Presentation to the Governor's Nuclear Advisory Council, Columbia, South Carolina

Overview of Pit Production Challenges at Los Alamos National Laboratory

Greg Mello, Executive Director, Los Alamos Study Group, April 29, 2024

If preparations for pit production must occur, it would be better to do this at one adequate site and facility, namely SRPPF, for reasons of cost, safety, risk to other NNSA programs, and environmental impact. The only real "downside" to such a policy is that it would limit warhead deployment on the Sentinel ICBM to the present single-warhead level for an unknown period of time. Despite decades of work, the LANL plutonium facility (PF-4) does not yet meet DOE safety standards and may never do so. PF-4, which is old and was built for R&D, not production, also houses several other NNSA programs, essential to the arsenal. The full scope of required investment at LANL remains unbounded and will grow. Inherent problems of the site and its facilities make success of current highly-ambitious plans doubtful. Even in the most successful case, LANL's pit production will be time-limited, as NNSA understands, and unable to support the U.S. arsenal. SRPPF, by contrast, could fully support the current U.S. nuclear arsenal or any smaller one. The best and only quasi-sustainable pit role for LANL is one of technology demonstration and training.

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Blog: Forget the Rest

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History of pit production at Los Alamos National Laboratory (LANL)

- **~150 simple pits, 1945-July 1949 (2, 7, 4, 37, ~100 in these years, respectively).**
- **From July 1949 to 2007, LANL was a pit R&D, not production, site.**
- **LANL made 30 War Reserve (WR) W88 pits over the 2007-2012 period (21 went to the stockpile), with a maximum of 11 in one year. This was a capability demonstration exercise, not an enduring production mission.**
- **LANL Plutonium Facility (PF-4) was subsequently shut down for 3+ years in 2013 due to egregious safety violations.**
- **From 2013 to now (11 years), LANL has had no actual WR pit production capability. Despite years of investment, PF-4, and some supporting LANL facilities, still do not meet DOE safety standards (discussed further below)**

Early plutonium pit and bomb production at LANL and elsewhere

Year	Stockpile	Notes
1945	2	DP facilities first operation Oct. or Nov. 1945; design began in Jan or Feb 1945; first bombing plan against Soviet cities delivered to Groves by end of August 1945
1946	9	7 of these usable; 2 lacked initiators. "Pincher" war plan against Soviets June 1946, LANL managers petition MED to get rid of all production work
1947	13	"One operable bomb in Jan. 1947," said David Lilienthal, AEC; Truman stunned
1948	50	Sandstone X-Ray test 4/14/48; Mk III (Fat Man) production immediately halted, switched to Mk IV; Sandia bomb assembly facility (Bldg 904) opened 9/1/1948, continued as primary assembly site through 1952
1949	250	Hanford took over all pit production July 1949; apparently no significant hitches
1950	450	
1951	650	
1952	1,000	Rocky Flats opened, Hanford continues pit production also
1953	1,350	

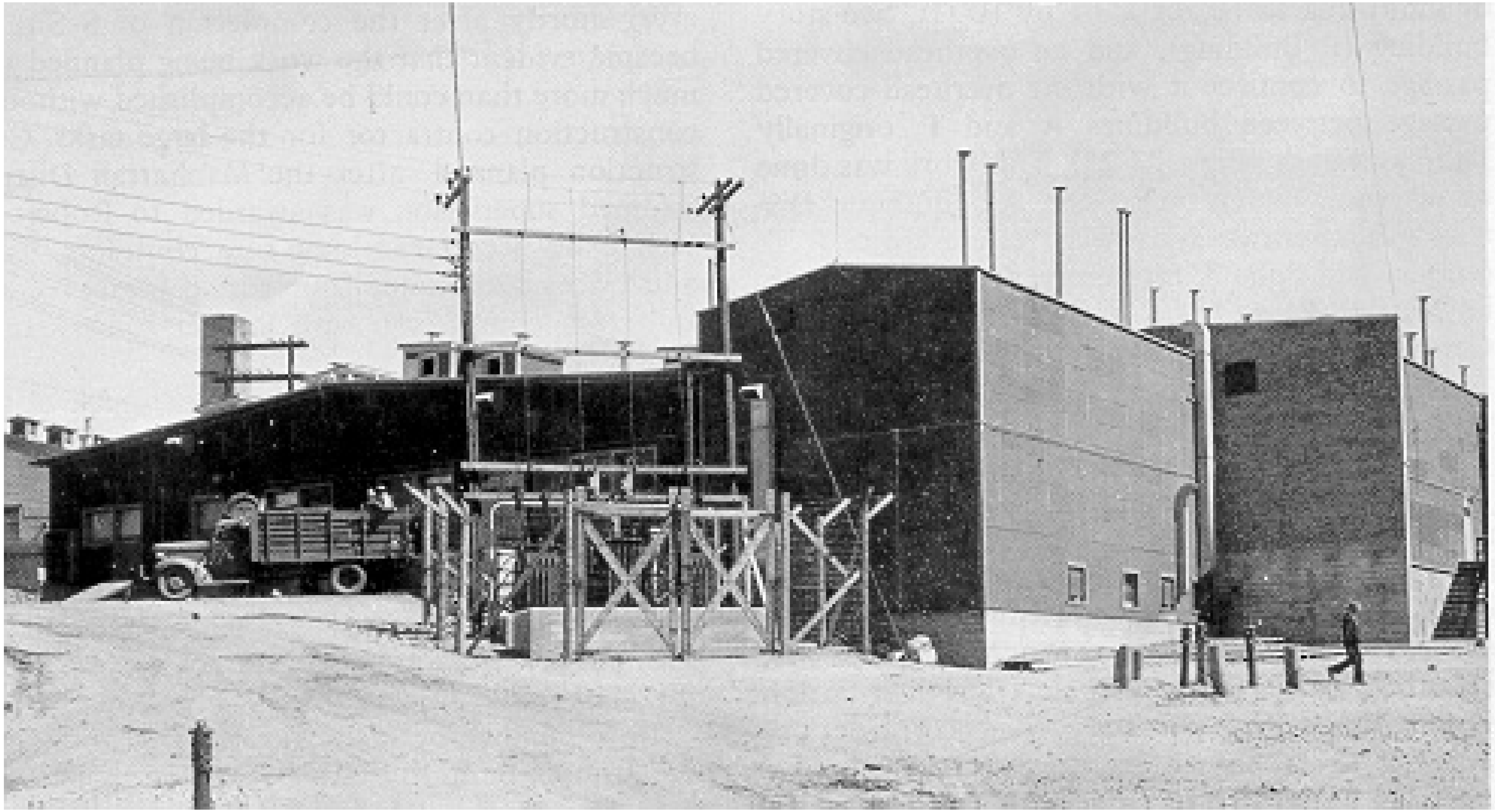
David Rosenberg, *Bull. Atom. Sci.* May 1982 pp. 25-30; Chuck Hansen, *US Nuclear Weapons, the Secret History,* 1987, https://www.sandia.gov/about/history/1940s/, Gregg Herken, *The Winning Weapon;* DOE *Linking Legacies;* "The Postwar Laboratory," Norris Bradbury et. al, 1946 LA-UR-16-28879.

Table 1. LANL Pit Manufacturing through FY11.

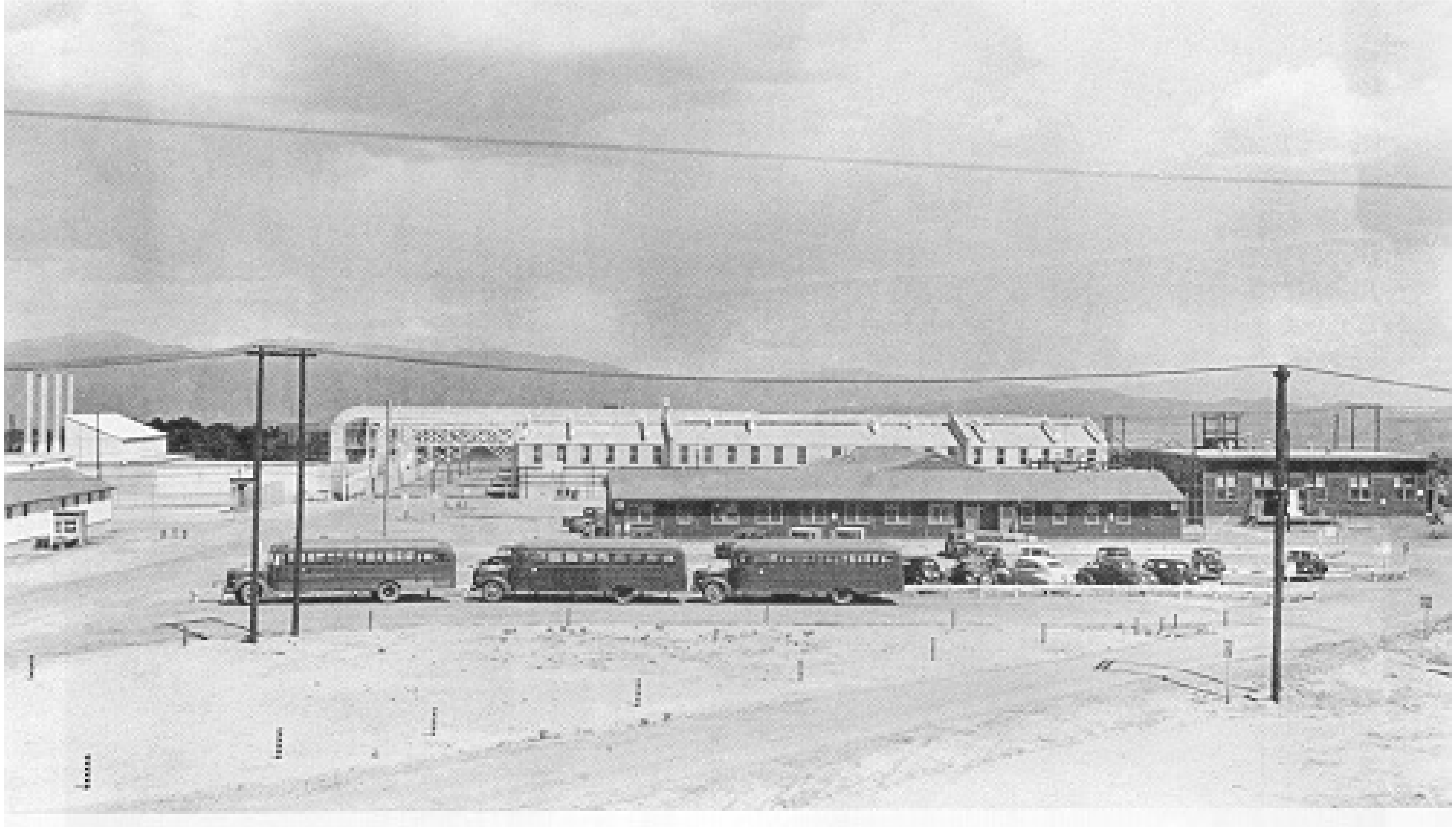
Fiscal Year	Total Pits Built against a 29 unit requirement	Pits delivered to the WR Stockpile	Pits delivered to Destructive Testing	Pits delivered to Shelf Life Surveillance
2007	11*	3	1	6
2008	6	5	0	1
2009	4*	4*	0	0
2010	6*	5	0	0
2011	2	3*	1*	0
2012	1	1	0	0
Total	30*	21*	2*	7

* One pit built in FY07 was accepted in FY09, One pit built in FY09 was accepted in FY10, and two pits built in FY10 were accepted in FY11

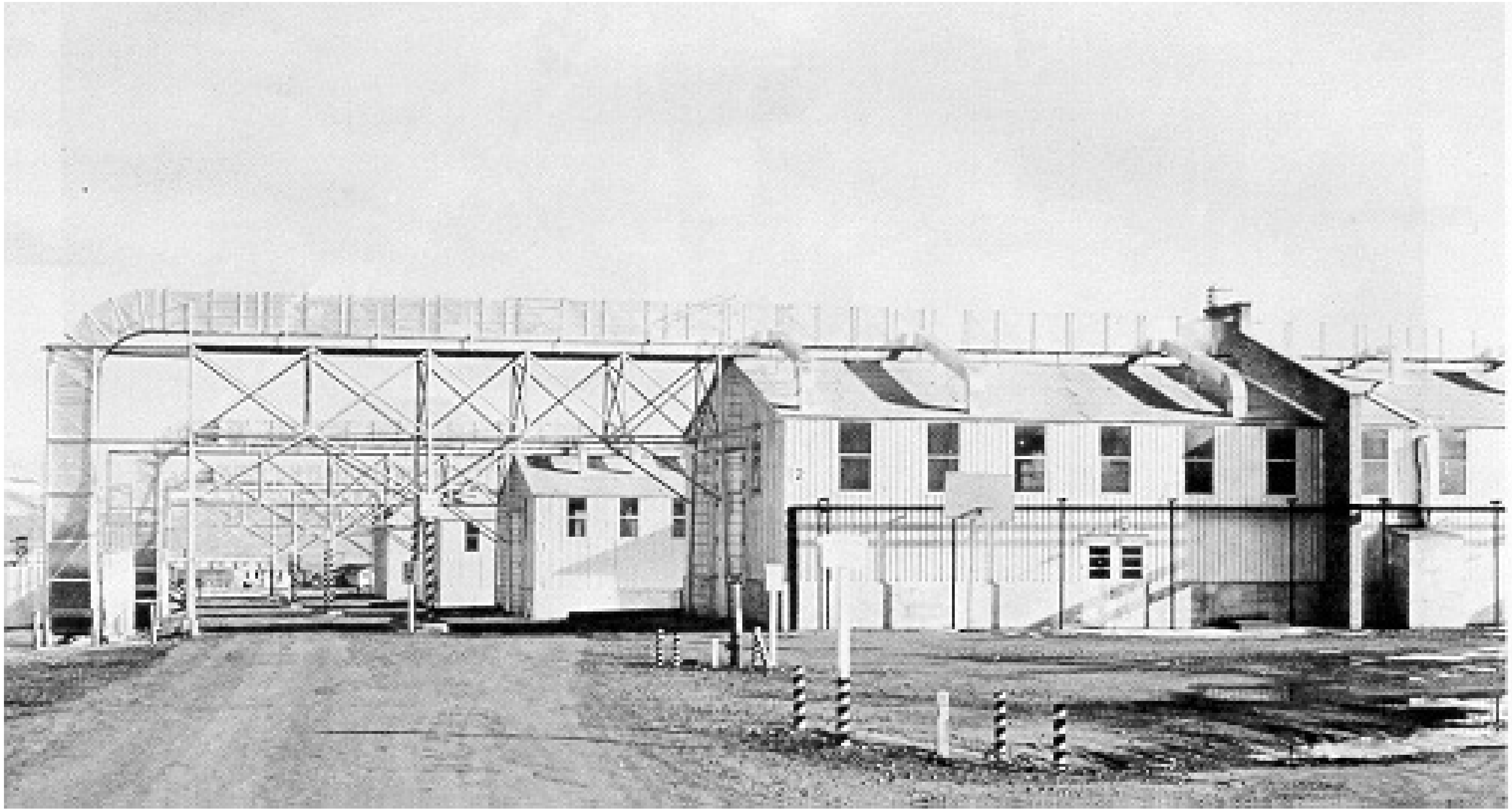
(From LA-UR-12-25400, "Pit Manufacturing Fiscal Year 2012 Program Report to the University of California, Bradford G. Story)



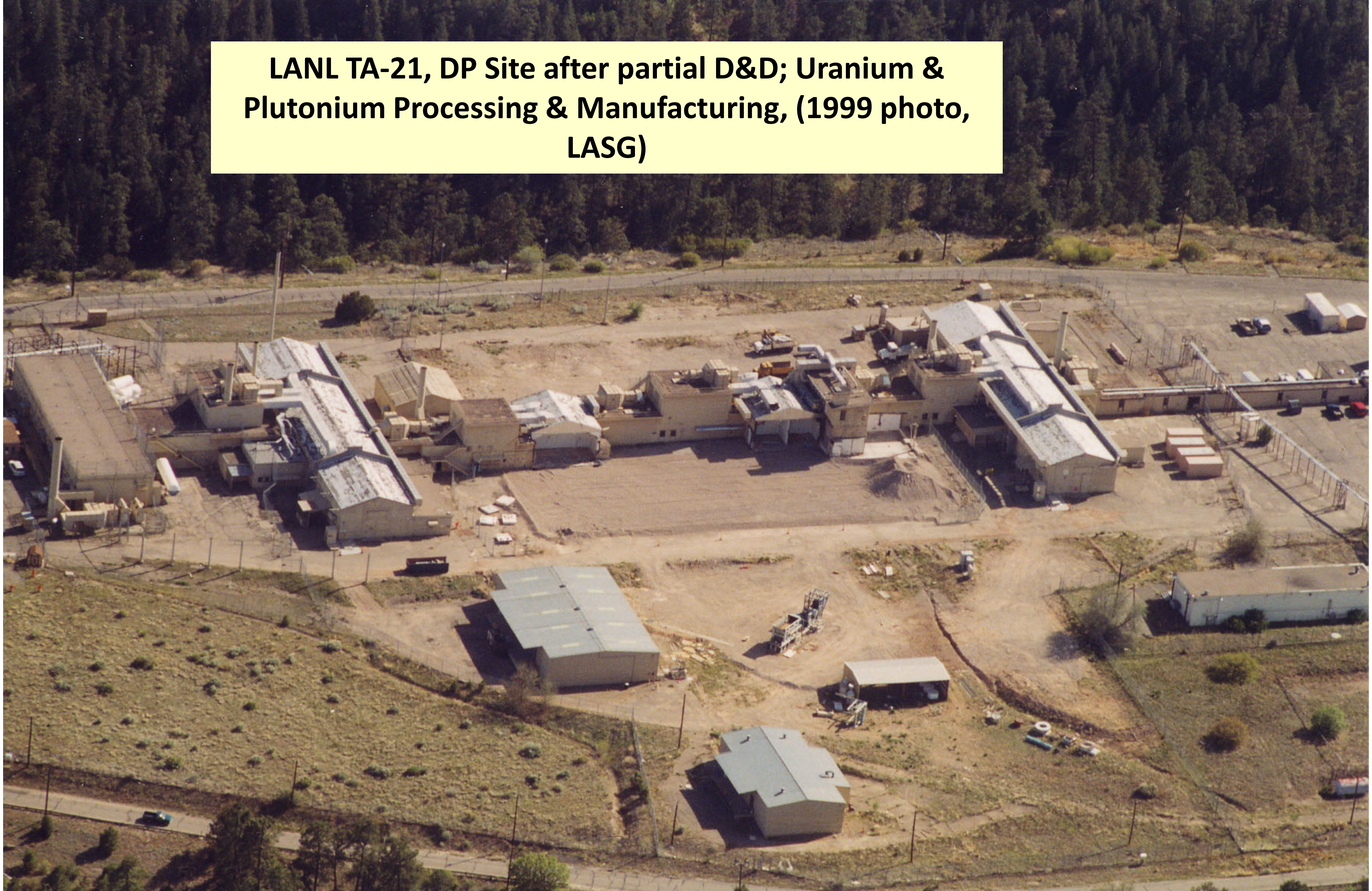
Building D, Los Alamos, circa 1944



DP Site ("D Prime"), TA-21, which replaced D Building in late 1945.

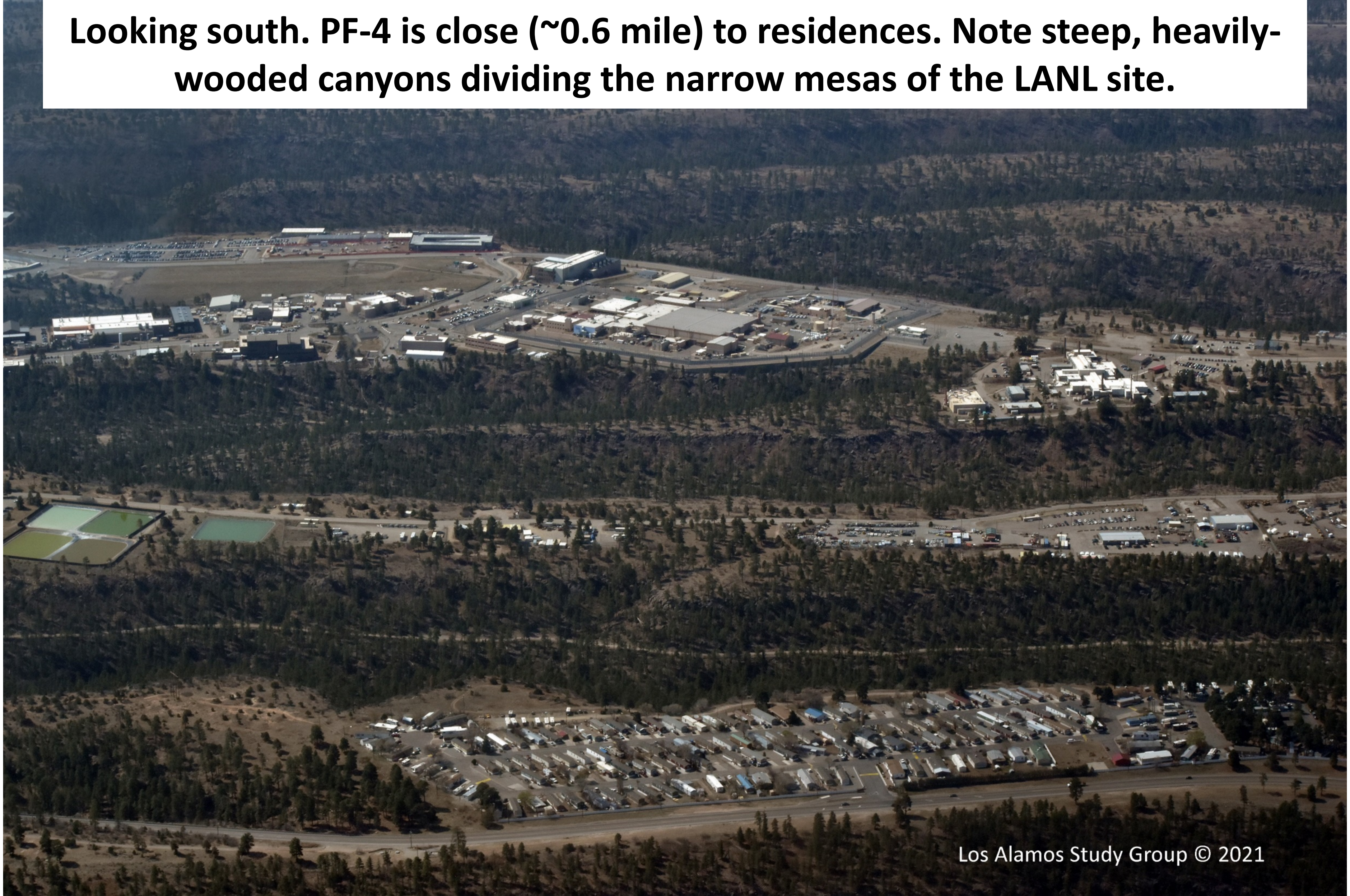


DP Site (TA-21); plutonium manufacturing in foreground

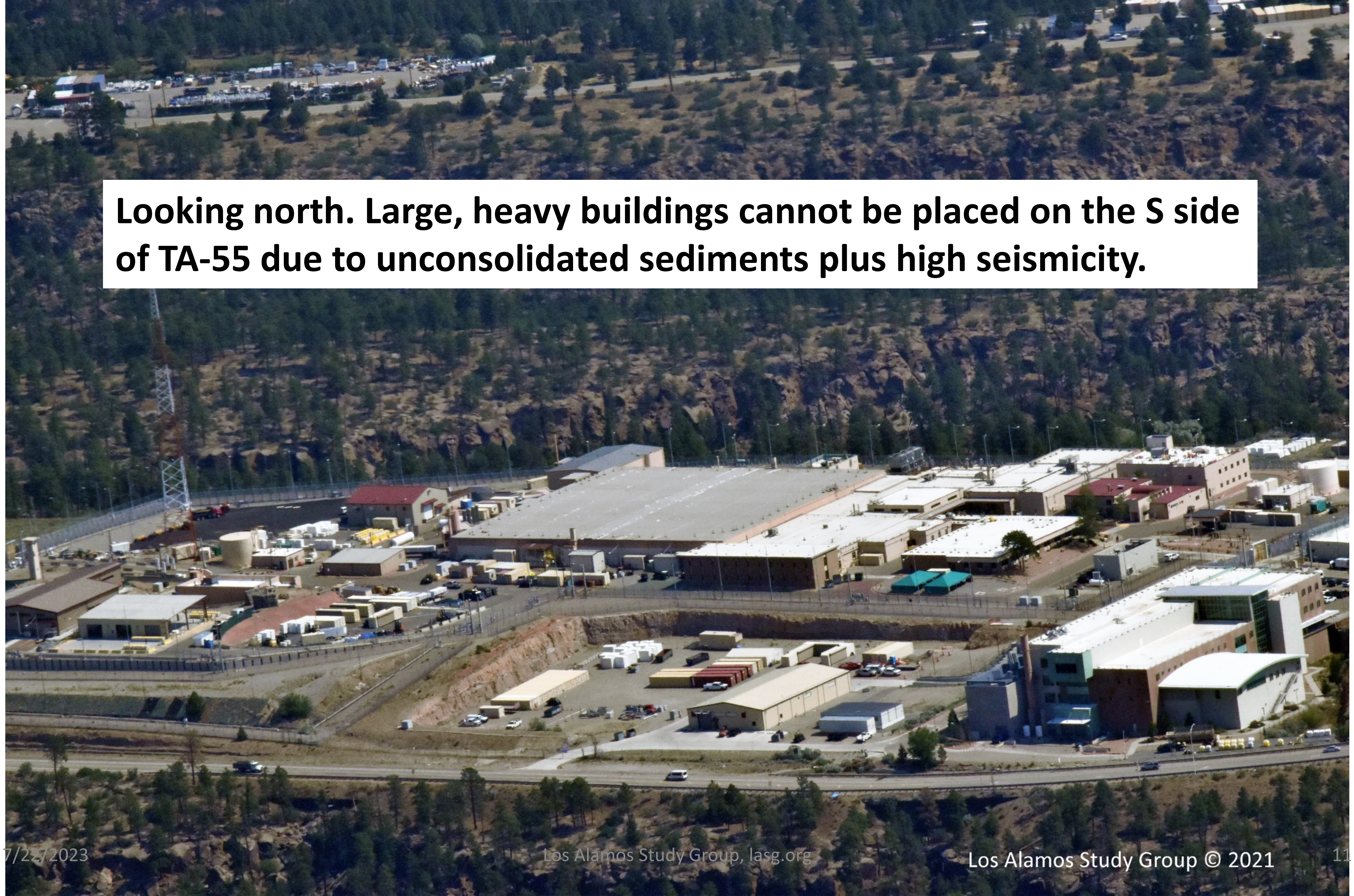


LANL TA-21, DP Site after partial D&D; Uranium & Plutonium Processing & Manufacturing, (1999 photo, LASG)

Looking south. PF-4 is close (~0.6 mile) to residences. Note steep, heavily-wooded canyons dividing the narrow mesas of the LANL site.



Looking north. Large, heavy buildings cannot be placed on the S side of TA-55 due to unconsolidated sediments plus high seismicity.

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Area G LLW disposal, TRU storage area; Pueblo Sacred Area, right.

Key issue: transportation (I)

Please see: [The troubled logistics of LANL pit production: how will LANL staff and contractors get to work?]

Enduring WR pit production is a new mission for LANL (2021 slide, updated)

Industrial plutonium pit production is a brand-new mission for LANL, recommended for the very first time on 5/10/18, placed in statute on 8/13/18, and detailed in twin NEPA decisions (here and here) on 9/2/20.

Until then, the LANL pit program had always been an "interim" "plutonium sustainment" program of strictly limited scale (≤20 pits/year), operating on a single work shift, with relatively modest cost (~$200 million/year).

The FY97 National Defense Authorization Act (NDAA) (signed 9/23/96) required a report on plans to produce plutonium pits at scale (p. 418). Pending those plans and a future decision based on them, DOE chose LANL for "development and demonstration work" (p. 11). The decision to limit pit production at LANL to a technology "sustainment" level was repeated multiple times, and any decision regarding capacity larger than 20 ppy postponed multiple times, until Sep. 2, 2020.

Subsequently, a capital project called the "Los Alamos Plutonium Pit Production Project" (LAP4) received the formal go-ahead ("CD-1") on April 28, 2021. Although it is the centerpiece of the pit effort, its limited scope (p. 204) and current high-end cost estimate of $3.9 B [$5.450 B in March 2024] show it is but a fraction of the total pit production effort, which reliable sources tell us LANL has estimated to cost $18 B over the current decade.

At present, LANL has no actual pit production capacity at all, beyond making developmental pits. In FY23, NNSA (meaning LANL, in the 2020s) is required to make one actual "War Reserve" pit, in FY24 10 pits, in FY25 20 pits, and in FY26 30 pits, which is the minimum rate LANL is required to maintain after that date. Upon information and belief, neither NNSA nor LANL expect to be able to exceed the 30 ppy *minimum* annual rate at LANL for the foreseeable future. This may translate to an *average* rate in the vicinity of 41 ppy (pp. 23, 51).

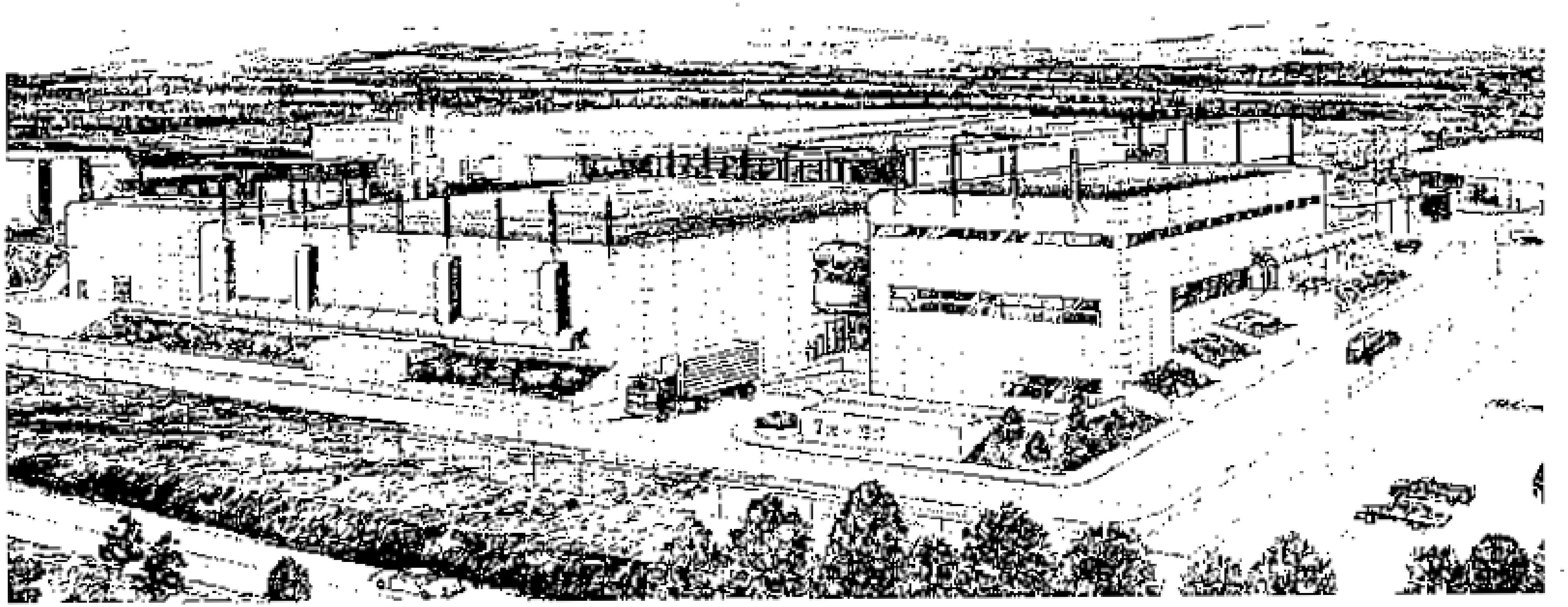
Failures of successive LANL pit production plans, to date

1. PF-4 + SNML, 1988-1991

In 1988 LANL, then directed by plutonium scientist Siegfried Hecker, began to plan for a large (193,000 sq. ft.) new plutonium facility at Technical Area (TA-)55 to greatly augment PF-4 capabilities, the Special Nuclear Materials Laboratory (SNML). As RFP shut down, LANL began acquiring key pit manufacturing personnel and equipment. Prominent experts and influential congresspersons began promoting LANL for pit production. Both New Mexico senators resisted this, as did the University of California and even LANL itself. SNML was put on hold in 1990 and canceled in 1991 in favor of the Chemistry and Metallurgy Research Upgrades (CMRU) project in TA- 3.

LALP-89-48 January 1990

Special Nuclear Materials Research and Development Laboratory Replacement Project at Los Alamos National Laboratory



Architectural rendering of the Special Nuclear Materials Research and Development Laboratory Replacement Project.

A glance back at LANL's first proposal for a post-Rocky Flats pit facility, to be located SW of PF-4 in TA-55

2. PF-4 + CMRU, 1991-2001

By 1993, DOE’s efforts to build a consolidated warhead production complex (“Complex 21”) had collapsed. LANL now actively sought the pit production mission, to be centered in PF-4 in TA-55 and enabled by CMRU.

A 1996 DOE study found LANL could solidify what it said was a pre-existing single-shift, 50 ppy capacity for $110 million (M) plus $30 M/year in added operating costs and $200 M in deferred PF-4 maintenance. If more pits were required LANL could provide a single-shift 100 ppy capacity for $44 M more.

As a result, DOE chose LANL over SRS for the "interim" pit production mission, set at ≤20 ppy because of the “small current demand” for pits.

LANL had no such capability. Key infrastructure elements weren't remotely suitable. CMRU proceeded haltingly for a decade before being found infeasible and was replaced by the Chemistry and Metallurgy Research Replacement (CMRR) project in 2001.

3. PF-4 + CMRR-NF + CMRR-RLUOB

After the Bush administration failed to convince Congress that a greenfield "Modern Pit Facility" (MPF) was justified, the incoming Obama administration again turned to LANL's PF-4 for pit production, this time to be augmented by two new buildings in TA-55: the Radiological Laboratory, Utility, and Office building (CMRR-RLUOB, now PF-400) and the large Nuclear Facility (CMRR-NF, originally >95% of the project's cost).

In 2010, DOE told DoD that LANL would be producing "a minimum of 50-80 pits/year in 2022" using PF-4 and the two CMRR facilities.

In 2012, CMRR-NF was indefinitely deferred. In 2014, it was cancelled. It too was infeasible. A subsequent NNSA study found that without CMRR-NF LANL was no longer be capable of 20-30 ppy absent a decade-long, $800 M effort and shifting some work to Lawrence Livermore National Laboratory.

RLUOB = Radiological Laboratory/Utility/Office Building
CMRR NF = Chemistry and Metallurgy Research Replacement Nuclear Facility
LLUOB = Light Laboratory/Utility/Office Building

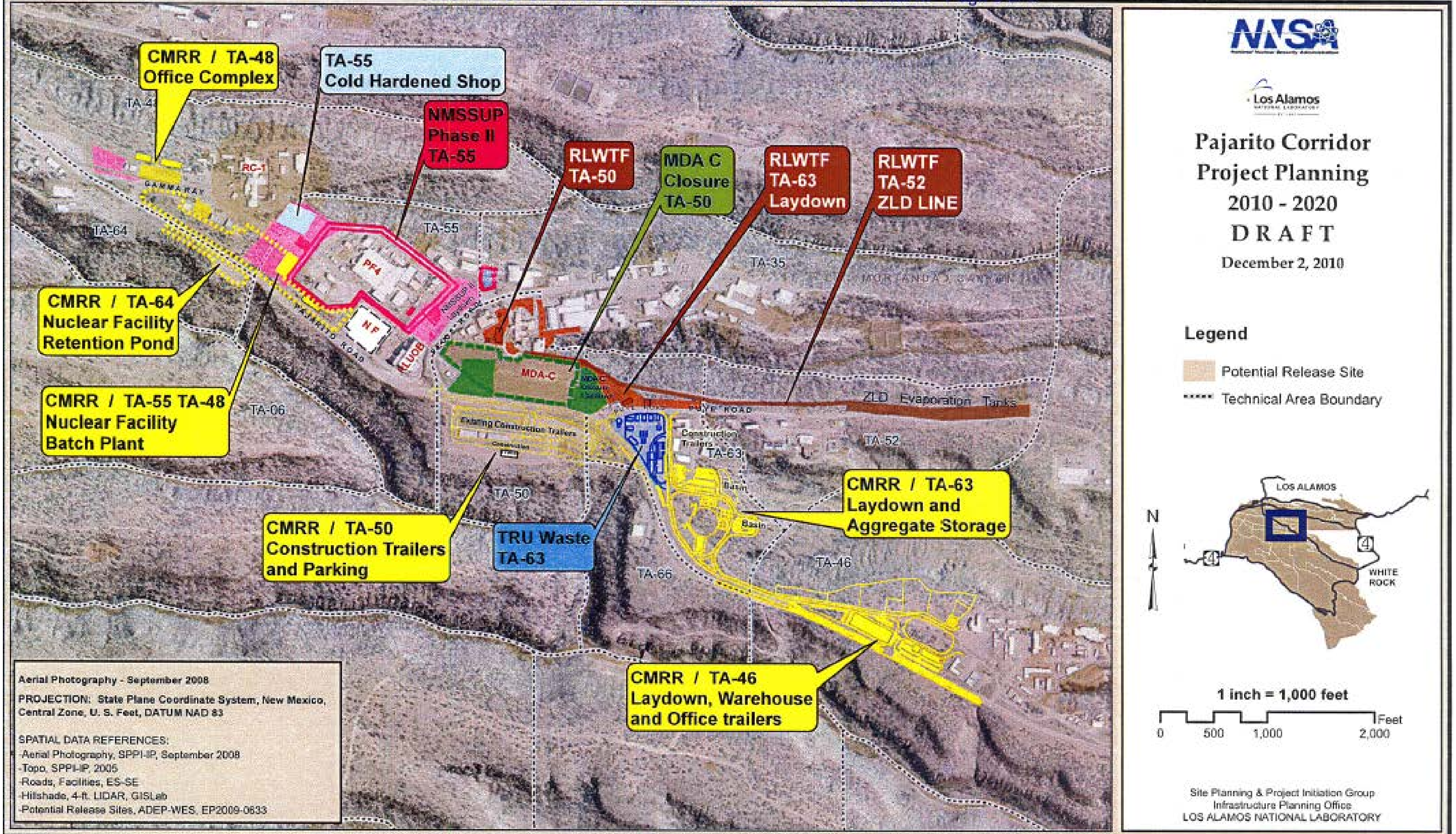
Figure S.3.4.1-7—TA-55 Site Plan Showing the Proposed CMRR and Manufacturing Annex Facilities

S.3.4.1.2.2 Los Alamos Upgrade Alternative to Provide Up To 80 Pits per Year ("50/80

Somewhat fanciful proposal for a pit factory at LANL, 2008.

Half of this was a real project (CMRR), most of which (CMRR-NF) was canceled due to LASG litigation and prior geologic acts of God.

Compare "Mfg. Annex LLUOB" to "Cold Hardened Shop," next slide



NNSA
Los Alamos
Pajarito Corridor
Project Planning
2010 - 2020
DRAFT
December 2, 2010
Legend
Potential Release Site
Technical Area Boundary
LOS ALAMOS
WHITE ROCK
N
1 inch = 1,000 feet
0
500
1,000
2,000
Feet
Site Planning & Project Initiation Group
Infrastructure Planning Office
LOS ALAMOS NATIONAL LABORATORY
CMRR / TA-48 Office Complex
TA-55 Cold Hardened Shop
NMSSUP Phase II TA-55
RLWTF TA-50
MDA C Closure TA-50
RLWTF TA-63 Laydown
RLWTF TA-52 ZLD LINE
CMRR / TA-64 Nuclear Facility Retention Pond
CMRR / TA-55 TA-48 Nuclear Facility Batch Plant
CMRR / TA-50 Construction Trailers and Parking
TRU Waste TA-63
CMRR / TA-63 Laydown and Aggregate Storage
CMRR / TA-46 Laydown, Warehouse and Office trailers
RC-1
PF4
NF
RLUOB
MDA-C
TA-64
TA-55
TA-35
TA-06
TA-50
TA-63
TA-52
TA-66
TA-46
ZLD Evaporation Tanks
Construction Trailers
Existing Construction Trailers
Basin
Basin
Aerial Photography - September 2008
PROJECTION: State Plane Coordinate System, New Mexico, Central Zone, U. S. Feet, DATUM NAD 83
SPATIAL DATA REFERENCES:
-Aerial Photography, SPPI-IP, September 2008
-Topo, SPPI-IP, 2005
-Roads, Facilities, ES-SE
-Hillshade, 4-ft. LIDAR, GISLab
-Potential Release Sites, ADEP-WES, EP2009-0633

4. PF-4 + “modules,” the "Plutonium Modular Approach" (PMA)

From 2012 to 2017 NNSA's pit production hopes – still all at LANL – shifted to a new plan, involving underground production "modules" adjacent to PF-4. In 2013 and in 2014 Congress mandated PMA construction. Mission need was established via CD-0 in 2015. This is now CD-0 for the Los Alamos Plutonium Pit Production Project (LAP4).

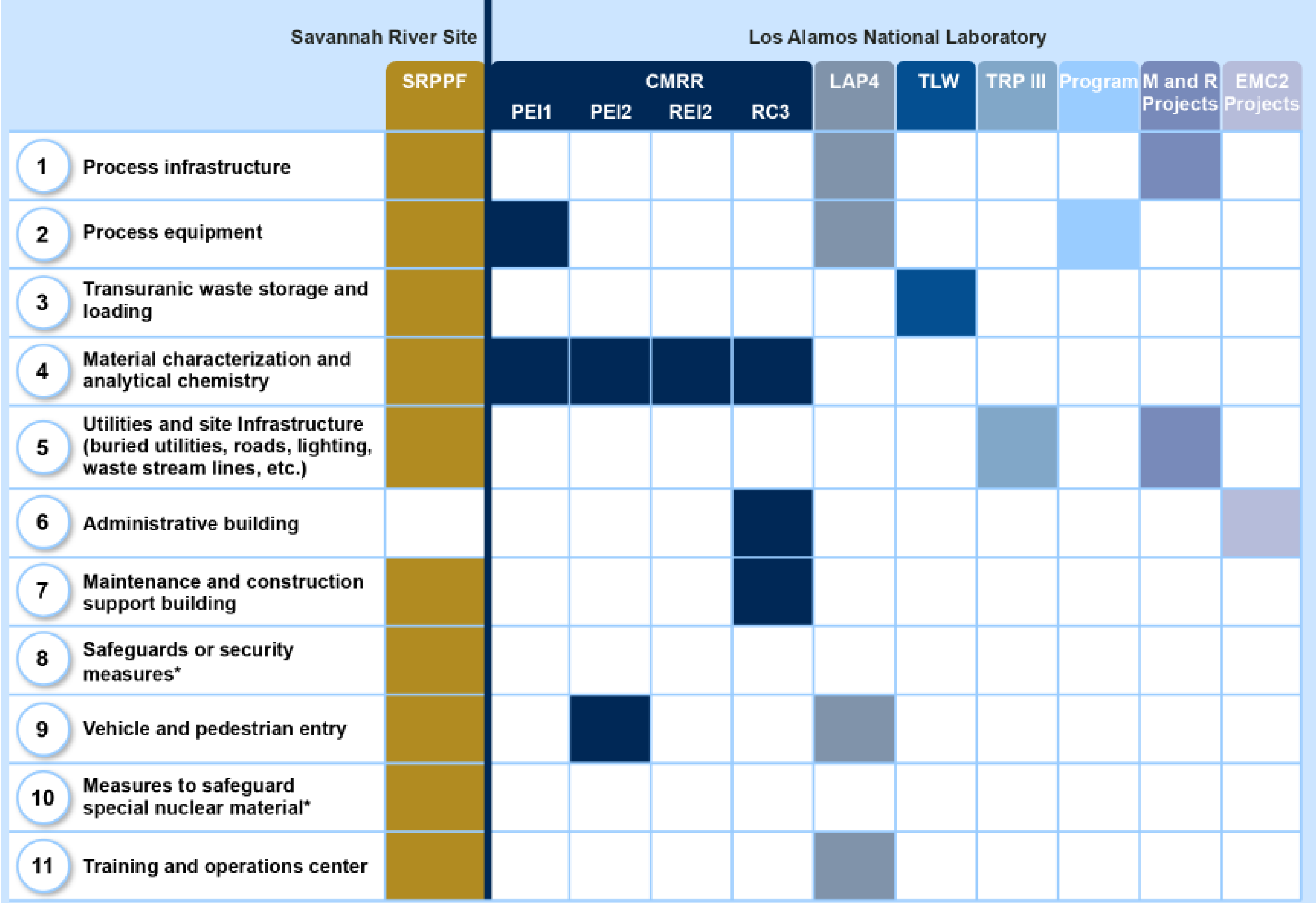
In August 2016 GAO issued a scathing review of PMA. In its 2017 *Analysis of Alternatives* NNSA found that TA-55 was too small to accommodate enough “modules” and the risk to existing Pu programs would be high. The 2018 *Engineering Analysis* found that LANL’s PMA plan (Option 2c) would take longer and have higher program risks than all other options examined.

PMA has vanished without a trace. The extra capacity embodied in the PMA concept is for now to be provided by two production shifts in PF-4.

Rendering of 3 module plan, 2018

5. PF-4 (as upgraded by LAP4) + TRPIII + PF-400 + TRUWF + TLWF + DAF + Sigma + new remote LANL campus(es) plus:

- **Pu Modernization Operations & Waste Management Bldg, Pu Mission Safety & Quality Bld, Pu Program Accounting Bldg, maybe Pu Production Bldg ($50 M each), maybe RACR ($37 M)**
- **Protective Forces Support Facil., Pu Engineering Support Bldg, ($99 M ea.)**
- **Pu-supporting small capital construction projects and equipment not included above**
- **Pu-supporting site-wide infrastructure improvements**
- **Site-wide and regional transportation investments**
- **Sigma Replacement (FY23 SSMP, pp. 117-118, FY24 SSMP pp. 129, 131; >"$750 M, FY24-34.") LASG est. >$1 billion**
- **PF-4 replacement/augmentation (FY21 Campus Master Plan p. 54), >>$10 billion if feasible (probably not) and if pursued (unlikely to be pit facility)**



* - Represents a pre-existing capability at Los Alamos National Laboratory

SRPPF: Savannah River Plutonium Processing Facility
CMRR: Chemistry and Metallurgy Research Replacement Project
PEI1: PF-4 Equipment Installation, Phase 1
PEI2: PF-4 Equipment Installation, Phase 2
REI2: RLUOB Equipment Installation, Phase 2

LAP4: Los Alamos Plutonium Pit Production Project
TLW: Transuranic Liquid Waste Treatment Facility Upgrade Project
TRP III: Technical Area-55 Reinvestment Project, Phase 3
Program: Plutonium Modernization Program
M and R Projects: Maintenance and Recapitalization Projects

From [GAO-23-104551](GAO-23-104551),

"NUCLEAR WEAPONS: NNSA Does Not Have a Comprehensive Schedule or Cost Estimate for Pit Production Capability," p. 70

Prospect: NNSA estimates of near-term LANL pit production

- 9 full "development" pits in FY2023; first production unit (FPU) of W87-1 in 4QFY24/1QFY25? (Hruby 4/18/24)
- Prep for production ≤10 ppy are funded by Pu Modernization.
- New "30 Diamond Strategy," aimed at optimizing activities to achieve 30 ppy at LANL ASAP (p. 231).
- Initial 30 pit per year (ppy) ***capacity*** (≠ ***production***) "in or near" FY2028 (Hruby 4/18/24). Apparently this is Key Performance Parameter (KPP) 30B KPP1: "Complete turnover to operations and equipment hot testing (as applicable) of the ***minimum*** equipment necessary for 30 WR ppy" (p. 237, emphasis added). 30 Base (30B) is the 2nd of 5 subprojects within the Los Alamos Plutonium Pit Production Project (LAP4, project 21-D-512).

NNSA estimates of near-term LANL pit production (continued)

- 30B KPP2: "Complete turnover to operations and equipment hot testing (as applicable) of the remaining equipment ***to support*** 30 WR ppy with ***moderate*** confidence." (p. 237, emphasis added). "Moderate" = 50% confidence (p. 236). Mean production will be ~30 ppy (see NNSA 2017, *Pit Production Analysis of Alternatives*, p. 41). This is 30B CD-4, estimated in 4QFY30. Equipment installation is not yet 30 WR ppy, however.
- 30R: "Complete equipment hot testing and turnover of all 30 ppy reliable equipment and structures, systems, and components in PF-4 and Sigma for *initiation of Process Prove-in activities*." (p. 237, emphasis added). 30 Reliable (30R) is the 3rd LAP4 subproject and aims at 90% confidence in ≥30 ppy with single-shift production, i.e. average production of ~40 ppy (AoA, p. 13) or ~36 ppy (NNSA CEPE, 2021, p. 7). Est. CD-4 for 30R is now 4QFY32.

Two estimates of WR LANL pit production, FY25-FY36, based on NNSA's public statements to date, assuming complete success

	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	Total
Low	1	5	10	15	20	25	30	36	36	36	36	36	**286**
High	1	10	15	20	25	30	35	40	40	40	40	40	**336**

Under these highly-optimistic assumptions (no serious problems, down-time, or accidents), total LANL production through 2040 would be 430-456 WR pits. Are these optimistic assumptions warranted? What additional infrastructure investments will be required as PF-4 reaches end of life?

Could LANL production be run with 2 shifts to get an additional 144-160 pits (574-616 pits total) over the FY33-FY40 period?

LANL pit production: cost and schedule overruns

A 1996 DOE study found LANL could solidify what it said was a single-shift, 50 ppy capacity for $110 million (M), plus $30 M/year in added operating costs and $200 M in separately-justified PF-4 deferred maintenance. Total capital cost for 50 ppy: $310 M in 1996 $, or **$622 M in 2024 $**.

If more pits were required LANL could provide a single-shift 100 ppy capacity for $44 M more, for a total of $616 M and $52 M/year in today's [2021] dollars. Total capital cost for 100 ppy: $354 M in 1996 $, **$710 M in 2024 $**.

It was on the basis of these estimates that LANL was chosen for the interim pit production mission (at ≤20 ppy).

Production at these levels could begin, it was said, in 5 years, i.e. 1Q 2002.

AoA, October 2017:

- Cost: $3 B (30 ppy *nominal*, not ≥30 ppy; also *temporary*). "[A]fter a new 80 WR ppy capability is established, PF-4 can return to the research and development mission for which it was built," p. 2)
- Schedule: 2026 for full nominal (“Pu Sustainment”) production at 30 ppy.
- Rejects two-site production and enduring reliance on PF-4 for production.
- Contra DOE O. 413.3B, no AoA supports the present strategy.

EA, April 2018:

- No cost or schedule estimates, except this major uncosted change: the nominal, temporary 30 ppy at LANL is now assumed to be ≥30 ppy and "enduring."
- Nota bene, the EA halved the assumed floor area needed per piece of equipment vs. the AoA, without explanation.

NNSA's FY25 budget request and supporting documents

Our current detailed cost estimate for LANL pit production is presented in slides below. LAP4 has yet to be baselined (CD2/3 expected 4QFY26), but we assume no further cost escalation in LAP4 or in other necessary construction, or in program costs, beyond those presented in March 2024. We assuming full production reliability. We omit important infrastructure costs not yet budgeted. Taken together, these are very optimistic assumptions.

Under these assumptions, we estimate total costs for start-up to reliable ≥30 ppy at $22.1 B by 4QFY32. We estimate forward costs from FY24 for this capability at $13.6 B.

Since 1996, estimated LANL startup costs have increased from $622 M to $22.1 B (a factor of 36x), for 60-80% of the then-claimed production capacity, using these optimistic estimates.

If we start from the "modern" 2017 estimate, cost growth to reliable full-rate production ($3B to $22B) is a factor of 7x – again, being optimistic.

	Prior years	2019	2020	2021	2022	2023	**2024 enacted**	Through 2024
LANL Pu Modernization Program; ~$3.0 B in pre-2019 costs omitted (GAO 2023: $3.6 B through 2020); assumes linear cost growth post-2029 @$87.1 M/year as seen from FY28 to FY29	-	271.6	287.0	610.6	660.4	767.4	833.1	3,430.1
LANL Plutonium Pit Production Project (LAP4), 21-D-512		1.9	58.1	226.0	350.0	588.2	670.0	1,894.2
Chemistry Metallurgy Research Replacement (CMRR) Project, 04-D-125	1,713.0	237.0	168.4	169.4	138.1	138.1	227.1	2,791.1
LANL Transuranic (TRU) Liquid Waste Facility, 07-D-220-04	93.3	1.0	1.7	37.7	30.0	24.8	-	188.5
LANL TA-55 Reinvestment Phase III (TRP-III), 15-D-302	43.2	1.8	0.5	32.0	32.0	30.0	30.0	169.5
Subtotal LANL Pu Modernization, incl. line item construction listed	1,849.5	513.3	515.7	1,075.7	1,210.5	1,548.5	1,760.2	8,473.4
23-D-518. Plutonium Modernization Operations & Waste Management Office Building					1.3	48.5		49.8
24-D-511, Plutonium Production Building ($49.5 M) (not funded in FY24 or requested in FY25)								-
25-D-510 25-D-510, Plutonium Mission Safety & Quality Building					0.5			0.5
Total LANL Pu Modernization	1,849.5	513.3	515.7	1,075.7	1,212.3	1,597.0	1,760.2	8,523.7

	2025 requested	FYNSP 2026	FYNSP 2027	FYNSP 2028	FYNSP 2029	Total 2025-2029	Total through 2029
LANL Pu Modernization Program; ~$3.0 B in pre-2019 costs omitted (GAO 2023: $3.6 B through 2020); assumes linear cost growth post-2029 @$87.1 M/year as seen from FY28 to FY29	984.6	945.5	972.1	1,018.5	1,105.6	5,026.3	8,456.4
LANL Plutonium Pit Production Project (LAP4), 21-D-512	470.0	770.0	900.5	905.0	510.0	3,555.5	5,449.7
Chemistry Metallurgy Research Replacement (CMRR) Project, 04-D-125	-	100.0	110.0	110.0	20.0	340.0	3,131.1
LANL Transuranic (TRU) Liquid Waste Facility, 07-D-220-04	-	-	-	-		-	188.5
LANL TA-55 Reinvestment Phase III (TRP-III), 15-D-302	39.5	12.9	-	-		52.4	221.9
Subtotal LANL Pu Modernization, incl. line item construction listed	1,494.1	1,828.4	1,982.6	2,033.5	1,635.6	8,974.2	17,447.6
23-D-518. Plutonium Modernization Operations & Waste Management Office Building	0.2					0.2	50.0
24-D-511, Plutonium Production Building ($49.5 M) (not funded in FY24 or requested in FY25)						0.0	0.0
25-D-510, Plutonium Mission Safety & Quality Building	48.5		0.5			49.0	49.5
26-D-XXX, Plutonium Program Accounting Building				48.7		48.7	48.7
27-D-XXX, Plutonium Engineering Support Building					98.7	98.7	98.7
27-D-XXX, Protective Forces Support Facility					98.7	98.7	98.7
28-D-XXX, Radiography/Assembly Complex Replacement (RACR) (being revised)						-	-
	1,542.8	**1,828.4**	**1,983.1**	**2,082.2**	**1,833.0**	**9,269.5**	17,793.2

	2030	2031	2032	Total 2025-2032	Total through 2032
LANL Pu Modernization Program; ~$3.0 B in pre-2019 costs omitted (GAO 2023: $3.6 B through 2020); assumes linear cost growth post-2029 @$87.1 M/year as seen from FY28 to FY29	1,192.7	1,279.8	1,366.9	8,865.7	12,295.8
LANL Plutonium Pit Production Project (LAP4), 21-D-512	-	-	-	3,555.5	5,449.7
Chemistry Metallurgy Research Replacement (CMRR) Project, 04-D-125	-	-	-	340.0	3,131.1
LANL Transuranic (TRU) Liquid Waste Facility, 07-D-220-04	-	-	-	-	188.5
LANL TA-55 Reinvestment Phase III (TRP-III), 15-D-302	-	-	-	52.4	221.9
Subtotal LANL Pu Modernization, incl. line item construction listed	1,192.7	1,279.8	1,366.9	12,813.6	21,287.0
23-D-518. Plutonium Modernization Operations & Waste Management Office Building	-	-	-	0.2	50.0
24-D-511, Plutonium Production Building ($49.5 M) (not funded in FY24 or requested in FY25)				0.0	0.0
25-D-510, Plutonium Mission Safety & Quality Building	-	-	-	49.0	49.5
26-D-XXX, Plutonium Program Accounting Building	-	-	-	48.7	48.7
27-D-XXX, Plutonium Engineering Support Building	-	-	-	98.7	98.7
27-D-XXX, Protective Forces Support Facility	-	-	-	98.7	98.7
28-D-XXX, Radiography/Assembly Complex Replacement (RACR) (being revised)				-	-
Pu-supporting line item construction, average $50 M/yr 2030 and after	50.0	50.0	50.0	150.0	150.0
	1,342.7	1,429.8	1,516.9	13,558.9	**22,082.6**

Small capital construction & equipment **may** not be included

Leased remote spaces, potential remote campuses not included

Pit Disassembly and Processing Facility postponed, not included

Pro-rata site-wide infrastructure not included

PF-4 replacement/augmentation (FY21 Campus Master Plan p. 54) not included

Pu-supporting line item construction, average $50 M/yr 2030 and after

Sigma Replacement (FY23 SSMP pp. 117-118; FY24 SSMP pp. 129, 131; >$750 M, FY24-34), included @ $1 B

	2033-2035 (3 years)	Total 2025-2035	Total through 2035	**2036-2039 (4 years)**	Total 2025-2039	Total through 2039
	4,623.3	13,489.0	16,919.1	7,383.8	20,872.8	24,302.9
	-	3,555.5	5,449.7	-	3,555.5	5,449.7
	-	340.0	3,131.1	-	340.0	3,131.1
	-	-	188.5	-	-	188.5
	-	52.4	221.9	-	52.4	221.9
	4,623.3	**17,436.9**	25,910.3	**7,383.8**	**24,820.7**	33,294.1
	-	0.2	50.0	-	0.2	50.0
		0.0	0.0		0.0	0.0
	-	49.0	49.5		49.0	49.5
	-	48.7	48.7		48.7	48.7
	-	98.7	98.7		98.7	98.7
	-	98.7	98.7		98.7	98.7
		-	-		-	-
	150.0	300.0	300.0	200.0	500.0	500.0
		-	-		-	-
		-	-		-	-
		-	-		-	-
		-	-		-	-
	300.0	600.0	600.0	400.0	1,000.0	1,000.0
		-	-		-	-
Totals	**5,073.3**	18,632.2	**27,155.9**	7,983.8	**26,616.0**	**35,139.7**

Cost per LANL pit under assumptions of complete success, no big problems

	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY39
Low	1	5	10	15	20	25	30	36	36	36	36	36	
Σ	1	6	16	31	51	76	106	142	178	214	250	286	394
High	1	10	15	20	25	30	35	40	40	40	40	40	
Σ	1	11	26	46	71	101	136	176	216	256	296	336	456

	FY32	FY35	FY39	**Total operating cost without further investment, $B, FY32-FY39, same assumptions:**
Total cost, $B, *no further cost escalation*	22.1	27.2	35.1	
Lower bound, $M/pit	126	92	77	
Upper bound, $M/pit	156	109	89	
Forward cost from FY24, $B, *no escalation*	13.6	18.6	26.6	7-year total cost: 13
Lower bound, $M/pit	77	63	58	Low marg. cost: 46
Upper bound, $M/pit	96	74	68	High marg. cost: 52

NNSA estimates a total cost for the W87-1 program at $15.9 B (in then-year dollars), which we may take as a minimum cost. (GAO's 2020 estimate was $9-15 B.) *Both estimates are exclusive of pit production.*

To provide an average of two MIRV warheads to 450 Sentinel missiles to supplement the available 500 W87-0 warheads (leaving 30 W87-0 surveillance units), plus 30 surveillance units plus just 20 spares would require a production run of 900 W87-1 warheads. Many people assume (why?) that NNSA's requirement is for 800 W87-1s. This would give a unit cost of $20M, exclusive of pits.

NNSA has said the lifetime of PF-4 could be extended to as late as 2045. Assuming all goes perfectly (it won't) LANL could make as many as 700 W87-1 pits by then; 600 is a more realistic best case. **LANL pit production is temporary, even in the most optimistic case.**

W87-1 pits are to be the exclusive province of LANL for at least the 2030s. ("Los Alamos to make plutonium cores ("pits") for new ICBM, Savannah River to make pits for new submarine missile warhead"). The total per-pit cost of these LANL pits would be about $83M, assuming total program success (forward-looking per-pit costs: $63M).

Were pit costs included, W87-1 unit costs would rise to $103M (using total pit cost), 5x the current estimated cost, or $83M (using forward pit cost), 4x the current estimate. Early termination of the LANL pit production program would save most of these costs.

What will pits cost at the Savannah River Site (SRS)?

Short answer: much less, but don't know for sure *how* much less. First, "then:"

1. In 2018, the estimated 50-year life-cycle cost (LCC) estimate (EA briefing, S.10) was $27.8 billion (B). This was for ≥50 pits per year (ppy), which leads to an expected average single-shift production of 84 ppy (AoA, p. 13). At that time, the estimated average cost for each of 4,200 pits was $6.6 million (M)/pit.

   The LCC for ≥80 ppy, leading to an average of 103 ppy (AoA, p. 13), based on that estimate would be in the $30.4 B - $33.0 B range.

   This is based on: a) the additional 22 pieces of equipment required, beyond the original 111 pieces (AoA, p. 17) (20% more), in an additional 6,350 sq. ft. of Hazard Category (HC) 2 space (AoA, p. 45); and b) the additional 185 staff said to be required (i.e. 10% more) (SRPPF FEIS, at p. S-27).

   The average cost for each of the assumed 5,150 pits is $5.9 M/pit to $6.4 M/pit.

   There are great economies of scale in pit production.

2. Increasing LCC by $2.6 B to $5.2 B buys 103 - 84 = 950 more pits, leading to a marginal cost of $2.7 M/pit to $5.5 M/pit. CBO (August 2020, p. 14) estimated marginal pit cost at a mature 50-ppy SRPPF to be $6.0 M/pit.

What will pits cost at the Savannah River Site (SRS)? Crudely…

- Assume operating costs scale from 2018 to today with the personnel requirement. Assume the SRPPF FSEIS accurately predicts this at 1,830 FTEs for ≥50 ppy (vs. 722 in 2018) and 2,015 for ≥80 ppy.
- Use 2017 NNSA modeling for total pit production for these requirements (4,200 & 5,150 respectively)
- Assume capital costs for ≥50 ppy and ≥80 ppy are only trivially different if ≥80 ppy is not in fact the SRPPF requirement.

	2024 SRNS Bottom-up est.		2024 NNSA high	
	≥50 ppy case	≥80 ppy case	≥50 ppy case	≥80 ppy case
Capital cost, $B	18.5	18.5	25	25
50-yr operating cost per above assumptions, $B	58.7	64.7	58.7	64.7
Total 50-year life-cycle cost, $B	77.2	83.2	83.7	89.7
Average cost/pit, $M	18.4	16.2	19.9	17.4
Marginal cost/pit (costs for ≥80 ppy minus costs for ≥50 ppy)/950 pits, $M	6.3		6.3	

By comparison, four years ago, CBO estimated marginal pit cost at SRS at $6 B (August 2020, p. 14).

Workforce Recruitment and Training

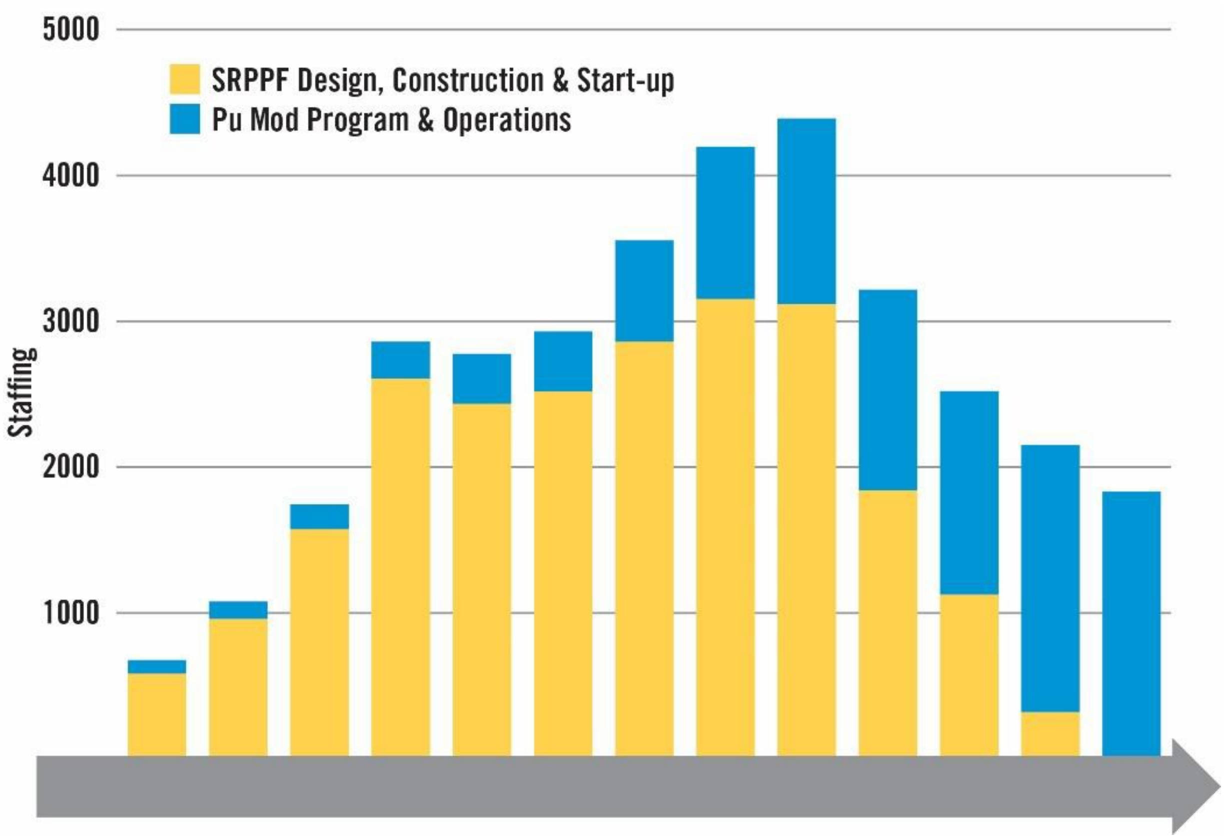
<u>Objective</u>: Recruit, hire, train and qualify ~1,800 future O&M and security staff over next 10 years

<u>Status</u>:

- Currently at 45 program staff (plus >600 project staff)
- Software model being utilized to balance staffing supply vs demand
- Working with colleges/tech schools to prime pipeline with candidates
- Active knowledge transfer program from LANL to SRS
- Benchmarking other NSE sites

<u>Near-Term Program Needs</u>:

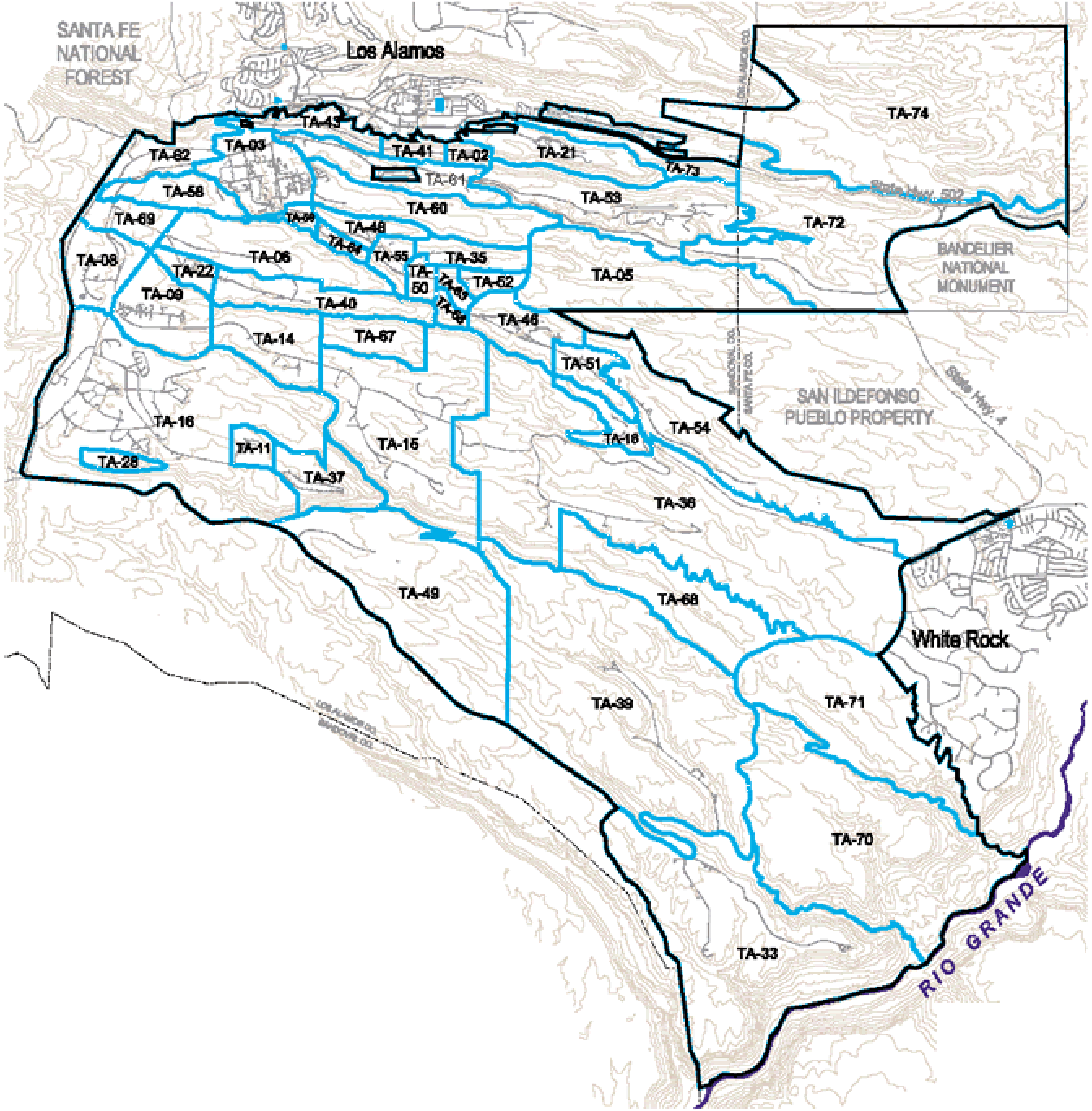
- Staffing – (see later slides)
- Other – Virtual Reality/Augmented Reality training platform for operators



NNSA, SRFO, slide 9, April 2022

LANL pit production: inherent geologic and geographical challenges

- Geographic isolation. Limited road access, long traffic standstills already, limited local housing, limited regional education and industry. Essentially no high-tech industry within 1.5 hour drive. Limited craft labor supply. Isolation underlies many other issues.
- Highly dissected topography, including near TA-55.
- LANL is effectively a rather small site, with few possible sites for nuclear facilities. Residences, highways, national monuments, tribal lands, are near nuclear facilities needed for pit production and waste staging.
- Unconsolidated sediments at modest depth beneath most or all LANL sites, amplifying seismic accelerations and providing poor lateral buttressing near mesa edges. At the surface, there is extensive fracturing of the more welded tuff, potentially destabilizing cliffs in major earthquakes, as LANL has observed (see LASG letter of 7/1/20 at 5.)
- High seismicity (Richter ≥7.0), near-surface (1-mile deep) epicenters, fault zone bordering site and splays traversing it.
- Pit production at LANL depends on a number of aging and/or questionable (PF-4, Sigma, Main Shops), new but with problems (TRUWF, RLUOB). Specialized functions (e.g. radiography) are challenged and may require workarounds (Pantex or DAF).


SANTA FE NATIONAL FOREST
Los Alamos
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TA-60
TA-72
State Hwy. 502
TA-69
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TA-08
TA-06
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BANDELIER NATIONAL MONUMENT
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TA-46
TA-14
TA-67
TA-51
SAN ILDEFONSO PUEBLO PROPERTY
State Hwy. 4
TA-16
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TA-11
TA-28
TA-37
TA-36
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White Rock
TA-39
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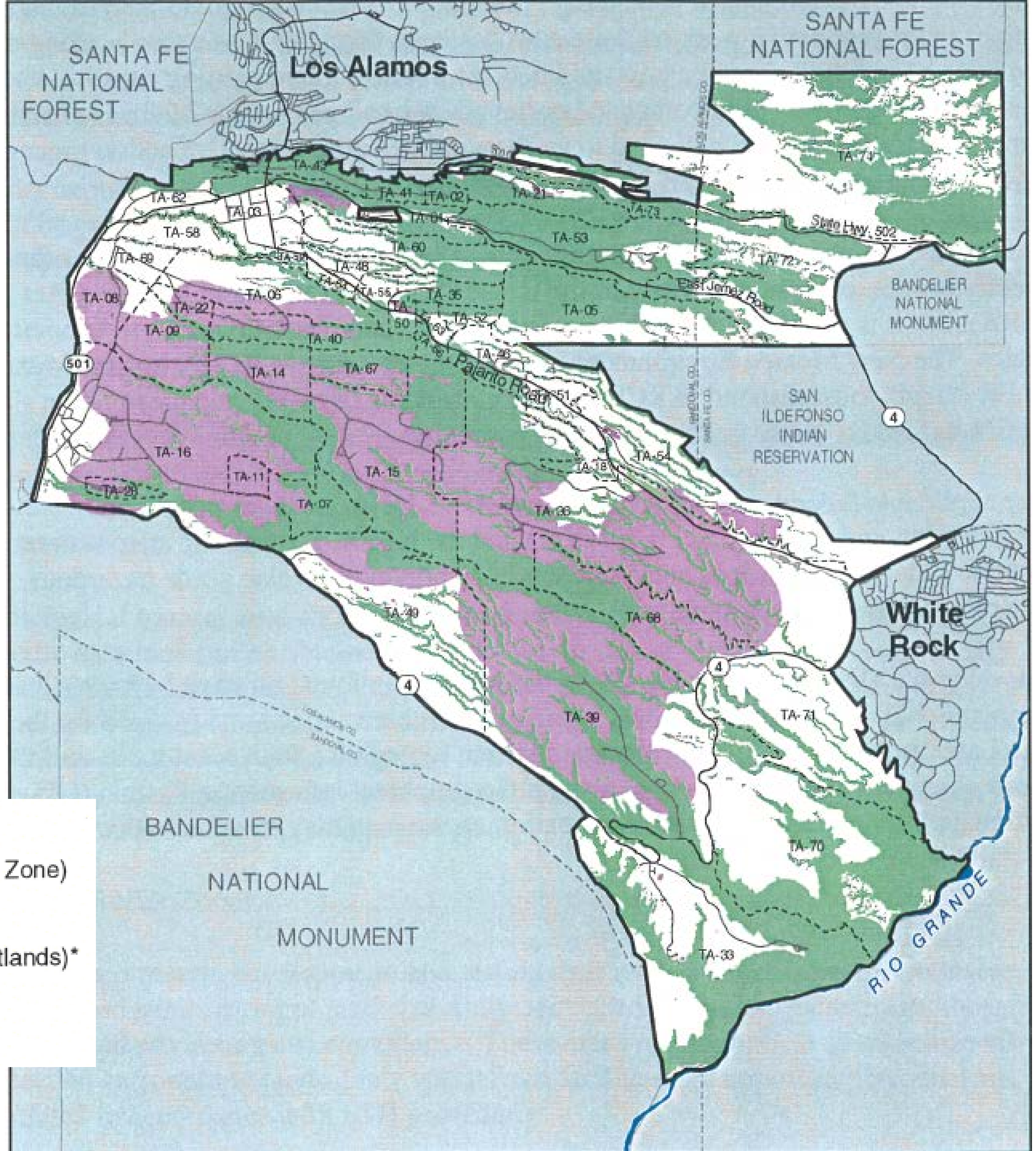
TA-33
RIO GRANDE

LANL operational and physical constraints, LANL, from 2000 Site Plan

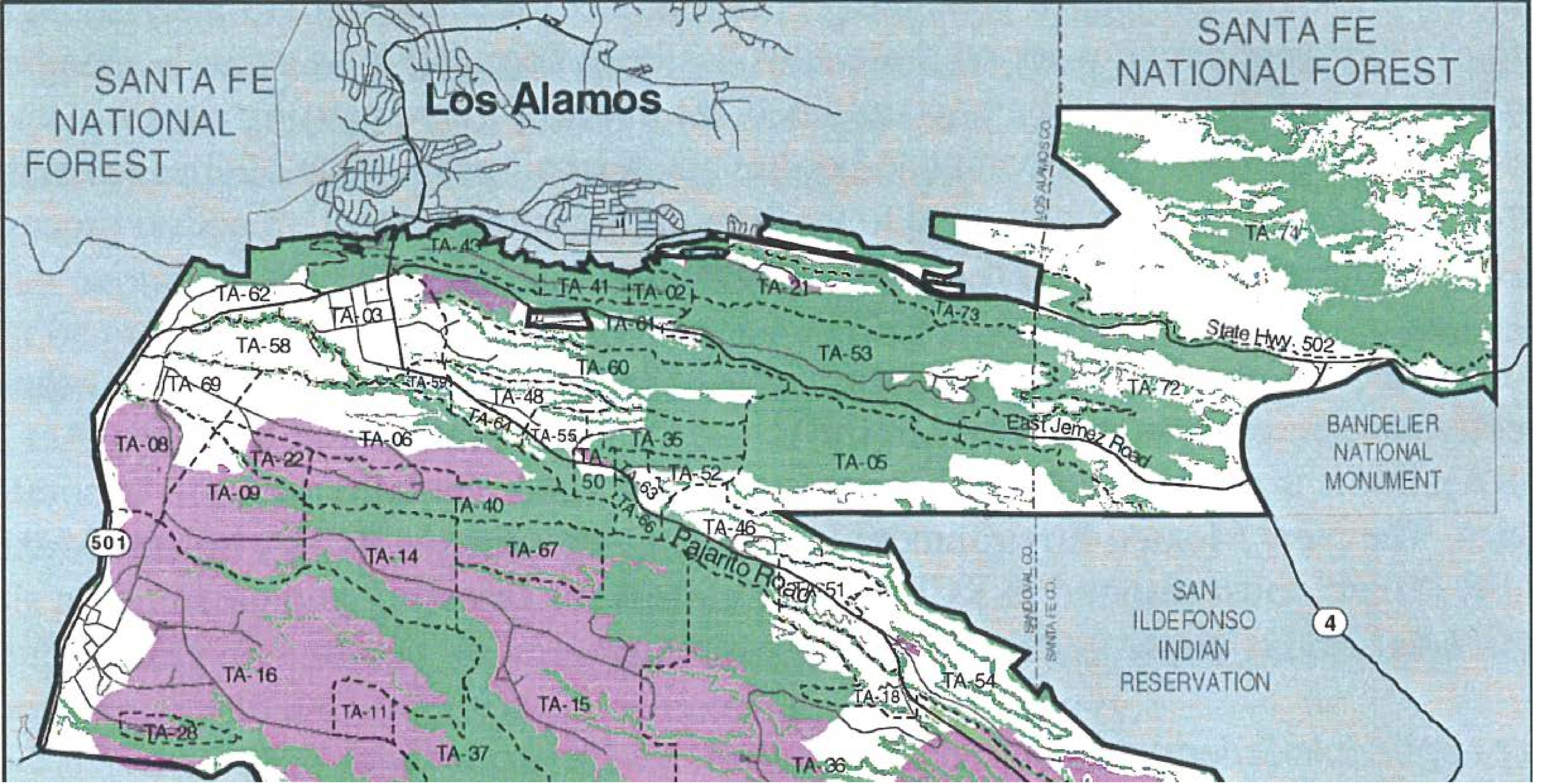


Operational Constraint (Hazardous Waste, Blast Buffer Zone)

Physical Constraint (Slope >20%, T&E Habitat, Wetlands)*

*Archeological Sites Not Shown

Also not shown: known active earthquake faults, buffer zones from site boundaries needed for a) security, b) limiting accidental exposures, and c) retaining open campus in TA-03.


SANTA FE NATIONAL FOREST
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SANTA FE NATIONAL FOREST
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State Hwy. 502
TA-69
TA-59
TA-48
TA-72
East Jemez Road
BANDELIER NATIONAL MONUMENT
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501
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TA-67
Pajarito Road
TA-51
SAN ILDEFONSO INDIAN RESERVATION
4
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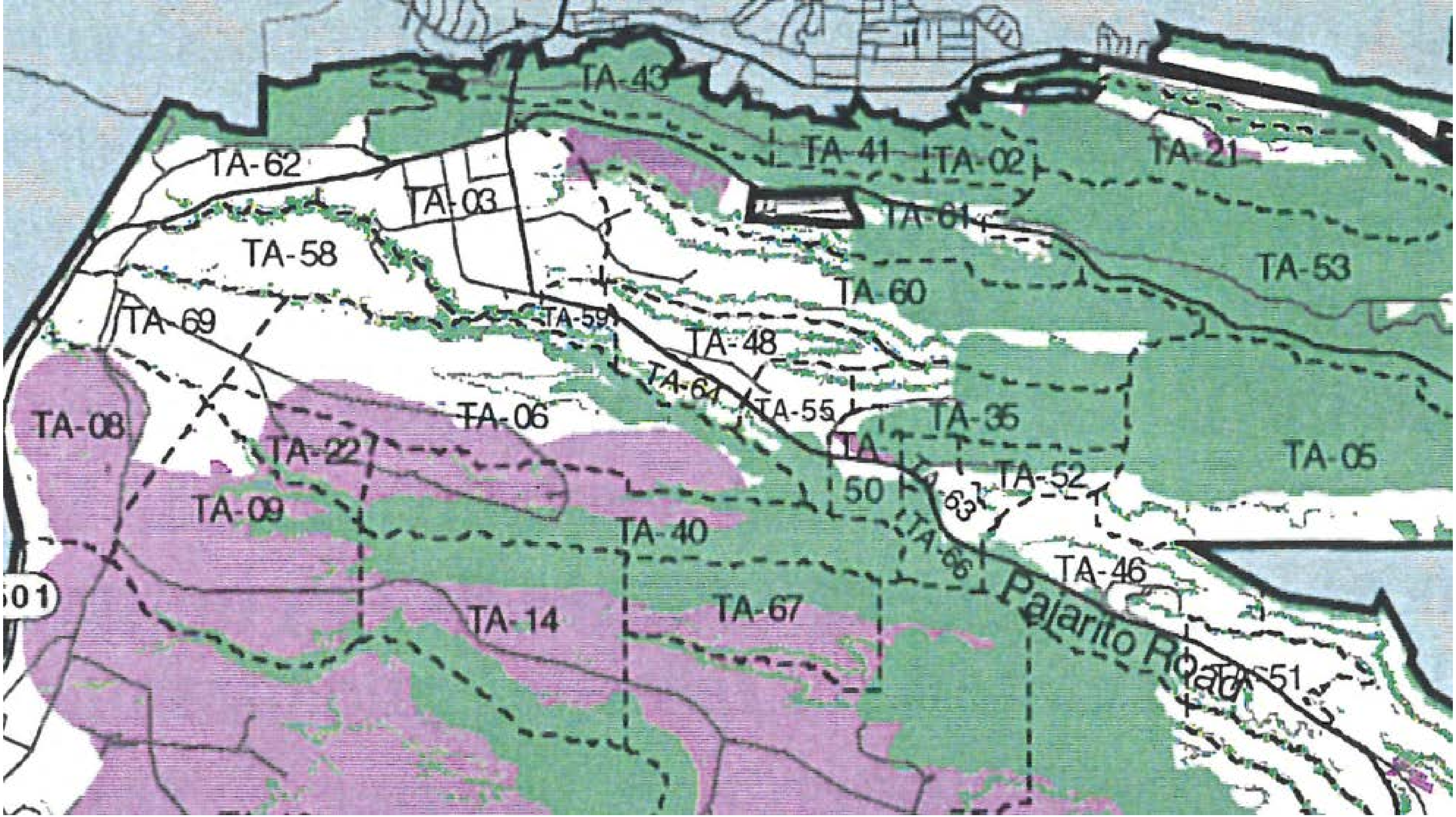
LOS ALAMOS CO.
SANTA FE CO.
SANDOVAL CO.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63
TA-09
TA-40
TA-66
TA-46
501
TA-67
TA-14
Pajarito Road
TA-51

PF-4 was built circa 1975 (opening in 1978) for R&D, not production. It is crowded, inside and out, requiring 24/7 work reach even 20 ppy (SA, 2020).

Seismic "demand" has increased x3 horizontally and x6 vertically since it was built (Keilers, NNSA, 2014).

No one knows when or how PF-4 will fail. Hopefully not too many people will be hurt.

Los Alamos Study group photograph, April 2021, looking S (from 12,000 ft).

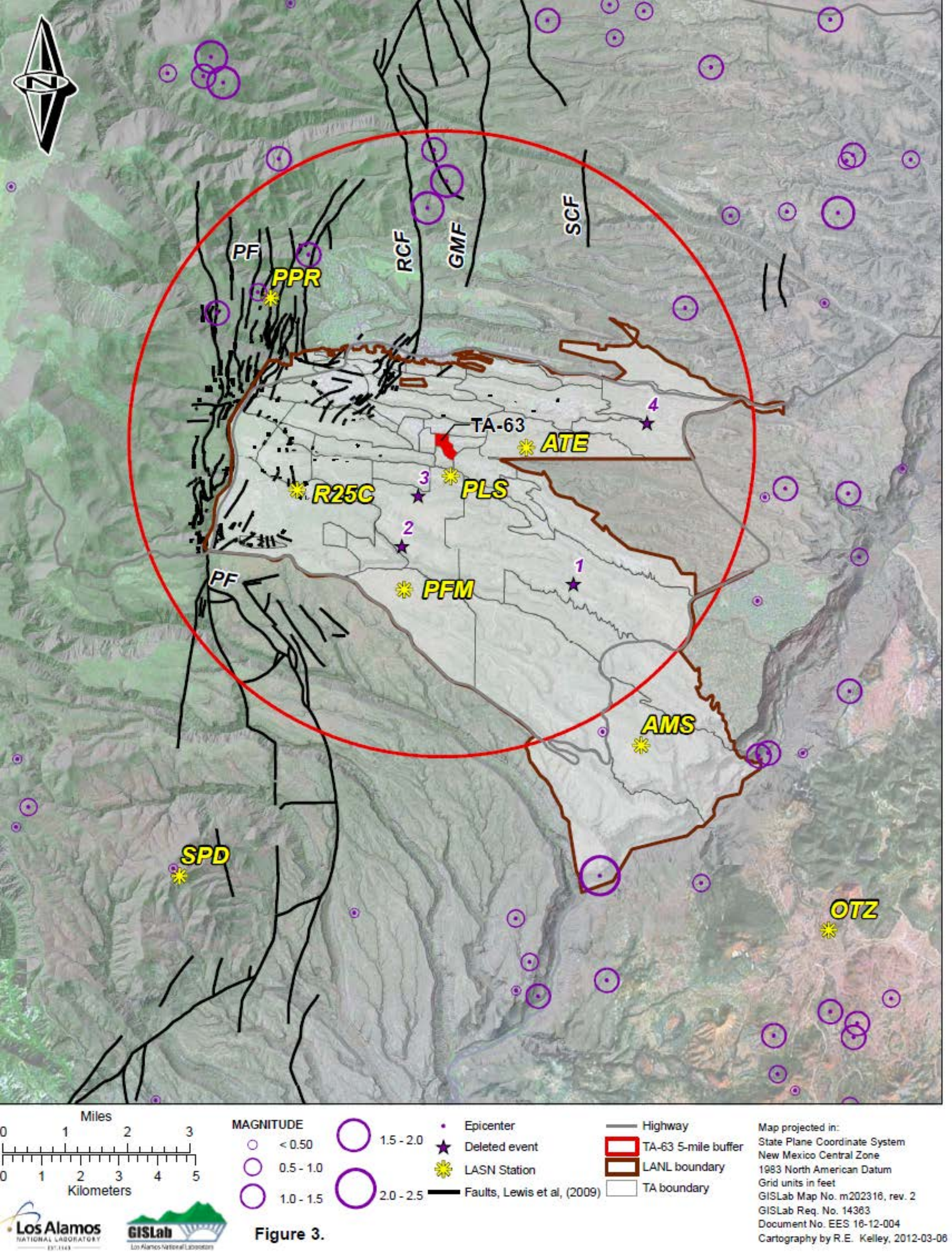
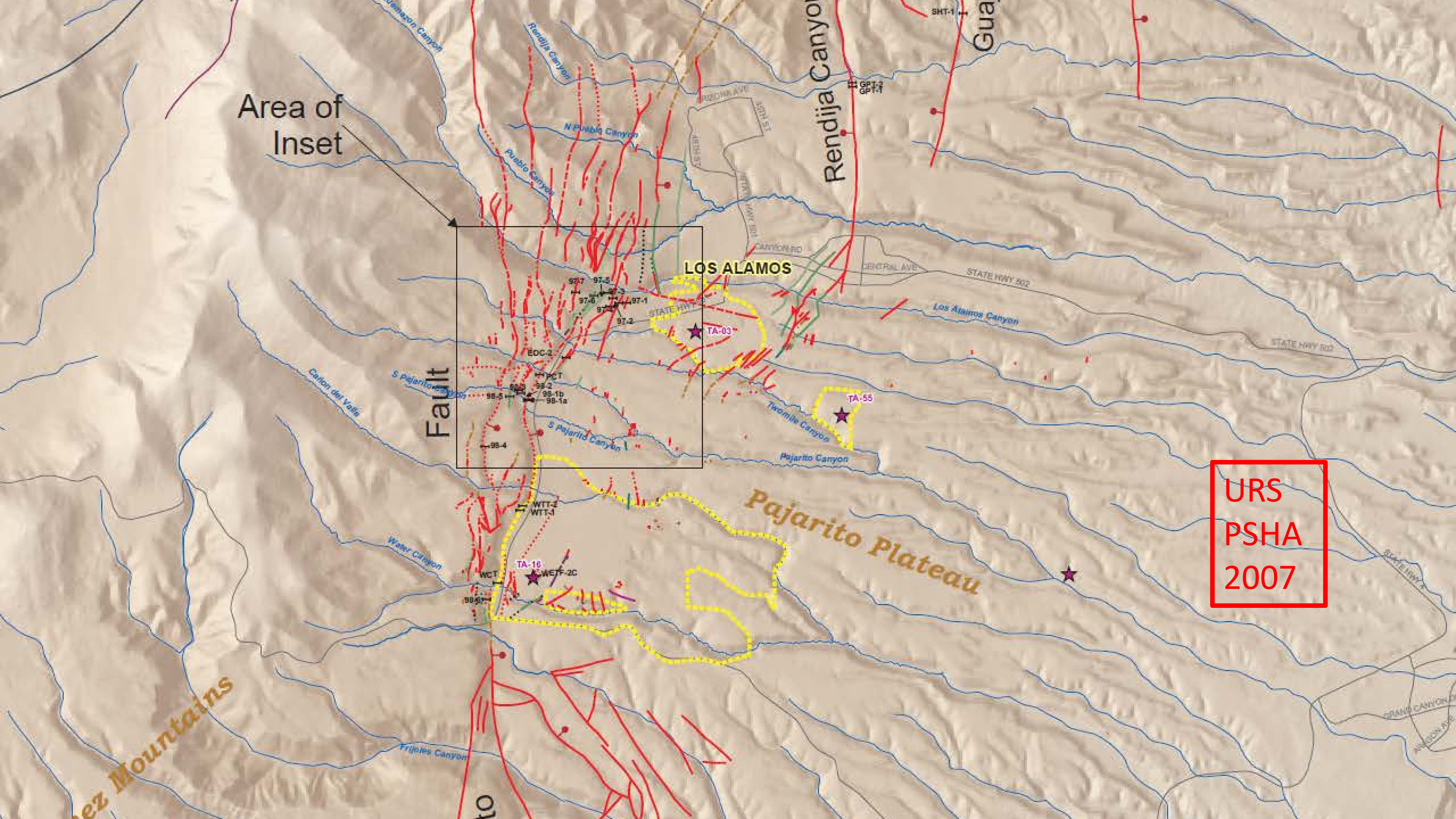


Figure 3.

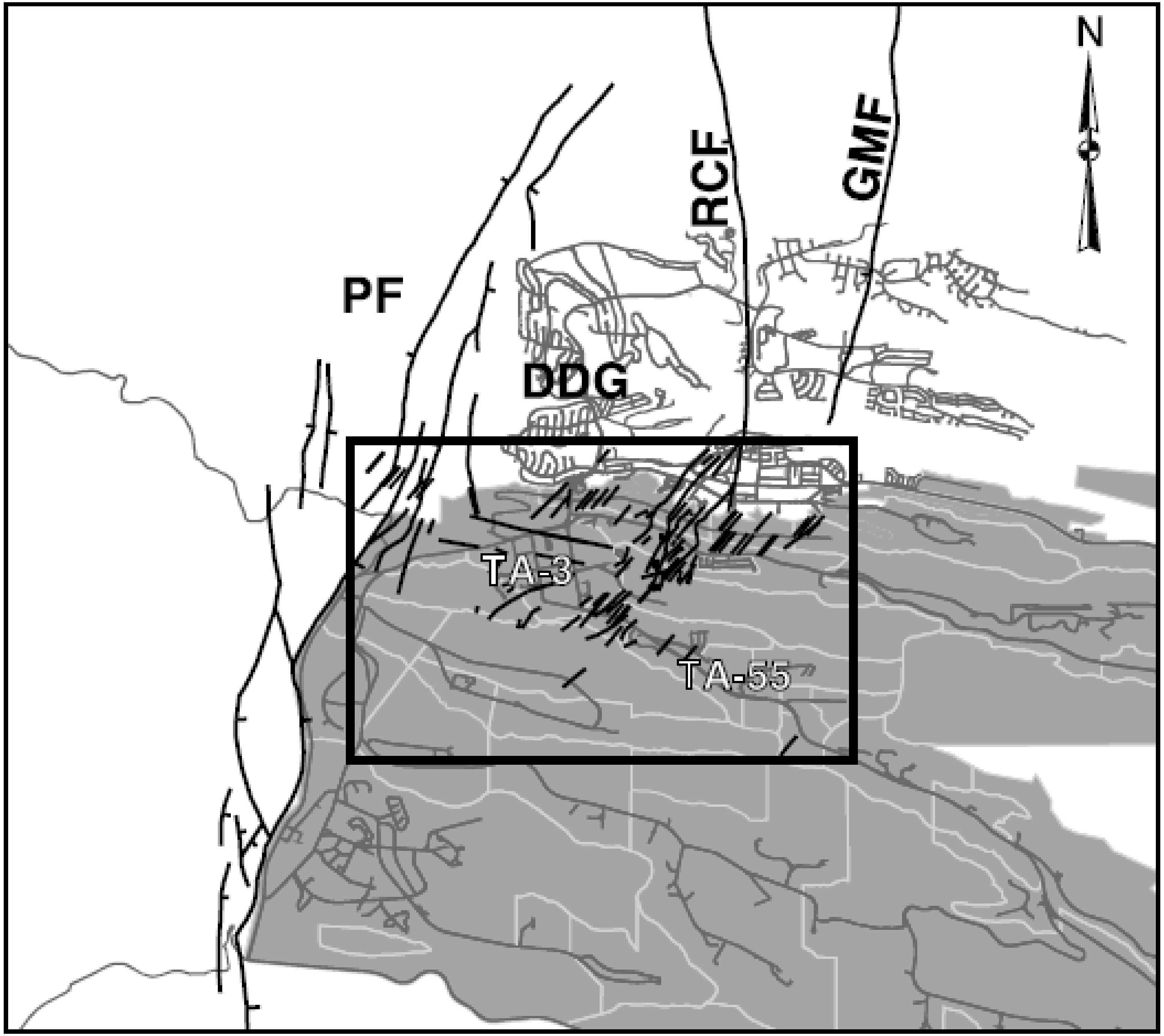
LANL sits on the western edge of the Rio Grande Rift, a graben bounded by more or less vertical faults. The Pajarito Fault System runs N-S along the western edge of LANL.

Faults also run through the LANL site and town. I do not believe that the relatively high density of faults mapped N and S of the lab magically becomes much lower beneath the lab itself. Other LANL publications do show faults (Guaje, Rendija) crossing the entire laboratory from N to S.

There is strong evidence of three earthquakes of 7.0 magnitude or greater in the Holocene. This system has shallow earthquakes (~ 1 mile), with relatively great acceleration (>1 g vertically), comparable to accelerations experienced at Fukushima. Unconsolidated ash layers amplify acceleration, including at TA-55. The rhyolite tuff of the Plateau may fracture almost anywhere, posing risks to cliff-side structures (e.g. the hospital) and to access roads, neither of which can be expected to remain open in any major quake.



Area of Inset
Fault
LOS ALAMOS
Pajarito Plateau
Rendija Canyon
N Pueblo Canyon
Pueblo Canyon
Los Alamos Canyon
STATE HWY 502
CENTRAL AVE
CANYON RD
TA-03
TA-55
TA-16
Twomile Canyon
Pajarito Canyon
S Pajarito Canyon
Cañon del Valle
Water Canyon
Frijoles Canyon
EOC-2
PCT
WTT-2
WTT-1
WCT
WETF-2C
98-4
GPT-2
GPT-1
SHT-1
URS
PSHA
2007



Gardner et al 1999, LANL

LANL has proposed multiple means for overcoming its isolation. This plan was presented by LANL on 8/8/19 as part of its regional "site plan," never subsequently shared with the public. The White House did not support it. It would blow up the region.

Proposed Rio Grande bridge crossing area looking north, LASG photo 2012.

Any such crossing would be higher controversial.

Bigger

Same plan, 1990 version.

The workforce and congestion imperatives behind this wild plan are non-trivial, given LANL's proposed growth, low availability of skilled labor, and lack of local housing.

LANL facility challenges: capacity, resilience, safety, longevity, costs

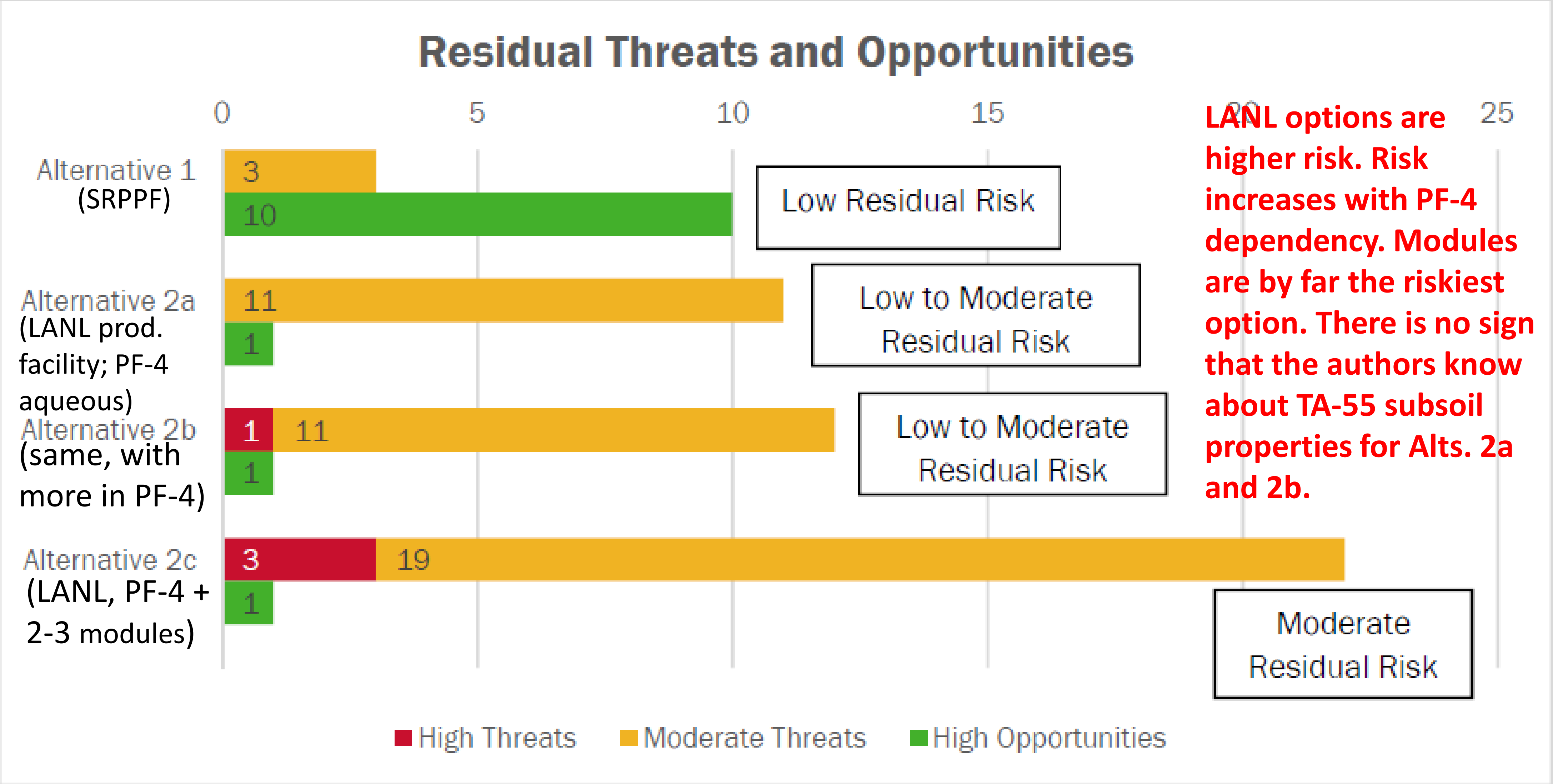
- Costs are discussed above.
- Longevity also; see “Risks for Sustainment of PF-4 at LANL, Report to Congress,” Nov 2020 (2045 implicit end of life); “LANL 2021 "Campus Master Plan," LA-UR-22-21424” (new or augmented PF-4 needed by 2040s).
- Capacity: NNSA speeches (e.g. Jill Hruby, 54:28 to 56:19) and budget requests (e.g. p. 236, March 2024), limit LANL production to (≥)“30 ppy,” which as noted above NNSA has estimated at 36-40 ppy (average). The 2017 AoA discusses the space limitations in PF-4 in depth. Additional Pu missions at PF-4 include (per GAO 2023, pp. 65-66): Pu-23 thermoelectric generator production; stockpile surveillance; produce components for subcritical experiments; fundamental science concerning the properties and aging of plutonium; oxidation of surplus Pu for disposition; produce americium oxide; surveil and monitor 3013 containers. Facility maintenance and basic operation, plus waste management, require significant area within PF-4.

Resilience of LANL pit production

- This topic is largely shielded by SRD and UCNI barriers. LANL analyzed six high-impact uncertainties in 2021 (Appendix A). See also the risk analyses in the AoA (for the ≥80 ppy mission) and the EA (for an additional ≥50 ppy at LANL); examples are in the next 2 slides.
- Historically, PF-4 operation has been shut down twice for fairly long periods (in 2004, when the whole lab was shut down, and at PF-4, for 4 years beginning in 2013). Numerous short shut-downs have also occurred; we do not have a tally.
- NNSA's pit production modeling accounts for equipment outages but not facility-wide shutdowns.
- "CEPE's [May 2021] assessment[of LANL pit production plans] concludes that there are significant risks in staffing, program management, production activities, supporting infrastructure, waste management, and other program requirements. The initial plan also provided no analysis describing the impact on all plutonium operations of…CEPE assesses that more work will need to be done to improve the current plan and mitigate risks."

Department of Energy/National Nuclear Security Administration/Defense Programs - October 2017					
Table 8-2. Summary of results of risk assessment for short list of alternatives ordered from high to low					
Risk Category	**ID#**	**Brief Description of Threat**	**PF-4 Alts.**	**LANL New**	**SRS MFFF**
High Risks that Discriminate Between Alternatives	C-10	Construction or repair and modifications impact ongoing site or facility operations, or ongoing site or facility activities impact construction or repair and modifications.	high risk	low risk	low risk
	O-1	Pit manufacturing adversely affects other site or facility projects, or other site or facility projects adversely affect pit production.	high risk	low risk	low risk
High Risks that Apply Equally to All Alternatives	C-4	Sufficient line item funds are not available (either in individual fiscal years or in total), resulting in a delay to completion of construction and startup.	high risk	high risk	high risk
	C-8	More stringent interpretations of safety requirements during design and construction require significant facilty structural or service system upgrades.	high risk	high risk	high risk
	C-9	Additional security provisions (e.g., clearances, escorts, fences, changes in the design basis threat) beyond those planned are imposed.	high risk	high risk	high risk
Moderate Risks that Distinguish Between Alternatives	C-11	Existing facilities require more work than planned to meet applicable codes and standards (i.e., latent conditions may unexpectedly come into play). Equivalently, unforeseen conditions in existing facilities during repair or upgrades result in more work than planned.	moderate risk	N/A	low risk
	C-24	Difficulties arise while transferring the MFFF facility licensing basis from NRC to DOE.	N/A	N/A	moderate risk
	C-5	Intra-agency and/or inter-agency disputes delay project and introduce extra costs or unwanted restrictions on the project.	low risk	low risk	moderate risk
	C-2	National and/or local policy/public opposition result in delays and extra costs.	moderate risk	moderate risk	moderate risk
	C-20	An external flood occurs during construction.	low risk	low risk	moderate risk
	0-17	An external flood occurs during operation.	low risk	low risk	moderate risk
From NNSA, "Plutonium Pit Production Analysis of Alternatives", (AoA), p. 64. Eliminated alternatives not shown.					
The AoA examined alternatives for an 80 ppy capability. NNSA's present plan includes the option of "surging" to 80 ppy in PF-4. The AoA notes that NNSA has rejected PF-4 as an enduring plutonium production facility (p. 47).					
high risk		**moderate risk**	**low risk**		

These discriminating high risks seen in 2017 still apply.



LANL options are higher risk. Risk increases with PF-4 dependency. Modules are by far the riskiest option. There is no sign that the authors know about TA-55 subsoil properties for Alts. 2a and 2b.

EA, 2018, p. 4-24 Figure 4-2: Alternative Qualitative Risk Comparison For 50 ppy + an assumed 30 at LANL.

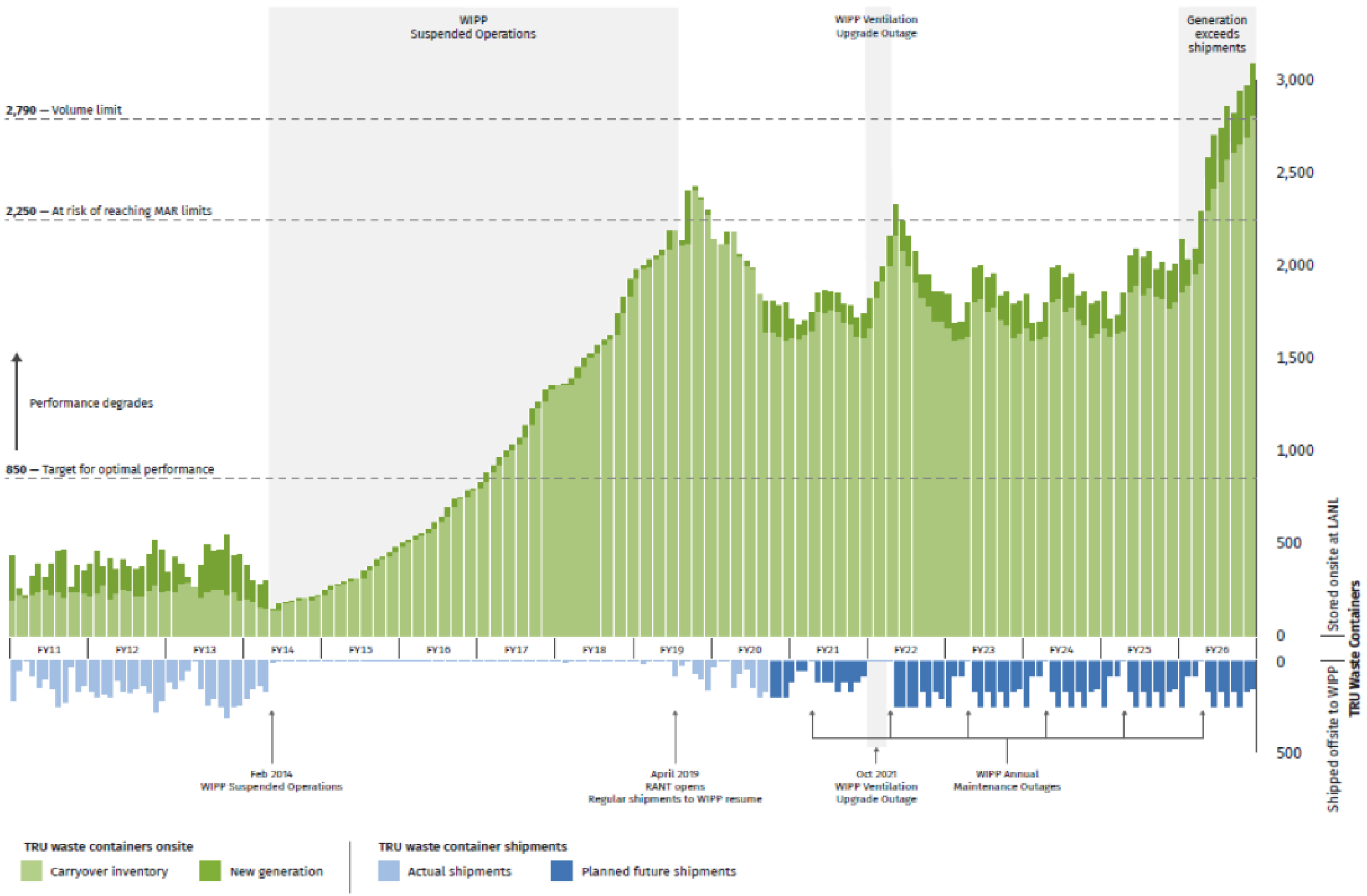


Figure 2: Transuranic (TRU) solid waste containers stored onsite and shipped offsite at LANL, based on forecasting included in the LANL Integrated Strategy.

Key issue: waste production and legacy TRU removal (I)

From NNSA, Assessment of Pit Production at LANL, Office of Cost Estimating & Program Evaluation (CEPE), May 2021, obtained by LASG FOIA appeal.

The Enduring Mission Waste Management Plan for LANL, LA-CP-20-20577, Sep 2020, obtained by LASG FOIA, provides no clarity because of the obviously-political redactions. LANL doesn't want the public to know.

Some recent articles on safety lapses at LANL; time does not permit any analytic treatment

Government watchdog says LANL could be doing more to prevent glove box contaminant releases, *Santa Fe New Mexican (SFNM),* Apr 17, 2024

Reports: 2 mishaps at LANL in one day, *SFNM,* Apr 8, 2024

- LANL director addresses rash of safety incidents, SFNM, Feb 10, 2024
- Los Alamos glovebox fire sprinklers could cause criticality, safety watchdog says, *Exchange Monitor,* Feb 9, 2024
- Los Alamos National Laboratory logs two more skin-contamination incidents, SFNM, Feb 5, 2024
- Los Alamos sees spate of radiological contamination episodes around plutonium facility, *Exchange Monitor,* Jan 18, 2024
- Report: Another LANL worker's skin contaminated, *SFNM,* Jan 16, 2024
- Report: Radioactive contaminants found on Los Alamos National Lab worker's skin, *SFNM,* Jan 9, 2024
- Glove box fire closed part of LANL plutonium facility in November, *SFNM,* Dec 19, 2023
- Glovebox Fire shuts portion of LANL plutonium lab for nearly two weeks, *Exchange Monitor,* Dec 15, 2023
- Glovebox Fire shuts portion of LANL plutonium lab for nearly a month, *Exchange Monitor,* Dec 12, 2023
- Workers Are Getting Paid to Do Nothing at Los Alamos National Laboratory, *The Nation,* Nov 9, 2023
- Chess, cards and catnaps in the heart of America's nuclear weapons complex, *Searchlight New Mexico,* Nov 8, 2023
- Lab contractor cited for 2022 glove box breach, *SFNM*, Nov 3, 2023
- LANL reports glove box breach, tritium drift weeks apart, *SFNM*, Nov 1, 2023
- Eight workers exposed to beryllium dust at LANL, a recurring problem, *SFNM,* Sep 27, 2023
- Safety Lapses at Los Alamos National Laboratory, *Searchlight New Mexico,* Jul 13, 2023
- Triad Hit By DOE With Preliminary Notice Of Violation For 5 Nuclear Safety Issues At Plutonium Facility PF4 In 2021, *Los Alamos Reporter,* May 31, 2023
- Watchdog agency grills LANL, nuclear officials on lab safety, *SFNM,* Nov 16, 2022

Key issue: waste production and legacy TRU removal (II)

- As of June 2022, there were 12,820 55-gal. drum-equivalents ("drums") of TRU buried at Area G, roughly 3,000 drums above-ground in tents (insert better number) at Area G, and ~400 drums of Triad TRU stored there also. In addition Triad was/is storing ~2,250 drums, making ~18,470 drums in all.
- New TRU from LANL Pu programs are the primary reason for the remaining large inventory of legacy TRU. Historically, most TRU shipped from LANL to WIPP has been new, not legacy.
- In the event of conflicts, disposal of new TRU from NNSA must be prioritized over legacy TRU. We do not believe NNSA has any realistic plan to remove the legacy TRU from LANL, let alone one that is funded.
- The new Radioactive Liquid Waste Treatment Facility (RLWTF) and Transuranic Liquid Waste Facility (TLWF) are not yet operational (RLWTF) or completed (TLWF). These have been under study and construction for 25 years.
- The new TRU (solid) waste facility was badly designed, inadequately sized, overpriced. Two of these, not just one, are needed to support pit production, according to NNSA in 2017.
- Demolition and disposal of contaminated buildings, e.g. CMR, Sigma, Main Shops, Radiochemistry (TA-48), Ion Beam building and many more. LANL projects over 1,000,000 sq. ft. of building demolition overall. Where will the construction waste go? The low-level waste (LLW)? How much TRU will be generated? When will NNSA budget for this? Eventually, PF-4, WETF, and other nuclear facilities will need to be demolished and disposed.
- To these waste streams, other operational wastes and environmental cleanup wastes must be added.
- What is the future of on-site disposal and closure at LANL? After 30 years, these questions remain up in the air, to keep NNSA's options open.
- Please note: environmental contamination at LANL was intentional, at every point in time. LANL knew better.

Extra slides, unfinished

Regional challenges: labor, transportation, housing, education, social problems

Key issue: hiring (I)

In its October 2017 and April 2018 studies (here, at p. 13, and here, at pp. 2-6, 2-7), NNSA assumed that LANL could produce 30 pits per year (ppy) during a single production shift. [note 2].

By February 2020 that had changed. In its congressional budget request for FY2021 NNSA admitted for the first time that LANL's plutonium facility would need to run "24/7" to meet its 30 ppy production goal (p. 194).

In March 2020, NNSA again spoke of "24-hour operations" with the addition of 1,600 full-time-equivalent (FTE) staff members *to reach just 20 ppy* (p. 12). Another 400 FTEs would be necessary to reach 30 ppy (p. 14).

Federal sources told us that as of January 2020 LANL employed about 2,000 full-time equivalents (FTEs) in pit production. By May 2020 LANL employed 2,316 FTEs in pit production (p. 9). In August 2020 NNSA stated it needed to hire an additional 1,900 FTEs to reach a 30 (ppy) capacity (p. 15, 17), bringing the total LANL future pit production workforce needed for the 30 ppy mission to at least 4,216 FTEs.

By contrast the 2018 Engineering Assessment (EA) for pit production estimated that to produce *all 80 ppy* at LANL, LANL would need from 833 to 1,156 total FTEs, including both direct- and indirect-funded activities. Thus, *LANL's estimated staffing requirements have grown by more than a factor of four over the past four years, for 38% as many pits. LANL's staffing needs have grown by a factor of 11 per prospective pit produced. Never before in U.S. history has planned baseline pit production been dependent on multiple production shifts.* [3]

Key issue: hiring (II)

LANL struggles with employee retention. Voluntary attrition exceeded 7.5% for most of 2019. According to GAO, it was "below 7.5% for all of calendar year 2020 and the majority of calendar year 2021" (p. 24). About half of this is retirements (p. 24). Involuntary attrition will add to this "below 7.5%". Students, postdocs, and craft employees are apparently not included in LANL's headcounts (p. 23). Of note, in its internal review of LANL pit production plans, NNSA reported that LANL had an annual attrition rate of 8% in 2021 (p. 4).

We have complied hundreds of negative individual reviews of work at LANL from open sources. And as noted in previous testimony, the Department of Labor has paid survivors of approximately 2,000 unique LANL workers death benefits. Cumulative EEOICPA benefits paid at LANL approach $1.5 billion. This is suffering and grief, not economic development.

Quoting again from GAO:

> …[NNSA] officials also acknowledged several challenges to attracting and retaining new talent. For example, **NNSA officials stated that Triad has already depleted the local talent pool in northern New Mexico.** Triad is targeting other geographic areas for recruitment, such as the city of Albuquerque. However, it is also competing with large technology companies moving into such areas that can offer high salaries and that do not require staff to commute long distances, according to NNSA officials. DOE’s Human Reliability Program also places unique requirements on certain employees, including that LANL staff with access to certain materials, nuclear explosive devices, facilities, and programs meet high standards for reliability and physical and mental suitability. NNSA officials also said that having to maintain security clearances and be subject to random drug testing can deter some potential employees. [emphasis added]

Key issue: hiring (III)

According to a recent NNSA report ("Evolving the Nuclear Security Enterprise," Sep. 2022), "[t]he NSE is experiencing tremendous workforce attraction and retention issues" (p. 3) nationwide. Further,

> One overarching theme from virtually all [of 250 federal and contractor management] interviewees is the challenge of remaining competitive in the current job market, and the difficulties in both attracting and retaining qualified personnel…Some recruitment and retention factors cannot be completely changed, such as **moral dilemmas about nuclear weapons**, desires to transition to full-time remote or work-from-home status, the complications of acquiring or maintaining security clearances, and specific locality preferences. (p. 10, emphasis added)

We will return to the moral issues involved in promoting and producing weapons of mass destruction shortly, as it centrally affects New Mexico's politics, social development, environment, and economic development.

In the meantime it is important for activists to realize that the moral dimension of nuclear weapons has practical implications, here and now.