Report

The U.S. Weapon-Grade Plutonium Shipment

Safety and Security Concern for the "Eurofab" Operation in France

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Executive Summary

The present report is a comprehensive update based on a briefing published by WISE-Paris in July 2003 on the US plan – also known as "Eurofab" – to have MOX Lead Test Assemblies (LTAs) fabricated in the French plant of ATPu, Cadarache.(1) Based on recent developments, it discusses the specific risks raised by this unprecedented operation, in particular at the transport and fabrication stages. This analysis includes a joint assessment,(2) by WISE-Paris and Large & Associates, in response to the French Institut de radioprotection et de sûreté nucléaire (IRSN) criticism over the independant reports they previously published on this issue.(3)

The "Eurofab" Option

The "Eurofab" plan, the core of which is the plutonium transport that just left the United States, on 20 September 2004, comprises the fabrication, using this weapon-grade plutonium originated from the U.S. nuclear stock, of four assemblies of so-called MOX fuel ("mixed oxides" of uranium and plutonium), and their return to the United States to be tested in reactors.

Although this unprecedented operation is developed in the framework of the U.S.-Russian agreement of September 2000 for the disposition of "surplus" military plutonium, it was not included in the program at that time. This development underlines the hurdles and difficulties that the U.S. part of the program faces. The key decision, in that respect, was the choice, in April 2002, to limit the plan to the MOX option and apply it to the whole of the 34 tons of U.S. plutonium to dispose of. The U.S. Government thus gave up its own initial project to develop the "dual track" strategy – two options serving as a back up to each other in case one would fail – in which 8.4 tons were to be disposed of in vitrified waste (ceramic), even though the U.S. Department of Energy (DOE) had concluded in February 2002 that the latter was the cheapest option.

As the U.S. industry does not have any industrial experience in plutonium recycling and in MOX fabrication, the program relies on the support of the European plutonium industry, especially

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COGEMA which is part of the consortium in charge of building the future U.S. MOX fuel plant, now under preliminary licensing. It is claimed that the May-June 2000 decision of the U.S. Government to have the four test assemblies, necessary to the qualification of this fuel without equivalent, fabricated in one of the European MOX fuel plants rather than to wait for the completion of the U.S. one – currently planned for 2008 – is a key to accelerate the program.

The choice of the ATPu plant of Cadarache, that was made official in August 2003, is also a sign of the difficulties encountered: out of the five possible plants, the two British plants (MDF, and the most recent, SMP, in Sellafield), which use a different process anyway, were dicredited by a bad operational record; the Belgian plant (P0, in Dessel), first preferred by the United States, had to be ruled out because of the political deadlock that the plan created in the Belgian Government in July 2002; finally, ATPu, although much older, was the only option left since the much recent plant, MELOX in Marcoule, would not be licensed to operate with that type of plutonium.

The choice of ATPu is making the risks linked to the operation maximum. Indeed, this new experience of MOX fuel fabrication using weapon-grade plutonium, never seen, will be tried in a plant which, because of its obsolescence regarding safety standards, in particular in the field of seismic risk, is no more authorized, since July 2003, to proceed with standard MOX fabrication. Moreover, the location of the plant is the most distant from the potential ports for the shipment's unloading, in that case Cherbourg, where the U.S. plutonium will arrive in very late September - early October 2004 before its transfer to La Hague for some conditioning; altogether, the overland transport of weapon-grade plutonium down, and the return of the test assemblies up, will cover around 1,000 km each way. Also, one specificity of the ATPu is that it is not equipped to proceed with the last operation in fuel fabrication, i.e. the assembling of fuel rods, which will require them to be transferred to MELOX for the fabrication of LTAs to be completed. In total, these operations should last for 4 to 6 months.

The Concern for Safety and Security Issues

In view of the industrial and political stakes, the risk assessment was therefore not the main decision criteria. Nevertheless, the "Eurofab" operation, because of the highly specific nature of the material, and the quantities involved – 140 kg of weapon-grade plutonium dioxide powder – considerably reinforces the safety and security problems usually linked to the operations considered, be it transport or fabrication. Although the equipments to be used (casks, machines, etc.) are regularly used with important quantities of plutonium, the demonstration of the feasibility of their use with this new material requires a specific assessment for each stage of the process.

Considering this requirement, even though the plutonium shipment has left the United States, some fundamental questions remain regarding the process, the scope and the results of safety and security assessments that served as a basis for the U.S. and French authorities to authorize the "Eurofab" operation.

In the United States, the DOE has only considered, when comparing the "Eurofab" option to the first planned domestic fabrication of the LTAs, the impacts on the national territory or the global commons (maritime transport), excluding the potential impacts of the operations planned in France. As such, the potential consequences of the project in France have not been specifically assessed by the U.S. authorities, for whom it was not part of the appreciation of the programme.

The export license granted on 16 June 2004 by the Nuclear Regulatory Commission (NRC) was challenged, unsuccessfully, by environmental organizations on the ground that it approves the application of double standards, on one hand the very tight requirements of the NRC for the safety and security of weapon-grade plutonium on the U.S. territory, and on the other hand the conditions planned for the maritime transport, under responsibility of the British company PNTL, and the operations in France. After an enquiry by the Gouvernment Accountancy Office (GAO), members of the U.S. Congress have questioned, in August 2004, why the U.S. government failed to develop its own assessment of the measures planned in Europe, instead relying on the guarantees offered by the British and French authorities –a situation that the federal government has not denied.

The conditions of the process by which, in France, the licenses requested for the "Eurofab" operations were gained, however, raise further doubts on the substance of the guarantees offered. Firstly, COGEMA has seemingly signed the contract for the fabrication of LTAs at ATPu, in August 2003, before it would receive the formal go-ahead of the French government, and in any case before it has even filed a request for license of this very specific operation to the competent authorities. The whole process has not been public.

The request for the authorization of the operations planned at ATPu was filed to the French safety authority, the Direction générale de la sûreté nucléaire et de la radioprotection (DGSNR), no earlier than in November 2003. Although the production of standard MOX had ceased in July 2003 for safety reasons, the basis for this LTAs demand is apparently a simple quantity calculation over the material involved compared to previous activity, instead of a specific assessment of the risks linked to the operation. Similarly, as regards overland transport operations, no indication was given that some specific analysis of the safety and security requirements for those transfers was conducted, as compared to the regular plutonium transports of the French reprocessing industry, although these do not meet the requirements applied on their territory by the U.S. authorities.

Safety and Security of the Plutonium Road Transport

Regarding the safety and security of plutonium transports, the French approach implicitly relies on the combination of two principles: first, that the requirements applicable to the safety of transports (the risk of radioactive release in the event of an accident) are able to guarantee the containment of the radioactive material against malevolent actions; and second, this is on provisio that a secrecy policy is applied to the transports, so as to prevent the most damaging malevolence situations.

The safety requirements are based on the international standard TS-R-1 of the International Atomic Energy Agency (IAEA) on the cask performance under mechanical impact, fire and immersion. The French authorities consider the cask used for the overland transport of plutonium powder, the FS47, to present an important safety margin as regards the IAEA criteria. In the field of security, on the contrary, there is no regulatory requirement for the cask behaviour to be demonstrated defeating some clearly defined aggressions. This is not compliant with IAEA recommendations for the physical protection on nuclear materials, as in INFCIRC/225/Rev.4, that the French authorities nevertheless have committed themselves to comply with in exchanges with the U.S. Government.

The arrival of U.S. plutonium takes place in the context of a growing controversy on the safety and security of the plutonium transports in France. Reports published by WISE-Paris in early 2003 and Large & Associates in early 2004 have strongly challenged the safety and security measures applied to these transports, highlighting the dramatic potential consequences of severe accidents and acts of terrorism. Also, actions by Greenpeace, based on on-the-ground observation of the times, dates and routes of the plutonium shipments, have clearly demonstrated the failure of the secrecy policy, even after it was bluntly reinforced by a highly controversial "defense secrecy" arret.

The French nuclear technical support organisation, the Institut de radioprotection et de sûreté nucléaire (IRSN) published in March-April 2004 a short rebuttal of the two reports above. The IRSN denies their conclusions as a whole, and confirms, showing an absolute certainty, that the FS47 can not breach in a realistic accident and therefore, the highest considered fraction release in the worst-case accident scenario for a plutonium transport in France is 0.07 g – a value which serves as a basis for the preparation of emergency planning.

WISE-Paris and Large & Associates' joint assessment of the IRSN demonstration concludes that it raises more questions than it brings answers, and that there is no substance in the programme of tests and simulations presented by the IRSN to support its conclusions that justifies such an absolute confidence. This assessment firstly points out the uncertainty inherent to the experimental method developed, mostly the extrapolation of computer simulations of the most damaging conditions based on real tests under less severe conditions. Then, the tests developed by the IRSN are in large part inadequate, notably the series of tests of the mechanical behaviour that describe handling incidents (vertical fall, longitudinal impact, in general on the shock absorber), and by no mean road transport events (transversal impact, no shock absorber). Finally, the IRSN does not explain how the results of the singular tests can be extrapolated to realistic accident situations (succession of the mechanical and thermal constraints, role of the transport rack), including what is the basis for its implicit reasoning that only one cask would fail in a vehicle where up to 10 are transported. Consequently, the IRSN does not appear well-founded when it denies, without explanation, any relevance to the most recent U.S. assessment, that uses a fraction release value, in a similar scenario, of 595 g per FS47 – that is, more by a factor of 8,500 than IRSN.

In addition, the IRSN's rebuttal does not comment on the security assessment, thus being silent on recent experiments conducted by the institute in the field of the physical protection of FS47, the results of which had just been exposed in a conference in the United States a few months before. These results, that relate to two series of tests comprising mock-up experiments and computer simulations of detonations of explosive loads close to the cask, and heavy-weapon shots, unambiguously demonstrate the potential for diversion (after the FS47 external shell is destroyed) and moreover significant dispersion of the plutonium. In particular, the tests clearly conclude that the FS47 integrity does not resist when fired by a rocket. This conclusion is contrary to the principle set by the French authorities themselves regarding the acceptability of the risk, which is that the radiological consequences of malevolent acts must not be greater than those expected in accident conditions.

Safety and Security of the MOX Pellets Fabrication in ATPu

The other highly sensitive stage of the process, regarding the risks, is the fabrication of MOX fuel rods in the obsolete facility of Cadarache, ATPu. This production takes place in a very blurry regulatory framework, with the operator taking advantage of a unique series of old and recent privileges regarding the regulatory framework in force for nuclear installations (as established, notably, by the decree n° 63-1228 of 11 December 1963).

The operating license of ATPu, which was built and started operation even before that framework was implemented, consists in a single declaration, by letter of the Commissariat à l'énergie atomique (CEA) in 1964, of its existence. This letter does not specify precisely the nature and the quantities of, and the process applied to nuclear materials, the definition of which rests in the hands of the safety authority and is not subject to public procedures. The ATPu could that way change from experimental to industrial production, first for fast breeder reactors and then for light water reactors, or adopt the MIMAS (Micronized Master Blend) process in 1996. Moreover, the facility, the "regulatory" operator of which remains its owner, the CEA, thus responsible for safety matters, has been operated since 1991 by COGEMA as its "industrial" operator, although there is no legal definition of this situation. Finally, ATPu has "ceased", in July 2003, its "commercial" production, a situation that does not match any regulatory provision, the regulatory procedure of "definitive shut-down" being defined by the removal of all nuclear materials from the facility and the approval of a safety assessment of the facility decommissioning, a file COGEMA had not even prepared.

This "closure" of ATPu, that the safety authority first demanded in 1995, is justified by the unsufficient design of ATPu regarding seismic hazard, while being very close to the active zone of the Durance seismic fault. The authorization granted for the LTA fabrication is based, as COGEMA and the authorities explain, on one hand on the fact that the facility still hold significant quantities of plutonium anyway – the activity of ATPu has been for the last year, and will be for another year at least, the conditioning in MOX scraps of plutonium stocks held in the facility, but also elsewhere in the Cadarache center, or even in other CEA centers –, and on the other hand on the estimate that the "source term" is at least 10 times lower than during full industrial production.

Both in quantitative and qualitative terms, this reasoning is unacceptable. At the quantitative level, the source term, that is the quantity of radioactive material that could be released in the worst-case accident scenario considered, would be still one tenth of the fully unacceptable amount considered during industrial production (where an operating stock of 1.5 t of plutonium was continuously stored in the facility), for which the DGSNR estimate was 13.8 kg : thus the risk to consider today is the release of around 1.4 kg of plutonium during the operations planned, which could lead to important contamination of the staff, the local population and a large area around the facility (although one must note that the weapon-grade plutonium would be less toxic from a radiological point of view than the reactor-grade plutonium usually processed). But also, the projected operation is coming on top of the activities required to remove the nuclear material from the plant, and does therefore not represent a division of the risk but its effective increase : first, because it will directly increase the real radioactive inventory of the facility during the few months required for this operation, then because this will result in a corresponding delay in the removal activities, the completion of which is the only way to terminate the risk.

The seismic risk is not the only concern in the field of safety and security for an operation involving weapon-grade plutonium, that present a much higher risk in terms of criticality, and also of strategic interest (regarding the risk of diversion) than ordinary. Not only these risks have seemingly not been fully assessed in a specific and deep manner, but recent events cast further doubts on the quality of safety and security at the plant.

First, contamination accidents, notably in April 2002, and more recently, on 6 September 2004 (where a member of the staff has seemingly been significantly exposed), have highlighted some important concern for safety in the field of the compliance with procedures, the radiological alert system, the plant decrepitude (contamination from one cell to the neighbouring ones through a crack in a wall) and the quality of public information.

Second, ATPu is faced with problems of nuclear materials accountancy that become, in view of the coming introduction of weapon-grade in the facility, of crucial importance. In particular, a report of the European Commission on its application of safeguards under Euratom concluded in December 2003 that an "unacceptable" quantity of plutonium was missing in the ATPu accountancy for the year 2002. Although the Commission and COGEMA have recently announced that a "satisfactory" explanation was provided, the problems pointed out, relating to the diverse and large stock of plutonium materials held in the facility and to the quality of measurements, still cast doubt, on the basis of available information, on the capacity to guarantee adequate accountancy during the LTA fabrication.

The present report is based, in particular, on the following analysis:

(a) ***Previous WISE-Paris Briefing on the choice of the ATPu for LTA fabrication:***

X. Coeytaux, V. Legrand, Y. Marignac & M. Schneider, *U.S. MOX 'Lead Test Assembly' Controversy: Fabrication at Cadarache, France – If too dangerous for European fuel, why just right for U.S. weapons plutonium*, WISE-Paris Briefing, July 2003.
http://www.wise-paris.org/english/ourbriefings_pdf/030729BriefLTA.env1b.pdf

(b) ***Joint Response to the Institut de radioprotection et de sûreté nucléaire (IRSN):***

Y. Marignac, X. Coeytaux, J. H. Large, *Plutonium Transports in France – Safety and Security Concerns over the FS47 Transportation Cask*, Joint Assessment, WISE-Paris / Large & Associates, 21 September 2004.
http://www.wise-paris.org/english/reports/040921JointAssessmentFS47.pdf

See also Joint Submission to the International Atomic Energy Agency (IAEA):

J. H. Large, Y. Marignac, *IAEA Requirements on Design Basis Threat Assessment - Non Compliance of Eurofab Shipment from US to France on UK Vessel: Security and Physical Protection Issues*, Submission to the International Atomic Energy Agency, 20 September 2004.
http://greenpeace.datapps.com/stop-plutonium/en/wise_large_report.pdf

(c) ***Rapports de WISE-Paris et de Large & Associates sur les transports de plutonium en France :***

Y. Marignac (Dir.), X. Coeytaux, M. Schneider & al., *Les transports de l'industrie du plutonium en France: une activité à haut risque*, WISE-Paris, February 2003.
English Summary: http://www.wise-paris.org/english/reports/030219TransPuMAJ-Summary.pdf
Report (in French): http://www.wise-paris.org/francais/rapports/transportpu/030219TransPuRapport.pdf
Appendices: http://www.wise-paris.org/francais/rapports/transportpu/030219TransPuRapport_Annexes.pdf

Large & Associates, *Potential Radiological Impact and Consequences Arising from Incidents Involving a Consignment of Plutonium Dioxide under Transit from COGEMA La Hague to Marcoule/Cadarache*, R3108-A6, 2 March 2004.
http://www.greenpeace.org/international_en/multimedia/download/1/424600/0/Large_report.pdf

The U.S. Weapon-Grade Plutonium Shipment
Safety and Security Concern for the "Eurofab" Operation in France

1. The "Eurofab" Option

The U.S. plutonium shipment to France for the fabrication of MOX test assemblies, a project known as the "Eurofab" option, marks a strategy to circumvent domestic delays and obstacles in the implementation of the U.S. military plutonium disposition plan through the support of the interested European plutonium industry.

1.1. The LTA Plan in the Plutonium Disposition Program

The plan to transport U.S. military plutonium to France for the fabrication of four test fuel assemblies that would be shipped back refers to the plutonium disposition agreement that was signed on 1st September 2000 between the U.S. and Russia. This unprecedented operation was not included in the initial program, however, but was developed by the U.S. administration as a follow-up to strategic turns and repeated delays in the implementation of the disposition agreement.

1.1.a. The limitation to the MOX option

The major turn was the progressive abandonment of the initial U.S. "dual track" option, i.e. fabrication into MOX for one part or the plutonium and immobilization in a waste form for the other part, in favour of a "MOX-only" approach, which consists of the conversion of all surplus military plutonium into mixed uranium-plutonium oxide fuel (MOX) and its loading into commercial reactors. The decision to abandon immobilization with existing high-level waste of 8.4 MT of plutonium of the original 34 MT declared surplus was made official by the U.S. Department of Energy's National Nuclear Security Administration (DOE/NNSA) on 19 April 2002.

Though a key basis for the dual track approach was the parallel development of two options as a security, each of them providing a back-up plutonium disposition solution in case the other one would fail, immobilization is no longer considered. The research activity on immobilization of plutonium in a ceramic form at DOE's Lawrence Livermore National Laboratory in California, as well as the plans for construction of an immobilization facility at DOE's Savannah River Site (SRS) in South Carolina were abandoned.

According to an official DOE assessment,[3] the immobilization option *"achieves full disposition […] of U.S. plutonium with the lowest cost"*. However unsubtantiated, the alleged ground for the decision is thus not the economics, but an unfavourable appreciation of the international context: the immobilization option *"would lead almost certainly to termination of bilateral plutonium disposition with Russia. Russia would have no incentive to complete disposition of its surplus plutonium"*, and *"this option would have limited support internationally"*.

1.1.b. The role of the European MOX industry

As the U.S. industry does not have any industrial experience in plutonium recycling and in MOX fabrication, the U.S. Department of Energy had to seek the necessary know-how in Europe, where it has been built up by COGEMA (France), Belgonucléaire (Belgium), ALKEM (Siemens, Germany) and British Nuclear Fuels Limited (BNFL, UK). Due to its expertise, COGEMA was included in the Duke COGEMA Stone & Webster (DCS) consortium, which has been awarded a Base Contract of $130 million in March 1999 to develop the U.S. MOX project.

COGEMA brought into the DCS consortium its experience in building and operating a MOX plant. The U.S. program includes the construction of a MOX fabrication facility at the Savannah River

3 National Nuclear Security Administration Office of Fissile Material Disposition, *"Report to Congress: Disposition of Surplus Defense Plutonium at Savannah River Site"*, 15 February 2002.

Site, based on the design of the French MELOX plant operated by COGEMA at the Marcoule site. Specific development steps have been defined in the DCS Base Contract:

- design and licensing of a plutonium/MOX fuel fabrication facility at the Savannah River Site;
- design and licensing of nuclear reactor modifications at Duke Power Company's Catawba and McGuire Nuclear Power Plants near Charlotte, North Carolina and Rock Hill, South Carolina – all four reactors of which are of the controversial ice-condenser PWR type;[4]
- qualification of plutonium/MOX fuel for use in U.S. light water reactors (LWR);
- design and certification of a first-of-its-kind plutonium/MOX fuel shipping package;
- fabrication and irradiation of plutonium/MOX fuel Lead Test Assemblies (LTAs).

LTA irradiation is crucial in order to qualify both the MOX fuel in the Duke reactors and the MOX fabrication process itself – the advanced MIMAS process – chosen for the SRS MOX facility. As it requires some time before it is completed, it is also an essential part of the time schedule of the overall program: LTA irradiation testing would take place over two irradiation cycles of 18 months each, with post irradiation examination taking about a year. Fabrication of the LTAs in the SRS MOX plant would push the start-up of the U.S. MOX program at least four years after the SRS MOX plant is completed and commissioned, which is planned for 2008 with a construction start in 2005, although this schedule is threatened by shortening of the proposed budgets in the U.S. Congress.

An early fabrication of the LTAs is therefore regarded as key to an early start of the U.S. MOX program. As the DOE's Los Alamos National Laboratory in New Mexico, initially chosen as LTA fabricator, was unable to produce the LTAs of the quality needed, thus resulting in delays and negative cost implications for the entire MOX program, the U.S. administration began to analyze the European plutonium industries' ability to fabricate the LTAs in order to speed up the qualification process.

In June 2000, the "Eurofab" plan, namely the fabrication of four LTAs in a qualified MOX fabrication plant in Europe using weapon-grade U.S. plutonium, emerged and became a major component of the European involvement in the U.S. plutonium disposition strategy.

1.2. Status of the LTA Plan

After it had concluded in May 2000 that the LTAs should be fabricated in existing MOX fuel facilities in Europe rather than at LANL as previously decided, the DOE commissioned DCS, as the team that was awarded the contract for MOX fuel fabrication and irradiation services, to assess the feasibility of this "Eurofab" option. Although DCS rapidly concluded favourably on the feasibility, it took some years before the choice of the plant to be used in Europe was decided, and agreement on the operations arranged with the concerned authorities and operator.

1.2.a. The choice of ATPu

There are three MOX fuel producers in Europe, operating five MOX fabrication plants: BNFL (MDF and SMP in Sellafield, UK),[5] Belgonucléaire (P0 in Dessel, Belgium) and COGEMA (ATPu in Cadarache and MELOX in Marcoule, France).

Although the reasons why the U.S. Government has not turn to the British option are unclear,[6] the main explanation is probably that, contrary to its competitors, the UK MOX fabricator BNFL is not

4 Virginia Power Company's North Anna-1 and -2 nuclear power reactors are still listed as "mission" reactors in the contract though the company has since dropped out of the DCS consortium.

5 Although no MOX assembly has been produced at SMP yet, more than two years after its start-up was authorized.

in a position to deliver MOX fabricated on the basis of the MIMAS process, chosen by the U.S. DOE for its weapons plutonium disposition program.

The LTA fabrication is a very specific operation, due to the characteristics of the initial material used which implies a number of unique handling issues at every step of the fabrication process and raises questions about radiation protection and proliferation resistance. Therefore, another key element for the choice of the MOX plant is the technical feasibility of the fabrication in the plant and its status regarding the overall operating license of the plant.

While the more recent MELOX plant is not licensed to handle separate weapon-grade plutonium,[7] the more sloppy regulatory framework of the older ATPu and P0 plants, and their flexible initial design features, which allows for the fabrication of plutonium fuels for Fast Breeder Reactors, i.e. fuels with high fissile content, makes the handling of the U.S. plutonium theoretically possible at those facilities. Licensing MELOX to handle such material appeared too lengthy and LTA fabrication would seriously disturb commercial operation at the plant.

The last key to the choice was political agreement. The U.S. Government initially turned to both French and Belgian Governments, with P0-Dessel being apparently pursued as the preferred option, after the April 2002 decision to abandon immobilization. After the decision of the Belgian authorities, following a political controversy inside the government on the issue, was first delayed in July 2002, then indefinitely postponed in December 2002, the ATPu remained as the only practicable option.

While the French safety authorities, the Direction générale de la sûreté nucléaire et de la radioprotection (DGSNR), stated in early July 2003 that no formal request had been received yet concerning the licensing of the LTAs fabrication at ATPu,[8] a plant which was about to cease commercial operation, the choice of Cadarache was announced less than two months later. The DOE declared, at the end of August 2003, that the contract for manufacture in Europe of the LTAs had been signed on 12 August 2003, and that the consortium responsible for implementing the US MOX program, DCS, entrusted execution of the contract to COGEMA,[9] which the company only confirmed on 5 September 2003.[10]

1.2.b. The plutonium journey and the operation schedule

In principle, the "Eurofab" option is simple: weapon-grade plutonium is to be transported across the U.S. to the east coast, then shipped overseas to Europe, transferred to a MOX plant in France where it will be incorporated in LTAs and finally shipped back to the U.S. to undergo test irradiation in one of the Duke Power reactors designated to use MOX on a commercial scale. In practice, the details of the operations reveal a much more complicated and exceptional process, as information available through the licensing processes has progressively showed.

The export license, eventually granted to the DOE on the 16 June 2004, allows for the shipment to France of 123.48 kg of weapon-grade plutonium in the form of 140.0 kg of PuO_2 powder.[11] The plutonium powder will be transported in casks of the French FS47 design (developed by

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6 *"Llew Smith: To ask the Secretary of State for Defence what recent requests he has received from the United States Government to provide lead test assemblies for the United States military nuclear programme. [100038] Mr. Ingram: None."* The Hansard, 5 March 2003, Columns 1-1052W.

7 The weapon-grade plutonium used in the framework of the LTA plan is enriched to about 93% in Pu-239, while the MELOX plant is not licensed to handle separate plutonium with less than 17% of Pu-240, because of the criticality risks encountered with plutonium with lower quantities of isotopes insuring moderation efficiency.

8 Personal communication, Jacques Aguilar, DGSNR, 3 July 2003.

9 See *Nuclear Fuel*, "Cogema wins contract for fabrication of test assemblies for U.S. MOX fuel", 1st September 2003.

10 "Disarmament agreements: the US Department of Energy (DOE) chooses AREVA for the manufacture of demonstration MOX fuel", AREVA press release, 5 September 2003.
See: http://www.arevagroup.com

11 U.S. Nuclear Regulatory Commission (NRC), *Export License n° XSNM03327*, issued 16 June 2004.

Transnucléaire, now COGEMA Logistics), which received Department of Transportation's design certification approval as of 4 August 2004.[12] Fresh MOX fuel would be loaded in FS65 type packages. According to details attached to the DOE's application to the NRC for the export license, submitted on 1st October 2003,[13] *"the material will be contained in eight or nine FS47 shipping packages, each of which contains five containers of plutonium oxide"*. As for the return, *"the assemblies and other material will be contained in six FS65 shipping casks"*; this includes MOX fabrication scraps, i.e. *"left over feed material [that] will be pelletized in the form of MOX fuel, inserted into fuel rods, and welded closed as is the practice with other fuel rods, (...) as well as spare and archive fuel rods"*.

According to the Nuclear Regulatory Commission (NRC), as of 15 June 2004, *"the plutonium oxide that DOE proposes to export [was] at the Los Alamos National Laboratory (LANL) in New Mexico. It would be transported by land from LANL to the Charleston Naval Weapons Station (NWS) in Charleston, South Carolina using the systems operated by the DOE, National Nuclear Security Administration, Office of Secure Transportation (OST). At the Charleston NWS, the material would be loaded onto two armed Pacific Nuclear Transport, Ltd. (PNTL) ships in shipping packages certified by the NRC, and transported to Cherbourg, France. The PNTL ships will sail in convoy for mutual protection"*.[14]

The shipment company, mostly owned by BNFL, shall be responsible for the plutonium up to the French harbor, where it will be taken over by COGEMA Logistics. Transport accross France will be realized by truck, from Cherbourg, north-west of the country, down to the south-east, where COGEMA's MOX facilities are located, and back, as shown on Figure 1.

The implementation of the French part of the plan will take the U.S. plutonium to a series of sites, starting with the reprocessing plant operated by COGEMA at La Hague, close to Cherbourg, where the shipment would be stored on arrival. The plutonium powder will then be transported to the ATPu plant in Cadarache, where it will be mixed with depleted uranium and fabricated into MOX fuel pellets that will be assembled into fuel rods. However, the ATPu facility is not equipped for assembling the rods into fuel assemblies. Under commercial operation, most of the fuel rods produced by the ATPu were transferred to the FBFC plant, in Dessel to be assembled, while the rest was treated in MELOX; the fuel rods fabricated with the U.S. weapon-grade plutonium will be transferred to MELOX, in Marcoule, where they will be assembled into the four LTAs. The fabricated assemblies will then be transported back to La Hague, stored there and finally transferred to Cherbourg, then returned to the U.S. aboard PNTL ships.

As for the construction of the MOX Fuel Fabrication Facility (MFFF) planned at Savannah River Site (SRS), for which the schedule for the decision on issuance of construction permit is now set to 28 February 2005,[15] the "Eurofab" option has been subject to delays in the decision process. The official schedule, as it stands now, was eventually set in the DOE's application for the export of 1st October 2003, that aimed for the shipment to take place in July/August 2004. However, there has been further delay: in the first days of September 2004, the PNTL ships *Pacific Pintail* and *Pacific Teal*, have left their home port of Barrow-in-Furness, in the UK, to sail to the U.S.; one of the ships entered the port of Charleston on Monday, 20 September 2004 and left the same day with the

[12] U.S. Department of Transportation (DOT), *Competent Authority Certification for a Type B(U) Radioactive Materials Package Design, Certificate USA/0675/B(U)F-96, Revision 0*, 4 August 2004.

[13] U.S. Department of Energy (DOE), *Application for License to Export Nuclear Material and Equipment*, n°XSNM03327, 10 October 2003.

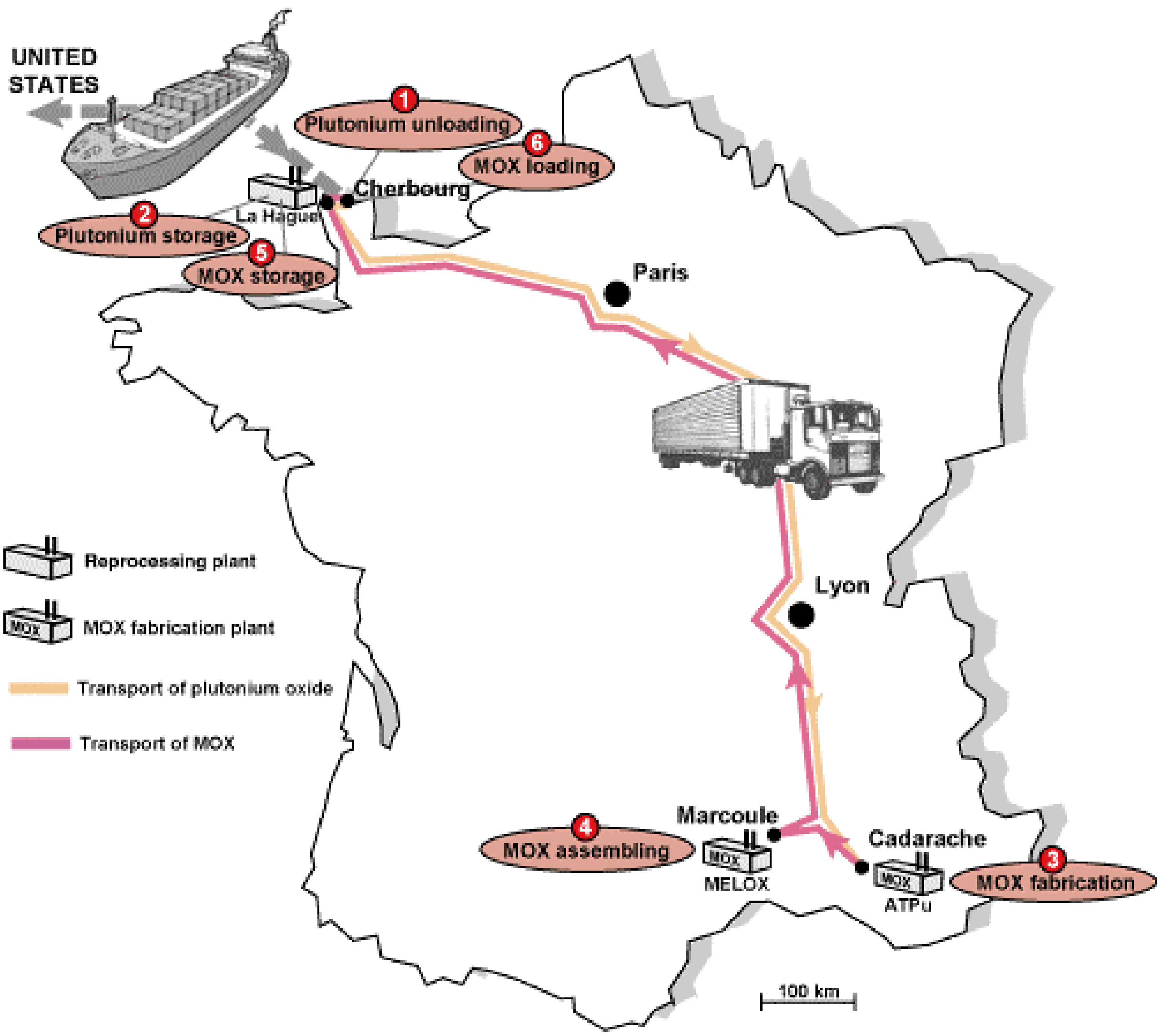
[14] NRC, *Memorandum and Order in the Matter of U.S. Department of Energy (Plutonium Export License), CLI-04-17*, 15 June 2004.

[15] See the "Licensing Schedule for the Mixed Oxide Fuel Fabrication Facility", as of 8 September 2004, on NRC's web site: http://www.nrc.gov/materials/fuel-cycle-fac/mox/licensing-schedule.html

plutonium shipment.[16] Considering operational delays, the plutonium shipment is expected to arrive in France of the very beginning of October 2004.

It is then expected that the completion of the transport on the French territory and fabrication stages in Cadarache and Marcoule will take at least 4 to 6 months, allowing for the LTAs to be delivered to the U.S. around March 2005 at the earliest.

Figure 1 Transports of plutonium in France under the "Eurofab" plan[a]



[a] The itinerary for overland transport is only indicative. According to Greenpeace on-the-ground observations, the French plutonium transports used to take quite systematically the motorways round the Paris and Lyon suburbs, and down the Rhône valley, but some changes in the itineraries have been introduced recently.

 Source : DOE, Supplement Analysis, November 2003; COGEMA, Greenpeace, 2004

[16] See for further detail:
Areva, "Maritime transport of plutonium oxide from the United States to FranceGreenpeace International", Press release, 21 September 2004.
Greenpeace International, "Nukes On Vacation – Nuclear Shipment Crosses Atlantic", Press Release, 21 September 2004.

2. The Safety and Security Concern

Since the choice of ATPu was made official in August 2003, plans for the implementation of the "Eurofab" option, additional details have been published in the framework of the subsequent licensing process. The unprecedented nature of the transport and fabrication have raised specific concerns regarding safety and security issues, that have been somehow reinforced by shortcomings in the licensing processes, in the U.S. as well as in France.

2.1. Specific Risks Arising from the LTA Plan

Because of the nature of the shipment, a plutonium of weapon-grade isotopic quality, under the form of oxide powder, and the important quantity involved, the risks usually associated with the various operations involved in the LTA plan, from transport to storage and fabrication, are strongly increased. This increase in safety and security risk requires to be fully assessed. In fact, while the equipments involved in the operations considered have been regularly used through the activity of the European plutonium industry, with reactor-grade plutonium, there is a need to demonstrate the feasibility of their use for this unprecedented specific material at each stage of the process.

The transportation of such a material accross the U.S., the Atlantic Ocean and France obviously marks a particular threat in terms of proliferation and international security, especially in the context of crisis of the post 9/11 era. Since it was decided that the weapon-grade plutonium would not be down-blended before shipping, it presents a very particular interest for any entity looking to acquire and use plutonium for a nuclear explosive or radiation dispersal device. Also, the isotopic composition of the plutonium to be fabricated into the LTAs could have an impact on safety, especially regarding the criticality risk. Transport casks and fabrication lines, even if they have demonstrated the ability to handle materials with high plutonium content, have never demonstrated that they could handle such reactive materials.

The potential consequences of events such as severe accidents during transport or fabrication processes, likely to initiate an uncontrolled chain reaction by changing the geometry of the plutonium, or a realistic terrorist attack, must be thoroughly taken into consideration when assessing the risks associated with the LTA plan.

2.2. Licensing, Safety and Security Issues

Seemingly, the licensing process in the U.S., and furthermore in France, have not comprised the development by the competent authorities of a comprehensive, in-deep review of the specific impacts of the planned operation that would match the level of concern raised by these unprecedent moves. Even though the shipment has departed the U.S., some essential questions remain unanswered as regards the process, the scope and the results of the assessment of the safety and the security of the Eurofab plan by the U.S. and French competent authorities.

2.2.a. Licensing process and security concern in the U.S.

Although the analysis of the Eurofab plan started as early as 2000, the decision announced in April 2002 to develop the MOX track only, and the subsequent demands from the U.S. Government to the French and Belgian authorities to consider this plan, mark the beginning of the licensing process on the U.S. side. In fact, it is DOE's stand, in its presentation to the French and Belgian governments, that it would undertake the preparation of an Environmental Impact Statement (EIS) on the LTA program.

According to a *"Draft Notice of Intent"* published in March 2002,[17] DOE intended to prepare a supplemental Environmental Impact Statement (EIS) on both the *"preferred"* Eurofab and SRS options, as required by the U.S. National Environmental Policy Act (NEPA). Analysis of the Eurofab alternative would entail evaluation of the *"potential impacts on the global commons"* of sea shipment of plutonium oxide to Europe and return of fabricated MOX LTAs back to the Duke Power reactor chosen for the LTA testing. However, as of 14 November 2003, DOE said in a notice that it had prepared a so-called Supplement Analysis (SA), as required, under DOE regulations, *"when it is unclear wether a supplement to an EIS is required, (…) to assist in making that determination"*.[18] As stated by the agency, the SA *"concludes that the proposed fabrication of lead assemblies in France would not result in impacts significantly different from or significantly greater than those described in previous DOE NEPA documents"*,[19] clearly contradicting its own commitment of March 2002.

Moreover, it must be stressed that this conclusion is drawn from the assessment of the risks associated to the international transport alone, and not that of all the operations involved on the French territory, that are *"outside the scope"* of the SA. In other words, the potential impact of the Eurofab plan in France was not fully assessed by the U.S. authorities, and was not even, inasmuch as the French authorities would bear responsibility for guaranteeing that this part of the program can not have an impact on the global commons, an element of the U.S. appreciation of the program.

Additionally, DOE had to secure an export license from the Nuclear Regulatory Commission, for which the Department's National Nuclear Security Administration (NNSA) applied on 1st October 2003, pursuant to the contract between the DCS joint venture and COGEMA signed on 12 August 2003. Finally, completion of the LTA plan will require the licensing of targeted reactors for the use of the specified MOX fuel, which the operator of the Catawba and McGuire plants, Duke Energy, has applied for as early as February 2003.

Greenpeace International and other environmental groups have made interventions, in particular on the claim of shortcomings in the safety and security assessments linked to the planned operations regarding U.S. standards, which have all been rejected.[20] Although the last part of the regulatory process, regarding the use of MOX in Duke reactors, is still going on, the early dropping of the supplemental EIS requirement for the Eurofab plan, and the granting, on 16 June 2004, of the Export License, followed by the granting of certificate of use of the FS 47 package, as of 4 August 2004, set the green light for the weapon-grade shipment to take place.

The concern for safety and security risks arising from the Eurofab plan, however, is still rising as the time of the transport gets closer. In August 2004, Members of the U.S. Congress have filed letters to the Secretary of Energy, the Nuclear Regulatory Commission and the Department of Homeland Security raising concern about the possibly unsufficient assessment of security in the planned transport *"in the post-September 11th environment"*.

Jim Turner, Ranking Member of the House Select Committee on Homeland Security, requested in June 2004 from the U.S. Government Accountability Office (GAO) to *"examine the security measures that are planned for the shipment [and] the extent to which NNSA coordinated its*

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17 U.S. Department of Energy, National Nuclear Security Administration, Draft *Notice of Intent to Prepare a Supplement to the Surplus Plutonium Disposition Environmental Impact Statement (Lead Mixed Oxide Fuel Assemblies)*, 6 March 2002

18 DOE, National Nuclear Security Administration, *Supplement Analysis - Fabrication of Mixed Oxide Fuel Lead Assemblies in Europe*, November 2003, DOE/EIS-0229-SA3.
http://www.nnsa.doe.gov/na-26/docs/FinalEurofabSA.pdf

19 DOE, National Nuclear Security Administration, "Amended Record of Decision - Surplus Plutonium Disposition Program", *Federal Register*, Vol. 68, N° 220, 14 November 2003, pp. 64611-64614.

20 Details of the opposition to the request filed by petitioners Greenpeace International, Charleston Peace and Blue Ridge Environmental Defense League against the plutonium export license can be found through the NRC web site research page under the number 11005440.
See: http://www.nrc.gov/reading-rm/adams/web-based.html

planning with other federal agencies".[21] On the basis of GAO's briefing, he raises a series of issues in a letter to Spencer Abraham, Secretary of Energy. He questions in particular the basis of *"independent oversight and review"* on which the NRC *"denied petitions from several public interest groups, finding that the shipment would have adequate physical security"*, when *"it appears that NRC did not perform an independent review of the security measures, relying instead on assurances provided by executive branch agencies"*, and *"the executive branch, in turn, appears to have relied upon assurances provided by the governments of the United Kingdom and France"*.

Another Member of Congress, Edward Markey, raised concern that *"the Bush Administration isn't doing enough to ensure that these deadly materials are fully protected against possible terrorist threats"*.[22] He also questioned in particular the confidence showed by the U.S. agencies in the French authorities assessment in view of *"the apparent inadequacy of security measures for the shipment in France"*, as illustrated by *"disturbing"* Greenpeace evidence that *"an attack on such a shipment would not pose much of a challenge, since the trucks were very easily identified, followed and filmed traveling along highways in France, and were only lightly guarded"*.[23]

The U.S. Department of Homeland Security answer to Edward Markey does not comment on the U.S. assessment of the French security measures. In fact, the letter suggests that it relied on the British assessment, the only new insurance given being that *"the United Kingdom has reviewed and approved all the French and U.S. security measures in place. This is the arrangement agreed to by all three nations."*[24]

2.2.b. Licensing, safety and security issues in France

As compared to the U.S., where at least the administrative requirements of the licensing are made clear and publicly discussed, the licensing framework of the LTA operation, and the actual status of the plan regarding the required licenses is absolutely blurry, due to a very secretive policy and the obsolescense of regulatory rules. Moreover, the sloppy regulatory background of ATPu allows the avoidance of any public involvement in the LTA fabrication decision, that would mainly require a simple "exceptional license" signed by the French safety authority, as soon as the French government, with no further need of any public consultation, would have given its green light to proceed.

Up to an early September 2004 declaration of the Minstry of Foreign Affairs,[25] the French government had never published any public statement that it had been approached by the U.S. DOE to consider fabricating LTAs at Cadarache. The government go-ahead is nevertheless necessary for an operation involving, amongst other things, the transfer to France and routing across French territory of around 140 kg of American military plutonium, or a quantity equivalent to more than 50 bombs! The French government, after authorizing a feasibility study of COGEMA on request

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[21] Letter from J. Turner, Ranking Member of the U.S. House of Representatives Select Committee on Homeland Security, to S. Abraham, Secretary of Energy, 12 August 2004.
http://www.house.gov/hsc/democrats/pdf/hsc_docs/Letterplutonium08_12_04.pdf

[22] Rep. Markey Questions Adequacy of Security for Weapons-Grade Plutonium Shipment to France, Press Release, 24 August 2004.
http://www.house.gov/markey/Issues/iss_nonproliferation_pr040824.pdf

[23] Letter from E. Markey, Member of the U.S. House of Representatives Energy and Commerce Committee, to N. Diaz, Chairman, Nuclear Regulatory Commission, 24 August 2004.
http://www.house.gov/markey/Issues/iss_nonproliferation_2ltr040824.pdf
Letter from E. Markey, Member of the U.S. House of Representatives Energy and Commerce Committee, to T. Ridge, Secretary, Department of Homeland Security, 24 August 2004.
http://www.house.gov/markey/Issues/iss_nonproliferation_ltr040824.pdf

[24] Department of Homeland Security Response to Markey Letter, 8 September 2004.
http://www.house.gov/markey/Issues/iss_homeland_resp040908.pdf

[25] Déclaration du porte-parole du Quai d'Orsay, "Début de l'opération ' EUROFAB' dans le cadre du programme d'élimination du plutonium militaire", 6 September 2004.
http://www.france.diplomatie.fr/actu/article.asp?ART=44192

from the American authorities in 2002, remained silent. Though Cogema claimed, in a 5 September 2003 press release, that *"the French nuclear industry has received agreement from government authorities to assist the DOE"*, this was never confirmed, and COGEMA had seemingly not received any green light before the contract was signed, on 12 August 2003.[26]

Similarly, the contract was awarded before COGEMA received any formal answer from the French safety authority, the DGSNR, on the project to proceed with the fabrication of the LTAs in the ATPu, at Cadarache. In fact, although COGEMA had sought insurance from DGSNR that it would not oppose the project in principle, the company had not even submitted the required specific safety analysis at the time. The authorization demand, based on a safety file dated 13 November 2003, was only submitted to the DGSNR as of 14 November 2003. No detail of the safety file was published, although it appears, from declarations to the media by DGSNR and COGEMA, that it did not include any specific impact assessment, rather basing the case on a raw calculation of the LTA source term as compared to that in previous industrial operation.

The fact that the contractual commitment with DCS was seemingly entered into without the forms of approval essential for its implementation is only one side of COGEMA's "fait-accompli" strategy on this issue. The contract also violates an earlier commitment to end commercial production at the ATPu, due to the unsufficient safety standards of the plant, as of 31 July 2003 – even if COGEMA uses the pretext, itself problematic from the regulatory point of view, of research and development activities.

The announcement of the end of commercial production sets the final point to an eight years-long struggle between the French safety authority and the industrial operator of ATPu, COGEMA, based on the latter's blackmail attempts to secure its activities over safety concerns.[27] The plant is situated close to one of the most active seismic zone in France, and must be shut down because of its poor seismic design, but COGEMA wanted first to secure guarantees over the licensing of the capacity extension of its other plan, Melox, in Marcoule.

As an end to a long period of bargain, which eventually saw the Government adopt COGEMA's view by licensing, after a short public enquiry, the Melox extension,[28] in order to *"transfer"* the ATPu capacity, *"commercial operation"* of the Cadarache MOX plant is stopped, according to COGEMA, since the 16 July 2003. This decision, which does not correspond to any defined stage of the French regulatory framework of the shut down of nuclear facilities, is in practice only materialized through the application of seals on two machines of the production line. According to Gilbert Dalverny, director of COGEMA-Cadarache, some sort of production at ATPu could go on *"until 2006, in order to use all the production scraps as well as all stocks of plutonium initially dedicated to Superphénix"*.[29] The facility will also be used, before it is effectively shut down, to condition plutonium waste accumulated in other parts of the Cadarache site, and possibly from other sites of the Commissariat à l'énergie atomique (CEA), the owner of the ATPu.

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[26] *Nuclear Fuel*, "Cogema wins contract for fabrication of test assemblies for U.S. MOX fuel", 1st September 2003.

[27] *ATPu (Plutonium Technology Facility) at Cadarache*. Briefing WISE-Paris, August 2000 (version 4).
Briefing: http://www.wise-paris.org/english/ourbriefings_pdf/000821BriefCAD1v4.pdf
Annexes (only in French): http://www.wise-paris.org/francais/nosbriefings_pdf/AnnexesBriefCAD1v3.pdf

[28] Décret n° 2003-843 du 3 septembre 2003 autorisant la Compagnie générale des matières nucléaires (COGEMA) à porter à 145 tonnes d'uranium et de plutonium la capacité annuelle de production de combustible nucléaire de l'installation nucléaire de base, dénommée Mélox, implantée sur la commune de Chusclan (département du Gard), et modifiant le décret du 21 mai 1990 modifié autorisant la création de cette installation nucléaire de base et son extension, *Journal Officiel*, n° 204, 4 September 2003, p. 15178.
http://www.legifrance.gouv.fr/WAspad/UnTexteDeJorf?numjo=INDI0301763D

[29] *Les Echos*, "Anne Lauvergeon confirme la fermeture de l'usine Cogéma de Cadarache", 21 January 2003.
Two cores of the Superphénix 1,200 MWe fast breeder reactor were fabricated at ATPu, one of them still unirradiated after the definitive shutdown of the reactor in 1997. As of June 2004, when a public enquiry took place to license the Superphénix site for long term storage of its irradiated and unirradiated fuel, at least half of the second core was still stored at ATPu.

However, no justification has been provided, in terms of risk assessment, to the deliberated risk of bringing new nuclear materials, including the U.S. plutonium, to an installation and of delaying the imperative task of evacuating the materials present in the facility at the end of commercial production. Also, it must be noted that this situation weakens the relevance of DOE's insistance not to delay the export on the ground that *"since the Cadarache plant will be permanently shut down in July 2005, missing this [summer 2004] shipment deadline would mean losing the only viable opportunity to make the lead assemblies"*, as stated by Linton Brooks, Head of DOE's NNSA.[30]

Although the prospect of an exceptional MOX fabrication in a facility declared "closed" because of its unsatisfactory safety is the main issue in the French licensing process of the LTA plan, other authorizations are required. As for the authorization to proceed in ATPu, granting of these additional authorizations does not require any public involvement. The specific authorizations relate mainly to (i) the assembling of the LTAs in the MELOX plant, which is not authorized to receive plutonium of this isotopic quality in separate form but might be granted the right to manipulate it in the form of MOX rods; (ii) the storage of the shipment, after arrival at Cherbourg and on the way back, at the La Hague plant;[31] and (iii) the overland shipment of the considered material using the FS47 and FS65 casks, that require specific transport agreements.

Although the planned operations are to take place in the coming months, as of 31 August 2004, no information has been made public yet on the decisions from the French authorities regarding the various licenses pending, although in early June 2004 AFP wrote: *"AREVA, which has already received the 'de principe' agreement of the French government is awaiting in the coming weeks the authorizations from the Safety authorities (ASN) to produce at Cadarache four demonstration MOX assemblies"*.[32] On 30 March 2004, when asked by WISE-Paris about details about the licensing status of the LTA plan, André-Claude Lacoste, Director of DGSNR, answered that a note of information would be published on the French safety authority's web site *"in the coming days"*,[33] detailing the licensing requirements and the progress in the licensing process. Not only such a note was never posted since on the web site, but WISE-Paris received no answer to a series of elementary questions regarding this licensing issue, addressed to the DGSNR on 8 April 2004.[34]

3. Safety and Security of the Plutonium Road Transport[35]

The coming transport of US military plutonium to France takes place in the context of a growing debate on the highly sensitive issue of plutonium transports, that are conducted on a regular basis in France to serve the ongoing activity of the reprocessing industry. Since the beginning of 2003, evidence provided by ground observation and independant expertise is increasingly challenging the official position of the French authorities regarding the safety, and more importantly the security, of the concerned transports.

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[30] *Nuclear Fuel*, "DOE, Greenpeace spar over license for export of MOX Pu to France", 19 January 2004.

[31] *NuclearFuel*, "Cogema submits U.S. MOX fabrication dossiers to French safety authorities", n°24, vol. 28, 24 November 2003.

[32] *Areva va recycler du plutonium militaire américain à des fins civiles*, AFP, 4 June 2004, translation WISE-Paris

[33] Personal exchange, following the DGSNR Press Conference for the presentation of its annual Report for the year 2003, 30 March 20004.

[34] Letter from Y. Marignac, Director of WISE-Paris, to A.-C. Lacoste, Director of the Direction générale de la sûreté nucléaire et de la radioprotection, 8 April 2004. The series of questions attached to the letter is available on demand.

[35] This section is based on a recent joint assessment prepared by WISE-Paris and Large & Associates in response to the IRSN rebuttal of their previous reports on the issue of plutonium transports in France: Y. Marignac, X. Coeytaux, J. H. Large, *Plutonium Transports in France – Safety and Security Concerns over the FS47 Transportation Cask*, Joint Assessment, WISE-Paris / Large & Associates, 21 September 2004. http://www.wise-paris.org/english/reports/040921JointAssessmentFS47.pdf

3.1. The French Authorities' Approach

The French competent authorities for the safety and security of the plutonium transports are respectively the French safety authority, the Direction générale de la sûreté nucléaire et de la radioprotection (DGSNR), and the High Civil Servant for Defense in the Minister of Industry, the Haut Fonctionnaire de Défense (HFD). Both rely, for the assessment of the risk and the adequacy of the measures, on the technical support provided by the IRSN.

3.1.a. The French general approach

In their duty to assess the risks associated with the plutonium shipment involved in the Eurofab program, the U.S. authorities have seemingly trusted the French authorities on the matter of the safety and security of the transports of nuclear material in general, and plutonium transports in particular. In fact, no indication has been made public that the transportation arrangements and safeguards applied by the French competent authorities will significantly differ from those in place for the existing French-origin react-grade PuO_2 consignments. This approach, which fundamentally eyes the plutonium transports as a routine operation of the reprocessing industry, conducted on a roughly weekly basis, is however very different from the U.S. concern for a single and exceptional shipment.

In summary, the philosophy of the French approach, which is "performance-based" rather than "compliance-based", is based on the combination of two essential principles:

- one is that the safety requirements for the withstanding of the casks to accidental conditions, based on a probabilistic approach, are sufficient to cover the potential situations arising from malevolent external aggressions,
- providing that, as a second principle, it is possible to prevent the threat of acts of terrorism, notably through a policy of secrecy on the routes and timetable of the plutonium transports.

The French Government has recently stated that the plutonium transports in France are *"presenting the highest level of security: all the standards required by the International Atomic Energy Agency are met and even surpassed"*.[36] The safety approach is based on the compliance of the casks with the International Atomic Energy Agency specified TS-R-1 accident conditions.[37] Although not binding, the requirements set by the IAEA regarding the security, in particular the physical protection of transports, are those of INFCIRC/225/Rev.4, wich France is committed to comply with as a signatory of the INFCIRC/274/Rev.1 *Convention on the Physical Protection of Nuclear Materials*.[38] A recent assessment by WISE-Paris and Large & Associates, however, outlines the inadequacy of the French approach with the IAEA requirements in the field of physical protection.[39]

As ackowledged by the French public support organization on nuclear safety and security issues, the Institut de radioprotection et de sûreté nucléaire (IRSN), in a recent paper summarizing *"the French approach concerning the protection of shipping casks against terrorism"*,[40] there exist no regulatory requirements in France regarding the security of the casks: *"though not explicitly*

[36] Minister of Industry, written answer of 18 May 2004 to A Thien Ah Koon, Member of the French Parliament, *Journal Officiel, Assemblée Nationale, Questions écrites*, p. 3684.

[37] IAEA, TS-R-1 Regulations for the Safe Transport of Radioactive Material, Safety Standards Series No. ST-l Requirements, Edition, Vienna 1996.

[38] IAEA, Convention on the Physical Protection of Nuclear Material, INFCIRC/274/Rev.1, May 1980. IAEA, The Physical Protection of Nuclear Material, INFCIRC/225/Rev.4 (corrected), June 1999.

[39] See J. H. Large, Marignac, Y., *IAEA Requirements on Design Basis Threat Assessment - Non Compliance of Eurofab Shipment from US to France on UK Vessel: Security and Physical Protection Issues*, Submission to the International Atomic Energy Agency, 20 September 2004.

[40] B. Autrusson, D. Brochard, "The French approach concerning the protection of shipping casks against terrorism", paper from a presentation given in *ASME Pressure Vessels and piping*, Cleveland (USA), 21-24 July 2003. http://www.irsn.fr/net-science/liblocal/docs/docs_DEND/frenchapproach.pdf

required in the French regulations, the security of the casks must be studied in the context of potential loads resulting from terrorism". However, contrary to requirements applying to the operators of nuclear facilities, *"there is no legal framework allowing the competent authority to require that the transporters or designers of packages perform the assessments of the casks behavior in such situations"*.

3.1.b. Safety and security assessment and acceptability

In effect, it appears that the security of the French designed casks used for the transport of nuclear materials has been "assessed" on the sole basis of their compliance with the safety requirements developed for accidental conditions. The FS47, the design of which was developed in the early 1980s by the COGEMA subsidiary Transnucléaire (now COGEMA Logistics), has seemingly been authorized and put into service without considering specific malevolent acts as, according to the same paper, the IRSN, *"in order to provide the Authority with elements of appreciation, has conducted analyses based on both experimentation and numerical modeling for various kinds of casks and loads, for the last ten years"* – and apparently never before, at least on the same scale.

This program, motivated by the concern that *"the potentiality of such an aggression exists and considering the number of shipments organized every year"*, includes research on the FS47, some of which is reported in the IRSN article and will be further discussed below. It is noteworthy that, in the absence of specific requirements, the IRSN bases its approach for assessing the security of the transport casks on that in force regarding nuclear facilities.[41] Also, according to the IRSN, *"the procedure to evaluate the consequences of terrorism against facilities requires two stages. The first one is the sensitivity study which aims to determine what could be the consequences (...). The second stage is the vulnerability assessment which aims to quantify the difficulty to perform the aggression"*.

In the French regulatory framework, which *"lays down a performance-based approach rather than a compliance-based approach"*[42] it is mostly vulnerability that is assessed in specific security studies – those not being applied to the transports. The *"analysis of the sensitivity involves using safety analyses to identify potential accident sequences"*, and is performed *"mainly by using a standard incident or accident list taken into consideration at the facility design stage"*[43] or the transport cask and vehicle design. In addition, regarding the objectives of physical protection, *"acceptable consequences are taken as being those leading to levels of radioactive releases less than, or equal to, those taken into account in the facility safety case (...)."*[44]

The quantities of plutonium concerned by nuclear transports are of course less than those currently stored in MOX facilities such as the Cadarache ATPu where the LTAs are to be fabricated. However, if the ATPu fabricated around 2.5 t of plutonium into MOX fuel every year, it is likely than only around 1 to 1.5 t of plutonium was present in the facility at the same time. This stock can be compared to the roughly 150 kg of plutonium transported by a single truck, which presents much less protections to external aggressions than the ATPu, enclosed in the Cadarache research center and equipped with storage cells. Moreover, because the plutonium transports evolve in a public environment, the survey of the external parameters is more difficult than in the context of a static installation.

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[41] As stated by IRSN, *op.cit.*, *"for the nuclear facilities, the French regulations state that the consequences of aggressions aiming at generating a safety hazard and/or radiological releases in the environment must be assessed* [and] *have to be evaluated in terms of safety, of pollution in the environment and of radiological consequences for the population"*.

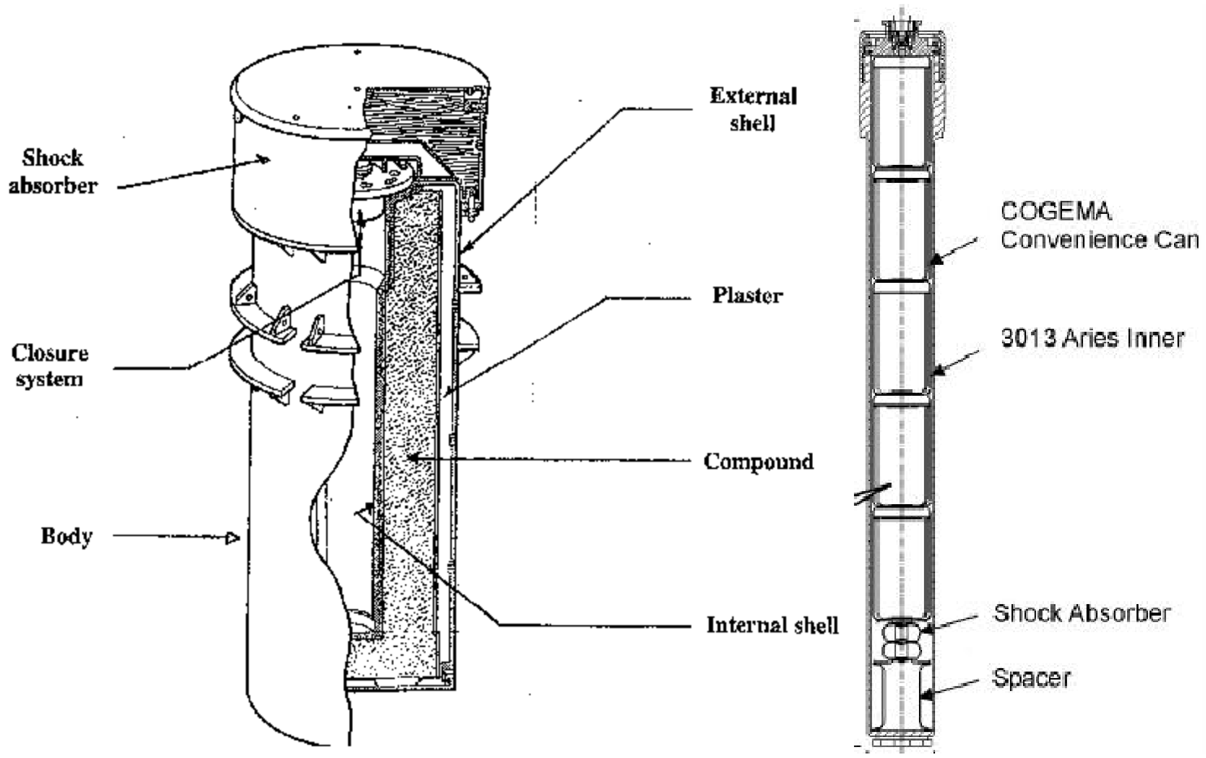
[42] R. Vernot, et al, *Physical Protection, Accountancy and Control Systems Vulnerability Assessments*, EUROSAFE 2002, Seminar 5 Nuclear Material Security.
http://www.eurosafe-forum.org/ipsn/pdf/euro2_5_5_physical_protection.pdf

[43] J. Aurelle, et al, *Short and Medium Term Consequences of the 11th September Attacks on Physical Protection Activities in France*, EUROSAFE 2002, Seminar 5 Nuclear Material Security.
http://www.eurosafe-forum.org/ipsn/pdf/euro2_5_2_consequences_france.pdf

[44] B. Autrusson, D. Brochard, *op. cit.*

Therefore, a transposition of the combined sensitivity and vulnerability approach to the transports indicates a potential for higher, or at least comparable risks, than those to be considered for the facilities. In particular, the lower level of protection – mainly those offered by the FS47 cask itself (see a drawing of the packaging in Figure 2) – and the higher level of vulnerability explain why the secrecy of the transports (routes and counter-measures equipping the trucks and trailers) is a key feature of the French security approach.

Figure 2 Drawing of the FS47 packaging (left) and its inner AA227 container containing up to five AA432 boxes (right)



Source : DGSNR, 2003; DOE, 2003

3.1.c. The French secrecy policy

The secrecy, however, has been regularly breached by Greenpeace in the last couple of years. Based on public information – mainly the ground observation of the routes and days of transports –, the environmental organisation demonstrated the flawness of this security feature by immobilizing for a few hours, in the center of the town of Chalon-sur-Saône, a truck transporting a shipment of around 150 kg of plutonium powder. In the following months, Greenpeace regularly published information, through a specific web site, showing the wealth of details on the transports that could be obtained through public means.[45]

As a main response to this challenge, the French authorities have introduced, on 24 July 2003,[46] a highly controversial decree censoring, under the law on national defense secrecy, the holding and release of any information concerning the conditions of storage, manipulation, or transport of nuclear materials. Following strong opposition, a new version was introduced as of

[45] See: http://www.stop-plutonium.org

[46] Arrêté du 24 juillet 2003 relatif à la protection du secret de la défense nationale dans le domaine de la protection et du contrôle des matières nucléaires, *Journal Officiel*, n° 183, 9 August 2003, p. 13859. http://www.legifrance.gouv.fr/WAspad/UnTexteDeJorf?numjo=INDI0301765A

26 January 2004, bearing a somehow more limited, although still vague, definition of the information covered by secret.[47] The new version was published together with a circular from its author, the Haut-fonctionnaire de défense (high civil servant for defense matters) of the Ministry of industry, Didier Lallemand.[48] Regarding the classification of information on transports, it clearly stipulates that secrecy specifically applies to the nuclear materials of category I and to the unirradiated materials of category II, which in practice respectively means the transports of separated plutonium and of unirradiated MOX fuel. This is made necessary while, *"considering the current level of existing threats"*, there is no need to classify information related to other transports of nuclear materials (irradiated materials under category II and all kind of materials of category III).

This "defense secrecy" decree, that is still challenged on juridical grounds by various concerned organisations, including WISE-Paris,[49] is in compliance with the DOE's demand of export license, which states that *"actual physical protection measures implemented in the fuel fabrication facilities and during transportation are classified, such classification being an important element of their effectiveness"*. However, as continued action by Greenpeace, including on-line real time information on ongoing plutonium shipments,[50] has showed, the classification methods can hardly guarantee secrecy when applied to identified transports on open roads. Therefore, the effectiveness of classification to assure nuclear materials security has not been demonstrated. This, in turn, is emphasizing the importance, for the security of plutonium transports, of the issue of the FS47 flask resistance to external events of the most damaging kind, as could be attempted by a well trained and equipped group of terrorists.

3.2. Potential for a Catastrophic Event

The situations that FS47 could realistically be exposed to, the projected behavior of mechanical and thermal protections included in the design of the cask under the subsequent conditions, the assessment of the quantities of plutonium powder likely to be released, the contamination arising from this dispersion and its potential radiological consequences have been discussed in a series of publications.

Expertise concluding in results challenging the official safety and security assessment of the plutonium transports in France has in particular been developed in two reports commissioned by Greenpeace to the French independant agency WISE-Paris[51] and to the British consultants Large & Associates,[52] respectively published in February 2003 and March 2004.

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47 Arrêté du 26 janvier 2004 relatif à la protection du secret de la défense nationale dans le domaine de la protection et du contrôle des matières nucléaires pris pour l'application du décret n° 98-608 du 17 juillet 1998 relatif à la protection des secrets de la défense nationale, *Journal Officiel*, n° 24, 29 January 2004, p. 2092.
http://www.legifrance.gouv.fr/WAspad/UnTexteDeJorf?numjo=INDI0402369A

48 Circulaire du 26 janvier 2004 prise pour l'application de l'arrêté du 26 janvier 2004 relatif à la protection du secret de la défense nationale dans le domaine de la protection et du contrôle des matières nucléaires, *Journal Officiel*, n° 24, 29 January 2004, p. 2098.
http://www.legifrance.gouv.fr/WAspad/UnTexteDeJorf?numjo=INDI0402369C

49 Several requests against the first and second version of the "Arrêté" have been presented to the Conseil d'Etat, notably by an environmental organisation (Greenpeace), independant information and expert agencies (CRII-Rad, WISE-Paris), and a journalists association (Reporters sans frontières).

50 See for instance details on Greenpeace "Stop-Plutonium" web site about a transport on 31 August and 1st September 2004.

51 Y. Marignac (Dir.), X. Coeytaux, M. Schneider & al., *Les transports de l'industrie du plutonium en France: une activité à haut risque*, WISE-Paris, February 2003.
English summary: http://www.wise-paris.org/english/reports/030219TransPuMAJ-Summary.pdf
Report, in French only: http://www.wise-paris.org/francais/rapports/transportpu/030219TransPuRapport.pdf
Appendices: http://www.wise-paris.org/francais/rapports/transportpu/030219TransPuRapport_Annexes.pdf

52 Large & Associates, *Potential Radiological Impact and Consequences Arising from Incidents Involving a Consignment of Plutonium Dioxide under Transit from COGEMA La Hague to Marcoule/Cadarache*, R3108-A6, 2 March 2004.
http://www.greenpeace.org/international_en/multimedia/download/1/424600/0/Large_report.pdf

3.2.a. Summary of WISE-Paris findings

The main approach of the report published by WISE-Paris in February 2003, based on an update of a 1997 report, was to confront the requirements applying to the casks' integrity, as derived from national and international safety regulation in force, to the conditions that could occur in the event of a conceivable accident or malevolent act.

To this end, the report first proposed a detailed evaluation of the high number of transports arising from the activities of the reprocessing industry, and of the quantities involved. The report estimated the number of transports involving plutonium, in a representative year, to around 450 consignments, for a cumulative transport of 39 tonnes of plutonium, of which around 89 consignments of separated plutonium in the form of dioxide powder (or 11.8 tonnes cumulated). These transports cover a cumulated distance of 250,000 km per year, of which almost half are covered by road transports of separated plutonium and MOX fuel.

It then compared the safety requirements applied to the design of FS47 and all the packages used for the transport of nuclear material to the statistics of accidentology, also taking into account the available information on specific road conditions encountered along the transport routes, such as high bridges, tunnels, etc.

The design basis of the transport casks, including the FS47 cask, as required from the French regulation, itself derived from the International Atomic Energy Agency safety standards, is driven by safety considerations of withstanding mechanical schocks and fire conditions, as could arise from an accident. The safety requirements for the FS47 guarantee the cask's resistance in the following conditions:

- a 9 meter drop onto an unyielding surface and a one meter drop onto a steel spike;
- an engulfing fire for 30 minutes at 800°C;
- immersion under a head of water of at least 0.9 m during 8 hours;

and, not applying to the overland transports but still relevant for the overseas part of the journey in the case of the U.S. plutonium shipment:

- immersion under a head of water of 200 m during at least one hour.

The report concluded, mainly from a thorough analysis of the statistics on transport of dangerous substances and accidents published by the French Ministry of transports, that the required *"mechanical and thermal design of the transport packages is minimal, or even inadequate"*, as real conditions beyond the safety requirements are encountered in 1 in 20 road accidents involving impact, and half of the accidents involving fire.

The report then sought to illustrate the risk arising from this gap between regulatory requirements and real conditions, through the description of plausible severe scenarios and their potential consequences. The scenarios developed were (i) a rail accident scenario in which rail cars transporting irradiated fuel are derailed in a tunnel, then hit by another train; (ii) an accident affecting a truck transporting plutonium oxide powder, and a subsequent collision by a tanker truck and hydrocarbon fire; and finally (iii) a similar scenario where the accident is replaced by an act of aggression such as a heavy artillery attack on the plutonium-carrying truck.

For each of these scenarios, indications regarding the level of radiological consequences to be expected are derived from assumptions of the fractions of plutonium likely to be realeased as a result of container failures considered to happen in the event. As for the scenarios of severe accident on a plutonium transport, considered in an area with a high density of population such as the northern suburb of Lyon, the report concluded that it could lead to more than 6,000 people being in the fall-out area – an ellipse of around 12 km^2, resulting in several tens of fatal cancers. In the case of a terrorist attack, those figures could go up to a population of 125,000 people, on a 250 km^2 area, likely to cause 500 fatal cancers on the long term.

The report stressed, however, that the above results should only be considered as an illustration of the potential order of consequences, as *"the detailed preparation of accident scenarios of this type is well beyond the scope of this study"*, adding that *"it would be desirable for the competent authorities – such as the Institut de radioprotection et de sûreté nucléaire (IRSN) – to enhance their technical support with detailed calculations of this type of accident (...), the results of* [which] *should be made public"*.

Finally, the report stressed the lack of information of the local authorities and the populations from local communities, suggesting a very low preparedness to an emergency situation concerning a plutonium transport, likely to reinforce the radiological consequences by delaying the implementation of appropriate countermeasures.

3.2.b. Summary of Large & Associates findings

The analysis conducted by the British consulting engineers of Large & Associates is more specifically centered on the risks associated to *"the road haulage of consignments of plutonium dioxide from the COGEMA reprocessing plant at la Hague near Cherbourg to the mixed oxide fuel fabrication plants at Cadarache and Marcoule in southeast France"*.

The report therefore focuses on the assessment of the consequences of severe external aggressions involving a typical French plutonium transport, i.e. two vehicles making up a convoy (as has been observed by Greenpeace), each of them carrying about 150 kg of plutonium dioxide. The impact is assessed in terms of the radiological and potential health consequences arising from a release to the atmosphere of plutonium dioxide.

The environmental impact study conducted by the U.S. DOE in the framework of its assessment of the Eurofab project[53] proposes an authoritative estimate of the fraction released in a severely damaging accident involving the considered plutonium consignment during the overland transport – that uses the same casks as are used in the French plutonium transports. The Large & Associates report uses this fraction, equal to 595 g of respirable-sized aerosol (or 3.5% of the content of the failing flask), as a reference assumption of the release in case of a cask failure, uniformly applied in all the scenarios.

This fraction is applied in scenarios of: (i) a severely damaging road accident in which one FS47 flask is breached, (ii) a similar road accident where three FS47 flasks fail in a single vehicle (to take account of the difference between the DOE analysis of a 3 FS47 consignment in one truck, and the practice of the French transports where each truck conveys 9 FS47); (iii) a road incident in which both vehicles of the convoy are caught in a road tunnel fire in which all flasks fail (that is, eighteen flasks), and (iv) a well planned and executed terrorist attack centred on one of the two vehicles (where nine flasks fail).

The report first discusses the probability of the accident scenarios, on the basis of U.S. probability calculations transposed to the French context of regular road shipments – although the report aknowledges this does not take account of differences in traffic conditions between the two countries. The assessment concludes in an overall severe accident probability of 1 out of 4 millions by year of operation. Moreover, *"the probability of a collision-with-truck-or-bus event at a velocity of, say, 80 kph followed by impact with an unyielding object (ie a bridge abutment) and then a high-*

[53] Successive documents assessing the FS47 safety in the framework of the plutonium transports required for the MOX program of the U.S. surplus plutonium disposition plan include the following filings to the NRC:

- Department of Energy, *Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement (Storage and Disposition PEIS)*, DOE/EIS-0229, December 1996;
- Department of Energy, *Surplus Plutonium Disposition Environmental Impact Statement (SPD EIS)*, DOE/EIS-0283, November 1999;
- Department of Energy, *Supplement Analysis, Fabrication of Mixed Oxide Fuel Lead Assemblies in Europe*, DOE/EIS-0229-SA3, November 2003.

temperature engulfing fire of 2.0 to 3.0 hours duration is 6.06E-07", or a risk of 1 out of 1.6 million.

The consequences of the radiological releases assumed in the scenarios of accidents or terrorist attack are then assessed, using reference computer models,[54] feeded with real meteorological, geographical and population data for the localities considered (near Paris and Lyon), to analyse the dispersion, the subsequent exposure of populations and the projected health impact. For the different scenarios, the numbers of individuals projected to suffer late mortality as a direct result of the releases range, depending on weather conditions and population density for the two different localities, in the forecast of 34 to 1,323 for the mean mortality, and 523 to 11,520 for the maximum mortality, the highest incidence being found in the tunnel fire scenario.

The report also discusses the order of the countermeasures required, and their probable low effectiveness. In the terrorist triggered release scenario, the numbers of public requiring to shelter, around Paris for example, could range from some 40,000 to several million individuals over an area of up to 900 km^2, and relocation zones could extend out to 15 km from the centre of the incident. The study underlines the potential economic and social impacts of such contamination, and recommends that they are separately assessed.

Finally, Large & Associates question, in view of their findings on the high risk posed by plutonium transports in France, the apparent weakness of safety and security measures imposed by the French authorities upon the plutonium shipments on French roads, as compared to the harsh constraints imposed upon such transits in the U.S. following recent evaluation of the safety case for the LTA project: *"using the same transport flask (FS47), the US restricts the number of flasks per vehicle to 3, whereas the French transport up to 9 fully loaded flasks per vehicle. The US road convoy comprises custom-built Safe Secure Transport (SST) trucks that are fully armoured and equipped with at least two systems that automatically prevent the removal of the flasks and armoured personnel carriers accompany the convoy throughout its transit, whereas the French vehicle seem to be little more that a commercial tractor unit hauling a standard trailer with an ISO container attached, with the two consignment trucks making up the convoy being accompanied by 6 to 8 Gendarmerie travelling in what seem to be a standard and unarmoured minibus and a car"*.

This difference is derived, the report goes on, from an incredible – and unexplained – gap in safety analysis from the two countries authorities where, although similar conditions of severity are considered, *"the US analysis reaches the conclusion that the FS47 flask could fail in a road accident and that there is a potential for 595 g release from each flask in transit which compares to the utter confidence of the French that the FS47 flask is failsafe, so much so that the worst credible accident would only result in a 0.07 g release"*.

3.3. IRSN Assessment of the FS47 Safety and Security

In a highly unusual move, the IRSN responded publicly by posting on its website a short complementary assessment, denying the similarly alarming conclusions of the two reports.[55] Based on some IRSN research on the integrity of the FS47, this paper however fails to take into account

[54] The dynamics of the developing plume concentration, dispersion and deposition fall-out are plotted using the NOAA HYSPLIT model, the USD Air resources Laboratory air concentration and dispersive model.
Plume rise prediction is by Hotspot, the Lawrence Livermore National Laboratory predictive software for release plumes.
The environmental impact, including human health consequences are modelled using COSYMA, the European Commission sponsored and approved nuclear accident assessment software modelling facility development of the MARIA (Methods for Assessing Radiological Impact of Accidents) code. The model adopts the universal assumption that the health risk is linear to radiation exposure and uses recommandations of the International Commission on Radiological Protection (ICRP) for morbidity and mortality factors and the use of the effective dose equivalent (EDE) method.

[55] IRSN, *Risques de rejet radioactif lors du transport routier de poudre d'oxyde de plutonium en colis FS47*, not dated (March/April 2004).
http://www.irsn.fr/vf/05_inf/05_inf_1dossiers/05_inf_35_pu/05_inf_35_pu.shtm

the results of another IRSN research, as published in the U.S. in 2003, that suggest a potential for significant plutonium releases.[56]

3.3.a. IRSN's rebuttal of the two independant reports

The short paper published by the IRSN[57] in response to WISE-Paris and Large & Associates studies dismisses their conclusions on a high risk to the populations. It confirms the IRSN assessment of 0.07 g as the maximum potential release of plutonium from a FS47 to be considered for emergency situations, and intends to justify why this value as compared to the up to 360,000 times greater assumptions considered in Large & Associates scenarios, up to a maximum potential release of 25 kg. However, the presented analysis falls short from a comprehensive demonstration to counter the two reports' criticism.

In first place, the IRSN does not comment, preliminary to further analysis, on the comparison between real accidental conditions and the mechanical and thermal safety requirements. The paper does neither discuss WISE-Paris findings on the inadequacy of safety requirements in view of the French statistics and traffic conditions for the transport of dangerous material, nor the Large & Associates conclusions regarding the low but not inconsiderable probability of severely damaging accidents involving the French plutonium road transports.

Nevertheless, the IRSN comments concentrate on the demonstrated margin between the regulatory safety requirements and the real limits of the FS47 mechanical and thermal resistance, on the basis of a pluriannual assessment it performed between 1994 and 2002 to characterize the FS47 safety performances. According to the findings of this program, the FS47 is able to resist much more severe conditions than those required by the French regulations:

- "it has been demonstrated in particular that in case of impact in realistic accidental conditions (impact at 70 km/h on diverse metallic targets, impact at 113 km/h on reinforced concrete surface), there was not any plutonium oxide confining failure";
- "it has been determined by calculations that, for a drop height of 50 meters, the cask damages are comparable to those occurring for a 9 meters drop on an unyielding surface";
- and, depending on the sealing materials used, the evaluated durations of confining integrity for a 800°C fire are comprised between 5 h 30 min and around 10 hours, and for a 1,000°C fire between 4 and 7 hours.

Based on these results, the IRSN draws an absolute conclusion *"that a transport accident cannot produce a breach in the cask"*. Therefore, *"the release of plutonium oxide in such an accident could only come from the loss of the sealing efficiency in the case of a long lasting fire, together with the degradation of one of the three inner containment barriers"*: a fraction of the small quantity of plutonium powder to be found in the flask cavity would be put in aerosol form and released due to the depressurization of the cavity with the seal degradation; IRSN evaluates this fraction at 0.07 g.

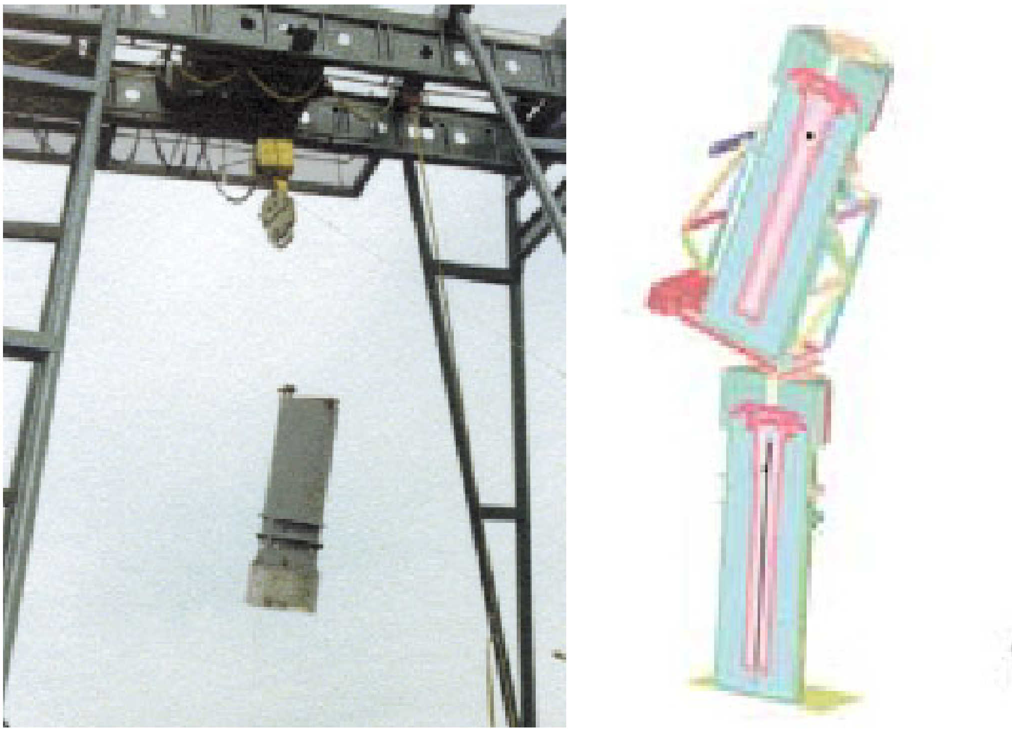
In conclusion, the IRSN confirms the value of 0.07 g of plutonium oxide as *"the maximum value that could be released"* in what it considers as the worst case scenario, namely *"the crash of a FS47 truck with a fuel tanker truck and a long lasting fire"*.

The assurance of the IRSN statement is surprising. The confidence drawn from the FS47 behaviour under tested conditions is not sufficient to conclude with certainty in the cask's integrity: in particular, the IRSN paper does not comment on the methodology used, nor it discusses the adequacy of the conditions of tests to those of conceivable accidents in road transports, neither it exposes the basis on which the scenario described is considered the worst possible event.

[56] B. Autrusson, D. Brochard, *op. cit.*

[57] IRSN, *op. cit.* Quotes in this section are translated from the French by WISE-Paris.

Figure 3 Real scale drop test (left) and computer simulation (right) to assess the FS47 behaviour in potential handling accidents



Source : DSIN, 2001; IRSN, 2002

First of all, it must be stressed that all the mechanical and thermal studies conducted in the program[58] consist, apart from a real test of a 800°C fire for 3 h 25 mn conducted in 1993, in numerical simulations. IRSN conclusions on the FS47 behaviour are therefore extrapolated, with the high level of uncertainty inherent to this methodology, from validated consistancy with the results of real experiments testing less severe conditions (as were performed for the certification of the design). As an exemple of the uncertainty swept by IRSN in its absolute statement, its own 2002 publication on the mechanical studies indicated, in the case of a FS47 falling from 16 m, in slanting position, onto another FS47 in vertical position (as illustrated in Figure 3, right), that *"the upper part of the closure system is impacted, but the computer model used is not precise enough to allow for assessing the damage and determining a potential loss of etancheity"*.[59]

As regards the conditions covered by the numerical tests performed, it must be noted that the mechanical studies only comprise non perforating impacts: although this potentiality should be

[58] The research programs on mechanical and thermal behaviour of FS47 that are the basis to the IRSN statement are respectively described and commented in:
- R. Vallée, L. Piot, "Simulations du comportement mécanique de colis de transport de matières radioactives sur cibles réelles", in *Rapport scientifique et technique IRSN, 2002*, IRSN, December 2002, pp. 102-108. http://www.irsn.org/net-science/liblocal/docs/docs_DIR/RST2002/Chap03_art1.pdf
- F. Chalon, M. Héritier, B. Duret, "Numerical Study of the Thermal Behaviour of Packages Subjected to Fires of Long Duration", in *Proceedings, PATRAM'98, 12th International Conference on the Packaging and Transportation of Radioactive Materials, Paris, 10-15 May 1998*, vol. 4, pp. 1773-1780.

Additionnal information can be found in:
- S Felix, F. Chalon & al, "Safety margins for radioactive material transport packages subject to fire: experimental work-development of numerical simulation tools", in *Rapport scientifique et technique IRSN, 2000*, IRSN, December 2000, pp. 87-93. http://www.irsn.fr/vf/09_int/09_int_3_lib/pdf/rst2000/087-93.PDF

[59] R. Vallée, L. Piot, *op. cit.* Translated from French by WISE-Paris.

considered in road accidental situations, the behavior of the FS47 for perforating impacts above the 1 m drop required by regulation is not discussed in the IRSN paper. Moreover, the mechanical resistance was only simulated in situations where the casks receive a longitudinal impact, falling from a vertical position onto an horizontal surface or an object (as shown in Figure 3). These clearly describe accidental situations in handling operations and not during the road transport, where the casks, also arranged in vertical position (see Figure 4 of the French usual arrangement of 10 FS47 packed in a transport rack), are more likely submitted to transversal impacts. Although the implicit assumption that the results of the simulations apply to the traffic accidents is therefore far from obvious, there is no indication in IRSN papers that this specific issue has been addressed.

Figure 4 A plutonium shipment of FS47 casks in vertical position in a rack, and its loading in an unarmoured truck, as commonly practiced in France

Source : DSIN, 2001

Another important issue is the consideration given to the combined impact on the FS47 of mechanical and thermal constraints, as should be analysed in the worst scenario the IRSN describes. In fact, it seems the IRSN assessment is based on the combination of the separate impacts on a FS47 of a mechanical shock with the impact on a FS47 of a thermal constraint, as if those two events could not be related. This is contrary to IAEA requirements for Type B(U) casks, which require the thermal test to follow the 9 m free drop impact test. Indeed, more realistically, the assessment of the impact of fire should apply to a potentially damaged cask – a case that the simulations described by the IRSN do not cover. In particular, the behaviour of warped or damaged metallic parts under thermal constraint might be different. Also, the more important damage that could suffer the softer components might increase the overall impact of the fire, as IRSN results demonstrate *"the inertia effect brought by the compound and plaster protecting the content is significant"* to limit its heating.[60]

Also, another obvious shortcoming of the IRSN conclusion on the maximum release to be considered for emergency planning is the absence of a demonstration of the reason why only one FS47 – out of a 9 or 10 casks shipment – would fail in the scenario assessed (since the highest value to take into account in an emergency situation regarding the real transport is equal to the considered fraction release of one FS47 failure). In fact, the IRSN does not indicate at all how the tests on one

60 F. Chalon, M. Héritier, B. Duret, *op. cit.*

single FS47 can be extrapolated to a full consignment of plutonium in an overland shipment. For instance, no consideration seems to be given to the potential role of the metallic rack holding the casks in the vehicle.

Finally, the definition of IRSN's worst case scenario for an accident involving a road plutonium transport might be discussed. In particular, a potentially more severe accident, involving a crash on an unyielding surface before a secondary crash from the fuel tanker truck, could be considered and its comparison with the IRSN reference scenario thoroughly assessed.

This is a key to understanding the reason for the huge difference of order between the French IRSN's statement and the assessment by the U..S. DOE. However, the consideration given in the IRSN paper to U.S. based figures on the FS47 plutonium fraction release is quite unsufficient.

In fact, the denial of recommendations in force in U.S. regulation on the fraction release to be considered is the sole basis for the IRSN to declare irrelevant the approach developed in the Large & Associates study. Explaining that this report uses assumptions of 3.5% or 10% release, the IRSN notices that *"the 10% value is that considered in the US-NRC study NUREG 0170 dated 1977"*.[61] The paper then dismisses this assumption on the grounds that *"the NUREG report mentions that this 10% value is an estimate of the maximum envelope fraction released"*,[62] that this value is based on experiments conducted on casks much lighter than the FS47 in the seventies that are not directly transposable and outdated.

Admissible as they are, these arguments do not suffice to explain the 25,000 factor that exists between this 10% estimate applied to a FS47 and the 0.0004% corresponding to the 0.07 g estimate of the IRSN. Most importantly, the IRSN paper fails to discuss the 3.5% value, which the Large & Associates study actually uses (the report only mentions the NUREG 10% value, but does not apply it in any scenario, apart from one variation of the tunnel fire). Furthermore, it does not even indicate the source of this 3.5% estimate, though the relevant justification to expect from the IRSN would be that of the difference between its estimate and this up-to-date and much specific assessment published by the DOE in November 2003 about the LTA plan – a difference that is still a factor of 8,500.

3.3.b. IRSN research on the FS47 security

Contrary to the confidence expressed by the IRSN in its April 2004 paper, the high uncertainties that remain undoubtedly require further assessment of the real safety of the FS47 in transport conditions. However, the most important shortcoming in this answer to WISE-Paris and Large & Associates reports is the absence of any comment on the security issue: no consideration is given to the criticism of the two studies on the FS47 resilience to potential acts of malevolence and its consequences.

This comes under the dogma of the French approach that safety requirements provide sufficient security as far as the transport cask is concerned. But the IRSN silence on this issue is especially shocking when confronting it to the IRSN publication on the *"French approach concerning the protection of shipping casks against terrorism"* that was made public only a few months before.[63]

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[61] NRC, *Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes*, NUREG-0170, December 1977.

[62] The ignorance of the basis of the most recent US DOE assessment was already demonstrated in dismissing comments of the French safety authority at the time of Large & Associates' report publication, in March 2004. For instance, *"Jacques Aguilar, director for fuel cycle and transport at nuclear regulatory agency DGSNR, said the 595 g release contained in the DOE EIS and assumed by Large was based on an 'empirical or envelope value' for release coefficient specified in a 1977 document, never updated"*, quoted in "Greenpeace: Pu shipments vulnerable; Cogema, French official disagree", *Nuclear Fuel*, vol. 29, n° 6, 15 March 2004.

[63] B. Autrusson, D. Brochard, *op. cit.* Although this paper may have been available to the 2003 Chicago conference delegates as of January 2004, it was definitely placed in public access through the IRSN web site on or about 23 February 2004.

This paper, in particular, exposes the research developed by IRSN on FS47 casks under the somehow new principle that *"though not explicitly required in the French regulations, the security of the casks must be studied in the context of potential loads resulting from terrorism"*. This research is conducted in two areas in particular: first, *"in 1996, IRSN has initiated a program concerning [the] FS47, used for the shipment of PuO_2 powder loaded by the detonation of a large amount of explosive"*; in addition, IRSN has performed real experiments on the impact of the FS47 of conical shaped charges some years ago, more recently completed by numerical simulations.

The explosion tests performed by IRSN consisted in the detonation of several hundreds kilograms of explosive very close to reduced scale mock-ups of the FS47 casks and the further development of numerical model validated by these experiments. The tests concluded in the structural integrity of the inner cylinder of the FS47 cask. However, the results showed all the physical protections prior to this last one were destroyed. This is in particular the case of *"the trailers walls* [which] *are simulated by a two-layer aluminum sheet"* in the expertiments – consistent with the use of an ISO container instead of armoured vehicle. In real tests performed, *"the presence of the wall induces a delay in attack of the external shell of the mock-up, but its influence on the shock propagation velocity and the maximal pressure remains limited"*. Then *"the external shell and the copper shell are seriously damaged"*. Only *"the central pipe was recovered slightly bent"* and finally *"no leakage had occurred"*. Exemples of the impact on the copper shell and the inner cylinder of the FS47 are shown on Figure 5.

Figure 5 Example of the impact of an explosive device
on the intermediate copper shell (left) and the inner container (right) of a FS47

Source : IRSN, 2003

These experiments demonstrate that, using the protections of the extermal shell and the intermediate copper shell of the FS47, the integrity of the inner cylinder and the containment of the plutonium powder can withstand considerable explosive loads. The results detailed in the IRSN paper are however not sufficient to infer a general rule.

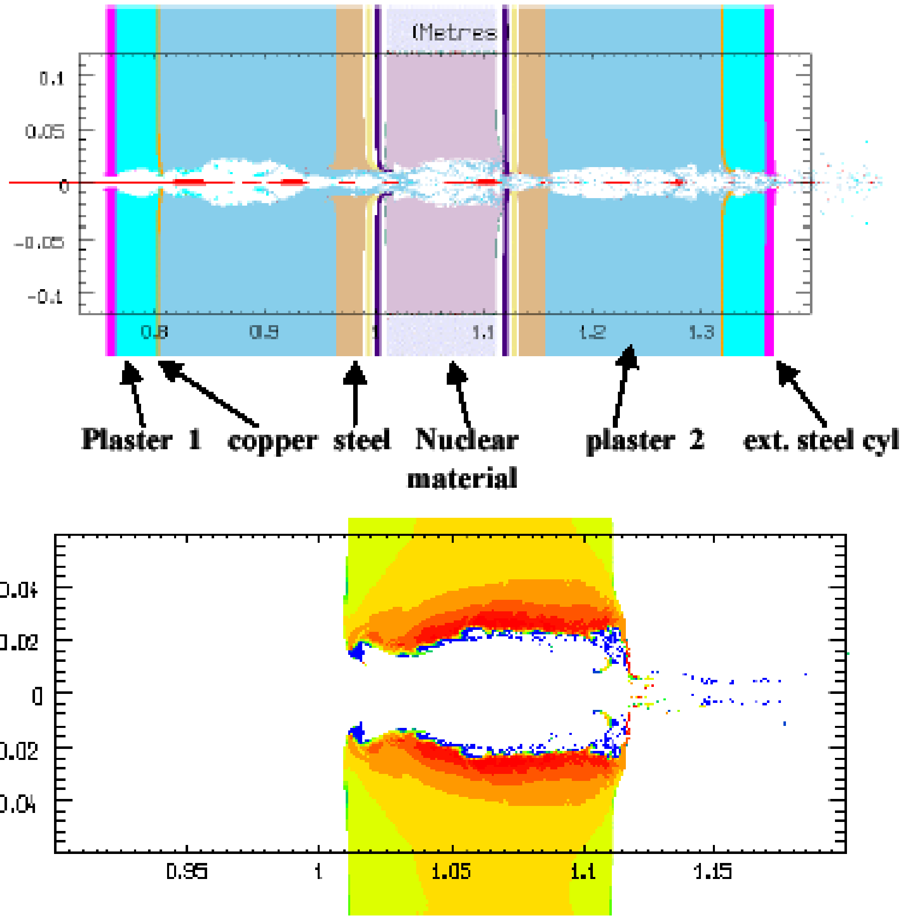
First of all, the expertiments and tests all use a similar single *"cylindrical explosive device with its axis parallel to the cask axis, (...) located close to the mock-up and primed in the center of its bottom face"* (apart from a computer variation where it is primed in its center). A confident assessment of the FS47 resilience to conservative explosive loads would require the definition of a representative set of test conditions regarding the shape, position and priming of the explosive load or loads (where the equivalent load is split in more than one explosive devices).

Moreover, like for the mechanical tests conducted for the safety assessments, the IRSN paper does not discuss the validity of the explosive tests results in the real transports situations. In particular, the FS47 cask was free-standing in the trial, whereas in a real shipment it would be restrained by the frame of the vehicle rack. Although its design supposedly includes high shock absorption, its presence *"would likely increase the equivalent plastic deformation of the inner tube locally to* *beyond its ductility threshold, bringing it to failure"*.[64] The IRSN paper mentions that *"two additional tests have been scheduled to investigate the behavior of the cask plug and the influence of the shipment configuration"*.

IRSN results conclude that *"the central stainless-steel cylinder would not rupture"*, as under the conditions of experiments and tests *"the maximum equivalent plastic deformation does not exceed 14% whereas the ductility threshold is close to 32%"*. The level of deformation, together with the projection of the inner cylinder, might also raise concern for the criticity of its plutonium content when bent, even if not breached. This question is not envisaged in the paper.

The second series of test performed by IRSN on the FS47 security are centered on the potential damages caused by a conical shaped charge, simulating a rocket fired on a plutonium transport. In fact, *"some years ago, IRSN has carried out tests on two FS47 casks filled with sand to simulate the* PuO_2 *powder, with a conical shaped charge (called CSC1) chosen on the basis of the availability, for the terrorists, of weapons with similar characteristics"*. More recently, *"IRSN has undertaken the development of numerical models to identify and understand the physical phenomena involved in the interaction between the jet and the cask"*, and *"also to estimate the consequences with a more efficient weapon called CSC2"*.

Figure 6 Impact of a moderate efficiency conical shaped charge: penetration of the cask (above) and interaction with the nuclear material (below)



Source : IRSN, 2003

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[64] J. H. Large, 2nd *Supplemental Declaration of 23 March 2004 of John H. Large in Support of Petitioners' Hearing Request and Petition to Intervene*, Declaration before the NRC, 23 March 2004.

There is far too little detail in the IRSN paper about the assumptions and results of the tests described for commenting them. However, clear conclusions are drawn on the qualitative assessment of the FS47 behaviour: *"these tests showed that the CSC1 passes through the first cask and slightly damages the second one without reaching its inner cylinder. An estimation of the quantity of nuclear material dragged out of the experimental device has been obtained"*. Moreover, *"calculations with CSC2 have shown the increase of damage to the casks (mainly the second one) and justify the need for dedicated experiments"*.

Results of the calculations for CSC1 are presented in Figure 6. Though difficult to interpretate, they clearly indicate that a conical shaped charge of a rather inefficient kind (as compared to those from more efficient weapons currently available)[65] hitting the cask perpendicular to its axis would penetrate the outer and intermediate shells, his jet passing through the inner cylinder and passing out the backside of the flask, therefore removing a volume of the plutonium oxide powder. Nevertheless, the IRSN paper stipulates that *"the diameter of penetration is underestimated and the removal of nuclear material is overestimated by the calculation (the latter being related with the fact that the nuclear material removed from the inner cylinder may reach the outside)"*.

3.3.c. Comments on the consistancy of IRSN statements

As the essence of terrorist acts is a willingness to provoke damage and confusion, there is no probabilistic limitation to the scenarios to be considered. Moreover, heavy attacks on the plutonium transports, that would have been disregarded as unthinkable before the attacks in New-York on 11 September 2001 and Madrid on 11 March 2004 (which accounts for an increase of terrorist activity in Europe), must now be regarded as conceivable.

According to the IRSN paper, *"the approach proposed by IRSN aims to determine the level of aggression against which the cask is protected"*, which is a distinctive approach of assessing the FS47 behavior and its consequences in realistic terrorist scenarios. For instance, *"internal threat has not been considered"* in the definition of the research program, on the questionable basis that *"such attackers don't have the tools fitted to damage significantly the cask"*. However, the application of realistic scenarios for a terrorist attack that would aim the plutonium transports on the French roads, to the results obtained by the IRSN on explosive tests conducted on the FS47 (with explosive devices and conical shaped charges) indicates a very high potential of danger.

The tests on conical shaped charges, which show that an attack using heavy weaponry on the unarmoured French plutonium trucks could likely result in an important breach in one or more of the FS47, must also be put in perspective taking account conceivable scenarios. In particular, the potential for plutonium release and large dispersion is very high in a scenario where such an attack is combined with the voluntary – or accidental – crash of a fuel tanker on the missile hit truck, and the subsequent long lasting engulfing fire, likely to cause even more damage to the burst open cask(s).

If the use of several hundreds kilograms of explosive can be seen as a conservative load regarding terrorist scenarios, a possible scenario corresponding to such an attack needs to be explicited. Since the experimental conditions simulated the presence of the trailer walls, the tests conducted may for instance account for a suicide car scenario. The IRSN satisfaction that the inner cylinder would keep its integrity must be mitigated. If this indicates that an attack aiming at the immediate dispersion of the plutonium could fail, this does not rule out a successful action. On the contrary, the tests results show that a powerful detonation close to the trailer could just provoke enough damage for easing the access to the nuclear material without dispersing it, which would be the terrorists' objective in an attempt of plutonium diversion (although one further issue in such a scenario would be the traceability of the FS47 inner cylinder, etc.). Alternatively, a successful

[65] According to available specifications, modern missile launchers would hit fixed or mobile targets, within a few hundred meters range (the M–47 Dragon, for instance, has a shooting range of 800 m for 70 km/h vehicles) with missiles of 100 mm diameter or more at a speed above 200 m/s. These are able to penetrate a 900 mm armor.

dispersion could be sought however, using the fact that the inner cylinder, without the mechanical and thermal protections that the FS47 offers, would be more easily damaged severely (for instance in a hydrocarbon fire as described above).

The IRSN would not comment these results in the view of conceivable terrorist actions, and indeed the whole approach of its programme is not to demonstrate the FS47 defeating some design basis threats (DBT)[66] for nuclear transports, a definition of which does not exist in the French regulatory framework.[14] In fact, the basic conditions of IRSN explosive tests and simulations do not match the real conditions of realistic scenarios where many factors must be taken into account.[67] Without offering the basis for an assessment of the FS47 behaviour in such events, the IRSN conclusions nevertheless highlight the potential for plutonium diversion or large dispersion scenarios.

The results of conical shaped charges tests, in particular, by suggesting that a significant plutonium fraction release could occur in a successful attack with armoured munitions, irremediably contradict the principle set for the acceptability of the threat, that the consequences of malevolent acts should not overcome, in terms of radioactivity releases, those taken into account in the safety case – that is, for the FS47 assessment by IRSN, an absolute confidence that the cask would not breach in any accidental situations. The "French approach" of the safety and security of the plutonium transports, as outlined by the IRSN papers discussed above, is therefore facing a crisis in its root principles, that the current policy of secrecy will not resolve.

In this context, it is of particular concern that the French authorities, as they prepare to guarantee the safety and security of the upcoming U.S. weapon-grade plutonium shipment, seemingly ignore the basis of the U.S. FS47 assessment, including the assumption on the potential release,

4. Safety and Security of the MOX Pellets Fabrication

The other important part of the "Eurofab" operation in France, also displaying high potential for safety and security risks. The project to fabricate MOX with plutonium of high Pu-239 content in a plant that does not meet current French safety standards can be considered to be at least highly surprising, the fact that this material presents a higher criticality sensitivity could turn the Eurofab plan into a significant threat. Altogether, some questions remain about the capacity of the operator and the control authority to properly consider the assessment of the risk and guarantee the safe and secure operation of the U.S. weapon-grade plutonium in the ATPu.

4.1. Regulatory "Gaps" at ATPu

The LTA fabrication is to take place in a plant, ATPu, which has benefitted of a quite unique series of regulatory privileges, in the sense that the status or the definition of key features such as its operational licence, its operator (CEA or COGEMA) or its "closure", do not match the common rules applicable to all nuclear installations.

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66 The Design Basis Threat, which the IAEA recommends to be defined by each State's Competent Authority as an essential tool of nuclear security, is defined in the French regulatory framework as *"the threat against which the licensee must be able to protect its facility"*. It comprises *"internal threats involving actions taken by insiders acting alone or not" and "external threats involving actions by small group of attackers"*, either *"a small team of attackers with limited resources"*, or *"a larger team with more sophisticated resources"* (in J. Aurelle, et al, *op. cit.*).

67 For instance, *"internal threat has not been considered"* in the definition of the research programme, on the basis that *"such attackers don't have the tools fitted to damage significantly the cask"* (in B. Autrusson, et al, *op. cit.*).

4.1.a. The permissiveness of ATPu licensing requirements

ATPu was created in 1961 to produce plutonium fuel for fast breeder (FBR) and light water (LWR) reactor experimental programs and was the first MOX production facility built in France. It is part of CFCa (Fabrication Complex of Cadarache), at Cadarache (Bouches-du-Rhône Department). While COGEMA is its "daily operator", the CEA (Commissariat à l'énergie atomique, the State Atomic Energy Commission) remains the operator in regulatory terms,[68] therefore in particular where safety is concerned. This distinction between the "industrial operator" and the "regulatory operator", although it has been endorsed by the French safety authority, is quite unique and has no basis in the French regulatory framework. On the contrary, the decree n° 63-1228 of 11 December 1963,[69] setting the rules applicable to INBs ("basic nuclear installations") and especially their regime of authorization, stipulates that a new authorization is necessary for an INB to change operator.

In the list of INBs established by the French nuclear safety authorities, no change in the authorization of the ATPu (INB n° 32) has been reported since its declaration of 27 May 1964 by the CEA. Because the ATPu was constructed and put into service before the basis of the French current nuclear regulatory framework was laid down – with the decree n° 63-1228 –, this declaration, which consists in a single line out of a small list of nuclear installations in a letter, stands for the ATPu license. In other words, there is no licensing limitation of the quantity of, the specifications of, and the process applied to nuclear materials in ATPu operation: the definition of those is in the hands of the safety authority and does not require public consultation (as would be required if those definitions were included in the license, as should be under the 1963 decree).

The regulatory situation of the ATPu has remained blurry all along its over four decades of operation. The operation changed from experimental MOX fabrication to the industrial fabrication of FBR fuel, and was later turned to the fabrication of MOX fuel for LWR without even public information on the justification and the safety and security case. For instance, the only public assessment offered by the French safety authority regarding the change from FBR to LWR fuel was that the plutonium quantities involved in the new activity remained lower than the envelope considered for the plant's previous safety assessment.

ATPu produced fuels for French Phenix and Superphenix FBRs until the late 1980s (probably a total of around 105 tHM), but after 1990, when COGEMA became the plant operator, the plant production turned essentially to MOX for LWRs. Until 1996, when the plant was qualified by Siemens to produce German MOX, the plant had only produced MOX for French LWRs. After 1996, the plant produced LWR MOX exclusively for German electric utilities, with the exception of 2.2 tHM of FBR fuel produced in 1998-1999 for the Phenix FBR According to Gilbert Dalverny, Director of ATPu, 336 assemblies' worth had been produced for German utilities as of the end of 2001,[70] which should correspond to around 180 tHM of German MOX.

4.1.b. COGEMA's industrial "blackmail" over safety

In addition to the weakness of the licensing process, the safety and security requirements included in the design of nuclear facilities were much lower, at the time of the conception and construction of the ATPu plant, compared to modern levels of acceptability. In particular, there were no specific rules for design regarding external events such as plane crashing or seismic hazard.

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[68] COGEMA has been the industrial operator of the ATPu since 1991. CEA-Cadarache management indicates on its website that *"having become a COGEMA establishment in 1991, CEA Cadarache (the CFCa) has found its place naturally in the COGEMA Group's fuel production cycle"*.

[69] Décret n° 63-1228 du 11 décembre 1963 relatif aux installations nucléaires, *Journal Officiel* du 14 décembre 1963, modifié.
http://www.asn.gouv.fr/textes/d63-1228.asp

[70] *NuclearFuel,* "COGEMA Prepares to Close up Shop at Cadarache MOX Plant Early 2003", n°26, 23 December 2002.

In the early 1990s the safety authority reevaluated the seismic resistance of the facility and discovered that the ATPu design was not at all adapted to the seismic risk level of the geographical area (see below). On 27 January 1995, the French safety authority informed CEA and COGEMA that ATPu had to be closed due to its non-conformity to anti-seismic norms and the impossibility for the facility to be modified to meet French seismic standards. The safety authority "*asks COGEMA to propose a plan for ATPu's future, including (...) a definitive and non-negotiable closure date for the facility, just after the year 2000*"[71].

After two follow-up letters from the safety authority[72], a first deadline was set for the 18 September 1996, but CEA and COGEMA did not even react. In a letter, dated 22 October 1997, the chairman of the safety authority André-Claude Lacoste informed CEA and COGEMA that "*this situation is not acceptable"*, and he demanded to receive "*as soon as possible the plan taken into account for ATPu's future, and (...) a closing date of this facility*"[73]. On 11 December 1997, CEA and COGEMA answered that a project of a containment superstructure designed for a seismic event was under consideration, but that they needed a few years before deciding to really build it or not. They added that "*from an industrial point of view, it is highly desirable, during the first decade of 2000, to profit from the significant modernization investments that were consented to since 1991 [...].*

Moreover, ATPu is used today to recycle into MOX fuel the German plutonium separated at the La Hague facility; for technical reasons, no other facility is at the present time able to serve such a mission. In the future, only MELOX, whose capacity will be raised to about 250 t/a of MOX fuel production, will be likely to guarantee such fabrication. Under these conditions, a hypothetical stop of ATPu cannot industrially be considered before the MELOX facility has undergone the evolution described above."[74]

"*Blackmailing"*, scribbled an official of the safety authority in the margin, in front of the last paragraph of the COGEMA letter... Although the authority put pressure on the operators, announcing it was ready to make authoritative decisions, CEA and COGEMA waited until July 2000 to answer and agreed to say that no technical solution was likely to be adopted to avoid the closure. After this point, the operator's strategy was to wait for a decision on MELOX public inquiry before deciding anything concerning the future of ATPu. The operators succeeded in protecting their commercial interests, in spite of significant safety concerns issued by the national nuclear safety authority.

4.1.c. The so-called ATPu "closure"

The industrial strategy has finally been accepted, and even adopted, by the French authorities. In October 2002, announcing the public inquiry into the extension project for the MELOX facility at Marcoule, the Ministries of Ecology and Industry stated that "*the purpose of this extension is to transfer to Marcoule the production of Cadarache facility, which has to be stopped soon*"[75].

Consequently, in January 2003, Anne Lauvergeon, chair of COGEMA/AREVA, finally announced that ATPu would stop commercial operation as of 31 July 2003. Before the regulatory closure can be achieved, the operator is required to submit to the safety authority a safety report explaining the possible ways to close the facility. This safety report had actually not been prepared by COGEMA, and the so-called "closure" was only to consist in a voluntary reduction of the nuclear material

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[71] DSIN, "*Compte rendu de la réunion du 27 janvier 1995*", letter DSIN/GRE/SD1/n°134/95, 28 March 1995.

[72] DSIN, Letter DSIN/FAR/SD1/n°11684/95, 9 June 1995 and DSIN, Letter DSIN/GRE/SD1/n°101/96, 18 June 1996.

[73] DSIN, Letter DSIN/FAR/SD1/n°11708/97, 22 October 1997.

[74] COGEMA, Letter DIR/CSN 97/932, 11 December 1997.

[75] Ministry of Environment, *"Public inquiry request related to the request of COGEMA to extend the site of Marcoule"*, Press release, 23 October 2002.

inventory, with the authority demanding, at that time, that COGEMA reduces the source term of the plant by a factor of 10 before 31 July 2003.[76]

The effective, but self-declared, end of "commercial production" of ATPu took place, according to COGEMA, on 16 July 2003. Meanwhile, following a public inquiry held in the first semester of the year, the company had gained confidence that it would obtain its requested increase of the MELOX Marcoule plant nominal capacity from 101.3 to 145 tHM/year.[77]

No safety case on the shut-down and decomissioning of the plant had been delivered by COGEMA at that time, therefore not getting the DGSNR approval that would be required for the "closure" of the plant to be effective in regulatory terms, which should also coïncide with the clearing of radioactive material present in the plant. On the contrary, the plant is to continue some activity to manage various plutonium materials, the detailed origin and quantities of which have not been published.

According to Gilbert Dalverny, then director of COGEMA-Cadarache, some sort of production at ATPu could go on "*until 2006, in order to use all the production scraps as well as all stocks of plutonium initially dedicated to Superphénix.*"[78,79] Since the commercial shutdown of the Cadarache's MOX plant, ATPu has been dedicated to empty the plutonium from some of the Cadarache's installations as well as MOX fabrication scraps conditioning. The plutonium is collected over the whole CEA nuclear center and brought to the ATPu, where it is to be fabricated into "storage MOX" assemblies, i.e. improper MOX for reactor use, because of the low control-quality requirements bound to its fabrication. It has even been suggested by declarations of the safety authorities, that some material from other CEA nuclear centers was, or would be collected to be conditioned in ATPu, although this was later officiously denied.[80] Nevertheless, it is noteworthy that, from the same source, as of mid-September 2003, collecting of nuclear materials on the Cadarache site had already started, while the specific necessary authorization of the safety authority for the collecting/conditioning operations had not been granted yet.

4.2. Seismic Hazard and Risk Assessment at ATPu

Although the blurry regulatory status of ATPu allowed for the French plutonium industry to develop the "Eurofab" plan, it would be difficult to explain to the French public that the Cadarache site is too dangerous for commercial MOX production for European use but not for handling of U.S. weapons-grade plutonium and its fabrication into MOX LTAs.

4.2.a. The source term calculation approach

In March 1994, an IPSN (Institut de protection et de sûreté nucléaire)[81] report established that seismic activity in the Cadarache region "*shows significant recurrence since the end of December 1993*".[82] The document stated moreover that a segment of the Durance seismic fault, a few kilometers from the Cadarache site, "*has experienced notable activity on several occasions, not only*

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[76] Personal communication with Jacques Aguilar, in charge of the fuel cycle department at the safety authority, DGSNR, 13 February 2003.

[77] *Investigation Plutonium*, "'Transfer'of MOX production capacity from Cadarache to Marcoule: one scandal after another", WISE-Paris, 8 September 2003. http://www.wise-paris.org/english/ournews/year_2003/ournews030909a.html

[78] Superphénix was a 1,200 MWe fast breeder reactor (FBR), definitely shut down in 1997.

[79] *Les Echos*, "Anne Lauvergeon confirme la fermeture de l'usine Cogéma de Cadarache", 21 January 2003.

[80] Personal electronic mail exchange of WISE-Paris with Philippe Saint-Raymond, then Assistant director of DGSNR, 16 September 2003.

[81] In 2002, IPSN and the Radiation Protection Office OPRI (Office pour la protection contre les rayonnements ionisants) merged into IRSN (Institut de radioprotection et de sûreté nucléaire)

[82] IPSN, *"Technical note SERGD 94/13"*, 1994.

since the setting up of the Cadarache unit (in 1966-67 and in 1985-86 especially), but also historically: it was the seat of intense activity throughout a large part of the 19th century beginning with an event of intensity VII-VIII on 20 March 1812".

This was determined thanks to the IRSN (Institut de radioprotection et de sûreté nucléaire) accelerogram network installed around the Durance fault, one of the most active seismic faults in France. The area around Cadarache has been the seat of destructive seismic disturbances (maximum intensities reach VIII on the MSK scale[83]) with a return period of around one per century. The last event of this type occurred in 1913.

On the basis of a Fundamental Safety Rule (RFS, Règle Fondamentale de Sûreté), dedicated to nuclear installations other than nuclear reactors,[84] it became clear that the ATPu was not designed to resist a Safe Shutdown Earthquake (SSE).[85] As of 1995, the French safety authority demanded the shutdown of the plant for a reasonable period, after 2000. Finally, after it imposed its blackmail on safety to obtain the "transfer" of capacity from ATPu to MELOX, COGEMA also imposed that the "closure" demanded would not be an effective shutdown but simply an agreeement, with no regulatory basis, on the end of "commercial" production: therefore, although the ATPu was declared "closed" in July 2003, it remained fully operational and in capacity of managing the LTA fabrication.

The LTA fabrication in Cadarache was however pending a specific authorization by the DGSNR, which required first that the safety authority recognize the activity as non commercial, and in second that it approves the safety assessment of the operation. This process does not require, under the suited "regulation" applied to ATPu, any consultation of the public, therefore very few information was provided on the assessment conducted prior to this unprecedented operation.

Although the commercial dimension of the LTA plan is obvious, there is no indication that this first condition has even been discussed. The approval therefore focused on the safety case, which both the company and the authority have downplayed. In fact, according to Philippe Saint-Raymond, then deputy director of DGSNR, COGEMA's safety file does not include any specific impact assessment, on the ground that the LTA's source term remains in the frame of *"the hypothesis that led to the dimensioning of the emergency plans"*.[86]

In other words, taking the seismic hazard aside, the French authorities appreciation was that no specific and thorough assessment would be needed to demonstrate the safe and secure conditions for this operation. The LTA fabrication is nevertheless a process specific to the characteristics of the initial material used. The weapons-grade plutonium used to fabricate MOX is enriched to around 93% in Pu-239, as shown in Table 1. The specific isotopic composition of weapons-grade plutonium implies a number of unique handling issues at every step of the fabrication process and raises questions about safety – in particular criticallity – and proliferation resistance, enough for the LTAs fabrication not to be authorized in the modern plant of Melox, submitted to more stringent safety rules.

[83] Medvedev-Sponheuer-Karnik scale (1964), which classifies earthquakes in function of their observed impacts. This is the scale used in France to measure seismic intensities.

[84] RFS I.1.c, in Ministries of Economy and of Environment, "*Sûreté nucléaire en France - Législation et réglementation*", Les éditions des Journaux officiels, 1999.

[85] The SSE is the design basis seism for a given facility. It is based on the concept of the Maximum Historically Probable Earthquake, defined as the maximum earthquake that is likely to happen over a period of time comparable to the "historical period" of about 1,000 years. The intensity of this seismic event increased by one unit on the MSK scale is used as the SSE intensity to determine the design basis of the facility.

[86] Personal electronic mail exchange, 20 November 2003.

Table 1 Lead Test Assemblies Plutonium Composition

Isotopes	Composition (%)	Mass (kgHM)	Radioactivity (TBq)
Pu-238	≈ 0.0	≈ 0.00	≈ 0
Pu-239	92.5	114.22	261
Pu-240	7.0	8.64	72.5
Pu-241	0.5	0.62	2,590
Pu-242	≈ 0.0	≈ 0.00	≈ 0
Total	100.0	123.48	2,920

Source : DOE / NNSA Application for Export License, 1st October 2003

4.2.b. Results and discussion of the source term calculation

The calculation of the source term, which serves as a basis to consider the operation safe, is itself not very clear from available information. In December 2002, COGEMA's estimate was reported as follows: *"because of the low enrichment in plutonium of the weapons-Pu rods compared to commercial MOX rods – 3% versus 9% – the source term due to four Eurofab elements would have a coefficient of 0.027 compared to that of the plant at full production, Cogema has calculated"*.[87] In July 2003, however, this calculation increased from this one to forty factor to one to ten: then, according to COGEMA, the project *"would not raise safety concern, because there would only be a very small quantity of plutonium there, less than one tenth of what was there when the plant was operated at its maximal capacity"*.[88]

This figure has been confirmed in more precise terms, although not officially, by the DGSNR. According to Philippe Saint-Raymond, during the collecting and reconditioning operations, quantities of plutonium that could be released into the environment, in case of a major earthquake accident, would be from 2.5 to 3.5 kg, to be compared with the former 13.8 kg during past commercial operations.[89] This source term would correspond to a running stock of plutonium during commercial operation, when the plant fabricated around 2.5 tons of plutonium into 40 tons of MOX annually, roughly equal to 50% of the year throughput, or 1.25 tons – so the estimate quantities of plutonium present in the facility during the current operations of reconditioning would be, in DGSNR calculation, around 200 to 300 kg of plutonium.

The weapon-grade plutonium quantities involved in the LTA fabrication can then be compared to those above. With 123.8 kg of metal plutonium (or 140 kg of PuO_2), the stock would be around one tenth of that considered in previous operation, and half of that considered for reconditioning operations. This leads to estimate that if a major earthquake took place during the LTAs fabrication, the release of weapons grade plutonium could amount up to 1.4 kg.

No estimate of the radiological risk for the staff, the population and the environment can be directly derived from this calculation, because other factors, such as the conditions of release (in particular the height of the plume, depending upon the presence of a fire or not), the staff condition in the accident situation, and the implementation of counter-measures to protect the population against radioactive contamination in the context of a major earthquake should be taken into account. It should also be noted that, in terms of radiotoxicity, the weapon-grade plutonium involved in the LTA fabrication would not be as dangerous as the reactor-grade plutonium considered in the ATPu normal operation – although it is still deadly if inhaled, for instance, in significant quantity.

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87 *Nuclear Fuel*, "Cogema prepares to close up shop at Cadarache MOX plant in early 2003", 23 December 2002.

88 *AFP,* "Risque sismique : l'usine Cogema de Cadarache cesse de produire", 28 juillet 2003. Translation of the declaration by WISE-Paris.

89 Personal electronic mail exchange, 16 September 2003.

The risk should however not been downplayed. Probabilities of fire at the ATPu in case of earthquake remain unknown. With absence of fire, the LTA source term could disperse in a restricted area of few kilometers only, but with very high levels of ground contamination, mainly affecting Cadarache center workers. In case of fire, a broader area could be concerned, potentially affecting populations, with an impact still to be estimated.

But it is the flawed basis of the reasoning, separately considering the risks associated to different materials in the ATPu as if they would not cumulate, which is the most unacceptable. In fact, only the complete removal of all nuclear materials will terminate the risk created by the unsufficient seismic design of the plant. Meanwhile, according to DGSNR own assessment, the unbearable risk of the time of full production is only reduced by a factor of 4 to 5, which is not likely to make it more acceptable.

In that respect, a very clear distinction should be established between the unavoidable clearing operations of the plant, that consists in removing nuclear material that would already be there at the time of "closure", and the ongoing collecting and reconditioning operation, that create a voluntary increase of the nuclear inventory of the facility – for which a clear assessment, including the comparison with the risks linked to other options, should be conducted on a case-by-case basis. On the contrary, the French safety authority has seemingly allowed for the COGEMA and CEA to start collecting nuclear material and bring it into this hazardous facility even before it had authorized the subsequent conditioning operations that justify it.

Moreover, the collecting and conditioning operations have clearly started before the LTA fabrication and will go on afterwards, meaning that some unknown radioactive inventory will be present in the facility during the few months of this operation, in addition to the U.S. weapon-grade plutonium. Also, this plutonium will only account for 3% to 4% of the full content of the MOX, the rest being uranium that will also be brought into the facility for the purpose of LTA fabrication, and is also a radiological threat in the case of significant releases.

Therefore, the LTA fabrication can by no mean be considered a division of the risk, as COGEMA and DGSNR have argued for it, but a fully voluntary, and significant increase of the source term of the plant in case of any accident, in particular a major earthquake, which the authorities consider would be likely to result in large releases of nuclear materials. Moreover, this operation, which will halt the clearing operations for a few months, implies that a corresponding further delay is seen acceptable by the authorities before the removal of all nuclear materials is complete, and the risk fully eliminated.

4.3. Other Safety and Security issues

The seismic risk is not the only concern in the field of safety and security for an operation involving weapon-grade plutonium, that present a much higher risk in terms of criticality, and also of strategic interest (regarding the risk of diversion) than ordinary. Not only these risks have seemingly not been fully assessed in a specific and deep manner, but recent events cast further doubts on the quality of safety and security at the plant.

4.3.1. Quality and control of the process

Only recently, in 1996, the ATPu plant turn from the old COCA process to the MIMAS (Micronized Master Blend) process, developed at the Belgian plant P0 and applied in MELOX and in the U.S. MOX plant project. This process comprises the following stages:

- Receipt of transport casks of plutonium and uranium powders, extraction of nuclear materials, identification, weighing and insertion in the process lines;
- Master blend, i.e. mixing of plutonium and uranium powders to which crushed MOX scraps can be added;
- Homogenization and micronization of the master blend in a dry ball mill;

- Final blend, i.e. addition of uranium powder to the micronized master blend, then homogenization;
- Pelletizing (pressing), sintering (in furnace) and rectification (grinding) to fabricate MOX pellets;
- Quality control;
- Rod fabrication and assembling.

ATPu is not equipped, however, to assemble the fuel rods, making it necessary to being the special LTA material – weapon-grade plutonium MOX fuel rods – to MELOX, where this is authorized by DGSNR although the same material would not be allowed, under current license, to enter the Marcoule facility in the form of powder.

There is very little public information regarding the quality analysis of the MIMAS process, the level of scraps generated in MOX fabrication, and the effective capacity for internal recycling of scraps. However, available figures indicate significant levels of scraps, up to 15%-30% in the early years of the MIMAS process, down to a few percents in standardized production, where refining of the process is easier. It is noteworthy that G. Lebastard, Director of COGEMA's fuel business unit, declared in December 2002, that changes in the fuel design produced at MELOX (because of the transfer of ATPu's production to MELOX) would probably rise the scraps level of the plant.[90] This indicates that the MIMAS process quality level is better adapted to a uniform production, and that changes in the design of the MOX fuels produced, are likely to entail quality problems.

This problem was confirmed with the quality-control scandals, which hit both BNFL in 1999 and Belgonucleaire in 2000. Analysis carried out on MOX fuel produced by Belgonucléaire for the Japanese utility TEPCO revealed that irregularities could be found with regard to the pellet diameter distribution on some MOX batches, possibly hiding data falsification or revealing the poverty of the quality-control in general.[91]

Moreover, its seems there could be some problems of homogeneity of the MOX produced with the MIMAS process. In fact, analysis has shown that in some parts of the MOX pellets, areas could be found with composition departing from the master blend specification, i.e. with plutonium hot spots involving enrichment levels significantly higher than the design basis. This lack of homogeneity could potentially have an impact on MOX management in reactor cores with regard to reactivity levels, and is of particular concern in the case of weapon-grade plutonium MOX, given its initial higher reactivity. No information is available regarding a specific assessment of quality control requirements and implementation that should apply to the LTA fabrication.

4.3.2. Recent contamination accidents

The issue of safety at the ATPu has been highlighted by a recent accident, on 6 September 2004, that involved some internal contamination of the facility and of one or more operators with plutonium and uranium oxide powder. Very few, late and contradictory information has been provided by the operator and the safety authorities on this accident.[92]

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[90] NuclearFuel n°26, op.cit.

[91] Green Action, *"Analysis Reveals Belgonucleaire's MOX Quality Control Data Highly Suspicious of Being Manipulated"*, 16 January 2001.

[92] The CEA issued a short press release on 9 September 2004, but the DGSNR only published an information notice on the incident on 16 September 2004. See:
CEA, "Incident à Cadarache", 9 September 2004. http://www.cea.fr/fr/actualites/article.asp?orig=actu&id=569
DGSNR, "Cadarache - Contamination d'un opérateur et de locaux lors d'une opération de manutention de matières radioactives, 16 September 2004. http://www.asn.gouv.fr/data/evenement/37_2004_cad.asp
WISE-Paris could only talk to DGSNR press officer, although communication was requested with M. Landier, Head of the nuclear division of the DRIRE in Marseilles, or with Jacques Aguilar, Head of the fuel cycle at DGSNR – the latter did not reply, as of 27 September 2004, to a list of questions sent by e-mail on 10 September 2004.

The accident seemingly occured during the transfer from one glove-box to another of material involved in the conditioning and evacuation of scraps activities. According to DGSNR, *"the contamination occured because of a defect in the containment envelope of the scraps batch and of the non compliance with handling procedures"*. Although contradictory information has been given regarding the nature of the envelope (metal box or vinyle), and no detail was provided on the nature of its defect and of the non compliance with procedures, apart the lack of radiological control of the body which does not fully explain the range of contamination. Contradictory information was also given regarding the triggering of the alarm, either due to the shoes contamination when one operator involved went out of the zone, or to the system monitoring background atmospheric radioactivity.

The event has been rated 1 on the INES scale (International Nuclear Event Scale), that ranges from 0 to 7. This does not fully account of the impact of the accident, where at least two operators have been subject to contamination, which has been confirmed for at least one of them. Although neither the CEA or the DGSNR published this information, the operator that they recognise as contaminated did not, apparently, wear a breathing protection at the time of the incident, therefore making it likely that he got exposed to a very serious health risk through plutonium inhalation. After it had announced to WISE-Paris that it would communicate on the results of the complementary medical tests conducted on this operator as of 17 September 2004, the DGSNR eventually declined, on 21 September 2004, to answer questions on this issue.[93]

The accident, anyway, involves a number of malfunctions that raise concern for the overall safety of the plant in the perspective of the LTA fabrication. In addition, it appears that at least 5 cells of the zone, plus the material corridor, have been contaminated, although this is not fully explained by the information published. This recalls of a previous contamination accident at ATPu, which occured in April 2002 and involved the loss of containment of a glove-box. Thorough analysis of unexplained contamination of more than one cell concluded, in July 2002, that the some contamination occured from one cell to two neighouring ones by some crack in the wall, raising questions on the condition of the plant. The enquiry also concluded in the unsatisfying response of the EDGAR alarms used for monitoring the atmospheric contamination. Finally, the accident of 6 September 2004 also highlights problems with access to information, a key condition to guarantee the control of safety and radioprotection.

4.3.c. Security and nuclear material accountancy

If the seismic risk has been largely assessed for the ATPu, several questions of security remain. The risks of possible internal or external malevolent aggressions have not been detailed although the MOX facility presents structural deficiencies suggesting a low resistance to external aggression scenarios such as explosion or plane crash. However, even a qualitative assessment of such scenarios is impossible due to the absence of information on the design basis of the plant, apart that the plant does not conform to the current requirements.

Another concern, given the highest strategic interest of the material considered for the LTA fabrication, is the risk of plutonium diversion during operations at the plant. Some recent events highlight the potential for such a scenario. The European Commission, under Euratom reported in December 2003 an important problem of Material Unaccounted For (MUF) in the facility in 2002. In fact, during the year, *"the annual verification of the physical inventory of the COGEMA-Cadarache plant in France found an unacceptable amount of Material Unaccounted For (MUF) on the plutonium materials."*[94]

Some information provided by the DGSNR press officer, as of 15 September 2004, in personal communication is contradictory with the DGSNR statement of 16 September 2004.WISE-Paris could not obtain any further clarification.

[93] Personal communications with DGSNR press officer.

[94] Commission of the European Communities, *Report from the Commission to the European Parliament and the Council - Operation of Euratom Safeguards in 2002*, Brussels, 10 December 2003, (COM(2003) 764 final).

The report stressed the fact that *"the operator has identified the possible causes of the MUF"*, revised *"his internal procedures for the accounting and follow-up of the stored material"* and reevaluated *"the accuracy of his measuring system"*. In fact, the European Commission and COGEMA now appear satisfied with the explanations provided by the industrial operator, mainly based on the presence of old and varied material in the ATPu plutonium inventory, and some measuring problems. Euratom officials, said *"the MUF wa connected with the fact that Cadarache had 'owned a lot of very old material,' including 'poorly-defined' material in storage stemming from military activities for which materials accounting data were 'not appropriate'"*, and also that *"MUF finding was related to 'differences in the quality of several instruments' used to measure the material"*.[95,96]

Assuming that a satisfactory explanation was provided to the 2002 accountancy problem, which COGEMA said actually *"required detailed study of several years' material balance"*, this does not imply that the cause of the problem can be solved with certainty. In fact, the explanations given reinforce the general impression that the plant, faced to old standard designs, bad condition of its equipment and accumulated stocks of old material, is not in condition to guarantee full safety and security of the LTA operation.

[95] *Nuclear Fuel*, "With Eurofab imminent, MUF issue said cleared up for Cadarache plant", vol. 29, n° 20, 27 September 2004.

[96] Although they don't directly relate to ATPu but to similarly old facilities of the Cadarache center, it is interesting to note that some incidents have been reported in the accountancy of traces of nuclear materials (uranium and plutonium) in radioactive waste at Cadarache, in July 2003 and July 2004, where in each case the mistake was by an order of 1,000 times (once in each way, over- and under-estimate).
See information notices by the DGSNR:
http://www.asn.gouv.fr/data/evenement/28_2004_cad.asp
http://www.asn.gouv.fr/data/evenement/27_2003_cada.asp