U.S. Department of Energy
Office of Safety Appraisals

Nuclear Criticality Safety Five-Year Outlay Program Plan

FY 1987-1991

November 16, 1988

ABSTRACT

This five-year Outlay Program Plan documents the bases and plans for the nuclear criticality safety budget of the DOE Office of Safety Appraisals. Actual expenditures in FY 1987 and current funding levels for FY 1988 are presented, with descriptions of the various program elements. This Plan also specifies the bases, assumptions and task planning for the FY 1989, 1990, and 1991 budgets. The FY 1988 funding level is $1390K, and is 75% of last years projection. Objectives of the program and future obligations dictate expenditures about double the OMB submittal of $1355K as the operating funding.

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TABLE OF CONTENTS

1. INTRODUCTION

1.1 GENERAL

Nuclear criticality safety continues to play an increasingly important role in the overall program of the U.S. Department of Energy (DOE). The nuclear production program operated by the DOE is vital to national security, and every effort must be put forth to minimize the probability of a nuclear criticality accident within the DOE complex. Such an event would be a serious detriment to the DOE nuclear program, and would also have an indirect, but very undesirable impact on the licensed nuclear industry.

The Office of Safety Appraisals (OSA) formulates departmental nuclear safety policy and oversees its implementation by the DOE program offices. Through its own program, OSA provides technical support and assistance to DOE programs in all nuclear safety activities, including nuclear criticality safety.

OSA funds specific nuclear criticality safety outlay projects to support its staff's efforts to discharge the office's nuclear criticality safety responsibilities. The outlay projects detailed in Section 3 of this report provide the knowledge to assess and enhance the criticality safety of all DOE nuclear operations.

The following Plan describes the OSA Nuclear Criticality Safety Outlay Program and its expected focus during the FY 1987-91 interval.

1.2 BUDGET ASSUMPTIONS

This plan recognizes the continuing substantial budget cuts that were imposed since the FY 1986-1990 Five-Year Outlay Program Plan (December 10, 1985). The new initiatives that were proposed at that time remain curtailed or deferred, or both. The logical progression of current activities is given priority over new initiatives, although to some extent the milestones in these activities continue to be stretched out to later achievement dates. The available funding is based on the assumptions given below.

Operating Budget Assumptions

FY 1987	Outlay funds in this Plan are those actually awarded (and expended) in the final Approved Financial Plan for FY 1987.
FY 1988	Outlay funds in this Plan are those stipulated by the FY 1987 Financial Plan, which is an 11% decrease from the FY 1987 expenditures.
FY 1989	A base plan for FY 1989 will be structured to adhere to the OMBB submittal, which represents an approximately 3% decrease from the approved financial plan for FY 1988. However, additional programmatic work is proposed, assuming the possible availability of incremental funding.
FY 1990-91	For the outyears, arbitrary assumptions are made for increases of 5.0% and 4.0%, respectively, of the previous year's funding level of the base plan.

Capital Equipment Funds

Sufficient capital equipment funds are assumed to be available to the Office of Safety Appraisals to support the Nuclear Criticality Information System (NCIS) at a level of $70K per year.

2. SUMMARY

The OSA Nuclear Criticality Safety Outlay Program is directed toward minimizing the probability that a nuclear criticality accident will occur in DOE facilities. The program is structured to optimize communications between centers of criticality expertise, to provide up–to–date documented information, to support development of adequate instrumentation and computational capability, and to support theoretical studies.

The proposed funding plan for FY 1987-1991 is summarized below, and is detailed in the body of this report. The funding cited for FY 1987 reflects the actual expenditures. Funding for FY 1988 is minimal and continued below the level for a viable program. The proposed funding for FY 1989-91 are the amounts estimated as needed to achieve Program objectives.

The Program has been assisted in the past by related activities conducted by other Program Offices. Program budget cuts and the imposition of cost-recovery practices at some sites have eliminated this tangential support. Further, the initiation of several experimental programs basic to the understanding of neutron physics in complex geometries and material distribution will require the initiation of planned activities in several Program elements for FY 1989 and 1990. With the exception of one year the cost in the area of Communications has been below the true cost. An increase of 40K over the FY 1988 level is required. The increase of 200K shown for the Program Element "Information & Reference Documents" is required to begin the revision of "Nuclear Safety Guide, TID-7016," which was last revised ten years ago, and to begin work on a new document "Comparison of Theoretical and Experimental Array Study Results for Interstitial Material Effects on Neutron Multiplication." The latter is timed to complement and coincide with an array experimental program supported by ONMP. In the area of computational capability the support for the availability of the MCNP code at LANL for criticality safety applications also has not been the true cost. The level of support is increased from 35K in FY 1988 to 150K in FY 1989.

The necessary base funding level for the Program Elements Communications, Information & Reference Documents, and Computational Capability should not be below 130K, 400K and 565K, respectively.

The deferred Program Element "Factors Affecting Criticality" should be restarted prior to, but not later than, FY 1990 because much of the activity in this element is relevant to the technical bases for National and International regulations governing the storage and transport of fissionable material. Issues concerning the IAEA regulations for the Safe Transport of Radioactive Materials will be considered by SAGSTRAM for resolution and incorporation in the revision of the regulations. It is appropriate, in conjunction with the NRC, that the questions before the IAEA, DOT, and NRC be reviewed and consensus be established for the US positions on relevant issues.

The projected FY 1989 level for the Program Element "Experimental Data" is double that of the FY 1988 funding. The increased funding is distributed among three projects, the "US/French exchange," "experiments addressing discrepant calculations," and "expansion of criticality safety experiments." The US/French project requires an increase of $125K to achieve goals supportive of DOE agreement obligations. A late start in FY 1988 for the project "experiments addressing discrepant calculations" allowed effective reprogramming of 70K to the needs in other Program Elements. The 50K increment to this project continues the required level of support. The remaining increment of 150K for the "expansion of criticality safety experiments" is consistent with the increased number of experimental programs.

The Nuclear Criticality Safety Five-Year Outlay Program Plan will continue to be updated and issued on an annual basis in order to remain compatible with the latest DOE budget guidance.

FIVE YEAR OUTLAY FUNDING PLAN

Nuclear Criticality Safety Program

(by major program element)

Program Element	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
Communications	85	90	130	133	146
Information & Reference Documents	456	400	600	800	800
Computational Capability	467	450 *	850	783	780
Factors Affecting Criticality	0	0	0	115	205
Instrumentation	0	0	0	260	225
Experimental Data	150	310	625	603	487
Theory	53	0	0	140	140
Other	60	150	150	150	150
TOTAL FORECASTED REQUIREMENTS	1265	1400	2355	2984	2933
TOTAL AVAILABLE OPERATING FUNDS	1265	1390	1355	1415	1465
CURRENT PROJECTED SHORTFALL	0	10	1000	1569	1468
TOTAL CAPITAL EQUIPMENT REQUIREMENTS	70	80	70	70	70
• OSA capital equipment budget	70	70	70	70	70
• Current projected shortfall	0	10	0	0	0

* Special projects @ 115K not funded.

FIVE YEAR OUTLAY FUNDING PLAN

Nuclear Criticality Safety Program

(by program subelement)

Program Subelement	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
COMMUNICATIONS					
• Technical Assistance & Support	60	65	104	101	110
• Conferences & Workshops	25	25	26	32	36
Subtotal	85	90	130	133	146
INFORMATION & REFERENCE DOCUMENTS					
• Nuclear Criticality Info System	400	400	400	400	400
• Maintenance of Basic Documents	50	0	200	400	400
Subtotal	450	400	600	800	800
COMPUTATIONAL CAPABILITY					
• Nuclear Criticality Safety Analytical Methods Resource Center	467	450 *	850	783	780
• Nuclear Criticality Safety Assessment Calculations	0	0	0	0	0
Subtotal	467	450	850	783	780
FACTORS AFFECTING CRITICALITY					
• Criticality Parametric Research Studies	0	0	0	115	205
Subtotal	0	0	0	115	205

* Special projects @ 115K not funded

FIVE YEAR OUTLAY FUNDING PLAN

Nuclear Criticality Safety Program

(by program subelement)

Program Subelement	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
INSTRUMENTATION					
• Neutron Detector for Criticality Alarm Systems	0	0	0	0	0
• Criticality Neutron Detector for Hostile Environments	0	0	0	16	25
• Instrumentation Proofing Support	0	0	0	0	0
• Multiplication Meters	0	0	0	100	200
Subtotal	0	0	0	260	225
EXPERIMENTAL DATA					
• Expansion of Criticality Safety Experiments	0	0	150	150	150
• U.S./French Exchange of Nuclear Criticality Safety Information	150	160	275	275	150
• Experiments Addressing Discrepant Calculations	0	150	200	178	187
Subtotal	150	310	625	603	487
THEORY					
• General Theory	0	0	0	0	0
• Transport Methods for Subcritical Arrays	53	0	0	140	140
Subtotal	53	0	0	140	140

FIVE YEAR OUTLAY FUNDING PLAN

Nuclear Criticality Safety Program

(by program subelement)

Program Subelement	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
OTHER					
• Nuclear Criticality Safety Internship	0	0	0	0	0
• Continuous Energy Monte Carlo Evaluation at LACEF	0	0	0	0	0
• Training	60	150	150	150	150
Subtotal	60	150	150	150	150
TOTAL FORECASTED REQUIREMENTS	1265	1400	2355	2984	2933

3. PROGRAM ELEMENTS

3.1 COMMUNICATIONS

Purpose: The *Communications* program element assures that all criticality experts and program workers who participate in or benefit from the overall Nuclear Criticality Safety Program have access to the most current and relevant information. This element includes technical assistance and support to the Office of Safety Appraisals also. The Nuclear Criticality Technology and Safety Project (NCTSP), located at the Oak Ridge National Laboratory, is responsible for this element.

Justification: The success of the Nuclear Criticality Safety Program depends upon effective communications between its participants. Input and critique from the best available experts in the field must be facilitated by the system to avoid the severe consequences of a criticality accident.

3.1 COMMUNICATIONS

3.1.1 Technical Assistance and Support

The Nuclear Criticality Technology and Safety Project (NCTSP) at ORNL provides general technical support and assistance to OSA. In addition, the NCTSP provides for other contingencies, such as procuring the services of consultants to respond to special unforeseen needs. This program subelement also involves special items that arise during pursuit of the overall program. One current task is participation in international nuclear criticality safety activities to enhance U.S. representation in the field. Participation in international programs is appropriate to the development and preparation of considered positions on regulatory proposals or changes, and will permit DOE to remain current with foreign activities.

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
1. Provide general technical support and assistance to OSA on demand and continue administration of all NCTSP activities.	53	65	100	97	100
2. Remain familiar with and represent the U.S. in international standards, regulatory, and research activities. This program will involve, but is not limited to, the following:					
• IAEA Advisory Groups and revision of regulatory documents.	1	0	4	4	4
• International Standards Organization activities	1	0	0	2	2
• Planned and conducted programs at international critical experiments facilities.	5	0	0	4	4
Subelement Budget	60	65	104	107	110

3.1 COMMUNICATIONS

3.1.2 Conferences and Workshops

The Nuclear Criticality Technology and Safety Project responds to specific requests from OSA, including the enhancement of communications among the entire community of nuclear criticality safety specialists. NCTSP continuously reviews the status of criticality safety and formulates proposed actions and projects, such as sponsoring periodic conferences and workshops. Since NCTSP was established in June 1983, four conferences and two workshops have been held. The conferences have been very successful with worldwide participation and excellent communication between attendees. The 1986 conference was held in Knoxville, TN in April/May. The workshops are organized to assemble criticality safety experts on an *ad hoc* basis to address specific problems. The first such workshop was held in Albuquerque in August 1985 on the subject of subcritical reactivity measurements.

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
1. Continue to hold annual conferences and promote attendance by nuclear criticality experts worldwide. The next conference is scheduled for April 18 through April 22, 1988 in Las Vegas, NV.	12	12	13	16	18
2. Continue to schedule and hold workshops on an *ad hoc* basis as required on specific subjects vital to nuclear criticality safety. Each workshop will be documented with proceedings.	13	13	13	16	18
• Workshops on the Influence of Neutron Spectra on Neutron Slowing-Down and Diffusion in Hydrogenous Moderated Fissure Material (Tucson, AZ, March 24-26, 1987). Proceedings will be published in 1988.					
• Workshop on Nuclear Criticality Alarm Systems to be held in Richland, Washington September 20-22, 1988.					
Subelement Budget	25	25	26	32	36

3.1 COMMUNICATIONS

3.1.3 Work Groups

Work groups endorsed by OSA have been organized by and operated under the sponsorship of NCTSP. These work groups are comprised of voluntary representatives of the various DOE contractors. The work groups are chartered to identify deficiencies in criticality safety and to propose possible resolutions. Existing groups and their objectives are listed in Appendix A of this Plan. Because the members of the work groups are volunteers, no funding is budgeted through OSA.

3.1 COMMUNICATIONS

	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
Total Element Budget	85	90	130	133	146

3.2 INFORMATION AND REFERENCE DOCUMENTS

Purpose: This program element is designed to keep basic informational references up to date, and to provide a communications network that will enable free and prompt exchange of information between nuclear criticality specialists.

Justification: Documentation of the most current state-of-the-art technology, research, and experience is essential to nuclear criticality safety practices in order to provide protection to the entire nuclear community and the public. Furthermore, a communications network to permit rapid interaction between experts in the field greatly enhances the quality and the speed with which protective measures can be implemented.

3.2 INFORMATION AND REFERENCE DOCUMENTS

3.2.1 Nuclear Criticality Information System

The Nuclear Criticality Information System (NCIS) is a long-term project that provides instant communications and interaction between nuclear criticality specialists worldwide. This communications network is centered at the Lawrence Livermore National Laboratory (LLNL), and is maintained and upgraded on a continuous basis. NCIS provides a broad-based resource of nuclear criticality specialists by linking its users to other information centers in science and technology. In addition to electronic communications, NCIS offers interactive database management plus bibliographic, textual, and numeric manipulation resources to a growing community of users.

		Operating Budget (K$)				
	Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
1.	*Overhead*					
•	*General Overhead*	124	83	99	100	101
	LLNL BER overhead: Prepare annual Field Task Proposal/Agreement, year startup accounting, year-end accounting, and long-range planning. LLNL Institutional R&D overhead. Travel which is not directly associated with a specific activity.					
•	*Maintain Computer System*	154	167	134	67	67
	Maintain the NCIS computer and its associated communications equipment. Maintain communications hardware such as modems, Ethernet controller/transceiver, tape drives, printers, and data-communications facilities (TYMNET, ARPANET, and telephone dial-up lines). Provide daily incremental backup dumps and weekly full dumps. Provide services for users which include hotline assistance, user manuals, and training. Purchase software and software licenses for commercial software used by NCIS. Purchase maintenance agreements for commercial software: operating system (OSx) and database (Ingres). Purchase subscription to American Nuclear Society Information Resource Service (ANSIRS). In FY 1987 this item provided for transferring the NCIS databases and user community to the new computer and upgrading					

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
the capabilities of NCIS to provide its expanding services to the criticality safety community.					
Subtotal (1)	**278**	**250**	**233**	**167**	**168**
2. *Continuing Tasks*					
Maintain Information Resources	41	25	25	25	25
Maintain and update the information resources available through NCIS to adequately reflect changes and growth in the project. This includes periodic updates to a brochure describing NCIS services and capabilities, revisions of the International Directory of Nuclear Criticality Safety Personnel, maintenance of the various databases accessible through NCIS, and a regular online listing which contains information on criticality safety conferences, recent publications in the literature, training courses and meetings, as well as new developments in NCIS, and other general information of interest to NCIS users. A topical, more informal, bulletin board service is also maintained.					
Reproduce and store in NCIS the draft criticality safety standards generated by ANSI-ANS to enable the nuclear community to participate in their review and to stay abreast of developments. Announce changes to drafts in the online news and maintain the draft standards current in a standards database in NCIS.					

3.2 INFORMATION AND REFERENCE DOCUMENTS—3.2.1, Continued

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
• *Interaction with Other DOE Projects* Provide support to DOE-funded criticality safety projects. This interaction enhances the ability of these projects to disseminate results of their work through electronic communications or NCIS publications. For the Nuclear Criticality Technology and Safety Project, NCIS will maintain online files of membership and activities of NCTSP-sponsored work groups, and will provide electronic mail accounts for effective communication between work group members. NCIS assists the Nuclear Criticality Safety Analytical Methods Resource Center to maintain the CESAR database on the NCIS computer. NCIS provides a gateway connection to ORNL for the use of KENO and other criticality safety computer codes. Also offers small criticality safety assessment codes to run on portable PCs: these codes will be available for examination and downloading directly from NCIS. Offer assistance in the form of user accounts and access to electronic mail to the U.S./French exchange of nuclear criticality safety information.	20	20	20	20	20
• *Nuclear Criticality Technology Publications* Continue to publish the Nuclear Criticality Technology series. These publications include proceedings of DOE-sponsored criticality safety workshops, a compendium of descriptions of criticality safety experiments currently planned at DOE-facilities, compendia of pertinent abstracts from the literature, in addition to general guidebooks, reports, and other publications determined in accordance with guidelines for suitability that were established in FY 1986.	15	20	20	20	20

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
Subtotal (2)	**76**	**65**	**65**	**65**	**65**
3. *Special Projects*					
• *General Literature of Criticality Safety* NCIS resumed work on the database of citations of general criticality safety interest. This information will be reviewed and prepared for publication. Begin work in FY 1990 and complete in FY 1991.	0	0	0	50	50
• *Nuclear Science Abstracts* About 4,000 citations satisfied requirements in a search of the old (before 1972) NSA files. These citations have been transferred to NCIS. Unfortunately, abstracts are not included in the electronic database. Rather than keyboard the abstracts we propose to issue a publication similar to UCRL-53369. This would include lookup tables based on author, report, data, and title, and a photocopy of the relevant abstracts printed in NSA.	0	0	0	0	26
• *Revise UCRL-52769* Publish a revision and update to "Nuclear Criticality Experiments from 1943 to 1978, an Annotated Bibliography" in FY 1988.	35	39	20	0	0
• *Revise UCRL-53369* Publish a revision to "Nuclear Criticality Safety Experiments, Calculations, and Analyses – 1958 to 1982".	0	0	20	40	20

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
• *Neutron Transport Code* Install an easy-to-use neutron transport code and cross section library, such as the LLNL SAN (Short ANISN) discrete ordinates code and 16-group cross section library. This code would be an important supplement to the NCSAC codes. It would be easy to use; input could normally be prepared without a users manual. Problems would be run during "off hours" when the computer would otherwise be nearly idle. Begin work in FY 1991.	0	0	0	0	50
• *Regulatory and Standards Information* It is important for criticality safety specialists, managers, and regulators to have access to regulations and standards. NCIS would install a database consisting of abstracts of orders, standards, regulations, and guidelines. Some sources of these are DOE orders, and orders from other agencies (NRC, FEMA, DOT, etc.) relating to criticality safety. Begin work in FY 1989 and complete in FY 1990.	0	0	39	57	0
• *TID-7028 Data* A revision to TID-7028 has been prepared at LANL. The curves in TID-7028 have been generated with the MAPPER computer program. The data could be transferred to NCIS and made available as an online database. Data to be transferred would be experimental data points which are difficult to extract from the published curves. Begin work in FY 1989 and complete in FY 1990.	0	10	2	0	0

Program		Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
• *Nuclear Criticality Safety Theory and Practice Textbook*		1	0	0	0	0
Supplements to the textbook are made available by the author via NCIS. Work was completed in FY 1987. Maintenance is included in (2) Continuing Tasks.						
Subtotal (3)		46	49	81	147	146
Subelement Budget						
	Operations	400	400	400	400	400
	Capital	70	80	70	70	70

3.2 INFORMATION AND REFERENCE DOCUMENTS

3.2.2 Maintenance of Basic Documents

Nuclear criticality safety is an active discipline which changes as new or improved technology becomes available. Reference material must be revised and updated to stay current with technological advancement. Accordingly, several documents basic to the needs of criticality safety are undergoing or are scheduled to undergo revision. Substantial progress has already been made on updating several of the documents cited below.

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
1. Revise TID-7028, "Critical Dimensions of Systems Containing U-235, Pu-239, and U-233," at LANL. This update is needed to include data that have become available during the last 20 years. The revision was published in FY 1987..	25	0	0	0	0
2. Revise LA 3611, "A Review of Criticality Accidents," at LANL. This revision will add descriptions of all criticality accidents since 1967, and is scheduled for publication in 1988.	25	0	0	0	0
3. Prepare and issue the new document, "Comparison of Theoretical and Experimental Array Study Results for Interstitial Material Effects on Neutron Multiplication." This study will be a joint effort of ORNL and LANL. The results are needed to validate the theory on this subject. This project is expected to be completed in FY 1991.	0	0	100	200	200
4. Revise TID-7016, "Nuclear Safety Guide" This document cites nuclear criticality limits on handling materials, and has not been revised since 1978. This revision will include new data from the revised TID-7028, and will be completed in FY 1992.	0	0	100	200	200
Subelement Budget	50	0	200	400	400

3.2 INFORMATION AND REFERENCE DOCUMENTS—3.2.2, Continued

Total Element Budget	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
Operations	450	400	600	800	800
Capital	70	80	70	70	70

3.3 COMPUTATIONAL CAPABILITY

Purpose: This program element is directed toward maintaining state-of-the-art computational capability in nuclear criticality safety.

Justification: Adequate computational capability is essential to a satisfactory application of the theory of neutron physics. Computational results must be verifiable by experiment; and since these results are relied upon to provide safety margins, discrepancies between computational and experimental results must always be resolved.

3.3 COMPUTATIONAL CAPABILITY

3.3.1 Nuclear Criticality Safety Analytical Methods Resource Center

The Nuclear Criticality Safety Analytical Methods Resource Center at ORNL develops and maintains state-of-the-art computational methods for criticality safety calculations. The Center also provides training and consultation as needed, and support for development and maintenance of nuclear criticality safety applications of the MCNP Monte Carlo code at LLNL.

		Operating Budget (K$)				
	Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
1.	*Continuing Efforts*					
	• *Analytical Assistance* Provide analytical assistance to users of the Oak Ridge criticality computer codes. Previously, only a limited amount of this service was provided to users on a no-cost, professional courtesy basis. Under this program, the service is now available as a funded activity.	41	50	52	55	58
	• *Technical User Support* Hold two-day training sessions in the use of the KENO Monte Carlo code about three times per year.	14	15	15	15	15
	• *Coordination with NCIS* Make the ORNL CESAR database accessible to criticality specialists via NCIS. Future activities and computational resources will make all of the Oak Ridge criticality codes available to outside users through NCIS.	41	45	45	45	45

3.3 COMPUTATIONAL CAPABILITY—3.3.1, Continued

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
• *KENO Maintenance* Correct errors and deficiencies in the KENO code. KENO IV has been in general use for several years and requires only low-level maintenance. KENO V has been available for about two years, but still requires substantial maintenance.	19	20	20	20	20
• *AMPX Maintenance* Maintain the AMPX cross-section processing capability. An essential aspect of a criticality computational capability is the availability of state-of-the-art neutron cross-section data. The AMPX cross-section processing system has been developed at Oak Ridge and applied in the processing of multigroup Criticality Safety Reference Libraries.	40	40	40	40	40
• *KENO VI Development* Enhance the KENO geometry package to allow more rigorous modeling of new concepts in fuel storage, as well as to improve modeling of existing facilities. A production version of KENO, which incorporates these enhancements, will be released as KENO VI. Programming on KENO VI with its geometric algorithm development began in FY 1986; the program was completed in FY 1987 and will be documented in FY 1988.	0	50	0	0	0

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
• *Maintain Criticality Safety Utility of MCNP* Routinely maintain and upgrade MCNP at LANL for criticality safety work.	35	35	150	150	150
• *Program Administration* Provide funding for general overhead (program administration, travel, etc.)	34	40	42	44	46
• *KENO Validation* KENO V KENO VI Validate KENO V for use in criticality safety. Validate KENO VI after the completion of its development. KENO is the most widely used U.S. criticality safety code. The KENO V version incorporated improvements over earlier versions. The improvements simplify input data. KENO VI, an enhanced geometric version, must also be validated after completion. The analyses for KENO V were completed in FY 1986 and was documented in FY 1987. Those for KENO VI will be completed and documented before the end of FY 1989.	 47 0	 5 65	 0 130	 0 105	 0 20
• *Computational Interface* Establish a computer interface to NCIS for improved access to KENO and related codes through a lease-to-purchase option.	0	70	70	30	30

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
• AMPX Development Enhance the AMPX cross-section processing system in those areas of particular importance to criticality safety. Initial efforts are being focused on resonance-processing treatments. A long-range objective is the capability to process the ENDF/B-VI data when they are released to evaluators. Resonance processing capability was enhanced in FY 1986. The ENDF/B-VI algorithms will be implemented in FY 1987 and FY 1988, and an AMPX-III document will be issued in FY 1989.	14	15	20	20	20
Subtotal (1)	280	450	584	524	444
2. *Special Projects*					
• *Methods Investigations* Investigate promising new methods that could enhance calculational capabilities.	20	22	22	24	26
• *Vector Code Development* Identify analytical simulations amenable to vector processing and develop effective numerical algorithms (KENO VII) in FY 1988 and confirm in FY 1989. Modern computer technology provides the opportunity to reduce computational time significantly through the use of vector processing. This program will be designed to	0	80	140	200	150

exploit technological advancements to achieve this objective.

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
• *GPRKINETICS* Expand the GPRKINETICS code to three dimensions and provide documentation of the methodology. Pulsed-neutron methods proposed for measuring the degree of subcriticality for a system require analytic calculation of certain quantities. The GPRKINETICS code has been used to calculate the needed quantities in two dimensions, but many systems require three-dimensional calculations. The 3-D diffusion program began in FY 1986, programming will be completed in FY 1987 and the 3-D diffusion code will be documented in FY 1988.	34	15	0	0	0
• *ENDF/B-VI Cross-Section Library* Begin this project in FY 1991. DOE has supported the measurement, evaluation, and compilation of neutron cross-section data by its various laboratories and through the Cross-Section Evaluation Working Group (CSWWG). The CSEWG is expected to complete its evaluation of ENDF/B-VI in the late 1980's. This project will facilitate use of the cross-section data in calculational codes, and will provide vitally needed access to multi-group libraries based on state-of-the-art differential data. Continued curtailment of funding has delayed its initiation to FY 1991.	0	0	0	0	100

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
• *Monte Carlo Kinetics* Frequency dependent Monte Carlo methods. Begin development of a Monte Carlo code to calculate quantities in the frequency domain to be used for noise analysis of subcritical systems.	0	0	0	35	60
Subtotal (2)	240	115	262	259	336
Subelement Budget	520	565	850	783	780

3.3 COMPUTATIONAL CAPABILITY

3.3.2 Nuclear Criticality Safety Assessment Calculations

This project is to develop at LLNL a series of Nuclear Criticality Safety Assessment Calculation (NCSAC) codes to run on small personal computers. The ability to run the codes on small computers offers many definite advantages, even though computation capability is available via large, sophisticated codes running on mainframe machines. Results of the more comprehensive calculations can be compared with the NCSAC results, and discrepancies might identify input errors common in the larger codes because of the complexity of input data. Calculations using the smaller codes are easier and less expensive, and also allow field calculations. All material developed in NCSAC will be available through NCIS.

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
Develop codes for operation on small personal computers:					
• *Nuclear criticality accident dynamics.*	0	0	0	0	0
• *Critical-mass calculations for arrays*	0	0	0	0	0
• *Critical-mass calculations for single units*	0	0	0	0	0
• *Consequence models for nuclear criticality accidents*	0	0	0	0	0
These codes have been developed and are available on NCIS.					
It is planned to make available on NCIS other PC programs developed within the complex available to the safety community.					
Subelement Budget	0	0	0	0	0

3.3 COMPUTATIONAL CAPABILITY

Total Element Budget	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
	520	565	850	783	780

3.4 FACTORS AFFECTING CRITICALITY

Purpose: This program element is designed to characterize and understand the differences between the process conditions and experimental conditions used in criticality safety research and development.

Justification: Models and safety concepts that are firmly founded on evaluated experimental data must be developed and assessed for use in safety evaluations. ORNL will conduct research studies on systems of fissionable materials. These studies will be designed to characterize parametric effects on the system's neutron multiplication factor. The research will provide guidance to develop needed data and experimental bases. The information will be validated and codified in a form useful to the definition of concepts and practices in safety assessments. These studies will also ultimately enable generalization of safety concepts, expressed in engineering terms.

3.4 FACTORS AFFECTING CRITICALITY

3.4.1 Criticality Parametric Research Studies

Present criticality parametric research studies at ORNL are structured to investigate the influence of insulating and other typical container materials used in transport on the criticality of arrays, and also the influence of low-density hydrogenous moderation in storage arrays. Future studies may include: characterization of the effects of various materials encountered in process operations as diluents or reflectors; development of criteria for reflector equivalence in a context applicable to the operational environment; and investigation of the effects of dispersions of finely divided fissionable materials in moderators..

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
1. Characterization of interspersed hydrogenous moderation introduced in the void regions of reflected arrays of fissile material.					
• *Effects of fissile and reflector material density on criticality*	0	0	0	10	5
Examine and model the reactivity worth of fissile material in simple geometries as the density of the core and reflector are changed. Critique the density-scaling law. Issue final report in FY 1992					
• *Neutron leakage fraction and neutrons produced per absorption*	0	0	0	10	10
Characterize these parameters at the critical state as the density of the fissile and reflector materials are varied. Develop a model for the behavior observed. Issue final report in FY 1991.					

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
• *Hydrogenous moderations of arrays* Examine the response of the array k_{eff} as moderation is varied in arrays of fissile material. Determine the contribution to k_{eff} from unit reflection and from neutron coupling. Issue final report in FY 1991.	0	0	0	20	20
• *Density analog modeling* Establish a correlation between reflected arrays and reflected low-density spheres. Issue report in FY 1991.	0	0	0	20	10
• *Influence of fissile materials form and compositions* Study the metals and oxides of uranium and plutonium, the uranium enrichment, and various reflector materials as above. Complete in FY 1991.	0	0	0	0	40
2. *Characterization of the influence of typical insulating and container material on array criticality.* The safety assessments of packages used in the transport of fissile materials is based predominantly on analyses by and results from sophisticated calculational codes.					
• *Reactivity worth of packaging materials in arrays* Examine the magnitudes of changes in array k_{eff} resulting from changes in packaging materials consistent with regulatory requirements. Develop a basis useful in assessing the results of package evaluations. Issue final report in FY 1991.	0	0	0	20	40

3.4 FACTORS AFFECTING CRITICALITY—3.4.1, Continued

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
• *Transport index assignment for packages* Examine the criteria of transport index assignment to packages. Formulate a generally applicable, consistent method of assigning transport indices to packages of fissile material. Complete in FY 1992.	0	0	0	15	20
• *Transport index of zero* Determine the necessary criteria for the assignment of a zero transport index to packages. Characterize the influences of co-mingling different packages. Complete in FY 1991.	0	0	0	20	40
• *Fissile-mass loadings for packages* Provide fissile materials mass loadings for typical packages, to be used as a basis for evaluating analyses and modeling of arrays of packages. Complete in FY 1992.	0	0	0	0	20

3.4 FACTORS AFFECTING CRITICALITY

Total Element Budget	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
	0	0	0	115	205

3.5 INSTRUMENTATION

Purpose: This program element is directed toward developing improved instrumentation in the field of nuclear criticality safety.

Justification: Detection of conditions in nuclear systems that could potentially lead to a critical or supercritical condition is still far from being completely reliable. Because of the severe possible consequences of an unexpected criticality, this program element is needed to introduce advanced technology into detection instrumentation, and to continue to improve the technological base upon which such instrument systems can be designed and operated. These systems include criticality alarms, neutron multiplication monitors, and dosimeters.

3.5 INSTRUMENTATION

3.5.1 Neutron Detector for Criticality Alarm Systems

The Neutron Criticality Alarm System project at LLNL is completed. This alarm system will be useful in facilities with high background gamma radiation. The only remaining effort in this project is publication of the final report.

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
System developed and field tested against full neutron spectrum (completed in Fy 1985). A brief preliminary report was published in August, 1986. Publication of the final report is scheduled for FY 1987. Publication costs were prepaid from the FY 1986 budget.	0	0	0	0	0
Subelement Budget	0	0	0	0	0

3.5 INSTRUMENTATION

3.5.2 Criticality Neutron Detector in Hostile Environments

In order to be useful in realistic environments, a neutron detector in criticality alarm systems must be able to function properly in hostile environments, such as high gamma radiation, high or low temperatures, electromagnetic interference, and physical vibration or shock. This project at LLNL will evaluate the performance of the recently developed criticality neutron detector (see Section 3.5.1) under all hostile conditions.

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
Evaluate and harden the neutron detector for criticality alarm systems for operation in hostile environments. Complete work and issue final rept by FY 1991.	0	0	0	160	25
Subelement Budget	0	0	0	160	25

3.5 INSTRUMENTATION

3.5.3 Instrumentation Proofing Support

The Instrumentation Proofing Support project at LANL will document the capabilities of the Los Alamos Advanced Nuclear Technology Group for characterizing and measuring nuclear radiation generation from critical assemblies, reactors, and accelerators at the Los Alamos Critical Experiments Facility (LACEF). The resulting document will be useful to all DOE installations that require radiation services.

	Operating Budget (K$)				
Program	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
Prepare and publish a document which characterizes in detail the nuclear radiation generation capabilities of the LACEF and the Los Alamos Advanced Nuclear Technology Group. Final preparation of this document is in progress; publication costs have been prepaid from the FY 1985 budget.	0	0	0	0	0
Subelement Budget	0	0	0	0	0

3.5 INSTRUMENTATION

3.5.4 Multiplication Meters

Current criticality safety practitioners employ two basic tools at the work site: a) administrative physical controls of magnitudes, positions, and movements of masses of fissionable materials, and b) criticality alarm systems. If the first tools works, no danger of nuclear criticality exists; but if the second is activated, catastrophic situation has already developed. At present, we have not effective measurement system in routine use for early detection of an approach to nuclear criticality; this program subelement will investigate the feasibility for developing a neutron multiplication meter.

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
Develop instruments and methods to warn operators of undesired, but less than catastrophic, increases in neutron multiplication. Design a practical system to detect and alarm approach to criticality, and test the resulting system in the field.	0	0	0	100	200
Subelement Budget	0	0	0	100	200

3.5 INSTRUMENTATION

Total Element Budget	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
	0	0	0	260	225

3.6 EXPERIMENTAL DATA

Purpose: This program element is structured to take advantage of experimental work undertaken by other DOE or foreign programs. The objective of the program element is to obtain and analyze additional experimental data useful to DOE-wide nuclear criticality safety activities.

Justification: An OSA capability to obtain experimental data supportive of criticality safety studies must be maintained and used to provide for: a) evaluation of analytic methods, b) resolution of discrepancies between experiments and calculated results, c) specific programmatic requirements and design problems, and d) unique training opportunities. The DOE critical experiments facilities and their associated experienced personnel are national resources, and continuation of these activities depends on support from the Program Offices.

3.6 EXPERIMENTAL DATA

3.6.1 Expansion of Criticality Safety Experiments

This project at LANL provides for handling uranium solutions in the Kiva 1 facility for experiments to measure the effects of neutron room return, interstitial material interactions and replicated and nonreplicated unit arrays. The experiments began in FY 1986 with Program Office funding, to support the calculational examinations in the "Computational Performance Assessment" project. In FY 1985, OSA funded the work to provide the capability to handle uranium solutions in Kiva 1. OSA will fund incremental effort in this program subelement toward the end of the Plan period.

	Operating Budget (K$)				
Program	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
Monitor experiments and (where appropriate) fund incremental effort to obtain the maximum amounts of safety and physics data.	0	0	150	150	150
Subelement Budget	0	0	150	150	150

3.6 EXPERIMENTAL DATA

3.6.2 U.S/French Exchange of Nuclear Criticality Safety Information

The project at LANL on the Criticality Information Exchange with France will provide for the U.S. (specifically LANL) to develop models and analyze data from the French SILENE burst reactor, and for the French to use their models to analyze data from the U.S. SHEBA solution reactor. The objective of this international collaboration is to increase operational safety in nuclear facilities by examining the behavior of fissile solutions at and above the delayed-critical reactivity region. This information will improve the understanding of neutron physics applied to accident conditions.

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
Exchange U.S. and French data derived from each country's respective reactor.	150	160	275	275	150
Subelement Budget	150	160	275	275	150

3.6 EXPERIMENTAL DATA

3.6.3 Experiments Addressing Discrepant Calculations

This program will provide experimental data useful to the resolution of observed discrepancies between experiments and calculations by today's methodologies. Information from the experimental measurements will be used to examined and test the implementation of the theory of neutron physics in calculational codes at ORNL and LANL.

		Operating Budget (K$)				
	Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
1.	*Program Management and Administration*	0	30	35	37	40
2.	*Generic Experiment Task*					
	• Experiment planning	0	5	5	5	5
	• Performance of experiments	0	90	125	100	100
	• Calculation of results and necessary code diagnostics	0	25	25	26	27
	• Documentation of results	0	0	10	10	15
Subelement Budget		0	150	200	178	187

3.6 EXPERIMENTAL DATA

Total Element Budget	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
	150	310	625	603	487

3.7 THEORY

Purpose: This program element provides support for work to improve the theoretical understanding of nuclear criticality and subcriticality.

Justification: Computing capability has progressed beyond our ability to predict the results with theory. Experimental verification is lacking for many critical assembly features revealed by calculations. Theory, experiments, and calculations must be brought into agreement to achieve better reliability in safety assessments of operations with fissile materials.

3.7 THEORY

3.7.1 General Theory

Measurement techniques have improved substantially over early capabilities. These techniques should be used to re-examine fundamental experiments in order to confirm our understanding of nuclear criticality and to develop an understanding of subcritical states.

	Operating Budget (K$)				
Program	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
The Office of Safety Appraisals will encourage cooperation among workers in theory, experiments, and calculations dealing with nuclear criticality safety. OSA will also assist in coordinating their efforts.	Activities supported by Program and Field Offices				

3.7 THEORY

3.7.2 Transport Methods for Subcritical Arrays*

Theoretical models exist only for subcritical configurations called "one-can systems." Theoretical models for "multi-can systems" need to be formulated. Such a model will be developed at ORNL under this program subelement.

Program	Operating Budget (K$) FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
1. Multi-can Model					
Develop a multi-can phenomenological model by using the multi-point kinetics equation and by considering the periodicity of the array. This model will enable criticality safety studies emphasizing the coupling between units. Green's functions will be used in the time domain to interpret experimental quantities obtained during pulsed-neutron source methods. The multi-can method development was completed in FY 1986; the method will be refined and demonstrated in FY 1987 and documented in FY 1988.	53	0	0	0	0
2. Stochastic Methods					
Develop stochastic methods for nuclear subcriticality surveillance and diagnostics. This program will start in FY 1990.	0	0	0	140	140

* Funded in FWP/A of the Nuclear Criticality Safety Analytical Methods Resource Center (see Section 3.3.1).

3.7 THEORY

Total Element Budget	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
	53	0	0	140	140

3.8 OTHER

Purpose: This program element allows for all additional work that is defined as necessary to the overall nuclear criticality safety program.

Justification: Some projects do not fit specifically into any of the defined categories of the general nuclear criticality safety program. This program element provides funding and support for such activities.

3.8 OTHER

3.8.1 Nuclear Criticality Safety Internship

The Nuclear Criticality Technology and Safety Project has organized a six-month intern program in nuclear criticality safety. Three months are spent at the Resource Center for Nuclear Criticality Safety Analytical Methods at ORNL, and three months at the Los Alamos Critical Experiments Facility. A seventh optional month is available for visiting different sites, or for project work at a specific site within the complex. OSA will offer the program to the DOE contractors. The announcement to the complex will contain requirements of sponsors and students.

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
Second internship completed in Fy 1986, and program effectiveness evaluated in Fy 1986. Offer program to DOE contractors in Fy 1987.	0	0	0	0	0
Subelement Budget	0	0	0	0	0

3.8 OTHER

3.8.2 Continuous Energy Monte Carlo Evaluation of the "Annular Tank Experiment" at LACEF

This subelement will provide a benchmark calculation using continuous-energy Monte Carlo calculations for comparison with standard KENO-IV discrete-energy calculations on the Annular Tank Assembly at the LACEF. The calculations will use the LANL transport code MCNP (Monte Carlo Neutron-Photon). This information is needed by OSA to address an apparent bias in the KENO calculational scheme.

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
Work currently being completed. A publication of the results is forthcoming.	0	0	0	0	0
Subelement Budget	0	0	0	0	0

3.8 OTHER

3.8.3 Training

This subelement will provide the continuation of the nuclear criticality safety training program that has been widely used by the DOE and contractor personnel for more than eight years. In addition to introducing fundamental concepts of criticality and practical examples of effective process controls, attendees have an opportunity to participate in a laboratory approach-to-critical.

	Operating Budget (K$)				
Program	**FY 1987**	**FY 1988**	**FY 1989**	**FY 1990**	**FY 1991**
Course offerings at LANL	60	150	150	150	150
Subelement Budget	60	150	150	150	150

3.8 OTHER

Total Element Budget	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
	60	150	150	150	150

APPENDIX A

Nuclear Criticality Safety Work Groups and Their Objectives

1) **Neutron Physics Theory** – to examine the theory of the fission process and related theory as used in nuclear criticality safety computational methods. The scope of this work group is to review discrepancies between experimental and calculated results, to identify deficiencies, to recommend experiments, and to develop a better understanding of subcritical situations.

2) **Accident Analysis** – to collect physical descriptions of intrinsic shutdown mechanisms for various types of fissile assemblies, to identify the important physical phenomena in each type of assembly, and to assess the limitations of the physical models in computing the consequences of postulated criticality accidents.

3) **Evaluation Techniques** – to examine the available methods for assessing process operations to identify and codify common elements of Contractor safety department practices. This work group will define acceptable techniques and define the criteria for and the adequacy of subcritical margins.

4) **Experiments** – to identify deficiencies in critical experimental data and to identify the data needed to support criticality safety activities within Contractor organizations. This group examines programmatically supported critical experiments and considers the feasibility of adjunct experiments or extensions of the experiments to measure additional physical parameters.

5) **Parameter Studies** – to characterize the neutron physics of fissile materials in the typical forms encountered in operations. This work group recommends studies of k_{eff} responses to parametric changes in geometry, density, reflector conditions, and neutron coupling between subcritical components of fissile material.

6) **Physical Criteria for Benchmark Experiments** – to identify and recommend criteria for the acceptance of critical and subcritical experiments as suitable benchmarks for evaluating analytic methods. This work group also examines criteria for external and internal consistency of nuclear parameters used in analysis.

7) **Rules, Regulations, and Standards** – to review applicable reference materials and regulatory requirements with the intent of resolving inconsistencies and clarifying ambiguities. This work groups also provides timely evaluations of such documents.

8) **Training** – to improve nuclear criticality safety education and training. This work group reviews training materials, methods, and techniques.

APPENDIX B

Key to Sources of Budgetary Funds for Nuclear Criticality Safety Program

The Nuclear Safety budget category is designated HA 01 06. However, the Control Numbers in the Federal Budget under this category do not correlate directly with the Program Elements by which this *Outlay Program Plan* is organized. The Plan is organized according to a logical categorization of the work by its own objective and by the site at which the work elements and subelements are performed. This Appendix gives a key to relate the program subelements to the Budget Control Numbers.

Subelement			Budget Control Number
3.1	*Communications*		
	3.1.1	Technical Assistance and Support	HA 01 06-104
	3.1.2	Conferences and Workshops	HA 01 06-104
	3.1.3	Work Groups	No OSA funding
3.2	*Information and Reference Documents*		
	3.1.2	Nuclear Criticality Information System	HA 01 06-011
	3.2.2	Maintenance of Basic Documents	HA 01 06-121,-191
3.3	*Computational Capability*		
	3.3.1	Nuclear Criticality Safety Analytical Methods Resource Center	HA 01 06-164
	3.3.2	Nuclear Criticality Safety Assessment Calculations	HA 0106-144
3.4	*Factors Affecting Criticality*		
	3.4.1	Criticality Parametric Research Studies	HA 01 06-165

Subelement			Budget Control Number
3.5	*Instrumentation*		
	3.5.1	Neutron Detector for Criticality Alarm System	No current OSA funding
	3.5.2	Criticality Neutron Detector for Hostile Environments	No current OSA funding
	3.5.3	Instrument Proofing Support	No current OSA funding
	3.5.4	Multiplication Meters	No current OSA funding
3.6	*Experimental Data*		
	3.6.1	Expansion of Criticality Safety Experiments	No current OSA funding
	3.6.2	U.S./French Exchange of Nuclear Criticality Safety Information	HA 01 06-163
	3.6.3	Experiments Addressing Discrepant Calculations	HA 01 06-244
3.7	*Theory*		
	3.7.1	General Theory	No OSA funding
	3.7.2	Transport Methods for Subcritical Arrays	HA 01 06-164
3.8	*Other*		
	3.8.1	Nuclear Criticality Safety Internship	HA 01 06-020 (ORAU)
	3.8.2	Continuous Energy Monte Carlo Evaluation of the "Annual Tank Experiment" at LACEF	(ORAU)