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Complex Transformation: *Nuclear Weapons Now, Nuclear Weapons Tomorrow, Nuclear Weapons Forever*

BY ARJUN MAKHIJANI, Ph.D., LISA LEDWIDGE, AND ANNIE MAKHIJANI

In his inaugural address in 1963, Governor George C. Wallace made his infamous statement in defense of racial segregation by defiantly announcing "segregation now, segregation tomorrow, segregation forever." On June 11, 1963, he stood at the door of the University of Alabama's Foster Auditorium trying to block two young African American students from entering, and stood aside only in the face of federal marshals and others. It was a stand in violation of the U.S. Constitution, since the Supreme Court, in its famous Brown v. Board of Education decision, had unanimously decided that racial segregation in schools was a violation of the Fourteenth Amendment. Apparently set on a similar course globally, with respect to nuclear weapons, the U.S. government – despite being party to the Nuclear Non-Proliferation Treaty and despite the U.S. Constitution declaring treaties "the supreme law of the land" – plans to ensure an "enduring stockpile"[1] of nuclear weapons.

Nevada Test Site. ***Preparations for an underground test. Final test preparations include running miles of cable downhole which will transmit vital test information to the diagnostic trailers to the left. A rack containing instrumentation to go downhole is assembled in the tower to the right. Subsidence craters from earlier underground tests dot the landscape.*** (Caption and photo courtesy of National Nuclear Security Administration/Nevada Site Office. (NF-1679) Photo taken 1992 or earlier.)

In December 2007, the National Nuclear Security Administration of the U.S. Department of Energy issued a Draft Supplemental Programmatic Environmental Impact Statement (Draft SPEIS) on the transformation of its nuclear weapons complex.[2] The re-invigorated complex would be the instrument that would enable the arsenal to endure, in the official view.

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Guest Article

French Nuclear Tests in the Sahara: *Open the Files*

BY BRUNO BARRILLOT[1]

On October 18, 1945, a few weeks after the bombings of Hiroshima and Nagasaki, General Charles de Gaulle, then President of the provisional government, created the French Atomic Energy Commission (abbreviated CEA) whose mission – kept secret until 1958 – was to equip France with a nuclear weapon. Following World War II de Gaulle calculated that France, ruined by the 1940 defeat by German invaders and then by the war, would need to develop nuclear weapons and nuclear energy in order to keep its place among the great nations. According to this thinking, the bomb would give it back its status of international power while nuclear energy would be the driving force of its industrial revival.

From 1945 to 1958, the CEA's official mission was to establish fundamental research and processes for civilian uses of nuclear energy. This was done without

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COMPLEX TRANSFORMATION

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In 1996, the World Court gave a unanimous advisory opinion that nuclear weapons states were obliged under Article VI of the Nuclear Non-Proliferation Treaty (NPT) to achieve nuclear disarmament "in all its aspects." In 1995 and again in the year 2000, at conferences of the parties to the NPT, the United States and all other nuclear weapon state parties affirmed that they would completely eliminate nuclear weapons. In the year 2000, they agreed to a specific set of 13 steps that would be milestones on the way to complete elimination of nuclear weapons.[3]

In 2005, the United States blocked all attempts even to get the 13 conditions mentioned in the final declaration of the NPT Review Conference, which ended in a dismal failure. In a post-conference summary, Joseph Cirincione of the Carnegie Endowment, noted:

> The United States did succeed in blocking any substantive discussion of the disarmament issues, but in so doing it ruined any substantive advances in the nonproliferation agenda....
>
> …Because the United States was not willing to compromise at all, because it went in with a basic attitude of "You're either with us or against us," because it felt that in the end it was better for the conference to crash and burn than for the United States to honor its disarmament obligations, none of the [positive] U.S. agenda was able to advance. The conference ended up as almost a completely wasted 30 days in New York.[4]

In the meantime, it had already jettisoned the Anti-Ballistic Missile (ABM) Treaty, whose continued implementation was one of the 13 steps, and rejected the Comprehensive Test Ban Treaty (CTBT), whose ratification was another.

Prior to testing its own nuclear arsenal, India had taken to calling the system, under which a few countries maintained nuclear arsenals without a clear path to their elimination while others were prohibited from getting them, by the epithet "nuclear apartheid." Official Indian representatives no longer use this phrase – after all, India is now a de facto member of the "nuclear club," acquiring a nuclear "honorary white" status, similar to the Japanese in the South African apartheid system. But the reality underlying "nuclear apartheid" persists. Complex Transformation would perpetuate it by enabling the United States to produce new nuclear weapons for half a century, while maintaining nuclear testing readiness.

The United States is not alone, of course. The other four nuclear weapon state parties to the NPT – Russia, Britain, France, and China – show no signs of giving up their arsenals and are maintaining and modernizing either the warheads or their delivery systems or both. But since the rejection of the CTBT, the withdrawal from the ABM Treaty, and the de facto rejection of the 13 steps, it has been the United States, playing the defiant role of the 1963 Alabama Governor at the door of the Nuclear Club, encouraging and entrenching the other weapon states in their nuclear recalcitrance. And India, Israel, and Pakistan – all nuclear weapon states – continue to remain in legal limbo in relation to their commitments, since none of them are parties to the NPT. Yet, in greater or lesser measure, all three are U.S. allies (as of this writing, February 2008).

The fact that the world does not have a federal institution that can enforce global elimination of nuclear weapons does not render the moral or legal situation any less obscure. It merely epitomizes the lack of equality before the law in international affairs, since the weapon states appeal to the very same NPT in bringing far weaker powers to heel, whether by sanctions or threat of war or actual war – yet another aspect of global apartheid.[5]

One element of the National Nuclear Security Administration's (NNSA) plan is the Reliable Replacement Warhead (RRW) program, though the

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Draft SPEIS claims that it is not essential to the Complex Transformation it seeks.[6] The RRW program aims to create a new generation of nuclear weapons that are more reliable, easier to maintain, and more secure in the sense of preventing unauthorized use.[7]

The "preferred alternative" specified in the Draft SPEIS has the following major elements:

- Plutonium manufacturing at Los Alamos National Laboratory, at a rate of 50 to 80 pits (the nuclear triggers of thermonuclear warheads) per year as well as plutonium research and development,
- Manufacturing of uranium warhead components at Y-12, in Oak Ridge, Tennessee, as well as uranium research and development,
- Assembly and disassembly of nuclear warheads, high explosive production, and smaller scale high explosive testing at Pantex, near Amarillo, Texas,
- Storage of category I and II Special Nuclear Material at Pantex, requiring the highest level of security,[8]
- Consolidation of tritium research and development at Savannah River Site (along with continued tritium production in commercial nuclear reactors belonging to the Tennessee Valley Authority),
- Maintenance of the Nevada Test Site in readiness to test within eighteen months and larger scale high explosive testing (more than 10 kilograms of high explosives).[9]

Some other elements include research and development of high explosives at Lawrence Livermore National Laboratory and very small-scale (less than one kilogram) high explosives testing and other research at Sandia National Laboratory.

Costs

NNSA's Complex Transformation plan would continue Cold War levels of spending on nuclear weapons work, more than $6 billion annually, for at least the next 25 years.[10] This does not include long-term cleanup and decommissioning. Nor does it take into account the Department of Energy's (DOE) tendency to vastly underestimate costs of major projects. Table 1 shows cost escalations in some of DOE's large projects.

Livermore and Los Alamos

Further, even though a part of the rationale for Complex Transformation is supposed to be consolidation of nuclear weapons related activities, the number of major facilities in the preferred alternative continues to be the same as at present. While the area of occupied buildings may go down, reducing buildings rather than eliminating superfluous sites where weapons related activities take place can hardly be called consolidation. Critical consolidation options were not examined, notably in relation to Los Alamos and Livermore.

Let us consider Livermore first. One new large machine at Livermore, the National Ignition Facility, is mired in cost overruns and technical difficulties. Given that the high energy facilities at Sandia National Laboratory in New

Table 1: Cost data in some major Department of Energy projects

Project	Early Estimate	Later Estimate
Superconducting Super-collider	$5.3 billion (1987)	$8.25 billion (1991)
National Ignition Facility	$2.03 billion (FY1998)	$3.26 billion (June 2000)
Savannah River Site Defense Waste Processing Facility	$1.2 billion (1987)	$3.9 billion (1992) ($2.1 billion plus $1.8 billion for supporting facilities)
Hanford Tank Waste Project (Phase I)	$4.3 billion (before September 1996)	$8.9 billion (August 1998)
All High-Level Waste Management Programs	$63 billion (1996)	$105 billion (2003)
Fernald Vitrification Project	$14.1 million (February 1994)	$20.6 million (December 1994) $56 million (July 1996) $66 million (September 1996)
Yucca Mountain	$17.5 billion (30 year cost estimated in 1990 adjusted to year 2000 dollars)	$58 billion (100 year cost estimated in 2000) DOE contractors said cost was understated by $3 billion since repository would not likely open in 2010 as claimed.

Sources: GAO/RCED-93-87 p. 2, GAO/RCED-97-63 p. 5, GAO/T-RCED-99-21 pp. 2-4, GAO-02-191 p. 19, GAO/T-RCED-93-58 p. 8, GAO-03-593 p. 17, GAO/RCED-92-183 p. 3, and Rowberg 2001[11] pp. CRS-3 and CRS-5

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Mexico have been performing relatively well,[12] the main tangible result of the National Ignition Facility has been to burn a hole in the taxpayers' pocketbook. As another example, a modest amount of high explosives research is to be carried out at Livermore. But high explosives research would also be done at Pantex, Sandia, and the Nevada Test Site. Why can't the research earmarked for Livermore be done at one of the other sites, especially as the quantities to be tested at Livermore are small?

The main tangible result of the National Ignition Facility has been to burn a hole in the taxpayers' pocketbook.

The need for continued production of plutonium pits is even more dubious. A recent study by the JASONs, an elite group of scientists who regularly provide analysis and advice to the government, including on nuclear weapons matters, concluded that the expected lifetime of existing plutonium pits was on the order of 100 years:

> Most primary types have credible minimum lifetimes in excess of 100 years as regards aging of plutonium; those with assessed minimum lifetimes of 100 years or less have clear mitigation paths that are proposed and/or being implemented.
>
> The Laboratories have made significant progress over the past 3-5 years in understanding plutonium aging and pit lifetimes. Their work is based on analyses of archival underground nuclear-explosion testing (UGT) data, laboratory experiments, and computer simulations. As a result of the Los Alamos/Livermore efforts, JASON concludes that **there is no evidence from the UGT analyses for plutonium aging mechanisms affecting primary performance on timescales of a century or less in ways that would be detrimental to the enduring stockpile.**[13] [emphasis added]

There is no need therefore for enhanced pit production capability, or indeed any pit production capacity at all. This appears to be little more than a vast and continuing pork barrel program for the nuclear weapons establishment.

Any arguments related to safety and reliability would either be related to secondary components or to the non-nuclear components. New pit production capacity is not relevant to these concerns, should they be legitimate. Moreover, in the context of the disarmament requirements of the NPT, they are not.

IEER's earlier research has shown that there has never been an aging-related safety defect in the primary component of nuclear weapons.[14] Moreover, almost all of the safety related problems were discovered within the first five years of warhead production. Reliability concerns are defined around whether the warhead would explode at or above the expected yield and as close to the target as designed (or closer). In the context of the need for greatly reducing the numbers of nuclear weapons and of nuclear disarmament, such concerns are not really relevant to U.S. treaty obligations. In the past it might have been argued that accurate performance estimation served a deterrence function.

But the Cold War is over and present security concerns relate mainly to terrorism. These concerns are unaffected by considerations of the exact yield of U.S. nuclear weapons. Rather it is the very existence of those weapons and the determination to hold on to them that gives rise to security concerns. Last year, in an historic opinion piece, four of the most respected establishment foreign policy thinkers, George P. Schultz, William J. Perry, Henry A. Kissinger, and Sam Nunn, expressed this reality:

> Nuclear weapons were essential to maintaining international security during the Cold War because they were a means of deterrence. The end of the Cold War made the doctrine of mutual Soviet-American deterrence obsolete. Deterrence continues to be a relevant consideration for many states with regard to threats from other states. But reliance on nuclear weapons for this purpose is becoming increasingly hazardous and decreasingly effective.
>
> North Korea's recent nuclear test and Iran's refusal to stop its program to enrich uranium – potentially to weapons grade – highlight the fact that the world is now on the precipice of a new and dangerous nuclear era. Most alarmingly, the likelihood that non-state terrorists will get their hands on nuclear weaponry is increasing. In today's war waged on world order by terrorists, nuclear weapons are the ultimate means of mass devastation. And non-state terrorist groups with nuclear weapons are conceptually outside the bounds of a deterrent strategy and present difficult new security challenges.[15]

Hence, even within the framework of conventional strategic thinking, the precise yield of nuclear weapons, should they be used, is essentially an academic matter; it should not be the object of vast expenditures that will set a poor non-proliferation example globally – traditionally known as "preaching temperance from a barstool."

Finally, the competition between Livermore and Los Alamos for the design of the nuclear components of the so-called "Reliable Replacement Warhead" was "won" by Livermore. In light of the multiple problems at Los Alamos, one clear option would be to end nuclear weapons design and production-related functions at Los Alamos. Since there is no need for new pit production, that option would include an end to new pit production.

Another option would be to end new nuclear weapons design, testing, and production functions altogether at both laboratories. This would be our preferred alternative.

Risks to human health

The problems are not limited to the risk of provoking nuclear proliferation and the waste of taxpayer dollars. The continued production of nuclear weapons can be expected to cause continued harm to health and the environment. Increasing nuclear weapons production will create new wastes, when old wastes have not yet been properly managed or even accounted for.

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DOE estimates that worker radiation exposure would result in about 0.1 additional cancer deaths per year.[16] Multiplying this value for annual expected deaths by the expected operation of 50 years, about five workers would be expected to die of cancer as a result of work-related radiation doses. The surrounding communities would also be at risk. For instance, some accidents, such as a fire or explosion in the feed casting furnace, could cause 11 to 20 cancer fatalities in the community around Los Alamos.[17] These are estimates straight out of the Draft SPEIS.

Further, the dose estimates for "non-involved" workers in case of accidents appear far too low. The Draft SPEIS assumes that the worker will be as much as one kilometer away from the location of the fire or explosion, when there is a significant chance that, given the layout of Los Alamos facilities buildings and roads, many workers would be a lot closer. External doses vary approximately according to the inverse square of the distance. For instance, if non-involved workers were within 100 meters (about 110 yards) from the accident location, the estimated dose would be roughly 100 times higher than the DOE estimate. The Draft SPEIS also does not provide estimates of how many "involved" workers – those at the place where the accident is hypothesized to occur – would die of cancer or direct injuries as a result of such accidents.

Risks to the environment

Then there is the matter of environmental pollution. Los Alamos has not been a very good neighbor in this regard as evidenced by the fact that plutonium, strontium, and other radionuclides have found their way into groundwater near Los Alamos. Because of past dumping, storm water in the canyons as well as groundwater nearby is contaminated – in excess of drinking water standards in some cases (see Tables 2 and 3). While the water is not used for drinking, it does flow into the Rio Grande.

Security problems at Los Alamos

In January 2007, the Director of NNSA was relieved of his responsibilities, at least partly due to LANL's repeated major security problems and scandals.[20]

One of the most important problems at LANL, but one that yet has not been fully investigated, has been its poor plutonium accounting as it relates to waste. There are two sets of books on plutonium accounts. One of these, the Nuclear Materials Management and Safeguards System (NMMSS), the master nuclear materials account, is at variance with the waste account, notably that compiled by LANL for the U.S. Environmental Protection Agency (EPA) as part of its program to send transuranic wastes to the Waste Isolation Pilot Plant (WIPP) for deep geologic disposal. A study by IEER has shown that the NMMSS account and WIPP account for plutonium in waste cannot both be right at the same time (though they may both be wrong).[21] The discrepancy amounts to about 300 kilograms. There are potentially serious environmental implications if the amount in waste is greater than now believed by 300 kilograms. There are potentially serious security implications if the NMMSS account is short by 300 kilograms.

Table 2: Some storm water data for canyons near LANL in picocuries per liter

	Onsite Canyons	Mortandad Canyon	Drinking water standard	Drinking water standard, if all 3 radionuclides are present equally
Americium-241	15	40	15	5
Plutonium-238	15	50	15	5
Plutonium-239/240	10	30	15	5

Values estimated from graphs in the 2006 Draft LANL SWEIS, Appendix F, Figures F-13, F-15, and F-16; Standard from 40 CFR 141.66 2005.[18]

Table 3: Groundwater contamination near LANL, 2001-2004 in picocuries per liter

	Canyon alluvial ground-water systems	Other springs	San Ildefonso Pueblo	Drinking water standard
Americium-241	0.5	0.03	0.02	15
Plutonium-238	0.6	0.015	2.0	15
Plutonium-239/240	0.25	0.015	0.01	15
Strontium-90	20	50	0.2	8

Values estimated from graphs in the 2006 Draft LANL SWEIS, Appendix F, Figures F-1, F-3, F-4, and F-5; Standard from 40 CFR 141.66 2005.[19]

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Repeated attempts to get the DOE and the NNSA, as well as the EPA, to seriously investigate this problem, which amounts to 60 bombs worth of plutonium, have failed.[22] IEER has received assurances from NNSA that the NMMSS account is correct. We have also received assurances from the EPA that the WIPP account is correct. These statements cannot both be correct – it is arithmetically impossible.

There have been many security-related scandals at Los Alamos, going back to the Manhattan Project, when the plutonium bomb design was stolen and given to the Soviets. More recently, in 2006, an employee was able to walk away with highly classified documents on a flash drive, which was found in a house-trailer.[23]

In comments on the scope of the Draft SPEIS,[24] IEER had pointed out that, in view of the severity and frequency of security related problems, DOE should consider at least one option that did not have any weapons function for Los Alamos. But IEER's recommendation was ignored.

As noted above, nuclear weapons functions were also retained for Livermore, even though there is scant justification for it, even within the framework of new weapons production capability. Hence, the preferred alternative is arguably the worst in many ways because it:

- wastes huge amounts of taxpayer money by keeping nuclear weapons functions at Los Alamos.
- centers plutonium pit production at Los Alamos, which has had serious plutonium accounting problems and many other security related problems and infractions – far more than Livermore.
- increases the risk of more serious pollution of ground and surface waters in and around Los Alamos, especially in case of fires or serious accidents, even after past weapons work has already created significant pollution that remains to be remediated.

Resumption of nuclear weapons testing?

There is a reasonable likelihood that nuclear weapons that incorporate new pit designs will have to be tested before they can be certified as safe and reliable components of the U.S. nuclear arsenal. IEER recognizes that the goal of the Stockpile Stewardship Program has been to certify "the safety and reliability of nuclear weapons without underground testing."[25] However, the introduction of newly designed pits, rather than the use of existing pits that have already been certified after the testing of existing weapon types, clearly raises the possibility that one or more types of nuclear warheads incorporating these new pit designs will need to be tested before they can be certified for the U.S. nuclear arsenal.

The possibility of testing has arisen already within official circles in the form of a refusal to make commitments on testing:

> On Friday, Bryan Wilkes, a spokesman for the National Nuclear Security Administration of the Energy Department, said the government would not proceed with the Reliable Replacement Warhead "if it is determined that testing is needed." But other officials in the administration, including Robert Joseph, the under secretary of state for arms control and international security, have said that the White House should make no commitment on testing.[26]

There is a reasonable likelihood that new pit designs will necessitate testing, especially given DOE's poor track record in major technical projects

Hence, even before a single spadeful of dirt has been turned to implement the new plan, government officials in positions of authority are not in accord. Moreover, once built, there is no guarantee that the specific uses to which the facilities will be put in 2030 or 2040 or 2050 are those that are envisioned today in terms of the types of pits that will be manufactured or the design goals that those weapons must meet. Meeting the requirements of the Department of Defense (DOD) and national security decision-makers is the stated goal of the Complex Transformation program. The Reliable Replacement Warhead program may be initiated with the intent that the warhead would not require testing, but that intent could fall by the wayside if, for instance, the directors of the national laboratories or DOD decision-makers decide after the initial pits are built that testing is needed for safety and/or reliability.

Testing is made even more likely by the recent poor record of the DOE in its performance on major technical projects, as discussed above. Design and manufacturing of a new pit that would be the key component of a warhead that could be certified without testing would be an enormous challenge under any circumstances. Under the management of the DOE as it has operated for the last two decades, the likelihood of testing and the environmental harm that it would cause is considerably greater. Management problems and unforeseen problems in design or new design requirements arising out of new functions of nuclear weapons in DOD's planning or any combination of these factors could lead to a lack of confidence in the reliability of new pits without testing.

Because testing is one reasonable and potential foreseeable consequence of embarking on new pit designs, IEER had said that the environmental impact of resuming nuclear weapons testing at the Nevada Test Site be analyzed in the Draft SPEIS. But this recommendation was also ignored.

Specifically, the analysis of the impacts of underground testing should take cognizance of the research that has been done at the Nevada Test Site (NTS) that indicates that plutonium in colloidal form may travel much faster than believed when testing was being carried out.[27] The examination of the impacts of testing at NTS must be done for the same reason that the impacts of accidents that can

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be reasonably regarded as possible, even though unlikely, is necessary as part of the NEPA process.[28] In this case, the likelihood of testing is far greater than that of many accidents that DOE has postulated and examined in the EISs that form the antecedents to the Draft SPEIS.

If the United States resumes testing, it is likely to result in the same by one or more of the other nuclear weapon states, such as Russia or China, or India. Note that China has not ratified the CTBT and is unlikely to do so unless the United States does it first; India has not signed it. There is no assurance that foreign resumption of testing would be underground, or, if it is underground, that it would not vent large amounts of radioactivity. Hence, the possibility that new pit designs would eventually lead to a complete breakdown of environmental norms cannot be ignored, even though this may now be regarded as unlikely. The direct and indirect environmental impacts on the United States of foreign resumption of testing should be examined as part of the overall potential impacts, in the same manner that accidents, even rather improbable ones, are considered.

Conclusions

The Draft SPEIS presents a shocking vista of 50 more years of plutonium and highly enriched uranium weapons parts, nuclear warhead assembly, an undiminished number of laboratories, potential worker cancer deaths, and potential contamination of communities, especially in case of certain accidents.

There is no analysis of the risk of security problems (including plutonium accounting problems) in view of the preferred alternative's recommendation to expand pit production at Los Alamos, where these problems have been rife. There is not a nod to U.S. obligations under the NPT as interpreted by the World Court. There is no analysis of the risk posed to the United States from the provocation to proliferation represented by continued pursuit of new nuclear weapons or even of the resumption of nuclear testing that may be a consequence of such a pursuit. There is no recognition of Article VI of the U.S. Constitution, which makes treaties the supreme law of the United States. The second paragraph of Article VI states, in full:

> This Constitution, and the laws of the United States which shall be made in pursuance thereof; and **all treaties made, or which shall be made, under the authority of the United States, shall be the supreme law of the land;** and the judges in every state shall be bound thereby, anything in the Constitution or laws of any State to the contrary notwithstanding. [emphasis added]

U.S. nuclear weapons posture has become increasingly like the global nuclear counterpart of the recalcitrant and illegal segregationist stand of George Wallace in 1963. To his credit, Wallace, in his later years, renounced that position. By what process shall the United States and the other nuclear weapon states arrive at the point of denouncing nuclear apartheid and embark on a course that would eliminate nuclear weapons globally? What better time to pose this question and pursue an answer than before an historic election in the United States?

Endnotes

1. The phrase is an official one, describing the goal of the Stockpile Stewardship Program, established in 1994. See, for instance, a 2004 DOE Factsheet on the program at http://www.nv.doe.gov/library/FactSheets/DOENV_1017.pdf.
2. U.S. Department of Energy, National Nuclear Security Administration, *Draft Complex Transformation Supplemental Programmatic Environmental Impact Statement*, DOE/EIS-0236-S4, December 2007, at http://www.eh.doe.gov/NEPA/docs/deis/deis0236S4/index.htm. This program was formerly called Complex 2030.
3. Nicole Deller, Arjun Makhijani, and John Burroughs, editors, *Rule of Power or Rule of Law? An Assessment of U.S. Policies and Actions Regarding Security-Related Treaties*, Apex Press, New York, 2003, pp. 24-29.
4. Joseph Cirincione, "Failure in New York," Carnegie Endowment for International Peace, June 7, 2005, at http://www.carnegieendowment.org/npp/publications/index.cfm?fa=view&id=17042. He is currently President of the Ploughshares Fund.
5. For an analysis of the global economic and political system as global apartheid, see Arjun Makhijani, *Manifesto for Global Democracy: Two Essays on Imperialism and the Struggle for Freedom*, Apex Press, New York, 2004.
6. Draft SPEIS 2007, Section 2.5.8.
7. For more information on RRW, see NNSA's March 2007 fact sheet, "Reliable Replacement Warhead Program," at www.nnsa.doe.gov/docs/factsheets/2007/NA-07-FS-02.pdf.
8. Draft SPEIS 2007 p. S-2.
9. Draft SPEIS 2007 Section 3.17.
10. Tom Clements, "DOE on that $150 billion for rebuilding the complex," e-mail on February 23, 2008, to the ANA Bananas listserv, quoting George C. Allen Jr., Director of the DOE's Office of Transformation.
11. Richard Rowberg, *The National Ignition Facility: Management, Technical, and Other Issues*, CRS report for Congress, Order code RL30540, Congressional Research Service, Washington, DC, updated November 8, 2001.
12. See, for instance, the description of some Sandia high energy experiments in Arjun Makhijani and Hisham Zerriffi, *Nuclear Safety Smokescreen,* Institute for Energy and Environmental Research, Takoma Park, Maryland, July 1998.
13. JASON Program Office, *Pit Lifetime,* R.J. Hemley, et al., JSR-06-335, MITRE, McLean, VA, January 11, 2007, p. 1. ("Approved for public release").
14. Hisham Zerriffi and Arjun Makhijani 1996, op.cit.
15. George P. Shultz, William J. Perry, Henry A. Kissinger, and Sam Nunn, "A World Free of Nuclear Weapons," *Wall Street Journal,* January 4, 2007, Page A15, posted at http://www.fcnl.org/issues/item.php?item_id=2252&issue_id=54.
16. DRAFT SPEIS 2007, Table 3.16-1.
17. DRAFT SPEIS 2007, Table 5.1.12-1a.
18. U.S. Department of Energy, National Nuclear Security Administration. Los Alamos Site Office, *Draft Site-Wide Environmental Impact Statement for Continued Operation of Los Alamos National Laboratory, Los Alamos, New Mexico,* DOE/EIS-0380D, June 2006, at http://www.eh.doe.gov/nepa/docs/deis/eis0380d/index.html and *Code of Federal Regulations. Title 40--Protection of Environment. Chapter I—Environmental Protection Agency. Part 141–National Primary Drinking Water Regulations,* 7-1-05 Edition, at http://www.access.gpo.gov/nara/cfr/waisidx_05/40cfr141_05.html.
19. ibid.

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20. "Statement from Linton Brooks," January 4, 2007, at http://www.nnsa.doe.gov/docs/newsreleases/2007/PR_2007-01-04_NA-07-01.pdf.
21. The analysis of this assertion is to be found in IEER's report, *Dangerous Discrepancies,* at www.ieer.org/reports/lanl/weaponspureport.pdf.
22. Correspondence with the EPA, DOE, NNSA, can be found at www.ieer.org/latest/pudiscrepanciesindex.html.
23. For a record of the many security-related infractions at Los Alamos, see the compilation by the Project on Government Oversight at http://www.pogo.org/p/homeland/ha-071212-lanl.html and the related document URLs at that location and at http://www.pogo.org/p/environment/eo-losalamos.html.
24. http://www.ieer.org/comments/dsmt/bombplexnoi.pdf.
25. Stockpile Stewardship Program, op.cit., at http://www.nv.doe.gov/library/FactSheets/DOENV_1017.pdf.
26. William J. Broad, David E. Sanger, and Thom Shanker, "U.S. Selecting Hybrid Design for Warheads," *New York Times*, 7 January 2007.
27. A. B. Kersting, D. W. Efurd, D. L. Finnegan, D. J. Rokop, D. K. Smith, and J. L. Thompson, "Migration of plutonium in groundwater at the Nevada Test Site," *Nature* 397 (1999) 56-59.
28. NEPA is the National Environmental Policy Act. It requires the production of an Environmental Impact Statement and a public comment process for all major federal actions.

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the knowledge of Parliament and with secret financing from the Présidence du Conseil.[2] All the facilities necessary for manufacturing the bomb were created before 1958, from the production of plutonium in the Marcoule reactors, which were fueled with natural uranium, to the development of the gaseous diffusion process for the enrichment of uranium in the CEA's research center in Saclay, located in the southwestern suburbs of Paris.[3]

France's determination to obtain the bomb was accompanied by a search for a nuclear test site. Jean-Marc Regnault's historical research reveals that the military authorities started the search for suitable sites as early as the mid-1950s.[4] The search for an underground site in France – in the Alps, the Pyrenées, and Corsica – was rapidly abandoned. In 1958, eight sites (seven in the Alps and one in Corsica) were listed but rejected. For six of the Alpine sites the reasons given were technical, ranging from highly fractured rock, risks of groundwater contamination, and potential lack of containment. There was no particular objection for the seventh site, albeit it was felt that its characterization would take too long. The Corsican site was rejected for fear of local opposition at a time when tourism was being developed.[5] The search shifted to France's colonial empire, specifically in the Sahara, the Tuamotu archipelago of French Polynesia, the Kerguelen Islands in the southern part of the Indian Ocean, and even in New Caledonia.

The Choice of the Sahara

Regnault's research in the military archives shows that, by the end of the 1950s, French military authorities had chosen, for technical and political reasons, to conduct the tests in the Sahara and in French Polynesia. The Polynesian archipelagoes, however, did not have the necessary naval and air infrastructure to host such a large-scale project. Before a test site could be built, preliminary work was required, which was expensive because of the great distance from France. As early as 1957 the Polynesian archipelago, being less densely populated, was chosen to carry out France's thermonuclear tests that could not be carried out in the Sahara because of their great power and the potential for very widespread radioactive fallout. But the infrastructure necessary to host such a vast project would not be ready until the mid-1960s.

Despite imminent negotiations for independence – the outcome of the Algerians' liberation war – construction of the Reggane test site, situated in central Sahara, was started in October 1957.

Despite imminent negotiations for independence – the outcome of the Algerians' liberation war – construction of the Reggane test site, situated in central Sahara, was started in October 1957.[6] The CEA and the French army, both in charge of the testing program, were given financial resources and massive manpower to build a "city," Reggane, in the middle of the desert and the experimental infrastructure, 50 kilometers (about 30 miles) north of Hammoudia, which was the location for detonating the bombs.[7] On April 11, 1958, the Président du Conseil, Félix Gaillard, announced that France's first atomic test would take place in early 1960.[8] By then, the Marcoule reprocessing plant would have produced enough plutonium for the first fission bomb.

The early announcement of France's intent to join the nuclear club took place in a political context where, under the pressure of the international scientific community, the three nuclear powers (the United States, the Soviet Union and Britain) were negotiating a moratorium on atmospheric testing set to begin in November 1958. France, which technically needed to conduct atmospheric testing for the development of its bomb, had to announce its intention to the world to become a nuclear power before the international rule of law could get in the way. This is the origin of France's official line, "the independence of France," started by General de Gaulle, which meant that France would position itself on the world stage as a power independent from the influence of the United States and the Soviet Union. During the following decades, France did not sign any nuclear treaties, such as, for example, the Non-Proliferation Treaty (NPT) and the Atmospheric Test Ban Treaty, that it considered obstacles to the realization of its nuclear ambitions. (France finally joined the NPT in 1992 and ratified the Comprehensive Test Ban Treaty in 1996.)

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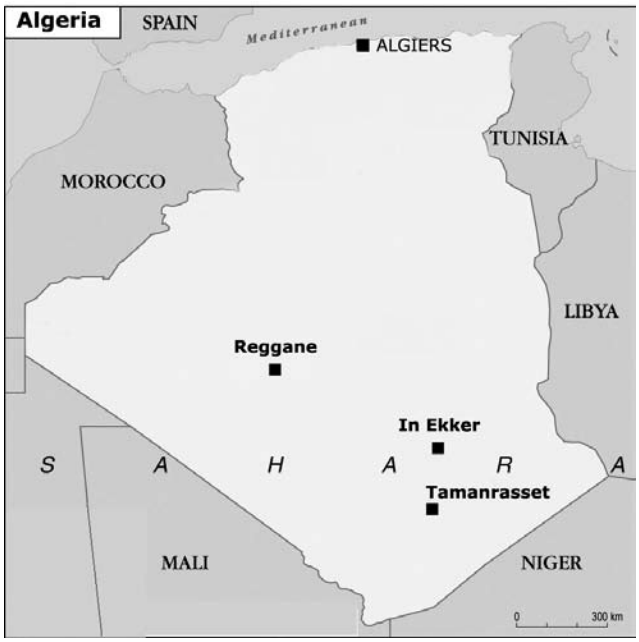
French atmospheric tests at Hammoudia

Between February 13, 1960, and April 25, 1961, France carried out four atmospheric tests at Hammoudia, Algeria, code named Gerboise bleue, Gerboise blanche, Gerboise rouge and Gerboise verte. (A gerboise is a small rodent that lives in sandy soils.) Apart from scanty data reproduced on maps in a 1960 CEA report, the official information on testing fallout remains secret.[9] At the time of the tests, as well as today, France claimed and continues to claim that the effects of the fallout were negligible both in the Sahara and in Polynesia. As recently as a February 2007 conference on the nuclear tests, organized by the Algerian government, the French Embassy in Algiers maintained that the Sahara desert tests were responsible for "an exposure to the local populations below the recommendations of the International Commission on Radiological Protection" and that "the monitoring of food products did not detect a level of contamination that would present a medical risk."[10]

Map of Algeria showing the location of France's two nuclear weapons test sites, Reggane and in Ekker.



Despite these official denials, the testimony of many witnesses to the tests recounts that there was fallout far from the test location as a result of the atmospheric tests. The testimony comes from veterans who were recording radioactivity hundreds of kilometers from Hammoudia as well as from authorities of neighboring countries. The U.S. Department of Energy's archives contain public data on the fallout in Tunisia. Mr. Yves Rocard, a scientific adviser of the CEA, attests in his memoir that French pilots "came face to face with their American colleagues who were making their own measurements," in Libya.[11]

In 1999, thirty-eight years after the atmospheric tests, a preliminary report of the International Atomic Energy Agency (IAEA) on the Saharan sites mentions

PHOTO: BRUNO BARRILLOT, NOVEMBER 17, 2007

Vitrified sand near ground zero of the atmospheric "Gerboise Bleue" nuclear test, France's first, which took place on February 13, 1960, near Reggane.

the persistence of zones contaminated with cesium-137, strontium-90, and plutonium-239, around ground zero of the four atmospheric tests of Hammoudia.[12] The veterans testified that the land around the ground zero locations was covered with a black stain of vitrified sand several hundred meters in diameter.[13] Nearly forty years later, the IAEA's experts could find only a few fragments of this vitrified black sand considered highly contaminated.[14] Therefore, it is plausible that this vitrified sand has been dispersed over vast areas by the sandstorms which routinely occur in this desert zone.

The veterans testified that the land around the ground zero locations was covered with a black stain of vitrified sand several hundred meters in diameter.

In spite of France's official denials, the protection of the test site personnel, in particular of the French soldiers and the locally hired civilian personnel, was hardly assured. On that point there are many similar accounts that describe the negligence of the military authorities.[15] Moreover, the Army's Radiological Protection Service failed to assure their monitoring and their protection. This is indicated, for example, by evidence provided by atomic veterans in court. They report that when they ask for their dosimetric records, the standard official response is that the personnel were not involved in tasks with the potential for radiological exposure. This act of bad faith on the part of the authorities in charge of radiological protection is so obvious that today many French courts give credit to the veterans' version of the events, while for many years they had routinely accepted the official version exonerating the French Defense Ministry. This change on the part of the courts may well be the result of several factors. Among them are (i) the airing on French national television of films that show negligence on the part of the military authorities in charge of the tests and their contempt for the protection of the personnel, (ii) the creation of veterans'

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associations in France and Polynesia since 2001, and (iii) the sharp increase (more than 300 today) in the number of court actions on the part of veterans, while in the previous 20 years the tribunals received only a few cases.

The recent disclosure of archives and documents reveals risky activities that were perpetrated by the same authorities that claim to be the guardians of the birthplace of human rights. For example, a French military unit was dispatched from Germany to the Sahara to march in the direction of ground zero a few moments after the test explosion, code named "Gerboise verte," the code name of the fourth atmospheric test on April 25, 1961.[16]

There are many accounts from veterans that were present at the tests. Here we summarize two in which the veterans believe that their health problems are related to the radiation they received at the time.

1. Roland W., a radiologist, recounts that he was sent to ground zero after the February 13, 1960 test (Gerboise bleue) without adequate protection. Two film badges (one in February, the other in April 1960) revealed high exposure. In between, in March 1960, he had a surgical intervention in his groin due to an inflamed lymph node. Subsequently, in 1968, he had another surgical intervention for osteomyelitis in his thigh bone and, in 1987, his thyroid was removed.[17]

2. Lucien P. worked as a miner and mason to prepare the galleries for the underground tests. (See the following sections). He recounts that on the day of the May 1st test he was 800 meters from the explosion and claims that he was irradiated by the radioactive cloud that escaped from the mountain. On May 14th, he resumed his work in a new gallery of the same mountain. One year later small areas of skin cancer appeared on his face and then a cancer in his jaw. Sometime later he suffered from polycythemia and then pulmonary sarcoidosis.[18]

Underground tests at In Ekker

As the Algerian war was coming to a close, the Polynesian sites were not yet ready for the next tests. Therefore, the French negotiators of the Evian agreement, that set the terms of France's withdrawal from Algeria, signed on March 19, 1962, obtained from their Algerian counterparts the use of the "facilities of In Ekker, Reggane and the whole of Colomb-Béchar Hammaguir" for five years.[19] Nowhere in the agreement is it written that the "facilities" of Reggane and of In Ekker were earmarked for nuclear tests but it is likely that the Algerians voiced their opposition to atmospheric tests. As a result, the French authorities in charge of the testing program were probably forced to conduct underground tests. But France apparently needed atmospheric tests for its future weapons.

After the "success" of the plutonium fission bombs in Hammoudia, France's objective was to obtain a thermonuclear weapon as soon as possible; its development would require above-ground testing due to their power. According to one expert of the CEA's Directorate for Military Applications, the types of weapons that France tested underground at In Ekker were "obsolete even before they could be produced."[20] In spite of that, before resuming atmospheric testing in 1966, as soon as the sites at the atolls of Moruroa and Fangataufa were ready, between November 7, 1961, and February 16, 1966, France carried out 13 underground tests in the granite mountain of Taourirt Tan Afella (one area of the In Ekker site) located at the western border of the Hoggar mountains. This site was selected without regard to public health. Indeed, Taourirt Tan Afella is a solid mass of rock with a forty kilometer (25 miles) circumference located only about 300 meters (about 980 feet) from the principal route that crosses the Saharan desert, starting at the Mediterranean, passing through the town of Tamanrasset in the Hoggar mountains and ending in the African sub-Sahara. After the 1999 IAEA investigation (see below) the Algerian Government erected a 40 kilometer, three-meter fence to prevent access to this dangerous, contaminated mountain. There is a military presence next to the fence, but it appears difficult to permanently monitor it. After the 1962 testing accident (see next section) the French government also built a fence but only to prevent access to the tunnel.

The 1962 testing accident

Four of the 13 underground tests, carried out in tunnels several hundred meters deep, dug horizontally into the mountain, were not "contained." In other words, either the mountain fissured or the sealing of the tunnels did not resist the force of the explosion, resulting in the release of radioactive gases and molten rock debris.

The containment measures failed at the time of the explosion: a radioactive cloud spread in the atmosphere and contaminated molten rocks were ejected from the tunnel.

The May 1, 1962 test, code named "Beryl," was carried out in the E2 tunnel dug in the mountain of Taourirt Tan Afella. The actual power of the bomb is still secret but it is estimated to have been between 10 and 30 kilotons.[21] However, the power of the bomb was possibly much higher due to a miscalculation.[22] The containment measures failed at the time of the explosion: a radioactive cloud spread in the atmosphere and contaminated molten rocks were ejected from the tunnel. A general panic followed and the 2,000 or so spectators fled, including two French ministers, Pierre Messmer and Gaston Palewski. The circumstances of this accident are now well-documented in the veterans' testimonies.[23] In a letter to his father, dated May 14, 1962, Michel R., a young soldier, describes in detail the unfolding of the test. Here are a few excerpts:

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> The detonation took place at 11 a.m. …. Right away blocks came loose and rolled off the mountain. …The color of the mountain changed from brown to white… As the noise from the explosion settled down, a new, more intense growling made us look toward the cavity where the galleries are situated. … Then we saw black smoke, resembling the smoke from a train engine, rising to take the shape of a real cloud. At that point the panic started (I am measuring my words). … I was told that farther back [Michel R. was closer] civilians and military personnel left everything and fled while at that time there was no danger yet.[24]

Official information on the accident minimizes its importance by claiming that a "fraction of the radioactivity, from 5 to 10 %, escaped from the tunnel in the form of lava and of projected scoria which were solidified at the entrance of the gallery, and in the form of aerosols and of gases that formed a cloud that climbed up to 2600 meters [8,530 feet] whose radioactivity was detected a few hundred kilometers away."[25] The report further adds that the cloud moved directly east where "there was no sedentary Saharan population," but acknowledges that locally about 100 people were affected by "a substantial contamination" (over 50 milliSievert (mSv)).[26]

The test explosion created a stream of radioactive lava. A 1999 IAEA report estimates that it was 210 meters (about 690 feet) long, with a volume of 740 cubic meters (about 26,130 cubic feet) and a weight of approximately 10,000 metric tons.[27] The IAEA report states that a person in the proximity of the lava would, over two days of eight hours each, receive a dose of 1.1 mSv (110 millirem).[28]

Eyewitness to the site conditions

At the end of the February 2007 conference in Algiers, the Algerian government organized a visit to the In Ekker site in which I took part. The participants, including many journalists from the Algerian, French, and Japanese media, were able to come close to the site where the 1962 testing accident occurred.

Our proximity probably allowed a better understanding of what could have occurred during the accident. Indeed, at the time of the explosion the witnesses could not be so close nor could they evaluate what had really occurred because of the general panic and flight away from the explosion. Today one can see that the radioactive lava was projected from the entry of the tunnel to the facing hill. This was not a mere flow: the violence of the explosion had spewed projectiles of radioactively contaminated molten rock.

We also saw layers of scoria, ejected lava that cooled during flight, at the tunnel entrance whose radioactivity, measured by a member of the Japanese delegation, was between 77 and 100 microGray per hour (µGy/h) (7.7 to 10 millirem per hour, or about one thousand times background radiation at sea level). A person standing for eight hours near this contaminated lava would receive an effective dose between 60 and 80 millirem. The surface of the solidified lava had deteriorated, possibly due to 45 years of weatherization.

The IAEA report notes that a person standing eight hours near or on lava with a radioactivity measuring 100 µGy/h would receive an effective dose of 0.5 mSv.[29] This broadly corresponds to the measurements taken at the time of the site visit on February 16, 2007, during which it was calculated that a person would receive an effective dose of 1 mSv in 12 hours for the lower 77 µGy/h and 1 mSv in 10 hours for the higher 100 µGy/h, the permissible maximum annual dose for the public set by the International Commission of Radiological Protection. The Algerian authorities who accompanied the visitors insisted that no one should remain more than 20 minutes in the area. Between 1966 and 2000, access to the site was possible through many breaches in the fence that was built by the French government after the accident. During those years nomads could have stayed and even recovered abandoned materials from this dangerous place.[30]

Our Algerian hosts explained that torrential rains occur regularly in this area, washing away sediments, and surface water fills the wadi (a dry riverbed that contains water during heavy rain) located at the foot of Taourirt Tan Afella before replenishing the groundwater. Moreover, one can easily locate the scoria and scattered pieces of lava because of their dark color and their very different structure from the lighter and very dense granite rock which forms the Taourirt Tan Afella mountain.

Accounts of incidents which occurred during the underground tests of the various nuclear powers often report "radioactive gas releases" for the simple reason that the majority of the underground tests were conducted in shafts, in particular in Moruroa, Fangataufa, and Nevada. More than 200 tests in tunnels, similar to those of Taourirt Tan Afella, were carried out by the Soviets in Novaya Zemlya and in Kazakhstan, but one does not have information on possible accidents. The United States also carried out about fifty underground tunnel tests at the Nevada Test Site that resulted in accidental gaseous releases, plus 108 operational releases.[31] Until more becomes known about Russian, Pakistani, and Chinese tests, one can then say that the May 1, 1962, accident is maybe unique in the world history of underground nuclear tests, at least so far as the lava stream is concerned. The "lava stream" of the Taourirt Tan Afella is a legacy, left without real protection, which will remain dangerous for centuries.

There are more disturbing observations: the entrance and surroundings of the E2 tunnel are still strewn with construction materials and other objects (electric cables, railings, conveyor belts, various scrap, etc.). We did not have enough time to evaluate the residual level of contamination of these materials; moreover, we did not have basic radiation protection gear to do so even if we had had the time. However, according to our Touareg[32] guides, many objects were taken over the years by local inhabitants or nomads who then used them as spare parts or incorporated them in traditional objects.

The Taourirt Tan Afella mountain, whose geological stability was praised by the Directorate of the tests, was

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strongly shaken and fissured by the 13 underground tests. Official reports show the effects of the explosions on the structure of the mountain.[33] In 1996, after the end of the Moruroa underground tests, the French installed a system of geomechanical monitoring to check the evolution of the faults and cracks. A similar system should be set up around the Taourirt Tan Afella mountain, which is also deteriorating due to extreme climatic conditions.

Other environmental damage

France conducted a total of 17 nuclear tests in the Sahara, four above-ground and 13 underground. In addition it conducted 40 "complementary" experiments. The Directorate of the French tests refers to these experiments as "cold tests" because they did not involve a nuclear chain reaction. Thirty-five of these experiments study the effect of a shock wave on plutonium pellets (20 grams each) at the Reggane site. The remaining five called "Operation Pollen," in which plutonium was dispersed in the air, took place near the Taourirt Tan Afella mountain. During one of the five experiments, a small military unit was ordered to conduct maneuvers on foot for several hours equipped with masks and protection gear. Today this zone, covering several hectares, is not easily identifiable because it has been covered by sand to such an extent that the 1999 IAEA mission could only take four samples. Experiments of the same type, that were conducted in Australia by the British in the early 1950s, contaminated soil at the Maralinga site to such an extent that it was necessary to carry out a vast remediation program that lasted from 1967 to the beginning of this century.[34]

Moreover, the Saharan atmospheric and underground nuclear tests produced large quantities of contaminated equipment and other materials. Vehicles, planes, and other military materials were exposed during the test, enormous quantities of water and liquids were employed for the decontamination of the materials and the personnel. This waste was buried under a couple inches of sand. Algerian witnesses affirm that most of these materials were taken by the local population, unaware of the potential health risks. In 2006, the government of French Polynesia was able to obtain from the French Defense Ministry the precise inventory and locations of disposal of similar waste produced at Moruroa and Fangataufa (the major part was immersed in the ocean). However, the Algerian government does not have any indication or maps to locate the disposal sites of the radioactive wastes. In the Sahara, the real problem for radiological risk management is that nomad communities and their herds or passing visitors can enter the contaminated region unaware of the potential danger.

It is well known among geologists that underneath the Saharan desert lie vast quantities of underground water recharged by torrential rains which occur very irregularly. Wells and artesian upwellings allow travelers to find water and for small communities to grow some food in the oases. The radiological monitoring of groundwater close to the old sites of the Saharan tests is not being done but is necessary. The United States has done this at the Nevada Test Site. Such monitoring is all the more important since the Algerian government is putting into place a large-scale project for the use of groundwater deep in the Sahara.

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Secrecy

The February 2007 conference in Algiers recommended "lifting the seal of national defense relating to the French nuclear explosions and experiments in the Algerian Sahara so they can be used as reference documents for researchers and experts."[35]

Each French nuclear experiment has been the subject of many reports written by the various services of the armies as well as the CEA. Despite the presence of a French expert in the mission of the IAEA in the Sahara, the report of the mission on the condition of the nuclear test sites in the Sahara does not have even one reference to a French report. The IAEA report says:

> The information set forth in this section was provided to the IAEA mission by the French authorities at the request of the IAEA. The information includes historical radiological data that were pertinent to the survey and estimates of the radiological conditions prevailing in 1999 prior to the IAEA mission. The estimates were extrapolated by the French authorities from data which are unpublished and not available to the public.[36]

Only some maps were provided to the Agency by the French authorities. The lack of official French references constitutes a very serious deficiency and a flagrant lack of transparency, especially considering how the French government handled information about the tests conducted in Polynesia.

Although all the official documents on the French Polynesian tests have not been communicated to the IAEA experts for their review on Moruroa and Fangataufa, the Defense Minister provided them with two volumes of technical documents (957 pages in all) as a contribution towards transparency.[37] At least the same should be done regarding the Saharan tests.

Opening the archives is all the more necessary because the historical context of the Franco-Algerian relations during the years 1960-1967 remains particularly obscure.[38] Also, the testimonies of the veterans and the local population need to be compared with the official documents. The secrecy is all the more prejudicial since it perpetuates misunderstandings that interfere with the re-establishment of friendly relations between France and Algeria.

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Needed: cleanup and monitoring

In the case of the Sahara, one could argue that it is too late to take protective measures more than 40 years after the tests. However, some radioactive materials remain harmful for hundreds, thousands, even millions of years. Other governments acknowledge this and have undertaken remediation and monitoring efforts. The British have undertaken the cleanup of the Australian desert sites contaminated by their tests. The U.S. has prohibited the final return of the inhabitants of Bikini on their atoll where they conducted 23 atmospheric tests.

The French have also preserved the designation of the atolls of Moruroa and Fangataufa as a military base, enabling them to continue to be closed to the public. Devices have been installed on the Polynesian test sites to maintain a certain level of environmental monitoring of contamination. The Sahara test sites should be able to benefit from the lessons of the monitoring and risk reduction examples at other test sites.

Health consequences

Today some of the health consequences of nuclear tests are well documented.[39] In the United States, for instance, a 1990 law provides for compensation to certain people who contracted a radiogenic cancer and who lived or worked downwind of the Nevada Test Site during the period of U.S. atmospheric nuclear weapons testing. Some Marshall Islanders have also been compensated for the harm to their health and property caused by U.S. nuclear testing. Veterans who participated in the tests and who get radiogenic cancers are also eligible for compensation.

In France, even if the state is still reluctant to acknowledge the health effects from testing, pressure from veterans' associations, the media, and members of Parliament could prompt the government to adopt similar compensation legislation. Nevertheless, evaluating the impact of the tests on the health of small populations living near the test site remains difficult. Because the registration of births, marriages, and deaths of the inhabitants of the Sahara goes back only to 1969, it will be difficult to carry out credible epidemiologic studies. Alarming accounts have been collected from the Touareg populations and from the sedentary communities of the oases, but according to the Algerian authorities, no registry of the diseases has been maintained and no epidemiologic studies have been carried out. According to a May 2007 report by the Comité de liaison pour la coordination du suivi sanitaire des essais nucléaires français (Coordinating Committee for the Monitoring of the French Nuclear Tests) under the Defense Ministry and the Nuclear Safety Authority, the paucity of health data and the relatively small number of potentially affected people would make it very difficult if not impossible to obtain convincing results.[40]

It will therefore be necessary to find another way to compensate for the health and environmental harm inflicted on these small populations by the nuclear tests. In February 2007, the conference organized by the Algerian government on the consequences of the nuclear tests drew up political demands such as "the acknowledgement of responsibility for harm done by colonialism." The recommendations are based on the demand for truth and transparency from the French, with concrete objectives:

- open the archives;
- publish maps of the test sites, identifying locations of radiological risks; and
- share in the financing of a monitoring system.[41]

These demands don't even begin to address the harm caused. The Algerian government appears to be determined to start a process of co-operation with the French to repair the damages caused by the French tests in the Sahara.

IEER Postscript: The pages of Science for Democratic Action *have carried a great deal of information and analysis about the harm done by U.S. nuclear weapons production and testing to the people of the United States itself. That is not only because IEER is based in the United States. It is also because the United States is by far the most open of the nuclear weapon states. Harm to the Marshall Islanders as a result of nuclear bomb testing there was acknowledged by the United States in the late 1970s; the dangerous conditions faced by U.S. armed forces personnel and downwinders began coming to widespread public attention shortly thereafter. France also endangered its own armed forces personnel and the people in two of its colonies – Algeria and Polynesia – as a result of its testing. Broad public debate about that harm has only recently begun. We invited this article about French nuclear testing in Algeria by Bruno Barrillot because he is a scholar and peace activist on the subject of the French nuclear weapons. He has done a great deal to help bring the subject of the harm done by French nuclear testing into the sunshine both in France and in Algeria. I want to thank him for the painstaking research he did for this article. As always, whenever IEER publishes a guest article, the analysis, opinions, and recommendations are those of the author and may or may not be shared by IEER. It is worth remembering when reading official French denials of harm that such denials were also common in the United States a quarter of a century ago. That changed because of the testimony of the atomic veterans, independent research, media exposure, and Congressional investigations, which pointed in the contrary direction as the 1980s wore on.*

— Arjun Makhijani

Endnotes

1. Bruno Barrillot is Director of the Centre de documentation et de recherche sur la paix et les conflits (CDRPC). He has written many books on French nuclear issues with a focus on the military. Annie Makhijani translated this article from the French.
2. Under the Fourth Republic (1944-1958) the Présidence du Conseil was composed of the Secretaries of State who answered directly to the Président du Conseil, or Prime Minister. They were not obligated to report to the Parliament. (Testimony of Général Crépin in, "Histoire du Comité des explosifs nucléaires," in *L'aventure de la bombe: De Gaulle et la dissuasion nucléaire, 1958-1969,* Plon, Paris, 1985, pp. 83-84).
3. Bruno Barrillot, *L'Héritage de la bombe*, CDRPC, Lyon, 2002, pp. 7-19 and Bruno Barrillot & Mary Davis, *Les dechets nucléaires militaries français,* Editions CDRPC, Lyon, 1994, pp. 68-69.
4. Jean-Marc Regnault. *The Journal of Military History* No 67 (October 2003), pp. 1223-1248.

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5. ibid., pp. 1229-1230
6. Charles Ailleret, *L'aventure atomique francaise: Comment naquit la force de frappe,* Paris, Grasset, 1968.
7. ibid.
8. Maurice Vaisse, "Le choix atomique de la France (1945-1958)," *Vingtième siècle: Revue d'histoire* no36 (oct-dec 1992), p. 21.
9. The map has been reproduced in Barrillot 2002, op.cit., p. 42.
10. Souhila Hammadi, "Essais nucléaires en Algérie: Paris rejette la responsabilité de la contamination," *Liberté-Algérie*, 6 Avril 2005 and France. Ministère de la Défense. Délégation à l'Information et à la Communication de la Défense, *Dossier de présentation des essais nucléaires et leur suivi au Sahara*, janvier 2007, pp. 4, 7, at http://www.ambafrance-dz.org/IMG/Essais_nucleaires.SAHARA.pdf.
11. U.S. Atomic Energy Commission, Office of Special Projects, *Report on Tunisian Gummed Film Data For February,* March 29, 1960, transmitted by letter from Edward R. Gardner, to Philip J. Farley, dated March 30, 1960 (DOE accession number: NV0027183); Yves Rocard, *Mémoires san concessions*, Grasset, Paris, 1988, p. 235.
12. IAEA, *Radiological Conditions at the Former French Nuclear Test Sites in Algeria. Preliminary Assessment and Recommendations,* International Atomic Energy Agency, Vienna, 2005, pp. 11 and 20-24.
13. Bruno Barrillot, *Les Irradiés de la République,* Editions Complexe, Bruxelles, 2003, p. 35.
14. IAEA 2005, op.cit., p. 26.
15. Barrillot 2003, op.cit.
16. Barrillot 2003, op.cit., p. 23.
17. Barrillot 2003, op.cit., p. 31.
18. Barrillot 2003, op.cit., pp. 76-78.
19. *Journal officiel de la République française,* 20 mars 1962, p. 3030.
20. "Declaration of Jean Viard," cited by Jean-Damien Pô, *Les moyens de la puissance: Les activités militaires du CEA, 1945-2000,* Fondation pour la recherche stratégique, Editions Ellipses, 2001, p. 111.
21. IAEA 2005, op.cit., p. 12.
22. Testimony of Mr. Audinet, manager in the Sodeteg, at the time, recorded by Pascal Martin in *Dans le secret du paradis,* a documentary broadcast on the national television channel, France 2, on 19 September 2002.
23. Barrillot 2003, op.cit., pp. 62-87.
24. Barrillot 2003, op.cit., pp. 65-68.
25. Christian Bataille & Henri Revol, *Les incidences environnementales et sanitaires des essais nucléaires effectués par la France entre 1960 et 1996 et éléments de comparaison avec les essais des autres puissances,* AN n° 3571, Sénat n°207, 5 février 2002.
26. Bataille & Revol 2002, op.cit., p. 36.
27. IAEA 2005, op.cit., p. 13.
28. IAEA 2005, op.cit., p. 50.
29. IAEA 2005, op.cit., p. 30.
30. Barrillot 2002, op.cit., pp. 83-84.
31. ORAU TEAM, Dose Reconstruction Project for NIOSH, Nevada Test Site: Site Description, ORAUT-TKBS-0008-2, http://www.cdc.gov/niosh/ocas/pdfs/tbd/nts2-r1.pdf, Table 2-5, p. 43.
32. Touareg are Muslim, Berber-speaking people inhabiting parts of the Sahara and Sahel.
33. Barrillot 2002, op.cit., pp. 71-73.
34. Bataille & Revol 2002, op.cit., pp.199-200.
35. Colloque international sur les conséquences des essais nucléaires dans le monde: cas du Sahara Algérien, Alger, 13-14 février 2007. Recommandations. (Translation of the quote from the French by Annie Makhijani.)
36. IAEA 2005 op.cit., p. 5.
37. This set of documents has been published: CEA-Direction des Applications Militaires, Ministère de la Défense, *Geomechanical and Radiological Impact of Nuclear Tests at Mururoa and Fangataufa*, La Documentation française, Paris, 1998.
38. The Algiers conference recommended "the intensification of the efforts of historians, experts and legal advisors to establish the truth on the controversial question of the use of civilian and military personnel as 'guinea pigs.'" It will also be necessary to shed light on the exercises during the 25 April 1961 Gerboise verte test. (Colloque 2007, op.cit. (Translation of the quote from the French by Annie Makhijani.))
39. In addition to the numerous testimonies from the veterans, one can visit the health study on the veterans of the French nuclear tests at www.aven.org (Association des vétérans des essais nucléaires). Also see IPPNW and IEER, *Radioactive Heaven and Earth: the Health and Environmental Effects of Nuclear Weapons Testing In, On, and Above the Earth,* New York, Apex Press, 1991.
40. DSND-ASN, *Rapport du Comité de liaison pour la coordination du suivi sanitaire des essais nucléaires français,* mai 2007, p.13, at http://www.dicod.defense.gouv.fr/defense/content/download/81908/744645/file/Rapport%20CSSEN%20-%20mai%202007.pdf.
41. Colloque 2007, op.cit.

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ATOMIC PUZZLER

Calculating CO_2 emissions from nuclear power

In this puzzler we will be calculating a portion of the indirect carbon dioxide emissions from a light-water reactor. While there are indirect emissions associated with the mining, milling, and transportation of the fuel and the construction of the power plant, we will focus on the enrichment of the uranium which is unique to the nuclear fuel cycle and the largest sources of indirect emissions for nuclear power in the United States. There are two dominant types of commercial enrichment in use today. This puzzler is about a calculation of the indirect carbon dioxide emissions from the operation of a gaseous diffusion enrichment plant such as the one in operation at Paducah, Kentucky. In the next puzzler, we will calculate the indirect carbon dioxide emissions from a gas centrifuge enrichment plant. Then we will be able to compare CO_2 emissions from nuclear power to those from coal and natural gas fired plants, which we calculated in previous puzzzlers (SDA vol. 14 numbers 3 and 4). Note: Enrichment services are measured in units known as kilogram Separative Work Units (kgSWUs). SWUs is pronounced "swooze".

1. A typical 1,000 megawatt light water reactor requires approximately 110 metric ton Separative Work Units (MTSWUs) per year of enrichment services in order to supply its fuel. Currently operating gaseous diffusion plants consume approximately 2,450 kilowatt-hours of electricity per kilogram SWU. How many kilowatt-hours of electrical energy are required to enrich the fuel for one year's worth of the operation at a nuclear power plant? *Hint: There are 1,000 kilograms in one metric ton.*
2. We will assume that the electricity consumed by the Paducah gaseous diffusion enrichment plant is supplied by the Tennessee Valley Authority (TVA). In 2004 and 2005, the TVA generated 61 percent of its electricity from coal, 29 percent from nuclear power, and 9.4 percent from hydroelectricity. The remainder came from renewables and other resources. In an earlier Puzzler we found that coal fired plants emit 982 grams of CO_2 per kilowatt-hour. How many kilograms of CO_2 would be emitted to supply the electricity to provide the enrichment services to fuel a nuclear reactor for one year? *Hint: Use the number of kilowatt-hours from question one and the given percentage of that electricity which would be supplied by coal while ignoring all other contributions.*
3. How many kilowatt-hours of electricity would be produced by a one thousand megawatt (1,000 MW = 1,000,000 kW) reactor over one year if it operated 85 percent of the time at full power (i.e., if it had an 85 percent capacity factor)? *Hint: How many hours are there in one year?*
4. How many grams of indirect CO_2 are emitted per kilowatt-hour of electricity generated by the nuclear reactor due to the enrichment of uranium at Paducah?

Send us your answers via e-mail (info[at]ieer.org), fax (1-301-270-3029), or snail mail (IEER, 6935 Laurel Ave., Suite 201, Takoma Park, Maryland, 20912, USA), postmarked by May 30, 2008. IEER will award a maximum of 25 prizes of $10 each to people who send in a completed puzzler, by the deadline, right or wrong. One $25 prize will be awarded for a correct entry, to be drawn at random if more than one correct answer is submitted. International readers submitting answers will, in lieu of a cash prize (due to exchange rates), receive a copy of the paperback, *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy* (IEER Press and RDR Books, 2007).

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