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Nuclear Fuel Cycle Reasoner: PNNL FY13 Report

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September 2013



Pacific Northwest
NATIONAL LABORATORY

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Richland, Washington 99352

Summary

An understanding of the Nuclear Fuel Cycle (NFC) is important for researchers, program managers and intelligence analysts. Over the last decade or more, several efforts have been made to document and represent the NFC such as the *Nuclear Fuel Cycle and Weapons Development Process*¹ (a.k.a. *Signatures Report*) and the related *Freeze Frame* schematic and activities. Few, if any, of these efforts have approached the problem from a formal knowledge engineering perspective.

Over the last two years, the *Nuclear Fuel Cycle Reasoner* project engineered a formal reasoning framework to represent the knowledge of a portion of the NFC. This framework is the basis of a tool to help DOE researchers, program managers and intelligence analysts better understand the processes, activities, materials and signatures of the NFC and the relationships between them.

In Fiscal Year 2012 the Semantic Nonproliferation Analysis Platform (SNAP) was developed as a preliminary graphical user interface to demonstrate the potential power of the underlying semantic technologies to analyze and explore facts and relationships relating to the nuclear fuel cycle (NFC).

In Fiscal Year 2013, the SNAP demonstration was enhanced with respect to query and navigation usability issues. The enhancements increased the utility of the SNAP demonstration by helping users understand the NFC by exploring concepts and the relationships between those concepts. This report summarizes FY13 activities and identifies sales and marketing interactions within 2013.

¹ John F. Wacker, ed., *Chemical and Radiological Signatures of Nuclear Weapons Production*. PNNL-NSD-0383 CD Rev 1, March 2003.

Contents

Summary	iii
1.0 FY13 Tasks.....	1
1.1 General and Conceptual Knowledge Navigation in SNAP.....	1
1.2 Federated Query Capability Added to SNAP.....	2
1.3 SNAP Demonstrations	2
2.0 Potential future applications	3
2.1 PNNL Internal	3
2.2 External	3

Figures

Figure 1 Query results for the major stages of the nuclear fuel cycle.....	1
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1.0 FY13 Tasks

1.1 General and Conceptual Knowledge Navigation in SNAP

The original focus of the SNAP application and demonstration was on interpreting facts. As facts were entered into the SNAP application, the reasoning framework would use the knowledge encapsulated in the nuclear fuel cycle ontology to interpret those facts and infer additional facts based on subject matter expertise. During the course of the project, it became apparent that access to the knowledge in the ontology was valuable to the user as well as the reasoning framework.

To assist users in better understanding the nuclear fuel cycle, query mechanisms were developed to allow questions to be asked by the user about general domain knowledge. Originally, a user could query the SNAP application for facts about a particular nation state’s nuclear fuel cycle. In FY13, the capability to query the SNAP application for general knowledge about the nuclear fuel cycle was added. Users can now ask a question such as; “What are the major stages of the nuclear fuel cycle?”

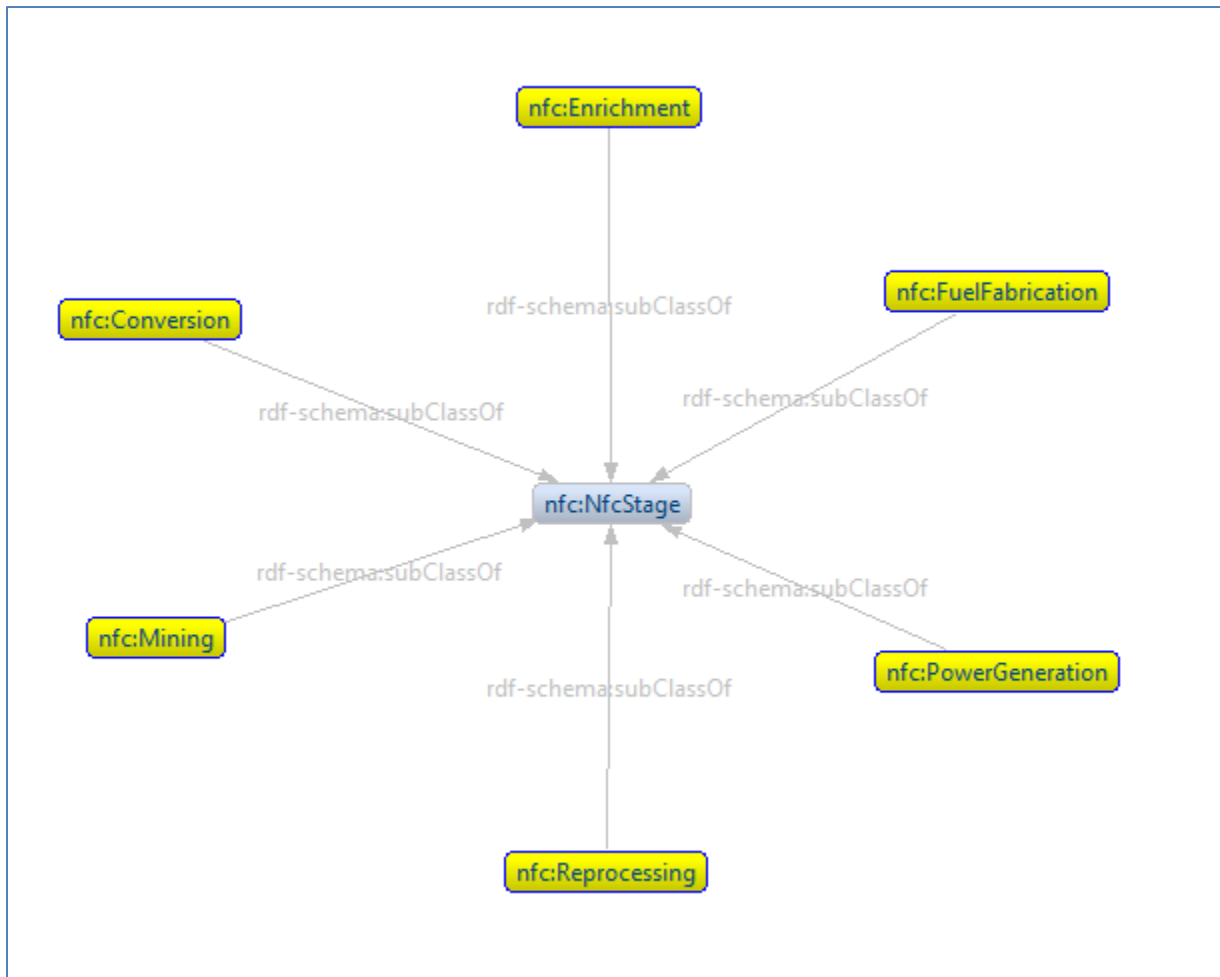


Figure 1 Query results for the major stages of the nuclear fuel cycle

The SNAP application had shown that ontologies and reasoning about the NFC could help analysts achieve quicker and more insightful situational awareness about a nation state's involvement with the nuclear fuel cycle processes. With this added capability the SNAP application can help analysts gain a better understanding of the nuclear fuel cycle itself.

1.2 Federated Query Capability Added to SNAP

In the practice of creating reasoning agents for the SNAP application demonstration the need to connect to and extract information from remote data sources, databases, and SPARQL endpoints was discovered. To facilitate Federated Queries the scope of the query capability from within the reasoning agents was expanded.

With this new expansion, the reasoning agents can now query remote data sources and add required facts to the contextual knowledgebases or to the local memories of the querying reasoners. This is a significant capability as it allows access to important data sources such as Wikipedia (DBpedia), CIA world fact book, CiteSeer Publications Endpoint, Data.gov, and many more. For a listing of the status of available SPARQL endpoints see <http://labs.mondeca.com/sparqlEndpointsStatus/>.

1.3 SNAP Demonstrations

A poster of the SNAP was presented at the NNSA's Office of Defense Nuclear Nonproliferation Research and Development (DNN R&D) Weapons & Materials Security (WMS2013) Team Program Review Meeting, at Sandia National Laboratory in Livermore, CA, on April 9th, 2013. The SNAP application software was demonstrated during the poster session.

The SNAP demonstrations were presented to groups and individuals who could potentially benefit from the capabilities of the software. Here is a partial listing of the demonstrations:

External Outreach Demonstrations:

- April 9, 2013 - WMS2013, review attendees
- April 13, 2013 - DNN R&D online meeting and demo, Jim Peltz, Brian Broadhead, Sandy Thompson, Jana Strasburg, Zoe Gastelum, NA-24 representatives.
- June 7, 2012 – EarlyX Foundation, Pepperdine University, Dat Do, John Shearer, Michael Sims, John McEntire
- June 19, 2013 – DOE CEDS, Phil Craig (Secure Cyber Systems)
- July 1, 2013 - PNNL Nonproliferation Technologies & Safeguards, Kevin Whattam, Jason Shergur, Hal Udem, Sandy Thompson

Internal Socialization Demonstrations:

- June 5, 2013 –Sarah Frazar (PNNL Nonproliferation Technologies & Safeguards (NT&S))
- June 6, 2013 – Future Power Grid Initiative (FPGI) LDRD MDART, Jodi Obradavich (PI)
- June 18, 2013 – NT&S LDRD Principle Investigator, Dale Henderson, Joel Doehle
- July 31, 2013 – Disruption of Illicit Nuclear Trafficking Laboratory Objective, Daniel Stephens, Luke Erikson, Jennifer Webster, Alex Endert, Sandy Thompson

2.0 Potential Future Applications

As a result of the aforementioned demonstrations several parties have shown interest in the technology. We will keep DNN R&D informed of the additional applications as time progresses.

2.1 PNNL Internal

The Future Power Grid Initiative (FPGI) Laboratory Directed Research and Development (LDRD) Multi-layer Data-driven Analysis and Reasoning Tool (MDART) project is now using the SNAP technology as a central component of their research. The Disruption of Illicit Nuclear Trafficking Laboratory Objective (DINT-LO) road mapping team is considering expanding the SNAP application for use in that domain in FY14. The Signature Discovery Initiative (SDI) is examining the underlying technologies to integrate SNAP signatures with signatures from other technologies.

2.2 External

The Early X Foundation, a group affiliated with Pepperdine University, has expressed potential interest in licensing the underlying technologies of SNAP. The subject matter of their interest is initially in much different areas, primarily focusing on the financial sector.

3.0 Conclusions

The *Nuclear Fuel Cycle Reasoner* project and the Semantic Nonproliferation Analysis Platform (SNAP) demonstrated the utility of the semantic technologies in the nuclear nonproliferation domain. As the amount of web-accessible data continues to increase, tools like SNAP provide a method of computational analysis that can aid human analysts by allowing the computer to handle pedestrian and routine analysis, maintaining innumerable facts in context and freeing the humans to use their cognitive ability on higher-level analysis.

4.0 Project Deliverables

Strasburg JD, RE Hohimer, ZN Gastelum, and JM Kornell. 2012. *Nuclear Fuel Cycle Reasoner: Topic Survey and Use Case*. PNNL-21151,

Hohimer RE, YG Pomiak, PA Neorr, ZN Gastelum, and JD Strasburg. 2013. *Nuclear Fuel Cycle Reasoner: PNNL FY12 Report*. PNNL-22462,

JD Strasburg, RE Hohimer, ZN Gastelum, YG Pomiak, S Hampton, PA Neorr, I Roberts, C. Noonan, J Kornell, M Brown, C Kimblin. 2013. *Nuclear Fuel Cycle Reasoner: Independent Review Presentation*. March 1, 2013.

JD Strasburg, RE Hohimer, ZN Gastelum, YG Pomiak, S Hampton, PA Neorr, I Roberts, C. Noonan, J Kornell, M Brown, C Kimblin. 2013. *Nuclear Fuel Cycle Reasoner: Demonstration and Discussion Presentation*. May 13, 2013.

Hohimer RE and JD Strasburg. 2013. *Nuclear Fuel Cycle Reasoner: PNNL FY13 Report*. PNNL-22792



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