# USNDP

## U.S. Nuclear Data Program
## Work Plan for
## Fiscal Year 2000


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# Introduction

At a meeting held in Washington, D.C. on July 27, 1999, the Director of the DOE Division of Nuclear Physics and the United States Nuclear Data Program Steering Committee requested that the Chair of the Nuclear Data Coordinating Committee prepare a work plan for the program to cover the period from October 1999 through September 2000. This work plan was to provide a detailed task description and effort level covering work funded by the program. The Chair of the U.S. Nuclear Data Coordinating Committee agreed to prepare this plan in consultation with the members of the Coordinating Committee and transmit it to DOE and the Steering Committee by the end of September. Subsequently, we were asked to include an impact statement for the case that the funding level is reduced by 10 percent and to propose additional tasks should the funding level be increased above the present funding level.

The attached plan was prepared with the assistance of the members of the Coordinating Committee who represent the participating organizations. Each Coordinating Committee member prepared a draft plan for his or her organization. The Coordinating Committee Chair prepared a unified work plan based on these submissions, which was reviewed several times by the committee members in order to prepare a comprehensive and agreed upon plan.

The tasks proposed by the different organizations were reviewed internally according to the following criteria, which were developed considering the mission and goals outlined in past review panel reports and oversight committee discussions, and in consultation with the DOE program manager.

1. A task meets one of the three program priorities:
   a) The maintenance and update of the USNDP nuclear physics databases,
   b) The improvement of dissemination of the information contained in those databases to the user community,
   c) The modernization of data evaluation software used by the program participants.
2. A task is useful to more than a single user community.
3. A task does not duplicate effort within or outside the program.

The plan is divided into six major components. Specific tasks have been assigned to one of these components. They are:

- NNDC Facility Operation
- Coordination
- Nuclear Physics Databases
- Information Dissemination
- Nuclear Structure Physics
- Nuclear Reaction Physics

The following section details the proposed work plan for FY2000, defining tasks, organizational responsibilities, and deliverables. One must understand that a plan is just a plan. To be

successful, the planning process must be flexible enough to be able to respond to unforeseen circumstances. It is envisioned that this document will serve as the basis for a performance review at the end of fiscal year 2000.

The detailed work plan is followed by an effort table, which was also requested at the meeting. The effort table provides a summary of the total effort devoted to the defined tasks and the distribution of effort within each organization. Each laboratory was asked to assume FY1999 funding without escalation.

The effort table is followed by summary of tasks, which could be undertaken, if overall program funding is increased. No priority has been assigned to the proposed tasks. The presentation is given in alphabetic order of organizations. Another section presents a detailed impact statement for a hypothetical program funding decrease of ten percent, again presented in alphabetical order of organizations.

Finally, the detailed plan submissions by each organization are attached as appendices to allow for more detailed explanation of their plans.

This document represents the first detailed work plan produced for the nuclear data program. I would like to express my appreciation to the members of the Coordinating Committee who demonstrated a high level of patience and cooperation as this work plan evolved.

# Work Plan Tasks and Deliverables

## I. NNDC Facility Operation

A. Management

Task includes planning, budgeting, personnel, interaction with BNL management, and interaction with funding authorities.

B. Library

NNDC maintains an archival collection of low and intermediate energy nuclear physics publications. This library supports the NNDC compilation activities and the U.S. nuclear data evaluation and international nuclear structure evaluation.

C. Computer Operation

The NNDC operates a DEC Alpha 4100 computer to support our compilation, evaluation, database maintenance, and information dissemination functions. Task includes software upgrades, hardware and software procurements, machine operations and internal user support.

**Deliverables:**

Upgrade to version 7.2 of VMS and install related required software upgrades.
Keep downtime to less than 3%.

D. NT Server Operation

The NNDC operates a DELL Work Station running WINDOWS-NT and WINCENTER software as a multi-user PC software server with output to staff X-window terminals. Task includes software upgrades and internal user support.

## II. Coordination

A. National Coordination

**BNL** -- Chair USNDP Coordinating Committee, Advisor to USNDP Steering Committee, Chair Cross Section Evaluation Working Group, USNDP specific tasks.

**Deliverables:**

Prepare FY2000 work plan for USNDP and present to DOE review.
Prepare FY2001 work plan for USNDP in time for FY2001 FWP submittals.
Participate in USNDP Steering Committee Meeting.
Chair USNDP Meeting at LBNL in April 2000.
Organize and chair CSEWG Meeting at BNL, November 1999.
Maintain USNDP WWW-site.

**Idaho** -- Chair U.S. Nuclear Data Program's Nuclear Structure Working Group, and help coordinate nuclear structure data work at different labs to advance USNDP goals.

**Deliverables:**

Organize and chair Nuclear Structure Working Group meeting at USNDP meeting, LBNL, April 2000.

**LANL** -- Chair U.S. Nuclear Data Program's Nuclear Reaction Working Group, and help coordinate nuclear reaction data work at different labs to advance USNDP goals. Member of USNDP Steering Committee. Chair of Evaluation Committee of the Cross Section Evaluation Working Group.

**Deliverables:**

Prepare FY2000 Reaction Working Group Work Plan, with BNL, for review by DOE.
Participate in USNDP Steering Committee meetings.
Organize and chair CSEWG Evaluation Committee meeting at BNL, November 1999.
Organize and chair Nuclear Reaction Working Group meeting at USNDP meeting at LBNL, April 2000.

**LBNL** -- Chair U.S. Nuclear Data Program's Data Dissemination Working Group, and help coordinate data dissemination work at different labs to advance USNDP goals. LBNL staff members serve as an advisor to USNDP Steering Committee. Included here is also the Isotopes project management responsibilities of interacting with LBNL management and the DOE program manager.

**Deliverables:**

Organize and chair Data Dissemination Working Group meeting at USNDP meeting at LBNL, April 2000.

B. International Coordination

**BNL** -- Member of Nuclear Reaction Data Center Network, Member Nuclear Structure and Decay Data Network, Advisor to U.S. Member of the International Nuclear Data Committee, incoming Chair of NEA Working Party on Evaluation Cooperation, participation in IAEA sponsored activities.

**Deliverables:**

Participate in meeting of NRDC in Obninsk, Russia, June 2000.
Chair NEA Working Party in Tokai, Japan in June 2000.
Lecture at IAEA training course on Online Nuclear Data Services, December 1999.
One consultancy to IAEA Nuclear Data Section, December 1999.

**Idaho** -- Chair USNDP Nuclear Structure Working Group and interact with international Nuclear Structure and Decay Data network on behalf of USNDP on technical matters. Chair the international Decay Data Evaluation Project.

**LANL** -- Participate in, and chair, international nuclear reaction data collaborations. This insures that the U.S. benefits from breakthroughs around the world, and plays a leadership role in new developments. LANL staff members chair NEA committees in fission spectra, and international model code development cooperation; and chair IAEA coordinated research programs on photonuclear reactions, and on reference input model parameters. LANL will host visits by foreign scientists with international reputations to benefit from the exchange of information and ideas.

**Deliverables:**

Participate in NEA evaluation meeting in Japan in June 2000.
Chair IAEA photonuclear data CRP in Japan, October 1999; complete IAEA "TECDOC" report.
Make latest version of NJOY data processing code available to the international community.
Host a couple of international visitors to collaborate on the evaluation of nuclear data.

## III. Nuclear Physics Databases

A. Nuclear Science References (NSR)

The NNDC is responsible for NSR, the bibliographic database for nuclear physics research. Task includes quality control, file update and maintenance and file distribution to collaborators. Entry preparation not included. Updates are done on a continuing basis.

**Deliverables:**
Database distributed to collaborators monthly.

B. Experimental Nuclear Structure Data File (XUNDL)

The NNDC is responsible for XUNDL, the database of unevaluated experimental nuclear structure data. Recent activity contains mostly "high-spin" data sets. NNDC responsibility is limited to maintaining database and access to it. Data set compilation coordinated through McMaster University. Updates are done as data sets are received.

C. Evaluated Nuclear Structure Data File (ENSDF)

The NNDC is responsible for the ENSDF database that contains evaluated experimental nuclear structure and decay data. The NNDC is responsible for maintaining the database and organizing the quality control (review) of evaluations submitted for inclusion. Task includes database updates and distribution to collaborators. Updates are done upon completion of reviews. Corrections implemented on a continuing basis.

**Deliverables:**
Database distributed to collaborators twice in the year.

D. Numerical Nuclear Data File (NuDat)

The NNDC is responsible for NuDat, an all numeric database of nuclear data including level and $\gamma$-ray properties extracted from ENSDF, ground and metastable state properties (Wallet Cards), atomic and nuclear radiations derived from ENSDF and thermal neutron cross sections and resonance integrals. Database is also available in a PC version. The database is updated twice a year.

**Deliverables:**
Database distributed to collaborators twice in the year.

E. Reaction Data Bibliography (CINDA)

The NNDC is responsible for the CINDA database that contains references to nuclear reaction data in the published and unpublished literature. Its contents are produced cooperatively by the four international neutron data centers with updates exchanged in an agreed computer format. The data is organized by data measured, not by reference. The database serves as an

index to the neutron data contained in the experimental database, CSISRS. The database is updated as transmissions from the data centers are received and checked.

**Deliverables:**

20 CINDA exchange files from cooperating centers will be added to the database.
A project CINDA2001 has been initiated to modernize the database and expand it to cover charged particle and photonuclear data references presently stored elsewhere.

**Deliverables:**

Database design will be completed.
Database update codes will be completed and tested.
Database retrieval codes will be completed in FY2001.

F. Experimental Reaction Data File (CSISRS)

The NNDC is responsible for maintaining the CSISRS database. This database contains experimentally measured nuclear reaction data covering the low and intermediate energy regions. Experimental data is compiled by many groups worldwide and exchanged in an agreed format, EXFOR. In support of the reaction data compilation effort, we maintain a database of validated coded information (thesaurus) called the EXFOR dictionary system. The effort described here includes the quality control, file update and data exchange activities. The database is updated as transmissions from the compiling centers are received and checked. The compilation activity is given under Nuclear Reaction Physics.

**Deliverables:**

Update CSISRS with 18 EXFOR exchange tapes from cooperating centers.

G. Evaluated Nuclear Data File (ENDF)

The NNDC is responsible for ENDF, a database of evaluated nuclear data required for many nuclear applications. The file contains complete descriptions of nuclear reactions of neutrons with many nuclides and elements for energies up to 20 MeV and radiations from radioactive decay. Some evaluations cover energies up to 150 MeV. A limited number of evaluations for incident charged particles are also included. The data are stored in the ENDF format developed at NNDC about 35 years ago. This format has been adopted as an international standard. In addition to the U.S. library, ENDF/B, the database contains evaluated data libraries from Western Europe, Japan, Russia and China. This activity includes the processing and quality control for the U.S. ENDF/B library, the distribution of this database in the United States and the exchange of libraries internationally.

**Deliverables:**

Release 7 of the ENDF/B-VI evaluated data library will be issued.

H. Database Software Maintenance

Includes software bug fixes and enhancements for the six nuclear physics databases maintained by NNDC.

I. Future Database Systems

The NNDC is assessing new database software and computer platforms in order to determine the future directions that our database and computer activities should take. Effort includes the operation of "experimental" computing systems and development of prototype databases for various available database software packages. The effort is co-funded by Clark University.

**Deliverables:**

Final report and recommendations are due July 1, 2000.

## IV. Information Dissemination

The goal of the dissemination activities of the USNDP is to provide scientists and engineers with nuclear data from the USNDP maintained nuclear databases in a variety of user-friendly formats and media.

A. Maintenance of Remote Access to USNDP Databases

The NNDC provides electronic access to the nuclear physics databases, which it maintains. This access is supported in two forms, remote login (TELNET) and via the WWW.

**Deliverables:**

No enhancements are planned for the remote login (TELNET) access software.
Add HTML and GIF output from MIRD interface on WWW.
Improved tabular output from ENSDF and XUNDL databases on WWW.

B. Customer Services

This task accounts for the non-electronic services which the USNDP renders to customers. At the scientific staff level, we mean direct assistance to users needing advice of nuclear data experts or advice on solving complex queries via electronic access to the database. The NNDC staff allocation at the support level is for maintaining a "help desk" and for administrative/clerical support of its customer services.

C. Web Site Maintenance

USNDP members who offer information through a Web site require resources to maintain currency and improve performance. All sites will coordinate their effort and implement a "USNDP approved site" program with an appropriate identifier.

**Deliverables:**

**NNDC** -- Effort required to keep the USNDP and the NNDC site current.

**LANL** -- Include access to new reaction and structure data evaluations, supported by DOE/Nuclear Physics, via the T-2 WWW site.
Add access to ENDF/B-VI, Release VI.
Complete development of "readable" output from ENDF formatted information.
Improve color data plotting capability.

**LBNL --** Continue development of WWW Table of Radioactive Isotopes.
Add bremsstrahlung database.
Add electron database.
Add genetic Feedings database.
Complete JAVA spectrum server.
Develop website for compiled capture gamma data as part of IAEA CRP.

Update Table of Superdeformed Bands and Fission Isomers with revised information prepared by McMaster.

**ORNL --** Investigate possibility of providing high quality graphical output of nuclear structure for web interfaces in conjunction with LBNL, BNL and SJSU.

**TUNL --** Add PDF versions of most recent review publications for A = 4, 11, 12, 14, and 15.
Add reference updates lists for A = 10 through 15.

**Common ENSDF Web Interface**

During FY2000, BNL, LBNL, ORNL, and SJSU will begin the development of the common web interface to the ENSDF, XUNDL and NSR databases. Three previously separate relevant tasks have been combined under this new project. These tasks are items D, E and F below. A plan outlining responsibilities and commitments for each of the four organizations will be completed before the end of 1999. Some of the following tasks may be redefined and resources reallocated as a result of the implementation of this new activity. The Work Plan for FY2000 will contain the details agreed in the upcoming planning exercise.

D. Interface to Isotope Explorer Java Applet

NNDC will extract information from ENSDF or XUNDL databases and serve this information in the format required by the IE Java Applet served from LBNL.

**Deliverable:**
Applet interface completed and implemented.

E. MacNuclide Project

MacNuclide is a PC-based nuclear data visualization tool being developed at San Jose State University. Current developments emphasize Java technology and the creation of applets to be run over the WWW.

**Deliverables:**
Test and release a platform independent Java-based version of MacNuclide.
Develop a database applet from MacNuclide database software.
Develop a chart applet interface using MacNuclide software.

F. Isotope Explorer Project

The Isotopes Project has developed a PC-based software for displaying data from ENSDF and references from NSR. A WWW-based version of this software is also available.

**Deliverables:**

**Isotope Explorer 2** -- Port from Borland to MFC compiler.

**Isotope Explorer 3** -- Add table sorting capability.
Provide a chart module as now exists in IE2.
Begin development of common web interface to ENSDF and XUNDL databases.

**Isotope Explorer Reference Server** -- Add links to additional journals.
Add new reference search criteria.

G. APS Link to NNDC Experimental Data Bases

Presently NNDC provides a link from our bibliographic databases to paper abstracts for journals which support this access. For those with subscriptions, the user can then access the complete paper. In cooperation with APS (Ridge), we will develop the ability to then go from the Phys. Rev. abstract/article to the NNDC database where data mentioned in the publication will be archived.

**Deliverable:**

Prototype system in operation.

H. Nuclear Reaction Data on a CD-ROM

The IAEA's Nuclear Data Section is planning to provide experimental and evaluated nuclear reaction cross sections from the CSISRS and ENDF databases on a CD-ROM with the necessary programs to retrieve and display the data. NNDC will participate in this project. The data display software was developed at the Ukrainian Nuclear Data Center in Slavutych.

**Deliverables:**

**BNL --** Provide experimental data retrieval and formatting software necessary for input to the display program.
Test finished product.

I. Nuclear Wallet Cards

The last edition of the Nuclear Wallet Cards was published in 1995. The initial printing has been exhausted. NNDC plans to issue an updated edition in this fiscal year.

**Deliverables:**

Publish sixth edition of the Wallet Cards in Spring 2000.
Place an electronic version on the NNDC WWW site.

J. Windows Version of PC-NuDat

The present version of the NNDC PC-based NuDat database operates under MS-DOS only.

**Deliverables:**

A Windows-95/98 version of PC-NuDat will be released.

## V. Nuclear Structure Physics

A. NSR Abstract Preparation

The literature search and preparation of KEYWORD abstracts for publications included in NSR require scientific expertise. Most of the entries are created by NNDC staff with some help from Russia and Japan.

**Deliverables:**

**NNDC --** Keyword abstracts for 3600 references will be prepared in FY2000.

B. Compilation of Experimental Structure Data

Compilation of currently published or completed experimental nuclear structure data (primarily high-spin) for inclusion in XUNDL.

**Deliverables:**

**McMaster --** Compiled data sets (in ENSDF format) of current publications, primarily in high-spin physics.

**ORNL --** Improved software for converting tabular/graphic published level-scheme data in journals and unpublished data supplied by researchers to Radware database, into ENSDF format.
Examples used in the development of these procedures will be submitted to BNL as XUNDL data sets**.**

C. Data Evaluation

The USNDP evaluates nuclide and mass chain nuclear structure and decay data for inclusion in the ENSDF database.

**Deliverables:**

**BNL --** Three and one-half equivalent mass chains will be evaluated.
Four equivalent mass chains will be reviewed.
Two physicists will be trained in evaluation.

**Idaho --** Evaluate one mass chain and one nuclide.
1-2 equivalent mass chains will be reviewed.

**LBNL --** Eight equivalent mass chains and seven nuclides will be evaluated.
Three equivalent mass chains will be reviewed.

**McMaster --** 1.5 equivalent mass chains (including some in the A=40-44 region) will be evaluated.
One equivalent mass chain will be reviewed.
Update super-deformed data in ENSDF.

**ORNL --** 1.0 mass chain equivalent in the region A>=250 will be evaluated.

**TUNL --** Publish evaluations for A = 5, 6, and 7 and submit results for inclusion in ENSDF.
Evaluate masses 8, 9 and 10.
Prepare ENSDF files for A = 8 through 13.

D. Ground and Metastable State Properties

This is the evaluation of data for the Nuclear Wallet Cards.

**Deliverables:**
NNDC will include the data revisions in the NuDat and ENSDF databases.

E. Radioactive Decay Data Evaluation

Decay data for nuclides of importance for metrology are evaluated in an international collaboration. When complete, these evaluations are entered into the ENSDF format and merged into the ENSDF database in the U.S.

**Deliverables:**
**LBNL --** Decay data sets for 7 nuclides of astrophysical interested will be evaluated.
Adopted and decay data sets for 4 nuclides will be coded into ENSDF format.
Host a training session for new evaluators organized jointly with INEEL.

**Idaho --** Decay data sets for 5 nuclides will be evaluated.

F. Thermal Capture Gamma Data Evaluation

This work is being performed by LBNL as part of an IAEA Coordinated Research Project entitled, "Prompt Gamma Activation Analysis." The specific task is to evaluate thermal and cold $(n,\gamma)$ data sets for stable nuclei.

**Deliverables:**
Thermal neutron capture gamma data sets for Z < 22 will be submitted for inclusion in ENSDF.

G. Entering Endt Data into ENSDF

Evaluations performed by the Utrecht group for A = 21 through A = 44 are published in Nuclear Physics but not coded in the ENSDF format. LBNL is entering reaction data sets from the 1998 update for A = 21 through A = 39 into the ENSDF format.

**Deliverables:**

Data sets for mass 21 through 39 will be submitted for inclusion in ENSDF.

H. ENSDF Physics and Checking Codes

The NNDC maintains ENSDF checking and physics programs on behalf of the national and international evaluator networks. Only maintenance and upgrades for format changes are planned.

# VI. Nuclear Reaction Physics

A. Experimental Data Compilation

The NNDC as part of a larger international cooperation has responsibility for compiling experimental nuclear reaction data that have been produced in the U.S. and Canada.

Incident neutron reactions have been well covered historically. NNDC thus concentrates on new measurements only.

Incident charged particle data have not been completely compiled in the past. NNDC is compiling new charged-particle measurements. However, because of emerging needs such as astrophysics, the NNDC is attempting to compile older data. Hence, there is a larger staff commitment to compiling this type of data.

NNDC is responsible for maintaining the manuals describing the EXFOR format and the methods for compiling different kinds of data.

**Deliverables:**

**NNDC --** Compile data from 120 charged-particle reaction publications.
Compile data from 30 neutron reaction publications.
A manual section on polarization data will be completed.

B. Compilation of RHIC and TJNAF Data

For several years, the NNDC has maintained a small pilot project to investigate the compilation of high-energy data measured on the BNL AGS. With the start up of the RHIC facility coming in FY2000, it is timely to determine whether there is enough support in the RHIC community to begin a long-term compilation activity and to determine what physical quantities measured experimentally need to be archived.

C. ENDF Manuals and Documentation

NNDC is responsible for maintaining the format and procedures manual for the ENDF system. We also produce the documentation supporting the contents of the ENDF/B library.

**Deliverables:**

The ENDF format manual will be updated and an electronic version placed on the WWW.
The ENDF summary documentation will be updated and an electronic version placed on the WWW.

D. ENDF Evaluations

Evaluated nuclear reaction data, for applications and for basic science needs, are stored in the ENDF database, which is maintained by BNL. As chair of the CSEWG evaluation committee, LANL staff works with BNL to insure quality control, particularly for new evaluations. New evaluations funded primarily from other sources are prepared for archival in the ENDF library.

**Deliverables:**

**LANL --** Work with BNL to issue Release VII of ENDF/B-VI.
Submit new Hg evaluations for ENDF, important for ORNL Spallation Neutron Source design.
Submit additional evaluations up to 150 MeV (e.g. bismuth) for ENDF.
Submit new silicon evaluation, guided by recent LANSCE measurements, to ENDF, important for single-event-upset calculations in microelectronics.

E. Nuclear Reaction Standards

Nearly all nuclear reaction data measurements are made relative to some reaction standard such as the hydrogen elastic cross section. Maintaining accurate current values for the standard cross sections is the objective of this task. The task can be accomplished only through international cooperation. The Nuclear Energy Agency is the umbrella organization for completing the project to update these recommended data. The IAEA is planning to initiate a Coordinated Research Program in support of this activity.

**NIST --** Coordinate the international standards activity. Determine the methodology for producing the new standards evaluation. Review existing experimental data and recommend new measurements as needed. Collaborate with Ohio University and LANL in the measurement of hydrogen elastic angular distributions. Publish an article on the hydrogen angular distribution measurements at 10 MeV neutron energy.

F. Nuclear Model Development

This task covers activities such as development and validation of nuclear reaction models used for prediction of nuclear reaction cross sections. The LANL code development work will be coordinated with the proposed LLNL work. The collaboration will include inter-comparison of results, validation of model with experimental data and development of new physics modules. The TUNL pre-compound code will be incorporated into the LANL code. Measurements made by ANL and other measurements made with DOE low-energy physics funds (e.g., Grimes, Haight, Becker and others) will play a crucial role in the validation of the models in these computer codes.

**ANL --** Perform neutron activation measurements in the energy range from 16 to 21 MeV to provide an extensive database for use in validating pre-compound nucleus modeling. This work is done in collaboration with IRRM, Geel, and Belgium at no cost to DOE other than salary and travel.

**Deliverables:**

Submit for publication an article on the nuclear model analysis of data previously acquired and published in this activity.

**LANL --** Nuclear reaction theory calculations have played a crucial role in the evaluation of nuclear data, and will continue to play an important part in future evaluations due to the decrease in operating experimental facilities throughout the world. The LANL GNASH code has proved to be an important tool, and we will develop a new version of this code to provide a state-of-the-art capability to predict reaction cross sections. This task also involves a close collaboration with experimentalists at LANSCE (R.C. Haight, J.A. Becker, S.M. Grimes) to interpret new measurements using the GEANIE γ-ray detector, as well as (n,charged-particle) data, resulting in advances in our understanding of nuclear reaction mechanisms, as well as improvements in our modeling codes.

**Deliverables:**

Produce first working version of McGNASH, our improved version of the GNASH Hauser-Feshbach code, using Fortran90 and modern coding practices, with numerous improved physics packages, particularly: level densities, preequilbrium reactions, transmission coefficients, and γ-ray strength functions. Include a Monte-Carlo option. (Note, this is highly leveraged with support from DOE/DP). Calculate and interpret γ-ray reactions measured with GEANIE at LANSCE, including n+$^{112}$Sn reactions producing far-from-stability products, and reactions in competition with fission. Study level densities, a crucial input in nuclear model calculations, using (n,z) measurements by Haight at LANSCE, and publish work on isospin and level densities in n+Si reactions.

**LLNL --** Develop a regional optical model potential for the actinides. Develop a platform independent Hauser-Feshbach calculation code.

**Deliverables:**

Complete analysis of actinide optical model parameters and publish results.
Complete programming of Hauser-Feshbach code and begin testing.

**TUNL --** Development of pre-compound nuclear reaction models. Improvement and benchmarking of the computer code PRECO. Extend code validity to higher energies for (n,n) reactions.

**Deliverables:**

Complete journal article on surface and collective effects.
Prepare a new release of PRECO code with a detailed user manual.

G. Evaluation of Data Needed for Astrophysics

The objective of this activity is to support the nuclear data needs of the increasingly sophisticated nuclear astrophysics universe modeling. The Astrophysics Task Force of the

USNDP, presently chaired by Michael Smith (ORNL) plans, initiates and implements cooperative nuclear data evaluation activities, which involve the nuclear data and the nuclear astrophysics communities.

**ANL --** Compile information on $^{31}P(p,\gamma)$ reactions. Evaluate resonance parameters for $^{31}P(p,\gamma)$ and $^{31}P(p,\alpha)$ reactions and determine their uncertainties. Search by indirect means for low-lying resonances for these reactions. Investigate direct reaction component and calculate Hauser-Feshbach contributions for proton energies above 2 MeV. Prepare an evaluation for these two reactions. This work is done in collaboration with Hiram College.

**Deliverables:**

An ANL report documenting the compiled experimental data.
File of evaluated data for these two reactions in ENDF format with appropriate documentation.

**BNL --** The incoming deputy head of the NNDC is an expert in evaluating nuclear reaction data with emphasis on incident energies above 10 MeV. The NNDC will build on this expertise to re-establish this evaluation capability at the NNDC. A new postdoc position will be established to initiate expanded support of nuclear astrophysics. One half of this effort will be devoted to evaluation of nuclear data for astrophysics. The new staff member will be trained in data evaluation. The selection of data to be evaluated will be made in consultation with the Nuclear Astrophysics Steering Committee.

**LANL --** Participate in USNDP effort to develop high-quality data for astrophysics calculations of nucleosynthesis. Make new calculated and evaluated results available to the wider astrophysics research community via the USNDP Dissemination Working Group.

**Deliverables:**

Resolve puzzle surrounding the $^{12}C(\alpha,\gamma)$ E1 and E2 capture at stellar energies to determine impact of this crucial reaction on helium burning in red giants, using R-matrix methods.
Analyze n-p capture, as well as other processes important in Big-Bang nucleosynthesis.
Initiate analysis to predict the $^{7}Be(p,\gamma)^{8}B$ cross section, for the solar neutrino problem.
Continue to contribute to the TUNL Energy Levels of Light Nuclei (A=5-10) effort.
Use Hauser-Feshbach methods to calculate photonuclear data important in nucleosynthesis.
Compute fission barriers using microscopic-macroscopic model for r-process termination.

**ORNL --** Evaluate capture reactions on radioactive proton-rich nuclei which are important for element synthesis and energy generation in stellar explosions. Evaluate capture reactions important for understanding Red Giant Stars. Evaluate reactions important for nuclear burning in the interior of the sun.

**Deliverables:**

An evaluated data file in ENDF format for $^{18}F(p,\alpha)$ and $(p,\gamma)$ reactions.
An evaluated data file in ENDF format for $^{17}O(p,\alpha)$ and $(p,\gamma)$ reactions.

H. Reaction Data for RIB Target Design

Radioactive Ion Beam facility design needs high-quality nuclear reaction data for target design, and facility design. LANL works with ORNL and ANL researchers to provide key reaction cross sections, using theory calculations and measurements to evaluate the data.

**Deliverables:**

Study theoretical and phenomenological methods for predicting production cross sections of neutron-rich products of fission reactions for a future database of fission products in n+U RIB production experiments.
Develop nuclear reaction model code tools for improved predictions of RIB cross sections including isospin dependence in optical models for nuclei with large isospin, and improvements in fission theory for predicting neutron-rich nuclides.
Guide/support RIB researchers at ORNL, ANL, and LBNL, in the use of the Los Alamos CINDER/LAHET code for predictions of radioactive products in RIB facilities.

## Funding Sources Outside the Nuclear Data Program

The information here in not complete. The information was not required but is included here to show some examples of related external funding for those organizations that are mostly funded by the US Nuclear Data program.

**BNL --** Produce computer-generated photoready copy for the Nuclear Data Sheets. Participate in an SBIR awarded to Scientific Digital Visions.

**LBNL --** Compilation of experimental data sets for XUNDL by a student from Westmont College. Collaboration with University of Lund on Isotope Explorer and WWW Table of Radioactive Isotopes.

**McMaster --** 0.5 FTE support from the Canadian research agency to evaluate A-chains/nuclides for ENSDF and to train/supervise summer students for compilation of experimental nuclear data for XUNDL.

**NIST --** The Department of Commerce through NIST supports the standards activity.

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# USNDP Level of Effort for October 1999 through September 2000

| | ANL | BNL | | Idaho | LANL | LBNL | LLNL |
|---|---|---|---|---|---|---|---|
| | | Sci/Pro | Support | | | | |
| | | | | | | | |
| **I. NNDC Facility Operation** | **0.00** | **1.40** | **1.35** | **0.00** | **0.00** | **0.00** | **0.00** |
| Management | | 0.45 | | | | | |
| Secretarial/Administrative Support | | | 1.00 | | | | |
| Library | | | 0.35 | | | | |
| Computer Operation | | 0.70 | | | | | |
| NT Server Operation | | 0.25 | | | | | |
| | | | | | | | |
| **II. Coordination** | **0.00** | **0.55** | **0.00** | **0.10** | **0.30** | **0.30** | **0.00** |
| National Coordination | | 0.35 | | 0.05 | 0.1 | 0.3 | |
| International Coordination | | 0.20 | | 0.05 | 0.2 | | |
| | | | | | | | |
| **III. Nuclear Physics Databases** | **0.00** | **2.65** | **1.50** | **0.00** | **0.00** | **0.00** | **0.00** |
| Nuclear Science References (NSR) | | 0.15 | 0.75 | | | | |
| Experimental Nuclear Structure Data (XUNDL) | | 0.10 | | | | | |
| Evaluated Nuclear Structure Data (ENSDF) | | 0.30 | 0.60 | | | | |
| Numerical Nuclear Data (NuDat) | | 0.10 | | | | | |
| Reaction Data Bibliography (CINDA) | | 0.25 | 0.05 | | | | |
| Experimental Reaction Data (CSISRS) | | 0.05 | 0.10 | | | | |
| Evaluated Nuclear Data File (ENDF) | | 0.25 | | | | | |
| Database Software Maintenance | | 0.65 | | | | | |
| Future Database Systems | | 0.80 | | | | | |
| | | | | | | | |
| **IV. Information Dissemination** | **0.00** | **1.60** | **0.50** | **0.00** | **0.10** | **1.00** | **0.00** |
| Maintenance of Remote Access to USNDP Data | | 0.25 | | | | | |
| Telnet Service | | *0.05* | | | | | |
| WWW Service | | *0.20* | | | | | |
| Customer Services | | 0.15 | 0.45 | | | | |
| Web Site Maintenance | | 0.15 | 0.05 | | 0.10 | 0.40 | |
| Common ENSDF Web Interface | | 0.10 | | | | 0.60 | |
| Interface to Isotope Explorer JAVA Applet | | *0.10* | | | | | |
| MacNuclide Project | | | | | | | |
| Isotope Explorer Project | | | | | | *0.60* | |
| APS Link to NNDC Experimental databases | | 0.65 | | | | | |
| Nuclear Reaction Data on a CD-ROM | | 0.05 | | | | | |
| Nuclear Wallet Cards, 2000 edition | | 0.20 | | | | | |
| Windows Version of PC-NuDat | | 0.05 | | | | | |

# USNDP Level of Effort for October 1999 through September 2000

| | McMaster | NIST | ORNL | | SJSU | TUNL | Program Total | |
|---|---|---|---|---|---|---|---|---|
| | | | Sci/Pro | Support | | | Sci/Pro | Support |
| | | | | | | | | |
| **I. NNDC Facility Operation** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **1.40** | **1.35** |
| Management | | | | | | | 0.45 | 0.00 |
| Secretarial/Administrative Support | | | | | | | 0.00 | 1.00 |
| Library | | | | | | | 0.00 | 0.35 |
| Computer Operation | | | | | | | 0.70 | 0.00 |
| NT Server Operation | | | | | | | 0.25 | 0.00 |
| | | | | | | | | |
| **II. Coordination** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **1.25** | **0.00** |
| National Coordination | | | | | | | 0.80 | 0.00 |
| International Coordination | | | | | | | 0.45 | 0.00 |
| | | | | | | | | |
| **III. Nuclear Physics Databases** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **2.65** | **1.50** |
| Nuclear Science References (NSR) | | | | | | | 0.15 | 0.75 |
| Experimental Nuclear Structure Data (XUNDL) | | | | | | | 0.10 | 0.00 |
| Evaluated Nuclear Structure Data (ENSDF) | | | | | | | 0.30 | 0.60 |
| Numerical Nuclear Data (NuDat) | | | | | | | 0.10 | 0.00 |
| Reaction Data Bibliography (CINDA) | | | | | | | 0.25 | 0.05 |
| Experimental Reaction Data (CSISRS) | | | | | | | 0.05 | 0.10 |
| Evaluated Nuclear Data File (ENDF) | | | | | | | 0.25 | 0.00 |
| Database Software Maintenance | | | | | | | 0.65 | 0.00 |
| Future Database Systems | | | | | | | 0.80 | 0.00 |
| | | | | | | | | |
| **IV. Information Dissemination** | **0.00** | **0.00** | **0.10** | **0.00** | **1.20** | **1.40** | **5.40** | **0.50** |
| Maintenance of Remote Access to USNDP Data | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 |
| Telnet Service | | | | | | | *0.05* | *0.00* |
| WWW Service | | | | | | | *0.20* | *0.00* |
| Customer Services | | | | | | | 0.15 | 0.45 |
| Web Site Maintenance | | | 0.10 | | | 1.40 | 2.15 | 0.05 |
| Common ENSDF Web Interface | | | 0.00 | 0.00 | 1.20 | 0.00 | 1.90 | 0.00 |
| Interface to Isotope Explorer JAVA Applet | | | | | | | *0.10* | *0.00* |
| MacNuclide Project | | | | | *1.20* | | *1.20* | *0.00* |
| Isotope Explorer Project | | | | | | | *0.60* | *0.00* |
| APS Link to NNDC Experimental databases | | | | | | | 0.65 | 0.00 |
| Nuclear Reaction Data on a CD-ROM | | | | | | | 0.05 | 0.00 |
| Nuclear Wallet Cards, 2000 edition | | | | | | | 0.20 | 0.00 |
| Windows Version of PC-NuDat | | | | | | | 0.05 | 0.00 |

# USNDP Level of Effort for October 1999 through September 2000

| | ANL | BNL | | Idaho | LANL | LBNL | LLNL |
|---|---|---|---|---|---|---|---|
| | | Sci/Pro | Support | | | | |
| | | | | | | | |
| **V. Nuclear Structure Physics** | **0.00** | **2.50** | | **0.30** | **0.00** | **2.30** | **0.00** |
| NSR Abstract Preparation | | 0.50 | | | | | |
| Compilation of Experimental Structure Data | | | | | | | |
| Evaluation of data for ENSDF | | 1.80 | | 0.30 | | 2.30 | |
| *Mass Chains and Nuclides* | | *1.70* | | *0.25* | | *1.55* | |
| *Ground and Metastable State Properties* | | *0.10* | | | | | |
| *Radioactive Decay Data Evaluation* | | | | *0.05* | | *0.25* | |
| *Thermal Capture Gamma Data Evaluation* | | | | | | *0.30* | |
| *Entering Endt Data into ENSDF* | | | | | | *0.20* | |
| ENSDF Physics and Checking Codes | | 0.20 | | | | | |
| | | | | | | | |
| **VI. Nuclear Reaction Physics** | **1.10** | **1.70** | **0.25** | **0.00** | **1.10** | **0.00** | **0.40** |
| Experimental Data Compilation | 0.00 | 0.65 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Neutron Data* | | *0.10* | *0.25* | | | | |
| *Charged Particle Data* | | *0.50* | | | | | |
| *EXFOR Manuals* | | *0.05* | | | | | |
| Compilation of RHIC and TJNAF Data | | 0.15 | | | | | |
| ENDF Manuals and Documentation | | 0.05 | | | | | |
| ENDF Evaluations | | | | | 0.10 | | |
| Nuclear Reaction Standards | | | | | | | |
| Nuclear Model Development | 0.40 | | | | 0.40 | | 0.40 |
| Evaluation of Data Needed for Astrophysics | 0.70 | 0.85 | | | 0.40 | | |
| Reaction Data for RIB Target Design | | | | | 0.20 | | |
| | | | | | | | |
| **DOE/Science Nuclear Data Funded Staff** | **1.10** | **10.40** | **3.60** | **0.40** | **1.50** | **3.60** | **0.40** |
| | | | | | | | |
| **Staff Supported by Other Funding** | | **0.40** | **0.40** | | | **1.00** | |
| | | | | | | | |
| **TOTAL STAFF** | **1.10** | **10.80** | **4.00** | **0.40** | **1.50** | **4.60** | **0.40** |

# USNDP Level of Effort for October 1999 through September 2000

| | McMaster | NIST | ORNL | | SJSU | TUNL | Program Total | |
|---|---|---|---|---|---|---|---|---|
| | | | Sci/Pro | Support | | | Sci/Pro | Support |
| | | | | | | | | |
| **V. Nuclear Structure Physics** | **0.50** | **0.00** | **0.60** | **0.25** | **0.00** | **1.15** | **7.35** | **0.25** |
| NSR Abstract Preparation | | | | | | | 0.50 | 0.00 |
| Compilation of Experimental Structure Data | 0.05 | | 0.10 | | | | 0.15 | 0.00 |
| Evaluation of data for ENSDF | 0.45 | | 0.50 | 0.25 | 0.00 | 1.15 | 6.50 | 0.25 |
| *Mass Chains and Nuclides* | *0.45* | | *0.50* | *0.25* | | *1.15* | *5.60* | *0.25* |
| *Ground and Metastable State Properties* | | | | | | | *0.10* | *0.00* |
| *Radioactive Decay Data Evaluation* | | | | | | | *0.30* | *0.00* |
| *Thermal Capture Gamma Data Evaluation* | | | | | | | *0.30* | *0.00* |
| *Entering Endt Data into ENSDF* | | | | | | | *0.20* | *0.00* |
| ENSDF Physics and Checking Codes | | | | | | | 0.20 | 0.00 |
| | | | | | | | | |
| **VI. Nuclear Reaction Physics** | **0.00** | **0.20** | **0.40** | **0.00** | **0.00** | **0.40** | **5.30** | **0.25** |
| Experimental Data Compilation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.65 | 0.25 |
| *Neutron Data* | | | | | | | *0.10* | *0.25* |
| *Charged Particle Data* | | | | | | | *0.50* | *0.00* |
| *EXFOR Manuals* | | | | | | | *0.05* | *0.00* |
| Compilation of RHIC and TJNAF Data | | | | | | | 0.15 | 0.00 |
| ENDF Manuals and Documentation | | | | | | | 0.05 | 0.00 |
| ENDF Evaluations | | | | | | | 0.10 | 0.00 |
| Nuclear Reaction Standards | | 0.20 | | | | | 0.20 | 0.00 |
| Nuclear Model Development | | | | | | 0.40 | 1.60 | 0.00 |
| Evaluation of Data Needed for Astrophysics | | | 0.40 | | | | 2.35 | 0.00 |
| Reaction Data for RIB Target Design | | | | | | | 0.20 | 0.00 |
| | | | | | | | | |
| **DOE/Science Funded Staff** | **0.50** | **0.20** | **1.10** | **0.25** | **1.20** | **2.95** | **23.35** | **3.85** |
| | | | | | | | | |
| **Staff Supported by Other Funding** | **0.50** | **0.80** | **0.00** | **0.00** | **0.00** | **0.00** | **2.70** | **0.40** |
| | | | | | | | | |
| **TOTAL STAFF** | **1.00** | **1.00** | **1.10** | **0.25** | **1.20** | **2.95** | **26.05** | **4.25** |

# Tasks for Consideration If Data Program Funding Is Increased

**Argonne National Laboratory**

1. Evaluation of Sulfur Data .25 FTE
   Accelerate training of post doc in nuclear reaction data evaluation and evaluate the (p,$\gamma$) and (p,$\alpha$) reactions for the stable sulfur isotopes which are important for astrophysical processes.

**Brookhaven National Laboratory**

1. Compilation of Relativistic Heavy Ion and Electron Data .5 FTE
   Support a post doc from the RHIC facility to assist in determining what kind of data needs to be archived and to begin compiling available prototypical data.
2. ENSDAT Enhancements .5 FTE
   ENSDAT is a user program, which provides Nuclear Data Sheets style output from ENSDF data files. HTML output and/or Java applets are needed to enhance usefulness.
3. NSDD Evaluator's Corner .5 FTE
   Provide direct access to the latest NSDD evaluator support programs by permitting remote operation on the NNDC computer using a WWW interface.
4. RADLIST upgrades .5 FTE
   RADLIST is the USNDP standard program for generating radiation tables from ENSDF. Effort is required to prepare current in-house version for general release, migrate program to Windows, and incorporate improvements made in France.

**Idaho**

Evaluate one additional priority nuclide, probably $^{156}$Gd.

**Los Alamos National Laboratory**

Complete a database of proton-induced cross sections and work with BNL to make this database available electronically. This database will be particularly useful for RIB target design.

**Lawrence Berkeley National Laboratory**

1. ENSDF Evaluations .5 FTE
   Increase current part-time ENSDF evaluator to full-time in order to increase the number of mass chain and nuclide evaluations performed.
2. Nuclear Astrophysics .5 FTE
   Hire a post-doc to perform nuclear structure and decay data evaluations of interest to nuclear astrophysics.

**Lawrence Livermore National Laboratory**

We propose to calculate proton- and neutron-induced reactions on nuclei near the N=50 closed shell that are important for astrophysics, using Hauser-Feshbach calculations with parameters specifically tuned to this mass region. We could start this with minimal resources in FY00 (about 0.1 FTE) but would have to follow this with adequate resources to hire a post doc for 2 years to complete the project.

**McMaster University**

Compile current nuclear structure experiments for low-spin physics for XUNDL.

**National Institute of Science and Technology**

If funding were increased at NIST, the time scheduled for completion of the nuclear data program tasks will be shortened. New activities using the special capabilities of NIST such as the Neutron Interferometry Facility or the new reactor facility that provides a monochromatic beam could be initiated to provide additional experimental data for the standards evaluation.

**Oak Ridge National Laboratory**

Additional effort would be devoted to evaluation of reaction data needed for nuclear astrophysics.

**San Jose State University**

Additional effort will be devoted to creating applets from MacNuclide that can be used in WWW pages.

**Triangle Universities National Laboratory**

TUNL would add decay and reaction information to the Update Lists provided on the TUNL website. In response to requests from the atomic physics ion beam analysis (IBA) community, TUNL could begin providing aids for interpreting A = 3-20 level diagrams on the TUNL website and links to references to cross section data as well as tabular data themselves for reactions of interest to IBA workers.

The nuclear modeling task is a continuous model and code development program. A 10% increase in funding would accelerate the pace of progress toward the long-range goals and increase the chances that significant progress could be made on the next phase of the work: benchmarking the model and code for (N,N) reactions at 45 to 100 MeV and resolving two open questions of physics in this domain.

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# Impact Of A Ten Percent Reduction In Funding

**Argonne National Laboratory**

The major impact of a 10% reduction in funds for FY2000 will be to reduce the effort level on the Astrophysics related tasks that constitute the major portion of the ANL work performed with nuclear data program funds. The result will be to extend the time required to complete projected tasks. The Nuclear Modeling task is a smaller part of the effort and involves international commitments, which cannot be modified on a short time scale. An additional longer-term consequence of a reduction in funding would be to negatively impact on Argonne's current plan to train a post doc to work independently on nuclear data activities so that the individual could eventually be hired to a staff position at ANL with the ability to make significant contributions to the U.S. Nuclear Data Program in the future.

**Brookhaven National Laboratory**

A 10% reduction in the level of funding for FY2000 for BNL will result in the termination of new initiatives involving the evaluation of nuclear data for astrophysics and the compilation of RHIC experimental data. If the funding level is not restored in escalated dollars within two years, one staff member will have to be terminated.

**Idaho**

One priority nuclide evaluation will not be carried out if the FY2000 funding is reduced by 10%.

**Los Alamos National Laboratory**

Effort would be reduced in the evaluation of nuclear data for astrophysics and in the theoretical interpretation of GEANIE experimental measurement results if a 10% reduction in FY2000 funding should occur.

**Lawrence Berkeley National Laboratory**

A 10% reduction in level of funding will result in a reduction in the amount of evaluation of radioactivity data for nuclear astrophysics. Further staff reductions are also likely.

**Lawrence Livermore National Laboratory**

We would stretch out our two proposed activities to accommodate a cut. Specifically, this would delay completion and publication of the optical model work in the actinides.

**McMaster University**

The compilation of experimental data for the XUNDL file will be curtailed if the funding level is reduced by 10%.

**National Institute of Science and Technology**

The time to complete scheduled tasks will be increased. The delay in completion of the new neutron standards measurements will result in a delay in completion of the standards evaluation that is needed for the next version of the evaluated nuclear data files.

**Oak Ridge National Laboratory**

A 10% reduction in funds will result in the elimination of the technical assistance, which would delay the completion of the evaluation work.

**San Jose State University**

No reduction in deliverables in the first year would occur as a result of a 10% reduction in funds. Initial work on projects with deliverables in FY2001 will be postponed causing a delay in completion of work scheduled for that year.

**Triangle Universities National Laboratory**

A 10 % reduction in funding would impact the dissemination efforts as follows:

(a) The number of new PDF documents based on the most recent review (TUNL or Fay Ajzenberg-Selove) to be provided on the TUNL website would be reduced. Most probably the PDF documents for A = 14, 15 would not be posted in FY 2000.

(b) Update lists for A = 14 and 15 would not be completed in FY 2000.

A 10 % reduction in funding would impact the nuclear model development efforts as follows:

As this is a continuous model and code development program, a 10% reduction in funding would slow the pace of progress toward the long-range goals and reduce the chances that the next formal release of the code will be available in FY 2000. Because of fixed "overhead" time commitments (seminars, report-writing keeping up on the literature) the impact would be greater than the nominal 10%.

# Argonne National Laboratory

Program Administration


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Program Technical Overview

The program consists of two major projects; each of these falls under the Reaction component of the DOE/SC-DNP nuclear data activity: i) compilation and evaluation of nuclear reaction data for astrophysics; ii) nuclear reaction data studies that contribute to improvement of pre-compound nuclear models used in obtaining cross-sections needed for such contemporary applications as RIB production. This work involves collaborations with Hiram College, Ohio, the Institute for Reference Materials and Measurements, Geel, Belgium, and Oak Ridge National Laboratory.

Detailed Program Technical Description

Task #1: Nuclear Data for Astrophysics

The objective of this project is ultimately to generate greatly improved evaluations of reaction cross sections and stellar reaction rates for hydrogen-induced reactions on stable nuclei in the mass range A = 30-50. This work complements ongoing studies of nuclear data for astrophysics off the line of stability (using RIB techniques) in progress at ORNL (funded by DOE/SC-DNP) and elsewhere. The ANL activity is conducted in collaboration with Prof. Laura Van Wormer at Hiram College (also funded by DOE/SC-DNP). Proton reactions in this mass range - in particular (p,gamma) and (p,alpha) - are considered by nuclear astrophysicists to be essential for understanding explosive (high temperature) nucleo-synthesis in Novae, Super-novae, and X-ray Bursters. The energy region of interest is from zero to about 5 MeV. Existing libraries of reaction rates used in contemporary stellar evolution calculations are largely based on Hauser-Feshbach (H-F) calculations which - in many cases - are seriously deficient due to the limiting

assumptions, e.g., the continuum level-density assumption. In order to obtain improved evaluations it is necessary to: i) compile information on discrete-resonance energies, strengths, and quantum numbers; ii) seek for "missing" resonances through indirect means such as transfer reactions, properties of isobaric analogue nuclei, etc.; iii) estimate the direct (non-resonant) proton-capture strength; iv) estimate possible reaction yields at very low proton energies due to existing bound-states near the proton binding energy; and, v) perform the best possible H-F calculations at incident proton energies above 2 MeV - a region where levels tend to overlap strongly and a discrete-level approach no longer works. The approach being used in the ANL/Hiram College collaboration is to first compile the available information on the discrete resonances - since they tend to dominate the reaction rates in this mass range - and then address the issue of providing corrections due to missing resonances, direct capture, and H-F contributions (at the higher proton energies). In addition, this evaluation project will address the issue of cross section uncertainties in the individual evaluations since such information is beginning to be included in contemporary astrophysics network calculations.

Task #2: Nuclear Data for Nuclear Modeling

Nuclear models are needed to calculate reaction cross sections in situations where experimental data are difficult to acquire. The pre-compound model for nuclear reactions has proved to be very useful - in the range from several MeV up to several hundred MeV - for this purpose in a number of applied areas, e.g., ATP, ATW, medical (proton and neutron radio-therapy), and fusion. In basic science this model is proving useful for computing the yields of RIB species from spallation targets. However, the pre-compound model requires accurate knowledge of parameters for each open reaction channel. Often this information is missing and blind inter-comparison exercises of nuclear modeling without prior agreement on the choice of parameters can lead to widely discrepant results. The goal of this work is to contribute to development of a set of systematics for this parameterization that can be applied to nuclear reaction cross section calculations. However, this can be accomplished only through extensive comparisons with experimental data when the latter can be measured. The ANL Nuclear Data Program is collaborating with the Institute for Reference Materials and Measurements (IRMM) of the European Commission, Geel, Belgium, in a project of measuring a large number of neutron activation reactions at energies well into the region where the pre-compound model is important (above 15 MeV). Experiments and data analysis are being carried out by ANL personnel in collaboration with IRMM staff, graduate students, and post docs. Results from this work are published in Physical Review (1998) and Nuclear Science and Engineering (accepted in 1999). The advantage to DOE/SC-DNP of this project is a significant leveraging of resources. Experiments can be carried out at a well-equipped accelerator facility in Belgium at no direct cost to DOE beyond staff effort and some travel expenses. Furthermore, staff and student personnel at the Belgian laboratory are contributing to the acquisition of data and its analysis in these experiments.

Work Plan for FY2000

The following tasks and component sub-tasks - and corresponding anticipated deliverables - are scheduled for the period in question:

Task #1: Nuclear Data for Astrophysics

Sub-task 1.a --- Finish compilation of information from the literature on the P-31(p,gamma) reaction. This work complements a similar already completed and documented activity on the P-31(p,alpha) reaction (Report ANL/NDM-144). [Work to be carried out by Staff].

*Deliverable*: Documentation in an ANL/NDM series report as well as in EXFOR format files to be transmitted to the NNDC at BNL

Sub-task 1.b --- Compile available information from the literature for the S-33,34,36(p,gamma) reactions. This work will complement a similar already completed and documented activity for the S-32(p,gamma) reaction (Report ANL/NDM-143). [Work to be carried out by Staff.]

*Deliverable*: Documentation in an ANL/NDM series report (a single report should suffice since these are minor sulfur isotopes) and in EXFOR format files to be transmitted to NNDC at BNL.

Sub-task 1.c --- An evaluation of the parameters for all known resonances in the P-31(p,gamma) and (p,alpha) reactions will be completed - including error estimates. In each case, the reaction cross-section contributions derived from these resonances constitute the major reaction strength for most astrophysical applications. [This work will be done mainly by a collaborator at Hiram College.]

*Deliverable*: To be determined. It is intended that this information eventually be incorporated in a comprehensive journal paper on evaluated cross sections and stellar reaction rates for the P-31(p,gamma) and (p,alpha) reactions when all aspects of the evaluation are completed.

Sub-task 1.d --- A detailed search will be performed to identify through indirect means any low-lying unbound resonances in the P-31(p,gamma) and (p,alpha) reactions that could strongly influence the reaction rates at low stellar temperatures. The corresponding resonance parameters will be estimated. A similar search for the effect of weakly bound resonances will be performed for these same two reactions. [Work to be carried out by Staff.]

*Deliverable*: To be determined. It depends on what the indicated search uncovers. It is intended that this information eventually be incorporated in a comprehensive journal paper on evaluated cross sections and stellar reaction rates for the P-31(p,gamma) and (p,alpha) reactions when all aspects of the evaluation are completed.

Sub-task 1.e --- A methodology for calculating the direct proton capture contributions to the (p,gamma) and (p,alpha) reaction cross sections in the mass A = 30-50 range will be sought and implemented at ANL. This work will involve acquisition of suitable computer codes and determination of appropriate parameterizations. The intent is to test this methodology first on the P-31(p,gamma) and (p,alpha) reactions. [Work to be performed by Post-doc.]

*Deliverable*: To be determined. It is intended that this information eventually be incorporated in a comprehensive journal paper on evaluated cross sections and stellar reaction rates for the P-31(p,gamma) and (p,alpha) reactions when all aspects of the evaluation are completed.

Sub-task 1.f --- Hauser-Feshbach calculations will either be performed (or the results from such calculations by other individuals will acquired through collaboration) for the P-31(p,gamma) and (p,alpha) reactions in order to define the cross sections for proton energies in the range 2-5 MeV. [This work will be done mainly by a collaborator at Hiram College.]

*Deliverable*: To be determined. It is intended that this information eventually be incorporated in a comprehensive journal paper on evaluated cross sections and stellar reaction rates for the P-31(p,gamma) and (p,alpha) reactions when all aspects of the evaluation are completed.

Sub-task 1.g --- Work will begin on preparation of a journal article to report on comprehensive evaluations of cross sections for the P-31(p,gamma) and (p,alpha) reactions, as mentioned above. [Work to be carried out by Staff, Post-doc, and collaborator from Hiram College.]

*Deliverable*: Draft manuscript – probably incomplete pending status of completion of the work described in Sub-tasks 1.c through 1.f.

Sub-task 1.h --- ANL will collaborate with ORNL to establish the appropriate probability distribution functions and Monte Carlo sampling schemes to use in propagating reaction-rate uncertainties in stellar nucleo-synthesis network calculations. This activity is already in progress during FY1999 and will continue in FY2000. [Work to be carried out by Staff.]

*Deliverable*: It is expected that the results of this work will be reported in a journal article to be prepared jointly with the ORNL nuclear astrophysics group.

Task #2: Nuclear Data for Nuclear Modeling

Sub-task 2.a --- Additional measurements will be performed at IRMM in Belgium for neutron activation reactions involving relatively short-lived reaction products. The energy range will be 16-21 MeV. Data analysis will continue for experimental results obtained

during this run period and similar data acquired earlier but not yet completely processed. [Work to be carried out by Staff.]

*Deliverable*: An experiment is scheduled to be performed in Belgium during late September and early October 1999. Timely reports on the outcome of this investigation will be presented to the USNDP Coordinating Committee.

Sub-task 2-b --- Previously published experimental neutron activation cross section results from the Belgian collaboration will be analyzed using nuclear reaction models. The impact of this work on the parameterization of these models will be examined. [Work to be performed by Post-doc.]

*Deliverable*: A manuscript reporting on the results of this investigation will be prepared.

Travel and Miscellaneous Expenses

Travel is an important necessity for the pursuit of this research program. Some foreign travel – mainly to Belgium – is required to participate in existing fruitful research collaborations. The Principal Investigator has been invited to participate - as a U.S. representative - in the activities of the recently re-organized Nuclear Energy Agency Working Party for Evaluation Cooperation. This committee coordinates international nuclear data activities and holds an annual meeting that may take place in either the U.S., Europe, or Japan. Domestic travel is essential to fulfill obligations to the U.S. Nuclear Data Program. The Principal Investigator is a member of the USNDP Coordinating Committee. Miscellaneous expenses include such item computer supplies and software, publication costs, etc.

Impact of FY2000 Budget

The major long-term tasks and corresponding objectives of the Argonne nuclear data program will not be altered significantly by the proposed budget scenarios for FY2000 (-10%, Flat, +10%). However, the pace at which work can be accomplished on the various sub-tasks involved in this program will obviously be affected because the level of available effort that can be allocated to this work is budget sensitive. The program described above basically assumes the ‘Flat’ scenario. More specifically, the following table shows the proposed allocation of effort and dollar-cost budget items for each of the three scenarios:

Table: Budget Scenarios for the Argonne Nuclear Data Program

| Task | Effort Source | Budget Scenario -10% | Flat | +10% |
|---|---|---|---|---|
| Task #1 | Staff Effort | 0.45 | 0.50 | 0.50 |
| Task #1 | Post-doc Effort | 0.20 | 0.20 | 0.45 |
| Task #1 | Total Effort | 0.65 | 0.70 | 0.95 |
| Task #2 | Staff Effort | 0.20 | 0.20 | 0.20 |
| Task #2 | Post-doc Effort | 0.15 | 0.20 | 0.20 |
| Task #2 | Total Effort | 0.35 | 0.40 | 0.40 |
| Staff Total Effort | | 0.65 | 0.70 | 0.70 |
| Post-doc Total Effort | | 0.35 | 0.40 | 0.65 |
| Program Total Effort | | 1.00 | 1.10 | 1.35 |
| Travel & Misc. Expenses | | $10K | $15K | $15K |

Notes:

1. Task # 1 (Evaluation of Data Needed for Astrophysics); Task # 2 (Nuclear Model Development).
2. Effort given in FTE units and dollar-cost budget items are in units of $10,000.

From a programmatic point of view, it is evident that increased or reduced funding will impact mainly on the work activity for the Astrophysics related topics because they represent the major portion of the program. This is a near-term issue because it is anticipated that the Astrophysics related projects will continue to grow in the future on a relative basis. However, a major reduction of effort for the Nuclear Modeling topics at the present time seems unwise since the leverage achieved by preserving an existing carefully cultivated collaboration with IRMM in Belgium would be lost before the tangible benefits are fully realized. A reduced budget would also have a negative impact on program-related travel.

From a personnel point of view, it is evident from this table that increased funding would be used mainly to expand the near-term allocation of Argonne post doc effort to the U.S. Nuclear Data Program thereby resulting in accelerated training of the individual in question and an enhanced probability that this individual could be retained as Argonne Staff to work in a sustained manner on the U.S. Nuclear Data Program in the future. By the same token, a reduction in funding would impact negatively on Argonne's plan to properly train an already recruited post doc to work independently on nuclear data activities and to thus be able to eventually promote this individual to a Staff position with full capacity to contribute significantly to the U.S. Nuclear Data Program in the future.

# Brookhaven National Laboratory

The National Nuclear Data Center work plan served as the template for developing the program-wide plan. Since all of the NNDC input information is included in the work plan text and the effort table, the NNDC plan is not repeated here.

# FY2000 Plan for the Nuclear Sciences Program at Idaho
## Work Plan

Direct support of ENSDF (0.3 FTE)

Carry out evaluations of data for nuclides identified by NNDC as having high priority for evaluation.

Complete and submit $^{161}$Dy evaluation (a priority nuclide)

Complete and submit evaluations for all other A=161 nuclides

Complete evaluation of a priority nuclide (probably $^{156}$Er)

Review, as requested, one or two A-chain evaluations, or equivalent nuclides, from other laboratories

Administration in support of ENSDF system (0.10 FTE)

Coordinate US NDP Working Group on Nuclear Structure and Decay Data Evaluation
Coordinate Center reports and activities for meeting of US NDP
Coordinate U. S. Center reports and activities for meeting of the international evaluators' network sponsored by the International Atomic Energy Agency

Participate in subcommittee on A=21-44 evaluations chaired by Denis DeFrenne

Participate in development of revised guidelines for $J^{\pi}$ assignments as part of subcommittee chaired by Denis DeFrenne

Administer and participate in Decay Data Evaluation Project, DDEP (0.05 FTE)

Coordinate decay data evaluation efforts of the several evaluators

Assist in training three new evaluators from Spain and United Kingdom

Create ENSDF data sets for evaluations done by some non-ENSDF evaluators

Complete five decay data evaluations

Adjustment for 10% less funding
Will not carry out the second priority nuclide evaluation listed above

Adjustment for 10% more funding
Will carry out an additional priority nuclide evaluation (probably $^{156}$Gd)

# LANL Group T-2 FY2000 Work Plan for US Nuclear Data Program (USNDP)

| | Description | Effort (FTEs) |
|---|---|---|
| 1 | USNDP Reaction Working Group Organization | 0.1 |
| 2 | Nuclear Physics ENDF Database | 0.1 |
| 3 | Astrophysics Reaction Data | 0.4 |
| 4 | Reaction data for RIB Target Design | 0.2 |
| 5 | Model code development, and reaction theory studies at LANSCE and GEANIE | 0.4 |
| 6 | WWW Dissemination of nuclear data | 0.1 |
| 7 | International nuclear data cooperation | 0.2 |
| 8 | Publications | |
| | | Total=1.5 |

1. USNDP Reaction Working Group Organization (0.1 FTE)

Chair US Nuclear Data Program's Reaction Working Group, and help coordinate reaction data work at different labs to advance USNDP goals. Member of USNDP Steering Committee. Chair of Evaluation Committee of the Cross Section Evaluation Working Group.

Deliverables:

Prepare FY2000 Reaction Working Group Work Plan, with BNL, for review by DOE
Participate in USNDP Steering Committee meetings
Organize and chair CSEWG Evaluation Committee meeting at BNL, Nov 1999
Organize and chair Reaction Working Group meeting at USNDP meeting, LBNL, April 2000.

2. Nuclear Physics ENDF Database (0.1 FTE)

Evaluated nuclear reaction data, for applications and for basic science needs, are stored in the ENDF database, which is maintained by BNL. As chair of the CSEWG evaluation committee, work with BNL to insure quality control, particularly for new evaluations. We will also submit new evaluations listed below (funded primarily from other sources) for archival in ENDF/B-VI.

Deliverables:

Work with BNL to issue Release VII of ENDF/B-VI
Submit new Hg evaluations for ENDF, important for ORNL Spallation Neutron Source design.
Submit additional evaluations up to 150 MeV (e.g. bismuth) for ENDF
Submit new Si evaluation, guided by recent LANSCE measurements, to ENDF, important for detector design, and single-event-upset calculations in microelectronics.

3. Astrophysics Reaction Data (0.4 FTE)

Participate in USNDP effort to develop high-quality data for astrophysics calculations of nucleosynthesis. Make new calculated and evaluated results available to the wider astrophysics research community via the USNDP Dissemination Working Group.

Deliverables:

Resolve puzzle surrounding the $^{12}C(\alpha,\gamma)$ E1 and E2 capture at stellar energies to determine impact of this crucial reaction on helium burning in red giants, using R-matrix methods.
Analyze n-p capture, as well as other processes important in Big-Bang nucleosynthesis
Initiate analysis to predict the $^{7}Be(p,\gamma)^{8}B$ cross section, for the solar neutrino problem
Continue to contribute to the TUNL Energy Levels of Light Nuclei (A=5-10) effort

Use Hauser-Feshbach methods to calculate photonuclear data important in nucleosynthesis
Compute fission barriers using microscopic-macroscopic model for r-process termination

4. Reaction Data for RIB target design (0.2 FTE)

Radioactive Ion Beam facility design needs high-quality nuclear reaction data for target design, and facility design. We have worked with ORNL and ANL researchers to provide key reaction cross sections, using theory calculations and measurements to evaluate the data, and will continue to address their needs in the future.

Deliverables:

Study theoretical and phenomenological methods for predicting production cross sections of neutron-rich products in fission reactions, for a future database of fission products in n+U RIB production experiments

Develop nuclear reaction model code tools for improved predictions of RIB cross sections (see 5 below), including isospin dependence in optical models for nuclei with large isospin, and improvements in fission theory for predicting neutron-rich nuclides.

Guide/support RIB researchers at ORNL, ANL, and LBNL, into the use of the Los Alamos CINDER/LAHET code for predictions of radioactive products in RIB facilities.

5. Model code development, and reaction theory studies at LANSCE and GEANIE (0.4 FTE)

Nuclear reaction theory calculations have played a crucial role in the evaluation of nuclear data, and will continue to play an important part in future evaluations due to the decrease in operating experimental facilities throughout the world. The LANL GNASH code has proved to be an important tool, and we will develop a new version of this code to provide a state-of-the-art capability to predict reaction cross sections. This also involves a close collaboration with experimentalist at LANSCE (R.C. Haight, J.A. Becker, S.M. Grimes) to interpret new measurements using the GEANIE gamma-ray detector, as well as (n,charged-particle) data, resulting in advances in our understanding of nuclear reaction mechanisms, as well as improvements in our modeling codes.

Deliverables:

Produce first working version *of McGNASH*, our improved version of the *GNASH* Hauser-Feshbach code, using Fortran90 and modern coding practices, with numerous improved physics packages, particularly: level densities, preequilbrium reactions, transmission coefficients, and gamma-ray strength functions. Include a Monte-Carlo option. (Note, this is highly-leveraged with support from DOE/DP)

Calculate and interpret gamma-ray reactions measured with GEANIE at LANSCE, including n+$^{112}$Sn reactions producing far-from-stability products, and reactions in competition with fission.

Study level densities, a crucial input in nuclear model calculations, using (n,z) measurements by Haight at LANSCE, and publish work on isospin and level densities in n+Si reactions.

6. WWW Dissemination of nuclear data (0.1 FTE)

Continue to develop our T-2 Online Nuclear Information Service, for convenient and wide access to our nuclear modeling research, data evaluations, and publications. Develop this WWW site in coordination with the USNDP Dissemination working Group.

Deliverables:

Include access to new reaction and structure data evaluations, supported by DOE/ Nuclear Physics, via the T-2 WWW site
Coordinate T-2 WWW site with other sites to include USNDP “star of approval”
Include WWW access to ENDF/B-VI Release 6, which is now available
Finish development of “interpreted ENDF” printout of reaction data

Include additional color-plot capabilities on T-2 WWW site

7. International nuclear data cooperation (0.2 FTE)

Participate in, and chair, international nuclear reaction data collaborations. This insures that the US benefits from breakthroughs around the world, and plays a leadership role in new developments. We chair NEA committees in fission spectra, and international model code development cooperation; and chair IAEA coordinated research programs on photonuclear reactions, and on reference input model parameters. Host a couple of high-quality foreign scientist to visit LANL to undertake USNDP work, to benefit from collaborative exchanges of information and ideas.

Deliverables:

US representative at NEA evaluation meeting in Paris, September 1999
Participate in NEA June 2000 meeting
Chair IAEA photonuclear data CRP in Japan, October 1999; complete IAEA "TECDOC" report
Make latest version of NJOY data processing code available to the international community
Host a couple of international visitors to LANL to collaborate on the evaluation of reaction data

8. Publications

We will document our work in refereed journal articles and laboratory reports.

**Implication of +/- 10% changes in funding for Group T-2:**

*+ 10% (an increase of 0.15 FTE): A new RIB database*

This extra funding would allow us to complete, and make available to the Nuclear Physics community, a RIB database of proton-induced cross sections, for RIB target design. The database would be useful primarily for obtaining production cross sections of proton-rich nuclei in (p,xn) reactions. It will contain information on over 650 target nuclei and extend up to 150 MeV incident energy – the information is obtained from our new Hybrid Monte Carlo preequilibrium and equilibrium model calculations. Our preliminary calculations have been very encouraging, when tested against measured data, but we still need to generate the database for all stable target nuclei, and need to transform the information into ENDF format. This will involve a close cooperation with the NNDC to make this new RIB database available through their WWW site, utilizing the NNDC retrieval and plotting codes for extracting and displaying excitation functions for the production cross sections of radionuclides.

(An increase of 10% funding would take us back to the funding level we were at approx. 1 year ago)

*-10% (a reduction of 0.15 FTE)*

Since the Data Program reaction work is already funded at a relatively low level, it would be difficult to absorb a cut of this level. We would remove the following items from the above Workplan:

- Use Hauser-Feshbach methods to calculate photonuclear data important in nucleosynthesis
- Compute fission barriers using microscopic-macroscopic model for r-process termination
- Study theoretical and phenomenological methods for predicting production cross sections of neutron-rich products in fission reactions, for a future database of fission products in n+U RIB production experiments

## ISOTOPES PROJECT NUCLEAR STRUCTURE AND DECAY EVALUATION/COMPILATION PLANS FOR FY2000

The Isotopes Project's plans for FY2000 include a mix of individual nuclide and entire mass chain evaluations chosen from those for which LBNL has been assigned responsibility. The former is particularly effective in enabling the prompt inclusion in ENSDF of major new data for nuclides on which current research activities are centered. The latter, however, provide a comprehensive view of the nuclear systematics of isobars. In addition, participation in two international collaborations will continue; these are concerned with evaluation of radioactive decay data (with emphasis on decays having specific astrophysical interest), and a systematic evaluation of nuclear structure aspects of (thermal/cold n,γ) data; each was undertaken in response to current research community needs. Also, Isotopes Project personnel will continue to participate in the coding of special non-US evaluations for inclusion in ENSDF and in the review of 3 mass-chain evaluations submitted to NNDC. The anticipated level of effort for the above activities is 2.0 FTE from LBNL employees plus 0.3 FTE from visiting evaluators.

- **Mass Chain Evaluation:**
  A = 83, 92,169, 210, 215, 219, 223, 227.

- **Individual Nuclide Evaluation:**
  $^{168}$Er, $^{179}$Ta, $^{191}$Bi.
  About 4 additional nuclides from LBNL-responsibility chains, to be chosen as new literature adds significant information.

- **Superheavy Element Evaluation:**
  Eight nuclides in the alpha-decay chain from $^{293}$118 to $^{265}$Rf.

*Effort for above items: 1.55 FTE (which includes 0.3 FTE from visitors)*

- **Continuation of (thermal/cold n,γ) Horizontal Evaluation:**
  Three-year IAEA CRP for Prompt Gamma Activation Analysis:
  This program covers the evaluation of (thermal/cold n,γ) data sets for all stable nuclide targets. Datasets for Z≤21 will be submitted by the end of FY2000 for inclusion in ENSDF.

*Effort: 0.3 FTE*

- **Continuation of Decay Data Evaluation Project (DDEP): Nuclear and Atomic Radiations**

  Emphasis is being placed on radionuclides that are of astrophysical interest.
  Decay data sets to be submitted in FY2000: $^{81}$Kr, $^{91}$Nb, $^{92g}$Nb, $^{92m}$Nb, $^{223}$Ra, $^{227}$Ac, $^{227}$Th.
  During FY2000, the Isotopes Project and the Idaho National Engineering Environmental Laboratory will also run a training session at LBNL for the new foreign evaluators who have just joined this collaboration.

*Effort: 0.20 FTE*

- **ENSDF Coding of non-US Evaluations:**

  **DDEP Radionuclides:**
  $^{68}$Ge, $^{68}$Ga, $^{125}$I, $^{141}$Ce:
  Decay and Adopted data sets for these radionuclides are being prepared for inclusion in the ENSDF database.

*Effort: 0.05 FTE*

  **A=21-39 (Endt; 1998 Update):**
  Reaction data sets based on the 1990 publication by Endt will be produced and combined with the previously compiled decay and adopted data sets in ENSDF. New data from Endt's 1998 update, along with updated decay data evaluations and the capture gamma evaluations (mentioned above) will be incorporated in these mass chains, prior to their submission to NNDC for inclusion in ENSDF.

*Effort: 0.2 FTE*

- **Compilation of XUNDL Datasets:**

  Several datasets, prepared in collaboration with LBNL by a student compiler from Westmont College, CA, are expected to be provided for XUNDL during FY2000.

*Effort: unknown at this time*

  Some additional datasets relevant to evaluations planned by Isotopes Project personnel will be submitted for inclusion in the XUNDL database. This procedure can significantly accelerate the user community's access to the data.

*Effort: no additional effort*

## ISOTOPES PROJECT ELECTRONIC DISSEMINATION FY2000 PLANS

In order to provide scientists and engineers throughout the world with user-friendly means to access the wide variety of nuclear data that have been compiled and evaluated, we plan to continue our development of electronic methods of data dissemination. For FY2000, here are the projects we will work on. This work will be done with a total of 2.0 FTE, which consists of 1.0 FTE staff and 1.0 FTE from visitors and students supported by Lund and EVITech.

- **Nuclear Astrophysics Home Page** (in collaboration with UC Santa Cruz):
  Update nuclear astrophysics reaction rates.

*Effort: 0.1 FTE*

- **Capture Gamma-Ray Data**
  As part of an IAEA Coordinated Research Program (CRP) for Prompt Capture Gamma-Ray Activation Analysis:
  Development of a website to provide capture-gamma data compiled in the CRP.

*Effort: 0.1 FTE*

- **Superdeformed Bands and Fission Isomers** (in collaboration with McMaster University):
  Preparation of a revised edition of the *Table of Superdeformed Bands and Fission Isomers* for publication in *Nuclear Data Sheets* and posting on the WWW.

*Effort: 0.1 FTE*

In collaboration with Lund University (Sweden) and EVITech (Finland):

- **Continue development of Isotope Explorer (IE):**

With the long-term goal of developing in collaboration with BNL, ORNL, and SJSU a single unified web interface to ENSDF and XUNDL data, this year we will make upgrades to IE that will be relevant to this multi-lab project for FY 2001.

- **IE2 (C++ version)**
  a. Port software from Borland to MFC compiler

*Effort: 0.1 FTE*

- **IE3 (JAVA/HTML)**
  a. Add sorting capability to tables
  b. Provide chart module as in IE2
  c. Begin development of common web interface to ENSDF and XUNDL databases

*Effort: 0.3 FTE*

- **IE Reference Server**
    a. Add links to additional journals
    b. Add additional reference search selection criteria

*Effort: 0.2 FTE*

- **Continue development of WWW Table of Radioactive Isotopes:**
    a. Add bremsstrahlung database
    b. Add electron database
    c. Add genetic feedings database
    d. Complete development of JAVA spectrum server

*Effort: 0.1 FTE*

Visiting research students supported by Lund University (Sweden) and EVITech (Finland)

*Effort: 1.0 FTE*

## ISOTOPES PROJECT MANAGEMENT

The group leader of the Isotopes Project works 30% of his time on USNDP activities. He is the leader of the USNDP Working Group on Data Dissemination, and serves as an ex-officio member of the USNDP Steering Committee. He oversees, coordinates, and directs the work of members of the Isotopes Project. This effort includes working with LBNL management, with other members of the USNDP, and with the program officers of the DOE.

*Effort: 0.3 FTE*

## EFFECTS OF + OR – 10% BUDGET CHANGES

If the budget for LBNL's Isotopes Project were to be increased in FY2000, this would allow us to increase both our evaluation and dissemination efforts. Specifically we would like to increase the evaluation effort of our current part-time ENSDF evaluator to full time so as to be able to perform more A-chain and nuclide evaluations. This would require an increase of 0.5 FTE. Secondly, as outlined in our portion of the Nuclear Astrophysics Data proposal submitted last year to the DOE, we would like to support at the 0.5 FTE level a new post-doc to perform structure and decay evaluations of current interest in astrophysics. This post-doc would also work with members of the astrophysics research community to supplement the nuclear astrophysics Home Page with new and additional astrophysics data. On the other hand, if our budget were to be reduced by 10%, we would not be able to sustain even the current level of evaluation and dissemination. Further staff reductions would be the likely result of such a cut.

# Lawrence Livermore National Laboratory Work Plan FY2000

Title: **Regional optical potential for the actinides**

Description: A new regional coupled-channel neutron optical potential for actinide nuclei will be developed, based on experience with a potential recently developed for evaluations of Pu and U. This potential will incorporate an improved systematic treatment of deformation parameters based on multipole moments extracted from a wide variety of experiments, and will incorporate energy dependence in the geometry arising from dispersion effects. The incident energy range will be 0-30 MeV.

FTE: 0.2

Leverage: Development of this potential was begun as part of the Stewardship Barn Book evaluations, and was concentrated on a few specific nuclei. Supplementing this effort with USNDC support will enable extension to the entire actinide region.

FY00 Deliverables: Completion of the regional actinide potential and publication of the results.

Title: **Development of techniques for nuclear reaction calculations**

Description: We are developing a suite of reaction modeling codes that will be suitable for investigating processes involving reactions on unstable targets, such as encountered in astrophysics, radioactive ion beam physics, and other applications. The first step will be development of a new Hauser-Feshbach code using object-oriented programming techniques. These techniques will eliminate the need for fixed dimensions within the program and will facilitate incorporation of special features, such as isospin conservation and nonstandard forms for level densities. The code will be written in ANSI standard C++ so that it can be released for use on a wide variety of platforms.

FTE: 0.2

Leverage: USNDC support will be used to design the structure of the Hauser-Feshbach code and implement it. Support from Laboratory programs will be used to develop or adapt specific models and libraries required by this code, such as spherical and coupled-channel optical models, fission models, level density prescriptions, mass and structure tables, and preequilibrium models.

FY00 Deliverables: Implementation of the new Hauser-Feshbach code and first test results, which will be compared with those from other codes available at Livermore, including STAPRE.

**Overall budget reduced by 10%:**

We would stretch out our two proposed activities to accommodate a cut. Specifically, this would delay completion and publication of the optical model work in the actinides.

**Overall budget increased by 10%:**

We would propose a new activity, described below, involving nuclear reaction modeling for astrophysics. We could start this with minimal resources in FY00 (about 0.1 FTE) but would have to follow this with adequate resources for 2 years to complete the project. These resources would be used to support a full-time postdoctoral employee.

Title: **Hauser-Feshbach modeling of reactions in the Sr-Y-Zr region relevant to the r-process and the light p-process**

Description: We will calculate proton- and neutron-induced reactions on nuclei near the N=50 closed shell that are important for astrophysics, using Hauser-Feshbach calculations with parameters specifically tuned to this mass region.

FTE: 0.1

Leverage: The calculational tools and input data for reactions in the Sr-Y-Zr region are similar to those for applications supported by Laboratory.

FY00 Deliverables: A complete cross section set for astrophysics will require approximately two additional fiscal years and will require USNDP support for a postdoctoral employee. During FY00 we would intercompare the various available prescriptions for the level densities needed for this work.

**Work Plan for FY2000 (October 1, 1999 to September 30, 2000)**

**McMaster University, Nuclear Data group**

The following work plan for FY2000 corresponds to the work directly connected with **0.5 FTE** support by the Nuclear Data Program of U.S. DOE.

Our work will be related, primarily, to Nuclear Structure and decay data evaluation for ENSDF.

1. Evaluation of **1.5 full-length mass chains** or its equivalent in terms of full Nuclide updates. The mass chains or the nuclides selected will be based on the priority list prepared by BNL.

2. Continuous update of ENSDF for currently (from 1999- onwards) published data on superdeformed structures.

3. Review of one full-length mass chain or its equivalent of individual nuclides.

4. Continue compilation (in ENSDF format) of currently (from 1999- onwards) published or completed nuclear level-structure data, primarily "high-spin", but including some low-spin data also. The compiled datasets will be included in XUNDL database. This effort would not exceed 10% of the total activity.

Commitment for items #1, #2 and #3, all related to evaluation activity for ENSDF: ~0.45 FTE.

Commitment for item #4, related to compilation activity for XUNDL: ~0.05 FTE.

**Scenario for 10% fluctuation in budget**: For our group, a change of 10% translates to 0.05 FTE. Keeping in view the ENSDF work as priority, a budget with –10% may result in dropping item #4 i.e. the compilation activity. On the other hand, a budget with +10% will allow us to compile the current literature with more completeness i.e. covering all nuclear level-structure papers, high-spin as well as low-spins.

Balraj Singh
Jim Waddington

First submission: August 24, 1999.
Revised: September 9, 1999

# National Institute of Standards and Technology

**Nuclear Data Verification and Standardization Program (total of 0.2 FTE from DOE)**

STRUCTURE ACTIVITIES:
NONE

REACTION ACTIVITIES:

Continue work on developing a strategy for performing an international evaluation of the neutron cross section standards. Coordinate, as chairperson, the activities of the Subgroup of the NEANSC Working Party on Evaluation Cooperation that promotes international cooperation on the evaluation of the nuclear data standards and is responsible for this evaluation. Begin to investigate procedures for doing the comprehensive evaluation. Test some of the programs that could be used for this effort. Continue examining the experimental database. [Involvement in this project now includes Austria, France, Germany, Japan and the USA. This activity is done under the auspices of the U.S. CSEWG, the NEANSC, and the IAEA. An IAEA Coordinated Research Program is being established so that meetings on the evaluation effort can be held.] (0.15 FTE)

Motivate and monitor measurements for use in standards evaluations, largely through the NEANSC Working Party on International Nuclear Data Measurement Activities. Continue the NIST-Ohio University-LANL collaboration on the analysis of the 10 MeV hydrogen angular distribution measurement and study techniques for a new measurement at 14 MeV. Investigate methods to improve the $^{10}B(n,\forall)$ standard. Coordinate CSEWG standards activities. Participate in CSEWG meetings. Participate in USNDP Coordinating Committee meetings. Maintain National Repository for Fissionable Isotope Mass Standards. [In order to effectively motivate and monitor standards experiments, which are needed for the standards evaluation, NIST has become an active participant in a number of experiments including measurements of the angular distribution of neutrons scattering from hydrogen which is one of the most important standards.] (0.04 FTE)

DISSEMINATION ACTIVITIES:

Update the NIST contribution to the unified USNDP website. Make presentations at meetings on the NIST standards activities. (0.01 FTE)

OTHER:

NIST provides approximately a 0.8 FTE support for these standards activities. Also independent of the standards program, there is a modest (0.3 FTE – 75% experimental and 25% evaluation) NIST effort in nuclear structure and decay studies.

The work plan assumes “flat dollars”. If there is a 10% reduction in funding, the time to complete the tasks will be increased. Then the standards measurements may not be done in time for them to be used in the evaluation or the evaluation may have to be delayed. Completion of the evaluation is being driven by the need to have it available for upcoming new versions of major evaluation projects. If there is a 10% increase in funding, it could be applied directly to reduce the time necessary to complete these tasks. It could also be used to initiate activities using the special capabilities at NIST such as the Neutron Interferometer Facility or the new reactor facility, which provides a monoenergetic neutron beam. Measurements at these facilities can provide data needed for nuclear data evaluations.

# Work Plan for the Nuclear Data Project for FY2000

## I. Nuclear Structure Evaluation

Our program for nuclear structure evaluation meets the present needs and interests of the nuclear research community, as stated in the 1998 Parker Report and rated highest priority:

*(b) the properties of exotic nuclei and their production cross sections (especially as related to radioactive beam facilities).*

A study on the systematic behavior of nuclear states and other nuclear properties in the heavy-mass region provides needed systematics of evaluated data to use for searches of superheavy elements, a field of high current interest in the community. This survey should serve as the basis for expectations of these properties in this region, and it should help the exploration of new regions. Such studies will also be valuable for contemplated experiments in the development of neutron-rich radioactive beams and in plans to study new nuclei with the use of radioactive beams, as well as stable beams. Most of the structure information in ENSDF for nuclei in the A∃248 region is not adequate for such a study, because much of the information has not been updated since 1989. During the last two years, the evaluations of the odd-mass nuclei and five of the even-mass nuclei in the 248#A#265 region have been completed. The remaining nuclear-structure data evaluations (evaluations of nuclei with mass 250, 254, 258, 262 and 266) are expected to be completed in FY2000, bringing the structure information for the heavy elements in the A∃248 region up-to-date which is one of the high priorities set by USNDP. It is anticipated that completion of the systematics work will extend to FY2001.

## II. Nuclear Reaction Evaluations for Astrophysics

Our program for nuclear reaction evaluations for astrophysics also meets the present needs and interests of the research community, as stated in the 1998 Parker Report and rated highest priority

*(a): the rates of nuclear astrophysics reactions.*

We plan to continue our evaluating of nuclear reactions of vital importance for studies in nuclear astrophysics. These reactions will help address some of the most fundamental questions in nature: What are the origins of the elements that make up our bodies and our world? How did the solar system, the sun, the stars, and the galaxy form, and how do they evolve? Progress in many such fundamental problems in nuclear astrophysics can be significantly aided by improvements in nuclear data. Our evaluation work in FY2000 will focus on: (1) capture reactions on radioactive isotopes on the proton-rich side of stability such as $^{18}$F - reactions that are important for understanding the element synthesis and energy generation in stellar explosions; (2) capture reactions that are important for understanding Red Giant Stars, such as reactions on $^{17}$O; and (3) reactions important for understanding the nuclear burning in the interior of our sun. These reactions will be studied over a variety of energy ranges as required for applications in astrophysics. All cross sections that are evaluated will be provided in an ENDF-style format. All reaction rates determined will be disseminated on the WWW. Since many reactions are dominated by resonances, all recommended resonance parameters will be provided in ENSDF-style formats.

## III. Database and Web Interface Development; Experimental Nuclear Structure Data Compilation (XUNDL)

Our programs for nuclear structure database development and dissemination provide *a modern and efficient user access to the nuclear data*, as recommended by the Parker Report as second priority, and for semi-automatic conversion of journal articles and other data sources into ENSDF-format data sets.

Software for semi-automatic extraction of tabular level-scheme data contained in PDF manuscripts into ENSDF-format data sets has been developed over the past year, and is now in extensive use as a production tool for data to be included in XUNDL, at ORNL and McMaster. Documentation has been written, and is available at http//radware.phy.ornl.gov/t2e.html. Some further development of this tool will be done to extend its applicability, and to make it more robust and easier to use. During the course of this development, ENSDF-format data sets will be created from published papers for testing purposes, and for the XUNDL database. Other types of data that could be automatically or semi-automatically converted to XUNDL data sets will be investigated; these may include user-contributed level schemes in various formats.

The RadWare software package provides an extremely user-friendly graphic interface to the ENSDF files. Methods for incorporating such high-quality graphical output into web interfaces to the ENSDF database will be explored, possibly in collaboration with the groups at LBNL and/or BNL. The development of on-line extraction of ENSDF data sets in RadWare format will also be pursued. Both of these efforts could build on a program for off-line conversion that already exists, but requires further development of the automatic graphical-layout routines.

The compilation and electronic dissemination of most recent data on reaction gammas will be done continuously throughout FY2000 as data become available. Upkeep of the RadWare database which is very much in accordance with the Steering Committee=s recommendation for addressing the immediate needs of the main stream research community, will be continued. This effort requires only minimal effort, at the level of a few days per year.

**If the budget for Nuclear Data Project for FY2000 will be**

1) flat (the FY1999 budget=FY2000 budget=$179K): the work plan will be as described in the work plan. Note that a flat budget requires a reduction of 0.1 FTE in scientific support and 0.25 FTE in technical support from the FY1999 levels.

2) increased by 10%: an additional 0.1 FTE will be available for the astrophysics reaction data evaluation and would thus increase the amount of work completed in FY2000.

3) decreased by 10%: it would eliminate all technical support leading to a slower completion of the nuclear structure evaluation effort.

FTE=s for FY2000 ORNL Work Plan

| | Flat budget | | 10% increase | | 10% decrease | | FTE=s for[$] FY1999 | |
|---|---|---|---|---|---|---|---|---|
| | Sci/Pro | Suppt. | Sci/Pro | Suppt. | Sci/Pro | Suppt. | Sci/Pro | Suppt. |
| Nuclear Structure Evaluation | 0.50 | 0.25* | 0.50 | 0.25* | 0.50 | 0 | 0.50 | 0.25 |
| Nuclear Astrophysics Reaction Data | 0.40 | | 0.45 | | 0.40 | 0 | 0.40 | |
| Database Systems and Web Interfaces | 0.20 | 0 | 0.25 | 0 | 0.20 | 0 | 0.30 | 0 |
| Reaction Data Bibliography | | 0 | | 0 | | 0 | | 0.25 |
| Total | 1.10 | 0.25 | 1.20 | 0.25 | 1.10 | 0 | 1.20 | 0.50 |

*Includes technical support for reaction data

[$] Level was sustained by carry over from FY1998

San Jose State University
**MacNuclide Project**

# Work Plan for FY2000

During the next year we will focus on two primary areas of software development. The first is the full release of a cross-platform compatible version of MacNuclide. A beta test copy is available at the web site www.macnuclide.com. Only a few minor changes are needed to the source code, and we will update the existing database prior to a full release. The beta test and full release will work on any computer platform that supports Java.

Much of our work over the next year focuses on breaking up our software into logical software components. This effort grew out of a goal presented a few years ago in a nuclear data network meeting in Livermore. During the meeting, Dick Meyer suggested that given the shrinking budgets it is becoming more critical to coordinate the software development activities. We believe the Java programming language may provide simple tools to meet that goal. Java allows portions of a software project to be assembled as individual components, which can reside within an application, as separate applications on the same computer, as separate applications on different computers, and as applets residing on a web page. We have produced a test of the concept on the web page known as NSRstats which is located at trinity.digitalcreativity.com/NSRstats. The web page contains (among other things) a nuclide chart applet which was taken from MacNuclide and which displays the number of recent references in NSR as a function of nuclide. The demonstration is clearly a success.

We intend to build upon the idea of breaking down the application and exploring how the components can best be used. Interactivity will be built into the nuclide chart component. We also intend to create a general interface between the chart component and an underlying database, thereby allowing any nuclear data center to use the nuclide chart as a custom interface on their web site. The next test will consider how the database can be removed from MacNuclide. It could sit on the local computer as a separate application or, using RMI technology, it could even sit at the National Nuclear Data Center. A hybrid model can even exist where two distributed database engines are linked together. We have talked with the NNDC about the feasibility of using the MacNuclide database engine as a data management tool for the Wallet Cards file and as a primary distribution mechanism for the binary information. We would like to further extend these ideas as part of a larger collaborative effort between several groups within the nuclear data network.

# TRIANGLE UNIVERSITIES NUCLEAR LABORATORY
# NUCLEAR DATA PROGRAM

**Work Plan for FY 2000**

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## NUCLEAR DATA EVALUATION PROJECT

**A = 3-20**

C.M. Cheves, J. L. Godwin, J.H. Kelley, J.E. Purcell, D.R. Tilley, H.R. Weller

NUCLEAR STRUCTURE FTE 1.15

EVALUATIONS:

Publish Energy Levels of Light Nuclei A = 5,6,7 (Nuclear Physics A)

Evaluate A = 8,9,10. Issue preliminary version for A = 8 and prepare for issuing preliminary versions of A = 9,10.

ENSDF:

Finalize and submit ENSDF Files for A = 5,6,7.

Prepare ENSDF files for A = 8,9,10.

Update existing A = 11, 12, 13 files (based on most recent Ajzenberg-Selove review) to include reaction information.

DISSEMINATION FTE 1.4

TUNL Nuclear Data Evaluation Project Website:

Provide new PDF documents based on most recent review (TUNL or Fay Ajzenberg-Selove) for A = 4, 11, 12,14,15. (Documents for A = 3, 5-10, 13, 16-20 are already posted).

Provide Update Lists for A = 10,11, 12, 13, 14, 15 level information (prepared by Jim Purcell) working ultimately to provide lists for all A = 5-20 nuclides with new references being added on a continuing basis. (Lists for A = 6,7,8,9 are already posted).

IMPACT OF A 10 % REDUCTION IN FUNDING (0.2 FTE)

A 10 % reduction in funding would impact the dissemination efforts as follows:

(a) The number of new PDF documents based on the most recent review (TUNL or Fay Ajzenberg-Selove) to be provided on the TUNL website would be reduced. Most probably the PDF documents for A = 14, 15 would not be posted in FY 2000.
(b) Update lists for A = 14 and 15 would not be completed in FY 2000.

IMPACT OF A 10 % INCREASE IN FUNDING (0.2 FTE)

(a) TUNL could begin adding decay and reaction information to the Update Lists provided on the TUNL website.
(b) In response to requests from the atomic physics ion beam analysis (IBA) community, TUNL could begin providing aids for interpreting A = 3-20 level diagrams on the TUNL website and links to references to cross section data as well as tabular data themselves for reactions of interest to IBA workers.

## PREEQUILIBRIUM PHENOMENOLOGY

Constance Kalbach Walker

NUCLEAR REACTIONS FTE 0.4

The ongoing work of this program is the development and benchmarking of the exciton model, its associated computer code PRECO, and a global set of model input. The code system also includes phenomenological models for the description of various direct reaction mechanisms involving complex particles (light ions) as well as the excitation of strong collective levels. The work in recent years has concentrated on reactions with nucleons in both the entrance and exit channels in order to study the exciton model without interference from direct mechanisms such as stripping/pickup or cluster breakup.

The benchmarking has been a slow and careful process involving the use, so far, of over 150 inclusive energy spectra from the literature. It showed the unanticipated need to completely rework the shell corrections to the state densities in both the preequilibrium and equilibrium phases of the reaction and to conduct a more comprehensive study of the amount of surface peaking of the initial target-projectile interaction. In addition, the model was extended to include secondary particle emission and a model for collective state excitation. A preliminary global input set has been developed and tested against data at excitation energies up to around 30 MeV [with limited tests above that], and successfully accounts for the continuum energy spectra in all four (N,N) channels.

Work over the next year will include completing a test run of the current version of the code/input against the full data base and preparing a journal article describing the results of the work on surface and collective effects. Interest has also been expressed in a new formal release of the model code PRECO, since many substantive changes have been made since PRECO-E Rev. 1 was issued in 1992. This will require a complete rewrite of the manual and program description. If it is deemed appropriate, the code could also to sent to NNDC to make it more widely available. Finally, as time permits, work on developing the model and benchmarking the code will continue, working up to higher incident energies for (N,N) reactions. Open questions in the 60 to 120 MeV range include the extent of isospin conservation in the preequilibrium phase of the reaction and the energy dependence of the average effective matrix elements for the residual interactions responsible for nuclear energy equilibration.

PLANNED WORK:

* Finish checking current version of model/input against full data base;
* Prepare and issue a new release of the code PRECO;
* Continue benchmarking the model/code/input for (N,N) reactions at higher incident energies.

DELIVERABLES:

* Journal article on surface and collective effects submitted
* New release of code PRECO including an extensive users manual

IMPACT 10 % REDUCTION IN FUNDING (0.05 FTE)

This is a continuous model and code development program. A 10% reduction in funding would slow the pace of progress toward the long-range goals and reduce the chances that the next formal release of the code will be available in FY 2000. Because of fixed "overhead" time commitments (seminars, report-writing, keeping up on the literature) the impact would be greater than the nominal 10%.

IMPACT OF A 10 % INCREASE IN FUNDING (0.05 FTE)

This is a continuous model and code development program. A 10% increase in funding would accelerate the pace of progress toward the long-range goals and increase the chances that significant progress could be made on the next phase of the work: benchmarking the model and code for (N,N) reactions at 45 to 100 MeV and resolving two open questions of physics in this domain.