

2002

USNDP

**Minutes of the
U.S. Nuclear Data Program
Meeting**

**Held at
Brookhaven National Laboratory
April 10-12, 2002**

TABLE OF CONTENTS

	<u>Page No.</u>
Chairman's Summary (P. Oblozinsky)	1
Meeting Agenda	1A
List of Attendees	1B
Coordinating Committee Summary (P. Oblozinsky)	2
Working Groups	
Minutes of the WG on Nuclear Structure and Decay Data Evaluation (R. Helmer)	3
ENSDF Evaluators' Session (J. Tuli)	3A
XUNDL Status Report (B. Singh)	3B
Status of ENSDF Analysis and Utility Codes	3C
Minutes of the WG on Nuclear Reactions (M.B. Chadwick)	4
Minutes of the WG on Dissemination (E. Norman)	5
Status of the USNDP Web Site (2000 and 2001) (T.W. Burrows)	5A
Task Forces	
Report of the TF on Astrophysics (M. Smith)	6A
Report of the TF on Rare Isotope Accelerator (M.B. Chadwick)	6B
Laboratory Reports	
ANL: Mid-Year Progress Report on Argonne Nuclear Data Activities	7A
BNL: Report of the National Nuclear Data Center to the 2002 USNDP Meeting	7B
Georgia: Nuclear Structure and Decay Data Evaluations of the Georgia Tech Group	7C
Idaho: Nuclear Structure and Decay Data Evaluations and Related Activities of the Idaho Group ...	7D
LANL: Los Alamos Nuclear Data Program	7E
LBNL: Isotope Project	7F
LLNL: Summary of 2001 LLNL Activities	7G
McMaster: Status Report of the Nuclear Data Project at McMaster University	7H
NIST: Nuclear Data Verification and Standardization Program - Progress Report	7I
ORNL: Nuclear Data Project Activities	7J
TUNL: Report to the USNDP	7K
Other Reports	
MIT: University of Massachusetts Lowell (LTI) Radiation Laboratory - Recent Publications	8

Chairman's Summary

US NDP Chairman's Summary

P. Oblozinsky
National Nuclear Data Center
Brookhaven National Laboratory

The 5th meeting of the United States Nuclear Data Program (USNDP) was held at Brookhaven National Laboratory, April 11-12, 2002. An informal technical session of the Nuclear Structure and Decay Data Working Group took place on April 10, 2002. The meeting was attended by 25 participants from 10 organizations, including an observer from the IAEA Nuclear Data Section. The Chairman of the Energy Sciences & Technology Department, Dr. William Horak welcomed the participants on behalf of Brookhaven National Laboratory. Dr. Ralph James, BNL Associate Laboratory Director for Energy, Environment and National Security attended a part of the concluding session.

Reactions

Reactions Working Group discussed modeling, astrophysics and ENDF evaluations. Modeling and code development primarily addressed improvements and validation of PRECO by TUNL, EMPIRE by NNDC, and McGNASH and HMS by LANL. Moller summarized activities of the Astrophysics Task Force and focused on work at LANL with emphasis on recent improvements in calculating fission barriers. This was complemented by Haight's report on experimental work at LANCE facility often motivated by nuclear astrophysics.

Evaluation activity is focusing on contributions to a new library, ENDF/B-VII, scheduled for release in 2005. LANL reported a number of completed and ongoing evaluations mostly up to 150 MeV, NNDC reported progress in fission products evaluations. Carlson reviewed status of new evaluation of neutron cross-section standards, a project of top importance for ENDF/B-VII.

Structure

Nuclear Structure and Decay Data Working Group focused on basic databases and future workshops. Compilation of NSR is progressing well and compilation of XUNDL reported excellent progress. New assignments for ENSDF were made, in particular A=21-30 to LBNL and about 10 mass chains to a new participant from ANL.

Manpower represents a serious challenge for ENSDF. New evaluators are clearly needed. This represents a broader international problem of the NSDD Network that will be addressed, in part, by future IAEA and ICTP Trieste Workshops to be held in November 2002 and November 2003.

Dissemination

NNDC presented its database migration project, moving from the current database management system adopted in 1980s to a new relational database management system. Completion of this project, planned for the end of FY04, will have substantial impact on future dissemination activities.

This includes unification of 3 reaction databases (CINDA, CSISRS, ENDF), and 3 structure databases (NSR, XUNDL, ENSDF), with a potential grand unification in future.

LBNL has shown detailed dissemination statistics of hits and retrievals with substantial growth in the last year, and advocated use of free non-commercial software ANALOG to analyze access log files. NNDC continues to use its traditional approach of counting retrievals, reaching 258,000 retrievals in FY01, a 14% percent increase over the previous year.

USNDP Organization

USNDP organization was reviewed. USNDP will proceed with two standing Working Groups and three Task Forces as follows:

- Reactions Data WG, chair Mark Chadwick, LANL
- Structure and Decay Data WG, chair Coral Baglin, LBNL
- Astrophysics TF, chair Michael Smith, ORNL
- Rare Isotope Accelerator TF, chair Mark Chadwick, LANL
- Impact of Nuclear Data on Society TF (new), chair John Kelley, TUNL

The Dissemination WG and High-Spin TF were terminated and the Impact of Nuclear Data on Society TF was established. This new task force should develop and maintain a broad registry of examples, which show the direct impact of nuclear data on various activities and applications that affect specific research efforts and society in general.

Regular annual meetings will include parallel sessions of Reactions Data WG, and Structure and Decay Data WG. Dissemination activities will be reported in a plenary session. Continuation of Astrophysics TF, and Rare Isotope Accelerator TF were endorsed with the understanding that they will duly proceed with their annual reports to USNDP. Proposals for new task forces are encouraged, they will be considered at the next meeting.

Work plan

It was noted that DOE sees the Work plan as a useful source of information. USNDP will continue to issue it on a regular basis. It was suggested that the allocation of manpower for administrative work, that tends to be increasing, be explicitly listed. A category of 'Other Funding' should be used more actively as an important indicator of leverage/synergy of the US NDP program. More copies of Work plan should be produced and electronic version will be made available.

Next Meeting

The next US NDP meeting will be held at McMaster University, McMaster, Canada, adjacent to the NSDD meeting organized biennially by the IAEA:

- US NDP Meeting, May 1-2 (Thursday-Friday), 2003
- Structure Workshop, May 5 (Monday) 2003, and
- NSDD Meeting, May 6-9 (Tuesday-Friday), 2003.

**U.S. Nuclear Data Program, Annual Meeting
Brookhaven National Laboratory
April 10-12, 2002**

Agenda

*** Wednesday, April 10 ***

- 13:00-17:00 Structure WG, NNDC conference room (J. Tuli, Chair)
- Informal Technical Session

*** Thursday, April 11 ***

8:30-10:00 Opening Session, Berkner Hall B

- Opening remarks (W. Horak, BNL, Chair, Energy Sciences & Technology, P. Oblozinsky, NNDC)
- US NDP budget briefing (P. Oblozinsky)

10:00-10:15 Break

10:15-12:30 Reactions and Structure, Parallel

- Reactions WG, Berkner Hall B (M. Chadwick, Chair)
 - Nuclear model development
 - Preequilibrium modeling (15'), C. Kalbach
 - BNL nuclear model code development with Empire (15'), P. Oblozinsky
 - LANL GNASH statistical model code development (15'), M. Chadwick
 - Other items (forthcoming NEA WPEC models workshop, ...)
 - Astrophysical reaction data
 - LANL astrophysical data work (20'), P. Moller
 - Other astrophysical data activities (20'), P. Moller for M. Smith (ORNL) and G. Hale (LANL)
 - Standards and Measurements
 - International evaluation of neutron cross section standards (30'), A. Carlson
 - Nuclear data experiments at LANSCE (15'), R. Haight
 - ENDF evaluations
 - LANL ENDF files supported by US NDP (5'), M. Chadwick
 - BNL evaluation activities (5'), P. Oblozinsky
- Structure WG, Berkner Hall C (R. Helmer, Chair)
 - NSR and XUNDL
 - NSR status (5'), D. Winchell
 - XUNDL status (5'), J. Cameron and D. Winchell
 - ENSDF
 - Processing and checking codes (10'), T. Burrows
 - Implementing of new internal conversion coefficient table (20'), R. Helmer
 - Evaluation production rate (5'), J. Tuli
 - Number of evaluators – past, present and future (5'), J. Tuli
 - Mass assignments (5'), F. Kondev
 - Training and other items
 - Evaluator training at IAEA Vienna and ICTP Trieste (10'), J. Tuli and A. Trkov
 - Report on informal meeting of 10 April (15'), J. Tuli

- Other items

12:30-14:00 Lunch

14:00-15:00 Dissemination and Laboratory Reports, Berkner Hall B

- **Dissemination WG (E. Norman, Chair)**
 - NNDC migration project (20'), D. Winchell
 - Development of a unified reaction data system (10'), V. McLane
 - LBNL dissemination (10'), R. Firestone
 - NNDC dissemination (10'), T. Burrows

15:00-15:15 Break

15:15-17:30 Dissemination and Laboratory Reports (Cont'd), Berkner Hall B

- **Laboratory reports (C. Dunford, Chair)**
 - NNDC report, P. Oblozinsky
 - ANL report, F. Kondev
 - Georgia Tech, J. Wood
 - Idaho, R. Helmer
 - LANL report, M. Chadwick
 - LBNL report, E. Norman
 - LLNL report, T. Hill
 - McMaster, J. Cameron
 - NIST report, A. Carlson
 - ORNL report, Y. Akovali
 - TUNL report, J. Kelley

18:00-19:00 Coordinating Committee meeting, Berkner Hall B

*** Friday, April 12 ***

8:30-10:15 Concluding session, Berkner Hall B (P. Oblozinsky, chair)

- Welcome by R. James, BNL Associate Lab Director
- Structure WG summary, R. Helmer
- Reactions WG summary, M. Chadwick
- Coordinating Committee highlights, P. Oblozinsky
- Future plans and coordination, WG chairs
 - FY02 (Structure, Reactions, Dissemination)
 - FY03 (Structure, Reactions, Dissemination)

10:00-10:15 Break

10:15-12:30 Concluding session (cont.), Berkner Hall B (P. Oblozinsky, chair)

- Next meeting
- Other business
- Adjournment at 12:30

U.S. Nuclear Data Program Meeting 2002

ATTENDEES LIST

Name	Affiliation
Yurdanur A. Akovali	Oak Ridge National Laboratory Oak Ridge, TN (USA)
Coral M. Baglin	Lawrence Berkeley National Laboratory Berkeley, CA (USA)
Thomas W. Burrows	Brookhaven National Laboratory Upton, NY (USA)
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Robert C. Haight	Los Alamos National Laboratory Los Alamos, NM (USA)
Richard G. Helmer	Idaho National Engineering & Environmental Laboratory Idaho Falls, ID
Tony S. Hill	Lawrence Livermore National Laboratory Livermore, CA (USA)
John H. Kelley	Triangle Universities Nuclear Laboratory Durham, NC (USA)
Filip G. Kondev	Argonne National Laboratory Argonne, IL (USA)
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Name	Affiliation
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Ivan A. Sirakov	Brookhaven National Laboratory Upton, NY (USA)
Alejandro A. Sonzogni	Brookhaven National Laboratory Upton, NY (USA)
Andrej Trkov	International Atomic Energy Agency Vienna, Austria
Jagdish K. Tuli	Brookhaven National Laboratory Upton, NY (USA)
Constance K. Walker	Duke University Durham, NC (USA)
David F. Winchell	Brookhaven National Laboratory Upton, NY (USA)
John L. Wood	Georgia Institute of Technology Atlanta, GA (USA)

Coordinating Committee Summary

USNDP Coordinating Committee Summary

P. Oblozinsky
National Nuclear Data Center
Brookhaven National Laboratory

The Coordinating Committee met in the evening of Thursday, April 11, 2002. The meeting was attended by 11 participants, including all Principal Investigators or their representatives. The Agenda included (1) Lessons from the Budget Briefing, (2) US NDP organization, (3) Mass assignments for ENSDF, and (4) Next meeting.

Budget Briefing. The Committee felt that the US NDP Budget Briefing, held at DOE, Germantown, on March 25, 2002, went well. The format developed for that meeting was found useful, it should be retained and refined as necessary in view of future briefings that are expected on annual basis. The Committee noted growing administrative load and the need to reflect this activity under appropriate administrative category of FTEs in the Work Plan rather than under 'evaluation'. It was noted that DOE SC is interested to know funding that can be viewed as having leverage/synergy effect on US NDP activities. This should be reported in the Work Plan under the category 'other funding', using the best judgment of each PI as to what should be included.

US NDP Organization. Dick Helmer, Idaho, stepped down as a chair of the Nuclear Structure and Decay Data Working Group after many years of distinguished service. Coral Baglin, LBNL, was selected as Dick's successor. The Dissemination WG was terminated, meaning that the USNDP will proceed with two standing Working Groups only, Reactions Data WG, and Structure and Decay Data WG. Also terminated was the High-Spin Task Force, while continuation of two others was endorsed (Astrophysics TF, and Rare Isotope Accelerator TF – former Radioactive Ion Beam TF). A new TF was created at the concluding plenary session (Impact of Nuclear Data on Society TF).

Regular annual meetings will include parallel sessions of Structure and Decay Data WG, and Reactions Data WG. Dissemination activities will be reported in a plenary session. Each TF should provide its annual report to USNDP. Proposals for new TF are encouraged, they will be considered at the next meeting.

US NDP Web page need to be updated. In several instances, information is quite obsolete. All Principal Investigators agreed to look into their part and provide relevant update to NNDC.

Mass Assignments. Mass assignments for ENSDF, as proposed by the Structure and Decay Data WG, were endorsed. The mass chain A=21-30 was assigned to LBNL. ANL was assigned mass chain A=199-209, with the understanding that A=206 has to be clarified with LBNL.

Next Meeting. The next US NDP meeting will be held early May 2003 at McMaster University, McMaster, Canada, adjacent to the NSDD meeting organized biennially by the IAEA.

Working Groups

Minutes of the Working Group on Nuclear Structure and Decay Data Evaluation

R. Helmer (Idaho), chair

This Working Group held its annual meeting on Thursday, 11 April 2002. It was chaired by Richard Helmer. The meeting consisted of a series of short presentations followed by questions and discussion on topics related to the production of the Evaluated Nuclear Structure Data File (ENSDF) and the Nuclear Structure Reference (NSR) and Unevaluated Nuclear Data (XUNDL) databases. For some topics, the material here can be supplemented by that appearing in the Center Reports given elsewhere in this report.

David Winchell described the progress in the NSR bibliographic system. The new entries totaled 4647 in 2001 and 1384 so far in 2002, for a total of over 167,000 entries in the database. He showed the statistics on the type of queries made of the system and time-of-day data which showed the presence of European queries.

A report on the XUNDL database was given by John Cameron. These data sets are prepared at McMaster University and they are able to keep up with the new publications. They make effective use of undergraduate students to extract information from papers and prepare the draft data sets. About 210 data sets have been added since the last US NDP meeting and the database now includes about 900 data sets.

Tom Burrows reviewed the status of the ENSDF processing and checking codes. He stated that he will be working on an update of RULER in which improvements in handling various forms of input uncertainties, especially asymmetric ones. It was suggested by Jagdish Tuli that an operational version of GAMAT would be useful. The original version of this code was written at LBNL, and the several attempts have been made to convert the original code to run on a PC, but they have been unsuccessful. Therefore, a completely new version will need to be written and this possibility will be explored.

It was noted that it would clearly be desirable to expand the manpower doing evaluations for ENSDF; this would reduce the average age of the data sets in ENSDF as well as increase the A-chain evaluations available for publication in Nuclear Data Sheets. This problem may be reduced by new US evaluators at Brookhaven National Laboratory and Argonne National Laboratory (ANL) as well as one in Australia.

A report was given by Andrej Trkov, representing the Nuclear Data Section of the International Atomic Energy Agency, Vienna, and J. Tuli on plans for training sessions on nuclear physics and data evaluation. A session will be held in November 2002 at the IAEA for 5 to 8 students. Another session is being planned at the International Center for Theoretical Physics in Trieste in

2003 for about 30 students. In each case a significant portion of the participants will be from developing countries and for them financial support will be available. It is expected that some of these students will be candidates to become ENSDF evaluators.

A discussion was initiated concerning the desirability of replacing the Hager and Seltzer internal-conversion coefficients that are currently used in ENSDF with the new values calculated by I. M. Band, M. B. Trzhaskovskaya, C. W. Nestor, Jr., P. Tikkanen, and S. Raman. However, J. Tuli stated that S. Raman had recently requested that we delay our use of the new tables while he prepares more information on the quality of these results. We agreed to such a delay.

J. Tuli reported on some of the discussions held the previous day in an informal workshop for the ENSDF evaluators. One of those discussions related to “horizontal evaluations” and other projects which can provide evaluated data for possible inclusion in ENSDF. J. Tuli suggested that the recent evaluations of proton-decay data by Alejandro Sonzogni are regular ENSDF evaluations since the data for complete nuclides was provided. The evaluations of the single quantities, such as the Q values or moments, would be considered “horizontal evaluations” and the data could be included directly into ENSDF as long as the values did not influence other calculated quantities.

Other evaluations that are underway are the Decay Data Evaluation Project (DDEP) led by E. Browne and R. Helmer and an IAEA CRP on the gamma-ray data for thermal- and cold-neutron capture on elemental samples, led by R. Firestone. It was agreed that the data from these evaluations will be supplied to the ENSDF file manager, J. Tuli, in the form of ENSDF data sets. These data will then be made available in new databases and will be available to ENSDF evaluators for integration into their evaluations.

Several other technical items related to the ENSDF and XUNDL databases were discussed at the NSDD Evaluator’s Session, held on 10 April 2002. These are summarized on the accompanying report of that session.

After the departure of the Utrecht group from the evaluation Network, the TUNL group had indicated an interest in doing the evaluations for masses 21-30, if they could obtain additional funding. Since they have not been funded for this work, they are not able to do these evaluations. To address this need, the LBNL group has offered to take this assignment. This arrangement will be finalized later. Filip Kondev, a new participant from ANL, suggested that ANL be assigned masses 199-209. This was generally agreed to and will be finalized at a later time. (Murray Martin is currently doing $A=208$ and he will finish this mass chain.)

ENSDF Evaluators' Session – Wednesday, April 10, 2002

J. Tuli (BNL), Chairman of the Session

Attendees: Y. Akovali, C. Baglin, T. Burrows, R. Helmer, J. Kelley, F. Kondev, E. Norman, A. Sonzogni, J. Tuli (Chair), D. Winchell, A. Trkov (guest)

1. XUNDL data: It was pointed out that the file is a compilation and evaluators need to evaluate before bring it into ENSDF. The rules for XUNDL, in particular for its JPI assignments, are quite different than in ENSDF and evaluators need to be aware of that. One has to be careful while taking the data directly from Radware site as it might have used default values for some properties, such as multipolarities, etc.
2. Conversion of Radware .ags files is available from McMaster
3. Spin/band designators J, J1, J2, ..., Jn should be used for the unknown J values
4. In NDS comment on conversion coefficients should include a statement that L=3, 4 conversion coefficients are reduced by 2.5% from their HS calculated values.
5. Evaluators should be aware of Raman's BE2 compilation published in ANDT vol. 78, p 1 (2001) and should be used in preference to their own averaging of old data. If there is new data since the compilation that, of course, need to be factored in.
6. Nick Stone's revised comment on magnetic moments will be incorporated in NDS. But the argument to be treated as strong will be left pending until its resolution at the McMaster meeting.
7. The use of "?" in XREF=A(E?) construction is allowed. It means that the correspondence with level E in reaction/decay "A" is not certain.
8. The use of "O" for other data sets in XREF designations is ambiguous and seems to confuse some readers. Tom Burrows will look into giving the designator explicitly for all the reactions involved.
9. A least-squares fitting program, like GAMUT, is needed for consistent creation of adopted gammas data set. The current LBL (Rick Firestone's) program is not reliable and Rick has promised to send its specifications/write up with algorithm details to NNDC.
10. The responsibility for evaluation of A=199-209, currently in NNDC,LBL (206) regions, will be taken over by ANL. The formal transfer will be recommended at the next NSDD meeting.
11. If Gary Mitchell of TUNL is no longer interested in evaluation of A=21-30, the responsibility for this region could be taken over by LBL (Rick Firestone).
12. If three or more nuclides for a mass chain are updated, it is desirable that the entire A-chain be reevaluated. This is, however, only a guideline and not a strict rule.
13. Horizontal Evaluation - definition:

14. An evaluation of only a few properties, e.g. T1/2, moments, masses, and not all the properties generally evaluated for ENSDF, for a set of nuclides constitutes a horizontal evaluation.
15. Minimum unit for an evaluation (unless, it is orthogonal to existing evaluation,
16. i.e., it does not materially change the existing levels and gammas) in ENSDF is a
17. nuclide.
18. 15. The evaluator of an evaluation is responsible for its content even if the
19. evaluation is in some other data center's permanent assignment.
20. Radioactive decay evaluations done by the DDP will be sent to NNDC as ENSDF files which will then be transmitted to ENSDF evaluators for inclusion in their evaluations. If the ENSDF evaluator is unable to provide a file for inclusion in ENSDF within a reasonable period of time the decay data sets will be stored in a separate experimental data base
21. Capture-gammas data sets in ENSDF format will be stored in an experimental
22. data base and ENSDF evaluators may use that in their evaluation.
23. SDB data sets will continue to be added to ENSDF as at present. When an SDB
24. band is seen to decay to lower levels the adopted levels will then need to be
 - a. modified. If the SDB evaluator is unable or unwilling to make those changes then
25. these data sets will also be added to an experimental data base for later
26. consideration by the ENSDF evaluator.

XUNDL Status Report (April 2001- March 2002)

(Prepared by B. Singh, McMaster, March 31, 2002)

Since the start of this project in January 1999, a total of about 850 datasets have been added to XUNDL, covering mainly high-spin level-scheme structures for about 655 nuclides ranging from ^{36}Ar to ^{254}No and spread over 190 A-chains. The data were extracted from about 750 primary publications published primarily during 1995-2002. About 85% contribution is from McMaster, while the remaining 15% datasets received from other data centers were reviewed/edited at McMaster prior to inclusion in XUNDL. The database is managed at NNDC by David Winchell and Tom Burrows.

The total number given above includes about 212 datasets which have been added since April 2001, about half of which were compiled since October 1, 2001 (i.e. FY 2002). In addition 26 datasets already in XUNDL were revised and updated based on new papers. During 2001-02 we have compiled several current low-spin papers also that were not in ENSDF. A compiled version of a paper is sent to NNDC for inclusion in XUNDL, generally within a month or so of its publication. Between April 2001 and March 2002, the following undergraduate students at McMaster have participated in XUNDL compilation work: George Reed (until August 2001), Roy Zwyina (since June 2001) and Michelle Lee (since February 2002). Roy and Michelle will continue to work with us during summer 2002. The students are trained in basic nuclear physics, ENSDF formats, semi-automatic translation codes, consistency checking codes such as FMTCHK, GTOL, etc. During summer 2002 we also plan to generate a new TABULAR-TEXT to ENSDF conversion code which would offer better flexibility in entering data automatically, and would include several additional features that are not present in the currently used code written (at our request) by David Radford (at ORNL) about three years ago.

In the current literature on experimental nuclear structure, the high-spin publications continue to dominate with about 75-80%

publications in this field, as judged from our regular scanning of web pages of primary nuclear physics journals (PRL, PR-C, NP-A, PL-B, EPJ-A, JP-G) for new data. As of March 31, 2002, we are current on the compilation of current high-spin (including some low-spin) publications, except for only 3 papers published during March, which are presently being compiled. Last summer we also compiled main high-spin papers for some of the outdated (>10 years or so) A-chains in ENSDF. As time permits, we plan to do the same this summer as well.

We frequently communicate with the authors of original papers to resolve data-related errors and inconsistencies, and to request additional details of data which are often lacking in publications due to space limitations or other reasons.

According to the monitoring of data retrievals from NNDC website by Tom Burrows, there have been on the average about 300-350/month retrievals from XUNDL database during the last ten months or so. The datasets in XUNDL are also being used by the ENSDF evaluators in their A-chain/nuclide evaluations. This should potentially speed up the data-evaluation process.

The data for superdeformed structures from new papers are evaluated (by McMaster group) on a continuous basis and added to ENSDF database. A 2001 update of the table of magnetic-rotational bands (by Amita, A.K. Jain and B. Singh) was made available on NNDC website in June 2001.

We think that amongst the two databases: ENSDF and XUNDL, the experimentally known/published high-spin level structures are now adequately and conveniently available to the research community through NNDC's on-line retrieval system, LBNL's Isotope explorer, and ORNL's Radware software. There may only be a few primary papers (perhaps no more than 100 or so) published during 1990-1997, the contents of which are probably still not included in any of the two databases mentioned above. We expect that within a year or so, the coverage of such data should almost be complete.

Status of ENSDF Analysis and Utility Codes

(March 21, 2001 to March 15, 2002)

Previous Status Reports

- [Nov. 10, 1998](#): Status report for the 1998 meeting of the IAEA-sponsored Nuclear Structure and Decay Data (NSDD) Network.
- [April 21, 1999](#): Status report for the 1999 USNDP Coordination Meeting
- [April 14, 2000](#): Status report for the 2000 USNDP Coordination Meeting
- [Oct. 24, 2000](#): Status report for the 2000 meeting of the IAEA-sponsored Nuclear Structure and Decay Data (NSDD) Network.
- [March 21, 2001](#): Status report for the 2001 USNDP Coordination Meeting
-

Current Status

- A. With the exception of RadList all ANSI, Open-VMS, Linux, and MS Windows versions are current with those maintained in-house at the NNDC.
- B. Code Revisions (See the relevant "Read Me's" for additional details):

- ENSDAT**
1. Linux version of ENSDAT available
 2. True Windows version available with GUI interface and ability to use Windows Printer Drivers
 3. Some bug fixes
- FMTCHK**
1. Allow non-unique forbidden UN for B and E records
 2. Added check to see if value for "FL=" consistent with E(level)-Egamma.
 3. Added consistency checks between fields on the E record and between fields on the B and E records and their continuation records.
 4. Several minor bug fixes and additional checks added.
- GTOL** Minor bug fix
- HSICC**
1. Added terminal warning if "S G" to be replaced has quantities not output by HSICC
 2. Minor bug fix
- HSMRG**
1. Increased tables to 2000 gammas
 2. Added check on "S G" records for quantities not output by HSICC.
- LOGFT** Minor bug fix
- PANDORA** Corrected problems introduced when ported to Linux
-

Future Plans

A. LOGFT:

The logic from the LBNL program ft has been incorporated into LOGFT to calculate 3rd and higher order unique forbidden transitions. Extensive testing and comparison with the LBNL programs beta and ft still remains before release.

The program currently assumes that the theoretical values used in calculating the electron-capture fractions have no uncertainties, resulting in an underestimate of the electron-capture fractions uncertainty. This will be corrected using the data of [Schönfeld](#).

B. RadList:

Calculation of subshell conversion- and Auger-electron and X-ray intensities will be added and the calculation of continua spectra improved. Logic to properly calculate the beta spectra for 3rd and higher order unique forbidden transitions will be added.

Tables

Analysis Codes							
Code	Function	Version No./Date	FORTRAN				Documentation
			ANS ^a	DVF ^b	VMS ^c	UNIX ^d	
ALPHAD	Calculates α R ₀ 's, HF's and theoretical T _{1/2} (α)'s	1.6 20010207	X	X	X	X	No (See "Read Me" file)
DELTA	Analyzes angular correlation data.	1.01 19930415	X	X	X	X	LUNFD/(NFFR-3048) 1-27
GABS	Calculates absolute ΔI 's.	9.2 20010207	X	X	X	X	Yes
GTOL	Determines level energies from a least-squares fit to E γ 's & feedings.	6.4a 20010611	X	X	X	X	BNL-NCS-23375/R LUNFD/(NFFR-3049) 1-27
HSICC	Interpolates internal conversion coefficients	11.13f 20011009	X	X	X	X	Nucl. Data A4, 1 Nucl. Data Tables A6, 235 Nucl. Data Tables A9, 119 BNL-NCS-23375/R (1977)
LOGFT	Calculates log <i>ft</i> .	7.2a 20010220	X	X	X	X	Nucl. Data Tables A10, 206 BNL-NCS-23375/R (1977)
NSDFLIB	Support subprograms for many codes	1.5d 19990628	X				Yes
PANDORA	Physics check of ENSDF data sets. Aids with adopted gammas & XREF.	6.6b 20010827	X	X	X	X	Yes
RadList	Calculates atomic & nuclear radiations. Checks energy balance.	5.5 19881005	X	X	X		BNL-NCS-52142
RULER	Calculates reduced transition probabilities.	1.3 20010207	X	X	X	X	Yes
a ANSI-standard FORTRAN 77			c OpenVMS Fortran				
b Compaq/Digital Visual Fortran (Win95/98/ME/NT/2000)			d Linux GNU f77 Fortran				

Utility Codes							
Code	Function	Version No./Date	FORTRAN				Documentation
			ANS ^a	DVF ^b	VMS ^c	UNIX ^d	
ADDGAM	Adds gammas to adopted data set.	1.4 20010207	X	X	X	X	No (See " Read Me " file)
COMTRANS	Converts the text comments of an ENSDF dataset to a "rich text format"	6.0 19991013		X ^e	X ^e		No (See " Read Me " file)
ENSDAT	Produces tables and drawings	11.5 20000924		X ^e	X ^e	X ^{e,f}	No (See " Read Me " file)
FMTCHK	ENSDF format checking	9.0c 200210212	X	X	X	X	No (See " Read Me " file or " Read Me " in HTML)
NSDFLIB	Support subprograms for many codes	1.5d 19990628	X				Yes
TREND	Tabular display of ENSDF data.	8.3 20010207	X	X	X	X	No (See " Read Me " file)
a ANSI-standard FORTRAN 77			d Linux GNU f77 Fortran, except as noted				
b Compaq/Digital Visual Fortran (Win95/98/ME/NT/2000)			e Only the executables are available				
c OpenVMS Fortran			f Lahey Fortran 95				

Minutes of the WG on Nuclear Reactions

Mark B. Chadwick, LANL (chair)

Present: C. Dunford, P. Oblozinsky, V. McLane, S. Mughabghab, A. Trkov, R. Haight, C. Kalbach, A. Carlson, P. Moller, T. Hill, E. Norman, I. Sirakov, R. Firestone, M. Chadwick

Connie Kalbach, “Preequilibrium modeling”

This year Kalbach worked on (a) code improvements fixing minor bugs found when PRECO was submitted to RSICC; (b) modeling cluster-in and cluster-out reactions. Connie requested (n, α) data from Bob Haight on targets with a neutron excess to test the $(2Z/A)^n$ dependence in her formalism, where the power n may be as high as six or even 12. Some physics insights gained include the M^2 dependence on target energy and mass, isospin conservation, and transfers of pairs of coupled particles. Chadwick requested input from Kalbach on benchmark spectra she uses, and trusts, at lower neutron and proton energies (say below 30 MeV) for validating the LANL HMS preequilibrium codes. NNDC offered to help Connie extract numerical data in the CSISRS.

Pavel Oblozinsky, “BNL model code development with EMPIRE”

Mike Herman of the IAEA is the principal developer, with help from Capote, Oblozinsky, Trkov, and Zerkin, and the latest released version is EMPIRE-2.17. Recent additions include use of the ECIS-95 coupled-channels optical code, use of the exciton model code DEGAS, and the DDHMS from LANL, as well as width fluctuations using the HRTW approach. New capabilities have been added to access RIPL-2 nuclear model parameter information.

Mark Chadwick, “LANL GNASH statistical model developments”

This talk addressed both the developments in the new McGNASH code, as well as the Monte Carlo preequilibrium module HMS. McGNASH has been upgraded to use advanced fortran-90 features, and to include a capability to use un-collapsed transmission coefficients. We are presently testing and validating our Moldauer width-fluctuation module through comparisons with COMNUC code predictions as well as through collaborations with Hilaire at Bruyeres-le-Chatel. Marshall Blann continues to visit LANL regularly to develop the HMS-ALICE code – a recent focus has been on incorporating angular momentum transfer to study isomer production. Chadwick showed predictions of isomer production compared with data used to validate the HMS code. This work will enable the extension of our LA150 activation ENDF file to include isomer production.

Michael Smith, “Astrophysical Task Force”, presented by P. Moller

Michael Smith’s viewgraphs summarized work at ORNL, BNL, LBL, LANL, LLNL, TUNL, & ANL on reactions and structure related to astrophysics. This included some recent collaborative work between experiments by Blackmon at Hollified/ORNL and theory by Hale at LANL on $^{14}\text{O}(a,p)^{17}\text{F}$ for the hot CNO cycle. Some proposals were presented for new work if new funding becomes available.

Peter Moller, “astrophysical nuclear structure and data work”

Moller described his latest theoretical developments in calculating beta decay (and beta-delayed neutron production), for global determinations of nuclear data used in nucleosynthesis calculations. Inclusion of Gross theory first-forbidden transitions reduced the overall uncertainties of delayed-neutron probability, and half-life, calculations. A table is available on the T-16 Web site containing these data, which will be upgraded soon. Moller has also continued to develop his fission model for calculating fission barriers (or, more correctly, fission potential landscapes in the shape multi-dimensional degrees of freedom). This theory also explains the overall features of paths leading to symmetric and asymmetric fission fragments. A major new direction in this work is to explore axial-asymmetric degrees of freedom, which are known from experimental fission probability measurements to be important. This should lead to more accurate fission barriers for r-process termination calculations.

Allan Carlson, “International evaluation of neutron cross section standards”

Carlson described the international collaboration to upgrade the standards, for ENDF/B-VII. NEA/WPEC and the IAEA are both providing organizational support for coordinating this effort – including a new IAEA/CRP to refine the evaluation methodology, and to better understand the uncertainties resulting from the covariance analyses. The first meeting will be in September 2002, and the overall time for the CRP may be 4 years. Some testing comparisons have already been made using the least-square codes GLUCS, GMA and OH-CODE. Hale’s new R-matrix n-p evaluation now agrees very well with the new 10 MeV Ohio-U data, and the comparison at 14 MeV (with other data) also looks very good. New branching-ratio data for Boron from Hamsch agrees much better with ENDF/B-VI compared to the older Weston data.

The ^{235}U Kawano evaluation differs from ENDF/B-VI significantly (2-3%) in the fast region. Kawano only used fission cross section and ratio fission cross section data, and he also used some additional actinide data. Whereas ENDF/B-VI also used other light-nucleus standard data, as well as some integral data, *e.g.* fission cross sections in an integral californium spectrum. Carlson has looked at the JENDL and ENDF data in the Cf spectrum, and the JENDL result appears to look better compared to the latest NIST experimental result, though the ENDF/B-VI value overlaps with the exp. error bar. Carlson has also determined that in the ENDF/B-VI procedure the inclusion of the light-nucleus standards R-matrix results pulls the fission cross section down in the few-MeV region by about a percent, helping to explain the ENDF-JENDL differences. He plans, by

the next CSEWG meeting, to produce an interim (preliminary) evaluation of the standards based just on a GMA analysis without the R-matrix contribution.

At high energies, Carlson showed Lisowski, Scherbakov, Newhauser, and Nolte data for ^{238}U . For ^{238}U , Lisowski is above Scherbakov, but the situation is inverted for ^{239}Pu . Also, for ^{238}U the Nolte data are significantly above the Lisowski and Scherbakov data.

Bob Haight, “Nuclear data activities at LANSCE”

Haight summarized experimental work at LANSCE that provides reaction cross section data (put in the NNDC CSISRS reaction database), as well as data for testing nuclear model code development work in the USNDP. This also leads to insights into nuclear level densities, isospin physics, and reaction mechanisms. Measurements include (n,x gamma), (n,z), fission, as well as n+p->d gamma (for Big Bang nucleosynthesis). GEANIE and FIGARO are used to measure gamma-rays from fast-neutron reactions. New measurements include As, Y, Zr, Ir, ^{209}Bi , $^{235,8}\text{U}$, $^9\text{Be}(t,a)$ targets. Haight showed a number of reaction cross sections inferred from GEANIE gamma-ray feeding measurements, compared to evaluated results from ENDF – in many cases ENDF upgrades are needed. The DANCE detector under construction at LANSCE will be used for measuring capture cross sections on ^{151}Sm , ^{171}Tm , $^{234,6}\text{U}$ etc – nuclei important in s-process nucleosynthesis and radchem diagnostics. Small target samples can be used in these measurements, for unstable targets.

LANSCE measurement plans: Plans: ^{171}Tm , $^{173,4,6}\text{Lu}$, ^{155}Eu (FY02); ^{238}Pu , ^{170}Tm (in FY03)

M. Chadwick, “LANL ENDF file evaluations”

Chadwick summarized recent ENDF evaluations submitted for ENDF/B-VII. They include: a suite of 7 uranium isotopes, including $^{235,8}\text{U}$; a new ^{239}Pu evaluation; and 14 mercury isotope evaluations for incident neutrons and protons up to 150 MeV. Additional evaluations that will be submitted in the future will be a new ^{208}Pb evaluation that better describes inelastic scattering (developed for AAA), extensions to 150 MeV for actinides; and a suite of light reaction evaluations for hydrogen, helium, and lithium isotope targets.

P. Oblozinsky, “BNL Evaluation activities”

Oblozinsky summarized BNL evaluation work on fission products that may be submitted to ENDF/B-VII. Oblozinsky chairs NEA/WPEC Subgroup 21, a study of the status of fission product evaluations, to determine which evaluations (ENDF, JEFF, JENDL, CENDL, BROND) appear to be best for possible selection for ENDF/B-VII.

Mughabghab is updating thermal capture cross sections (isotopes and elements with $Z < 60$ so far). He initiated a project of updating neutron resonance and average resonance parameters (50 nuclides evaluated so far).

R. Firestone, “thermal neutron capture gamma-ray data”

Firestone summarized his results obtained as part of an IAEA capture gamma-ray CRP. The Budapest measurements have measured capture data for all elements through uranium. Significant deficiencies were found in the Lone database. Also, Los Alamos (Frankle) has evaluated 83 data sets for $Z=1-30,32, 52,64,73,74$. Said Mughabghab will work to integrate these new results into his work.

To do list:

Kalbach: will provide recommendations on benchmark databases

Oblozinsky: will collaborate with LANL on validating HMS, k-parameter used in HMS, and ^{193}Ir ; also interested in collaborations on ^{237}Np

Chadwick: will work with BNL, LLNL, on validating McGNASH width fluctuations

Moller: results for beta decay delayed n, fission barrier, will be archived too at BNL

Minutes of the WG on Dissemination

**USNDP Meeting
Brookhaven National Laboratory
April 10-12, 2002**

**Eric B. Norman
Working Group Chair**

Hard-copy publications such as the *Nuclear Data Sheets* and the *Nuclear Wallet Cards* remain popular with users of nuclear data. Internet access to nuclear data has continued to grow. All of the data centers involved in web-based dissemination reported increased usage of their sites. In the course of the preparation for the DOE budget briefing that took place in late March, it was discovered that each institution has its own system for determining web usage. This led to some difficulties in presenting numbers in a consistent way. As discussed below, there is potentially now a system that could be used to resolve this issue.

Each data center continues to maintain and update their sites. However, due to the lack of manpower, there has been little development of new dissemination software in the last year. Most of the activities of the Dissemination Working Group are described in the center reports that were prepared and posted prior to the USNDP meeting. The following presentations were made during the Dissemination Working Group's session.

Dave Winchell described the work on database migration that is going on at the NNDC. A commercial software package (Sybase Adaptive Server Enterprise 12.5) has been selected, purchased, and installed on a Linux server at BNL. A new relational NSR database has been created and the related software needed to make this database useable is being developed. Development work on creating new ENSDF and EXFOR databases is underway.

Vicki McLane described the cooperative effort with the IEAE Nuclear Data Section in developing a unified dissemination system for nuclear reaction data. This would allow users to come to one site to retrieve bibliographic, experimental, and evaluated nuclear reaction data. (A copy of the viewgraphs are attached).

Rick Firestone described the statistics he obtained for the usage of the LBNL web sites during the past year. He then described a freely-available program called *Analog* that allows web-site operators to monitor the usage of their sites. It was agreed that Rick would send to all data centers the information needed to install this program on their sites and that each site would then use this program on a trial basis to monitor the site usage.

Tom Burrows described the increased usage of the BNL web sites during the past year. He also pointed out the need for updating some of the home pages for individual institutions in the USNDP.

It was noted that the amount of effort within the USNDP devoted to dissemination activities has decreased over the last several years. As a result it was suggested by Rick Norman, and then agreed to unanimously by the USNDP Coordinating Committee that the Dissemination Working Group should be eliminated. However, the very important work in dissemination will continue under the Structure and Reactions Working Groups.

Status of the USNDP Web Site (2000 and 2001)

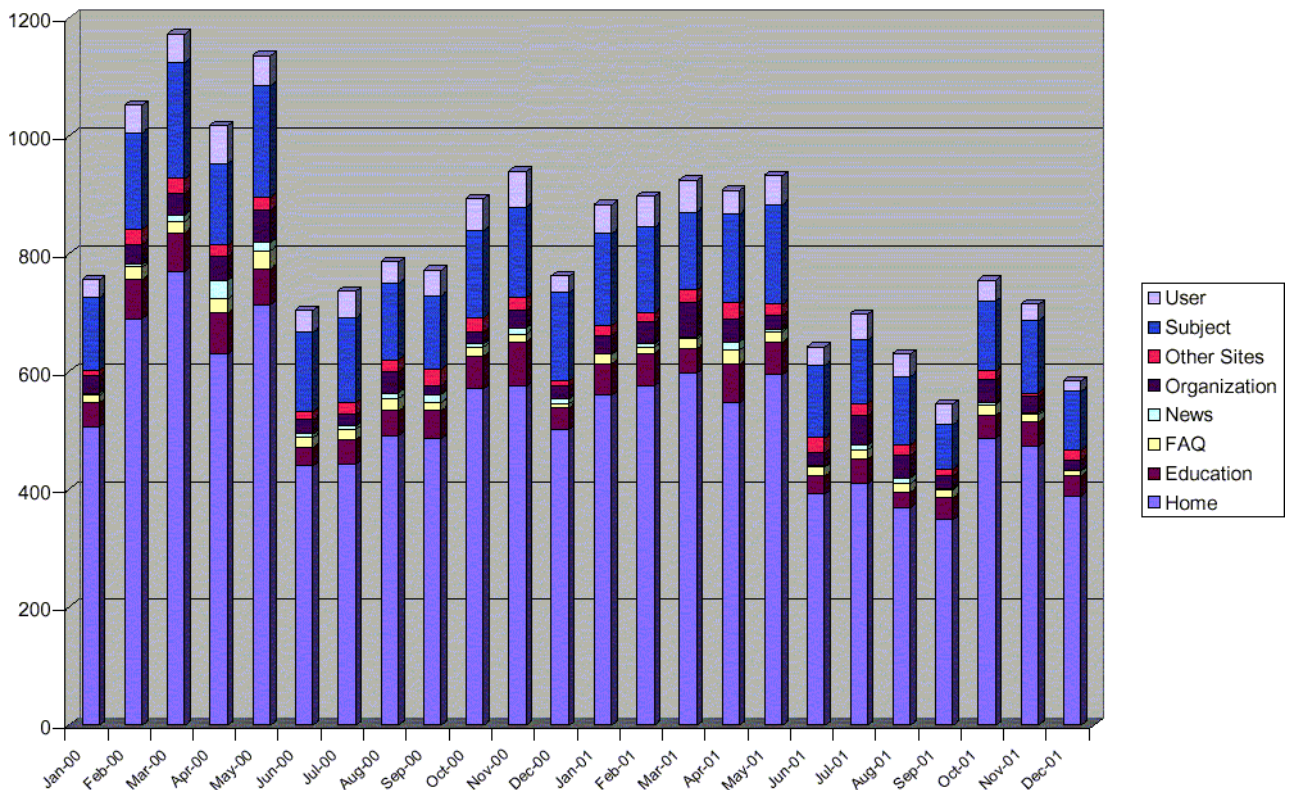
T.W. Burrows

April 8, 2002

Usage

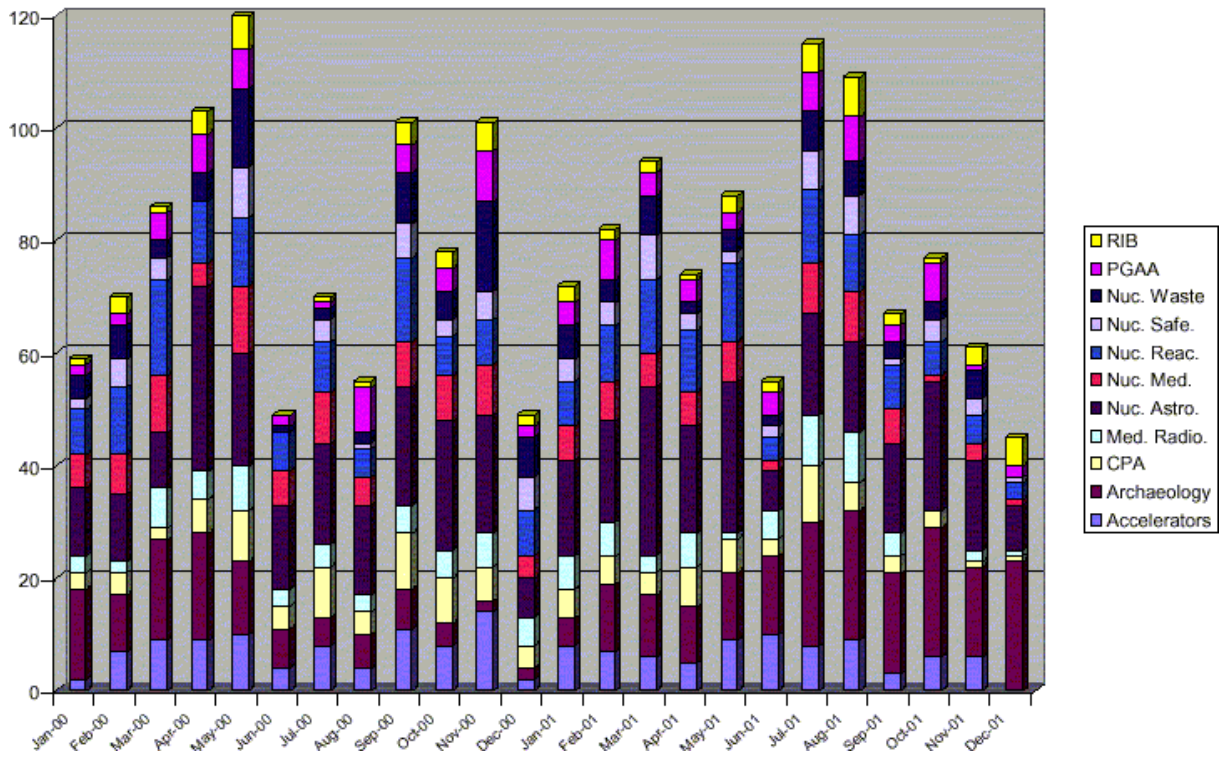
As shown in the following [figure](#) summarizing the queries of the main pages of the USNDP Web site, usage was relatively constant in 2000 and 2001 with totals of 10,730 and 9,115, respectively. Besides the home page, the Subject (17% each year), Education (6% each year), and User (5% each year) pages were the most accessed.

USNDP Main Pages



Access of the various User Views were also relatively constant in these two years (see the following [figure](#)). Nuclear Astrophysics (22% and 23%), Nuclear Reactors (13% and 11%), and Archaeology (12% and 20%) were the most visited views.

User Views



Status of USNDP Pages

The Subject, User, and Education Views need to be revisited and updated as necessary. In addition, no work has been done on designing an Education View for the USNDP as discussed in the 1998 meeting.

Several elements of the Organization View appear to warrant updating. Some of these are:

1. Working Groups - The Nuclear Reaction Working Group description has not been updated since June 11, 1998.
2. Task Forces - The Astrophysics page has not been updated since June 5, 1998 and the Radioactive Ion Beam since Aug 24, 1998.
3. Laboratories & Agencies - Some of the pages describing the centers participating in the US Nuclear Data Program appear to be out of date and may need updating. The following table summarizes this and also gives the revision dates of the Centers home pages, if applicable.

CENTER		USNDP Page	Home Page	Comment
ANL		19-Mar-2002	4-Mar-2002	
BNL		30-Jan-2002	29-Mar-2002	
Idaho Group		30-Jan-2002		
LBNL		26-Oct-2001	23-April-2001	
LLNL		8-Apr-1996		Bad link to home page from USNDP
LANL	LANSCE-3	25-Mar-1999	29-Mar-2002	Link to USNDP site not found
	Group T-2	25-Sep-1998	18-Jan-2002	
M ^c Master		23-Sep-1998		
NIST		14-Mar-2000	20-Mar-2002	Link to USNDP site not found
ORNL	Astrophysics	20-Sep-2000	8-Jan-2001	
	NDP	27-May-1998	25-Oct-2001	
TUNL	NDEP	18-May-1999	18-Feb-2002	
	Program on Nuclear Reaction Phenomenology	8-Apr-2002	22-Oct-1998	

4. Directory - The directory is primarily based on the contents of the NNDC AdList as of May 27, 1998. Some updating has been done based on feedback received from USNDP members but more information is needed. The NNDC AdList may also need updating for the USNDP distribution.

Task Forces

Report of the Astrophysics Task Force ORNL Nuclear Data Project

Nuclear Astrophysics Data Activities (prepared by M. Smith)

At ORNL, evaluations of the $^{18}\text{F}(p,\gamma)$ and $^{18}\text{F}(p,\alpha)$ reactions, important for understanding stellar explosions, and $^{17}\text{O}(p,\gamma)$ and $^{17}\text{O}(p,\alpha)$ reactions, important for understanding the evolution of Red Giant Stars, are nearing completion. The reactions on ^{18}F are incorporating the latest exciting new experimental results with an ^{18}F beams from ORNL's Holifield Radioactive Ion Beam Facility, as well as new Thomas-Ehrman level shift calculations and an improved non-resonant reaction rate calculation. The new reaction rates will be put into formats requested by astrophysicists and distributed over the WWW. A draft of a paper and a Ph.D. thesis have been completed.

Also in progress is a project examining evaluated cross sections for the 19 reactions important for the Solar Neutrino Problem. These cross sections are being converted into reaction rates, parameterized, and compared to analytical approximations. We extended our analysis to include NACRE evaluations of these rates, and made fits to NACRE rates in a standardized format needed by astro modelers and compared these rates to other evaluations. A draft of a paper on this work been completed.

ORNL is also leading a novel effort to gauge the influence of nuclear reaction rate uncertainties (such as those determined from detailed cross section evaluations) on nucleosynthesis predictions in novae. Additionally, initial assessments of level structure of Ar isotopes for hydrogen burning on Cl have been made, to initiate evaluations relevant for nuclear burning in stellar explosions. For FY03, we plan to evaluate additional capture reactions on radioactive proton-rich nuclei which are important for element synthesis and energy generation in stellar explosions. We also will evaluate capture reactions important for understanding Red Giant Stars and nuclear burning in the interior of the sun. Specific reactions we will investigate include those on isotopes such ^{33}Cl , ^{25}Al , and ^{26}Si .

Rare Isotope Accelerator Task Force Report to US NDP, April 2002

Mark Chadwick, LANL (chair)

This report summarizes recent work at Los Alamos related to RIA target design. Note that additional (modest) funding in addition to USNDP funds were provided by the RIA R&D Committee.

FY01 technical activity

During FY2001 we have been working on the development of a reliable code to model light-ion- and proton-induced reactions at intermediate energies for RIA application. We have interacted with ANL and ORNL RIA researchers to ensure alignment with RIA needs (e.g. at the ORNL workshop in 2001, at our LANL RIA applications workshop, and during visits). One consequence of these discussions was the stimulation to improve modeling capabilities of light-ion-induced reactions (or rather, heavy targets incident on light ions in inverse kinematics).

We have made dramatic improvements to the predictive capability of our CEM2k intranuclear cascade code, based on analyses of newly-published GSI data. This is particularly relevant to RIA, since our predictions of radionuclide yields in spallation are much-improved. CEM2k also better models data for secondary neutron, protons, and complex particle production and spectra. Extensive benchmarking work has been done to validate this work, and this was documented in a LANL report for our RIA collaborators. This improved code has been delivered to the MCNPX team to replace the previous version, CEM97. (Physics model improvements that led to these advances included extending the time for the cascade phase of the reaction; using exact reduced masses and binding energies and imposing energy-momentum conservation in each event; and using more accurate inverse-cross-sections).

As a next step, we focused on ion-induced reactions for RIA, for studies of radionuclide production in reactions on lithium and helium targets. Through collaborations with Dr. K.K. Gudima (a visitor to LANL) we have developed the Los Alamos version of the Quark-Gluon String Model (LAQGSM), which now includes our CEM2k code. Our developments to this code were documented in a User Manual (LANL Report LA-UR-01-6804) and it has been tested on a large number of reactions induced by protons and light ions of different energies. At Jerry Nolen's request, we studied new data from GSI on heavy ions + 2H at ~ 1 GeV/amu in inverse kinematics. Predictions using our LAQGSM code, together with a fission fragment distribution model we included, agreed well with the GSI data. We have made similar advances for the modeling of other light-ions, including 4He, 12C.

Planned work for FY02

We will continue to collaborate and interact with RIA researchers to ensure that the code developments we make are integrated for use into RIA design calculations. This will include the use of our simulation codes to model reactions on lithium targets, such as the experiment planned at Argonne. To do this will require further work on the development and benchmarking of our codes for reactions on light-ion targets.

Fission fragment yields are predicted poorly by many cascade codes, and we want to develop capabilities to better model these processes (which produce neutron-rich radionuclides). Our initial work with Furihata's fission fragment model shows promise. We also plan to improve descriptions of light fragment emission by incorporating new routines to describe better inverse cross sections and Coulomb barriers, and to better simulate the kinetic energies of emitted particles.

Papers describing RIA work

- 1) S. G. Mashnik, M. B. Chadwick, H. G. Hughes, E. J. Pitcher, R. E. Prael, D. J. Vieira, L. S. Waters, and W. B. Wilson, "Nuclear Reaction Modeling for RIA ISOL Target Design," LANL Report LA-UR-01-1494; Proc. International Conference on Physics with Radioactive Ion Beam (ISOL'01), Oak Ridge, TN, March 11-14, 2001.
- 2) Konstantin K. Gudima, Stepan G. Mashnik, and Arnold J. Sierk, "User Manual for the code LAQGSM," LANL Report LA-UR-01-6804; <http://lib-www.lanl.gov/la-pubs/0081xxxx.pdf>.
- 3) S. G. Mashnik and A. J. Sierk, "Recent Developments of the Cascade-Exciton Model of Nuclear Reactions," Los Alamos National Laboratory Report LA-UR-01-5390, Los Alamos (2001); Proc. International Conference on Nuclear Data for Science and Technology (ND2001), October 7-12, 2001, Tsukuba, Ibaraki, Japan; <http://lib-www.lanl.gov/la-pubs/0081526.pdf>. (To be published in the Journal of Nuclear Science and Technology).
- 4) Stepan G. Mashnik, Arnold J. Sierk, and Konstantin K. Gudima, "Complex Particle and Light Fragment Emission in the Cascade-Exciton Model of Nuclear Reactions," Los Alamos National Laboratory Report LA-UR-01-5669, Los Alamos (2001); Abstract submitted to the 12th Biennial Topical Meeting of the Radiation Protection and Shielding Division (RPSD) of the American Nuclear Society, April 14-17, 2002, Santa Fe, NM.
- 5) S. G. Mashnik, K. K. Gudima, and A. J. Sierk, "Merging the CEM2k and LAQGSM Codes with GEM2 to Describe Fission and Light-Fragment Production," Abstract submitted to the 6th Int. Workshop on Shielding Aspects of Accelerators, Targets and Irradiation Facilities (SATIF-6), April 10-12, 2002, Stanford Linear Accelerator Center, CA 94025, USA; LANL Report LA-UR-02-0608, Los Alamos (2002).

Laboratory Reports

Mid-Year Progress Report on Argonne Nuclear Data Activities

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Prepared for the Annual *U.S. Nuclear Data Program* Coordination Meeting,
Brookhaven National Laboratory, 10-12 April 2002

Abstract

Activities of the Argonne Nuclear Data Program since the beginning of FY 2002 are outlined. Both the Nuclear Structure and Decay, and Nuclear Reactions activities are covered.

I. Nuclear Data Compilation and Evaluation

I.1 Nuclear Structure and Decay Data (0.5 FTE)

During FY2002, Argonne began working, on a part-time basis, on nuclear structure and decay data evaluation for the International Nuclear Structure and Decay Data (NSDD) network. It has been decided - via consultation with the ENSDF leadership and colleagues from the NSDD network - that the initial effort should be focused on complete ENSDF evaluations for nuclei within the $A = 177$ chain. For almost all of these nuclides, a large amount of new experimental information exists that has not been included in the ENSDF database since the last evaluation. This work is nearing completion and the full report will be submitted to NNDC by the end of May 2002. Argonne was also involved in a review of selected evaluations submitted by members of the NSDD network for publication in the journal *Nuclear Data Sheets*. Specifically, a review for nuclides within the mass chain $A = 103$ was completed during FY2001. A review of the $A=170$ chain was submitted at the end of February 2002 to NNDC. Argonne is also contributing to the activities of the Decay Data Evaluation Project (DDEP). In the second half of FY2002 we intend to submit one evaluated decay dataset to the Chairman of the Decay Data Evaluation Project, including the corresponding files for inclusion in ENSDF. Argonne initiated a special (horizontal) evaluation of properties of nuclear isomeric states in deformed nuclei in the $A = 180$ mass region that are of interest to the basic nuclear structure and applied nuclear physics communities. This project is carried out in collaboration with scientists from the Australian National University, Canberra, Australia, and University of Surrey, U.K. When completed (2-3

years timeframe), the data will be included in the ENSDF database and the corresponding results will be published on the USNDP Web site in coordination with the USNDP Dissemination Working Group. One of the investigators in the program (FGK) is also involved in limited experimental nuclear structure activities that are conducted mainly at the ATLAS facility of the Argonne Physics Division. Some of the results from this effort have been already published in refereed journal articles and included in the ENSDF database. Some unpublished data were also made available to other members of the NSDD network for inclusion in ENSDF.

I.2 Nuclear Reaction Data (0.4 FTE)

A report dealing with methods for representing and propagating large errors in nuclear data was completed and is now available on the Web as Argonne National Laboratory Report ANL/NDM-154. A journal version of this report has been accepted for publication as a regular article in Nuclear Instruments and Methods in Physics Research A. Preparation of a final report documenting an evaluation of the $^{31}\text{P}(p,\gamma)^{32}\text{S}$ and $^{31}\text{P}(p,\alpha)^{28}\text{Si}$ reactions that are important to stellar evolution and nuclear astrophysics is nearing completion. It is intended that this report be available on the Web by mid-year FY2002. The extensive numerical information contained therein will also be made available on the USNDP Web site. One of the investigators in the program (DLS) spent two weeks at Ohio University during early December 2001. There he participated in a collaborative experiment that was undertaken to measure spectra, total yields, and angular distributions of neutron fields produced by 2-7 MeV deuterons on thick targets of Ag, and thin targets of T, D, Ti, O, and C. The purpose of the experiment was to characterize the background neutron sources associated with using Ti-T targets (on Ag backing) for the production of quasi-monoenergetic neutron fields in the energy range 14-20 MeV. Finally, extensive neutron activation data measured recently at IRMM, Geel, Belgium, for the energy range 14-20 MeV were compiled in EXFOR format and transmitted to the Nuclear Data Bank, Paris, France. The materials included in this compiled data set were Tc, V, Ni, Co, Cu, Pb, and Mo.

II. Data Dissemination

Argonne continues to develop, update, and maintain the ANL Nuclear Data Measurement Report Series, ANL Nuclear Data Information, and Experimental Resources for Nuclear Data Web sites. It is envisioned in the future to upgrade significantly the latter site in coordination with the USNDP Dissemination Working Group and the experimental nuclear data community.

III. Publications (FY2001-present)

III.1. Publications in scientific journals and conference proceedings

24 articles were published in peer-reviewed scientific journals with international circulations; 20 contribution papers and abstracts were published in national and international conference proceedings, and meetings.

III.2. Invited presentations at national and international conferences, and meetings

1. **F.G. Kondev**
High Seniority Intrinsic and Collective Structures in ^{175}Hf
2001 Gordon Research Conference on Nuclear Chemistry, Colby-Sawyer College, New London NH, 17-21 June 2001, USA

III.3. Invited seminars and colloquia

1. **D.L. Smith**
FIGARO: Fissile Interrogation Using Gamma Rays from Oxygen
Nuclear Chemistry Division, Forschungszentrum-Juelich, Juelich, Germany, February 2001
2. **F.G. Kondev**
K-Isomers – From Nuclear Structure to Advanced Applications
Idaho Accelerator Center, Idaho State University, Pocatello, USA, October 2001
3. **F.G. Kondev**,
Spectroscopy at the Extremes: A Journey in the Past, the Present and the Future
Department of Nuclear Physics, Australian National University, Canberra, Australia, May 2001

Report of the National Nuclear Data Center to the 2002 US Nuclear Data Program Meeting

NNDC Operations

Since the last meeting of the US Nuclear Data Program, several personnel changes have taken place at the NNDC. Charlie Dunford stepped down after 10 plus years of outstanding service as the NNDC Head. Pavel Oblozinsky took over as the NNDC Head effective February 1, 2002, while Charlie continues to serve as the NNDC Deputy Head. Two staff members retired with no replacement. Pauline Dixon (support staff, CSISRS compilation and ENSDF processing) retired in June 2002, followed by Bob Kinsey (scientific staff, dissemination software and utility codes development) who retired in December 2002. The NNDC now consists of 10 scientific/professional staff, 3 support staff and 3 guest scientists. In addition, Professor He Dong Choi, Department of Nuclear Engineering, Seoul National University, Korea, is spending his sabbatical year at the NNDC starting February 2002.

We continue to provide secretariat functions and chair for the US Nuclear Data Program (USNDP) and for the US Cross Section Evaluation Working Group (CSEWG). In December 2001, the final report on the accomplishments of the Nuclear Data Program for fiscal year 2001 was completed and distributed. The Work Plan for fiscal year 2003 was completed and distributed in February 2002. Both of these documents were completed with the assistance of the Coordinating Committee of the USNDP. Pavel Oblozinsky replaced Charlie as the head of the US delegation to the NEA Working Party on Evaluation Cooperation. This group coordinates the international nuclear data evaluation activities for applied nuclear technologies. Pavel Oblozinsky replaced Richard Meyer as the US representative on the International Nuclear Data Committee, which advises the International Atomic Energy Agency on its nuclear data program.

The main work of the NNDC continues to be performed on our Compaq Alpha Server 4100. The nuclear databases reside on this computer and the related analysis, maintenance, or dissemination programs run on it. Due to the inherently more secure operating system on this computer (OpenVMS), we have been able to maintain a fairly open environment. We will be striving to continue to serve databases efficiently while conforming to the cyber security requirements of DOE. The effort to migrate from OSU Httpd web server to Apache based Compaq Secure Web Server is well underway.

To support Database Migration Project described below, we operate several servers running Windows-NT or Linux. We operate one server as database server, running Sybase ASE, where various databases are developed, and another as an in-house test web server where various

data dissemination programs are tested. We are working to implement a secure and workable computer environment that includes a web server located outside the firewall communicating with a database server inside the firewall through a secure channel.

NNDC staff use PC's running Windows 2000 on their desks, and we maintain Windows NT and Linux servers to meet the NNDC computing needs.

Nuclear Database Migration Project

During the last year, the NNDC has purchased and installed the Sybase Adaptive Server Enterprise (ASE) software on a Linux server. Relational versions of NSR, ENSDF, and several reaction databases are being developed and loaded on this platform. For web-based retrieval of the data, we will be using Java Server Pages (JSP) hosted by www2.bnl.gov, a laboratory maintained computer outside of the security firewall.

A second Linux server has been purchased and will be used for web application development, and to host a copy of the databases in "warm stand-by" mode for use in case of hardware failure on the main server.

During the coming year, administrative functions for NSR will be transferred to the new system. This involves the development of new software and the modification of legacy codes, where appropriate, to work with the relational database. Once this is accomplished, the VMS-based version of the database will function as a mirrored copy of the data, updated on a weekly basis. Similar steps will be taken for the other databases over the next two years.

Nuclear Structure Data

Evaluation Work:

The following A-chain evaluations were completed: A=68 (Burrows), 136 (Sonzogni), 143 (Tuli). The following nuclides were evaluated: ^{49}Mn , ^{49}Fe , ^{50}Fe , ^{50}Co (Burrows), 26 p-decaying nuclides (Sonzogni), 99Tc (Tuli, Singh), ^{48}Ni , ^{55}Zn , ^{56}Zn , ^{137}Cs , ^{137}Nd (Sonzogni). Since last meeting A=139 (Burrows), 143 (Tuli), 144 (Sonzogni), and nuclides: 99Tc (Tuli, Singh), 26 p-decaying nuclides have been published. All other nuclides (Burrows, Sonzogni) were added to ENSDF.

Nuclear Data Sheets:

Eleven issues of Nuclear Data Sheets consisting of ENSDF evaluation have been edited, prepared and sent to Academic Press for publication (Blennau, Tuli). The twelfth issue consisting of NSR updates was prepared and sent to Academic Press (Tallarine, Winchell).

Evaluated Nuclear Structure Data File (ENSDF) and NUDAT:

The ENSDF database has been continuously updated and maintained (Tuli) during the past year. The contents of the database have been distributed to the network in August 2001 and March 2002 (Blennau, Tuli). NuDat has been updated following each distribution (Tuli).

Nuclear Wallet Cards File:

The Wallet Cards file has been updated twice, following ENSDF distribution (Tuli).

ENSDF Analysis and Utility Codes:

The ENSDF analysis and utility codes are maintained and upgraded (Burrows, Dunford, Kinsey). The current status of these codes will be available on the Web prior to the USNDP meeting.

Nuclear Science References:

During calendar year 2001, over 4600 new entries were added to NSR. Keyword abstracts were prepared for approximately 3300 of these entries. Distributions of new and updated entries were carried out on a monthly basis.

Other Activities:

J.K. Tuli spent a week at IAEA in Vienna, December 2001 to plan for an evaluators' training workshop to be held at Vienna in November 2002.

Nuclear Reaction Data

CSISRS/ENDF/CINDA Related Codes

The NNDC continues to provide updates of CSISRS, CINDA, and ENDF codes to the following data centers: NDS (IAEA), VNIIEF (Russia), and the CNDC (China). (McLane)

Viktor Zerkin of the NDS has made two visits to the NNDC, each for two weeks, and D. McLane visited the NDS for one week to discuss the design of a new relational nuclear reaction database.

Release 6.13 of the ENDF Utility codes is being prepared. The codes have been upgraded to correct all reported bugs and to process all format changes approved at the November 2001

CSEWG meeting. Graphical input interfaces will be included for UNIX and Windows versions of CHECKR, FIZCON, PSYCHE, STANEF and INTER.

Nuclear Reaction Evaluation

A collaboration with LANL and IAEA Vienna on the development of a modular code for nuclear reaction data evaluations continued. The pre-equilibrium Monte Carlo code HMS was extended to account for angular momentum conservation, of importance for modeling isomer and discrete gamma-ray production. The modular code Empire-II was extended by adding a module based on the exciton model code Degas, motivated by the need to handle direct-semidirect capture in the fast neutron energy region. Further major extension of the code Empire-II represents its new module, a coupled-channels optical model code Ecis-95, with NNDC responsible for the validation part. All these updates (Degas, Ecis, HMS) are included into recently released Empire-2.17. (Oblozinsky)

The cooperation with the Korean Atomic Energy Research Institute (KAERI) on 19 fission product cross-section evaluations continued in the fast neutron energy range. Yong-Deok Lee spent 1 month at the NNDC. Use was made of the latest version of the code Empire-II, including preequilibrium modeling of fast neutron capture, and coupled-channels optical model for deformed nuclei. All evaluations were preliminary completed, including 6 highly deformed nuclei where coupled-channels optical model is of importance. (Oblozinsky)

Review of all available fission product cross sections from the five international data files (ENDF/B, JEF, JENDL, BROND and CENDL) has started as an international project under NEA WPEC (new Subgroup 21). The project intends to review all 211 evaluations in the fission product region ($32 < Z < 68$), to focus on the bulk of evaluations and to recommend the best evaluations for inclusion into the future ENDF/B-VII library. Web page of SG21 was created and graphical inter-comparison was prepared for a trial sample of 20 nuclides. These were reviewed. A complete package of 211 graphical inter-comparisons was prepared. (Oblozinsky, Sirakov)

A grant proposal for a joint project with the Nuclear Physics Data Center, VNIIEF, Sarov, Russia on the Compilation and Evaluation of Alpha-Induced Nuclear Reaction Cross Sections for Astrophysics is under consideration by the U.S. Civilian Research and Development Foundation (CRDF) Cooperative Grant Program.

Nuclear Reaction Data

The compilation of neutron and charged-particle nuclear data (CPND) continues. As of March 30, 2002, the NNDC has entered more than 975 references of data measured in the U.S. and Canada. The database now contains more than 960 thousand data points for CPND, and more than 6.5 million data points for all nuclear reactions. (McLane, Dixon)

Release 8 of ENDF/B-VI was issued. (McLane, Sirakov)

Other Activities

Victoria McLane participated in Nuclear Reaction Data Center meeting in Vienna in May 2001.

Pavel Oblozinsky and Victoria McLane gave invited talks at the International Conference on Nuclear Data for Science and Technology, October 2001, Tsukuba.

Pavel Oblozinsky gave a summary talk on files and applications at the International Conference on Nuclear Data for Science and Technology, October 2001, Tsukuba.

Pavel Oblozinsky gave an invited talk on applied nuclear physics at the Workshop on Spallation Neutron Sources, Oak Ridge, March 2002.

Data Dissemination

Internet

Internet access to the data and information available at the NNDC consists of:

1. TELNET (T.W. Burrows, C.L. Dunford, V. McLane)
2. Web (R.E. Arcilla, M. Blennau, T.W. Burrows, C.L. Dunford, R.R. Kinsey, V. McLane, Y. Sanborn, J.K. Tuli, D.F. Winchell)
3. Anonymous FTP (T.W. Burrows, C.L. Dunford, R.R. Kinsey)

As shown in Fig. 1, there was about a 14% increase in the number of retrievals over the Internet between 2000 and 2001. NuDat and NSR continue to be the most popular with 22% and 25% of the 2001 retrievals, respectively. Retrievals from the nuclear reaction databases (CINDA, CSISRS, ENDF) accounted for 17% of the retrievals while retrievals from ENSDF, MIRD, and XUNDL amounted to 21%. Retrievals *via* the Web, including the NSR SQL Server accounted for about 90% of the total with approximately 9% and 1% *via* TELNET and anonymous FTP, respectively.

Strong usage of the ENSDF and NSR link managers continued in 2001. In addition to NNDC pages, URL's using at least one of these include:

Atom.kaeri.re.kr	nucleardata.nuclear.lu.se	radware.phy.ornl.gov
us.fl14.mail.yahoo.com	www-nds.iaea.org	www-nds.ipen.br
www.elsevier.nl	www.fysik.lu.se	www.google.com
www.google.de	www.td.anl.gov	www.tunl.duke.edu

Additions and Improvements

1. CINDA, CSISRS, and NSR links to the APS Link Manager were extended back to include all of Physical Review from Series II on and all of Physical Review Letters and Reviews of Modern Physics. NSR now contains links to somewhat over 40,000 journal abstracts from 15 journals.
2. DOE has adopted the PDF version of the 2000 edition of the Nuclear Wallet Cards as the standard for the NMMSS (Nuclear Material Management and Safeguards System) and DOE Nuclear Material Inventory Radioactive Decay Constants. At the request of the DOE Office of Security we have added links to the NNDC home page and other relevant NNDC Web pages indicating this.
3. Balraj Singh's Table of Magnetic Dipole Rotational Bands, Norm Holden's History of the Origin of the Chemical Elements and Their Discoverers, Alejandro Sonzogni's proton emitter evaluation, and the WPEC SG21 Assessment of Neutron Cross-Section Evaluations for the Bulk of Fission Products were added to the NNDC site.
4. A Nuclear Reaction Model Codes site was set up and currently contains: ABAREX (R.D. Lawson and A.B. Smith. ANL), EMPIRE-II (M. Herman, IAEA, R. Capote, Univ. Sevilla, P. Obložinsky, BNL, and A. Trkov, IAEA), and PRECO-2000 (C.K. Walker. TUNL). This begins to satisfy a need expressed at the 1998 meeting of the USNDP.
5. Improved tabular representation of data from ENSDF, MIRD, and XUNDL was implemented. This representation attempts to provide the best encoding of Greek characters and symbols based on the browser and operating system. Cross-references in ENSDF adopted datasets are also linked to the source datasets.
6. A Web interface to the utility code QCALC, which calculates decay Q-values and reaction Q-values and threshold energies, was implemented.
7. The Web interface to CSISRS was upgraded to use the program ZVView¹ as a helper application.

Under Development

1. Work has begun on porting the Web database interfaces to the new relational databases.
2. The NNDC is currently porting its Web site from the Ohio State University Web Server to Compaq's version of Apache for OpenVMS.
3. A preliminary version of the new experimental nuclear reaction database has been completed by V. Zerkin of the IAEA NDS and has been installed at NNDC for testing.

¹ Developed by Viktor Zerkin, IAEA Nuclear Data Section.

Future Plans

1. We still hope to finish the interface to the ENSDF and XUNDL databases, which formats the information for the Isotope Explorer Java Applet. This implementation will be hampered by lack of documentation on the formats and syntax required by the applet.
2. Dependent on resources, a data link manager will be completed. This will allow Physical Review C and other journals to provide links from their articles to the corresponding experimental data in databases resident at the NNDC.
3. An improved HTML encoding of Greek letters and symbols will be implemented for NSR.
4. Work will begin on the CINDA relational database in May.

Hard Copy and CD-ROM

(M. Blennau, P. Dixon, R.R. Kinsey, V. McLane, J. Tallarine, J.K. Tuli, D.F. Winchell)

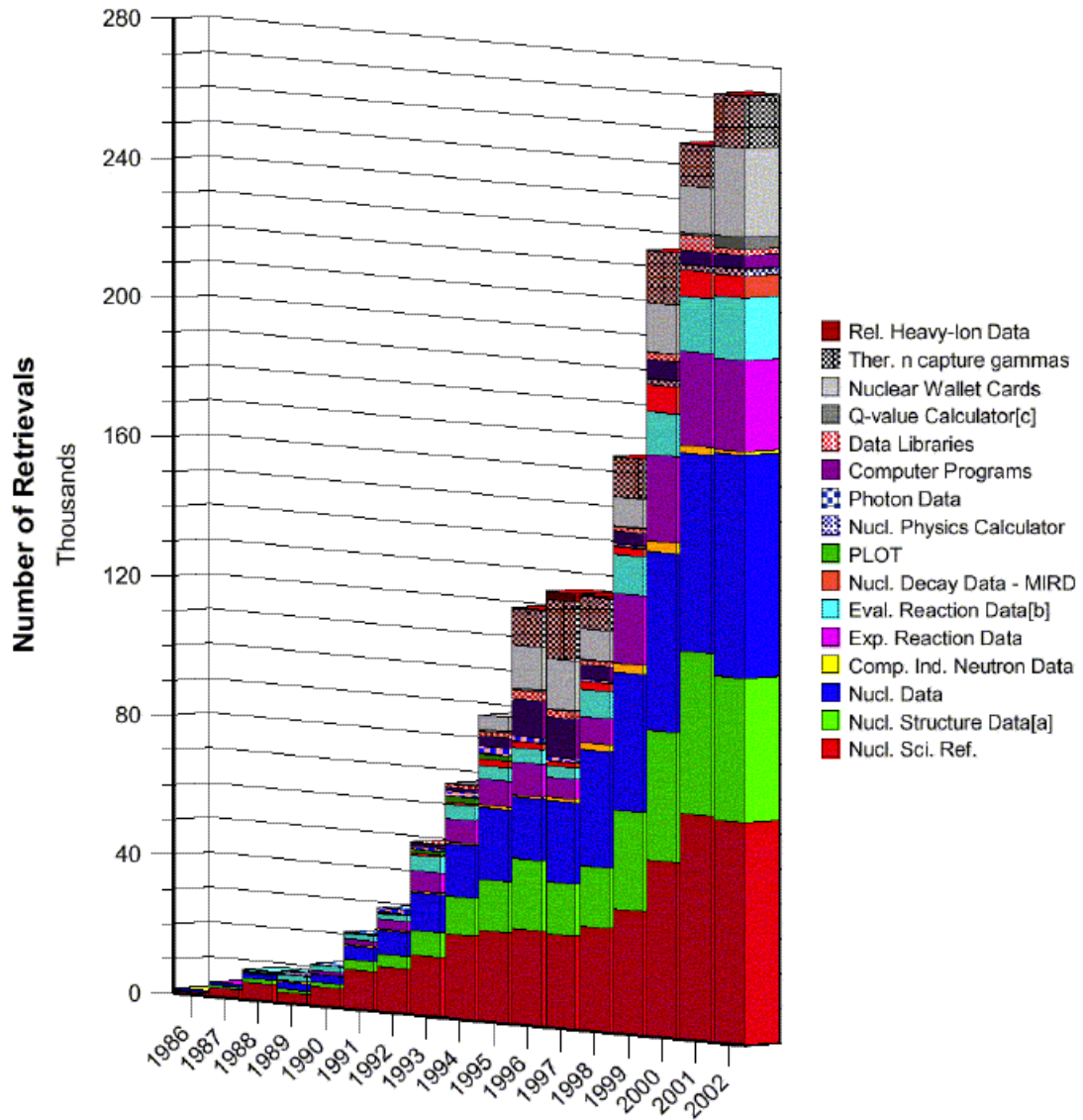
The *Nuclear Data Sheets* continue to be edited and produced by the NNDC for publication by Academic Press. The cost of this activity is fully covered by royalties and other payments received from Academic Press. Eleven issues are devoted to publication of ENSDF evaluations. The December issue is devoted to "Recent References" which are the yearly updates to Nuclear Science References. Academic Press continues to make the *Nuclear Data Sheets* available over the Web. Since Elsevier now owns Academic Press, we anticipate that Elsevier will make the journal available on their Web sites.

The NNDC satisfied 1 request each for the entire NuDat database on CD-ROM and the EPDL97 CD-ROM and 3 requests for ENDF6 release 8 on CD-ROM between March 19, 2001 and March 15, 2002.

User Outreach

The NNDC continues to host the USNDP Web site and the CSEWG Web site. An updated NRDC Website has been put up on the NNDC site and the NNDC is currently hosting a site for the International Nuclear Structure and Decay Data Network.

*NNDC On-Line Data Service, Web, & FTP Retrievals 1986-2002**



* Extrapolated as of March 31, 2002.

^a Includes proton emitters (added to Web February 21, 2002).

^b Includes WPEC SPG 21 fission product cross sections (added to Web March 15, 2002).

^c Added to Web September 11, 2001.

Figure 1

Nuclear Structure and Decay Data Evaluations of the Georgia Tech Group

for report to the meeting of the

U.S. Nuclear Data Program
April 11-12, 2002 at Brookhaven National Laboratory

A program of horizontal systematics has been initiated at Georgia Tech in the last $1\frac{1}{2}$ years. The goal of the program is most succinctly described as “mining the ENSDF Library for global nuclear structure features”. In the first phase of the program we undertook to extract all B(E2) values for all doubly-even nuclei from the Library. To this end, the best suited programming language was determined to be Perl. The program which was developed delivered ~ 3100 B(E2)’s. In the second phase of the program we have written a new code that has an improved ability to identify entries in the ENSDF Library and we have begun to look in detail at the list of values generated by the code and various sources of B(E2) values (line-by-line inspection of the complete ENSDF Library; individual entries in Nuclear Data Sheets; original journal articles). We find an additional ~ 500 entries in the ENSDF Library. While the number of errors, inconsistencies, ambiguities, ... is fairly low, to achieve a globally reliable procedure for this horizontal search (and potentially, others), we are attending to a number of detailed issues. Some examples are: incompletely or unevaluated entries in ENSDF; entries of more than one value for a B(E2) with inadequate commentary; incorrect commentaries. Our goals in this second phase of the program are: to develop a search program which can deliver 99+% of all B(E2)’s in doubly-even nuclei where such B(E2)’s can be deduced from data; provide feedback to evaluators on errors and ambiguities in ENSDF; provide suggestions on changes in ENSDF entries (both adopted values and commentaries).

21 March 2002

Nuclear Structure and Decay Data Evaluations
and Related Activities of the Idaho Group

for report to the meeting of the

U. S. Nuclear Data Program
April 11-12, 2002 at Brookhaven National Laboratory

I. Mass-chain Evaluations

Within the Nuclear Structure and Decay Data Evaluation Network, the Group working at the Idaho National Engineering and Environmental Laboratory has the responsibility for the twelve mass chains 87 and 153-163. The participants in this work are R. G. Helmer and C. W. Reich. Since the last network meeting in April 2001, the complete evaluation for $A=87$ has been carried out. We are currently working on $A=156$ and 159.

The current status of our twelve A chains is as follows:

Mass	Last publication date
87	3/2002
153	2/1998
154	10/1998
155	4/1994
156	1/1992
157	6/1996
158	3/1996
159	5/1994
160	8/1996
161	8/2000
162	7/1999
163	1/2000

II. Decay Data Evaluation Project, DDEP

R. G. Helmer was the coordinator of this international group that is carrying out evaluations of decay data for a set of nuclides that are important for several applications. This group includes non-ENSDF evaluators from France, Germany, Russia, Spain, and the United Kingdom, along with ENSDF evaluators E. Browne and R. G. Helmer. Dr. Helmer organized and chaired a meeting of this group in Braunschweig, Germany in May 2001 and at that time turned the coordination duties over to E. Browne.

During the last year, evaluations have been submitted for ${}^7\text{Be}$, ${}^{64}\text{Cu}$, ${}^{110}\text{Ag}$, ${}^{110}\text{Ag}^m$, and ${}^{155}\text{Sm}$.

The DDEP is the main contributor to a current Coordinated Research Program, CRP, of the International Atomic Energy Agency, IAEA, which is preparing a set of decay data evaluations to be included in its update of their report entitled "X-ray and Gamma-ray Standards for Detector Calibration" (IAEA-TECDOC-619 (1991)). The DDEP members have contributed the methodology to be used and will contribute many of the decay data evaluations.

III. Coordinating Activities

R. G. Helmer has been involved in the planning for the portions of this US NDP meeting related to its Working Group on Nuclear Structure and Decay Data Evaluations.

IV. Related Activities

R. G. Helmer is a member of the IAEA CRP discussed above that will provide evaluated decay data for detector calibration.

Los Alamos Nuclear Data Program

*Mark B. Chadwick,
Group Leader, Nuclear Physics Group T-16, LANL*

Overview:

- **Experiments at LANSCE**
- **Nuclear reaction databases (ENDF)** *(covered in morning)*
- **Nuclear model codes** *(covered by MBC in morning session)*
- **RIA**
- **Astrophysics** *(covered by Moller in morning session)*
- **Standards for reaction data** *(esp. n+p)*
- **WWW Dissemination**
- **International cooperation**

Presented at the US NDP meeting, BNL, April (2002)

Nuclear Data Measurement Program at LANSCE

Bob Haight
LANSCE-3

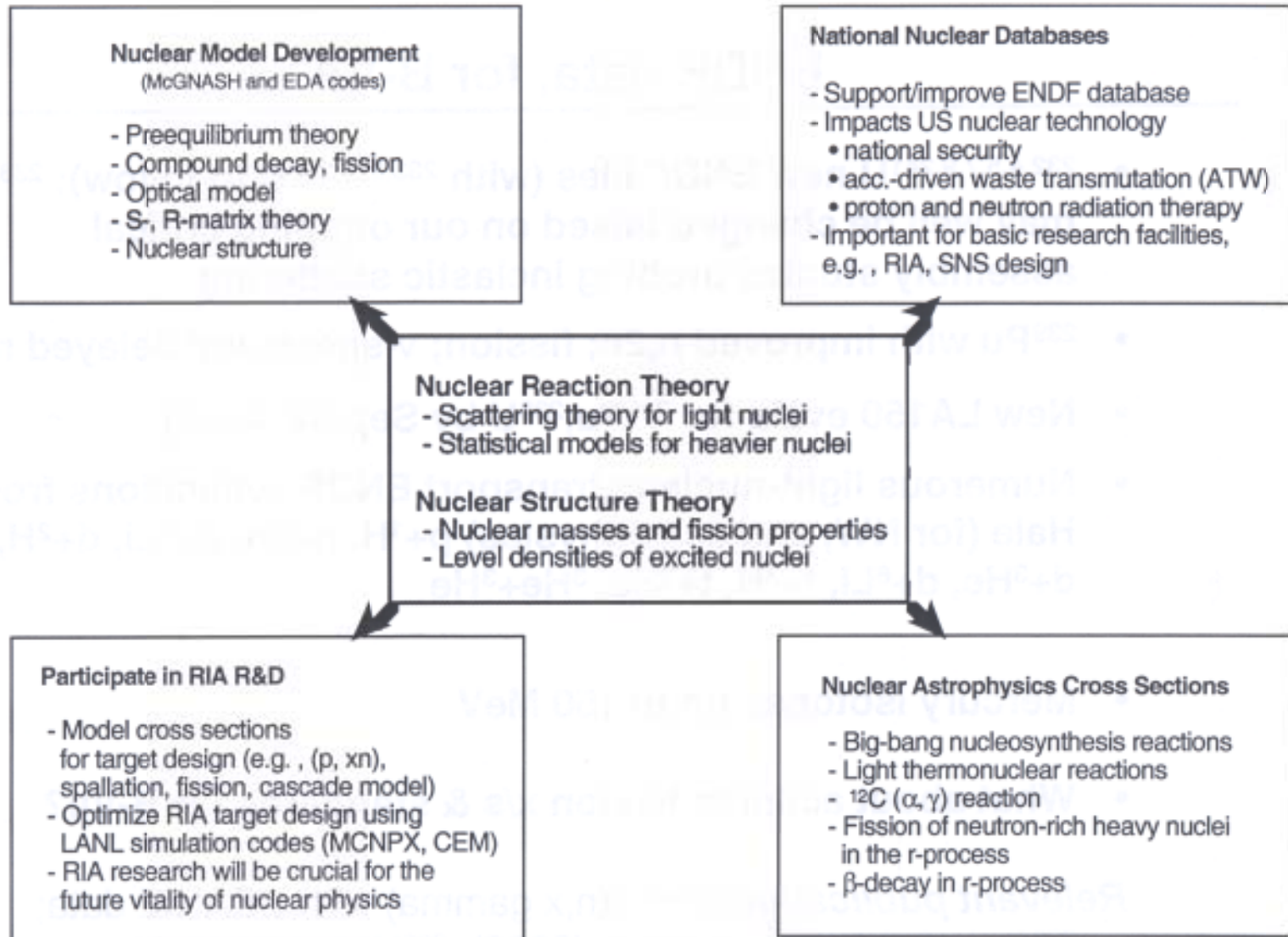
LANSCCE Program – $E_n > 100$ keV

- (n,x γ):
 - GEANIE: ^9Be , $^{191,193}\text{Ir}$, ^{233}U , ^{239}Pu (with LLNL)
 - FIGARO: ^{56}Fe , $^{58,60}\text{Ni}$, ^{59}Co , $A \sim 90$, ^{99}Tc , ^{181}Ta , ^{197}Au
- (n,n' γ): FIGARO -- ^{56}Fe , $^{58,60}\text{Ni}$
- (n,z): Ca, S (up to ~ 50 MeV with Ohio U); Fe, Cr (up to 100 MeV for AAA program)
- Fission
 - Fission neutron spectrum (with CEA) – ^{238}U now, ^{235}U , ^{239}Pu later
 - Fission product yields from x-rays (with CEA)
 - Fission product yields from gamma rays
 - Fission cross section ^{238}Pu (with CEA) - planned
- n+p \rightarrow d + γ for Big Bang nucleosynthesis

LANSCCE Program – $E_n < 500$ keV

- (n, γ):
 - DANCE: ^{151}Sm , ^{171}Tm , ^{234}U , ^{236}U , others
- (n, α)
 - proposed by ORNL
- Fission cross sections
 - Lead slowing-down spectrometer (being designed)
 - ^{235}mU
 - Other actinides

Nuclear Data Program, T-16 LANL



ENDF data, for B-VII

- $^{232,4,5,7,9,241}\text{U}$ new ENDF files (with $^{233,236,240}\text{U}$ to follow); ^{238}U may well be changed based on our ongoing critical assembly studies probing inelastic scattering
- ^{239}Pu with improved n,2n; fission; v-spectrum; delayed n
- New LA150 evals for $^{239}\text{Pu}, ^{238}\text{U}$ by Sep 02 (AAA)
- Numerous light-nucleus transport ENDF evaluations from Hale (for NW, and astrophysics) $p+^1\text{H}$, $p+^3\text{H}$, $p+^7\text{Li}$, $d+^2\text{H}$, $d+^3\text{He}$, $d+^6\text{Li}$, $t+^3\text{H}$, $t+^3\text{He}$, $^3\text{He}+^3\text{He}$
- Mercury isotopes up to 150 MeV
- What about actinide fission x/s & standards for B-VII?

Relevant publications: $^{238}\text{U}(n,x \text{ gamma})$ with GEANIE data;
 $^{239}\text{Pu}(n,2n)$ in Phys Rev. C (2002), ^{235}U paper with Y

ENDF

ENDF Support

- + Got final approval for an extended format for radionuclide production.
- + Contributed extensive testing and sensitivity results for the Los Alamos fast critical assemblies GODIVA, JEZEBEL, the flattops, etc.
- + Reformatted the photoatomic, electroatomic, and atomic relaxation data for ENDF and got them approved for the latest release of EMDF/B-VI.
- + Joined a committee to work on format specifications for ENDF/B-VII.

Processing Code Development

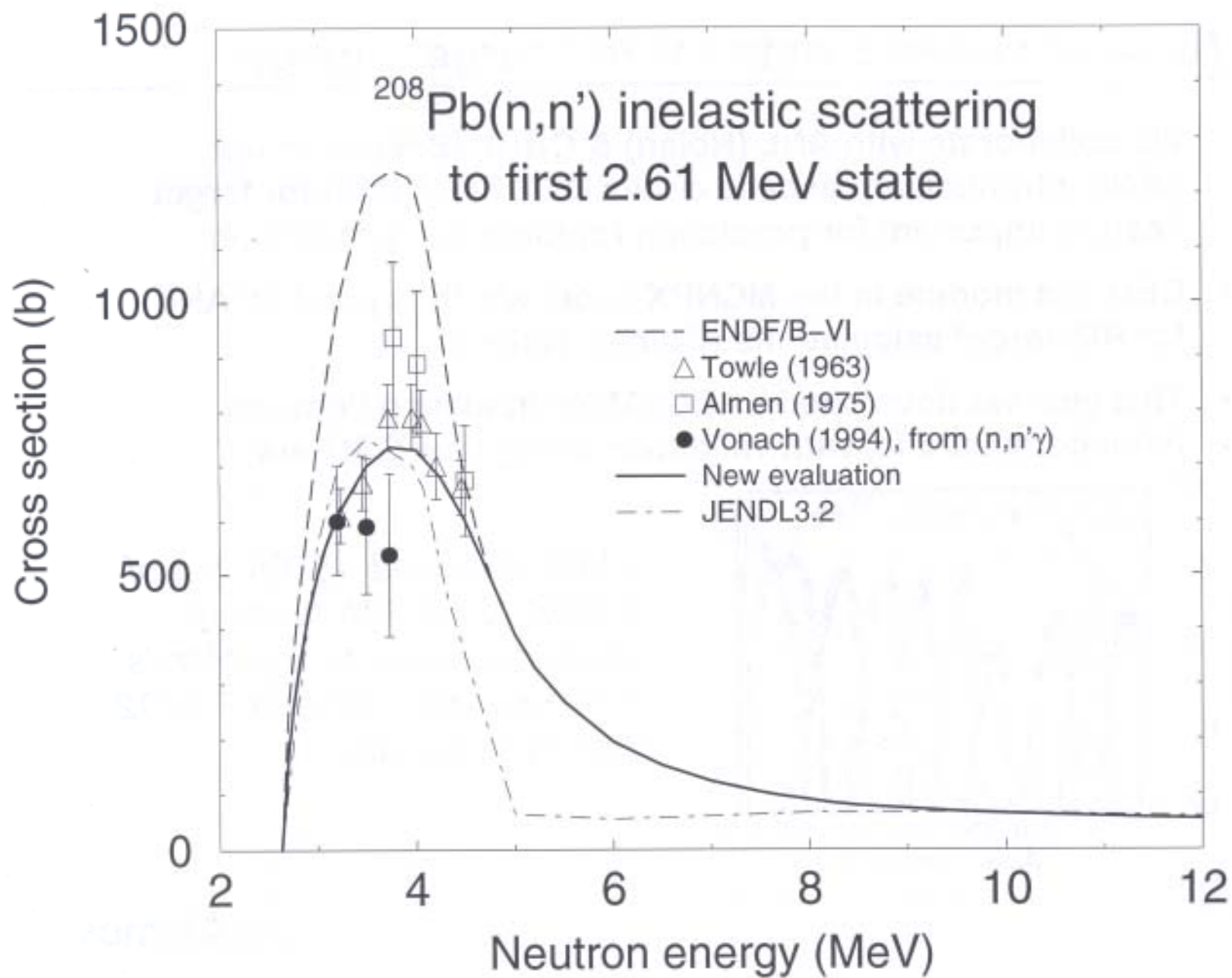
- + Implemented a capability to generate libraries of ENDF delayed neutron for the MCNP Monte Carlo code.
- + Made initial steps towards processing capabilities for the new photoatomic and atomic relaxation data, with special emphasis on a new library for MCNP.
- + Processed the new IAEA photonuclear data into libraries for MCNP and made them available to the world community through our web site.
- + Completed most of the work on a new modernized Fortran-90/95 version of the NJOY Nuclear Data processing System and rewrote the NJOY report to reflect the new version of the code and all the other changes made since the last report in 1994.

Nuclear reaction model code development

- **McGNASH code development** (Talou, Chadwick)
 - Major upgrade to use advanced f90 features
 - Width fluctuation physics in (with Hilaire, Bill)
 - Removed GNASH-type T_{ij} collapse T_1
 - Validation against GNASH
 - Being used for $n+^{193}\text{Ir}$ (new GEANIE data)

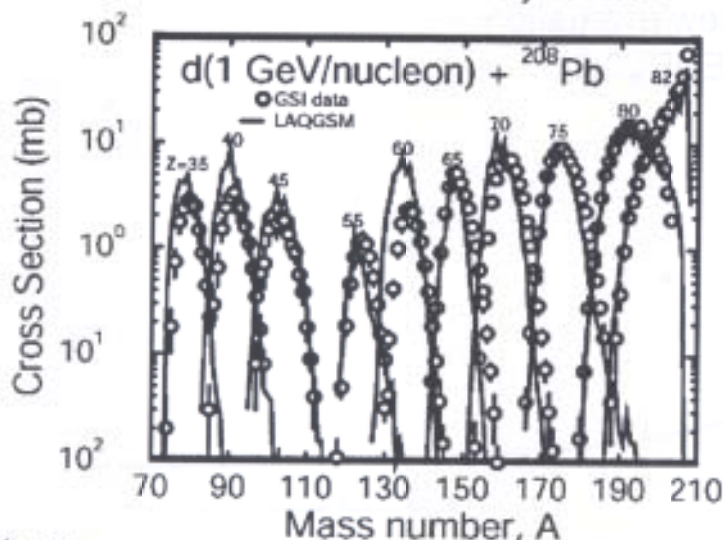
- **HMS preequilibrium (& HMS-ALICE)** (Blann, Chadwick, Oblozinsky)
 - Angular momentum transfer in preeq and compound processes included using semiclassical algorithms
 - Huizenga-Vandenbosch ansatz used for *isomer x/s*
 - Upgrading our LA150 activation library to include isomer production using HMS-ALICE

Relevant publications: isomers with Blann (Japan), Pt(n,nx γ), PRC 2001, Mo(n,x γ)PRC 2001, O(n,x γ), NSE (2001) — with GEANIE data



Nuclear codes & data for RIA target design

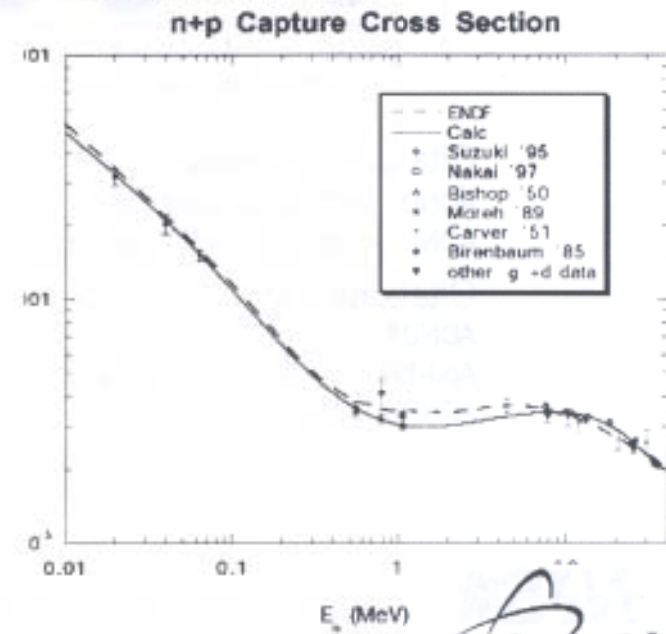
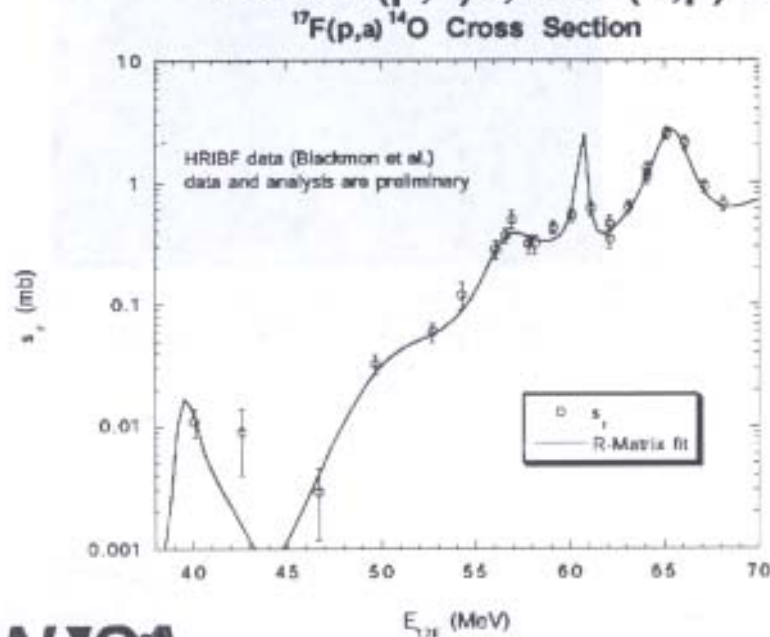
- We collaborate with ANL (Nolen) & ORNL (Beene) on our LANL intranuclear cascade codes CEM / LAQGSM for target design: important for predicting radionuclide production
- CEM is a module in the MCNPX code, which is used by ANL for RIA target calculations (Gomes, Nolen)
- This year we developed LAQGSM for modeling light-ion induced reactions, with validation using new GSI data



*FY01: received ~\$60K out of \$100K LANL RIA funding;
Presented case to Jay Marx's RIA R&D committee in Feb'02
For FY02 funding.*

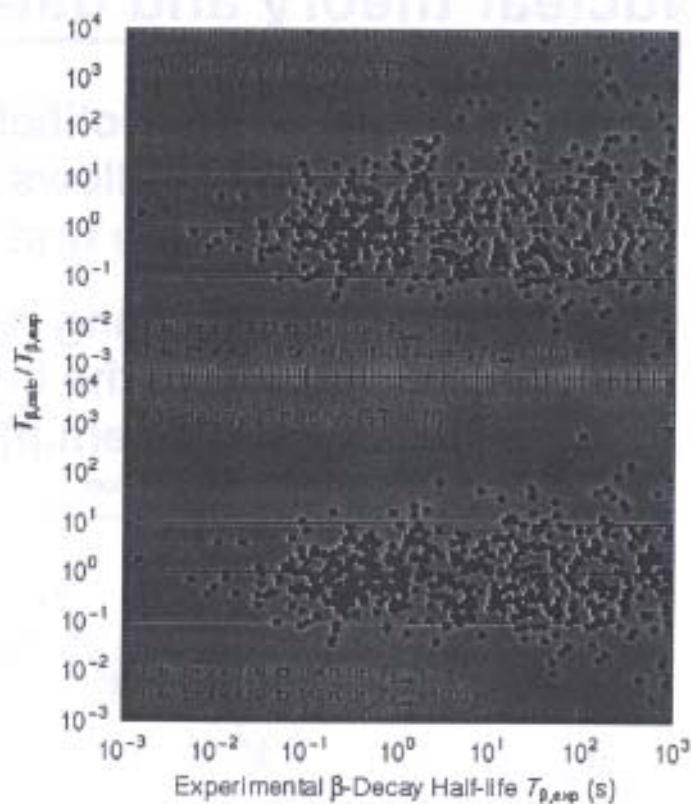
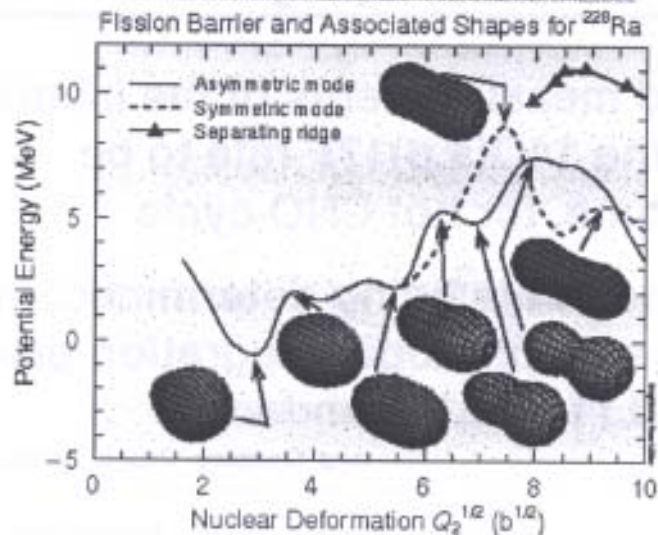
Nuclear theory and data for astrophysics: R-matrix

- **Left:** New ORNL/Holifield measurements of the inverse process, $^{17}\text{F}+p$, allows the $^{14}\text{O}(\alpha,p)^{17}\text{F}$ rate to be determined for the first time, for hot CNO cycle
- **Right:** This Big-Bang reaction is being determined, including information from the inverse photodisintegration process; also $^7\text{Li}(p,\alpha)\alpha$, & $^7\text{Be}(n,p)^7\text{Li}$ for ^7Li abundance



Nuclear Structure Model for Astrophysical Data (Fission, β -Decay, Masses)

Nature 409, 15 February, 2001, p. 785-790



Citations Masses:

ADNDT-1995 540 (In 2001 120)
 ADNDT-1988 183, ADNDT-1981 430

Citations Astro:

ADNDT-1997 140
 ApJ-1993 115, Phys. Rep.-1998 73
 ADNDT-1980 73

WWW dissemination

- + Changed over to a bigger, faster web server machine (apache under linux, dual 800 MHz processors, 36 GB)
- + Upgraded the pages to be a little prettier, to reflect the T5/T2->T16 merger, and to clean up obsolete stuff
- + Recoded the Nuclear Data Viewer using the PHP web scripting language
- + Added the new atomic information (photoatomic, electroatomic, atomic relaxation) for browsing the evaluations and plotting cross sections
- Added the new photonuclear data (color Postscript plots, browsing of evaluations, plotting of cross sections, MCNP Monte Carlo files)

International nuclear data cooperation

- **Significant participation in Oct'01 Tsukuba int. data conference (invited talks, program and advisory committees)**
- **Attend NEA/WPEC in Geel, May 2002 (Chadwick, Madland)**
- **NEA/WPEC Subgroup A models meeting in Geel (Talou)**
- **Give NJOY lectures at Trieste (MacFarlane)**
- **Advisor at IAEA/INDC meeting in May 2002 (Haight)**
- **Chair IAEA RIPL-2 CRP (Young)**

- **Haight & Chadwick chairing next international data conference in Santa Fe, 2004 (Eldorado Hotel)**



Isotopes Project

LAWRENCE BERKELEY NATIONAL LABORATORY

E.B. Norman (Project Leader)

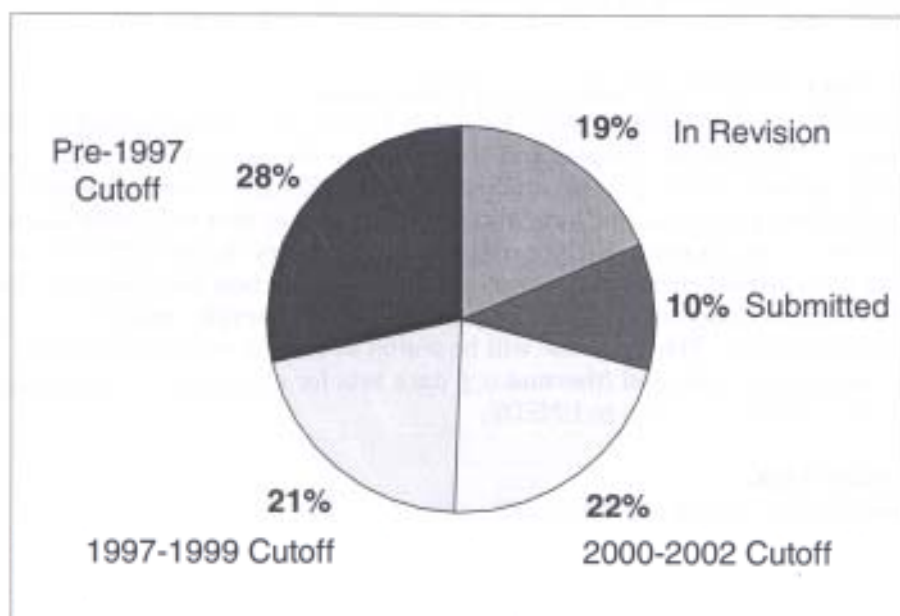
Report prepared for the USNDP Annual Meeting, April 10-12, 2002 at Brookhaven National Laboratory.

A. NUCLEAR DATA EVALUATION ACTIVITIES April 2001 - April 2002

MASS CHAIN RESPONSIBILITY, STATUS (~500 nuclides)

Permanent: A = 59, 81, 83, 90-93, 166-187, 189, 191-193, 206, 210-212, 215, 219, 223, 227
Temporary: A = 235, 239

The literature cutoff dates for the ~500 permanently-assigned nuclides are summarized below.
(Both temporarily-assigned chains have been evaluated and submitted for publication.)



PERSONNEL (EVALUATION)

Isotopes Project personnel involved in data evaluation/compilation are as follows:

C. Baglin	1.0 FTE	E. Browne	1.0 FTE
R. Firestone	0.6 FTE		

In addition, one guest spent leave with the Isotopes Project: Professor Shiu Chin (Alice) Wu (Taiwan) (July - August '01, Jan. '02). Dr. Wu evaluated A=189.

Ongoing international collaborations exist with Gabor Molnar (Hungary) and Zhou Chunmei (China) (preparation of evaluated (n,γ) data), and with French, German, British, US, Spanish, Brazilian and Russian scientists participating in the radioactive Decay Data Evaluation Project (DDEP).

EVALUATION ACCOMPLISHMENTS (since April 2001 Meeting)

- **Mass Chain Evaluations:**

Submitted: 59, 170, 171, 189, 235, 239 (these chains include 7 priority nuclides)

Published: 59, 83, 215, 219, 223, 227, 231

- **Complete Nuclide Evaluations:**

The nuclide evaluations (listed below) were undertaken because of their 'priority' status (those marked with *), because of the existence of significant newly-published information that could be expeditiously included in ENSDF (thus improving the timeliness of the file), because of the need to revise α -decay parent or daughter information (for internal consistency of the file), or because of the absence of a published evaluation for the nuclide.

- Published: $^{183}\text{Tl}^*$
- Unpublished (reviewed and added to ENSDF): ^{187}Bi .

- **DDEP Evaluation:**

- Chaired international meeting in Braunschweig, May 2001
- Reviewed ^{228}Th , ^{224}Ra , ^{220}Rn , ^{210}Po , ^{212}Pb , ^{212}Bi , ^{212}Po , ^{208}Tl , ^{131}I , ^{131m}Xe , ^{64}Cu .

- **Continuation of IAEA CRP to develop an (n,γ) Database:**

This 3-year IAEA-sponsored Coordinated Research Project is to be completed in 2002. It aims to produce a database of energies and cross sections for use in thermal/cold neutron-induced prompt gamma-ray activation analysis (PGAA). ENSDF thermal neutron capture isotopic data are being updated in China and the US to obtain best values for gamma-ray yields per 100 neutron captures. CRP participants in Hungary and the US will then combine these data with measured elemental gamma-ray and cross section data from the Budapest Reactor to produce recommended values for prompt-gamma energies and cross sections and other useful information. The database will be tested at several neutron facilities. A complete revised set of evaluated (thermal n,γ) data sets for all isotopes will ultimately be submitted to NNDC for inclusion in ENSDF.

- **Reviews of Evaluations:**

Mass Chains: A=250, 254, 258, 262.

B. NUCLEAR DATA DISSEMINATION ACTIVITIES April 2001 - April 2002

DISSEMINATION RESPONSIBILITY, STATUS

The Isotopes Project supports WWW dissemination home pages for Isotope Explorer, Table of Radioactive Isotopes, Nuclear Astrophysics, Neutron Capture, Spontaneous Fission, Radioactive Decay, Nuclear Structure, Atomic Masses, Education, and other topics. The demand for these services has increased substantially each year. In 2001, the Isotopes Project served over 118,000 distinct hosts who downloaded nearly 84 GB of data in 1.8 million retrievals as indicated in Figure 1. The bulk (915,000) of these retrievals were ENSDF datasets, most directly accessed by Isotope Explorer 2. Home page usage during 2001 is summarized in Table 1.

Table 1. Home Page Usage Summary from the LBNL Isotopes Project Server

	1996	1997	1998	1999	2000	2001
Total Requests	240,035	509,920	902,024	1,934,757	2,799,762	3,537,263
Users per Month	1,542	3,190	4,470	5,855	8,945	13,729
ENSDF Isotopes	68,264	162,468	246,525	395,727	515,914	689,615
XUNDL Isotopes	0	0	0	3,738	7,114	90,058
WWW TORI Search	0	0	50,217	189,979	NA*	NA*
NSR Searches	0	12,253	32,212	44,586	28,302*	33,684
Education	0	0	6,701	21,727	54,361	85,324
Astrophysics	3,956	8,322	7,254	9,782	9,452	11,018
Atomic Masses	3,124	5,935	8,070	12,334	19,575	23,419
Radioactive Decay	3,152	5,563	7,319	8,794	11,039	16,091
Nuclear Structure	1,729	2,920	4,394	5,547	6,498	8,415
Neutron Capture	0	0	3,013	7,540	9,269	11,493
Fission	0	0	2,476	5,589	6,547	10,556
Isotopes Project	3,665	6,166	11,323	22,892	31,851	42,041

* LBNL only. Lund statistics are not available.

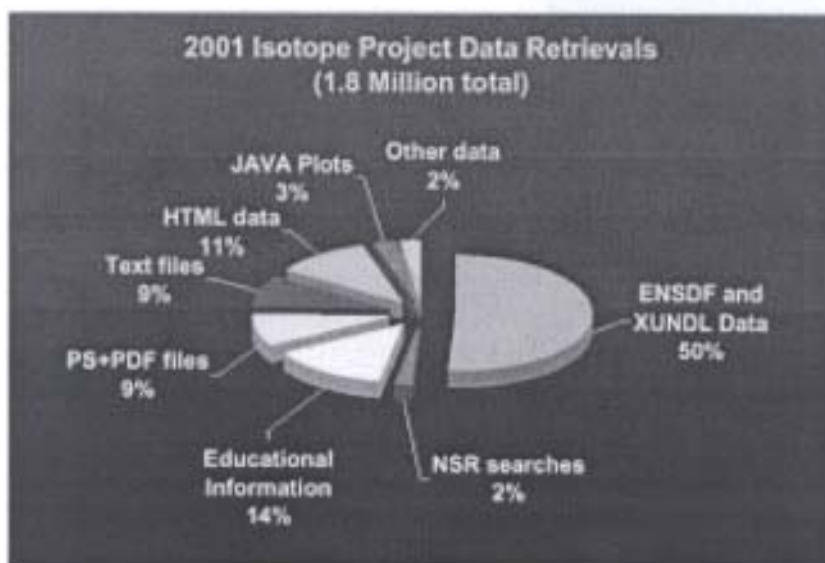


Figure 1. Distribution of Isotopes Project server data retrievals in 2001. This information was gathered directly from the log files.

PERSONNEL

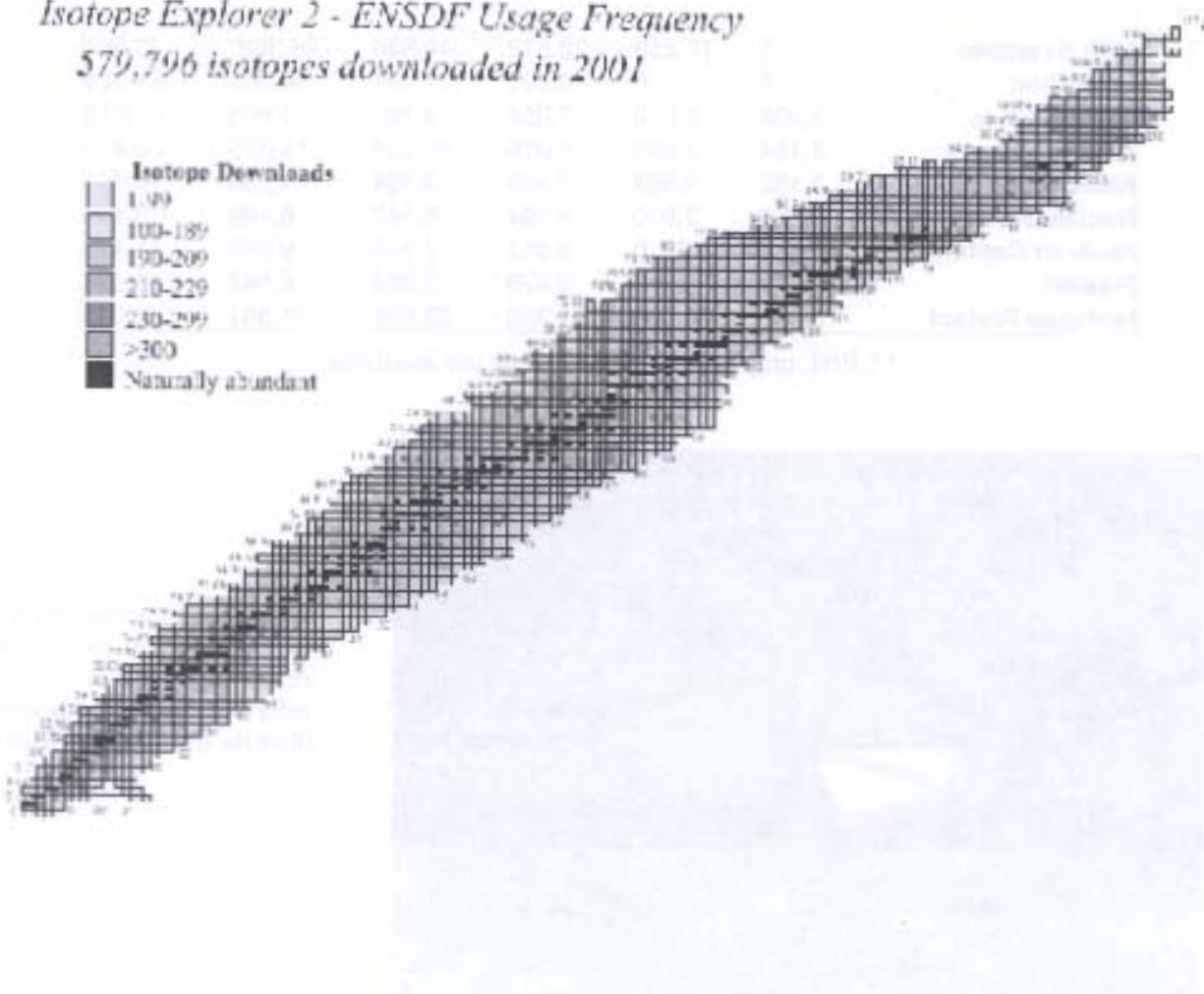
Isotopes Project personnel involved in data dissemination are as follows:

R. Firestone 0.3 FTE

ISOTOPE EXPLORER 2 and 3

Isotope Explorer 2 users directly access complete ENSDF isotope datasets without need for a browser. All data in the file are frequently accessed as indicated in Figure 2. Isotope Explorer 3 provides Internet access to ENSDF, XUNDL, SDBAND, and TORI databases. Java language is still limited for displaying Greek characters, slanted text, and other desired capabilities. Files cannot be saved and the output is often too slow. These difficulties have limited the acceptance of Isotope Explorer 3, which is used by less than 10% of all Isotope Explorer users. Isotope Explorer 3 is currently being worked on and is temporarily not available.

Isotope Explorer 2 - ENSDF Usage Frequency
579,796 isotopes downloaded in 2001



ISOTOPE EXPLORER REFERENCE SERVER

The Isotope Explorer reference server supports rapid searches of the NSR file by selected criteria such as author(s), nuclide, publication year, keynumber, keyword, reaction, etc. References to recent AIP journal articles are linked directly to the papers. Recently a second mirror server has been added to provide better service for users.

WWW Table of Radioactive Isotopes

The WWW Table of Radioactive Isotopes contains a database of alpha-, beta- and gamma-ray decay data from ENSDF that is searchable on the Internet. Work is in progress to calculate bremsstrahlung and conversion electron spectra and to generate genetic feedings.

WWW HOME PAGES

The Isotopes Project supports WWW home pages for a variety of topics of interest in nuclear science. A new page for nuclear structure and decay systematics was added in FY2001 at the behest of the recent Nuclear Reactions Town Meeting in Berkeley.

EDUCATIONAL OUTREACH

The Isotopes Project maintains an Educational home page that provides a periodic table linked to information about the isotopes of any element, and animated graphics (Gifs) displaying various nuclear and astrophysical phenomena. This service has proven very popular, as evidenced by e-mail exchanges, among middle-school, high-school, and college students, as well as many adults. Teachers frequently use this site as part of their lesson plan. In 2001, 191,000 isotope summaries were downloaded and animated Gifs were visited 58,000 times, accounting for about 14% of site usage.

PGAA DATABASE SEARCH

The Isotopes Project is developing dissemination software as part of its commitment to the IAEA Coordinated Research Project for the *Development of a Database for Prompt γ -ray Neutron Activation Analysis*. Beta test software, developed in collaboration with EVITech, has been prepared in Javascript for Internet dissemination, and in JAVA for standalone distribution. Both programs are similar to the LBNL/Lund *Table of Radioactive Isotopes*, and support both data retrievals and searches by element and/or γ -ray energy. Further development is continuing in collaboration with the IAEA.

C. PUBLICATIONS (since April '01 Meeting)

- **Nuclear Data Evaluation**

- a) **Journals**

Nuclear Data Sheets for A=215, 219, 223, 227, 231, E. Browne, Nuclear Data Sheets **93**, 763 (2001).

Nuclear Data Sheets for A=83, S.-C. Wu, Nuclear Data Sheets **92**, 893 (2001).

Nuclear Data Sheets for ^{183}Tl , Coral M. Baglin, Nuclear Data Sheets **95**, 49 (2002)

Nuclear Data Sheets for A=59, Coral M. Baglin, Nuclear Data Sheets **95**, 215 (2002).

A New Gamma-Ray Spectrum Catalog and Library for PGAA, Zs. Revay, G.L. Molnar, T. Belgya, Zs. Kasztovsky, R.B. Firestone, J. Radioanal. Nucl. Chem. **248**, 395 (2001)

- b) **Reports**

Thermal-Neutron Capture Data for A=26-35, C. Zhou and R.B. Firestone, INDC(CPR)-054 (2001).

Development of a Database for Prompt Gamma-ray Neutron Activation Analysis, R.B. Firestone, INDC(NDS)-424, June 2001.

Report on the Activities of the Decay Data Evaluation Project, Edgardo Browne, Marie-Martine Bé, T. Desmond MacMahon and Richard G. Helmer, October 3, 2001, Saclay Report (in press).

- **Data Evaluation Talks/Posters:**

Nuclear Data for Basic and Applied Research in the 21st Century, USNDP and Nuclear Structure and Decay Data Network (presented by E.B. Norman), International Nuclear Physics Conference 2001, Berkeley, LBNL-48247, 632 (2001).

A New Prompt Gamma-Ray Database for Cold and Thermal Neutron Capture, R.B. Firestone, G. Molnar, Zs. Revay and Zs. Kasztovsky, International Nuclear Physics Conference 2001, Berkeley, LBNL-48247, 438 (2001).

From Data Evaluation to Research, E. Browne, American Nuclear Society 2001 Winter Meeting, Reno, Nevada, November 2001, Transactions **85**, 232 (2001).

- **Other research Publications:**

- a) **Journals**

Search for the Decay of the 3.5 eV Level in ^{229}Th , E. Browne, E.B. Norman, R.D. Cnaan, D.C. Glasgow, J.M. Keller, J.P. Young, Phys. Rev. C **64**, 014311 (2001).

Influence of Physical and Chemical Environments on the Decay Rates of ^7Be and ^{40}K , E.B. Norman, G. A. Rech, E. Browne, R.-M. Larimer, M. R. Dragowsky, Y. D. Chan, M. C. P. Isaac, R. J. McDonald and A. R. Smith, Phys. Letters **519B**, 15 (2001).

Q_{5c} Value and Internal Bremsstrahlung Spectra of ¹⁷⁹Ta, M. M. Hindi, B. O. Faircloth, R. L. Kozub, K. R. Czerwinski, R.-M. Larimer, E.B. Norman, B. Sur, and I. Zliven, Phys. Rev. C **63**, 065502 (2001).

Half-life of the 6.3-keV Isomer in ¹²¹Sn, G.A. Rech, E. Browne, I.D. Goldman, F.J. Schima, and E.B. Norman, accepted for publication in Phys. Rev. C (2002).

⁶⁶Ga: a Standard for High-Energy Calibration of Ge Detectors, C.M. Baglin, E. Browne, E.B. Norman, G.L. Molnar, T. Belgia, Zs. Revay, F. Szelecsenyi, Nuclear Inst. and Methods in Physics Research A **481**, 365-377 (2002).

Neutron-Induced Prompt Gamma Activation Analysis (PGAA) of Metals and Non-metals in Ocean Floor Geothermal Vent-Generated Samples, D.L. Perry, R.B. Firestone, G. Molnar, Zs. Revay, Zs. Kasztovszky, R.C. Gatti, and P. Wilde, Journal of Anal. At. Spectrom. **17**, 32 (2002).

b) Conference Presentations

Search for the Decay of the 3.5 eV ²²⁹Th^m, E. Browne, E.B. Norman, *R.D. Cnaan, D.C. Glasgow, J.M. Keller, J.P. Young*, International Nuclear Physics Conference 2001, Berkeley, LBNL-48247, 552 (2001).

¹⁰²Rh^m: Could it be a cosmic-ray chronometer?, P. Perso, N. Added, ..., E.B. Norman, et al., International Nuclear Physics Conference 2001, Berkeley, LBNL-48247, 66 (2001).

⁶⁶Ga Emission Probabilities for Ge Detector Calibration, C.M. Baglin, E. Browne, E.B. Norman, G.L. Molnar, T. Belgia, Zs. Revay, F. Szelecsenyi, International Nuclear Physics Conference 2001, Berkeley, LBNL-48247, 434 (2001).

Terrestrial Evidence for a Nuclear Catastrophe in Paleo-Indian Times, R.B. Firestone and W. Topping, International Nuclear Physics Conference 2001, Berkeley, LBNL-48247, 483 (2001).

A New Prompt Gamma-Ray Database for Cold and Thermal Neutron Capture, R.B. Firestone, G. Molnar, Zs. Revay and Zs. Kasztovszky International Nuclear Physics Conference 2001, Berkeley, LBNL-48247, 438 (2001).

Compact Neutron Generators for Environmental Recovery Applications, K.N. Leung, R.B. Firestone, T.P. Lou, J. Reijonen, and J. Vujic, Proc. International Conf. On Environmental Recovery of Yugoslavia, ENRY2001, 27-30 September 2001, Belgrade.

Development of a Database for Prompt Gamma-ray Neutron Activation Analysis, H.D. Choi, R.B. Firestone, R.M. Lindstrom, G.L. Molnar, A.V.R. Reddy, V.H. Tan, C.M. Zhou, R. Paviotti-Corcuera, and A. Trkov, Proc. International Conf. On Nuclear Data for Science and Technology, 7-12 October 2001, Tsukuba, Ibaraki, Japan.

New Catalog of Neutron Capture Gamma Rays for Prompt Gamma Activation Analysis, G.L. Molnar, Zs. Revay, T. Belgia, R.B. Firestone, Proc. International Conf. On Nuclear Data for Science and Technology, 7-12 October 2001, Tsukuba, Ibaraki, Japan.

c) Invited Talks

Application of Prompt Gamma-ray Activation Analysis (PGAA) With a Portable Neutron Source, R.B. Firestone, August 28, 2001, Lawrence Livermore National Laboratory.

Prehistoric Supernovae, R.B. Firestone, Nuclear Physics Forum, October 25, 2001, University of California, Berkeley.

Cosmic Consequences for Radiocarbon Dating, R.B. Firestone, Archaeological Research Faculty Lecture, Archeometry Network 2001-02 Series, October 29, 2001, University of California, Berkeley.

Summary of 2001 LLNL Activities

Tony S. Hill

In a matter of a couple of years, the Computational Nuclear Physics group at LLNL has undergone a complete turnover of personnel. The new personnel are being trained. We are developing local expertise with the ENDF format specifics by translating the ENDF data into the local ENDL format. We are also developing codes that will allow LLNL evaluators to produce ENDF files. An ENDL database management system is being developed to include the ability to handle cross section uncertainty information and the capability to produce ENDF output files. Our goal is rejoin the nuclear data community.

The Nuclear Theory and Modeling Group has completed the recalculation of the important rad-chem reactions for an array of Ga, Th, Gd and Sm isotopes. A new set of calculations performed for ^{241}Am , which includes data taken by LLNL. A new microscopic approach to determining level densities has been developed and will be implemented in upcoming evaluations of new ^{11}B and ^{18}O data to be taken by LLNL this summer. The c++ reaction code library being developed at LLNL, MOARC, has reached several milestones – the overall design specifications have been completed and the architecture has been successfully tested and found to be in complete agreement with STAPRE (the code system will be ready for astrophysics October 2002).

Status Report of the Nuclear Data Project at McMaster University
(April 2001 – March 2002)
(Report prepared by B. Singh March 31, 2002)

ENSDF RELATED WORK:

Permanent responsibility: **A=31-44, 64, 89, 98, 100, 149, 151, 164, 188, 190, 194.**

During 2001-2002, we also worked on other priority A-chains and nuclides, which are outside our A-chain responsibility.

Mass-chain/Nuclide Evaluations published or submitted since April 2001:

A-chain updates:

A=98: B. Singh and Z. Hu, NDS (submitted February 2002, pre-review stage) **(FY02).** (at least 80% contribution by the McMaster group).

A=190: B. Singh, NDS (submitted December 2001, review stage) **(FY02).**

A=79: B. Singh, NDS (submitted March 2001, galley stage)**(FY01+FY02).**

A=188: B. Singh, NDS 95, 387-542 (2002) **(FY01+FY02).**

A=41: J.A. Cameron and B. Singh, NDS 94, 429-604 (2001) **(FY01).**

A=86: B. Singh, NDS 94, 1-130 (2001) **(FY01).**

A=164: B. Singh, NDS 93, 243-445 (2001) (partly **FY01).**

A=130: B. Singh, NDS 93, 33-242 (2001) (partly **FY01).**

A=43: J.A. Cameron and B. Singh, NDS 92, 783-892 (2001) (partly **FY01).**

Nuclide updates for ENSDF:

¹⁵²Dy: B. Singh, NDS (Submitted January 2002, pre-review stage)(FY02).

¹⁹⁹Pb: B. Singh and G. Reed, NDS 94, 397-427 (2001) (FY01+FY02).

⁹⁹Tc: J.K. Tuli, G. Reed and B. Singh, NDS 93, 1-32 (2001) (FY01).

⁶⁰Zn, ⁶⁰Ga, ¹⁶³Lu: (FY02) (by B. Singh)

¹³²Pr, ¹³³Sm, ¹⁶⁸Hf, ¹⁹⁹Ir, ¹⁹⁹Fr: (FY01) (by B. Singh)

Superdeformed structures in ENSDF: Data from 10 primary publications during 2001-2002 for the following nuclides were evaluated and included in ENSDF by B. Singh.

⁴⁰Ca, ¹⁰⁸Cd, ¹⁴⁶Gd, ¹⁹⁴Hg: (FY02)

¹⁵⁴Er, ¹⁹⁰Hg, ¹⁹⁶Pb, ¹⁹⁸Pb, ²⁴⁰Pu: (FY01)

As of March 31, 2002, we are current on the coverage of SD band data in ENSDF.

Review work: A=198 was partially reviewed by B. Singh in December 2001.

Compilation of data from recent literature (XUNDL database):

Since April 2001, about **210** compiled (but checked for level-scheme consistency) datasets were prepared by the McMaster group in ENSDF format using semi-automatic coding procedures as described in the last year's meeting. About **25** previous datasets in XUNDL were revised/edited to incorporate newer papers for these nuclides. During summer 2001, we also compiled main high-spin papers for about 5 outdated A-chains in ENSDF. We regularly scan web pages of primary nuclear physics journals (PRL, PR-C, NP-A, PL-B, EPJ-A, JP-G) for current publications in experimental nuclear structure. Presently, we are almost current on the coverage of high-spin papers in XUNDL, except 4 papers published during March 2002, which are presently being compiled. A major part of the compilation work since April 2001 has been done by undergraduate students (working part-time) at McMaster: George Reed (until August 2001), Roy Zwyina

(since June 2001) and Michelle Lee (since February 2002). Each dataset was checked thoroughly by B. Singh, before submitting it to BNL for inclusion in XUNDL database. About **50%** of the XUNDL work, described above, was accomplished during **FY 2002**. We continue to actively communicate with the authors of original papers to resolve data-related inconsistencies and to request additional data details.

Work in progress:

A=40. Complete ENSDF style datasets for all reactions and adopted properties. Except for ^{40}K and ^{40}Ca , all the other nuclides have been completed. We expect to submit this A-chain by the end of May 2002. (**FY01+FY02**).

A=165. This mass chain in ENSDF dates back to 1990, although a few of the nuclides were updated by our group in 1998. Work is in progress to update all the nuclides in this A-chain, with expected completion during the current fiscal year. (**FY02**).

Update of SD band data: Continuous update will be done as new papers appear.

Compilation of experimental nuclear-structure papers for XUNDL:

Work will continue on the compilation of (primarily high-spin) data reported in current publications. If time permits, we also plan to compile main high-spin papers for some of the outdated (>7 years or so) A-chains in ENSDF. We also plan to generate a new computer code for conversion of TABULAR-TEXT to ENSDF. The new code would offer better flexibility in entering data automatically in ENSDF format and would include additional features that are not present in the currently used code written by David Radford about 3 years ago.

Other data-related work:

Magnetic-rotational bands:

The 2001 update of Table of Magnetic Dipole Rotational Bands by Amita, A.K. Jain and B. Singh (first published in Atomic Data and Nuclear Data Tables, **74**, 283-331 (2000)), was made available on NNDC website in June 2001. We intend to update this table on an annual basis. (This is a

collaborative work with a nuclear theory group in India.)

Personnel and funding of the data project at McMaster:

J.C. Waddington (Professor, PI of the data group at McMaster),

J.A. Cameron (Emeritus-Professor),

B. Singh (Research Scientist-Nuclear Data Evaluator).

Current funding is 0.5 FTE from US DOE, and 0.5 FTE from Canadian sources.

National Institute of Standards and Technology
Nuclear Data Verification and Standardization Program

PROGRESS REPORT

USNDP Meeting
April 10-12, 2002

Staff (total of about 0.6 FTE):

Allan Carlson, David Gilliam, Paul Huffman, and Roald Schrack.

In addition to the effort shown here, NIST supplies almost half of the total support for the standards program.

Nuclear Structure Activities:

None are supported by DoE funding. A modest effort (1 FTE) in structure and decay studies is supported by NIST funds.

Nuclear Reaction Activities:

Neutron cross section standards

Introduction

It has been almost 15 years since the last comprehensive evaluation of the neutron cross section standards. Significant improvements have been made in the standard cross section database since that time, particularly for the H(n,n), $^{10}\text{B}(n,\alpha)$, and $^{235}\text{U}(n,f)$ reactions. The standards are used internationally. Improvements in the standards increase the accuracy of all measurements made relative to them. Evaluations continue to be done using standards that are now out-of-date. In response to the need for new evaluations, working groups were formed by a number of nuclear data organizations. The WPEC formed a subgroup, the CSEWG established a Task Force and the IAEA initiated a Coordinated Research Project (CRP). These groups are working cooperatively to update the previous work by including standards measurements made since the last evaluation was completed and to improve the evaluation process. NIST has maintained a leadership role in each of these groups. Direct involvement in these working groups now includes Austria, China, France, Germany, Japan, the Republic of Korea, Russia and the USA. The new international evaluation will include the H(n,n), $^3\text{He}(n,p)$, $^6\text{Li}(n,t)$, $^{10}\text{B}(n,\alpha)$, $^{10}\text{B}(n,\alpha_1\gamma)$, Au(n, γ), $^{235}\text{U}(n,f)$, and the $^{238}\text{U}(n,f)$ standard cross sections. For some of the standards, the energy region will be extended to 200 MeV to provide new standards in this emerging important energy region. Efforts will be made to investigate the need for a new thermal constants evaluation. A new evaluation will not be made for the C(n,n) cross section because little new data have been obtained since the ENDF/B-VI evaluation and what has been obtained is consistent with that work.

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.

Progress on the evaluation

WPEC Standards Subgroup: In order to assist in obtaining the international

involvement needed for this evaluation, the WPEC formed a new Subgroup to promote international cooperation on the nuclear data standards. This Subgroup was very helpful in the initial developmental stages. Its most important contribution has been the motivation of needed experimental work, especially on the ^{10}B cross sections. NIST has taken the lead role in encouraging, motivating and coordinating of new measurements that can be used in the standards evaluation. Many experiments have been completed; however, most of the experiments are still in the data taking or data analysis stage.

- Chaired WPEC Standards Subgroup
- Preliminary results are now available for experiments by Hamsch and Bax, and Giorginis and Khriachkov that were recommended by NIST on the $^{10}\text{B}(n,\alpha)$ cross sections.
- Measurements by Guohui Zhang et al. of the $^{10}\text{B}(n,\alpha)$ cross sections are being extended to lower neutron energies as suggested by NIST
- Important new measurements by Nolte et al. of the $^{235}\text{U}(n,f)$ and $^{238}\text{U}(n,f)$ above 20 MeV suggested by NIST were reported at the ND2001 conference. The new $^{235}\text{U}(n,f)$ measurements are particularly important since they are the only accurate data except those of Lisowski et al. which are the basis for the standard in the energy region above 20 MeV.

Investigation of possible experiments for inclusion in the standards database: This process includes checking the documentation for corrections that may need to be made and looking for possible errors or missing information. The investigative procedure leads to estimates of the uncertainties and correlations within an experiment and correlations with other experiments.

- Table 1 lists standards related experiments which are under investigation. Only experiments for which data have been obtained or measurements are underway (or nearly started) are listed. The initial emphasis has been on the traditional standards in their normal regions of applicability.

IAEA CRP Activities: The IAEA CRP on improving the neutron cross section standards was approved by the INDC in October 2001. The participants of the CRP now include Siegfried Tagesen and Herbert Vonach, University of Vienna, Austria; Vladimir Pronyaev, IAEA, Austria. Chen Zhenpeng, Tsinghua University, China; Hartmut Hofmann, Erlangen-Nuernberg University, Germany; Toshihiko Kawano, Kyushu University, Japan; Soo Youl Oh, Korea Atomic Energy Research Institute, Republic of Korea; Sergey Badikov and Evgeny Gaj, Institute of Physics and Power Engineering, Russia; Allan Carlson, NIST, Gerald Hale, LANL and Nancy Larson, ORNL, USA. These participants provide strengths in such areas as R-matrix analyses, generalized least-squares fitting, database studies and theoretical model calculations. The main objectives of the CRP are the following: Improve the methodology for determination of the covariance matrix in R-matrix fits; Upgrade the computer codes using this methodology; Study the reasons for uncertainty reduction in R-matrix fits; Evaluate cross sections and covariance matrices for the light elements, $\text{H}(n,n)$, $^3\text{He}(n,p)$, $^6\text{Li}(n,t)$, $^{10}\text{B}(n,\alpha,\gamma)$, and $^{10}\text{B}(n,\alpha)$; Establish the methodology and computer codes for combining the light element with the heavy element evaluations.

The CRP has just begun its work and should complete its actions in CY-2005. In order to be able to use the new standards in ENDF/B-VII, the cross sections must be

available before CY-2005. The plan is to have the standards ready before CY-2005, but additional work by the CRP on the uncertainties and documentation will extend into CY-2005.

An important task for the CRP is to try to understand in detail how standard error propagation in simultaneous evaluation or R-matrix analyses can result in very small uncertainties, and whether there are more reasonable corrections or algorithms to employ. An initial effort of the CRP is an investigation of the small uncertainty problem through several tests of codes. There is a comparison of the R-matrix parameters, cross sections obtained from those parameters and the uncertainties of the values obtained, for several R-matrix codes which fit data from a common database. It is necessary to select a database containing measurements which can be properly used in the comparison. For example some of the codes can not handle certain types of input data correlations. A similar comparison is underway for simultaneous evaluation least-squares codes. Again the database must be carefully selected so that the types of data and correlations present in the measurements are consistent with the codes being investigated. Comparison of combining procedures is also contemplated. This work should lead to identification of possible differences between R-matrix and generalized least squares fitting that may have contributed to the small error estimates obtained in the 1987 ENDF/B-VI evaluation.

The R-matrix codes being used in this study are EDA (LANL), SAMMY (ORNL), a form of KALMAN (Kyushu University) and RAC (Tsinghua University). The generalized least squares codes being used for this study are GLUCS (Obninsk and the University of Vienna), GMA (ANL and JAERI) and KALMAN.

An interesting CRP effort is theoretical calculations, from first principles, for the lighter systems, beginning with $^3\text{He} + n$. This work could provide information on the determination of parameters used in the R-matrix description such as distant level parameters. It could then possibly provide improved values of those parameters or improved uncertainties in them so more realistic R-matrix uncertainties could be ascertained.

In its later phase, the CRP will study methods for doing the final evaluation, such as a single step global process, which were not feasible with the computer capability available in 1987 when the ENDF/B-VI evaluation was completed. Following this phase, using the tools developed from that activity and the critically reviewed and assembled experimental data, the new evaluation will be done.

If a new method for doing the evaluation does not become available, plans have been made for performing the evaluation using a procedure which is somewhat improved compared with the ENDF/B-VI standards evaluation.

- Wrote (with V. Pronyaev) the successful CRP proposal
- Chairing CRP
- Participating in intercomparison of results with various codes

Held a standards meeting at ND2001:

- A special meeting was planned and organized which was held during the ND2001 conference to discuss the progress which had been made and plans for additional work on both the experimental and evaluation efforts for the standards.

Experimental and other work:

- The hydrogen scattering angular distribution measurements at 10 MeV neutron energy have been published in the Physical Review.
- Diagnostic work is underway which will lead to a new experiment at 15 MeV neutron energy to improve the understanding of this important standard.
- The NIST National Repository for Fissionable Isotope Mass Standards continues to acquire and monitor samples.
- As a member of the International Technical Program Committee for the ND2001 conference, manuscripts were reviewed and corrections were suggested for the papers which will be published in the proceedings of the conference.
- As a member of the Program Committee for the 11th International Symposium on Reactor Dosimetry, work was done to define the technical program and abstracts were reviewed for possible inclusion in the Symposium.

Dissemination:

- An invited talk was given on the international evaluation of the neutron cross section standards at the ND2001 conference.
- An invited talk on database studies for the international evaluation of the standards is being prepared for the 11th International Symposium on Reactor Dosimetry.

Table 1. New Experiments for the Standards Database

⁺⁺ means the data have been reviewed and are in the library

⁺ means the data are available and the review process is underway

no superscript means that final data are not available (possibly final data not taken yet)

H(n,n)

+Boukharouba, Phys Rev C 65, 014004, 10 MeV, angular distribution from 60° to 180°, additional work planned for 14 MeV

Vigdor (IUCF) 185-195 MeV, angular distribution from 90° to 180°. Data have been obtained and they are under analysis.

⁺Nakamura, J. Phys. Soc. Japan 15 (1960) 1359, 14.1 MeV; error in transformation from laboratory to CMS angles; needs correction for proton scattering, an estimate of error associated with neglecting these corrections was made; tail problems; note Table II uncertainty is statistical only (mb/sr).

⁺Shirato, J. Phys. Soc. Japan 36 (1974) 331, 14.1 MeV, needs correction for proton scattering; tail problems

⁺Ryves, 14.5 MeV, $\sigma(180^\circ)/\sigma(90^\circ)$, Ann. Nucl. Energy 17, 657 (1990)

[†]Buerkle, 14.1 MeV, angular distribution from 89.7° to 155.7°, Few-Body Systems 22, 11 (1997)

Olsson (Uppsala group), 96 & 162 MeV, angular distribution from 70° to 180°

Benck, (Louvain la Neuve), Proc. Conf. on NDST, Trieste (1997), 28-75 MeV, angular distribution from 40° to 140°

³He(n,p)

^{††}Borzakov, 0.26 keV to 142 keV, relative to ⁶Li(n,t), Sov. J. Nucl. Phys. 35, 307 (1982)

³He total cross section

+Keith, 0.1 to 500 eV, BAPS DNP Oct 1997 paper IG.03 and thesis of D. Rich

⁶Li(n,t)

Bartle, 2 to 14 MeV, angular distribution, Proc. Conf on Nuclear Data for Basic and Applied Science, Sante Fe (1985), p. 1337

Koehler, 1 keV to 2.5 MeV, angular distribution data (ratio of forward and backward hemispheres responses), private comm.

Gledenov, .025 eV, ??, 87KIEV 2 237

Guohui Zhang, 3.67 and 4.42 MeV, angular distribution, Comm. Of Nuclear Data Progress No.21 (1999) China Nuclear Data Center, also NSE 134, 312 (2000)

¹⁰B(n,α₁γ)

^{††}Schrack, 0.2 MeV to 4 MeV, relative to Black Detector (at ORNL), NSE 114, 352 (1993)

[†]Schrack, 10 keV to 1 MeV, relative to H(n,n) prop ctr (at ORNL), Proc. Conf. on NDST, Gatlinburg (1994)p. 43

[†]Schrack, .3 MeV to 10 MeV, relative to ²³⁵U(n,f) ion chamber (at LANL), Private comm.

¹⁰B(n,α) Branching Ratio

^{††}Weston, 0.02 MeV to 1 MeV, Solid State detectors, NSE 109, 113 (1991)

Hambach and Bax, ND2001, keV to MeV, Frisch gridded ion chamber, in progress.

¹⁰B(n,α)

Haight, 1 MeV to 6 MeV, angular distribution at 30°, 60°, 90° and 135°, private comm.

Hambach and Bax, ND2001, keV to MeV, angular distribution, Frisch gridded ion chamber, in progress.

Giorginis and Khriachkov, MeV energies, angular distribution, VdG data

Guohui Zhang, 4.17, 5.02, 5.74, 6.52 MeV angular distribution, submitted for publication to NSE

^{10}B total cross section

Wasson, 0.02 MeV to 20 MeV, NE-110 detector, Proc. Conf. on NDST, Gatlinburg (1994), p. 50

Plompen, 0.3 MeV to 18 MeV, scintillator, LiI and Li-glass detectors, Proc. Conf. on NDST, Gatlinburg (1994), p. 47 and Proc. Conf. on NDST, Trieste (1997), p. 1283

Brusegan, 80 eV to 730 keV, Li-glass detector, Proc. Conf. on NDST, Gatlinburg (1994)p. 47 and Proc. Conf. on NDST, Trieste (1997)p. 1283

$^{10}\text{Be}(p,n)^{10}\text{B}$

Massey, E_p from 1.5 MeV to 4 MeV, data at 0° , private comm. New measurements to be made at lower energies (~ 0.5 MeV). Also possibly $^{10}\text{Be}(p,\alpha)$

$\text{Au}(n,\gamma)$

^{††}Sakamoto, 23 keV and 967 keV, photoneutron source, activation experiment, NSE 109,215 (1991)

^{††}Davletshin, .16 MeV to 1.1 MeV, relative to H(n,n), Sov. J. At. Energy 65, 91 (1988),
(Corrected data from Sov. J. At. Energ. 58, 183 (1985))

^{††}Davletshin, .16 MeV to 1.1 MeV, relative to H(n,n), Sov. J. At. Energy 65, 91 (1988),

^{††}Davletshin, .62 MeV to .78 MeV, relative to $^{235}\text{U}(n,f)$, Sov. J. At. Energy 65, 91 (1988),

Kazakov, Yad Konstanty, 44, 85 (1990)

Demekhin, 2.7 MeV, Proc. 36th All Union Conf. on Nuclear Data, p. 94 (1986)

Voignier, ~ 0.5 MeV to ~ 3 MeV, private comm.

$^{235}\text{U}(n,f)$

Nolte, 30 to 150 MeV, ND2001, preliminary

Newhauser, 34, 46, and 61 MeV MeV, absolute, *removed from database*

[†]Carlson, 0.3 MeV to 3 MeV, relative to black detector, Proc. IAEA Advisory Group Meeting on Nuclear Standard Reference Data, Geel Belgium, p.163, IAEA-TECDOC-335 (1985)

[†]Carlson, 2 MeV to 30 MeV, relative to H(n,n), Proc. Spec. Meeting on Neutron Cross Section Standards for the Energy Region above 20 MeV, Uppsala, Sweden, 1991, Report NEANDC-305, "U", p. 165

[†]Johnson, 1 MeV to 6 MeV, relative to a dual thin scintillator, Proc. Conf. on NDST Mito (1988) p.1037

[†]Iwasaki, 14 MeV, relative to H(n,n) and associated particle, Proc. Conf. on NDST Mito (1988) p. 87

[†]Lisowski, 3 MeV to 200 MeV, relative to H(n,n), Proc. Spec. Meeting on Neutron Cross Section Standards for the Energy Region above 20 MeV, Uppsala, Sweden, 1991, Report NEANDC-305, "U", p. 177, and private communication.

Merla, ⁺⁺2.56, [†]4.45, ⁺⁺8.46, [†]14.7, [†]18.8 MeV ?, associated particle, Proc. Conf. on NDST Juelich (1991) p.145

²³⁸U(n,f)

Nolte, 30 to 150 MeV, ND2001, preliminary

Newhauser, 34, 46, and 61 MeV MeV, absolute, *removed from database*

Baba, 0.5 MeV to 7 MeV and 14 MeV, relative to ²³⁵U(n,f), J. Nucl. Sci. & Techn.,26,11 (1989)

[†]Lisowski, 0.8 MeV to 350 MeV, relative to H(n,n), Proc. Spec. Meeting on Neutron Cross Section Standards for the Energy Region above 20 MeV, Uppsala, Sweden, 1991, Report NEANDC-305, "U", p. 177, and private communication.

[†]Merla, 5 MeV +?, associated particle, Proc. Conf. on NDST Juelich (1991) p.145

[†]Shcherbakov, 1-200 MeV, relative to ²³⁵U(n,f), ISTC 609-97, see also Fomichev, 0.7 MeV to 200 MeV, relative to ²³⁵U(n,f), Proc. Conf. on NDST, Trieste (1997), p.1283

⁺⁺Winkler, 14.5 MeV, relative to Al(n, α) & ⁵⁶Fe(n,p), Proc. Conf. on NDST Juelich (1991), p.514

²³⁸U(n, γ)

⁺⁺Kobayashi, 0.024 MeV, 0.055 MeV, 0.146 MeV, relative to ¹⁰B(n, $\alpha_1\gamma$), Proc. Conf. on NDST Juelich (1991), p. 65

[†]Quang, 23 keV and 964 keV, photoneutron source, activation experiment, NSE 110, 282 (1992)

⁺⁺Adamchuck, 10 eV to 50 keV, relative to ¹⁰B(n, $\alpha_1\gamma$), J. Atomic Energy, 65, 920 (1989)

⁺⁺Buleeva, 0.34 MeV to 1.39 MeV, relative to H(n,n) and ²³⁵U(n,f), Sov. J. Atomic Energy, 65, 930 (1989)

Voignier, ~0.5 to 1 MeV, private comm.

$^{239}\text{Pu}(n,f)$

[†]Shcherbakov, 1-200 MeV, relative to $^{235}\text{U}(n,f)$, ISTC 609-97 (2000)

[†]Staples, 0.5 MeV to 400 MeV, relative to $^{235}\text{U}(n,f)$, NSE 129, 149 (1998)

[†]Lisowski, 0.8 MeV to 350 MeV, relative to H(n,n), Proc. Spec. Meeting on Neutron Cross Section Standards for the Energy Region above 20 MeV, Uppsala, Sweden, 1991, Report NEANDC-305, "U",

Progress Report of the
ORNL Nuclear Data Project Activities
for report to the U.S. Nuclear Data Program Meeting

April 11-12, 2002

The Nuclear Data Project's program for nuclear structure evaluation, reaction data evaluation for nuclear astrophysics, and experimental nuclear structure data compilation meets the present needs and interests of the nuclear research community. Our work completed during April 2001-April 2002 which is in accordance with the guidelines set by the International Nuclear Data Network and the USNDP advisors, is outlined below.

I. Nuclear Structure Evaluation (0.6 FTE)

We continue our study on the systematic behavior of nuclear states and other nuclear properties in the heavy-mass region which provides needed systematics of evaluated data to use for searches for superheavy elements, a field of high current interest in the community. This survey should serve as the basis for expectations of the properties of nuclei in this region, and should help the exploration of new mass regions. Such studies will also be valuable for experiments using 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. To be most useful, this systematic study requires the information given to be complete and up-to-date.

The Center for Nuclear Structure and Reaction Data of Kurchatov Institute has transferred, on a temporary base, their responsibility for nuclei with mass numbers 242 and 244 which have not been updated since 1985 and 1986, respectively, to the Nuclear Data Project. They also asked ORNL to complete the evaluation of A= 238 nuclei.

Current Evaluation Status:

- A=250, 254, 258, 262 and 266 mass chains *are published*: Nucl. Data Sheets 94, 131 (2001) (Akovali).
- A=242 mass chain *is completed*, and it has been reviewed (Akovali.)
- A=244 mass chain *is nearly completed*. We expect to submit it by June 2002 (Akovali).
- A=238 mass chain *is in progress* (Martin.)
- A=208 mass chain *will be completed* after submission of A=238 evaluation (Martin.)

Reviews of Evaluations:

- A=215, 219, 223, 227 and 231 mass-chain evaluations *are reviewed* (Akovali)

II. Nuclear Reaction Evaluations for Astrophysics (0.48 FTE)

We continue our evaluations of nuclear reactions of vital importance for studies in nuclear astrophysics. These reactions 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 focuses primarily on reactions important for understanding the nuclear burning in the interior of our sun, as well as capture reactions on radioactive isotopes on the proton-rich side of stability that are important for understanding the element synthesis and energy generation in stellar explosions.

These reactions are being 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.

Accomplishments:

- The evaluations of reactions listed below are nearing completion.
 - **$^{18}\text{F}(\text{p},\alpha)$** and **$^{18}\text{F}(\text{p},\gamma)$** reactions, important for understanding of stellar explosions,
 - **$^{17}\text{O}(\text{p},\alpha)$** and **$^{17}\text{O}(\text{p},\gamma)$** reactions, important for understanding of Red Giant Stars and Novae.
- Assessments of the rates of the thermonuclear reactions at the core of our sun are in progress.

III. Database and Web Interface Development; Experimental Nuclear Structure Data Compilation (XUNDF) (0.1 FTE)

Some further development of the software for semi-automatic extraction and conversion of tabular level-scheme data contained in PDF manuscripts into ENSDF-format data sets, is being 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 are created from published papers for testing purposes, and for the XUNDF database.

The compilation and electronic dissemination of most recent data on reaction gammas are done continuously as data become available. Upkeep of the RadWare database is continued.

Other types of data that could be automatically or semi-automatically converted to XUNDF data sets will be investigated; these may include user-contributed level schemes in various formats.

Triangle Universities Nuclear Laboratory
Report to the US Nuclear Data Program
 2 April 2002

I. TUNL Nuclear Data Evaluation Project

A. Personnel

Staff:	Jennifer Godwin	Dissemination Coordinator	Duke/TUNL
	Grace Sheu	Research Secretary	Duke/TUNL
	John Kelley	Research Assistant Professor	NCSU/TUNL
	Xiaodong Hu	Research Scientist	Duke/TUNL
	Ron Tilley	Professor of Physics, Emeritus	NCSU/TUNL
	Henry Weller	Professor of Physics	Duke/TUNL

Collaborators: Gerry Hale - LANL, Hartmut Hofmann - Universitat Erlangen-Nurnberg,
 Jim Purcell - Georgia State University, D.J. Millener - BNL

B. Publication Status

TUNL is responsible for data evaluation in the mass range from $A = 3 - 20$, and for continuing the "Energy Levels of Light Nuclei" series that was carried on by Fay Ajzenberg-Selove. The current publication status of these evaluations is summarized below:

<i>Nuclear Mass</i>	<i>Publication</i>	<i>Reviewers</i>	<i>ENSDF Status</i>
$A = 3$	<i>Nucl. Phys.</i> A474 (1987) 1	TUNL	Adopted Levels
$A = 4$	<i>Nucl. Phys.</i> A541 (1992) 1	TUNL ^a	Adopted Levels
$A = 5-7$	<i>Nucl. Phys. A (Accepted)</i>	TUNL	Adopted Levels
$A = 8-10$	<i>Nucl. Phys.</i> A490 (1988) 1	Penn ^c	Adptd Lvls, γ -rays, decay & rx data
$A = 11-12$	<i>Nucl. Phys.</i> A506 (1990) 1	Penn	Adptd Lvls, γ -rays, decay & rx data
$A = 13-15$	<i>Nucl. Phys.</i> A523 (1991) 1	Penn	Adptd Lvls, γ -rays, decay & rx data
$A = 16-17$	<i>Nucl. Phys.</i> A564 (1993) 1	TUNL	Adptd Lvls, γ -rays, decay & rx data
$A = 18-19$	<i>Nucl. Phys.</i> A595 (1995) 1	TUNL	Adptd Lvls, γ -rays, decay & rx data
$A = 20$	<i>Nucl. Phys.</i> A636 (1998) 247	TUNL ^b	Adptd Lvls, γ -rays, decay & rx data

a) With G.M. Hale, b) with S. Raman
 c) See Evaluations in progress

C. Evaluations in Progress

<i>Nuclear Mass</i>	<i>Status</i>
$A = 5-7^a$	Accepted for publication in Nuclear Physics A ^b
$A = 8-10$	$A = 8$ & 9 preprint versions have been distributed Evaluation of $A = 10$ is in progress

a) With Gerry Hale and Hartmut Hofmann
 b) Prepublication version is available online

D. Online Services

TUNL continues to develop new online services for the nuclear science and applications communities. In addition to the "Energy Levels of Light Nuclei" publications listed in the table above, TUNL prepublication versions for the $A = 5-7$, $A = 8$ and $A = 9$ reviews are also available online. PDF documents for earlier Fay Ajzenberg-Selove evaluations are being made available. Our new HTML project is online with a growing collection of HTML documents for individual nuclides that provide dynamic links to tables, diagrams, reaction discussion and NSR references.

Energy Level Diagrams are provided for $A = 4-20$ nuclei. Update Lists are available which provide brief descriptions of important research bearing on level information published since the last full evaluation. References for the Update Lists are given for each nuclide with experimental and theoretical subdivisions for each, and include links to the NSR database. The Update Lists for $A = 5-15$ nuclei are currently online; lists for other nuclei are being prepared.

E. ENSDF Files

ENSDF files are consistent with the most recent publications for $A = 3-20$.

II. TUNL Program on Preequilibrium Reaction Phenomenology

A. Personnel

Staff: Constance Kalbach Walker Sr. Research Scientist Duke/TUNL

B. Model and Code Development

The TUNL preequilibrium reaction code PRECO-2000 and its extensive users manual were completed shortly after the April 2001 USNDP meeting. The Radiation Safety Information Computer Center (RSICC) at Oak Ridge tested the code on a variety of FORTRAN compilers, and these turned up a number of small errors which were corrected. The code was then released for dissemination through both RSICC and the code distribution center at the NNDC.

Most of the remaining effort over the past year involved additional work on the direct reaction models in the code, particularly the model for nucleon transfer reactions. The formalism for these reactions has been extended to higher incident energies for proton and alpha particle projectiles, while data on deuteron and ^3He projectiles have been included. Finally newer data for incident neutrons at 50 to 63 MeV are being analyzed, though the experimental results from different laboratories currently appear to be yielding somewhat contradictory results, particularly with regard to the amount of surface localization of the initial interaction. Results from this year include:

- The emergence of several differences between stripping and pickup reactions in the nucleon transfer model. In most cases a qualitative understanding of the physics behind these differences undergirds the phenomenology.
- The inclusion of secondary preequilibrium emission following direct stripping reactions. (This turns out not to be very important.)
- A more complete description of the excitation of additional particle-hole pairs during nucleon transfer reactions.
- A revised target mass dependence of the average effective mean-square matrix elements in the exciton model.

In addition, this work has highlighted the need for additional data on charged particle production in neutron induced reactions at energies from 25 to at least 50 or 60 MeV. Data on a broad range of target masses is critical for future model development.

The work on the complex particle channels is being completed and written up as a journal article. After completion of this work, the users manual will be updated and the code will be prepared for the release of PRECO-2002. In addition, data from neutron induced reactions at higher energies will be analyzed as they become available. The allocation of any remaining time this year will depend on input from code users.

Other Reports

**University of Massachusetts Lowell (LTI)
Radiation Laboratory.
Recent Publications.**

The following three papers have been presented at the International Conference on Nuclear Data for Science and Technology, Oct. 7-12, 2001, Tsukuba, Japan:

"The Statistical Distribution of the Number of Prompt Fission Gamma Rays", Chuncheng JI, Gunter H.R. KEGEL, James J. EGAN, David J. DESIMONE, Afrim ALIMETI Carlos ROLDAN, Xudong CHEN.

"Neutron inelastic scattering cross sections from $^{159}\text{Tb}(n,n'\gamma)$ ", Pil-Neyo SEO, James J. EGAN, Gunter H. R. KEGEL, David J. DESIMONE, Young J. KO, Don-Soo KIM, and Chuncheng JI.

"Measurement of the Difference in Decay Rate for ^7Be in Li and ^7Be in Ta", David J. SOUZA, Gunter H.R. KEGEL, James J. EGAN, David J. DESIMONE, Pil-Neyo SEO.

The following paper has been submitted to *Nuclear Science and Engineering* for publication:

"Total Neutron Cross Section Measurements of ^{235}U , ^{159}Tb , and ^{169}Tm in the Region from 200 to 400 keV", P.-N. Seo, Y. J. Ko, G. H. R. Kegel, J. J. Egan, and D. J. DeSimone.

Preprints of these papers are available upon request from Gunter_Kegel@uml.edu or James_Egan@uml.edu.