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# Software Platform Evaluation

## Verifiable Fuel Cycle Simulation (VISION) Model

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November 2005

Idaho National Laboratory

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**U.S. Department of Energy**
**Office of Nuclear Energy, Science, and Technology**
**Under DOE Idaho Operations Office**
**Contract DE-AC07-05ID14517 (INL)**

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Rev. 1

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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, Evalation, and Trade Study (SETS) working group FY05 Year End Report, *Fuel Cycle Scenario Definitions, Evalation, 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.

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[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 compliers. 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:<br>1) Professional $1,200<br>2) DSS $2,000 | Versions:<br>1) Expert $2,550<br>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 |
| Builtin 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 to[7]

- 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** | **FORTRAN** |
|---|---|---|---|
| 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.

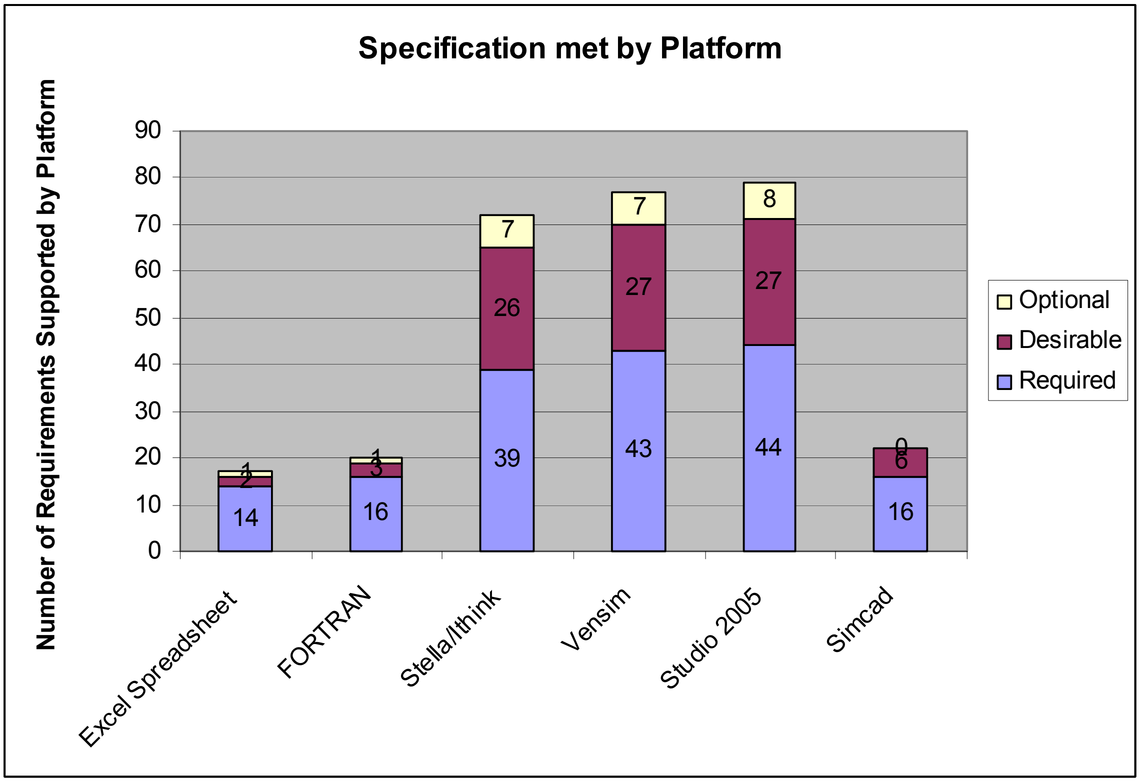



**Figure 1. Number of specifications supported by a platform without platform modification.**

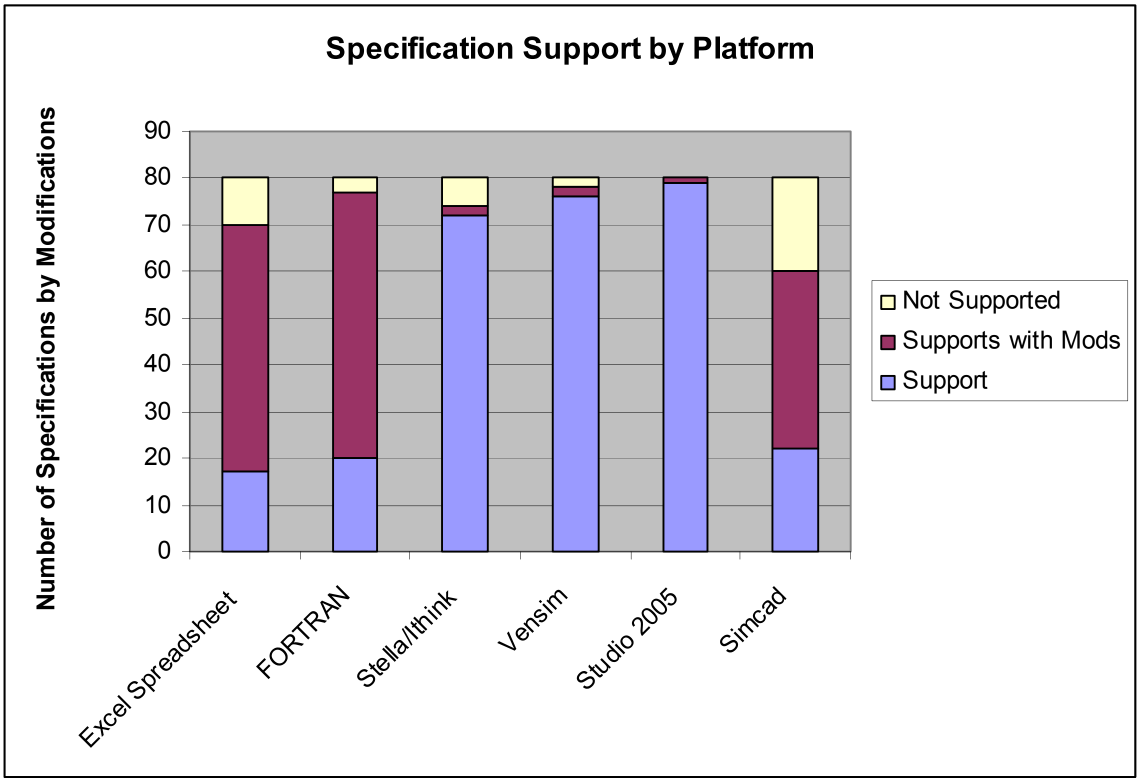



**Figure 2. Number of specifications supported without and with a platform modification.**

| | | 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 | $/participant | $/license/year |
| **Excel Spreadsheet** | Lead | | 0 | 0 | 0 | | | As available | Unavailable |
| | Assistant | | 0 | 0 | 0 | | | | |
| **Programming Languages**[8] | 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 | | | | |
| **Vensim**[10] | Lead | $2,000 | 1 | $1,200 | 2 | $0 | 1 | 2 days @$1000 | $300 |
| | Assistant | $1,200 | 5 | 0 | 0 | | | | |
| **Studio 2005**[11] | 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 develop[16] 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.

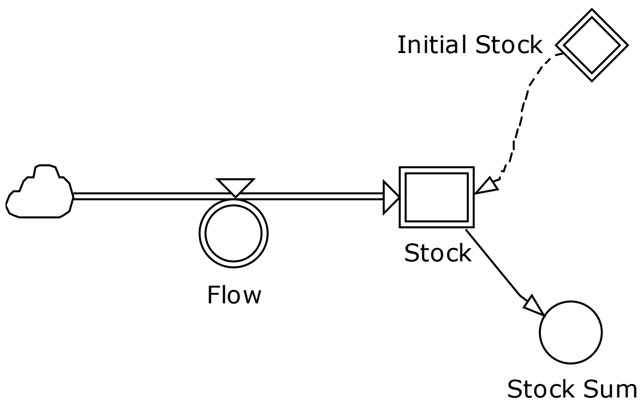
| | Reviewer | | | | | | |
|---|---|---|---|---|---|---|---|
| | **One** | **Two** | **Three** | **Four** | **Five** | **Six** | **Seven** |
| **Experience** | | | | | | | |
| Stella | Some | None | Some | None | Some | Some | Lots |
| Vensim | Lots | Some | None | Lots | Some | Lots | Lots |
| Studio 2005 | Lots | Lots | Lots | Lots | Some | None | Some |
| **Development Time** | | | | | | | |
| Vensim vs Stella | Less | NA | NA | NA | More | Same | Same |
| Vensim vs Studio 2005 | Same | Same | NA | Same | More | NA | Less |
| Stella vs Studio 2005 | More | NA | Less | NA | Same | NA | Less |
| **Verification & Validation Time** | | | | | | | |
| Vensim vs Stella | Less | NA | NA | NA | Less | Less | Less |
| Vensim vs Studio 2005 | Same | More | NA | Less | Less | NA | Same |
| Stella vs Studio 2005 | More | NA | More | NA | Same | NA | More |
| **Ease of Developing a User Interface** | | | | | | | |
| Vensim vs Stella | Not as good | NA | NA | NA | Not as good | Not as good | Not as good |
| Vensim vs Studio 2005 | Not as good | Not as good | NA | Not as good | Not as good | NA | Not as good |
| Stella vs Studio 2005 | Same | NA | Not as good | NA | Not as good | NA | 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<br>SNL<br>ANL | Considerable<br>Some<br>Considerable | Considerable<br>Considerable<br>Some | Some<br>Considerable<br>None |
| Requirements not supported by a platform or needing platform modification to support | | 4.4 Input interface<br><br>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<br>41% Moderate<br>6% Difficult | 53% Easy<br>44% Moderate<br>3% Difficult | 62% Easy<br>38% Moderate<br>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 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Priority | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments |
| | **Total Required** | | 6 | 24 | 4 | | 10 | 21 | 3 | | 32 | 1 | 1 | | 33 | 1 | 0 | | 34 | 0 | 0 | | 8 | 15 | 11 | |
| 1.1 | Track Mass Inventories | 1 | | 1 | | Very Difficult - Excel is not designed to track flows. There may be some add-on package that could support this requirement | | 1 | | Very Difficult but can be programmed | 1 | | | Tracking inventories is easy with SD Software | 1 | | | Tracking inventories is easy with SD Software | 1 | | | Tracking inventories is easy with SD Software | 1 | | | Simple but tracks at discrete level -- too much detail |
| 1.2 | Track Isotopes Mass Inventories | 1 | | 1 | | Very Difficult - Excel is not designed to track flows. There may be some add-on package that could support this requirement | | 1 | | Very Difficult but can be programmed | 1 | | | Tracking inventories is easy with SD Software | 1 | | | Tracking inventories is easy with SD Software | 1 | | | Tracking inventories is easy with SD Software | 1 | | | Simple but tracks at discrete level -- too much detail |
| 1.3 | SNF composition | 1 | | 1 | | This will be very difficult to accomplish with Excel | | 1 | | Difficult but can be programmed | 1 | | | This is relatively simple at the elemental level but difficult at the isotopic level because of the limited array structures | 1 | | | This is simple at the elemental level but will require complex arrays to track at the isotopic level | 1 | | | This is simple at the elemental level but will require complex arrays to track at the isotopic level | | 1 | | Not trivial but can be accomplished |
| 1.4 | U Needed | 1 | | 1 | | This will be very difficult to accomplish with Excel | | 1 | | Difficult but can be programmed | 1 | | | Relatively simple to implement | 1 | | | Relatively simple to implement | 1 | | | Relatively simple to implement | | 1 | | Difficult but can be implemented |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.6 | Transportation Volume | 2 | 1 | | | Excel can support this but will require extensive coding | 1 | | | Relatively easy to program | 1 | | | Simple to implement | 1 | | | Simple to implement | 1 | | | Simple to implement | 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 | | | Relatively easy to program | 1 | | | Simple to implement | 1 | | | Simple to implement | 1 | | | Simple to implement | 1 | | | Simple to implement |
| 1.8 | Energy Efficiency Factor | 1 | | 1 | | This can be done with Excel but will require some coding | | 1 | | Difficult but can be programmed | 1 | | | Easy to implement once all the elements needed for the calculation | 1 | | | Easy to implement once all the elements needed for the calculation | 1 | | | Easy to implement once all the elements needed for the calculation | | 1 | | Difficult but can be implemented |

| Requirement | | | Excel Spreadsheet | | | | FORTRAN | | | | Stella/Ithink | | | | Vensim | | | | Studio 2005 | | | | Simcad | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name | Priority | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments |
| | | | | | | | | | | | | | | are in the model | | | | are in the model | | | | are in the model | | | | |
| 1.9 | Radiotoxicity Index Of SNF/HLW | 1 | | 1 | | This can be done with Excel but will require some coding | | 1 | | Difficult but can be programmed | 1 | | | simple to implement | 1 | | | simple to implement | 1 | | | simple to implement | | 1 | | Difficult but can be implemented |
| 1.10 | Radioactive Decay | 2 | | | 1 | This would be extremely difficult | | 1 | | Difficult but can be programmed | 1 | | | Difficult but can be programmed | 1 | | | Difficult but can be programmed | 1 | | | Difficult but can be programmed | | | 1 | Not supported |
| 1.11 | Heat Load | 1 | 1 | | | This would be extremely difficult | | 1 | | Difficult but can be programmed | 1 | | | Simple to Implement | 1 | | | Simple to Implement | 1 | | | Simple to Implement | | 1 | | 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 | | | Simple to implement but requires new structure | 1 | | | Simple to implement but requires new structure | 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 | | | Simple to implement but requires new structure | 1 | | | Simple to implement but requires new structure | 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 | | | Simple to implement but requires new structure | 1 | | | Simple to implement but requires new structure | 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 | | | Simple to implement but requires new structure | 1 | | | Simple to implement but requires new structure | 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 | | | Simple to implement but requires new structure | 1 | | | Simple to implement but requires new structure | 1 | | | Simple to implement does not require 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 | | | Simple to implement but requires new structure | 1 | | | Simple to implement but requires new structure | 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 | | | Simple to implement but requires new structure | 1 | | | Simple to implement but requires new structure | 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 | | | Simple to implement but requires new structure | 1 | | | Simple to implement but requires new structure | 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 Mods | Does Not Support | **Comments** | Supports | Supports with Mods | Does Not Support | **Comments** | Supports | Supports with Mods | Does Not Support | **Comments** | Supports | Supports with Mods | Does Not Support | **Comments** | Supports | Supports with Mods | Does Not Support | **Comments** | Supports | Supports with Mods | Does Not Support | **Comments** |
| 2.9 | Manual Cost Overrides | 2 | | 1 | | Excel can support this but will require extensive coding | | 1 | | Relatively easy to program | 1 | | | Simple to implement but requires new structure | 1 | | | Simple to implement but requires new structure | 1 | | | Simple to implement does not require new structure | | 1 | | Not directly supported but can be accomplished |
| 2.10 | Cost Uncertainty | 2 | | 1 | | Excel can support this but will require extensive coding | | 1 | | Can be done but would require significant programming | | | 1 | Not Supported | 1 | | | Can be implemented | 1 | | | Can be implemented | | | 1 | Not supported |
| 2.11 | Case Cost Comparability | 1 | | 1 | | Excel can support this but will require extensive coding | | 1 | | Relatively easy to program | 1 | | | Simple to Implement | 1 | | | Can be implemented | 1 | | | Can be implemented | 1 | | | Supported |
| 2.12 | Fuel Cycle Economic Analysis | 1 | | 1 | | Excel can support this but will require extensive coding | | 1 | | Relatively easy to program | 1 | | | Supported | | 1 | | Can be implemented | 1 | | | Can be implemented | | 1 | | Not directly supported but can be accomplished |
| 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 | | Relatively simple to implement once program is working for a single run | 1 | | | Simple to implement | 1 | | | Simple to implement | 1 | | | simple to implement | | 1 | | Relatively simple to implement |
| 3.2 | Sensitivity | 3 | | 1 | | This can be done with Excel but will require some coding | | 1 | | Very difficult to program | 1 | | | Supported but limited | 1 | | | Very powerful | 1 | | | Very powerful | | | 1 | Not Supported |
| 3.3 | Optimize A Scenario | 3 | | 1 | | This can be done with Excel but will require some coding | | 1 | | Requires special programming | | | 1 | Not Supported | 1 | | | Very powerful | 1 | | | Very powerful | | | 1 | Not Supported |
| 3.4 | Reactor Construction | 1 | | 1 | | This can be done with Excel but will require some coding | | 1 | | Not difficult but will require extensive programming | 1 | | | Relatively simple to implement | 1 | | | Relatively simple to implement | 1 | | | Relatively simple to implement | | | 1 | Not Supported |
| 3.5 | Reactor Number And Mix | 1 | | 1 | | Not difficult but will require extensive programming | | 1 | | Not difficult but will require extensive programming | 1 | | | Relatively simple to implement | 1 | | | Relatively simple to implement | 1 | | | Relatively simple to implement | | | 1 | Not Supported |
| 3.6 | Separation and Fuel Fabrication Capacity | 1 | | 1 | | Not difficult but will require extensive programming | | 1 | | Not difficult but will require extensive programming | 1 | | | Relatively simple to implement | 1 | | | Relatively simple to implement | 1 | | | Relatively simple to implement | | | 1 | Not Supported |
| 3.7 | Data Confidence Intervals | 2 | | 1 | | Supported | | 1 | | Relatively easy to program | 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 Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | 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 | | | 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 | | | Yes | | 1 | | Not directly supported but can be accomplished |
| 3.10 | Dynamically create reprocessing capacity | 2 | | 1 | | Not directly supported but can be accomplished | | 1 | | Relatively easy to program | 1 | | | Yes | 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 | 1 | | | Very good user interface tools | | 1 | | Limited user interface tools | 1 | | | Very extensive and sophisticated interface tools | 1 | | | 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 | 1 | | | Very easy to implement |
| 4.3 | Multi-dimensional Arrays | 1 | | 1 | | 2-dimensional only | 1 | | | Not difficult but will require extensive programming | 1 | | | 2-dimensional only | 1 | | | Limited | 1 | | | Supports unlimited array structures | | | 1 | Not supported |
| 4.4 | Input interface | 1 | | 1 | | Using Visual Basic | | | 1 | GUI only | | | 1 | Supports a GUI interface and program level control but can't do input decks but can interace with Excel files | 1 | | | Supports a GUI interface, data from files and program level control | 1 | | | 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 | | | 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 | | | Easy to implemeht | | | 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 | | | 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 | | | 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 Mods | Does Not Support | **Comments** | Supports | Supports with Mods | Does Not Support | **Comments** | Supports | Supports with Mods | Does Not Support | **Comments** | Supports | Supports with Mods | Does Not Support | **Comments** | Supports | Supports with Mods | Does Not Support | **Comments** | Supports | Supports with Mods | Does Not Support | **Comments** |
| 4.10 | Reprocessing Throughput | 1 | | 1 | | This can be done with Excel but will require some coding | 1 | | | This can be done but will require extensive coding | 1 | | | Can be implemented | 1 | | | Can be implemented | 1 | | | Can be implemented | | | 1 | Not supported |
| 4.11 | The Size/Throughput Rates | 2 | | 1 | | Excel can support this but will require extensive coding | 1 | | | Relatively easy to program | 1 | | | Simple to implement but requires new structure | 1 | | | Simple to implement but requires new structure | 1 | | | Simple to implement | | | 1 | Not supported |
| 4.12 | Modes of Operation | 1 | | | 1 | Not Supported | | 1 | | Difficult | 1 | | | Moderate | 1 | | | Moderate | 1 | | | Moderate | | | 1 | Not supported |
| 4.13 | Location Scenarios | 2 | | 1 | | Excel can support this but will require extensive coding | | 1 | | This will be difficult to program | 1 | | | This could be difficult to implement | 1 | | | This could be difficult to implement | 1 | | | This could be difficult to implement | 1 | | | part of the power of Simcad |
| 4.14 | Modes Of Transportation | 2 | | 1 | | Excel can support this but will require extensive coding | | 1 | | Easy to program | 1 | | | Simple to implement | 1 | | | Simple to implement | 1 | | | Simple to implement | 1 | | | Part of the power of Simcad |
| 4.15 | Energy Outlook | 1 | | 1 | | This can be done with Excel but will require some complex coding | 1 | | | This can be done but will require extensive coding | 1 | | | Can be implemented | 1 | | | Can be implemented | 1 | | | Can be implemented | | | 1 | Not supported |
| 4.16 | Timing And Sequencing | 1 | | 1 | | This can be done with Excel but will require some coding | | 1 | | This can be done but will require extensive coding | 1 | | | Can be implemented | 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 | | This can be done but will require extensive coding | 1 | | | Can be implemented | 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 | | This can be done but will require extensive coding | 1 | | | Can be implemented | 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 | | This can be done but will require extensive coding | 1 | | | Can be implemented | 1 | | | Can be implemented | 1 | | | Can be implemented | | 1 | | Can be implemented |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |

| Requirement | | | Excel Spreadsheet | | | | FORTRAN | | | | Stella/Ithink | | | | Vensim | | | | Studio 2005 | | | | Simcad | | | |
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| No. | Name | Priority | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | Does Not Support | Comments | Supports | Supports with Mods | 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 | | This will be very difficult to implement |
| 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 | Not supported |
| 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 | | Simple task |
| 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 | 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 | 1 | | | This can be done in a limited fashion | | | 1 | Not Supported | 1 | | | Easy to implement | | | 1 | Not supported |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.32 | Fuel Blending | 3 | | | 1 | Not Supported | | 1 | | Easy to program | 1 | | | Easy to implement | 1 | | | Easy to implement | 1 | | | Easy to implement | | | 1 | Not supported |

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| 4.33 | Interface with DPL | 1 | | | 1 | Not Supported | 1 | | | Yes | | | 1 | Does not support | | 1 | | Difficult but can be implemented | | 1 | | Difficult but can be implemented | | 1 | | Supported but limited |
| 4.34 | Number of Isotopes | 1 | 1 | | | Excel can support this but only in a limited capacity | | 1 | | Relatively easy to program | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | | 1 | | Can be implemented |
| 4.35 | On/Off | 1 | | 1 | | Yes | | 1 | | Relatively easy to program | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes |
| 4.36 | Missing Economic Data Alert | 2 | | 1 | | Excel can support this but will require extensive coding | | 1 | | Easy to Program | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes |
| 4.37 | Model Configuration | 2 | | | 1 | Not Supported | | 1 | | Difficult to Program | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes |
| 4.38 | Minimum Isotopes | 1 | 1 | | | Yes | | 1 | | Relatively easy to program | 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 | 1 | | | 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 | | Relatively easy to program | 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 | | Relatively easy to program | 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 | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | | 1 | | Can be implemented |
| 4.43 | Unlimited Capacity | 1 | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes |
| 4.44 | Limited Capacity | 1 | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes |
| 5.1 | Computer | 1 | 1 | | | Windows based only | 1 | | | Windows, Web-based, | 1 | | | Windows based or Mackintosh | 1 | | | Windows based | 1 | | | Windows based | 1 | | | Windows based |
| 5.2 | Software | 1 | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes |

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| 5.3 | Transparent Architecture | 1 | | | 1 | Not Supported | | | 1 | Not Supported | 1 | | | This is part of the power of System dynamic software | 1 | | | This is part of the power of System dynamic software | 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 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes |
| 5.5 | Distribution | 3 | 1 | | | Yes | 1 | | | Yes | 1 | | | Minimum Cost $100 | 1 | | | Yes | 1 | | | Yes | | | 1 | Costs |
| 5.6 | Number of Characters | 1 | 1 | | | Yes | 1 | | | Yes | | | 1 | Limited | 1 | | | Yes | 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 | | | Yes | | | 1 | Limited | | | 1 | Limited | 1 | | | Yes | 1 | | | Yes |
| 5.8 | Number of model Elements | 1 | 1 | | | Yes | 1 | | | Yes | | | 1 | Limited | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes |
| 5.9 | Locked Version | 1 | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes |
| 5.10 | Configuration Control | 1 | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes | 1 | | | Yes |