Appendix C
Tritium Inventory

In this appendix several estimates using different assumptions are made of the total tritium inventory in weapons and available for weapons The first, which is referred to as the "steady-state estimate," assumes that there was no change in the tritium inventory during the late 1970s In other words, the amount produced equalled the amount lost through radioactive decay during this period The tritium in the U S stockpile is produced at the Savannah River Plant The second inventory estimate made assumes that the routine atmospheric releases of tritium from the tritium recovery operations at SRP are proportional to the amount of tritium processed (i e , produced)

In an attempt to place upper and lower bounds on the tritium inventory estimate two additional estimates are also made using tritium release data from SRP

Steady-State Estimate

The tritium production rate from FY 1977-FY 1980 is estimated to have averaged 2 2 ± 0 7 kg per year [1] DOE statements[2] indicate that this was designed to offset losses due to radioactive decay Thus a determination of the steady state tritium inventory in that period is found by setting the production rate equal to the rate of radioactive decay [3] Setting the production rate $P = 2.2 \pm 0.7$ kg per year yields a steady state tritium inventory $I = 40 \pm 13$ kg The tritium production rate in FY 1981 is estimated to have been 2 6 kg and in FY 1982-84 averaged 10 6 kg per year (see Savannah River Production, Chapter Three) Thus, allowing for radioactive decay, the tritium inventory at the end of FY 1984 based on the steady state assumption is estimated to be 63 ± 20 kg

Estimates Based on Atmospheric Releases of Tritium

The SRP production reactors have been producing tritium in quantity since 1956 A second estimate of tritium production at SRP is made by analyzing the tritium losses from the lithium target processing facility (the 200-H separations area) Tritium is recovered from Li-Al targets by heating the irradiated targets to high temperatures to drive out the tritium gas

The combined atmospheric releases of tritium from the F and H separations areas at Savannah River through the year 1983 are presented in column 2 of Table C 1 and Figure C 1 These are routine releases, mainly from tritium processing in the 200-H area An examination of these data indicates that the tritium releases during 1965-70 and 1974-81 were relatively low, and there were few if any dedicated tritium production runs during these years Also, the tritium releases per megawatt-day of production during these periods are comparable, suggesting that the tritium release fraction from the separations area has remained relatively constant over the lifetime of the facility—at least through 1981

It is assumed that in the years 1960-63 a single reactor was dedicated to tritium production and there was no incidental production of tritium in control rods, as occurred later on Using the average thermal output for SRP reactors (see Table 3 2), the tritium production in this period was 7 92 ± 2 53 kg annually The uncertainty is derived from including the possibility of tritium production in control rods, at a rate of 0 0008 g/Mwd of thermal output Based on these assumptions, the annual tritium production is estimated in Column 3 of Table C 1 The total tritium production (uncorrected for radioactive decay) through 1984 is about 179 kg Tritium has a half-life of 12 33 years; consequently, 5 5 percent of the existing inventory is lost each year through radioactive decay As shown in the table, this quantity would have decayed by the end of 1984 to 79 ± 25 kg

As seen from Table C 1 this method predicts that all reactors were dedicated to tritium production in 1958—that is, an estimated 25 7 kg of tritium was produced in 1958 compared to a maximum production of 26 2 kg, based on a thermal energy production of 2 1 million Mwd [4]

Bounding Estimates

In an attempt to bound the estimates of tritium production a low estimate is made by assuming that there were no dedicated tritium runs prior to FY 1982 Here it is assumed that the production rate per reactor has remained at a constant of 0 002 g/Mwd through 1981,

1 This is accountable from about equal rates of production in control rods (0 001 g/Mwd) and in blankets and dischargeable targets during plutonium production operations

2 There is a constant supply [of tritium] produced for nuclear weapons in the stockpile The tritium also decays The quantity that you have in the stockpile has to have makeup to keep a constant quantity Duane C Sewell ASDP in HASC, FY 1980 DOE p 30

The vital role of tritium in the U S nuclear stockpile demands a minimum of [deleted] reactors be on line and available to meet steady state tritium makeup needs Duane C Sewell ASDP in HASC FY 1981 DOE p 133

Continued production and processing of tritium is necessary just to maintain the supply need for the stockpile Long Range Nuclear Weapon Planning Analysis or the Final Report of the DOD/DOE Long Range Resource Planning Group 15 July 1980 p 66

3 Setting $\frac{dI}{dt} = P - \lambda I = \left(P - \frac{0.693I}{T_{1/2}}\right) = 0$ where P is the rate of production I is the inventory λ is the radioactive decay constant and $T_{1/2}$ is the radioactive half-life $T_{1/2} = 12.33$ years for tritium

Table C 1

Tritium Release and Estimated Tritium Production at SRP

Calendar Year	Routine Release to Atmosphere from F and H Separations Areas (10^3 curies)[a]	Estimates of Tritium Production and Inventory: Constant Release Fraction — Annual Production (kg)	Constant Release Fraction — Inventory (kg)	Low — Annual Production (kg)	Low — Inventory (kg)	High — Annual Production (kg)	High — Inventory (kg)
1955	20	0 2	0 2	1 00	1 0	0 50	0 5
1956	420	4 9	4 9	2 45	3 3	7 35	7 6
1957	1120	12 8	17 1	3 65	6 7	15 51	22 3
1958	2250	25 7	41 2	4 20	10 4	28 35	48 6
1959	820	9 4	48 0	5 60	15 5	10 16	55 8
1960	645	7 4	52 6	6 25	20 7	10 94	63 4
1961	654	7 5	57 0	6 45	25 8	11 29	70 9
1962	736	8 4	62 0	6 35	30 5	11 11	77 9
1963	736	8 4	66 8	6 30	35 0	11 02	84 3
1964	963	11 0	73 9	6 45	39 4	12 18	91 6
1965	311	3 6	73 3	4 25	41 4	2 13	88 6
1966	301	3 4	72 6	4 40	43 4	2 20	85 9
1967	308	3 5	72 1	5 20	46 1	2 60	83 7
1968	411	4 7	72 7	4 95	48 4	4 95	84 0
1969	272	3 1	71 8	3 50	49 1	3 50	82 8
1970	246	2 8	70 6	3 00	49 4	3 00	81 2
1971	379	4 3	70 9	2 85	49 4	2 85	79 5
1972	530	6 1	73 0	3 50	50 1	10 21	85 1
1973	312	3 6	72 4	3 77	51 1	3 77	84 1
1974	189[b]	2 2	70 6	3 82	52 0	3 82	83 2
1975	143[b]	1 6	68 3	2 82	51 9	2 82	81 4
1976	125	1 4	66 0	4 05	53 0	4 05	80 9
1977	192	2 2	64 5	2 62	52 6	2 62	79 0
1978	192	2 2	63 1	2 42	52 1	2 42	77 0
1979	180	2 1	61 7	2 38	51 6	2 38	75 2
1980	200	2 3	60 5	2 90	51 6	2 90	73 9
1981	231	2 6	59 8	2 76	51 4	2 76	72 5
1982	257	10 8	67 0	10 79	59 1	10 79	79 1
1983	407	10 2	73 2	10 21	65 8	10 21	84 7
1984	-	10.2	79 2	10.21	72 2	10.21	90 0
Total Production		178 6		139 3		208 6	

a Sources: C Ashley C C Ziegler Releases of Radioactivity at the Savannah River Plant 1954 through 1978 DPSPU 75-25-1 February 1980 p 102 For 1979 the total atmospheric release from E I Dupont Environmental Monitoring in the Vicinity of the Savannah River Plant: Annual Report for 1979 DPSPU 80-31-1 was diminished by 160 000 curies approximately the average release from reactors and the 400-D laboratory for years 1977 and 1978 For 1980 the total atmospheric release estimated from Radioactive Waste Management at the Savannah River Plant National Research Council Washington, D C 1981 Fig 7 p 2 was diminished by 160,000 curies Releases for 1981-83 from Savannah River Plant Technical Reports DPSP 82-1-1 DPSP 83-1-1 and DPSP 84-1-1 cited in letter from Ernest Chaput, DOE Savannah River Operations Office to Thomas B Cochran 13 September 1984

b Excludes accidental releases: 470,000 curies released 2 May 1974; 182 000 curies released 31 December 1975

with one half of the tritium produced in control rods, and the other half produced in blankets and dischargeable targets inside driver assemblies[5] The total production under this assumption would be 139 ± 46 kg through 1984 Decayed to the end of 1984, this would be about 72 ± 24 kg This surely underestimates the actual production since dedicated tritium production runs very likely were made in the 1950s to meet thermonuclear program needs Also, it is known that there have been other tri-

4 This comparison assumes tritium produced in FY 1958 is processed in calendar 1958 Maximum tritium production = (0 9/72) g/Mwd where 0 9 g Pu (equivalent) per Mwd and 1/72 g T = 1 g Pu (equivalent) This assumes no production in control rods

5 During plutonium production runs prior to 1968 SRP reactors were fueled with uniform cores of natural uranium It is unlikely therefore that dischargeable lithium targets were utilized during plutonium runs prior to 1968

tium campaigns prior to 1980 One is reported to have occurred in 1972 and another probably occurred in 1963-64, when routine atmospheric releases peaked

A high estimate of tritium production is found by first estimating, the number of reactors dedicated to tritium production from the quantity of tritium released annually, and then calculating tritium production from the combined annual thermal output of the Savannah River reactors (from Table 3 2)

Here, it has been assumed that no reactors were dedicated to tritium production during the periods of low tritium release (1955, 1965-71, and 1973-81); one reactor was dedicated to tritium production during 1959-64, 1972, and 1982-84; two reactors in 1956; three in 1957, and five in 1958 In all years 0 001 g of tritium is assumed to have been produced per megawatt-day in control rods Also, in later years, 1968-84, an additional 0 001 g of tritium is assumed to have been produced in blankets and dischargeable targets in those reactors dedicated to plutonium production As seen by the last two columns in Table C 1, these assumptions give a total production through 1984 of 209 ± 70 kg, and 90 ± 30 kg decayed to the end of 1984

Summary

Based upon the calculations in this appendix and assuming no significant quantities of tritium produced since 1956 were burned, released, or sold, the best estimate of the tritium inventory at the end of FY 1984 lies in the range of 70 to 80 kg, with an uncertainty of ± 25 kg Taking into account the loss of 5 5 percent of the inventory each year this inventory is the result of the cumulative production between FY 1955-84 of some 175 kg of tritium, with an uncertainty ± 60 kg

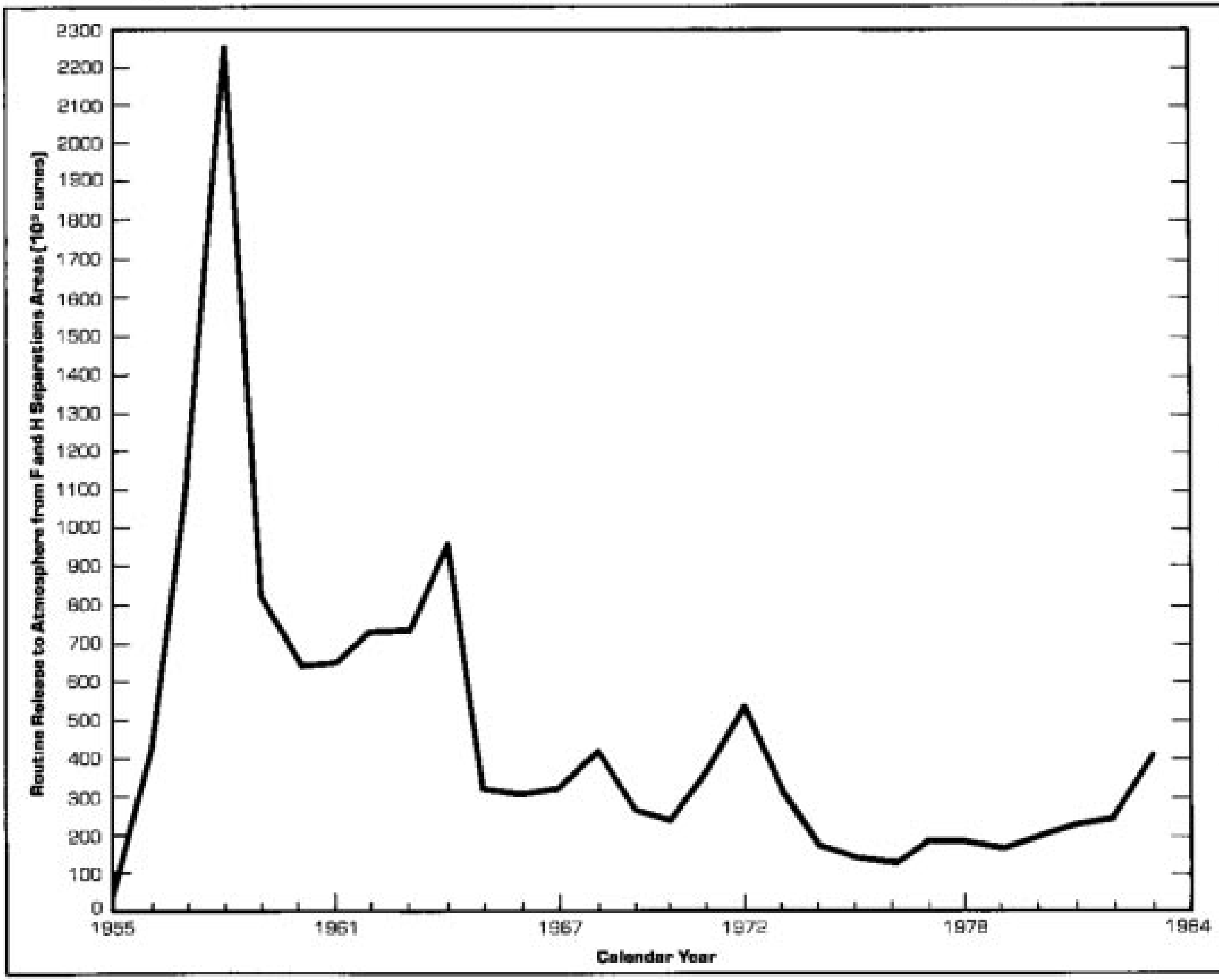


Figure C 1 Releases of tritium to the atmosphere at SRP

Appendix D
Inventory of Highly Enriched Uranium Allocated for Warheads

The highly enriched uranium in the nuclear weapons stockpile, including uranium currently available for new weapons, was produced in the gaseous diffusion plants prior to mid-1964 [1] "Weapon grade" uranium metal, commonly referred to as oralloy,[2] contains about 93 5 percent U-235 Based on materials balance considerations, the quantity of U-235 available for weapons is limited by AEC purchases of uranium concentrate (U_3O_8) between 1943 and the end of FY 1964 (see Table D 1, column 9, and Figure 3 4) and by the separative work production of the enrichment complex during this period (Table D 1, column 2 and Figure 3 5)

Most of the uranium enriched prior to FY 1965 was for warheads If all the separative work performed by the enrichment complex prior to FY 1965 had gone into the production of oralloy, about 751 MT would have been produced (see Table D 1, column 6) From this amount it is necessary to subtract the equivalent oralloy production that did not end up in the warheads and the inventory allocated for warheads The dominant corrections are uranium in process and in working inventory at the enrichment plants at the end of FY 1964, uranium used as fuel through 1964 in U S production reactors, naval propulsion reactors, and central station electric power reactors, and uranium used in weapons tests Smaller amounts of uranium were used through FY 1964 in U S research and test reactors and were exported for civilian reactors and under military agreements with the United Kingdom and France

A check on uranium feed requirements as derived from the reported separative work production is provided by the annual and cumulative uranium concentrate purchases (Table D 1, columns 8 and 9) The difference between uranium requirements and purchases provides the inventory of uranium concentrate at the end of FY 1964 [3] Table D 1 indicates that there was an apparent stockpile of about 46,800 tons U_3O_8 at the end of FY 1964 [4] But as will be seen, most of this was used to fuel the production reactors and additional quantities were in process

Uranium in Process

The uranium in process at the gaseous diffusion plants at the end of FY 1964 is estimated to be no more than 10 percent of the annual separative work production, equivalent to 7 5 MT of oralloy product,[5] and perhaps as much as several thousand MT equivalent of natural uranium feed [6] In addition, a four month working inventory of enriched UF_6 equivalent to 5 16 million SWU or 25 MT of oralloy product is assumed to have been on hand at the diffusion plants at the end of FY 1964 [7]

Production Reactor Fuel

At Hanford, the amount of U-235 allocated to the production reactors through FY 1964 consisted of the U-235 consumed during that period plus the U-235 tied up in various stages of the fuel cycle

Through FY 1964 eight Hanford graphite reactors accumulated 41 million Mwd of operation, producing an estimated 35 MT of plutonium (see Table 3 3) The Hanford production reactors were originally fueled with natural uranium passed once through The plutonium was recovered from the irradiated fuel, but the uranium, containing perhaps 85 percent of the original U-235, was dis-

1 There has been no production of HEU for weapons since 1964 The Enriched Uranium Conversion Facility used to convert UF_6 to UF_4 at the Oak Ridge Y 12 plant received its last material in July 1964 This was processed prior to August or September 1964 at the latest at which time the plant was placed on standby It is not expected to be restarted by DOE prior to FY 1988 Since this is the only facility for this purpose DOE (AEC) has lacked the capability to convert highly enriched UF6 to metal in quantity since mid-1964

2 Oralloy was the code word used for U 235 or highly enriched uranium metal during the Manhattan Project The name derives from Oak Ridge Alloy

3 In 1951 the AEC set a goal of maintaining sufficient stock feed reserves for 30 months; Lee Bowen A History of the Air Force Atomic Energy Program 1943 1953 Vol IV, p 29 Bowen cites a memorandum from the MLC to the AEC Supplemental Report on Fissionable Materials Production Plant Expansion Study, 29 September 1951 JCS 1823/73 This would suggest that some 54 000 tons of U_3O_8 should have been in stock feed reserve at the end of FY 1964 when uranium enrichment for weapons ceased

4 In the calculations for Table D 1 it is assumed that tails accumulated since 1944 were stripped in the years FY 1956 and FY 1957 when the tails assays dropped temporarily to 0 183 and 0 199 percent respectively This action would have been taken shortly after completion of the Paducah gaseous diffusion plant to increase the feed reserve at a time of rapidly increasing separative work production At Paducah construction of 4 plants (C-31 C-33 C-35 and C-37) occurred during FY 1951-1955 Paducah was to process great quantities of depleted uranium from the "bottom of the Oak Ridge cascade; Richard G Hewlett and Francis Duncan A History of the United States Atomic Energy Commission II: Atomic Shield (1947 1952) U S AEC Report No WASH-1215 1972 p 554

5 534 thousand SWU was in process at the end of FY 1969 and 434 thousand SWU at the end of FY 1970 with a production of 6 to 7 MSWU annually; Howard Hale DOE private communication with Milton M Hoenig September 1983

6 At the end of FY 1982 there was 480 thousand SWU in process in some 8100 MT of natural uranium equivalent (0 2 percent tails); Ibid

7 AEC planning estimates include a working inventory equivalent to about 4 months production of enriched uranium for the purpose of meeting fluctuations in demand and of providing a working inventory of various assays This working inventory is in addition to the plant's in process inventory; GAO Report to the Joint Committee on Atomic Energy of the United States Possible Transfer of the Atomic Energy Commission s Gaseous Diffusion Plants to Private Ownership 20 May 1969, p 58 reproduced in JCAE Selected Materials Concerning Future Ownership of the AEC's Gaseous Diffusion Plants June 1969 p 333 DOE testified in 1978 that a working inventory of 9 0 MSWU is now required to operate the enrichment complex HCST, Fiscal Year 1983 Department of Energy Budget Review (Uranium Enrichment) Vol VI p 197

8 At Hanford the first three fuel separations facilities (T Plant, B Plant and U Plant) used a bismuth phosphate process for extraction of plutonium and uranium was not recovered Following startup of the REDOX Plant in August 1951 the U Plant was converted to recover the uranium from stored radioactive waste The B and T plants were shut down in 1952 and 1956 respectively From 1952 to 1958 the radioactive waste at Hanford was mined from the storage tanks and the U Plant was used for radioactive recovery ERDA FES Waste Management Operations, Hanford Reservation ERDA-1538 December 1975 pp II 1-10 to 14

Table D 1
Uranium Enrichment Activities FY 1944-FY 1964
Production of HEU Equivalent

FY	Enrichment[a] Production MSWU Annual	Enrichment[a] Production MSWU Cumulative	Tails[b] Assay Percent	HEU Equivalent[c] Production MTU Annual	HEU Equivalent[c] Production MTU Cumulative	Feed[d] Requirements Thousand Short Tons U_3O_8 Annual	Feed[d] Requirements Thousand Short Tons U_3O_8 Cumulative	Uranium[e] Purchases Thousand Short Tons U_3O_8 Annual	Uranium[e] Purchases Thousand Short Tons U_3O_8 Cumulative
1944	-	-	-	-	-	-	-	4 81	4 81
1945	0 07	0 07	0 529	0 58	0 58	0 30	0 30	0 50	5 31
1946	0 25	0 32	0 529	1 59	2 17	1 08	1 38	4 10	9 41
1947	0 38	0 70	0 488	2 32	4 49	1 27	2 62	1 66	11 07
1948	0 39	1 09	0 515	2 45	6 94	1 52	4 14	2 01	13 08
1949	0 43	1 52	0 506	2 67	9 61	1 58	5 72	2 24	15 32
1950	0 50	2 02	0 495	3 07	12 68	1 73	7 45	3 06	18 38
1951	0 55	2 57	0 506	3 42	16 10	2 03	9 48	3 69	22 07
1952	1 54	4 11	0 447	9 05	25 15	4 17	13 65	3 66	25 73
1953	2 25	6 36	0 439	13 09	38 24	5 83	19 48	2 89	28 61
1954	4 53	10 89	0 366	24 37	62 61	8 60	28 08	4 69	33 30
1955	8 05	18 94	0 278	38 53	101 14	10 84	38 92	5 94	39 24
1956	13 72	32 66	0 163	35 47	136 61	0 0	38 92	10 43	49 68
1957	14 53	47 19	0 199	52 35	188 96	4 56	43 48	16 16	65 84
1958	14 85	62 04	0 297	73 04	262 00	21 49	64 98	26 37	92 21
1959	15 60	77 64	0 339	81 19	343 19	26 57	91 55	33 33	125 54
1960	16 11	93 75	0 337	83 64	426 83	27 23	118 77	34 58	160 12
1961	16 61	110 36	0 343	86 85	513 68	28 73	147 51	32 26	192 38
1962	16 23	126 59	0 341	84 66	598 34	27 86	175 36	29 36	221 74
1963	15 48	142 07	0 313	77 87	676 21	23 83	199 19	26 98	248 72
1964	15 48	157 55	0 285	74 90	751 11	21 42	220 61	18 68	267 40

a James H Hill and Joe W Parks *Uranium Enrichment in the United States* CONF-750024-7, Energy Research and Development Administration 5 March 1975 Figure 1 p 13

b Tails assays after FY 1964 were: FY 1965, 0 197; FY 1966-71 0 200; FY 1972-75 0 300; FY 1976-79, 0 250; FY 1979-80, 0 200

c 94 percent U-235 Unit is metric tons of uranium metal (MTU) Enrichment of F kg of feed (assay x_f) produces P kg of product (assay x_p) and T kg of tails (assay x_t) with $P/F = (x_f - x_t)/(x_p - x_t)$ The number of separative work units (SWU) is $S = [V(x_p) - V(x_f)]F - [V(x_t) - V(x_f)]P$ where $V(x) = (1 - 2x)\ln[(1 - x)/x]$

d Assumes tails stripping in FY 1956-1957 FY 1956: strip tails from FY 1945-FY 1953 requiring 13 72 MSWU and producing 35 5 MT HEU; FY 1957: strip tails from FY 1953-FY 1955 requiring 9 98 MSWU and producing 33 2 MT HEU

e See Table 3 15

carded In the early 1950s, the AEC began recovering the uranium from the fresh and stored processing waste, and the fuel cycle was closed [8] In order to maintain the reactivity of the plants, it became necessary to slightly enrich the fresh fuel [9] It is estimated to have taken approximately two years to recycle the spent uranium fuel—that is, two years to irradiate, cool, process, recover, and refabricate the uranium fuel

Assuming the Hanford reactors used natural uranium feed and the uranium recovered from spent fuel was re-enriched to normal assay (0 711 percent U-235) with enrichment tails assay of 0 32 percent U-235,[10] some 12,000 MTU of natural uranium feed (16,000 short tons U_3O_8 containing 88 MT U-235) were required to operate the reactors to the end of FY 1964 Out of this, about 49 MT of U-235 were consumed in the eight reactors, and an additional 39 MT of U-235 ended up as enrichment tailings A further two-year fuel supply would have tied up an additional 7800 MT of natural uranium (10,000 short tons U_3O_8 containing about 55 MT of U-235), since the Hanford reactors produced about 3 MT of plutonium per year, requiring some 1300 MT fresh fuel (9 2 MT U-235) for each metric ton of plutonium

The five Savannah River heavy water reactors accumulated 24 5 million Mwd of operation through FY 1964, producing an estimated 23 7 MT of plutonium equivalent, including an estimated 90 kg of tritium (6 5 MT Pu equivalent) [11] The Savannah River reactors used

9 Hewlett and Duncan *Atomic Shield* p 62

10 The operating enrichment tails assay at the enrichment complex has been reduced from about 0 529 percent in the 1940s to 0 2 percent currently (Table D 1) From Table D 1 the average tails assay for FY 1944-FY 1964 was 0 32 percent which was also the average value for the years FY 1950-FY 1964

11 The tritium production estimate is taken from Table 1 Appendix C for the constant release fraction case (column 3)

HEU driver fuel in dedicated tritium runs They used natural uranium or LEU fuel when producing plutonium until 1968 when HEU driver fuel was introduced

Some 5600 MT of natural uranium feed (7300 short tons U_3O_8 containing 40 MT U-235) are estimated to have been required for operating the reactors during plutonium production to the end of FY 1964, allowing for enrichment of the recovered uranium in the gaseous diffusion plants Of this, 22 MT of U-235 in natural or LEU fuel were consumed by the reactors, and an additional 18 MT of U-235 ended up as enrichment tailings Allocation of a two-year fuel supply for each reactor would tie up an additional 1660 MT of natural uranium (2200 short tons U_3O_8 containing about 11 8 MT U-235), since in the SRP heavy water reactors some 830 MT of (5 9 MT U-235) natural uranium feed is required for each metric ton of plutonium produced

The production of 90 kg of tritium through FY 1964 would have consumed 8 6 MT of U-235 in HEU driver fuel Assuming a fuel cycle inventory in the reactors and in fresh and spent fuel of five HEU driver charges (8 MT U-235), the total HEU committed to the tritium production at SRP through FY 1964 contained about 16 6 MT U-235 It is assumed here that no HEU recovered by the Idaho Chemical Processing Plant was used for driver charges prior to FY 1965

The N-reactor began operating at Hanford on 31 December 1963 The reactor requires about 800 MT of slightly enriched uranium (approximately 1 percent U-235) per year when operating in the weapon-grade plutonium production mode (6 percent Pu-240) It is assumed that by the end of FY 1964 some two years supply of fuel was committed, requiring about 1500 short tons U_3O_8 feed

In sum, an estimated 18 MT of HEU (17 MT U-235) and some 41,000 short tons U_3O_8 were tied up in production reactor fuel requirements

Naval Reactors

By the end of 1964, there were sixty-two nuclear powered naval vessels (fifty-eight submarines and four surface ships), driven by seventy-two naval reactors In addition there were six land-based naval prototype reactors Through the end of FY 1964, it is estimated that the Navy had procured 180 reactor cores and performed less than ten refuelings [12]

An estimated 185 naval reactor cores were processed at the Idaho Chemical Processing Plant by the end of FY 1984[13] and approximately 8940 kg HEU containing 6974 kg U-235 was recovered [14] Hence the average naval core processed through FY 1984 yielded 48 kg HEU containing 38 kg U-235 The corresponding average fresh core is estimated to have contained about 90 kg HEU (97 3 percent U-235) [15] Through the end of 1964, the fresh naval cores that were irradiated, discharged, and processed contained an estimated 70 kg HEU (97 3 percent U-235), on the average, assuming that only 40 percent of the original U-235 was destroyed [16]

These data suggest that through FY 1964 some 13 MT of HEU (97 3 percent U-235) was required for fresh naval reactor fuel and less than 0 4 MT of U-235 was recovered from spent fuel

Domestic Power Reactor Program

Prior to 1967 the Atomic Energy Act provided for Presidential determination as to the quantities of special nuclear materials that were to be available for distribution to licensed users within the United States and to nations having agreements for cooperation with the United States

In 1954 the AEC undertook several actions designed to accelerate the development of civilian power reactors, including initiating construction of the Shippingport Atomic Power Station This 68 Mwe pressurized water reactor achieved criticality in December 1957, becoming the first large-scale civilian nuclear power plant built in the United States [17] Also, in 1954, the AEC began development of several prototype reactors including boiling water, fast breeder, and an experimental sodium graphite reactor [18] Only four of these small experimental civilian power projects went online between 1956 and 1964 [19]

Early in 1955 the AEC launched the Power Demonstration Reactor Program designed to encourage private investment in larger scale nuclear power plants Under the first two rounds, six power plants were undertaken and came on line between 1960 and 1965 [20] This was followed by the AEC's announcement in 1957 of a third round aimed at advanced reactor technologies Four pro-

12 The procurement of new reactor cores as of the end of 1964 is estimated by extrapolated data for 1969 and 1974 On 5 May 1969 Admiral Rickover testified that the Navy had procured 297 reactor cores and conducted 66 refuelings SAC FY 1970 DOE Part 4 pp 3684-86
On 25 February 1974 Admiral Rickover testified that the Navy had procured 409 reactor cores and conducted 124 refuelings JCAE NNPP 1974 p 5
On 24 April 1979 Admiral Rickover testified that the Navy had procured 598 nuclear cores and performed 166 refuelings JEC Economics of Defense Policy Part 2 p 449

13 This estimate is based on 175 refuelings conducted as of 4 March 1981 (HAC FY 1982 EWDA Part 7 p 346) and 166 refuelings as of 24 April 1979 (JEC Economics of Defense Policy Part 2 p 449) and an assumed fifteen months between refueling and chemical processing of the fuel

14 These estimates are taken from the summary of ICPP reprocessing quantities (Volume III Table 5) where it has been assumed that 2700 kg of HEU containing 2300 kg U-235 recovered in 1958-59 were SRP production reactor fuels

15 The average burnup (U-235 fissioned) would be 40 percent and the average amount of U-235 consumed would be 60 percent

16 As points of reference in 1959 a highly enriched prototype submarine reactor core containing 40 kg of U-235 was being considered for export to France JCAE Agreements for Cooperation for Mutual Defense Purposes June-July 1959 p 51 The core of the first British submarine the Dreadnought contained 40 kg of HEU; John Simpson, *The Independent Nuclear State: The United States Britain and the Military Atom* (New York: St Martin s Press 1983) p 203

17 A 60 Mw_e LWBR core replaced Shippingport s PWR core in 1977 The reactor was retired in 1982

18 Experimental Boiling Water Reactor (EBWR) (boiling water; 100 Mw_t, 4 Mw_e; 1956-67); Experimental Breeder Reactor 2 (EBR-2) (sodium cooled fast; 62 5 Mw_t, 20 Mw_e; April 1962-present); Sodium Reactor Experiment (SRE) (sodium graphite; 20 Mw_t, 5 7 Mw_e; 1957-64); Boiling Water Reactor Experiment No 5 (BORAX 5) (boiling water, integral nuclear superheat; 20 Mw_t, 2 6 Mw_e; April 1962-64); Experimental Gas Cooled Reactor (EGCR) (gas cooled graphite moderated; 84 3 Mw_t, 20 Mw_e; terminated 1966 prior to construction); Experimental Organic Cooled Reactor (EOCR) (organic cooled and moderated; 40 Mw_t, no electrical; terminated 1962 prior to operation

19 EBWR EBR-2 SRE and BORAX-5

20 Yankee-Rowe (PWR; 110 to 175 Mw_e; 1960-present); Enrico Fermi (LMFBR; 60 9 Mw_e; 200 Mw_t; 1963-67 retired 1972); Hallam (sodium cooled graphite moderated thermal reactor; 75 Mw_e; 240 Mw_t; 1962-64 retired 1964); Elk River (BWR 22 Mw_e; 58 2 Mw_t; 1962-68 retired 1968); Piqua Power Station (organic-cooled and moderated; 45 5 Mw_t, 11 4 Mw_e; 1963-66 retired 1966); LaCrosse (BWR; 165 Mw_t, 50 Mw_e; 1967-present)

Table D 2

Amount of Highly Enriched Uranium (>90%) Supplied to Experimental Power Reactors through Fiscal Year 1964

Reactor* (MWt)	Startup	Shutdown	Enrichment (%)	Yearly U-235 Requirement (kg/yr)	Total U-235 Requirement (kg)	Reprocessor
EWBR (100)	1956	1967	93[a]	—	30[a]	Stored at SRP[a]
HWCTR (61)	1962	1964	93?	—	50[b]	Stored at SRP[c]
VBWR (33)	1957	1963	90	—	35[d]	INEL[d]
SRE (20)	1957	1964	93	—	150[e]	Stored at SRP[f]
OMRE (12)	1957	1963	90	—	75[g]	INEL
MSRE (8)	1965	1969	93	8[h]	32[i]	?
BORAX 1,2,3,5	1953	1965	90-93	—	50[j]	INEL[j] but some stored there
EBR-1 (1 4)	1951	1962	90	—	150[i k]	INEL
HRE-1 (1)	1952	1954	93	1[h]	5	?
HRE-2 (5)	1957	1961	93	5[h]	25	?
LAPRE 1 (2)	1956	1957	93	—	4[l]	?
LAPRE 2 (1)	1958	1959	93	—	4[l]	?
EOCR (40)	terminated in 1962		93	—	65[m]	INEL
				TOTAL	675	

* The unabbreviated names of the reactors are listed in DOE *Nuclear Reactors Built Being Built or Planned* TIC-8200-R annual

a Only the second core of the EBWR (inserted in early 1960s) contained HEU; M T Simnad *Fuel Element Experience in Nuclear Power Reactors An AEC Monograph*, Gordon and Breach Science Publishers 1971, p 345 About 27 kilograms of EBWR spent fuel (enriched to 92 percent in uranium-235) are stored at SRP; DOE Spent Fuel and Radioactive Waste Inventories Projections and Characteristics RW-0006 September 1984

b The core contained 27 kilograms of uranium-235 in driver elements; R R Burn *Research, Training, Test and Production Reactor Directory*, American Nuclear Society 1983 p 777 Two cores were used in this reactor; JCAE FY 1969 AEC p 308

c About 32 kilograms of uranium-235 in spent HWCTR spent fuel is stored at SRP; DOE Spent Fuel

d The first core used HEU; the reactor was modified in 1960 to low enriched uranium; M T Simnad *Fuel Element* p 349 In the early 1960s about 33 kg of U-235 was recovered from VBWR spent HEU at the Idaho reprocessing facility; AEC *Annual Report to Congress* 1964 p 61

e Only the second core of the SRE reactor contained HEU; M T Simnad *Fuel Element* p 465 The amount is estimated (see footnote f)

f Spent fuel from the SRE reactor containing 143 kg of U-235 and enriched to 92 percent is stored at SRP; DOE Spent Fuel It is assumed that this is the entire core

g Three cores were fabricated for the OMRE reactor; JCAE FY 1965 AEC Each core contained about 25 kg of U-235; M T Simnad, *Fuel Element* p 437

h This is a rough estimate assuming that for each MWt one kg of U-235 is required each year

i Assumes only one core

j It is estimated that BORAX 1 and 2 contained about 15 kg of U-235 and BORAX 3 contained a little less than 15 kg of U-235; JCAE *Accelerating Civilian Reactor Program* 1956, p 54 BORAX 5 is estimated to have required about 20 kg of U-235, most of which is currently stored at INEL; DOE Spent Fuel

k The EBR 1 used three cores each containing about 50 kg of U-235; M T Simnad *Fuel Element* p 516

l JCAE, *Accelerating Civilian Reactor Program* 1956 pp 54-57

m R R Burn *Research Training* p 668

Source: David Albright private communication

jects in the 15 to 60 Mwe range were undertaken and came on line between 1962 and 1964[21]

In addition to the AEC and cooperative development programs, seven privately funded reactor projects came on line between 1957 and 1966[22]

The fuel, furnished by the AEC for all of these reactors through FY 1964 is estimated in Tables D 2, D 3, and D 4 to have required about 3 MT of U-235 contained in HEU (greater than 90 percent U-235) plus lower enriched uranium requiring about 4000 short tons U_3O_8 feed and 1 7 million kg SWU These fuel requirements are equivalent to 12 6 MT HEU (93 5 percent U-235) plus 2000 short tons U_3O_8[23]

Research and Test Reactors

Through 1964 there were nine AEC-owned civilian, and ten AEC-licensed, research and test reactors with rated power levels greater than five Mw_t (see Tables D 5 and D 6) All of these reactors operated using HEU The fuel requirement through FY 1964 for these together with the smaller reactors (1 to 5 Mw_t) is estimated in the tables to be 2 8 MT of U-235, equivalent to 3 MT of HEU (93 5 percent U-235)

There were eight other safety research and test reactors prior to 1965, operating either under transient power conditions or at power levels below one Mw_t The fuel requirements for all of these were too small to have con-

21 Pathfinder (BWR 190 Mw_t 58 5 Mw_e; 1963 67); Carolinas-Virginia Tube Reactor (PWR 17 Mw_e 1963 67); Peach Bottom (HTGR; 115 Mw_t, 40 Mw_e; 1966-1974 retired 1974); Big Rock Point (BWR, 240 Mw_t 48-75 Mw_e; 1962-present)

22 Vallecitos BWR (33 Mw_t 5 Mw_e; 1957 63); Dresden 1 (PWR; 700 Mw_t, 184 to 220 Mw_e; 1959-78 retired 1984); Saxton (PWR; 23 5 Mw_t 3 Mw_e; 1962-72); Indian Point 1 (PWR; 615 Mw_t [140 Mw_t nuclear supplied] 265 Mw_e; 1962-74, retired 1980); Humboldt Bay (BWR; 242 Mw_t 48 to 65 Mw_e; 1962-76 retired 1983); ESADA Vallecitos Superheat Reactor; 15 Mw_t; 1963-67)

23 The 4000 short tons U_3O_8 and 1 7 million kg SWU could have been utilized to produce 8 7 MT HEU (93 5 percent U-235) from 2000 short tons U_3O_8 operating the enrichment plant at 0 32 percent tails assay with 2000 short tons U_3O_8 left unenriched

Table D 3

Amount of Highly Enriched Uranium (>90% U-235) Supplied to Civilian Power Reactors Through Fiscal Year 1964

Reactor	Power (MWt)	Startup	Shut Down	Enrichment (%)	Uranium-235 Requirement Through 1964 (kg)	Total U-235 Require-ment (kg)	Reprocessor
Shippingport	236	1957	1982	92	680[a]	1020[a]	INEL?[a]
Indian Point 1	615	1962	1980	93	1100[b]	1100	West Valley[c]
Elk River	58	1962	1968	93	344[h]	344[h]	Italy, but large amount stored at SRP[i]
Pathfinder	190	1963	1967	93	50[d]	100[d]	INEL[e]
Peach Bottom	115	1966	1974	93	220[f]	440[f]	Stored at INEL[g]
	TOTAL				2,390	3,000	

a The first core used four seeds containing 345 kg of U-235 and the second core used two seeds each containing 336 kg of U-235; M T Simnad *Fuel Element Experience in Nuclear Power Reactors*, An AEC Monograph Gordon and Breach Science Publishers 1971 p 211 and F Duncan and J M Holl Shippingport: The Nation s First Atomic Power Station, History Division Department of Energy undated appeared in HASC NNPP-1983 The second seed of the second core was not fabricated before the end of FY 1964; Duncan *op cit* The seeds from the first core were most likely reprocessed at INEL It is unclear what happened to the seeds in the second core although it can be expected that they will (or have been) reprocessed at INEL

b Only the first core of Indian Point 1 used HEU fuel; M T Simnad *Fuel Element* pp 288-289

c Almost all of the spent HEU fuel was reprocessed at West Valley in 1968; G Rochlin et al , West Valley: Remnant of the AEC *Bulletin of the Atomic Scientists* (January 1978) table 2

d Two cores were fabricated for the Pathfinder reactor although the second core was not fabricated until a few years after FY 1964; JCAE FY 1965 AEC; JCAE FY 1967 AEC Each core contained 50 kg of U-235; M T Simnad *Fuel Element* pp 405-6

e Not all of the HEU fuel from the Pathfinder reactor has been reprocessed About 50 kg of slightly irradiated fuel is currently stored at INEL; DOE Spent Fuel RW-0006 September 1984

f Two cores were fabricated for the Peach Bottom reactor; H L Brey and H G Olson Fort St Vrain Experience *Nuclear Energy* 22, 2 (April 1983): 120 Each core contained about 220 kg of U-235; M T Simnad *Fuel Element* p 116 Because the second core was inserted after 1968 it is assumed that only one core was fabricated by the end of FY 64; Operating History of U S Nuclear Power Reactors Appendix 4, JCAE FY 1970 AEC Part 2 p 1581

g At the end of 1983 Peach Bottom spent fuel containing about 330 kg of HEU of which about 220 kg is U-235 is stored at INEL; DOE Spent Fuel

h One core was inserted into the Elk River reactor and another was being fabricated in March 1964; JCAE FY 1965 AEC p 781 Each core contained 172 kg of U-235; M T Simnad *Fuel Element*, p 378

i At the end of 1983 about 190 kg of 93 percent enriched uranium spent fuel from the Elk River reactor were stored at SRP; DOE Spent Fuel In the 1970s a small amount of Elk River fuel was reprocessed at the ITREC facility in Italy; S Cao et al Italian Experience with Pilot Reprocessing Plants IAEA-CN-36/304 May 1977

Source: David Albright private communication

tributed significantly to the estimate of oralloy production made here

Rocket Propulsion Reactors

Under Project Rover, a joint NASA-AEC program to develop a nuclear propulsion reactor for space travel, there were seven nuclear rocket reactor experiments conducted between 1960 and 1965 These reactors had power levels ranging between 100 Mw_t and 1070 Mw_t The combined power of all seven was 4820 Mw_t Two additional experiments were conducted after 1965 (1400 Mw_t (1967) and 4200 Mw_t (1968)) DOE ultimately recovered 2 819 MT U-235 at the ICPP from fuel used in Project Rover [24]

Exports for Foreign Civilian Reactors

Through 1964 the United States exported 1 9 MT of HEU to foreign research reactors, containing 1 6 MT of U-235 [25] During this same period only 97 kg of uranium containing 80 kg U-235 were returned to the United States [26]

Consumption in Nuclear Weapons Tests[27]

The United States conducted 374 nuclear tests through 1964 plus three joint U S -UK tests (see Appendix B) These tests correspond to about 1 4 percent of the current nuclear weapons stockpile of about 26,000 warheads Thus the total HEU expended in tests conducted prior to the end of 1964 was about 10 MT (about 20 kg HEU per warhead)

Weapon Grade Uranium Inventory in 1964

The inventory of weapon grade uranium (93 5% U-235) at the end of FY 1964, when oralloy production ceased, can now be estimated by subtracting the uranium used in other activities from the purchases before FY 1965 According to Table D 7 a stockpile of some 657 MT (93 5 percent U-235) was available for weapons at the

24 ICPP, private communication to David Albright 1985 See also *Nuclear Fuel* (27 August 1984): 13 Earlier it was reported that there were 2800 kg of unprocessed Rover fuel; SASC FY 1979 DOE p 46

25 Donald P Hodel Secretary of Energy *Yearly Export Totals and Summary of Totals: Exports of Low Enriched Uranium High Enriched Uranium Uranium-233 Plutonium and Heavy Water January 1 1954 Through February 28 1983* Enclosures 1 and 2 in a letter to Representative Richard Ottinger 10 May 1983

26 DOE NMMSS Report U S Origin Impacts (computer printout) enclosure in letter from Robert A O Brien Jr to Thomas B Cochran 13 December 1984

27 Perhaps a dozen nuclear weapons were lost in accidents See U S Nuclear Weapons Accidents: Danger in Our Midst *The Defense Monitor* Volume X Number 5 1981

Table D 4

LEU-Fueled Power Reactors: Domestic Separative Work Requirements (SWU) Through Fiscal Year 1964

Reactor[a]	Fuel Charge[b] (kg Uranium)	Enrichment[b] (%)	Number of Cores Produced[c]	Total (kg SWU)	Feed (MTU)
Indian Pt 1	20,000	3.4	1	79,980	158
Yankee-Rowe	20,800	3.4	2	166,320	328
	20,800	4.0	3	317,310	588
Big Rock Pt	11,700	3.2	3[b]	127,860	259
Dresden 1	51,500	2.0	2	162,120	442
Humboldt Bay	13,840	2.6	1	36,040	78
	13,840	2.2	0.5[d]	13,425	34
La Crosse	8,600	3.63	1	37,940	73
Bonus Boiler	2,810	2.4	1	6,380	15
Superheater	1,790	3.25	1	6,680	13
Hallam	29,200	3.6	1	127,230	245
	29,200	4.9	1	197,400	342
Piqua	6,550	1.9	1	9,610	26
Carolina-Virginia Tube Reactor	3,280	1.75	2	8,120	24
Pathfinder Boiler	6,560	2.2	1	12,740	32
EBR-2	350	49.0	2	68,840	88
Fermi	2,000	25.6	2	195,410	258
EBWR	5,600	1.44	1	4,440	16
EVESR	2,200[e]	5.4[e]	2[f]	34,040	58
EBOR	160[g]	62.5[g]	1	20,430	26
EGCR	9,860[h]	2.55[h]	1	24,840	56
Saxton	1,270	5.7	1.5	15,780	26
SRE	3,000	2.8	1	8,830	19
	3,000	6.2	1	21,980	37
VBWR	800	3.0	1	2,630	6
NS Savannah	?	?	1	?	?
			TOTAL	1,706,385	3,247

a The unabbreviated names of the reactors are contained in DOE *Nuclear Reactors Built, Being Built, or Planned* DOE/TIC-8200-annual

b Unless otherwise noted the source is M T Simnad *Fuel Element Experience in Nuclear Power Reactors* an AEC Monograph Gordon and Breach Science Publishers 1971

c Unless otherwise noted the number of cores whose uranium was enriched prior to the end of FY 1964 is based on AEC tables listing power reactor fuel elements fabricated through various years that are in the hearings of the JCAE authorizing AEC legislation or reporting on the development of the atomic energy industry

d Partial reloads of the core

e R R Burn *Research, Training, Test and Production Reactor Directory* American Nuclear Society 1983 p 646

f Appendix 4, Operating History of U S Nuclear Power Program in JCAE FY 1970 AEC Part 2

g R R Burn *Research Training* p 987

h AEC Costs of Nuclear Power TID-8531 January 1961

Source: David Albright private communication

end of FY 1964

This estimate, 657 MT, is judged to have an error of about 10 percent and should be taken as an upper limit on oralloy production It is consistent with a previous report that "more than half a million kilograms [500 MT] of weapon-grade uranium were produced in the United States since 1945 "[28]

Removals 1964-90

Since FY 1964, the inventory of HEU available for weapons has been further reduced by fuel requirements of the Savannah River production reactors, fuel needs for research and test reactors, uranium exports to Britain and France for military purposes, and nuclear tests

Presently highly enriched uranium metal is provided from the current DOE inventory at the Y-12 plant for nuclear weapons components and for fuels for the Savannah River production reactors, and DOE research and test reactors It is assumed this has been the practice ever since the AEC placed its Enriched Uranium Conversion Facility (for conversion of UF_6 to UF_4) on standby in early FY 1965 and will continue until 1988-90 when the facility is scheduled to be reactivated

28 John McPhee, *The Curve of Binding Energy* (New York: Farrar Straus & Giroux 1974) p 21

Table D 5
Amount of HEU (>90%) Required in DOE Civilian Research and Test Reactors (>1 MWt)

Reactor* (MWt)	Startup	Shutdown	Enrichment (%)	Yearly U-235 Requirement (kg/yr)[a]	U-235 Requirement Through 1964 (kg)	Total U-235 Requirement Through 1984 (kg)	Reprocessor
ATR (250/125[b])	1967	—	93	175 0[c]	—	3900[d]	INEL
HFIR (100)	1965	—	93	140 0[e]	—	2800	SRP
HFBR							
(40)	1965	1982	93	40 0[f]	—	720	SRP and INEL[g]
(60)	1982	—	93	59 0	—	120	SRP and INEL[g]
ORR (30)	1958	—	93	18 0	130	490	SRP and INEL[h]
OWR (8)	1956	—	93	5 4	49	160	INEL
BMRR (3)	1959	—	90-93	0 2	1	5	?
BSR (2)	1950	—	93	0 5	8	18	SRP and INEL
TSR-2 (1)	1960	—	93	0 2	1	5	SRP and INEL
ETR (175)	1957	1972[i]	93	180 0[j]	1440	2700	INEL
MTR (40)	1952	1970	93	40 0[f]	520	720	INEL
ALRR (5)	1965	1977	93	5 0[f]	—	60	SRP
CP-5 (5)	1954	1979	93	5 0[f]	55	125	Some at SRP
SER (5)	1961	1970	93	5 0[f]	20	45	INEL
Retired Reactors (1 to 5 Mwt)				-	70	120	INEL and SRP?
				TOTAL	2,294	11,988	

* The unabbreviated names of the reactors are listed in U S Department of Energy *Nuclear Reactors Built Being Built or Planned*, DOE/TIC-8200-R47 August 1983

a Unless otherwise noted the source of this data is letter to K L Mattern DOE from J E Matos Argonne National Laboratory Subject RERTR Program Reactor Summary—September 1982 22 September 1982

b The ATR only ran at 250 MWt in 1967 In 1968 it ran at about 220 MWt and after that the power was reduced gradually to about 120 or 130 MWt by 1975 (INEL personal communication, May 1984)

c Each year the ATR requires about 150 to 175 new fuel elements each containing 1 075 kg of U-235 (INEL personal communication May 1984) If the average power of the ATR is 125 MWt about 1 3 to 1 5 kg U-235 is required per MWt per year

d Using the information in footnotes b and c and assuming a linear decrease in power from 1968 until 1975 the ATR has required about 3900 kg of U-235 through 1984

e HFIR staff Oak Ridge Tennessee, personal communication May 1984 An independent estimate was derived from the average amount of spent fuel sent to SRP for reprocessing From 1978 through 1984 the average amount of HEU returned was 120 kg of HEU The average burnup of the U-235 in the fuel was 30 percent (R R Burn *Research Training Test and Production Reactor Directory* American Nuclear Society 1983) This burnup corresponds to the spent fuel having an enrichment of about 85 percent U-235 or containing on average about 100 kg of U-235 Since about 30 percent of the original U-235 is burned up (either it is fissioned or converted into U-236) the annual need for fresh U-235 for HFIR is about 140 kg of U-235

f This is a rough estimate of the amount of U-235 required yearly based on assuming that one kilogram of uranium-235 is needed each year per MWt for the HFBR (Matos RERTR Program)

g Due to a ban on shipments of spent fuel through New York city no fuel was shipped off-site from 1976 until 1985 The spent fuel from this reactor is being sent to INEL Once the current backlog of spent fuel is sent to INEL it will probably be sent to SRP Previous to 1976 or 1977 the spent fuel was most likely sent to SRP

h Starting in 1982 ORR spent fuel was sent to INEL for reprocessing During 1985 or early 1986 shipments to SRP should resume From 1978 through 1981 ORR sent on average 15 kg of spent HEU per year to SRP for reprocessing

i In 1972 ETR was shutdown to install a sodium loop for fast breeder reactor research After 1972 until the reactor was shutdown in 1982 it used very little HEU fuel The ETR may be restarted and will require about 180 kg of U-235 per year

j INEL personal communication May 1985

Source: David Albright private communication

The SRP reactors, as noted previously, were converted to HEU driver fuel for plutonium production in 1968 No dedicated tritium runs occurred between 1965 and 1972 From FY 1969 through FY 1984 the SRP production reactors operated 25 5 million Mwd; an additional 13 5 million Mwd are projected to accumulate between FY 1985 and FY 1990 Of the total 39 million Mwd, an estimated 7 million Mwd is generated in reactors dedicated to tritium production and "high flux" operation and the remaining 32 million Mwd is in reactors producing plutonium, where the power distribution is about 75 percent in the highly enriched drivers and 25 percent in the depleted uranium targets Consequently, highly enriched driver fuel contributes some 31 million Mwd of operation between FY 1965 and FY 1990, consuming an estimated 38 MT U-235 (41 MT weapon-grade HEU equivalent)

An additional 19 MT U-235 (20 MT weapon grade HEU equivalent) are probably tied up in the fuel cycle (in and out of reactor inventories) However, this must be reduced by 8 MT, the amount of U-235 assumed to be in the fuel cycle pipeline in FY 1964[29]

A considerable portion of the HEU needed to fuel the SRP production reactors since FY 1964 has come from

29 Assumes a three-year pipeline An SRP reactor charge contains up to 1 6 MT of U-235 and some 2 6 MT of HEU was scheduled for recovery in FY 1980; HASC FY 1980 DOE p 752

Table D 6

Amount of HEU (<90%) Required in NRC (or AEC)-Licensed Reactors (<1 MWt)

Reactor[*] (MWt)	Startup	Shutdown	Enrichment (%)	Yearly U-235 Requirement (kg/yr)[a]	U-235 Requirement Through 1964 (kg)	Total U-235 Requirement Through 1984 (kg)	Reprocessor[b]
NBSR (20)	1967	—	93	13 0	—	230	SRP
MURR							
(5)	1966	1974	93	9 0[c]	—	80	?
(10)	1974	—	93	19 0	—	190	SRP
MITR (5)	1958	—	93	5 4	38	146	SRP or INEL
UCNR (5)	1961	—	93	5 4	22	130	SRP
GTRR (5)	1964	—	93	1 9	2	40	SRP?
FNR (2)	1957	—	93	3 3	26	80[d]	SRP
RINSC (2)	1964	—	93	2 5	3	53	SRP
UVAR (2)	1960	—	93	1 3	7	33	SRP
ULR (1)	1974	—	93	0 2	—	2	not applicable
NASA-TR (60)	1963	1974	93	30 0[e]	60	330	INEL and SRP[f]
WTR (60)	1959	1962	93	—	80[g]	80[g]	INEL
GETR							
(30)	1958	1966	93	30 0[h]	210	270	INEL
(50)	1966	1977	93	50 0[h]	—	550	INEL
BAWTR (6)	1964	1971	93	6 0[h]	6	42	?
Retired Reactors (1 to 5 Mwt)				-	50	150	INEL[i] and SRP
			TOTAL		504	2406	

* The unabbreviated names of the reactors are listed in DOE, *Nuclear Reactors Built, Being Built, or Planned* DOE/TIC-8200-R47 August 1983

a Unless otherwise noted the source is letter to K L Mattern DOE from J E Matos Argonne National Laboratory Subject: RERTR Program Reactor Summary—September 1982 29 September 1982

b Unless otherwise noted the source is R R Burn *Research, Training, Test and Production Reactor Directory* American Nuclear Society 1983

c Scaled

d The Ford reactor converted to low enriched uranium fuel in the early 1980s

e This estimate of the yearly requirements of uranium-235 for the NASA-TR is derived from the average annual amount of uranium-235 recovered from its spent fuel at SRP and INEL and the enrichment of the recovered HEU (*Annual Report to Congress of the Atomic Energy Commission* for the years 1964 1965 and 1967 and *Major Activities in the Atomic Energy Programs* January-December 1966 January 1967)

f *Annual Report* op cit After 1967 it is assumed that half of the U-235 was recovered at SRP and half at INEL

g *Annual Report to Congress of the Atomic Energy Commission for 1964* p 61

h Rough estimate based on assuming 1 kg U-235 per year per MWt (Matos RERTR Program)

i Some of the spent fuel from the IRL reactor was reprocessed at INEL (*Annual Report* op cit 1964 1966)

Source: David Albright private communication

uranium recovered from naval (and research) reactor spent fuel, primarily in Idaho Through FY 1984 28 8 MT of uranium containing 22 8 MT U-235 were recovered at ICPP, and perhaps as much as 25 MT U-235 (27 MT weapon grade HEU equivalent) will be recovered through 1987 An additional 4 MT HEU will be recovered at SRP from research reactor fuel This suggests that possibly a total of some 21 MT of U-235 will be withdrawn from the HEU inventory to meet SRP reactor driver fuel requirements between FY 1965 and FY 1990

About 15 to 20 MT of uranium from the HEU stockpile will be needed to supply domestic and foreign research and test reactors between FY 1965 and FY 1990 (see Table D 7)

The United States has supplied approximately 9 (or 5) MT[30] of HEU to the United Kingdom for submarine reactors and weapons under the U S /UK Defense Agreement signed in 1958 If the HEU was supplied in metal form it would have come from pre-1964 production HEU stocks If it was supplied as UF6, it could have been from HEU enriched after 1964 In addition, the United States committed itself in May 1959 to supply France with up to 0 44 MT of enriched uranium "for use in the development and operation of a land-based prototype submarine nuclear propulsion plant "[31] Up to 0 3 MT was to be enriched to 90 percent in the isotope U-235, with the remainder enriched up to 20 percent [32]

Finally, some additional 370 nuclear tests (includ-

30 Nine MT is based on the assumption that the U S /UK barter arrangement called for the exchange of 1 76 kg HEU for each kg of plutonium; 5 MT assumes an exchange ratio of one

31 JCAE *Agreements for Cooperation for Mutual Defense Purposes* June July 1959 pp 12 72 73

32 U S Department of State memorandum to the American Embassy Paris 7 May 1959

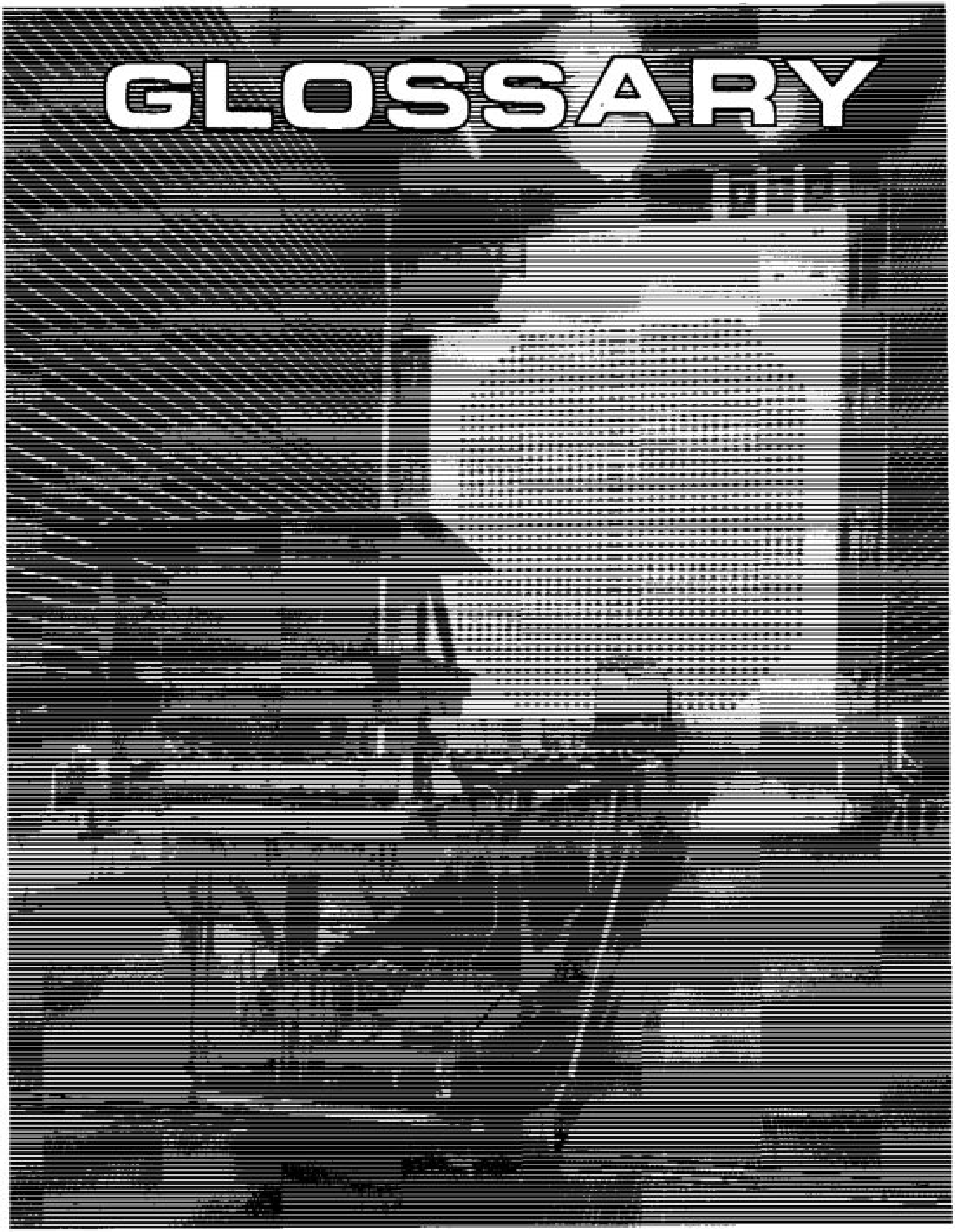
Table D 7
Estimate of U.S. Stockpile of Weapon-Grade Uranium (1984)

Activity	HEU (93 5% U-235) Equivalent (MTU)	U_3O_8 (thousands short tons)
Through FY 1964		
Uranium Purchases (FY 1943-FY 1964)		266 6
Enrichment Plant Production (FY 1943-mid-FY 1964)	751 1	-220 6
In Process	-7 5	-
Working Inventory	-25 0	-
Production Reactors	-18 0	-41 0
Naval Reactors	-13 0	
Domestic Power Reactor Program	-12 6	-3 0
Research and Test Reactors	-3 0	
Rocket Propulsion Reactors	-3 0	
Exports for Foreign Civilian Reactors	-1 6	
Weapons Tests	-10 0	
Subtotal - End FY 1964	approx 657 0	approx 2 0
FY 1965-90		
SRP Driver Fuel Consumed in Reactors	-41 0	
Additional Fuel Cycle Inventory	-12 0	
U-235 Recovered at ICPP & SRP	27.0	
SRP Subtotal	-26 0	
Domestic and Foreign Research and Test Reactors	-15 0 to -20 0	
Weapons Tests	-10 0	
Exports Under Military Agreements	-0.4 to -9.4	
Subtotal (FY 1965-90)	-51 4 to -65 4	
Available for Weapons	592 to 605	

ing 14 joint U S /UK tests) were announced during the 1965 through FY 1984 period, requiring an estimated 10 MT of HEU

In sum, the additional drawdowns of the HEU stockpile through FY 1990 total some 51 to 65 MT weapon-grade HEU (93 5 percent U-235) equivalent, as indicated in Table D 7, leaving the estimated HEU inventory available for weapons at the end of FY 1984 at about 600 MT

This 600 MT estimate is an upper limit on the HEU inventory available for weapons There are surely additional inventories and drawdowns which have not been taken into account The authors believe a better estimate of the HEU inventory reserved for weapons is 500 MT


GLOSSARY

Glossary of Terms

Actinides	The series of heavy radioactive metallic elements of increasing atomic number from actinium (89) through hahnium (105)
Advanced Gas Centrifuge (AGC)	High speed, high-efficiency gas centrifuge for enriching uranium hexafluoride
Advanced Isotope Separation (AIS)	Processes under development for enriching uranium, including Molecular Laser Isotope Separation (MLIS), Atomic Vapor Laser Isotope Separation (AVLIS), the Plasma Separation Process (PSP), and the Advanced Gas Centrifuge (AGC)
Airburst	The explosion of a nuclear weapon in the air at height greater than the maximum radius of the fireball
Alpha particle	A positively charged particle, made up of two neutrons and two protons, emitted by certain radioactive nuclei The nucleus of He-4 atom
Anti-submarine warfare (ASW)	Methods of warfare utilizing specialized sensors, data processing techniques, weapons platforms, and weapons intended to search for, identify, and destroy submarines
Anti-ballistic missile (ABM)	A defense missile used to intercept and destroy an attacking strategic ballistic missile
Aqueous phase	In solvent extraction, the water-containing layer, as differentiated from the organic phase
Arming	As applied to weapons and ammunition, the changing from a safe condition to a state of readiness for initiation
Arms control	The process of limiting or reducing arms to lessen the risk of conflict and to reduce the consequences of a conflict should it occur
Arms control agreement verification	The collection, processing, and reporting of data indicating testing or employment of proscribed weapon systems, including country of origin and location, weapon and payload identification, and event type
ATMX	The designation assigned to a special railcar used to transport nuclear weapons Only series 500 and 600 ATMX cars are nuclear weapons transporting railcars
Atomic bomb	An explosive device whose energy comes from the fissioning of uranium or plutonium A fission bomb, as distinguised from a hydrogen bomb
Atomic demolition munition (ADM)	Nuclear device designed to be detonated on or below the surface, or under water, to block, deny, and/or canalize enemy forces
Atomic number	The number of protons in an atomic nucleus
Atomic weight	The mass of an atom expressed in atomic mass units (amu), usually relative to carbon-12, which is defined to have a mass of 12 amu Approximately, the sum of the number of neutrons and protons in the nucleus
Ballistic missile	A missile that follows a ballistic trajectory, relying only on gravity and aerodynamic drag when its thrust is terminated
Ballistic missile defense (BMD)	A defensive system designed to destroy incoming ballistic missiles or their warheads Usually conceived as structured in several different layers that attack missiles in any of their trajectory phases: boost phase, post-boost phase, midcourse phase, and terminal (or reentry) phase
Beryllium	Element with atomic number 4 and atomic weights between 6 and 11 Used in nuclear weapons as a neutron reflector and a neutron source

Beta particle — An electron or positron emitted by an atomic nucleus during radioactive decay

Blanket — A layer of assemblies containing fertile material, such as uranium-238 or thorium-232, surrounding the core of a nuclear reactor, for the purpose of absorbing escaping neutrons

Blast — The pressure pulse (shock wave) in air initiated by the expansion of the hot gases produced by an explosion

Blast yield — That portion of the total energy of a nuclear explosion that is manifested as a blast (or shock) wave

Boosted fission weapon — A nuclear weapon in which neutrons produced by thermonuclear reactions serve to enhance the fission process The thermonuclear energy represents only a small fraction of the total explosion energy

Burnup — The precentage of fuel atoms fissioned during operation of a nuclear reactor Also, the energy produced by a nuclear reactor, usually expressed as Mwd per MT of fuel

Byproduct material — Any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the production or utilization of special nuclear material

Chain reaction — A series of reactions in fissionable material in which neutrons that are the product of fission reactions induce subsequent fissions

Cladding — The material forming the outer layer of a nuclear fuel element May be aluminum, steel, or Zircalloy, an alloy of zirconium

Command disable system — A system incorporating command and control features that destroys a weapon's ability to achieve a significant nuclear yield

Component — Any operational, experimental, or research-related part, subsection, design, or material used in the manufacture or utilization of a nuclear weapon, nuclear explosive device, or nuclear weapon test assembly

Control rods — Rods of neutron absorbing material that are inserted into the core of a nuclear reactor to control its operation

Conversion ratio — The ratio of the number of atoms of new fissile materials produced in a reactor to the number of atoms of fissile material consumed This ratio is usually less than unity

Crater — The pit, depression, or cavity formed in the surface of the earth by a surface or underground explosion Crater formation can occur by vaporization of the surface material, by the scouring effect of air blast, by throwout of disturbed material, or by subsidence In general, changes from one process to the next occur with increasing depth of burst The *apparent crater* is the depression which is seen after the burst; it is smaller than the true crater, which is covered with a layer of loose earth, rock, etcetera In a deep underground burst when there is no rupture of the surface, the resulting cavity (a sealed pocked of smoke and gas) is called a *camouflet*

Critical facility — A research facility that contains nuclear material and can sustain a chain reaction but produces no power and requires no cooling Its core is designed for great flexibility and uses fuel that can be repositioned and varied to investigate different reactor concepts and core configurations

Critical mass — The least mass of fissionable material that will allow a self-sustaining nuclear chain reactor The critical mass depends on the type of fissionable isotope, its chemical form, geometrical arrangement, and density

Critical nuclear weapons design information (CNWDI) — That TOP SECRET Restricted Data or SECRET Restricted Data revealing the theory of operation or design of the components of a thermonuclear or implosion-type fission bomb, warhead, demolition munition, or test device Specially excluded is information concerning arming, fuzing, and firing systems; limited life components; and total contained quantity of fissionable, fusionable, and high explosive materials by type Among these excluded items are the components which Service personnel set, maintain, operate, test or replace

Cruise missile — A low-flying, air-breathing, guided missile that, like an aircraft, relies on propulsion to balance drag and aerodynamic lift to balance gravity

Cryogenic — Relating to the production of very low temperatures

Curie (Ci) — A unit of radioactivity; the activity of a quantity of any radioactive nuclide undergoing 37 thousand million disintegrations per second

Custody — 1 As defined in the AEC-DOD Stockpile Agreement, custody is the responsibility for the control of transfer and movement of, and access to, weapons and components Custody also includes the maintenance of accountability for weapons and components 2 As used within the individual Military Services, custody is the guardianship and safekeeping of nuclear weapons and their components and of source and special nuclear material Custody may or may not include accountability

Depleted uranium — Uranium having a concentration of U-235 smaller than found in nature (0 711 percent)

Detonator — A device containing a sensitive explosive intended to produce a detonation wave for detonating a high explosive element

Deuterium — A hydrogen isotope (atomic weight 2) with one proton and one neutron in the nucleus Represented by letter D or by H-2 Used as a thermonuclear fuel constituent and as a neutron moderator (in the form of heavy water) in nuclear reactors

Disablement — The rendering of a nuclear weapon incapable of achieving a nuclear yield for some specified period of time Not included in disablement are the prevention of the recovery of active nuclear material and preventing the obtainment of classified design information

Electromagnetic pulse (EMP) — A sharp pulse of radio-frequency (long wavelength) electromagnetic radiation produced when a nuclear explosion occurs in an unsymmetrical environment, especially at or near the earth's surface or at high altitudes It is caused by Compton-recoil electrons and by photoelectrons The intense electric and magnetic fields can damage unprotected electrical and electronic equipment over a large area

Electron-volt — A unit of energy 22 5 billion trillion electron-volts equal one kilowatt-hour

Enhanced radiation weapon — A nuclear explosive device designed to maximize nuclear radiation effects and reduce blast and thermal effects

Enrichment — Increasing the concentration of one isotope of an element relative to the other isotopes For example, uranium-235 relative to uranium-238 or plutonium-239 relative to plutonium-240

Feed material — A nuclear material introduced at the start of a process or operation (e g , uranium hexafluoride (UF_6) as the feed to an enrichment process or uranium metal as the feed to a fuel fabrication process)

Fertile isotope — An isotope that is converted into a fissile isotope, either directly or after a brief decay process, by absorbing a neutron For example,

	fertile U-238 captures a neutron to form U-239, which subsequently decays to fissile Pu-239
Fireball	The luminous sphere of hot gases produced by a nuclear explosion
Firing system	The system of components in a nuclear weapon that converts (if necessary), stores, and releases electrical energy to detonate the weapon when commanded by the fuzing system
Fissile material	An isotope that readily fissions after absorbing a slow neutron, emitting 2 to 3 neutrons Fissile materials are U-235, U-233, Pu-239, and Pu-241
Fission	The splitting of the nucleus of a heavy atom following absorption of a neutron into two lighter nuclei, accompanied by the release of neutrons, X-rays, gamma rays, and kinetic energy of the fission products
Fissionable material	A material that will undergo nuclear fission Includes fissile materials, but also isotopes such as U-238 that are fissioned only by fast neutrons
Fission products	The product nuclei resulting from the fission of a heavy nucleus (e g , uranium-235 or plutonium-239) These are distinguished from the *direct fission products* or *fission fragments* that are formed by the actual splitting of the heavy-element nucleus The fission fragments are radioactive and decay into daughter products The complex mixture of fission products thus formed contains about 200 different isotopes of over thirty elements
Fission weapon	A nuclear warhead whose material is uranium or plutonium that is brought to a critical mass under pressure from a chemical explosive detonation to create an explosion that produces blast, thermal radiation, and nuclear radiation The complete fission of one pound of fissionable material would have a yield equivalent to 8000 tons of TNT Commonly known as atomic bomb
Fission yield	The amount of energy released by fission in a thermonuclear (fusion) explosion as distinct from that released by fusion
Formerly Restricted Data (FRD)	Information removed from the Restricted Data category upon a joint determination by the Department of Energy (or antecedent agencies) and Department of Defense that such information relates primarily to the military utilization of atomic weapons and that such information can be adequately safeguarded as classified defense information (Section 142d, Atomic Energy Act of 1954, as amended)
Fuel cycle	The set of chemical and physical operations needed to prepare nuclear material for use in reactors and to dispose of or recycle the material after its removal from the reactor
Fuel element	A rod, tube, or other form into which nuclear fuel is fabricated for use in a reactor
Fuel fabrication plant	A facility where the nuclear material (e g , enriched or natural uranium) is fabricated into fuel elements for a reactor
Fuel processing plant	A plant where irradiated fuel elements are dissolved, waste materials removed, and reusable materials are recovered
Fusion	The process in which two light nuclei atoms, especially isotopes of hydrogen, combine to form a heavier nucleus with the release of a substantial amount of energy Extremely high temperatures, resulting in highly energetic, fast-moving nuclei, are required to initiate fusion reactions
Fusion weapon	Nuclear warhead containing fusion materials (e g , deuterium and tritium) that are brought to critical density and temperature conditions by use of a primary fission reaction (thermonuclear) in order to initiate and sustain a rapid fusion process, which in turn creates an explosion that

	produces blast, thermal radiation, and nuclear radiation Commonly known as hydrogen bomb or thermonuclear weapon
Fuze	A union of one or more subassemblies or major components that, when combined with other major assemblies as required (such as bomb, power supply, etc), is capable either in itself or in conjunction with a firing set of controlling the electrical or mechanical arming and firing of a weapon
Fuzing system	The system of components in a nuclear weapon that determines the time and place to detonate the weapon
Gamma ray	High-energy electromagnetic radiation emitted by nuclei during nuclear reactions or radioactive decay
Gaseous diffusion	An isotope separation process used for enriching uranium in uranium-235 based on the fact that the lighter isotopes of a gas diffuse through a porous barrier at a greater rate than the heavier isotopes
Gas centrifuge	A rotating cylinder that can be used for enrichment of uranium hexafluoride gas The heavier uranium isotope U-238 tends to concentrate at the walls of the rotating centrifuge, leaving uranium enriched in U-235 near the center
Gun-type weapon	A device in which two or more pieces of fissionable material, each less than a critical mass, are brought together very rapidly so as to form a supercritical mass that can explode as the result of a rapidly expanding fission chain
Half-life	The time in which one half of a quantity of identical radioactive atoms decays
Heavy metal	The fuel materials, including uranium, plutonium and thorium, with atomic numbers of 90 and above
Heavy water	Water containing significantly more than the natural proportion (1 part in 6500) of deuterium atoms (as D_2O) to ordinary hydrogen atoms (as H_2O)
Heavy water reactor	A nuclear reactor that uses heavy water as moderator and/or coolant
Helium	Element (symbol He) with atomic number 2 and atomic weights between 3 and 8
Highly enriched uranium (HEU)	Uranium that is enriched in U-235 to above 20 percent, usually 90 percent or greater
High-level waste (HLW)	The highly radioactive waste containing fission products that is discharged from a nuclear fuel processing plant
Homogenous core	A reactor core composed of only one type of fuel assembly
Igloo	An earth-covered structure of concrete and/or steel designed for the storage of ammunition and explosives
Implosion weapon	A weapon in which a quantity of fissionable material, less than a critical mass at ordinary pressure, has its volume suddenly reduced by compression (a step accomplished by using chemical explosives) so that it becomes supercritical, producing a nuclear explosion
Inertial confinement fusion (ICF)	A concept for attaining the density and temperature condition that will produce nuclear fusion by use of lasers or particle beams to compress and heat small pellets of fusion fuel The energy released is in the form of fast neutrons, X-rays, charged particles, and debris
Initial operational capability (IOC)	The date when the first combat missile unit is equipped and trained, and logistic support established to permit performance of combat missions in the field An initial operational capability date is associated with each new missile system as a target date for delivery of combat equipment,

	repair parts, maintenance equipment, and publications, plus supply of trained personnel
Intercontinental ballistic missile (ICBM)	A land-based rocket-propelled vehicle capable of delivering a warhead over intercontinental distances Once rocket propulsion is terminated an ICBM travels on a ballistic trajectory
Intermediate-range ballistic missile (IRBM)	A ballistic missile, with a range capability from about 1500 to 3000 nautical miles
Ion exchange	Chemical methods of recovering products or removing impurities from solutions involving the exchange of ions between the solution and an insoluble resin Used in uranium milling to recover uranium from acid leach liquors and in fuel processing for final product decontamination and the separation of certain fission products from high level waste For the separation of metals, ion exchange is preferable over solvent extraction for small quantities or low concentrations
Irradiation	Exposure to neutrons in a nuclear reactor More generally, exposure to any source of radiation
Isotopes	Atoms of the same chemical element having different numbers of neutrons in their nucleus An isotope is specified by its atomic number and a symbol denoting the chemical element (e g , U-235 for uranium with 235 neutrons and protons)
Joint test assembly (JTA)	Warheads and bombs employed in test projects JTAs are non-nuclear test configurations with appropriate instrumentation installed
	Joint test assembly, pre-build Instrumented warheads on bombs assembled alongside war reserve weapons The nuclear explosive package is excluded, with instrumentation substituted that will allow subsystem evaluation at a later time during weapon evaluation
	Joint test assembly, rebuild Weapons randomly selected from War Reserve stockpile in which the nuclear explosive package is removed and instrumentation substituted prior to evaluation
Joint test subassembly (JTS)	The instrumented package substituted for the nuclear explosive package
Kiloton (Kt)	The energy of a nuclear expolsiton that is equivalent to the explosion of 1000 tons of trinitrotoluene (TNT) high explosive
Laser	A device that produces a coherent, intense, and collimated beam of electromagnetic radiation of well-determined wavelength, through a physical process known as stimulated emission
Laser isotope separation (LIS)	An enrichment process in which desired isotopes are separated by differentially exciting a vapor or gas with a finely tuned laser Used to separate U-235 from U-238 and Pu-240 and Pu-244 from Pu-239
Light-water reactor	A nuclear reactor that uses ordinary water as moderator and coolant
Liquid-metal fast breeder reactor	A nuclear reactor that uses a liquid metal (e g , sodium) for cooling, operates with high-energy (fast) neutrons, and produces more fissionable material than it consumes
Lithium	Element with atomic number 3 and atomic weight between 5 and 9 As thermonuclear fuel constituent, it is usually compounded with deuterium
Low-enriched uranium	Uranium enriched in U-235 to less than 20 percent, usually 2 to 4 percent
Mean free path	The average path distance a particle (neutron or photon) travels before undergoing a specified reaction (with a nucleus or electron) in matter

Megaton (Mt) A measure of the explosive yield of a nuclear weapon equivalent to one million tons of trinitrotoluene (TNT) high explosive Equal approximately to one thousand million calories or 4 2 thousand million million joules

Megawatt thermal (Mw_t) A measure of the rate of heat production (power output) in a nuclear reactor equal to one million watts

Megawatt-day (Mwd) A measure of thermal energy production in a nuclear reactor One Mwd is equal to 86 4 thousand million joules

Military characteristics Those characteristics of equipment upon which depend its ability to perform desired military functions Military characteristics include physical and operational characteristics but not technical characteristics

"Mod" designator number Modifications made to the major assembly design of a weapon system Mod-0 is the first version of a weapon design, with subsequent modifications of the weapon design numbered consecutively

Moderator A material (e g , water, heavy water, or graphite) in the core of a nuclear reactor that slows neutrons by elastic collision, thus increasing their chance of absorption by a fissile nucleus

Metric Ton (MT) 1000 kilograms, or 2205 pounds

Multiple independently targetable reentry vehicle (MIRV) Multiple reentry vehicles carried by a ballistic missile, each of which can be directed to a separate and arbitrarily located target

Multiplication Factor (k) A quantity that describes the degree to which a chain reacting system can sustain operation k is equal to the ratio of the number of neutrons in a given generation to the number in the preceding generation When k is equal to unity, the fission chain reaction is self-sustaining and the reactor is "critical"; for k less than unity, the chain reaction dies out and the reactor is "subcritical"; for k greater than unity the reaction grows and is "supercritical "

National Security Information A category of information classified under Executive Order 12356, "National Security Information "

Natural uranium Uranium as found in nature, containing about 0 711 percent of U-235, 99 3 percent of U-238, and a trace of U-234

Neutron flux A measure of the intensity of neutron radiation equal to the product of neutron density and velocity Expressed as the number of neutrons per square centimeter per second

Neutron generator A high-voltage vacuum tube used in contemporary nuclear weapons to furnish neutrons at a precise instant to begin fission reactions in fissile cores

Nuclear component A part of a nuclear weapon that contains fissionable or fusionable material

Nuclear device Nuclear fission or fission and fusion materials, together with the arming, fuzing, firing, chemical explosive, canister, and diagnostic measurement equipment, that have not reached the development status of an operational weapon

Nuclear radiation Particle and electromagnetic radiation emitted from atomic nuclei in various nuclear processes The important nuclear radiations, from the weapons effects standpoint, are alpha and beta particles, gamma rays, and neutrons X-rays are not nuclear radiations since they do not originate in atomic nuclei

Nuclear reactor A device in which a controlled, self-sustaining nuclear reaction can be maintained with provisions for cooling to remove generated heat Types include power reactors, research and test reactors, and production reactors

Nuclear waste The radioactive by-products formed by fission and other nu-

	clear processes in a reactor Separated from spent fuel in a processing plant
Nuclear weapon	A device that releases nuclear energy in an explosive matter as the result of nuclear reactions involving the fission or fusion of atomic nuclei, or both
Nuclear weapons effects	Effects associated with the explosion of a nuclear weapon, including blast, heat, X-rays, prompt nuclear radiation, and electromagnetic pulse
Nuclear winter	Global effects of nuclear war resulting in the lowering of land surface temperatures to near freezing or below due to the spread of massive amounts of smoke from fires and dust through the atmosphere screening out the sun's energy
One-point detonation	A detonation of high explosive which is initiated at a single point This type of detonation may be intentionally initiated in certain self-destruct systems
One-point safe	The probability that the detonation of the high explosive of a nuclear weapon by initiation at any one point has a chance of no greater than one in a million of producing a nuclear yield in excess of 4-pounds TNT equivalent It is a term to describe the degree of safety in a nuclear weapon
Oralloy	Abbreviation for Oak Ridge Alloy Highly enriched uranium metal, typically 93 5 percent U-235, used in nuclear weapons
Organic phase	In solvent extraction processes (e g , PUREX) for fuel processing, the solvent (organic) containing layer, as differentiated from the aqueous phase
Permissive action link (PAL)	A device included in or attached to a nuclear weapon system to preclude arming and/or launching until the insertion of a prescribed discrete code or combination
Pipeline	Refers to the quantity of an item required in the supply system to maintain an uninterrupted replacement flow
Pit	The components of a warhead located within the inner boundary of the high explosive assembly but not including safing materials
Plutonium	A heavy, man-made, radioactive metallic element (symbol Pu) The most important isotopes are Pu-238 and Pu-239
Plutonium-239	A fissile isotope produced by neutron capture in uranium-238 It is used in the core of nuclear weapons
Plutonium-240	An isotope of plutonium, produced in reactors by neutron capture in Pu-239 Because of its high rate of spontaneous fission, its presence increases the chance of preinitiation and affects the design and operation of nuclear explosive devices
Preinitiation	The initiation of the fission chain reaction in the active material of a nuclear weapon at any time earlier than at which either the designed or the maximum compression or degree of assembly is attained
Primary	The fission trigger or first stage of a multistage thermonuclear weapon or device
Production	The conversion of raw materials into products and/or components through a series of manufacturing processes It includes functions of production engineering, controlling, quality assurance, and the determination of resources requirements
Production reactor	A nuclear reactor that is designed primarily for the production of plutonium, tritium, and other isotopes by neutron irradiation of selected target materials

PUREX	Abbreviation for Plutonium U[R]anium E[X]traction A solvent extraction process commonly used in fuel processing that individually separates the uranium, neptunium, and plutonium from the accompanying fission products contained in the irradiated fuel
Quality assurance (QC)	A continuing program of test and evaluation to determine whether weapons materiel is of satisfactory quality, to determine the degree of conformance to design intent, and to determine the status of functional stockpile readiness through the use of periodic inspection reports and other checks
Radioactivity	The spontaneous disintegration of an unstable atomic nucleus resulting in the emission of either alpha or beta particles, gamma rays, or neutrons
Reactor core	The central portion of a nuclear reactor containing the fuel elements
Reclama	A request to duly constituted authority to reconsider its decision or its proposed action
Recycle	The reuse of unburned uranium and plutonium in fresh fuel after separation from fission products in spent fuel at a reprocessing plant
Reentry vehicle (RV)	That portion of a ballistic missile which carries the nuclear warhead It is called a reentry vehicle because it reenters the earth's atmosphere in the terminal portion of the missile trajectory
Reflector	A layer of material immediately surrounding a reactor core which scatters back or deflects into the core many neutrons that would otherwise escape Also, in nuclear warheads Common reflector materials are graphite, beryllium, and natural uranium
Reprocessing	The chemical treatment of spent reactor fuel to separate the plutonium and uranium from the fission products and from each other
Research and development (R&D) phases	The phases through which R&D effort passes in its evolution from initial inception to mature technology are: (1) basic research, (2) applied research, (3) exploratory development, (4) advanced development, and (5) engineering development
Research reactor	A nuclear reactor that is designed primarily for training and research
Resonance capture	An inelastic nuclear collision that occurs because of the strong tendency for a nucleus to capture incident particles or photons of electromagnetic radiation having particular (resonant) energies
Restricted Data (RD)	All data (information) concerning: (a) design, manufacture, or utilization of atomic weapons; (b) the production of special nuclear material; or (c) the use of special nuclear material in the production of energy, but shall not include data declassified or removed from the restricted data category pursuant to Section 142 of the Atomic Energy Act (Section 11w, Atomic Energy Act of 1954, as amended)
Safing	As applied to weapons and ammunition, the changing from a state of readiness for initiation to a safe condition
Salt cake	The damp solid formed when the liquid fraction of the high-level waste is removed through the use of an evaporation crystallizer
Scrap	Rejected nuclear material removed from the process stream Often requires separation from contaminants or chemical treatment to return the material to a state acceptable for subsequent processing
Separative work	A measure of the effort required in an enrichment plant or unit to separate uranium of a given U-235 content into two fractions, one having a higher percentage and one having a lower percent-

age of U-235 The unit of separative work is the kilogram separative work unit (kg SWU)

Solvent extraction	Chemical methods of recovering metals based on their preferential solubility in solvents immiscible in water Used in uranium milling to separate uranium from leach liquor and in fuel processing to separate plutonium and uranium from fission products
Source material	As defined under the Atomic Energy Act, ores containing uranium or thorium
Special isotope separation (SIS) plant	DOE facility using the atomic vapor laser isotope separation (AVLIS) process (or molecular laser isotope separation (MLIS) process) to enrich plutonium in the isotope Pu-239
Special nuclear material (SNM)	As defined under the Atomic Energy Act, plutonium, uranium-233, and uranium enriched in the isotope U-233 or the isotope U-235 SNM does not include source material such as natural uranium or thorium
Spent fuel	Fuel elements that have been removed from the reactor because they contain too little fissile material and too high a concentration of radioactive fission products They are highly radioactive
Stimulated emission	Physical process by which an excited molecule is induced by incident radiation to emit radiation at an identical frequency and in phase with the incident radiation
Stockpile	Nuclear storage Also, the total number of nuclear weapons which a nation maintains in storage at all locations and potentially available for deployment
Stockpile to target sequence	1 The order of events involved in removing a nuclear weapon from storage, and assembling, testing, transporting, and delivering it on the target 2 A document that defines the logistical and employment concepts and related physical environments involved in the delivery of a nuclear weapon from the stockpile to the target It may also define the logistical flow involved in moving nuclear weapons to and from the stockpile for quality assurance testing, modification and retrofit, and the recycling of limited life components
Strategic forces	Nuclear weapons and delivery systems designed for nuclear attack against strategic targets or for active defense agains such an attack Bombers, missile systems, and strategic interceptors Commonly refers to offensive weapons in the United States and Soviet Union that can deliver a nuclear strike on each other or a third party
Stripping	In uranium enrichment, the process of enriching the tails of an enrichment plant or previous enrichment stage In the PUREX solvent extraction process, the transfer of product from the organic phase back into the aqueous phase
Subcritical	An assembly containing an insufficient quantity of fissile fuel to sustain a fission reaction
Submarine-launched ballistic missile (SLBM)	A ballistic missile carried in and capable of being launched from a submarine
Tactical nuclear weapons	Nuclear capable devices assigned to support the conduct of battles and deployed close to likely areas of military engagement
Tails	The depleted stream of an enrichment plant or stage after the enriched product is removed Expressed as percent of U-235 content Also, applies to the depleted stream from uranium milling
Tamper	A heavy, dense material surrounding the fissionable material in an atomic weapon, for the purpose of holding the supercritical assembly together longer by its

	inertia, and also for the purpose of reflecting neutrons, thus increasing the fission rate of the active material
Target	Material irradiated with neutrons in a production reactor in order to produce plutonium-239, tritium, uranium-236, plutonium-238, or other desired isotopes
Thermal neutrons	Low-energy, low-speed neutrons in thermal equilibrium with their surroundings Frequently, neutrons with speed of 2200 m/s
Thermal reactor	A reactor in which the fission chain reaction is sustained by low-energy (thermal) neutrons which have been moderated to thermal energy in order to increase reaction probabilities
Thermonuclear weapon	A nuclear weapon (also referred to as hydrogen weapon) in which the main contribution to the explosive energy results from fusion of light nuclei, such as deuterium and tritium The high temperatures required for such fusion reactions are obtained by means of an initial fission explosion
Thorium-232	A naturally occurring isotope from which the fissile isotope U-233 can be bred by neutron capture
Transuranic (TRU) elements	Elements with atomic number greater than uranium (atomic number 92) They include neptunium, plutonium, americium, and curium
Tritium	An isotope of hydrogen, with an atomic number 1, atomic weight of 3, and a nucleus composed of one proton and two neutrons Tritium decays by beta decay, with a half-life of 12 3 years It can be produced by lithium-6 bombardment in nuclear reactors or in the fusion fuel of thermonuclear weapons Represented by T or H-3
Uranium-233	A fissile isotope bred by neutron capture in thorium-232 It is similar in weapons use to Pu-239
Uranium-235	The only naturally occurring fissile isotope Natural uranium has 0 7 percent of U-235 Reactors use natural or enriched uranium as fuel Weapons use uranium enriched to about 93 5 percent U-235
Uranium-238	A fertile isotope from wich Pu-239 can be bred It comprises 99 3 percent of natural uranium
Uranium hexafluoride	A volatile compound of uranium and fluorine that is a white crystalline solid at room temperature and atmospheric pressure but vaporizes upon heating, at 56 6 degrees C Feedstock in gaseous diffusion, gas centrifuge, and other enrichment processes
Uranium milling	The process by which uranium ore containing only a very small percentage of uranium oxide (U_3O_8) is converted into material containing a high percentage (80 percent) of U_3O_8, often referred to as yellowcake
Uranium ore concentrate	U_3O_8, often referred to as yellowcake
Vitrification	The solidification process in which high level waste is melted with a frit to form a glass
Warhead	That part of a missile, projectile, torpedo, rocket, or other munition which contains either the nuclear or the thermonuclear system, high explosive system, chemical or biological agents, or inert materials, intended to inflict damage
War reserve (nuclear)	Nuclear weapons materiel stockpiled in the custody of the Department of Energy or transferred to the custody of the Department of Defense and intended for employment in the event of war
Weapons grade (or weapon-grade)	Nuclear material considered most suitable for a nuclear weapon Uranium enriched to about 93% U-235 (Oralloy) or plutonium with greater than about 93%

	Pu-239 Weapons can be fabricated from lower grade material
Wooden bomb	A concept which pictures a weapon as being completely reliable and having an infinite shelf life while at the same time requiring no special handling, storage, or surveillance
X-rays	Intermediate energy electromagnetic radiation, typically emitted during atomic transitions, having wavelength shorter than 10 billionths of a meter Differentiated from more energetic and shorter wavelength gamma rays, which originate in the nucleus
X-ray laser	A laser producing a beam of coherent x-rays A device driven by a nuclear explosion to produce a burst of coherent X-ray radiation before the device is vaporized by the fireball
Yellowcake	The product of the uranium milling process, containing about 80 percent U_3O_8 Loosely, U_3O_8 itself
Yield	The energy released in a nuclear explosion, expressed usually as the number of tons of TNT releasing the same amount of energy The total yield is manifested as nuclear radiation, thermal radiation, and blast energy, the actual distribution being dependent upon the medium in which the explosion occurs, the type of weapon, and the time after detonation
Yield-to-weight ratio	The ratio of the yield to the mass of a nuclear warhead Expressed as Kt per kg or Mt per kg
Yield-to-volume ratio	The ratio of the yield to the volume of a nuclear warhead

Glossary of Abbreviations and Acronyms

A

AASM	Advanced Air-Surface Missile System
AAU	Argonne Associated Universities
ABM	Anti-Ballistic Missile
ADM	Atomic Demolition Munition
AEC	Atomic Energy Commission
AF	Air Force
AFB	Air Force Base
AFGL	Air Force Geophysics Laboratory
AFS	Air Force Station
AFSC	Air Force Systems Command
AFRRI	Armed Forces Radiobiology Research Institute
AFWL	Air Force Weapons Laboratory
AGC	Advanced Gas Centrifuge
AIS	Advanced Isotope Separation
Al	Aluminum
ALO	Albuquerque Operations Office
Am	Americium
AMAC	Aircraft Monitor and Control
AMC	Army Materiel Command
AMCCOM	Army armament Munitions and Chemical C[O]mmand
AMU	Atomic Mass Unit
ANCA	Army Nuclear and Chemical Agency
ANL	Argonne National Laboratory
Ar	Argon
ARES	Advanced Research EMP Simulator
ARHCO	Atlantic Richfield Hanford C[O]mpany
ARSTAF	A[R]my S[TAF]f
ASD	Aeronautical Systems Division
ASDP	Assistant Secretary for Defense Programs
ASN (R,E & S)	Assistant Secretary of the Navy (Research, Engineering, and Systems)
ASROC	Anti-Submarine R[OC]ket
ASTD (AE)	Assistant to the Secretary of Defense (Atomic Energy)
ASW	Anti-Submarine Warfare
ATB	Advanced Technology Bomber ("Stealth")
ATF-1	Advanced Toroidal Facility-1
AVLIS	Atomic Vapor Laser Isotope Separation
AWST	*Aviation Week and Space Technology* (magazine)

B

B	Bomb
BCSR	Boeing Computer Services, Richland, Inc
Be	Beryllium
BeO	Beryllium Oxide
BMD	Ballistic Missile Defense
BNL	Brookhaven National Laboratory
BOAR	Bureau of Ordnance Atomic Rocket
BPET	Breeder Processing Engineering Test
BWIP	Basalt Waste Isolation Project
BWR	Boiling Water Reactor

C

CARL	Comparative Animal Research Laboratory

CCD	Counter[C]urrent Decantation
Cf	Californium
CFMO	Central Scrap Management Office
CFX	Californium Multiplia
CG	Consolidated Guidance
CGN	Nuclear powered cruiser
Ci	Curie
Cm	Curium
CND	Campaign for Nuclear Disarmament
CNO	Chief of Naval Operations
CO_2	Carbon Dioxide
COE	Chief Of Engineers
CPDF	Centrifuge Plant Demonstration Facility
CSA	Chief of Staff of the Army
CUP	Cascade Upgrade Program
CVN	Nuclear-powered aircraft carrier
CY	Calendar Year

D

D	Deuterium
D_2O	Deuterium Oxide ("heavy water")
DARCOM	Army Material Development And Readiness C[OM]mand
DARPA	Defense Advanced Research Projects Agency
DCNO	Deputy Chief of Naval Operations
DCP	Development Concept Paper
DCSLOG	Deputy Chief of Staff for L[OG]istics
DCSOPS	Deputy Chief of Staff for Operations and Plans; or in the Air Force Deputy Chief of Staff, Operations, Plans and Readiness
DCSRDA	Deputy Chief of Staff, Research, Development, and Acquisition
DEIS	Draft Environmental Impact Statement
DG	Defense Guidance
DNA	Defense Nuclear Agency
DOD	Department of Defense
DOE	Department of Energy
DPS	Decision Package Sets
DRAAG	Design Review And Acceptance Group
DRP	Defense Review Panel
DSARC	Defense Systems Acquisition Review Council
DSCS	Defense Satellite Communications System
D-T	Deuterium-Tritium
DU	Depleted Uranium
DWPF	Defense Waste Processing Facility

E

EBR	Experimental Breeder Reactor
EBT-B	Elmo Bumpy Torus-B
ECF	Expended Core Facility
EG&G	(Formerly) Edgerton, Germeshausen, and Grier, Inc
EMP	Electro[M]agnetic Pulse
EMPSAC	EMP Simulator for Aircraft
ENICO	Exxon Nuclear Idaho C[O]mpany
EOD	Explosive Ordnance Disposal
EPA	Environmental Protection Agency
ER	Enhanced Radiation
ERAB	Energy Research Advisory Board
ERDA	Energy Research and Development Administration
ESD	Electronic Systems Division
ETR	Eastern Test Range
eV	Electron Volt
EWD	Energy and Water Development
EWDA	Energy and Water Development Appropriation Subcommittee

F

F	Fuel-grade; or Fluorine
FBM	Fleet Ballistic Missile

FCDNA	Field Command Defense Nuclear Agency
FEIS	Final Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FFTF	Fast Flux Test Facility
FMEF	Fuels and Materials Examination Facility
FMPC	Feed Materials Production Center
FPU	First Production Unit
FRD	Formerly Restricted Data
FTE	Full-Time Equivalents
FY	Fiscal Year

G

g	Gram
GAO	General Accounting Office
GCEP	Gas Centrifuge Enrichment Plant
GDP	Gaseous Diffusion Plant
GE	General Electric Company
GLCM	Ground-Launched Cruise Missile
GOCO	Government Owned-Contractor Operated
GS	Dual-Temperature Water-Hydrogen Sulfide Exchange
GSA	General Services Administration

H

H	Hydrogen
H_2O	Hydrogen Oxide ("Water")
HAC	House Appropriations Committee (see Chapter One, footnote 9)
HASC	House Armed Services Committee (see Chapter One, footnote 9)
HEAF	High Explosive Application Facility
He	Helium
HE	High Explosive
HEDL	Hanford Engineering Development Laboratory
HEHF	Hanford Environmental Health Foundation
HEU	Highly Enriched Uranium
HLOS	Horizontal Line Of Sight
HLW	High Level Waste
HP	Horse[P]ower
HPD	Horizontal Polarized Dipole
HQ	Head[Q]uarters
HQMC	Head[Q]uarters, Marine Corps
HSTC	House Science and Technology Committee
HTGR	High Temberature Gas Reactor
HTRE	Heat Transfer Reactor Experiment
HUMINT	H[UM]an I[NT]elligence
HWR	Heavy Water Reactor

I

ICBM	Intercontinental Ballistic Missile
ICPP	Idaho Chemical Processing Plant
ID	Inside Diameter
IFPF	Idaho Fuels Processing Facility (Now ICPP)
IG	Inspector General
IHE	Insensitive High Explosive
INC	Insertable Nuclear Component
INEL	Idaho National Engineering Laboratory
INFCE	International Nuclear Fuel Cycle Evaluation
IOC	Initial Operational Capability
IPNS	Intense Pulsed Neutron Source
IRBM	Intermediate-Range Ballistic Missile
ISPM	International Solar Polar Mission
ISX-B	Impurity Studies Experiment-B

J

JAIEG	Joint Atomic Information Exchange Group
JAJ	J A Jones Construction Service Company

JCAE	Joint Committee on Atomic Energy
JCS	Joint Chiefs of Staff
JEC	Joint Economic Committee
JLRSA	Joint Long-Range Strategic Appraisal
JNACC	Joint Nuclear Accident Coordinating Center
JPAM	Joint Program Assessment Memorandum
JSAM	Joint Strategic Assessment Memorandum
JSCP	Joint Strategic Capability Plan
JSPD	Joint Strategic Planning Document
JSPS	Joint Strategic Planning System
JTA	Joint Test Assembly
JTCAMS	Joint Ta[C]tic[A]l Missile System

K

K	Kilo- (1000)
KEH	Kaiser Engineers Hanford Company
Kg	Kilogram
KJ	Kilo[J]oule
KMR	Kwajalein Missile Range
Kt	Kilotons
Kwh	Kilowatt-hour

L

LAMPF	Los Alamos Meson Physics Facility (Now Clinton P Anderson Meson Physics Facility)
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LCTF	Large Coil Test Facility
Li	Lithium
Lithco	Lithium Corporation of America
LIS	Laser Isotope Separation
LLNL	Lawrence Livermore National Laboratory
LLW	Low Level Waste
LMFBR	Liquid Metal Fast Breeder Reactor
LoADS	Low Altitude Defense System
LSI	Large Scale Integrated
LWBR	Light Water Breeder Reactor

M

M	Meter; million (10^6)
MC	Military Characteristics
MED	Manhattan Engineer District
MENS	Mission Element Needs Statement
MeV	Million Electron Volts
MFTF-B	Mirror Fusion Test Facility-B
MIR	Major Impact Report
MIRV	Multiple Independently targetable Reentry Vehicle
Mk	Mark
MLC	Military Liaison Committee
MLIS	Molecular Laser Isotope Separation
MM	Minute[M]an
MMP	Materials Management Plan
MRS	Monitored Retrieval Storage
MSWU	Million Separative Work Units
Mt	Megaton
MT	Metric Ton
MTU	Metric Ton Uranium
Mw	Megawatt
Mwd	Megawatt-day
Mw_e	Megawatt (electric)
Mw_t	Megawatt (thermal)

N

N	Neutron
NASAP	Nonproliferation Alternative Systems Assessment Program
NATO	North Atlantic Treaty Organization
NAVMAT	N[AV]al M[AT]eriel
NBC	Nuclear Biological and Chemical

NDB	Nuclear Depth Bomb
NDEW	Nuclear-Driven Directed Energy Weapons
NDRC	National Defense Research Council
NDT	Non[D]estructive Testing
NERP	(Oak Ridge) National Environmental Research Park
NFS	Nuclear Fuel Services
nm	Nanometer (10^{-9} meter)
NMC	Naval Material Command
NMMSS	Nuclear Materials Management and Safeguard[S]
NNPP	Naval Nuclear Propulsion Program
Np	Neptunium
NPR	New Production Reactor
NR	Nuclear powered Research submarine
NRC	Nuclear Regulatory Commission
NRDC	Natural Resources Defense Council, Inc
NRL	Naval Research Laboratory
NSC	National Security Council
NSDD	National Security Decision Directive
NSDM	National Security Decision Memorandum
NTRS	National Reactor Testing Station (Now INEL)
NTS	Nevada Test Site
NUMEC	Nuclear Materials Equipment Corporation
NVO	Nevada Operations Office
NWCF	New Waste Calcining Facility
NWDG	Nuclear Weapons Development Guidance
NWEF	Naval Weapons Evaluation Facility
NWSM	Nuclear Weapons Stockpile Memorandum

O

O	Oxygen
OD	Outside Diameter
ODCSOPS	Office of the Deputy Chief of Staff for Operation[S] and Plans
OJCS	Office of the Joint Chiefs of Staff
OMA	Office of Military Application
OMB	Office of Management and Budget
ONEST	Overseas Nuclear Emergency Search Team
ORAU	Oak Ridge Associated Universities
ORGDC	Oak Ridge Gaseous Diffusion Complex
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
OSD	Office of the Secretary of Defense
OSRD	Office of Scientific Research and Development
OUSDRE	Office of the Under Secretary of Defense for Research and Engineering

P

PAL	Permissive Action Link
PBFA	Particle Beam Fusion Accelerator
PD	Presidential Directive
PDM	Program Decision Memorandum
PFM	Process Facility Modification
PHOTINT	P[HO]tographic I[NT]elligence
PNL	Pacific Northwest Laboratory
POG	Program Officers Group
PPBS	Planning, Programming, and Budgeting System
PSP	Plasma Separation Process
PSR	Proton Storage Rin
Pu	Plutonium
PuLIS	Plutonium Laser Isotope Separation
PUREX	Plutonium U[R]anium E[X]traction
PWR	Pressurized Water Reactor

R

R	Republican
R&D	Research and Development
RBOF	Receiving Basin for Offsite Fuel
RD&T	Research, Development and Testing
RDT&E	Research, Development, Testing and Evaluation
REEC	Reynolds Electrical and Engineering Company
RHO	Rockwell Hanford Operations
RMI	Reactive Metals, Inc
RRR	Reduced-Residual-Radioactivity
RTG	Thermoelectric Generator
RV	Reentry Vehicle

S

S	Second
SAC	Strategic Air Command; or Senate Appropriations Committee (see Chapter One, footnote 9)
SADM	Special Atomic Demolition Munition
SAF	Secure Automated Fabrication
SAGA	Studies, Analysis and Gaming Agency
SAMTO	Space And Missile Test Organization
SASC	Senate Armed Services Committee (see Chapter One, footnote 9)
SECDEF	S[EC]retary of D[EF]ense
SEU	Slightly Enriched Uranium
SICBM	Small ICBM
SIGINT	S[IG]nals I[NT]elligence
SIS	Special Isotope Separation
SLBM	Submarine-Launched Ballistic Missile
SNL	Sandia National Laboratories
SNLA	Sandia National Laboratories at Albuquerque
SNLL	Sandia National Laboratories at Livermore
SNM	Special Nuclear Material
SOW	Stand[O]ff Weapon
SR	Savannah River
SRAM	Short-Range Attack Missile
SRL	Savannah River Laboratory
SRO	Savannah River Operations office
SRP	Savannah River Plant
SSBN	Nuclear-powered ballistic missile submarine
SSN	Nuclear-powered attack submarine
STL	Simulation Technology Laboratory
STS	Stockpile-to-Target Sequence
SUBROC	S[UB]marine R[OC]ket
SWU	Separative Work Unit

T

T	Tritium; Tera- (10^{12})
TAN	Test Area North
TASM	Tactical Air-to-Surface Missile, or Tomahawk Anti-Ship Missile
TBP	Tri[B]utyl Phosphate
TFTR	Tokamak Fusion Test Reactor
TRADOC	T[RA]ning And D[O]ctrine Command
TREAT	Transient Reactor Test Facility
TRU	T[R]ans[U]ranic waste
TTR	Tonopah Test Range
Tw	Terawatt (10^{12} watts)

U

U	Uranium
UCCND	Union Carbide Corporation, Nuclear Division
UF_4	Uranium tetra[F]luoride
UF_6	Uranium hexa[F]luoride
UO_2	Uranium Dioxide
UO_3	Uranium Trioxide
U_3O_8	Uranium Oxide ("yellowcake")
UK	United Kingdom
UNH	Uranyl Nitrate Hexahydrate, $UO_2(NO_3)_2 6H_2O$

UNI	United Nuclear Industries, Inc
U S	United States
USACDA	United States Arms Control and Disarmament Agency
USD(P)	Under Secretary of Defense, Policy
USDRE	Under Secretary of Defense for Research and Engineering
U S S R	Union of Soviet Socialist Republics

V

VLA	Vertical-Launch ASROC
VLSI	Very Large Scale Integrated
VPD	Vertical Polarized Dipole

W

W	Warhead, or Weapon-grade
WCF	Waste Calcining Facility
WEC	Westinghouse Electric Corporation
WHC	Westinghouse Hanford Company
WIPP	Waste Isolation Pilot Plant
WPPSS	Washington Public Power Supply System
WSCR	Weapon Design and Cost Report
WTR	Western Test Range

Y

Yr	Year

Z

ZPPR	Zero Power Plutonium Reactor
ZPR	Zero Power Reactor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