant	\$2,550	6	0	0					
Simcad	Lead	\$2,000	3	0	0		\$2,000	15	Special pricing per request	\$500
	Assistant	\$2,000	6	0	0					

Table 3. Software platform cost factors.

⁸ The approximate cost per license depends on the product but most packages are around \$1000 per license.

⁹ Developer licenses at a Lab above the three needed for the developers are assumed to be available for users. This assumption will reduce the number of user licenses needed across the complex for this platform.

¹⁰ Developers would need the DSS version (1 per lab) the remainder could use the Professional version.

¹¹ Developers would need the Enterprise version (2 per Complex) the remainder could use the Expert version.

Software Platform	Work Effort Time (weeks)		
	Model Development	Verification and Validation	Documentation
Excel Spreadsheet	30	10	4
Programming Languages	25	8	4
Stella/Ithink	15 ¹²	8	4
Vensim	20 ¹³	4	4
Studio 2005	20 ¹⁴	4	4
Simcad	30	6	4

Table 4. Time to Develop the DYMOND Model

¹² Future development only
¹³ Porting Stella model and future development
¹⁴ Porting Stella model and future development

	Stella/ Ithink	Vensim	Studio 2005
Cost to provide developers licenses to each Lab	\$0	\$2,000	\$0
Cost to bring complex to 15 user licenses	\$800	\$6,000	\$16,800
Annual Tech Support for 9 licenses	\$2,700	\$2,700	\$4,500
Materials Cost Sub Total	\$3,500	\$10,700	\$21,300
Labor Costs			
Model Development ¹⁵	\$60,000	\$80,000	\$80,000
Model Verification and Validation	\$32,000	\$16,000	\$16,000
Documentation	\$16,000	\$16,000	\$16,000
Labor Cost Sub Total	\$108,000	\$112,000	\$112,000
TOTAL	\$111,500	\$122,700	\$133,300

Table 5. Cost to equip the DOE complex for a software platform and develop¹⁶ the VISION model in that platform.

¹⁵ Labor costs are based on \$4,000 per week.

¹⁶ Development costs for the Stella/Ithink software platform is for adding additional specifications from the VISION SRS not currently found in the DYMOND model. Development costs for all other platforms are for development of a new model with all specifications found in the VISION SRS.

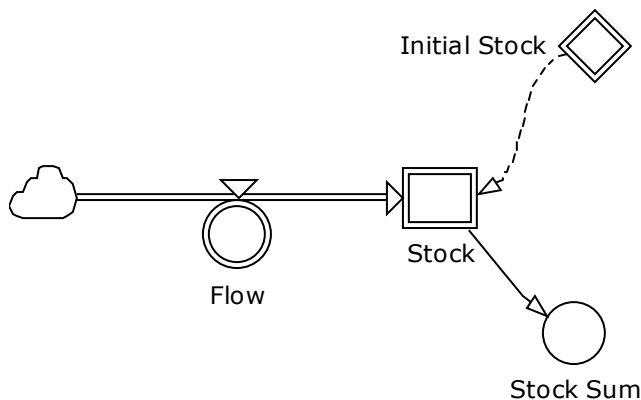
Reviewer						
	One	Two	Three	Four	Five	Six
						Seven
Experience						
Stella	Some	None	Some	None	Some	Some
Vensim	Lots	Some	None	Lots	Some	Lots
Studio 2005	Lots	Lots	Lots	Lots	Some	None
						Some
Development Time						
Vensim vs Stella	Less	NA	NA	NA	More	Same
Vensim vs Studio 2005	Same	Same	NA	Same	More	Less
Stella vs Studio 2005	More	NA	Less	NA	Same	Less
Verification & Validation Time						
Vensim vs Stella	Less	NA	NA	NA	Less	Less
Vensim vs Studio 2005	Same	More	NA	Less	Less	Same
Stella vs Studio 2005	More	NA	More	NA	Same	More
Ease of Developing a User Interface						
Vensim vs Stella	Not as good	NA	NA	NA	Not as good	Not as good
Vensim vs Studio 2005	Not as good	Not as good	NA	Not as good	Not as good	Not as good
Stella vs Studio 2005	Same	NA	Not as good	NA	Not as good	Not as good

Table 6. Reviewers comparison of the first software platform vs. the second software platform for development time, V&V time and User Interface.

Array Limitation and Performance between Software Platforms

To evaluate each platform against array limitations a simple model was built in each of the 3 software platforms. The array sizes used were from Steve's list of current array sizes for the different array elements identified so far. Isotopes 60 elements, Reactor type 6 elements, Reactor Zone 4 elements, Recycle Pass 5 elements, Chemical Form (Fuel Type) 8 elements, and Region 6 elements.

Model



Initial Stock Values: 0

Flow is 1 per time step into each array element.

Time : 2000 to 2100 with a time step of 0.25 years.

Performance:

Array Size	Powersim	Vensim	Stella
1..60	1 seconds	1 second	1 second
1..60, 1..6	1 seconds	1 second	2 seconds
1..60, 1..6, 1..4	1 second	6 seconds	NA
1..60, 1..6, 1..4, 1..5	2 seconds	Error	NA
1..60, 1..6, 1..4, 1..5, 1..8	4 seconds	Error	NA
1..60, 1..6, 1..4, 1..5, 1..8, 1..8	25 seconds	Error	NA

Results: Vensim states that the software can handle 11 columns which it can but it is very limited in the number of total elements it can handle. Powersim was the only one of the three software packages that could handle a large 6 element array structure.

Performance becomes a big issue if the arrays become very big so we need to plan to stay with as few of array elements as possible.

Powersim has the most powerful and easy equation editor for working with array structures. Stella's editor is awkward and Vensim's is not much better.

Conclusions

There were six specific software platforms, within three platform classes, plus a hybrid system that were evaluated against the criteria for the broad systems model. In actuality, any of the software platforms could be used to develop some type of analysis tool. The software platform evaluation is trying to establish which tool or combination of tools would accomplish the goals in the most complete, timely and cost effective manner.

The overall analysis, evaluating software platforms against criteria, suggests that the most appropriate type of platform would be the System Simulation Software platform. The top three software platforms scored against the program criteria were Powersim Studio, Vensim and Stella/Ithink. This seems reasonable since these software programs were designed to support the analysis of complex systems and model their behavior over time which is the basis for the broad system study for AFCI.

Satisfying the requirements outlined in the specification document was only one criterion that should be used to judge the qualifications of the modeling platform. Other criteria should be considered when deciding on the appropriate software platform such as, cost of the software, development time and experience using the platform. In addition to scoring highest against the program criteria, the partners involved in the model development have extensive knowledge in developing System Dynamic models using each of the three selected modeling software platforms. Key considerations for the three systems simulation platforms are summarized in Table 7.

The class of platform is the first selection filter to consider in the platform evaluation. If the platform class selected is the System Simulation platform, the next filter requires the selection of the particular software platform from that class, in other words, selecting Powersim Studio, Vensim or Stella/Ithink. This becomes much more difficult since the software platforms have been developed to basically satisfy the same needs. This is where experience, cost and overall program support becomes important. Which software program will be the most versatile and cost effective package from which to develop the model?

The three program partners have extensive knowledge in using the system dynamics software packages but each has expertise in the different packages. SNL has extensive knowledge of Powersim Studio, ANL has used Stella/Ithink extensively and the INL has used Stella/Ithink and also Vensim extensively but not much with Powersim Studio.

Key Consideration		Software Platform		
		Stella/Ithink	Vensim	Studio 2005
Lab Experience	INL SNL ANL	Considerable Some Considerable	Considerable Considerable Some	Some Considerable None
Requirements not supported by a platform or needing platform modification to support		4.4 Input interface 4.23 Save Input Files	4.1 Graphical User Interface	All supported
Percent of required specifications (34) by level of difficulty to implement		53% Easy 41% Moderate 6% Difficult	53% Easy 44% Moderate 3% Difficult	62% Easy 38% Moderate 0% Difficult
Total Equipment cost		\$3,500	\$9,500	\$22,500
Total Labor Cost		\$108,000	\$112,000	\$112,000
Interface tools needed		None Needed	Graphical User Interface	None Needed
Other factors				
High end tools (Sensitivity analysis, optimization, units checking, etc)		Low	High	High
Development Tools (Multi-dimensional arrays, equation editor, etc.)		Low	High	High
Model Expansion Capability over DYMOND		Low	High	High

Table 7. Key considerations for platform selection from the three systems simulation platforms.

The selection criteria favor Powersim Studio; however, other factors could affect the decision. Powersim Studio offers a relatively complete, powerful modeling platform but is more expensive and has a steeper learning curve for model developers. The preliminary model, DYMOND, was developed in Stella/Ithink so there would be no need to translate the model into another platform but Stella/Ithink lacks the powerful modeling tools of Vensim and Powersim Studio and lacks the ability to add much more capability to the current version of DYMOND. Vensim offers a powerful modeling environment at a cost per package less than Powersim Studio but would require a user interface be developed in a programming language such as C# or Delphi. The final decision should weigh each of these factors, satisfying selection criteria, learning curve, interface tools and cost, to determine which package would satisfy the overall program needs.

Reference Documents

AFCI Economic Benefits and Systems Analysis Team. January 2005. *Software Requirements Specification for the Verifiable Fuel Cycle Simulation (VISION) Model*. Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho 83415. INEEL/EXT-05-02643, Rev. 0

Coyle, R. G. May 1996. *System Dynamics Modelling – A Practical Approach*, Chapman and Hall;

Shropshire, D.E., K.A. Williams, W.B. Boore, J.D. Smith, B.W. Dixon, M. Dunzik-Gougar, R.D. Adams. 2004. *2004 Advanced Fuel Cycle Cost Basis*. Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho 83415. INEEL/EXT-04-02282 Draft.

Appendix A. Detailed Evaluation of Software Platforms against Requirements

Requirement		Excel Spreadsheet			FORTRAN			Stella/Ithink			Vensim			Studio 2005			Simcad			Comments							
No.	Name	Priority	Supports	Supports with Mols	Does Not Support	Comments	Supports	Supports with Mols	Does Not Support	Comments	Supports	Supports with Mols	Does Not Support	Comments	Supports	Supports with Mols	Does Not Support										
	Total Required		6	24	4		10	21	3		32	1	1	0		33	1	0		34	0	0		8	15	11	
1.1	Track Mass Inventories	1	1	1		Very Difficult - Excel is not designed to track flows. There may be some add-on package that could support this requirement		1			1				Tracking inventories is easy with SD Software	1				1				1			Simple but tracks at discrete level – too much detail
1.2	Track Isotopes Mass Inventories	1	1	1		Very Difficult - Excel is not designed to track flows. There may be some add-on package that could support this requirement		1			1				Tracking inventories is easy with SD Software	1				1				1			Simple but tracks at discrete level – too much detail
1.3	SNF composition	1	1	1		This will be very difficult to accomplish with Excel		1			1				This is simple at the elemental level but will require complex arrays to track at the isotopic level					1				1			Not trivial but can be accomplished
1.4	U Needed	1	1	1		This will be very difficult to accomplish with Excel		1			1				Relatively simple to implement	1				1				1			Difficult but can be implemented
1.6	Transportation Volume	2	1			Excel can support this but will require extensive coding	1				1				Simple to implement	1				1				1			Simple but tracks at discrete level – too much detail
1.7	Number Of Shipments	2	1			Excel can support this but will require extensive coding	1				1				Simple to implement	1				1				1			Simple to implement
1.8	Energy Efficiency Factor	1	1	1		This can be done with Excel but will require some coding		1			1				Easy to implement once all the elements needed for the calculation	1				1				1			Difficult but can be implemented

Requirement		Excel Spreadsheet			FORTRAN			Stella/Ithink			Vensim			Studio 2005			Simcad		
No.	Name	Priority	Supports	Supports with Mols	Does Not Support	Comments	Supports	Supports with Mols	Does Not Support	Comments	Supports	Supports with Mols	Does Not Support	Supports	Supports with Mols	Does Not Support	Comments	Supports	Comments
1.9	Radioactivity Index Of SNF/HLW	1		1		This can be done with Excel but will require some coding		1		are in the model	1			1			are in the model		
1.10	Radioactive Decay	2			1	This would be extremely difficult		1		Difficult but can be programmed	1			1			Difficult but can be programmed		Difficult but can be implemented
1.11	Heat Load	1	1			This would be extremely difficult		1		Difficult but can be programmed	1			1			Difficult but can be programmed		Difficult but can be implemented
2.1	Facility Ownership Cost	2		1		Excel can support this but will require extensive coding		1		Relatively easy to program	1			1			Simple to implement and does not require new structure	1	Can be implemented
2.2	AFCI Cost Modules	1		1		Excel can support this but will require extensive coding		1		Relatively easy to program	1			1			Simple to implement but requires new structure	1	Not easily supported
2.3	Total Costs	1		1		Excel can support this but will require extensive coding		1		Relatively easy to program	1			1			Simple to implement but requires new structure	1	Not easily supported
2.4	Separation Cost	3		1		Excel can support this but will require extensive coding		1		Relatively easy to program	1			1			Simple to implement and does not require new structure	1	Easy to implement
2.5	Fuel Fabrication Cost	3		1		Excel can support this but will require extensive coding		1		Relatively easy to program	1			1			Simple to implement but requires new structure	1	Not directly supported but can be accomplished
2.6	Front-end Fuel Cycle Supply and Demand	3		1		Excel can support this but will require extensive coding		1		Relatively easy to program	1			1			Simple to implement does not require new structure	1	Not directly supported but can be accomplished
2.7	Back-end Fuel Cycle	3		1		Excel can support this but will require extensive coding		1		Relatively easy to program	1			1			Simple to implement does not require new structure	1	Not directly supported but can be accomplished
2.8	Facility Conversion Costs	3		1		Excel can support this but will require extensive coding		1		Relatively easy to program	1			1			Simple to implement does not require new structure	1	Not directly supported but can be accomplished

Requirement		Excel Spreadsheet			FORTRAN			Stella/Ithink			Vensim			Studio 2005			Simcad		
No.	Name	Priority	Supports	Supports with Mlods	Does Not Support	Comments	Supports	Supports with Mlods	Does Not Support	Comments	Supports	Supports with Mlods	Does Not Support	Comments	Supports	Supports with Mlods	Does Not Support	Comments	
2.9	Manual Cost Overrides	2	1			Excel can support this but will require extensive coding	1	1		Relatively easy to program	1			Simple to implement but requires new structure	1	1		Simple to implement does not require new structure	
2.10	Cost Uncertainty	2	1			Excel can support this but will require extensive coding	1	1	1	Not Supported	1			Can be implemented	1		1	Can be implemented	
2.11	Case Cost Comparability	1	1			Excel can support this but will require extensive coding	1	1		Simple to implement	1			Can be implemented	1		1	Can be implemented	
2.12	Fuel Cycle Economic Analysis	1	1			Excel can support this but will require extensive coding	1	1		Supported	1	1		Can be implemented	1			Can be implemented	
3.1	Alternative Comparison	1	1			This will require that the user save the data from each run and then manually compare the results.	1	1		Simple to implement	1			Simple to implement	1			simple to implement	
3.2	Sensitivity	3	1			This can be done with Excel but will require some coding	1	1		Supported but limited	1			Very powerful	1			Very powerful	
3.3	Optimize A Scenario	3	1			This can be done with Excel but will require some coding	1	1	1	Not Supported	1			Very powerful	1			Very powerful	
3.4	Reactor Construction	1	1			This can be done with Excel but will require some coding	1	1		Relatively simple to implement	1			Relatively simple to implement	1			Relatively simple to implement	
3.5	Reactor Number And Mix	1	1			Not difficult but will require extensive programming	1	1		Relatively simple to implement	1			Relatively simple to implement	1			Relatively simple to implement	
3.6	Separation and Fuel Fabrication Capacity	1	1			Not difficult but will require extensive programming	1	1		Relatively simple to implement	1			Relatively simple to implement	1			Relatively simple to implement	
3.7	Data Confidence Intervals	2	1			Supported	1	1		Yes	1			Yes	1			Yes	
																1		Not directly supported but can be accomplished	

Requirement		Excel Spreadsheet			FORTRAN			Stella/Ithink			Vensim			Studio 2005			Simcad		
No.	Name	Priority	Supports	Supports with Mols	Does Not Support	Comments	Supports	Supports with Mols	Does Not Support	Comments	Supports	Supports with Mols	Does Not Support	Supports	Supports with Mols	Does Not Support	Comments	Supports	Comments
3.8	Reactor Construction based on Burnup	2	1			Excel can support this but will require extensive coding	1			Relatively easy to program	1			Yes	1		Yes	1	Not directly supported but can be accomplished
3.9	Reactor Number and Mix based on Burnup	2	1			Not directly supported but can be accomplished	1			Relatively easy to program	1			Yes	1		Yes	1	Not directly supported but can be accomplished
3.10	Dynamically create and reprocessing capacity	2	1			Not directly supported but can be accomplished	1			Relatively easy to program	1			Yes	1		Yes	1	Not directly supported but can be accomplished
4.1	Graphical User Interface	3	1			Excel supports some simple controls but very limited	1			Easy to design and implement				Limited user interface tools	1		Very extensive and sophisticated interface tools		Limited user interface tools
4.2	Default Values	1	1			Easy to implement	1			Easy to implement	1			Very easy to implement	1		Very easy to implement	1	Very easy to implement
4.3	Multi-dimensional Arrays	1	1			2-dimensional only	1			Not difficult but will require extensive programming	1			Limited	1		Supports unlimited array structures	1	Not supported
4.4	Input interface	1	1			Using Visual Basic			1	Supports a GUI interface and program level control but can't do input decks but can interface with Excel files	1			Supports a GUI interface, data from files and program level control			Supports a GUI interface, data from files and program level control	1	Not supported
4.5	Select Inappropriate Input Warnings	2	1			Not directly supported but can be accomplished	1			Relatively easy to program	1			Yes	1		Yes	1	Not directly supported but can be accomplished
4.6	Reactor Mixes	1	1			This can be done with Excel but will require some coding	1			Not difficult but will require extensive programming	1			Easy to implement	1		Easy to implement	1	Not supported
4.8	Fuel "Types" and burn-up	1	1			This can be done with Excel but will require some complex coding	1			Not difficult but will require extensive programming	1			Easy to implement	1		Easy to implement	1	Not supported
4.9	Burn up Rates	2	1			Excel can support this but will require extensive coding	1			Relatively easy to program	1			Yes	1		Yes	1	Not directly supported but can be accomplished

Requirement		Excel Spreadsheet			FORTRAN			Stella/Ithink			Vensim			Studio 2005			Simcad		
No.	Name	Priority	Supports	Supports with Mols	Does Not Support	Comments	Supports	Supports with Mols	Does Not Support	Comments	Supports	Supports with Mols	Does Not Support	Comments	Supports	Supports with Mols	Does Not Support	Comments	
4.10	Reprocessing Throughput	1	1			This can be done with Excel but will require some extensive coding	1			Can be implemented	1			Can be implemented	1			Can be implemented	
4.11	The Size/Throughput Rates	2	1			Excel can support this but will require extensive coding	1			Simple to implement but requires new structure	1			Simple to implement but requires new structure	1			Simple to implement	
4.12	Modes Of Operation	1		1		Not Supported	1			Moderate	1			Moderate	1			Moderate	
4.13	Location Scenarios	2		1		Excel can support this but will require extensive coding	1			This could be difficult to implement	1			This could be difficult to implement	1			This could be difficult to implement	
4.14	Modes Of Transportation	2		1		Excel can support this but will require extensive coding	1			Simple to implement	1			Simple to implement	1			Simple to implement	
4.15	Energy Outlook	1		1		This can be done with Excel but will require some complex coding	1			Can be implemented	1			Can be implemented	1			Can be implemented	
4.16	Timing And Sequencing	1		1		This can be done with Excel but will require some coding	1			Can be implemented	1			Can be implemented	1			Can be implemented	
4.17	Select Input Materials Streams	1		1		This can be done with Excel but will require some complex coding	1			Can be implemented	1			Can be implemented	1			Can be implemented	
4.18	Select For Recycled Streams	1		1		This can be done with Excel but will require some coding	1			Can be implemented	1			Can be implemented	1			Can be implemented	
4.19	Loading And Fuel Management Scheme	1		1		This can be done with Excel but will require some coding	1			Can be implemented	1			Can be implemented	1			Can be implemented	

Requirement			Excel Spreadsheet			FORTRAN			Stella/Ithink			Vensim			Studio 2005			Simcad							
No.	Name	Priority	Supports	Supports with Mlods	Does Not Support	Comments	Supports	Supports with Mlods	Does Not Support	Comments	Supports	Supports with Mlods	Does Not Support	Comments	Supports	Supports with Mlods	Does Not Support	Comments							
4.21	Interest Rate	2		1		Excel can support this but will require extensive coding		1		Easy to program	1		Easy to implement	1		Easy to implement	1		Easy to implement	1		Supports	Supports with Mlods	Does Not Support	Comments
4.22	Objective Function	2		1		Excel can support this but will require extensive coding		1		This could be programmed but will be difficult	1		Not Supported	1		Part of the power of Vensim	1		Part of the power of Powersim Studio	1					This will be very difficult to implement
4.23	Save Input Files	1		1		This can be done with Excel but will require some complex coding		1		Easy to implement	1		Not Supported, you have to save each model each time.	1		Relatively simple task	1		Simple task	1					Not supported
4.24	Graphical Output	1	1			Excel has excellent graphical output		1		Relatively easy to program	1		Offers a limited set of output capabilities	1		Supports a vast amount of output types	1		Supports a vast amount of output types	1					Limited amount of output tools
4.25	Select Outputs	1	1			Excel has excellent selection capability for output		1		Relatively easy to program	1		Offers either table or chart outputs	1		Offers a relatively good selection of output tools	1		Supports a vast amount of output types	1					Limited amount of output tools
4.26	Flag Extreme Conditions	3		1		Excel can support this but will require extensive coding		1		Easy to program	1		Limited but can be done	1		Limited but can be done	1		Easy to implement	1					Not supported
4.27	Drill Down Capability	2		1	1	Not Supported		1		Not Supported	1		Yes	1		Yes	1		Yes	1					Not Supported
4.28	Time Step Capability	2		1		Not Supported		1		Easy to Program	1		Yes	1		Yes	1		Yes	1					Supported
4.29	Save Output Files	2		1		Easy to implement		1		Easy to program		1	Not Supported, you have to save the model each time.	1		Easy to implement	1		Easy to implement	1					Easy to implement
4.30	Internal Consistency Checks	2		1		Not Supported		1		Easy to program			This can be done in a limited fashion			Not Supported	1		Easy to implement						Not supported
4.32	Fuel Blending	3				Not Supported		1		Easy to program	1		Easy to implement	1		Easy to implement	1		Easy to implement	1					Not supported

Requirement		Excel Spreadsheet			FORTRAN			Stella/Ithink			Vensim			Studio 2005			Simcad			Comments					
No.	Name	Priority	Supports	Does Not Support	Comments	Supports	Does Not Support	Supports with Mtds	Does Not Support	Comments	Supports	Does Not Support	Supports with Mtds	Does Not Support	Supports	Does Not Support	Supports with Mtds	Does Not Support							
4.33	Interface with DPL	1		1	Not Supported	1		Yes		Does not support			1		Difficult but can be implemented			1		Difficult but can be implemented			Supports	Does Not Support	Supported but limited
4.34	Number of Isotopes	1	1		Excel can support this but only in a limited capacity			1		Yes	1				Yes			1		Yes			1		Can be implemented
4.35	On/Off	1		1	Yes			1		Yes	1				Yes			1		Yes			1		Yes
4.36	Missing Economic Data Alert	2			Excel can support this but will require extensive coding			1		Yes	1				Yes			1		Yes			1		Yes
4.37	Model Configuration	2		1	Not Supported	1		Difficult to Program		Yes	1				Yes			1		Yes			1		Yes
4.38	Minimum Isotopes	1	1		Yes			1		Yes	1				Yes			1		Yes			1		Supports this element but limited in scope
4.39	Reprocessing Throughput	2		1	Not Supported	1		Easy to Program		Yes	1				Yes			1		Yes			1		Difficult to program
4.40	Fuel Recipes	1	1		This can be done with Excel but will require some complex coding			1		Yes	1				Yes			1		Yes			1		Can be implemented
4.41	Reactor Types	1		1	This can be done with Excel but will require some complex coding			1		Yes	1				Yes			1		Yes			1		Can be implemented
4.42	Defined Energy Outlooks	1	1		This can be done with Excel but will require some complex coding	1		Relatively easy to program		Yes	1				Yes			1		Yes			1		Can be implemented
4.43	Unlimited Capacity	1	1		Yes	1		Yes		Yes	1				Yes			1		Yes			1		Yes
4.44	Limited Capacity	1	1		Yes	1		Yes		Yes	1				Yes			1		Yes			1		Yes
5.1	Computer	1	1		Windows based only	1		Windows, Web-based,		Windows based or Mackintosh	1				Windows based			1		Windows based			1		Windows based
5.2	Software	1	1		Yes	1		Yes		Yes	1				Yes			1		Yes			1		Yes

Requirement			Excel Spreadsheet				FORTRAN				Stella/Ithink				Vensim				Studio 2005				Simcad			
No.	Name	Priority	Supports	Supports with Mlods	Does Not Support	Comments	Supports	Supports with Mlods	Does Not Support	Comments	Supports	Supports with Mlods	Does Not Support	Comments	Supports	Supports with Mlods	Does Not Support	Comments	Supports	Supports with Mlods	Does Not Support	Comments				
5.3	Transparent Architecture	1		1		Not Supported	1			This is part of the power of System dynamic software	1				1			This is part of the power of System dynamic software	1			This is part of the power of SimCad				
5.4	Non-Proprietary	1	1			Yes	1			Yes	1				1			Yes	1			Yes				
5.5	Distribution	3	1			Yes	1			Minimum Cost \$100	1				1			Yes			1	Costs				
5.6	Number of Characters	1	1			Yes	1		1	Limited	1				1			Yes	1			Yes				
5.7	Number of Array Elements	1		1		This can be done with Excel but will require some complex codi			1	Limited				1				Yes	1			Yes				
5.8	Number of model Elements	1	1			Yes	1		1	Limited	1				1			Yes	1			Yes				
5.9	Locked Version	1	1			Yes	1			Yes	1				1			Yes	1			Yes				
5.10	Configuration Control	1	1			Yes	1			Yes	1				1			Yes	1			Yes				