REMARKS ON NEUTRONICS R&D NEEDS

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WHY DO NEUTRONICS R&D?

- ENGINEERING FEASIBILITY OF FUSION MUST BE DEMONSTRATED WITHIN THE NEXT TWO DECADES

- NEUTRONICS IS A KEY ELEMENT IN A NUMBER OF ENGINEERING FEASIBILITY ISSUES, FOR EXAMPLE:

  - TRITIUM BREEDING RATIO THAT SATISFIES SELF-SUFFICIENCY REQUIREMENTS IN AN ENGINEERING SYSTEM

  - ADEQUATE SHIELDING OF MANY RADIATION-SENSITIVE COMPONENTS

- NEUTRONICS EFFORT CAN HELP IMPROVE THE CREDIBILITY AND ATTRACTIVENESS OF NEAR-TERM AND FUTURE FUSION DEVICES, FOR EXAMPLE:

  - ENERGY MULTIPLICATION IN THE BLANKET (DIRECTLY RELATED TO COST OF ENERGY)

  - THICKNESS OF SHIELD IN THE INBOARD REGION OF TOKAMAKS (VERY HIGH SENSITIVITY OF CAPITAL COST)

HOW MUCH MORE NEUTRONICS R&D IS NEEDED?

- NEUTRONICS IS RELATIVELY MATURE FIELD:
  - NEUTRONICS R&D CANNOT BE EXPECTED TO BE VERY LARGE UNDER THE SEVERELY CONSTRAINED BUDGET FOR THE NEXT SEVERAL YEARS

- HOWEVER, A REASONABLE SIZED NEUTRONICS R&D PROGRAM MUST BE MAINTAINED TO:
  - HELP RESOLVE FEASIBILITY ISSUES (E.G., TRITIUM BREEDING)
  - ASSURE ADEQUATE PERFORMANCE OF NEAR-TERM DEVICES IN AREAS WHERE MISTAKES ARE COSTLY (E.G., SHIELDING/ACTIVATION)
  - HIGH PAY-OFF AREAS:
    1) ENERGY MULTIPLICATION
    2) SHIELD THICKNESS
    3) IN GENERAL, "REDUCE DEGREE OF CONSERVATISM"

- WE MUST WORK HARD TO KEEP THE PROGRAM FOCUSED AND WITH CLEAR PRIORITIES

- LONG-TERM CRITICAL NEEDS MUST NOT BE SACRIFICED IN THE RUSH TO SATISFY NEAR-TERM NEEDS

FUSION DEVICES

1990's

Physics Devices (e.g., TFCX)
Engineering Testing Devices

Beyond 2000

ETR/DEMO

Beyond 2010

First Commercial Demonstration

Neutronics

- Shielding in all devices
- Blankets in devices in the 1990's (tritium-producing blankets or test modules)
- Demands on accuracy of prediction will increase as economics becomes an issue

GENERAL CLASSIFICATION OF REQUIRED NEUTRONICS SHIELDING R&D

- IMPROVEMENTS IN ACCURACY OF PREDICTION:
  - NUCLEAR DATA:
    - BASIC MEASUREMENTS, EVALUATION
    - PROCESSING, GROUP STRUCTURE, ETC.
  - METHODS AND CODES:
    1) TRANSPORT CODES:
       DISCRETE ORDINATES, MONTE CARLO
    2) RESPONSE FUNCTIONS:
       KERMA FACTORS (HEATING), RADIOACTIVITY, DPA, ETC.

- IMPROVEMENTS IN CAPABILITIES TO ESTIMATE UNCERTAINTIES IN PREDICTION:
  - ESTIMATES OF ERRORS IN BASIC DATA
  - SENSITIVITY/UNCERTAINTY ANALYSIS METHODS AND CODES
  - ANALYTICAL BENCHMARKS
  - INTEGRAL EXPERIMENTS

- INFORMATION ON DESIGN CRITERIA, E.G.:
  - DATA ON CHANGES IN PROPERTY OF SPECIFIC MATERIALS/COMPONENTS AS A FUNCTION OF IRRADIATION DOSE (E.G., J_C FOR SUPERCONDUCTOR, ρ FOR COPPER STABILIZER, ELECTRICAL AND MECHANICAL PROPERTIES OF INSULATORS)
  - BETTER UNDERSTANDING OF SUBSYSTEM/SYSTEM TRADE-OFFS

NEUTRONICS/SHIELDING PARAMETERS OF INTEREST

- Tritium Breeding Ratio
- Nuclear Heating
- Gas Production
- Atomic Displacements
- Radioactivity-Related Parameters

Table XVII. Probability of Use and Priority of Data Needs for Elements of Importance to Tritium Breeding

Element	Probability of Use	Priority for Data Needs	Comments
Lithium/Lithium Compounds			
Lithium	H	1	Definite
Lead	H	1	Li-Pb
Oxygen	H	3	Li_2O
Aluminum	M	1	$LiAlO_2$
Silicon	M	1	Li_2SiO_3
Zirconium	M	1	Li_2ZrO_3
Titanium	L	1	Li_2TiO_3
Neutron Multiplier			
Beryllium	H	1	
Lead	M	1	
Bismuth	L	2	Bi-Pb
Zirconium	L	3	Zr_5Pb_3
Coolant			
Helium	M	3	
Hydrogen	H	3	H_2O
Oxygen	H	3	H_2O
Structural Material			
Iron	H	1	SS
Chromium	H	2	SS
Nickel	H	2	SS
Manganese	H	2	SS
Vanadium	H	1	
Niobium	L	3	
Moderator/Reflector			SS, H_2O
Carbon	M	3	
In-Vessel Components			
Copper	H	2	
Vanadium	M	2	
Niobium	M	2	
Tungsten	M	3	
Tantalum	L	3	

[a]Judgement on the probability of using the material in fusion blankets: H=high, M=medium, L=low.
[b]Priority for data needs takes into account of (a) the probability of using the material, (b) effect on tritium breeding, and (c) uncertainties in presently available data.

TABLE 4-4
SOME TYPICAL REQUIRED ACCURACIES IN FUSION REACTOR SHIELDING

First Wall/Blanket	
Nuclear heating	Total 2%, spatial distribution, 10%
Tritium production	Breeding ratio 2%, local 5%
Atomic displacement, helium production	10%
Transmutations	20%
Induced activation	50%
Bulk Shield	
Nuclear heating	Gross 20%, local 30%
dpa and He and H production, activation	Factor of 2
Tritium production	Factor of 3
Main (Superconducting) Magnets	
Nuclear heating, dpa	Gross 10%, local 20%
H, He production	Gross 40%, local 80%
Activation	Factor of 2
Penetration Duct Walls	
Nuclear heating	Local 20%
dpa and He and H production	Local 50%
Penetration Functional Equipment (e.g. vacuum pumps, neutral beam injectors)	
Nuclear heating	Gross 30%, local 50%
dpa and He and H production	50%
Activation, tritium production	Factor of 2
Reactor Floor (outside the shield and inside the containment building)	
Biological dose after shutdown	Factor of 2
Biological dose during operation	Factor of 3
Coolant Minifolds and Heat Exchangers	
Biological dose after shutdown	Factor of 2
Containment Building	
Nuclear heating	Factor of 2
dpa and He and H production	Local factor of 4
External Biological Dose (outside containment building)	Factor of 3