US-JAPAN COLLABORATION ON FUSION BLANKET NEUTRONICS: BACKGROUND, SCOPE AND OBJECTIVES

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NEUTRONICS WORKSHOP
FEBRUARY 2-3, 1984
UCLA

AGENDA

Neutronics Workshop
February 2-3, 1984
UCLA Faculty Facility (Sierra Room)
Los Angeles, California

NOTE: Attendance at Workshop sessions is limited to participants listed. Speakers for presentations are shown in parenthesis.

Thursday, February 2

Session I: Working Group for DOE-JAERI Collaboration on Fusion Blanket Neutronics

Participants: M. Abdou, S. Berk, G. DiIorio, Y. Gohar, J. Jung, R. Santoro, M. Youssef, and T. Yule

8:30 - 8:40 Greetings and Introductions (Abdou)
8:40 - 9:00 Background, Scope and Objectives of the Collaboration (Abdou)
9:00 - 9:25 Overview of Plan for DOE Contributions to the Collaboration: Tasks, Organizational Responsibilities, and Schedules (Abdou, Youssef)
9:25 - 9:45 Description of JAERI's FNS Facility and Comparison to Other Neutron Sources (Yule, DiIorio)
9:45 - 10:00 Break
10:00 - 11:00 Review of First Collaborative Experiment (DiIorio)
11:00 - 11:30 Review of ANL Experimental Technique and Instrumentation Development (Yule)
11:30 - 12:30 Lunch
12:30 - 1:15 Review of ANL Analytical Activities (Jung, Gohar)
1:15 - 2:00 Review of UCLA Analytical Activities and LANL Contributions (Youssef)
2:00 - 3:15 Discussion of Future Plans for the Collaboration: Agreements and Commitments (All)
3:15 - 3:30 Break

Session II: Definition and Development of Plans/Specifications for Benchmark Calculations to Compare Codes and Data Bases

Participants: All Session I Participants and E. Cheng, L. Ku, J. Lee, and M. Sawan

3:30 - 3:45 Review of Needs and Proposed Plans (Abdou, Youssef)
3:45 - 4:10 Review of Helium Cooled Blanket and Other Benchmarks (Cheng)
4:10 - 4:35 Review of Lithium Self Cooled Blanket and Other Benchmarks (Gohar)
4:35 - 5:00 Review of Lithium-Lead Cooled Blanket and Other Benchmarks (Sawan)
5:00 - 5:25 Review of Water Cooled Blanket and Other Benchmarks (Jung)
5:25 - 6:25 Definition of Benchmarks and Development of Plans/Specifications

Friday, February 3

Session III: Review of Neutronics Integral Experiments: Objectives, Status and Plans

Participants: All Session II Participants and B. Engholm, N. Hertel, R. Haight, and G. Woodruff

9:00 - 9:40	Review of FNS Experiments at JAERI (Abdou, Youssef, DiIorio)
9:40 - 10:20	Review of Beryllium and Other Experiments at LLNL (Lee, Haight)
10:20 - 10:30	Break
10:30 - 11:10	Review of LOTUS Experiments at EPFL - Switzerland (Woodruff)
11:10 - 11:50	Review of LBM Experiment at TFTR (Engholm)
11:50 - 12:00	Review of Experiments at University of Texas (Hertel)
12:00 - 1:00	Lunch
1:00 - 1:40	Review of Shielding/Streaming Experiments at ORNL (Santoro)
1:40 - 2:15	Discussion of Future Options for Experiments at ORNL and for Collaborations Among Integral Experiment Programs (All)

Session IV: Discussion of Neutronics R&D Needs

Participants: All Session III Participants

2:15 - 2:35	Near-Term Needs (Gohar, Ku, Santoro)
2:35 - 2:55	Long Term Needs (Abdou)
2:55 - 3:35	General Discussion (All)
3:35 - 3:45	Break

Session V: Special Topics

Participants: All Session IV Participants

3:45 - 4:05	Overview of Nuclear Data Activities (Cheng)
4:05 - 4:25	Review of Results from LLNL Meeting on Neutronics Codes and Data Bases at the NMFECC (Ku)
4:25 - 4:45	Discussion of Ideas for Fusion Neutronics Working Groups or Other Committees to Guide Neutronics Programs (All)

Session VI: Conclusions

Participants: All Session V Participants

4:45 - 5:30	General Workshop Discussions, Agreements/Commitments and Wrap-up (All)

PURPOSES OF THE WORKSHOP

PRIMARY TOPICS

- COORDINATION OF US-JAPAN COLLABORATION ON NEUTRONICS
- BENCHMARK CALCULATIONS

ADDITIONAL TOPICS

- REVIEW OF OTHER NEUTRONICS INTEGRAL EXPERIMENTS
- OTHER TOPICS OF SPECIAL INTEREST:
  - R&D NEEDS
  - NUCLEAR DATA ACTIVITIES
  - IDEAS FOR NEUTRONICS WORKING GROUP(S)

US-JAPAN COLLABORATION

TOPICS

- BACKGROUND, SCOPE AND APPROACH
- PLAN FOR DOE CONTRIBUTIONS TO THE COLLABORATION:
  - TASKS
  - ORGANIZATIONAL RESPONSIBILITIES
  - SCHEDULES
- DESCRIPTION OF FNS FACILITY
- REVIEW OF FIRST COLLABORATIVE EXPERIMENTS PERFORMED IN NOVEMBER/DECEMBER, 1983
- REVIEW OF SPECIFIC US TASKS:
  - EXPERIMENTAL TECHNIQUES, INSTRUMENTATION
  - ANL ANALYTICAL ACTIVITIES
  - UCLA ANALYTICAL ACTIVITIES
  - ORNL ACTIVITIES
- WORKSHOP DISCUSSIONS:
  - FUTURE PLANS, AGREEMENTS AND COMMITMENTS
  - SPECIFIC ITEMS:
    1) BERYLLIUM
    2) BREEDING MATERIAL FOR PHASE II
    3) MARCH 12-19 JOINT WORKSHOP

HISTORY OF DOE-JAERI COLLABORATION

- DESCRIPTION OF FNS WAS PRESENTED IN AN IAEA WORKSHOP IN OCTOBER, 1981. A TOUR OF THE FACILITY WAS ARRANGED; US TECHNICAL EXPERTS ATTENDING THE WORKSHOP WERE IMPRESSED BY FNS AND THE FACT THAT IT WAS BUILT AND DEDICATED TO FUSION NEUTRONICS.

- PRELIMINARY DISCUSSIONS ON COLLABORATION WERE HELD DURING THE OCTOBER, 1981 WORKSHOP. DR. NAKAMURA WAS INVITED TO VISIT THE US.

- DR. NAKAMURA VISITED THE US IN MAY, 1982. GENERAL FRAMEWORK FOR THE COLLABORATION WAS DISCUSSED.

- A US TEAM CONSISTING OF SIX EXPERTS VISITED JAERI (AND JAPANESE UNIVERSITIES) AND PARTICIPATED IN A US-JAPAN WORKSHOP IN DECEMBER, 1982. A JOINT US-JAERI REPORT DETAILED AREAS AND PRINCIPLES OF COLLABORATION.

- SINCE THEN, THERE HAS BEEN A LARGE NUMBER OF WRITTEN AND TELEPHONE COMMUNICATIONS TO FINALIZE THE AGREEMENT.

- A WRITTEN TEXT OF THE AGREEMENT WAS AGREED UPON BY BOTH PARTIES IN AUGUST, 1983.

- BEYOND THAT, THE NEUTRONICS AGREEMENT HAD TO AWAIT RESOLUTION OF ISSUES IN THE OVERALL "UMBRELLA" AGREEMENT FOR US-JAPAN COOPERATION.

POSITIVE ENCOURAGING ASPECTS OF THE AGREEMENT

- ENTHUSIASM ON BOTH SIDES.

- AGREEMENT PROVIDES FOR NEARLY EQUITABLE SHARES OF RESPONSIBILITIES AND BENEFITS (ALTHOUGH JAERI FEELS THE US SHOULD CONTRIBUTE MORE TO THE COST OF EXPERIMENTS).

- THERE IS WILLINGNESS ON THE WORKING LEVEL TO FACILITATE THE COOPERATION AND OVERCOME UNNECESSARY "RED TAPE." FOR EXAMPLE, G. DIIORIO PARTICIPATED IN THE FNS EXPERIMENTS IN NOVEMBER/ DECEMBER, 1983, WITHOUT A FORMAL AGREEMENT IN PLACE.

- NEAR-TERM PROGRAMMATIC GOALS FOR DOE AND JAERI ARE NOT SUFFICIENTLY DIFFERENT TO PRECLUDE MEANINGFUL COOPERATION.

JAERI: Li_2O IS THE ONLY BREEDER MATERIAL OF INTEREST.

US: Li_2O IS ONE OF SEVERAL HIGH-PRIORITY MATERIALS.

US-JAPAN COLLABORATION

TERMS OF AGREEMENT

OBJECTIVES

PLAN AND CONDUCT JOINT NEUTRONICS EXPERIMENTS AT FNS AND ANALYZE THE RESULTS FOR THE PURPOSES OF:

- IDENTIFYING DEFICIENCIES IN DATA AND METHODS.
- PROVIDING KEY INPUT TO PREDICTING THE OVERALL UNCERTAINTY IN PRESENT ESTIMATES OF BREEDING RATIO FOR CANDIDATE BLANKET CONCEPTS. FEASIBILITY ISSUE: CRUCIAL TO REJECTION/SELECTION OF CANDIDATE BLANKET CONCEPTS AND DEMONSTRATING THAT A FEASIBLE ENGINEERING CONCEPT EXISTS.
- VALIDATING METHODS AND DATA.

GENERAL FEATURES OF SCHEDULED COLLABORATIVE EXPERIMENTS

- TWO EXPERIMENTAL PHASES:
  - PHASE I: SEPTEMBER, 1983 TO DECEMBER, 1984
  - PHASE II: JANUARY, 1985 TO MARCH, 1986
- EACH PHASE CONSISTS OF THREE EXPERIMENTS:
  - EACH EXPERIMENT LASTS FOR ONE MONTH
  - SCHEDULE FOR EXPERIMENTS: SEPTEMBER AND MARCH
- PHASE I:
  - MATERIALS AND GEOMETRY FOR THE EXPERIMENTS ARE FIXED
  - BREEDER MATERIAL COST PAID FOR ENTIRELY BY JAERI
  - BREEDER MATERIAL IS LI_2O
  - GEOMETRY IS SLAB-TYPE (PSEUDO-CYLINDRICAL SLAB)
  - US WILL PROVIDE BERYLLIUM FOR ONE OF THE EXPERIMENTS
- PHASE II:
  - MATERIALS AND GEOMETRY REMAIN TO BE DETERMINED
  - US WILL PAY FOR THE COST OF THE BREEDER MATERIAL AS WELL AS SHIPPING; JAERI WILL PAY FOR CONSTRUCTION OF EXPERIMENTAL CONFIGURATION
  - US SHOULD TAKE THE INITIATIVE ON SUGGESTING THE CHARACTERISTICS OF PHASE II EXPERIMENTS
  - A KEY TOPIC FOR THE MARCH, 1984 JOINT WORKSHOP

ELEMENTS OF US PARTICIPATION/RESPONSIBILITIES

- PLANNING:
  - PARTICIPATE IN PLANNING THE EXPERIMENTS
  - PHASE I WAS PLANNED PRIMARILY BY JAERI
  - US SHOULD BE ACTIVE IN PLANNING PHASE II

- EXPERIMENTAL PERSONNEL:
  - US EXPERIMENTALIST TO PARTICIPATE IN CONDUCTING THE EXPERIMENTS AT FNS (TWO PERIODS PER YEAR, EACH PERIOD IS ONE MONTH AND FOUR WEEKS)

- ANALYTICAL:

  US PARTICIPATES IN:
  - PRE-EXPERIMENT ANALYSIS (FOR GENERAL PLANNING AS WELL AS FINE TUNING OF THE EXPERIMENTS)
  - POST-EXPERIMENT ANALYSIS: NEUTRON TRANSPORT, NUCLEAR RESPONSE CALCULATIONS, SENSITIVITY ANALYSIS, ETC. (MOST CRITICAL TO US NEEDS; A GOOD PART OF OUR EFFORT)
  - PROVIDING JAERI WITH "STANDARD" LIBRARIES AND CODES

- EXPERIMENTAL TECHNIQUES AND INSTRUMENTATION DEVELOPMENT:
  - DEVELOP AND PROVIDE INSTRUMENTATION FOR KEY MEASUREMENTS; DETAILS HAVE BEEN AGREED UPON

- MATERIALS:
  - BERYLLIUM FOR LATTER PART OF PHASE I
  - BREEDER MATERIAL FOR PHASE II

OTHER GENERAL ITEMS OF COLLABORATION

- Personnel exchange as appropriate, e.g., JAERI analysts visits to US

- Joint workshops: once per year

- Information exchange:

  - Experimental results will be provided by JAERI to the US. Care will be exercised in disseminating the information to those outside the collaboration. Publications will require prior joint approval by the two technical coordinators (Nakamura and Abdou).

- Enhance collaboration on other areas of neutronics:

  - Nuclear data measurements, evaluation

  - Data libraries

  - Method and code development

US-JAPANESE UNIVERSITIES COLLABORATION

- INCENTIVES:
  - OKTAVIAN FACILITY HAS EXCELLENT CAPABILITIES
  - EXPERIMENTAL PROGRAMMATIC GOALS ARE DIVERSE (MAY SERVE US NEEDS BETTER IN THE LONG TERM)
  - EXCELLENT EXPERIMENTALISTS/ANALYSTS (E.G., PROF. TAKAHASHI)

- HISTORY/STATUS:
  - SEVERAL MEETINGS/DISCUSSIONS WITH OSAKA (PROF. SUMITA)
  - AGREEMENTS CAN BE DEVELOPED AMONG TECHNICAL EXPERTS
  - HOWEVER, FORMAL AGREEMENT COULD NOT BE REACHED FOR REASONS THAT EXTEND OUTSIDE THE SCOPE OF NEUTRONICS

- RECOMMENDATIONS:
  - FIND MECHANISMS FOR INFORMAL EXCHANGE OF INFORMATION
  - TRY TO EXPLORE AGAIN POSSIBILITIES FOR FORMAL AGREEMENT

$TBR \equiv$ TRITIUM BREEDING RATIO

$T_R \equiv$ REQUIRED TBR

$$T_R = 1 + G_O + \Delta_G$$

$G \equiv$ DOUBLING TIME MARGIN

$\Delta_G \equiv$ UNCERTAINTY IN REQUIRED G

DOUBLING TIME MARGIN

- REQUIRED TO COVER FOR:
  - LOSSES DUE TO RADIOACTIVE DECAY OF T BETWEEN PRODUCTION AND USE
  - SUPPLYING INVENTORY FOR STARTUP OF OTHER FUSION REACTORS
  - HOLD UP INVENTORY TO ACCOUNT FOR TIME DELAY BETWEEN T PRODUCTION AND USE AS WELL AS RESERVE STORAGE
- G_O IS A FUNCTION OF:
  - $I \equiv$ TRITIUM INVENTORY (BLANKET, FUELING, STORAGE, ETC.)
  - $T_D \equiv$ DOUBLING TIME

$\Delta_G \equiv$ UNCERTAINTY IN G_O

- EXAMPLES OF UNCERTAINTIES ARE:
  - T INVENTORY IN BLANKET
  - NECESSARY STORAGE RESERVE
  - T FRACTIONAL BURNUP IN THE PLASMA

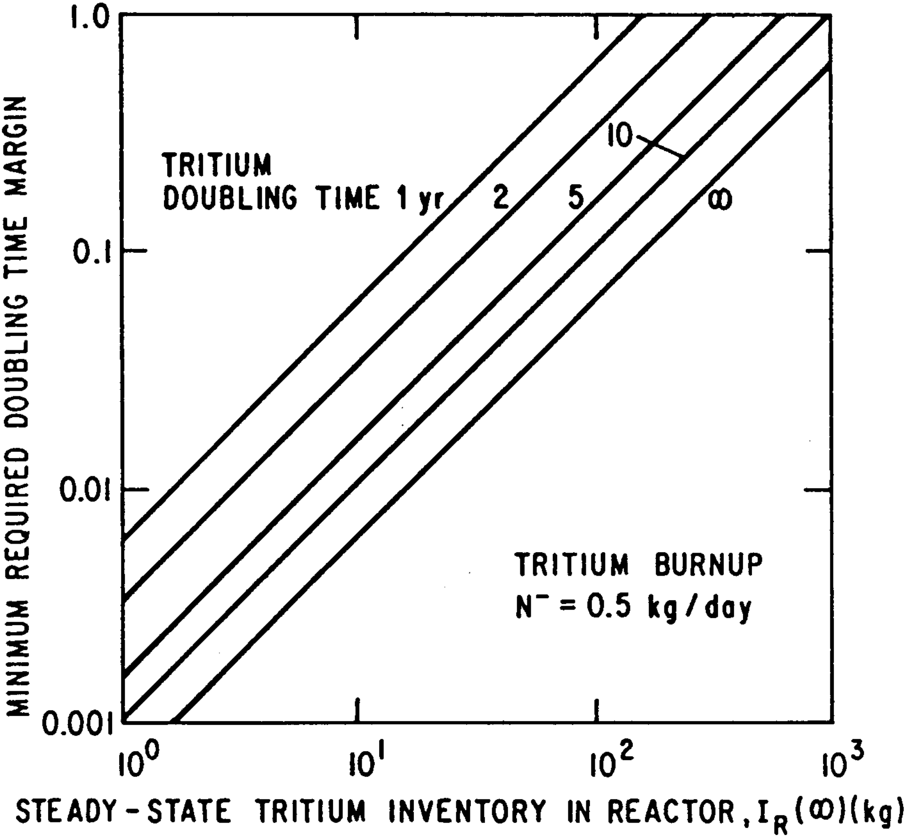

Figure III.2-2. Minimum required doubling time margin as a function reactor tritium inventory at several values of the doubling time.

$T_A \equiv$ ACHIEVABLE TBR

- PROBLEM: WE CANNOT PREDICT PRECISELY T_A BECAUSE:
  - WE DO NOT KNOW THE EXACT SPECIFICATIONS OF WHAT TO BUILD
  - FOR GIVEN REACTOR SPECIFICATIONS, WE CANNOT PREDICT PRECISELY THE PERFORMANCE

- WE CAN ONLY CALCULATE A TBR FOR A REFERENCE SYSTEM WITH ASSUMPTIONS ABOUT ITS SPECIFICATIONS

$$T_A = T_C - \sqrt{\Delta_S^2 + \Delta_P^2}$$

$T_C \equiv$ TBR CALCULATED (THE BEST WE KNOW HOW TODAY, 3D, ETC.) FOR A SPECIFIED BLANKET IN A SPECIFIED REACTOR

$\Delta_S \equiv$ UNCERTAINTY ASSOCIATED WITH SYSTEM DEFINITION [CHANGES IN CALCULATED TBR RESULTING FROM CHANGES IN THE REFERENCE REACTOR SYSTEM (E.G., REFERENCE REACTOR SYSTEM HAS LIMITER AND REACTOR TO BE BUILT COULD HAVE A DIVERTOR)]

$\Delta_P \equiv$ UNCERTAINTIES IN PREDICTING TBR FOR A GIVEN SYSTEM

$$\Delta_P = \sqrt{\Delta_M^2 + \Delta_D^2 + \Delta_C^2}$$

$\Delta_M \equiv$ UNCERTAINTIES ASSOCIATED WITH GEOMETRIC MODELING

$\Delta_D \equiv$ UNCERTAINTIES ASSOCIATED WITH NUCLEAR DATA

$\Delta_C \equiv$ UNCERTAINTIES ASSOCIATED WITH CALCULATIONAL METHODS

TYPES OF UNCERTAINTIES
IN PREDICTING ACHIEVABLE TBR

UNCERTAINTIES ASSOCIATED WITH SYSTEM DEFINITION (Δ_S)

- FIRST WALL/BLANKET DEFINITION
  - CONFIGURATION DETAILS, STRUCTURE, COOLANT, MANIFOLDS, FORM AND POROSITY OF SOLID BREEDERS, THERMOPHYSICAL PROPERTY VARIATIONS, ETC.

- REACTOR DEFINITION
  - TECHNOLOGY CHOICES (TYPE OF RF VS. NEUTRAL BEAMS, LIMITER VS. DIVERTOR, ETC.)
  - REQUIREMENTS AND SPEFICICATIONS FOR SPECIFIC TECHNOLOGY CHOICES (E.G., SIZE AND CONFIGURATION OF PENETRATIONS FOR LIMITER, MATERIAL CHOICES FOR LIMITER)
  - PRESENCE OF YET UNDEFINED COMPONENTS (E.G., PENETRATIONS FOR DIAGNOSTICS AND FUELING, I&C
  - POSSIBLE NEED FOR COMPONENTS TO SATISFY YET UNDEFINED REQUIREMENTS (E.G., PASSIVE COPPER COILS IN THE BLANKET FOR PLASMA STABILIZATION, SECTOR TO SECTOR ELECTRICAL JOINTS, ETC.)

$\Delta_P \equiv$ Uncertainties associated with predicting TBR for a given system

- Approximations in Geometrical Modeling (Δ_M)
  - Approximating engineering 3D surfaces and volumes by traditional mathematically convenient shapes (intersection of cones, cylinders, spheres, cubes, etc.)
  - Approximating discrete by continuous geometric zones
  - Approximating the details of heterogenity
- Nuclear Data (Δ_D)
  - Uncertainties in basic nuclear data
  - Approximations in data processing
  - Approximations in final data libraries (number of energy groups, weighting functions, etc.)
- Calculational Methods (Δ_C)
  - Inherent in methods and codes
  - Introduced by analyst (e.g., order of S_N, P_N, etc.)

PROPOSED FIGURE OF MERIT FOR TBR

$$I = \frac{T_C - (1 + G_O)}{\sqrt{\Delta_G^2 + \Delta_S^2 + \Delta_P^2}} \qquad 0 \leqslant I \leqslant 1.0$$

T_C ≡ NET TBR CALCULATED FOR THE BLANKET UNDER CONSIDERATION IN 3D GEOMETRY FOR REFERENCE REACTOR CONDITIONS (E.G., MARS WITH A SET OF ASSUMPTIONS ABOUT DESIGN CHOICES; OR STARFIRE WITH SPECIFIED LIMITER, LOWER HYBRID, ETC.)

G_O ≡ REQUIRED DOUBLING TIME GAIN UNDER REFERENCE CONDITIONS AND ASSUMPTIONS

Δ_G ≡ UNCERTAINTY IN PREDICTING REQUIRED DOUBLING TIME MARGIN

Δ_S ≡ UNCERTAINTY ASSOCIATED WITH SYSTEM DEFINITION

Δ_P ≡ UNCERTAINTY IN PREDICTING TBR FOR A GIVEN SYSTEM

PROCEDURE AND RESPONSIBILITIES

- EACH CONCEPT DESIGN GROUP WILL DEVELOP THE BLANKET DESIGN TO THE DEGREE OF DETAIL REQUIRED FOR CALCULATING T_C

- JUNG (WITH ASSISTANCE FROM OTHERS) WILL CALCULATE T_C FOR TOKAMAKS

- T_C FOR MIRRORS WILL BE CALCULATED BY: ? AND GORDON

- UNCERTAINTY TERMS WILL BE EVALUATED FOR EACH CONCEPT FOR BOTH MIRRORS AND TOKAMAKS:

Δ_G	JUNG
Δ_S	GOHAR/JUNG/SHIN/ABDOU
Δ_M	SHIN/ABDOU/JUNG
Δ_D	YOUSSEF
Δ_C	GOHAR/JUNG/YOUSSEF/ABDOU

TRITIUM BREEDING PROGRAM

- REDUCE UNCERTAINTIES IN PREDICTING TRITIUM BREEDING RATIO (T)

- IMPROVE PREDICTABILITY OF UNCERTAINTY IN T

TRITIUM BREEDING PROGRAM ELEMENTS

REDUCE UNCERTAINTIES IN PREDICTING T

- DESIGN DEFINITION:
  - NARROW MATERIALS AND DESIGN CONCEPTS
  - GREATER ENGINEERING DETAIL
- CALCULATIONS:
  - MODEST IMPROVEMENT IN METHODS
  - MORE DETAILED GEOMETRICAL MODELING
- NUCLEAR DATA:
  - MEASUREMENTS
  - EVALUATION
  - DATA REPRESENTATION AND PROCESSING

TRITIUM BREEDING PROGRAM ELEMENTS (CONTD.)

IMPROVE PREDICTABILITY OF UNCERTAINTY IN T

- INTEGRAL EXPERIMENTS:
  - BASIC EXPERIMENTS
  - SIMPLE ENGINEERING EXPERIMENTS
  - MOCK-UP
- SENSITIVITY ANALYSIS:
  - IMPROVE METHODS
  - PERFORM SENSITIVITY STUDIES

(GEOMETRY, MATERIAL COMPOSITION, CROSS SECTIONS, SECONDARY NEUTRON SPECTRA)