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# Design Concepts and Process Analysis for Transmuter Fuel Manufacturing

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*Task 22*

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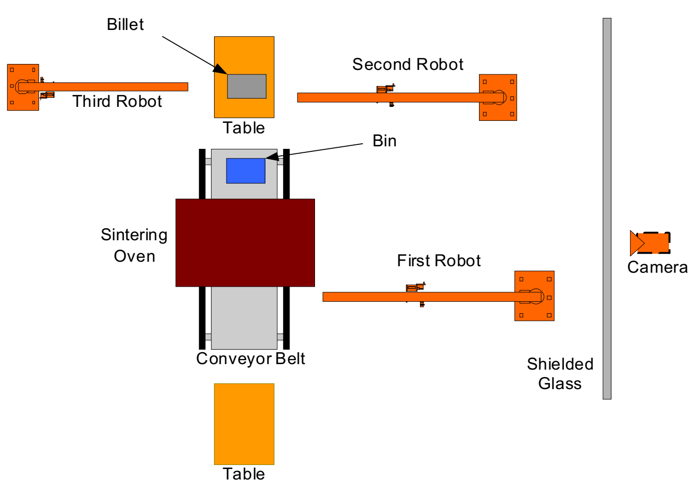
## BACKGROUND

The safe and effective manufacturing of actinide-bearing fuels for any transmutation strategy requires that the entire manufacturing process be contained within a shielded hot cell environment. To ensure that the fabrication process is feasible, the entire process must be designed for remote operation. The equipment must be reliable enough to perform over several decades, and also easy to maintain or repair remotely. The facility must also be designed to facilitate its own decontamination and decommissioning. In addition to these design factors, the potential viability of any fuel fabrication process will also be impacted by a number of variables, such as the current state of technology, potential problem areas, deployment scaling, facility safety, and cost.

## RESEARCH OBJECTIVES AND METHODS

The goal of this research project is to provide technical support to process designers working on the development of the fuel cycles for transmutation applications. Detailed process models have been developed to better define the impact of fuel choice on the transmuter fuel cycle, including relative process losses, waste generation, and plant capital cost. These process models provide insight regarding required plant size and number of plants needed to mesh with the fuel recycling line. They also determine requirements for automation.

Manufacturing models for large-scale production in a hot cell environment have also been developed. Combined, these two models allow the assessment of plant layout, and provide the framework for estimation of plant capital and operating cost estimates, and for feasibility in general. The operations of robotic equipment and the sensor technology required for safe ad reliable robot control have been evaluated through simulations in three-dimensional space. The manufacturing technology developed for hot cell applications is also applicable to other, more general uses, where occupational hazards prevent human presence near processes.




*Schematic of the floor layout of a hot cell manufacturing dispersion fuel.*

The research work was divided into several tasks:

<u>Conceptual 3D modeling: Hot Cell Robotics and Equipment Simulation</u> – A literature survey and detailed analysis of the research and development pertaining to candidate processes for transmuter fuel manufacture continued from previous years. Industry standards were used to refine equipment, instrumentation, and control specifications, and assessed the reliability and safety of operations. Monitoring of the market continued for equipment and components, which were evaluated with regard to suitability for automated manufacturing under hot cell conditions.

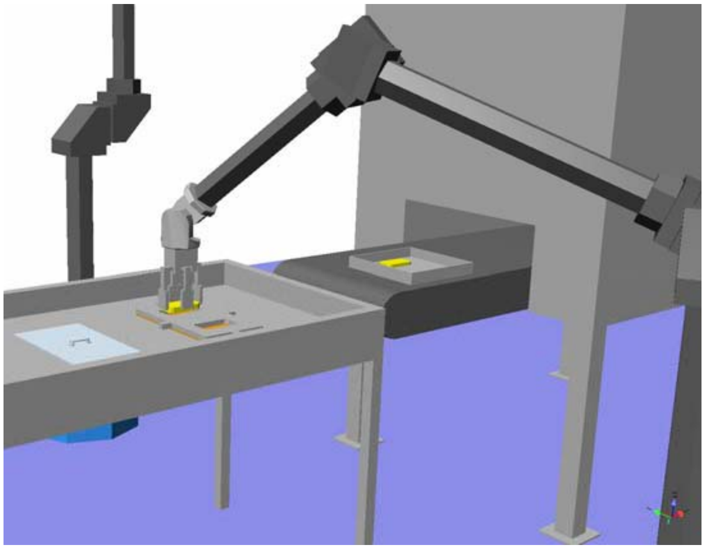
<u>Simulations</u> – This task modeled manufacturing processes to generate a realistic assessment of plant layout, size, feasibility, and technology development required for large-scale remote fabrication of fuel. Modeling of the candidate fuel manufacturing processes was performed using the MSC.visualNastran and ProEngineer simulation software tools. The modeling of dispersion and TRISO fuels has been completed. A parametric study to determine the process reliability and possible reliability improvements for various fuel types and equipment configurations is ongoing.

<u>Cost, Feasibility, and Large Scale Deployment</u> – This task developed the database necessary to provide cost estimates and differential cost for various fuel manufacturing options. Efforts began to tabulate and quantify estimates regarding projected cost, reliability, and plant life.

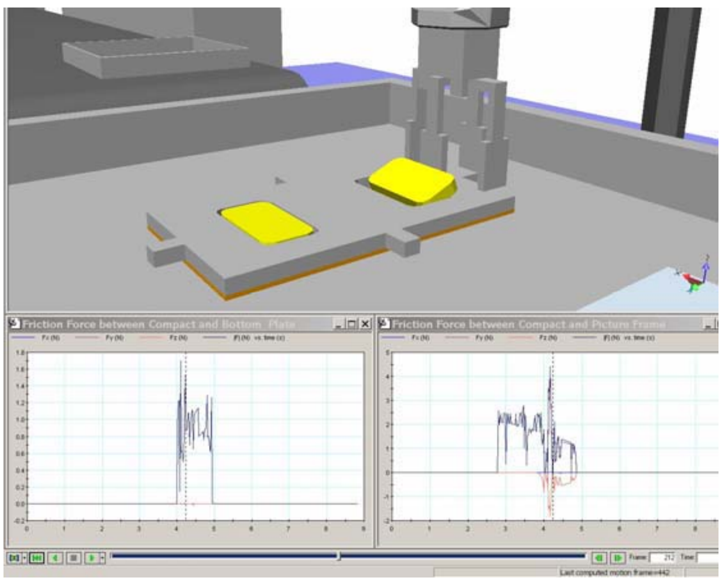
## RESEARCH ACCOMPLISHMENTS

A simulation model with a Waelischmiller hot cell robot was developed and coupled with MatLab control software. Matlab provides the interface with the robot and is used to control the system. The simulation renders a realistic simulation of the forces and torques present during robot motion. A 3-D manufacturing process simulation using CAD models and the Newtonian dynamics of the moving components has been developed.

When designing and analyzing operations inside a hot cell, considerable efforts are usually devoted to mockup studies that seek to anticipate both normal operations and accidents. The Visual



*Dispersion Fuel Manufacture: Manipulator placing a sintered compact into the billet.*



*Dispersion Fuel Manufacture: Friction forces between compact and cladding during insertion into the billet*

Nastran models represent a virtual mock-up facility, in which multiple accident scenarios were examined and analyzed in detail.

Results exist in the form of movies, data sets, and images. Simulations for six-axis Wälischmiller robots were developed and their proper kinematic configuration was verified. The simulations permit the detailed analysis of forces and torques in any modeled part or component.

## ACADEMIC YEAR HIGHLIGHTS

- "Conceptual Workcell Design and Throughput Analysis for Robotic Transmuter Fuel Fabrication," by G.F. Mauer and J. Renno was published in the Proceedings of the ANS Winter Annual Meeting, November 2004.
- "Design Concepts and Process Analysis for Transmuter Fuel Manufacturing," by G.F. Mauer was published in the Proceedings of the 8$^{th}$ Partitionin an Transmutation Information Exchange Meeting, OECD Nuclear Energy Agency, Las Vegas, NV, November 2004.
- Jamil Renno completed and defended his M.Sc. thesis in Mechanical Engineering (March 2005). Thesis title: "Virtual Design and Modeling of Various Manufacturing Processes for Remote Fuel Fabrication of Transmuter Fuel."

The simulations are numerically extensive, and a single simulation can require hours to complete, depending on the complexity of the model. The speed of the simulation has been increased substantially through continuous equipment upgrades, which were essential in enabling more detailed model refinements without undue elongation of simulation run times.

## FUTURE WORK

Further efforts will be devoted to increasing data and knowledge regarding the cost and feasibility of automated fuel manufacture in a hot cell by analyzing candidate manufacturing processes. Artificial intelligence concepts will be developed further with respect to object identification and hot cell dynamics simulations. Failure scenarios are being analyzed with regard to plant reliability, and the introduction of redundant equipment and sensors for the purpose of increasing plant reliability. A literature study to retrieve failure and reliability data is under way. The placement of robots in the hot cell is being evaluated with regard to optimizing their capability for redundancy in the event of equipment failure or maintenance.

A visit of the MELOX plant in Marcoule is planned for July 2005 with the objective of gaining insights into the design and operations experience gained from an operational plant.

The results of the simulations will be used by AFCI program personnel to perform sensitivity studies on the impact of different fuel types on transmutation system operation. Conceptual designs of the fuel fabrication processes will allow evaluations of issues related to maintainability, robust design, and throughput rate, and lead to identification of areas where improvements in technology are required to meet the goals of the transmutation system.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**Students**

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**Collaborators**

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