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Total Pages 650

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February 16, 1998

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sandia national laboratories

DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW
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AUTHORITY: ☐AOC ☐ADC ☐ADD
NAME: DICK CRANER
2ND REVIEW-DATE: 7-26-99
AUTHORITY: ADD
NAME: Philip Ulmer
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2 CLASSIFICATION CHANGED TO:
3 CONTAINS NO DOE CLASSIFIED INFO
[✓ 4] COORDINATE WITH: DOD
5 CLASSIFICATION CANCELLED
[✓ 6] CLASSIFIED INFO BRACKETED
7 OTHER (SPECIFY):

Survey of Weapon Development and Technology (WR708) (U)

~~Restricted Data~~

~~This document contains Restricted Data as defined in the Atomic Energy Act of 1954. Unauthorized disclosure subject to Administrative and Criminal Sanctions.~~

~~Classified By: John C. Hogan~~
~~Title/Org: Manager, DP Knowledge Integration & Ed, 5507, 8/22/97~~
~~Derived From: CG-W-5, 01/84~~
~~TCG-DS-1, 04/86~~
~~TCG-BTS-1, 10/84~~
~~TCG-SAFF-1, 12/86~~
~~TCG-UC-2, 10/93~~

~~CRITICAL NUCLEAR WEAPON DESIGN INFORMATION~~
~~– DOD DIRECTIVE 5210.2 APPLIES –~~

~~NUCLEAR WEAPON DATA~~

~~SIGMA 1 & 2~~

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DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW
1st REVIEW DATE: 2/22/01
AUTHORITY: DD
NAME:
2nd REVIEW-DATE:
AUTHORITY: DD
NAME: Dick Craner, SNL
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4 COORDINATE WITH:
5 CLASSIFICATION CANCELLED
[✓ 6] CLASSIFIED INFO BRACKETED
7 OTHER (SPECIFY):

Corporate Training & Development

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

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SESSION I

- COURSE OVERVIEW
- WEAPON COMPLEX & DEVELOPMENT PROCESS

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY
WR708

Day	Time	Session	Title	Instructor
Monday	8:00 - 12:00	1	Course Overview - Introduction	Hogan
		2	Physics - Explosion Theory	Hogan
	1:00 - 4:00	2	Physics - Explosion Theory (cont)	Hogan
		3	Nuclear Effects	Hogan
Tuesday	8:00 - 12:00	4	High Explosives - Detonators	Hogan
		5	Fission	Hogan
	1:00 - 4:00	5	Fission (cont)	Hogan
		6	Thermonuclear	Hogan
Wednesday	8:00 - 12:00	6	Thermonuclear (cont)	Hogan
		7	Safety	Layne
	1:00 - 3:00	7	Safety (cont)	Layne
		8	Use Control - Access Control	Layne
	3:00 - 4:00	9	Weapons Systems	Rogulich
Thursday	8:00 - 9:00	10	Dismantlement	Hogan
	9:00 - 11:00	11	Arming, Firing and Initiation	Curtis
	11:00 - 12:00	12	Nuclear Testing	Hogan
	1:00 - 4:00	13	Transfer Systems	Robinson
		14	Fuzing	Hartwig
		15	Arms Control	Layne
Friday	8:00 - 9:00	15	Arms Controls (cont)	Layne
	9:00 - 10:00	16	Non-Proliferation/Counter Proliferation	Taylor
	10:00 - 11:00	17	Stockpile Matters	Layne
	11:00 - 11:15		Summary Hogan	
	12:00 - 3:30	18	Nuclear Weapons Musuem Tour	Hogan

WR708 - Course Objectives
What We hope you learn

- The nuclear physics principles
- Nuclear weapons engineering implementation
- Depth and breath of the nuclear weapons program
- Principles of nuclear surety
- Surety as implemented in the enduring stockpile weapons
- Operation of the enduring stockpile weapons
- Similarities/differences of the weapons
- The evolution of nuclear stockpile over the last 50 years
- The principle drivers of the nuclear stockpile over the last 50 years
- Nuclear weapons subsystem components and their evolution

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Course Themes

- Stockpile surety
- Stewardship
- Historical teaching approach
- Extensive use of hardware
- Survey of almost all aspects of nuclear weapons

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OVERVIEW (Continued)

- There have been weapon system, aircraft and missile trades which have over the last 50 years driven the nuclear weapons community to design smaller, lighter, yet higher-yield weapons.
- A systems engineering approach is required when viewing nuclear weapons.
- Arms control is a major driver for weapons reduction.
- History and early weapon development is extremely important to the understanding of third world proliferation.

Nuclear Weapons Development Drivers

- Nuclear surety
- Service Requirements/weapon system interfaces
  - less manpower intensive
  - less weight and volume
- National security strategy/policy
  - United States
  - CINC's
  - NATO
- Arms control
  - limit technology
  - limit growth
  - eliminate categories
  - reduce numbers

National Security Strategy: Deterrence

Decade	Implementation
1950	Massive Retaliation
1960	Flexible Response
1970	Flexible Response
1980	Flexible Response
1990	Last Resort

SIGNIFICANT HISTORICAL EVENTS RELATIVE TO NUCLEAR WEAPONS

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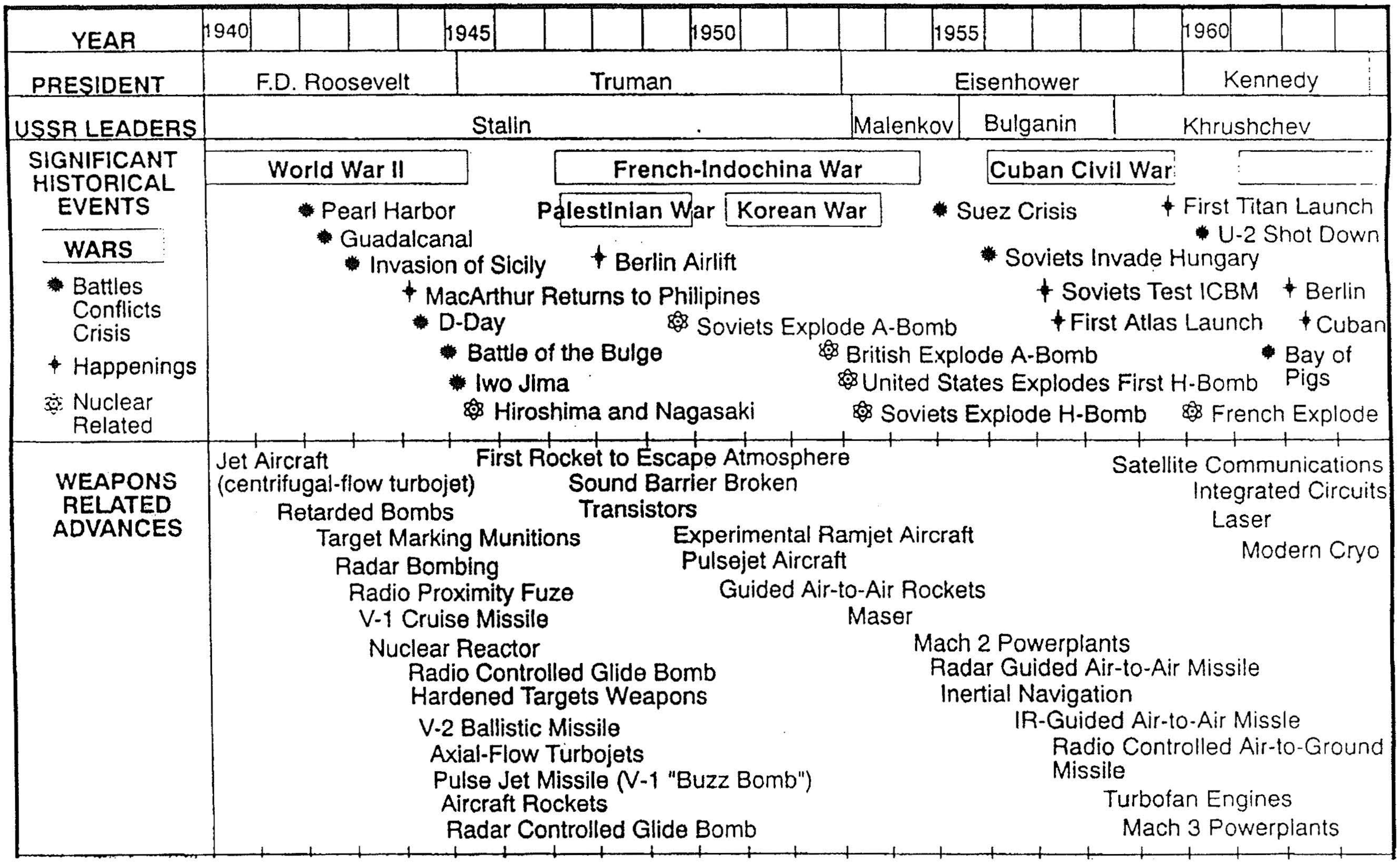

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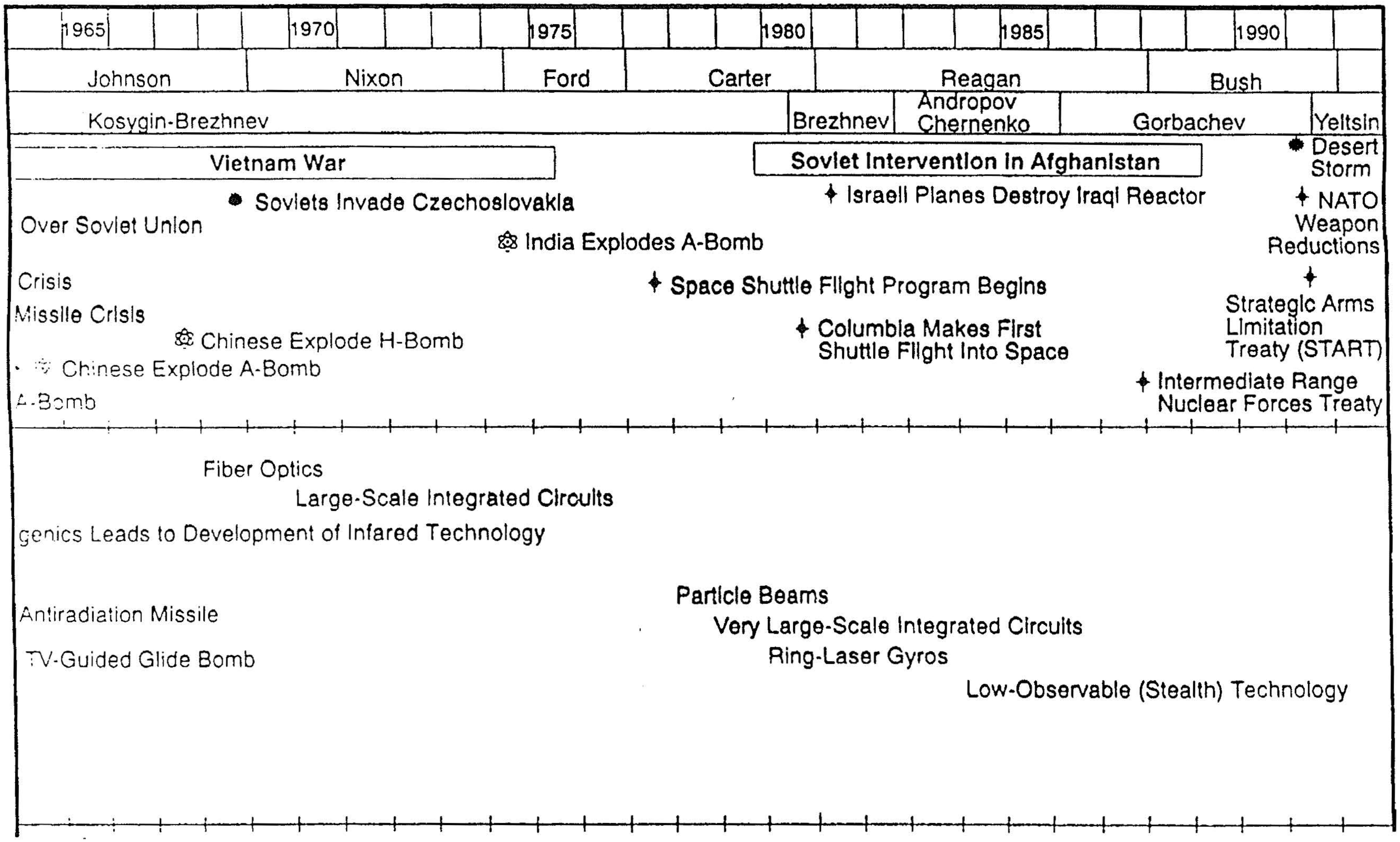
SIGNIFICANT HISTORICAL EVENTS RELATIVE TO NUCLEAR WEAPONS



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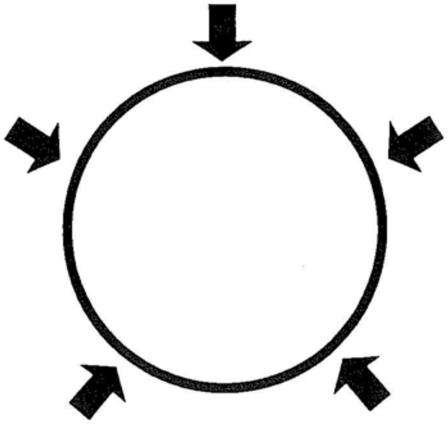
Strategy, Arms Control, and Weapon Systems Technology Drive Stockpile Requirements

Strategy	Threat	Tech.	Size/Wt.	Yield	Arms Control	Number
1950 Massive retaliation	Global	A/C & missiles inaccurate	Large	Very high	Very limited talks	Growing
1960 Flexible response	Global Theater	A/C & missiles improve	Decrease	Decrease	Limited talks	Growing
1970 Flexible response	Global Theater	A/C & missiles improve accuracy	Decrease even more	Tactical needed lower yields	SALT ABM limitations	Decline
1980 Flexible response	Global Theater	A/C & missiles very accurate	Large decrease	Continued decrease	Mutual elimination & reduce	Decline more
1990 Last resort	Theater Global	A/C & missiles very accurate	Remain small	Remain same	Large cuts mutual elimination/ unilateral	Large reduction

SELECTED HARDWARE ORIENTATION

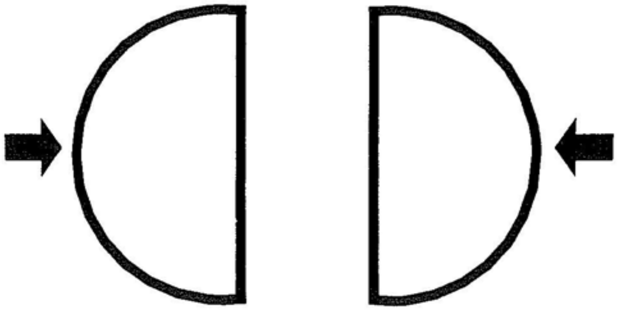
Fission Primaries

IMPLOSION



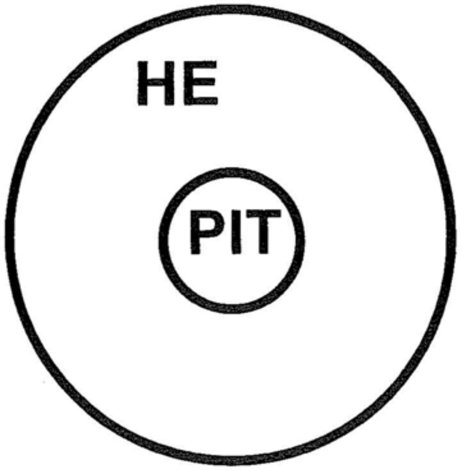
Critical Mass Achieved
with Compression from HE

GUN TYPE

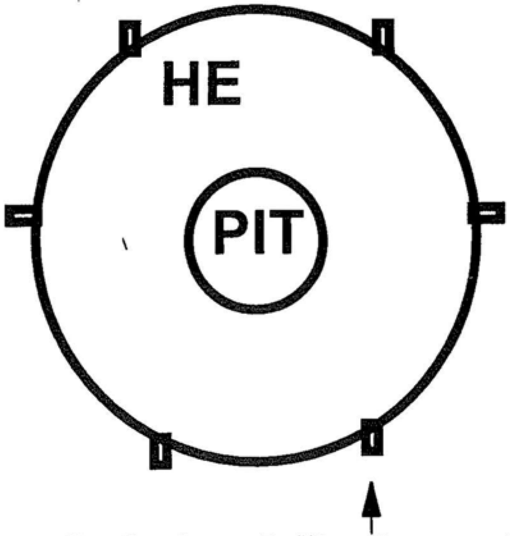


Critical Mass Achieved with
"Lots of Special Nuclear Material"

Fission Primary

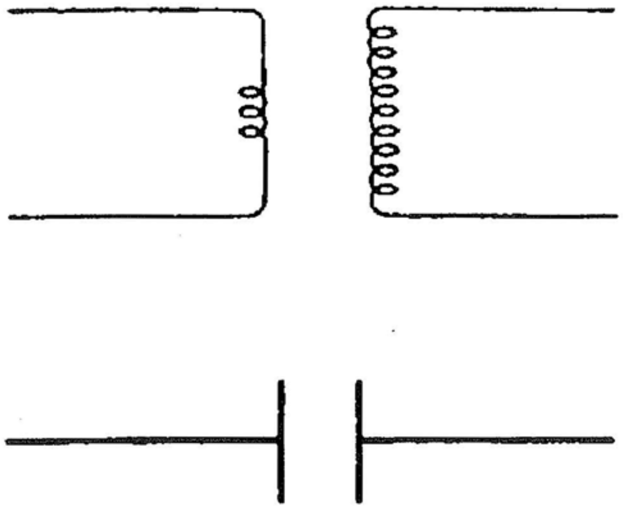


Detonators Required to Fire the HE

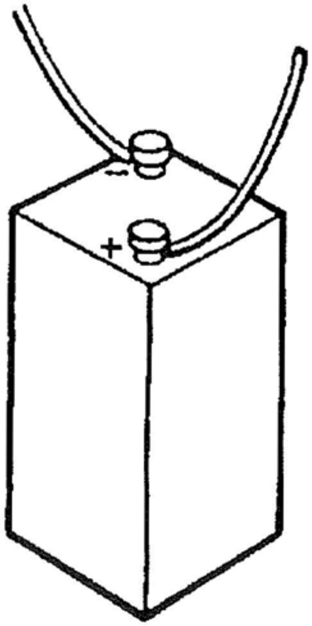


Original Detonators Large

Basic Electronics Needed to Fire the Detonations

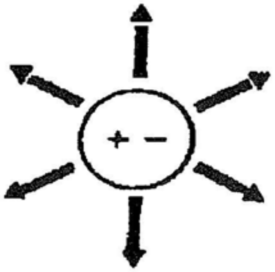


FIRE SET
Evolved from Large to Compact

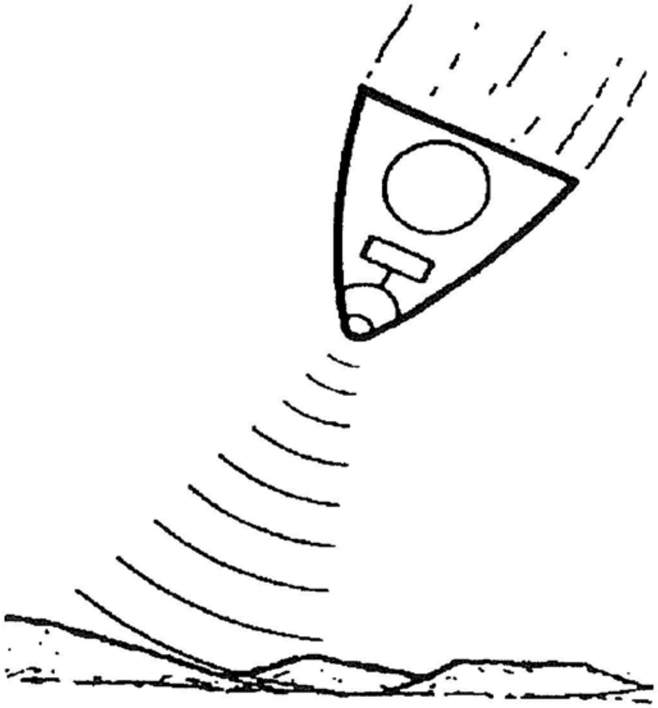


POWER SOURCES
Originally Lead Acid (car battery style)
Evolved to Thermal Batteries

Additional Elements Required for Detonation



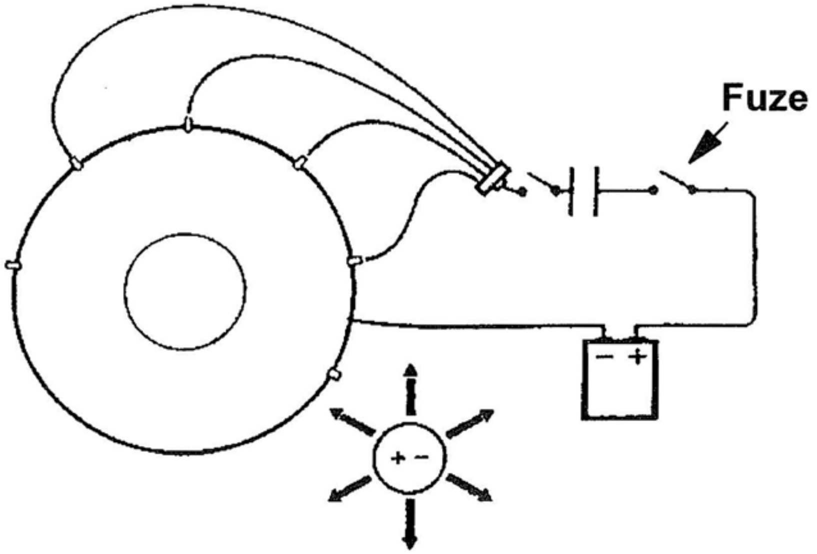
Neutron Source



Fuzes

- Height of Burst
- Impact

Basic Elements of a Nuclear Weapon



GAS BOOSTING

- INITIAL FISSION RAISES BOOST GAS TO FUSION TEMPERATURES

- D • T REACTIONS RELEASE A FLOOD OF HIGH ENERGY NEUTRONS FOR FISSIONING OF Oy AND/OR Pu

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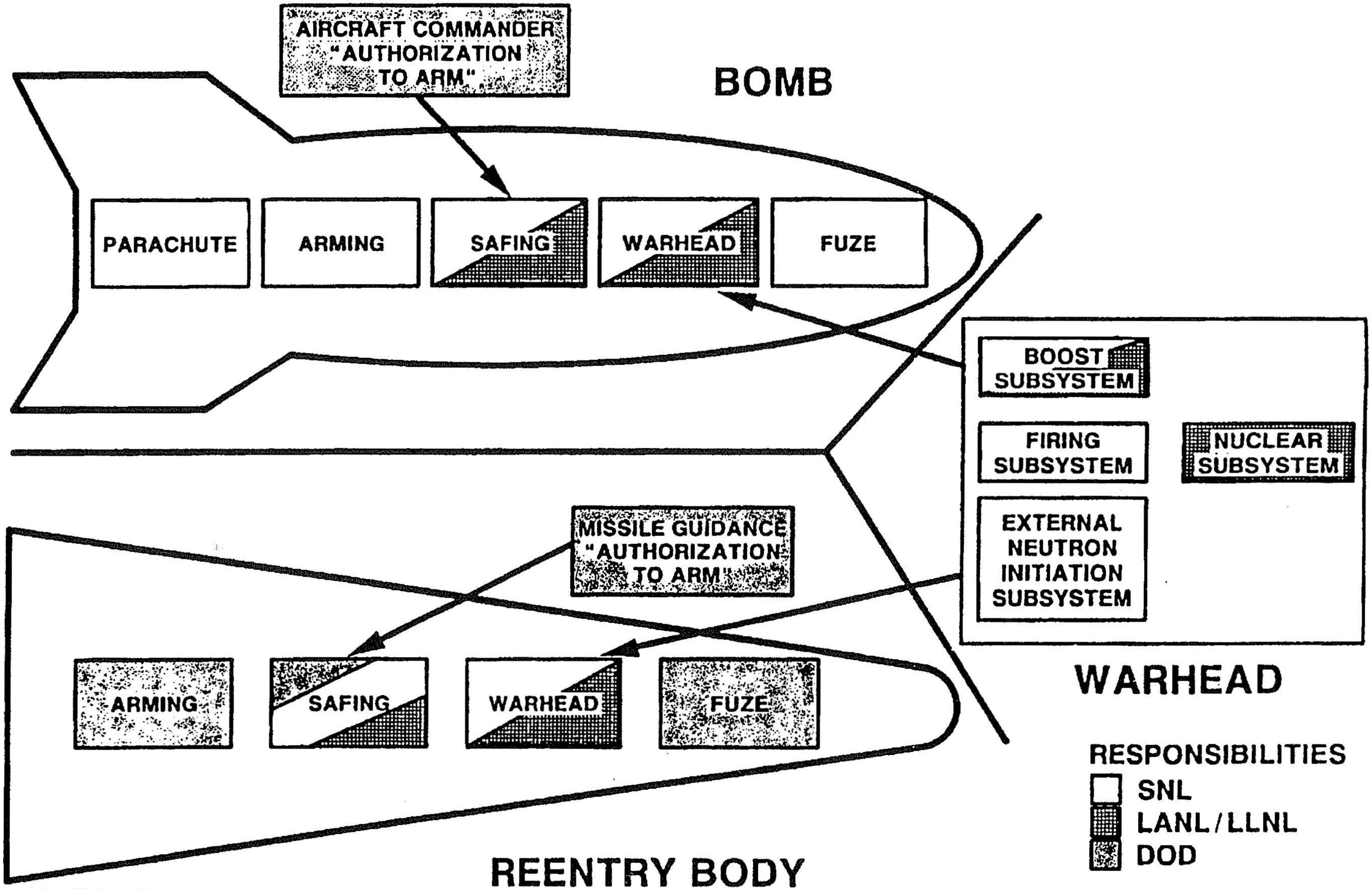
DIVISION OF RESPONSIBILITIES



AIRCRAFT COMMANDER "AUTHORIZATION TO ARM"

BOMB

PARACHUTE

ARMING

SAFING

WARHEAD

FUZE

BOOST SUBSYSTEM

FIRING SUBSYSTEM

NUCLEAR SUBSYSTEM

EXTERNAL NEUTRON INITIATION SUBSYSTEM

MISSILE GUIDANCE "AUTHORIZATION TO ARM"

ARMING

SAFING

WARHEAD

FUZE

WARHEAD

REENTRY BODY

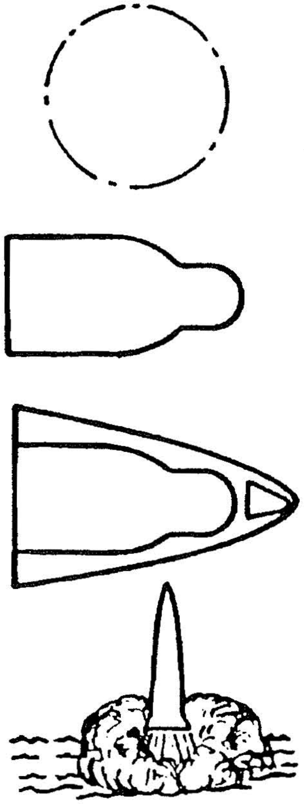
RESPONSIBILITIES

☐ SNL
▨ LANL / LLNL
▩ DOD

89B5000.58

TERMINOLOGY

NUCLEAR PACKAGE PHYSICS PACKAGE	PRIMARY/SECONDARY (Includes High Explosive)
NUCLEAR WARHEAD	NUCLEAR PACKAGE & WEAPON ELECTRICAL SYSTEM & PLUMBING
NUCLEAR WEAPON	NUCLEAR WARHEAD & ARMING & FUZING & AERODYNAMIC CASE, ALSO REENTRY VEHICLE
NUCLEAR WEAPON SYSTEM	NUCLEAR WEAPON & DoD DELIVERY SYSTEM



- THE TERM <u>NUCLEAR DEVICE</u> USUALLY IMPLIES A TEST WARHEAD BUT IS SOMETIMES USED IN A PLACE OF EITHER NUCLEAR PACKAGE OR WARHEAD

- THE ARMY USED THE TERM NUCLEAR WARHEAD SECTION TO INCLUDE WARHEAD + AK + BALLISTIC BASE

WEAPON PROGRAM OBLIGATIONS

STOCKPILE MANAGEMENT:

MAINTENANCE OF THE NATIONAL STOCKPILE OF NUCLEAR WEAPONS IN A SAFE, SECURE, RELIABLE, READY CONDITION

WEAPONIZATION:

DEVELOP AND PRODUCE NUCLEAR WEAPONS FOR STOCKPILE AS JOINTLY AGREED TO BY DOD & DOE AND AS AUTHORIZED BY THE PRESIDENT

WEAPON TECHNOLOGY:

PURSUE TECHNOLOGY IN THE SCIENCE & ENGINEERING OF NUCLEAR WEAPONS SO THAT OUR UNDERSTANDING & ABILITY TO DEVELOP IS SECOND TO NONE

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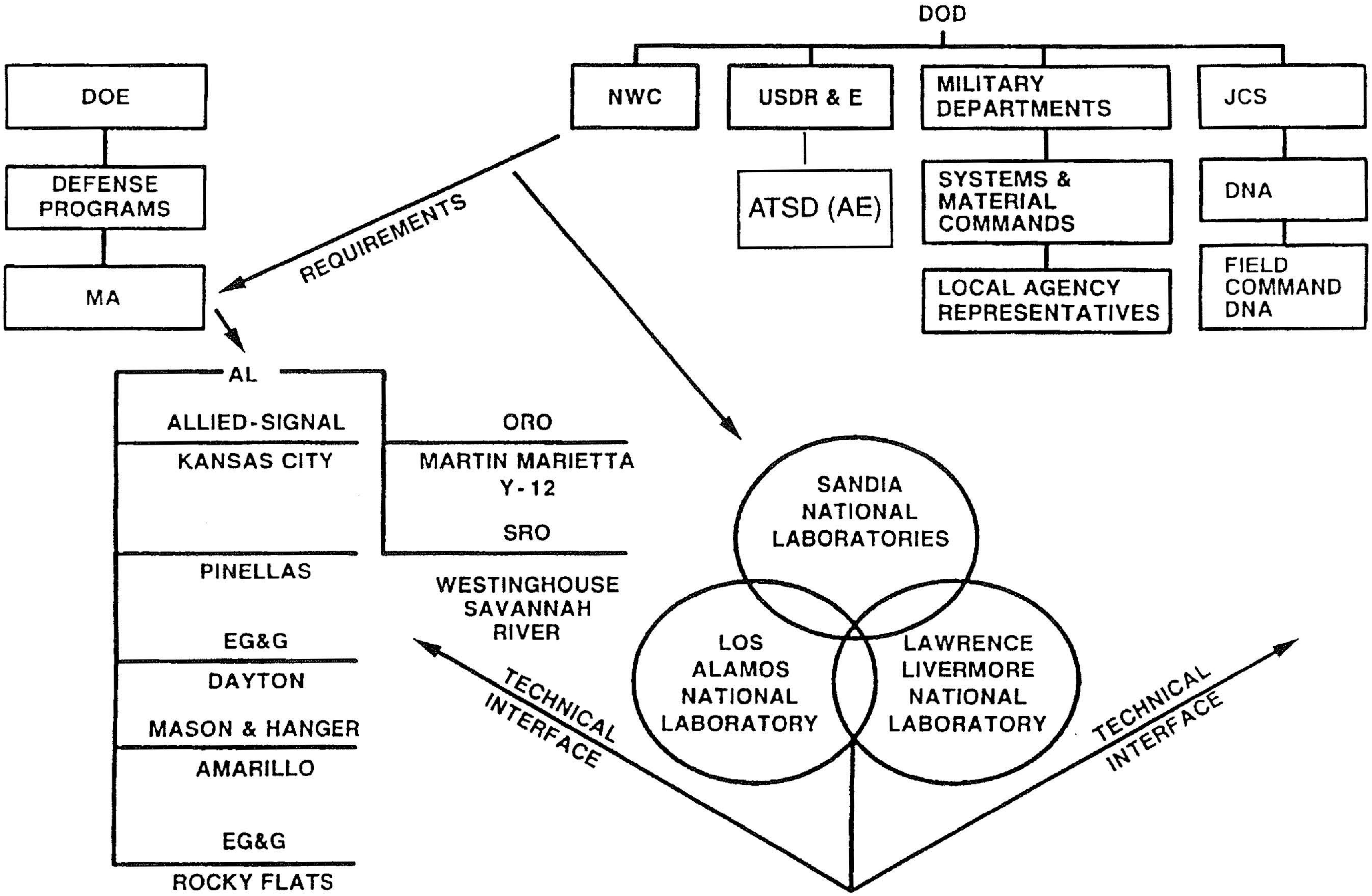
As the nuclear weapons systems integrator for the DOE, Sandia has responsibility for:

- Fire set development--neutron generator, batteries, capacitors, etc.
- Electrical & mechanical interface compatibility
- Electrical detonation safety
- Use control & use control equipment
- Handling and aneillary equipment
- Stockpile surveillance (reliability)--testing & evaluation
- Military training & manuals
- Field support
- Weapon systems (including DoD hardware) independent evaluations
- DOE & DoD security facility upgrade
- Safe secure trailers (total life cycle) & DOE courier training
- Neutron generator production

SANDIA-DOE / DOD INTERFACES

WEAPON PROGRAM



DOD

NWC

USDR & E

ATSD (AE)

MILITARY DEPARTMENTS

SYSTEMS & MATERIAL COMMANDS

LOCAL AGENCY REPRESENTATIVES

JCS

DNA

FIELD COMMAND DNA

DOE

DEFENSE PROGRAMS

MA

REQUIREMENTS

AL

ALLIED-SIGNAL

KANSAS CITY

PINELLAS

EG&G

DAYTON

MASON & HANGER

AMARILLO

EG&G

ROCKY FLATS

ORO

MARTIN MARIETTA

Y-12

SRO

WESTINGHOUSE SAVANNAH RIVER

SANDIA NATIONAL LABORATORIES

LOS ALAMOS NATIONAL LABORATORY

LAWRENCE LIVERMORE NATIONAL LABORATORY

TECHNICAL INTERFACE

TECHNICAL INTERFACE

Rocky Flats
Golden, Colorado
-Historical Context-

Contractor:	EG&G
Principal Missions:	Fabrication of beryllium, plutonium on uranium alloy; Plutonium recovery and research; Fabrication of pressure vessels

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Kansas City Plant
Kansas City, Missouri

Contractor: Allied-Signal

Principal Missions: Fabrication and assembly of electrical, electronic, electro-mechanical, precision mechanical, rubber and plastic components;
Heavy machining

Y-12 Plant
Oak Ridge, Tennessee

Contractor: Martin Marietta

Principal Missions:
- Fabrication of test and stockpile secondary assemblies;
- Fabrication and research in uranium;
- Machining

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Pinellas Plant
St. Petersburg, Florida

Contractor:	Martin Marietta speciality components, inc.
Principal Missions:	Neutron generators, thermal batteries, Radioisotopic Thermoelectric Generator (RTGs), lightning arrestor connectors, capacitors, neutron detectors

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Savannah River Plant
Aiken, South Carolina

Contractor: Westinghouse

Principal Missions: Production of tritium and plutonium;
Fill reservoirs with tritium

Pantex Plant
Amarillo, Texas

Contractor: Mason and Hanger

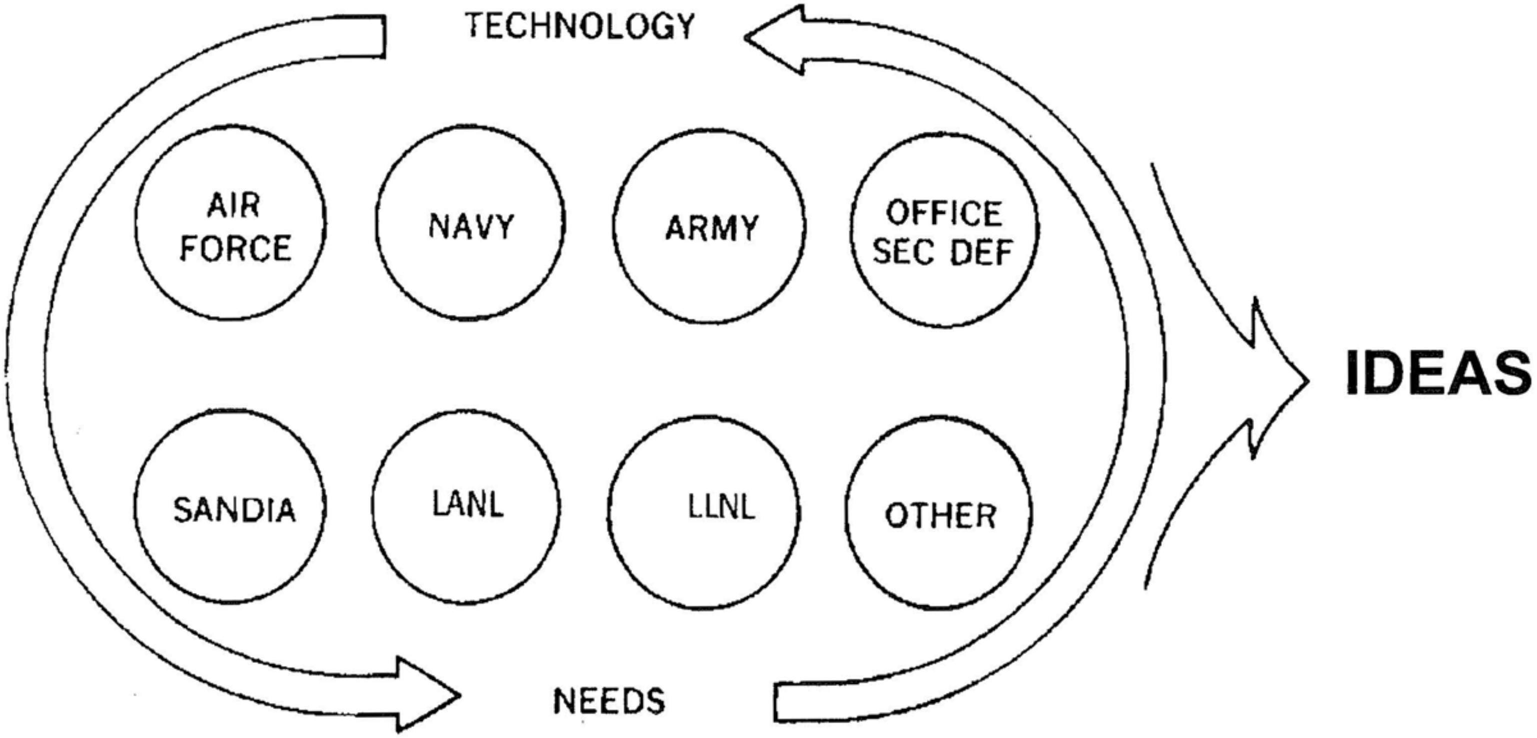
Principal Missions: Fabricate high explosive system;
Final assembly, disassembly and retirement of weapons

Historical Pressure on Nuclear Designs

	PEACETIME EMPHASIS	WARTIME EMPHASIS
IMPROVE	SAFETY SECURITY CONTROL	SURVIVABILITY DELIVERABILITY EFFECTIVENESS FLEXIBILITY BATTLE MANAGEMENT
REDUCE	MAINTENANCE MOVEMENT TRAINING	REACTION TIME OPERATIONAL CONSTRAINTS COLLATERAL DAMAGE

PHASE 1 CONCEPT FORMULATION

(φ1)



Phase 1 - Weapon Conception

DOE

Continuing studies by DOE agencies. Studies may be informal and independent from DoD or may be conducted jointly with DoD. May result in the focusing of sufficient DoD interest in a modification of a present weapon or in the development of a new type weapon to warrant formal study.

DoD

Continuing studies by DoD agencies. May be independent of the DOE or may be conducted jointly with DOE. Sufficient attention may become focused on an item to warrant a formal program study. DoD requests DOE to make a program study on a new idea for a weapon or component or may initiate its own study.

PHASE 2 FEASIBILITY

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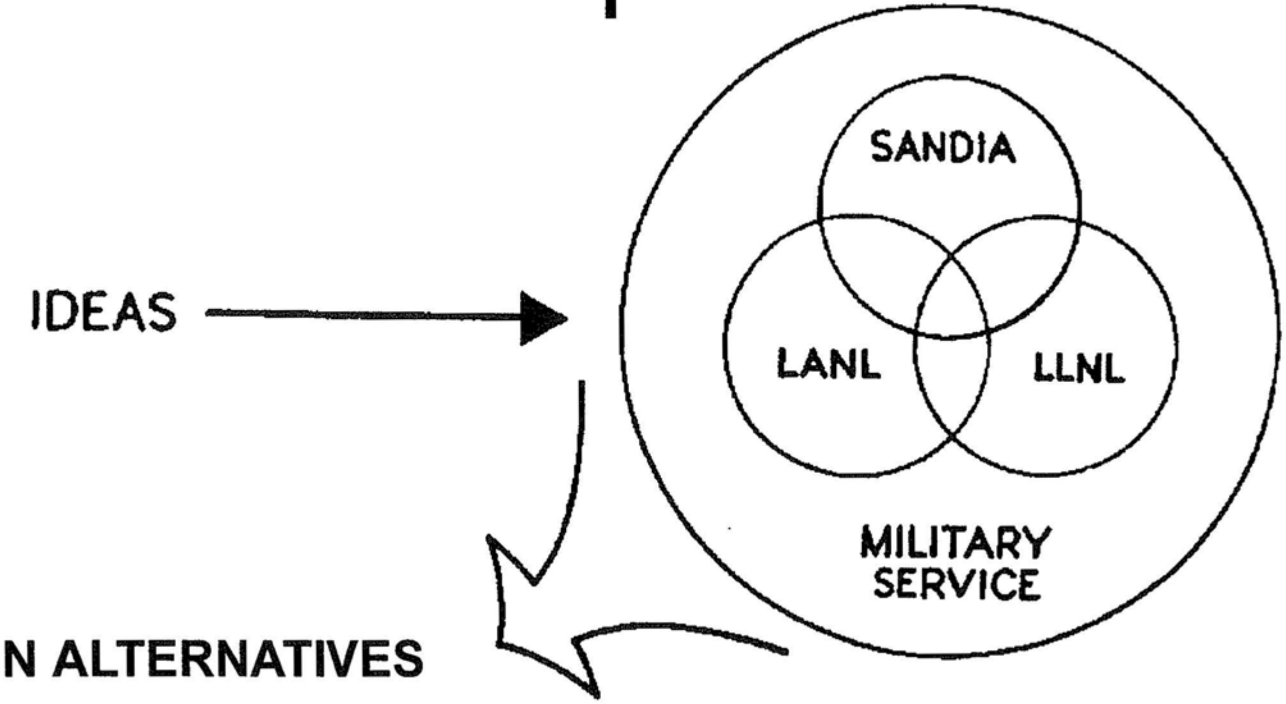

DESIGN ALTERNATIVES
MAJOR IMPACT
REPORT

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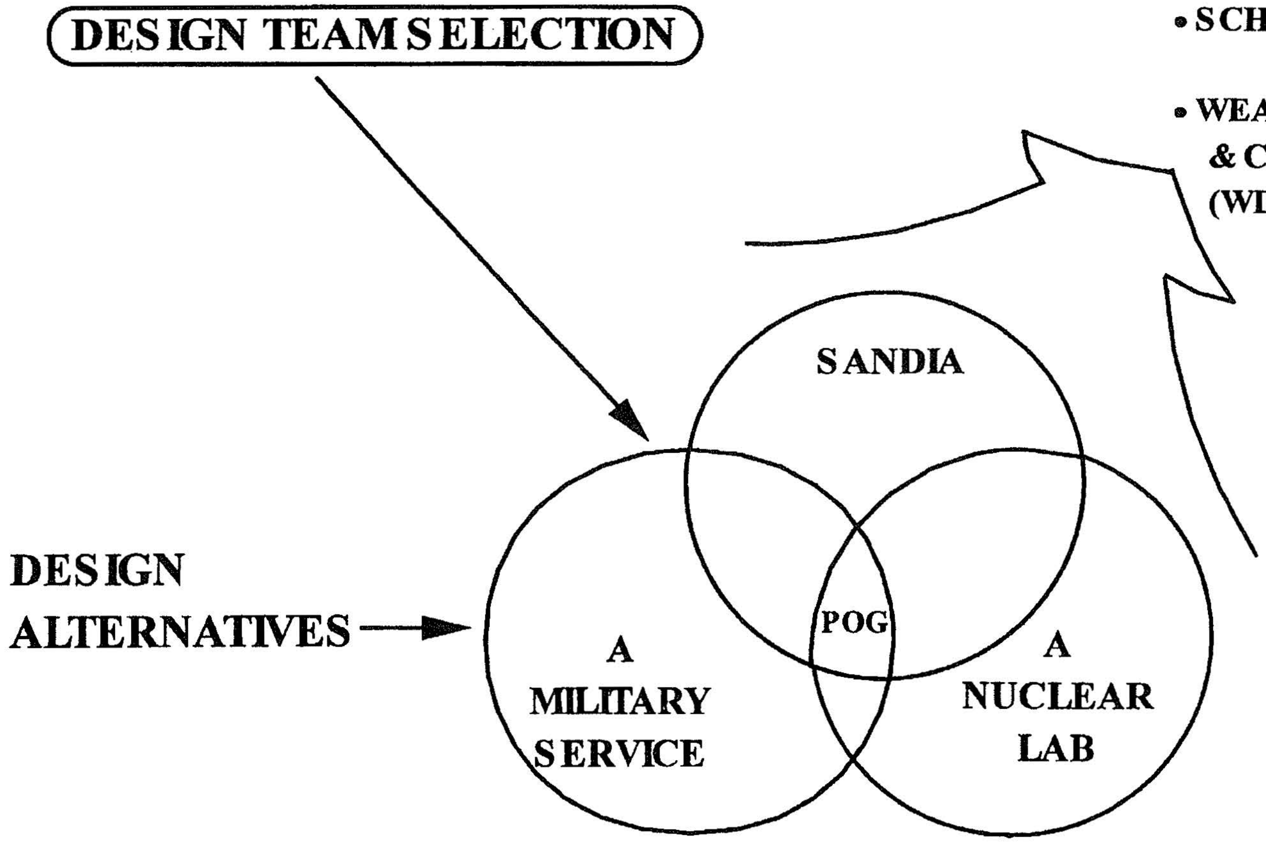
Phase 2A VALIDATION (Φ2A)

- SELECT BASELINE DESIGN & LAB
- SCHEDULE
- WEAPON DESIGN & COST REPORT (WDCR)



DESIGN TEAM SELECTION

DESIGN ALTERNATIVES

SANDIA

POG

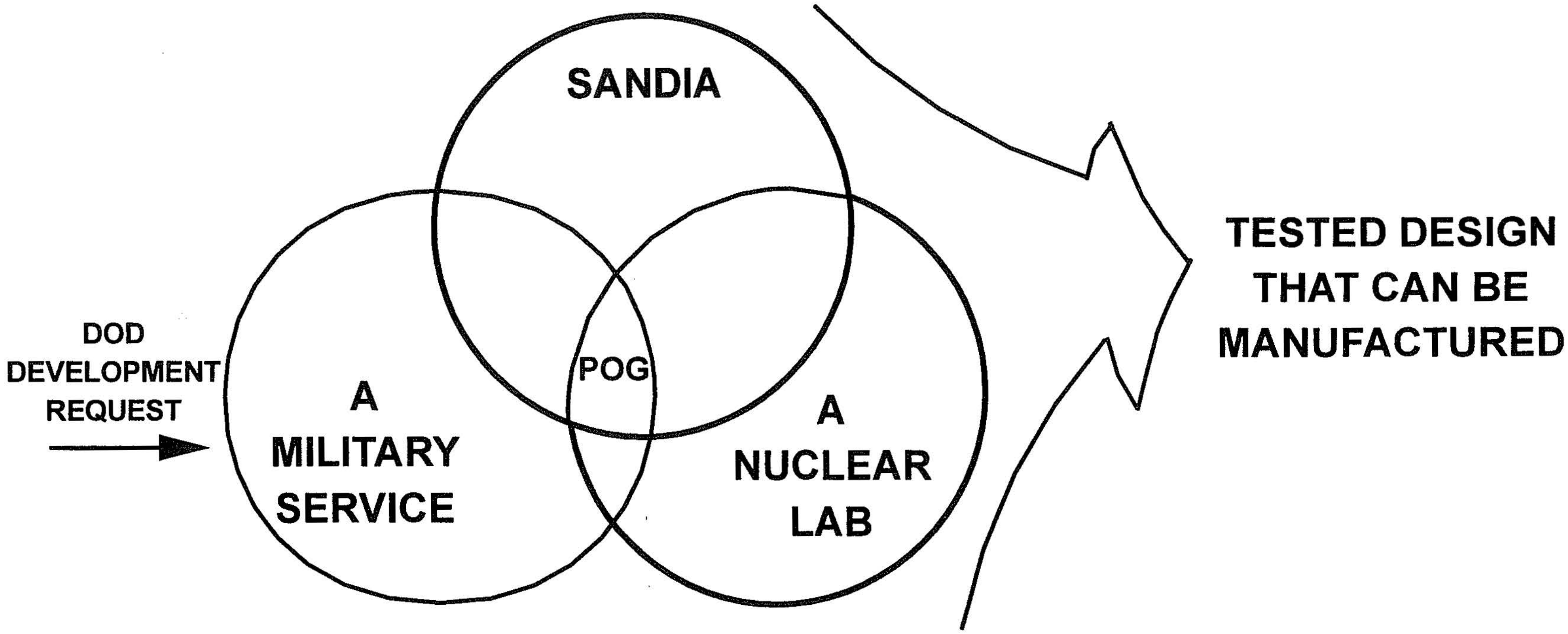
A MILITARY SERVICE

A NUCLEAR LAB

Phase 2A - Design Definition and Cost Studies

A DOE design team will normally be selected and a Project Officer Group will be formed. The POG will conduct trade-off studies to identify baseline design(s) which best balances resources and requirements. Review and revise draft MCs and STs. Establish tentative development and production schedule and division of responsibilities. A Weapon Design and Cost Report will be prepared.

Phase 3 ENGINEERING DEVELOPMENT (φ3)



DOD DEVELOPMENT REQUEST

SANDIA

A MILITARY SERVICE

POG

A NUCLEAR LAB

TESTED DESIGN THAT CAN BE MANUFACTURED

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Phase 3 - Development Engineering

DOE

Launches a development program based on required military characteristics. Produces prototypes for DOE and DoD evaluation.

Provides development specifications to DoD as they become available.

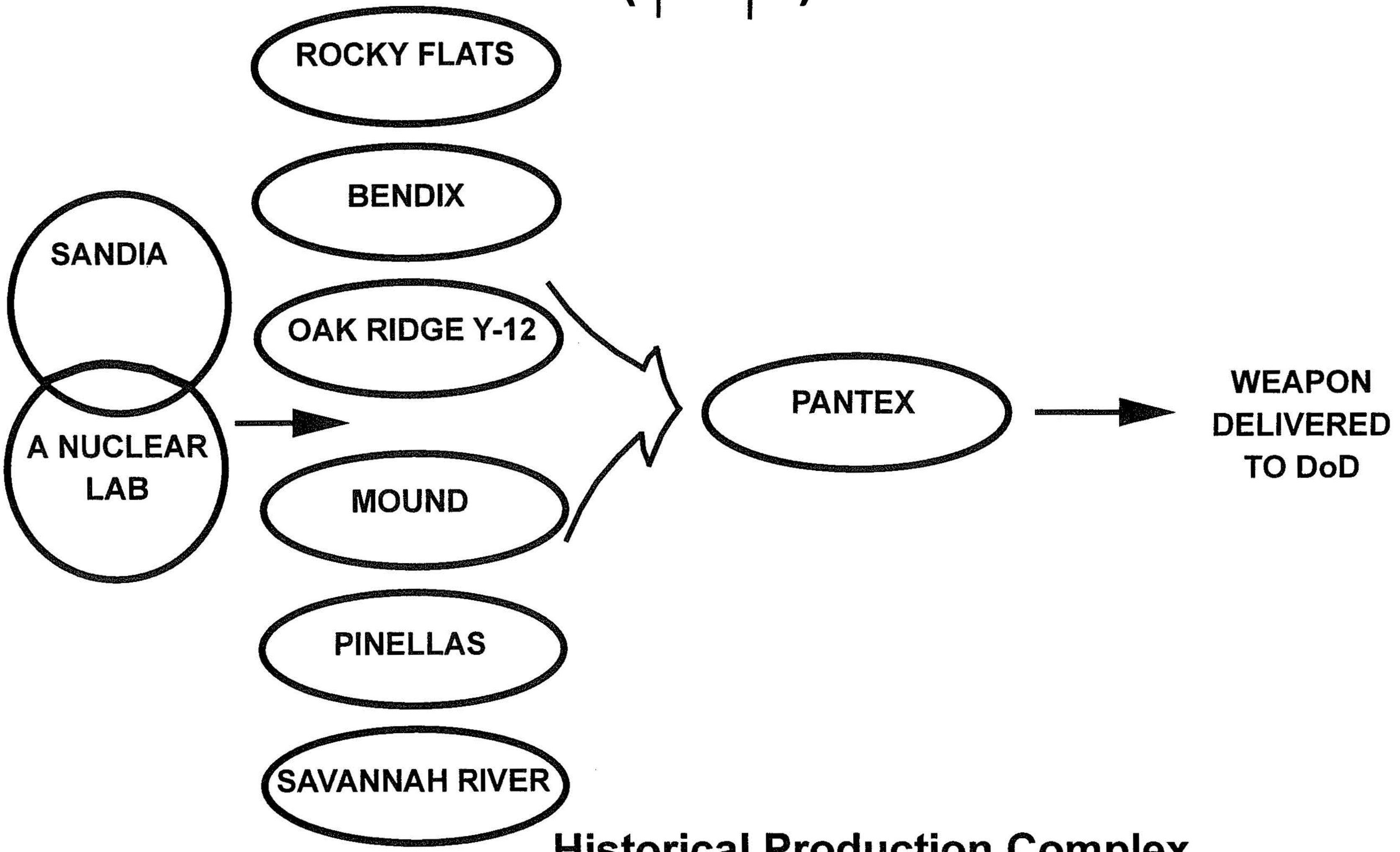
Determines the developmental design release date and submits a final report on the development design to the DoD.

DoD

Maintains liaison with DOE field agencies and conducts independent evaluation of prototypes as considered necessary.

Studies the development specifications of the weapon design and gives appropriate guidance to the DOE.

Phase 4-6 PRODUCTION
(φ4-φ6)



- Historical Production Complex
- Reconfiguration Will Impact

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Phase 4 - Production Engineering

DOE

Proceeds with production engineering of weapon, tooling, and layout of manufacturing facilities, without waiting for formal comments of DoD on the developmental design. Such guidance is integrated when received. Further prototype evaluation is performed during this phase.

Prepares product specifications for production release and furnishes these specifications to the DoD for review.

DoD

Reviews product specification.

Maintains liaison with appropriate DOE agencies on product design changes and specifications and gives appropriate guidance to DOE.

Continues evaluation of prototypes as considered necessary.

Phase 5 - First Production

DOE

Initiates manufacture of weapons according to product specifications by production tools, without waiting for DoD's comments on product specifications. DOE performs own evaluation and on basis of preliminary evaluation releases weapons to DoD for testing, training, and other purposes. Makes final evaluation and approves weapon model as suitable for standardization.

DoD

Completes operational suitability tests and makes independent evaluation of production type weapons. If weapon as designed, produced, and approved by DOE is satisfactory, approves the weapon as standard.

Phase 6 - Quantity Production and Stockpile

DOE

Brings various production facilities up to full production pursuant to DoD requirements. Maintains production, inspection and quality control programs to ensure that each article produced meets specifications.

Maintains quality assurance and functional surveillance programs to ensure the continued quality of weapons in stockpile, in accordance with current agreements with respect to stockpile operations. These programs and the data obtained thereof will be made available to the DoD.

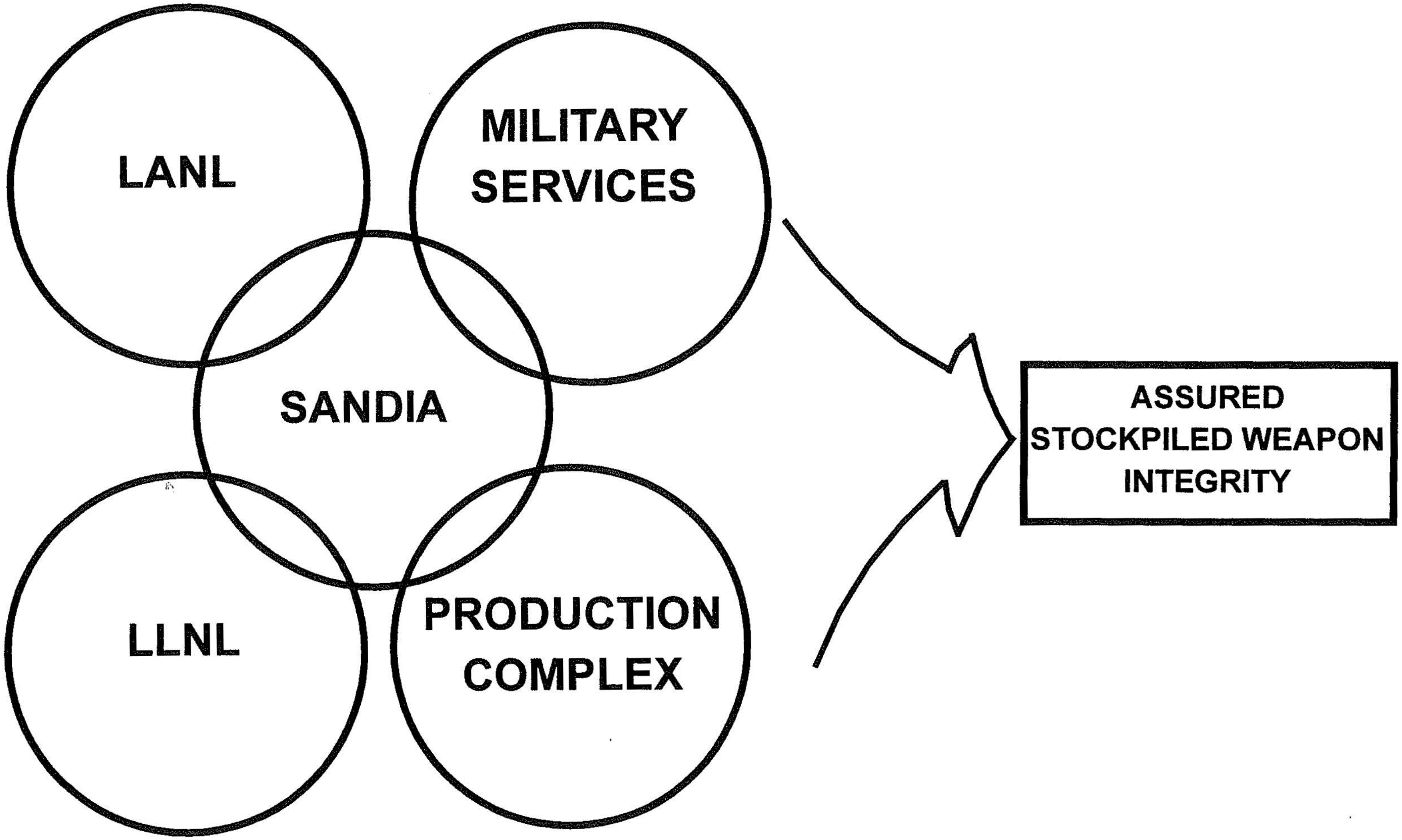
DoD

Maintains liaison with DOE agencies at production facilities. Continues appraisal of weapon performance.

Maintains liaison with DOE to review performance and technical advances in anticipation of modernization changes.

Reviews DOEs quality assurance and functional surveillance programs and results and submits appropriate comments and recommendations to the DOE. Maintains functional surveillance program in accordance with current agreements with respect to stockpile operations.

Phase 6 STOCKPILE SURVEILLANCE
(φ6)



LANL

MILITARY SERVICES

SANDIA

LLNL

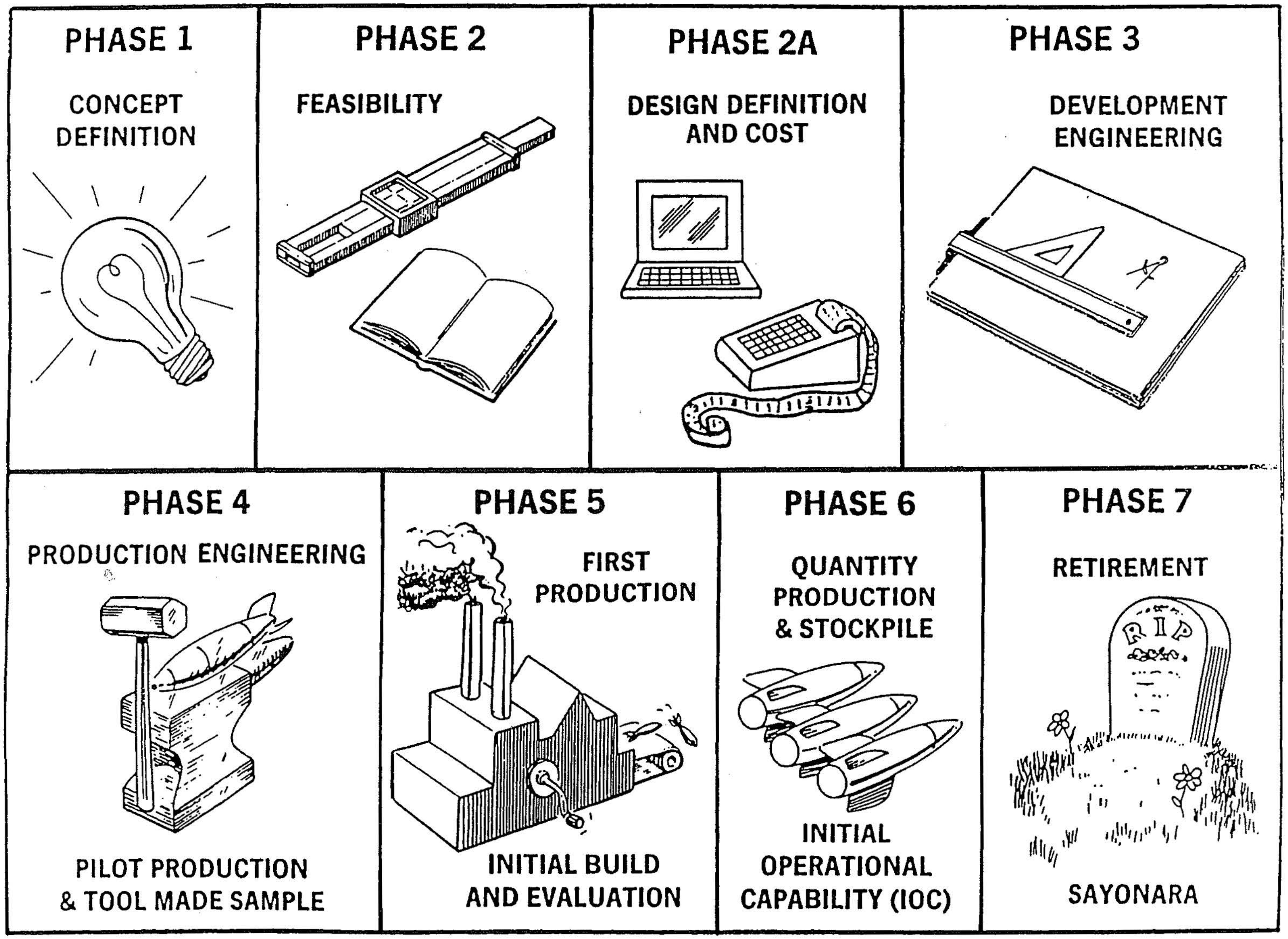
PRODUCTION COMPLEX

ASSURED STOCKPILED WEAPON INTEGRITY

Nuclear Weapon Life Cycle

(The following pages are for reference. Not all of the material will be presented during the briefing)

WEAPON DEVELOPMENT



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Phase 1 -- Concept Definition

Initiation:	Informal agreement between participants to undertake study
Purpose:	Study a Service requirement or DOE technological breakthrough/innovation for weapon application
Organization:	Joint DoD/DOE Study Group with appropriate working groups. (Note: it can be a DOE or DoD-only study group.) Working Groups: Surety, Requirements Analysis, Mission Analysis,
Warhead	Design, and Systems Engineering
Deliverables:	Phase 1 Study Report [In some cases: Draft Military Characteristics (MCs) & Draft Stockpile-to-Target Sequence (STS)]

Phase 1 Activities

Military Characteristics

Warhead performance requirements

Warhead physical characteristics

Requirements for nuclear safety

Phase 1 Activities

Stockpile-to-Target Sequence

Logistical employment concepts

Operational employment concepts

Normal & abnormal environments applicable to MC safety requirements

Phase 1 -- Concept Definition

Initiation: Informal agreement between participants to undertake study

Purpose: Study a service requirement or DOE technological breakthrough/innovation for weapon application.

Organization: Joint DoD/DOE Study Group with appropriate working groups. (Note: it can be a DOE or DoD-only study group.) Working Groups: surety, requirements analysis, mission analysis, warhead design, and systems engineering

Deliverables: Phase 1 study report [In some cases: Draft Military Characteristics (MCs) & Draft Stockpile-to-Target Sequence (STS)]

Duration & Cost: Normally 1 year and low cost

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Phase 2 -- Weapon Feasibility

Initiation: Formal request from DoD [ATSD (AE)] to DOE to participate with DoD in study.

Purpose: Develop various weapon alternatives to fulfill service requirements.

Organization: Joint DoD/DOE Study Group with appropriate working groups. [Sometimes a Project Office Group, (POG) is formed.] Working Groups: Surety, requirements analysis, mission analysis, warhead design, and systems engineering.

Deliverables:
Phase 2 study report with warhead alternatives
Draft Military Characteristics (MCs)
Draft Stockpile-to-Target Sequence (STS)
Nuclear Safety & Use Control Themes
Major Impact Report (MIR)
Decision Cost Estimates

Duration & Cost: Normally 2 years and low cost.

Parallel DoD Activities: Milestone 1 Concept Demonstration Approval precedes Phase 2.

Phase 2A -- Design Definition & Cost

Initiation:	Normal included as part of Phase 2 authorization. If not, then formal ATSD (AE) request to DOE is required
Purpose:	Develop a definitive cost estimate of the selected warhead design
Organization:	Formal Project Officers Group with appropriate subgroups. Subgroups: Safety & Surety, Maintenance & Logistics, Command & Control, Military Characteristics, Interface, and Stockpile-to-Target Sequence, among many
Deliverables:	Phase 2A Study Report Final Military Characteristics (MCs) Final Stockpile-to-Target Sequence (STS). DoD/DOE Memorandum of Understanding
Duration & Cost:	Normally 6 months and low cost

Phase 3 -- Development Engineering

Initiation:	ATSD (AE) formally passes MCs, STS, and MOU to DOE/DP requesting their acceptance and requesting DOE participation in Phase 3 activities
Purpose:	Develop a finalized and tested weapon design that meets MC and STS criteria, and that can be produced by the DOE production complex
Organization:	Formal Project Officers Group with appropriate subgroups. Subgroups: Safety & Surety, Maintenance & Logistics, Command & Control, Military Characteristics, Interface, and Stockpile-to-Target Sequence, among many
Deliverables:	Phase 3 Study Report Final tested weapon design to include all required H & T gear.
Duration & Cost:	Normally 2.5 - 3 years and high cost
Other Activities:	DRAAG begins its activities, reviews PWDR. JNWPS manual begun

Phase 4 -- Production Engineering

Purpose:	DOE production complex determines how it will produce the warhead. DOE production complex tools up necessary production lines
Duration & Cost:	Normally 2.5 years and high cost
Other Activities:	All weapons manual produced First generation training of military initiated DRAAG continues its activities, reviews IWDR

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Phase 4 Activities

DOE Production Complex

Allied Signal, Kansas City Division

Location: Kansas City Missouri

DOE Contractor: Allied Signal Corporation

Product:

- Non-nuclear electrical, electronic, electromechanical, mechanical, plastic, and nonfissionable metal components
- Pinellas - Neutron detectors, LACs, among others
- Rocky Flats - Reservoirs and SST construction
- Mound - Flat & round cables and ACORNS

Phase 4 Activities

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Phase 4 Activities

DOE Production Complex

Savannah River Plant

- **Location:** Aiken, South Carolina
- **DOE Contractor:** Westinghouse Corporation
- **Product:**
  - Tritium, special isotopes, targets, and naval reactor fuel material
  - Fill boost reservoirs and ship them to the military
  - Mound - Gas transfer systems

Phase 4 Activities

DOE Production Complex

Sandia National Laboratories

- **Location:** Albuquerque, New Mexico
- **DOE Contractor:** Lockheed-Martin Corporation
- **Product:**
  - Pinellas - Thermal batteries, neutron generators, CAP assemblies, capacitors, and frequency devices/clocks

Phase 4 Activities

DOE Production Complex

Los Alamos National Laboratory

- **Location:** Los Alamos, New Mexico
- **DOE Contractor:** University of California
- **Product:**
  - Pinellas - Neutron tube target loading
  - Rocky Flats - Beryllium technology and pit support functions
  - Mound - High power detonators and calorimeters

Phase 4 Activities

DOE Production Complex

Pantex Plant

- Location: Amarillo, Texas
- DOE Contractor: Mason & Hanger
- Product:
  - Explosive components
  - Assemble all nuclear weapons
  - Disassemble all weapons

Phase 4 -- Production Engineering

Purpose:	**DOE Production Complex determines how it will produce the warhead. DOE Production Complex tools up necessary production lines**
Duration & Cost:	**Normally 2.5 years and high cost**
Other Activities:	**All weapons manuals produced First generation training of military initiated DRAAG continues its activities, reviews IWDR**

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Phase 5 -- First Production

Purpose:	**Produce initial products for new material evaluation testing. Refine production lines as a result of new material testing. Increase production rate to that required in Phase 6**
Duration & Cost:	**Normally 6 months and low cost**
Other Activities:	**DRAAG completes its activities. Nuclear certification of receiving service units**

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Nuclear Weapons Safety Study Group (NWSSG)

Chaired by Representative Service

Membership includes DOE, Defense Nuclear Agency, and representatives from Service Operational and Developmental Commands

Performs Safety Studies

- Initial Safety Study - as early as possible in weapon development
- Pre-operational Safety Study - at least 120 days before IOC
- Operational Safety Review - within 2 yrs of fielding and every 5 yrs thereafter
- Special Safety Study - whenever system changes or problems require it

Phase 6 -- Quantity Production & Stockpile

Purpose:	Produce War Reserve (WR) warheads in quantities directed by the Nuclear Weapons Stockpile Memorandum (NWSM) to support military IOC
Other Activities:	Operational activities Logistics activities Nuclear accident/incident activities Technical inspections of nuclear-certified units Stockpile quality assurance and reliability testing Weapon modifications and retrofits Inactive stockpile

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Phase 6 Activities

Nuclear Weapon Operations

Nuclear weapon stockpile demonstrable element of nuclear deterrent strategy
- Ability to employ effectively
- Surety

Deployment
- Peacetime threat
- Wartime threat
- Peacetime storage
- Wartime storage

Employment
- Rigorously controlled process
- Presidential release to a unified commander
- Conveyance of presidential release to executing commander
- Execution of nuclear mission by delivery units

Phase 6 Activities

Nuclear Weapon Operations (cont.)

Command and Control

- Provides critical link and positive control by the President
- Designated communications systems
- Specific authentication procedures and codes

Training

- Ensure maximum unit and force readiness
- Exercises are still conducted

Personnel Reliability and Assurance Program

- Ensures highest possible standards of individual realiability
- DoD (PRP) DOE (PAP)

Phase 6 Activities

Logistics Activities

Transportation

Logistic movements (DOE and DoD)
Operational movements (DoD)
Safety and Security are important considerations

Storage

DOE DoD Security Areas

Maintenance

Normally accomplished by the custodial service
Accomplished at weapon storage area maintenance facilities or in maintenance trucks (USAFE)
LLCE--boost reservoirs, neutron generators, RTGs

Phase 6 Activities

Accident/Incident Activities

Nuclear Weapon Accident--unexpected event involving:

- Accidental or unauthorized launching, firing, or use by US forces or U.S. supported allied forces of a nuclear capable system
- An accidental, unauthorized, or unexplained nuclear detonation
- Non-nuclear detonation or burning of a nuclear weapon or nuclear component
- Radioactive contamination
- Jettisoning of a nuclear weapon or nuclear component
- Public hazard, actual or perceived

Nuclear Weapon Significant Incident--unexpected event involving:

- Evident damage to a nuclear weapon
- Immediate action for safety or security
- Adverse public reaction
- A situation that could lead to a nuclear weapon accident

Accident/Incident Response Preparation

- DoD (EOD) and DOE (ARG) personnel continuously trained
- EOD manual and ARG procedures kept updated
- Joint DoD/DOE Accident/Incident training exercises held

Phase 6 Activities

Technical Inspections

Performed by Service or Field Command, Defense Nuclear Agency teams

Conducted at least annually

Used to recertify nuclear capable units

Emphasis on safety as well as operational requirements

Phase 6 Activities

Stockpile Quality Assurance and Reliability Testing

Begun after the system has been in the field for a year

Consists of two types of testing:
- Stockpile Laboratory Testing (SLT)
- Stockpile Flight Testing (SFT)
- Used to include Stockpile Confidence Testing (SCT), but the UGT Moratorium has effectively canceled them

Each year test units chosen at random from the active stockpile

Test units disassembled at Pantex Plant
- Non-nuclear components tested via SLT and SFT
- One nuclear physics package testing non-nuclearly at physics lab

All but one test unit rebuilt and returned to the field

Each Service tests non-DOE system components

Phase 6 Activities

Weapon Modification and Retrofits

Can be done in the field or at Pantex Plant

Modifications and retrofits usually incorporate new technology to increase weapon safety and/or reliability

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Phase 6 Activities

Inactive Stockpile (IS)

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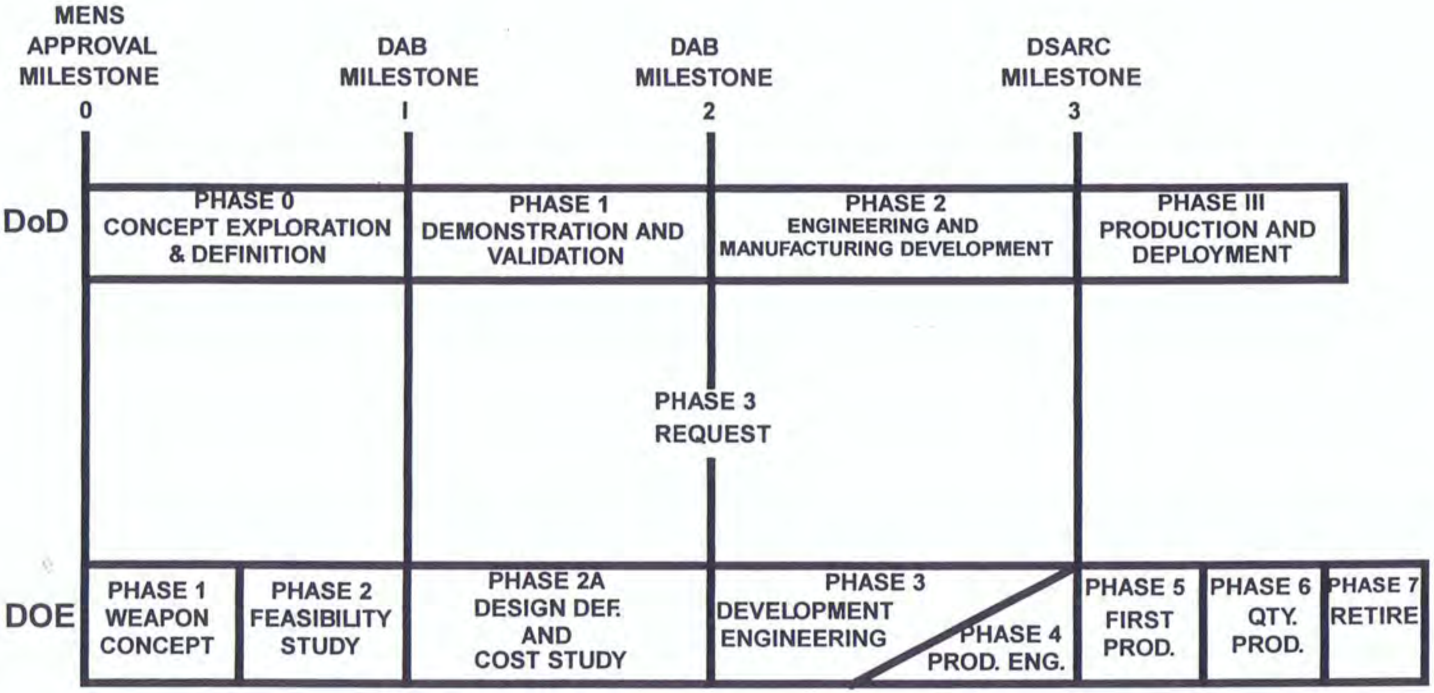
Components may be stored to upgrade IS weapons to the status of the same weapons in the active stockpile

Phase 7-- Retirement

Purpose:	**To identify warheads to leave the active stockpile and to be dismantled by the Doe Productive Complex**
Other Activities:	**Temporary storage of retired weapons by military is required as Pantex cannot accept all retired warheads** **Proper disposal of dismantlement waste stream** **Storage of nuclear components at Pantex due to inability to dispose of them** **Special nuclear material is reclaimed and retained**

DOD and DOE Acquisition



MENS APPROVAL MILESTONE 0

DAB MILESTONE I

DAB MILESTONE 2

DSARC MILESTONE 3

DoD

- PHASE 0 CONCEPT EXPLORATION & DEFINITION
- PHASE 1 DEMONSTRATION AND VALIDATION
- PHASE 2 ENGINEERING AND MANUFACTURING DEVELOPMENT
- PHASE III PRODUCTION AND DEPLOYMENT

PHASE 3 REQUEST

DOE

- PHASE 1 WEAPON CONCEPT
- PHASE 2 FEASIBILITY STUDY
- PHASE 2A DESIGN DEF. AND COST STUDY
- PHASE 3 DEVELOPMENT ENGINEERING
- PHASE 4 PROD. ENG.
- PHASE 5 FIRST PROD.
- PHASE 6 QTY. PROD.
- PHASE 7 RETIRE

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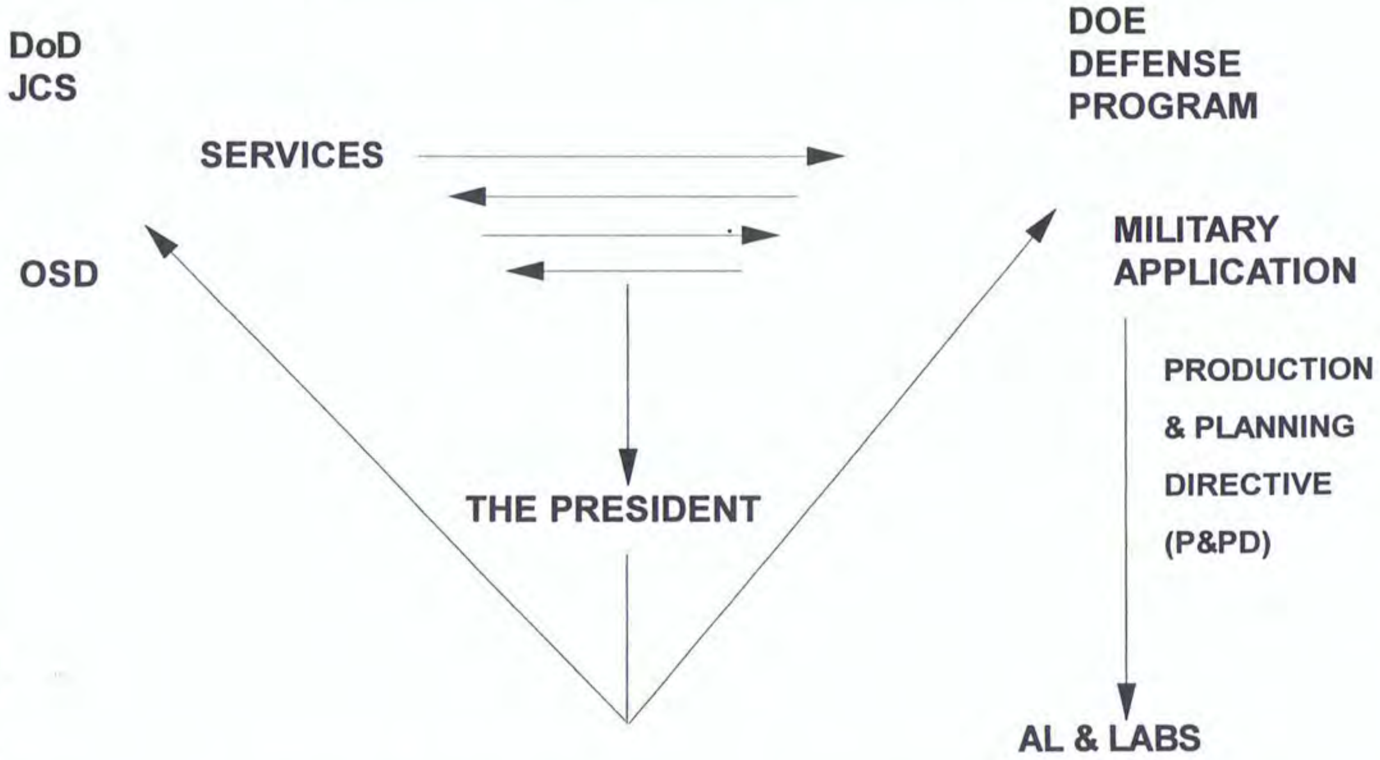
ANNUAL STOCKPILE PAPER



DoD
JCS

SERVICES

OSD

DOE
DEFENSE
PROGRAM

MILITARY
APPLICATION

PRODUCTION
& PLANNING
DIRECTIVE
(P&PD)

THE PRESIDENT

AL & LABS

LOOKS 11 YEARS AHEAD FOR PLANNING
AUTHORIZED 5 YEARS OF PRODUCTION
AND LONG LEAD PROCUREMENT
DoD & DOE MAY ADJUST UP TO 10%

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GLOSSARY

ABM	Anti Ballistic Missile
ACDA	Arms Control and Disarmament Agency
ADM	Atomic Demolition Munition
AEC	Atomic Energy Commission - then ERDA, now DOE
AF&F	Arming, Fuzing and Firing
AFAP	Artillery Fired Atomic Projectile
AFWL	Air Force Weapons Laboratory - now Phillips Laboratory
AK	Adaptation Kit
α	Alpha (Neutron Multiplication Rate)
ALCM	Air Launched Cruise Missile
AL	Albuquerque Operations Office
AMAC	Aircraft Monitor and Control
ASDP	Assistant Secretary (DOE) for Defense Programs
ATSD (AE)	Assistant to the Secretary of Defense for Atomic Energy
AWLPG	AL Workload Planning Guidance
Barn	Unit of cross section - 10^{-24} cm^2
Boosting	The use of deuterium/tritium to increase primary yield
Burnt Orange	The colors of a well-known outstanding university
CAT (A,B,C,D,E, or F) PAL	Permissive Action Link - code controlled open switch in the weapons arming circuit. Characteristics as defined in the "General Characteristics" of PAL definition
CD	Command Disable (locally initiated disablement of a nuclear weapon. Not, certficate of deposit, but can be command destruct

CDU	Capacitor Discharge Unit
CEP	Circular Error Probable; circle within which 50% of the weapons are expected to hit
Channel	The space around the secondary and between the primary and secondary but inside the radiation case
CHE	Conventional High Explosive (means non-IHE)
CINC	Commander-in-Chief
CNWDI	Critical Nuclear Weapon Design Information - a DoD category of Secret RD information or higher pertaining to sensitive weapon design information; not, Caught Naked While Driving Intoxicated
Critical Mass	The minimum amount of fissionable material capable of supporting a chain reaction under precisely specified conditions
CTB	Comprehensive Test Ban
DAB	Defense Acquisition Board
DASMA	Deputy Assistant Secretary for Military Applications
Depleted Uranium	Uranium which has had much of the isotope U^{235} removed; essentially U^{238}
Destruct	Normally refers to the intentional destruction of a weapon by the high order detonation of the weapons HE at a single point
Disablement	Usually nonviolent actions taken on weapon hardware to prevent normal use. Disablement and destruct normally differ in degree
DMA	Directory of Military Application - now DASMA
DNA	Defense Nuclear Agency
DoD	Department of Defense
DRAAG	Design Review and Acceptance Group
EBW	Exploding BridgeWire (Detonator)
EMP	Electromagnetic Pulse

EMR, EMI	Electromagnetic Radiation, Electromagnetic Interference
ENDS	Enhanced Nuclear Detonation Safety
Enhanced Electrical Safety	Embodiment of the exclusion region, strong-link, weak-link, unique signal concept (ENDS)
EOD	Explosive Ordnance Disposal
EP	Earth Penetrator
ER	Enhanced Radiation - usually neutron enhancement
ERDA	Energy Research Development Administration - was AEC, now DOE
ESD	Environmental Sensing Device
FEBA	Forward Edge of Battle Area - now FLOT
FLOT	Forward line of troops
FPU	First Production Unit
FRD	Formerly Restricted Data. Same as RD for foreign nationals
FRP	Fire Resistant Pit
Fuze	Component or subsystem that triggers the firing set. Use of fuse will likely bring abuse on you from old fuzing heads
FY	Fiscal Year
GLCM	Ground Launched Cruise Missile
HE	High Explosive
HOB	Height of Burst - vertical distance from the Earths surface to the point of burst
ICBM	Intercontinental Ballistic Missile
IFI	In-Flight-Insertion (mechanism)
IHE	Insensitive High Explosive - some form of TATB
INC	Insertable Nuclear Capsule
INF	Intermediate Range Nuclear Forces

Interstage Area	The space between the primary and secondary
Intrinsic Radiation	Naturally occurring neutron and gamma radiation present at the surface of a weapon
IOC	Initial Operational Capability
JAIEG	Joint Atomic Information Exchange Group
JCAE	Joint Committee Information Exchange Group
JCS	Joint Chiefs of Staff
JTA	Joint Test Assembly
kT	Kiloton equivalent of TNT hydrodynamic yield
LANL	Los Alamos National Laboratory
Lay-down	A form of weapon delivery and/or fuzing. Parachute delivered bomb from very low altitudes with delayed groudburst using a timer fuze
Limited Stockpile Item	A stockpiled weapon which has not been accepted as a "standard" item and for which the DoD has requested additional development
LLC	Limited Life Component; component which must be periodically replaced due to aging
LLNL	Lawrence Livermore National Laboratory
LPO	Lead Project Officer
LRNTF	Long Range Theater Nuclear Forces
MA	Military Application (DOE) - usually refers to the DASMA office or staff
MAR	Major Assembly Release; SNL prepared, AL approved statement that war reserve weapon material is satisfactory for release on a designated date to the DoD for specified use qualified by exceptions and limitations
MIR	Major Impact Report
MIRV	Multiple Independently Targetable Reentry Vehicle

Mk#	Mark Number. The system of certifying nuclear weapons <u>and</u> RV/RBs, cars, and other assorted goods (like TV programs!) For nuclear weapons - now replaced by W for Warhead and B for Bomb or other
MLC	Military Liaison Committee - historically was the coordinating and interchange of information focus between DoD and DOE
MRR	Minimum Residual Radiation - now RRR
MRV	Multiple Reentry Vehicle
MT	Megaton, million tons equivalent TNT. Also metric tons - 1000 kilograms
OMA	Office of Military Application - now office of DASMA
OMB	Office of Management and Budget
One Point	The detonation of the weapon HE at a single point

Oy	Oralloy - Oak Ridge Alloy. Uranium enriched in the isotope U^{235} to 93.5%
OSD	Office of the Secretary of Defense
PL	Phillips Laboratory (formerly Air Force Weapons Lab)
PAL	Permissive Action Link - coded use control feature
PA&E	Program Analysis and Evaluation, OSD, (not program annihilation and elimination)
P&PD	Production and Planning Directive
P&S	Production and Surveillance
PM-NUC	Program Manager - Nuclear Munitions (Army program office for nuclear-no longer active)
POC	Programs of Cooperation
POG	Project Officers Group
POM	Meeting of the POG
Primary	The "fission" device
Pu	Plutonium, a reactor produced fissionable material obtained by bombarding U^{238} with neutrons
QA	Quality Assurance - DoD uses QART—Quality Assurance, Reliability Testing
QRA	Quick Reaction Alert; weapon system deployed in a state that would allow its employment in a stated minimum specified time
RB	Reentry Body - Navy term for RV
RD	Restricted Data; all data concerning design, manufacture, or utilization of nuclear weapons and the production of special nuclear material which has not been removed by the Atomic Energy Act of 1954
Rolomite	A Sandia designed ESD sensor
RRR	Reduced Residual Radiation - reduced fission devices—formerly MRR (Minimum Residual Radiation)
RTG	Radioisotopic Thermoelectric Generator

RV	Reentry Vehicle Army, Air Force - Navy calls them RBs, definitely not a recreational vehicle
SAC	Strategic Air Command
Secondary	The "thermonuclear" device
Sec Def	Secretary of Defense
Shake	10^{-8} seconds
SLBM	Submarine Launched Ballistic Missile
SLCM	Sea Launched Cruise Missile
SNL	Sandia National Laboratories
SNM	Special Nuclear Material - Pu, Oy
SP	Strategic Programs - Navy SLBM office
Specified Command	Combat command with a broad and continuing mission - usually a single service such as the Strategic Air Command
SRAM	Short Range Attack Missile
SS Material	Source Strength Material - DOE audits one kilogram quantities (includes depleted and natural uranium)
SSPO	Strategic Systems Program Office - now SP
Standard Stockpile Item	A nuclear weapon which meets the approved military characteristics to DoD"s satisfaction
Stockpile Nuclear Test	QA test of a system withdrawn from the stockpile. That rare instance that a stockpiled weapon is tested downhole at NTS - a stockpile "confidence test"
STS	Stockpile-to-Target Sequence
TATB	Triamino-Trinitro-Benzene; see IHE
TTR	Tonopah Test Range - Sandia's testing range at Tonopah, Nevada

TREE	Transient radiation effects on electronics
Tritium	Third isotope of hydrogen, radioactive gas used to boost weapons
TTBT	Threshold Test Ban Treaty
Tu	Tuballoy - natural uranium. Sometimes also includes depleted uranium, i.e., essentially U^{238}
$V-\gamma$ Map	A contour depicting permissible velocity and reentry angle combinations for a missile RV/RB
Unified Command	A combat command with a broad and continuing mission composed of forces of two or more services under a single commander
USANCA	U.S. Army Nuclear and Chemical Agency
USDR&E	Under Secretary of Defense for Research and Engineering
WR	War Reserve nuclear weapons material (in DOE or DoD custody) intended for employment in the event of war
Weapons Grade Pu	Plutonium which has 6% or less Pu^{240} content; Pu^{239} is the good stuff
WDCR	Weapon Design and Cost Report
WES	Warhead Electrical System
WS^3	Weapon Secure, Safe, Storage
WSV	Weapons Storage Vault (Weapons Security Vault)
X-unit	A device used to provide energy to initiate nuclear system detonators

WEAPONS/WEAPON APPLICATIONS

WEAPON*	APPLICATION	SERVICE
FATMAN	BOMB	AF
LITTLEBOY	BOMB	AF
Mk III	BOMB	AF
Mk 4	BOMB	AF
T-4	ATOMIC DEMONITION MUNITION	A
Mk 5	BOMB	AF,N
Mk 5	MATADOR	AF
Mk 5	REGULUS I	N
Mk 6	BOMB	AF
Mk 7	BOMB	AF,N
Mk 7	HONEST JOHN	A
Mk 7	CORPORAL	A
Mk 7	BOAR	N
Mk 7	BETTY	N
Mk 7	ATOMIC DEMONITION MUNITION	A
Mk 7	NIKE HERCULES	A
Mk 8	BOMB	N
Mk 9	280-mm AFAP	A
Mk 11	BOMB	N

*Absence of entry indicates system not fielded

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WEAPON	APPLICATION	SERVICE
Mk 12	BOMB	AF,N
Mk 14	BOMB	AF
Mk 15	BOMB	AF,N
Mk 17	BOMB	AF
Mk 18	BOMB	AF,N
Mk19	280-mm AFAP	A
Mk21	BOMB	AF
Mk23	16" AFAP	N
B24	BOMB	AF
W25	GENIE	AF
B27	BOMB	N
W27	REGULUS I	N
B28	BOMB	AF,N
W28	HOUNDDOG	AF
W28	MACE	AF
W30	TALOS	N
W30	ATOMIC DEMONITION MUNITION	A
W31	HONEST JOHN	A
W31	NIKE HERCULES	A
W31	ATOMIC DEMONITION MUNITION	A
W33	8" PROJECTILE	A,N

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WEAPON	APPLICATION	SERVICE
W34	LULU	N
W34	ASTOR	N
B34	HOTPOINT	N
B36	BOMB	AF
W38	ATLAS	AF
W38	TITAN I	AF
B39	BOMB	AF,N
W39	B-58 pod	AF
W39	REDSTONE	A
W39	SNARK	AF
W40	BOMARC	AF
W40	LACROSSE	A
B41	BOMB	AF
B43	BOMB	N,AF
W44	ASROC	N
W45	BULLPUP	N
W45	TERRIER	N
W45	LITTLE JOHN	A
W45	MADM	A
W47	POLARIS	N
W48	155-mm AFAP	A,N

WEAPON	APPLICATION	SERVICE
W49	ATLAS	AF
W49	THOR	AF
W49	JUPITER	A,AF
W49	TITAN I	AF
W50	PERSHING	A
W50	NIKE ZEUS	A
W52	SERGEANT	A
W53	BOMB	AF
W53	TITAN II	AF
W54	FALCON	AF
W54	DAVY CROCKETT	A
W54	SADM	A,N
W55	SUBROC	N
W56	MINUTEMAN	AF
B57	BOMB/DEPTH BOMB	AF,N
W58	POLARIS A3	N
W59	MINUTEMAN I	AF
B61	BOMB	AF,N
W62	MINUTEMAN II	AF
W66	SPRINT	A
W68	POSEIDON C3	N
W69	SRAM	AF

WEAPON	APPLICATION	SERVICE
W70	LANCE	A
W71	SPARTAN	A
W72	WALLEYE	AF
W76	TRIDENT I	N
W78	MINUTEMAN III	AF
W79	8" AFAP	A,N
W80	SLCM	N
W80	ALCM	AF
B83	BOMB	AF
W84	GLCM	AF
W85	PERSHING II	A
W87	PEACEKEEPER ICBM	AF
W88	TRIDENT II	N

SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

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SESSION II

- REVIEW OF WEAPONS PHYSICS
- THEORY OF NUCLEAR EXPLOSIONS

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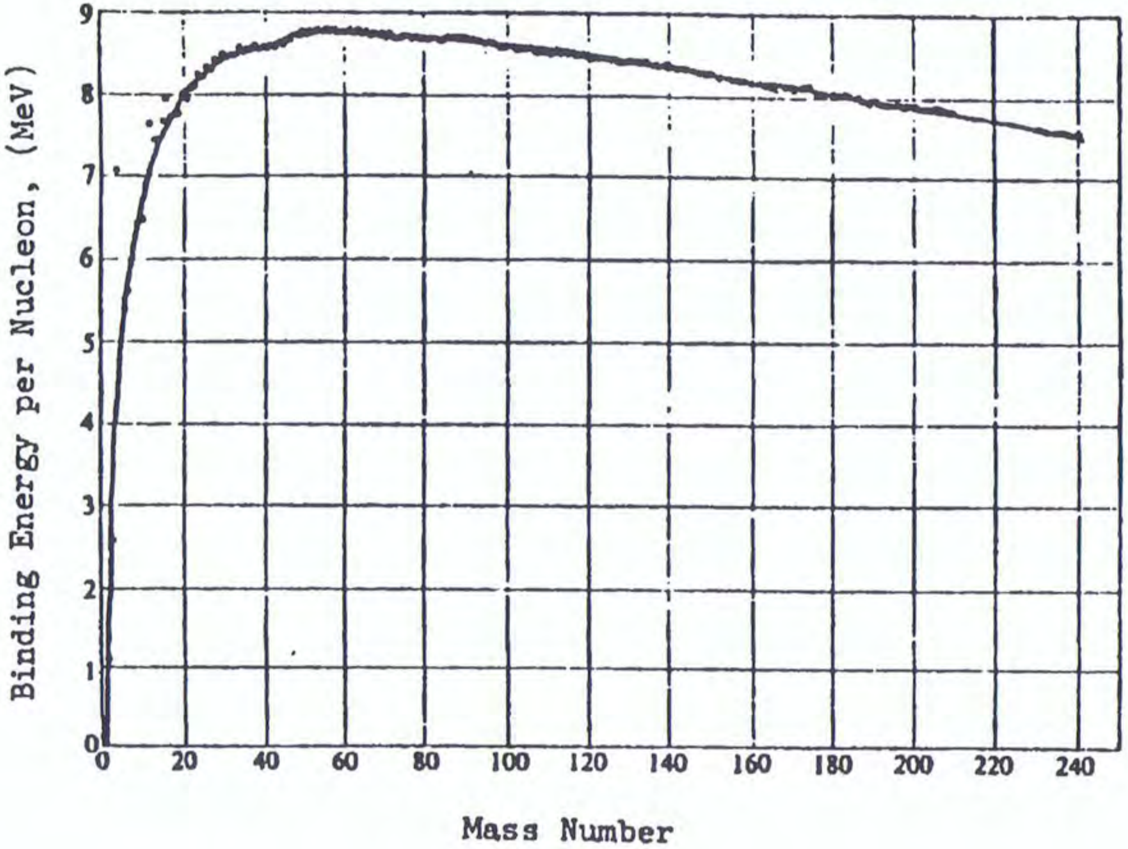
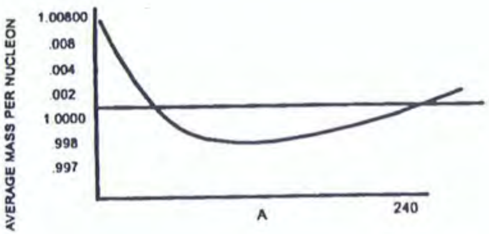
Weapons Physics and Nuclear Material

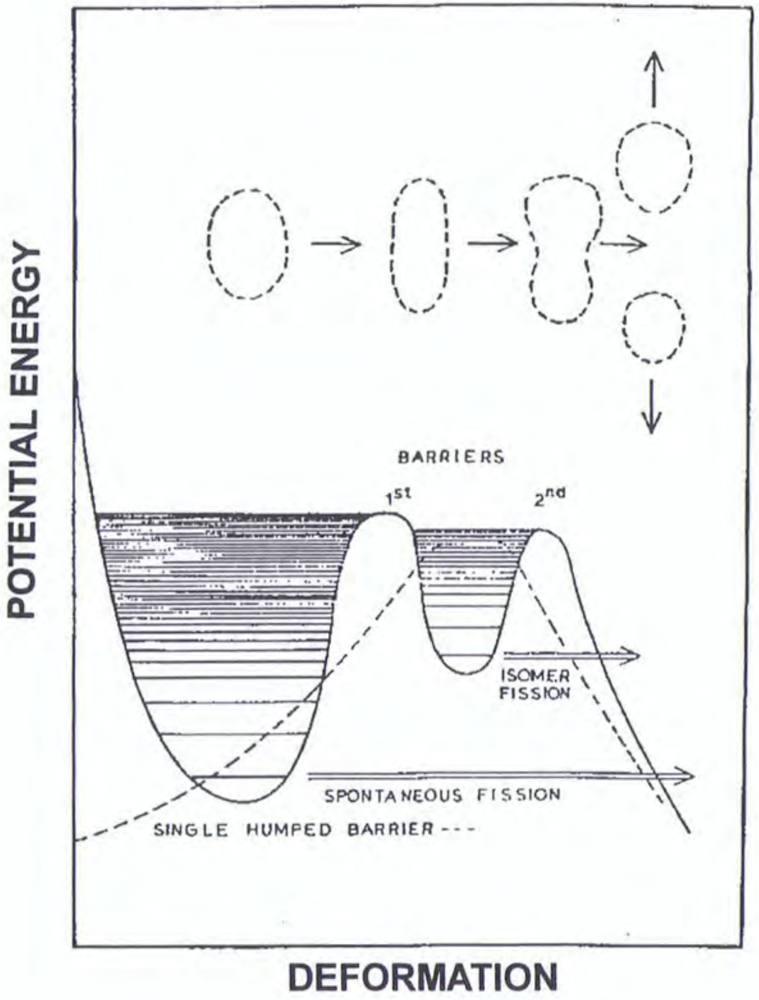
- Several basic nuclear physics concepts and the properties of the nuclear fissile material are very important to the understanding of weaponization
- The physics of fission
- Nuclear properties
- Availability of material
- How the fissile material is obtained
- Energy available and energy trades

NUCLEAR BINDING ENERGY

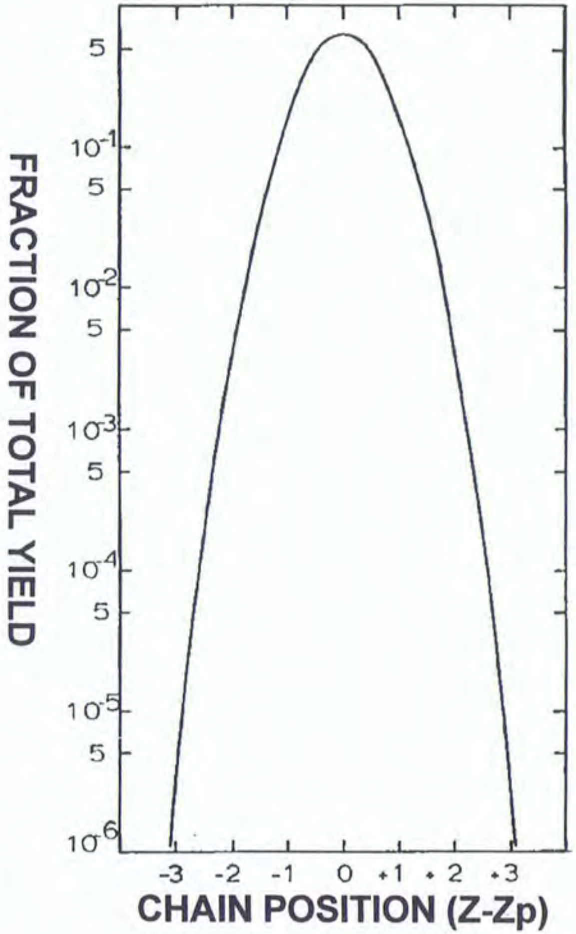




LIQUID DROP MODEL APPLIED TO POTENTIAL BARRIERS



CHARGE DISTRIBUTION CURVE



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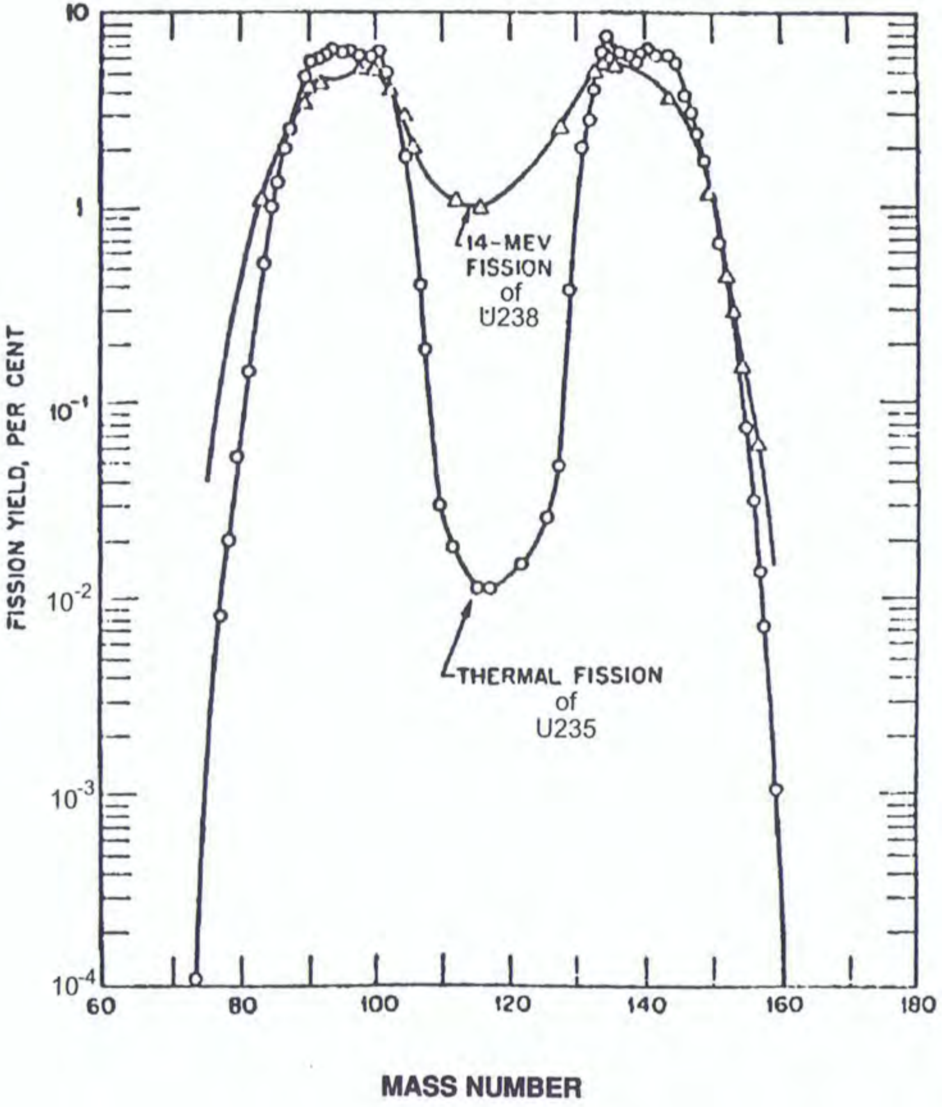

LIKELIHOOD FOR FISSION FRAGMENT

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Terminology

Asymmetric fission - division of excited nucleus into two unequal fragments with masses about 100 & 140 ama.

Binary - division at scission point into two parts.

Cross-Section - probability that a certain reaction between a nucleus and an incident particle or photon will occur, as in a neutron and U^{235} (measured in "barns")

Fission Fragment - fragment after scission but before prompt neutron emission

Fission Product - fragment after prompt neutron emission

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The Gang of Four

$^{238}U_{92}$ % in nature - 99.27 When the $^{238}U_{92}$ is extracted, it is called depleted ^{238}U or TUBALLOY or D38 (from UK WWII effort - TUBE ALLOY) Will fission but not fissile Physically separated	^{239}Pu % in nature - essentially zero (mine in South Africa) Made in reactor: $n + {}^{238}U = {}^{239}Pu$
^{235}U % in nature - 00.73 Concentrated to 93.5% Called ORALLOY for Oak Ridge Alloy	^{240}Pu % in nature - essentially zero Made by reactor If you leave the ^{239}Pu in "too long," it will absorb a n ➡ ^{240}Pu Spontaneously fissions (originally a problem for pre-ignition)

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CALCULATION OF ENERGY RELEASE

$$_{92}U^{235} \;+\; _{o}n^{1} \longrightarrow {}_{42}Mo^{95} \;+\; _{57}La^{139} \qquad 7_{-1}e^{o} \;+\; 2_{o}n^{1}$$

235.0439
1.0087

236.0526 amu ⟶

94.905837
138.906400
.003850
2.017340

235.8334 amu atomic mass unit

MASS DEFECT OF .219 amu

n = 1.00867 amu
p = 1.00728 amu
e = .00055 amu

$$(.219 \text{ amu}) \quad (931.4 \ \frac{\text{MeV}}{\text{amu}}) \ \doteqdot \ 204 \ \text{MeV}$$

THE EXAMPLE STARTED WITH

$$_{54}Xe^{139} \xrightarrow{3\,\beta} {}_{57}La^{139} \qquad \text{AND} \qquad _{38}SR^{95} \xrightarrow{4\,\beta} {}_{42}Mo^{95}$$

FISSION CHAIN

THEORETICAL FISSION ENERGY

- THERE ARE $\frac{6.025X10^{23}}{235.0439}$ ATOMS PER GRAM OF ${}_{92}U^{235}$

- THEREFORE, 1 kg OF ${}_{92}U^{235}$ HAS $2.5634X10^{24}$ ATOMS

- HENCE, @ 180 MeV PER FISSION 1 kg OF ${}_{92}U^{235}$ WOULD PRODUCE $4.6141x10^{26}$ MeV IF EACH ATOM WERE FISSIONED.

- CONVERTING TO KILOTONS

- $(4.6141X10^{26}\ \text{MeV})\ (3.824X10^{-26}\ \frac{\text{kT}}{\text{MeV}}) \doteq 18\ \text{kT}$

FACTORS AFFECTING CRITICAL MASS

- GEOMETRY
- AMOUNT OF MATERIAL
- TYPE OF MATERIAL
- PURITY OF MATERIAL
- SURROUNDING MATERIAL
- DENSITY

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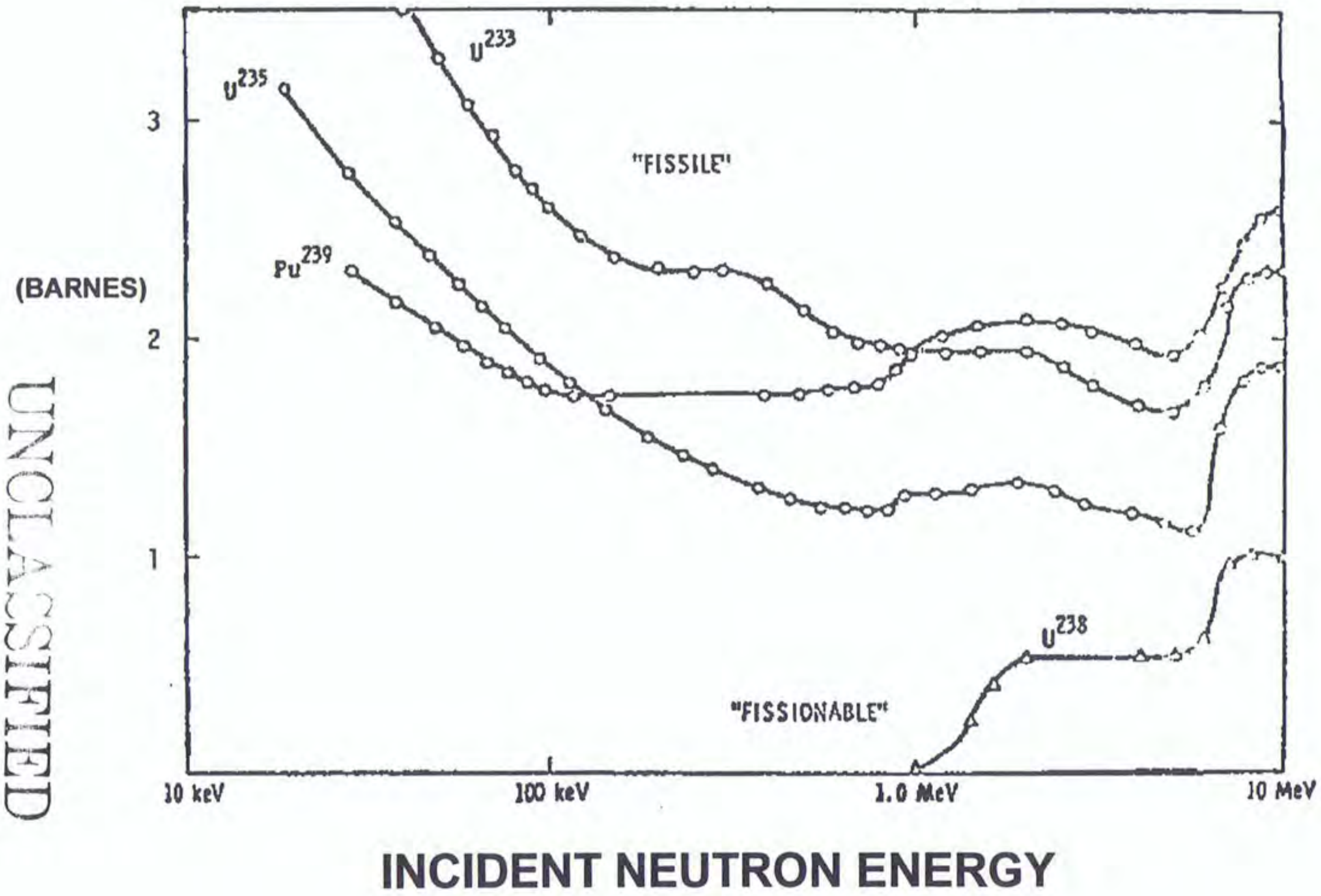
FISSION CROSS SECTIONS



NOTE: The thermal neutron energy is not on the chart

Variation of Cross Section x Ave. # Neutrons for ^{235}U

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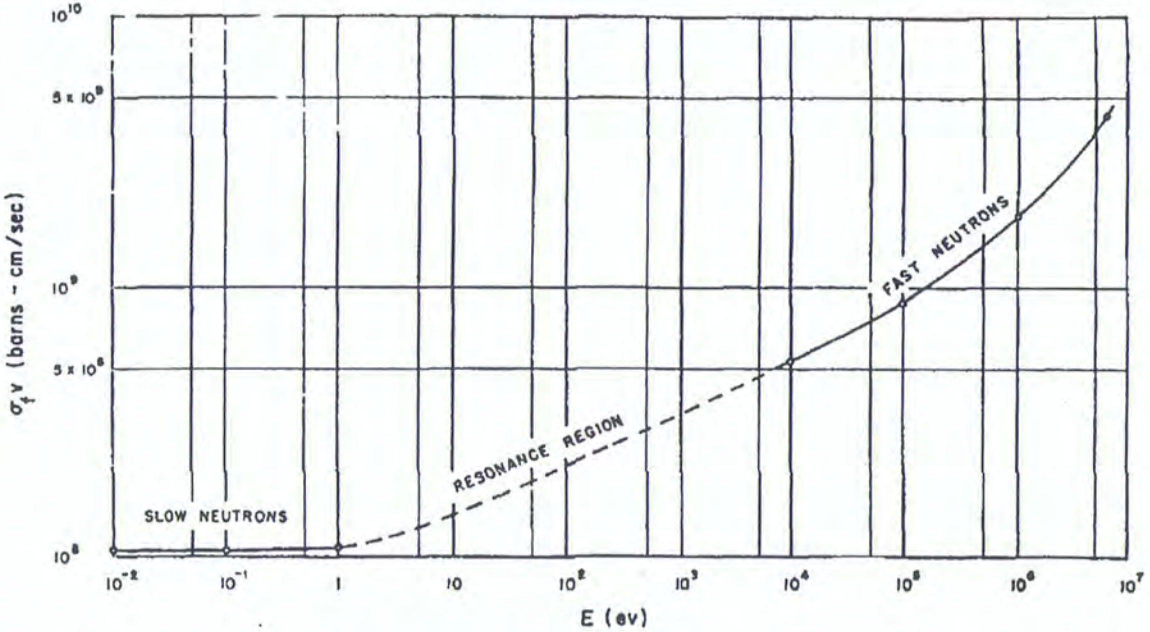


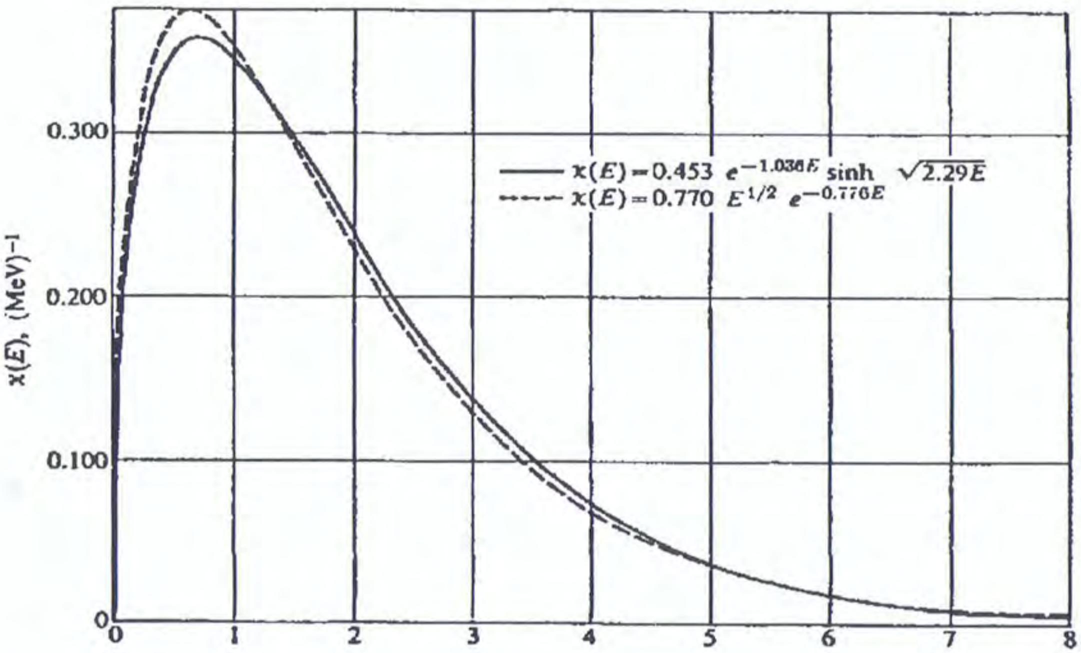
Neutron Energy

Fission is more effective at higher energies N

Smallest fission generation time at high energies ($T = 1/N\sigma_f \cdot v$)

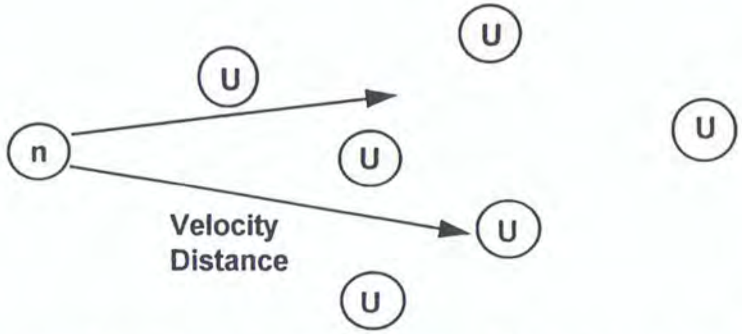
Neutron Energy (MeV)

U_{235} Fission Neutron Energy Spectrum



(Reference, Lamarsh, 1966)

"A Shake"



- **Fission mean free path - how long before it clobbers an atom like URANIUM**
- **Average velocity - how fast it is going**

- $$\tau = \frac{\textit{fission mean free path}}{\textit{average velocity of neutron}}$$

These values are derived experimentally and are related to the fission cross section and velocity of the neutron.

- $\tau = 10^{-8}$ **Seconds or 1 shake**
  (real fast like the shake of a lamb's tail)

We Care About Neutrons

- An efficient way to fission U^{235} or Pu^{239} is with neutrons.
- The fission of one atom of U^{235} or Pu^{239} releases approximately 200 MeV.
- To create an explosion by fission, a bunch of neutrons are required.
- The more neutrons--the more fission, i.e., We Care About Neutrons!
- Remember that each fission gives off integral numbers of neutrons--about 2-4, but over a bunch of fissions, we measure an average (i.e., 2.54 etc.) and this varies with input neutron energy.

υ = average number of neutrons

- The whole idea of sustaining the fission process is to get these fission neutrons to go fission more U^{235} or Pu^{239}.
  - If all the neutrons escape without fissioning anything, then the reaction fizzles! (The population becomes extinct.)
  - If at least one of the 2 to 4 neutrons fission something every generation, then we have a steady state condition--a reactor.
  - If most of the neutrons fission another atom etc., etc., we have a run-away condition--a nuclear explosion.

We Care About the Neutrons that Escape

- We call the escapees "lost neutrons," and the abbreviation is l (the letter after k).

- So the number of neutrons available for population growth is the average number per fission (u), i.e., 2.54 minus the lost ones.

- Someone called this k.

- Therefore: $k = u - l$
  - for every neutron causing fission in one generation k will cause it in the next generation.

We Care About the Multiplication

- Now let's look at a bunch of fissions and bunch of neutrons.
- If we start with some number of neutrons (one or more), let that number equal n.

n = number of neutrons at beginning of a generation

- Remember, k= number of neutrons available for Round 2...
- And k times n equals number of neutrons at the next generation.
- Don't forget we've used up the original neutrons (n) in the first fission process..
- The gain of neutrons is thus:

$$n \bullet k - n$$

(number of neutrons we started with)•(average number in a fission of Round 2 (etc.)) minus the ones we used up in the previous round.

Determine Growth Rate

- We still care about neutrons, but we really care about the rate (speed) that they are produced.

- The rate is the $\frac{\text{change in the number of neutrons}}{\text{change in time}}$

- Mathematically this is represented

$$\frac{Dn}{Dt} \longrightarrow \frac{dn}{dt}$$

- To get the rate change, we divide the actual gain in neutrons by time (t)

$$\frac{nk - n}{t}$$

- Therefore $\frac{dn}{dt} = \frac{nk - n}{t}$

Apply Basic Calculus

- $$\frac{dn}{dt} = \frac{nk - n}{\tau} = \frac{n(k-1)}{\tau}$$
- *Let* α *"alpha"* $= \frac{k-1}{\tau}$ *substitution gives*
- $$\frac{dn}{dt} = n\alpha;$$ *Rearrange (cross multiply and divide)*
- $$\frac{dn}{n} = \alpha\, dt$$ *Integrate from zero neutrons (N_o) to N neutrons.*
- $$N = N_o e^{\alpha t}$$

  If α *is known, one can calculate the number of neutrons at any time (t).*

The Energy Released is Proportional to the Number of Fissions

$\alpha \approx \frac{\mu - \iota - 1}{\tau} \approx \frac{3 - 1 - 1}{\tau} \approx \frac{1}{\tau}$ **1 gen / shake for 1 MeV neutron**

where: μ **= ave# Neutrons**
ρ **= Post Neutons**

$$N = N_o e^{dt} \cong N_o e^{\frac{t}{\gamma}} = e^g$$ **where g = Number of generations**

The energy released is proportional to the number of fissions
The numer of fissions is proportional to the number of neutrons
1 fission $\cong 7 \times 10^{-21}$ **tons of TNT**
At g = 48 we would have $\approx$ **9800 lbs.**

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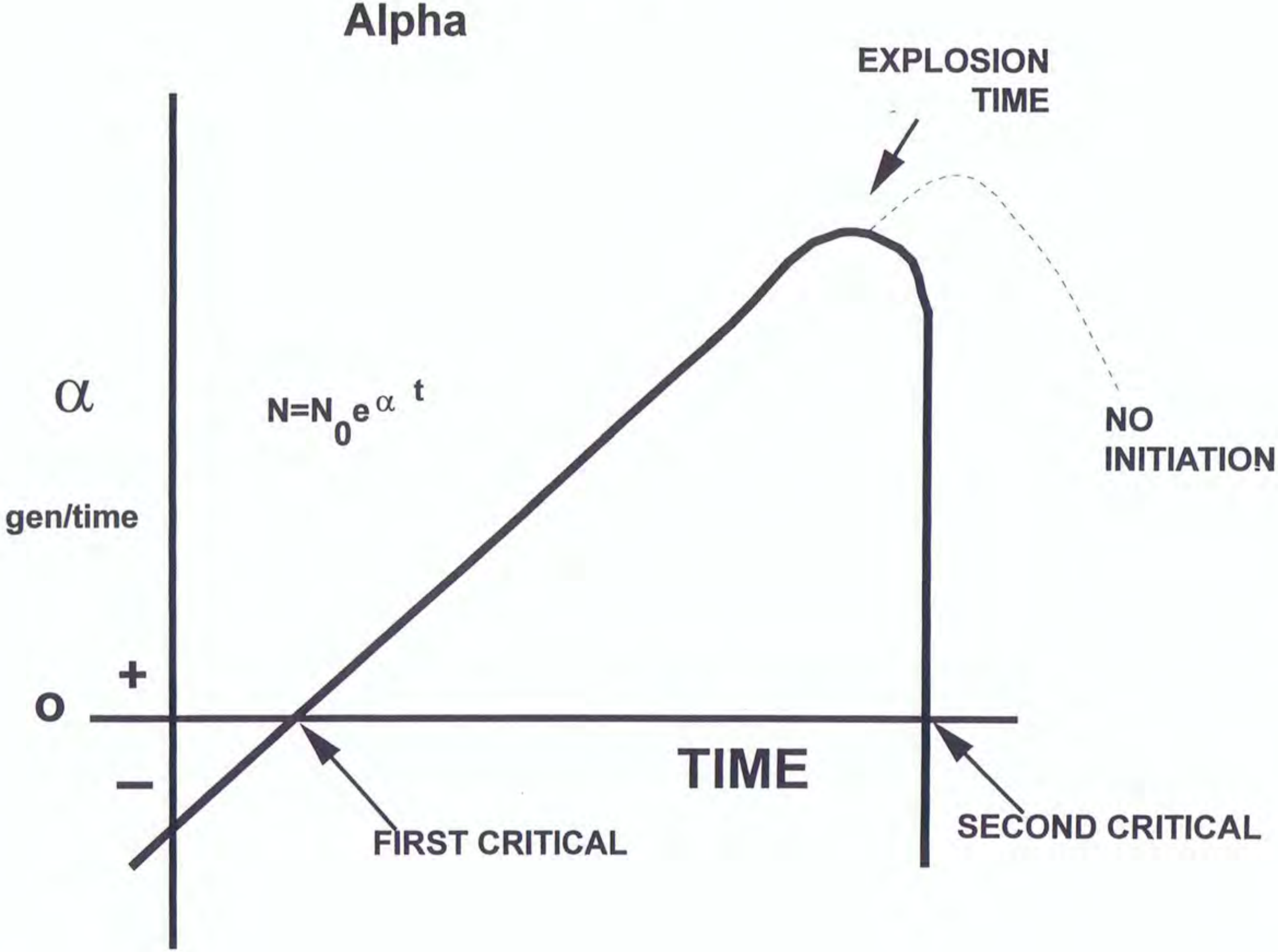
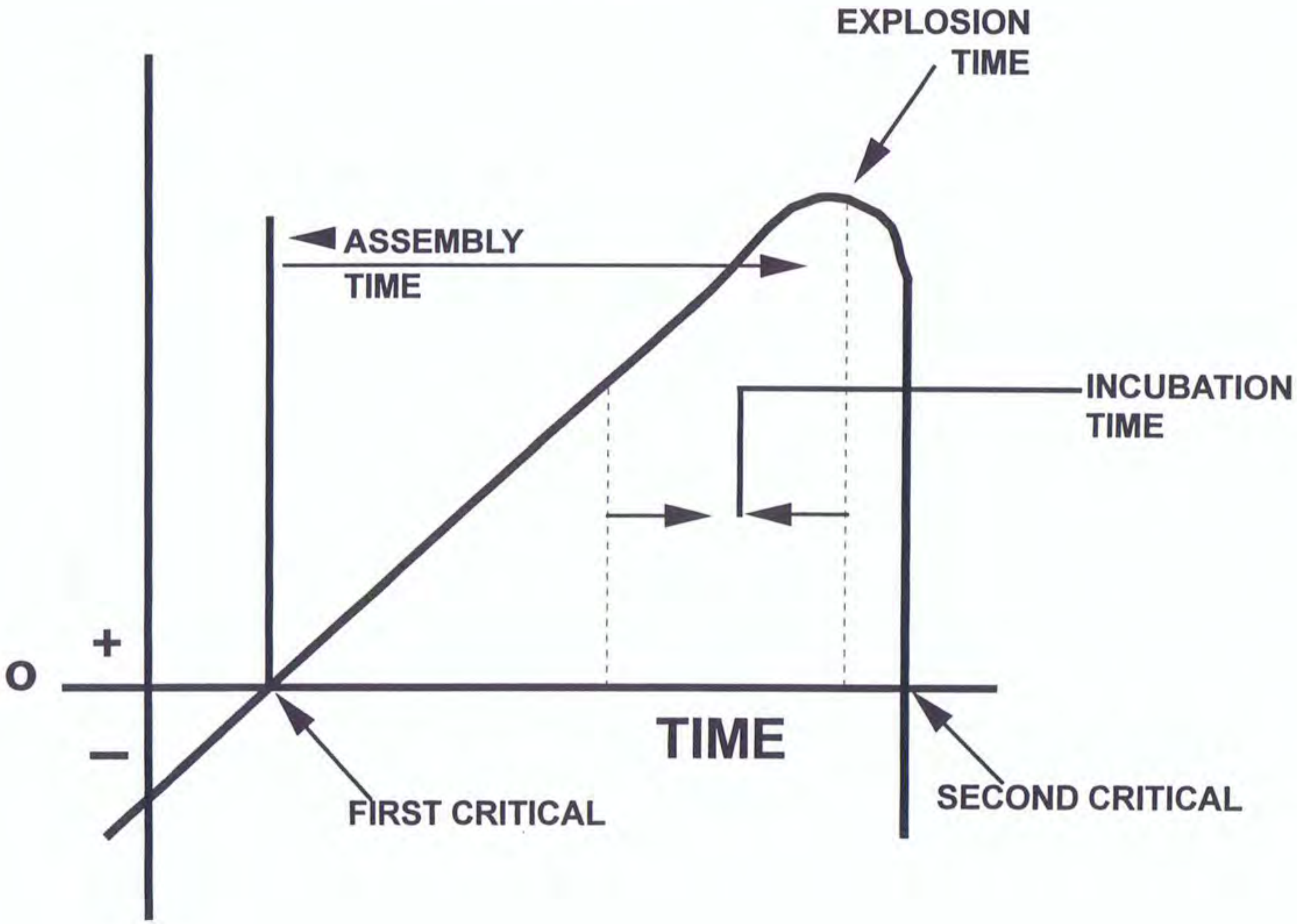
α - Curve


Alpha
EXPLOSION TIME
α
gen/time
$N=N_0e^{\alpha t}$
NO INITIATION
+
o
–
TIME
FIRST CRITICAL
SECOND CRITICAL

α - Curve


EXPLOSION TIME
ASSEMBLY TIME
INCUBATION TIME
+
O
–
TIME
FIRST CRITICAL
SECOND CRITICAL

α - Curve

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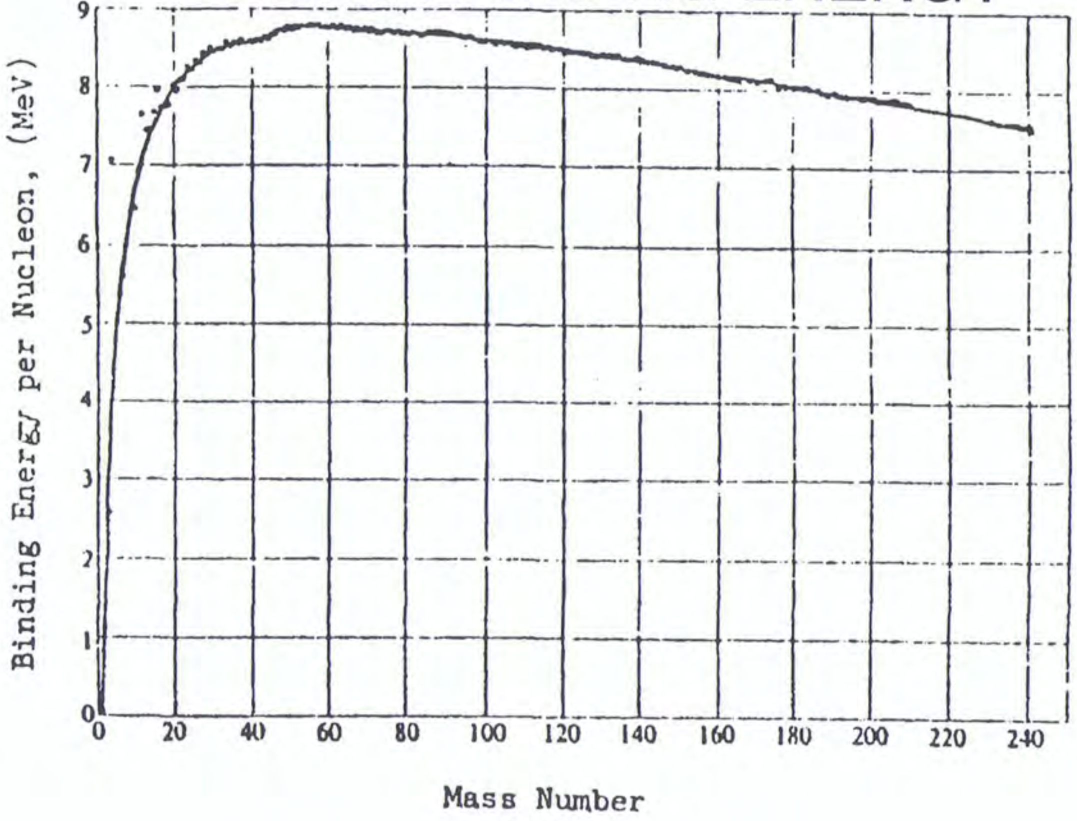
NUCLEAR BINDING ENERGY



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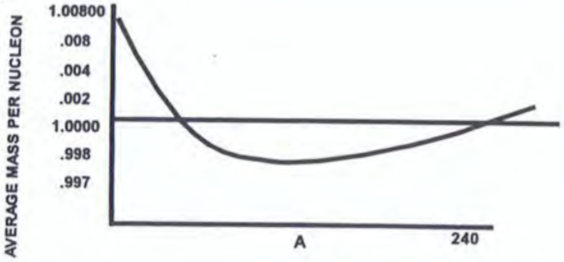


Potential Fusion Reactions

$$
\begin{aligned}
{}_1D^2 + {}_1D^2 &\rightarrow {}_2He^3 + {}_on^1 + 3.27\text{ MeV} \\
&\rightarrow {}_1T^3 + {}_1H^1 + 4.03\text{ MeV}
\end{aligned}
$$

$${}_1D^2 + {}_1T^3 \rightarrow {}_2He^4 + {}_on^1 + 17.6\text{ MeV}$$

$${}_1D^2 + {}_2He^3 \rightarrow {}_2He^4 + {}_1H^1 + 18.3\text{ MeV}$$

$${}_1T^3 + {}_1T^3 \rightarrow {}_2He^4 + 2{}_on^1 + 11.3\text{ MeV}$$

$${}_3Li^6 + n \rightarrow {}_2He^4 + {}_1T^3 + 4.6\text{ MeV}$$

Theoretical Fusion Energy in Equal Atom Mixture of Li^6D

$$1 \text{ kg of } Li^6 \text{ has } \frac{6.025\text{x}10^{26}}{6.0151} = 1.00165\text{x}10^{26}\text{ Atoms}$$

$$1 \text{ kg of } D \text{ has } \frac{6.025\text{x}10^{26}}{2.0141} = 2.99141\text{x}10^{26}\text{ Atoms}$$

Hence,

$$.25084 \text{ kg of D has } \left(\frac{2.01410}{6.01512 + 2.0141}\right)\left(2.99141\text{x}10^{26}\right) \cong .75038410^{26}\text{ Atoms}$$

$$.7491 \text{ kg of } Li^6 \text{ has } \left(\frac{6.01512}{6.01512 + 2.0141}\right)\left(1.00165\text{x}10^{26}\right) \cong .750390\text{x}10^{26}\text{ Atoms}$$

$$Li^6 + {}_0n^1 \Rightarrow \left(.75039\text{x}10^{26}\right)\left(4.6\right)\text{MeV} \cong 13.2\text{kT}$$

$$D + T\ \left(.75039\text{x}10\right)\left(17.6\text{MeV}\right) \cong 50.5\text{kT}$$

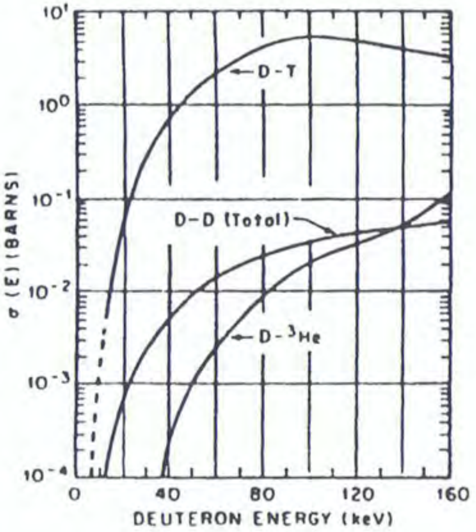
TEMPERATURE EXPRESSED IN kT (ENERGY)

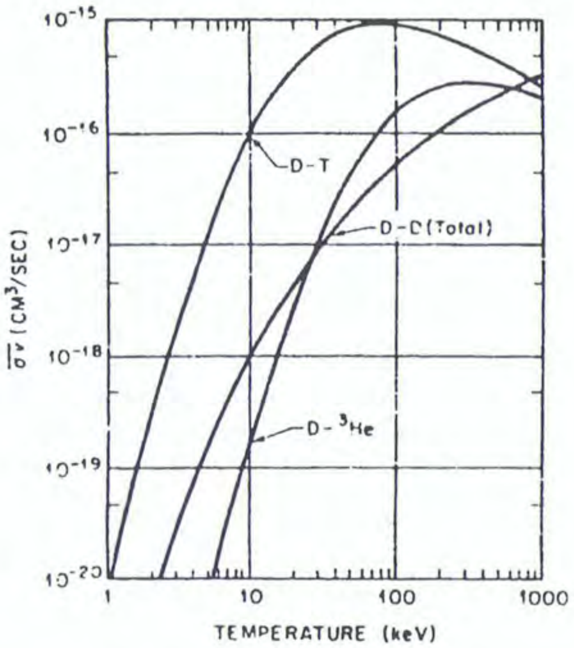
$$\text{where K is Boltzmann Constant} \left\{ \begin{array}{l} 1.38X10^{-16}\ \text{erg/ }^{\circ}\text{K} \\ 8.62X10^{-8}\ \text{keV/ }^{\circ}\text{K} \end{array} \right.$$

$$T\ (\text{in keV}) = 8.62X10^{-8}\ T\ (\text{in }^{\circ}\text{Kelvin})$$

Temperature of 1 keV = $1.16x10^{7}$ degrees Kelvin

Rational for Choice of Fusion Reaction





FUEL

- **^{6}LiD (95% ^{6}Li, 5% ^{7}Li)**

- **Tritium**

$$^{6}\mathrm{Li} + \mathrm{n} \rightarrow {}^{4}\mathrm{He} + {}^{3}\mathrm{T} + 4.6\ \mathrm{McV}$$

- **Fusion**

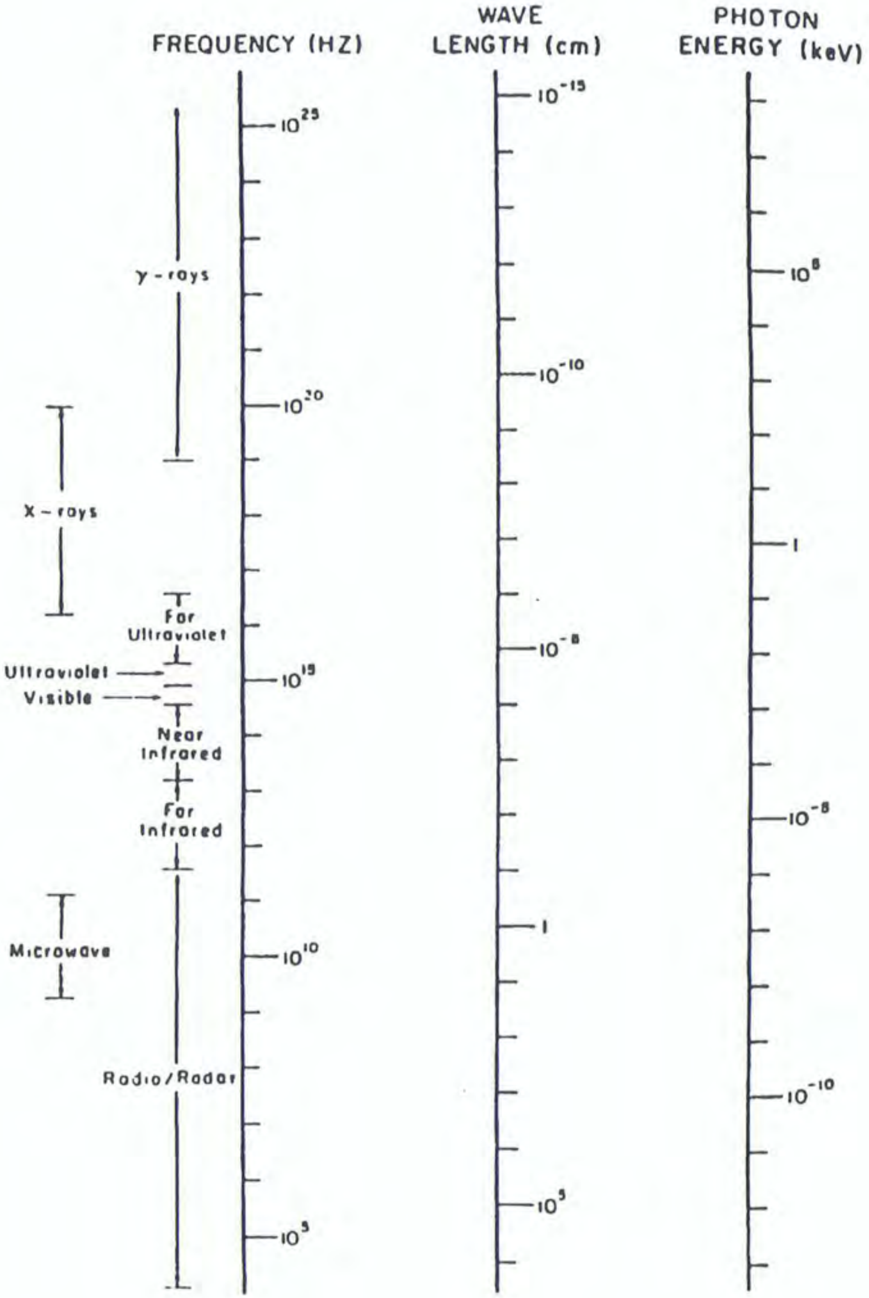
$$^{3}\mathrm{T} + {}^{2}\mathrm{D} \rightarrow {}^{4}\mathrm{He} + \mathrm{n} + 17.6\ \mathrm{McV}$$

$$^{2}\mathrm{D} + \mathrm{n} \rightarrow \mathrm{H} + {}^{2}\mathrm{n}$$

- **Net Reaction**

$$^{6}\mathrm{Li} + \mathrm{D} \rightarrow 2\ {}^{4}\mathrm{He} + 22.3\ \mathrm{McV}$$

$$\boxed{\text{Net Energy} = 22.3\ \text{McV per Event}}$$


FREQUENCY (HZ)
WAVE LENGTH (cm)
PHOTON ENERGY (keV)
10^{25}
10^{20}
10^{15}
10^{10}
10^{5}
10^{-15}
10^{-10}
10^{-5}
1
10^{5}
10^{5}
1
10^{-5}
10^{-10}
γ - rays
X - rays
Far Ultraviolet
Ultraviolet
Visible
Near Infrared
Far Infrared
Microwave
Radio/Radar

Thermal Nuclear Plasma

AT FUSION TEMPERATURES, WE HAVE A PLASMA OF IONS (NUCLEI AND ELECTRONS).

$$\text{ENERGY} = aT_{(\text{ion})} + bT_{(\text{electron})} + cT^4_{(\text{radiation})}$$

IF PLASMA IS IN THERMODYNAMIC EQUILIBRIUM THE THREE TEMPERATURES ARE EQUAL ➡ AT HIGH TEMPERATURES, RADIATION WILL DOMINATE.

REFERENCES

AN INTRODUCTION TO NUCLEAR WEAPONS; WASH 1037 REVISED; SRD (n) SIGMA 1 etc.; GLASSSTONE AND REDMAN.

SOURCE BOOK ON ATOMIC ENERGY; GLASSTONE; UNC 3rd EDITION

BASIC NUCLEAR PHYSICS; INTERSERVICE NUCLEAR WEAPONS SCHOOL

DNA PUBLICATIONS – TECHNOLOGY ANALYSIS REPORT

SANDIA, LLL, LANL TECHNOLOGY REPORTS

SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

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SESSION III

- **NUCLEAR EFFECTS**

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CONVENTIONAL EXPLOSIVE

RELEASE OF ENERGY ARISES FROM THE BREAKING OF CHEMICAL BONDS (ELECTRON BONDS) IN THE HIGH EXPLOSIVE MATERIAL

NUCLEAR EXPLOSIVE

RELEASE OF ENERGY ARISES FROM THE BREAKING OR MAKING OF NUCLEAR BONDS (HADRON-HADRON)

FISSION AND FUSION YIELDS ENERGY RELEASE + PARTICLES

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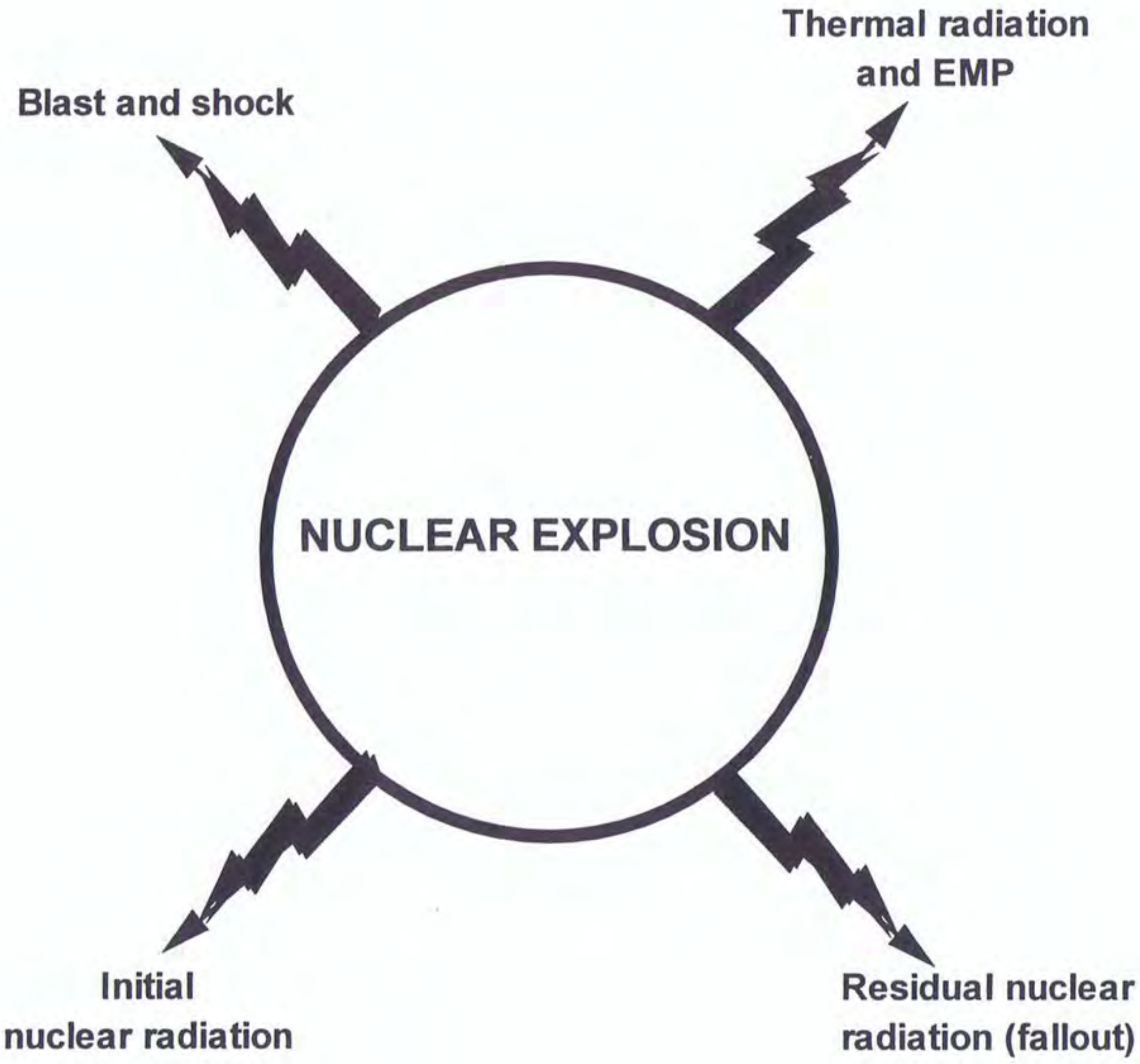
Effects of a Nuclear Explosion



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Nuclear Effects Generalities

Subject Generally Divided into 3 areas

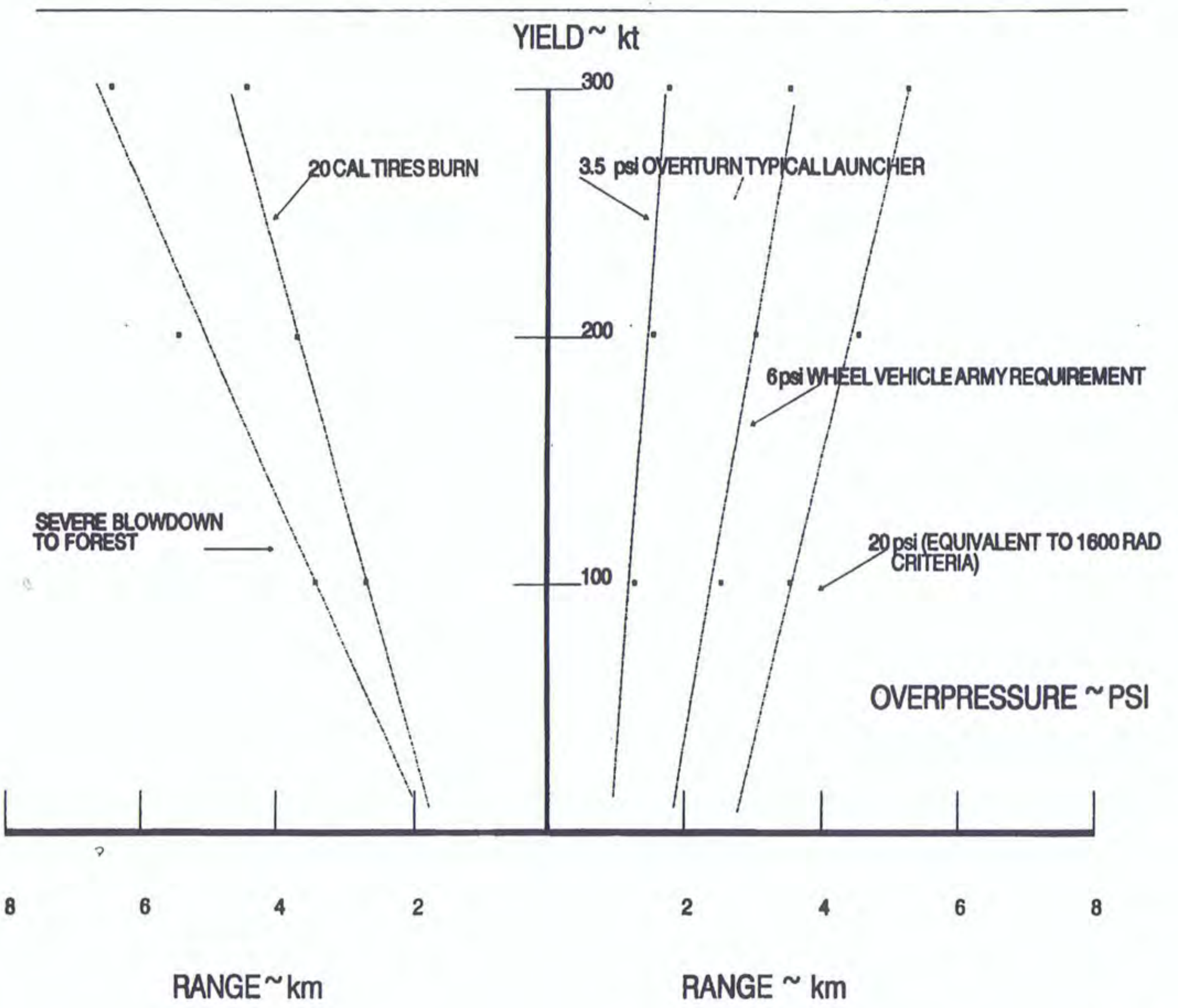
- Phenomenology
  - Physics at the weapons source
- Interaction of the nuclear
- Military effects
  - Smashing (over pressure)
  - Turning over (dynamic - winds)
  - Fires (Thermal pulse)
  - Radiation
  - Craters

What are Nuclear Effects Calculations Used For?

- Determine how "hard" (radiation, blast, etc.) to make the weapon system (major cost implication)
- Determine the proper yield/accuracy combination
- Placement of weapon system on the battlefield
- Targeting
- Number of nuclear weapons required to achieve an objective
- Safety zones
- Etc.

- Historically, this is an area that has caused much discussion and argument. However, over the years, DNA has developed tools to standardize the methodology and has contributed greatly to the understanding of this area.
  - Textbooks
  - Nomograms/Slide Rules
  - T159 - Programs
  - HP 41 CX - Programs
  - Personal Computer Software

NUCLEAR SEPARATION DISTANCE



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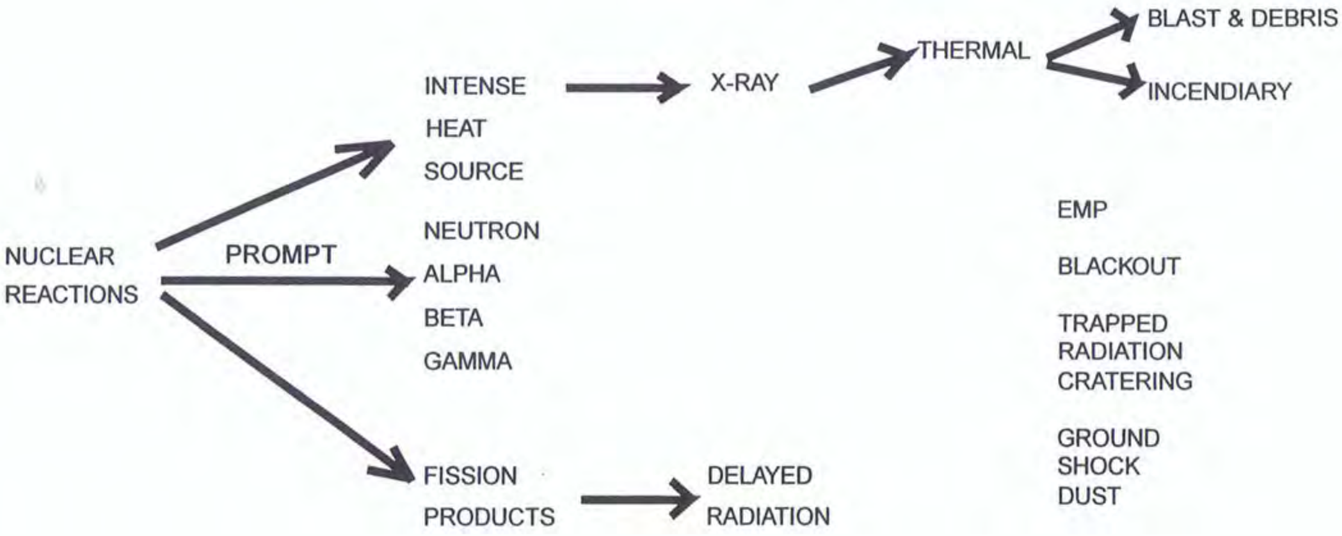
CONVENTIONAL WEAPON

CHEMICAL REACTIONS → THERMAL → BLAST & SHRAPNEL

THERMAL → INCENDIARY

NUCLEAR WEAPON



NUCLEAR REACTIONS → INTENSE HEAT SOURCE → X-RAY → THERMAL → BLAST & DEBRIS

THERMAL → INCENDIARY

NUCLEAR REACTIONS → PROMPT → NEUTRON, ALPHA, BETA, GAMMA

NUCLEAR REACTIONS → FISSION PRODUCTS → DELAYED RADIATION

EMP

BLACKOUT

TRAPPED RADIATION
CRATERING

GROUND SHOCK
DUST

Nuclear Effects

DIRECT
WEAPON
OUTPUT

TRANSMISSION
THROUGH
SOME
MEDIA

"NEW PHENOMENA"
MAY BE GENERATED
AS IT GOES THROUGH
A MEDIA

PHENOMENOLOGY AT
THE TARGET

SYSTEM
INTERACTIONS

THE NUCLEAR PHENOMENOLOGY EXPERIENCED BY A SYSTEM DEPENDS ON:

- •YIELD OF WEAPON
- •DESIGN OF WEAPON
- •WHERE WEAPON WAS DETONATED
- •WHERE SYSTEM IS
- •FOR SOME EFFECTS, WHAT SYSTEM IS DOING

NEUTRONS COME DIRECTLY FROM

Fission

N + fissionable material ➛ two or more fission fragments + neutrons + energy

And

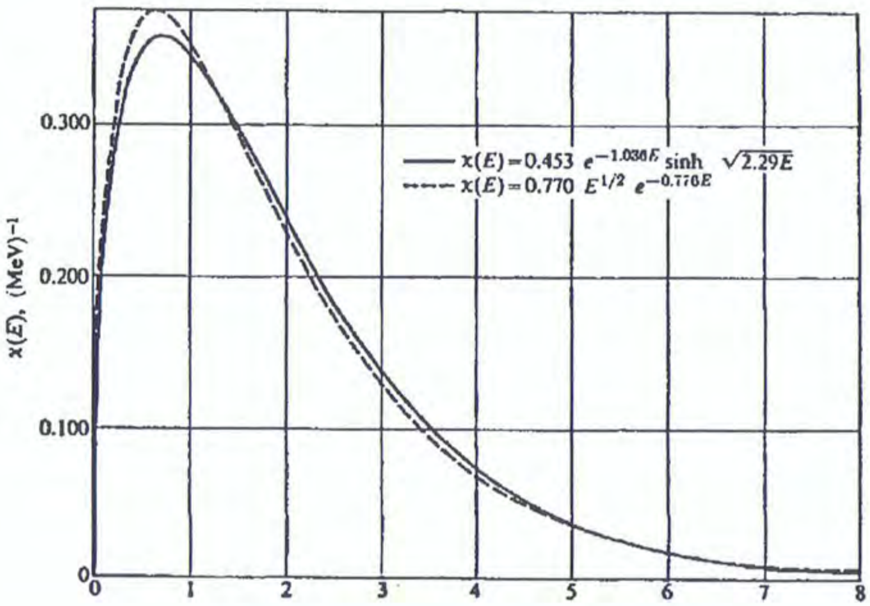
Fusion

D + T ► H_e^4 + neutron + energy

T + T ► H_e^4 + 2 neutrons + energy

D + D ► H_e^3 + neutron + energy

Fission Neutron Energy Spectrum



Neutron Energy (MeV)

Reference: Lamarsh, 1966

Neutron Spectra

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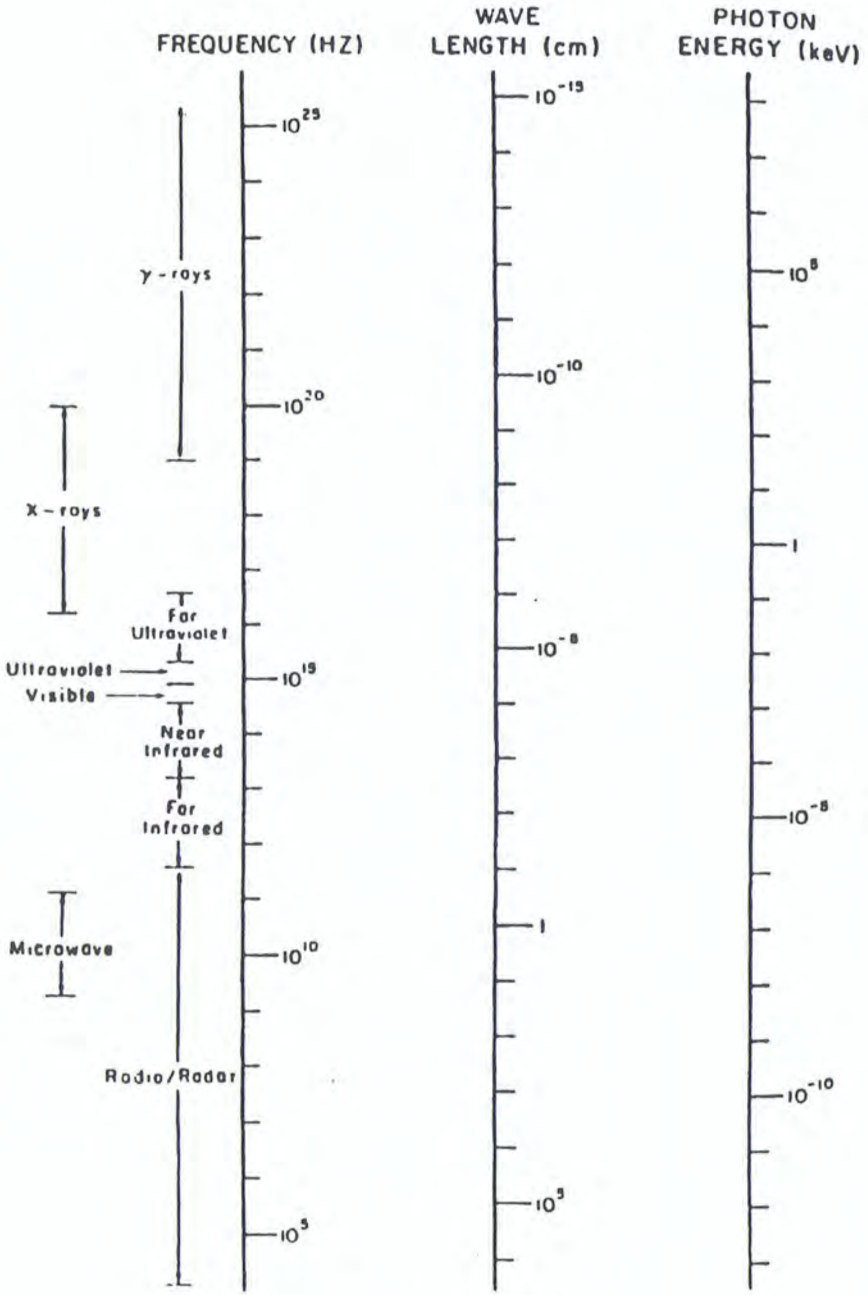

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GAMMA RAYS

ELECTROMAGNETIC RADIATION

SOURCE:

- DETONATION FISSIONS

EARLY

- NEUTRON INELASTIC SCATTER IN WEAPON DEBRIS
- NEUTRON INELASTIC SCATTER IN THE AIR AND GROUND

LATER

- CAPTURE OF SLOW NEUTRONS BY NITROGEN
- FISSION PRODUCT DECAY

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BLAST AND THERMAL

IT'S HOT, HOT,----
SO IT RADIATES HEAT

THERE'S HIGH, HIGH, HIGH PRESSURE----
SO IT TRANSMITS A PRESSURE PULSE

SEQUENCE OF EVENTS AFTER A NUCLEAR DETONATION IN THE ATMOSPHERE

1. ONCE UPON A TIME THERE WAS A NUCLEAR WEAPON--NOW THERE'S THIS 10 MILLION PLUS DEGREE BLOB OF VAPORIZED MATERIAL OCCUPYING ROUGHLY THE SAME VOLUME (78% OF ENERGY IS IN X-RAY).

2. THIS VOLUME RADIATES ELECTROMAGNETIC ENERGY IN THE X-RAY SPECTRUM.

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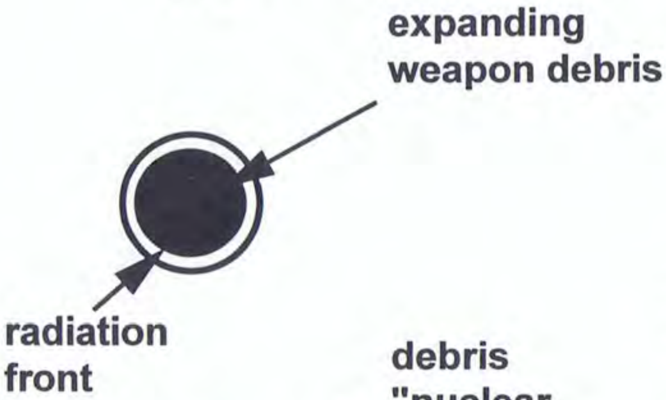
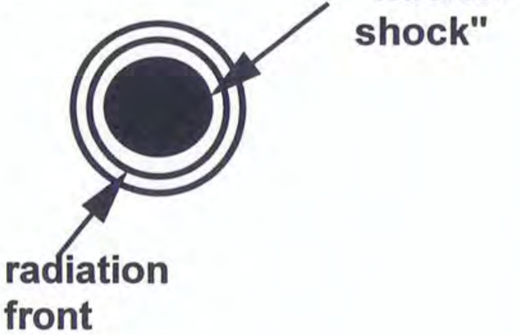
3. THE MEAN FREEPATH OF "X-RAYS" IS .3 cm AT SEALEVEL. THE SURROUNDING LAYER OF AIR IS SUPERHEATED. INITIAL X-RAY FIREBALL

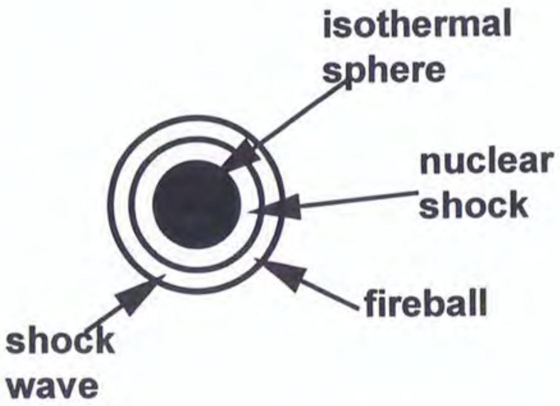
4. THIS ABSORPTION AND RERADIATING PROCESS RESULTS IN A RAPIDLY EXPANDING RADIATION FIREBALL. RADIATION GROWTH PHASE.



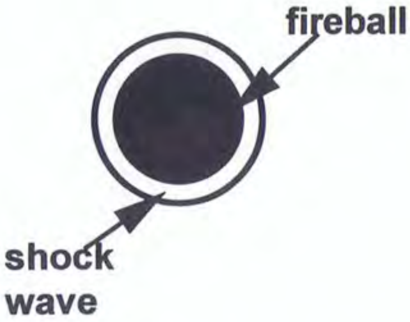
5. THE WEAPON DEBRIS SNOWPLOWS AIR AND A "NUCLEAR SHOCK" IS FORMED. RADIATION FIREBALL CONTINUES TO GROW, BUT GROWTH SLOWS BECAUSE COOLING REDUCES MFP.



6. [redacted] SHOCKWAVE ASSOCIATED WITH THE FRONT BECOMES DOMINANT. NUCLEAR SHOCK STARTS TO "CATCH-UP." <u>HYDRODYNAMIC SEPARATION</u>

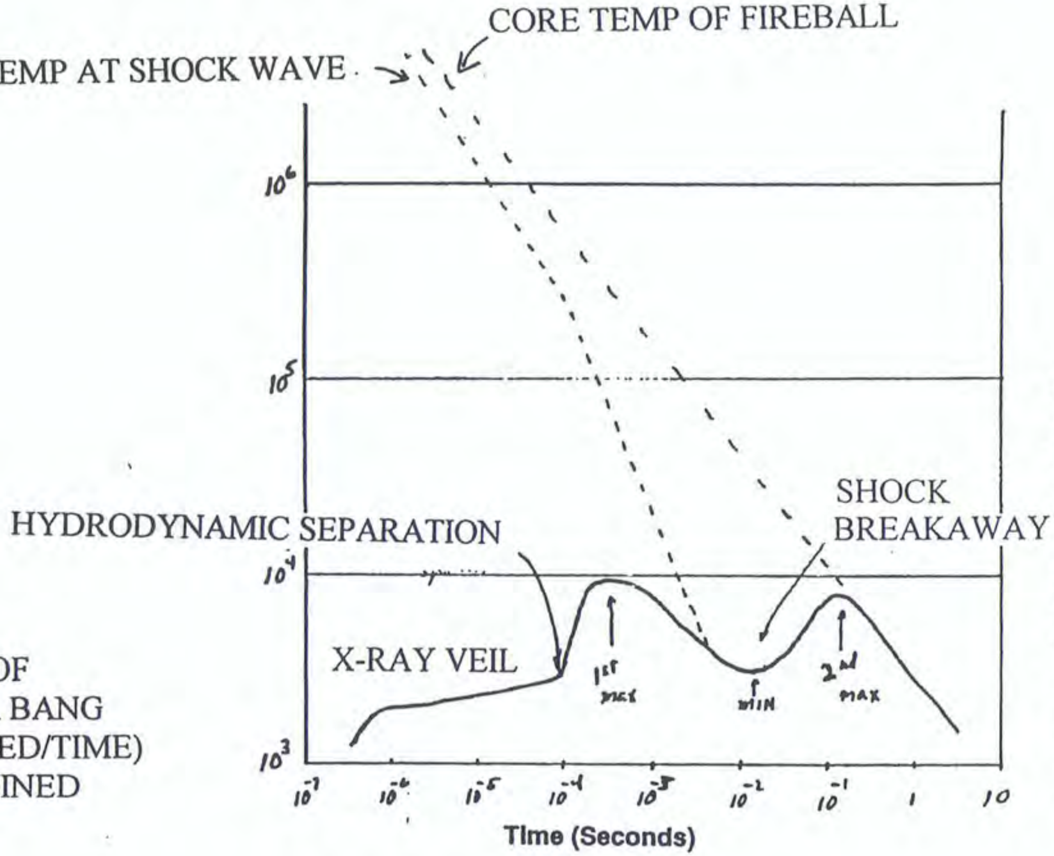


7. NUCLEAR SHOCK CATCHES UP, BUT REINFORCED SHOCKWAVE COOLS TO 3,000 DEGREES CELSIUS AND STARTS TO BECOME TRANSPARENT. <u>SHOCK BREAKAWAY.</u>



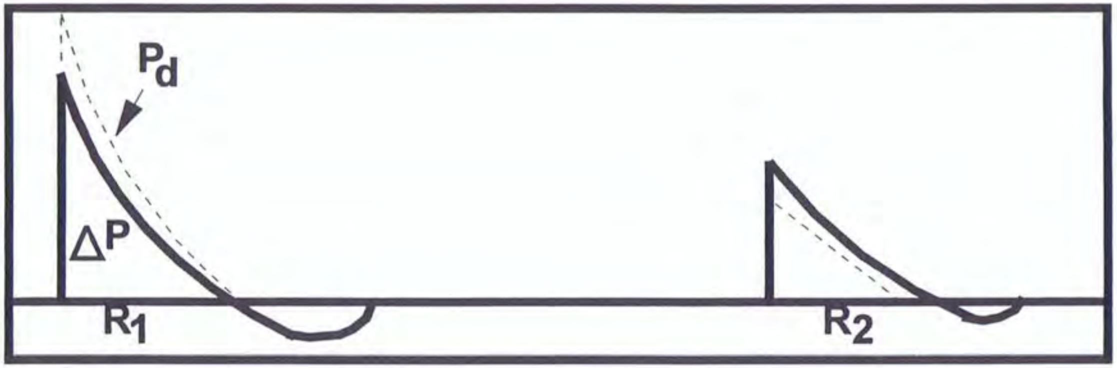
8. NO FURTHER INTERACTION BETWEEN EXPANDING SHOCKWAVE AND FIREBALL.

THERMAL Observed Thermal Pulse



USE: FROM A KNOWLEDGE OF SHOCK BREAKAWAY AND A BANG METER (DISTANCE TRAVELED/TIME) THE YIELD CAN BE DETERMINED

BLAST



$R_2 > R_1$

OVERPRESSURE $\Delta P = P - P_o$
DYNAMIC (GUST) $P_d = 1/2\ MV^2$
TIME DEPENDENCE

$P_d > \Delta P$ $(\Delta P > 100$ PSI)

$P_d < \Delta P$ $(\Delta P < 100$ PSI)

AWAY FROM <u>SOURCE</u> AIRBLAST

SCALABLE PHENOMENA — SACH'S SCALING $\left[\frac{D_1}{D_0}\right] = \left[\frac{W_1}{W_0}\right]^{1/3}$

BASIS IS COMPLETE DATA FOR 1 CASE EX: 1 kT STANDARD

FOR ALTITUDES OTHER THAN SEA LEVEL $\left[\frac{D_1}{D_0}\right] = \left[\frac{W_1}{W_0}\right]^{1/3} \left[\frac{P_0}{P}\right]^{1/3}$

OTHER IMPORTANT ASPECTS:
- MACHSTEM AND TRIPLE POINT PATH
- OPTIMAL HOB FOR MAXIMIZING OVERPRESSURE
- PRECURSOR

WILL BE COVERED LATER AND IN THE EFFECTS MOVIE

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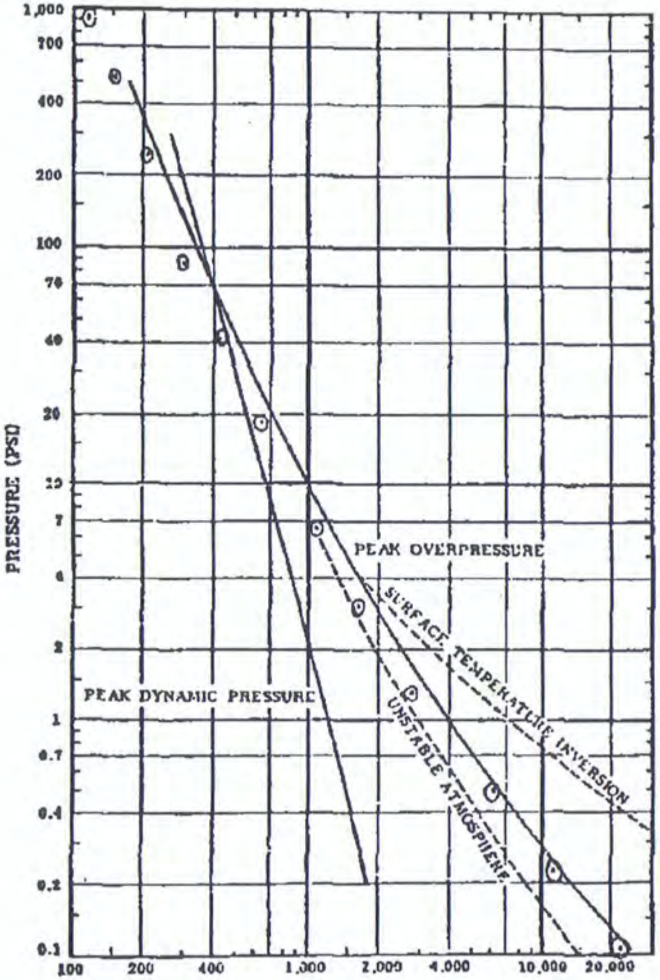
⊙ = Data from AFWL - TR 73-75



Distance from Ground Zero (feet)
1 Kiloton Standard (from Glasstone)

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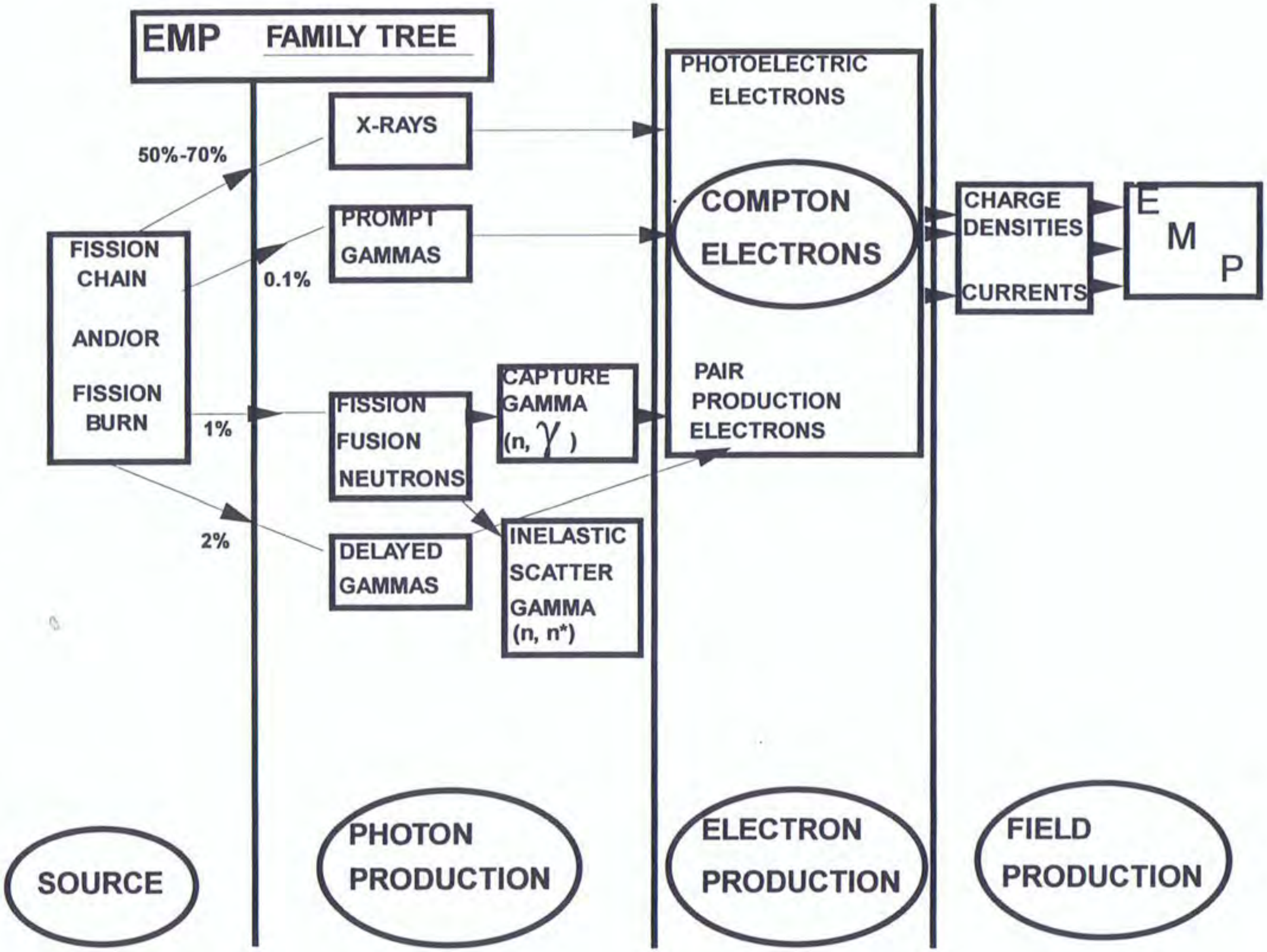

EMP FAMILY TREE

FISSION CHAIN AND/OR FISSION BURN

50%-70%

0.1%

1%

2%

X-RAYS

PROMPT GAMMAS

FISSION FUSION NEUTRONS

DELAYED GAMMAS

CAPTURE GAMMA (n, γ)

INELASTIC SCATTER GAMMA (n, n*)

PHOTOELECTRIC ELECTRONS

COMPTON ELECTRONS

PAIR PRODUCTION ELECTRONS

CHARGE DENSITIES

CURRENTS

E M P

SOURCE

PHOTON PRODUCTION

ELECTRON PRODUCTION

FIELD PRODUCTION

Bottom Line: electron moves in assymetric field

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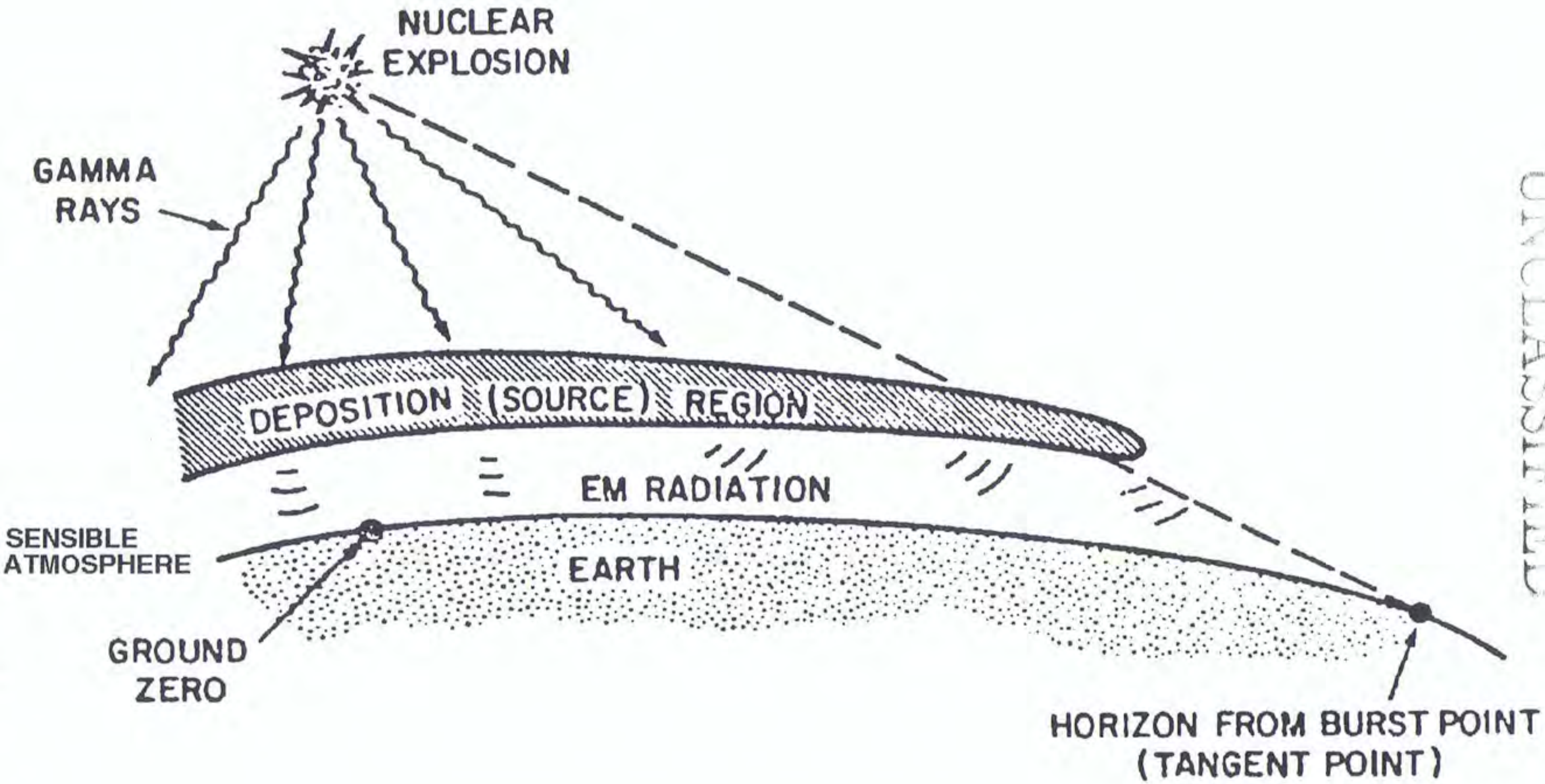
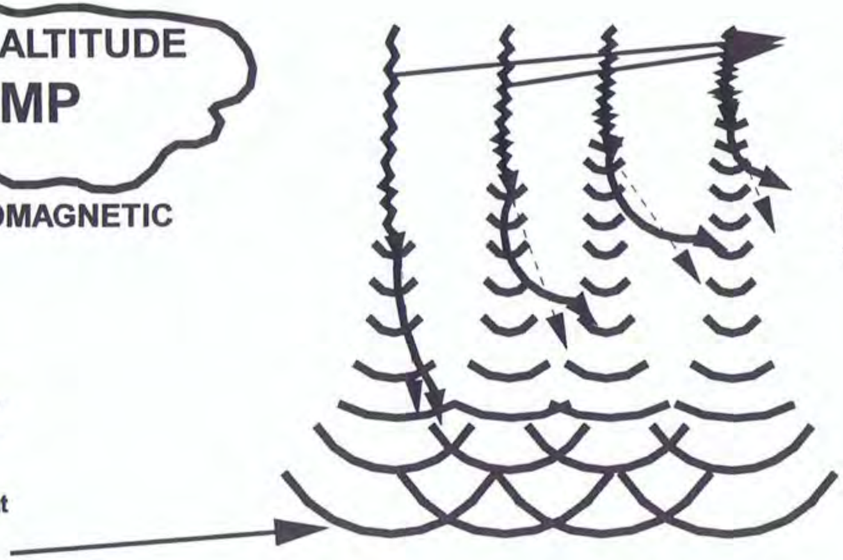
High Altitude EMP



HIGH ALTITUDE EMP

ELECTROMAGNETIC PULSE



Compton Electrons turning in Earth's magnetic field

High Altitude **EMP**

Constructive interference of radiation from different electrons

KEY Points

1. Each γ gives a downward traveling compton electron.
2. The electrons are turned by the earth's magnetic field.
3. The relativistic electrons radiate energy downward.
4. The γ 's and EMP radiation travel at the same speed.
   This leads to constructive interference of radiation from all electrons.

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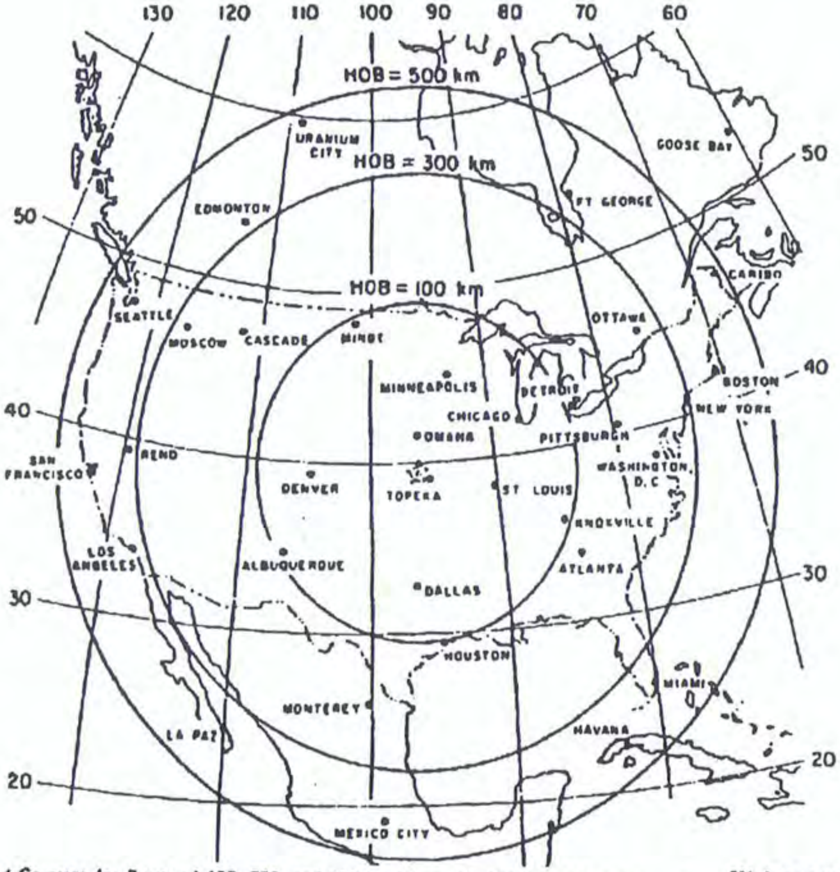
EMP PULSE



Ground Coverage for Bursts of 100, 300, and 500 km (about 62, 186, and 310 miles) for a Large Yield Burst Above the Geographical Center of the (counterminous) United States

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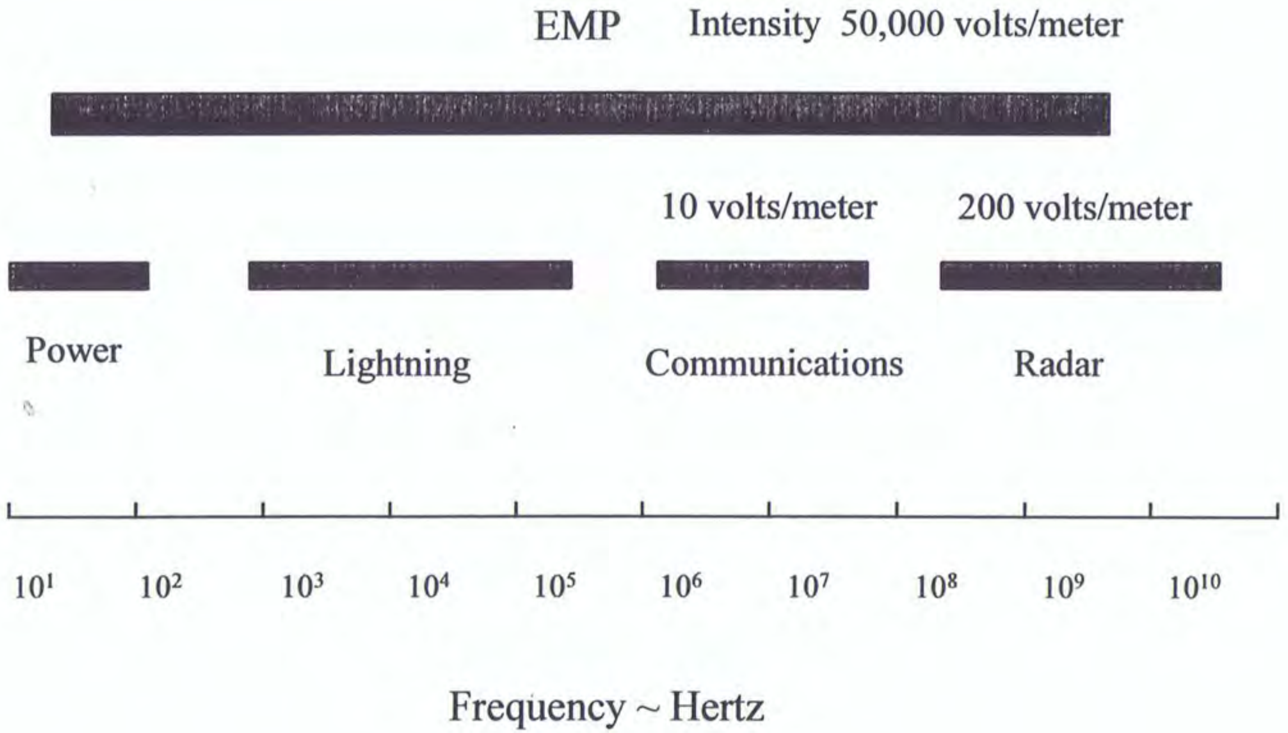
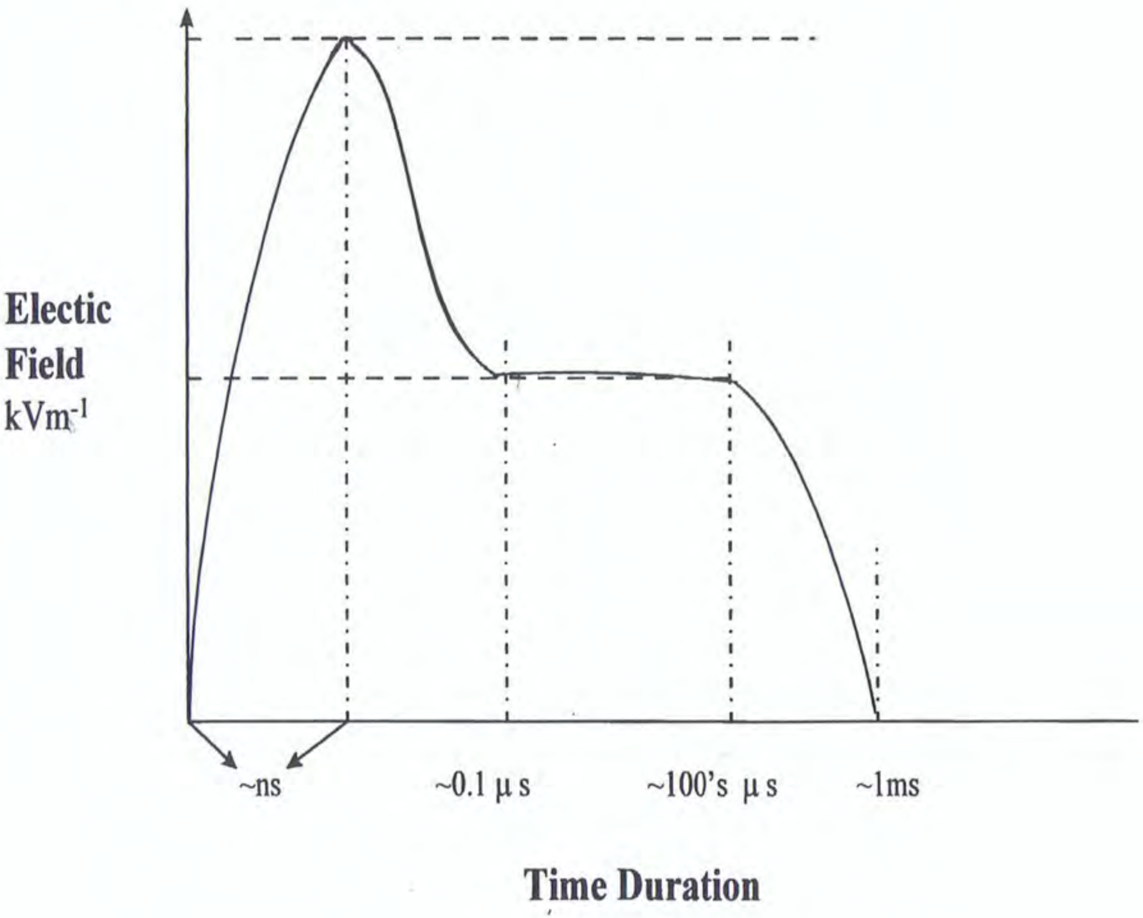
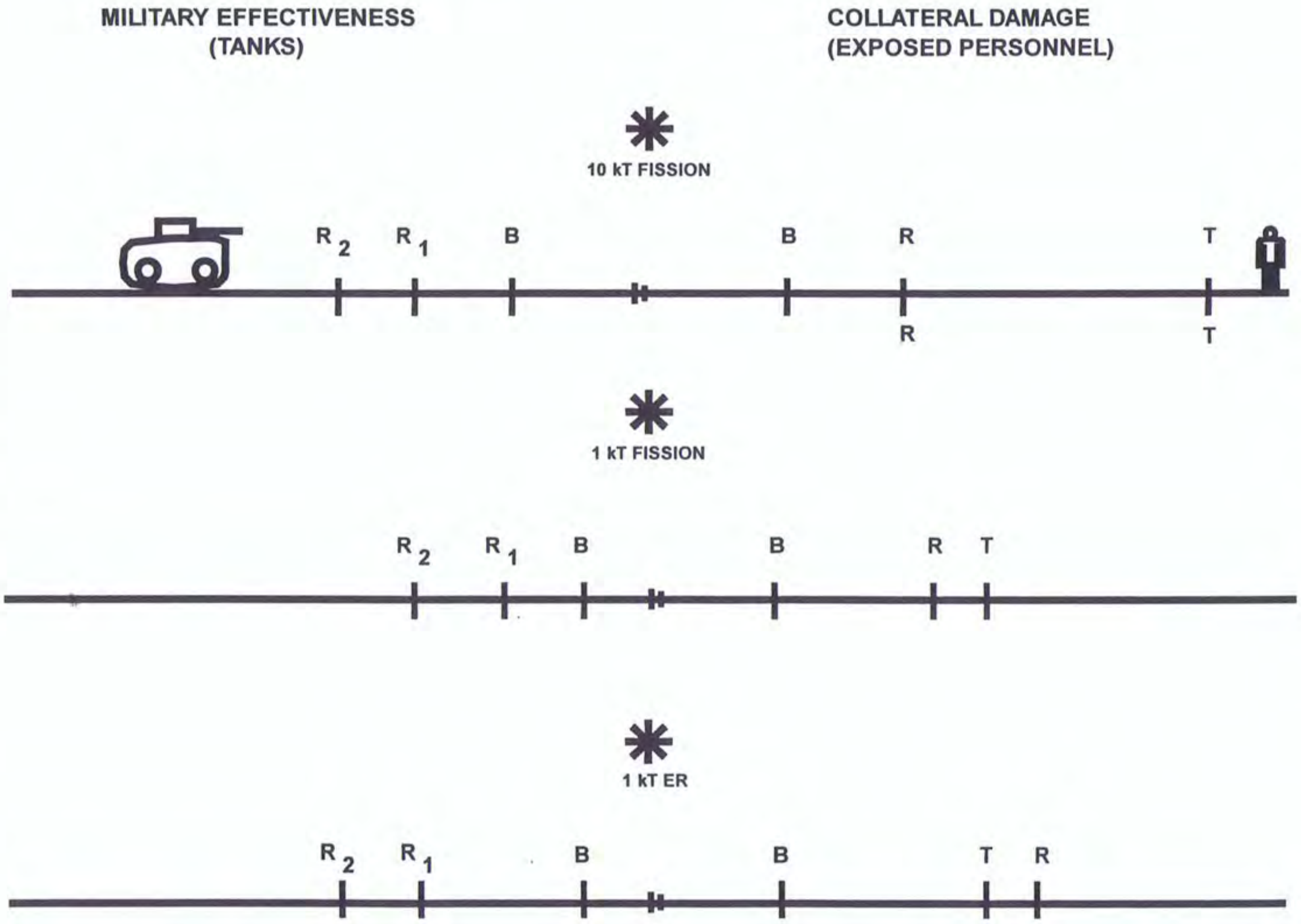
Frequency Spectrum Comparison



Representative EMP Pulse

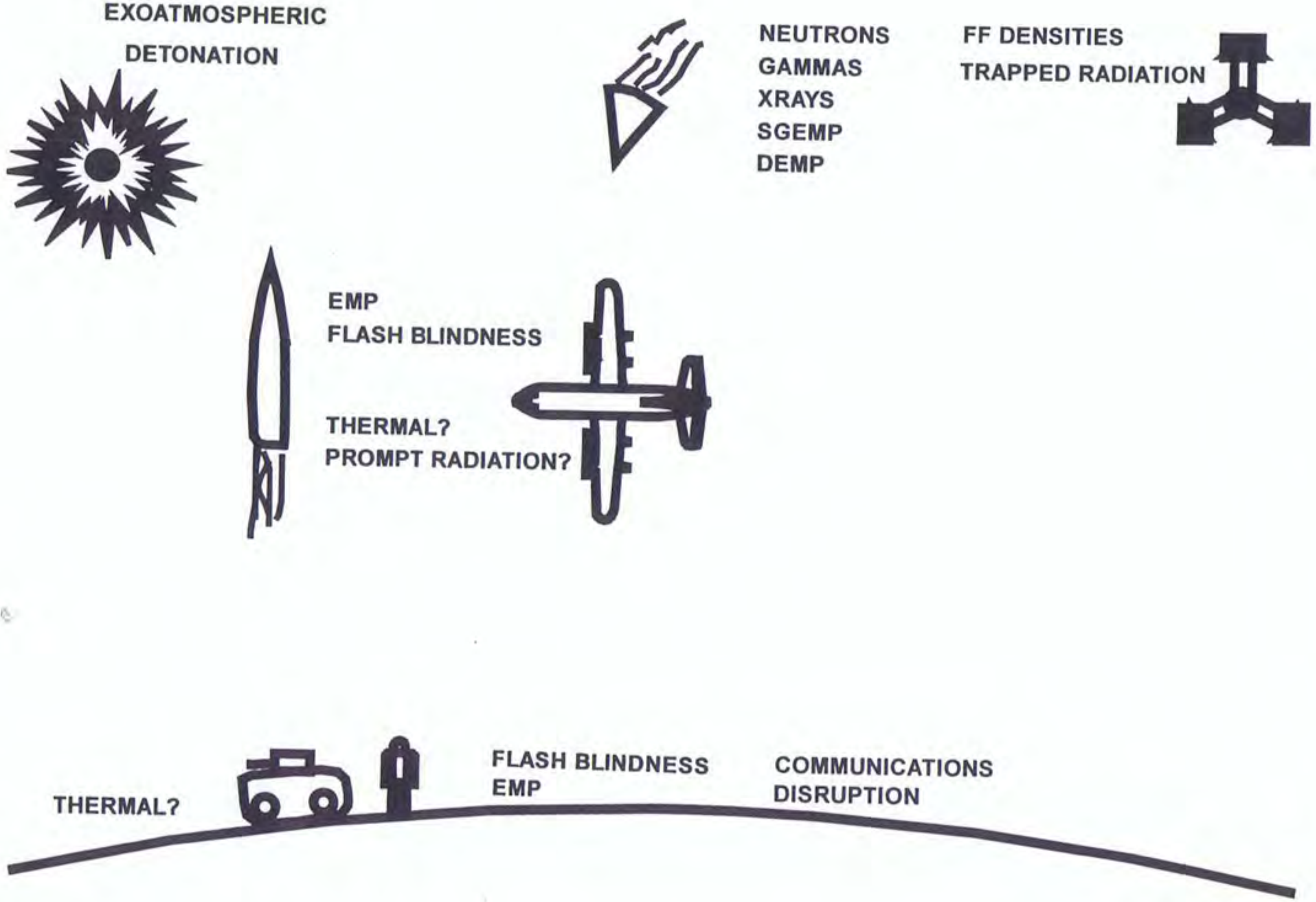



MILITARY EFFECTIVENESS
(TANKS)
COLLATERAL DAMAGE
(EXPOSED PERSONNEL)
10 kT FISSION
R_2
R_1
B
B
R
T
R
T
1 kT FISSION
R_2
R_1
B
B
R
T
1 kT ER
R_2
R_1
B
B
T
R

1 MT DETONATIONS AT VARIOUS HOB's (CO-Altitude)

	N 10^{12} n/cm ^{2}	N 10^{15} n/cm ^{2}	$\dot{\gamma}$ 10^8 rad/sec	$\dot{\gamma}$ 10^{13} rad/sec	X-ray 20 cal/cm ^{2}	X-ray 130 cal/cm ^{2}	Thermal 4 cal/cm ^{2}	Thermal 80 cal/cm ^{2}	Over 2 psi	Over 10 psi	Over 3000 psi
Exoatmospheric	157	5.6	760	2.4	56.8	22.2	-----	-----	-----	-----	-----
100,000 ft	12.5	5.5	190	2.3	10.4	6.0	98	22	8.5	4.6	.7
1,800 ft	6.2	2.5	9.0	1.3	-----	-----	49	19	29.5	10.8	.8
Surface	5.6	2.3	8.5	1.3	-----	-----	40.4	12.1	25	10	1.1

Distances to Effect Levels in kilo-feet



EXOATMOSPHERIC
DETONATION

NEUTRONS
GAMMAS
XRAYS
SGEMP
DEMP

FF DENSITIES
TRAPPED RADIATION

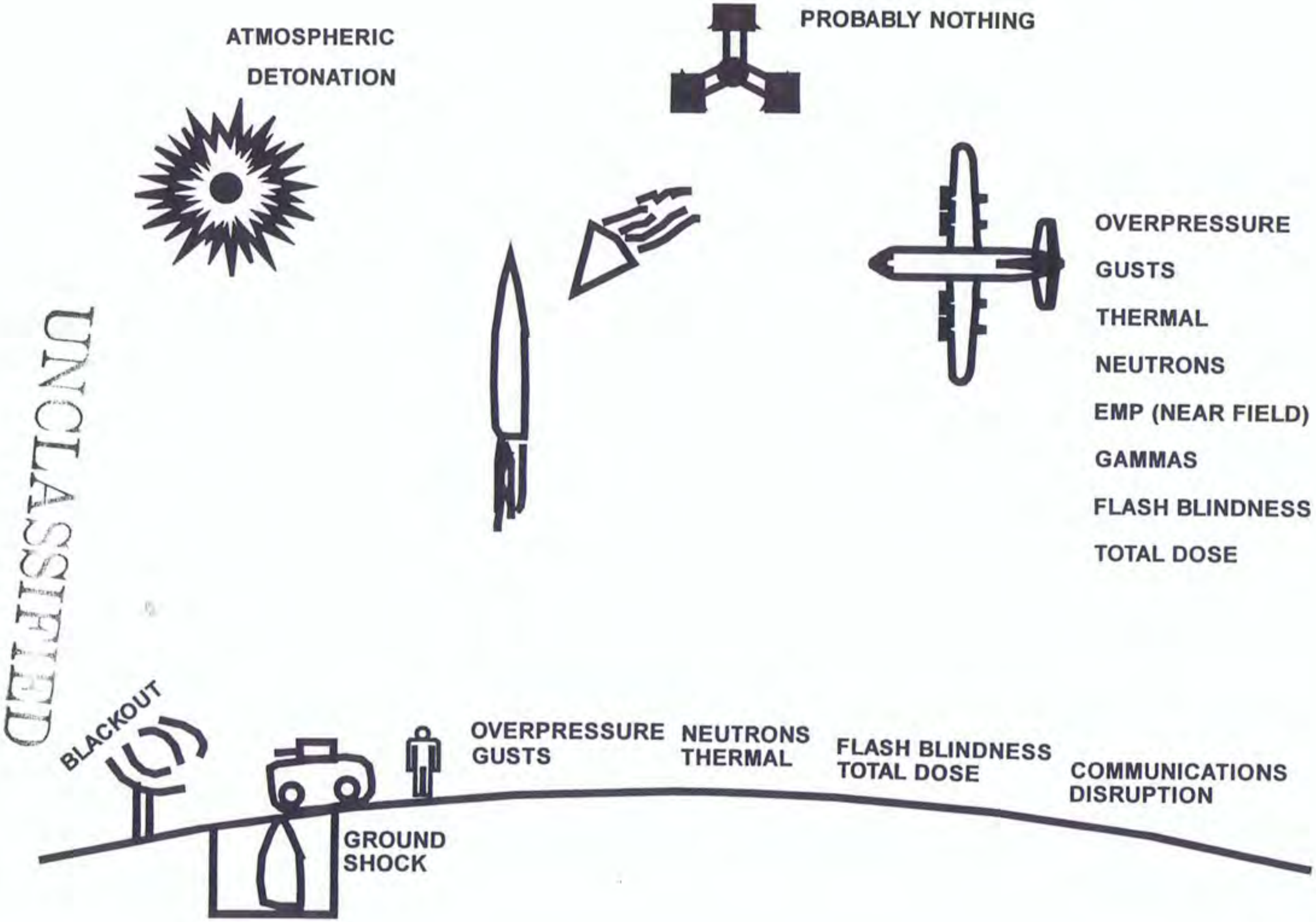
EMP
FLASH BLINDNESS

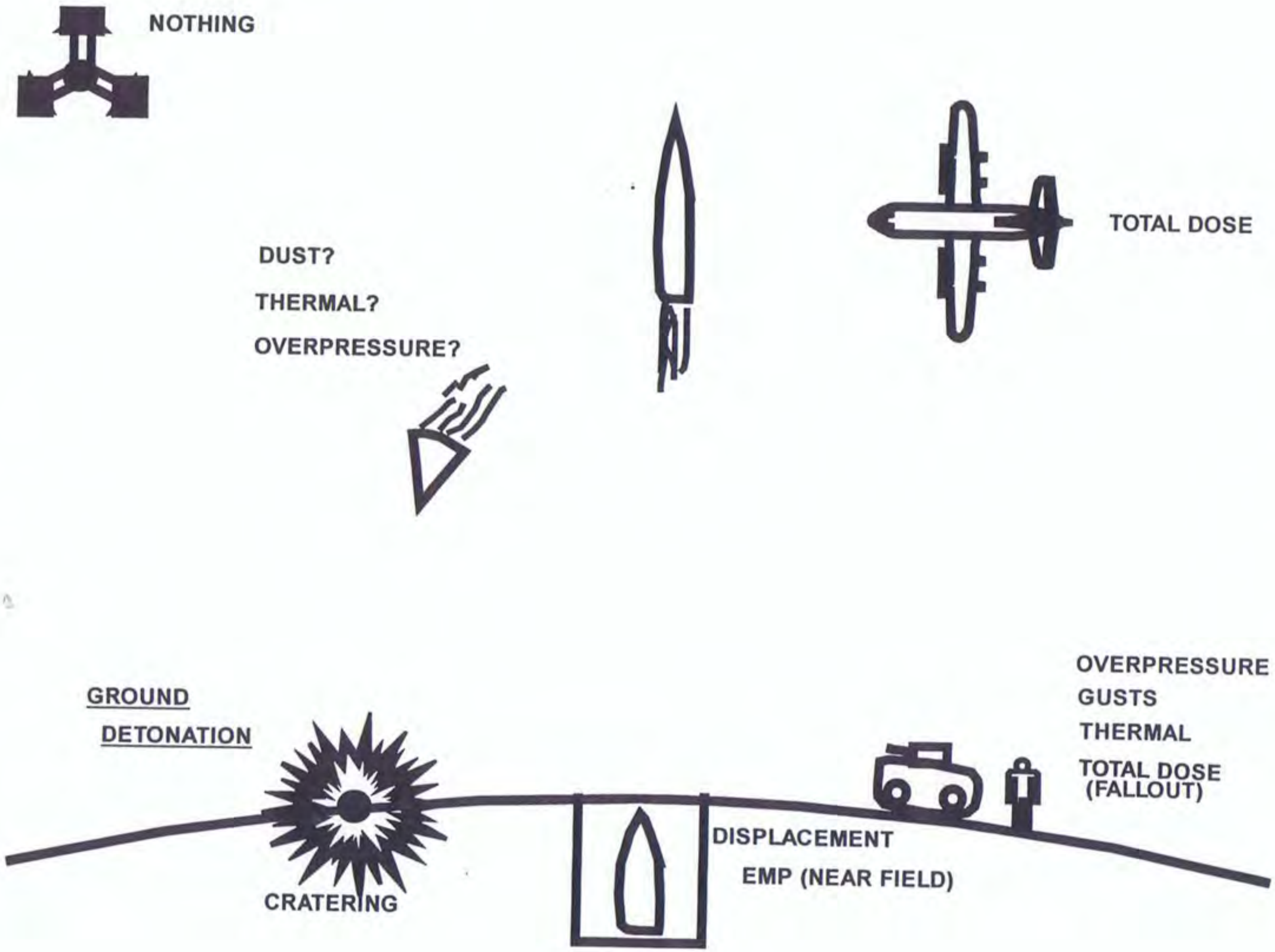
THERMAL?
PROMPT RADIATION?

THERMAL?

FLASH BLINDNESS
EMP

COMMUNICATIONS
DISRUPTION


ATMOSPHERIC DETONATION
PROBABLY NOTHING
OVERPRESSURE
GUSTS
THERMAL
NEUTRONS
EMP (NEAR FIELD)
GAMMAS
FLASH BLINDNESS
TOTAL DOSE
BLACKOUT
GROUND SHOCK
OVERPRESSURE
GUSTS
NEUTRONS
THERMAL
FLASH BLINDNESS
TOTAL DOSE
COMMUNICATIONS DISRUPTION


NOTHING
DUST?
THERMAL?
OVERPRESSURE?
TOTAL DOSE
GROUND
DETONATION
CRATERING
DISPLACEMENT
EMP (NEAR FIELD)
OVERPRESSURE
GUSTS
THERMAL
TOTAL DOSE
(FALLOUT)

Useful Rules-of-Thumb for Prompt Effects

- Emergency Risk
  - Thermal -- 3 cal/cm2
  - Blast -- 4 psi
- Casualty from Blast
  - Exposed personnel -- 18 psi
  - Severe Tank Damage -- 49 psi
- Radiation Dose
  - Casualty -- 8,000 rads
  - Emergency Risk -- 150 rads

Radiation Dose Immediate Casualty -- 8,000 rads

Range	Yield	Adjustment factor
~0.5 km	~1 KT fission	~100m range for every factor 2 in yield
~1 km	~ 1 KT enhanced Radiation	~100m range for every factor 2 in yield
~1 km	~ 25 KT typical Fission	~100m range for every factor 2 in yield

Radiation Dose-Prompt Effects

Casualty	8,000 rads	~0.5 km	1 KT fission
Casualty	8,000 rads	~ 1 km	1 KT ER
Casualty	8,000 rads	~ 1 km	25 KT fission
Emergency Risk	150 rads	~1.5 km	1 KT ER
Emergency Risk	150 rads	~1.5 km	25 KT fission

SOME EFFECTS LEVELS OF INTEREST

PEOPLE

THERMAL	2-5 CAL/CM2
OVERPRESSURE	>7 PSI
RADIATION	>100 RADS

Nuclear Targeting

- Through intelligence data, the targets have a vulnerability number associated with it that allows the DoD to assign a weapon VN number.
- Vulnerability Number (VN)

  XXPA XXQA

  First 2 digits are related to the amount of pressure:
  - P = over pressure (smash)
  - Q = dynamic pressure (winds)
  - A = adjustment for yield (tables geared to 20 kT)
- A typical VN:

  Airfield = 12 P0 ~ 10 psi

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REFERENCES

- THE EFFECTS OF NUCLEAR WEAPONS 3RD EDITION, GLASSTONE AND DOLAN, 1977, UNC

- CAPABILITIES OF NUCLEAR WEAPONS, DNA EM-1 PARTS I & II, SRD RS-3141 8798

SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

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SESSION IV

- HIGH EXPLOSIVES
- DETONATORS

PRIMARY	SECONDARY
•EASILY IGNITED WITH QUICK TRANSITION TO DETONATION	•INSENSITIVITY
•SMALL QUANTITY REQUIRED	•HIGH ENERGY DENSITY

PHYSICAL SEPARATION - TETRYL

PURF PLOSIVE COMPOUNDS.

Material[a]	Chemical name	Other designations	Color
*BTF	Benzotris-[1,2,5] oxadiazole-[4,4,7]-trioxide	Benzotrifuroxan, hexanitrosobenzene	Buff
*DATB	1,3-Diamino-2,4,6-trinitrobenzene		Yellow
*DIPAM	3,3-Diamino-2,2',4,4',6,6'-hexanitrobiphenyl	Hexanitrodiphenyl-amine hexite, dipicrylamine	—
*DNPA	2,2-Dinitropropyl acrylate		Off-white
*EDNP	Ethyl-4,4-dinitropentanoate		Yellow
*FEFO	Bis(2-fluoro-2,2-dinitroethyl)-formal		Straw
**HMX	1,3,5,7-Tetranitro-1,3,5,7-tetraazacyclooctane	Cyclotetramethylene tetranitramine, octogen	White
*HNAB	2,2',4,4',6,6'-Hexanitroazo-benzene		Orange
*HNS	2,2',4,4',6,6'-Hexanitrostilbene		Yellow
**NC (12% N)[b]	Partially nitrated cellulose	Nitrocellulose (lacquer grade), cellulose trinitrate, piroksilin	White
*NC (13,35% N, min)[b]	Partially nitrated cellulose	Nitrocellulose, guncotton	White
*NG	1,2,3-Propanetriol trinitrate	Nitroglycerin	Clear
*NM	Nitromethane		Clear
*NQ	Nitroguanidine	Aminomethaneamidine	White
**PETN	Pentaerythritol tetranitrate	Penthrite, TEN	White
**RDX	1,3,5-Trinitro-1,3,5-triaza-cyclohexane, hexahydro-1,3,5-trinitro-s-triazine	Cyclotrimethylene trinitramine, hexogen cyclonite,Gh	White
*TACOT	Tetranitro-1,2,5,6-tetraazadi-benzocyclooctatetrene	Tetranitrodibenzo-1,3a,4,6a-tetraazapentalene	Red-orange
**TATB	1,3,5-Triamino-2,4,6-trinitro benzene		Bright yellow
**Tetryl	2,4,6-Trinitrophenylmethyl-nitramine		Yellow
**TNM	Tetranitromethane		Clear
**TNT	2,4,6-Trinitrotoluene	Trotyl,T,tol	buff to brown

**Denotes it has been used in nuclear weapons

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Cast explosives: names and formulations.

	Formulation (wt%)[b]			
Explosive[a]	TNT	RDX	Other ingredients	
Baratol	24		$Ba(NO_3)_2$	76
Boracitol	40		Boric Acid	60
*Comp B, Grade A[c]	36	63	Wax	1
Comp B-3	40	60		
*Cyclotol[d]	25	75		
H-6	30	45	Wax	5
			Al	20
			$CaCl_2$	0.5
*Octol	25		HMX	75
*Pentolite[d]	50		PETN	50
Tritonal	80		Al	20

[a] Properties of materials marked with asterisks are summarized in data sheets (Section IV).

[b] The weight percent values given in the table are nominal and subject to some variation.

[c] Comp B, Grade A is formulated as a 60/40 RDX/TNT mixture, but high-quality castings usually are higher in RDX content due to the removal of a TNT-rich section at the top of the casting.

[d] There are several cyclotols and pentolites. The most common cyclotol is RDX/TNT 75/25. The most common pentolite is PETN/TNT 50/50.

Plastic-bonded explosives: Names and formulations.

Explosive[a]	Other ingredients	Formulation		Color
		Ingredient	wt%	
*LX-04-1	PBHV-85/15	HMX	85	Yellow
		Viton A	15	
*LX-07-2	RX-04-BA	HMX	90	Orange
		Viton A	10	
*LX-09-0	RX-09-CB	HMX	93	Purple
		pDNPA	4.6	
		FEFO	2.4	
LX-09-1		HMX	93.3	Purple
		pDNPA	4.4	
		FEFO	2.3	
*LX-10-0	RX-04-DE	HMX	95	Blue-green spots on white
		Viton A	5	
LX-10-1		HMX	94.5	Blue-green spots on white
		Viton A	4.5	
*LX-11-0	RX-04-PI	HMX	80	White
		Viton A	20	
*LX-14-0		HMX	95.5	Violet spots on white
		Estane 5702-FI	4.5	
*PBX-9007	PBX-9007 Type B	RDX	90	White or mottled gray
		Polystyrene	9.1	
		Di(2-ethyl-hexyl)-phthalate	0.5	

Plastic-bonded explosives: Names and formulations. (cont.)

		Formulation		
		Rosin	0.4	
*PBX-9010		RDX	90	White
		Kel-F	10	
*PBX-9011	X-0008	HMX	90	Off-white
		Estane 5740-X2		
*PBX-9205		RDX	92	White
		Polystyrene	6	
		Di(2-ethylhexyl)-phthalate	2	
*PBX-9404	PBX-9404-03	HMX	94	White or blue
		NC (12.0% N)	3	
		Tris (B-chloro-ehtyl)-phosphate	3	
*PBX-9407		RDX	94	White or black
		Exon 461	6	
*PBX-9501		HMX	95	White
		Estane	2.5	
		BDNPA	1.25	
		BDNPF	1.25	
PBX-9502		TATB	.05 Kel F	
LX-17		TATB	.075 Kel F	

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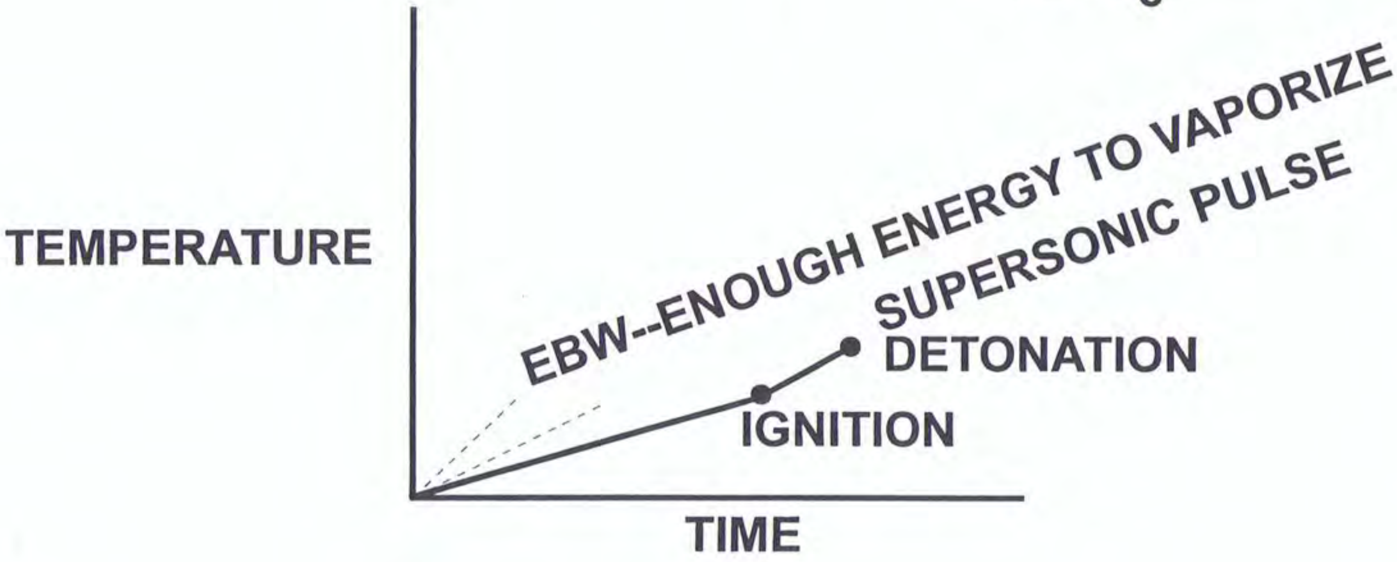
LEAD AZIDE
PbN_6



EBW (EXPLODING BRIDGEWIRE) EVOLVED

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REFERENCES

- AN INTRODUCTION TO NUCLEAR WEAPONS; WASH 1037 REVISED; GLASSTONE, JUNE 1972
- PROPERTIES OF CHEMICAL EXPLOSIVES AND EXPLOSIVE SIMULANTS; LLL JULY 31, 1974, DOBRATZ UCRL - 51319, REV 1
- SENSITIVITY OF INITIATION-SYSTEM DETONATORS: REVIEW OF CURRENT AND ADVANCED TECHNOLOGIES; R. E. SETCHELL; SAND91-1590

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No Notes for this Section

REFERENCES

- AN INTRODUCTION TO NUCLEAR WEAPONS; WASH 1037 REVISED, GLASSTONE, JUNE 1972
- SOURCE BOOK ON ATOMIC ENERGY; GLASSTONE, 3rd EDITION
- NUCLEAR TEST SUMMARY TRINITY — HARDTACK DASA 1220; RS3141/10349
- VARIOUS WEAPON DEVELOPMENT REPORTS

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No Notes for this Section

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REFERENCES

- AN INTRODUCTION TO NUCLEAR WEAPONS; WASH 1037 REVISED, GLASSTONE, JUNE 1972

- SOURCE BOOK ON ATOMIC ENERGY; GLASSTONE, 3rd EDITION

- NUCLEAR TEST SUMMARY TRINITY — HARDTACK DASA 1220; RS3141/10349

- VARIOUS WEAPON DEVELOPMENT REPORTS

SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

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SESSION VII

- NUCLEAR DETONATION SAFETY
- NUCLEAR MATERIAL SCATTER

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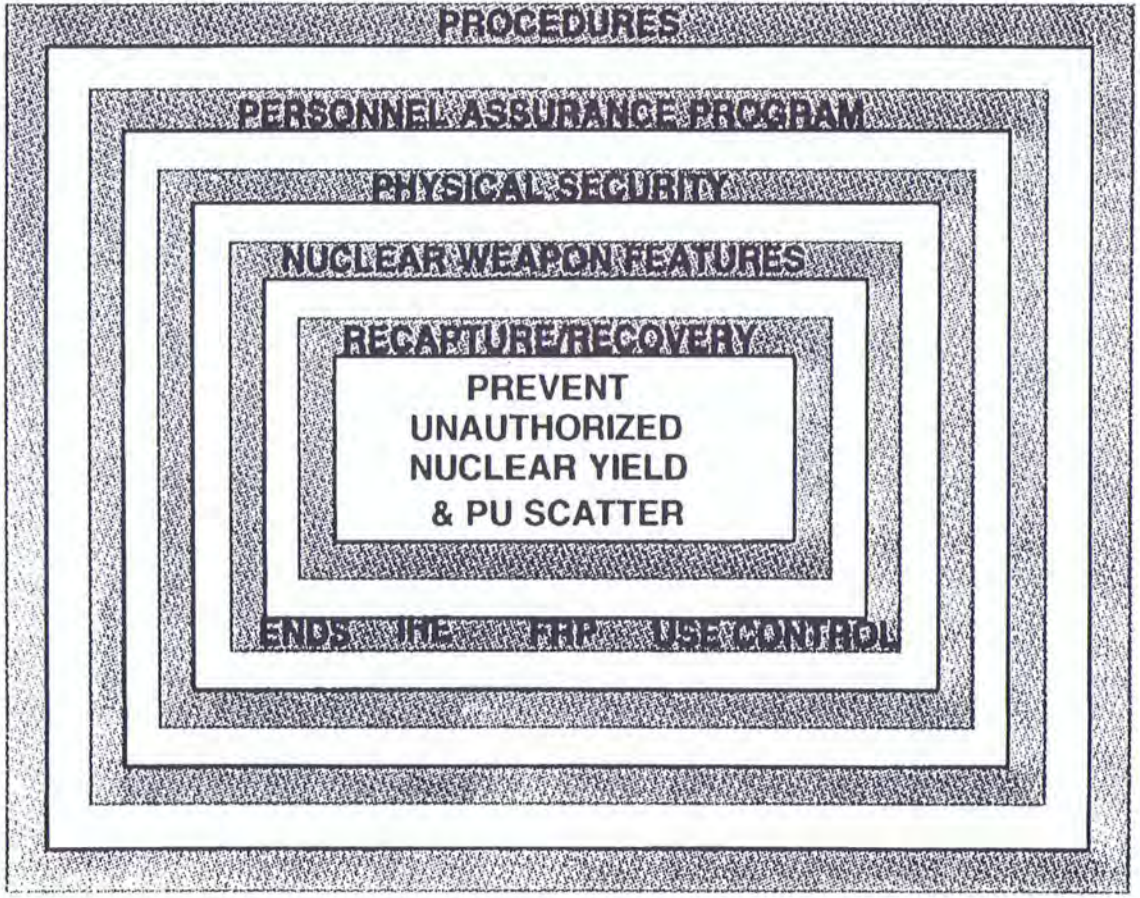
Surety

PART OF A LAYERED NATIONAL PROGRAM PROTECTING AGAINST UNAUTHORIZED NUCLEAR DETONATION OR PLUTONIUM SCATTER

THE ADVERSARY: → **Accidents - Safety**
Humans - Security & Use Control



PROCEDURES

PERSONNEL ASSURANCE PROGRAM

PHYSICAL SECURITY

NUCLEAR WEAPON FEATURES

RECAPTURE/RECOVERY

PREVENT UNAUTHORIZED NUCLEAR YIELD & PU SCATTER

ENDS IHE FRP USE CONTROL

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Nuclear Weapon Surety aims to prevent three consequences

Nuclear yield - release of nuclear energy greater than the energy of four pounds of high explosive

Launch or release - sending a nuclear weapon toward a target

Pu dispersal - release of plutonium outside the weapon

The goal of surety standards

Compliance with nuclear weapon system surety standards should provide assurance against undesired consequences
(nuclear yield, launch, or Pu dispersal)
resulting from any causes
(either intended or unintended).

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Consequences

Causes	☑	☑	☑
	☑	☑	☑

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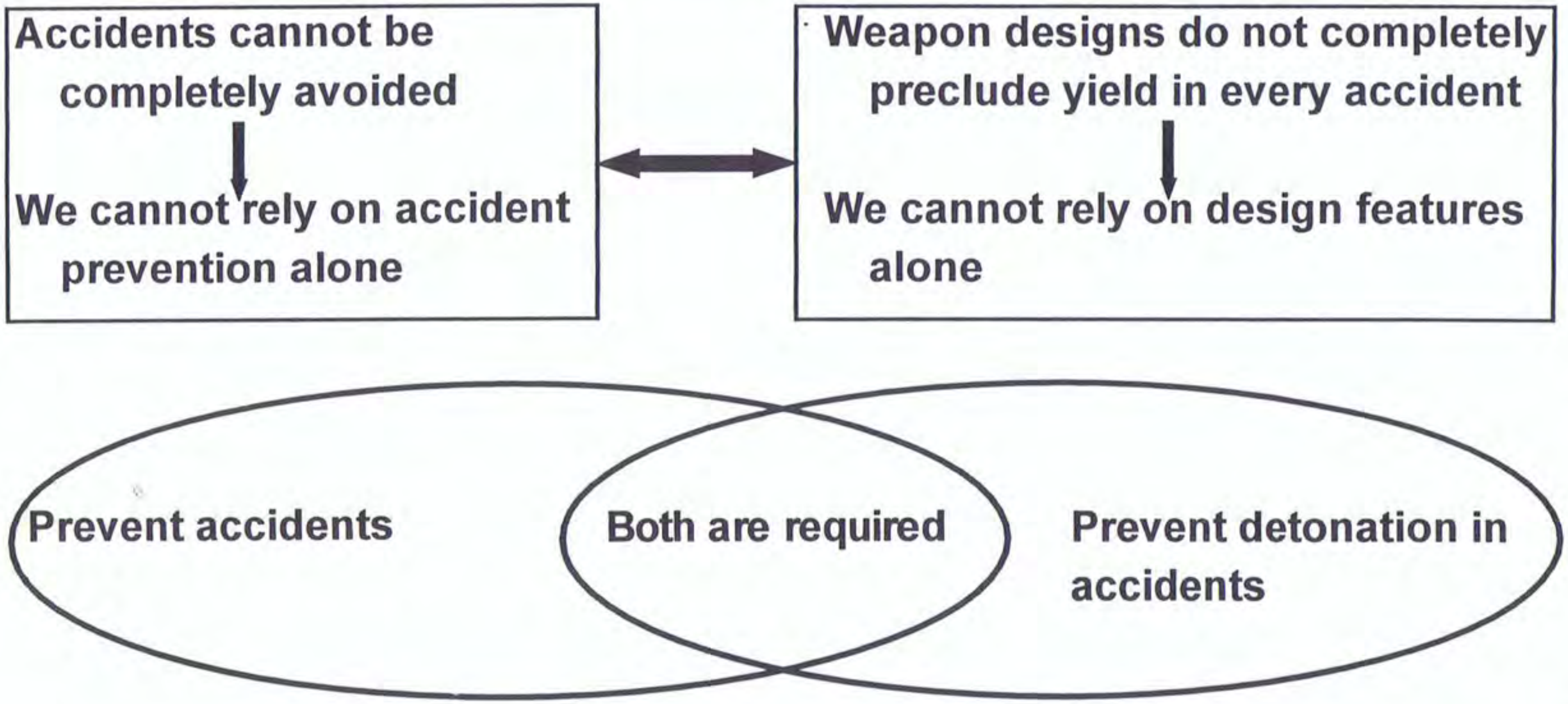
The dual approach to nuclear weapons safety



Accidents cannot be completely avoided

We cannot rely on accident prevention alone

Weapon designs do not completely preclude yield in every accident

We cannot rely on design features alone

Prevent accidents

Both are required

Prevent detonation in accidents

DOE shares responsibility for safety, security, and control

From the 1983 <u>Memorandum of Understanding between DOE and DoD on Objectives and Responsibilities for Joint Nuclear Weapon Activities</u>

"The obligation of the DoD and the DOE to protect public health and safety provides the basic premise for dual-agency judgment and responsibility for safety, security and control (S^2C) of nuclear weapons. This check-and-balance role shall continue. The DoD and the DOE share the responsibility to:

1) Identify and resolve health and safety problems connected with nuclear weapons. In particular, the DOE has a continuing responsibility to participate with the DoD in the consideration of these health and safety problems for nuclear weapons in DoD custody.

2) Prevent unauthorized use of a nuclear weapon through the use of positive control measure...

3) Determine the adequacy and effectiveness of physical security measures..."

Department of Defense Directive

3150.2

Replaces DoD 5030.15...February 8, 1984

SAFETY STANDARDS

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1. There shall be positive measures to prevent nuclear weapons involved in accidents or incidents, or jettisoned weapons, from producing a nuclear yield.

2. There shall be positive measures to prevent deliberate prearming, arming, launching, firing, or releasing of nuclear weapons, except upon execution of emergency war orders or when directed by competent authority.

3. There shall be positive measures to prevent inadvertent prearming, arming, launching, firing, or releasing of nuclear weapons in all normal and credible abnormal environments.

4. There shall be positive measures to ensure adequate security of nuclear weapons, pursuant to DoD Directive 5210.41.

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DOE Order 5610.10

10/10/90

Nuclear Explosive Safety Standards

a. There shall be positive measures to prevent nuclear explosives involved in accidents or incidents from producing a nuclear yield.

b. There shall be positive measures to prevent deliberate prearming, arming, or firing of a nuclear explosive except when directed by competent authority.

c. There shall be positive measures to prevent the inadvertent prearming, arming, launching, firing, or releasing of a nuclear explosive in all normal and credible abnormal environments.

d. There shall be positive measures to ensure adequate security of nuclear explosives pursuant to the DOE safeguards and security requirements.

e. There shall be positive measures to prevent accidents, inadvertent, or deliberate unauthorized dispersal of plutonium to the environment.

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DOE Nuclear Explosive Surety Standard

All DOE nuclear explosive operations shall meet the the following qualitative surety standards to prevent unintended nuclear detonation, fissile material dispersal from the pit, or loss of control. There shall be positive measures to:

- Minimize the possibility of accidents, inadvertent acts, or authorized activities that could lead to fire, high explosive deflagration, or unintended high explosive detonation;
- Minimize the possibility of fire, high explosive deflagration, or high explosive detonation, given accidents or inadvertent acts;
- Minimize the possibility of deliberate unauthorized acts that could lead to high explosive deflagration or high explosive detonation;
- Ensure adequate security of nuclear explosives;
- Minimize the possibility of or delay unauthorized nuclear detonation.

Reference: DOE Order 452.1, October 4, 1996

Positive Measures

From DOE Order 5610.10

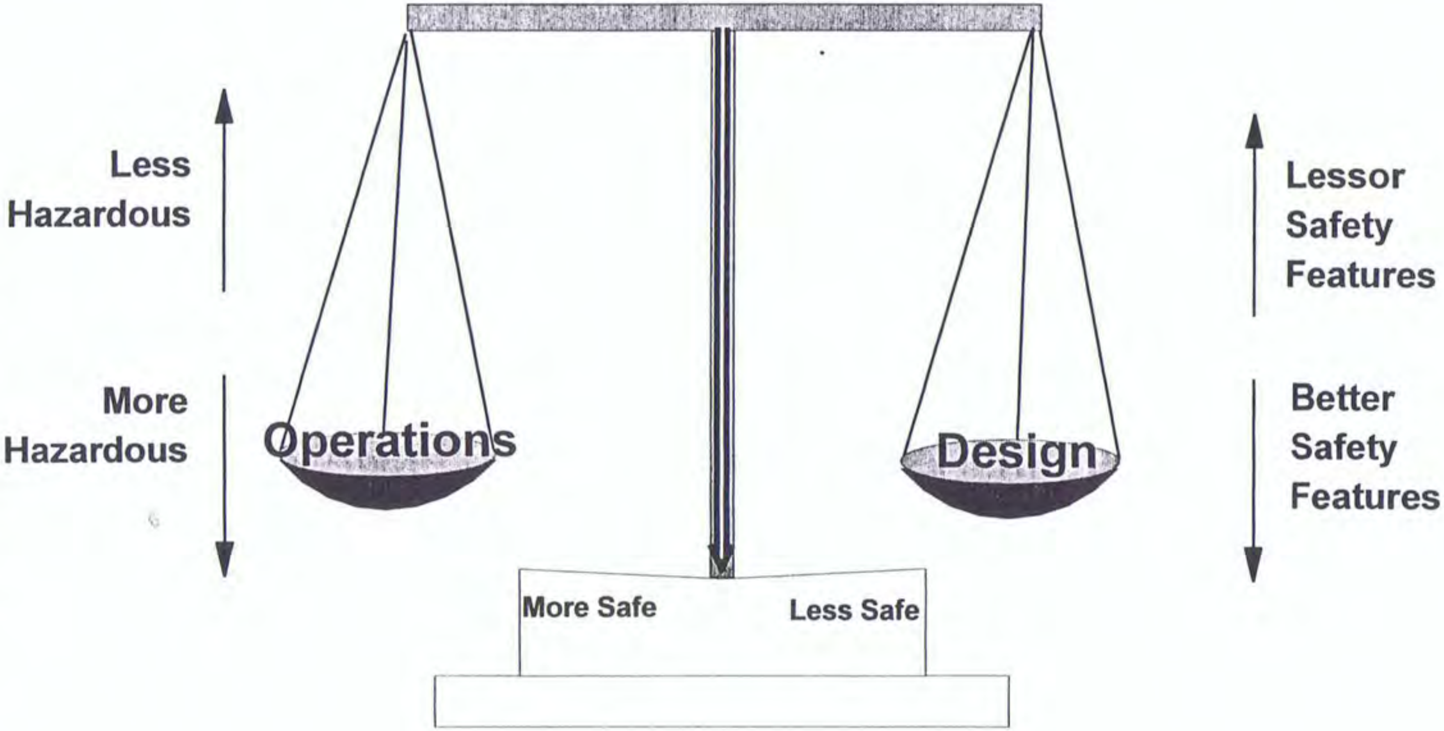
- Design features, safety rules, procedures, or other controls used individually or collectively to provide nuclear explosive safety.
- Positive measures are intended to assure a safe response in applicable operations and be controllable.
- Examples
    strong-link switches
    other safety devices
    administrative procedures and controls
    general and specific nuclear explosive safety rules
    design control of electrical equipment and mechanical
    tooling physical, electrical, and mechanical restraints
    incorporated in facilities and transport equipment

Explanation of normal and abnormal environments

Normal environments (temperature, shock, electrical connections, etc.) are those defined in the weapon or system specifications and intended to be tolerated by the weapon or system. The system is designed to function normally during its entire lifetime if it experiences normal environments.

Abnormal environments are conditions experienced by the weapon or system that are outside the defined normal environments (more extreme temperatures, shocks, voltages, etc.). The weapon or system is not required to function after exposure to an abnormal environment.

OPERATIONS & SAFETY DESIGN MUST BE BALANCED



Less Hazardous

More Hazardous

Operations

Design

More Safe

Less Safe

Lessor Safety Features

Better Safety Features

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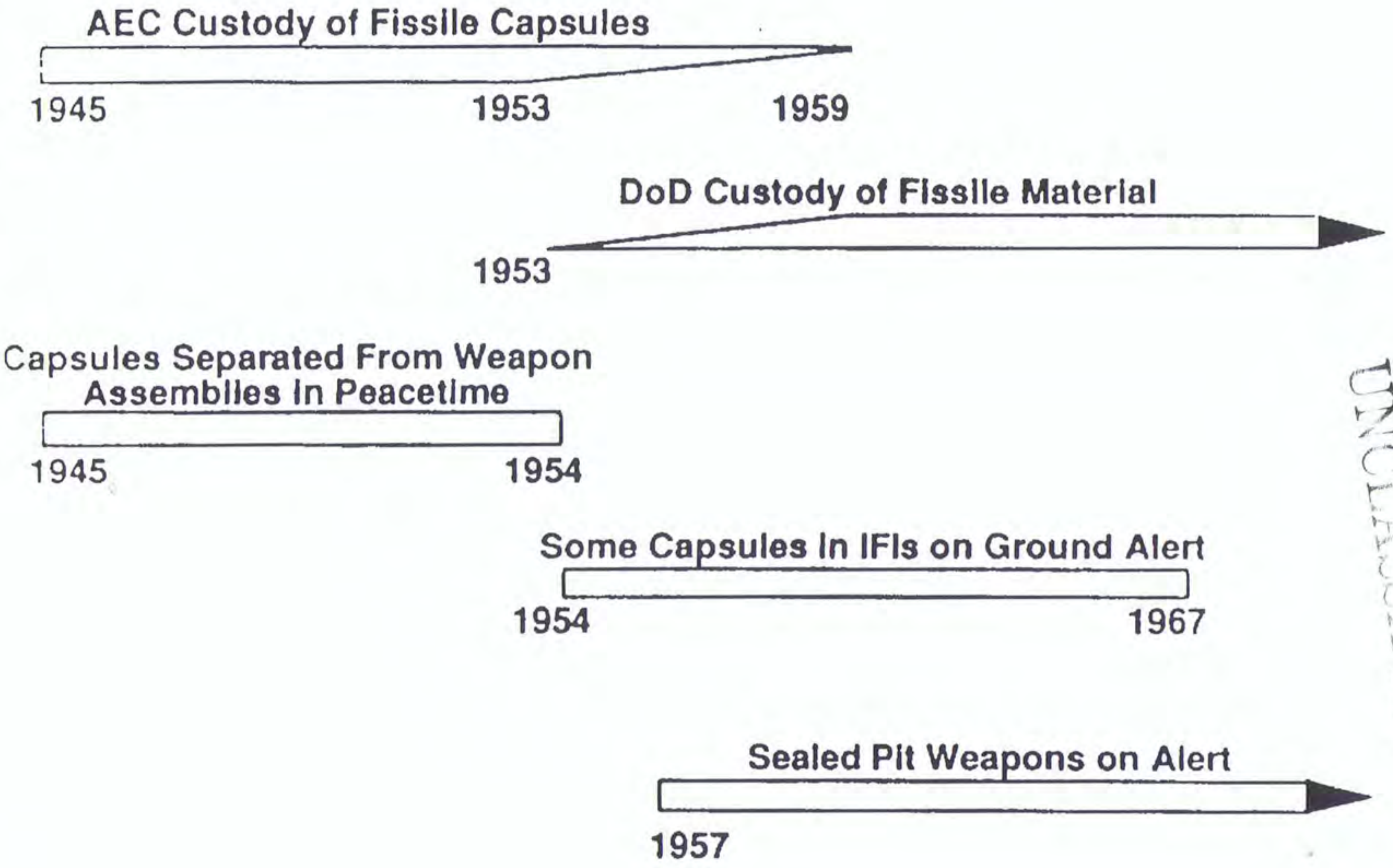
U. S. NUCLEAR DEPLOYMENTS CHANGED



AEC Custody of Fissile Capsules

1945 1953 1959

DoD Custody of Fissile Material

1953

Capsules Separated From Weapon Assemblies In Peacetime

1945 1954

Some Capsules In IFIs on Ground Alert

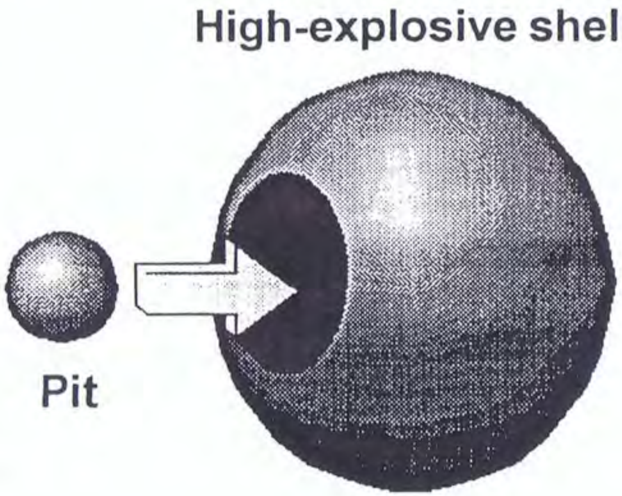
1954 1967

Sealed Pit Weapons on Alert

1957

Manually Inserted Capsules

1948 - 1951



- Safety Theme: Separation of fissile material and HE
- Analysis: Accident must assemble weapon

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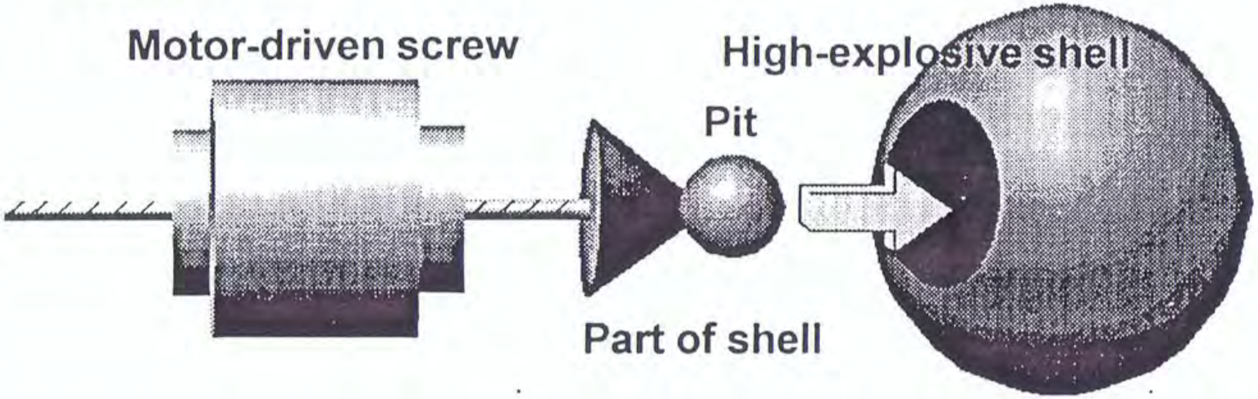
Mechanically Inserted Capsules

1952 - 1967



- Safety Theme: Separation of fissile material and HE and electrical isolation
- Analysis: Accident could assemble weapon by operating motor or by mechanical damage

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Sealed-pit Weapons

1957

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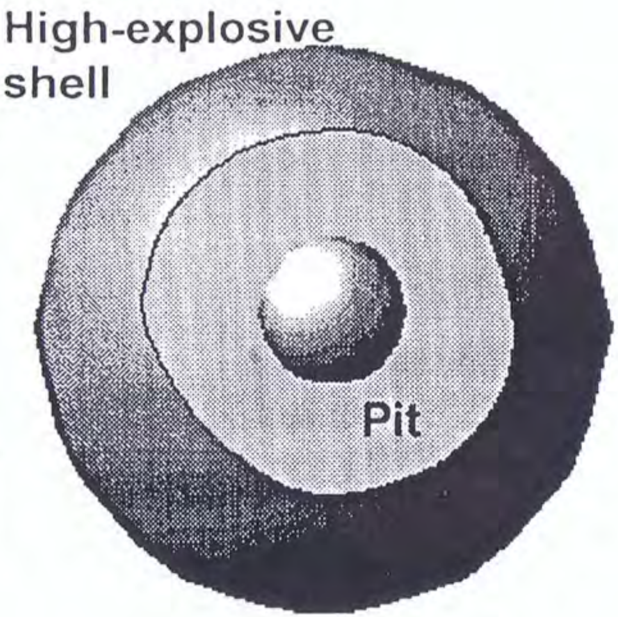

- Safety Theme: Electrical isolation and one-point safety
- Analysis: Accident could generate firing signals; not one-point safe

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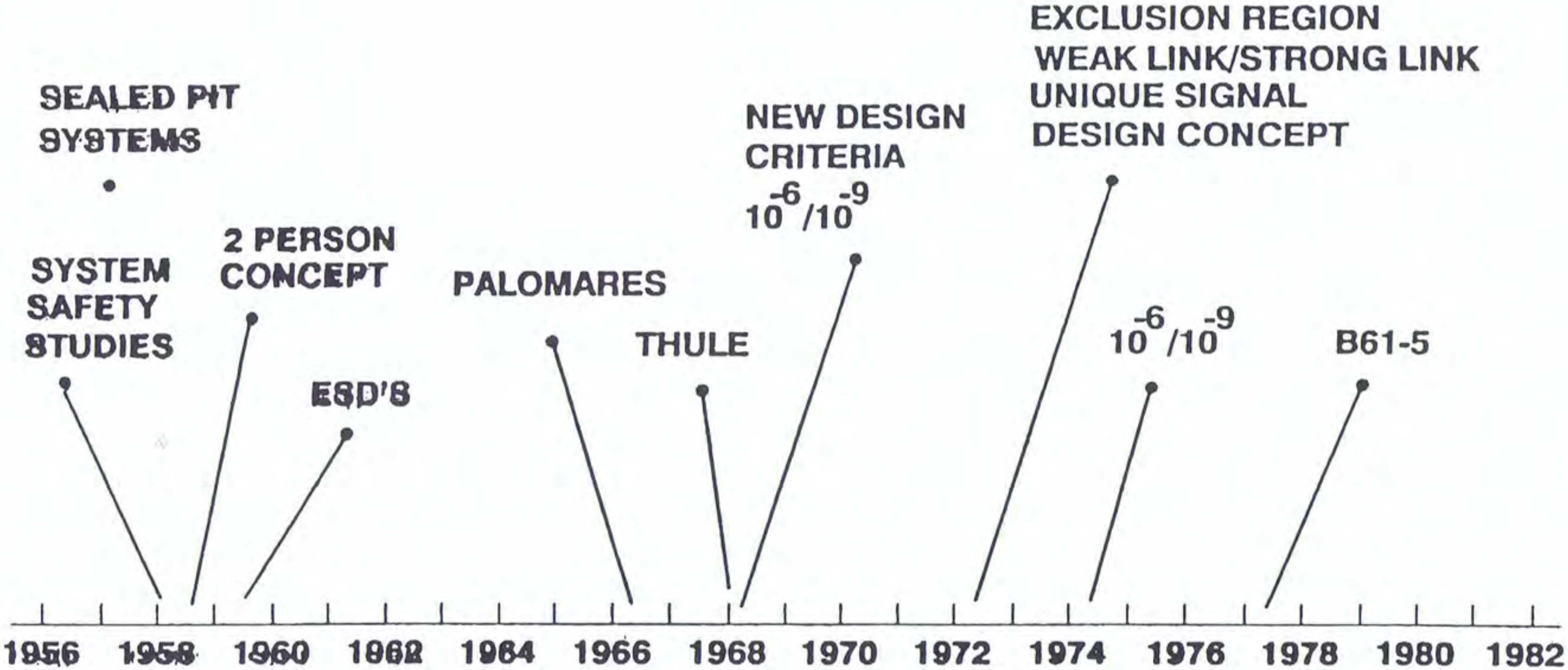
EVOLUTION OF NUCLEAR SAFETY



SEALED PIT SYSTEMS

SYSTEM SAFETY STUDIES

2 PERSON CONCEPT

ESD'S

PALOMARES

THULE

NEW DESIGN CRITERIA $10^{-6}/10^{-9}$

EXCLUSION REGION
WEAK LINK/STRONG LINK
UNIQUE SIGNAL
DESIGN CONCEPT

$10^{-6}/10^{-9}$

B61-5

Early Electrical Isolation Safety Features

1950 - 1970

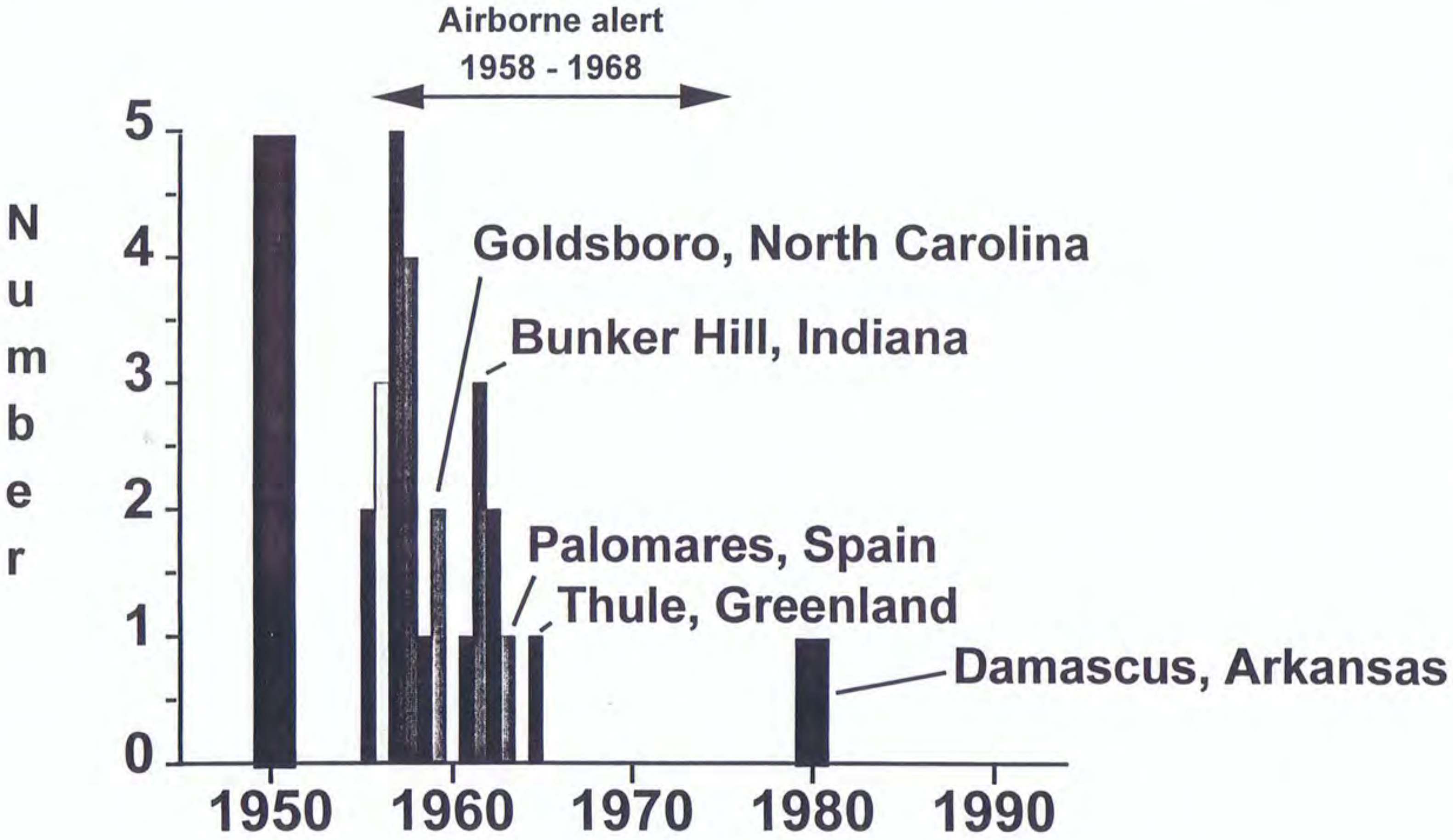
- Removable safing plugs
- Circuit board and cable isolation
- Removable or external power supplies
- Ready-safe switches
- Thermal fuses
- Environmental sensing devices

Environmental Sensing Devices (ESDs)

An open switch in the prearming circuits.

It is closed after sensing an environment experienced by the weapon system when enroute to the target.

US Nuclear Weapon Accidents



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B-52G INCIDENT
GRAND FORKS AFB
15 SEPTEMBER 1980

DURING A CARTRIDGE START FOR AN ALERT EXERCISE, AN ALERT CONFIGURED B-52G EXPERIENCED A FIRE IN THE NUMBER 5 ENGINE. 30 KNOT WIND WAS FORTUITOUSLY BLOWING FROM DIRECTION DIRECTLY AFT OF AIRCRAFT. FIRE WAS FOUGHT FOR THREE HOURS BEFORE FUEL FLOW TO ENGINE POD WAS SHUT OFF AND FLAMES EXTINGUISHED. ENGINE POD AND LEADING EDGE OF WING WERE DAMAGED, ALONG WITH SOME MINOR DAMAGE TO FUSELAGE SKIN.

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Nuclear Weapon Accident--Definition
DOD Directive 5100.52

An unexpected event involving nuclear weapons or nuclear components that results in any of the following:

(1) Accidental or unauthorized launching, firing, or use by U.S. forces or U.S. supported allied forces of a nuclear capable weapon system.

(2) An accidental, unauthorized, or unexplained nuclear detonation.

(3) Non-nuclear detonation or burning of a nuclear weapon or nuclear component.

(4) Radioactive contamination.

(5) Jettisoning of a nuclear weapon or nuclear component.

(6) Public hazard, actual or perceived.

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Accidents (mainly air-delivered systems) eventually led to reexamination of the premature nuclear yield criteria and to the present nuclear detonation safety design criteria.

Need for a Safety Process

- As the deployment dates for sealed pit weapons approached, the Armed Forces Special Weapons Project (AFSWP) and the Services became uncomfortable with their lack of knowledge and understanding of weapon safety designs.

- 1957, AFSWP convened a safety Board to examine the sealed pit weapon systems becoming available.

- Between 1957 and 1960, the Air Force convened joint safety study groups as weapons entered the stockpile.

- A formal, Joint DoD/DOE Nuclear Weapons System Safety process was established in 1960.

DoD/DOE Nuclear Weapon Safety Process

- Joint Safety Study of Each Weapon System and Operational Concept
  - Determine if Weapon System Meets the 4 Qualitative Standards
  - Develop Operation Safety Rules

    <u>and</u>

  - Ensure Maximum Safety Consistent with Operational Requirements

1968 -- DoD/DOE Agree on Premature Nuclear Detonation Design Safety Criteria

- The probability of a premature nuclear detonation due to component malfunctions, in the absence of any input signals except for specified (e.g. monitoring and control), shall not exceed.

(1) For normal storage and operational environments described in the STS, 1 in 10^9 per weapon lifetime.

(2) For the abnormal environments described in the STS, 1 in 10^6 per weapon exposure or accident.

1968 -- DoD/DOE Agree on One-Point Detonation Design Safety Criteria

---

One Point Safety

a. In the event of a detonation initiated at any one point in the high explosion system, the probability of achieving a nuclear yield greater than four pounds TNT equivalent shall not exceed one in one million.

b. One-point safety shall be inherent in the nuclear design, that is, it shall be obtained without the use of a nuclear safing device.

Four Pounds

"The four pounds TNT equivalent evolved from a U.S. Navy requirement based upon personnel exposure in the engine room of an aircraft carrier resulting from a small nuclear yield occuring on the flight deck 50 feet above the engine room (Ref. 5). A study concluded that a detonation giving a nuclear contribution equivalent to 44 pounds of TNT would result in a 50% sickness dose (SD_{50}) of 200 neutron rad to personnel in the engine room. To be conservative, a reliability factor of 10 was applied and the result rounded to four pounds. Another study, conducted in 1967 by the U.S. Army Nuclear Defense Laboratory, concluded that 8.5 pounds TNT equivalent would produce 200 neutron rad at 50 feet. This figure had a reliability factorr of two applied and the result rounded to four pounds, also."

Reference: "One-Point Safety," Defense Science, LANL, March-April 1983

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Conclusion of Stockpile Study

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New approach to nuclear weapon safety needed

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Safety Goals for Abnormal Environments

- Assured, predictable, safe response of the warhead electrical system
- Maintain predictable, safe response until intended use
- Minimize safety critical components and dependence on knowing accident scenario

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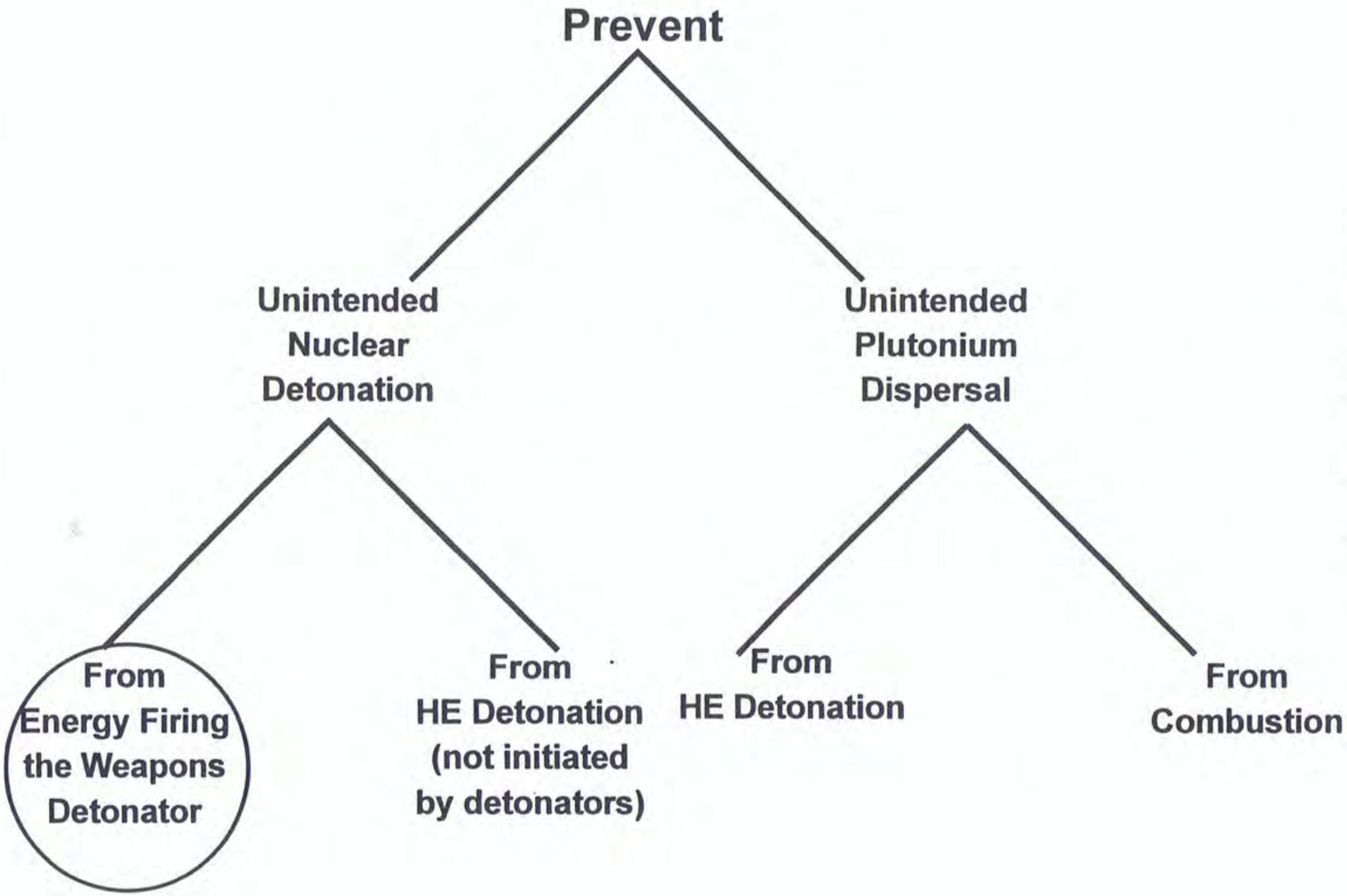
Modern Nuclear Safety -- The 4 I's

- **Isolation**
  - **Barriers**
  - **Stronglink switches**
- **Incompatibility**
  - **Unique signals**
- **Inoperability**
  - **Co-location of stronglinks and weaklinks**
- **Independence of safety subsystems**

MORE SPECIFICALLY THE SAFETY GOALS ARE TO



Prevent

Unintended Nuclear Detonation

From Energy Firing the Weapons Detonator

From HE Detonation (not initiated by detonators)

Unintended Plutonium Dispersal

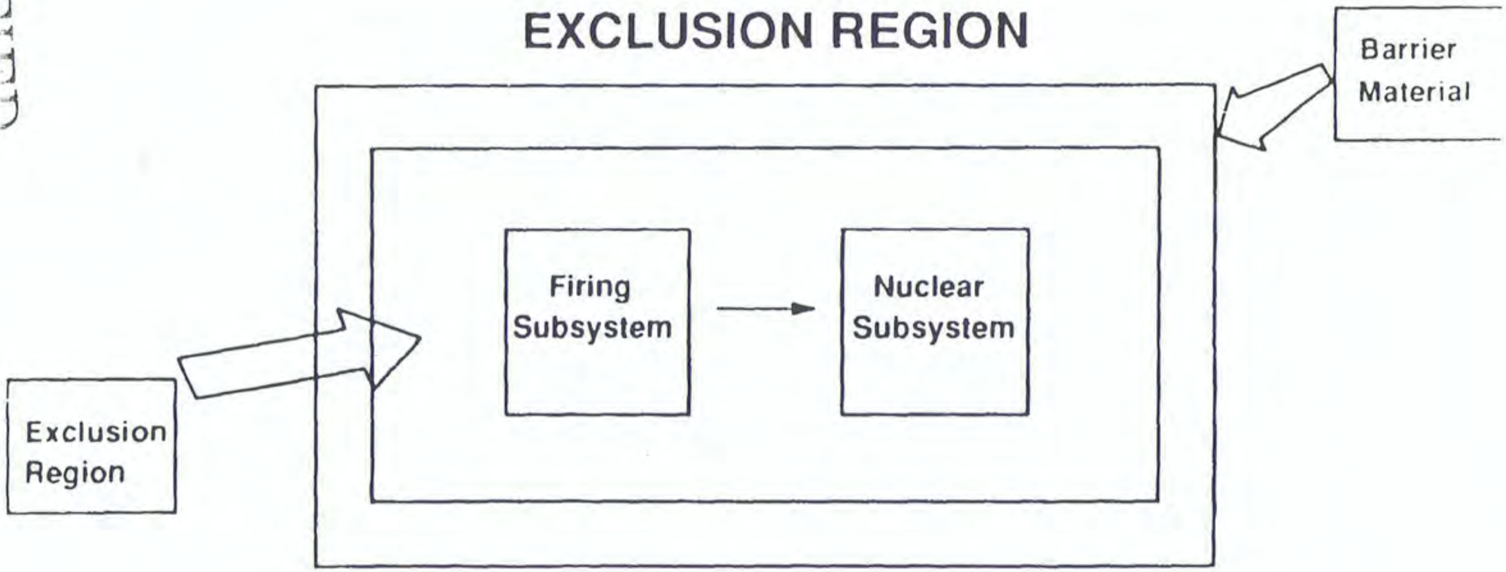
From HE Detonation

From Combustion

MODERN SAFETY DESIGN PHILOSOPHY

Co-locate detonation-essential components and protect them from abnormal environments by an exclusion region

Nuclear Safety Theme
EXCLUSION REGION



Barrier Material

Firing Subsystem

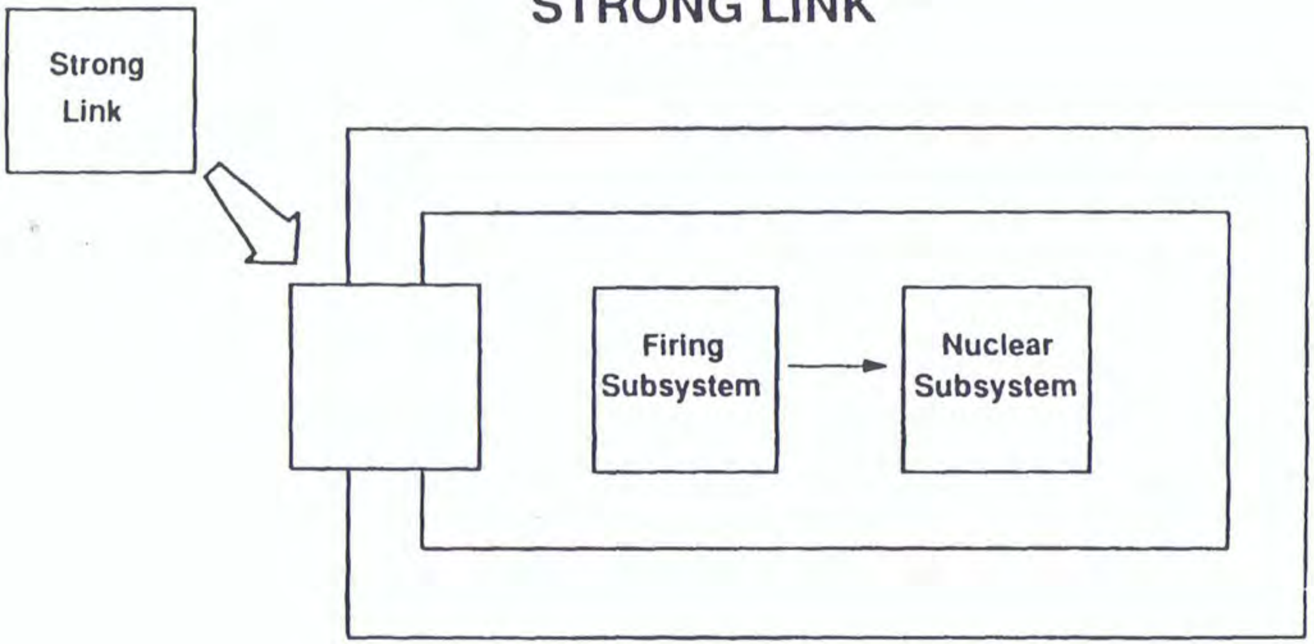
Nuclear Subsystem

Exclusion Region

MODERN SAFETY DESIGN PHILOSOPHY (cont)

Allow energy/signals into the exclusion region only through a strong link

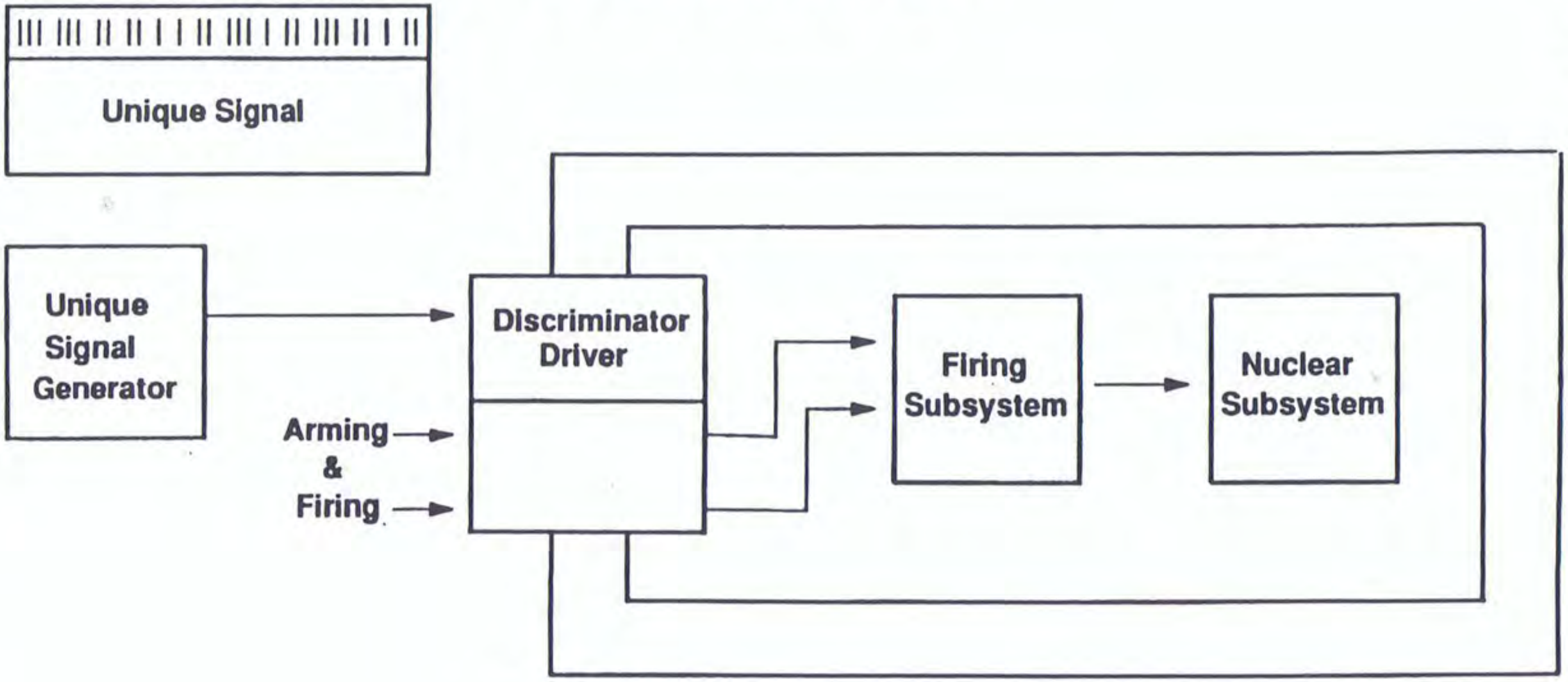
Nuclear Safety Theme
STRONG LINK



MODERN SAFETY DESIGN PHILOSOPHY (cont)

Control the strong link(s) with a unique signal not duplicated elsewhere in the system

Nuclear Safety Theme
UNIQUE SIGNALS

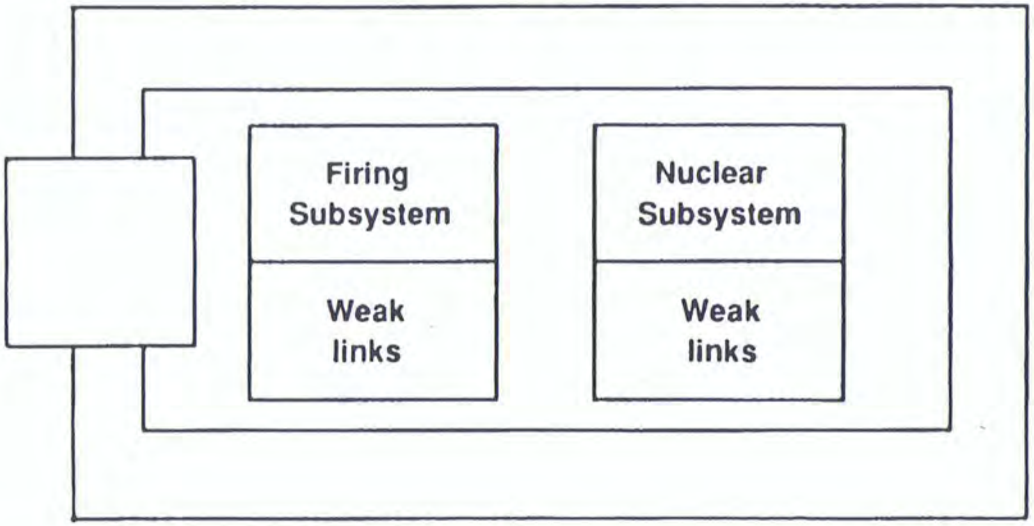


MODERN SAFETY DESIGN PHILOSOPHY (cont)

Finally, to address credible but catastrophically severe environments, co-locate *weak link* detonation-essential components which will predictably become inoperable prior to the barrier or strong links losing their integrity.

Nuclear Safety Theme

WEAK LINKS



Firing Subsystem

Weak links

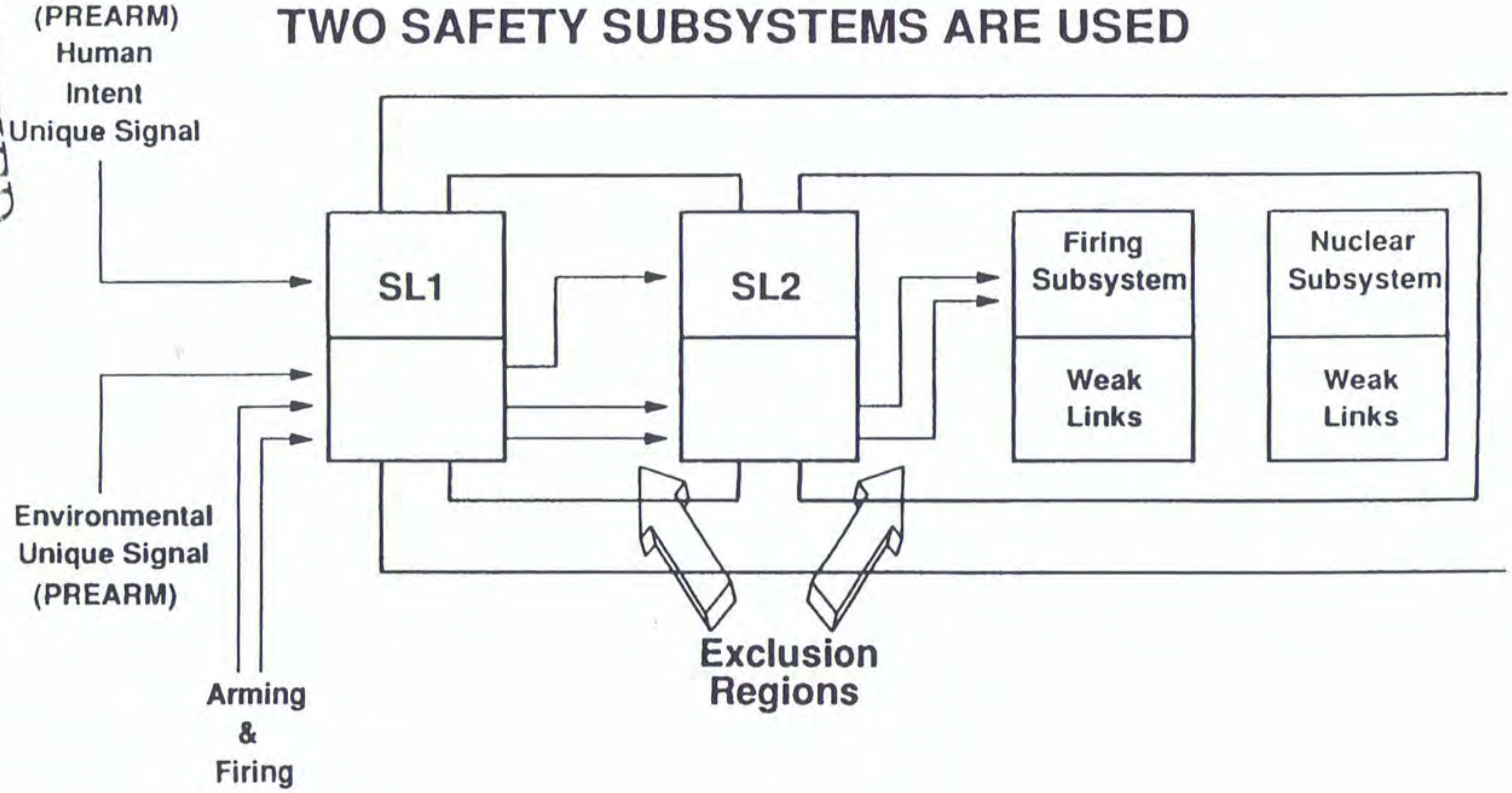
Nuclear Subsystem

Weak links

BECAUSE THE REQUIREMENT (LESS THAN ONE-IN-A-MILLION) IS QUITE STRINGENT

Nuclear Safety Theme

TWO SAFETY SUBSYSTEMS ARE USED



(PREARM)
Human
Intent
Unique Signal

SL1

SL2

Firing
Subsystem

Weak
Links

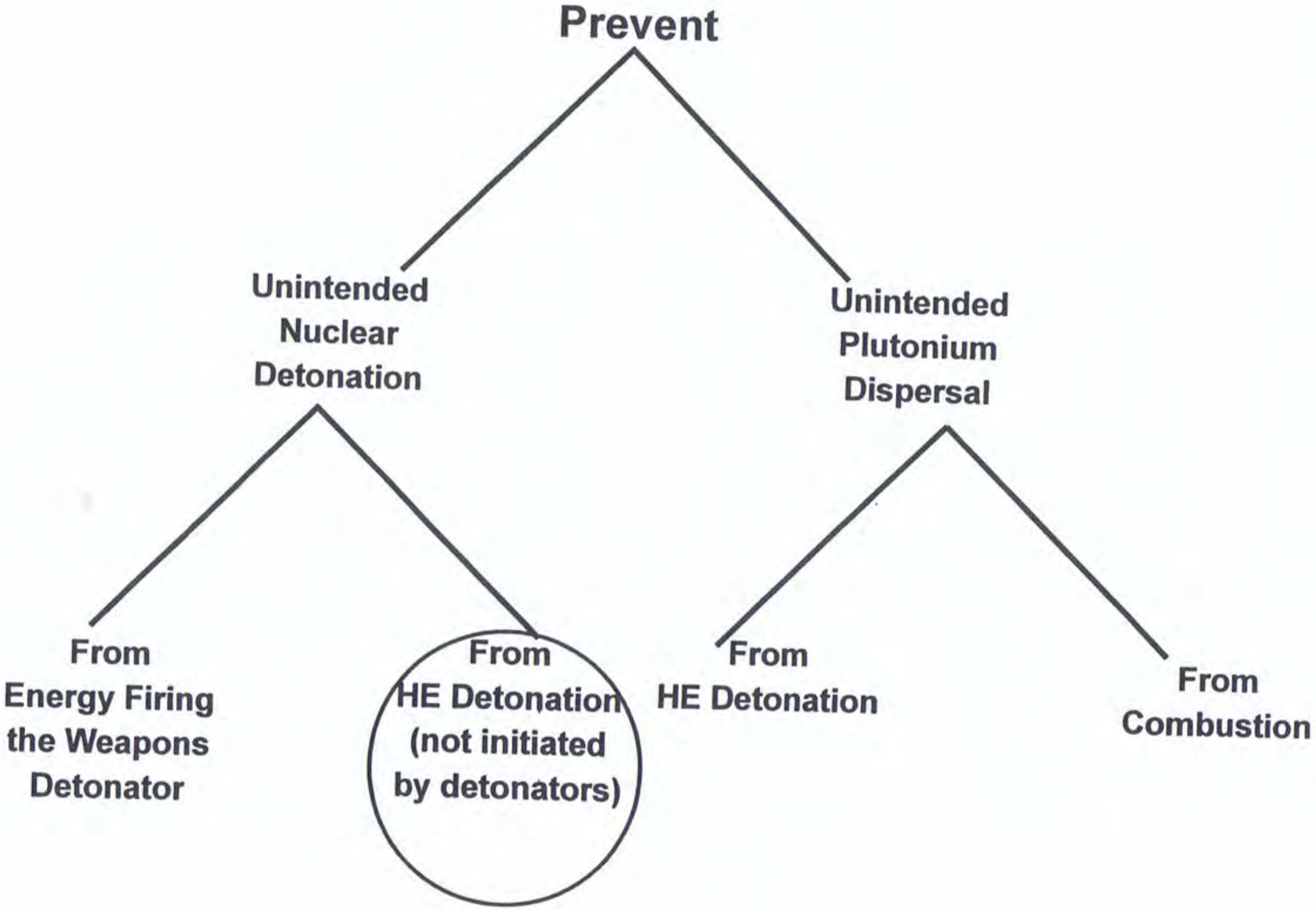
Nuclear
Subsystem

Weak
Links

Environmental
Unique Signal
(PREARM)

Arming
&
Firing

Exclusion
Regions



Prevent

Unintended Nuclear Detonation

Unintended Plutonium Dispersal

From Energy Firing the Weapons Detonator

From HE Detonation (not initiated by detonators)

From HE Detonation

From Combustion

ONE POINT SAFETY

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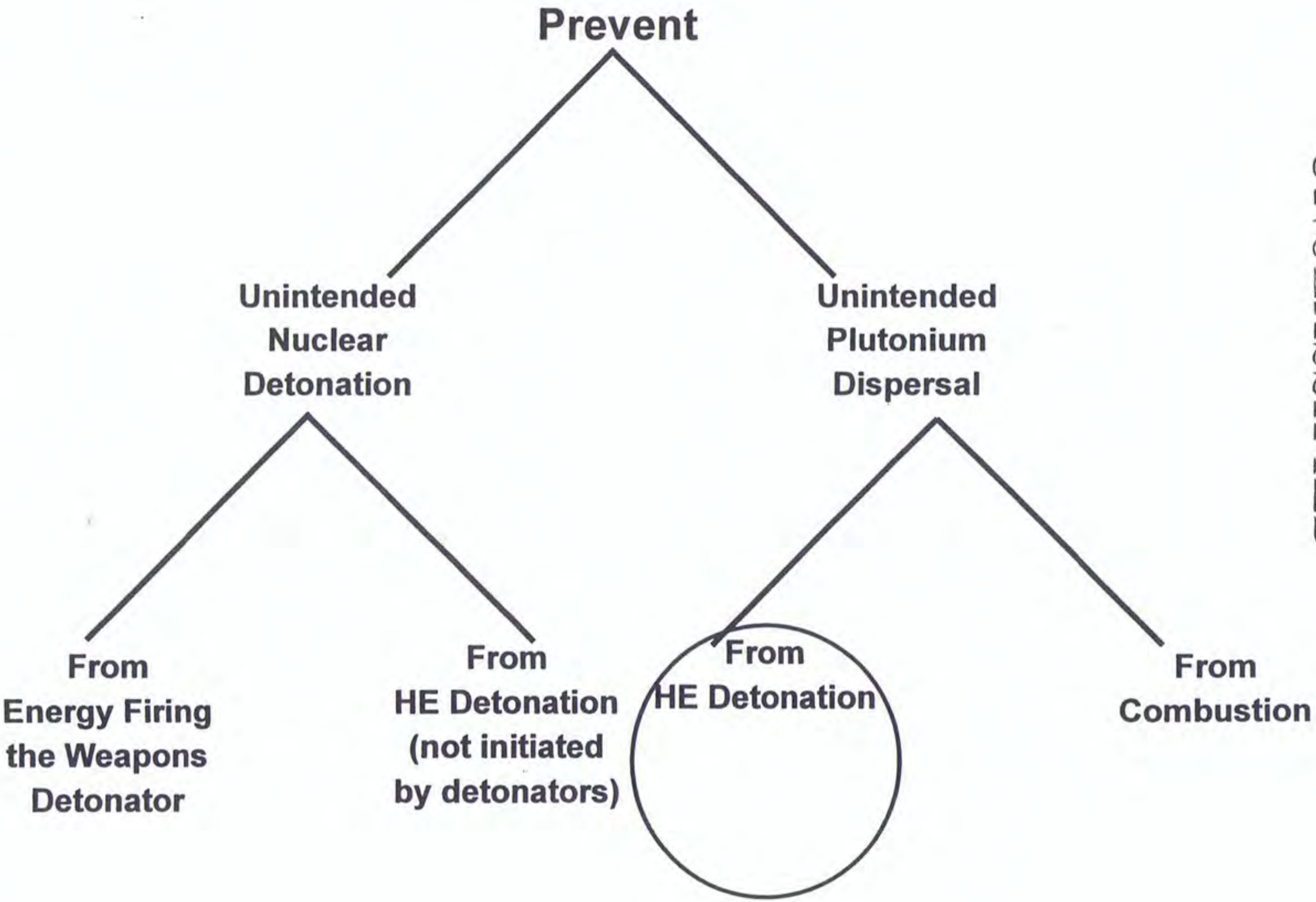

Prevent

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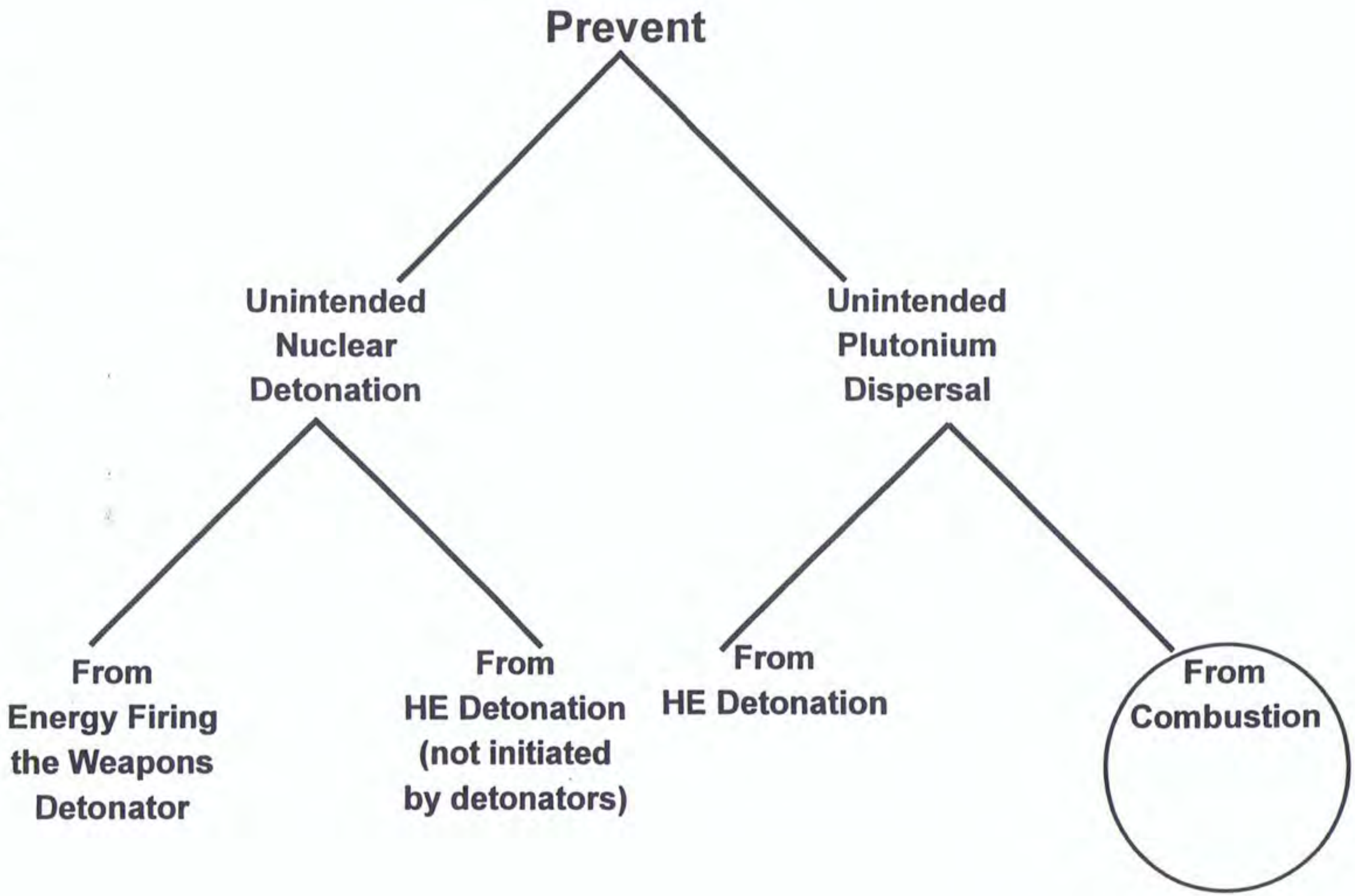

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

SESSION VIII

- PROTECTION OF NUCLEAR WEAPONS
- ACCESS CONTROL MEASURES
- USE CONTROL MEASURES

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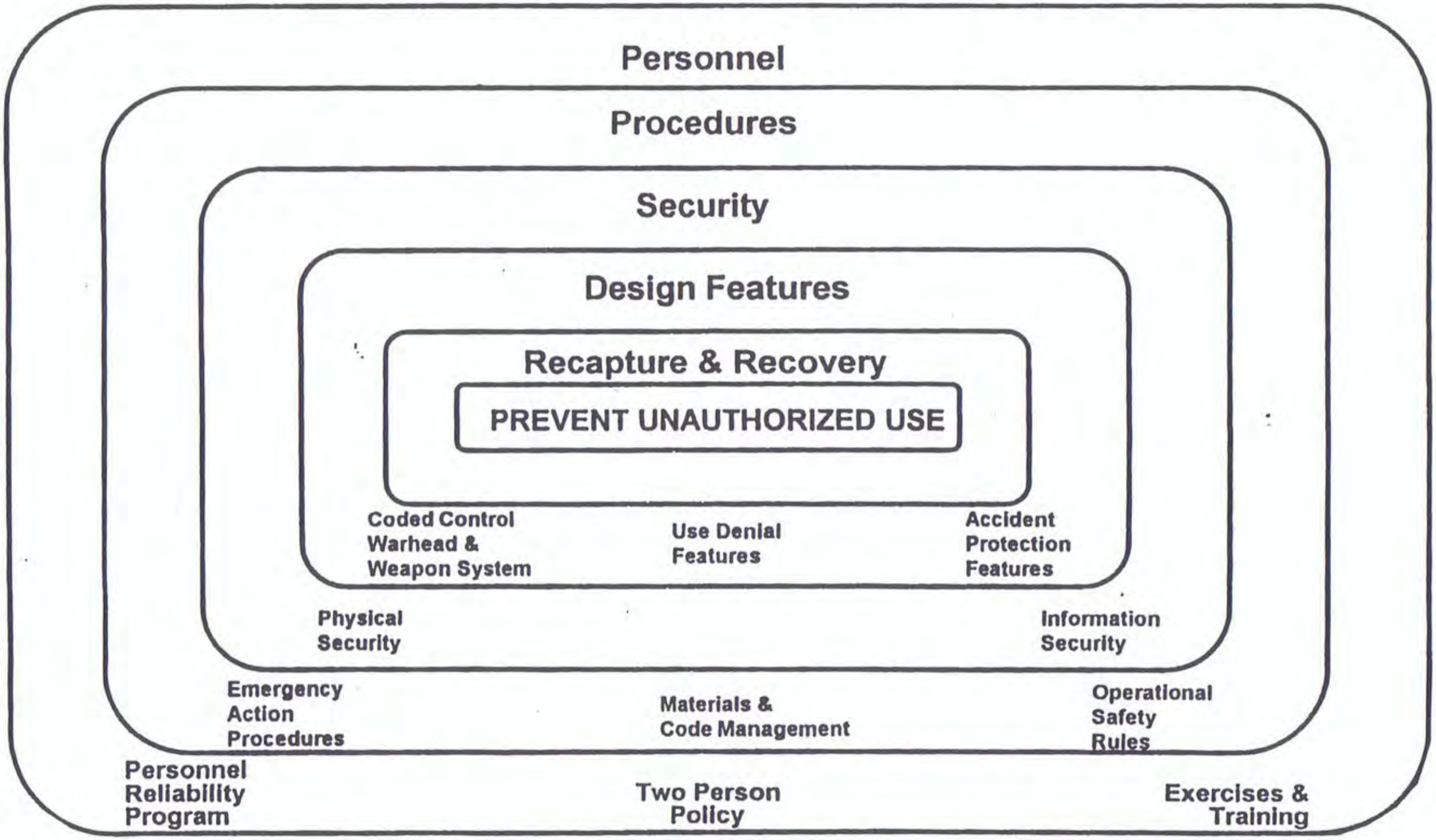
Layered Positive Measures to Assure Against Unauthorized Use

The Adversary: Humans or Accidents



Personnel

Procedures

Security

Design Features

Recapture & Recovery

PREVENT UNAUTHORIZED USE

Coded Control Warhead & Weapon System

Use Denial Features

Accident Protection Features

Physical Security

Information Security

Emergency Action Procedures

Materials & Code Management

Operational Safety Rules

Personnel Reliability Program

Two Person Policy

Exercises & Training

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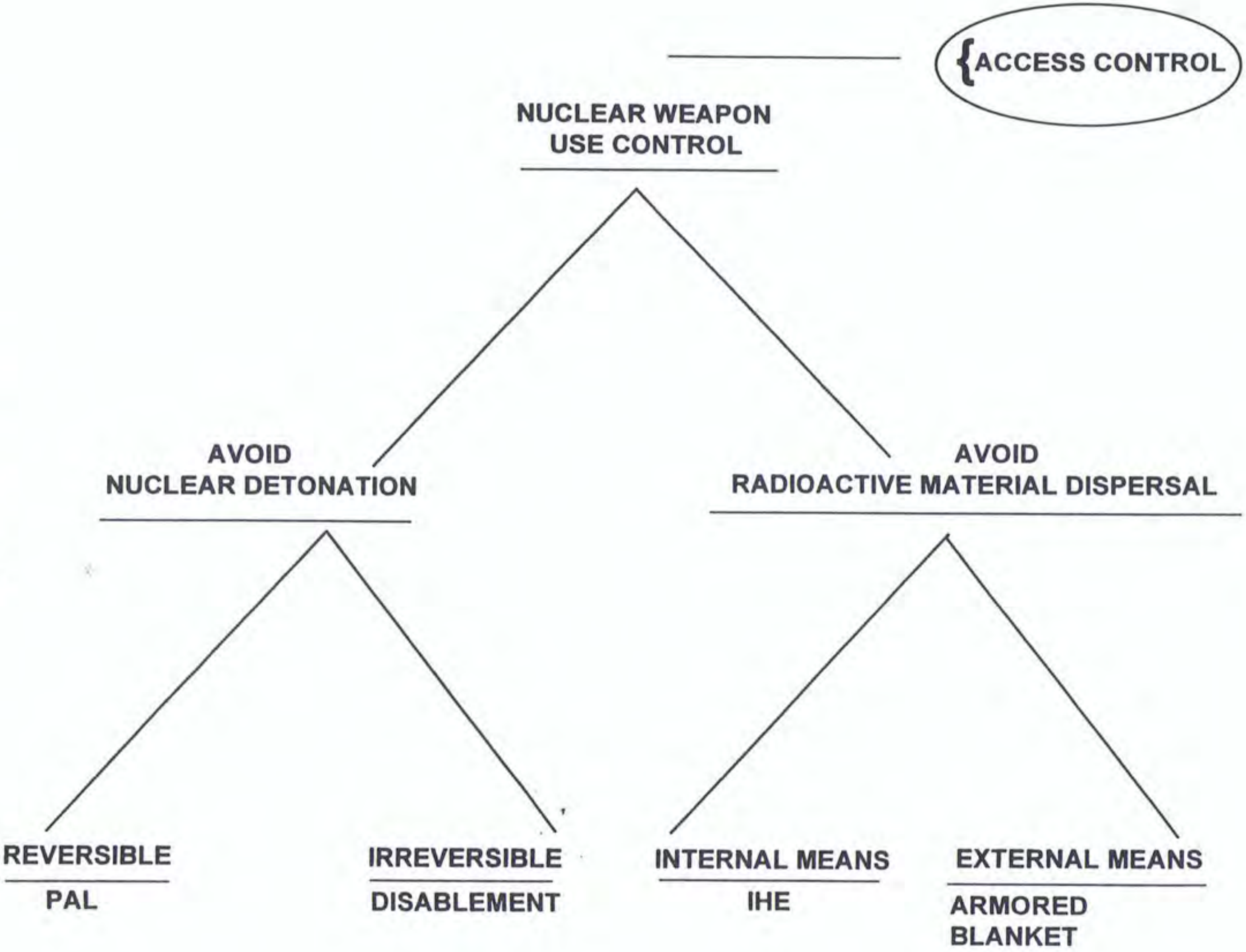
THE NUCLEAR WEAPONS ACCESS CONTROL AND USE CONTROL PROGRAMS TRY TO:

- Prevent unauthorized access to a nuclear weapon
- Prevent loss of custody of a nuclear weapon
- Prevent an intended (but unauthorized) nuclear explosion
- Prevent an intended (but unauthorized) dispersion of SNM

AND...


{ACCESS CONTROL
NUCLEAR WEAPON USE CONTROL
AVOID NUCLEAR DETONATION
AVOID RADIOACTIVE MATERIAL DISPERSAL
REVERSIBLE
PAL
IRREVERSIBLE
DISABLEMENT
INTERNAL MEANS
IHE
EXTERNAL MEANS
ARMORED BLANKET

ACCESS CONTROL (TO THE WEAPON) IS ANALOGOUS TO ACCIDENT PREVENTION - IF NO UNAUTHORIZED ACCESS (ACCIDENT) OCCURS, THERE IS LESS POTENTIAL FOR A PROBLEM.

HOWEVER, USE CONTROL FEATURES STILL ASSUME SOME LEVEL OF ACCESS CONTROL EXISTS OR CAN BE REESTABLISHED.

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ENVIRONMENTAL SENSING DEVICES (ESDs)

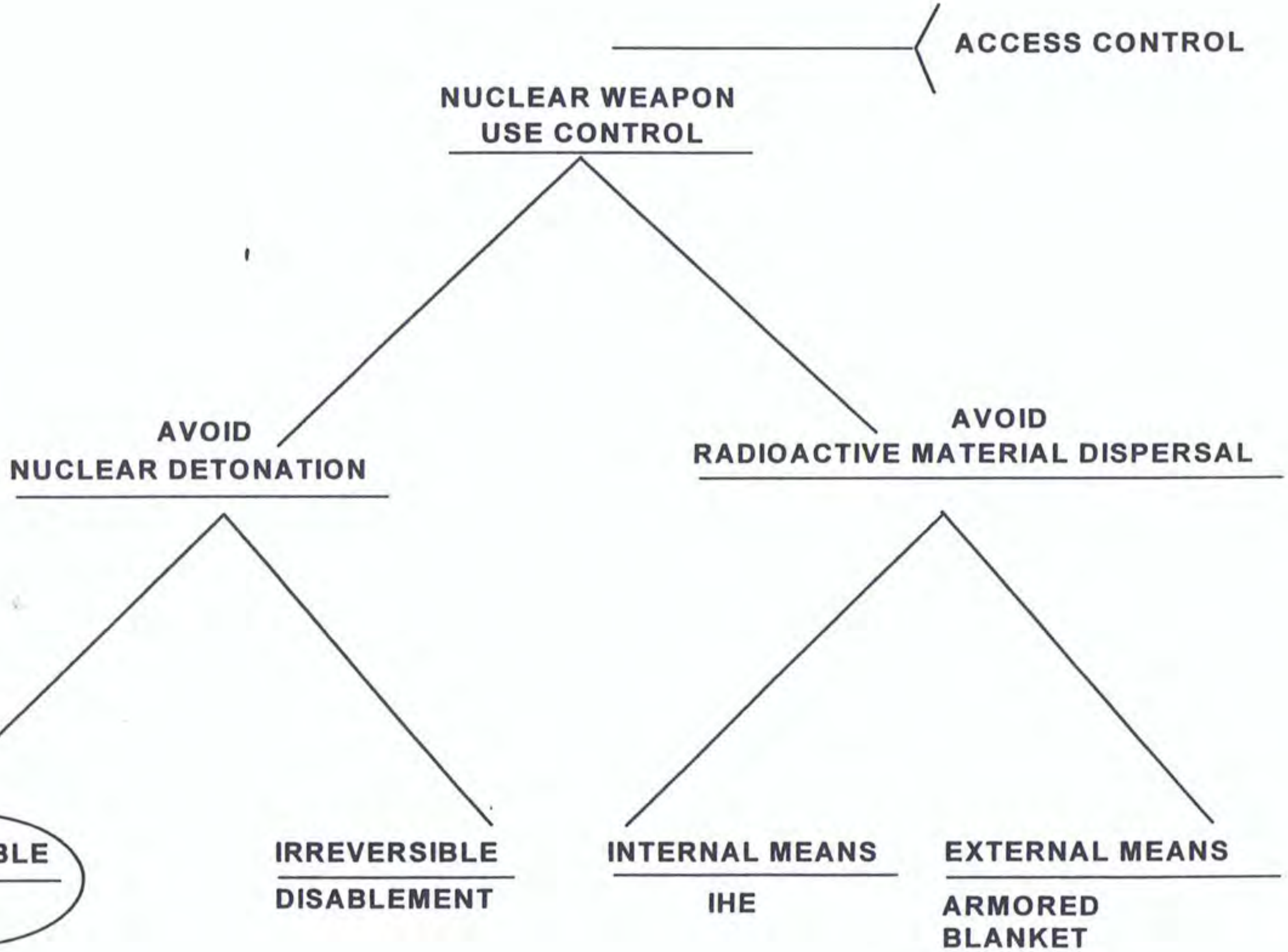
An open switch in the prearming circuits.

It is closed after sensing an environment experienced by the weapon system when enroute to the target.

INTENDED USE AND NON-INTENDED USE MODE OPERATION

- **Intended Use Mode**
  - **—Use of the warhead, weapon and weapon system as designed to operate when used against a target.**

- **Non-Intended Use Mode**
  - **—Detonation "in place"; operation of weapon/weapon system in other than intended use mode.**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NUCLEAR WEAPON USE CONTROL
AVOID NUCLEAR DETONATION
AVOID RADIOACTIVE MATERIAL DISPERSAL
REVERSIBLE
PAL
IRREVERSIBLE
DISABLEMENT
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PAL (Permissive Action Link)

A code controlled switch which interrupts the warhead's arming circuit

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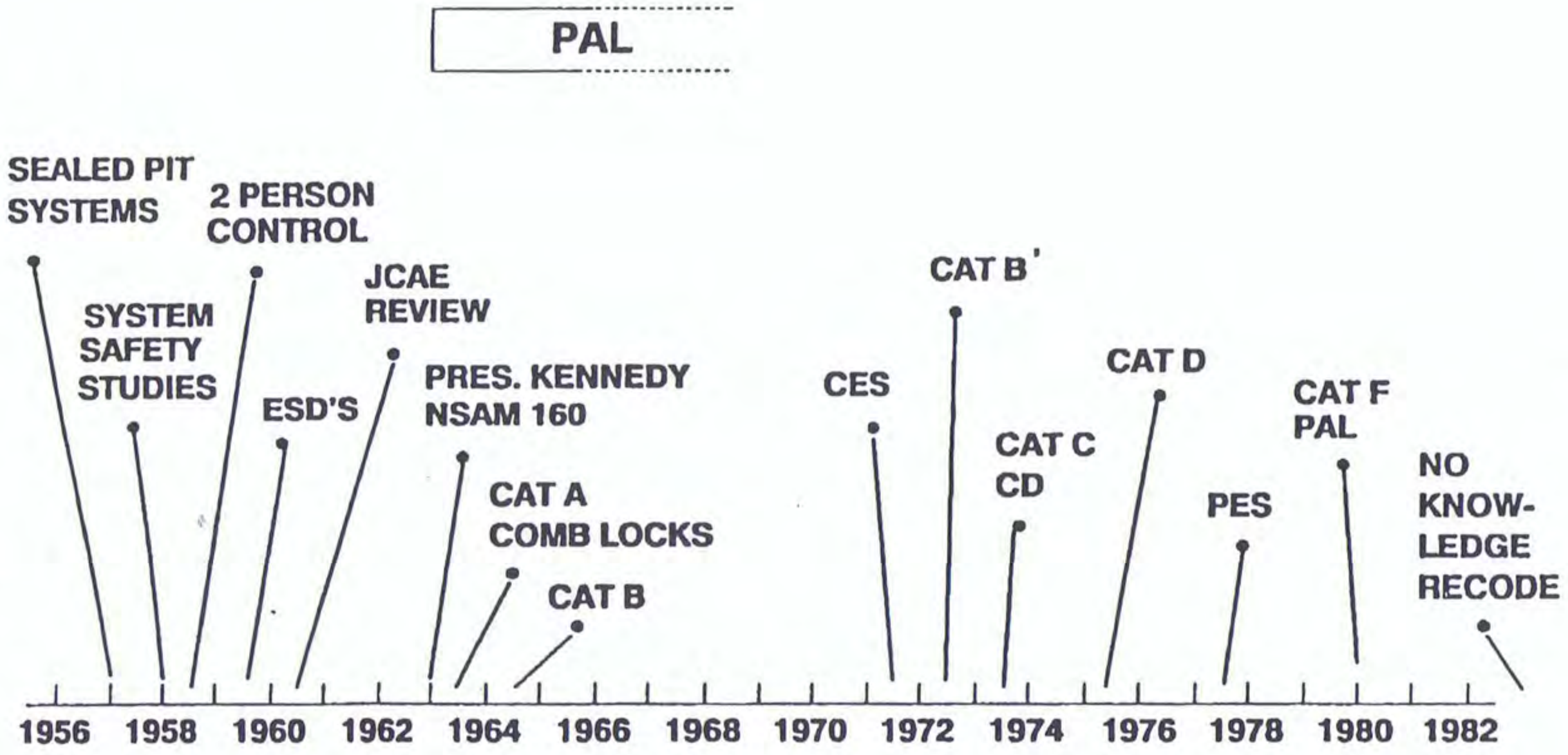
EVOLUTION OF NUCLEAR WEAPON USE CONTROL



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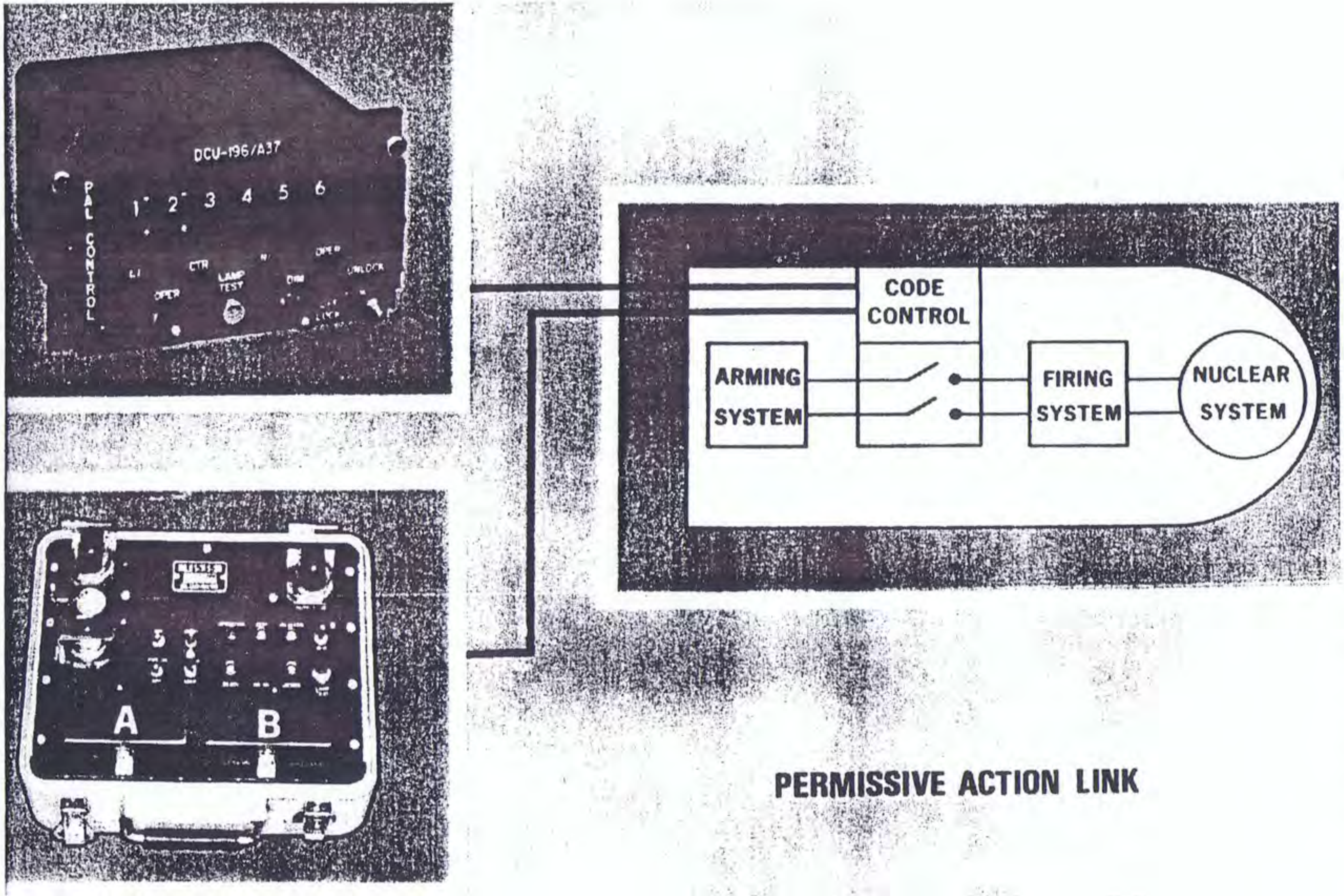

PERMISSIVE ACTION LINK

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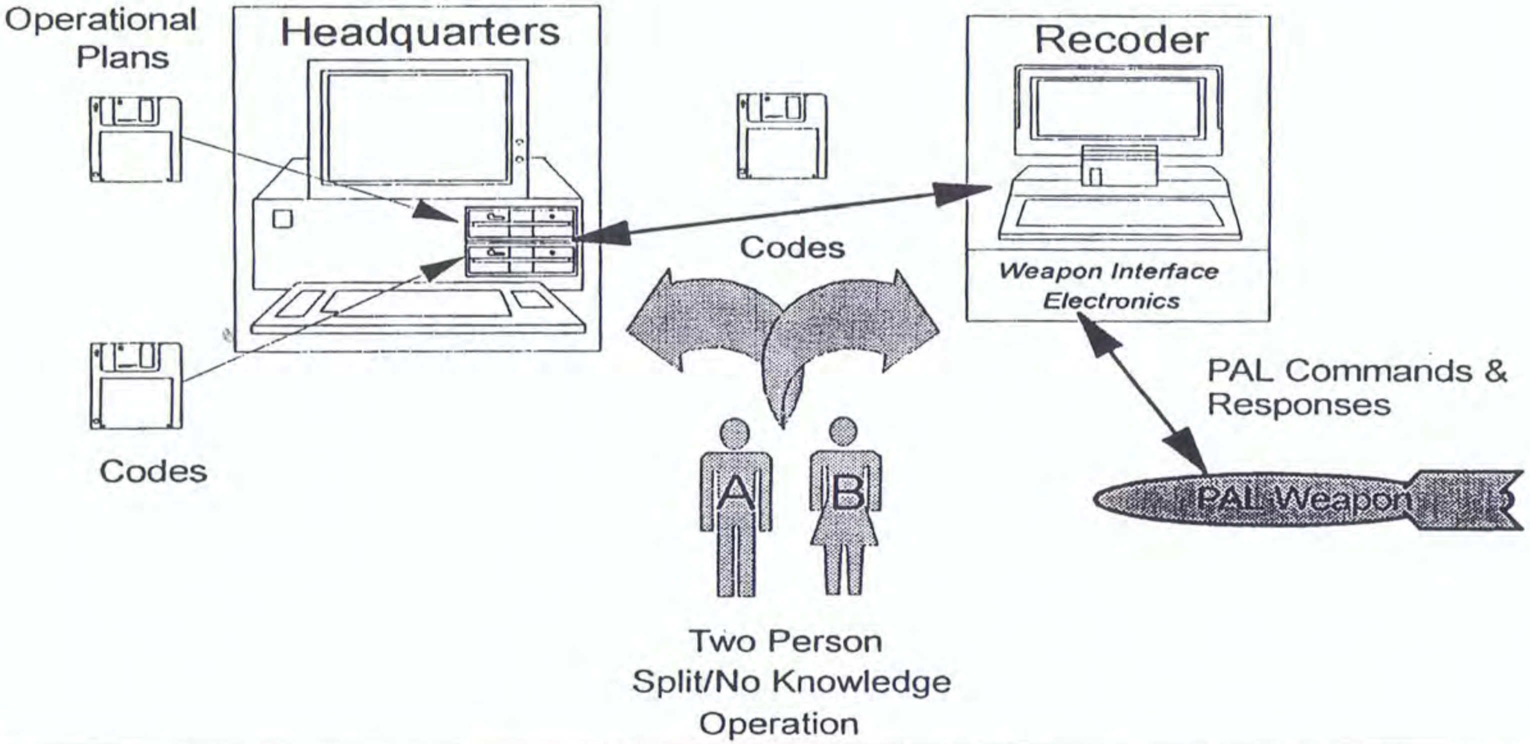
PAL Code Management



Operational Plans

Headquarters

Codes

Codes

Recoder

Weapon Interface Electronics

PAL Commands & Responses

Two Person Split/No Knowledge Operation

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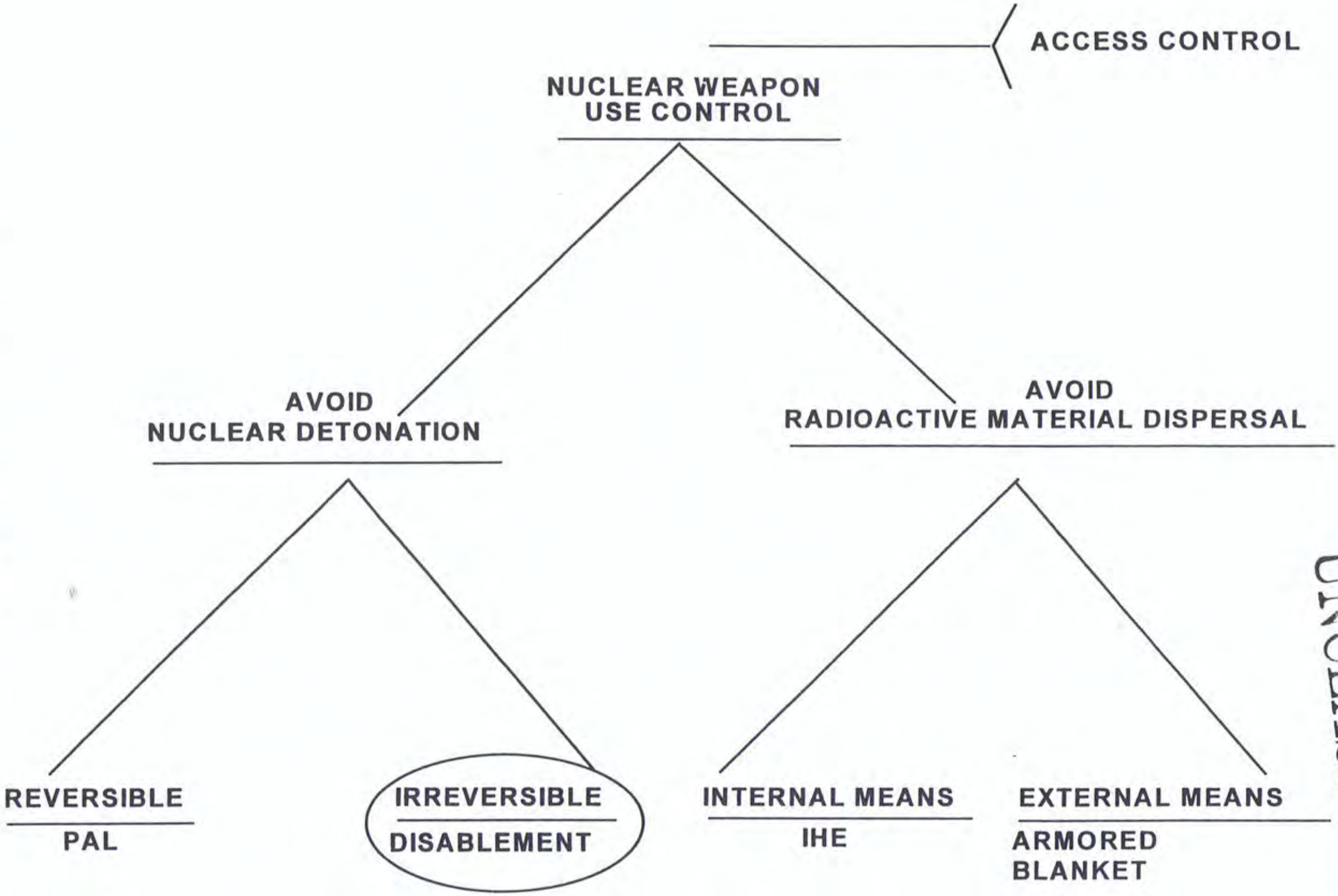

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DISABLEMENT

- When initiated, disables certain key nuclear detonation-essential components.

- Non-violent outside the weapon case.

Warhead Use Control

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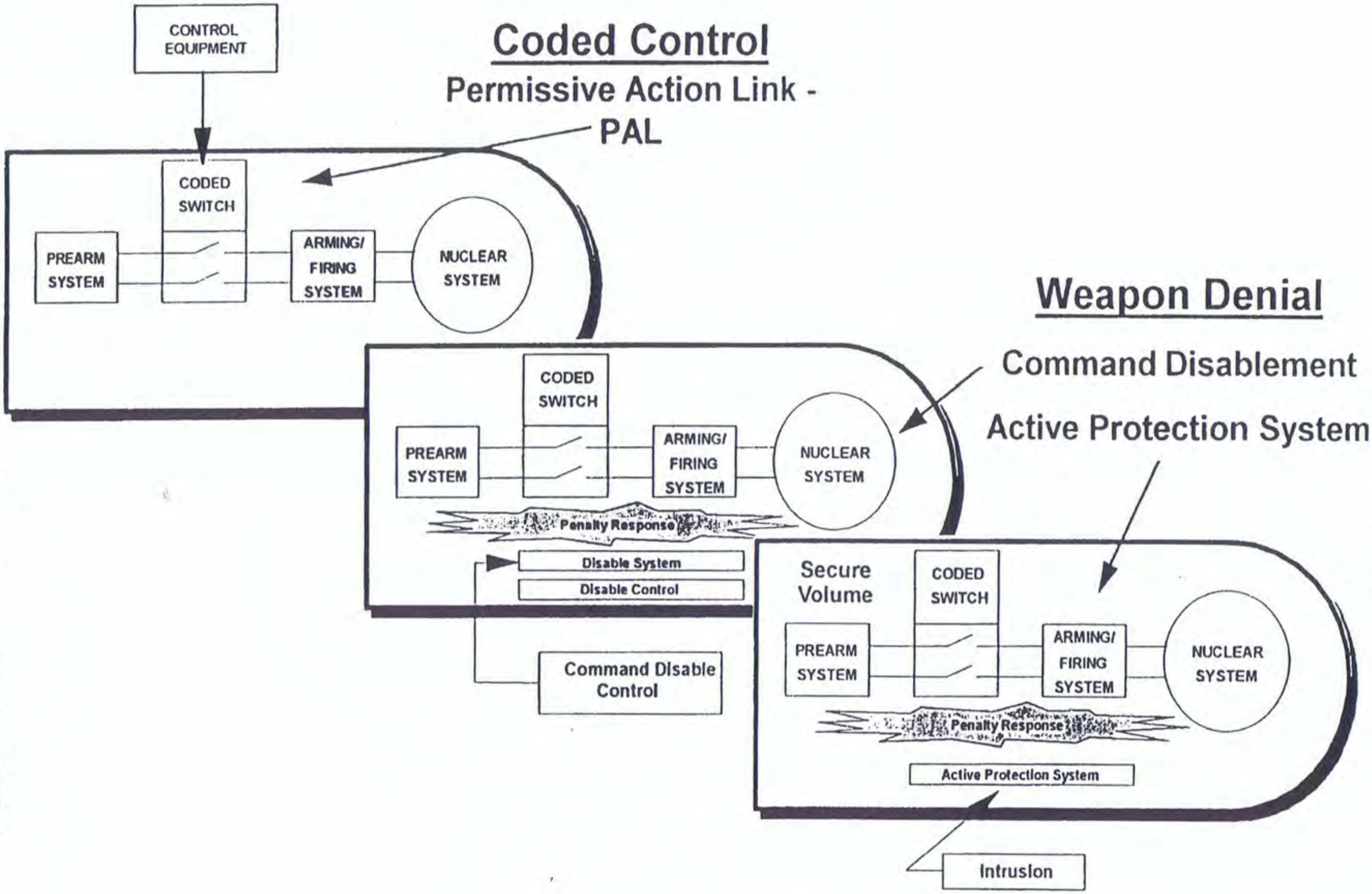

Coded Control

Permissive Action Link - PAL

Weapon Denial

Command Disablement

Active Protection System

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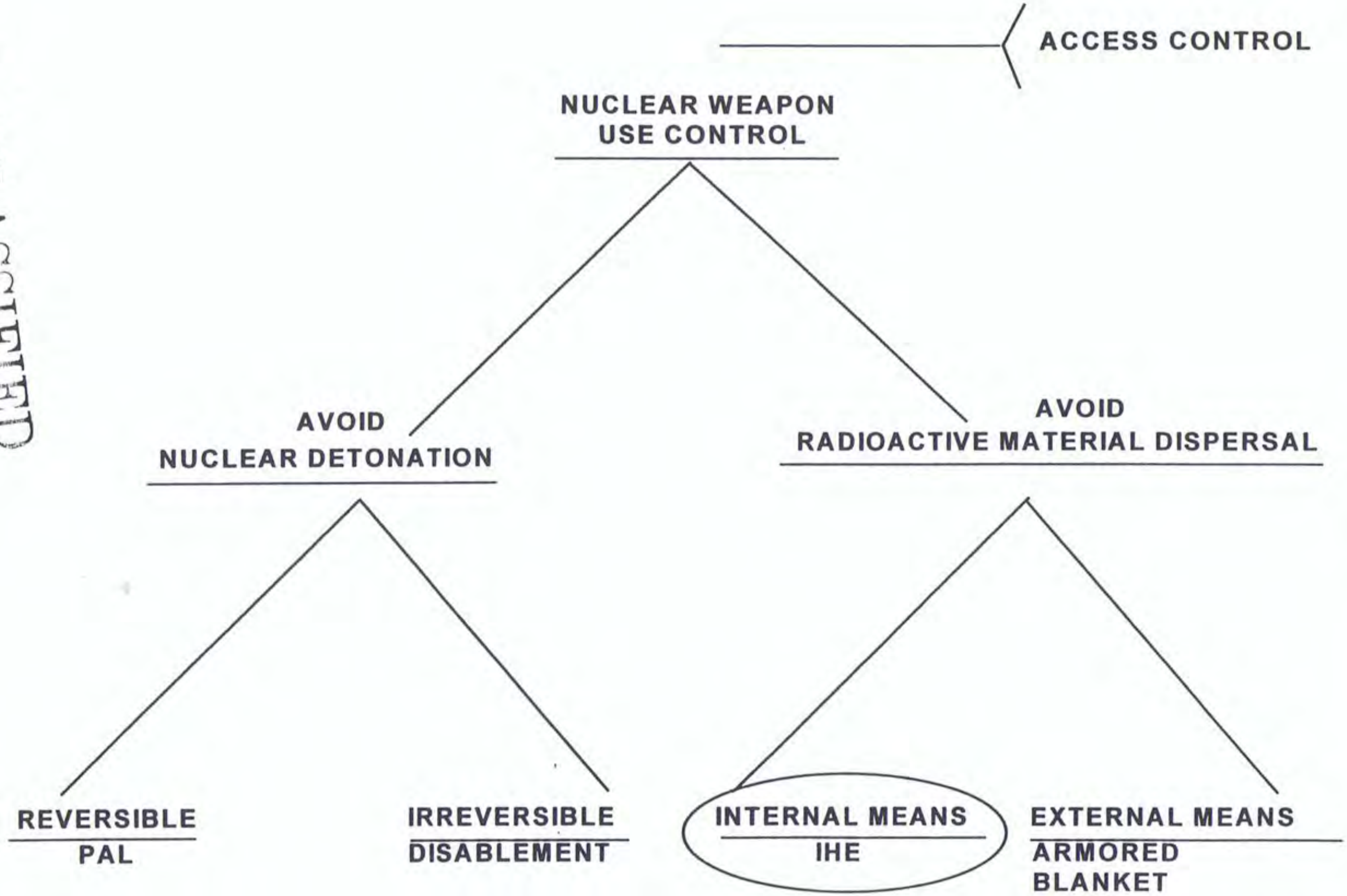
ACCESS CONTROL
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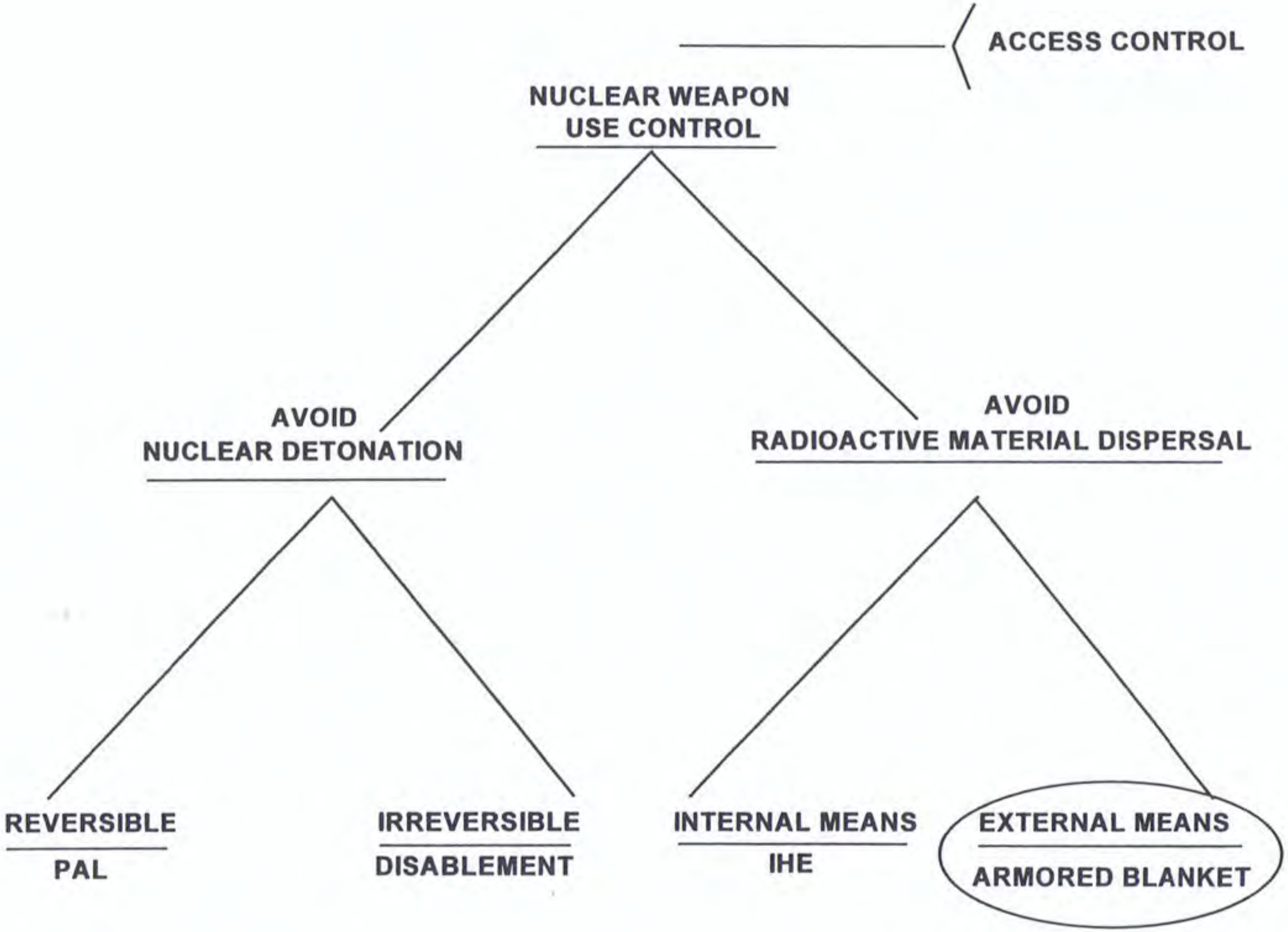
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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

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SESSION IX

AIRCRAFT WEAPON SYSTEMS

- WEAPON SYSTEMS
- REQUIREMENTS
- NUCLEAR WEAPONS SYSTEMS FOR ENDURING STOCKPILE
- AIRCRAFT INTERFACE

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SANDIA NATIONAL LABS AIRCRAFT COMPATIBILITY DEPARTMENT

- Our charter is to ensure the Department of Energy that a capability exists between US nuclear weapons and the aircraft they are carried on throughout their life in the inventory.
- Our department was established in the early 1960's.
- We work with the military, aircraft contractor, and Sandia's weapon departments in the design of the aircraft/weapon interface.
- We define the requirements the military and contractor must comply with before final design approval can be granted.
- We conduct a wide range of electrical and mechanical tests to verify a capability exists.

An Overview of the Evolution of Aircraft Monitor and Control (AMAC) Systems

- The AMAC acronym was created to describe the dedicated "black boxes" that monitor and control nuclear weapons.
- From 1945 to 1961, no standard weapon interface existed. Early bomb technology drove the design of the AMAC Systems.
- Little Boy (B1) and Fat Man (B2) were controlled by an AMAC known as a Flight Test Box (FTB). The FTB could measure battery voltages, turn on radars, and could verify certain components had not failed. Two manually inserted arming plugs were used to arm the weapons prior to pressurization of the cockpit at 8000ft.
- Manually inserted arming plugs were also used on the B3 (production Fat Man) and B4-0 bombs.
- 1950 saw the first bomb (B5) to incorporate a cockpit controlled inflight insertion (IFI) mechanism for enhanced nuclear safety. This device was the forerunner of the Ready/Safe switch, and it required a new AMAC to control this bomb feature.

An Overview of the Evolution of Aircraft Monitor and Control (AMAC) Systems

- 1952 saw the first fighter-carried bomb (B7). It had an AMAC controlled retractable fin for ground clearance.
- By 1952 there were three AMAC systems for bomber aircraft and one for fighter aircraft.
- In the late '40s and early '50s AMAC systems were built around the specific needs for the bombs, not the aircraft.
- In 1954 Sandia started a program to standardize AMAC functions for new weapons under development.
- The result of this effort resulted in the T249 AMAC for bomber and fighter aircraft usage.

An Overview of the Evolution of Aircraft Monitor and Control (AMAC) Systems

- New bombs designed during the mid to late '50s were made compatible with the T249 rather than building a unique AMAC for a specific bomb.

- AMAC design specifications, defined jointly by the DOE and DoD, first appeared in December 1961.

- AMAC specifications such as Bomber System A, Fighter System A & B, and Aero 6B were the forerunners of todays AMAC systems.

- Today's nuclear-capable aircraft, with the exception of the B-52 ALCM/ACM AMAC Systems, have what is known as a System 1 AMAC interface.

- The System 1 specification first appeared in September 1963.

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System 1 Offered Many Improved Features in Safety and Compatibility

- A current-limited Monitor State allowing weapon status to be checked without applying Safe power.
- Dedicated weapon status monitor pins for Safe, Arm, Permissive Action Link (PAL), and Weapon Present ID.
- (3)
- Category (CAT) B PAL [6/63] and CAT D PAL [8/75] enhanced weapon security.
- Unique Signal Generator (USG) [8/75] enhanced weapon safety in abnormal environments.
- Command Disable (CD) [10/81] provided the ability to render a weapon useless from the cockpit.

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Conclusion

- All aircraft nuclear weapon interfaces built to date have been analog.
- AMAC systems have transitioned from separate to integrated designs.
- A System 2 AMAC specification, based on MIL-STD-1760, exists that defines a digital interface for possible use in future nuclear weapons.
- The number of nuclear capable aircraft has decreased considerably in recent years.

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

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SESSION X

- **Nuclear Weapons Dismantlement**

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Dismantlement Topics

- Process
- Magnitude
- DOE/Labs Organiztion
- Technology Applications
- Laboratories Increased Presence at Pantex
- Lab-to-Lab Interchanges with Russians

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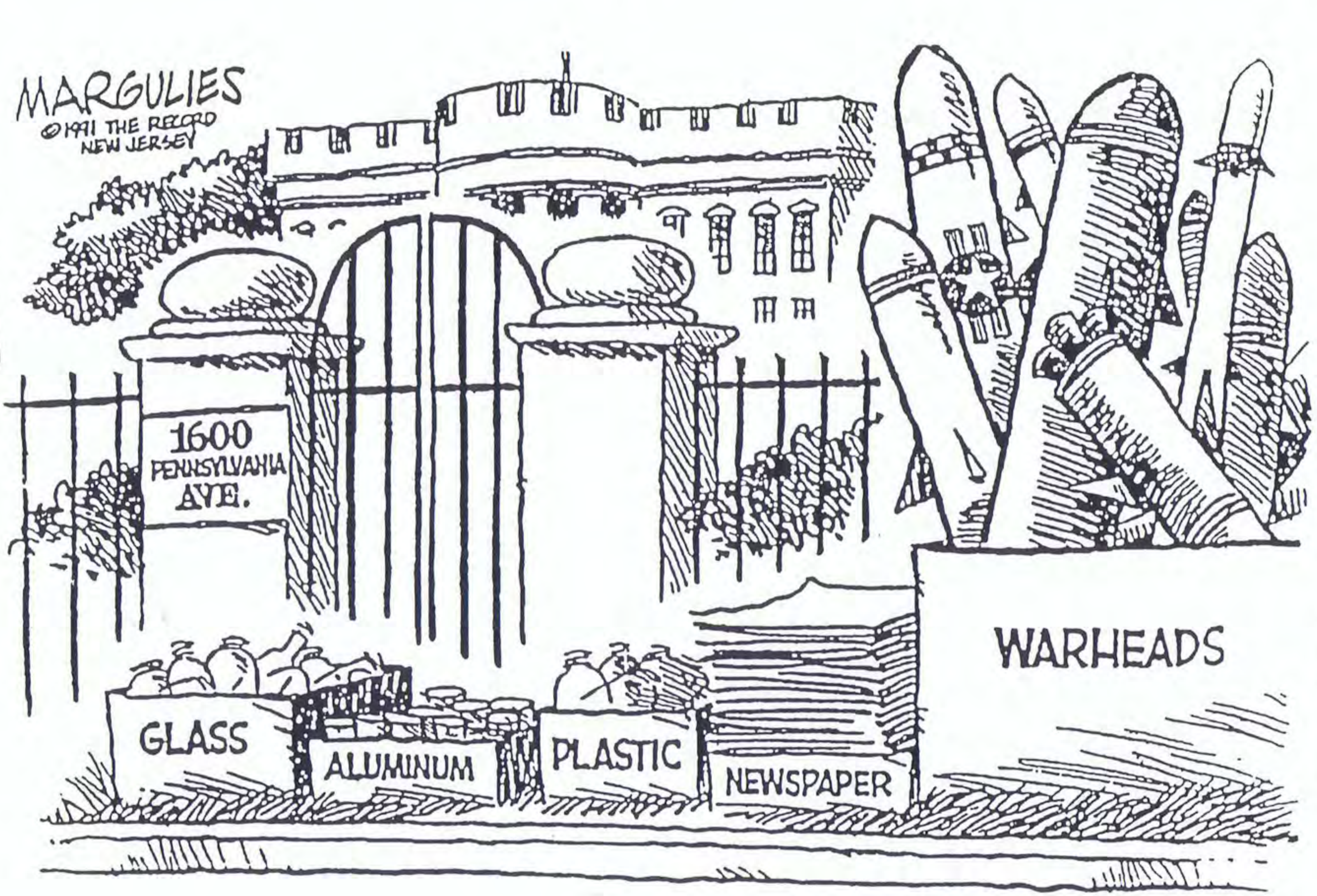
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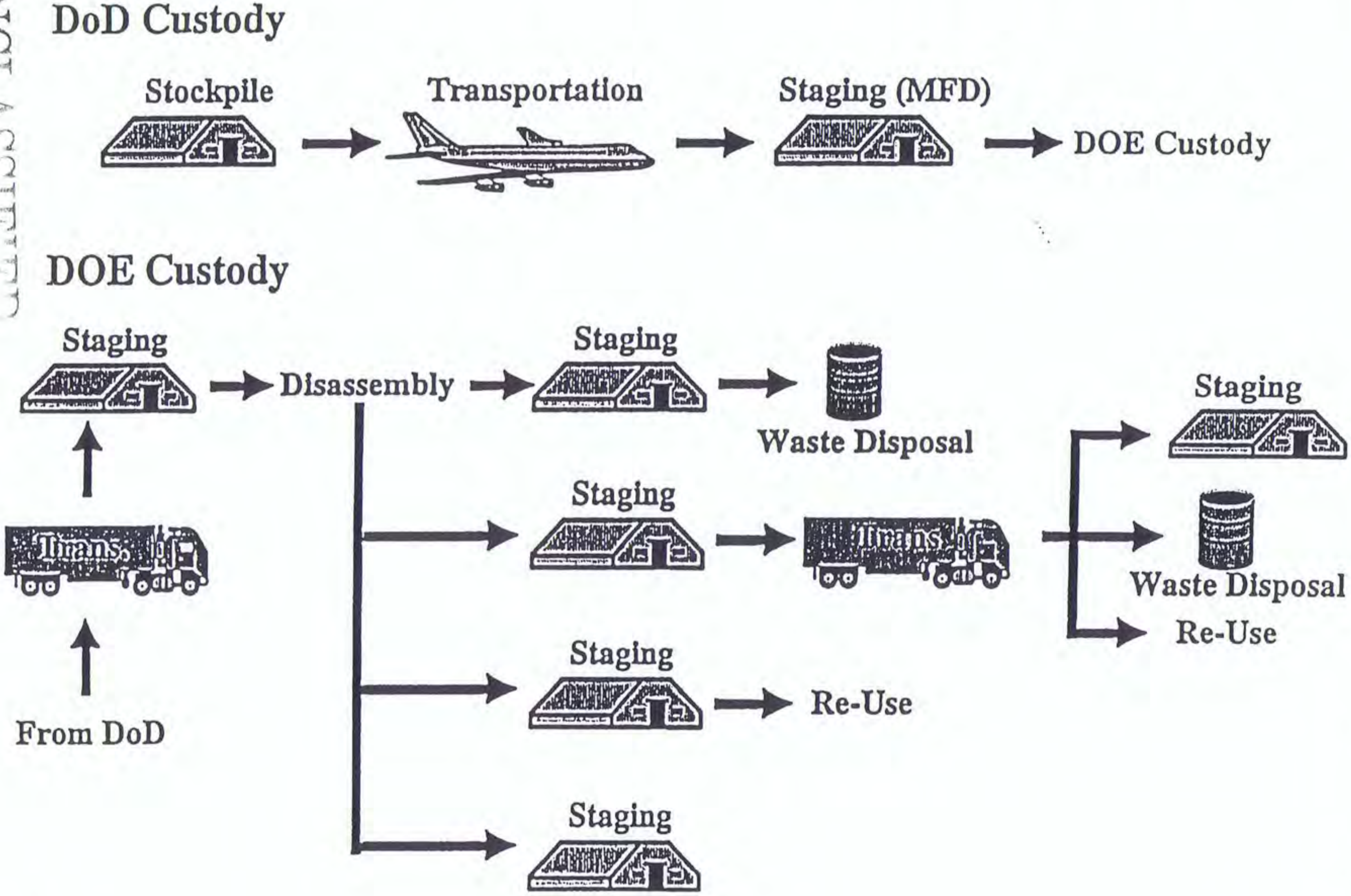
NEWSPAPER

Nuclear Stockpile Dismantlement Process



DoD Custody

Stockpile → Transportation → Staging (MFD) → DOE Custody

DOE Custody

From DoD → Trans → Staging → Disassembly

Disassembly → Staging → Waste Disposal

Disassembly → Staging → Trans → Staging / Waste Disposal / Re-Use

Disassembly → Staging → Re-Use

Disassembly → Staging

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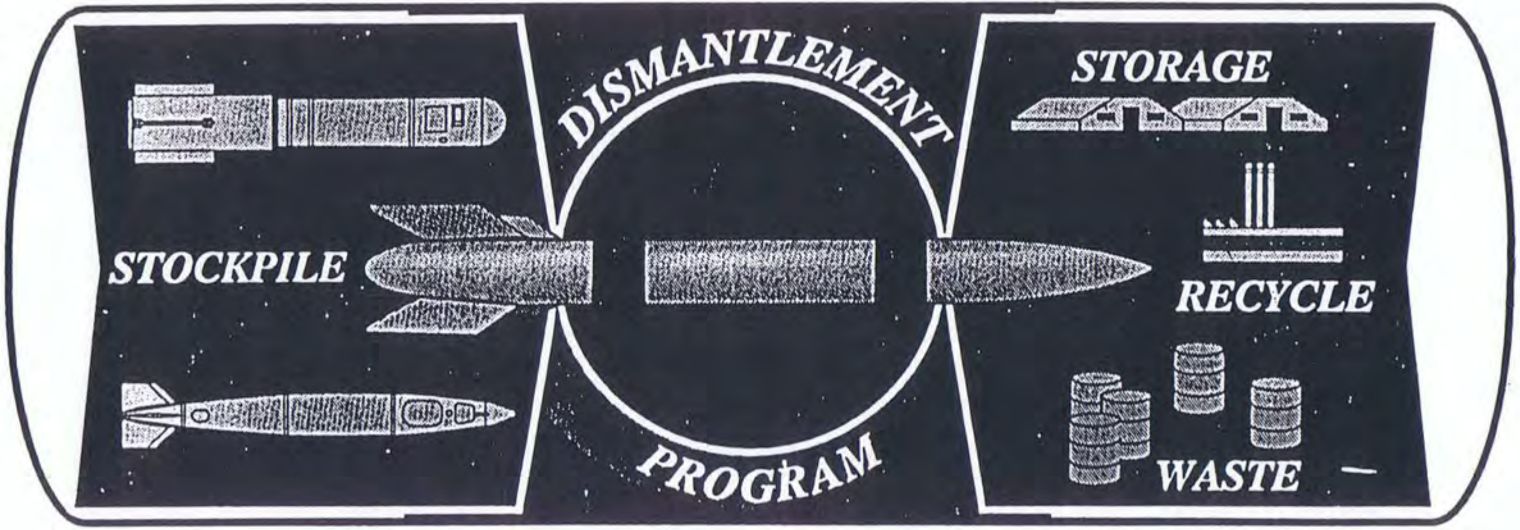

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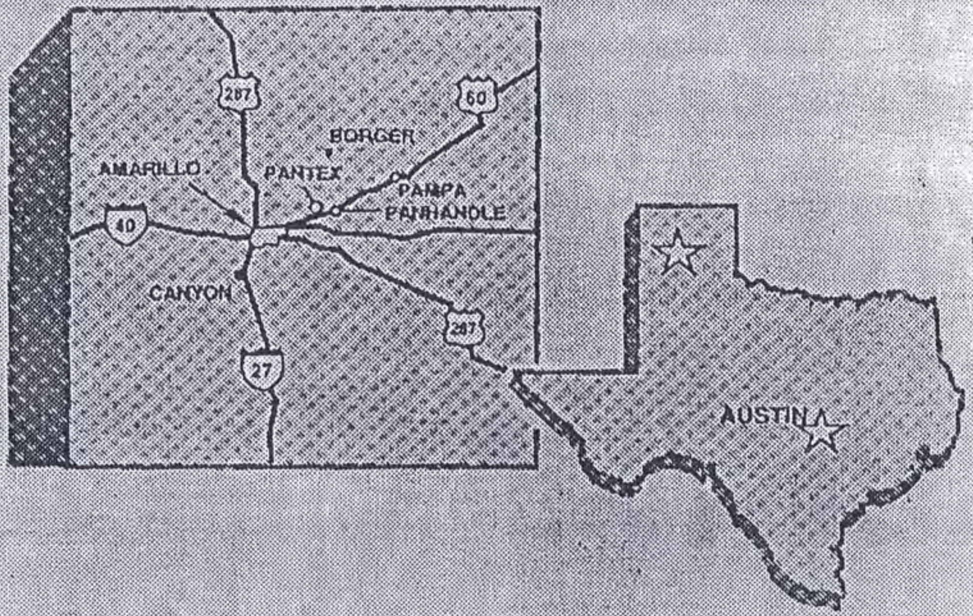
PANTEX PLANT LOCATION



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Pantex Organization Responsibilities

- Government owned facility
- DOE Amarillo Area Office (reports to AL)
  - Administers operating contract
- Mason & Hanger - Silas Mason Co., Inc.
  - Management and operating (M&O) contractor
- Battelle Memorial Institute
  - Subcontractor for Environment, Safety, and Health (ES&H)
- Sandia National Laboratories
  - Operates Weapons Evaluation Test Laboratory (WETL)

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Pantex Plant Statistics

- $190M operating budget
- 2945 employees
  - 2600 M&H
  - 250 Battelle
  - 78 AAO
  - 17 Sandia
- 16,000 acres
- 2.5M sq. ft. buildings (425 units)

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Size of Dismantlement

- Pantex capability approximately 2000 per year
- Backlog of weapons
- Retirements continue
- [redacted]
- Taper off to support retirements as they occur

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Stockpile (P&PD 93-2)

SRD Viewgraph

Shows
Stockple, Reserves, and Retiring

(Not included herein)

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Department of Energy
Executive Mangement Team for Dismantlement

- Formed by DASMA
- Covers all aspects of retirement, return, disassembly, waste characterization, and disposal
- Develop integrated departmental positions and strategies for dismantlement
  - Internal to DOE
  - With DoD
- Membership with DoD
  - DOE/AL, DOE/HQ, LANL, SNL, LLNL
  - Reports to DASMA weapons panel

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Department of Energy
Executive Management for Dismantlement

DOE/AL	Deborah Monette	Chair
DOE/HQ	Karen Lombardo	Exec Sec
LANL	Mike Kelly	
LLNL	Jerry Dow	
SNL	Paul Longmire	

Dismantlement Priorities

- Weapons Shipment Planning
  - Priority based on risk analysis
- Material Destination - Disposal
  - Identification
  - Characterization
  - Obey Laws
- Storage of SNM
  - Keep at Pantex until better solution found

DISMANTLEMENT PRIORITIZATION PROCESS

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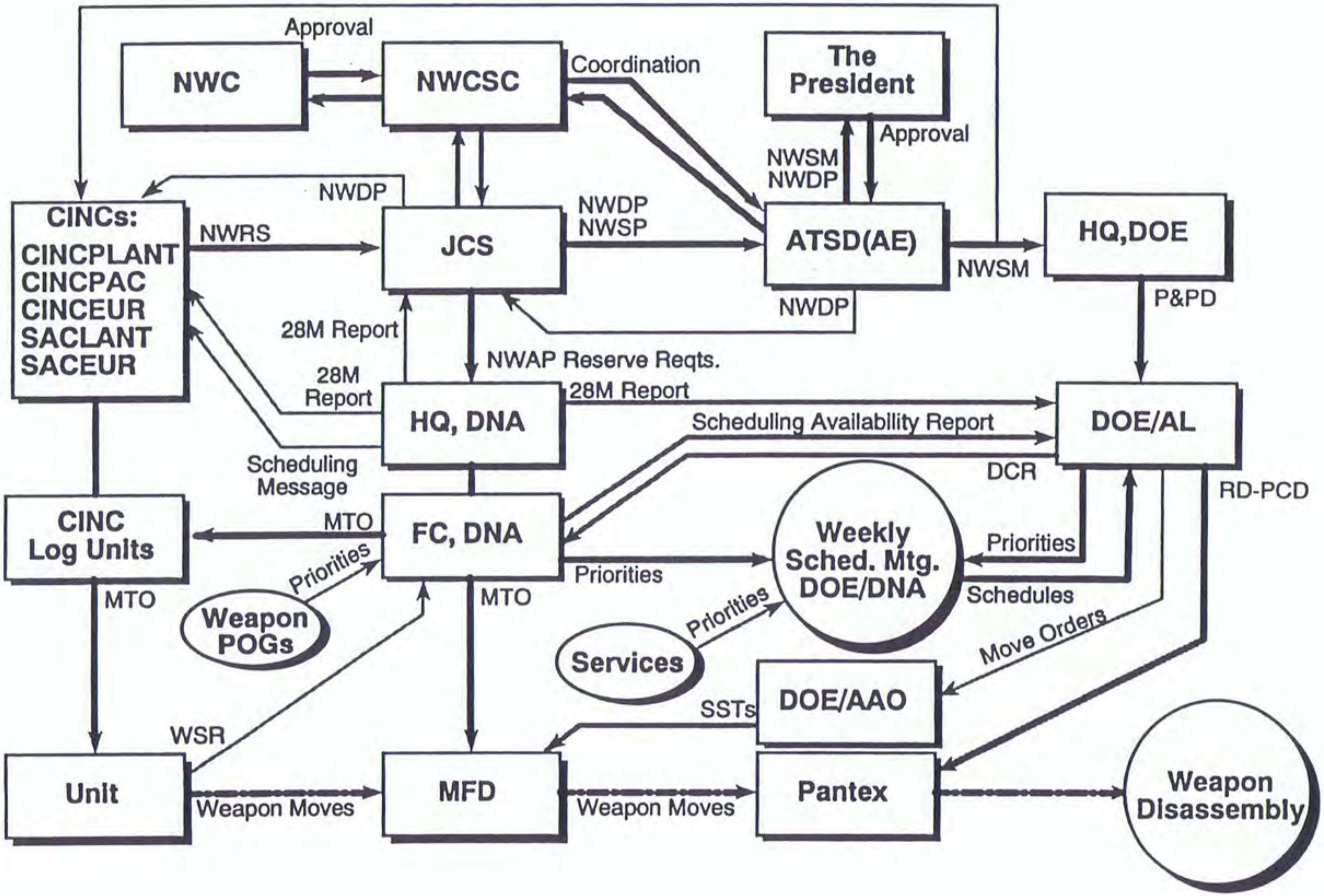

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Dismantlement Prioritization Working Group

- Joint DOE/DoD group chaired by Sandia
- Initial phase identified and ranked weapons based on weapon features
- Dismantlement process from initial retirements to disposal was defined
- Influences that determine priorities were identified
- DOE issues such as staging requirements and transportation assets were examined
- Software written to process data
- Group continues for information exchange and planning assistance

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Information Systems

- Developing database for material identification and characterization
- Compatible with each DOE design agency and production agency
- Allows Pantex to receive information electronically
- Allows each DA and PA to enter their desired data
- Replaces old scrapbook system at Pantex

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DOE Dismantlement Policy

Component Retention, Reuse, or Evaluation

- For each weapon in the dismantlement process, a laboratory study will be conducted to determine if any of the major assemblies, components, or their subcomponents should be:
  - (1) Retained for reuse
  - (2) Salvaged for their strategic or economic value
  - (3) Retained for safety and use-control effectiveness evaluations
  - (4) Evaluated to provide further statistical data regarding the quality and reliability of comparable hardware in the enduring stockpile

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Non-Nuclear Hardware From Dismantled Weapons

- All hardware scheduled for disposal unless otherwise requested
- Sandia plans to request designated hardware to be returned for evaluation
- Possible storage of Sandia hardware for future use when a direct replacement in the enduring stockpile, e.g., mods of B61
- Los Alamos plans no storage of hardware except for Detonators
- LLNL plans no storage of hardware
- Evaluation units for LANL and LLNL will be requested as needed

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Component Commonality Matrix, A Few Examples

Dismantled Weapons	Enduring Stockpile			
	B61	W78	B83	W76,W80,W87,W80
B57	Solder Conn		Para chute	
W68	Trig Ckt	Trig Ckt	Trig Ckt	
W70	LAC	LAC N.G.	LAC	

W56, B61-0,
W69,
W71, W79

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DOE Dismantlement Policy
Component Retention, Reuse, or Evaluation

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DSD Manual

The Demilitarization and Sanitization for Disposition (DSD) Manual defines the process to be utilized in the nuclear weapons complex for applying the general guidelines to define and document a demilitarization, sanitization, and/or render-safe process. The process description covers the use of the Demilitarization/Sanitization Table, the Weapon Component Data Sheets, and the issue resolution process.

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MMSC Demilitarization/Sanitization

Part Nomenclature	Demilitarization	Sanitization	Render Safe	Method
Actuators/Squibs	Yes	No/Yes	Yes	Fire or explosive disposal (some use control items may require sanitization)
Connectors	No	No/Yes	No	None (unless rad hardening potting used, then sanitization required)
Detonators and Cable Assemblies	Yes	Yes	Yes	Fire - shred cable/crush header or explosive disposal (protect# info.)
Foams, cushions compression pads, desiccants, plastics, etc.	No	No/Yes	No	None (shred, melt, or burn if show classified contours or shock mitigation info.)
Mechanical Hardware (O-rings, brackets, bolts, cover plates, rings, etc.	No	No	No	None (part identifier removed if association makes classified)
Neutron Generator, Electronic	Yes	Yes	Yes	Crush (remove rad tube?)
Neutron Generator, Explosive	Yes	Yes	Yes	Fire (mixed waste) or timer driver to explosive disposal/tube to rad waste
Reservoir	Yes	Yes	Yes	Bury (remove rad material if appropriate)
Thermal Battery	Yes	No	Yes	Fire
Timers	No	No	No/Yes	None (fire - remove explosives if appropriate)
Use Control, PAL, CD Hardware	Yes	Yes	Yes	Expend, crush, shred, bury as appropriate

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Nuclear Material Storage/Disposal

- All pits put in interim storage
- Yet to determine ultimate fate of plutonium

- Secondaries under study
  - Portion to be stored
  - Portion to be disassembled into basic materials

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SNM Storage Problem

- Present Storage Magazines
  - Containers stored vertically in planar array
  - At present rate magazines full in March 1994
- Proposed Changes
  - Containers stored horizontally in multi-layers
  - Activate additional magazines
  - Problem Created
    - High radiation levels
    - Worker could receive yearly allowable dose in approximately one day
- Solution
  - Use machines to load, retrieve, and inventory

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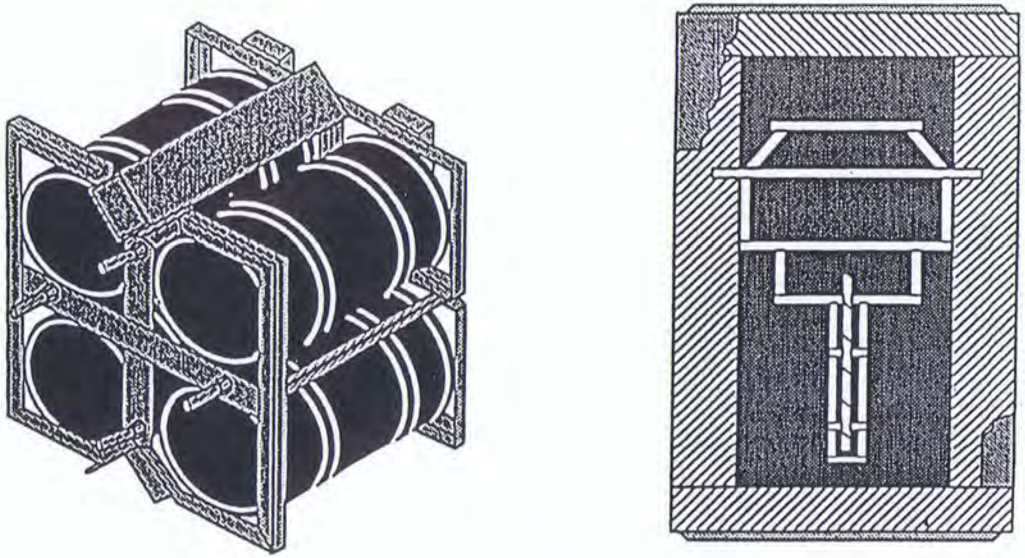
Project Stage Right Storage



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External Oversight

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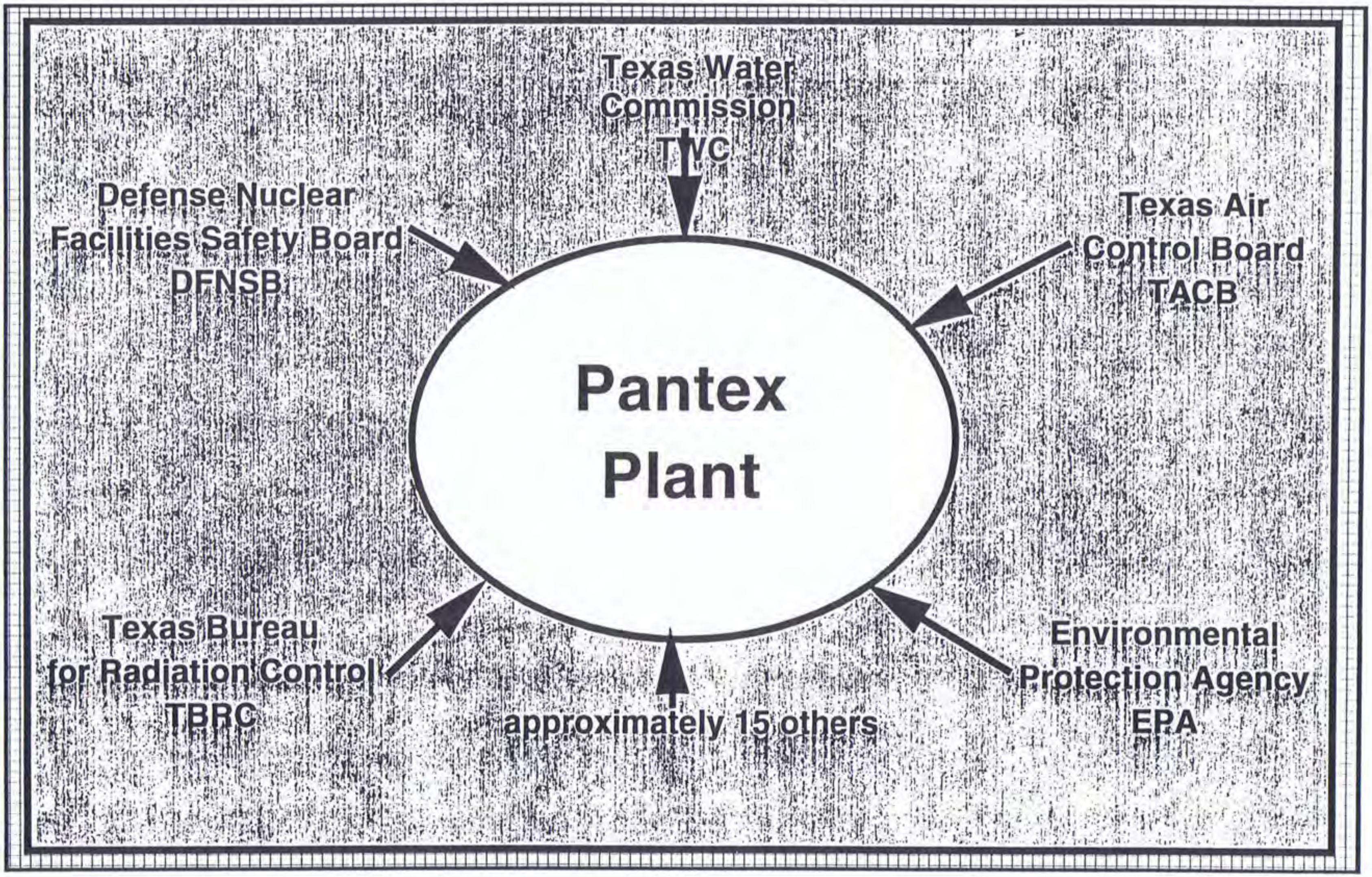

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Sandia/Pantex Robotics

- Weighing and Leak Checking System (WALS)
- Disassembly
- System Studies

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Quality Evaluation for Dismantlement (QED)

- Concept originated in DOE Policy
  - Generated by EMTD and approved by DP-20
- Labs assess dismantlement process
- Level 1-Weapon receipt through disassembly
- Level 2-Subassembly and component preparation for disposal
- Joint Lab team effort to provide the best technical advice
- M&H-Battelle retains overall responsibility
- Defense Nuclear Facility Safety Board values to process

- Level 1 evaluations performed on W48, B57, W68, and W70
- Official Laboratory Quality Releases in December 1992
- Planning for Level 2 underway

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Lead Lab Approach

- Preserve technology at Laboratories
- Utilize limited resources supporting process and manufacturing development
- Maintain Laboratories' unique technical competence
- Enhance Laboratories' capability to provide limited backup
- Facilitate further enhancement of technology transfer
- Increases scope of Laboratories' functions and responsibilities
- Role and relationships of Labs and Production agencies will change
- Lead Lab responsible for maintaining technical excellence in production technology
  - "Cradle to grave"

Pantex Lead Lab Assignments

- Weapon assembly/disassembly
  - Sandia, Paul Longmire
  - Nuclear subassembly
    - Los Alamos, Luis Salazar
- High Explosives
  - LLNL, Dick Hatfield
- Responsible for developing and certifying processes at plants for Complex 21
- Follow-on to Technology Assessment and Selection Panel (TASP)--currently in operation

Tri-Lab Project Office

- 10/92 letter from Bruce Twining, MGR DOE/AL

"Laboratories play a stronger, more direct role, and well-defined role in nuclear operations, wherever they occur, with a first-step emphasis on Pantex operation"

"Establish a Joint Laboratory Technical Support Office"

- Tri-Lab Project Office in operation
  - Ribbon cutting ceremony Sept. 29, 1993
  - Four offices for each Lab
  - Three on-site residents from LLNL--Two from LANL
  - One resident from SNL--one more in process
- Full office facilities, e.g,, adm. support, repository

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Coopertive Program between US and Russian Labs

- Participants
  - US--Sandia, Los Alamos, and LLNL
  - Russia--Chelyabinsk and Arzamas-16
- Unclassified, non-sensitive information exhanges
- Four areas of activity
  - Risk assessment--Stan Spray
  - Transportation Surety--John Kane
  - Hazardous Materials--Paul Longmire
  - Communication and Translation--Patricia Newman
  - Hazardous materials includes handling, material ID, and waste management

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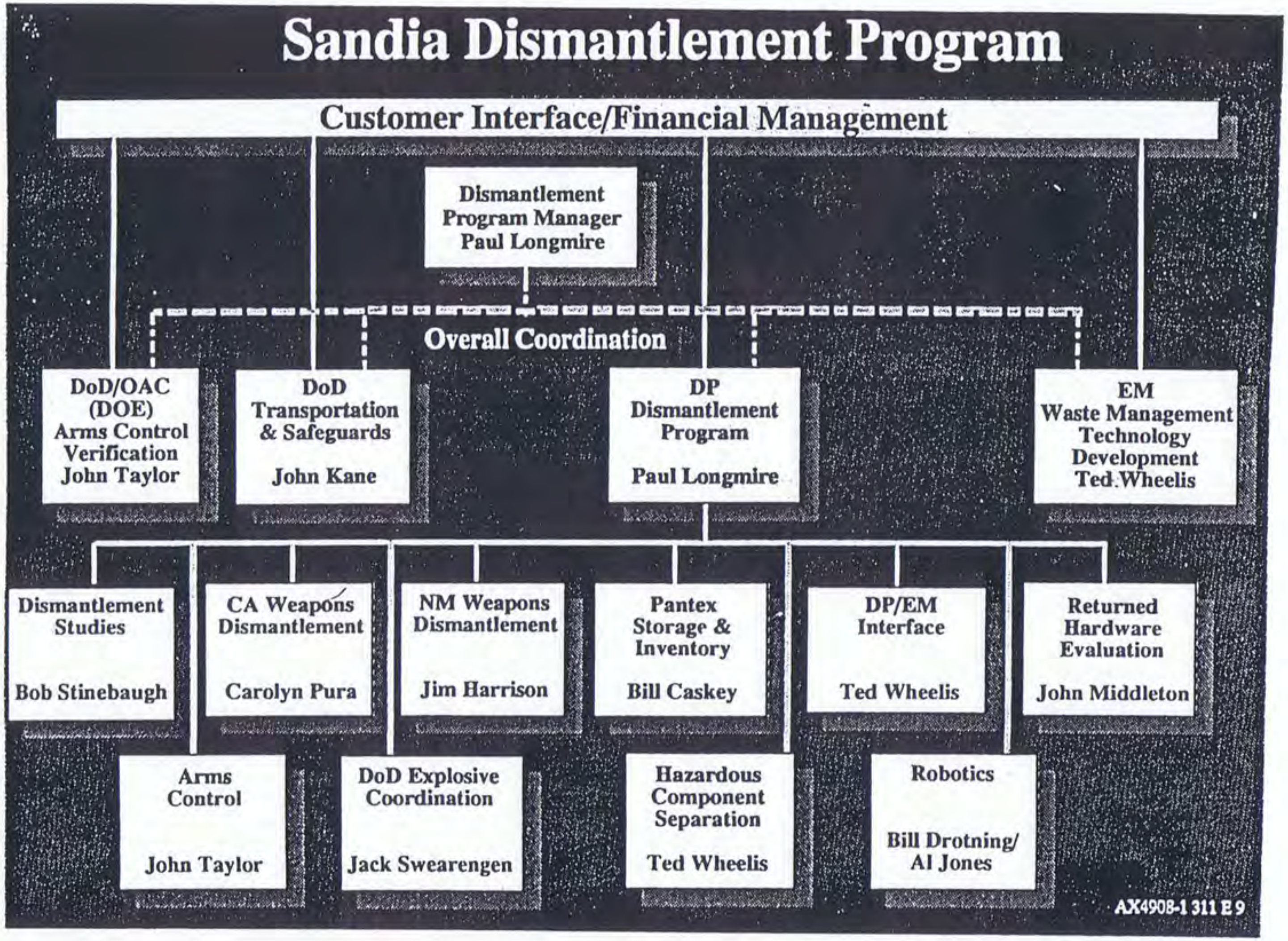

Sandia Dismantlement Program

Customer Interface/Financial Management

Dismantlement Program Manager Paul Longmire

Overall Coordination

DoD/OAC (DOE) Arms Control Verification John Taylor

DoD Transportation & Safeguards John Kane

DP Dismantlement Program Paul Longmire

EM Waste Management Technology Development Ted Wheelis

Dismantlement Studies Bob Stinebaugh

CA Weapons Dismantlement Carolyn Pura

NM Weapons Dismantlement Jim Harrison

Pantex Storage & Inventory Bill Caskey

DP/EM Interface Ted Wheelis

Returned Hardware Evaluation John Middleton

Arms Control John Taylor

DoD Explosive Coordination Jack Swearengen

Hazardous Component Separation Ted Wheelis

Robotics Bill Drotning/ Al Jones

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

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SESSION XI

- DETONATORS
- FIRING SYSTEMS
- NEUTRONS INITIATION
- POWER SUPPLIES

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Topics to be discussed

- Review of implosion assembly (IA) operation
- Review of stockpile detonators
- Firing system components
- Operation of explosive firing sets
- Stockpile firing sets
- Nuclear safety
- Production
- Future systems

Assumptions for briefing

- Students have an undergraduate background in engineering or science

Basics of an Implosion Assembly (IA)

Typical hot wire detonator
(Firing current ~ 5 amps)

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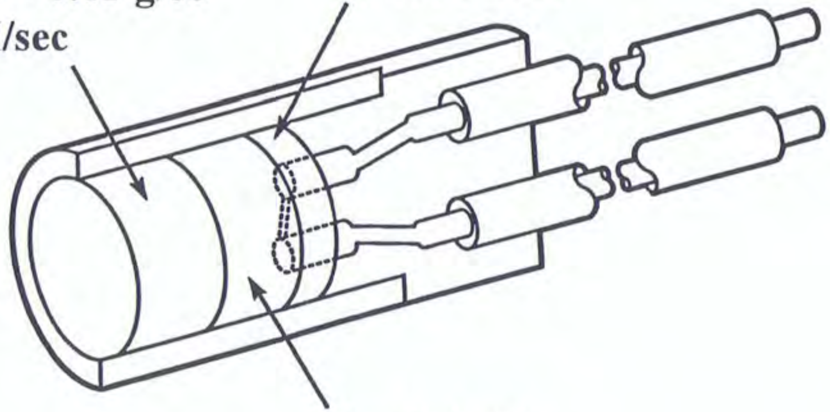

RDX or PETN
Density ~ 1.65 g/cc
8300 M/sec

Lead Styphnate
Density ~3.0 g/cc
5200 M/sec

Lead Azide
Density ~ 4.0 g/cc
5100 M/sec

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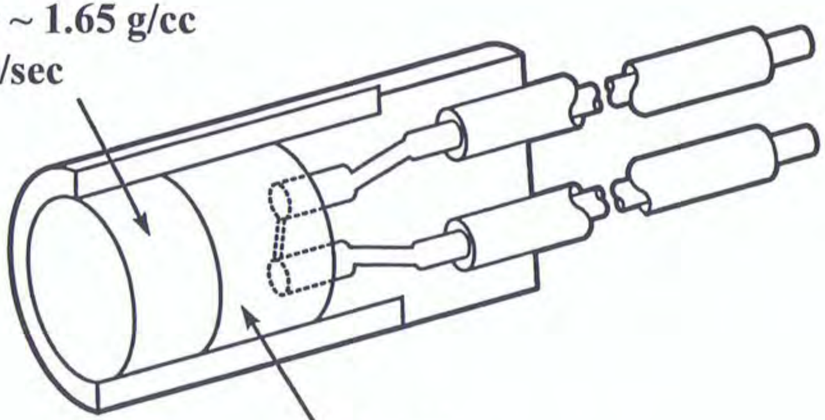
An exploding bridgewire (EBW) detonator (1.5 X 40 mil gold) initiation requires ~ 300 amps



RDX or PETN
Density ~ 1.65 g/cc
8300 M/sec

PETN
Density ~ 0.85 g/cc
5000 M/sec

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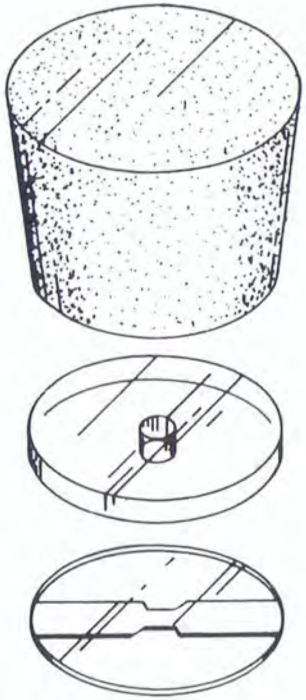
A basic exploding foil initiator (EFI), slapper detonator, consists of three components



Secondary Explosive Pellet (Typically HNS IV)

Insulating disk with barrel (hole)

Etched metal foil with insulated flyer

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The Mechanical Safe and Arm Device (MSAD) controls the detonator pellet in the W84 and W87

EBW and EFI comparison for detonators which requires **approximately** the same initiation energy

	Exploding Bridge Wire	Exploding Foil Initiator
Energy	250 mJ	250 mJ
Current	1000 Amps	2,500 Amps
Function time	2.0 μs	0.5 μs
Energy coupled into explosive	~ 20 % of stored energy	~ 5 % of stored energy
Explosive	PETN (0.8 gm/cc)	HNS (1.6 gm/cc)
HE melting point	140° C (100° C degrades)	320° C (doesn't degrade)

* EBWs need recovery; slappers don't.

* Slappers are more environmentally rugged.

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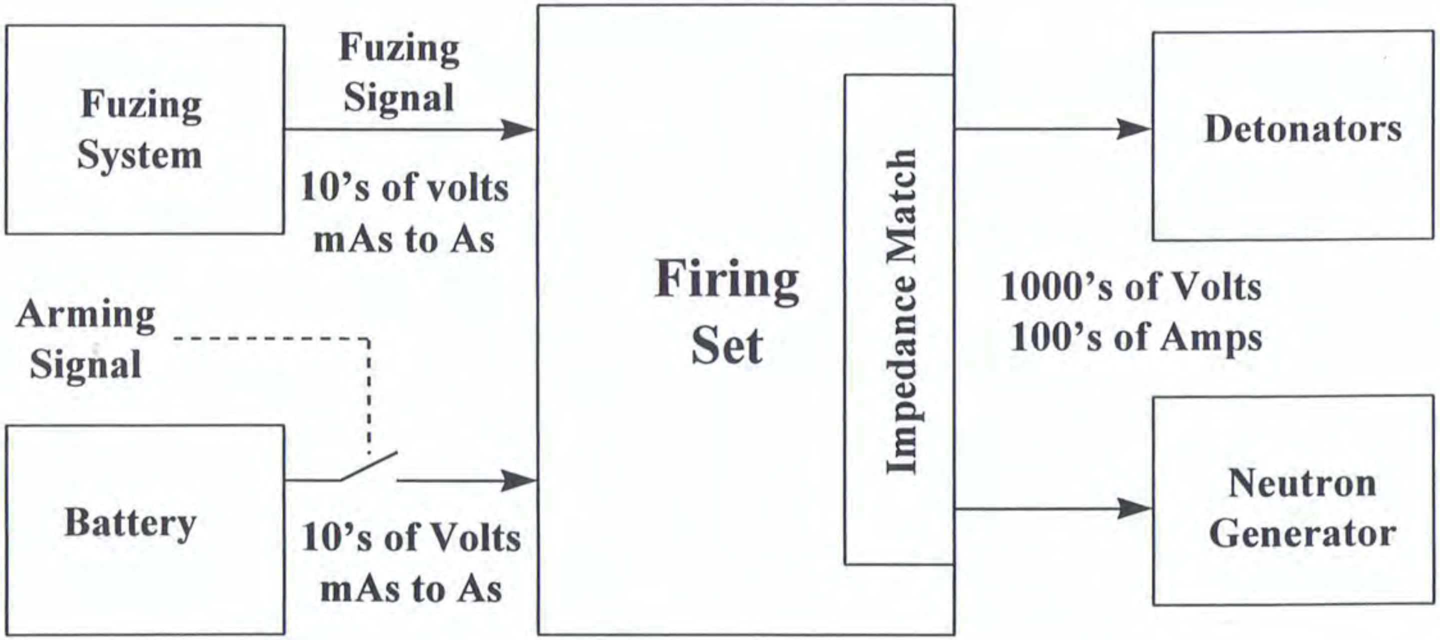
Firing set provides: 1) Low to high voltage/current conversion; 2) Fuze/Fire interface; & 3) Det/NG interface



Fuzing System

Fuzing Signal

10's of volts
mAs to As

Arming Signal

Battery

10's of Volts
mAs to As

Firing Set

Impedance Match

1000's of Volts
100's of Amps

Detonators

Neutron Generator

{Arming, Fuzing and Firing (AF&F)}

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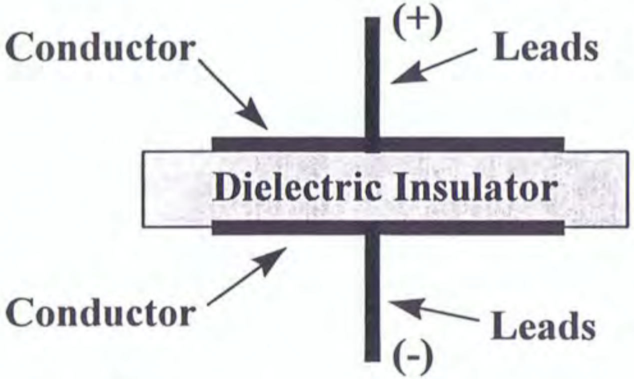
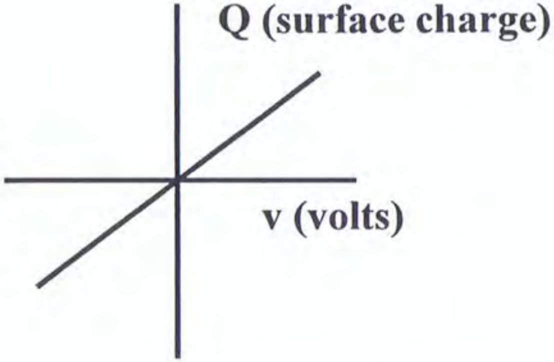
What is a capacitor? Basically two conductors seperated by a dielectric





$$\text{Energy} = 1/2\ CV^2 = 1/2\frac{Q^2}{C}$$

- Q is the charge in coulombs
- C is the capacitance in farads
- V is the potential in volts

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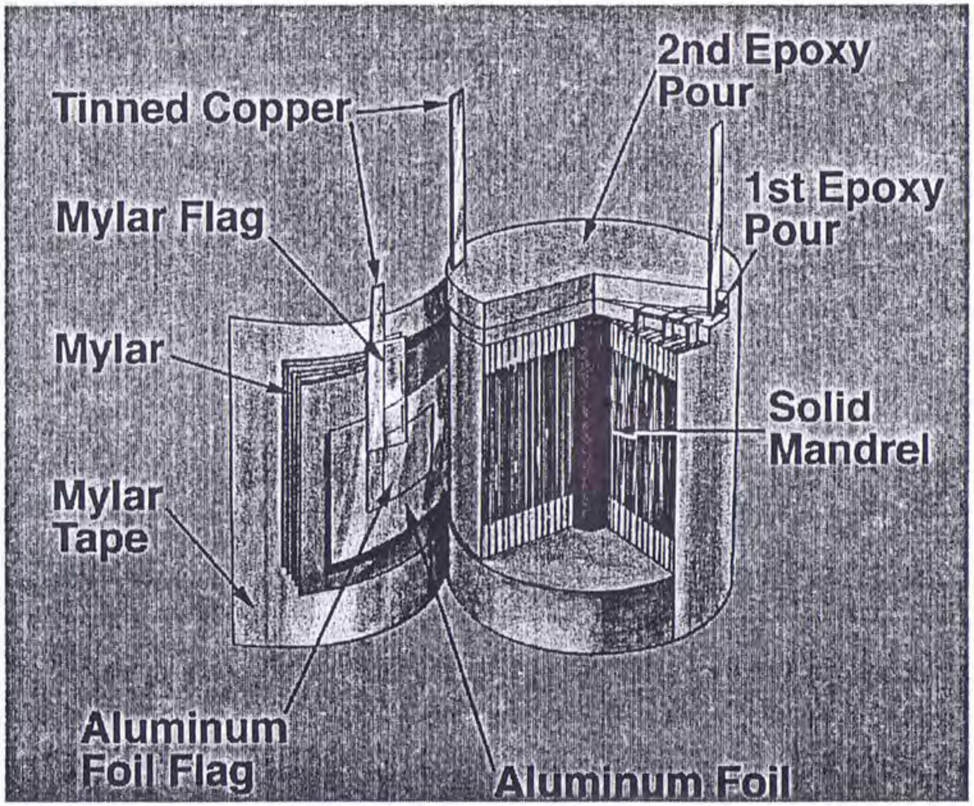
High voltage firing set capacitor (High Energy Density (HED) capacitor)



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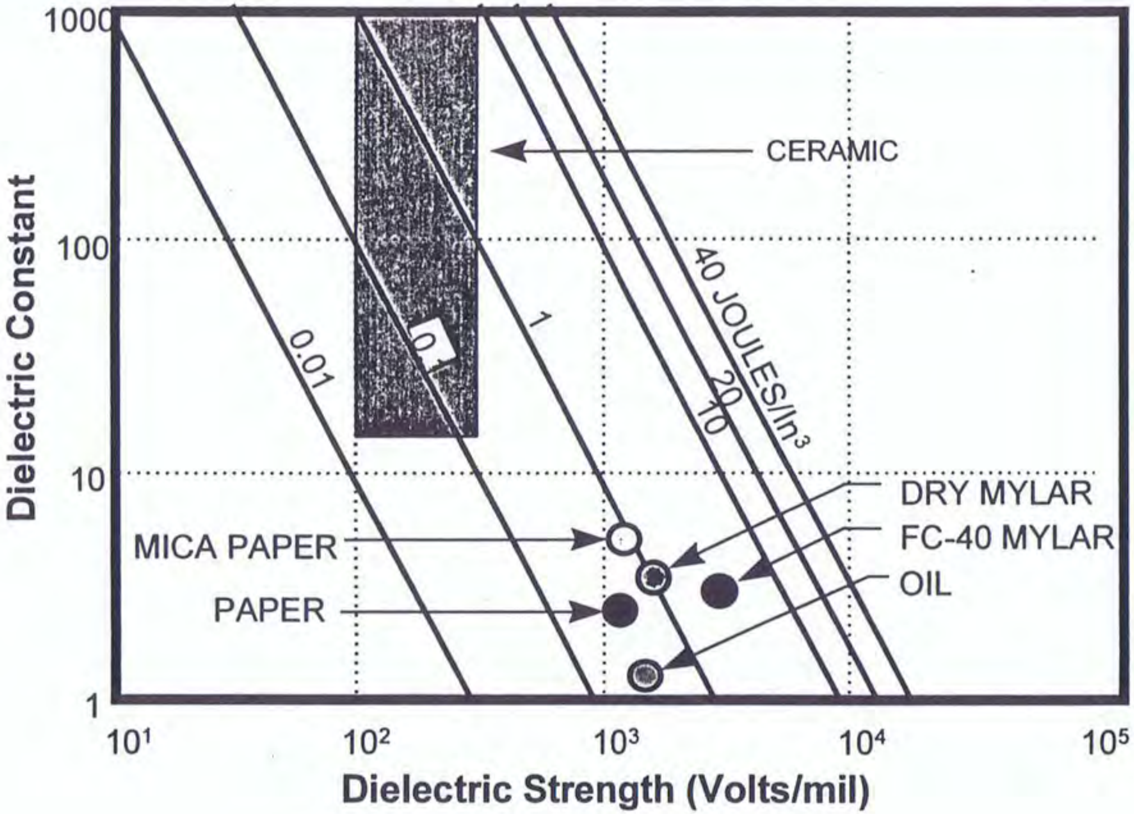
Tradeoff of dielectric strength and dielectric constant - at field use condition



Firing set capacitor bank for a large number of detonators

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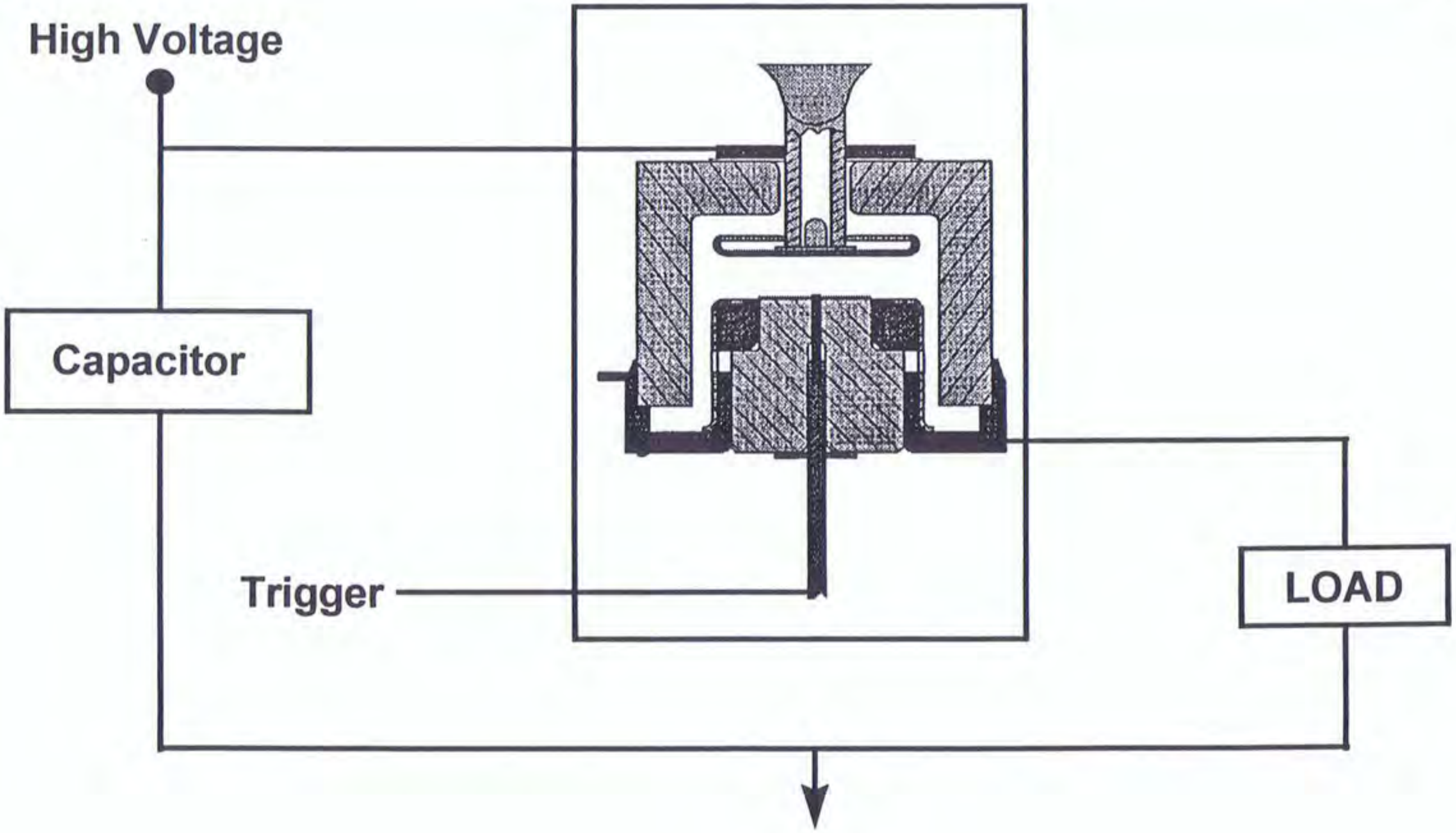
Examples of high energy density capacitors

Basic operation of a switch tube



High Voltage

Capacitor

Trigger

LOAD

Vacuum and gas switches

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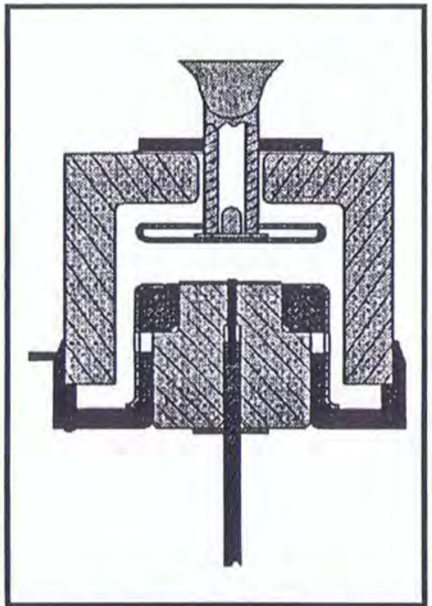
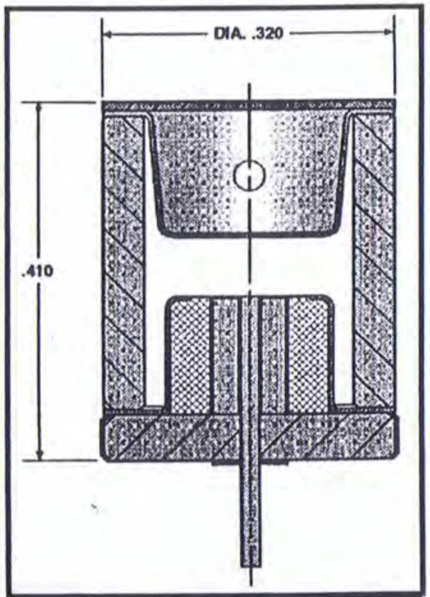
Technology shift has led to reduced complexity and more repeatable processes



Typical Sprytron

❶ **Fab/Test Cycle Time ~ 2-4 months**
❷ **Unit Cost ~ $2-3K**
❸ **Facility Space ~ 65,000 sq. ft.**
❹ **Facility Cost ~ $5M**
❺ **Multiple operations to closure**

❶ **Fab/Test Cycle Time ~ 2-4 weeks**
❷ **Unit Cost ~ $200-400**
❸ **Facility Space ~ 5,000 sq. ft.**
❹ **Facility Cost ~ $1M**
❺ **Single Step closure**



Poco Sprytron

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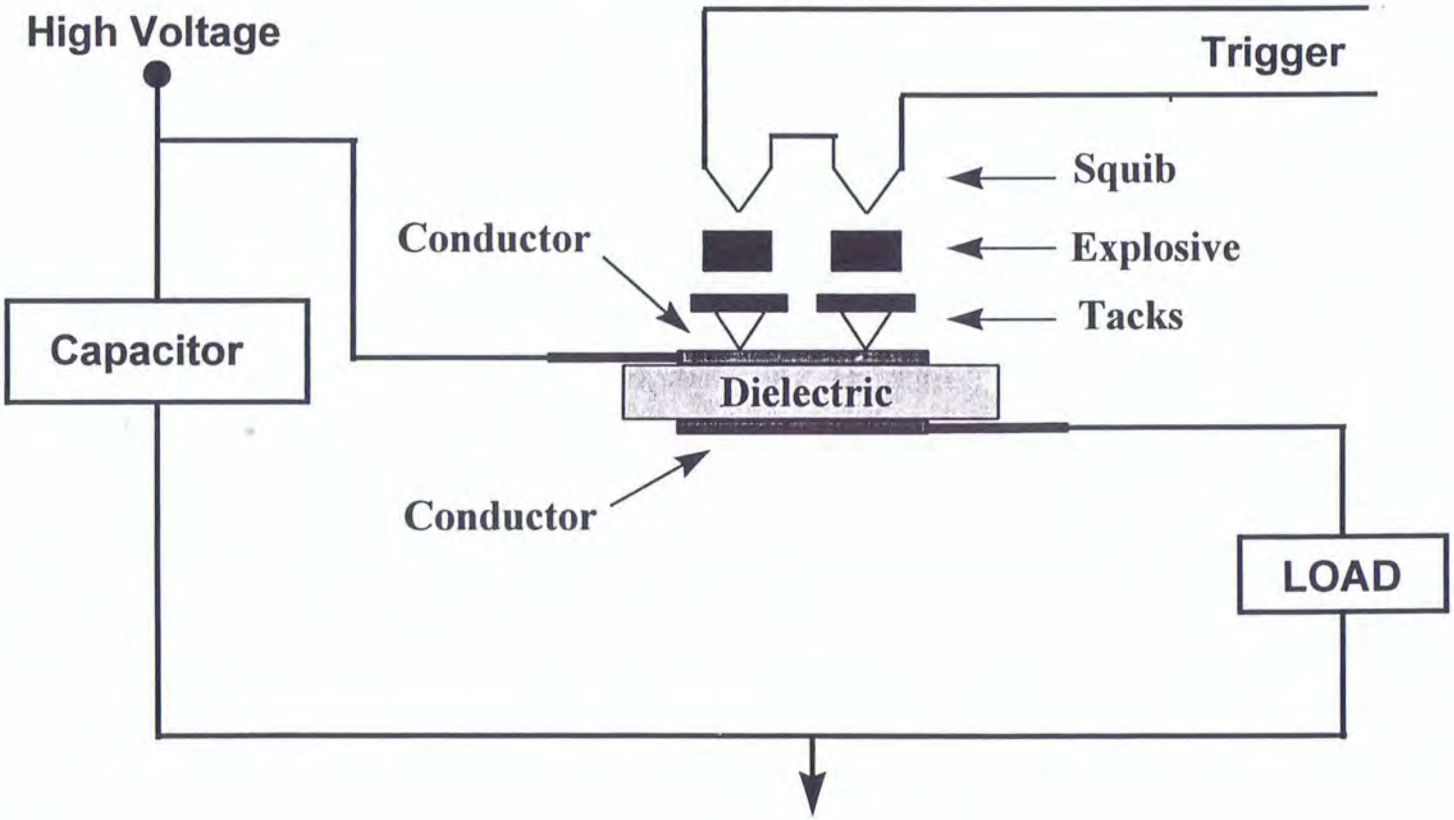
Explosive tack switch system - (Solid dielectric switch (SDS), Explosively driven switch)



High Voltage

Trigger

Squib

Explosive

Tacks

Conductor

Capacitor

Dielectric

Conductor

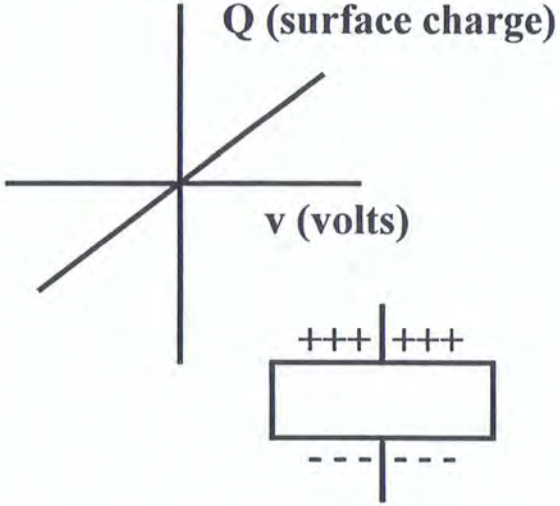
LOAD

There are two technology areas that have been employed in the stockpile

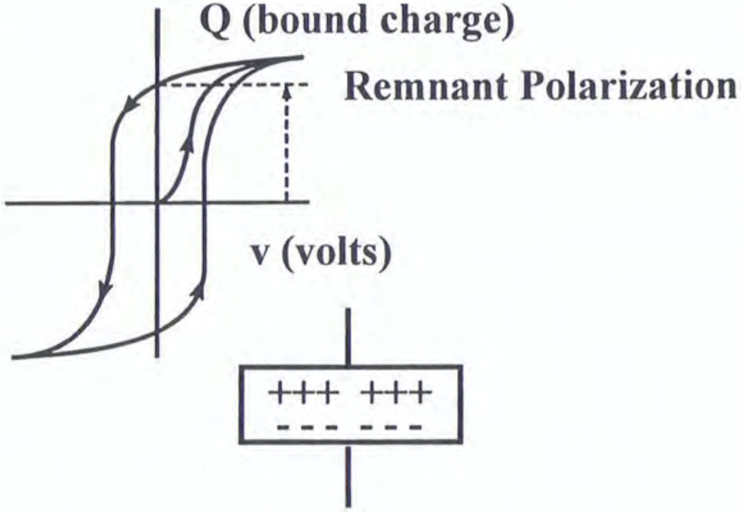
- Capacitor Discharge Unit (CDU) Firing Set
  - Typically all electric
  - Re-testable when it is all electric
- Explosive-to-Electric Transducers (EETs)
  - Chemical energy from explosives are used in the production of electrical energy
  - Single pulse or one shot device

Ferroelectric (FE) material retains a bound charge like a capacitor retains a surface charge

CDU



FE



$$\text{Energy} = 1/2\ CV^2 = 1/2\frac{Q^2}{C}$$

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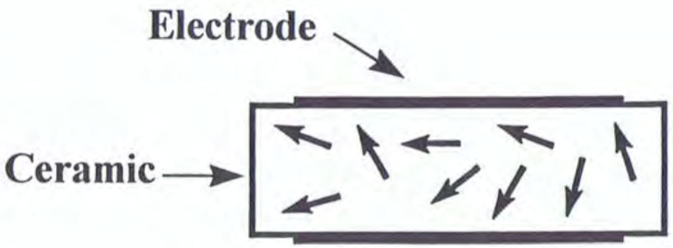
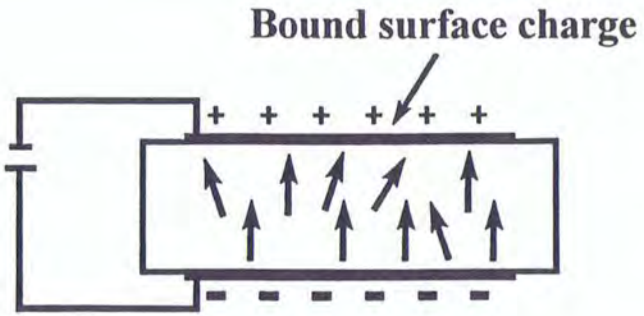
Bound charges are formed in a ferroelectric (FE) material during poling process



Unpoled Ceramic

Polycrystaline multidomain ferroelectric ceramic



Polling Process

Domains aligned by impressing external electric field

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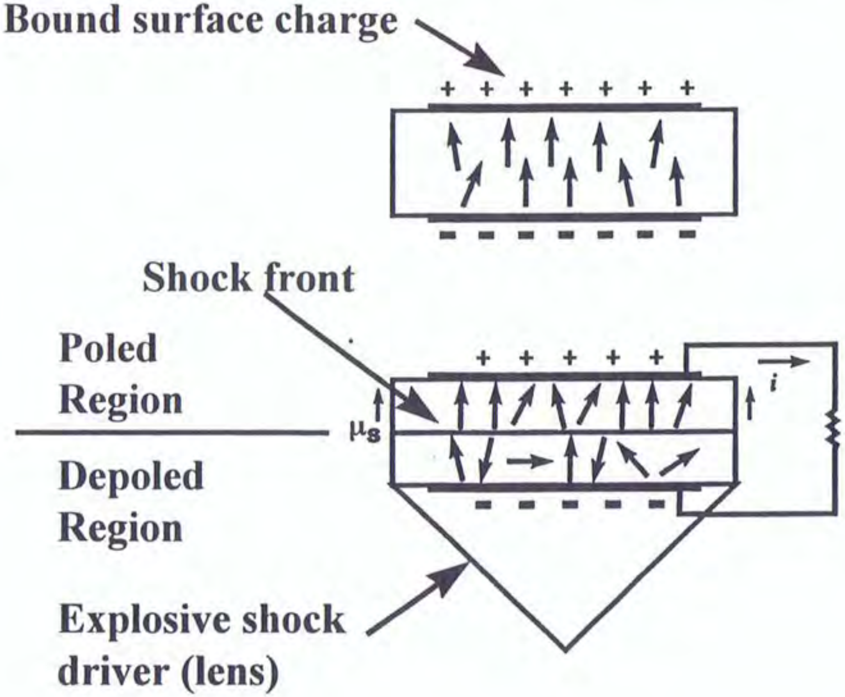
A shock wave of the correct magnitude releases bound charges in ferroelectric (FE) material



Poled Ceramic

Bound surface charge remains due to internal electric field

Shock Depoling Process

Shock wave randomizes dipoles elminating internal field, thus freeing bound charge to external circuit.

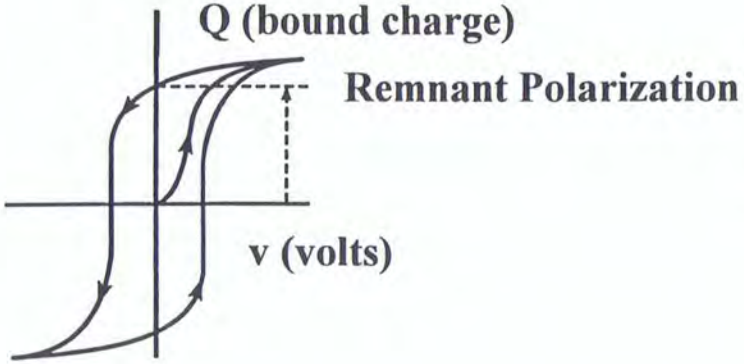
Ferroelectric firing set

B54 and/or Isolator

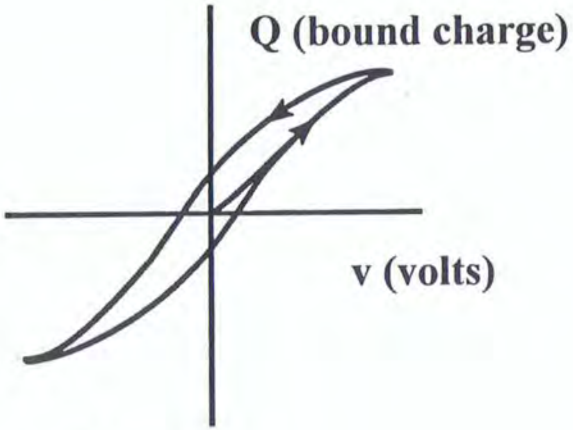
Define isolator and where it is used and why it is used

Slim Loop Ferroelectric (SFE) material reduces remnant polarization to fraction of a micro coulomb

FE



SFE



$$\text{Energy} = 1/2\ CV^2 = 1/2\frac{Q^2}{C}$$

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MC3028 Firing set

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Firing set technology comparisons

Firing Set Technology	Typical Application	Relative Advantages	Relative Disadvantages
CDU	Bombs & Cruise missiles	Retestable no HE	Special effort to Harden
FE	Isolators	Power source not required, small, inherently rad hard	HE required Stored energy
SFE	Missiles (RBs, RVs)	Small, inherently rad hard	HE required Requires trigger
FM	Artillery shells (AFAPs)	Fastest arm/disarm Small, rad hard	HE required
CMF	Under ground testing (UGT)	Large output current & energy, rad hard	Long function time, HE required, requires timed trigger

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Firing sets have many complex requirements beyond that of initiating detonators

- Firing set complexity may be driven by
  - Nuclear safety
  - Radiation
  - Use control
  - Housing/mounting for other components
  - Testability
  - Manufacturability
  - Cost
- There may not be syngerism between requirements

Nuclear safety requirements require the implementation of several complex features

Principles	Implementation
Isolation	Barriers, Strong links
Inoperability	Weak links, Colocation
Incompatibility	Unique signal operated devices
Independence	Multiple independent safety subsystems

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Firing system with enhanced nuclear detonation system (ENDS) features

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Capacitor technology - tradeoff of thermal weak link properties and radiation properties

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Packaging of the printed wiring assembly (PWA) in the B83 firing set before "sylgard 184 GMB"

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Packaging of the printed wiring assembly (PWA) in the B83 firing set <u>after</u> “sylgard 184 GMB”

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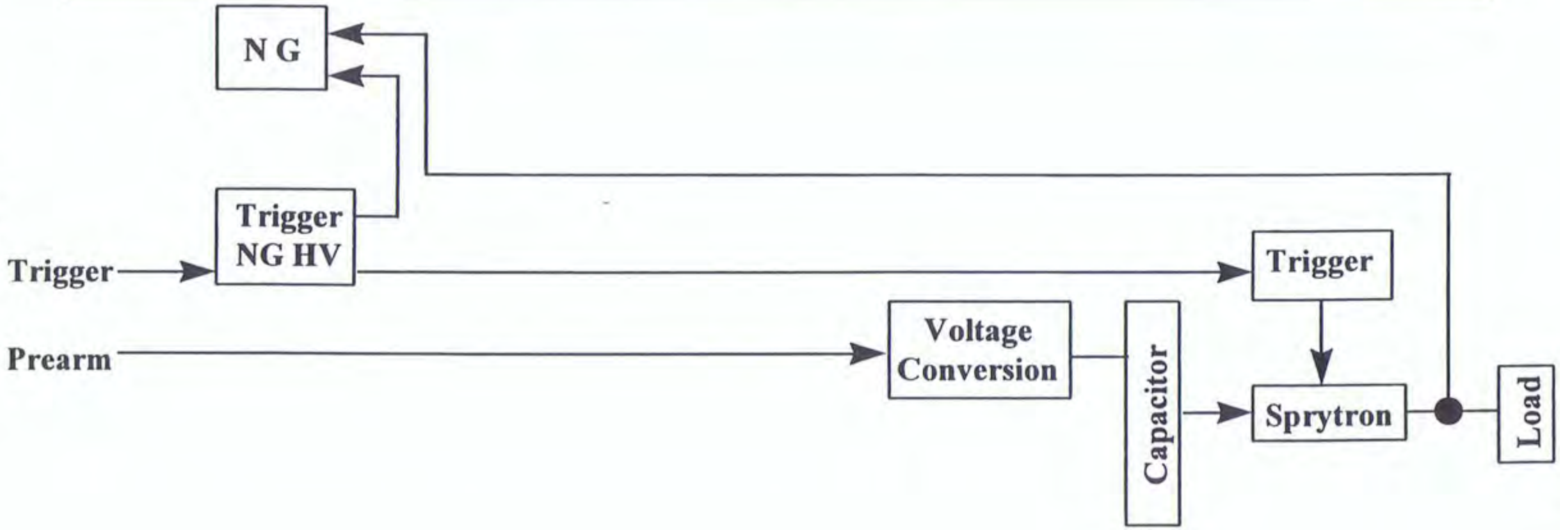
Simple nuclear weapon firing set



N G

Trigger NG HV

Trigger

Prearm

Voltage Conversion

Capacitor

Trigger

Sprytron

Load

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Firing systems in the active stockpile

Firing sets and detonators in the active stockpile

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Firing set production is ongoing at a low level

Weapon	MC Number	Technology	Quantity
B83	MC3971A	CDU	~ 10/month ongoing
W87	MC3719	CDU	~ 3-4/month starting 1998

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Roadmap for Advanced Firing/Detonation Systems (AF/DS) supports future stockpile needs

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Stockpile Firing Systems

Increased Surety

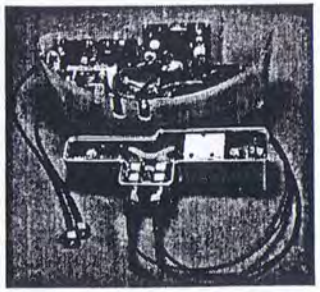
Miniaturization/
Increased System
Functionality

Present → Future

Support Stockpile Life Extension Program

Micro-CDUs

Detonator Stronglinks



Direct Optical Initiation

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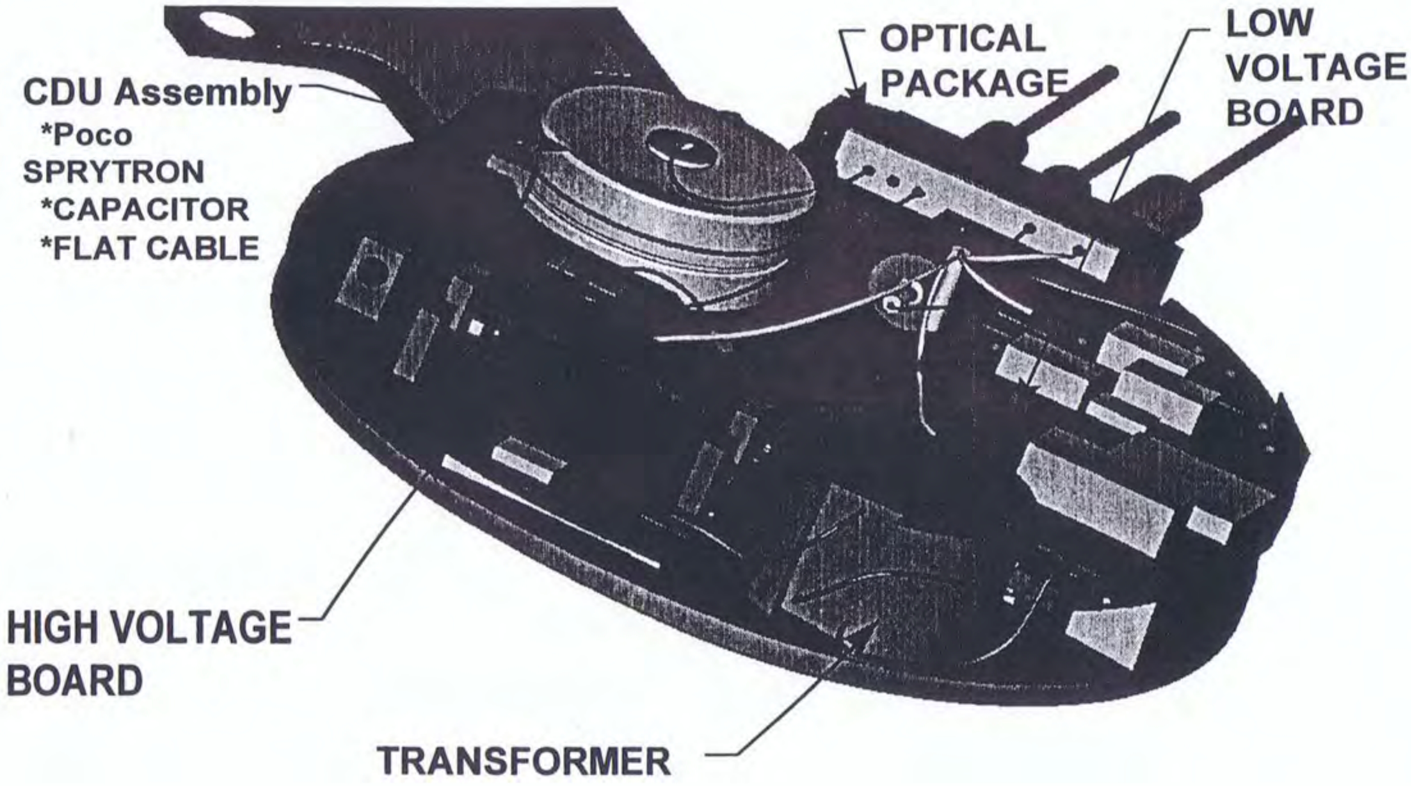
Micro firing set



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Micro CDU firing set working prototype

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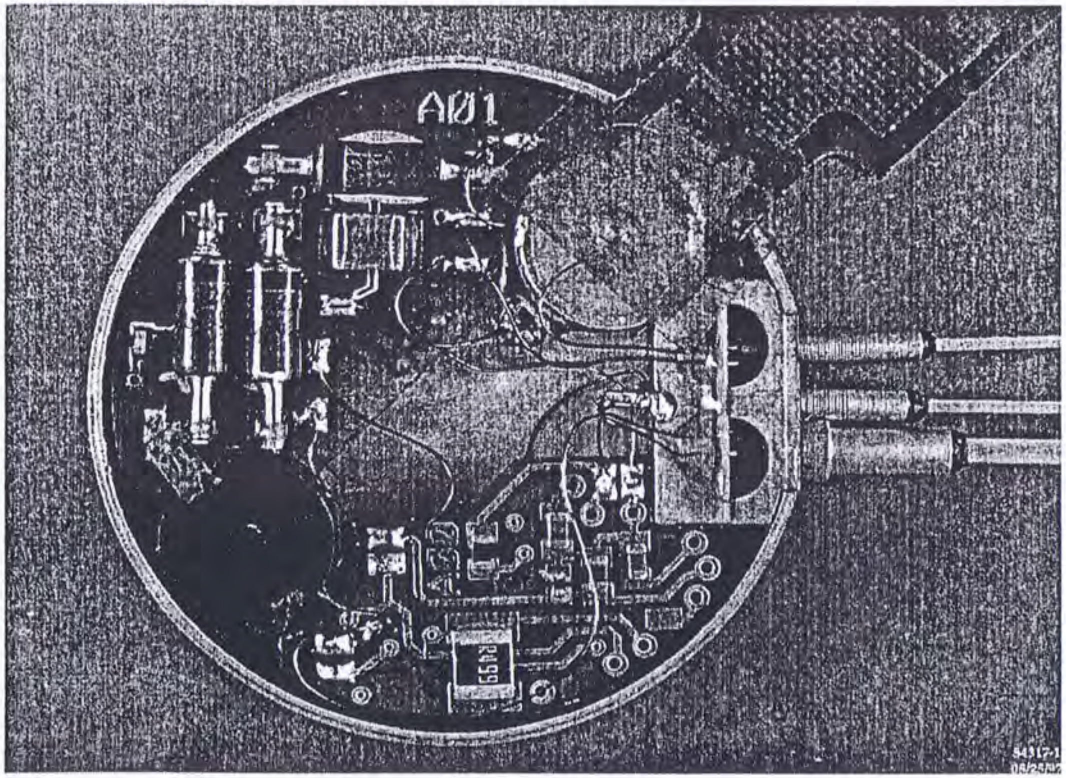

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Micro CDU - 0.23 in^3 - Working prototype

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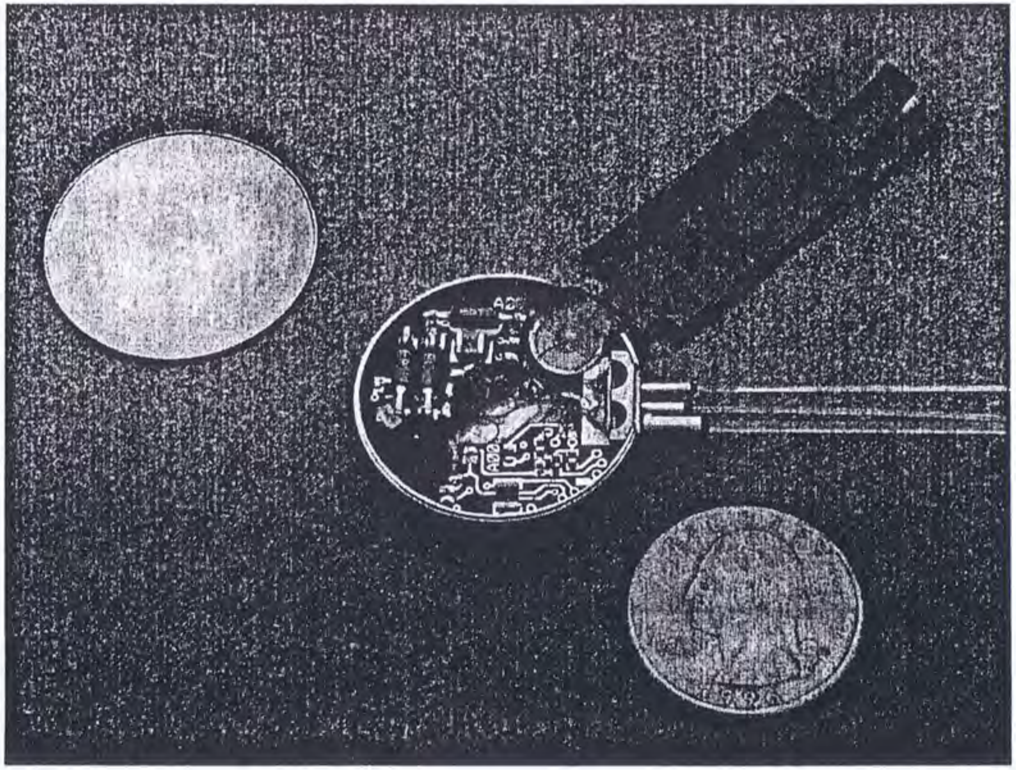

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Neutron Initiators
Topics to be discussed

- Internal initiators
- External initiators
- Movie - An overview of neutron source technology
- Technology involved
- Evolution of neutron generator development
- Production
- Future systems

Basics of an Implosion Assembly (IA)

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Neutron yield is dependent on ion source material and ion energy

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Neutron multiplication rate

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There are two fundamental reasons neutron sources are used in weapons

- Jump start the weapon
- Stabilizes the output

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Alpha curve

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Show Movie

Basics of how a neutron tube work

Picture of a neutron tube

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Neutron generator using an explosive to electric (EET) power supply

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Neutron generator using an electronic power supply

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Implosion Assembly (IA) timing requirements

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Neutron generations requirements over time

Neutron generator timing is affected by several factors

- System center time shift with temperature
- Neutron generator center time shift with temperature
- Neutron generator jitter
- Firing set jitter
- Weapon detonator jitter
- Neutron generator detonator jitter (explosive NG)
- Shift in electronic components (electronic NG)

Neutron generator "family" picture

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SNL is now the production agency for neutron generators

- The targets will be loaded at LANL
- The first production requirement is for the W76 (2000)
  - MC4277 Neutron Tube
  - MC4380 Neutron Generator
- Future need for a small tube/generator for W80
  - FY2008? (P&PD 96-0)
  - Requires the small neutron tube, MC4300
  - MC4600 neutron generator

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MC4380 Neutron generator

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MC4300 Neutron Tube

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Design evolution from the MC4300 neutron tube (W76) to the MC4600 neutron tube (future applications)

Power Systems

- Basic battery types
- Examples of non thermal batteries
- Thermal battery applications
- Thermal battery operation
- Examples of thermal batteries
- Power supply design influences
- Battery performance
- Evolution of Battery Development
- Production
- Future Technology

Basic battery types

- Primary: not rechargeable
  - Active: power immediately available
  - Reserve: must be activated
- Secondary: rechargeable
- Nearly all nuclear weapon batteries are primary batteries
- Most weapon batteries are reserve batteries

Types of power sources in nuclear weapons

- Thermally activated
- Rechargeable - Ni/Cd
- Reserve - Zn/AgO
- Active - Li/SO_2
- Active and reserve - $Li/SOCL_2$
- RTG (fissionable heat source)
  - Radio isotropic Thermal electric Generator (RTG)
- Double-layer capacitor

Non thermal battery applications

- **SA2039**

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Picture of a generic thermal battery

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Picture of thermal battery cell

- Current
- Voltage
- Anode, cathode, electrolite
- Thermal vs current handling requirements

Thermal batteries are used in many nuclear weapon applications

- RADARs
- Programmers
- Timer
- Firing sets
- Spin rocked motors
- Parachute deployment
- Telemetry
- Command disable
- Command enable
- Fin activation

What is a thermal battery?

- Thermal batteries are primary reserve batteries that employ inorganic salt electrolytes, which are nonconductive solids at ambient temperatures, and integral pyrotechnic materials scaled to supply sufficient thermal energy to melt the electrolyte.

Movie

- **Thermal Battery Ignition**

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Thermal battery performance- voltage - with constant load

Thermal battery performance- current - with constant load

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Calcium chromate performance

Lithium battery performance

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Power supply design influences

- Reliability (0.995 - 0.997)
- Shelf life - Thermal battery > 25 years
- Ruggedness - W82 AFAP application
- Operating temperature
- Current density
- Pulse capability
- Voltage - determined by cell chemistry

Thermal batteries are mechanically and environmentally robust

- Example of the W82 AFAP MC3714 environmental requirements
  - Spin: 18,000 rpm
  - Setback acceleration : 17,000 g's, 10 ms
  - Angular acceleration: 40,000 rad/sec^2
  - Ramming shock: 440 g, 1.83 ms, haversine
  - Rebound acceleration: 4000 g's 0.3 ms

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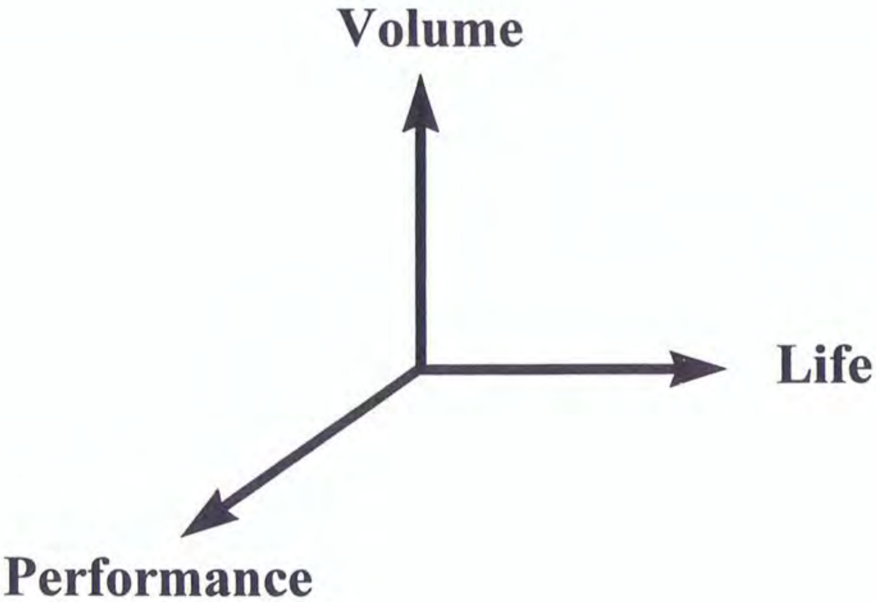
The three dimensional design space for batteries is volume, performance, and life



Volume

Life

Performance

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Picture showing thermal battery performance versus size

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Typical thermal battery performance Values based on Li(Si)/FeS_2 system

Battery Type	Active Life (sec)	Min Volts (v)	Current Density (mA/cm^2)	Specific Power (W/Kg)	Volume (cc)
Pulse	0.050	17.5	7500	8000	10
Pulse	5	26	1000	1700	10
Power	200	12	1800	740	1640
Power	60	25	300	260	137
Power	120	26	120	80	360
Power	1200	26	100	80	320
Long Life	4500	13	55	18	320

Examples of batteries used in the US nuclear weapons program

Weapon	Technology	Cell Voltage	Approx. Date
Little Boy	Lead Acid	2.0 volts	1945
Fat Man	Lead Acid	2.0 volts	1945
MK4,5,6,7	Nickel-Cadium	1.2 volts	1953
MK15	Thermal CA-$CaCr0_4$	2.5 volts	1955
W62	Silver-Zinc	1.8 volts	1970
W70	Thermal Li/FeS_2	1.9 volts	1973
B83	Thermal Li/CoS_2	1.8 volts	1980's

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W76 thermal battery

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MC2936 thermal battery

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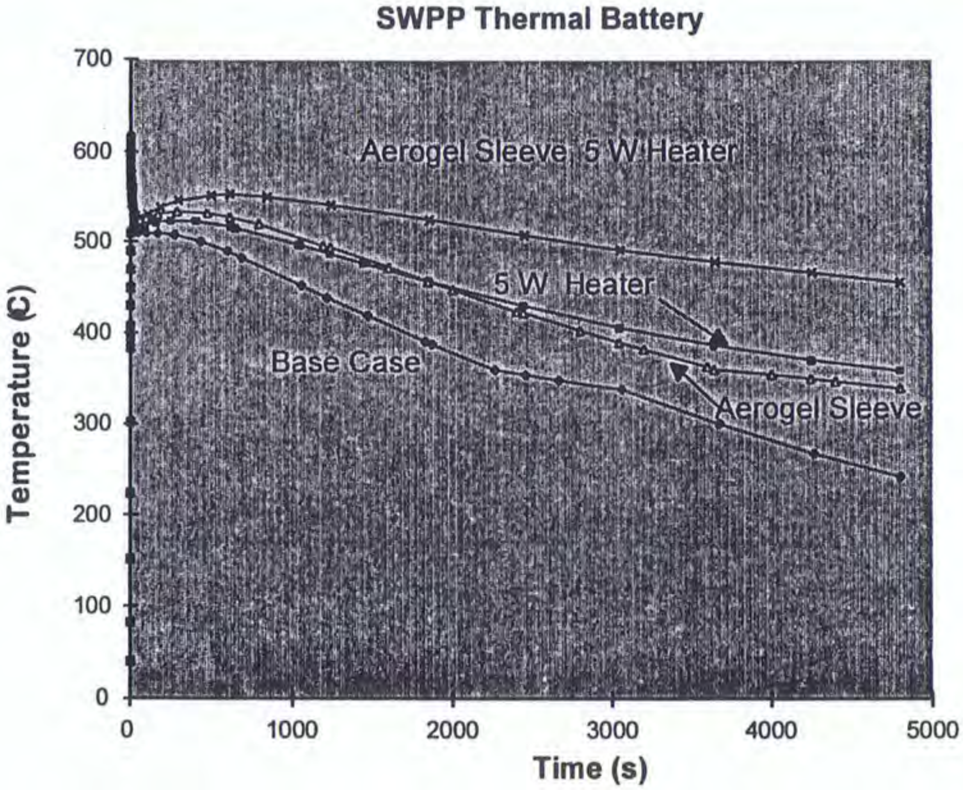
Battery production is currently taking place at three production agencies (PAs)

- Eagle Pitcher
  - The primary PA which resulted from the nonnuclear reconfiguration study
- SNL
  - The backup site for production which resulted from the nonnuclear reconfiguration study
- Enser Corporation - Private Corporation
  - Recently formed out of Martin Marietta Specialty Components, Inc. (GEND, Pinellas Plant)

Battery production is at a low level

Company	Nomenclature	Type	Application	Quantity
Eagle Pitcher	SA3562	Zn/AgO	JTA	~ 2 Dozen
	MC3471A	Thermal	B61	300-400
	MC2736A	Thermal	JTA	~ 2 Dozen
Enser	MC3323A	Thermal	W80 JTA	~ 2 Dozen
SNL	MC4152	Thermal	B61 Common JTA	~ 2 Dozen

Aerogel and a heater may increase battery output without increasing volume



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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

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SESSION XII

•NUCLEAR TESTING

PHYSICS PACKAGE DEVELOPMENT TOOLS

- THEORY
- NON-NUCLEAR TESTING
- NUCLEAR TESTING

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NON-NUCLEAR IMPLOSION DIAGNOSTICS

- PHERMEX (RADIOGRAPHY)
- PIN DOME
- HIGH SPEED PHOTOGRAPHY

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NUCLEAR TESTING

- WEAPON DEVELOPMENT
- EFFECTS
- VULNERABILITY AND HARDENING
- STOCKPILE RELIABILITY
- PEACEFUL NUCLEAR EXPLOSIVES

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DIAGNOSTICS

- YIELD
- "ALPHA"
- CHANNEL TEMPERATURES
- INTERSTAGE TIME
- OTHER

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REFERENCES

- LA2000 1947 SRD
- WT900 DEC 1953 SRD

FIREBALL YIELD

- SAND 77-0402 - “SHOCK PROPAGATION...” SLIPHER
- DNA-119M REPORT
- DASA 1211 - 1220 REPORTS
- LLNL RESEARCH MONTHLY 3141-83-1033 (DIAGNOSTICS)
- DNA 170M REPORTS
- LASL-LLL SPECIFIC TEST REPORTS

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY WR708

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SESSION XIII

•TRANSFER SYSTEMS

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GAS TRANSFER SYSTEM TECHNOLOGY

STEVEN ROBINSON, 8412

COMPONENT DEVELOPMENT DEPARTMENT

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SANDIA GAS TRANSFER SYSTEMS

- Classification
- Introduction
- Examples
  - Systems
  - Reservoirs
  - Valves
- Concerns

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BOOSTING

DEUTERIUM AND TRITIUM ARE USED TO MAKE PLUTONIUM BURN MORE EFFICIENTLY (I.E., TO "BOOST" THE FISSION YIELD).

HIGH EXPLOSIVE

↓

"SLOW" FISSION BURN

↓

IGNITION OF D/T

↓

FLOOD OF HIGH ENERGY NEUTRONS

↓

"FAST," EFFICIENT FISSION BURN

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Tritium

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WEAPON BOOSTING REQUIRES THE ABILITY TO STORE MIXTURES OF HYDROGEN ISOTOPES AND TO DELIVER THE APPROPRIATE MIXTURE ON DEMAND

THIS REQUIRES

- **Containment reservoirs**
- **Flow Systems**
- **Explosive Valves**

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CHALLENGES WITH GAS TRANSFER SYSTEMS

- Long Term Degradation
- Constancy of Delivery
- Complex Plumbing
- Minimization of Weight and Volume
- Cost

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STOCKPILE LIFE, YEARS

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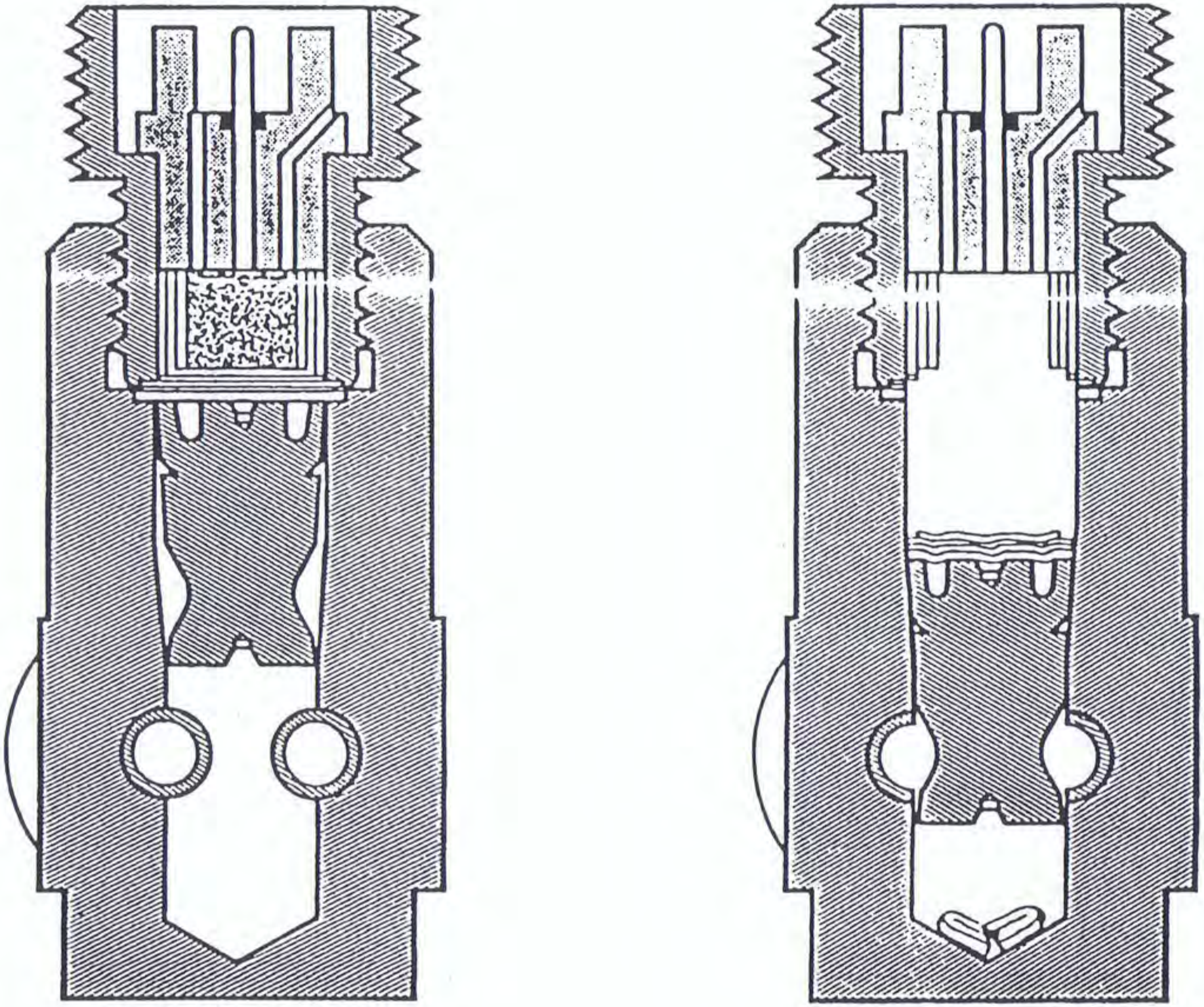

BEFORE

AFTER

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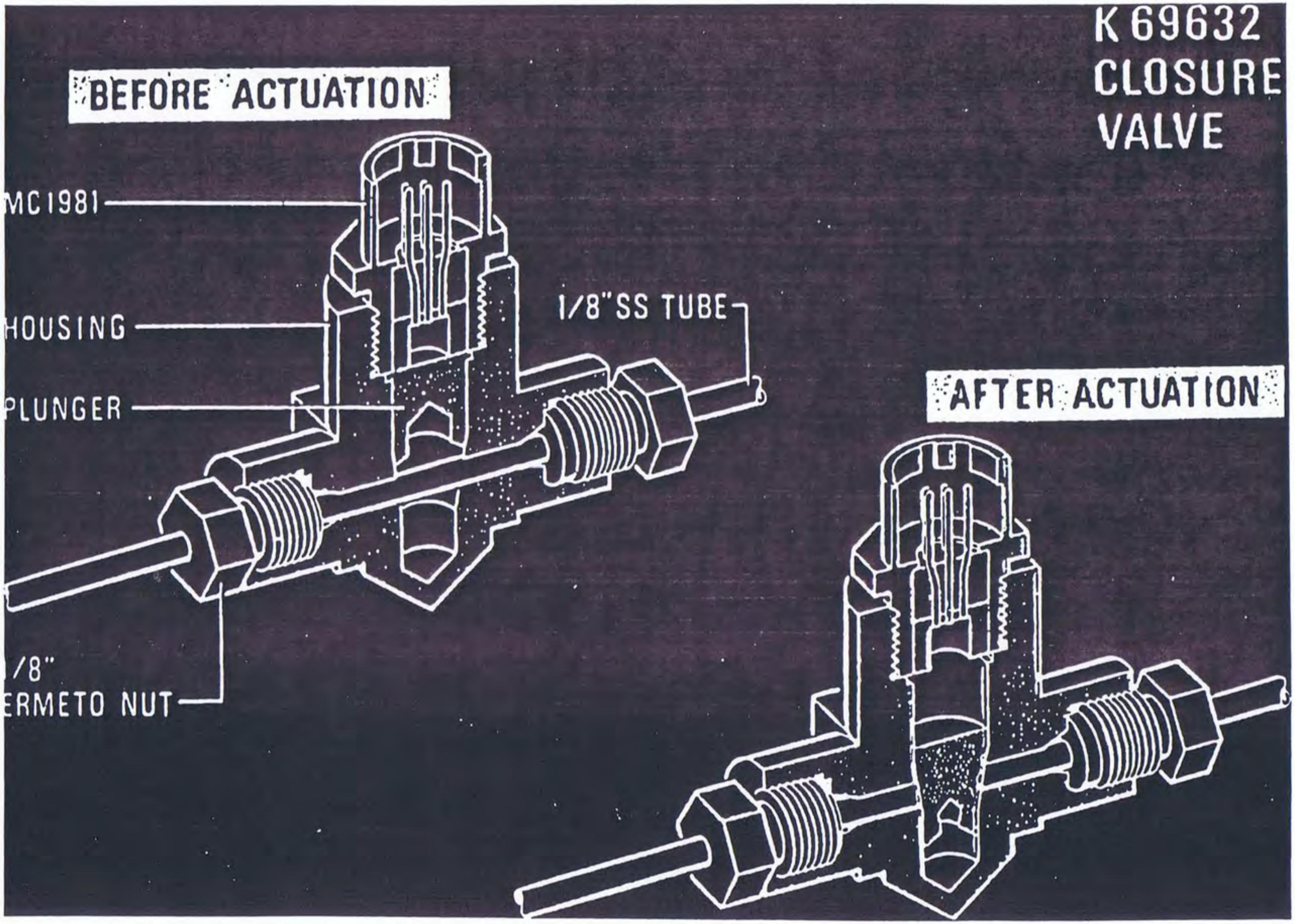
EXPLOSIVE VALVE OPERATIONAL SEQUENCE


K 69632
CLOSURE
VALVE
BEFORE ACTUATION
MC1981
HOUSING
PLUNGER
1/8" SS TUBE
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ERMETO NUT
AFTER ACTUATION

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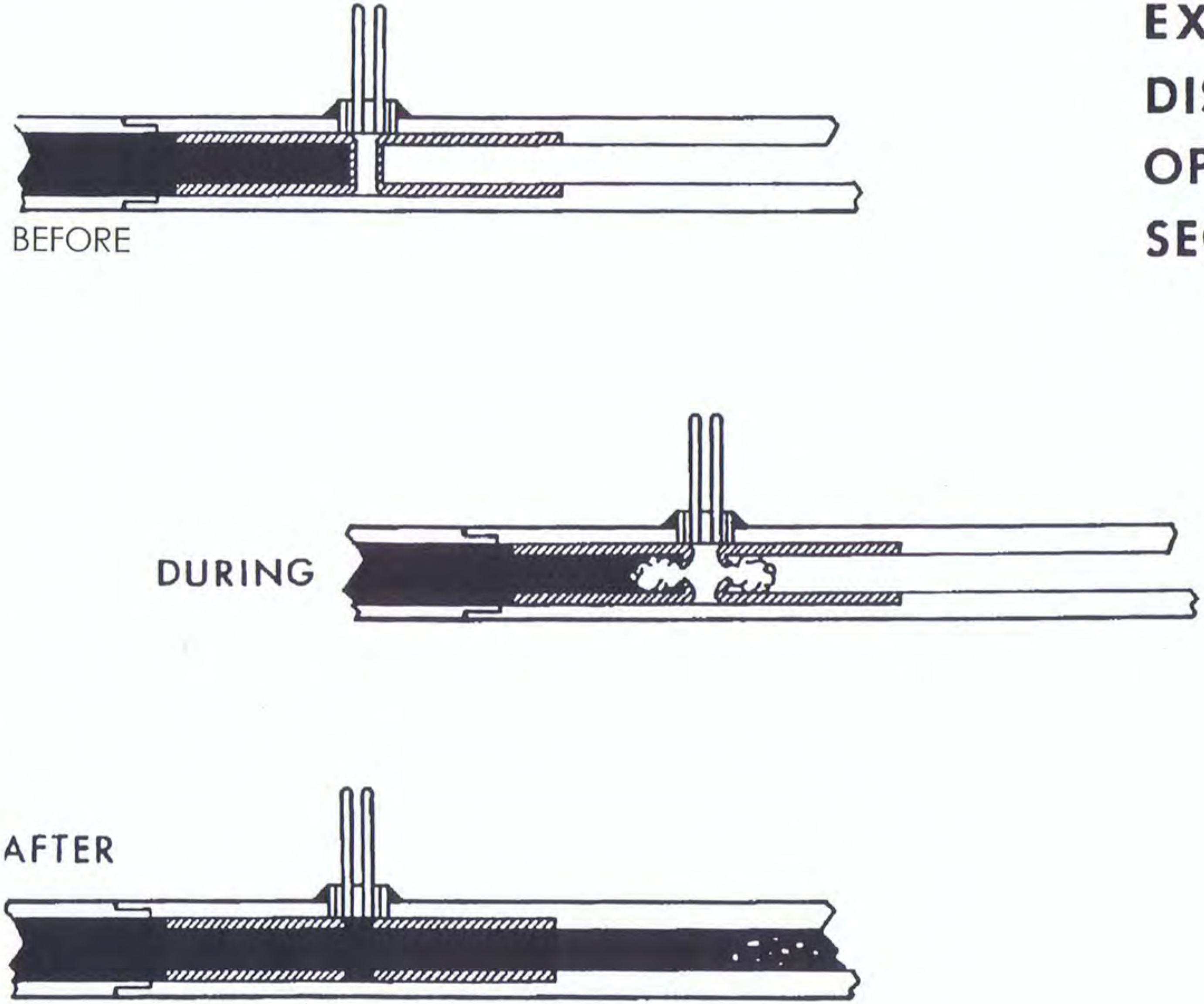
EXPLODING DISK VALVE OPERATIONAL SEQUENCE



UNIQUE DESIGN PROBLEMS IN TRITIUM RESERVOIRS (U)

- *System*
  - Must Deliver In Specified Time
  - Must Be Consistent
  - Satisfy Weight And Space Requirements
  - Fire And Accident Considerations

- *Long Term Degradation*
  - Subject To Hydrogen Embrittlement
  - Subject To Helium Embrittlement
  - Withstand Pressure Increase With Time
  - Subject to Radiation Induced Effects (Loss of Permeability, Stoichiometry)

- *Safety*
  - Must Be Super Safe Against

    Burst

    Permeation (Walls, Welds, Stringers)

Consequences of a stockpile tritium release:

a. Weapon reliability

b. Personnel safety

c. Political/environmental ramifications

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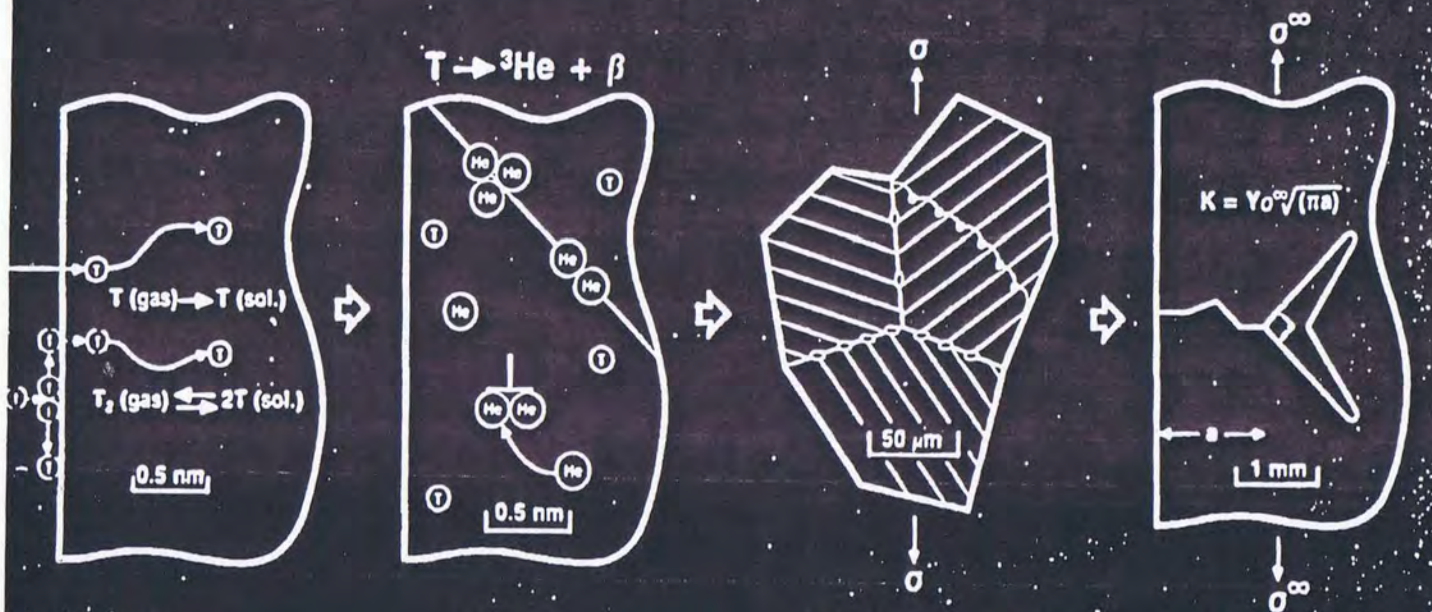
Helium from tritium decay produces cumulative, irreversible damage in stockpile materials



- Tritium entry
- Helium precipitation
- Microstructural damage
- Property degradation

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Specifications

- Narrow chemistry——promotes weldability
- Grain size——less than ASTM 5
- Vacuum—arc—remelt (VAR) material
    - Inclusions——ultraclean
    - Ferrete distribution—— < 3% minimize stringers

Acceptance

- Chemistry
- Metallography
    - Grain size
    - Ferrite distribution
    - Inclusion
- Ultrasonics——porosity

For tritium reservoirs, it is necessary to improve the material properties

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It is most important to clean all surfaces of undesirables

CLEANING

Why

- To remove residues and oxides which could interface with welding, plating, or heat treating processes
- To remove any metallic materials imbedded into the surfaces permitting the formation of a continuous protective oxide film
- To prevent sources of rusting and corrosion on the surfaces
- To remove contaminants which could react with tritium

How

- Detergent solutions agitated ultrasonically
- Nitric acid solutions for dissolving imbedded copper and iron particles
- Nitric—hydrofluoric acid solutions for dissolving oxide films and imbedded particulate matter, and to etch certain stainless steel alloys
- Freon and alcohol rinsing for removing organic contaminants
- High purity water for rinsing
- High temperature vacuum bake

We take extreme care to verify cleanliness

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CLEANLINESS VERIFICATION

- Monitor the resistivity of the rinse water to verify the absence of ionizable material
- Use analytical rinses to check for organic and inorganic contaminants with infrared spectrophotometer and ion chromotagraphy
- Perform particulate analysis on each reservoir
- Check for imbedded iron particles with a copper sulfate test
- Borescopic examination where applicable
- Visual examination for discoloration, staining, or superficial corrosive attack

Both piece parts and assemblies are cleaned prior to inspection

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Inspection and gaging costs approximate one-third of the piece part costs

INSPECTION AND GAGING

To assure:

- Interchangeability of piece parts
- Fit with next assembly
- Conformation with engineering drawings

We inspect and gage using:

- In process monitoring—feedback
- Open——set up inspection
- Dedicated gages
- Contour gages
- Air gages——non-contact
- Statistical sampling
- Control of numerical machine tapes
- Coordinate measuring machines

To minimize scrap and rework costs, we inspect early in the process

Mechanical joints are not used for storage of tritium

ASSEMBLY AND JOINING

Joining:
- Weldments
  - Gas-tungsten are——autogenous and wire feed
  - Electron beam——autogenous and wire feed
  - Laser
  - Friction
  - Inertia
  - Resistance forge weld
- Brazes
  - Copper
  - Copper-silver-tin

Inspection and Control:
- Process monitor
- Radiographic
- Ultrasonic
- Dye Penetrant

All pressure rated components are pressure tested

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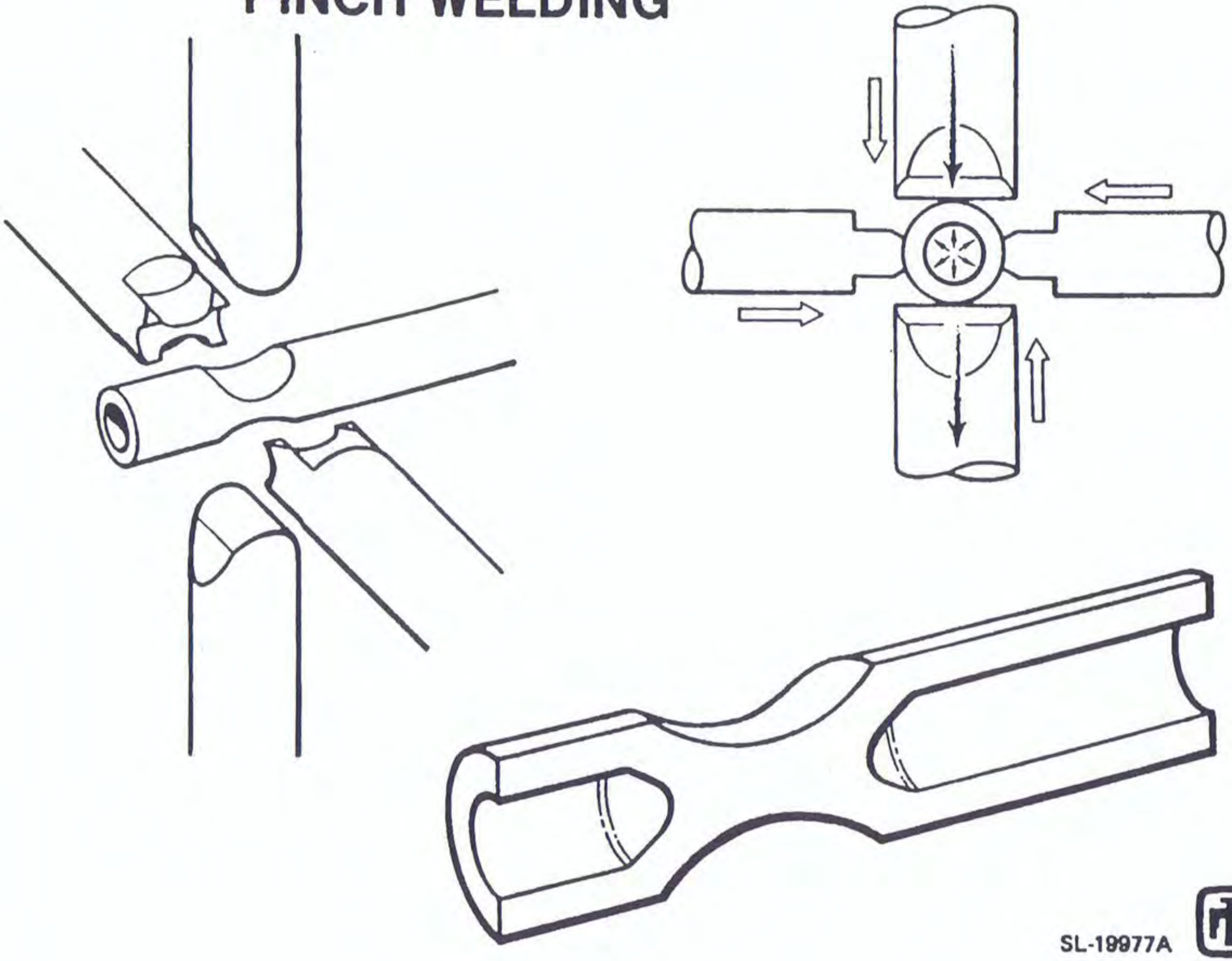
PINCH WELDING



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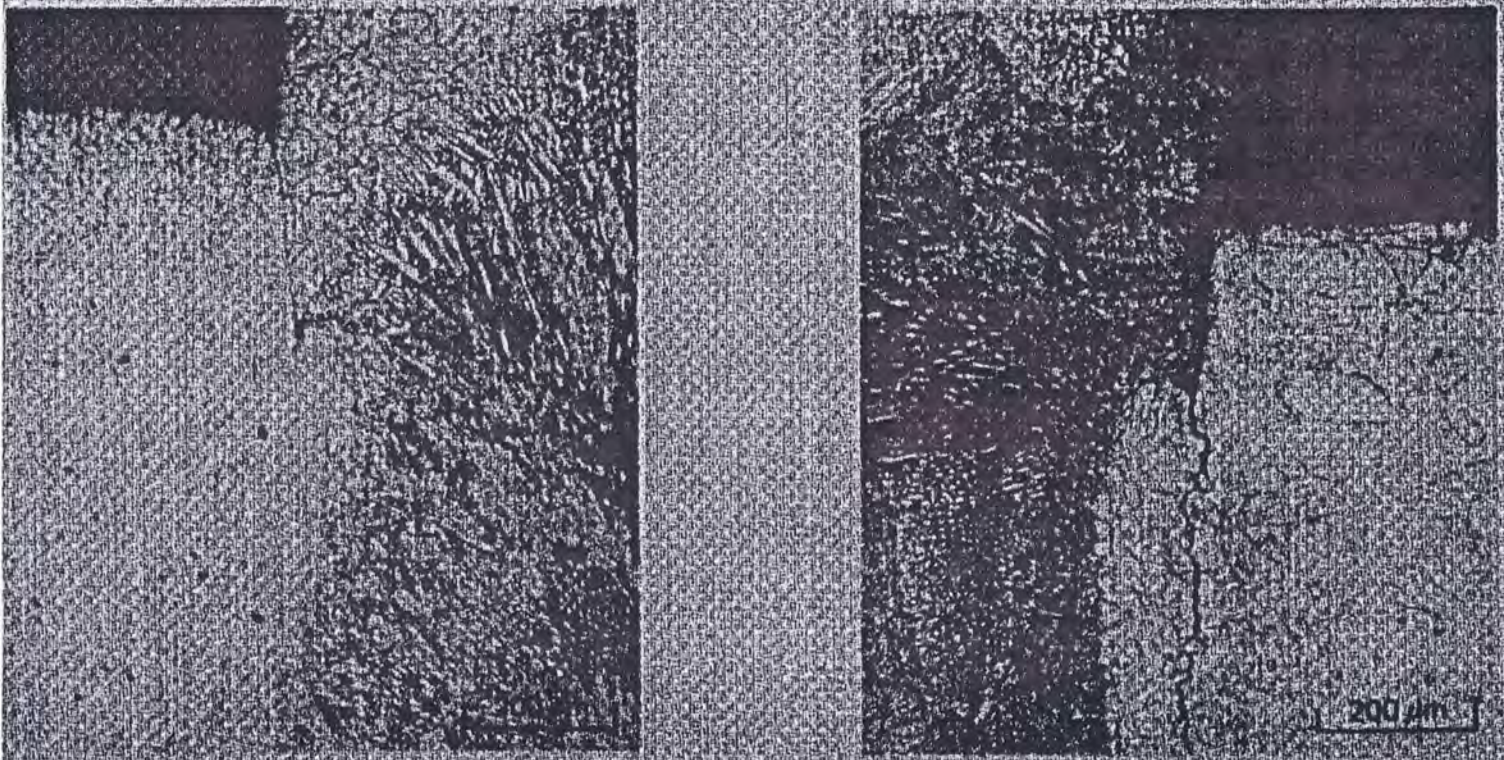
Crack growth experiments show tritium (and helium) to be much more deleterious than hydrogen or deuterium.



No crack growth is seen in

HYDROGEN

Crack growth is seen in

TRITIUM

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PRODUCT DEVELOPMENT (U)

AT SANDIA - R&D

- MATERIALS SELECTION AND TESTING
  SPECIMEN AND STRUCTURAL ANALYSIS
- COMPONENT DESIGN
  DRAWING AND SPECIFICATIONS
- PROTOTYPE DEVELOPMENT
  FABRICATION AND JOINING
- COMPONENT EVALUATION
  STORAGE AND STRUCTURAL TESTING
- SYSTEMS TESTING
  LABORATORY AND FLIGHT TESTS
- PRODUCT DEFINITION

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PRODUCT DEVELOPMENT (U)

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WE HAVE NO REASON TO ASSUME WE FOUND ALL THE TRITIUM SURPRISES

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It is not possible to extrapolate with adequate confidence, tritium effects on components

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

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SESSION XIV

- •RADAR FUZING TECHNOLOGY
- •OTHER FUZING MODES
- •ADVANCED FUZING CONCEPTS

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Nuclear Weapon Fuzing Technology

- Introduction to Fuzing Components & Systems
- Radar Fuzing
- Contact Fuzing
- Inertial, Barometric, and Timer Fuzes
- Fuzing Systems
- ***Future*** Fuzing Systems
    - SLBM Warhead Protection Program

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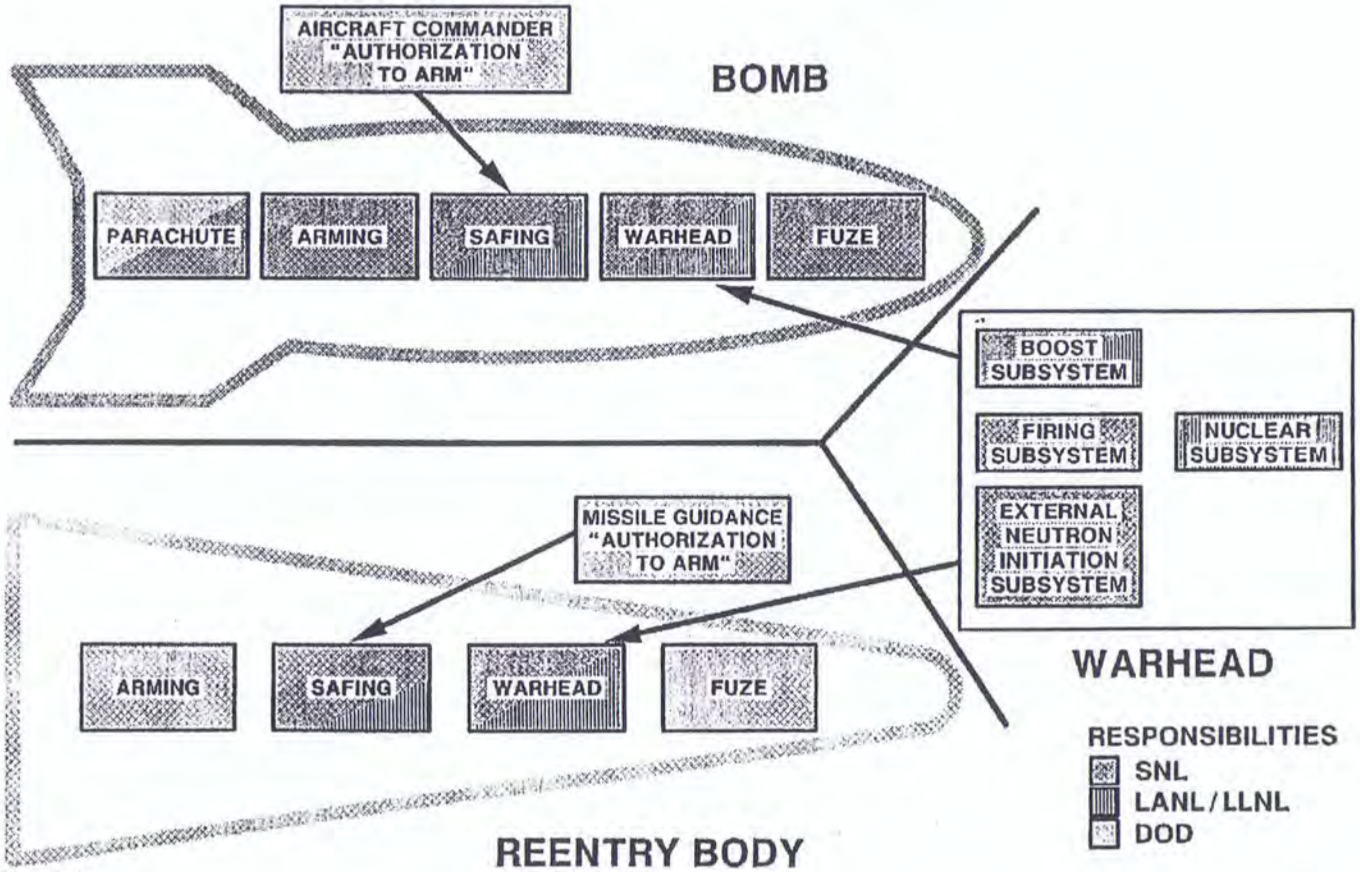
What is a Fuze ?

- Mechanism(s) within a weapon responsible for optimizing the location of weapon detonation
- Initiates the final, irreversible phase of weapon detonation
    - Follows “arming” functions, which are
        - reversible
        - time-uncritical
    - Precedes “firing”



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Fuzing System Hierarchy

Components:

Radars
(Antennas)

Clocks

G-switches

Pressure sensors
(Baro/hydro)

Accelerometers

Programmers

Crush sensors

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Fuzing System Hierarchy

Components:

Radars

(Antennas)

Clocks

G-switches

Pressure sensors

(Baro/hydro)

Accelerometers

Programmers

Crush sensors

Sub-Systems:

Airburst radars

Proximity radars
(prox time-down)

Timers

G-started timers

Pressure-started timers

G-started integrating accelerometers (FBIAs)

Path length

Radar-Updated Path Length (RUPL)

Impact fuzes

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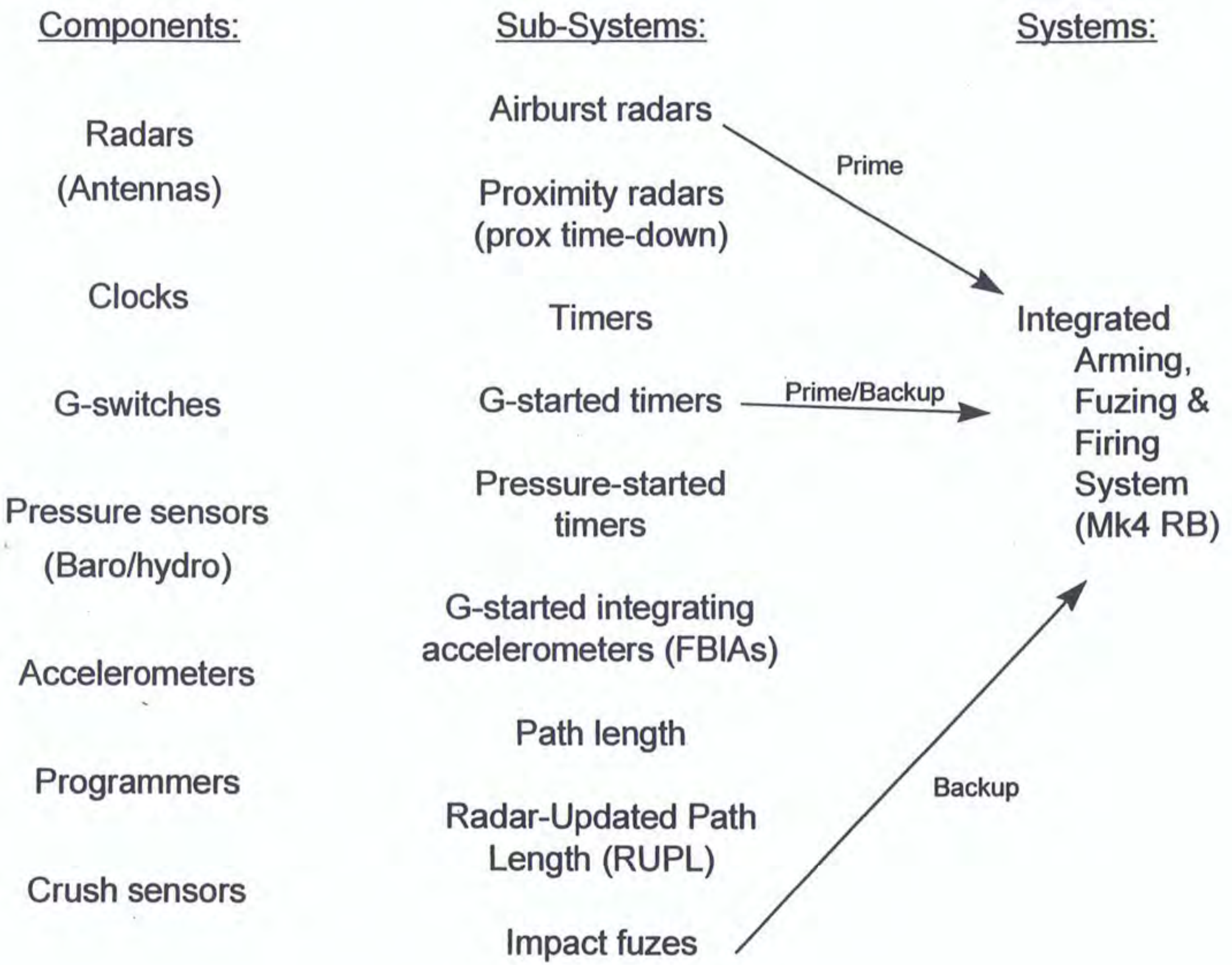
Fuzing System Hierarchy



Components:

- Radars (Antennas)
- Clocks
- G-switches
- Pressure sensors (Baro/hydro)
- Accelerometers
- Programmers
- Crush sensors

Sub-Systems:

- Airburst radars
- Proximity radars (prox time-down)
- Timers
- G-started timers
- Pressure-started timers
- G-started integrating accelerometers (FBIAs)
- Path length
- Radar-Updated Path Length (RUPL)
- Impact fuzes

Systems:

- Integrated Arming, Fuzing & Firing System (Mk4 RB)

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Fuzing System Hierarchy

Components:

Radars

(Antennas)

Clocks

G-switches

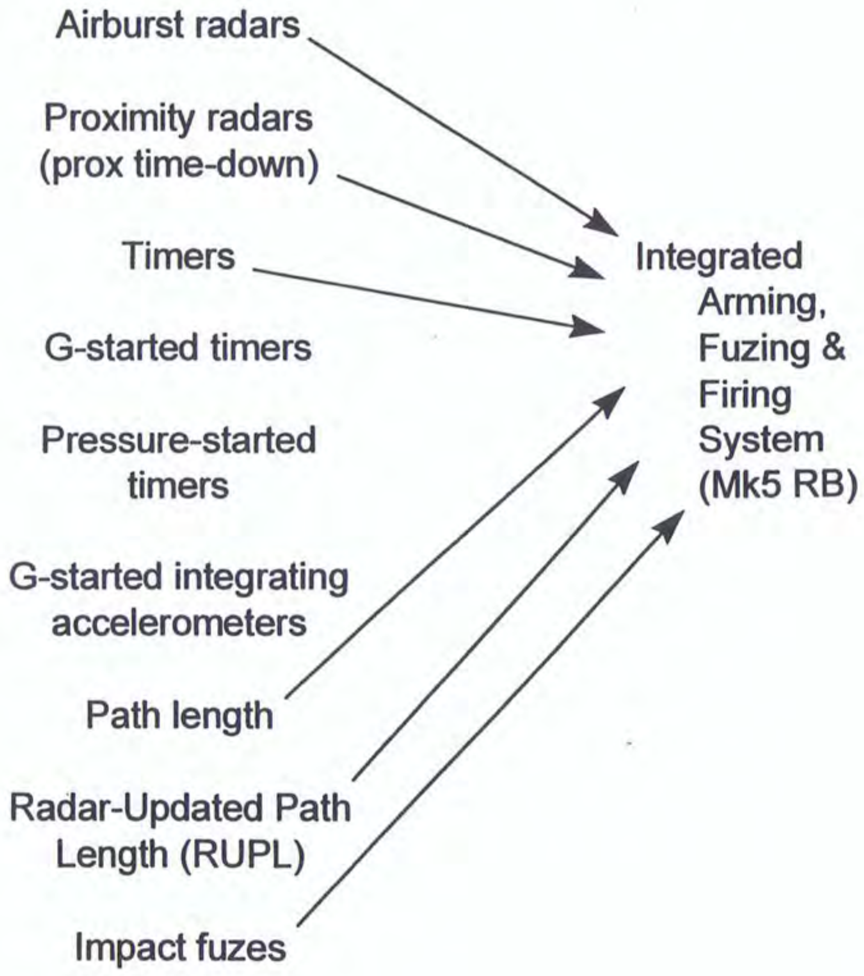
Pressure sensors

(Baro/hydro)

Accelerometers

Programmers

Crush sensors



Sub-Systems:

Airburst radars

Proximity radars (prox time-down)

Timers

G-started timers

Pressure-started timers

G-started integrating accelerometers

Path length

Radar-Updated Path Length (RUPL)

Impact fuzes

Systems:

Integrated Arming, Fuzing & Firing System (Mk5 RB)

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How is a Fuze selected?

Traditional fuzing system priorities:

- Reliable
- Light weight (reentry body)
- Accurate
- Small (reentry body)
- Flexible
- Testable
- Producible
- Inexpensive

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How is a Fuze selected?

Future fuzing systems must be:

- Inexpensive
- Producible
- Reliable
- Accurate
- Certifiable (test & analysis)
- Flexible
- Small (reentry body)
- Light weight (reentry body)

Radar Fuzing

- Role of radar fuzing
- Basic radar fuze operation
- Radar design issues
- Current technology

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Why use a radar ?

- Height of burst precision to maximize extent of low overpressure levels
    - setability
    - accuracy
- Height of burst control to minimize fallout
- Dependable surface fuzing
    - Ensure detonation prior to collision
- Accurate altitude reference for improving inertial fuze accuracy (radar-updated path length fuze)

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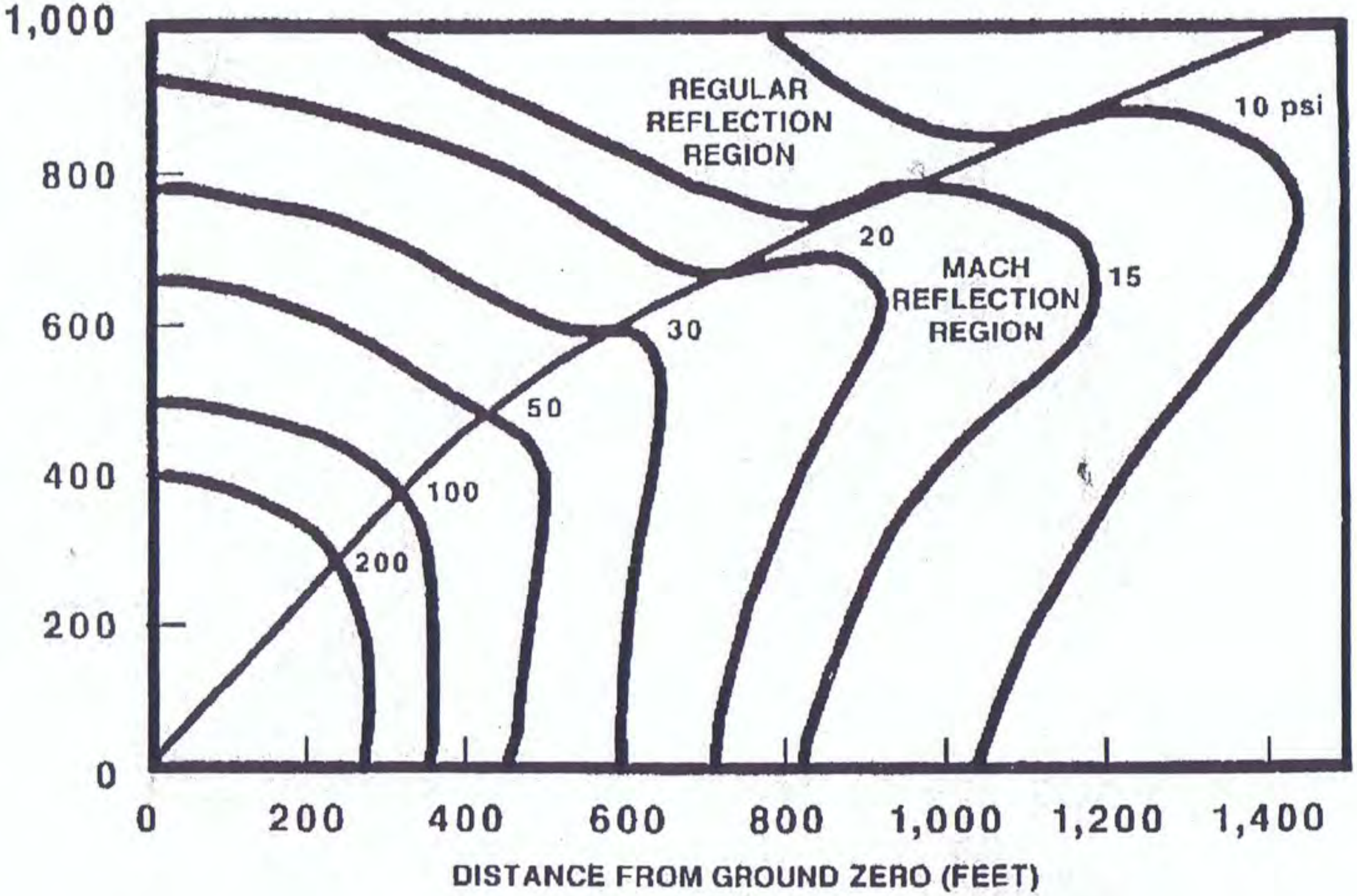
PEAK OVERPRESSURES ON THE GROUND FOR A 1-KILOTON BURST



REFERENCE: GLASSTONE AND DOLAN, THE EFFECTS OF NUCLEAR WEAPONS, 3RD EDITION US DOD AND DOE, 1977

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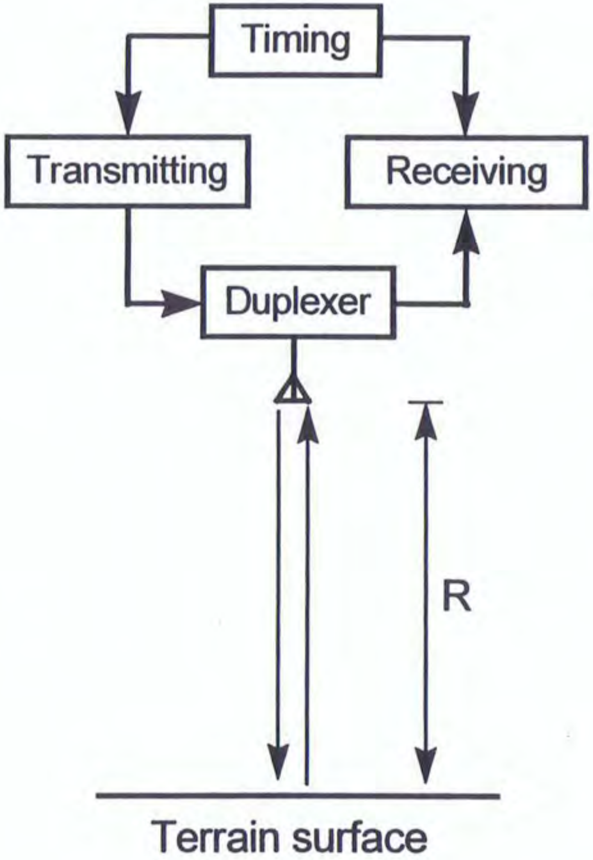
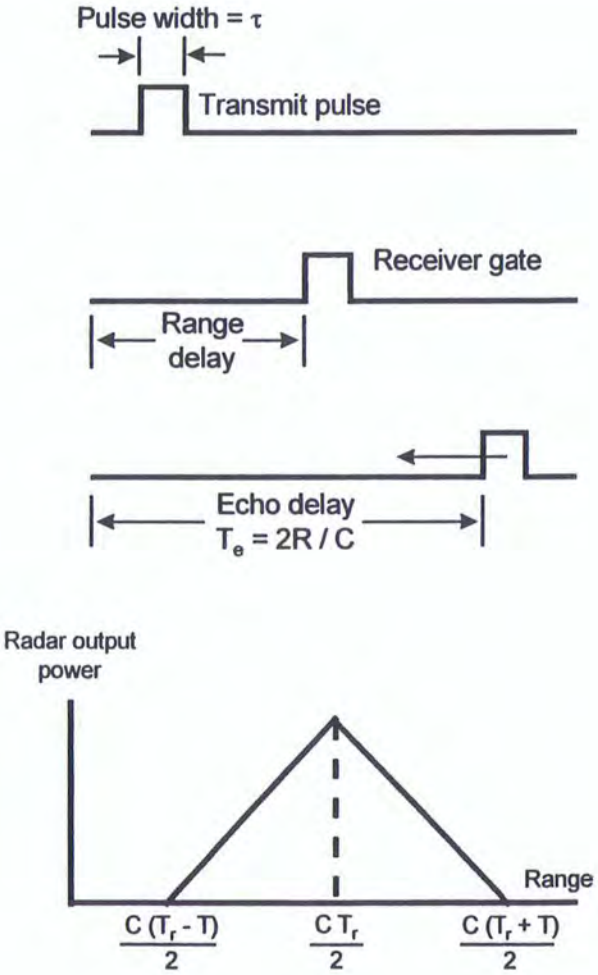
Basic Radar Operation





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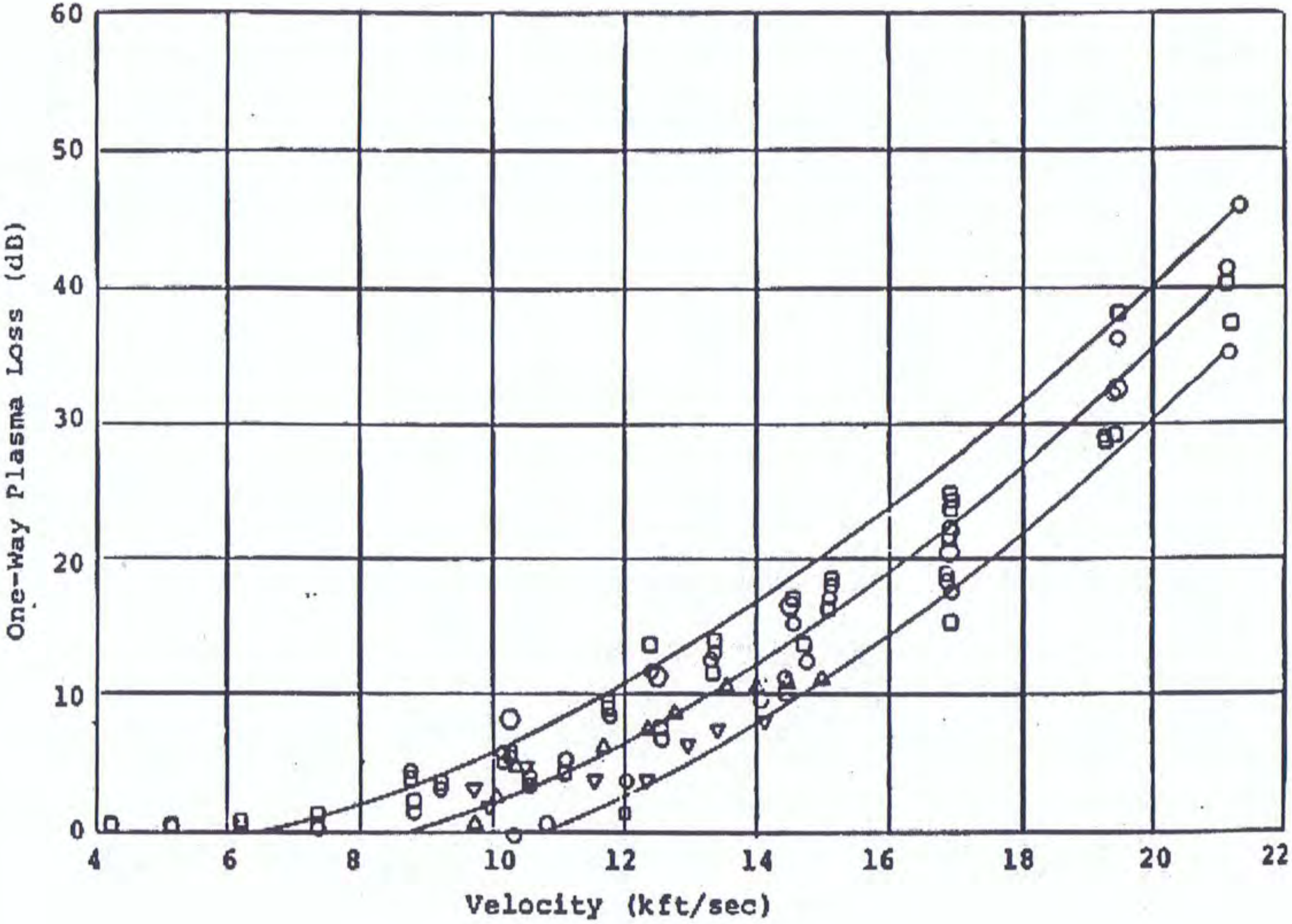
Radar design considerations

- Immunity to electronic countermeasures
  - prevent premature detection of “radar-like” signals (“spoofing”)
  - ensure detection of radar return in presence of RF energy saturation (“dudding”)

- Plasma loss (space shuttle “black-out”)
  - affects both transmit ***and*** receive
  - varies with: velocity
    altitude
    nosetip and heat shield materials



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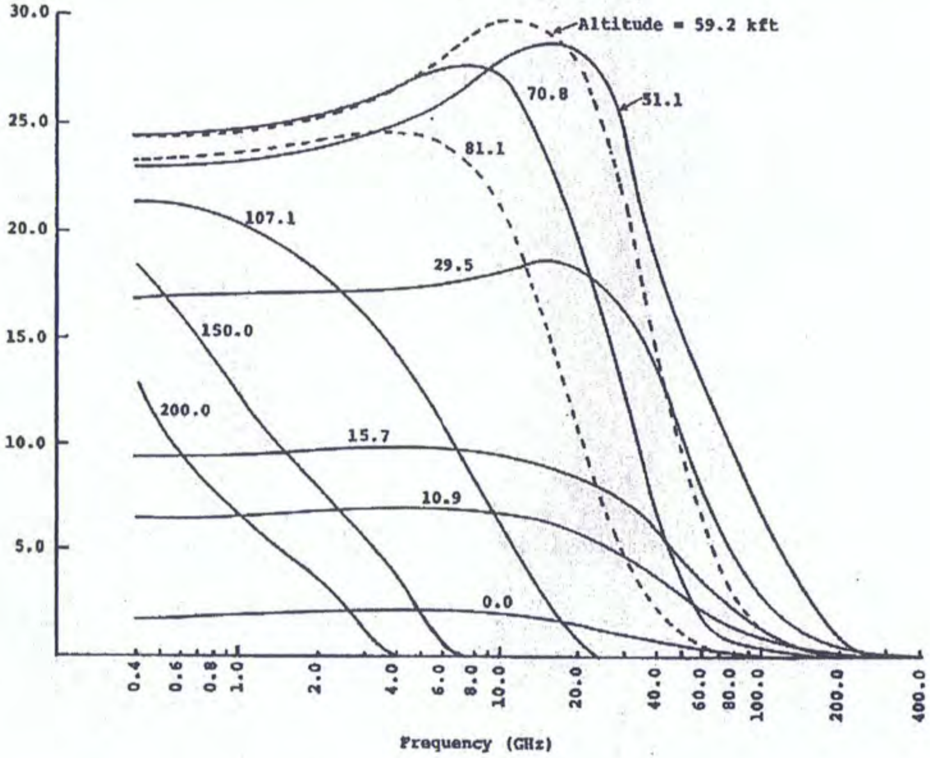
One-way plasma loss vs. frequency for ABRV-3 trajectory



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Radar design considerations, cont'd

- Antenna gain patterns
    - affects both transmit ***and*** receive
    - must accommodate all flight path angles and roll orientations
- Target reflectivities
    - peak reflectivity & angular attenuation
- Frequency
    - Higher frequencies required for proximity fuze narrow pulse width
    - Higher frequencies require less "real estate" for antenna windows
        - Smaller antennas thought to have less impact on reentry body flight
    - Lower frequencies have lower "path loss" requiring less receiver loop sensitivity

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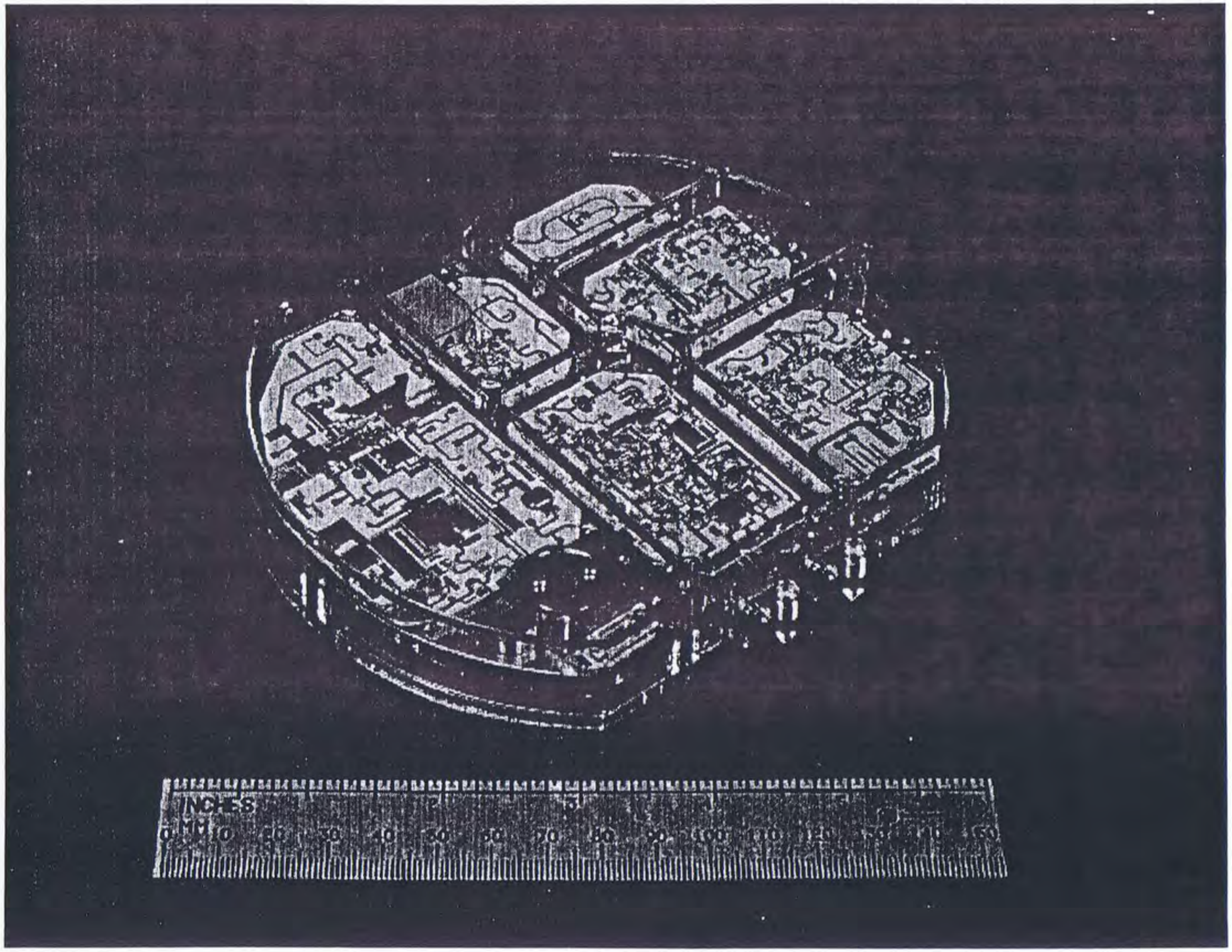

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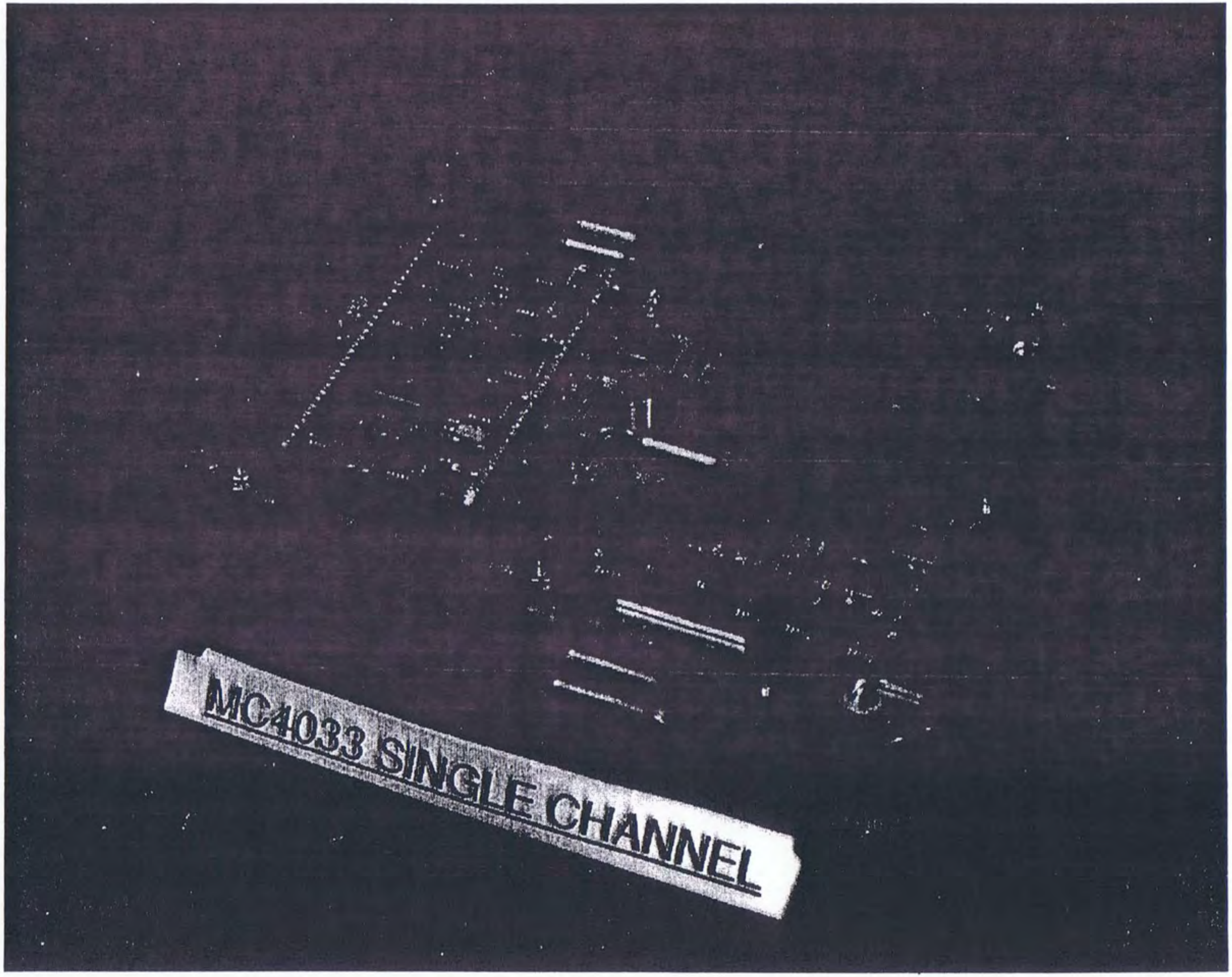

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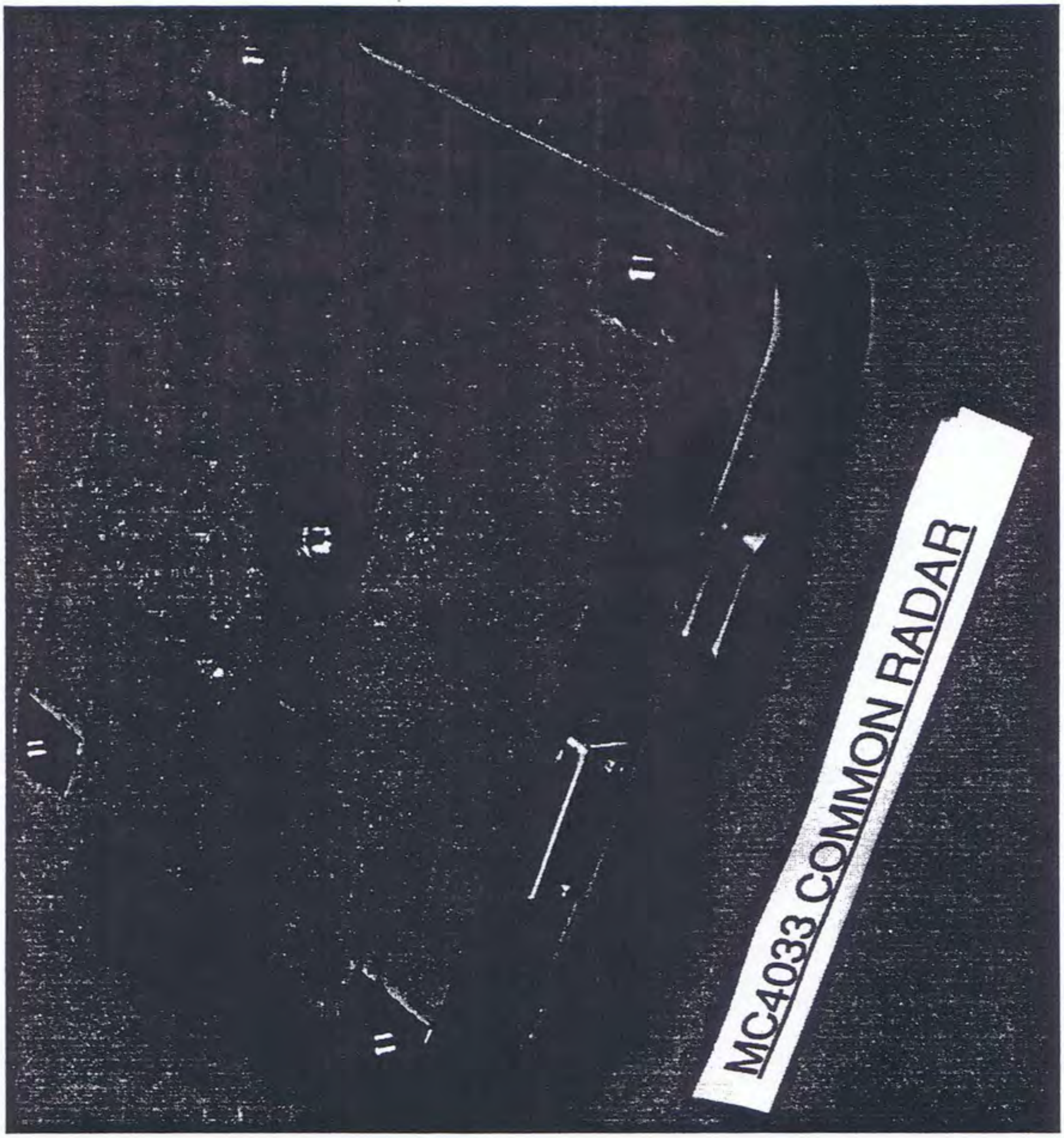
MC4033 COMMON RADAR

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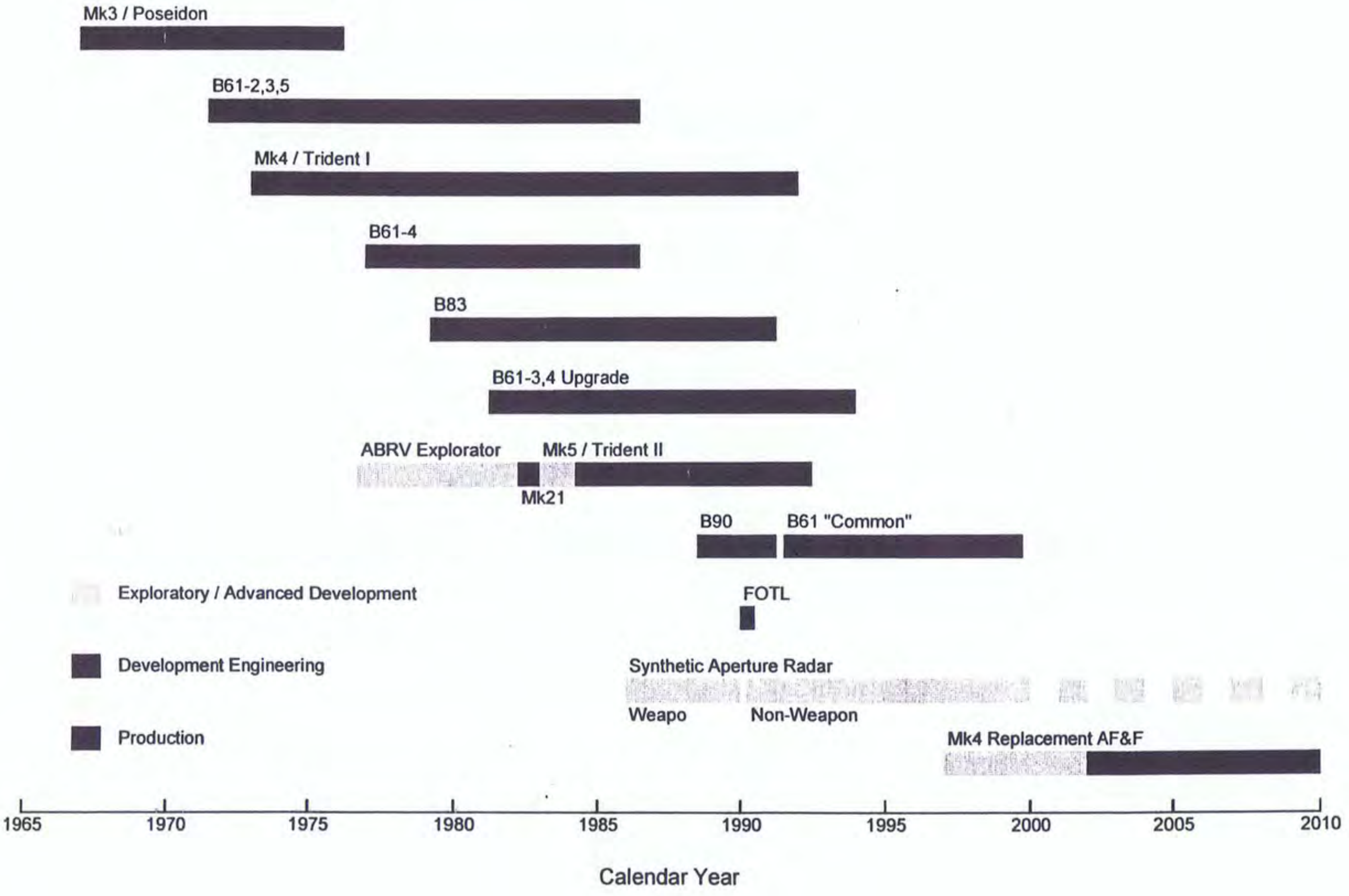
Sandia Fuze Development & Production
(1965 - 2010)



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Contact Fuzing

Contact fuze characteristics

- Output directly triggers firing set for fast operation

  OR

  initiates delay mechnism for weapon designed for impact survivability

- Piezoelectric materials release charge (voltage) when shocked
  - generally not requiring external "poling" or charging

- Use pervasively throughout the stockpile for both selectable and backup fuzing

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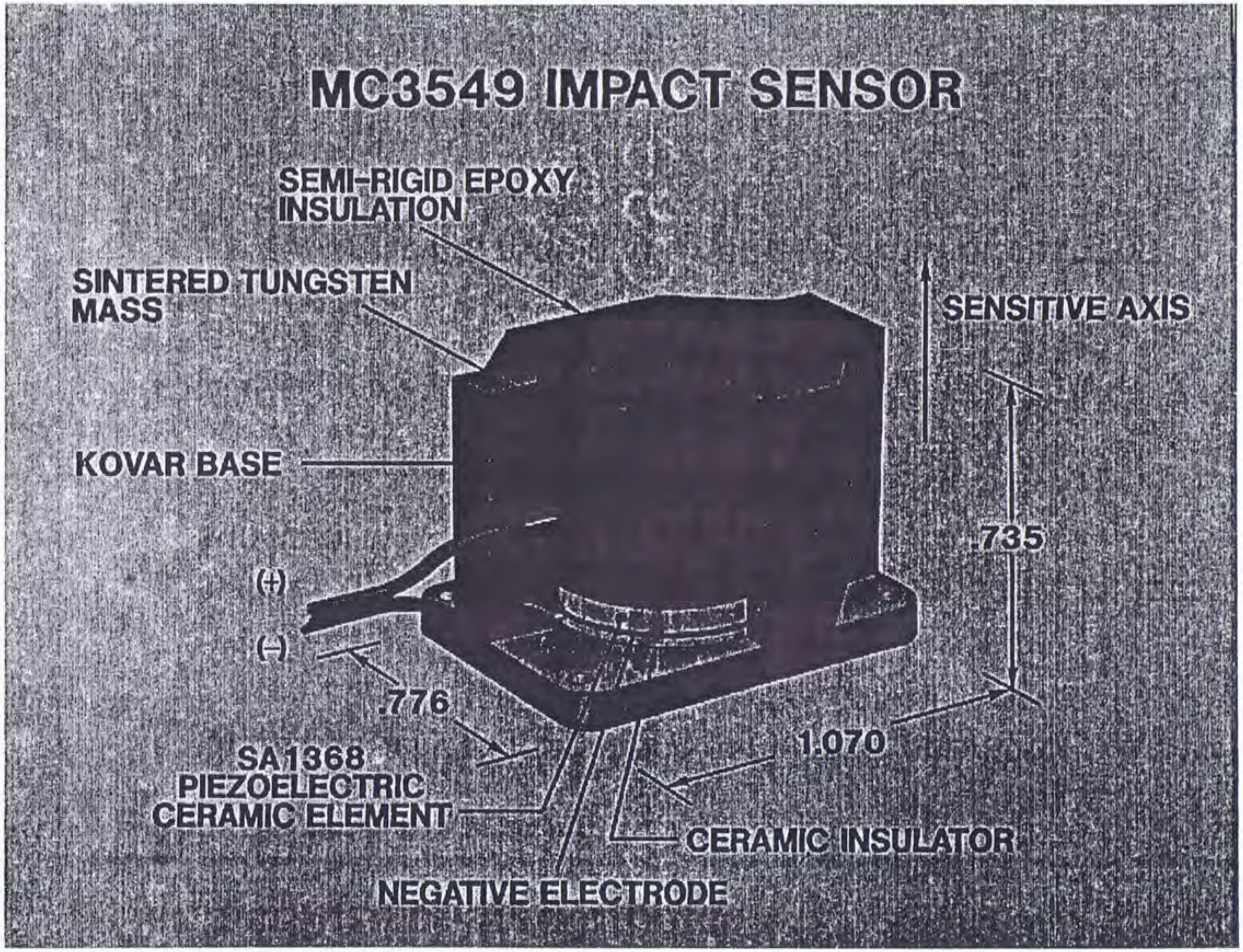
MC3549 IMPACT SENSOR



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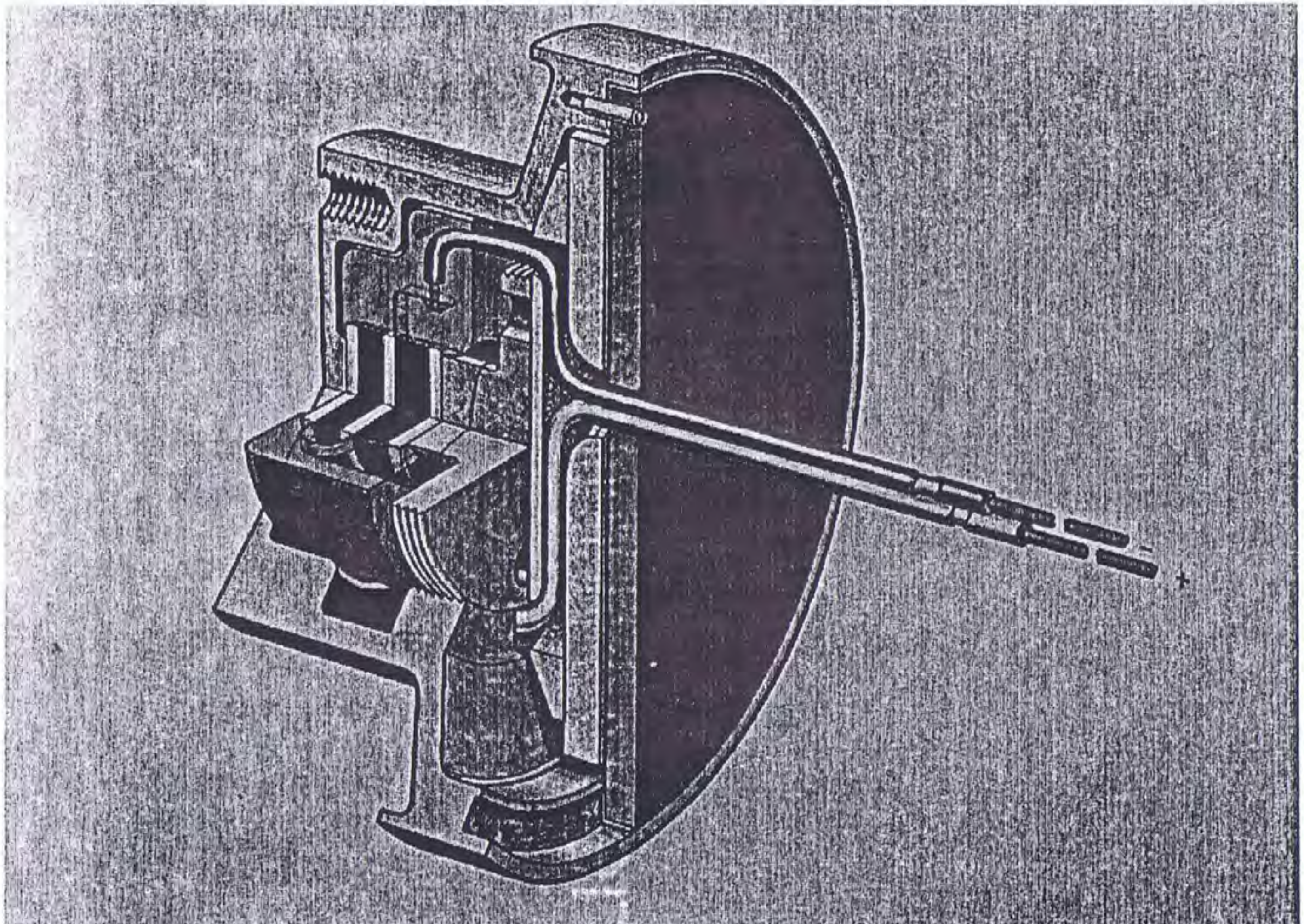

MC 2984 IMPACT FUZE

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Contact Fuze Characteristics

- Advantages
  - Very little penalty in weight, cost or volume
  - Desirable as backup to air burst fuzing
  - Radiation hardened and immune to jamming
  - Very reliable as a component
  - Maximizes crater volume and ground motion in comparison to other air burst options
- Disadvantages
  - Reduced “effects radius” for air burst targets
  - Range offset associated with backup role
  - Qualification / testing has been costly
  - Dependability concerns (system reliability)

Contact fuzing degree of difficulty

	Component	System
Design	Easy	Easy
Validate	Fairly easy	Very difficult

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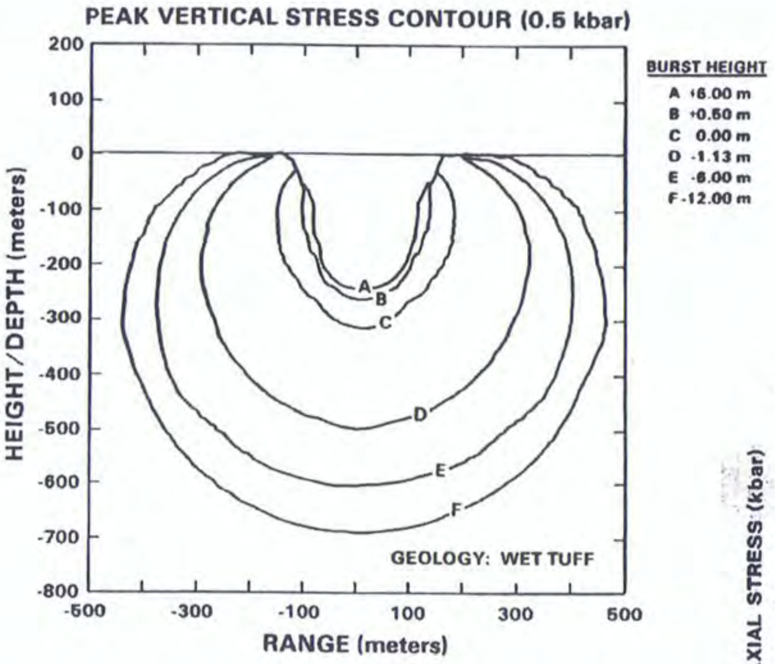
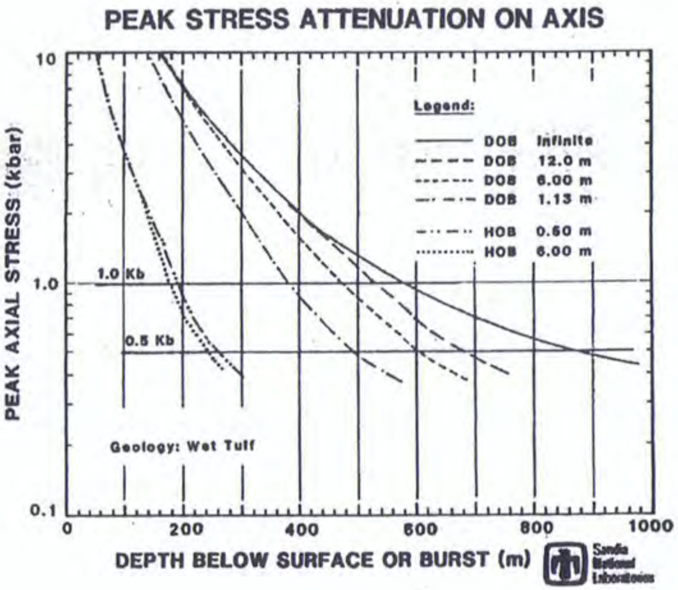
Contact vs. Proximity - Ground shock environments



PEAK VERTICAL STRESS CONTOUR (0.5 kbar)

Proximity fuzing consistently results in minimal degradation in ground shock environments when compared to contact



PEAK STRESS ATTENUATION ON AXIS

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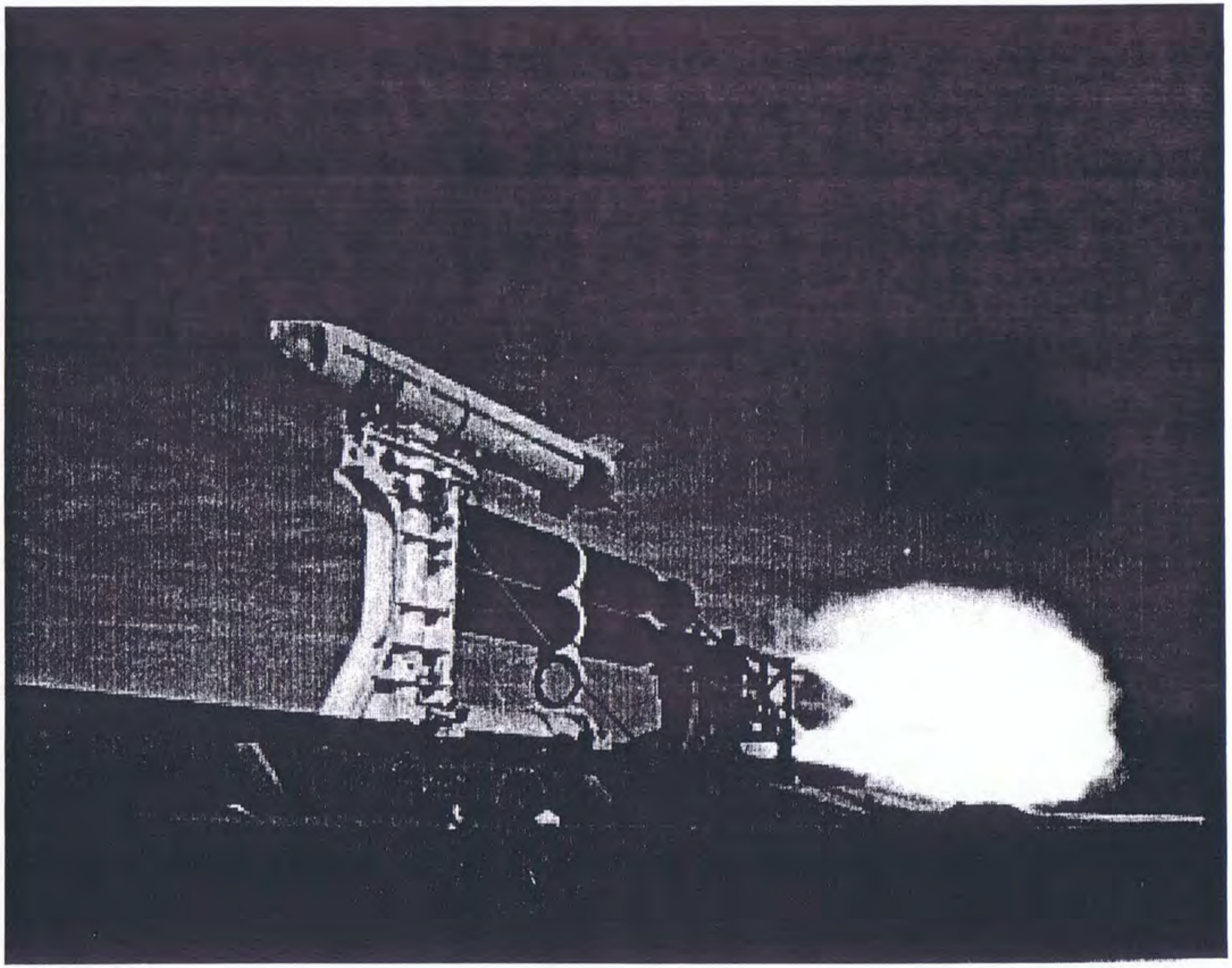

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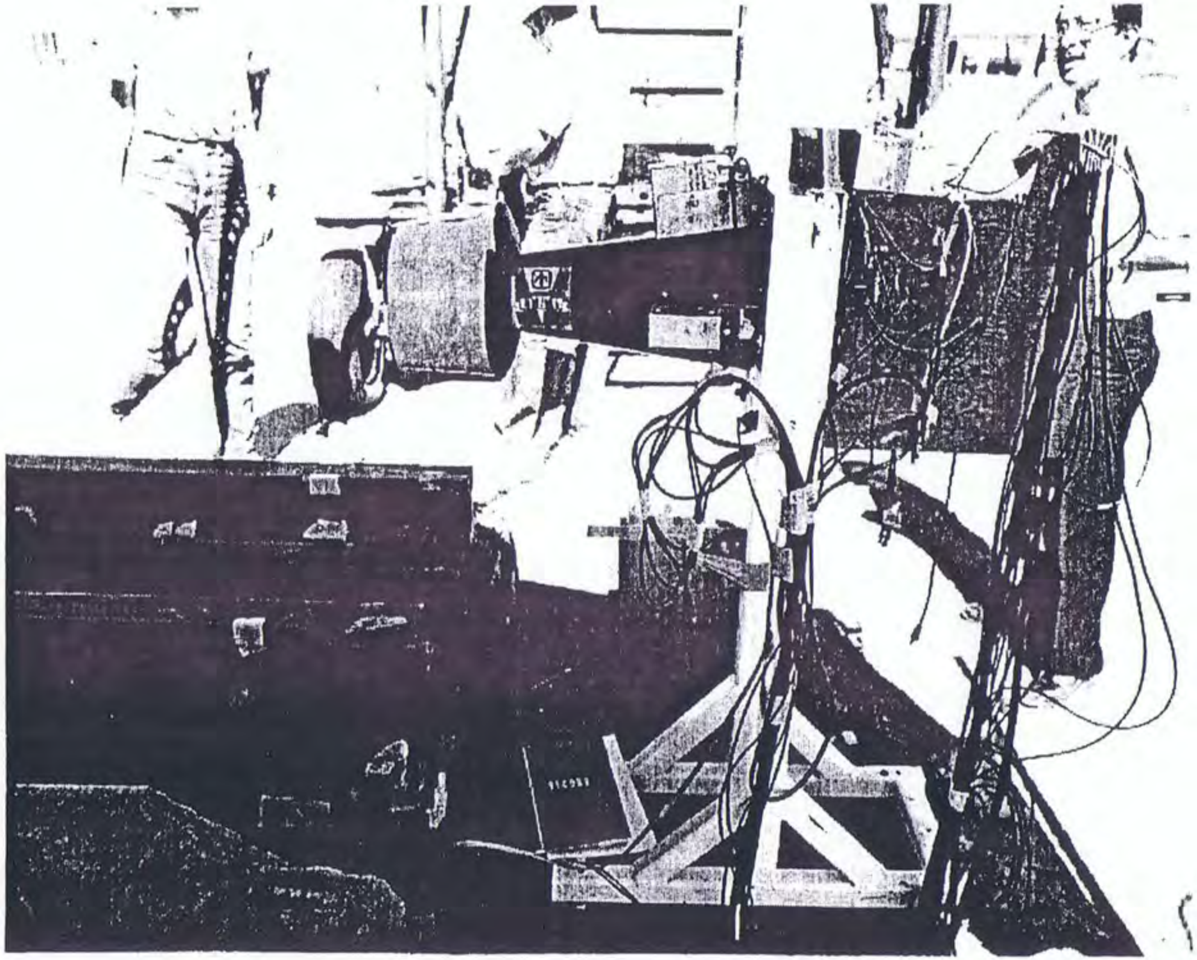
Figure 29



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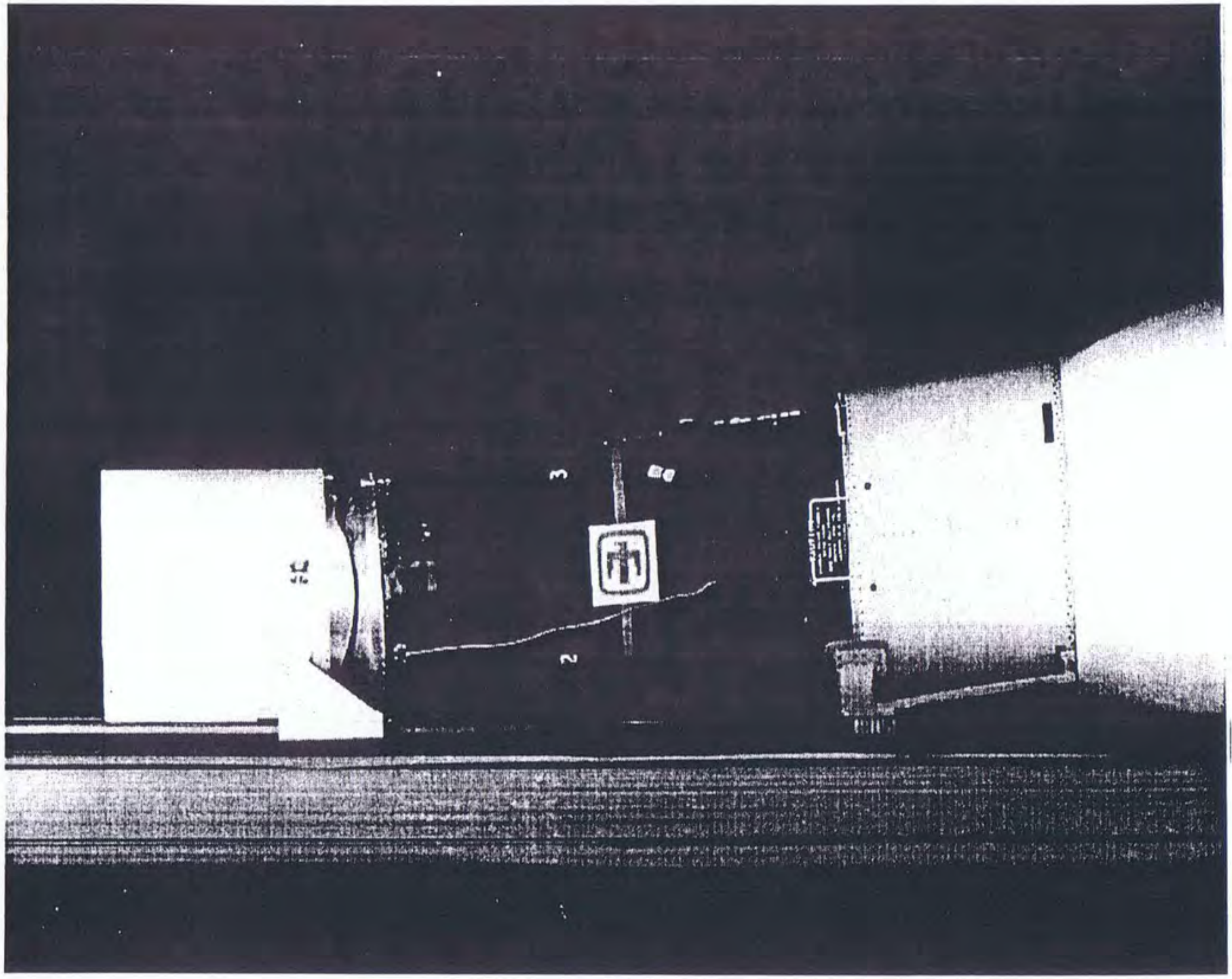

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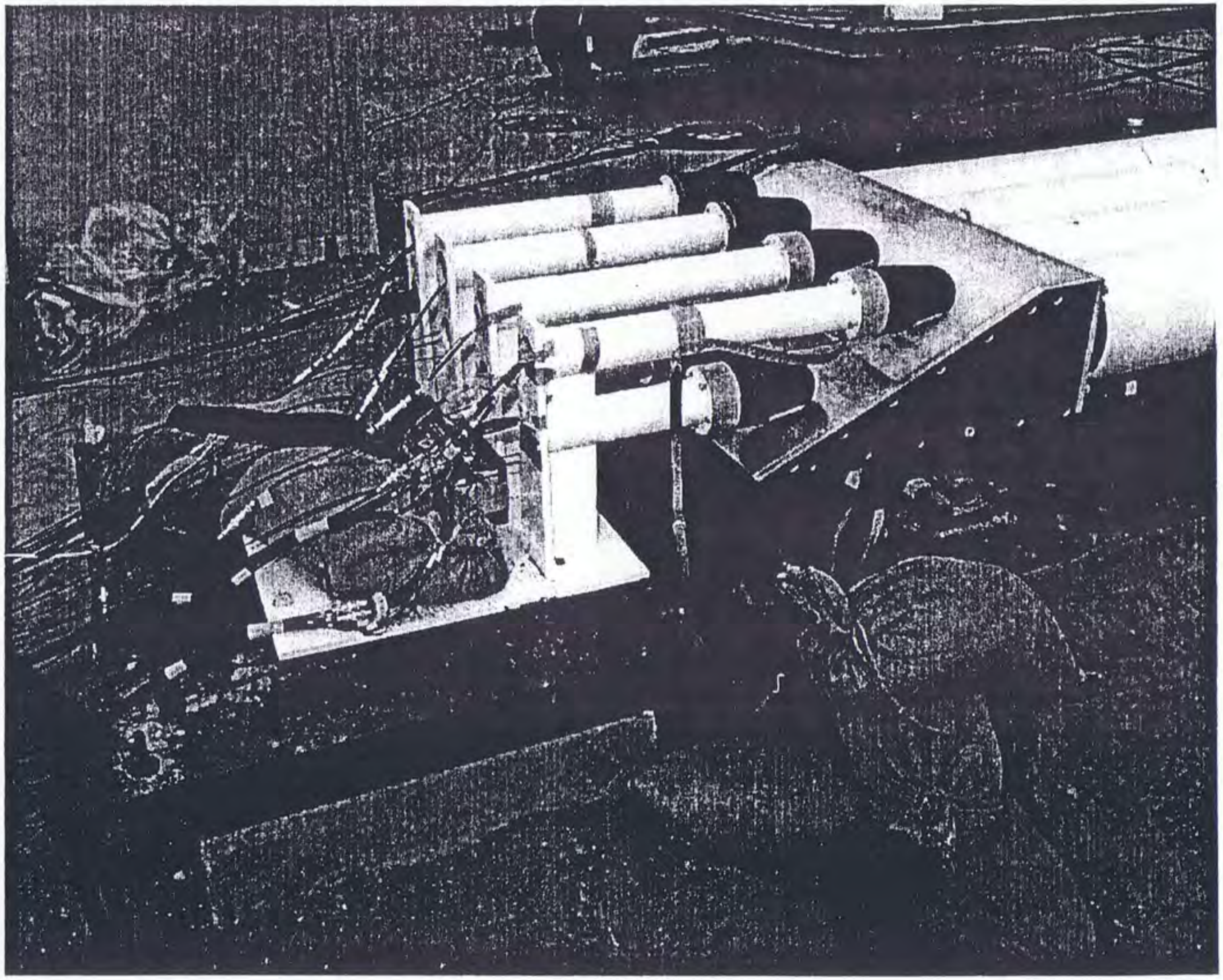

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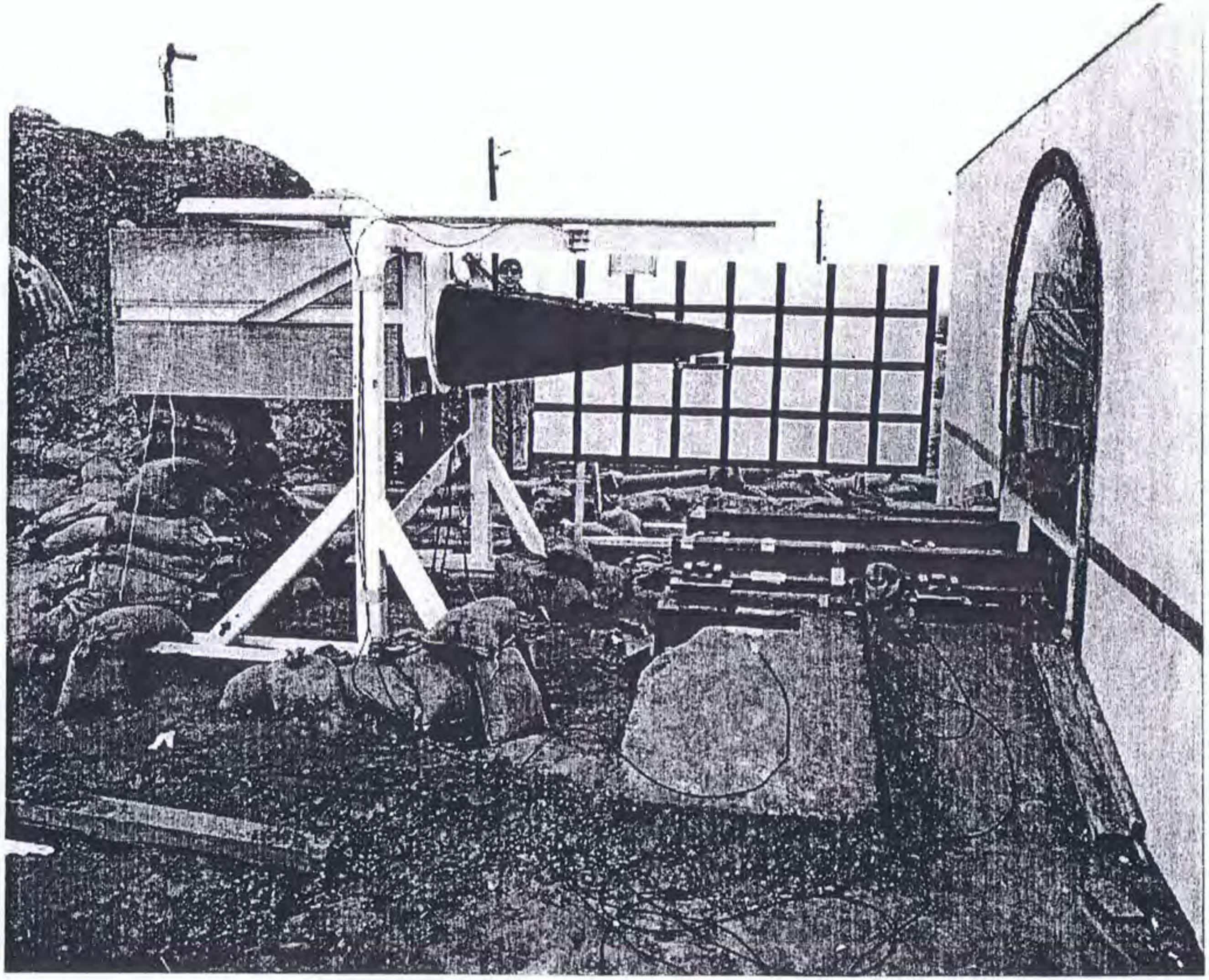

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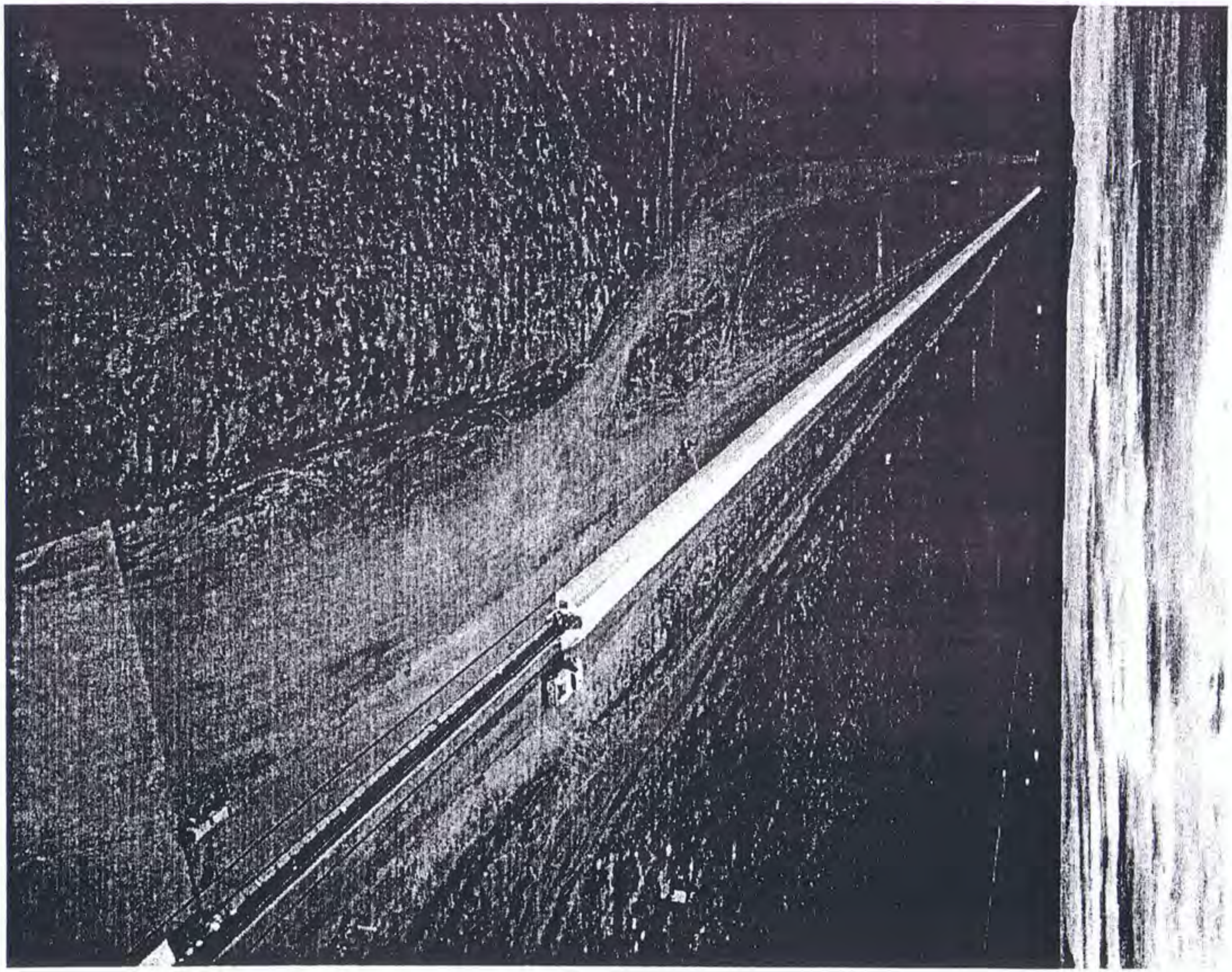

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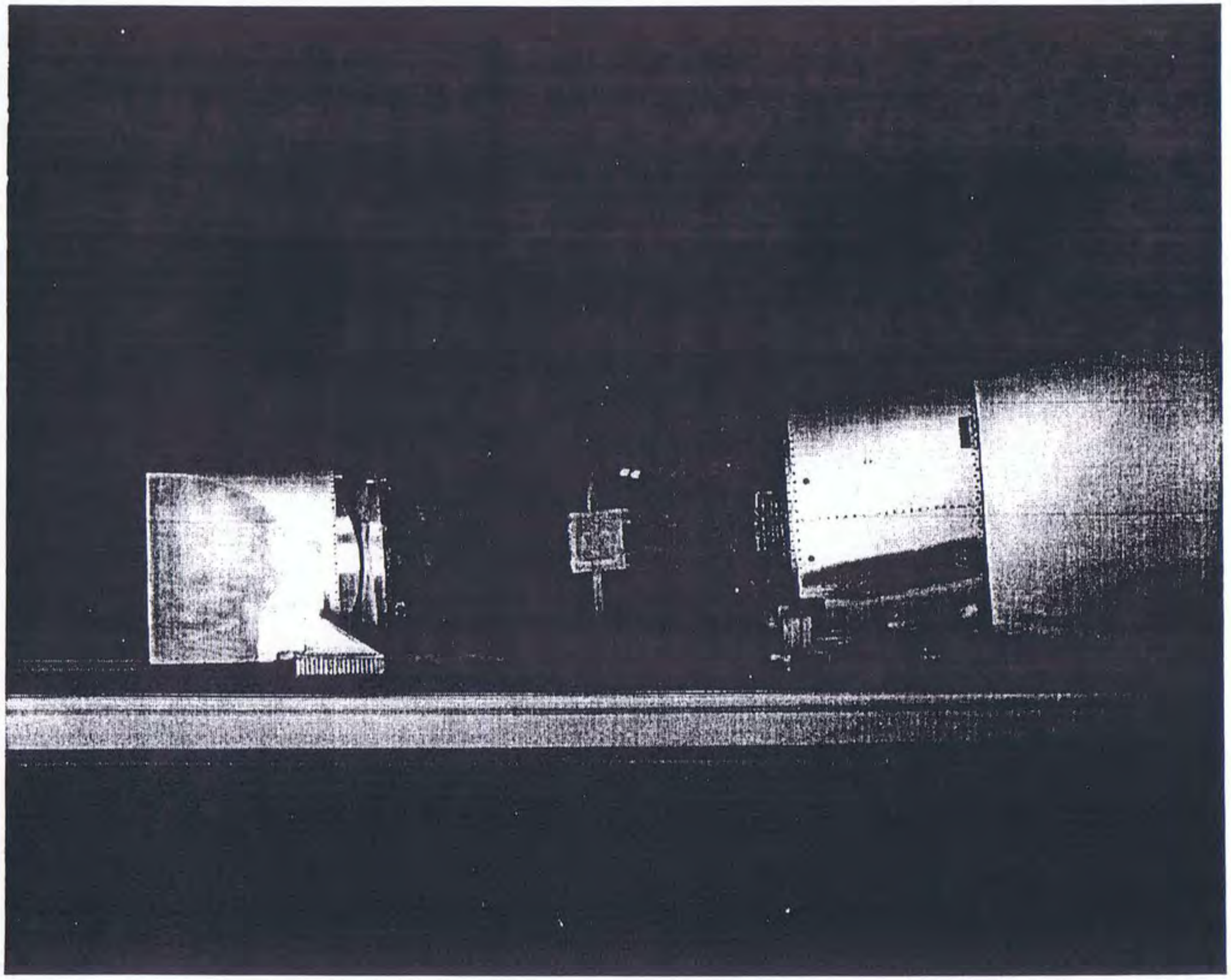

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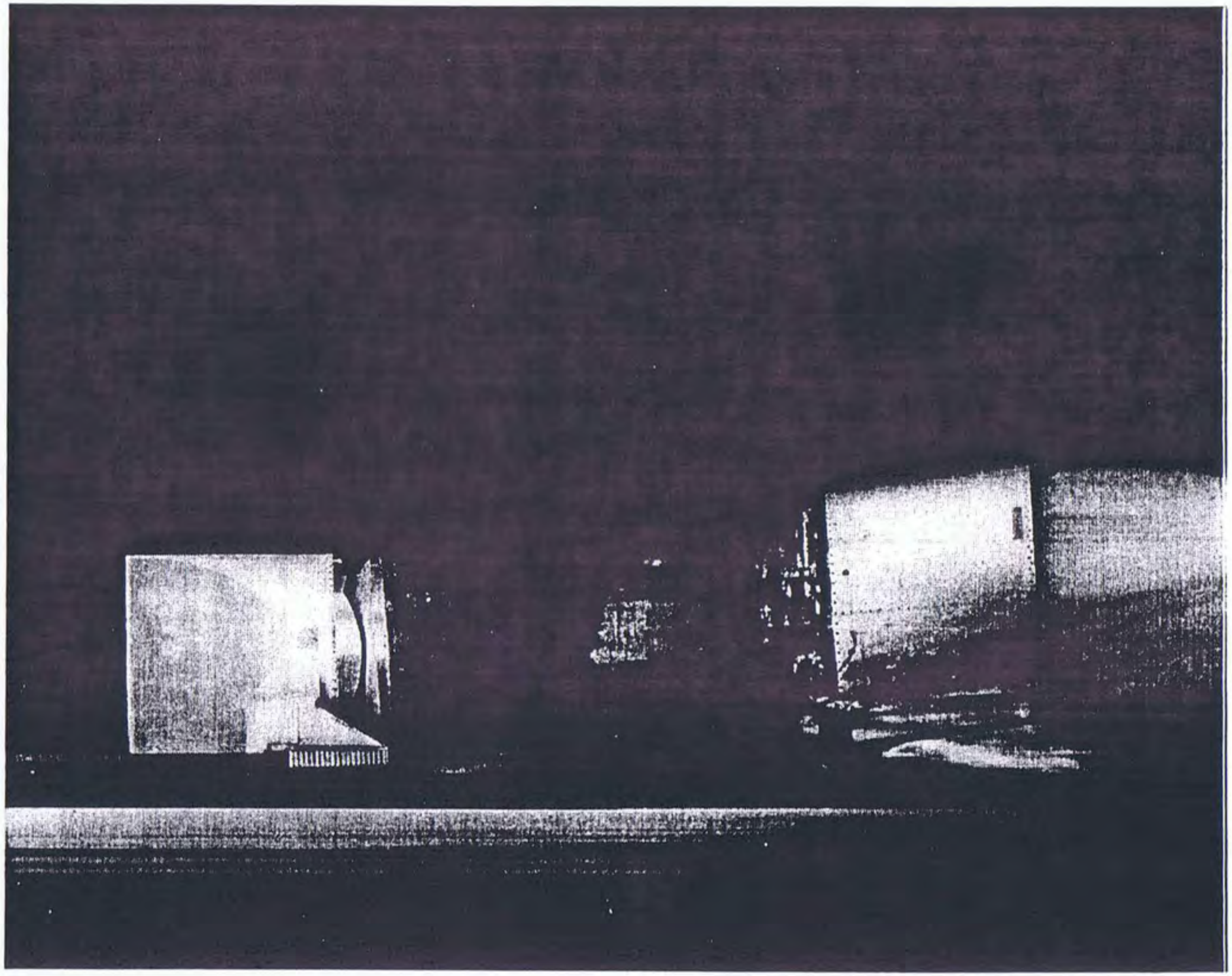

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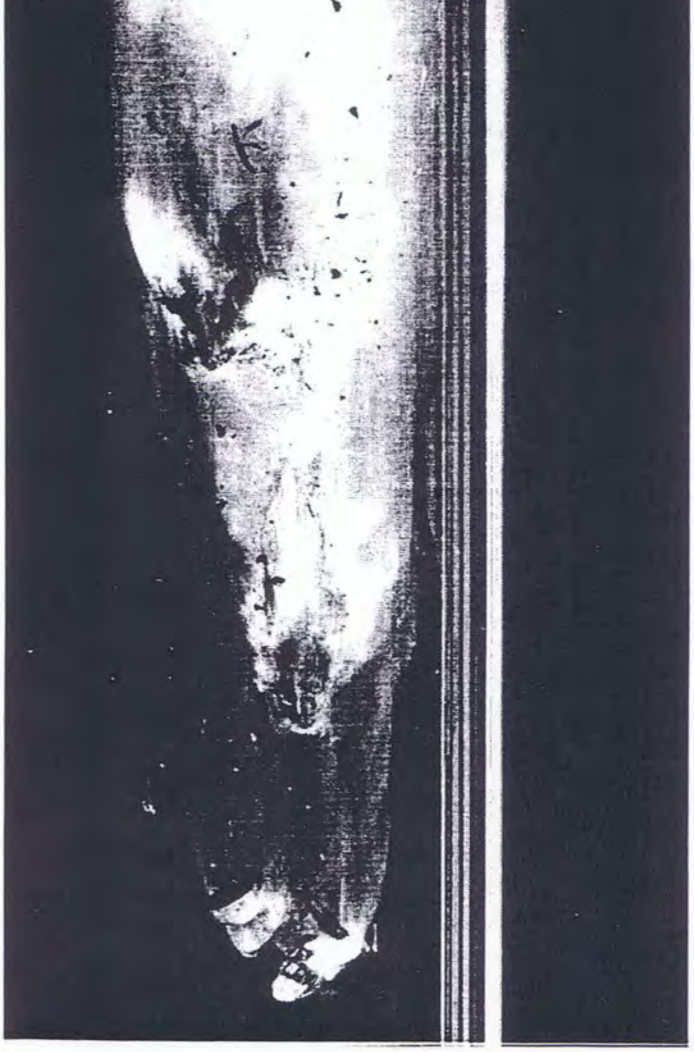

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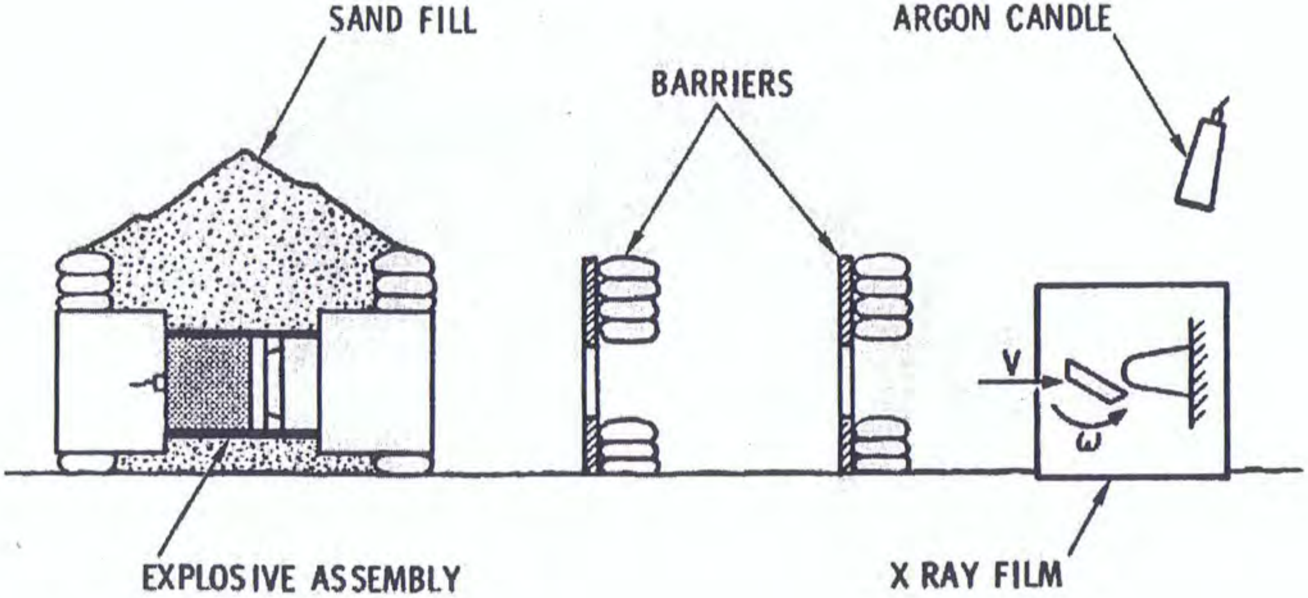

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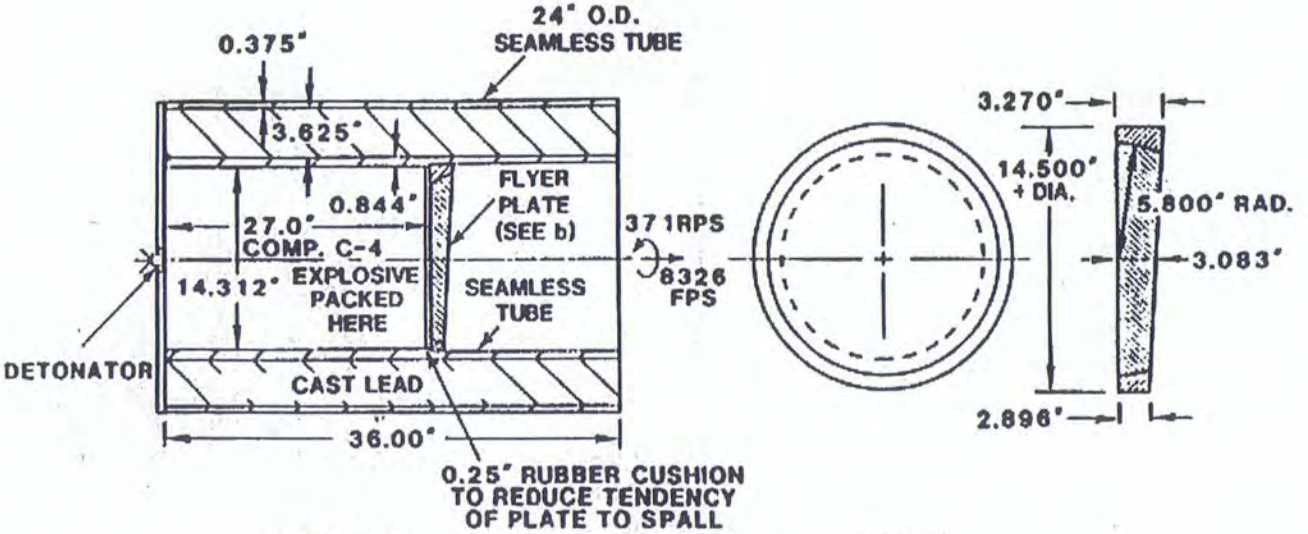
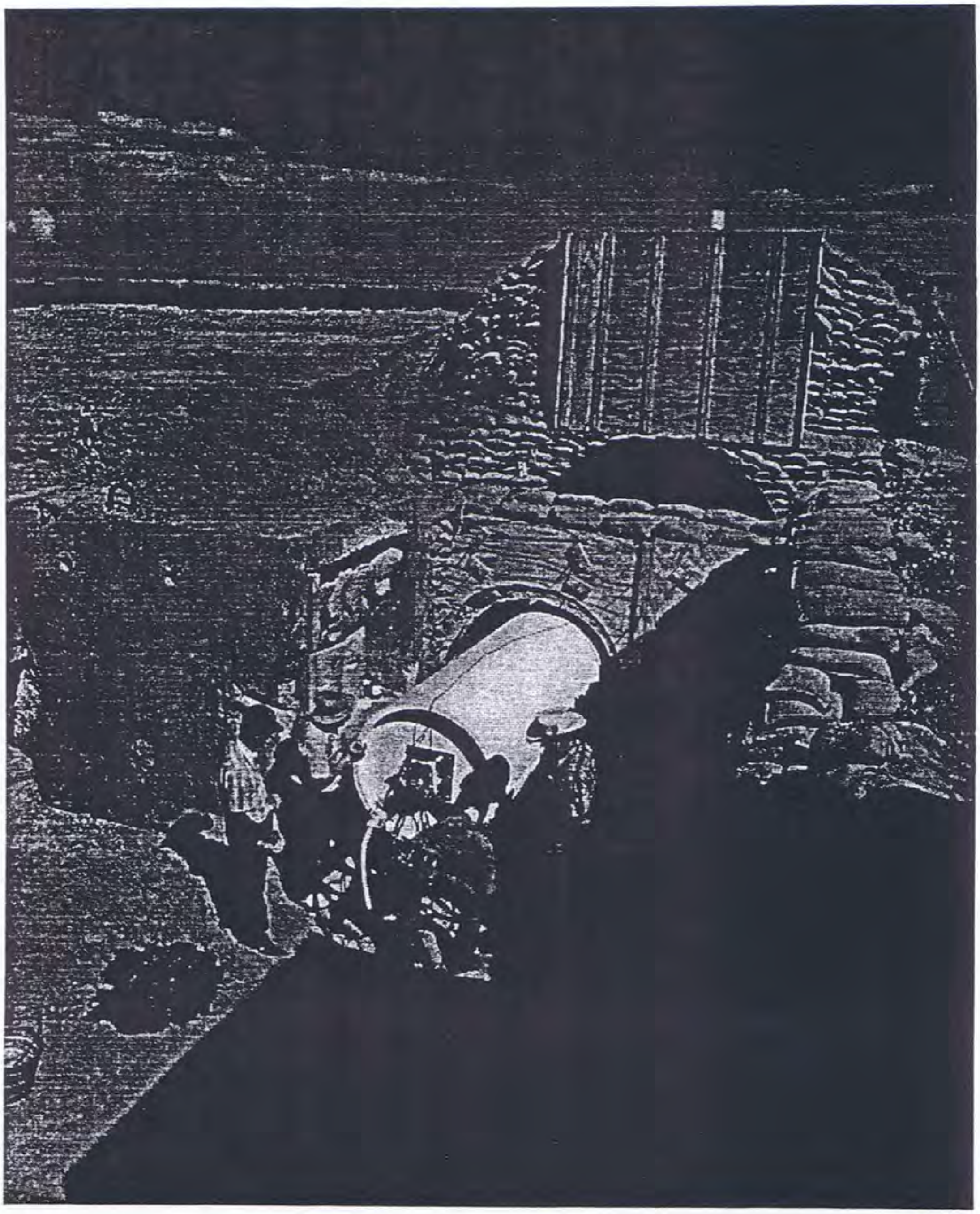
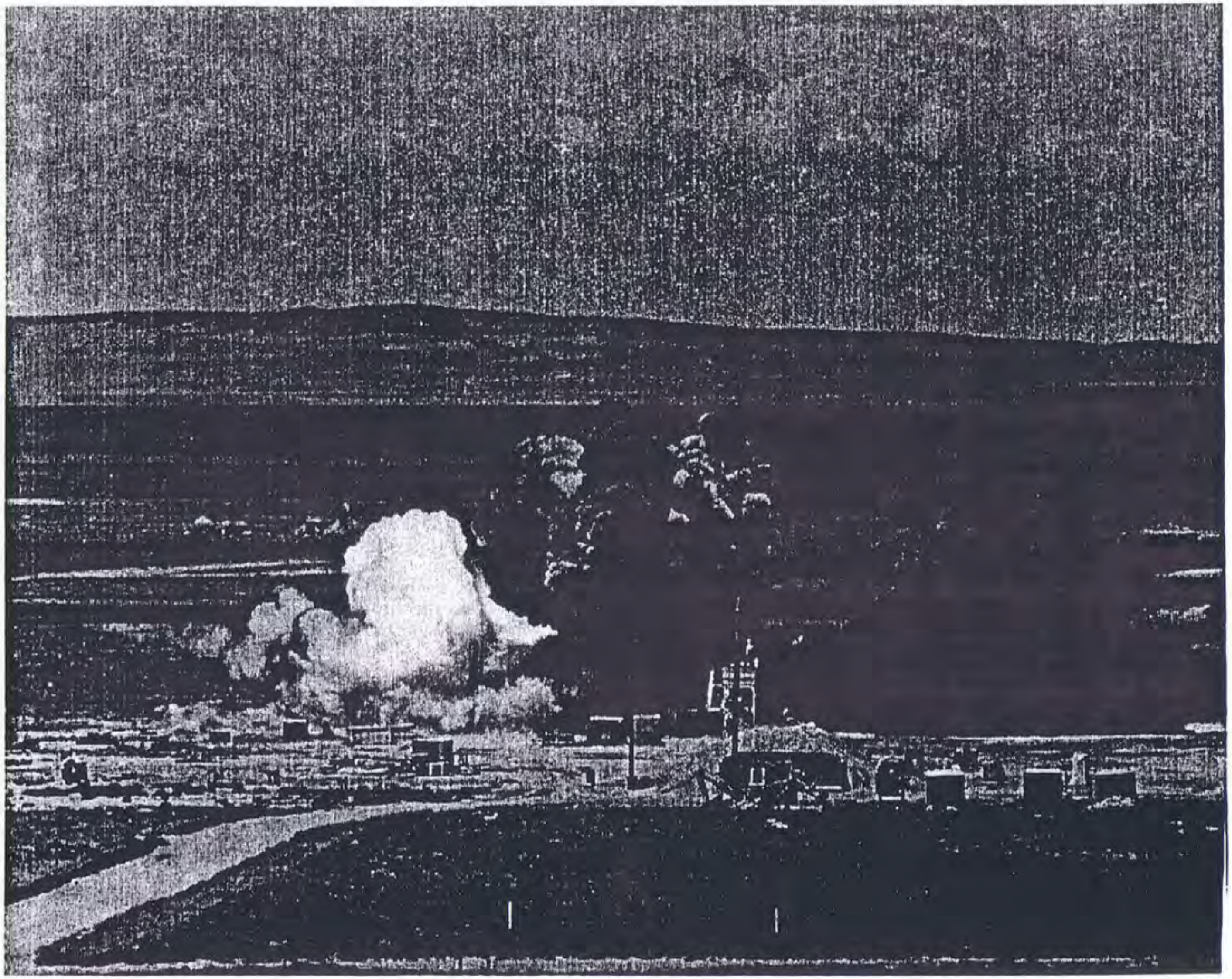


a) BARREL

b) FLYER





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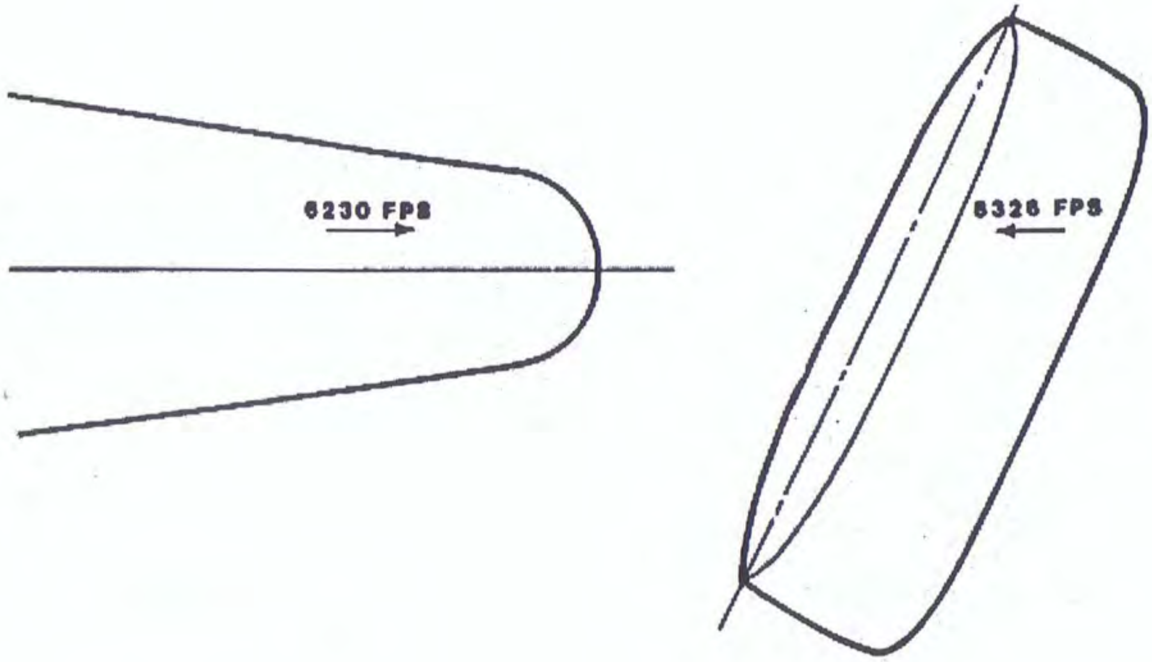

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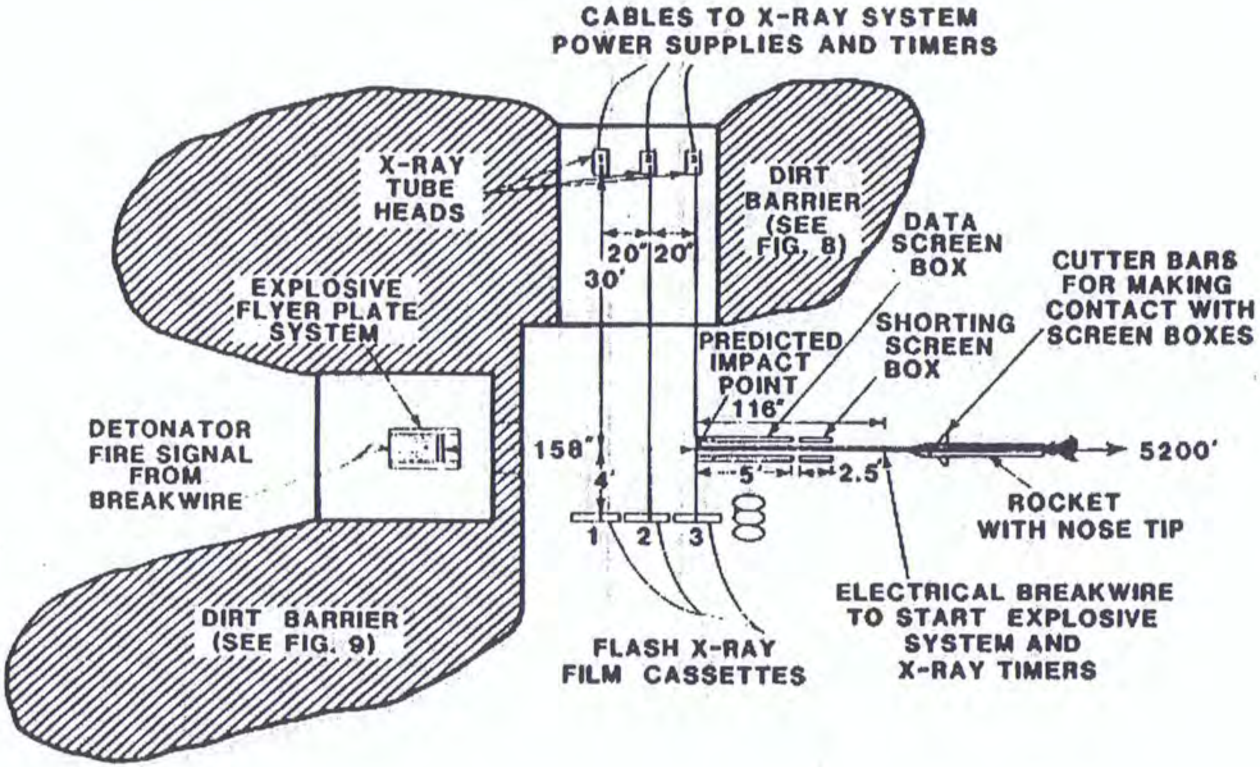
CABLES TO X-RAY SYSTEM POWER SUPPLIES AND TIMERS
X-RAY TUBE HEADS
DIRT BARRIER (SEE FIG. 8)
20" 20"
30'
DATA SCREEN BOX
CUTTER BARS FOR MAKING CONTACT WITH SCREEN BOXES
EXPLOSIVE FLYER PLATE SYSTEM
PREDICTED IMPACT POINT
SHORTING SCREEN BOX
116"
DETONATOR FIRE SIGNAL FROM BREAKWIRE
158"
4'
5'
2.5'
5200'
ROCKET WITH NOSE TIP
1
2
3
ELECTRICAL BREAKWIRE TO START EXPLOSIVE SYSTEM AND X-RAY TIMERS
DIRT BARRIER (SEE FIG. 9)
FLASH X-RAY FILM CASSETTES

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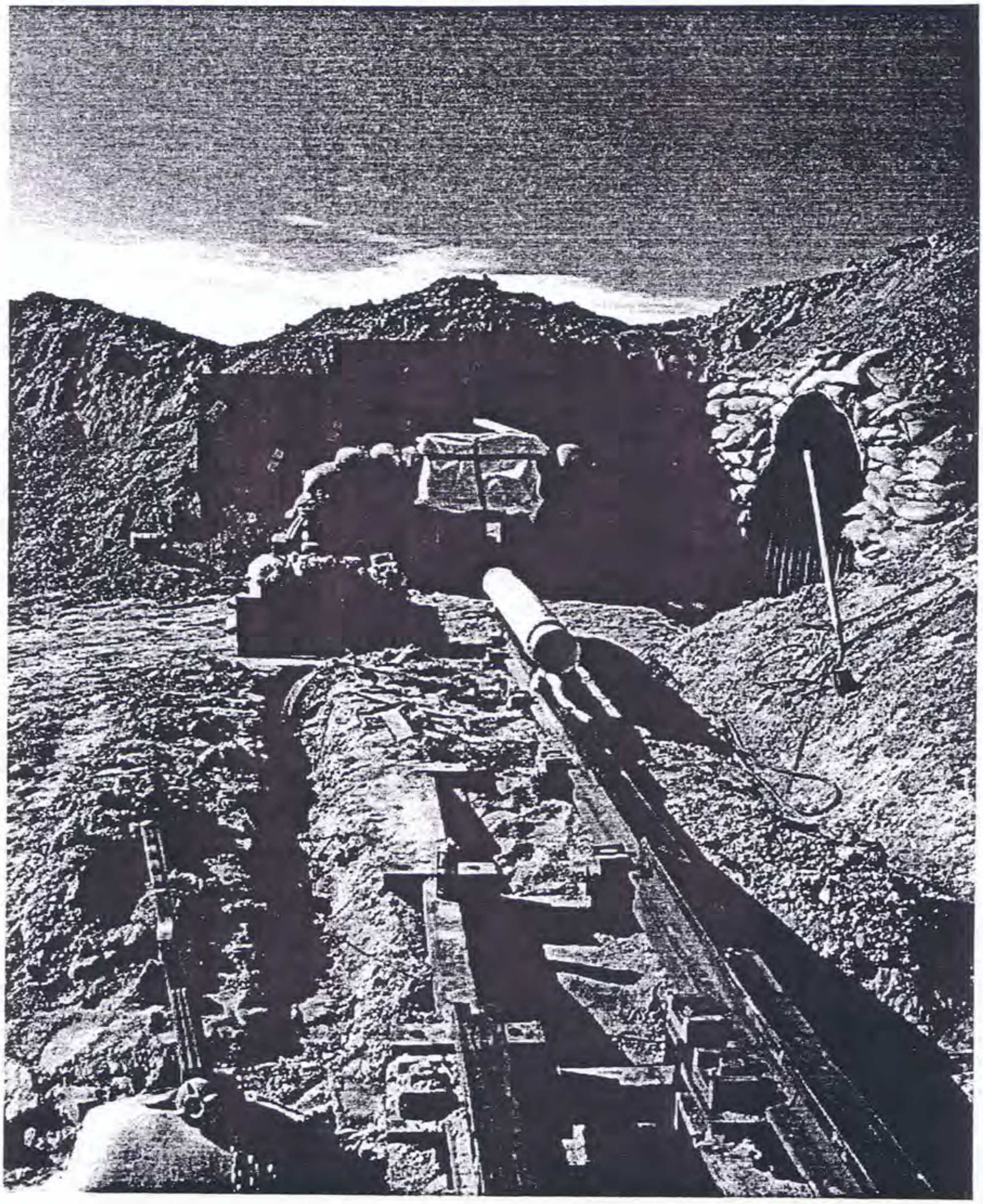

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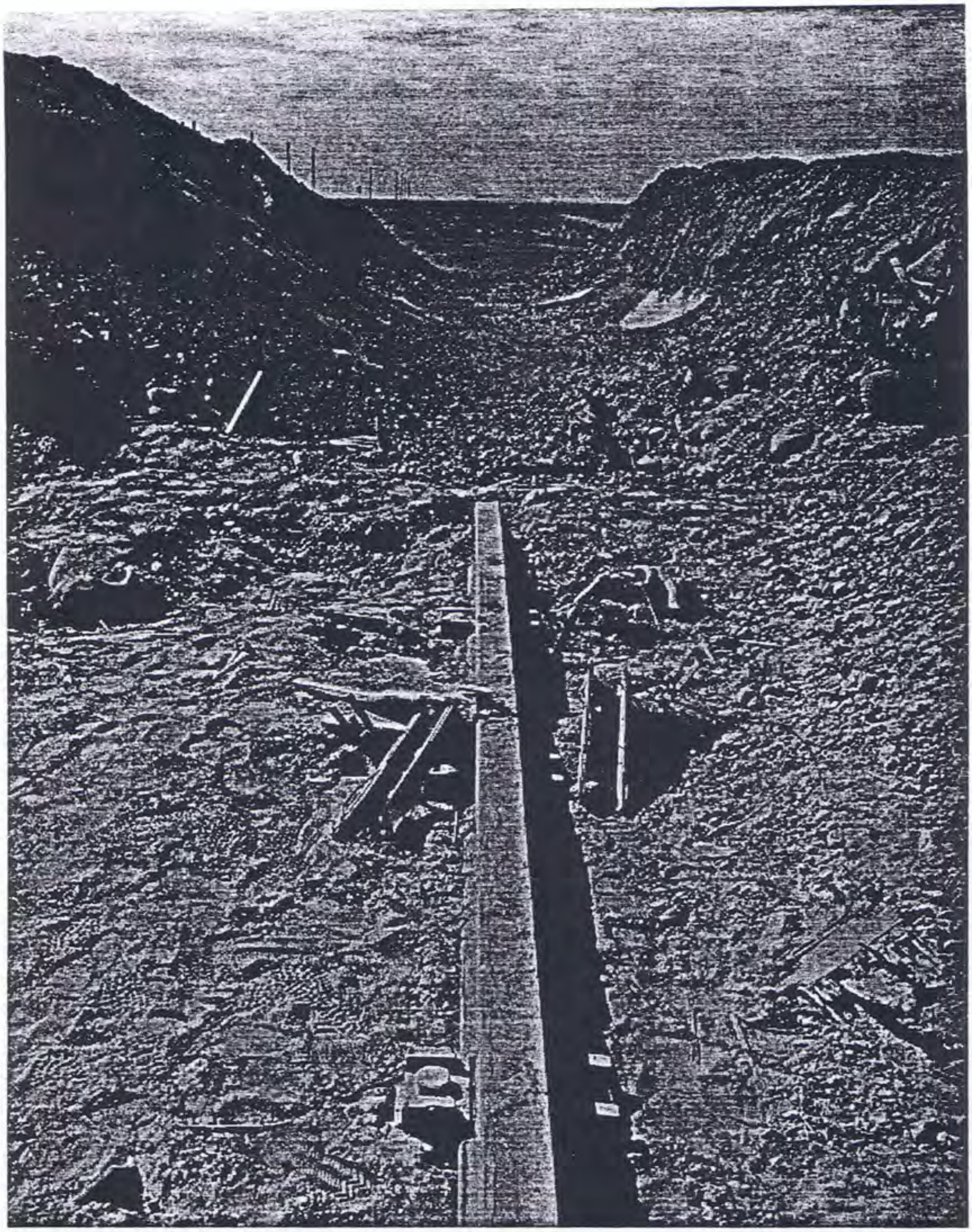

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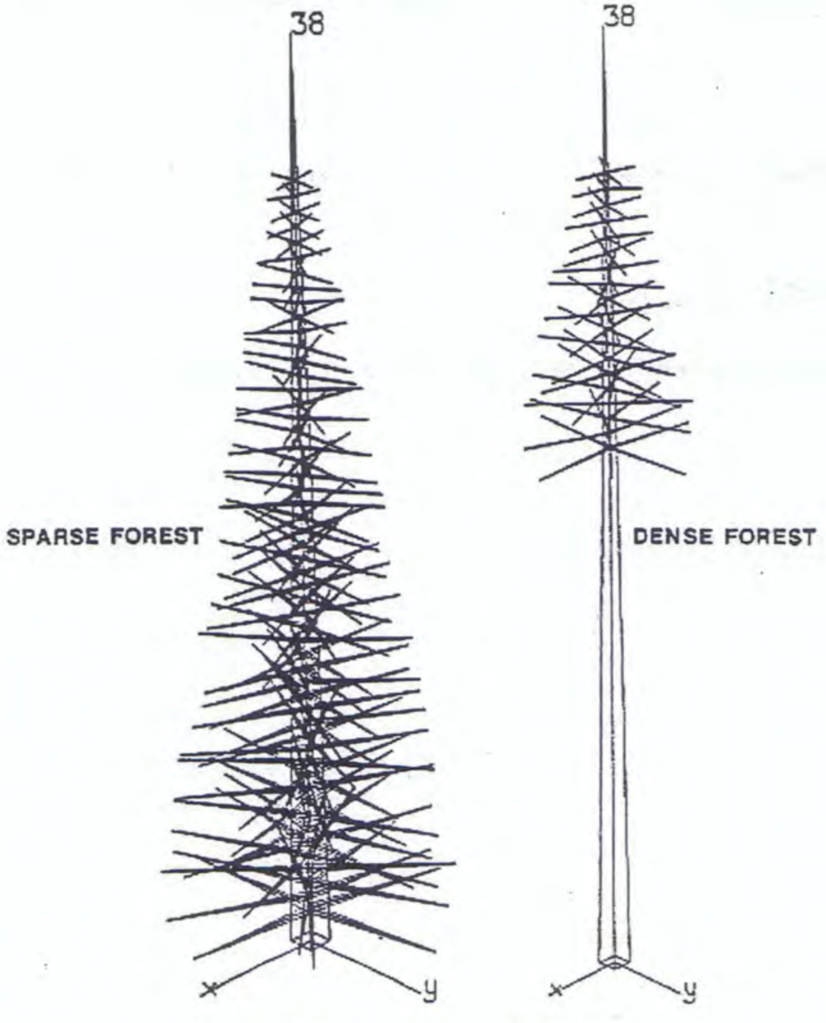

Pine Tree Models for Sparse and Dense Forests

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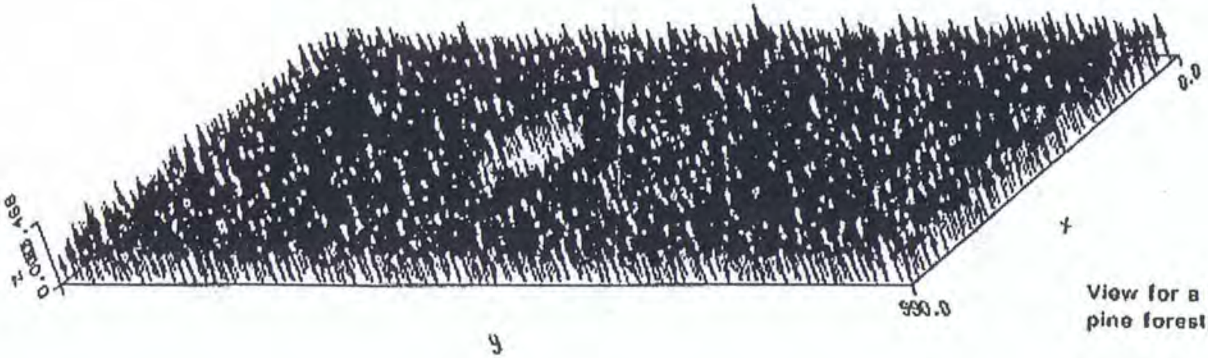
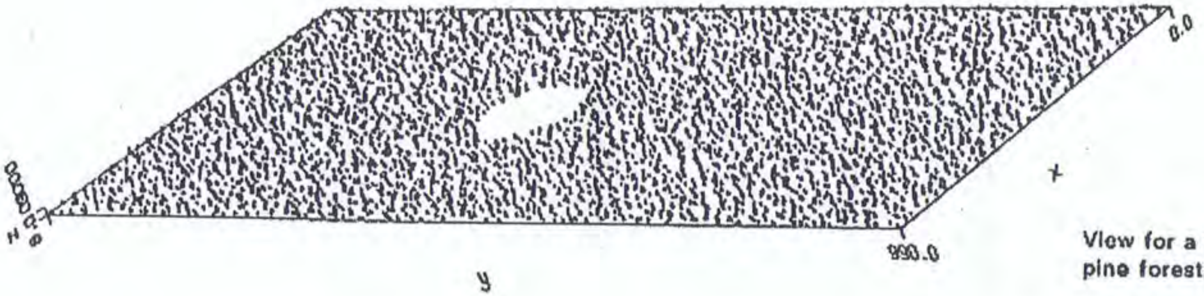


View for a 100 year old pine forest, P=0.80



View for a 7 year old pine forest, P-0.13

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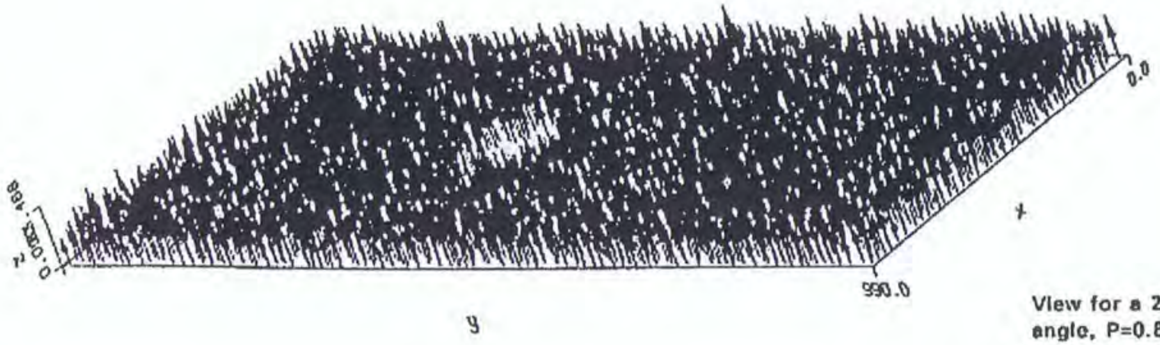
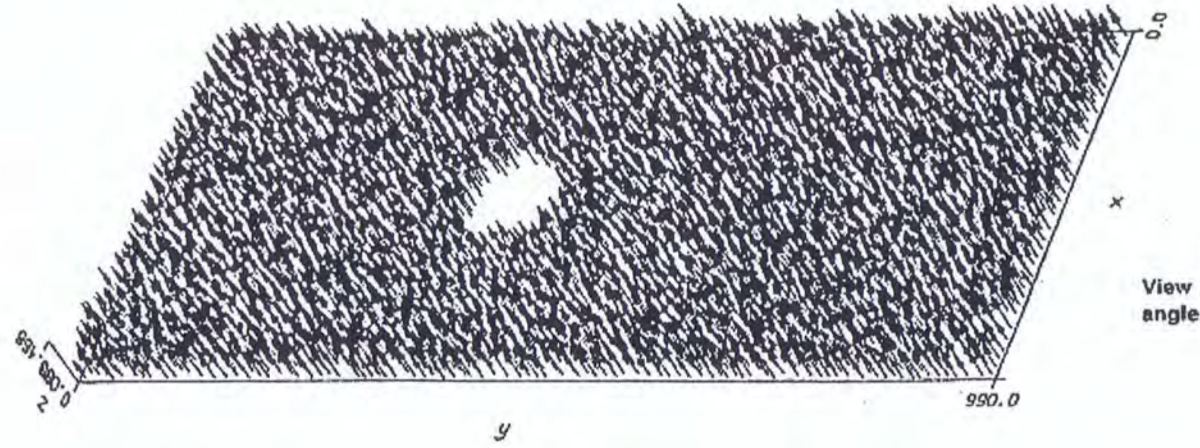


View for a 20° impact angle, P=0.80



View for a 40° impact angle, P=0.54

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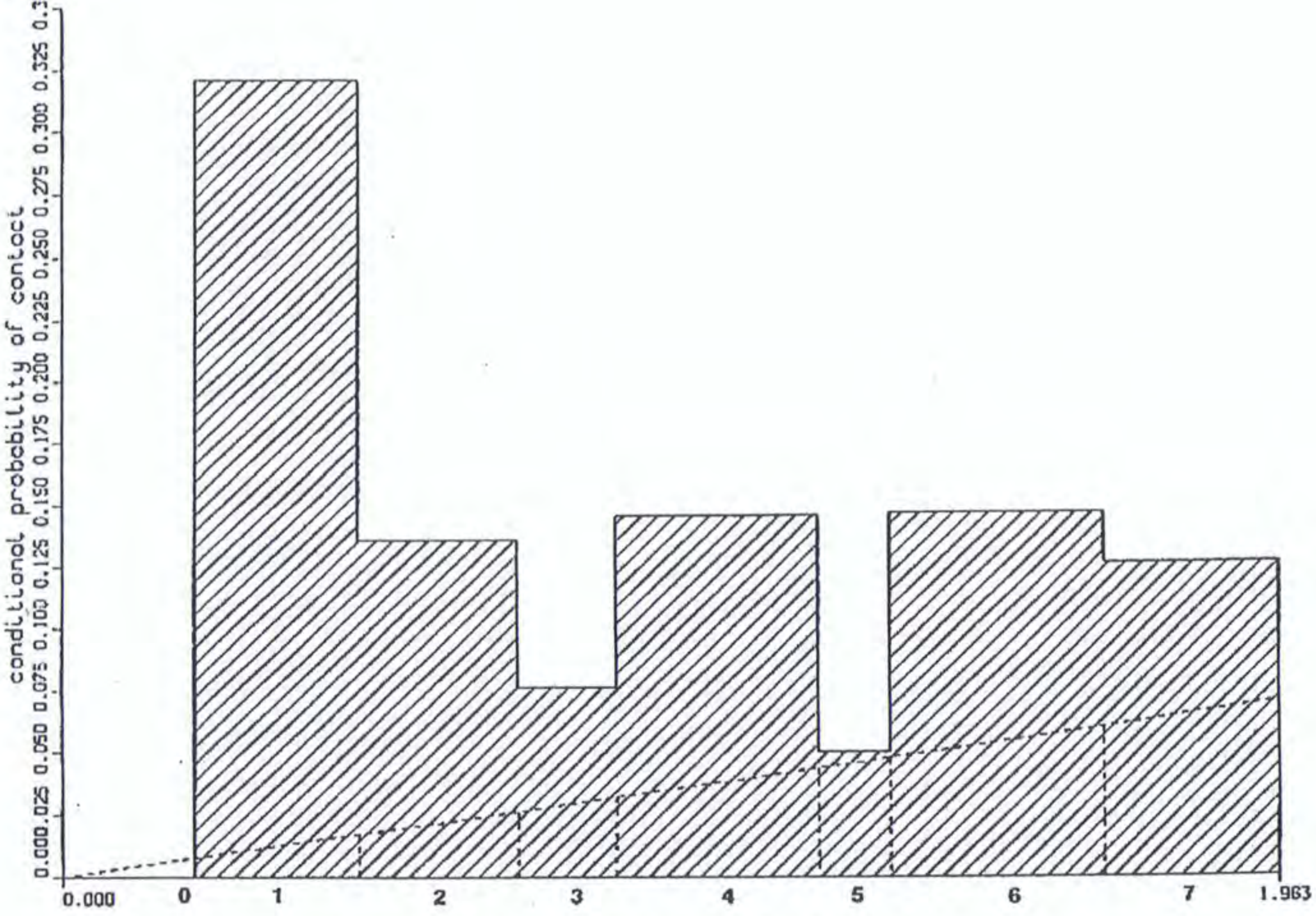

Conditional Probabilities of Tree Impacts on the Reentry Vehicle Surface

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Improved surface fuzing concepts have been explored for every new reentry system

- Faster-responding impact sensors
  - concepts include:
    - faster-sensing mechanisms
    - forward deployment of traditional sensors
  - little, if any, additional protection against impact irregularities

- Radar proximity fuzing
  - adequate survivability for all impact scenarios
  - little, if any, degradation in burst height effectiveness

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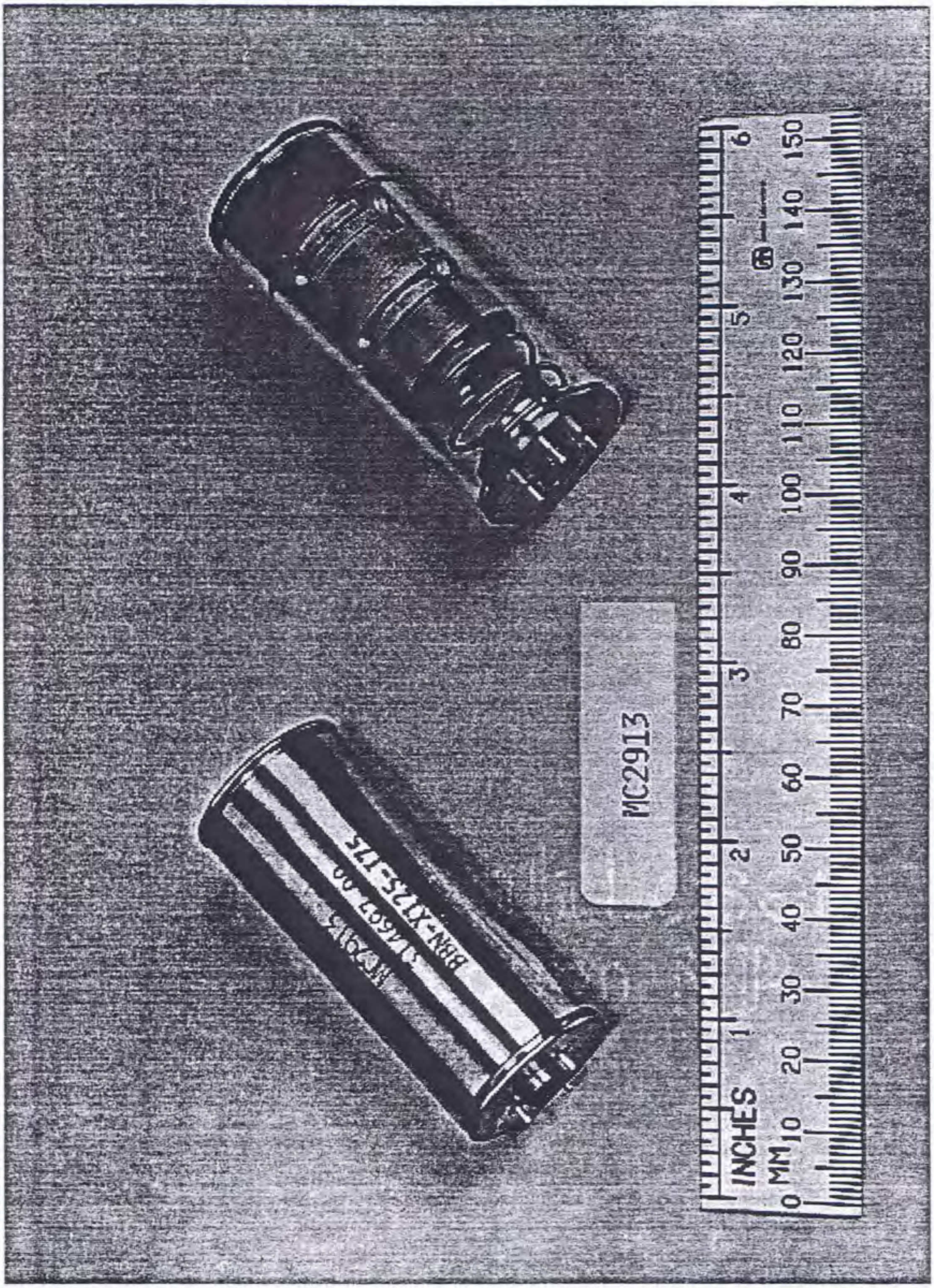
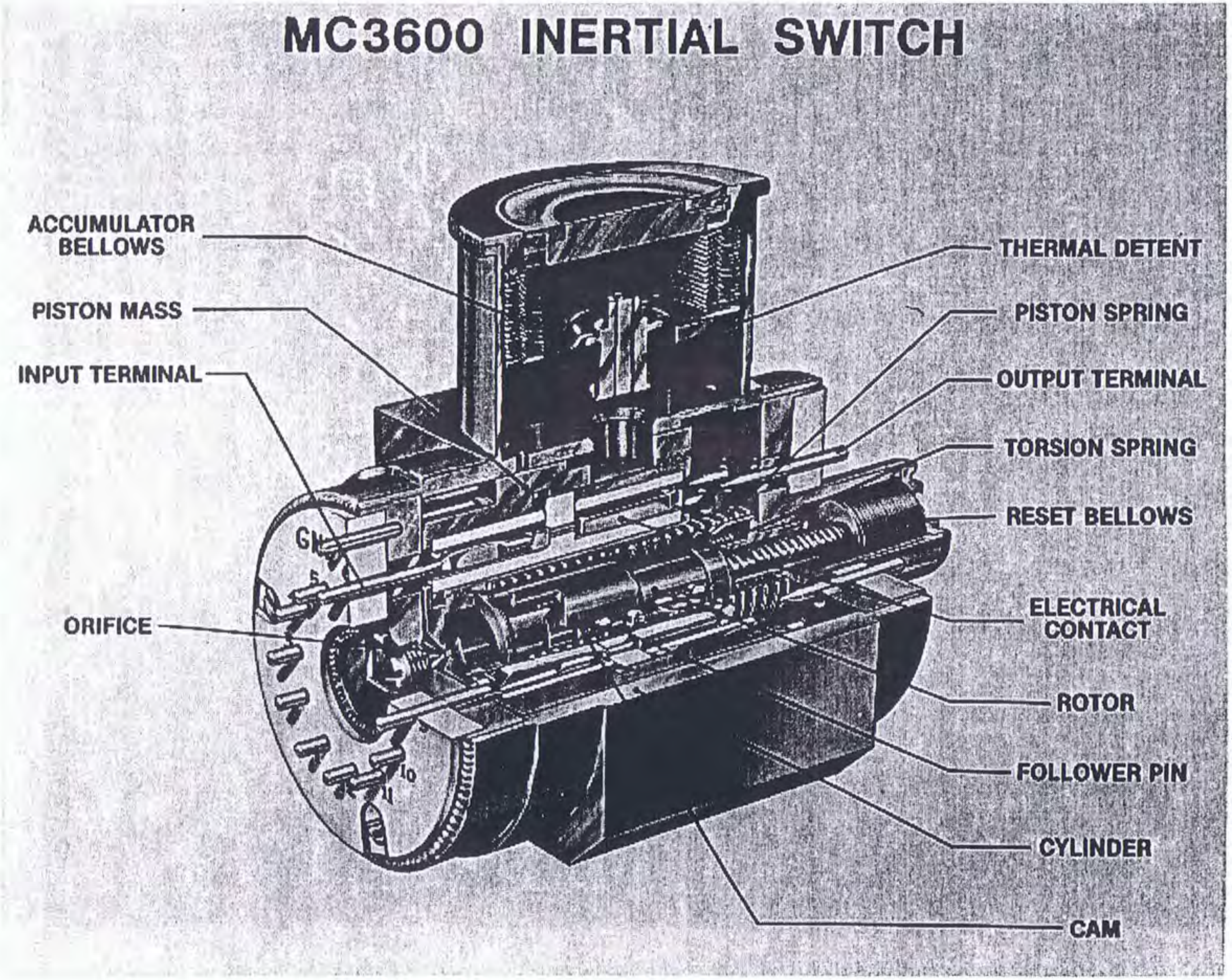
3

Inertial Devices

- ***Mechanical*** g-switches & integrating accelerometers
  - Stand-alone inertial fuze or initiation of reentry timer fuze
  - Closure of electrical contacts cause by completion of sensing mass travel
  - Features to attain minimum g's and g-seconds
    - Fluid-metering
    - Escapement mechanism
  - Mechanical feature variations limit accuracy to 1%
  - Extensive use as nuclear safety switches

- ***Electronic*** integrating accelerometers
  - Stand-alone inertial fuze or part of "path length" mechanization
  - Control circuitry generates "restoring current" proportional to acceleration
  - Provides continuous measurement of integrated deceleration
  - Electrical circuit tolerancing controls accuracy to 0.1%


MC2913
INCHES
MM


MC3600 INERTIAL SWITCH

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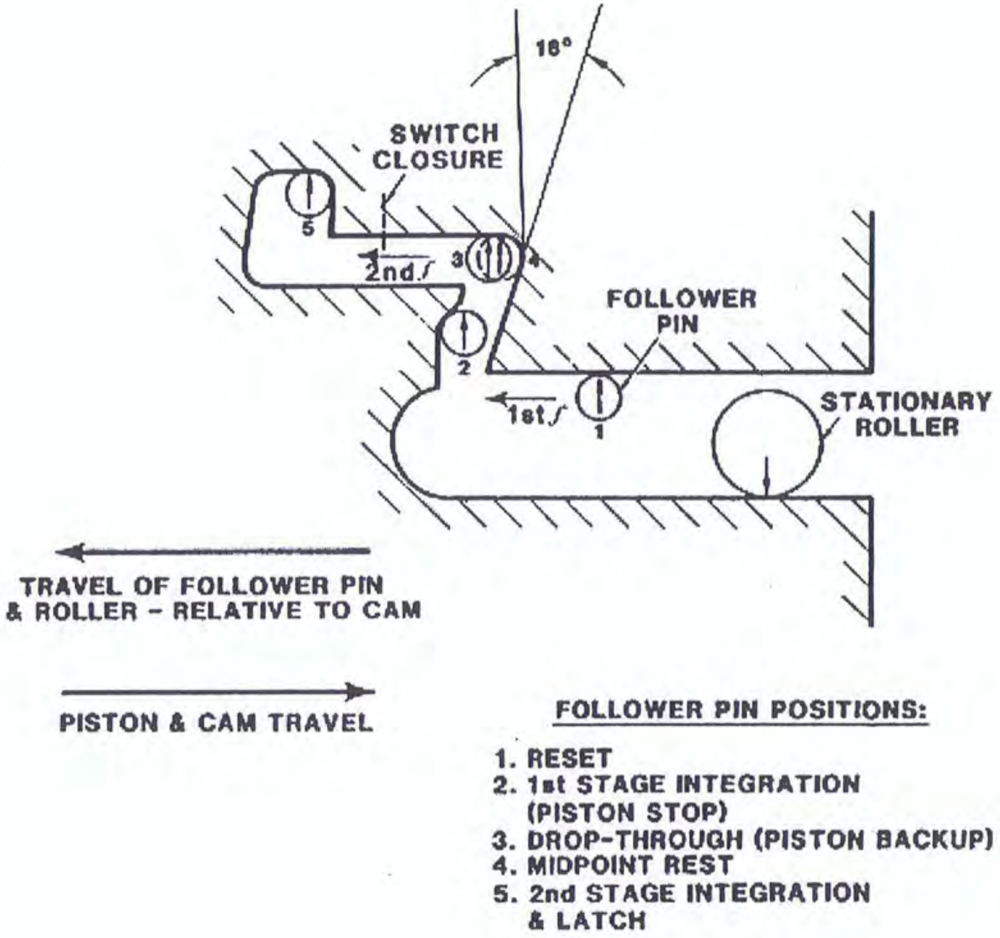

FOLLOWER PIN POSITIONS:

1. RESET
2. 1st STAGE INTEGRATION (PISTON STOP)
3. DROP-THROUGH (PISTON BACKUP)
4. MIDPOINT REST
5. 2nd STAGE INTEGRATION & LATCH

TWO-STAGE CAM SCHEMATIC

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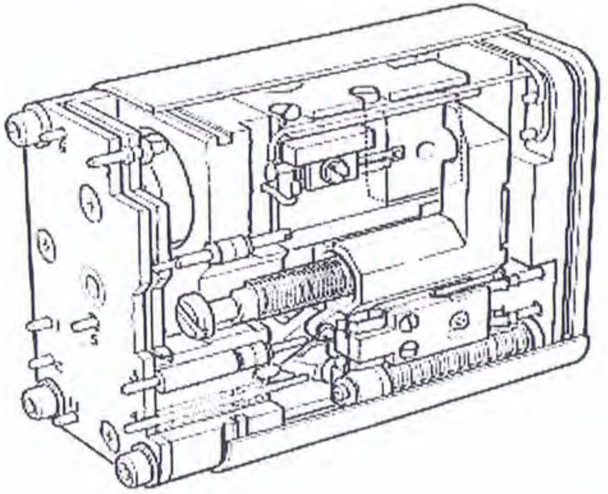
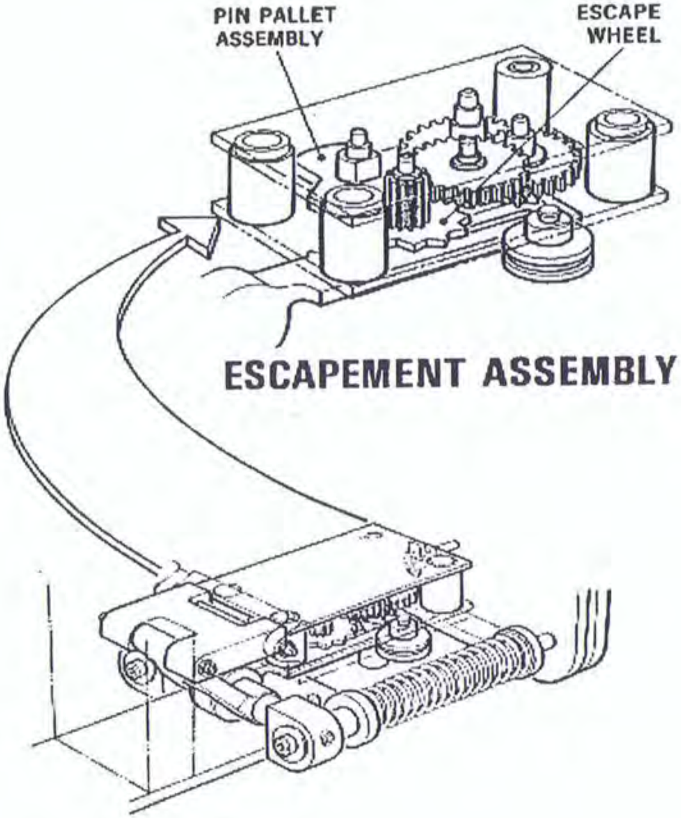
Sandia Laboratories



MC 2897 INERTIAL SWITCH



ESCAPEMENT ASSEMBLY

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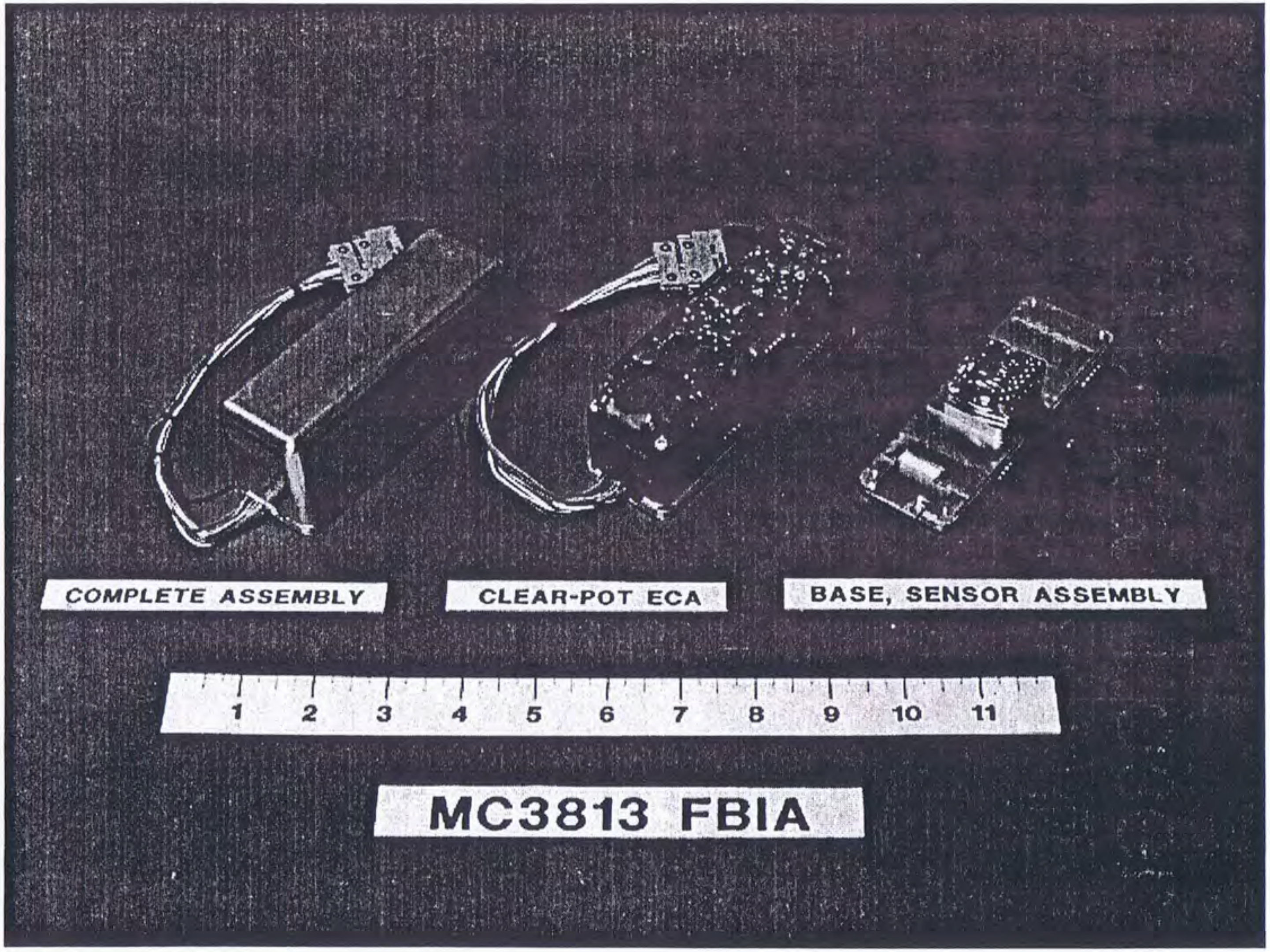

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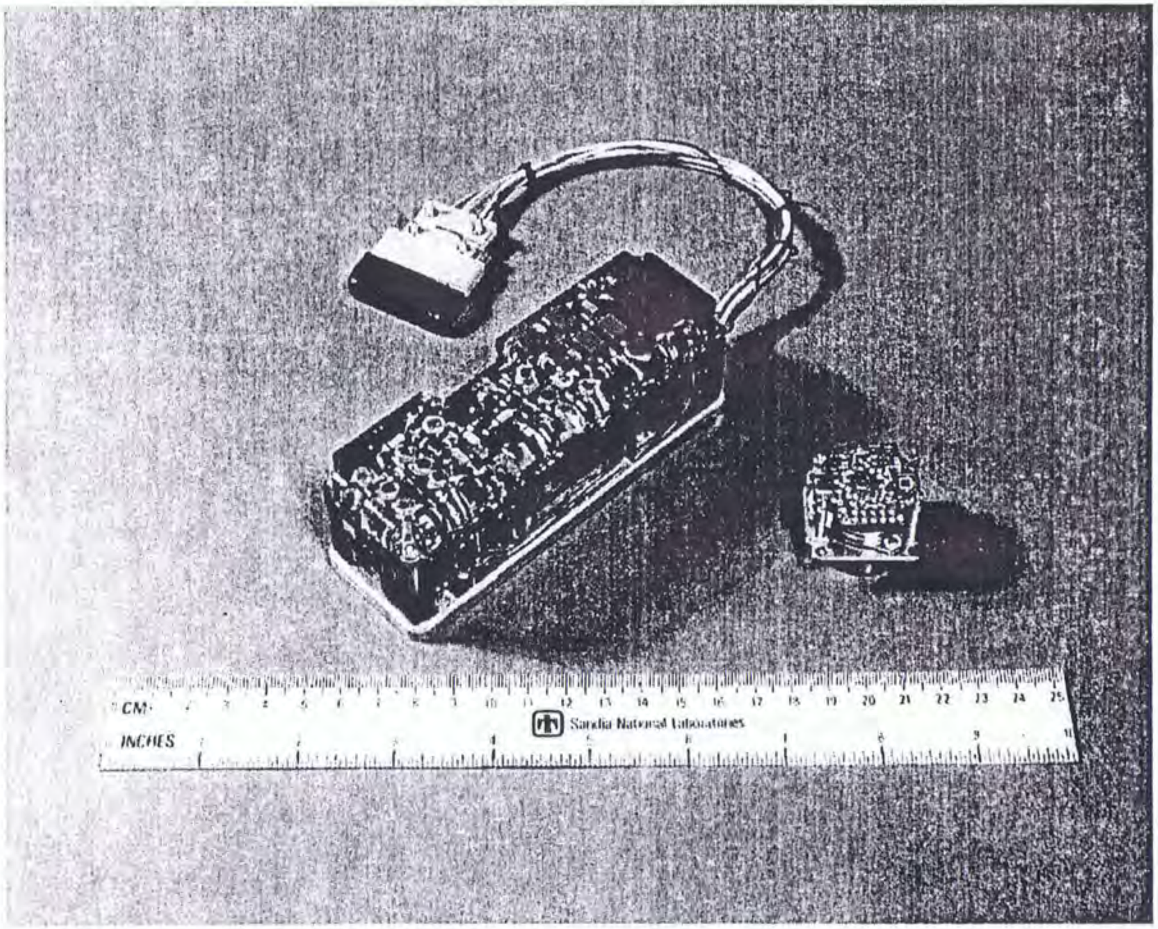

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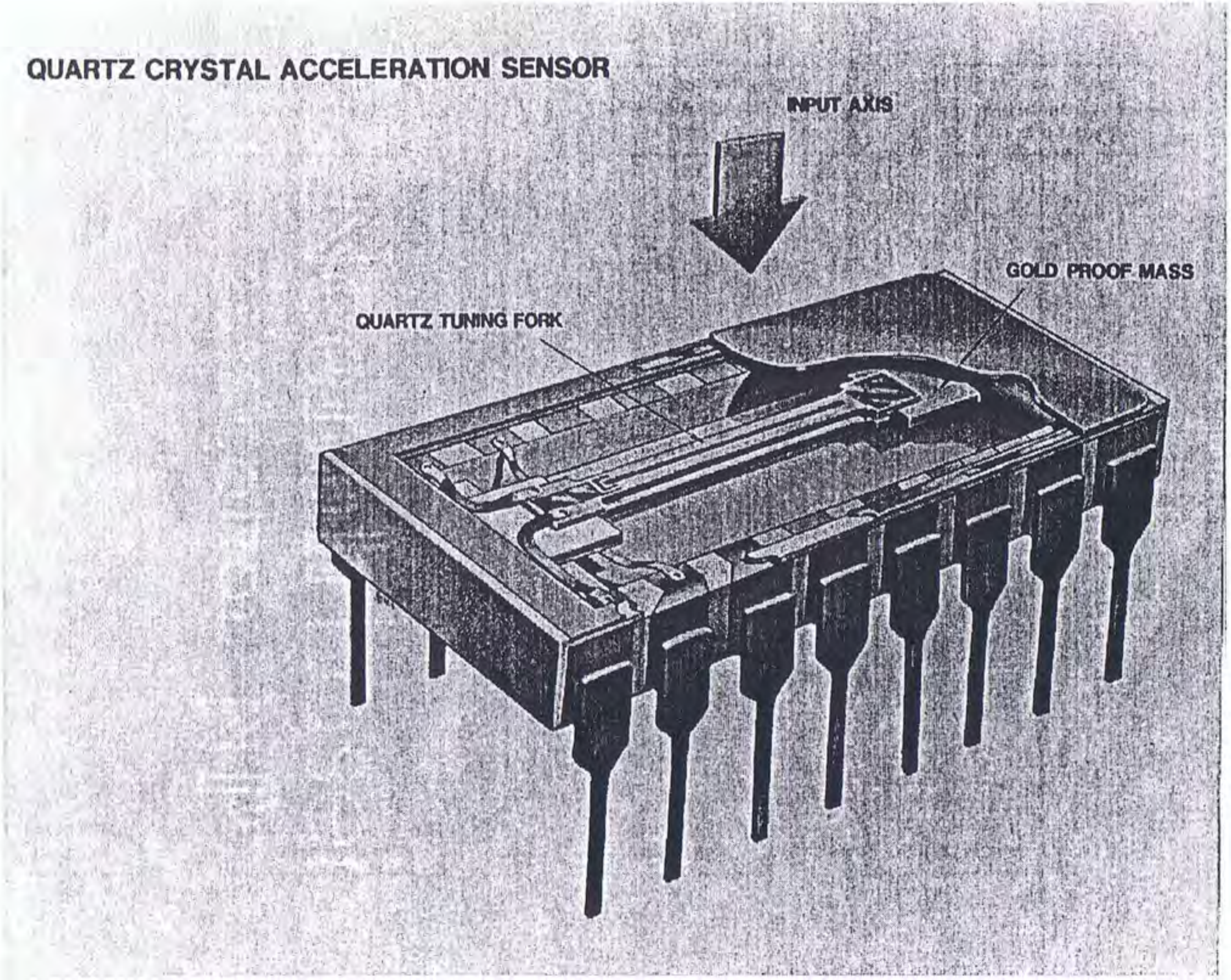

QUARTZ CRYSTAL ACCELERATION SENSOR

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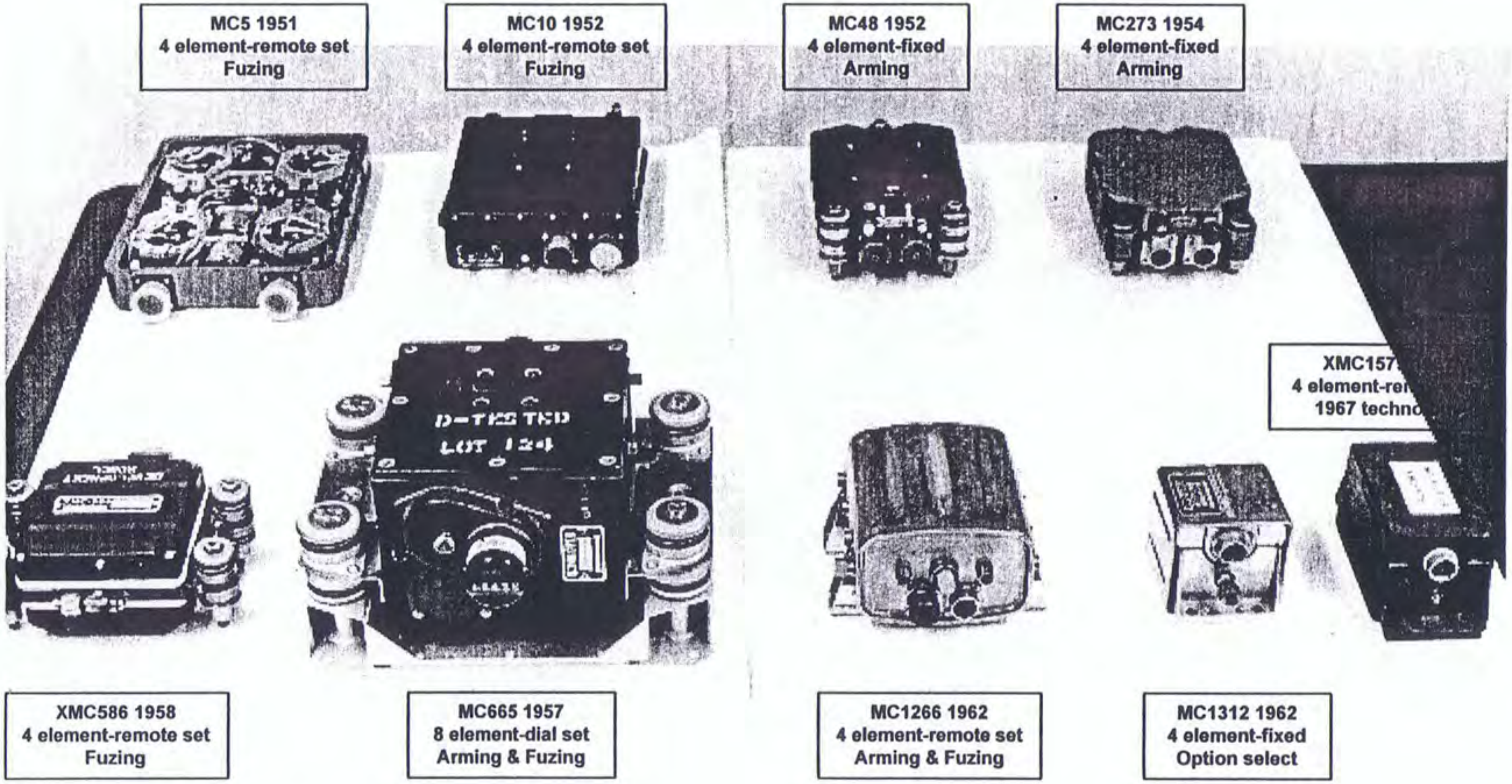
Barometric Switches



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Timers

- Reentry body fuzing
  - Primary fuze on older systems
  - High altitude fuze and/or backup to radar on recent systems
  - Candidate fuze for earth penetrating weapons
- Bomb fuzing
  - Also uses timer for safe escape in laydown mode
- Artillary projectiles and special munitions
- Depth bombs
  - Timer initiated by water impact or hydrostatic pressure

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Timers (cont'd)

- Mechanism for initiating arming functions, I.e., batteries
- Critical element of any programmer and/or computer for warheads, bombs, guidance platforms, etc.
- Technology evolution

Mechanical	Approximately 5% accuracy
Electronic (LC)	Smaller with approximately 2% accuracy
Crystal	Smallest with accuracy measured in parts million

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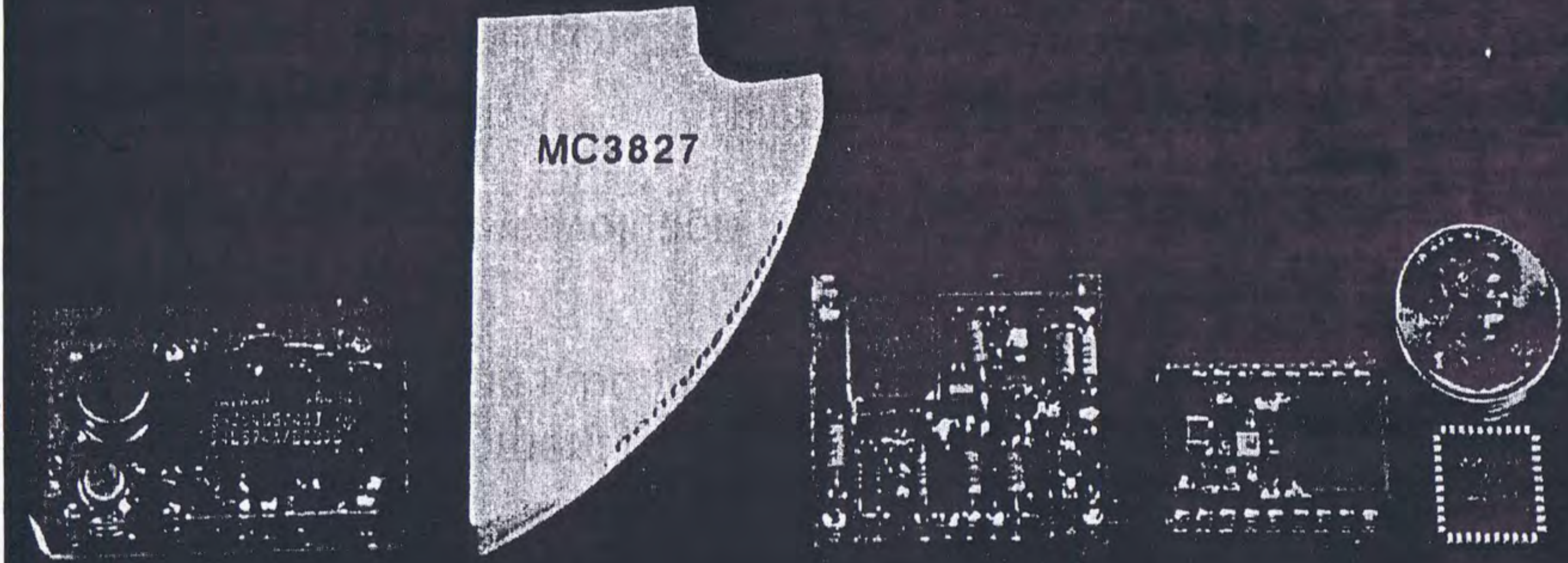
Some Clocks In Stockpile



MC3648
B61-7

MC3827
Trident II

MC4178
B61JTA

MC4081
B61-3,4,10

MC3852
Code
Activated
Processor

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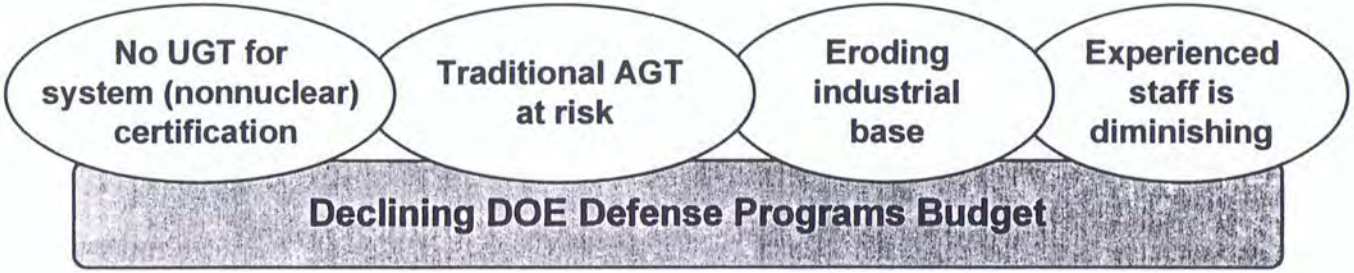
Stockpile Stewardship will require Maintenance, Refurbishment & Repair

Future:

- Performance certification (both current & new)
- Design & manufacturing (when required)

Environment:



No UGT for system (nonnuclear) certification

Traditional AGT at risk

Eroding industrial base

Experienced staff is diminishing

Declining DOE Defense Programs Budget

Current need:

- Stockpile design options
- Capability sustainment

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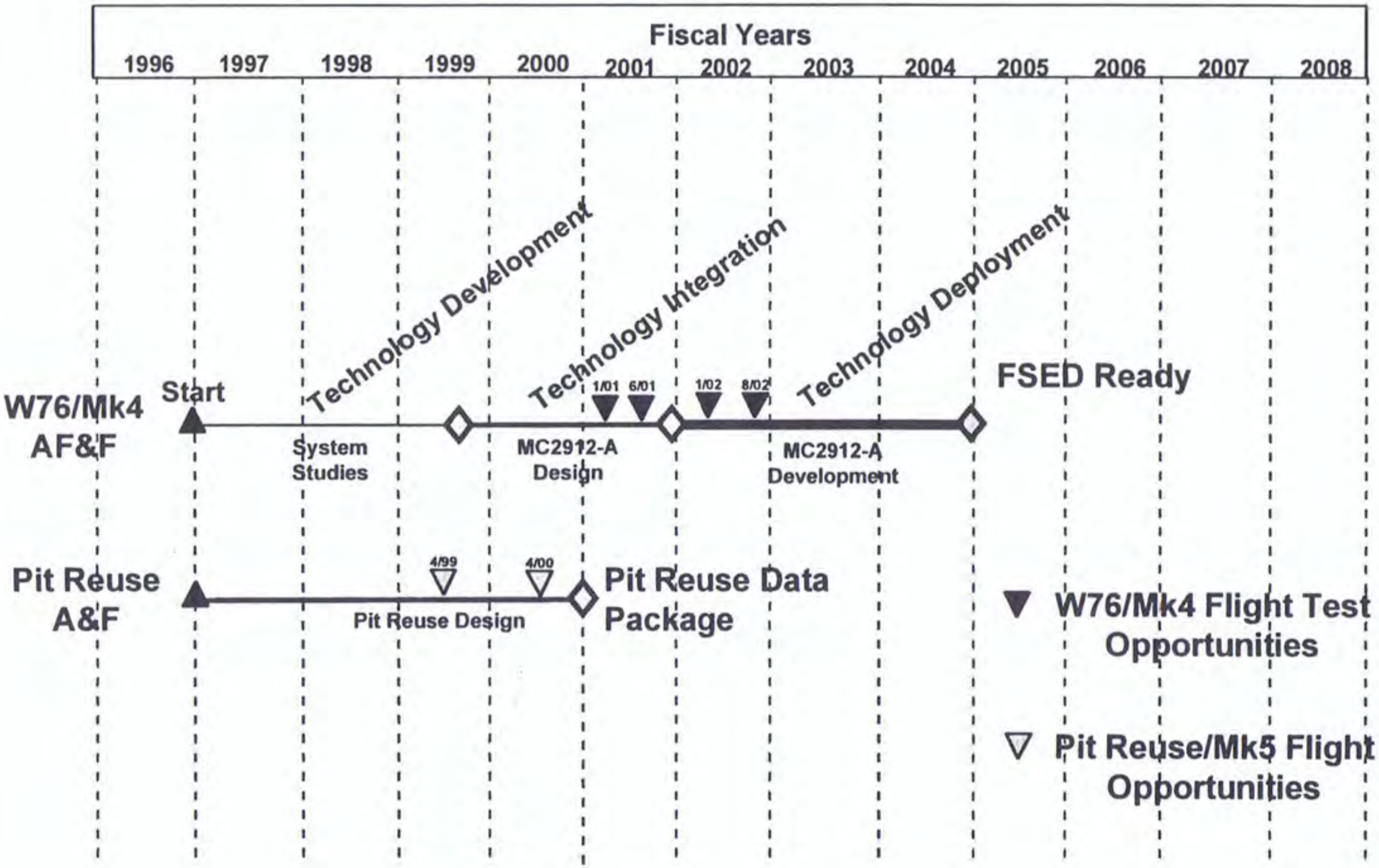
SWPP DoD/DOE MOU (draft)

- Purpose for MOU
    - Program authorization
    - Roles & responsibilities
- Program Objectives
    - Exercise DOE capabilities relevant to SLBM
    - Demonstrate viability of system & component replacement options for W76 & W88
    - Emphasis on non-producible hardware and development of certification methods
    - Does not include fabrication of stockpile hardware
- Deliverable
    - Design Data Package for each option -- design definition, manufacturing & certification feasibility, identification of subsequent activities

Reentry systems advanced AF&F project



Fiscal Years

1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008

W76/Mk4 AF&F

Start

Technology Development

Technology Integration

Technology Deployment

FSED Ready

1/01 6/01 1/02 8/02

System Studies

MC2912-A Design

MC2912-A Development

Pit Reuse A&F

4/99 4/00

Pit Reuse Design

Pit Reuse Data Package

▼ W76/Mk4 Flight Test Opportunities

▽ Pit Reuse/Mk5 Flight Opportunities

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Fuzing options for replacement Mk4 AF&F

Mk4

- airburst radar, 3 ranges
- inertial airburst, g-started timer
- contact backup

Mk5

- radar-update path length (RUPL)
- airburst radar, 5 ranges
- inertial airburst, path length
- high airburst, timer
- proximity radar
- contact backup

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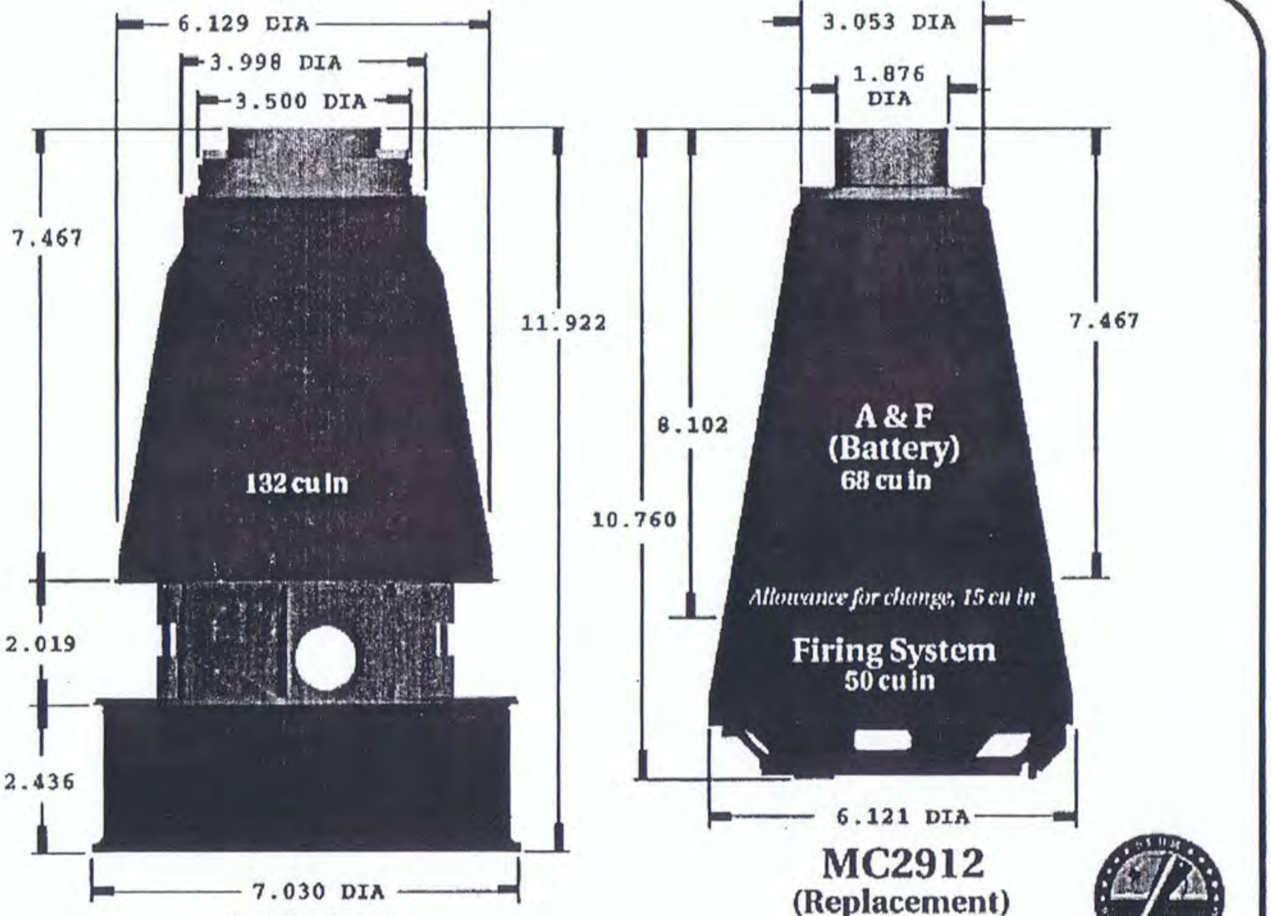

MC3810

MC2912
(Replacement)

Sandia National Laboratories

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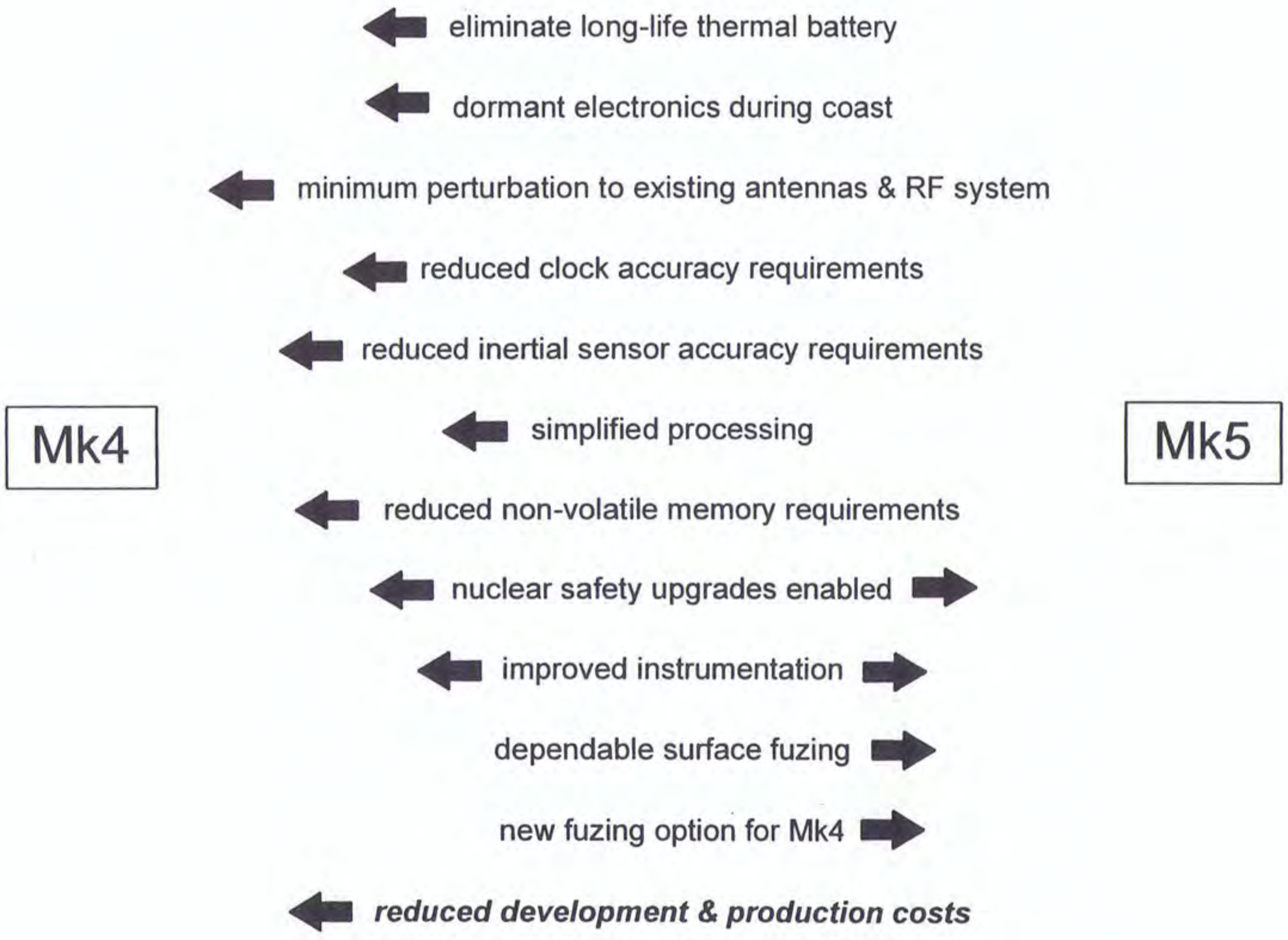
Fuzing options for replacement Mk4 AF&F



Mk4

Mk5

← eliminate long-life thermal battery

← dormant electronics during coast

← minimum perturbation to existing antennas & RF system

← reduced clock accuracy requirements

← reduced inertial sensor accuracy requirements

← simplified processing

← reduced non-volatile memory requirements

← nuclear safety upgrades enabled →

← improved instrumentation →

dependable surface fuzing →

new fuzing option for Mk4 →

← ***reduced development & production costs***

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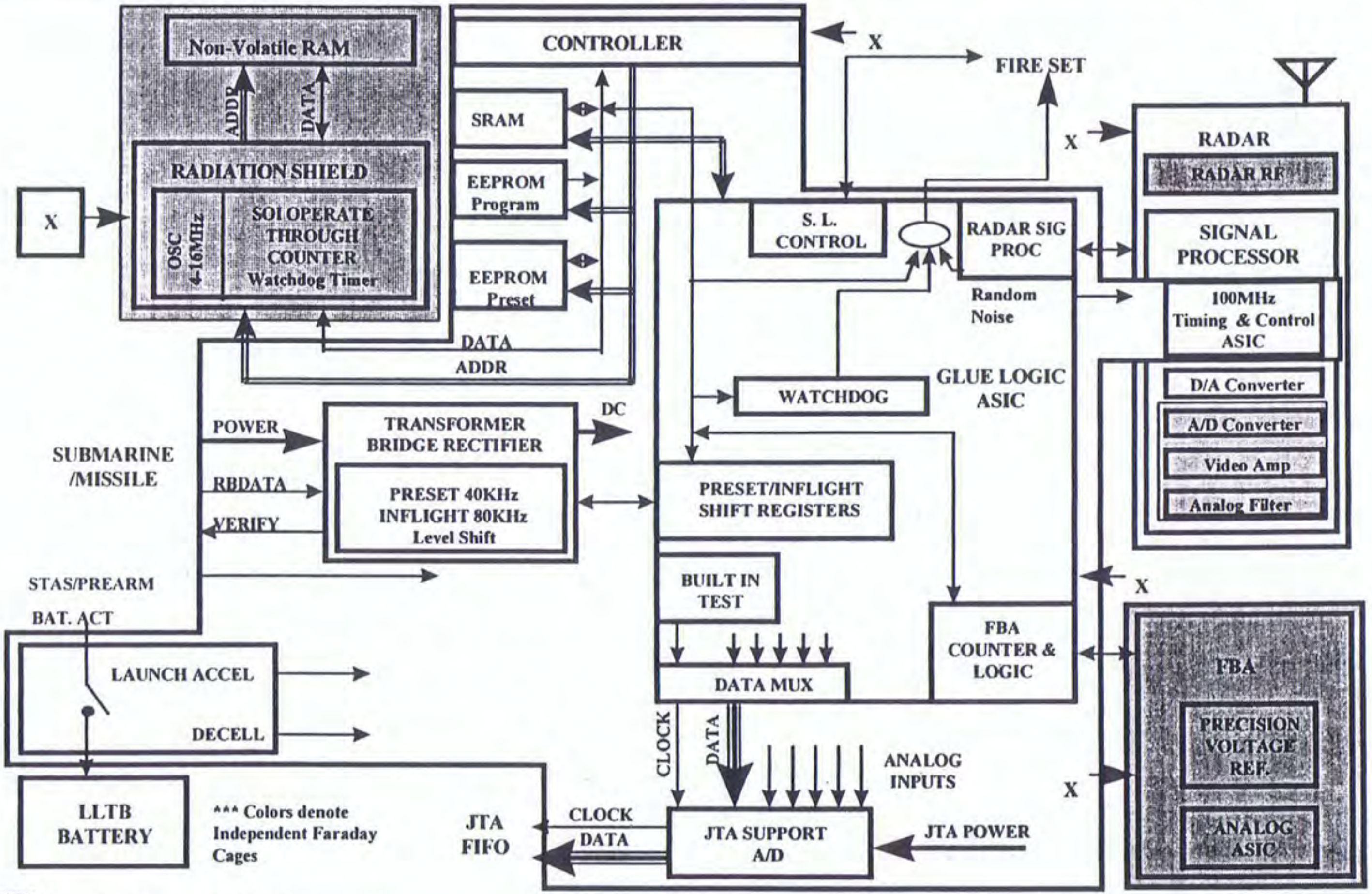
A&F architecture to support W76/Mk4 and Pit Reuse


Non-Volatile RAM
ADDR
DATA
RADIATION SHIELD
OSC 4-16MHz
SOI OPERATE THROUGH COUNTER Watchdog Timer
X
CONTROLLER
SRAM
EEPROM Program
EEPROM Preset
DATA
ADDR
X
FIRE SET
X
RADAR
RADAR RF
SIGNAL PROCESSOR
100MHz Timing & Control ASIC
D/A Converter
A/D Converter
Video Amp
Analog Filter
S. L. CONTROL
RADAR SIG PROC
Random Noise
WATCHDOG
GLUE LOGIC ASIC
SUBMARINE /MISSILE
POWER
RBDATA
VERIFY
TRANSFORMER BRIDGE RECTIFIER
DC
PRESET 40KHz INFLIGHT 80KHz Level Shift
PRESET/INFLIGHT SHIFT REGISTERS
STAS/PREARM
BAT. ACT
BUILT IN TEST
FBA COUNTER & LOGIC
X
LAUNCH ACCEL
DECELL
DATA MUX
FBA
PRECISION VOLTAGE REF.
ANALOG ASIC
X
CLOCK
DATA
ANALOG INPUTS
LLTB BATTERY
*** Colors denote Independent Faraday Cages
JTA FIFO
CLOCK
DATA
JTA SUPPORT A/D
JTA POWER

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

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SESSION XV

•ARMS CONTROL ISSUES

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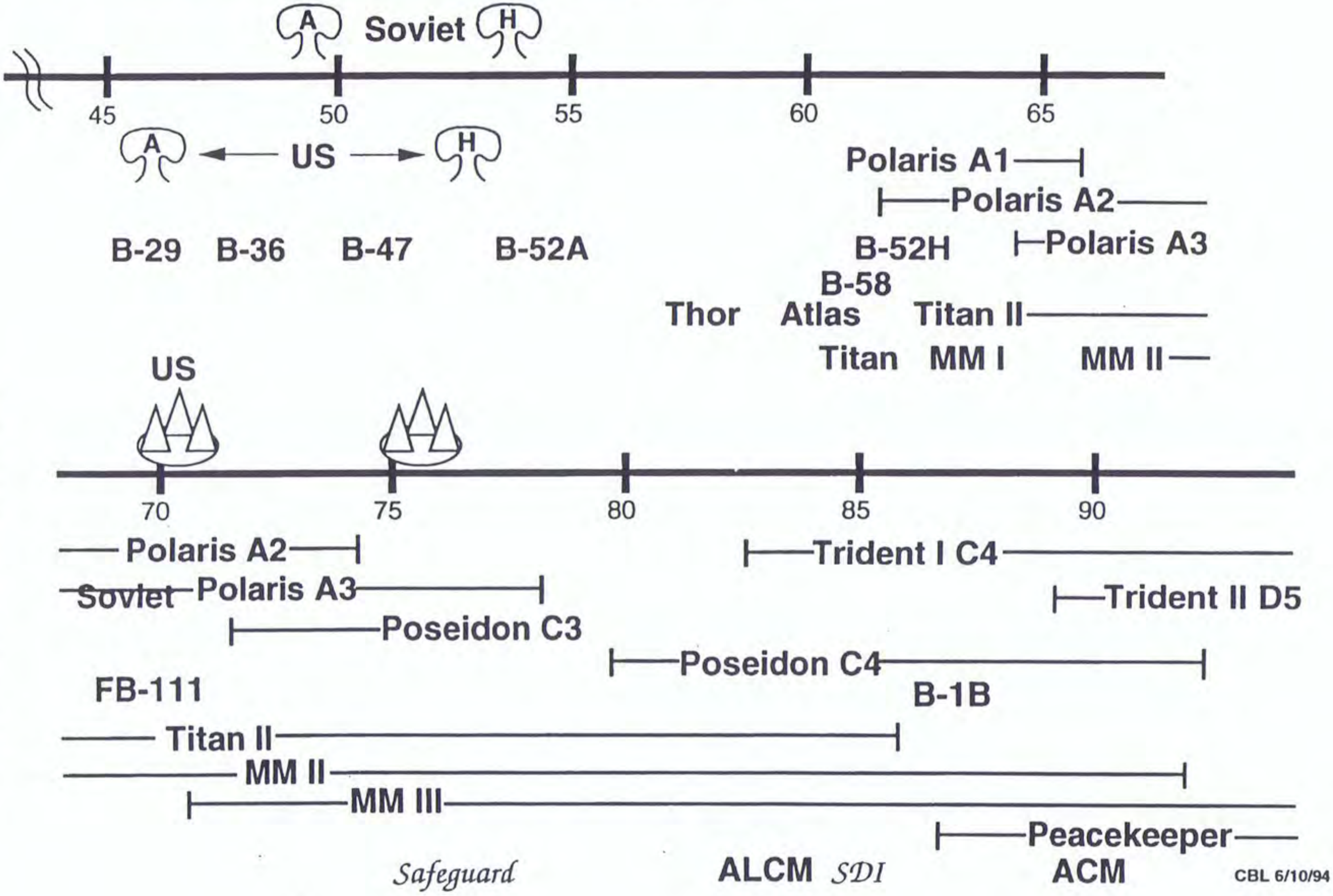
Strategic Delivery Systems



Soviet

45 50 55 60 65

US

Polaris A1

Polaris A2

B-29 B-36 B-47 B-52A

B-52H

Polaris A3

B-58

Thor Atlas Titan II

Titan MM I MM II

US

70 75 80 85 90

Polaris A2

Trident I C4

~~Soviet~~ Polaris A3

Trident II D5

Poseidon C3

Poseidon C4

FB-111

B-1B

Titan II

MM II

MM III

Peacekeeper

Safeguard

ALCM *SDI*

ACM

CBL 6/10/94

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The Evolution of Response Time

1948	Berlin blockade	2 days to assemble
1957	Suez	few hours to launch
1959	DEFCON established	
1960	JSTPS & SIOP	1/3 of bombers ready for immediate take-off
1962	Cuban missile crisis	1/8 on airborne alert

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Arms Control Treaties

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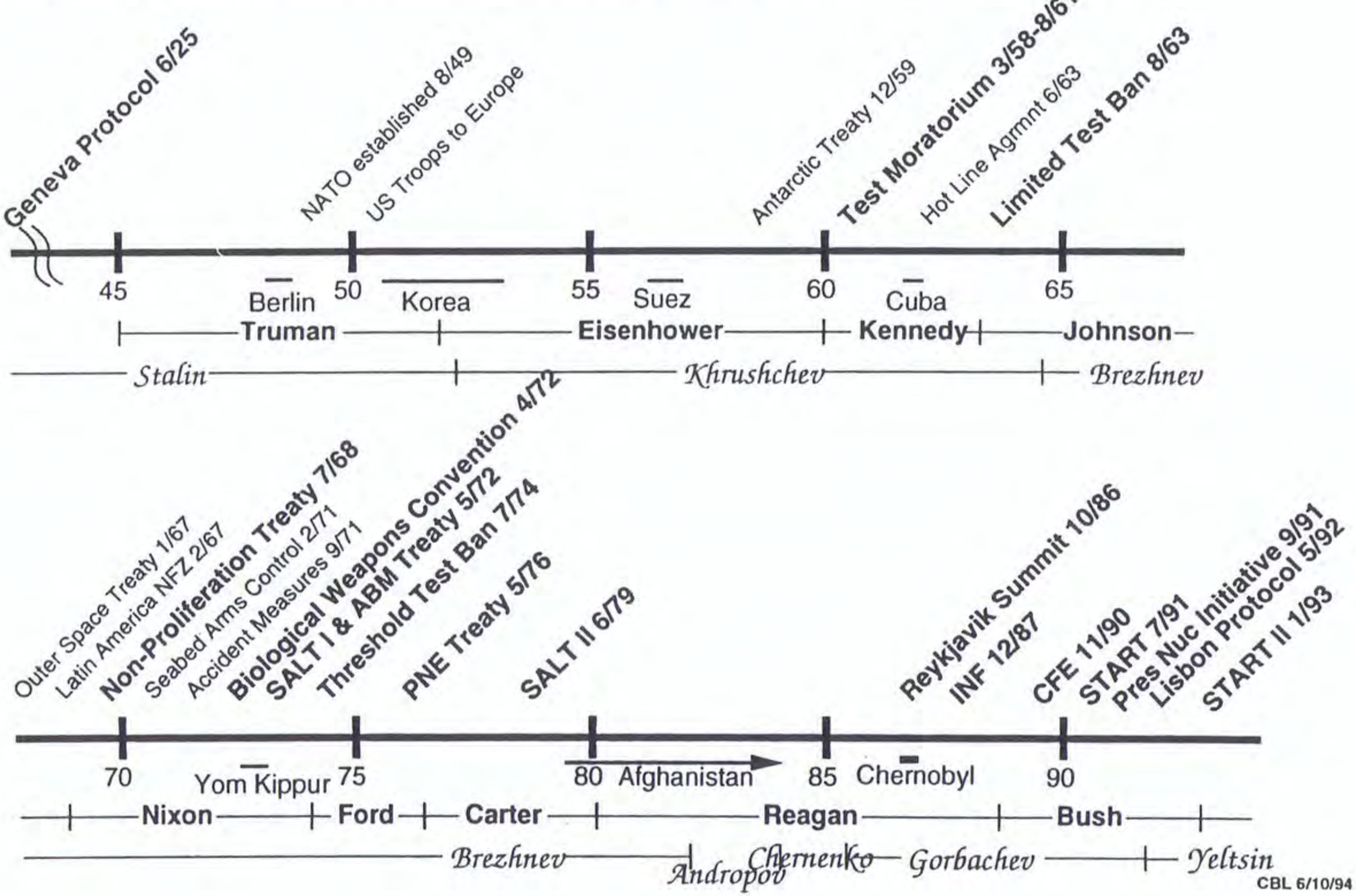

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The Geneva Protocol - 1925

Banned the use in war of asphyxiating, poisonous, or other gases and of bacteriological methods of warfare

US ratified in 1975

All major states now parties

UN Conference on Disarmament is working toward a ban on production and stockpiling

Test Moratorium - 1958 to 1961

In March 1958, Soviets declared moratorium

In October, negotiations on CTBT began & Eisenhower announced 1-yr U. S. moratorium

May 1960 U-2 incident scrubbed planned summit

Kennedy Administration resumed talks

August 1961, citing French test, Soviets resumed testing

Soviets conducted over 50 tests in the last 3 months of 1961

The Limited Test Ban Treaty - 1963

Limited nuclear tests to underground

Original signatories were US, Soviet Union, and UK

US ratified 10/63

More than 100 parties now

France ceased above ground tests in 1974,
China in 1980

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The Nonproliferation Treaty - 1968

- Eisenhower proposed "Atoms for Peace" in 1953
- IAEA established in 1957 to promote and monitor
- Nuclear Nonproliferation Treaty was negotiated from 1965 and signed in 1968
- NPT Review Conferences every 5 years
- After 25 years (April 1995) the Review and Extension Conference (Chaired by Amb. Dhanapala) decided on indefinite extension
  - without a vote
- In exchange for peaceful use of atomic energy, signatories agree to safeguards

States not party to the NPT (as of 1/23/97)

- Brazil
- Cuba
- India
- Israel
- Macedonia
- Pakistan
- Serbia/Montenegro

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Biological and Toxin Weapons Convention

Outlaws development, production, stockpiling of all biological or toxin weapons and requires destruction of existing stocks

No specific verification provisions

Signed in 1972 and ratified by the US in 1975

Nixon ended US program in 1969 and destroyed stocks

Soviet incident at Sverdlovsk in 1979

SALT I - 1972

Interim Agreement on Strategic Offensive Arms

Limited launchers (silos and sub tubes) to the then current number

US - 1710 SU - 2347

Limit on heavy launchers (SS-9 and later SS-18)

Five year duration

US ratified in Oct 1972

Reagan repudiated SALT I and II in May 1986

Joint Statement on the ABM Treaty - March 21, 1997

- Preserve the ABM Treaty, prevent circumvention, and enhance viability
- TBM systems may be deployed, but must not threaten strategic nuclear forces
- TBM systems will not be deployed against each other (?)
- SCC to complete demarcation between TBM and ABM
  - target missile velocity < 5 km/s, range < 3500 km
  - no space based TBM interceptors based on OPP

CBL 5/28/97

ABM Treaty - 1972

Johnson and McNamara tried to convince Kosygin at Glassboro to limit ABM systems - June 1967

US announced Sentinel program in September1967

ABM talks were postponed by Soviet invasion of Czechoslovakia in 1968

Nixon changed concept to Safeguard, protecting ICBMs and Washington, DC

Treaty prevents defense of territory, limits to 2 sites with 100 interceptors, limits LPARS

Forbids mobile ABMS or sea, air, or space systems

OPP, Krasnoyarsk, SCC, capabilities questions

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Threshold Test Ban Treaty - 1974

Signatories are the US, Soviet Union, and UK

Limits nuclear tests to 150kT

Verification by NTM (seismic)

A two page treaty

Joint Verification Experiment in 1988

US ratified in 1989

Peaceful Nuclear Explosives Treaty - 1976

Limited peaceful nuclear explosives to 150kT

Permitted maximum aggregate yield of 1.5 MT, with on site monitoring for yields above 150kT

Plugged a loophole in the TTBT

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SALT II - 1979

Limited and reduced SNDVs

All SNDVs	**2250**	**(2504 actual)**
MIRVed ICSs, SLs, bombers	**1320**	
MIRVed ICs, SLs	**1200**	
MIRVed ICs	**820**	

One new type, no new heavies, MIRV limits

CM counting rules, FRODs, Backfire statement

Verification by NTM, no encryption

12/79 Afghanistan, withdrawn from ratification

"Fatally flawed," no undercut, then terminated 5/86

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Conventional Forces in Europe - 1990

MBFR talks ended after 15 years in February 1989

CFE talks formally opened March 1989, with the 23 members of NATO and the Warsaw Pact

Treaty signed November 1990

Treaty limits equipment in the Atlantic to the Urals (ATTU) region

Limits on tanks, artillery, ACVs, combat aircraft, attack helicopters

Wide-ranging and intrusive verification regime

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START Treaty - 1991

Signed July 31, 1991, 5 months before the end of SU

Lisbon Protocol, signed May 1992, committed Russia, Ukraine, Belarus, and Kazakhstan to START (and NPT)

START limits SNDVs and deployed warheads:

	START	US forces*	Soviet forces*
SNDVs	1600	2246	2500
ICBM & SLBM Warheads	4900	8210	9416
Total Warheads	6000	10563	10271
Heavy ICBM Warheads	1540	------	3080
Mobile ICBM Warheads	1100	------	618
Throw-wt ICs & SLs (metric tons)	3600	2631	6626

*as of 9/90

Nuclear Posture Review - 9/94

- **Strategic Forces**
  - **No more than 20 B-2 bombers**
  - **Reduce B-52 force from 94 to 66**
  - **Reduce Trident fleet from 18 to 14**
  - **Maintain single RV MM III**
- **Non-Strategic Nuclear Forces**
  - **Maintain European NSNF at current level**
    (<10% of Cold War levels)
  - **Eliminate nuclear weapons capability from surface Navy**
  - **Retain cruise missile capability on subs**
  - **Retain land-based DCA**

Comprehensive Test Ban Treaty - 200?

- Adopted by the UNGA 9/10/96
  - CD could not reach consensus (India)
- EIF requires 44 states with reactors
  - includes India, Iran, Egypt, Israel, North Korea, Pakistan
- Activities not prohibited - finessed
  - US "true zero" yield
- Zero not verifiable, less than 1kT too expensive
- International Monitoring System
  - Seismic, Radionuclide, Hydroacoustic, Infrasound
  - OSI requires 30 of 51 Executive Council votes

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CBL 5/28/97

START III - 200?

- Clinton and Yeltsin at Helsinki Summit, March 21, 1997
  - Immediate START III negotiations upon START II EIF
  - 2,000 - 2,500 strategic warheads by end of 2007
  - Transparency of strategic warhead inventories
  - Measures to promote irreversibility of warhead reductions
  - Deactivation of SNDVs under START II by end of 2003
  - Elimination deadline for SNDVs extended to end of 2007

Joint Statement on Parameters on Future Reductions in Nuclear Forces

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The President's Nuclear Initiative-1991

Sept 1991

- Eliminate ground launched tactical nuclear weapons
  - Lance and AFAPs
- Withdraw tactical nuclear weapons from surface ships, subs and P-3 bases
  - B-57, SLCM, B-61
- Stand down strategic bombers from alert
- Stand down MMII
- Cancel mobility for PK and SICBM
- Cancel SRAM II
- Propose joint elimination of MIRVed ICBMs

Jan 1992

- Build only 20 B-2s
- Cancel SICBM
- Halt production of ACM
- Halt production of W88 for Trident II

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START II - 1993

Treaty between the Russian Federation and US, signed by Bush and Yeltsin January 3, 1993, codifed agreements of the Washington summit of June 17, 1992.

START II builds on START - and requires START

	START	START II Ph1	START II Ph Ph2
Start Warheads	6000	3800-4250	3000-3500
ICBM & SLBM Warheads	4900	no sublimit	no sublimit
MIRVed ICBM Warheads	N/A	1200	0
SLBM Warheads	N/A	2160	1700-1750
Heavy ICBM Warheads	1540	650	0
Mobile ICBM Warheads	1100	1100	1100

Phase one to be complete 7 years after entry-into-force, Phase two by 2003

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Comprehensive Test Ban

- Negotiations ongoing at the UN CD
- China testing through '96
- France resumed (8 tests) 9/95 - 5/96
- Activities not prohibited
  - US - "true zero"
  - UK - soon, US codes
  - France - OK
  - Russia - eventually
  - China - waffling, still wants PNEs
- Zero not verifiable, less than 1kT too expensive
- International Monitoring System
  - Seismic - 50 stations, 50 - 150 auxiliaries
  - Radionuclide - Ba140, 75 - 100 stations, US wants Xe
  - Hydroacoustic
  - Infrasound - 50 - 60 stations
- Implementing agency - IAEA or ?

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Books of interest

The Making of the Atomic Bomb, Richard Rhodes, 1986.
Pulitzer prize winner, follows the scientific discoveries that led to the bomb, particularly good at the personalities involved, finishes with vivid descriptions of Hiroshima and Nagasaki. Excellent and entertaining.

At the Highest Levels, Michael R. Beschloss and StrobeTalbott, 1993.
Intimate details of the end of the Cold War, as seen at the top.

Lenin's Tomb, David Remnick, 1993.
Details the end of the Soviet Union from the viewpoint of the Russian people and their legacy. Choppy, but a very human picture of the great event.

The Wizards of Armageddon, Fred Kaplan, 1983.
Follows the policy and strategy decision regarding nuclear weapons, much emphasis on the early RAND personalities. Very good and readable.

Nonproliferation

A New Challenge to the US Nuclear Weapon Program

SESSIONS XVI
John Taylor
National Security Policy Research Department
Sandia National Laboratories

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Some Definitions

Proliferation is the spread of weapons of mass destruction (WMD)-- typically nuclear, biological, and chemical weapons--and the systems which deliver them.

Nonproliferation is the use of the full range of political, economic and military tools to prevent proliferation, reverse it diplomatically, or protect our interest against an opponent armed with WMD or missiles.

Counterproliferation measures are the activities of the DoD across the full range of U.S. efforts to combat proliferation.

The Changing Context

Old	New
Bipolar Rigidity	Multipolar Complexity
Predictable	Uncertain
Communism	Nationalism/Religious Extremists
U.S. Dominant Western Power	U.S. Militarily No.1 - Not Economical
Fixed Alliances	Ad Hoc Coalitions
"Good Guys and Bad Guys"	"Grey Guys"
U.N. Paralyzed	U.N. Viable

Ref.: National Security in the 1990s: Defining a New Basis for U.S. Military Forces, Rep. Les Aspin, Chrmn House Armed Services Committee, January 6, 1992

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Nonproliferation Initiative

The Changing Threat

Old	New
Single (Soviet)	Diverse
Survival at Stake	American Interests at Stake
Known	Unknown
Deterrable	Non-Deterrable
Strategic Use of Nukes	Terroristic Use of Nukes
Overt	Covert
Europe-Centered	Regional, Ill-Defined
High Risk of Escalation	Little Risk of Escalation

Ref.: National Security in the 1990s: Defining a New Basis for U.S. Military Forces, Rep. Les Aspin, Chrmn House Armed Services Committee, January 6, 1992

A Snapshot of the World

- 253 Sovereign nations, dependent areas, etc.
- 189 (±) Countries
- 177 Members in the United Nations
- (171 Members in FIFA!)

- 60 conflicts in progress involving more than 130 states or subnational entities

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All the World's Conflicts - May 1996

Area **Countries** **Intensity** **Nature of Conflict**

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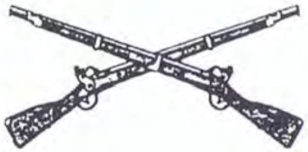
Summary and Analysis

Intensity by type and percent of total

High	1	(0)	1%	(0%)
Medium	17	(18)	28%	(30%)
Low	42	(40)	71%	(70%)
Totals	60	(58)		

Numbers in ( ) from
last reporting period (2/96).



Number and Percentage by Conflict Type

Territory	15	28%
Ethnic	31	53%
Oil	4	7%
Civil War	30	52%
Religious	9	16%

Percent of Total by Region

Europe	12%
Latin America	19%
Africa	31%
Middle/Near East	12%
South Asia	8%
Southeast Asia	7%
Far East	10%

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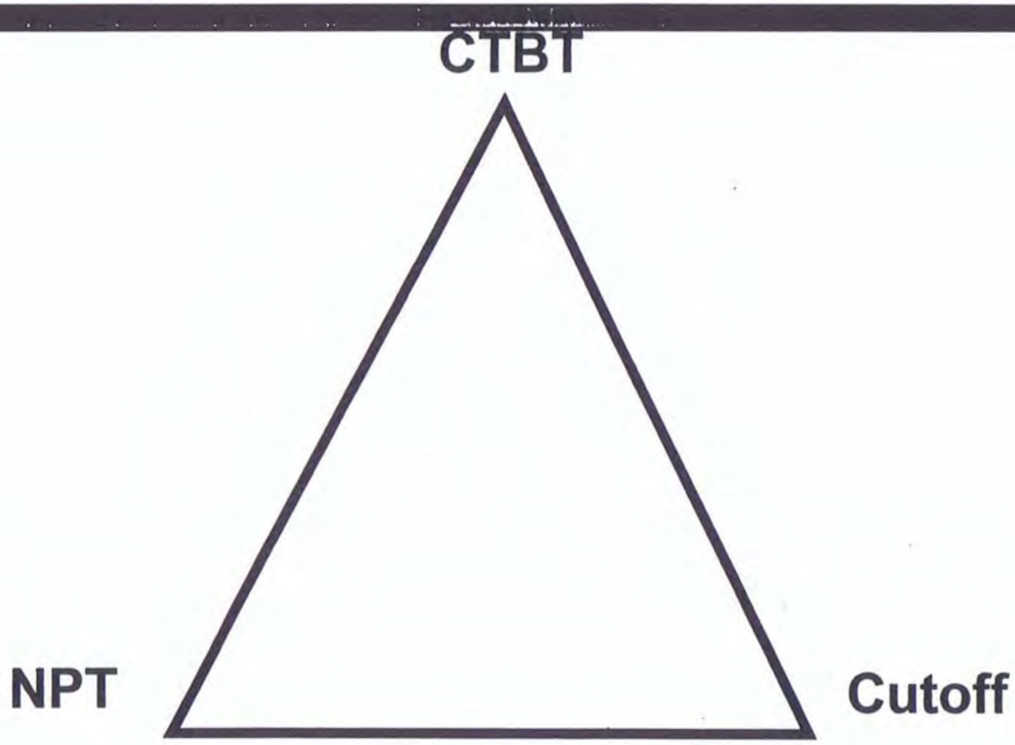
Nonproliferation Initiative

Alva Myrdahl's Historical View of Nuclear Weapon Controls



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What Constitutes a Weapon of Mass Destruction

- Indiscriminate nature of use
- Effect not confined to belligerents
- Excessive injury -- "cruel and unusual"
- Inability to defend against effectively
- Use would overwhelm medical and evacuation resources
- Notion of "terror"

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Motivation to Acquire Weapons of Mass Destruction

Great Powers have always countered the weapons of other great powers (e.g., USSR in the late 1940s)

Fear that a great power ally will not follow through (e.g., UK, France)

Fear over nuclear capabilities of potential adversaries (e.g., PRC, India, Pakistan, Iran, perhaps US in 1940s)

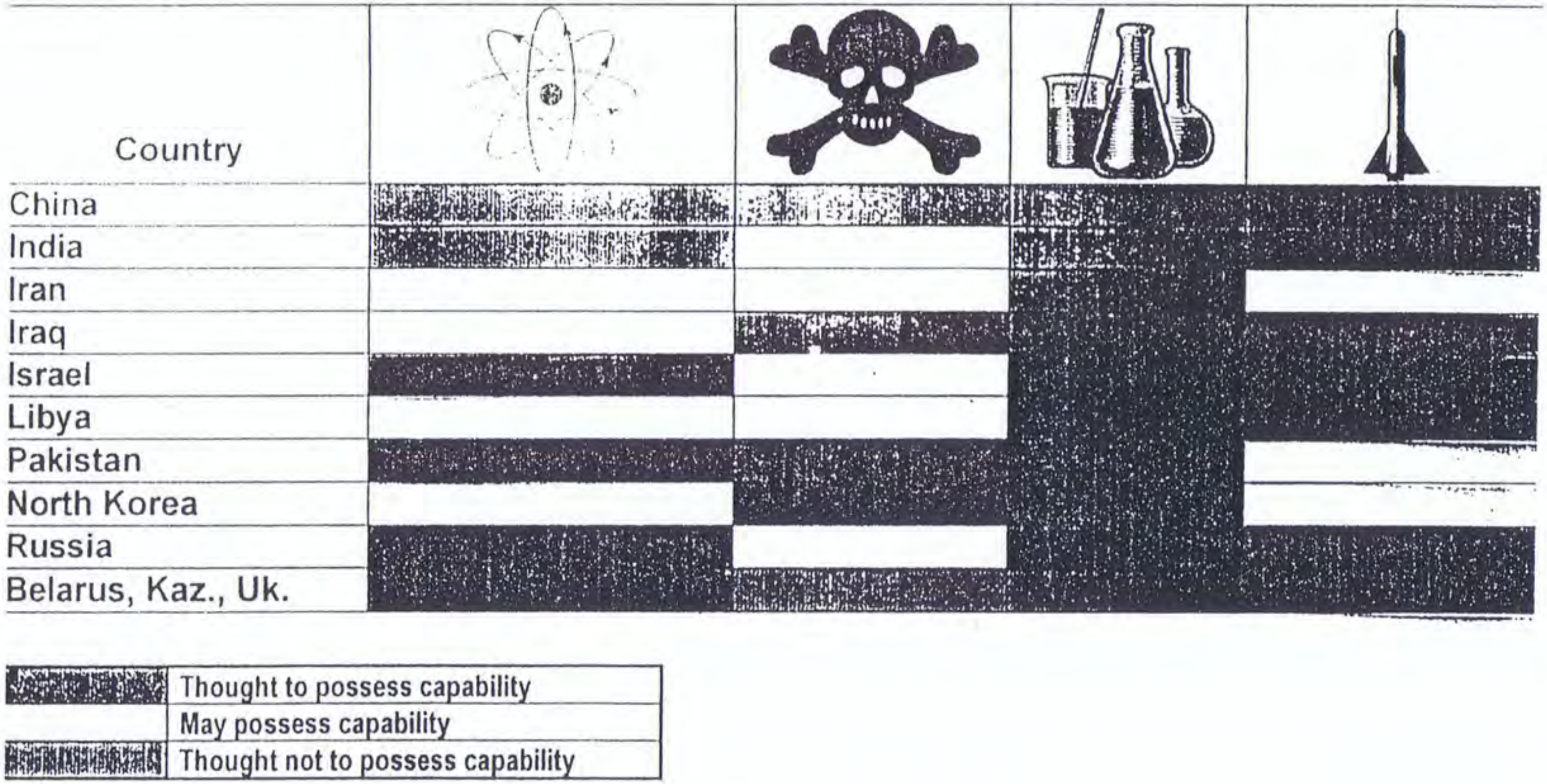
Fear of adversaries conventional strength (e.g., Israel, perhaps US in 1940s)

Cheaper than conventional defense (e.g., US in 1950s)

Desire for offensive capability (e.g., US in 1940s?)

Status in world or region (e.g., Iraq)

Some Proliferants of Concern



"Cost Effectiveness" of Weapons of Mass Destruction

The cost of producing, storing and delivering weapons can be estimated as the amount of money to deliver one lethal dose.

For nuclear weapons = $2000

For chemical weapons = $100

For biological weapons = $1

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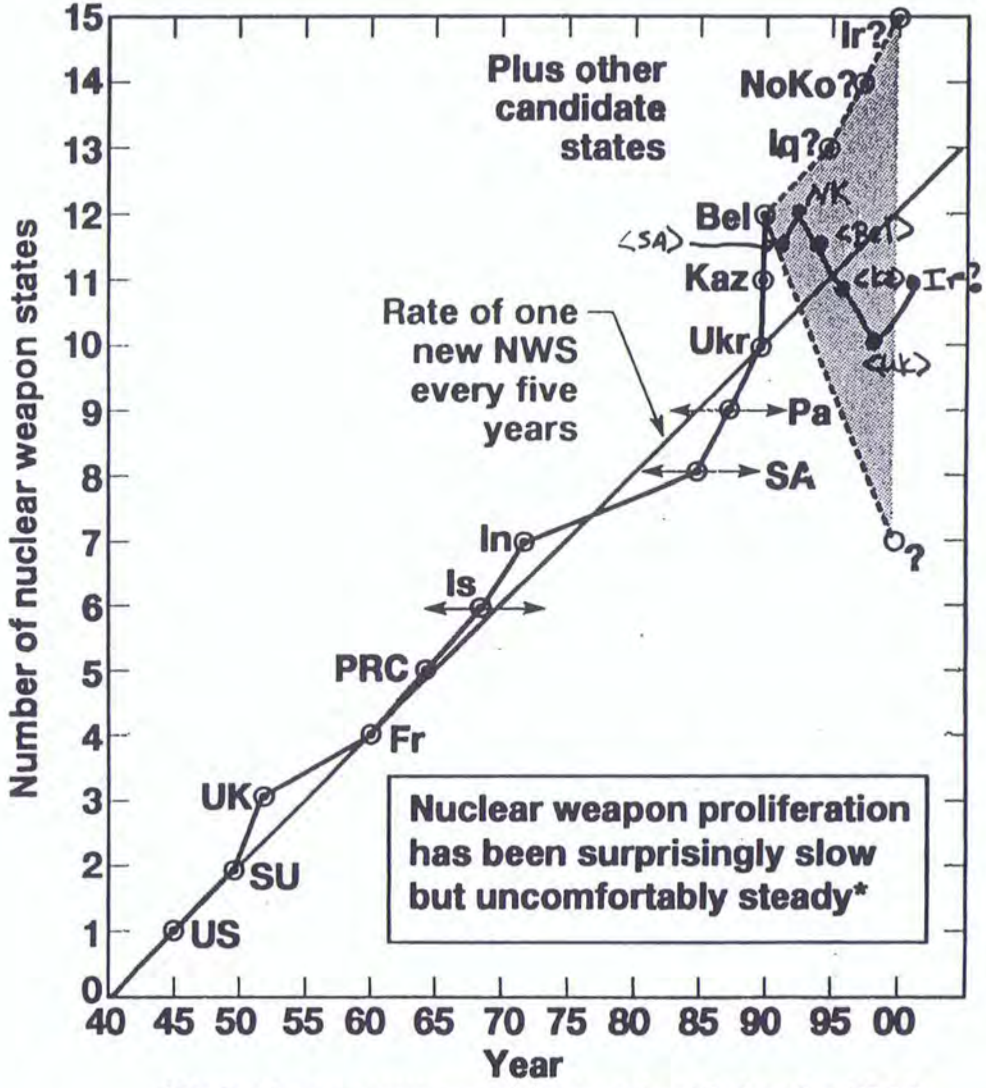
How many nuclear weapons states will there be in the year 2000?



Nuclear weapon proliferation has been surprisingly slow but uncomfortably steady*

*Data from news and journal articles in 1992

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Nonproliferation Initiative

Nuclear Proliferation: A Current Status

- Acknowledged/Declared Nuclear Weapon States
  - US, UK, China, France, Russia
- Undeclared but widely suspected Nuclear Weapon States
  - India, Pakistan, Israel
- "Inheritors" of Soviet weapons
  - Ukraine, Kazakhstan, Belarus
- Virtual Nuclear Weapon States (e.g., weapon capabilities but no weapons)
  - Japan, Germany
- Threshold Nuclear Weapon States
  - North Korea
- Aspiring Proliferators
  - Iraq, Iran, Libya, Algeria, various terrorist organizations
- Rollback cases
  - Argentina, Brazil, Sweden, Switzerland, Egypt, Taiwan, South Africa(?)

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There have been some Nonproliferation Successes

-- Sweden abandoned its programs in the 1970s.

-- South Africa stopped its programs in 1992 (6 weapons).

-- Argentina and Brazil renounced their programs.

-- Taiwan and South Korea abandoned their programs in the 1980s.

-- Iraq's program "put on hold" by Desert Storm and UN Resolution 687 and 715.

-- Belarus, Kazakhstan, and Ukraine (?) have agreed to return the FSU weapons to Russia.

-- NPT indefinitely extended by "pseudo consensus"

WMD Technological Capabilities

Nuclear:

5 acknowledged possessors, 30 countries with "capability"

Chemical:

20-24 possessors, 80-90 countries and some subnational entities with "capability"

Biological:

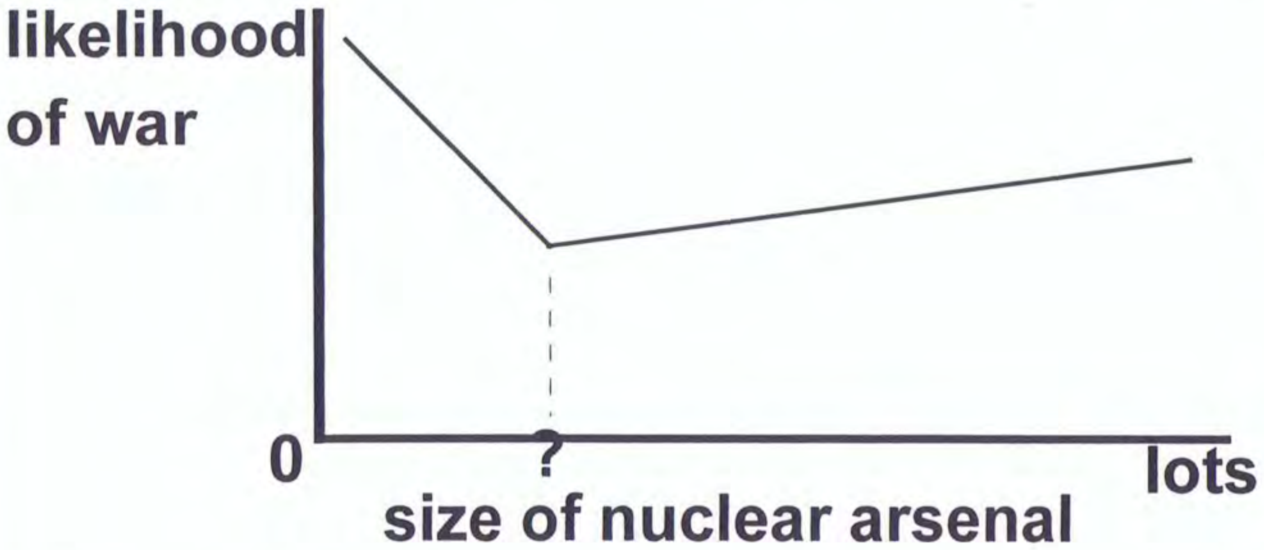
10-12 possessors, virtually every state and several subnational entities are "capable"

(Conventional weapons:

virtually every country possess, 10-40 are major suppliers)

Why Not Zero?

Many nations and individuals want us to completely eliminate weapons -- attractive philosophy but dubious policy:



There may be things worse than nuclear weapons (e.g. biologics)

Qualitative Level of Proliferation Concern

Cold War (20,000)

START I (10,000)

START II (5,000±1500)

NAS (1,500)

Zero (0)

In the land of the blind, the one-eyed man is king.

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Nonproliferation Initiative

Options across the Nonproliferation -- Counterproliferation Spectrum

disincentives ↔ **incentives**

venues

Economics — blockades, sanctions   export controls   foreign aid ↔

Politics — political isolation   int'l organizations   alliances ↔

Military Force — war   peacekeeping   covert operations   military sales   military asst. ↔

confrontation ↔ **cooperation**

COUNTERPROLIFERATION ↔ **NONPROLIFERATION**

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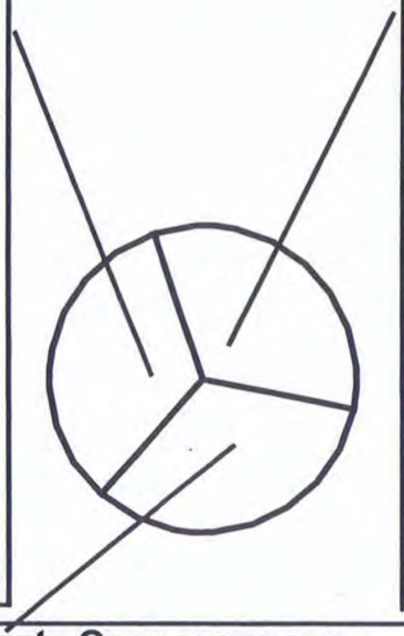
Activities Which Accomplish Objectives



Reduce Demand
- International agreements
- Regional security agreements
- Transparency and confidence building
- Responsible behavior by nuclear weapon states
- Penalties for violating international norms
- Minimizing utility

Control Supply
- International Export Control Regimes
- IAEA Safeguards
- Elimination of sources of supply
- Monitoring and enforcement of export controls or embargoes
- Responsible behavior by nuclear weapon states

Mitigate Consequences
- Sanctions and embargoes
- Military activities
- Covert operations

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Nonproliferation Initiative

Goals of Proliferation Controls (non → counter)

-- **REMOVE MOTIVATION** FOR POSSESSION OF NUCLEAR WEAPONS

-- **INTERDICT DEVELOPMENT AND ACQUISITION**

-- **DETER EMPLOYMENT** OF KNOWN OR SUSPECTED STOCKPILES OF NUCLEAR WEAPONS

-- **ELIMINATE INFRASTRUCTURE** BY PERSUASION, INTERNATIONAL SANCTIONS (e.g., Res 687)

-- PROACTIVELY **DESTROY FACILITIES** (e.g., Osirak)

Secondary Impacts of Nonproliferation Initiatives

- o NPT//NPT Extension Conference (1995):
  - -- Mandates for movement toward global reductions
  - -- Mandate for a CTB by 1996
  - -- Mandate for "FISS_BAN"
  - -- Mandate for Negative Security Assurances
  - -- Improved Safeguards
- o Negotiations on control on fissile materials:
  - -- Codify in-place current US and Russian practices
  - -- Inspection regimes and transparency
  - -- Possible attempts to restrict tritium production
- o Export Controls
  - -- Heightened concern over "dual use" systems and commodities

Nonproliferation Initiative

Issues on the Nonproliferation platter

- -- Control over the nuclear arsenal (and direction) of the FSU
- -- North Korea--good deal? bad deal?
- -- CTBT--linkage to NPT formalized during EXCON
- -- China, France--steadfastly continuing to test
- -- The Israeli nuclear arsenal
- -- The nuclear relationship between India and Pakistan--imminent missile deployment (M11 vs Prithvi)?
- -- Iran--a new reactor (Bushehr) for Israel to target?

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

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SESSION XVII

- STOCKPILE STEWARDSHIP
- SUMMARY/DISCUSSION

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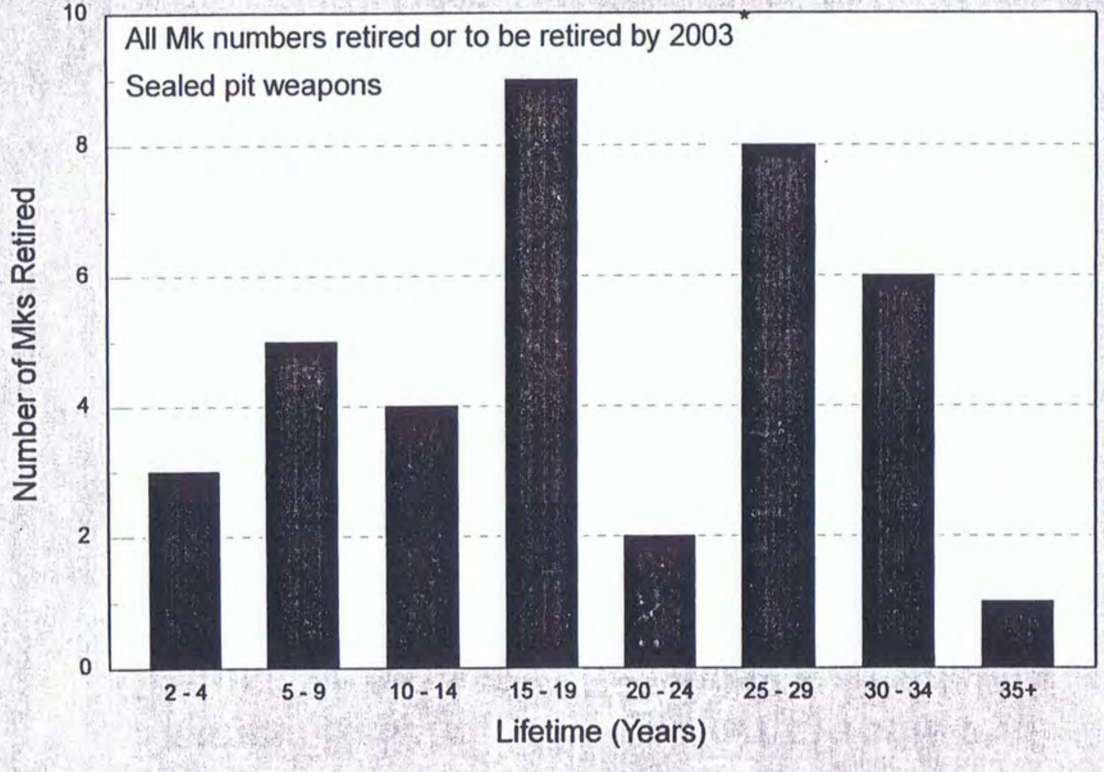
Mk Number Lifetime



All Mk numbers retired or to be retired by 2003*

Sealed pit weapons

2 - 4	3
5 - 9	5
10 - 14	4
15 - 19	9
20 - 24	2
25 - 29	8
30 - 34	6
35+	1

* As projected by P&PD 94-0

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Weapon Histories Lead to a New Question

- "What is required to sustain a weapon while it is in the stockpile?"
  - The DOE has active programs to:

    Upgrade a weapon's surety

    Maintain a weapon's reliability

    Incorporate new operational features into a weapon

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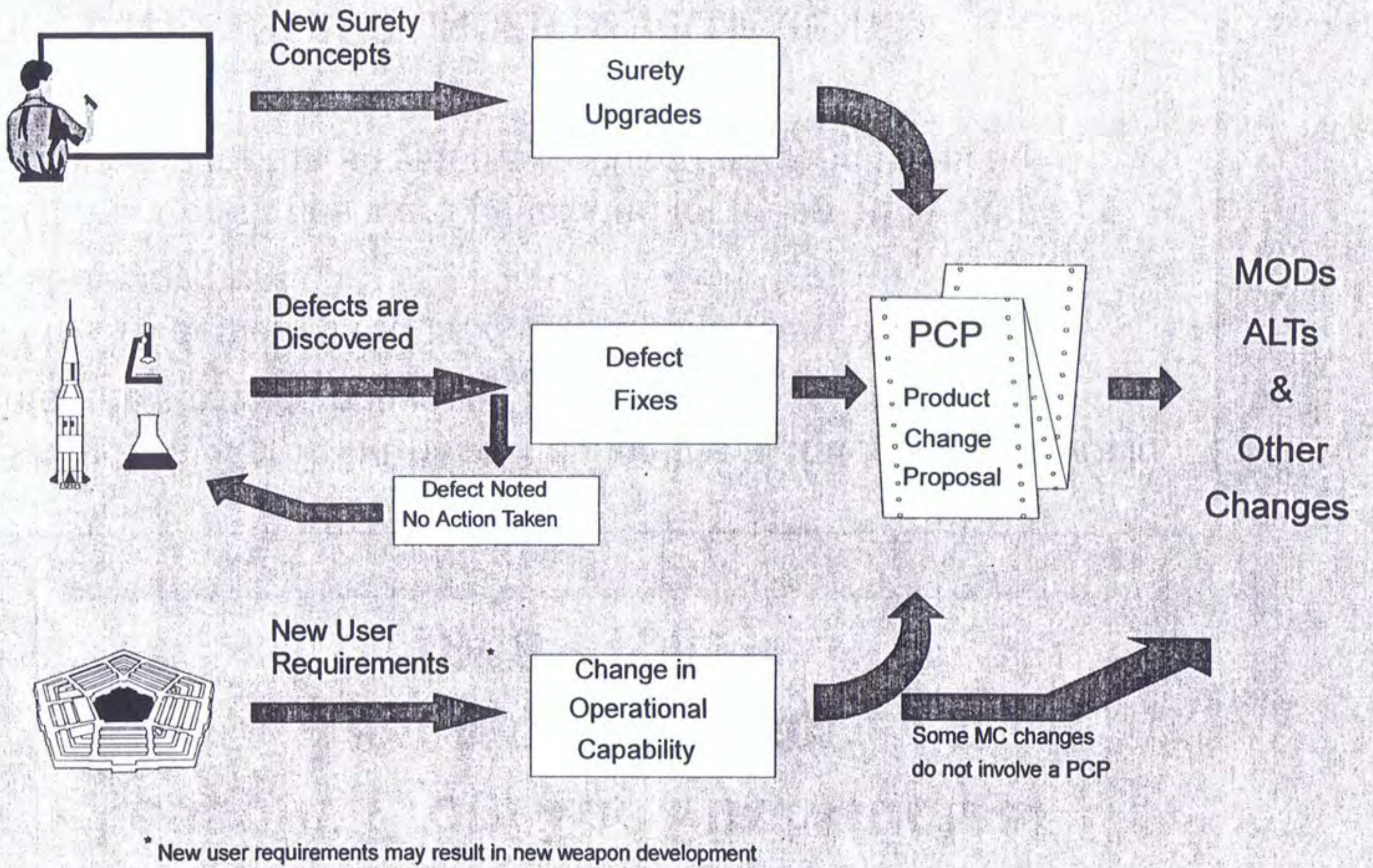
How Changes Are Made To Stockpiled Weapons



* New user requirements may result in new weapon development

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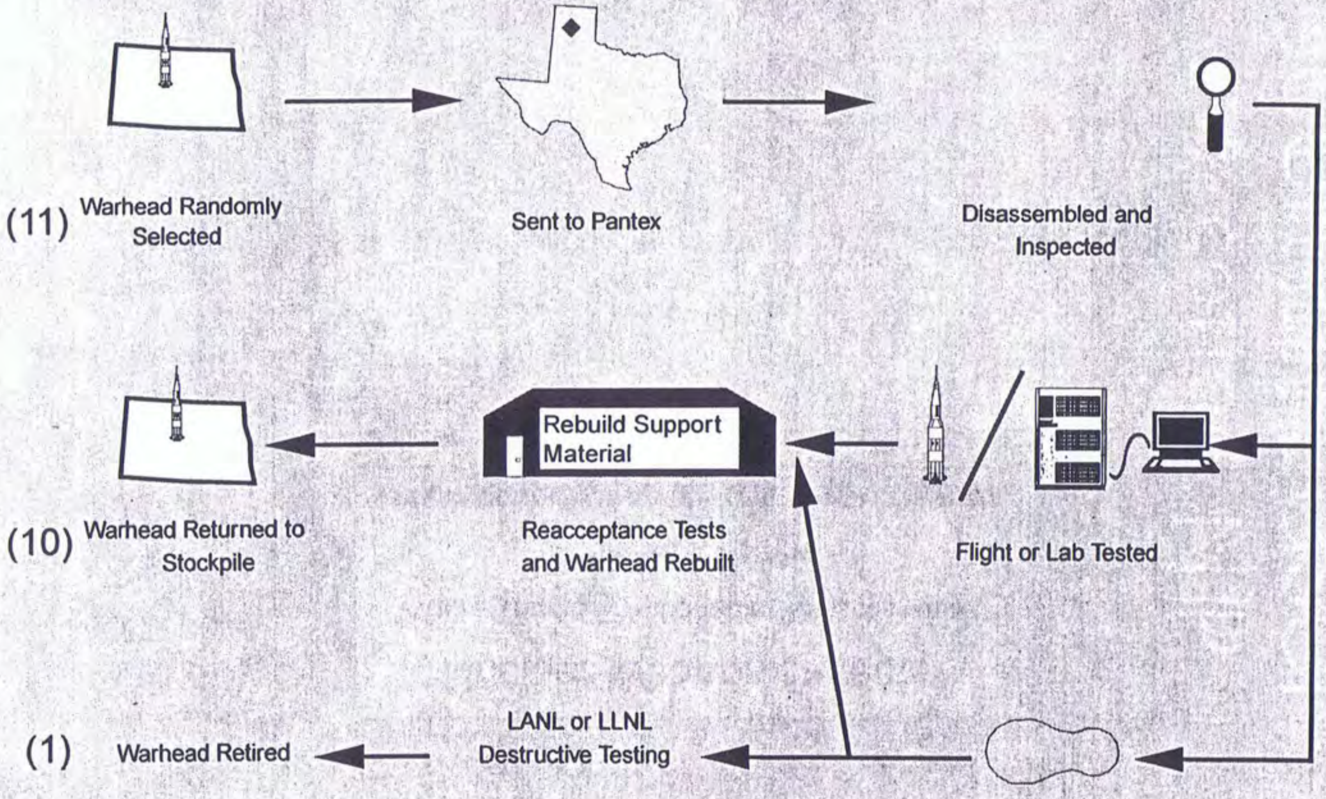
The Stockpile Evaluation Process



(11) Warhead Randomly Selected

Sent to Pantex

Disassembled and Inspected

Flight or Lab Tested

Rebuild Support Material

Reacceptance Tests and Warhead Rebuilt

(10) Warhead Returned to Stockpile

LANL or LLNL Destructive Testing

(1) Warhead Retired

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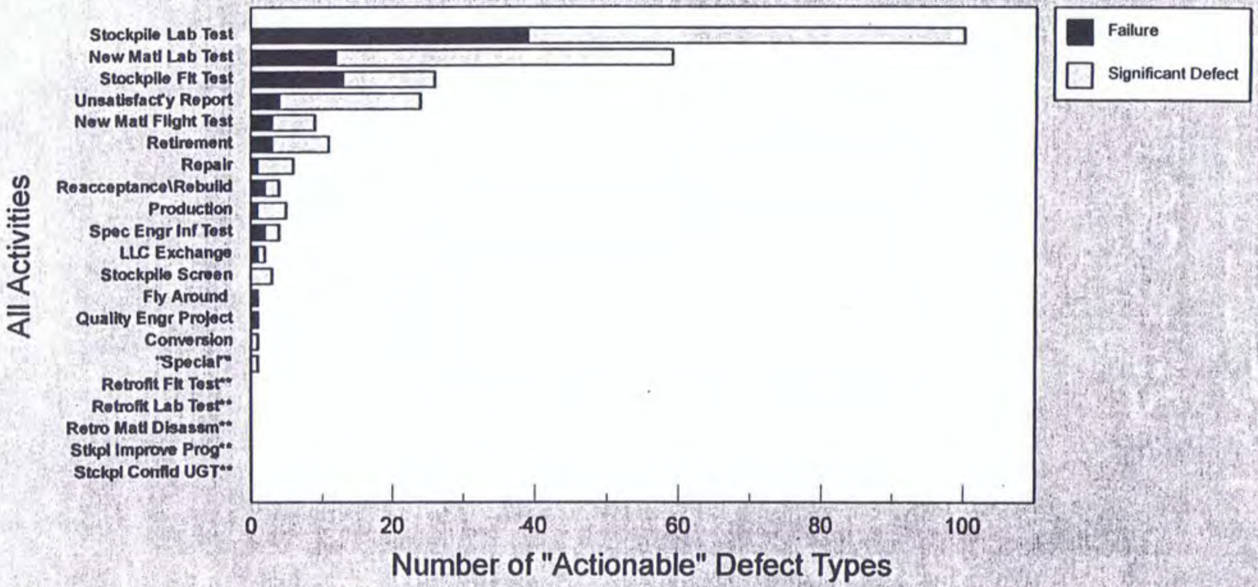
Nuclear Weapon Defects

Where The 257 "Actionable" Defect Types
Were First Discovered



* Designation in the Historical Summary

** No "Actionable" Defect Types first discovered

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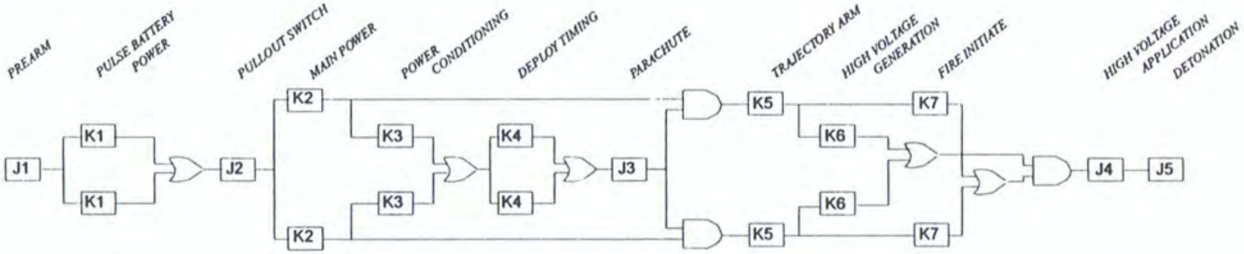
Reliability Impact Assessed For All Defects

- CONTINUAL PROCESS TO DEFINE WEAPON RELIABILITY -

- Reliability assessment first established during weapon development
  - Reliability model developed



  - Sandia + Physics Lab inputs
- Reliability impact assessed during formal defect investigation (SFI)
  - Data collected from relevant sources
  - Added to existing data base
  - New assessment made (some defects assessed with no reliability impact)

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PCP Includes MOD & ALT

- Product Change Proposal (PCP)
  - Initiates & authorizes any accountable change to a War-Reserve (WR) weapon & its associated gear or non-WR units
  - Range in importance from (H1324 for the W71) Change in Wrench
  - Normally includes MOD & ALT
- Modification Number (MOD)
  - Assigned to any change to a WR weapon that alters its operational capability
- Alteration Number (ALT)
  - Assigned to any accountable change to a WR weapon & its associated gear or non-WR units

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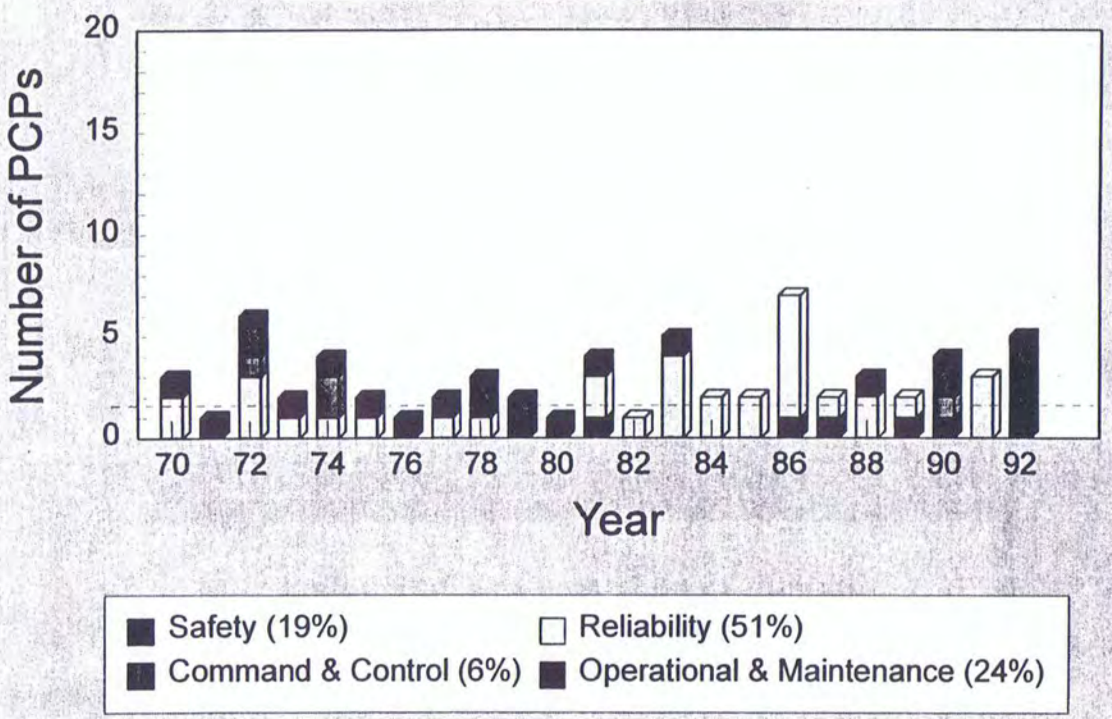
"Major" PCPs (1970 - 1993)

67 PCPs by Type of Change



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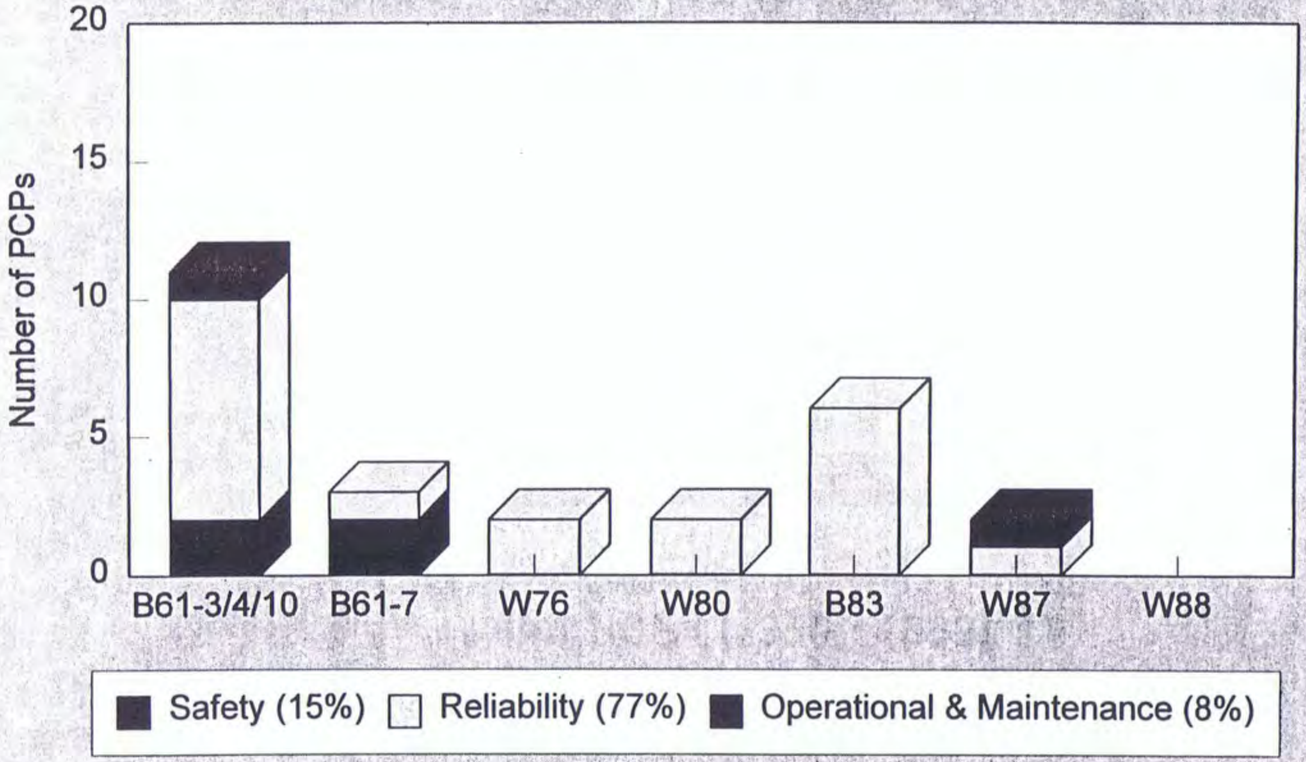
Stockpile Weapons in 2004

"Major" (26) PCPs by Type of Change



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Future Workload Issues

DOE

historical data suggest that:

- 1 "actionable" defect will be discovered each year.
- About 2 PCPs will be approved each year - 1 of these will constitute a major change.

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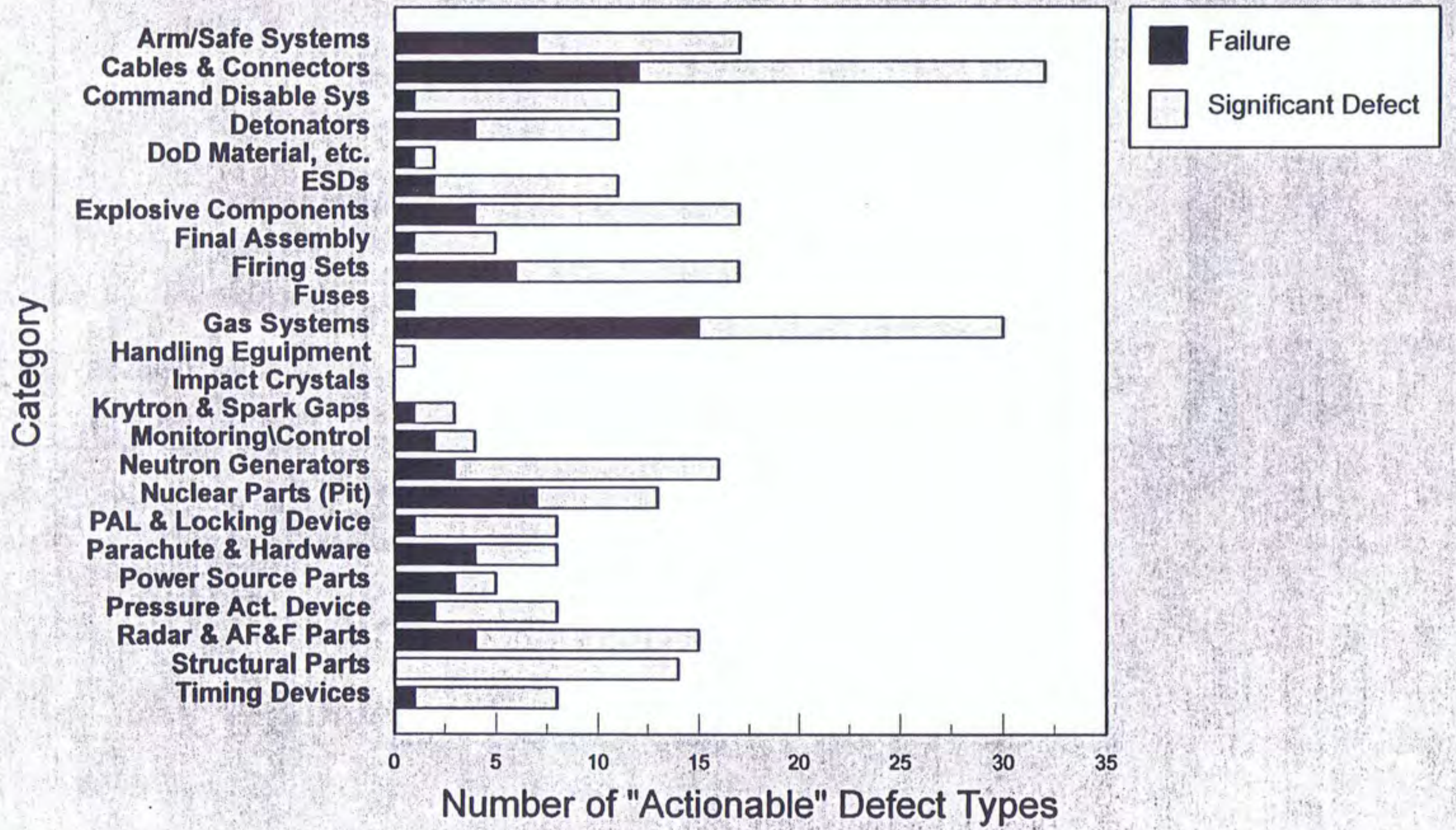
257 "Actionable" Defect Types Grouped By Design Skill Categories



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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

SESSION XVIII

- **FIELD TRIP TO THE DEFENSE NUCLEAR WEAPONS SCHOOL'S WEAPON DISPLAY AREA**

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