Pit production workshop sponsored by the Los Alamos Study Group & the Princeton Program on Science and Global Security

NNSA pit production strategy: no clear goals, plans, or likelihood of success

Production at LANL has high risks and costs, few or no program benefits

Greg Mello, Executive Director, Los Alamos Study Group, October 1, 2020

NNSA, DoD and Congress appear to have two distinct pit production goals: 1) to reach ≥80 ppy by 2030, and 2) to acquire an enduring single-shift pit production capacity at that level (i.e. 103-125 ppy on average, AoA p. 13). Achieving the first goal will be very expensive and risky, has low probability of success, is not necessary to support all current and planned deployments, and competes with enduring pit production (goal #2) for resources, while making no significant contribution to that second goal. Early-time production does help enable the full W87-1 program, i.e. with full MIRV capability. Early-time LANL production is now a >$10 B megaproject, including program costs. If successful, it will produce pits at 6-10x the cost of SRS pits, roughly triple the unit cost of the W87-1 warheads it provides, and double the cost of the W87-1 program overall. In addition to being "very high risk" (IDA), the attempt to jump-start industrial production at LANL via 24/7 operations is likely to create systemic risk across all LANL programs, not just risk to other LANL Pu programs, as multiple capacity issues at LANL reach critical thresholds. NNSA now finds itself saddled with two pit megaprojects, for no truly good or sound reasons.

Please accept if you can my apologies for the many acronyms in this presentation.

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Blog: Forget the Rest

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Key recommendations, *assuming the nuclear weapons business is more or less as usual* (not at all what we prefer but what most of you must perforce assume for now):

- Utilize, invest in, make safe, and conserve LANL's aging plutonium assets for plutonium science, surveillance, certification, aging studies, training, pilot production of pits, technology development, technology transfer, pit reuse, and heat source manufacture. **Make no significant number of pits at LANL, where unresolvable problems and intense challenges extend from the current aging, inadequate facilities to the LANL site, institutions, and location.**
- ***If pits might be required in the 2030s*, formally require the early completion (CD-4) and operation of an enduring SRPPF complex in the 2035 timeframe, not by 2030**, this being the realistic schedule now. **SRPPF should be built for ≥80 ppy,** very little different from today's ≥50 ppy in investment, space, and staffing.
- Retire the W78 warhead (the current plan, but we prefer sooner) and if possible the ICBM upload hedge with it.
- Choose one, in declining order of preference; all are less risky, better, & cheaper for NNSA than current plans:
    - Deploy W87-0 warheads on all 400/450 *life-extended MMIIIs* or any subset thereof; a much simpler LEP without new characteristics (and pits) could be undertaken if needed or desired for workload leveling;
    - Deploy W87-0 warheads on all 400/450 *GBSD* missiles or any subset thereof; again with a simpler LEP as needed;
    - Reuse W87-0 *pits* to build enough W87-1s to populate GBSD *without a MIRV option*, FPU 2030 as planned;
    - Reuse W87-0 pits for W87-1 *with a MIRV option*, FPU 2030, adding new pits as they become available in the mid-2030s from SRPPF only. This is the current plan (EIS-0541 pp. 1-5, 1-6), except that NNSA's plan adds early-year pits from LANL, at great cost and risk, and not just to this program.
- Obviously the fewer silos, missiles, and warheads there are, the easier and cheaper all this work becomes for all concerned. This goes all the way: we believe ICBMs especially, and so all these warhead types, make the US less safe.

Some key conclusions, beyond those on the title page (I):

- NNSA's and Congress' pit production policies since late 2017 have been characterized by too little careful planning and budgeting and too much wishful thinking. Details matter a great deal. Policy and law do not suspend engineering and geological realities. Ideology and partisan politics are playing large roles. **Congress, its research agencies, and the next administration need to carefully re-scrub pit production policy, starting with a careful review of what has been learned and forgotten or hidden over the past decade.**
- **The two-site strategy is based on an arbitrary deadline which will not be met. It is as unnecessary as it is costly and risky. LANL is the problem site.** House Democrats and others, by downplaying or ignoring LANL's problems, are inadvertently endorsing a two-site strategy with maximum fiscal waste as well as the fully-MIRVed W87-1 program. **DoD and NNSA will never fall for the theory that LANL can make all necessary pits for the US arsenal – or that decisions about regarding where and how to do so can wait another decade.**
- **There is a widespread misconception that NNSA seeks to "expand" LANL's pit production capacity, or wishes to establish a "second" pit production site.** After 24 years with this mission assignment, LANL has no pit production capability at all. It is not yet known if establishing any significant capability, even temporarily, with modern safety and environmental standards, in LANL's old PF-4 facility (located 0.6 miles from residences) will be possible.
- **Establishing a modest short-term capability at LANL, should it be possible, will be very costly**, as NNSA's budget requests and other documents now reveal. This is wasteful "artificial emergency" spending.
- **As NNSA said in 2017, establishing an *<u>enduring</u>* pit capability at LANL, assuming that is possible, would take significantly longer and cost significantly more than establishing a larger, more flexible, enduring capacity at SRS, because a brand-new nuclear facility would be required.** Dependence on multiple production shifts would raise operational costs very high, as is now the case for a planned 20 ppy, and will prove infeasible if continued.

Key conclusions (II):

- Understandably, GAO and CBO have underestimated pit costs so far by omitting recent budgeted LANL pit infrastructure and program costs (GAO), or by omitting LANL costs altogether by using marginal costs from a mature SRPPF (CBO). **NNSA has made audit difficult by hiding most of its current and near-term expenses over the FYNSP in its "baseline" (20 ppy) program.** SRS costs are not yet fully developed as of this writing.
- As NNSA understood in 2017 and we believe still does, PF-4, which will be 50 years old in 2028, cannot be an enduring pit production facility, assuming it can be brought up to modern safety standards in the first place. **Replacement of PF-4 may not be possible given LANL's geology, topography, seismology, and proximity to residences, businesses, sacred tribal lands, highways, and the national monument which borders LANL on portions of two sides.**
- There is no evidence that NNSA has a comprehensive or fully-costed plan for its two-site pit production strategy. To the extent they are estimated, program details (e.g. staffing) are hidden as are post-FY2025 costs.
- Stockpile-significant pit production at LANL is not necessary for any purpose, including to train SRS workers. **As SRPPF begins operation it will be much easier to temporarily transfer a few LANL staff to SRS than to temporarily transfer many SRS workers to LANL for training.** The latter would be infeasible in any case.
- Since stockpile-significant pit production at LANL is not necessary, LANL need not hire the planned additional 2,000 pit production workers and support staff. The existing 2,000 such workers are more than enough.
- **The subsurface geology and topography of TA-55, in combination with the site's seismicity, make large nuclear facilities with safety-class systems impractical on the steep south side of that small technical area**, as these factors and others did in the case of CMRR-NF. The proposed TA-55 **"modules" would lack safety-class systems**, which would consume too much real estate on the narrow mesa. TA-55 is a problematic location.

Key conclusions (III):

- **The large quantities of legacy TRU waste stored ~100 meters from potential public receptors at LANL are dangerous.** This protracted situation is concerning to state and local governments and tribes and is now a first-level concern. Pit production wastes would consume most if not essentially all the space in the available WIPP shipment schedule, stranding legacy waste.
- The two-site strategy ignores the great economies of scale in pit production, which in this case also carries benefits of flexibility (two production lines if needed), internal redundancy of key equipment, and therefore resilience.
- Hiring, training, and keeping workers will not be easy. It will be easier at a smaller scale, i.e. at one facility.
- The primary stated concern of the managers of the U.S. nuclear establishment as regards pit production over the last 25 years, the common thread, has been *to minimize risk to the U.S. nuclear arsenal*. This perceived risk has a number of components, but the most basic one is that the U.S. has no enduring way to make any significant number pits for any reason whatsoever in the years to come. A temporary facility does not solve this problem. **Having or even planning an enduring pit production capability removes a great deal of perceived risk to the stockpile, apart from the actual pits made.** It does not have to run at “top speed” to do this. It does have to be enduring, adequate, and optimized or balanced, i.e. built to purpose.
- To succeed, patience, prudence and a sense of proportion are assets, not vaulting ambition. *That* has been tried and has failed many times. Trying to do too much too fast is a recipe for failure, as the IDA has emphasized. Speed is the problem, not the solution.
- **As we have repeatedly said, the perceived need for warheads and therefore pits is misplaced and dangerous.** That is a story for another day, but that day must and will come soon. Even the best plans will be obsolete tomorrow.

Pit production: schedule issues

Warhead Type	Date of Entry into Stockpile	Planned LEP[1]	First Prod. LEP	Planned Repl.[2]	Projected FPU[5] for Replacement	Nuclear Component Age at Initial Replacement[6]
B61-3/4*	1979	B61-12 LEP	2020	FAW[3]	~2040-2050	~60-70 yrs
B61-7/11**	1985/1997	B61-12 LEP	2020	FAW	~2040-2050	~60-70 yrs
B83-1**	1983	Retired by 2025	n/a	n/a	n/a	n/a
Cruise Missile W80-1	1982	W80-4 LEP	2025	FAW	~2040-2055	~60-75 yrs
SLBM W76	1978	W76-1 LEP	2008	FBW[4]	~2045-2047	~65-70 yrs
ICBM W78	1979	n/a	n/a	W87-1	~2030	~50 yrs
ICBM W87	1986	Partial LEP	1999	FBW	~2035-2040	~50-55 yrs
SLBM W88	1989	Alt 370 Refresh	2022	FBW	~2035-2040	~45-50 yrs

* Non-strategic bomb ** Strategic Bomb [1] Life extension programs (LEP) reuse nuclear components [2] Replacement requires nuclear component production [3] Future Air-Delivered Warhead (FAW) timeframe identified; characteristics to be determined [4] Future Ballistic Missile Warheads (FBW) initial studies planned; diversity and characteristics to be determined [5] First Production Unit [6] Replacement dates are notional

DoD is comfortable with these through 2040-2055. **It is too soon to meaningfully plan for them.**

Being retired

Of current concern

From DoD, *Nuclear Matters, 2020 edition*

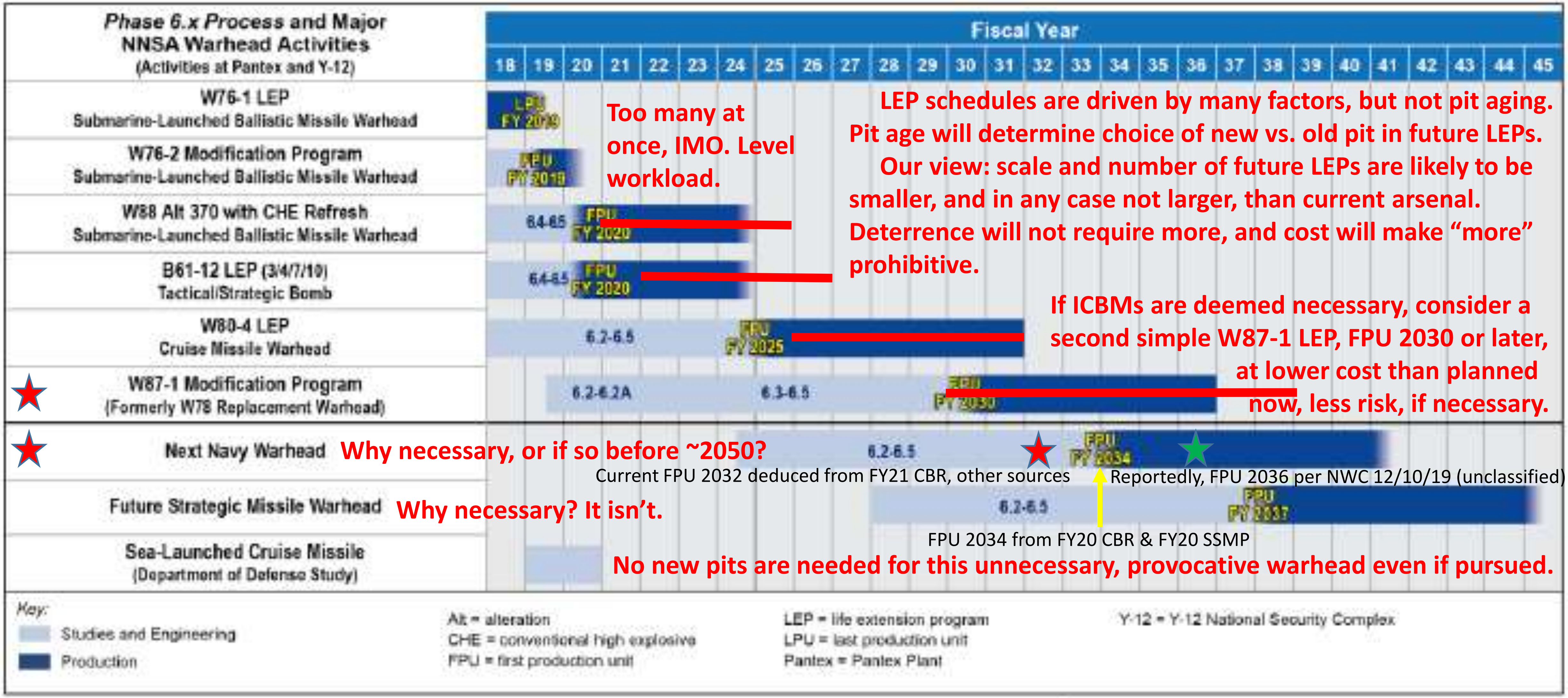


Figure 2–2. NNSA warhead activities[2]

From NNSA FY2020 SSMP, July 2019 (update expected – when?). Red bars are production schedule as of May 2020, from LASG sources and GAO-20-573R (p. 16). (Some) FPU dates (not W87-1) are apparently now classified.

When can NNSA reach ≥80 ppy? (For the current official NNSA estimate of production by year see GAO, p. 16)

- DPAG (2000), p. 4: 14 years from pre-conceptual design to full production in new facility, "barring national emergency"
- MPF (2003), pp. S-13,14: 15 yrs to CD-4, 2 yrs more to full production in new facility, i.e. 17 years.
- AoA (2017), p. 61: 15 yrs to ≥80 ppy (SRPPF, remodeling existing cold facility), range 13-19 yrs; 18 yrs to ≥80 ppy (LANL, new facility), range 16-20 yrs. These schedules include a full EIS (not on critical path) and 5 yrs for War Reserve (WR) qualification and ramp-up to full production. There is little chance of ≥80 ppy production before 2033 (p. 2), i.e. 2034 likely earliest given one yr delay after AoA. For ≥80 ppy (SRPPF), range is 2030-2037 (s. 9) adding one yr delay. The new-facility ≥80 ppy option at LANL would not be ready until 2034-2039 (s. 9), adding one yr delay.
- EA (2018), p. 3-16: 8-12 yrs to CD-4 for ≥50 ppy (SRPPF), i.e. 2026-2030. Critical path analysis (e-p. 214) shows 5 yrs for hot commissioning and transition to WR production, i.e. 13-17 yrs in all, i.e. 2030-2034.
- The high-risk "PF-4 surge + modules" plan (Alt. 2c) has a CD-4 range of 2025-2029 (for PF-4 work) and 2032-2035 (for the modules) (p. 3-16). If either were being chosen, variations on Alts. 2a and 2b should be visible in budget documents, but aren't. Modules remain a statutory requirement and may be planned for the late 2020s.
- IDA/DoD (2019), p. vi, no historical precedent supports CD-4 by 2030; no NNSA project ≥$700 M has taken less than 16 years to CD-4, therefore at least 2034 to CD-4 and 2039 to full production assuming 5 yr ramp-up needed per AoA/EA.
- SRNS (2020), s. 3: CD-4 in 2025, for ≥50 ppy by 2030. This appears to be an optimistic outlier.
- NNSA (2020), p. 200: CD-4 2026-2031 ("based on EA"), to achieve ≥50 ppy by 2030.

NNSA cannot be certain when (or if) it can achieve ≥80 ppy. Success is more likely by ~2035 than 2030. **Q1: Would it take SRPPF longer to reach ≥80 than ≥50 ppy, given adequate, undivided resources?** A1: Hiring and training workers is likely to be the main cause for delay of ≥80 ppy, given the almost indistinguishable difference in capital cost between the two capacities. **Q2: Why divide efforts and resources between two sites, beyond that needed at LANL for pilot production?**

The pit reuse option: going, going….

- Reminder: **the simplest, cheapest, and most tested form of pit reuse is *warhead reuse***, e.g. populating GBSD missiles with fairly modern, accurate, IHE-equipped W87-0/Mk-21 and foregoing the MIRV hedge, which we believe has negative strategic utility under all scenarios. **Also, adding a newly-designed, newly-built warhead with new materials probably doesn't lower stockpile risk below that now available from a single well-understood design** (related: JASON, p. 5). The opposite, more likely.
- Part of the current risk mitigation strategy to achieve a 2030 FPU for W87-1 and maintain production thereafter is the "judicious" re-use of pits (EIS-0541 pp. 1-5, 1-6) (GAO pp. 34-38). These are presumably W87-0 pits, of which there are ~540, of which ~ 200 are currently deployed (Kristensen & Korda 2020), leaving ~250 for immediate re-use if ~40 are kept for surveillance and spares and 50 for the reserved MMIII/GBSD missiles. This is more than LANL can likely produce through 2030. The other ~290 pits could be reused as MMIII missiles are replaced, more than LANL's nominal 30 ppy production through the end of the LEP, i.e. 2038. **The only purpose served by LANL production, should it succeed, is to help enable, with high risk and cost, a new-pit W87-1 with a 2030 FPU in MIRV quantities.**
- Pit reuse was a viable, tested alternative to pit production in the past for selected systems and remains so for W87-1 in the short run, despite concerns about "impair[ed] performance margins" and "increase[d] performance uncertainty" due to Pu aging (GAO, p. 35). **As existing pits age these concerns will increase, closing the pit reuse window. Pit reuse cannot preclude the need for enduring pit production capacity.**
- **A *temporary* pit capability, i.e. one based in PF-4, adds little or no value past ~2035 while incurring large costs and risks.** Meanwhile pit reuse and rebuild capability compete with pit production in PF-4 for space and allowable material at risk (MAR) (AoA p. 47). The Pu Sustainment Program NNSA planned a pit reuse capability of up to 90 ppy at LANL (FY2016 SSMP, p. 2-34). This capability costs little (AoA, pp. 16-17) and should be protected and prioritized.
- If future LEPs have ~30-yr lifetimes, given the ~15 yrs necessary to acquire enduring pit production capability, design and acquisition should begin now, assuming pit lifetime is to be kept < ~ 80-85 years. If future LEPs have shorter (e.g. 15-yr) lives acquisition can be delayed accordingly. **We believe it unlikely any pits > what? 50-60 yrs? will be put into a new, deployed LEP.**

Pit production: safety and risk issues

Institute for Defense Analyses, May 2019, “Independent Assessment of the Plutonium Strategy of the National Security Administration”

Summary of Main Findings

1. Eventually achieving a production rate of 80 ppy is possible for all options considered by the EA, but will be extremely challenging.
2. No available option can be expected to provide 80 ppy by 2030. DoD should evaluate how to best respond to this requirement shortfall.
3. Trying to increase production at PF-4 by installing additional equipment and operating a second shift is very high risk. **NNSA’s chosen path. Rejected by NNSA in 2017 AoA. Ranked highest risk in 2018 (EA).**
4. Effort to identify and address risks is underway, but is far from complete.
5. Strategies identified by NNSA to shorten schedules will increase the risks of schedule slip, cost growth, and cancellation.

“[P]ursuing an aggressive schedule creates major risk to achieving an 80-ppy production capability under any option. Put more sharply, eventual success of the strategy to reconstitute plutonium pit production is far from certain…….[P]roducing more than 30 ppy using a two-shift "surge" at LANL appears technically possible, but would be very challenging to execute and could jeopardize executing the [Plutonium Sustainment Program] as well as other LANL programs.” (pp. v, viii)

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

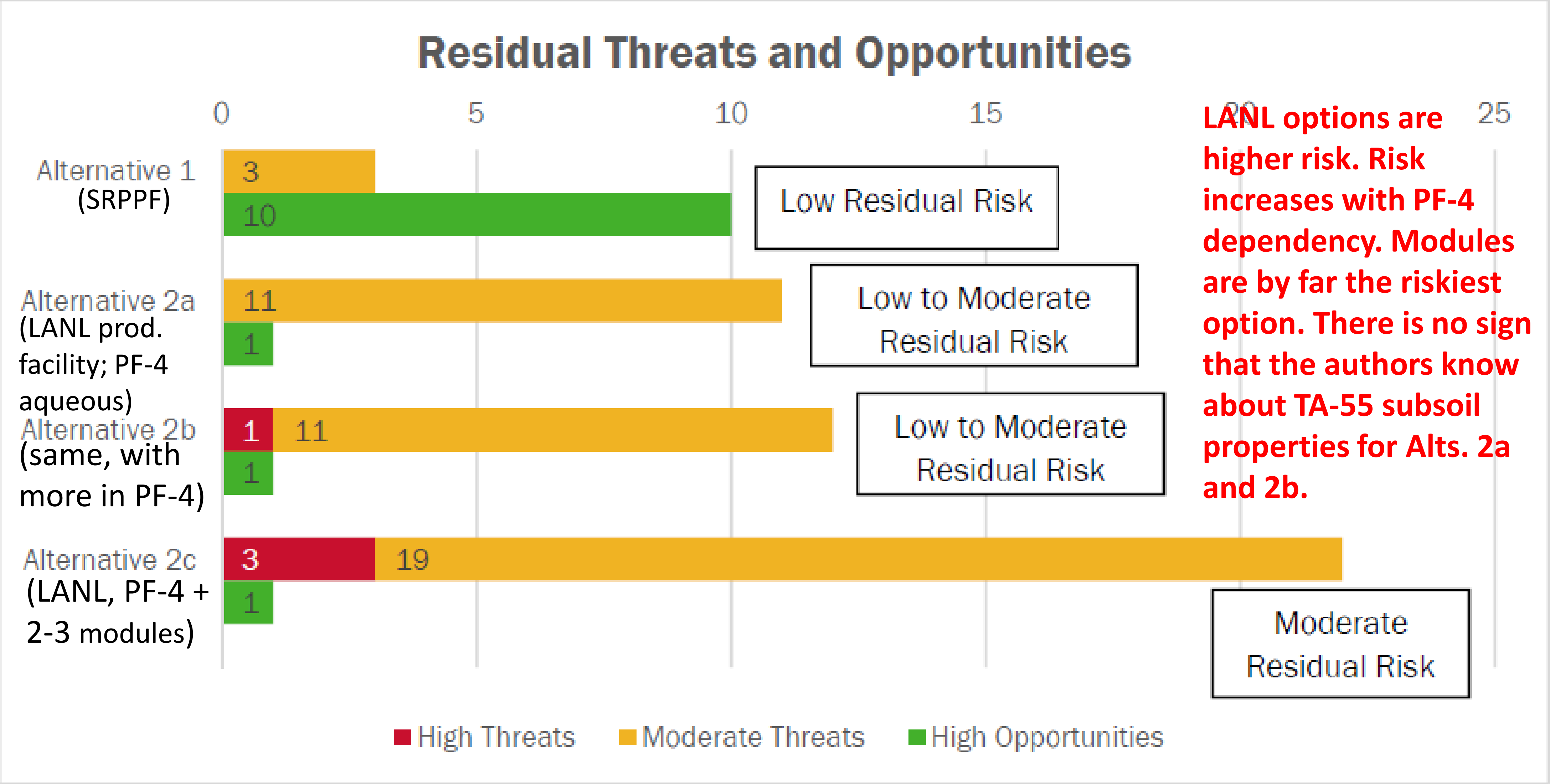
Risk Category	ID#	Brief Description of Threat	PF-4 Alts.	LANL New	SRS MFFF
High Risks that Discriminate Between Alternatives	C-10	Construction or repair and modifications impact ongoing site or facility operations, or ongoing site or facility activities impact construction or repair and modifications.			
	O-1	Pit manufacturing adversely affects other site or facility projects, or other site or facility projects adversely affect pit production.			
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.			
	C-8	More stringent interpretations of safety requirements during design and construction require significant facilty structural or service system upgrades.			
	C-9	Additional security provisions (e.g., clearances, escorts, fences, changes in the design basis threat) beyond those planned are imposed.			
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.		N/A	
	C-24	Difficulties arise while transferring the MFFF facility licensing basis from NRC to DOE.	N/A	N/A	
	C-5	Intra-agency and/or inter-agency disputes delay project and introduce extra costs or unwanted restrictions on the project.			
	C-2	National and/or local policy/public opposition result in delays and extra costs.			
	C-20	An external flood occurs during construction.			
	0-17	An external flood occurs during operation.			

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.

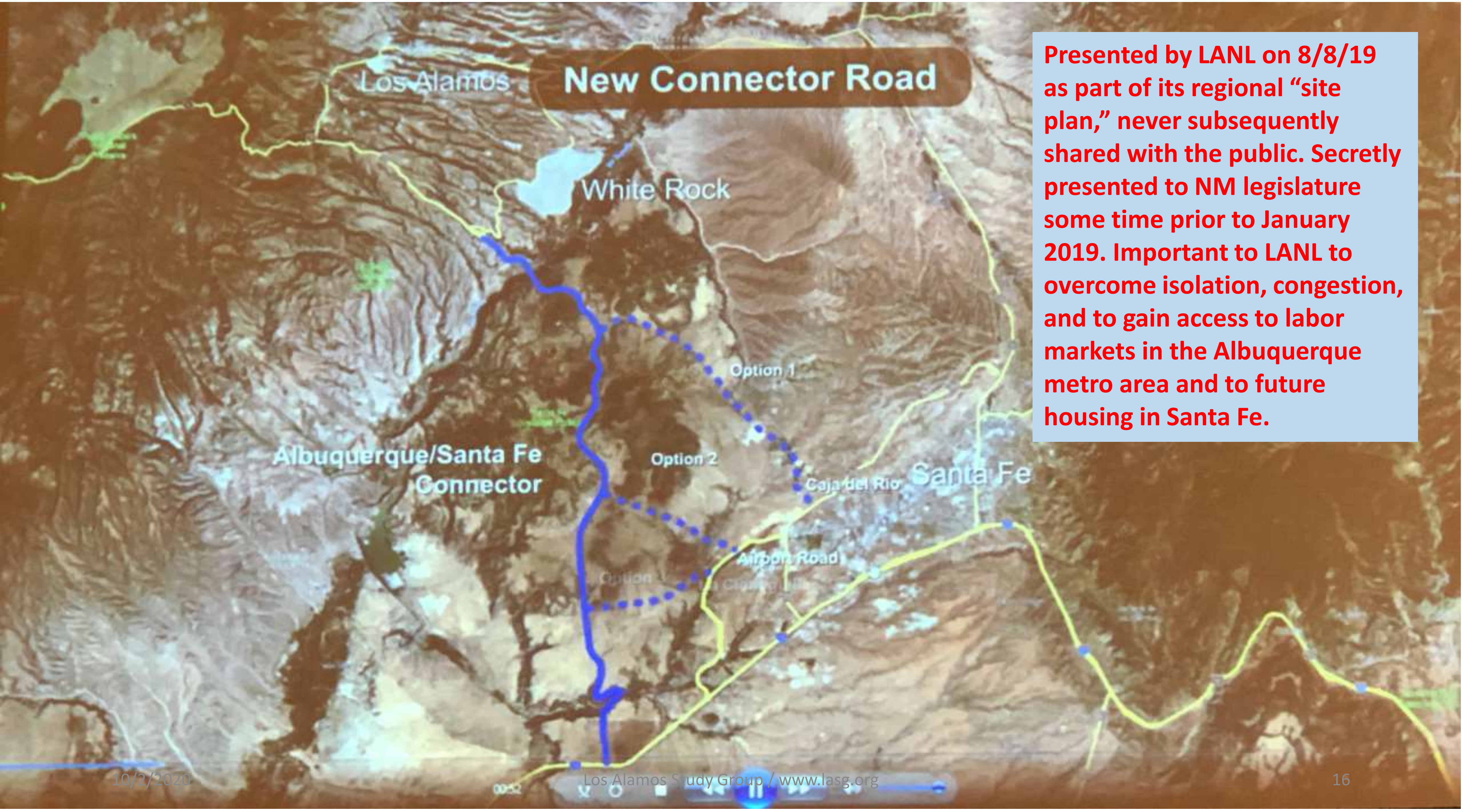
EA, 2018, p. 4-24

Figure 4-2: Alternative Qualitative Risk Comparison

For 50 ppy + an assumed 30 at LANL.

Why do some of us say that industrial pit production is virtually impossible at LANL?

- 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. This issue underlies many others.
- Highly dissected topography, including at 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.
- LANL R&D culture. LANL does not and dare not identify as a high-hazard nuclear facility.
- Institutional arrogance, persisting across decades and not easily changed.
- 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), new but with problems (TRUWF, RLUOB), or just plain decrepit facilities (Main Shops). Specialized functions (e.g. radiography) are challenged and may require workarounds (AoA, EA: rely on Pantex?).
- Negative social attributes of northern New Mexico: high rates of multigenerational poverty, addiction. Lack of qualified workforce regionally, high “hotel load” for construction, low educational attainment of population statewide.
- Limited state government response to chronic social and economic problems – no solutions or answers in sight. Improvements would be many years away.
- Rising concerns about waste, LANL expansion from local government; concerns re waste, cleanup from State.



Presented by LANL on 8/8/19 as part of its regional "site plan," never subsequently shared with the public. Secretly presented to NM legislature some time prior to January 2019. Important to LANL to overcome isolation, congestion, and to gain access to labor markets in the Albuquerque metro area and to future housing in Santa Fe.

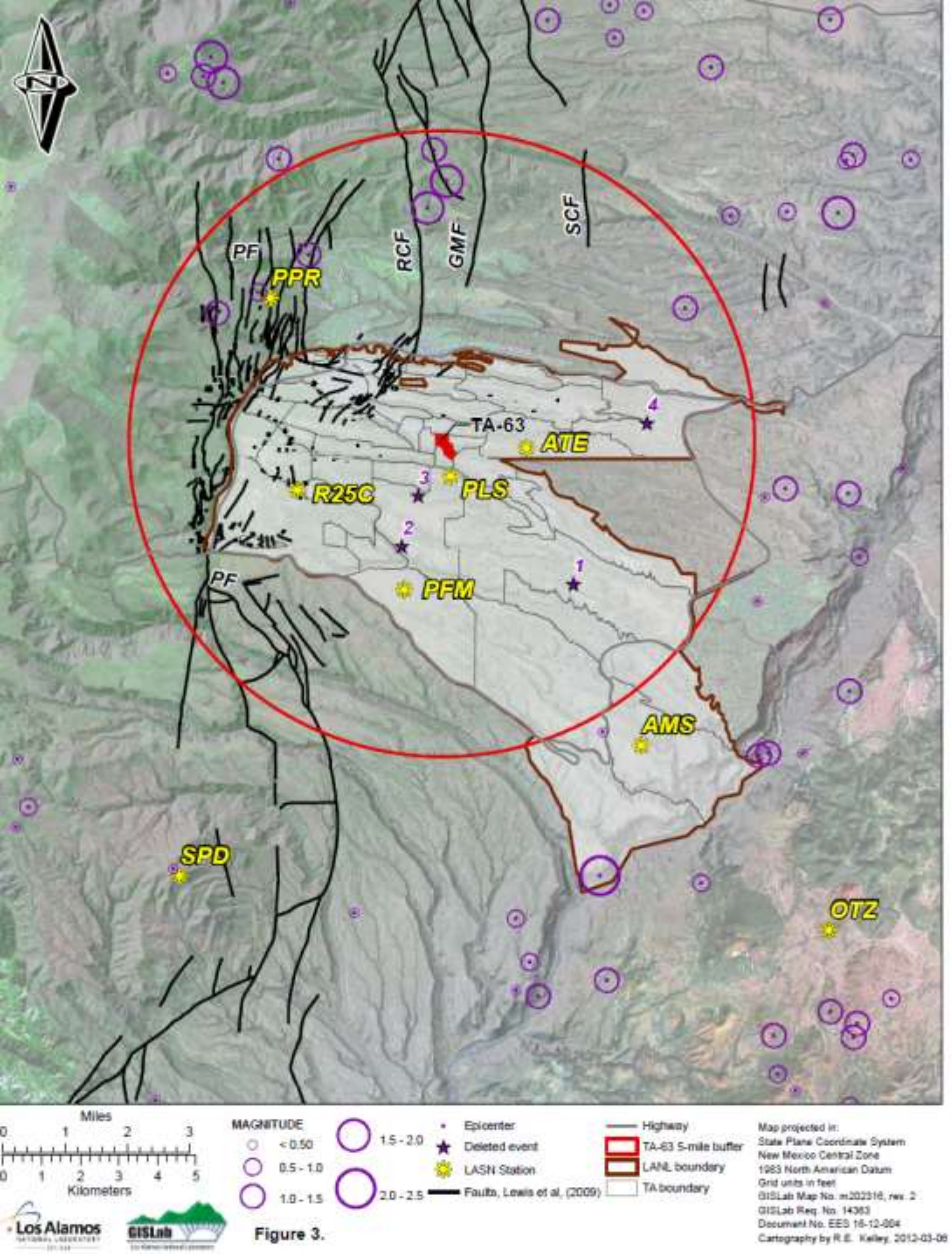
Proposed Rio Grande bridge crossing area looking north, LASG photo 2012.

Any such crossing would be higher controversial.

Bigger

Same plan, 1990 version.

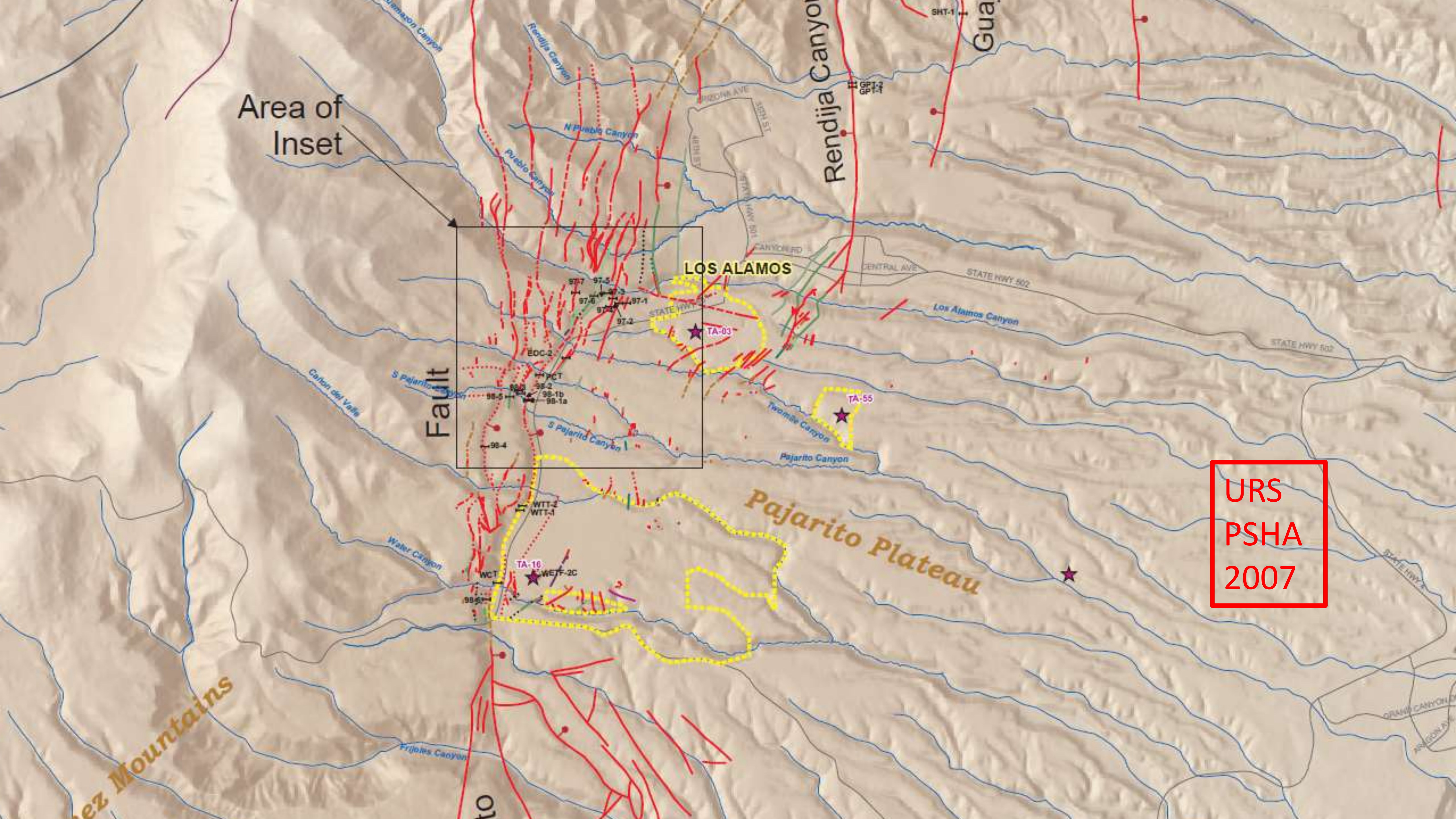
The workforce and congestion imperatives behind this wild plan are non-trivial, given LANL's proposed growth, low availability of skilled labor, and lack of local housing.



LANL 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.

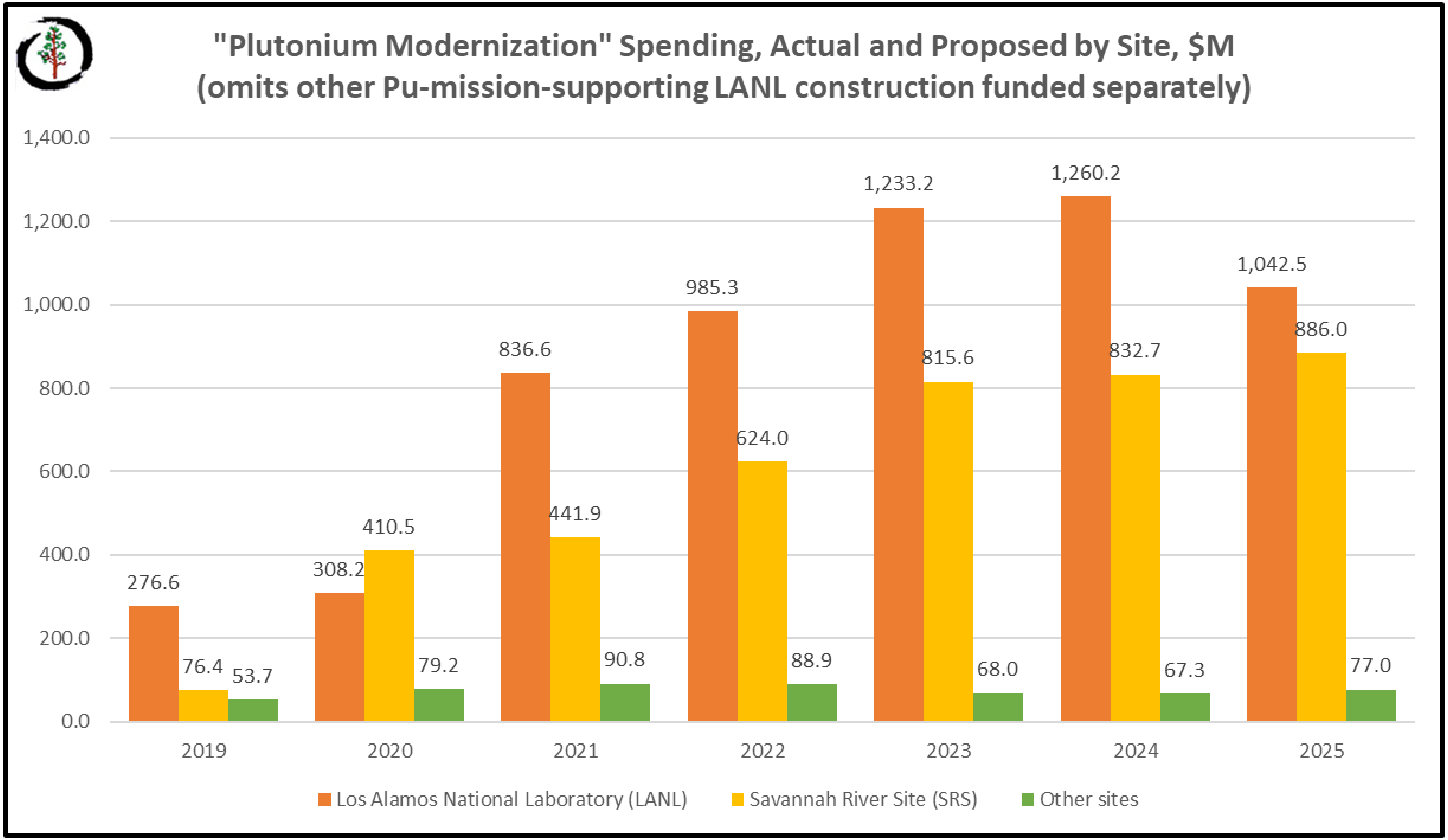

Area of
Inset
Fault
LOS ALAMOS
Rendija Canyon
Rendija Canyon
N Pueblo Canyon
Pueblo Canyon
Los Alamos Canyon
S Pajarito Canyon
Cañon del Valle
Twomile Canyon
Pajarito Canyon
Water Canyon
Frijoles Canyon
STATE HWY 502
STATE HWY 501
CANYON RD
CENTRAL AVE
TA-03
TA-55
TA-16
WETF-2C
Pajarito Plateau
Mountains
URS
PSHA
2007

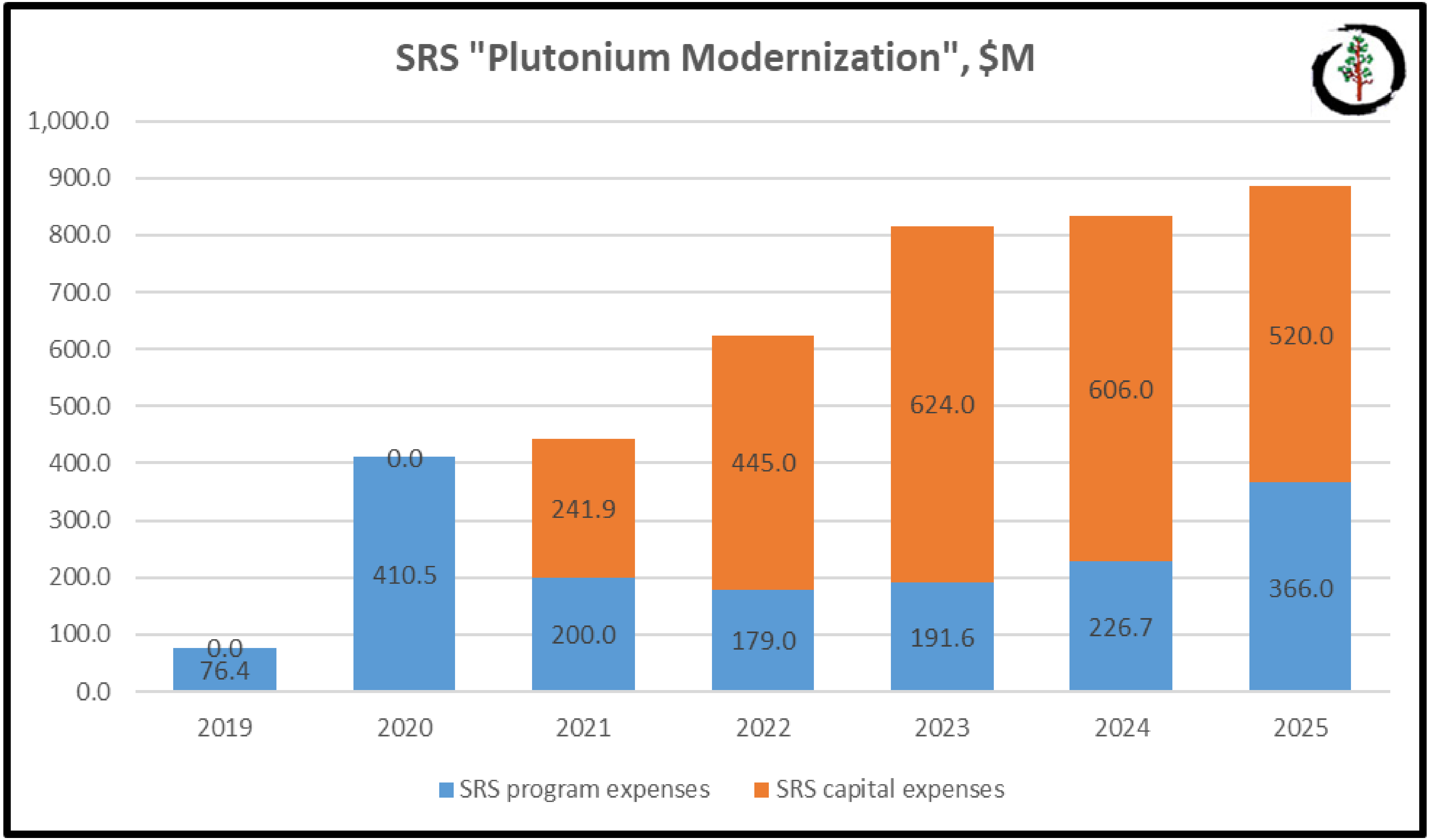
Is there a window of practical, safe pit production at LANL's PF-4? It is unlikely. (Los Alamos Study Group, 18 May 2019)

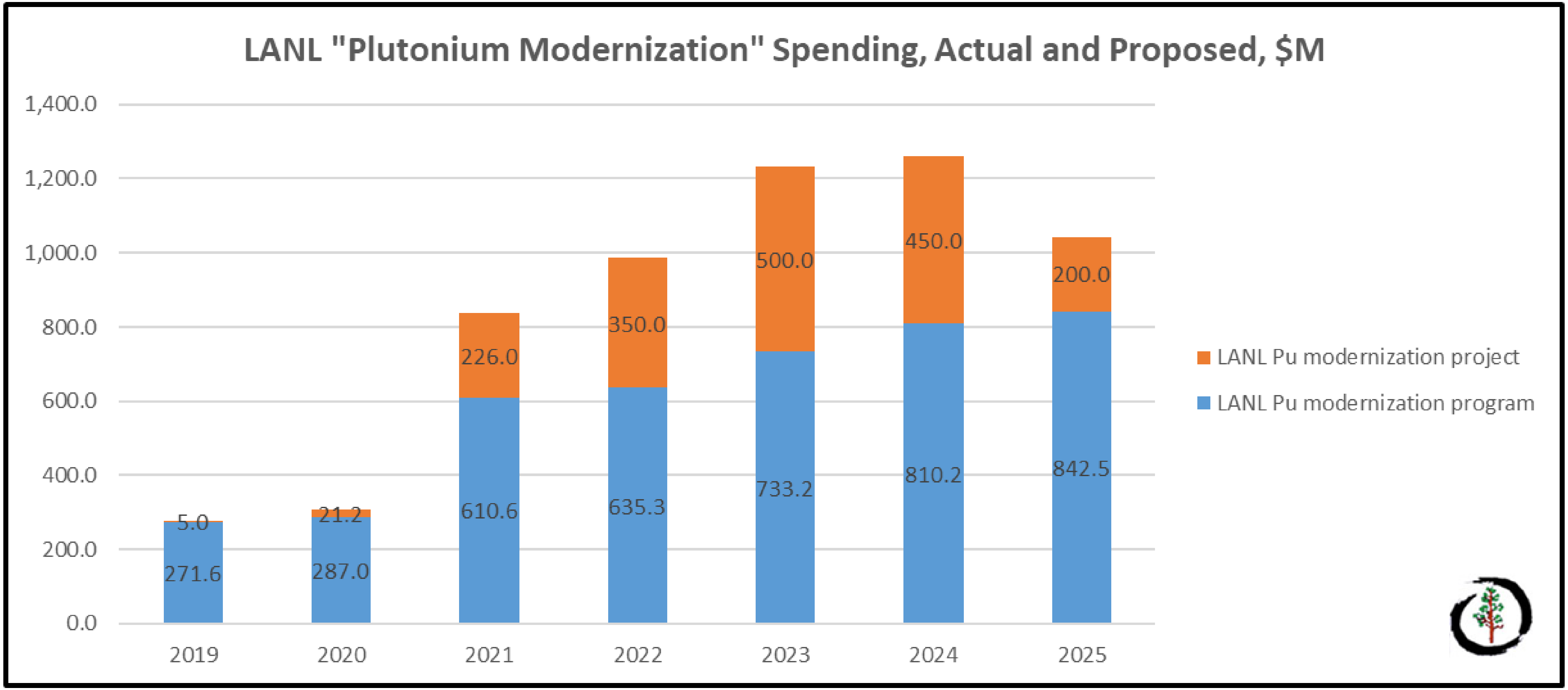
Year	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Needed TA-55 and TA-50 infrastructure tests, analysis, and upgrades, not all-inclusive																						
Column testing, seismic analysis; could be fatal to PF-4 operation as HC II Nuclear Facility; analysis may also limit MAR	(DNFSB WSR 12/28/18)			Necessity, feasibility, scope, and duration of possible PF-4 alterations are unknown at present				If needed, design and construction of a greenfield PF-4 replacement could begin in ~2022, with 30 ppy ops in ~2035. There is no room for a PF-4 replacement at TA-55. A separate 30 ppy production facility could not be built at TA-55 without massive disruption & risk. See other slides.														
PC-3 fire suppression system upgrade	(DNFSB WSR 1/4/19)							PF-4 replacement, which is unlikely to be possible for a number of reasons, would be vastly expensive (>$10 B).														
Internal firewall upgrade to 2 hours	(DNFSB WSR 1/4/19)																					
PC-3 active ventilation, fire alarm upgrade	(DNFSB WSR 1/4/19)																					
Fire water loop integrity	(DNFSB WSR 1/4/19)																					
CMRR subproject REI2	(DOE CBR)																					
CMRR subproject PEI1	(DOE CBR)																					
CMRR subproj. PEI2 (to Pu Pit Prod. Project, PPP)	(DOE CBR) Scope, cost, & duration of Pu Pit Proj. (PPP) unknown; purpose is to take LANL from 10 to 30 ppy so duration shown accordingly																					
CMRR subproj. RC3 (to PPP)																						
TA-55 Reinvest. Project III	Duration: >2024 (CBR) by ~2 yrs (estimate)																					
TRU liquid waste (TA-50)	Duration unclear but >2024 (CBR)																					
War reserve (WR) pit production expected (pits per year, ppy)																						
1	(funded by Pu Sustainment Ops)				X																	
10						X																
20	(funded by Pu Pit Production Project, scope TBD)						X															
30 (average)								X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
≥30 (NNSA: 41 average)	Infeasible (AoA p. 2)				We believe multi-shift production would lead to fairly prompt and repeated pauses and shut-downs due to single-point failures and overwhelmed chokepoints. Inadequate and inappropriate facilities, management, training, and institutional culture would be exposed. Existing PF-4 missions would be threatened, as would worker and public safety. Recovery could be difficult and might not be successful.																	
≥50 (NNSA: 84 average)	Infeasible (AoA p. 2)																					
≥80 (NNSA: 103 average)	Infeasible (AoA p. 2)																					
Cumulative WR pits (theoretical, 30 ppy average)					1	11	31	61	91	121	151	181	211	241	271	301	331	361	391	421	451	481
Model (heuristic only): probability of effective PF-4 end of life (EEOL) by given year assuming normal distribution, 10 year standard deviation																						
2039 est. EEOL (NNSA, FY2014 CBR p. WA-211)	.02	.03	.04	.04	.05	.07	.08	.10	.12	.14	.16	.18	.21	.24	.27	.31	.34	.38	.42	.46	.50	.54
2034 est. EEOL (assumed earlier EOL with 30 ppy)	.07	.08	.04	.04	.05	.07	.08	.21	.24	.27	.31.	.34	.38	.42	.46	.50	.54	.58	.62	.66	.69	.73

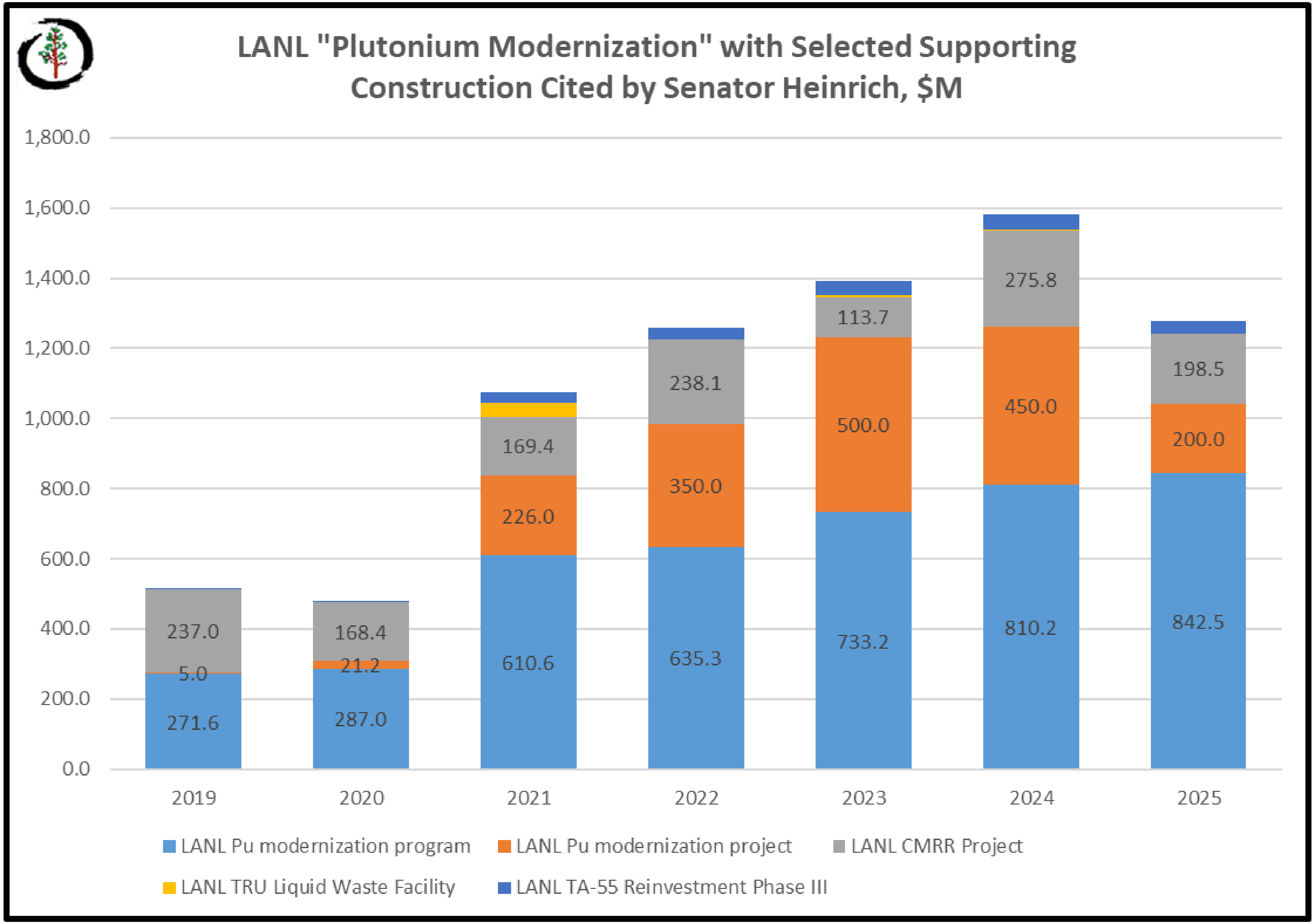
Pit production: cost issues

Plutonium (Pu) Modernization Spending, Actual and Proposed by Site, $M								
	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**Total**
Los Alamos National Laboratory (LANL) Pu Operations (pp. 102, 106)	271.6	287.0	610.6	635.3	733.2	810.2	842.5	4,190.4
LANL Plutonium Pit Production Project (LAP4), 21-D-512 (pp. 102, 106, 193)	5.0	21.2	226.0	350.0	500.0	450.0	200.0	1,752.2
Subtotal LANL Pu Modernization	**276.6**	**308.2**	**836.6**	**985.3**	**1,233.2**	**1,260.2**	**1,042.5**	**5,942.6**
Not included in the above:								
LANL Chemistry Metallurgy Research Replacement (CMRR) Project, 04-D-125 (pp. 364, 369)	237.0	168.4	169.4	238.1	113.7	275.8	198.5	1,400.9
LANL Transuranic (TRU) Liquid Waste Facility, 07-D-220-04 (pp. 364, 369)	1.0	1.7	37.7	3.0	4.0	3.2	0.0	50.6
LANL TA-55 Reinvestment Phase III (TRP-III), 15-D-302 (pp. 363, 369)	1.8	2.0	32.0	33.0	41.0	41.8	38.5	190.1
Total LANL Pu Modernization*	**516.4**	**480.3**	**1,075.7**	**1,259.4**	**1,391.9**	**1,581.0**	**1,279.5**	**7,584.2**
Savannah River Site (SRS) Pu Operations (pp. 102, 106)	76.4	410.5	200.0	179.0	191.6	226.7	366.0	1,650.2
Savannah River Plutonium Processing Facility (SRPPF) Design & Construction, 21-D-511 (pp. 102, 106, 199)	0.0	0.0	241.9	445.0	624.0	606.0	520.0	2,436.9
Total SRS Pu Modernization	**76.4**	**410.5**	**441.9**	**624.0**	**815.6**	**832.7**	**886.0**	**4,087.1**
Enterprise plutonium support, multiple sites, (pp. 102, 106)	**53.7**	**79.2**	**90.8**	**88.9**	**68.0**	**67.3**	**77.0**	**524.9**
Total Complex-wide Pu Modernization	**646.5**	**970.0**	**1,608.4**	**1,972.3**	**2,275.5**	**2,481.0**	**2,242.5**	**11,671.3**


"Plutonium Modernization" Spending, Actual and Proposed by Site, $M
(omits other Pu-mission-supporting LANL construction funded separately)
1,400.0
1,200.0
1,000.0
800.0
600.0
400.0
200.0
0.0
276.6
76.4
53.7
308.2
410.5
79.2
836.6
441.9
90.8
985.3
624.0
88.9
1,233.2
815.6
68.0
1,260.2
832.7
67.3
1,042.5
886.0
77.0
2019
2020
2021
2022
2023
2024
2025
Los Alamos National Laboratory (LANL)
Savannah River Site (SRS)
Other sites


SRS "Plutonium Modernization", $M
1,000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
0.0
76.4
0.0
410.5
241.9
200.0
445.0
179.0
624.0
191.6
606.0
226.7
520.0
366.0
2019
2020
2021
2022
2023
2024
2025
SRS program expenses
SRS capital expenses


LANL "Plutonium Modernization" Spending, Actual and Proposed, $M
1,400.0
1,200.0
1,000.0
800.0
600.0
400.0
200.0
0.0
5.0
271.6
21.2
287.0
226.0
610.6
350.0
635.3
500.0
733.2
450.0
810.2
200.0
842.5
2019
2020
2021
2022
2023
2024
2025
LANL Pu modernization project
LANL Pu modernization program


LANL "Plutonium Modernization" with Selected Supporting Construction Cited by Senator Heinrich, $M
1,800.0
1,600.0
1,400.0
1,200.0
1,000.0
800.0
600.0
400.0
200.0
0.0
2019
2020
2021
2022
2023
2024
2025
271.6
5.0
237.0
287.0
21.2
168.4
610.6
226.0
169.4
635.3
350.0
238.1
733.2
500.0
113.7
810.2
450.0
275.8
842.5
200.0
198.5
LANL Pu modernization program
LANL Pu modernization project
LANL CMRR Project
LANL TRU Liquid Waste Facility
LANL TA-55 Reinvestment Phase III

What will pits cost? (I)

1. At SRS: average LCC cost per pit

The 50-year life-cycle cost (LCC) estimate (EA briefing, S.10): $27.8 billion (B). There are no more recent open estimates, whether of LCC, total SRPPF construction, or total SRPPF startup costs.

This is for ≥50 pits per year (ppy), which leads to an expected average single-shift production of 84 ppy (AoA, p. 13).

Average cost for each of 4,200 pits: $6.6 million (M)/pit

The LCC for ≥80 ppy, leading to an average of 103 ppy (AoA, p. 13), will be in the $30.4 B - $33.0 B range (see 3. below).

Average cost for each of 5,150 pits: $5.9 M/pit to $6.4 M/pit.

2. At SRS: marginal LCC cost per pit

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.

3. Economies of scale at SRS: pit production has great economies of scale

Increasing capacity at SRPPF from ≥50 to ≥80 ppy will require an additional 22 pieces of equipment 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). This is less than 2% of total SRPPF space (EA, p. 2-30). The marginal cost of this equipment and space is too small to compute.

If operational costs – principally staff – scale with equipment, they will be 20% ($5.2 B) higher. This is a conservative estimate, because many support functions will not increase that much.

The SRS pit production EIS says (at p. S-27) that increasing capacity at SRPPF from ≥50 to ≥80 ppy will require an additional 185 staff (i.e. 10% more). This is likely to be somewhat non-conservative. Increasing operational costs by 10-20% (i.e. bracketing these estimates) in Table 3-16 of the EA leads to an LCC for the ≥80 ppy case of $30.4 B to $33.0 B.

What will pits cost? (II)

4. At LANL, average accrued cost* per pit through 2030 (*LANL LCC is unknown; see discussion, slide IV in this series)

There is $7.6 B programmed for Pu modernization and supporting activities at LANL over FY19-25 (see below). Assume the LANL pit capability requires $0.4 B in post-FY25 capital costs for a round total of $8 B in startup costs for FY19-30.

By the end of FY19 LANL employed 2,000 individuals in pit production and support activities (NNSA briefing of Jan 2020). LANL will need to hire 2,000 additional staff to achieve 30 ppy production (draft SA, March 2020, pp. 12, 15). (See also final SA, pp. 15, 18). Overall, LANL needs 4,000 staff to achieve ≥30 ppy.

Fully-burdened personnel costs at LANL are roughly $3.29 B / 13,137 employees or $250,438/person. Pit production and supporting staff will thus cost ~$1.00 B/year. This is our estimate of annual pit program costs. Consider this included in startup costs over FY19-25 but accruing after FY25.

Total pit production costs through 2030 are $8 B + $5 B, plus costs for 5 years of post-FY25 maintenance, waste management, and a pro-rata share of LANL's extensive overall capital expansion and renewal program, which together we might conservatively estimate at $1 B, gives a total cost of $14 B for LANL pit production over the FY19-30 period.

Over this period we may estimate LANL pit production as increasing, per statute, to 30 ppy in FY26 and thereafter to ≥30 ppy, i.e. an average of 43 ppy (AoA, p. 13), leading to a total production of 233 pits through 2030, or $60.0 M/pit. We do not credit (or credence) LANL "surge" production beyond an average of 43 ppy.

5. At LANL, average accrued cost per pit through 2040, assuming no PF-4R

Very optimistically assuming no investment in a PF-4 replacement ("PF-4R") is necessary during the 2030s, and allowing $2 B in maintenance, waste management, and pro rata LANL capital investments over FY26-39, leads to a total cost of $25 B for 663 pits, or $37.7 M/pit.

What will pits cost? (III)

6. At LANL, average accrued cost per pit through 2040, with PF-4R

More realistically, assume a PF-4R is required and that it is built in the 2030s. Optimistically, assume a LANL site could be found (a building of this scale and character might not be buildable at TA-55; see below). Assume a PF-4R could be built for $10 B (59,600 sq. ft. x ~$180/sq. ft. in 2020 $ = $10.7 B, not counting $1 B PIDAS or any other infrastructure such as roads and bridges, radioactive waste lines, etc.). This gives a total cost of $35 B for 663 pits or $52.8 M/pit.

7. At LANL, average accrued cost per pit over 50 years, with PF-4R

The above assumptions, with a 2%-of-asset-value maintenance investment per year and $80 M per year for waste management and pro-rata site-wide improvements but nothing for decommissioning and disposal (D&D), lead to a ballpark $82 B in overall cost for 2,181 pits or $37.6 M/pit.

8. Comparison of SRS and LANL pit costs

Average pit costs at SRS are 6-10x lower than at LANL, with early LANL pits in the 2020s being particularly expensive if LANL production turns out to be short-lived. Once pit production is established at SRS, the marginal pit cost at SRS may be even lower in relation to LANL's costs. *It is difficult to even guesstimate a true marginal pit cost at LANL because so many of LANL's operational and support requirements are challenged by even a basic 30 ppy capability.*

9. How do these cost differences affect W87-1 warhead cost?

CBO estimates non-pit warhead costs at $9-14 M each (August 2020, p. 14), i.e. $15-$20 M, including a $6 M pit. **Using LANL pits in the W87-1 approximately triples this unit cost.** GAO estimates (p. 22) a total cost of $9-15 B for the W87-1 program. **Establishing industrial pit production at LANL for the W87-1 at least doubles W87-1 program cost.**

What will pits cost? (IV)

10. The longevity of LANL's nominal 30 ppy capacity, LANL's ability to surge beyond this level, and the nature and cost of additional nuclear facilities and other infrastructure needed at LANL, are all unknown.

It is not possible to estimate LCCs at LANL under these circumstances. In the slides above we attempted to do so using scenarios, but **beyond FY2025 – still prior to start of 30 ppy production – the cost and risk situation becomes very sketchy.** Even now the situation is unclear, given the current safety problems of PF-4, uncertainties at RLUOB, LANL's dangerous and controversial legacy TRU inventory, and several other unsolved problems.

Our scenarios above use an optimistic "≥30" ppy *industrial* capacity (average: 43 ppy), not the 2017 Plutonium Sustainment Program target of a *nominal* (or "up to"; AoA, p. 4) 30 ppy. GAO uses 30 ppy (p. 16).

PF-4 cannot contribute to pit production beyond a nominal initial 30 ppy (not "≥30" ppy), as Administrator Klotz decided in June 2017 (AoA, pp. 47-48). Even 30 ppy was assumed transient. When a pit production capability is established, "PF-4 can return to the research and development mission for which it was built" (AoA, p. 2). **All dependence on PF-4 for subsequent enduring pit production is "high risk" (AoA, p. 40).** The greater the dependence on PF-4, the greater the risk (EA, p. 4-24).

Assuming pit production can be established in PF-4, current requested investments will not suffice to create enduring production at any level, because as Administrator Gordon-Hagerty has frequently said, PF-4 is old. It is not an enduring reliable asset, especially if subjected to multi-shift production. Further nuclear facilities are required but not openly planned or budgeted.

In 2017 the cost of establishing nominal 30 ppy production at LANL was thought to be $3 B. GAO used a similar figure (p. 15). **Our estimate is >4x greater. There is no longer a clear production goal at LANL.** NNSA is preparing for required but undefined "surge" preparations at LANL along with its nominal 30 ppy (2017) (AoA, p.) and ≥30 ppy (2018) assignments. This is a "very high-risk" strategy (IDA/DoD p. vii).

Extra slides

(Feb. 2019):Filtering realistic options by factual constraints: summary (1 of 2)

Constraints	1. LANL PF-4 - dependent options, all capacities	2. LANL TA-55 options independent of PF-4, all capacities	3. LANL Greenfield options, all capacities	4. MFFF at SRS options, higher capacity
Land area	Tight	Tight, affecting construction and risk to programs	Not limiting	Not limiting
Vertical depth	Either shallow (modules) or deep (large building)	Either shallow (large flat building) or deep; great disruption of missions	Probably either shallow (large flat building) or deep, not in between	N/A
Earliest start date (AoA)	2026 (small, unstable production); impossible to do larger production	2037 at the earliest, slow or slowest option	2037 at the earliest, slow or slowest option	2035, soonest option
End of life	Unknown, 2020s earliest to 2040s latest	Not limiting	Not limiting	Not limiting
Risk to other missions	High	Very high	Not limiting	Not limiting
Capital cost	Low for < 30; high for >30 ppy	Very high	extremely high	Least

Filtering realistic options by factual constraints: summary (2 of 2)

Constraints	1. LANL PF-4 - dependent options	2. LANL TA-55 options independent of PF-4	3. LANL Greenfield options, all capacities	Constraints
Production Capacity, flexibility	Low capacity, flexibility, resilience; poor/no ability to augment with new construction	Presumably not limiting but possible inherent site limitations for some functions	Not limiting	Not limiting
Safety	Impaired: substandard, old building and systems; repairs may not last; status of safety unknown at present	Presumably not limiting; new construction but site crowded and poor, compromises necessary	Not limiting; new construction	Not limiting; best construction
Workforce competence	Initial small workforce OK?; growth potential unknown; LANL issues	Unknown due to greater acquisition time lag; LANL cultural issues	Unknown due to greater acquisition time lag; LANL cultural issues	Initial workforce from/trained by LANL; growth potential good
Mission compatibility	Low	Low	Low	High
Overall results	**Temporary, uncertain for <30 ppy, impossible for higher ppy**	**Highest risk, high cost, slow or slowest**	**Very high cost, risk high but lower than TA-55 options; slow/slowest**	**Fastest, cheapest, least risk, enduring, flexible if competently pursued**