January 7, 2005

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	Docket No. 70-3103
Louisiana Energy Services, L.P. National Enrichment Facility	ASLBP No. 04-826-01-ML

DIRECT TESTIMONY OF DR. ARJUN MAKHIJANI REGARDING NUCLEAR INFORMATION AND RESOURCE SERVICE AND PUBLIC CITIZENS'S CONTENTION EC-4

Q: Please state your name, affiliation, and qualifications.

A. My name is Dr. Arjun Makhijani. Among my credentials is a doctorate in Engineering from the Electrical Engineering Department of the University of California at Berkeley (1972, specialization: the application of plasma physics to controlled nuclear fusion). I am President of the Institute for Energy and Environmental Research (IEER), an organization, which, among its activities, assesses environmental damage from the operation of nuclear fuel facilities, and estimates the compliance of those facilities with environmental regulations, mainly relating to radioactive materials and wastes and to radioactivity exposures. In addition, I am, in my personal capacity as part of a non-IEER team, currently one of the principal personnel who have

been chosen by the U.S. government to carry out an audit of the radiation dose reconstruction that is being done for nuclear weapons complex workers who have applied for compensation under the Energy Employees Occupational Illness Compensation Program Act.

I have authored and co-authored numerous studies, articles, and books examining nuclear-related issues, including emissions from nuclear weapons plants, nuclear fuel cycle related issues, nuclear weapons production and testing, and nuclear waste. Among other things, I was the principal author of the first ever independent source term reconstruction from a nuclear weapons plant (the Feed Materials Production Center), done in 1989.

Chapters I have co-authored include "Dismantling the Bomb," and "Nuclear Waste Management and Environmental Remediation," in Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940, Stephen I. Schwartz, editor, Brookings Institution Press, Washington, D.C., 1998. I am also a co-author of "The Production of Nuclear Weapons and Environmental Hazards," a chapter appearing in Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and its Health and Environmental Effects, MIT Press, Cambridge, Massachusetts, 1995. I am principal editor of this book.

I have served on the Radiation Advisory Committee of the Science Advisory Board of the United States Environmental Protection Agency (EPA), and on the EPA's advisory subcommittee on Radiation Cleanup Standards of the National Advisory Committee on Environmental Policy and Technology. From 1997 to 2002, I was part of an IEER team that monitored three independent audits of the compliance of the Los Alamos National Laboratory in New Mexico with radiation

regulations under the Clean Air Act, specified in 40 CFR 61, Subpart H. The audits and the IEER monitoring of the audits were the result of a federal consent decree issued after the court found Los Alamos National Laboratory to be in violation of 40 CFR 61, Subpart H.

My current resume is attached to this testimony.

Q. What is the purpose of your testimony today?

A. I am testifying in support of contention EC-4, which is advanced in this proceeding by Nuclear Information and Resource Service and Public Citizen. That contention states as follows:

> CONTENTION: Petitioners contend that the Louisiana Energy Services, L.P. Environmental Report (ER) lacks adequate information to make an informed licensing judgment, contrary to the requirements of 10 C.F.R. Part 51. The ER fails to discuss the environmental impacts of construction and lifetime operation of a conversion plant for the Depleted Uranium Hexafluoride ("UF_6") waste that is required in conjunction with the proposed enrichment plant.
>
> The DEIS fails to discuss the environmental impacts of the construction and operation of a conversion plant for the depleted uranium hexafluoride waste. The DEIS entirely relies upon final EISs issued in connection with the construction of two conversion plants at Paducah, Kentucky, and Portsmouth, Ohio, that will convert the Department of Energy's inventory of depleted uranium (DEIS at 2-28, 2-30, 4-53, 4-54). Such reliance is erroneous, because the DOE plants are unlike the private conversion plant contemplated by LES.

Q. What materials have you reviewed in preparation for your testimony?

A. Part of my preparation was working with and assigning tasks to Dr. Brice Smith, recently promoted to senior scientist as of December, and our librarian Lois Charmers. I reviewed various parts of the LES license application, including the Environmental Report and the Safety Analysis Report, submitted by LES to the Commission in support of its application, that relate to

the depleted uranium to be generated by the facility, the management of that material, and its deconversion and disposal. I also reviewed various documents prepared by LES and persons working for LES that shed light on LES's plans for disposition of depleted uranium. I have also reviewed documents on uranium risks including those from scientific journals as well as publications from national and international bodies such as the National Research Council, the Royal Society, and the World Health Organization.

In addition, I have reviewed the Draft Environmental Impact Statement (DEIS) as well as the Final Environmental Impact Statement for the proposed Claiborne Enrichment Facility. I have revisited the history of 10 CFR 61.55 as well as other parts of 10 CFR 61. I have reviewed several related Department of Energy documents, such as the Environmental Impact Statements for the proposed Portsmouth and Paducah conversion plants (DOE/EIS-0359 and DOE/EIS-0360) and the 1999 DOE Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride, DOE/EIS-0269. I have also reviewed some of the supporting documents for those studies such as the 1997 Lawrence Livermore National Laboratory Engineering and Cost Analyses.

I have studied these and related areas for many years, and so cannot make a full list of all the materials I have reviewed that may shed light on the questions before the Board. For a further listing of documents reviewed as part of my work in this case in collaboration with Dr. Smith, I refer you to the reference list in Makhijani and Smith, Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County, New Mexico by LES, Nov. 24, 2004, filed in this proceeding.

Q. Focusing on the impact of construction and operation of a deconversion plant, can you explain what disclosure of such impact you have found in the documents concerning this license application?

A. Starting with the license application, I found the following:

First, the initial application, filed in December 2003, does not discuss the impact of deconversion at all. There is reference to the fact that DOE has contracted for the construction of DUF_6 conversion plants at Paducah and Portsmouth in the first Environmental Report at page 4.13-2, but there is no discussion of the impact of such plants.

Second, in Revision 2 of the application, the following language appears at page 4.13-3:

> "The environmental impact of a UF_6 conversion facility was previously evaluated generically for the Claiborne Enrichment Center (CEC) and is documented in Section 4.2.2.8 of the NRC Final Environmental Impact Statement (FEIS) (NRC, 1994a). After scaling to account for the increased capacity of the NEF compared to the CEC, this evaluation remains valid for the NEF. In addition, the Department of Energy has recently issued FEISs (DOE, 2004a; DOE, 2004b) for the UF_6 conversion facilities to be constructed and operated at Paducah, KY and Portsmouth, OH. These FEISs consider the construction, operation, maintenance, and decontamination and decommissioning of the conversion facilities and are also valid evaluations for the NEF."

The Commission staff has also issued its Draft Environmental Impact Statement, NUREG-1790, in September 2004 (DEIS). This document has the following disclosure concerning the impact of alternative deconversion facilities:

The DEIS states that the NEF would produce up to 7800 metric tons of DUF_6 per year. (page 2-16). The DEIS states that it is assumed that the proposed deconversion facility for the NEF

depleted uranium will use the same technology as the DOE plants; this is described as a continuous dry conversion process based on the process used by Framatome ANP in Richland, Washington. (page 2-28). As for location, the DEIS states that the deconversion plant could be located (a) at Metropolis, Illinois (pages 2-29, 2-30) or (b) at or near to the proposed NEF (page 2-30). It also states that deconversion might be carried out at the DOE plants by extending their operation (page 2-31).

Addressing the impacts of deconversion, the DEIS states that the "impacts of conversion at a private conversion facility or at DOE conversion facilities are similar because it is assumed that the facility design of a private conversion facility would be similar to the DOE conversion facilities." (page 4-53; see also 4-54). The DEIS states:

> "Because the operations would be the same as the DOE conversion facilities, the environmental impacts from normal operations of an adjacent conversion facility would be representative of the impacts of the DOE facilities and the proposed NEF. Therefore, the maximum occupational and member of the public annual exposures would be approximately 6.9 millisieverts (690 millirem) and 5.3×10^{-5} millisieverts (5.3×10^{-5} millirem), respectively. The impacts due to accidents would be bounded by the proposed NEF's highest accident consequence—the hydraulic rupture of a UF_6 cylinder. This maximum accident impact would be a collective dose of 12 person-sieverts (12,000 person-rem) or equivalent to 7 latent cancer fatalities." (page 4-54).

The DEIS also states that the impact of use of DOE conversion facilities would be scaled to the impact of the operation of those facilities to process DOE depleted uranium. (page 4-56). The DEIS also contains a discussion of the impacts of routine operation and accident scenarios involving the NEF itself in Chapter 4 and Appendix C.

Q. Given that the DEIS refers to the environmental impact statements for the DOE deconversion facilities, what do such statements disclose that is relevant to the operation of the NEF and the depleted uranium produced by the NEF?

A. DOE released two very similar environmental impact statements for the Paducah and Portsmouth deconversion facilities. A few main points can be noted about these documents:

- Currently there are no DOE or general NRC guidelines that govern the free release of contaminated hydrofluoric acid or calcium fluoride.[1]

- In the analysis of proposals to construct and build the DOE deconversion facility it was determined that the accident scenarios with the largest consequences were primarily those involving hydrofluoric acid.[2] If the preferred option of neutralizing the HF and disposing of the calcium fluoride as LLW is replaced by a decision by LES to produce and ship anhydrous HF (AHF), the potential impacts on the environment are likely to be higher. However, given that no existing facility for UF_6 deconversion currently produces AHF, the fact that the cumulative transportation distances considered for the DOE facilities are different from those that may be required for shipping the material generated by the proposed LES facility[3], as well as the fact that the health and environmental impacts on routine operation from the greater volatility and general hazards posed

[1] DOE Paducah ROD 2004 p. 44657 - 44658 and DOE Portsmouth ROD 2004 p. 44652 - 44653
[2] Paducah EIS from Appendix D page 18-19
[3] Currently no commercial deconversion facility exists in the U.S. that would be able to accept the DUF6 from the proposed LES enrichment facility and thus no quantification of this potential impact was attempted.

by anhydrous HF versus aqueous HF were not analyzed by the DOE EIS for the Paducah or Portsmouth facilities cited by the NRC in the LES DEIS analysis[4], it is not possible at this time to quantify the potential impacts of such a decision.

- ~~The ultimate disposal of the depleted uranium presents even more difficult issues than does deconversion. No final disposal strategy has been chosen or fully analyzed by the DOE in relation to the management of its depleted uranium stockpile since the DOE is still considering possible, but unlikely, uses for its DU.[5] No credible environmental analysis can be done on a generic basis. A plausible strategy necessarily includes identification of a specific site and a process for its thorough characterization and licensing, as well as a reasonable scientific expectation that it will be able to meet the established dose limits. The likelihood that the production of UO_2 rather than U_3O_8 by the deconversion process would be more suited for final disposal should be considered by LES and the NRC in the ER and EIS which is not done in the DOE EISs referred to. For a further discussion I refer you to the report by Makhijani and Smith, Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County, New Mexico by LES, Nov. 24, 2004, filed in this proceeding.~~

Q. Moving to the proposal before the Commission, what do you understand LES proposes to do with the DUF_6 from the NEF?

[4] NRC NEF EIS Draft 2004 p. 2-30
[5] DOE Paducah EIS 2004 p. 2-11, 2-17, and 2-25

A. The LES DEIS contains the following description of the two options proposed for the management of the DUF_6 that would be generated by the proposed NEF:

> The first option would be to ship the material to a private conversion facility prior to disposal (Option 1). An alternative available under the provisions of the USEC Privatization Act of 1996 would be to ship the material to the DOE's conversion facility at Portsmouth, Ohio, or Paducah, Kentucky, for temporary storage and eventual processing by the DOE conversion facility prior to disposal by DOE (Option 2).[6]

In addition, LES has publicly stated that

> For many reasons, including the large volume of byproduct already in storage in the US, the DOE deconversion facilities are not LES's path of choice for byproduct deconversion. LES has continually supported the development of a commercial, private deconversion facility. In fact, the company will seek to develop long-term supply contracts with potential deconversion operators in order to assist in their financing and licensing efforts to build such a facility.[7]

LES has stated that its preferred option is the deconversion of the DUF_6 to DU_3O_8 followed by its disposal as a bulk powder in an abandoned mine or potentially at a shallow land disposal facility. In addition, LES has stated that it will consider the following reactions for producing the DU_3O_8

$$UF_6 + 2\ H_2O \rightarrow UO_2F_2 + 4\ HF$$

followed by

$$3\ UO_2F_2 + H_2 + 2\ H_2O \rightarrow U_3O_8 + 6\ HF.$$

[6] NRC NEF EIS Draft 2004 p. 2-28
[7] LES NEF UF6 info sheet p. 3

LES has not decided whether the hydrofluoric acid generated will be neutralized to form calcium fluoride (CaF_2) or distilled to form anhydrous hydrofluoric acid (AHF), however, the NRC stated that CaF_2 disposal was the only scenario that was reasonable to include in the DEIS:

> The hydrofluoric acid could be sold to a commercial hydrofluoric acid supplier for reuse if the radioactive content is below free release limits, or it could be converted to calcium fluoride (CaF2) for sale or disposal. Because conversion of the large quantities of DUF6 at the DOE Portsmouth and Paducah Gaseous Diffusion Plant sites would be occurring at the same time the proposed NEF would be in operation, it is not certain that the market for hydrofluoric acid and calcium fluoride would allow for the economic reuse of the material generated by the proposed NEF. Therefore, only immediate neutralization of the hydrofluoric acid by conversion to calcium fluoride with disposal at a licensed low-level radioactive waste disposal facility is considered in this analysis.[8]

Q. With these understandings, what criticisms do you have of the disclosure that has been made in the ER and the DEIS of the impacts of conversion of depleted uranium?

A. ~~The specific steps in the deconversion of DUF_6 to a more stable chemical form for long-term disposal depends on the final choice for which potential form is to be produced. In particular, the steps for producing uranium oxide (U_3O_8) or uranium dioxide (UO_2) are different and result in different impacts such as the level of contamination in the resulting hydrofluoric acid or calcium fluoride. The choice of disposal strategy will have a significant impact on the choice of which deconversion process is to be pursued.~~

The choice of deconversion process that is to be pursued involves important trade-offs that require additional analysis by LES and the NRC. In addition, if any consideration is to be given by LES to the possible production and sale of anhydrous hydrofluoric acid for reuse, than an examination of this option's environmental impacts should also be carried out.

[8] NRC NEF EIS Draft 2004 p. 2-29

Q. The regulations require an ER and a DEIS to consider appropriate alternatives for achieving the aims of the project. (10 CFR 51.45(b)(3), (c); 51.71(a), (d)). Please explain the respects in which the ER and DEIS disclosure does not cover all deconversion products that are appropriate to be considered for deconversion.

A. In analyzing the impacts of the deconversion process, the choice must be made between deconversion product (i.e. U_3O_8 or UO_2). The choice of deconversion process that is to be pursued involves important trade-offs that require additional analysis by LES and the NRC. One of the most important inputs to such a decision is the suitability of the deconversion product for ultimate disposal. The enrichment plant that LES proposes to build will generate significant quantities of DU over the coming decades which will also likely be a time of rapid and significant expansions in the understanding of uranium and its various health effects both in isolation and in combination with other environmental stressors. In this context LES and the NRC, which is legally charged with protecting the public health, must pursue a management and disposal strategy that will have a high probability of doing just that and they must also be prepared to modify and adapt this plan in the event that radiation risks in general and uranium risks in specific are found to be greater than previously considered and that provisions are undertaken to specifically protect both women and children's health. While conversion reduces the risk of DU storage, it does not, in itself, represent a strategy for long-term disposal. The two are closely related but distinct problems.

Uranium is still officially classified as a source material by the U.S. Department of Energy (DOE) as well as by the NRC. This will remain the case in the absence of a specific ruling from the Commission that depleted uranium is a waste. No final disposal strategy has been chosen or fully analyzed by the DOE in relation to the management of its depleted uranium stockpile since the DOE is still considering possible, but unlikely, uses for its DU. LES has also not definitively decided whether it considers the depleted uranium to be generated by the proposed enrichment facility to be a resource or a waste, though it claims that it can decide this question without reference to any regulatory authority.

In the present LES case, the NRC staff has again taken the position that DU is Class A low-level waste and that it might be disposed of by shallow land burial in a dry location. Although a number of low-level waste disposal sites were noted in the LES DEIS, no specific option was chosen and none of the indicated sites would likely be able to safely dispose of the DU in shallow trenches. Significantly, no estimates of the possible doses under dry conditions for any locations are given in the DEIS in support of this proposed disposal option despite the failure of the eastern site considered for shallow disposal in the CEC case to meet the 25 mrem annual dose limit. The NRC also states that doses from deep disposal of depleted uranium in a mine would be low and provides estimates of doses under a well water and river water scenario. As presented in the DEIS these estimates are greatly below the regulatory limit of 25 mrem per year for LLW disposal.[9] The estimates as provided are stated to be based on the CEC estimates in the FEIS of 1994. However, despite this assertion, the NRC has failed to provide the methods and assumptions underlying the dose calculation and the details of the CEC FEIS calculation are apparently no longer available, even to the NRC itself. Moreover, the doses in the current LES

[9] NRC NEF EIS Draft 2004 p. 4-59

DEIS are not broken down by radionuclide and the totals as presented are different from those reported in the CEC FEIS by nearly a factor of 2 with one notable exception. The difference in most of the results may be explained, at least in part, by the fact that the proposed LES enrichment facility will generate roughly twice the amount of depleted uranium tails that must be disposed of. However, the estimate for the drinking water dose in the river drinking water scenario following disposal in a sandstone/basalt site are almost 54,000 times lower in the LES DEIS than the results presented in the CEC FEIS.[10]

The doses from U-238 estimated in the CEC FEIS for deep disposal are incredibly low (literally). The annual background dose due to drinking water with approximately 0.1 pCi/liter of uranium in it amounts to about 0.02 mrem EDE (effective dose equivalent). The drinking water dose estimated from the disposal of pure DU_3O_8 powder in a mine was estimated by the NRC in the CEC case to be a million to a trillion times lower than this typical background level. Indeed, the highest well water dose estimated by the NRC is less than that caused by the ingestion of an amount of uranium that would result in just the disintegration of six uranium atoms in the entire body over an entire year. The lowest drinking water dose for U-238 reported would imply that the total amount of energy deposited in a 70 kilogram adult from the uranium absorbed through the drinking water would be equal to less than the amount of energy required to ionize a single hydrogen atom.[11]

Given the specific activity of uranium, its increasing radioactivity over time due to the ingrowth of decay products, and uranium's other chemo-toxic characteristics, it will likely be difficult to

[10] NRC NEF EIS Draft 2004 p. 4-55, 4-59 and NRC CEC EIS Final 1994 p. A-1, A-14 to A-15
[11] NRC CEC EIS Final 1994 p. A-14 to A-15

find an adequate site for the disposal of DU, whatever classification it might be given by the Commission, that will be able to demonstrate compliance with the 25 mrem dose criteria and all other health restrictions with reasonable assurance. Thus the proposal of a generic site in lieu of a detailed investigation of a particular site cannot be considered a plausible strategy for the ultimate disposal of the large amount of depleted uranium that would be generated by the proposed LES enrichment facility. The likelihood that the production of UO_2 rather than U_3O_8 by the deconversion process would be more suited for final disposal should be considered by LES and the NRC in the ER and EIS which is not done in the DOE EISs referred to. For a further discussion of this point I refer you to the report by Makhijani and Smith, Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County, New Mexico by LES, Nov. 24, 2004, filed in this proceeding.

In addition, the specific steps in the deconversion of DUF_6 to a more stable chemical form for long-term disposal depends on the final choice for which potential form is to be produced. In particular, the steps for producing uranium oxide (U_3O_8) or uranium dioxide (UO_2) are different and result in different impacts such as the level of contamination in the resulting hydrofluoric acid or calcium fluoride. The choice of disposal strategy will have a significant impact on the choice of which deconversion process is to be pursued.

LES has stated that its preferred option is the deconversion of the DUF_6 to DU_3O_8 followed by its disposal as a bulk powder in an abandoned mine or potentially at a shallow land disposal

facility. In addition, LES has stated that it will consider the following reactions for producing the DU_3O_8

$$UF_6 + 2\ H_2O \rightarrow UO_2F_2 + 4\ HF$$

followed by

$$3\ UO_2F_2 + H_2 + 2\ H_2O \rightarrow U_3O_8 + 6\ HF$$

On the other hand, depleted uranium hexafluoride may also be converted into UO_2 instead by the following reactions

$$UF_6 + 2\ H_2O \rightarrow UO_2F_2 + 4\ HF$$

followed by

$$UO_2F_2 + H_2 \rightarrow UO_2 + 2\ HF$$

As discussed in Makhijani and Smith, Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County, New Mexico by LES, Nov. 24, 2004, the depleted uranium that would be produced as a result of the proposed LES enrichment facility is analogous to transuranic waste and, if ultimately declared a waste by the Commission, will likely require fabrication into a suitable waste form and disposal in a mined repository such as the Waste Isolation Pilot Plant. The DU_3O_8 that would result from the first deconversion process shown above would be less dense and less uniform in particle size than the DUO_2 that would result from the second process. These properties make it less suitable for processing into a waste form that would aid in the development of a disposal strategy protective of the public health and capable of meeting the existing regulatory limits for uranium

exposure. On the other hand, the smaller more uniform particle size of the DUO_2 that is an advantage in waste form processing also adds to the level of uranium contamination in the resulting byproducts (i.e. the hydrofluoric acid and the calcium fluoride that would result from neutralizing the HF) as well as adding to the airborne releases of uranium from the process building stack of the deconversion facility. The estimated stack releases of uranium for a DUO_2 facility are more than three and a half times those of a DU_3O_8 facility.[12] The ER and the DEIS do not address the relative environmental performance of DU_3O_8 and DUO_2 or of their fabrication in waste forms suitable for disposal in such as way that would have a high probability of protecting the public heath.

Q. In listing appropriate alternative deconversion products, what alternatives should be included?

A. A possible waste form that should be examined for the ultimate disposition of depleted uranium is the encapsulation of DUO_2 in an engineered ceramic that locks up the material on the atomic scale and has been demonstrated to have a very low leach rate. An example of such a waste for would be Synroc or an equivalent titanate ceramic as has been proposed for the immobilization of high level waste as well as for plutonium waste. Potential unknowns surrounding this option include the fact that little industrial experience exists with these ceramic materials and the experience that does exist is for a relatively low throughput facility.[13] In considering the impacts that this type of waste form preparation would have on the mobility of the depleted uranium, and thus on the peak doses that would be expected, the analysis needs to

[12] LLNL 1997 (EA) p. 6.4-7-2, 6.5-7-2, 6.6-7-2, and 6.7-7-2
[13] LLNL Wilt 1997 p. 11

~~also examine the environmental impacts that would accompany the mining and processing of mineral sands in sufficient quantities to manufacture the large amounts of ceramic material needed for the disposal of such a large quantity of depleted uranium as that which would be generated by the proposed LES facility. These factors are not analyzed in the ER or the DEIS.~~

Q. Please explain what is lacking in the ER and the DEIS as regards analysis of deconversion processes.

A. There is no adequate discussion in the ER, the LES DEIS, or the DOE EISs for the Paducah and Portsmouth facilities of the anhydrous hydrofluoric acid (AHF) process or its operations issues, environmental impacts and transportation risks. LES has not yet formally selected a deconversion process, and the production of AHF process is one alternative under possible consideration.

When the engineering analysis was completed in 1997, apparently no large-scale facility had been put into routine industrial use anywhere. The "Draft Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride - Rev. 2" from the Lawrence Livermore National Laboratory (LLNL), which is included as supporting material to the DOE programmatic EIS, states that

> Distillation is a common industrial process and was the design basis for this suboption. The processing of the azeotrope and the process parameters for the conversion reactors were patterned after the General Atomics/Allied Signal response to the RFR and the Sequoyah Fuels Corp. patented process. This representative process has not been industrialized, but the initial research and development have been completed.[14]

[14] LLNL 1997 (EA) p. 3-8.

Cogema has not itself operated a deconversion facility that converts the HF into anhydrous hydrofluoric acid (AHF) at its plant in France. The costs, operations issues, environmental impacts and transportation risks of AHF in the context of deconversion of DUF_6 are at this stage not based on actual experience. If the preferred option of neutralizing the HF and disposing of the calcium fluoride as LLW is replaced by a decision to produce and ship anhydrous HF, the potential impacts on the environment are likely to be higher and should be considered in the LES EIS.

Q. In analyzing the impacts of the AHF process, what factors would need to be considered?

A. If any consideration is to be given by LES to the possible production and sale of anhydrous hydrofluoric acid for reuse, then an examination of this option's operations issues, environmental impacts and transportation risks should also be carried out. This analysis would require the identification of

- A location for the deconversion plant.
- ~~A design of the deconversion plant that corresponds to a firm disposal strategy that has been approved by the NRC at the Commission level. This NRC approval is necessary because the end point of the deconversion depends on the final waste form of the DU and the disposal strategy. Specifically, whether the final form would be U_3O_8 or UO_2 and whether disposal would be as a powder, grout, or ceramic form would be needed for a design of the plant, even if all the processing did not take place there. For instance, processing into a zircon waste form would mean that UO_2 powder would be produced but it would not be compacted. By~~

~~contrast, compaction would likely be required if the DU were to be disposed of as a powder.~~

- ~~A specific, firm location for a DU disposal site that has a certified characterization and licensing process to assure compliance with the appropriate regulations and with the protection of the public health.~~

This has not yet been done in the ER or DEIS nor in the DOE EISs for the Paducah or Portsmouth facilities.

In the analysis of proposals to construct and build the DOE deconversion facility it was determined that the accident scenarios with the largest consequences were primarily those involving hydrofluoric acid.[15] In considering the differences between the properties of aqueous HF and anhydrous HF, the EIS for the Paducah deconversion facility points out that

> It should be noted that there may be differences in the accident impacts between releases of AHF and aqueous HF, and that these differences were not fully evaluated in the critique… Anhydrous HF has a much higher volatility than aqueous HF, and therefore would result in a larger amount of material being dispersed to the environment if equal amounts were spilled. At this time, it is not clear if production of aqueous HF would result in a significant reduction in accident risk.[16]

In the same EIS, it was also reported that an accident involving a railcar in an urban setting under unfavorable weather conditions could potentially cause irreversible damage to people within an area covering seven square miles downwind with up to 300 fatalities. For comparison, this is an area roughly one-fifth of the size of Santa Fe, New Mexico. The DOE analysis goes on to

[15] Paducah EIS from Appendix D page 18-19
[16] Paducah EIS from Appendix D page 19

conclude that, "[a]s noted above, shipment of aqueous HF may have different risks than shipment of AHF."[17]

If the preferred option of neutralizing the HF and disposing of the calcium fluoride as LLW is replaced by a decision to produce and ship anhydrous HF, the potential impacts on the environment are likely to be higher. However, given that no existing facility for UF_6 deconversion currently produces AHF, the fact that the cumulative transportation distances considered for the DOE facilities are different from those that may be required for shipping the material generated by the proposed LES facility[18], as well as the fact that the health and environmental impacts on routine operation from the greater volatility and general hazards posed by anhydrous HF versus aqueous HF were not analyzed by the DOE EIS for the Paducah or Portsmouth facilities cited by the NRC in the LES DEIS analysis[19], it is not possible at this time to quantify the potential impacts of such a decision.

Q. Under LLNL's assumptions, what airborne emissions would be released from the deconversion plants that you believe should be considered?

A. The generation of hydrofluoric acid (HF) in large amounts would result in an exhaust gases that are highly acidic and chemically hazardous if sufficiently concentrated. Therefore, a scrubber system is proposed to remove most of the HF that will be produced during routine operations. According to engineering analysis performed by Lawrence Livermore National

[17] Paducah EIS from Appendix D page 20
[18] Currently no commercial deconversion facility exists in the U.S. that would be able to accept the DUF6 from the proposed LES enrichment facility and thus no quantification of this potential impact was attempted.
[19] NRC NEF EIS Draft 2004 p. 2-30

Laboratory for depleted uranium deconversion facilities, the proposed type of scrubber would be able to remove up to 99.9 percent of the HF from the exhaust gases. The estimated composition of the exhaust gases under four scenarios as presented in the LLNL engineering analysis is shown in the following table:

Table: Estimated concentration of hydrofluoric acid and uranium oxide in the exhaust gas from the process building under a variety of assumptions regarding the chemical form of the uranium oxide and whether the HF is neutralized with lye to CaF_2 or processed for resale as AHF. The implied uranium concentration in the HF is calculated assuming 99.9% of the HF is removed by the scrubber prior to release at the stack and that no uranium oxide is removed in that process.

Scenario	HF pounds per year emitted after scrubbing	Pounds of uranium oxide per year in scrubbed exhaust	Implied contamination of the HF, ppm of U
U_3O_8 with AHF sale[(a)]	900	3.3	3.1
U_3O_8 ; CaF_2 process without HF sale[(b)]	300	3.3	---
UO_2 with AHF sale[(c)]	900	12	11.7
UO_2 ; CaF_2 process without HF sale[(d)]	300	12	---

Notes:

(a) LLNL 1997 (EA) p. 6.4-7-2

(b) LLNL 1997 (EA) p. 6.5-7-2

(c) LLNL 1997 (EA) p. 6.6-7-2

(d) LLNL 1997 (EA) p. 6.7-7-2

These releases correspond to annual airborne emissions of approximately 0.51 to 1.9 millicuries of uranium under routine operation. A private conversion facility built to handle the smaller amount of depleted uranium that would be generated at the proposed LES enrichment facility in comparison to the DOE stockpile which formed the basis of the LLNL analysis would be expected to have proportionally lower absolute levels of these emissions assuming the same scrubber efficiencies. A consideration of the impacts for lower filter efficiency should be

included in the assessment of the routine impacts of the deconversion facility. Low scrubber efficiency was frequently experienced in the scrap recovery operations at the uranium plant near Fernald, Ohio, for instance.[20]

Q. What disposition should be considered for the HF?

A. Currently there are no DOE or general NRC guidelines that govern the free release of contaminated hydrofluoric acid or calcium fluoride.[21] The NRC has granted a license to the Framatome Advanced Nuclear Power, Inc. uranium fuel fabrication facility in Richland, Washington, for the release of HF containing up to 6.4 ppm of uranium and the European limit for release of HF from the Cogema Pierrelatte deconversion plant is 5 ppm.[22] The cost analysis of a uranium deconversion plant intended to process the DOE's stockpile of DUF_6 conducted by Lawrence Livermore National Laboratory concluded, however, that

> In addition to the uncertain market, there is concern about possible public reaction to uranium contaminants. If the fluorine chemical is to be sold in North America, it may be subjected to higher purity standards due to the source material.[23]

The implied uranium concentrations of uranium in the hydrofluoric acid given in the above table assume that no uranium oxide was removed by the HF scrubber and, therefore, the actual total contamination of the acid is likely to be higher than these levels. Given the fact that the value for the DU_3O_8 facility is close to the existing U.S. and European benchmarks and the fact that the value for the DUO_2 facility is roughly twice as large, as well as the caution raised by the LLNL

[20] Viollequé et al. 1995, Appendix I. See especially Table I-10 through I-13, which indicate highly variable scrubber performance, ranging from better than manufacturer specifications to nearly complete failure of scrubbers. Sodium hydroxide was the scrub fluid. Thus, even if a 99.9 percent efficiency scrubber is installed, maintaining the efficiency at such a high level would be difficult and expensive due to the corrosive nature of HF.
[21] DOE Paducah ROD 2004 p. 44657 - 44658 and DOE Portsmouth ROD 2004 p. 44652 - 44653,
[22] DOE Paducah EIS 2004 p. E-13 and LLNL Cost Analysis 1997 p. 50-51
[23] LLNL Cost Analysis 1997 p, 50-51

analysis regarding the potential for even tighter standards in the U.S. in the future, suggests that it should be assumed that the hydrofluoric acid resulting from the deconversion of the DUF_6 from the proposed LES facility will not be able to be resold on the open market.

One possibility for the use of this material that would not be hampered by the projected levels of contamination would be its reuse in manufacturing new UF_6 from natural uranium. However, in the present context this is not likely to be a plausible option for LES given the very large amounts of hydrofluoric acid that will be being produced by the government's deconversion facility for the DOE stockpile of depleted uranium. In particular, the suggested use of the HF by the uranium fuel facility in Metropolis, Illinois, is not likely to be attractive given the proximity of the Paducah deconversion plant to be operating in nearby Paducah, Kentucky. The Portsmouth deconversion plant in Piketon, Ohio, which would also generate large amounts of HF, is also much closer than the proposed LES facility in southeastern New Mexico. These facts were explicitly considered by the NRC and in the DEIS for the proposed LES facility when it concluded that CaF_2 disposal as LLW was the only scenario that was reasonable to include in the DEIS. The potential need for disposing of the calcium fluoride (CaF_2) as LLW comes from the fact that it is expected to be contaminated by the presence of the uranium in the hydrofluoric acid.[24]

Assuming that, other than the presence of uranium, the calcium fluoride can be considered non-hazardous waste, the contaminated CaF_2 would qualify as Class A low-level waste that could likely be disposed of in a suitable 10 CFR 61.55(a) facility. The treatment and disposal of this waste stream would add to the environmental impacts of the routine operation of the

[24] Paducah EIS p. E-5

deconversion facility and these impacts should be considered for the specific case of the proposed LES facility in the ER and DEIS.

Q. ~~Are there other impacts that you believe should be considered in the DEIS?~~

A. ~~There are impacts involving the cost of different deconversion options, and impacts concerning the impact and cost of various disposal methods. It is my understanding that such questions have been scheduled for consideration at a later time. If they are under consideration at this point, I respectfully refer the Board to the report Makhijani and Smith, Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County, New Mexico by LES, Nov. 24, 2004, filed in this proceeding.~~

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Education:

Ph.D. University of California, Berkeley, 1972, from the Department of Electrical Engineering. Area of specialization: plasma physics as applied to controlled nuclear fusion. Dissertation topic: multiple mirror confinement of plasmas.

M.S. (Electrical Engineering) Washington State University, Pullman, Washington, 1967. Thesis topic: electromagnetic wave propagation in the ionosphere.

Bachelor of Engineering (Electrical), University of Bombay, Bombay, India, 1965.

Current Employment:

1987-present: President and Senior Engineer, Institute for Energy and Environmental Research, Takoma Park, Maryland. (part-time in 1987).

February 3, 2004-present, Associate, SC&A, Inc., one of the principal investigators in the audit of the reconstruction of worker radiation doses under the Energy Employees Occupational Illness Compensation Program Act under contract to the Centers for Disease Control and Prevention, U.S. Department of Health and Human Services.

Other Long-term Employment

1984-88: Associate Professor, Capitol College, Laurel, Maryland (part-time in 1988).

1983-84: Assistant Professor, Capitol College, Laurel, Maryland.

1977-79: Visiting Professor, National Institute of Bank Management, Bombay, India. Principal responsibility: evaluation of the Institute's extensive pilot rural development program.

1975-87: independent consultant (see page 2 for details)

1972-74: Project Specialist, Ford Foundation Energy Policy Project. Responsibilities included research and writing on the technical and economic aspects of energy conservation and supply in the U.S.; analysis of Third World rural energy problems; preparation of requests for proposals; evaluation of proposals; and the management of grants made by the Project to other institutions.

1969-70: Assistant Electrical Engineer, Kaiser Engineers, Oakland California. Responsibilities included the design and checking of the electrical aspects of mineral industries such as cement plants, and plants for processing mineral ores such as lead and uranium ores. Pioneered the use of the desk-top computer at Kaiser Engineers for performing electrical design calculations.

Professional Societies:

Institute of Electrical and Electronics Engineers and its Power Engineering Society
American Physical Society
Health Physics Society
American Association for the Advancement of Science

Awards:

The John Bartlow Martin Award for Public Interest Magazine Journalism of the Medill School of Journalism, Northwestern University, 1989, with Robert Alvarez.

Consulting Experience, 1975-1987

Consultant on a wide variety of issues relating to technical and economic analyses of alternative energy sources; electric utility rates and investment planning; energy conservation; analysis of energy use in agriculture; US energy policy; energy policy for the Third World; evaluations of portions of the nuclear fuel cycle.

Partial list of institutions to which I was a consultant in the 1975-87 period:

Tennessee Valley Authority
Lower Colorado River Authority
Federation of Rocky Mountain States
Environmental Policy Institute
Lawrence Berkeley Laboratory
Food and Agriculture Organization of the United Nations
International Labour Office of the United Nations
United Nations Environment Programme
United Nations Center on Transnational Corporations
The Ford Foundation
Economic and Social Commission for Asia and the Pacific
United Nations Development Programme

Languages: English, French, Hindi, Sindhi, and Marathi.

Reports, Books, and Articles (Partial list)

(Newsletter, newspaper articles, excerpts from publications reprinted in books and magazines or adapted therein, and other similar publications are not listed below)

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CERTIFICATE OF SERVICE

Pursuant to 10 CFR § 2.305 the undersigned attorney of record certifies that on January 7, 2005, the foregoing Direct Testimony of Dr. Arjun Makhijani Regarding Nuclear Information and Resource Service and Public Citizen's Contention EC-4 was served by electronic mail and by first class mail upon the following:

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