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NUCLEAR TERRORISM

WHAT CAN WE LEARN FROM "LOS ALAMOS"?

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ABSTRACT

The international security community is increasingly concerned about the nexus between indiscriminate terrorism and the proliferation of nuclear technology and materials. Many nuclear terrorism threat assessments focus primarily on terrorist motivations to employ an atomic bomb, the availability of nuclear know-how and technology, and the opportunity for clandestine organisations to acquire fissile material. Scholars and experts, however, often neglect to elaborate on the challenges for terrorist organisations in organising and implementing the construction and detonation of a crude atomic bomb. This will most likely be a complex project. This article will therefore explore the organisation of such an endeavour. To be precise, we will highlight the impact of the organisational design of the terrorist group. The organisational design determines the division of tasks and how coordination is achieved among these tasks. It therefore has a strong impact on the functioning of any organisation, especially an innovative and complex terrorism project. Building on a case study of Los Alamos, we inductively infer that terrorist organisations face an inherent effectiveness-efficiency trade-off in designing a nuclear armament project.

Introduction

The construction and detonation of an atomic bomb by a terrorist organisation is one of the major threats to international security. The nexus between indiscriminate terrorism and nuclear technology proliferation ignites concern in many. Nonetheless, nuclear terrorism threat assessments differ widely.[1] Its sensational character can inspire inflated threat scenarios. Diverse types of terrorist organisations and a variety of conceivable pathways are often united in a single worst-case scenario of imminent nuclear threat. Reacting to these inflated scenarios could result in excessive and adverse countermeasures. It would be equally rash, however, to simply assume that a terrorist organisation could not possibly develop a crude nuclear bomb.[2] This is a convoluted problem with widespread factors, scenarios, and pathways. It is important to correctly assess the threat.

Traditional nuclear terrorism threat assessments focus primarily on terrorist motivations to use atomic weapons, the availability of nuclear know-how and technology, and/or clandestine organisations' opportunities to obtain fissile material. First, experts concentrate on the instrumental, ideological and psychological mechanisms that influence whether a terrorist organisation would construct and detonate a crude nuclear bomb. Terrorist organisations differ in their strategic and organisational goals, operational skills and opportunities, and attitudes towards risks and innovation. However, their clandestine nature and the lack of empirical cases obscure reliable conclusions with respect to terrorist organisations' motivations to induce nuclear *terror,* let alone follow through on the threat it implies.[3] Second,

accumulating technological progress and globalisation are often considered to signal the increasing availability of nuclear weapons technology and know-how.[4] Sceptics of this claim traditionally point to problems in exploiting these opportunities by terrorist organisations, including the need for both tangible and intangible skills, nuclear weapon design complexities, and wrong or incomplete information.[5] Finally, nuclear terrorism threat assessments focus on the strengths and vulnerabilities of the nuclear security regime and the different types of fissile material that terrorist organisations might acquire. Discussions on this theme primarily focus on the strengths and weaknesses of the nuclear security regulatory framework and the corresponding nuclear security culture.[6] "Conflicting intuitions" often clash in these three interlocking debates about nuclear terrorism.[7]

This article will specifically focus on the challenge of organising a nuclear terrorism project. Michael Levi, for instance, correctly argued that we should not only consider isolated variables or individual parts of a nuclear terrorism plot.[8] It is necessary to explore the complexity of terrorist organisations implementing a nuclear armament project. This is a critical gap in the traditional literature.[9] Experts often refer to a *well-organised and sophisticated,*[10] a *technically sophisticated,*[11] or *organisationally sophisticated*[12] terrorist group. However, rather than systematically reflecting upon the meaning of these concepts, most of the literature diverts attention to circumscribing the threat by means of the aforementioned traditional variables. Once an interest in nuclear weapons by a terrorist group has been established, threat assessments tend to focus on the state's security vulnerabilities. These are more tangible, objective factors. Implementation of the armament dynamic is taken for granted and the process itself is understudied. Traditional approaches insufficiently integrate questions such as who is

likely to make the decisions in a nuclear terrorism project; what this implies; how unforeseen obstacles are dealt with; and what role security and safety play throughout assembly of the bomb.[13]

This article first elaborates on the need for an organisational perspective in nuclear terrorism threat assessments. The terrorist organisation is the unit of analysis. The second section explains why a case study of "Los Alamos" - the first unified atomic bomb program - enables us to better understand the likelihood of nuclear terrorism. The article then inductively outlines the main organisational dynamics and challenges to this project. We embed these findings in the relevant literature from the field of organisational theory, particularly regarding the importance of the organisational design, and theoretically assess its potential application to a nuclear terrorism project. This article concludes by suggesting that terrorist organisations aiming to construct and detonate a crude nuclear device inherently must cope with a trade-off between effectiveness and efficiency. The type of organisational design that enhances the likelihood that a terrorist organisation can *effectively* complete the nuclear armament simultaneously leads to an increased likelihood of *less efficient* functioning by the terrorist organisation with respect to both its security and its strategic goals.

Designing nuclear terrorism: an organisational approach

Terrorist groups are organisations: they adopt terrorist tactics from a range of perceived alternatives in order to achieve their collective preferences and goals.[14] Roles and responsibilities must be allocated, monitored and coordinated to achieve the organisation's objectives.[15] In this respect, one can generally distinguish between the

organisation's strategic goals and its organisational goals. First, terrorist organisations have the strategic ambition of bringing about major religious, social and/or political change (e.g. the consolidation of a caliphate, the overthrow of a regime, or greater territorial autonomy). Second, terrorist organisations simultaneously seek to "maximize their strength and ensure their survival."[16] They need to endure in order to achieve their strategic objectives.[17] Besides these key objectives, however, terrorist organizations can also consider particular tactical goals (e.g. a successful attack, outbidding of opponents) and the inherent rewards of struggle (e.g. a sense of identity and pride).[18] These various goals can potentially contradict each other. In contrast with other social forms, such as a family, an ethnic group, or a community, an organisation is defined by this issue of specifically pursuing a diversity of goals.[19]

Terrorist organisations are, in this view, not *sui generis.* They fit within a broader category of phenomena. As a result, we can place a terrorist organisation in this broader – organisational - perspective to better assess, explain and counter this phenomenon. In light of their shared features, we can expect to better understand terrorist organisations by learning from the behaviour of other organisations.[20] Like other organisations, terrorist organisations face various organisational challenges. For instance, a terrorist organisation must determine how to efficiently use their limited resources in a given clandestine operational environment to effectively achieve their various goals. Such organisational dynamics are expected to impact a terrorist organisation pursuing a nuclear capacity. Unlike traditional nuclear terrorism threat assessments, this article focuses specifically on the nature and impact of these organisational dynamics and variables.

In what follows, we outline what we consider to be a most likely nuclear terrorism scenario. We thereby aim to illustrate that the implementation of the nuclear armament dynamic is expected to be a more sophisticated endeavour than standard operations for the context in which the terrorist group operates.[21] It is likely to be complicated by various non-routine and unexpected situations. The way in which this endeavour is organised is therefore expected to impact their capability to effectively arrive at the successful construction and detonation of a crude atomic bomb.

A most likely nuclear terrorism scenario

There are many pathways to terrorist nuclear capacity. The exact scenario depends on a variety of factors, such as the terrorist organisation's resources, the (state) assistance they would receive, and/or their exact operational environment and its opportunities. The exact (impact of the) organisational dynamics and variables will vary depending on the precise pathway. However, it is impossible to include every potential course of action. To remain focused, this article will start from a most likely nuclear terrorism scenario. Though established after consulting the relevant academic literature and various conversations with nuclear terrorism experts, any such hypothetical scenario will remain open to discussion.[22] Nevertheless, we believe our most likely nuclear terrorism scenario will illustrate the expected organisational complexity of such an endeavour.

The first hurdle in any nuclear terrorism project is the acquisition of fissile material: all nuclear weapons are based on the process of nuclear fission. The appropriate amount and type of fissile material is a precondition to construct a crude nuclear device. In this

scenario, we assume that the indigenous production of fissile material by a terrorist organisation is unlikely. Mining, milling and enriching natural uranium still requires a complex, timely, expensive, and large-scale industrial endeavour. This requires a substantial investment by the terrorist organisation and raises the risks of detection by counterterrorism forces.[23] We consider the external procurement of fissile material by means of theft, attack or purchase to be a more plausible option. A few of the most likely tasks in doing so are the identification and reconnaissance of the target, brokering reliable contacts to carry out the mission, ensuring the flow of material and financial support, circumventing security measures at the target, and establishing a viable way out and/or illicitly traffic the fissile material to the machine-shop. Although we expect insider assistance to the terrorist organisation, we assume that no systematically organised state assistance will help in deliberately transferring the fissile material to the terrorist organisation. A state is expected to be reluctant to relinquish control over these expensive and destructive weapons. They might be used in a counterproductive way. Moreover, even a remote prospect of retaliation is likely to have a strong deterrent effect. A survey of 83 nuclear experts confirmed that the "prospect that a nuclear weapons state might deliberately transfer nuclear weapons or materials directly to a terrorist was seen as the least likely method."[24]

This illuminates our following assumption that a terrorist organisation is not likely to attain the appropriate amount and type of fissile material. The element, shape, quantity and (chemical) composition of the fissile material are essential in assembling the nuclear device. Although the nuclear security regime suffers from severe shortcomings, it is wrong to assume that the optimal type and quantity of fissile material is easily available to terrorist organisations. Considering the aforementioned acquisition methods,

terrorist organisations are to a substantial extent dependent on their operational and organisational opportunities. It is thus plausible to assume that the fissile material they might attain needs to be processed in one way or another.[25]

This leads us to the second hurdle in our scenario. A terrorist organisation would need to manufacture the crude nuclear device. This includes the development of a functioning design, the establishment of a secure machine-shop, and the actual engineering of the atomic weapon. These three tasks need to be attuned to each other. The precise amount and type of fissile material impacts the design and engineering requirements of the atomic bomb. Our most likely scenario therefore expects a terrorist organisation to recruit and secure at least a small team with a particular set of skills. Some of the people expected to be needed in this phase of the project are physicists, metallurgists, explosives experts, chemists, engineers, electricians, and people with clandestine procurement skills.[26] These people need to be integrated in a well-functioning team. The technical complexity of the various tasks and the clandestine operational environment increase the likelihood of various non-routine and unexpected situations.

The last hurdle in our scenario refers to the illicit smuggling of the bomb or its components, and the bomb's detonation. We expect a terrorist organisation to be likely to illicitly smuggle fissile material, non-nuclear components, or an intact bomb at some point during the project. This is an issue of substantial debate. Zimmerman and Lewis, for instance, consider terrorists to be more likely to build the device within the target country. This would eliminate "the risks of moving the bomb across a border."[27] Admittedly, several terrorist organisations have set up machine shops in countries they have attacked (e.g. the FARC's submarine production). However, considering the

substantial investments at stake and the potential backlash when detected, we assume that a terrorist organisation would prefer to reduce the risks related to the construction of the bomb: procuring nuclear and non-nuclear components, securing the machine-shop, and protecting the assembly team is less challenging if the terrorist organisation operates in a less hostile environment. This enables them to maximise security while manufacturing this unique device, a process which could easily take several months. Illicit smuggling of material, on the other hand, is generally accepted to be not very perilous. Nonetheless, it would require a few people with expertise on (nuclear) trafficking techniques and tactics.

Next, once the atomic bomb has arrived in the target country, our scenario assumes a surface-burst delivery of the device. An air-burst delivery would imply various complex design issues. The deployment team would need to check the functionality of the device, might need to ensure communication with senior leadership (depending on the command and control posture), secure the operation, and actually detonate the crude atomic bomb. This step is probably the least challenging step in a terrorist nuclear project. However, last-minute doubts, malfunctions in the device, detection by counterterrorism forces, or other contingent factors might complicate matters.

In summary, it is clear that our most likely nuclear terrorism scenario is a complex endeavour. Even though some dimensions of this scenario might deviate from what would actually happen, as is always the case in any hypothetical scenario, the implementation of the nuclear armament dynamic is likely to go beyond standard operations for the context in which the terrorist group operates. Considering the unique character of the project, its various technical challenges, and the organisation's

clandestine operational environment, we expect the terrorist group to frequently encounter non-routine and unexpected situations. Any technical mistake, personal disagreement or outsider intrusion during this process might endanger the actual construction and detonation of the bomb. As Clausewitz would phrase it, the *fog of nuclear terrorism* would be strongly present. Organisational dynamics and variables would have an important impact on the terrorist organisation's capability to effectively complete such a project. As will become clear by the end of this paper, we see that the *organisational design* has a particular important role to play. The organisational design determines the division of tasks and how coordination is achieved among these tasks. It thereby strongly impacts the functioning of an organisation.[28]

The relevance of "Los Alamos"

Research on the organisational dynamics of a nuclear terrorism project has not yet been developed to a stage where it can be tested. It is still in an exploratory phase. In order to better understand these dynamics, this article examines a proxy case – that of "Los Alamos" – and extrapolates relevant findings from this case to the previously identified nuclear terrorism scenario. Considering the lack of empirical cases, learning about an analogous case enables us to draft new insights with respect to the nuclear armament dynamic. Indeed, the aim of this case study is both idiographic and hypotheses-generating: it is idiographic in the sense that we aim to inductively describe, explain and interpret the main organisational dynamics of "Los Alamos." Simultaneously, we also aim to generate plausible hypotheses with respect to organisational dynamics in the identified nuclear terrorism scenario. "Los Alamos" is in many ways of similar organisational complexity as the previously identified nuclear

terrorism scenario. We build on these shared organisational commonalities to better understand the challenges of nuclear terrorism.

"Los Alamos", also codenamed "Project Y", was a part of the Manhattan Project tasked with the design and construction of the first atomic bombs.[29] Research on nuclear fission started at various universities in the 1930s. However, "Los Alamos" was the first unified research and development program. The laboratory established at the Los Alamos Ranch School was the first to succeed in assembling a nuclear weapon.[30] While this project leaves us with few insights with respect to traditional nuclear terrorism variables, it is an interesting case as it demonstrates fundamental organisational commonalities to the previously identified nuclear terrorism scenario: "Los Alamos" was a more sophisticated effort than standard operations for the context in which they were operating. The implementation of this unique technical project had to cope with a clandestine operational environment and a tight schedule. A variety of non-routine and unexpected situations arose throughout its completion.

"Los Alamos" was a top-secret atomic weapons laboratory. Any type of interruption, detection or information breach could endanger the American strategic advantage in the Second World War as well as the following Cold War. Secrecy was a continuous concern of its military commander, General Leslie R. Groves. The geographical isolation of the town is indicative of the project's secret character.[31] Likewise, a nuclear terrorism project would need to be completed in a clandestine operational environment. Any interruption, detection, or leak could undermine the project. Even more, counterterrorism efforts could compromise the security and survival of the terrorist organisation.

Second, “Los Alamos” maintained a tight schedule. Nuclear weapons were considered to be an important asset in bringing the war to its conclusion. The United States wanted to complete their nuclear armament as soon as possible to counter the perceived threat by the German nuclear program.[32] This implied an important strategic and political advantage. Likewise, we can safely assume that a terrorist organisation would prefer to complete a nuclear project as soon as possible. Any delay would increase the chances of detection by counterterrorism forces as well as the amount of allocated resources.

Finally, various non-routine and unexpected situations arose throughout “Los Alamos”, which was characterised by a “trial-and-error” methodology. [33] However, for instance, the fact that they succeeded in surmounting the sudden discovery of plutonium’s incompatibility with the gun-type design is a prime example of the project’s adaptive and creative character. This organisational feature is also applicable to the previously identified nuclear terrorism scenario. Technology implementation is not simply transferring existing knowledge to its own organisation:[34] admittedly, “Los Alamos” differs from various nuclear terrorism scenarios as the project employed vast numbers of people, had a huge amount of resources to its disposal, and did not face the same exact technical challenges. Notwithstanding these particular differences, however, the previously identified nuclear terrorism scenario is likewise expected to face various non-routine and unexpected situations. Adding the previously mentioned shared features to the equation as well, we expect a nuclear terrorism project to require a continuously adaptive and creative character.

Building on these shared organisational features, this article ultimately aims to explore and better understand the organisational dynamics of a most likely nuclear terrorism

scenario. There are two possible points of criticism to this approach. First, it is often claimed that this research design "maintains a bias towards verification, understood as a tendency to confirm the researcher's preconceived notions." However, while this verification bias is ultimately also a fundamental human characteristic, the design is dictated by the exploratory nature of the article. It enables us to focus in-depth on the role of various relevant variables.[35] This leads us to a second potential point of criticism: adopting "organisational commonalities" as the criterion for case selection, this article could also focus on more recent or smaller clandestine state nuclear projects (e.g. South Africa, Pakistan or North Korea). A preliminary scan of the literature, however, clarifies that data on the internal dynamics of these projects is often shrouded in mystery. In the case of "Los Alamos", however, there are both many testimonies of people directly involved in "Los Alamos" and seminal secondary literature on the project's internal dynamics publicly available.[36] The quantity and quality of data is of essential importance to this exploratory design. Each source contributed to our in-depth understanding and thematic identification of key organisational dynamics at play. The plurality of sources strengthens the validity of this exploratory research.[37]

Organisational challenges at "Los Alamos"

The following section aims to inductively describe, explain, and interpret the main organisational challenges at "Los Alamos." We have identified four intertwined organisational issues: resource support, level of autonomy, information-sharing, and clear and compelling goals.[38] This article embeds these issues in the relevant literature by highlighting the beneficial nature of the overall *professional design* of this project, which advanced its effective achievement. These insights will finally account for our

exploration of the organisational dynamics in the previously identified nuclear terrorism scenario.

Resource support

Diverse resources were successfully acquired, allocated, and deployed at "Los Alamos." Ample qualitative human resources were of vital importance to the project's effectiveness: they succeeded in finishing this technically complex project in a timely manner while coping with a clandestine operational environment. Sufficient physical resources (e.g. money and crude materials) were equally important in order to fully exploit the potential of these qualitative human resources.

"Los Alamos" was characterised by the successful recruitment and employment of some of the brightest minds at that time (e.g. Hans Bethe, Enrico Fermi, Emilio Sègre, Seth Neddermeyer, George Kistiakowsky, et al.). However, this was no easy task. Many people were engaged in various war time efforts, such as the development of advanced radar technology. Robert Oppenheimer, the scientific director of the project, recruited the very first men by travelling from university to university working on the topic of nuclear fission.[39] While the secret nature of the project brought along the "problem of how much one could say,"[40] potential participants needed to be convinced to move to an isolated, well-secured area. Participation in the project entailed various personal and professional sacrifices.[41] Not all joined the project. However, despite these problems, the organisation succeeded in recruiting and employing a sufficient number of well-skilled persons throughout the project. The nucleus of the organisation ultimately came from several groups working for Oppenheimer in Berkeley.[42] Scientific interest in the

innovative nature of the job and acknowledgement of its importance are often mentioned as grounds for these successful recruitment efforts. People drove effective progress at "Los Alamos." Often adopting a "trial-and-error" methodology, they surmounted various non-routine and unexpected situations.[43] Outside help, such as the British mission and consultants of different universities, contributed to this effort. This availability of skilled people entailed substantial benefits to the effectiveness of the project, not the least of which was the flexible deployment of human resources. Luis Alvarez explains further:

> "Los Alamos was fortunate to have a full complement of high-caliber nuclear physicists. Because it did, a physicist of Emilio's (Sègre) skills could be diverted to from apparently more essential tasks to measure the rates of spontaneous fission in samples of uranium and plutonium, constants we thought we already knew. His discovery of the high spontaneous-fission background of reactor-bred plutonium was the most important single event at Los Alamos in the first months after I arrived. It had fateful consequences for bomb design and for the work of Kistiakowski's X-division."[44]

However, the potential of these human resources could only be optimally exploited if a sufficient amount of physical resources was available: first, ample federal funding and a competent and flexible procurement office allowed for the (sufficiently) steady flow of non-nuclear components and fissile material. There was no substantial scraping for resources by the project's participants.[45] This enabled the minimisation of human frustration, operational delays, and engineering errors, though not their complete elimination. Although prospects sometimes looked dim, the organisation succeeded, for

instance, in the timely delivery of a sufficient quantity of fissile material. This was essential to carry out some necessary experiments.[46] Second, besides these crude materials needed to build the bomb, it was equally important to create an operational environment in which scientists and technicians could "dedicate themselves fully to their scientific vocation."[47] The isolated and clandestine character of "Los Alamos" often had a negative impact on people's general living conditions.[48] Concerns about physical and psychological safety and security can distract people from their job. However, people at "Los Alamos" tried to make life as pleasant as possible. For instance, more than thirty recreational and cultural organisations were established.[49] Physical resources should support the creation of such a favourable operational environment to optimise the functioning of the organisation's human resources.

Level of autonomy

The project's operators largely succeeded in maintaining their scientific autonomy and decision-making power with respect to their field of expertise. This was not self-evident due to the military and clandestine nature of "Los Alamos." Although high levels of scientific autonomy entailed certain risks related to divergent behaviour, it benefited the creative application of individual knowledge, stimulated team work, and enhanced more objective operational decision-making.[50]

"Los Alamos" was intended to be operated as a military laboratory. Compartmentalised units would only receive information that they "needed to know."[51] This would have ensured more rigid top-down control over the execution and secrecy of the project. However, when Oppenheimer was trying to convince scientists to join "Los Alamos," it

became clear that many of them disavowed a military chain-of-command. This was ill-suited for scientific decision-making.[52] The civilian laboratory where scientists discussed their work with peers and openly exchanged information was beneficial in stimulating creative progress, team work, and good operational decision-making. It advanced the project's adaptiveness and flexibility. Oppenheimer, a scientist himself, supervised all the scientific work. There was no military control over the flow of information among the scientific staff. The secret character of the project was nevertheless maintained by building the laboratory within a guarded area, the security of which was in the hands of the military.[53] This system succeeded in reducing subjective interference by military or political institutions while simultaneously remaining secure; scientific control over the tasks and activities was reinforced. Kistiakowsky, for instance, recalled that Lord Cherwell, the scientific advisor to Winston Churchill, came to Los Alamos in 1944:

> "I took him around Los Alamos and gave him absolutely the whole story. He listened to me and told me that Baratol was going to be no good for the lenses, that I should use commercial dynamite. I explained to him why, on theoretical grounds, dynamite couldn't work and we parted friends. A little later Oppenheimer called me in to tell me about Churchill's personal cable to Roosevelt saying that certain people, specifically Kistiakowsky at Los Alamos, are barking up the wrong tree, since Baratol is not going to work, and that they should use dynamite…. So I went through a rather large X (Explosives) Division personnel list, singled out individuals who hadn't contributed anything, constituted a group out of them, and so dynamite didn't delay the project in the slightest."[54]

However, this approach entailed a heightened risk with respect to divergent behaviour by individual scientists: first, scientific autonomy and lack of top-down control increased the likelihood that friction between scientists would occur. For instance, Bethe and Oppenheimer were greatly annoyed by Teller working on the thermonuclear bomb rather than the implosion design. Oppenheimer ultimately decided to replace Teller.[55] Second, scientific autonomy did sometimes lead to the "we know best syndrome."[56] David Busbee, for instance, designed the first S-site plant, which was meant to provide more space to the explosives programme, following his own naval ordinance concepts at the time. He aimed to pour "large castings for the full-scale implosion assembly." Kistiakowsky, however, recalls that the plant was "a monstrosity from our point of view" and "never used afterwards."[57] Finally, the lack of an outside opinion increased the risk of "group-think."[58] Neddermeyer's first theoretical analysis of the implosion design of a nuclear bomb faced stiff opposition by Oppenheimer, Fermi and Bethe. Manley stated that "nobody…really took (implosion) very serious." Later, however, Bohr went beyond their incredulity to pursue this truly original idea. As it would turn out, the implosion design was a more efficient way to detonate an atomic bomb.[59]

Divergent behaviour can lead to human frustrations, operational delays, and engineering errors. Each of these issues might undermine the effectiveness of the project. Nonetheless, the risks ultimately did not trump the advantages. Scientific autonomy allowed for better operational decision-making while simultaneously strengthening the adaptive and creative functioning of the team.

Information-sharing

Scientific autonomy goes hand-in-hand with high levels of information-sharing. Free flows of communication stimulated the combination of knowledge and enhanced the sense of common purpose at "Los Alamos." However, the multitude of communication and coordination mechanisms inherently entailed increased security risks. Any information breach could undermine the effectiveness of the project and the United States' broader strategic advantage.

Various communication and coordination tools were established to increase the project's effectiveness: the heads of the operating groups were in contact with each other through the coordinating council; individual divisions and groups had their own meetings, seminars, published reports, and informal talks; the "Los Alamos" library reproduced and distributed progress reports by various groups at the laboratory; and weekly colloquiums with all the laboratory employees with a scientific degree or equivalent were organised to discuss the technical program.[60] These channels were informative and deliberative. This intense flow of information stimulated not only creativity and flexibility: by encouraging "out-of-the-box" thinking, it also fostered a "sense of common effort and responsibility" by illuminating the joint nature of this effort.[61] Manley stated that:

> "Each scientist could discuss his work with his peers … these discussions brought forth ideas and were excellent morale boosters. I'm sure the work went faster and more effectively as a result. After all, a reason to create Los Alamos was to improve the communication between all those engaged in the weapon problem."[62]

Moreover, different liaison contacts were established between "Los Alamos" and other units active in the Manhattan Project. In order to develop the bomb, they required information, e.g. about the form and processing history of the fissile material produced at Oak Ridge.[63] Liaison officers held an important role in coordinating the overall project.

However, this abundant flow of information did inherently imply increased risks with respect to security breaches. Regular presence at the various formal and informal meetings, which were open to many members of "Los Alamos", provided that person with a "generally complete and accurate picture of the problems and progress of the laboratory."[64] Although the isolated nature of "Los Alamos" reinforced the safekeeping of information, it could not prevent leaks from occurring. There were many instances of security breaches, of which the case of Klaus Fuchs arguably posed the most substantial threat. Klaus Fuchs was a theoretical physicist who managed to participate in different discussions and meetings at "Los Alamos"; however, he had communist sympathies. He forwarded a great deal of the information gathered to Russia. Though it remains unclear what damage he actually caused, some believe he "probably shortened the Russian atomic bomb development by two years."[65] Although his intentions were not necessarily focused on undermining "Los Alamos," his actions did damage the greater strategic interests of the United States.

Clear and compelling goals

The formulation of clear and compelling goals advanced the effectiveness of "Los Alamos." A clear goal sharpens the focus of the project while a compelling goal inspires

the team in rallying around the project. This was an important tool in coping with some of the aforementioned organisational challenges (e.g. individual divergent behaviour and security breaches). However, formulating clear and compelling goals is not self-evident. An unsuccessful attempt might actually increase the risks related to detection, defection, and leaks.[66]

Clear goals allowed the project to steadily progress and remain focused. All scientists received Robert Serber's lecture *The Los Alamos Primer* when arriving at "Los Alamos", which brought them up to speed with the principles and goals of the project. Rhodes notes in this respect that "the scientists' euphoria at finally learning in detail what they had only previously guessed or heard hinted, measures the extent to which secrecy had contorted their emotional commitment to the work."[67] Continuous formal and informal meetings throughout the project subsequently enhanced clarity on the project's (intermediary) goals. Second, "Los Alamos" was characterised by relatively compelling goals. The Second World War stimulated the scientists and technicians' motivation to build a nuclear bomb. Taking into account the perceived German nuclear threat, operators were readily emotionally attracted to the project. For example, President Roosevelt had Oppenheimer read a personal letter at a colloquium:

> "I wish you would express to the scientists assembled with you my deep appreciation of their willingness to undertake the tasks which lie before them in spite of the dangers and the personal sacrifices. I am sure we can count on their continued wholehearted and unselfish labors. Whatever the enemy may be planning, American science will be equal to the challenge."[68]

Clear and compelling goals enhanced the organisation's coherence, focus, and perseverance. Nonetheless, it simultaneously entailed certain risks. Formulating clear goals often goes hand-in-hand with formulating compelling goals. However, a clandestine organisation is vulnerable if the formulation of goals is clear but not compelling. The aforementioned example of Klaus Fuchs demonstrates the potential security risks connected to uncompelled workers. Moreover, when it became clear that Germany was nearly defeated, some people, such as Szilard or Rotblat, argued against using the weapons. Such moral qualms about the goals of the project could undermine its ultimate effectiveness. Second, leadership needs to remain vigilant so that the formulation of clear goals does not evolve into top-down meddling in day-to-day affairs. This might be counterproductive to the project's effectiveness as well. As previously mentioned, it can undermine the scientists and technician's operational decision-making and hamper their adaptive and creative functioning.

The latter remark points to the overall importance of good leadership. Besides the synergy between Groves and Oppenheimer, Oppenheimer's role in effectively building the bomb is often praised.[69] While coping with a clandestine operational environment, they succeeded in providing sufficient resources and clear and compelling goals while simultaneously preserving scientific autonomy for the scientists and technicians. Although any (moral) qualm or security breach could have undermined the effectiveness of the project and the broader strategic advantage of the U.S., they ultimately succeeded in uniting diverse individual human resources in a high-performing, multidisciplinary team.

The professional design of "Los Alamos"

The following section reflects on the organisational dynamics identified and embeds them in the relevant literature in the field of organisation theory. We focus specifically on the impact of the *design* of the organisation. This refers to the division of labour into various tasks and how coordination is achieved among these tasks.[70] It refers to the institutional circumstances in which the members of the project operate, thereby constituting the common thread that permeates the organisational issues previously identified. The organisational design is an essential tool in striking "a balance between external pressures from the organisation's environment and internal pressures from, for example, its choice of technology."[71] Different types of design relate to different sources of control and coordinating mechanisms vis-à-vis the work: for example, a more bureaucratic type of organisational design is controlled by managers that adopt more standardised coordination mechanisms (e.g. formal rules). [72] The organisational design influences the organisation's resource allocation, their levels of scientific autonomy and information-sharing, and the clear and compelling nature of its goals.

"Los Alamos" can generically be identified by its *professional* design. This refers to the "institutional circumstances in which the members of the occupations rather than consumers or managers control the work."[73] Also described as an adhocracy design, it is characterised by the fact that a great deal of power is given to operational experts. Considering their highly specialised skills, they are essential in effectively executing the variety of complex tasks and activities.[74] Human resources were one of the vital driving forces behind the effectiveness of "Los Alamos." They had the capability to resolve non-routine and unexpected situations. Top-down meddling by managers needed to be

avoided. A professionally designed organisation therefore limits strict behavioural formalisation, centralised decision-making, and tight planning and control systems. This would thwart the flexibility, creativity, and adaptability needed of the experts. One can clearly retrace these organisational elements at "Los Alamos." As previously outlined, the project was characterised by high levels of scientific autonomy and information-sharing. Various liaison devices encouraged mutual adjustment. Such a professional design is, ultimately, characterised by more organic rather than bureaucratic sources of control and coordination. This optimises the organisation's functioning in a complex and dynamic environment and increases the likelihood that the organisation can effectively achieve "sophisticated innovation."[75]

However, as also illustrated by our case study, any professionally designed organisation is inherently susceptible to two major organisational problems: first, this particular institutional set-up brings about an increased risk of divergent behaviour by the organisation's members. Different experts work together in a flexibly regulated environment. This inherently entails some level of fluidity and ambiguity when it comes to the tasks to be performed and the coordination between these different tasks. The likelihood of divergent behaviour increases. The tensions between Teller and Bethe or Kistiakowsky and Neddermeyer demonstrate the case in point. More bureaucratic sources of control and coordination could reduce the likelihood of diverging behaviour.[76] However, it would impede the organisation's flexibility. Second, this type of design is an inherently inefficient way of organising. While it increases the likelihood that an organisation can effectively complete a complex project, it requires various resources and a great deal of communication and coordination. Although "Los Alamos"

was ultimately effective in building the first atomic bombs, it was often necessarily so by means of a "trial-and-error" methodology.

"Los Alamos" succeeded in surmounting these organisational problems, not least via the abundant flow of resources and the formulation of clear and compelling goals. However, the question arises of to what extent these organisational dynamics and challenges would also be applicable to nuclear terrorism.

Exploring the terrorist nuclear armament dynamic

Reflecting on the terrorist nuclear armament dynamic, this article introduces the idea of an *effectiveness-efficiency* trade off: as previously explained, we expect a nuclear terrorism project to go beyond the standard operations of a terrorist organisation. They are likely to frequently encounter non-routine and unexpected situations. Implementation of such an endeavour would require a creative and adaptive attitude. Building on the various shared features with "Los Alamos", we expect that a professionally designed terrorist organisation is most likely to effectively complete the nuclear armament dynamic. This design, however, simultaneously increases the likelihood of a less efficient functioning terrorist organisation with respect to both its security and its strategic objectives.

Effectiveness…

We expect a professional design to be the most appropriate institutional disposition to increase the likelihood that a terrorist organisation can effectively complete the nuclear armament dynamic.

Human resources are expected to be a driving force to the success of a nuclear terrorism project. A variety of non-routine and unexpected tasks and activities as diverse as reconnoitring a nuclear facility, designing the bomb, casting fissile material and smuggling non-nuclear components needs to be completed successfully. Operational control should be situated at the level of the experts. Preserving their autonomy and allowing for the exchange of information enhances their objective decision-making. Various tasks need to be coordinated to achieve the intended outcome. An indicative example is the fact that the design and non-nuclear components of the atomic bomb must be attuned to the type and quantity of fissile material that the terrorist organisation can obtain. As it is difficult to standardise and/or formalise this process, more information-sharing and liaison contacts between different persons and units is required. While the leadership needs to contribute to the coordination and integration of these diverse experts into a well-functioning team, they must refrain from centralised, top-down meddling: setting tight intermediary goals, impeding horizontal communication and coordination, imposing (pet) solutions at the expense of practical progress, or adopting stringent timing requirements is expected to increase the risks of operational delays, errors, and frustrations. For instance, as Lord Cherwell pushed for the use of commercial dynamite at "Los Alamos," unduly (ambitious) demands by terrorist leaders could induce operators to disregard some essential engineering

considerations in a nuclear terrorism project or to neglect diverse security issues (e.g. entering the nuclear black market without regard for security). Meanwhile, however, the leadership should invest in creating a favourable operational environment by sustaining the flow of resources and formulating clear and compelling goals.

These professional design characteristics would strengthen a terrorist organisation's potential for creativity and flexibility. It would increase the likelihood that they could cope with the expected non-routine and complex tasks of a nuclear terrorism project. However, this design would be inherently susceptible to two major organisational problems.

…versus efficiency

A terrorist organisation pursues both organisational and strategic goals. A professionally designed terrorist nuclear armament project, though optimising the likely effectiveness of the project, is expected to entail a less efficient functioning terrorist organisation with respect to these goals: this institutional configuration could endanger both the security of the organisation as well as the achievement of its strategic goals.

A professional design entails increased risks to the security of the terrorist organisation. First, we expect the terrorist organisation to require human resources with particular skills. However, each recruitment effort brings in challenges. The international nuclear job market is not entirely populated by top scientists and technicians; it is mixed with mediocre scientists and technicians, con men, fraudsters and potential spies with false claims. The terrorist organisation would need to separate the (scientific) wheat from the

chaff. The problem of "how much one can say" is prominent. Next, we expect high levels of scientific autonomy and information-sharing throughout the project. Experts are likely to have a great deal of operational control. Such a flexible environment, which implies increased levels of fluidity and ambiguity with respect to the (coordination of) different tasks, leads to an increased likelihood of divergent behaviour. Human frustrations, operational delays and engineering errors could occur. This increases the likelihood of (moral) qualms, detection, and defection, thereby potentially compromising the security of the terrorist organisation.

These issues are problematic for a terrorist organisation. A terrorist equivalent of Klaus Fuchs might prove disastrous for them. While "Los Alamos" was a secret project, it is generally perceived as a legitimate endeavour. Most nuclear terrorism projects, however, can be expected to enjoy less popular support. This makes the terrorist organisation even more vulnerable to any security breach. Any detection of a nuclear terrorism plot could lead to a strong counterterrorism response, endangering both the success of the project as the security and survival of the organisation.

It follows that a nuclear terrorism plot is expected to be an inefficient method for a terrorist organisation to achieve their strategic goals: while the more effective design of a nuclear terrorism project entails substantial security risks, the leadership is expected to invest a substantial amount of their limited human and physical resources in a nuclear terrorism project. Meanwhile, leadership must remain wary of attempting to closely control the operators. Any terrorist organisation pursuing a nuclear capacity would thus likely need to be at peace with a high risk of failure and substantial costs related to this endeavour. A nuclear terrorism project could potentially undermine the

organisation's operational capacity and security, thereby also inhibiting them from achieving their strategic objectives.

Conclusion

Michael Levi wrote in 2009 that we must understand "how to think about nuclear terrorism."[77] Rather than merely reflecting on worst-case scenarios and individual variables, which nevertheless also has its place, it is important to emphasise various possibilities with respect to nuclear terrorism and the interaction between the different tasks and activities.[78] It follows that we must design our defence as an integrated system, with "each part of the defense not only complementing other defensive elements but also reinforcing them."[79]

Embracing this notion, this article focused on the often neglected issue of how to organise the implementation of a (most likely) nuclear terrorism project. While Levi often more implicitly touched upon this particular theme, this article aimed to more systematically reflect upon the actual organisational dynamics within the enemy organisation. Building on the organisational commonalities with "Los Alamos", we introduced the idea of an effectiveness-efficiency trade off: a professionally designed terrorist organisation is most likely to effectively complete the nuclear armament process. This institutional disposition, however, simultaneously increases the likelihood of a less efficient functioning terrorist organisation with respect to both its security and its strategic objectives. A terrorist organisation could decide to move, for instance, to a more bureaucratic organisational design (by, e.g. limiting scientific autonomy) to reduce the security risks related to such an endeavour. However, this would probably limit the

effectiveness of the project. It would most likely reduce the terrorist organisation's capacity to actually produce a yield-producing nuclear explosion or substantially lengthen the process of doing so.

We will further consider how this illuminates our better understanding of (the likelihood of) nuclear terrorism. Adopting a rational perspective, this article pointed to the expected inefficient nature of nuclear terrorism as a method to achieve the group's organisational and strategic goals. Such a project is likely to cost substantial human and physical resources while entailing various risks to the security of the organisation. Simultaneously, it is doubtful whether a successful nuclear terrorist attack would actually help the organisation in advancing their strategic goals. Abrahms, for instance, convincingly argues that greater civilian target selection (as would undeniably be the case for nuclear terrorism) leads target countries to infer that the terrorists want to destroy their society and beliefs.[80] Policy concessions become unlikely. Moreover, such an indiscriminate attack could both alienate the organisation's constituency and lead to strong counterterrorism measures. This is counterproductive for both the organisational and strategic objectives of the terrorist group.[81] From a rational perspective, it is therefore dubious whether nuclear terrorism would work better than other methods. This is only strengthened by the likely inefficient nature of this particular tactic.

However, this does not imply that we should assume that no terrorist organisation would ever pursue a nuclear capacity. Terrorist organisations that irrationally believe in their odds of success, are driven by more value-rational objectives[82] or confronted with an exceptional opportunity, might decide to go nuclear. While qualifications to the

findings of this article should be treated carefully for now, it seems worthwhile to look into counterterrorism efforts based on these findings. This could strengthen Levi's idea of an integrated defence even further.

First, it is worth contemplating an upgrade of counterterrorism measures focussed on potential operators. These operators will be a driving force throughout a nuclear terrorism project. Various counterterrorism measures might impede their succesful participation in a nuclear terrorism project: complicating recruitment of potential operators (e.g. sensibilization throughout the training of nuclear experts); setting up follow-up and screening programs for (former) nuclear scientists and technicians; or planting false information or sting operations. This can cause doubts, delays, and errors in a nuclear terrorism project. Second, counterterrorism efforts should focus on exploiting the potential inefficiencies related to a nuclear terrorism project. On one hand, this refers to the security risks for a terrorist organisation. Divergent behaviour can be stimulated by, for instance, providing viable exit-options for individual terrorists and dispersing (ideological) counter-narratives. On the other hand, this refers to nuclear terrorism as a tactic to achieve their strategic objectives. We should continuously emphasise the lack of political utility of nuclear terrorism for any terrorist organisation. Although a value-rational organisation might dismiss these arguments, it could lead to elements within the project to doubt the goals of the organisation. It is clear that these counterterrorism measures are closely related.

These insights are only first explorations. Further research is needed to validate these findings. As previously mentioned, one can focus on studying more recent state nuclear projects with fundamental commonalities to our most likely nuclear terrorism scenario.

The South African, Pakistani and North Korean nuclear programmes seem of particular relevance due to their clandestine and relatively small nature. One could study whether or not similar dynamics were at play throughout these programs. One could also look for the application of similar dynamics in complex terrorism attacks. As examples of such complex engineering efforts, Aum Shinrikyo's 1995 Sarin attack or the PIRA's development of more advanced mortar systems come to mind.

End notes

[1] More sceptical opinions on the likelihood of nuclear terrorism are voiced by, e.g., Michael Levi, *On Nuclear Terrorism* (Cambridge & London: Harvard University Press, 2009); John Mueller, *Atomic Obsession: Nuclear Alarmism from Hiroshima to Al Qaeda* (Oxford: Oxford University Press, 2010); Robin Frost, *Nuclear Terrorism after 9/11* (USA & Canada: Routledge, 2005). Other scholars and experts are more concerned about nuclear terrorism, e.g.: Matthew Bunn and Anthony Wier, "Terrorist Nuclear Weapon Construction: How Difficult?," *The Annals of the American Academy* 607 (September 2006), pp. 133–49; Charles Ferguson and William Potter, The Four Faces of Nuclear Terrorism (United States: Center for Non Proliferation Studies, 2004); Charles Blair, "Jihadists and Nuclear Weapons," in *Jihadists and Weapons of Mass Destruction* (CRC Press, 2009), pp. 193–240. Graham Allison, *Nuclear Terrorism: the Ultimate Preventable Catastrophe* (United States: Henry Holt & Company, 2005).
[2] Gary Ackerman, "Designing Danger: Complex Engineering by Violent Non-State Actors: Introduction to the Special Issue," *Journal of Strategic Security* 9 (1) (2016), p. 1;
[3] Some notable work covering this dimension of nuclear terrorism threat assessments is: Gary Ackerman, "Motivations for Engaging in Nuclear Terrorism," Expert Series Fund for Peace, 2006; Bruce Hoffman, "Terrorism and WMD: Some Preliminary Hypotheses," *The Nonproliferation Review* 4 (3) (1997): 45–53; Jenkins, *Will Terrorists Go Nuclear?*
[4] Rolf Mowatt-Larssen et al., "The U.S.-Russia Joint Threat Assessment on Nuclear Terrorism" (Harvard Belfer Center, May 2011).p.12.
[5] Some notable work covering this dimension of nuclear terrorism threat assessments is: Carson Mark et al., "Can Terrorists Build Nuclear Weapons?" (Washington: Nuclear Control Institute, 1987), http://www.nci.org/k-m/makeab.htm; Ferguson and Potter, *The Four Faces of Nuclear Terrorism*.
[6] Some notable work covering this dimension of nuclear terrorism threat assessments is: Igor Khripunov, Nikolay Ischenko, and James P. Holmes, *Nuclear Security Culture: From National Best Practices to International Standards* (IOS Press, 2007); Michelle Cann, "Nuclear Security Commitment Making: Results of the Summit Process," in *Nuclear Terrorism: Countering the Threat*, Global Security Studies (London & New York: Routledge, 2016), 215–32."NTI Nuclear Materials Security Index," *Nuclear Threat Initiative*, 2016, http://ntiindex.org/data-results/theft-data/.
[7] Brecht Volders and Tom Sauer, "Introduction to the Book," in *Nuclear Terrorism: Countering the Threat*, Global Security Studies (London & New York: Routledge, 2016), 3–12.p.7.
[8] Levi, *On Nuclear Terrorism*.
[9] The logic of this idea has been explored with respect to nuclear proliferation by states (e.g. Jacques Hymans, *Achieving Nuclear Ambitions; Scientists, Politicians and Proliferation* (United States: Cambridge University Press, 2012)) and biological and chemical weapon proliferation by terrorist organizations (e.g. Jean Pascal Zanders, "Assessing the risk of chemical and biological weapons proliferation to terrorists," *The Nonproliferation review* 6(4) (1999)). This argument has, however, to my knowledge not sufficiently been explored with respect to nuclear terrorism.
[10] Bunn and Wier, "Terrorist Nuclear Weapon Construction: How Difficult?"
[11] Mowatt-Larssen et al., "The U.S.-Russia Joint Threat Assessment on Nuclear Terrorism."
[12] Peter Zimmerman and Jeffrey Lewis, "The Bomb in the Backyard," *Foreign Policy*, October 16, 2009.
[13] Ackerman, "Designing Danger: Complex Engineering by Violent Non-State Actors: Introduction to the Special Issue." pp. 4-7. The work of Ackerman and his colleagues might be one of the most notable exceptions to this gap in the literature.
[14] See for instance: Colin Wight, Rethinking Terrorism: Terrorism, Violence and the State, Rethinking World Politics (Palgrave Macmillan, 2015); Martha Crenshaw,"The Logic of Terrorism: Terrorist Behavior as a Product of Strategic Choice," in Origins of Terrorism: Psychologies, Ideologies, Theologies, State of Mind (John Hopkins University Press, 1998).
[15] Some interesting work on this broadly established claim is: Jacob Shapiro, *The Terrorist's Dilemma: Managing Violent Covert Organization* (Princeton: Princeton University Press, 2013); Michael Kenney, *From Pablo to Osama: Trafficking and Terrorist Networks, Government Bureaucracies, and Competitive Adaptation* (Pennsylvania: The Pennsylvania University Press, 2007); Eli Berman, *Radical, Religious and Violent: The New Economics of Terrorism* (Cambridge: MIT Press, 2009).
[16] Peter Krause, "The Political Effectiveness of Non-State Violence: A Two-Level Framework to Transform a Deceptive Debate," *Security Studies* 22 (2) (2013), pp. 259–94.
[17] Audrey Kurth Cronin, *How Terrorism Ends: Understanding the Decline and Demise of Terrorist Campaigns* (Princeton: Princeton University Press, 2009)., p.75.
[18] Richard English, *Does Terrorism Work: A History* (United Kingdom: Oxford University Press, 2016). p.30

[19] John McAuley, Joanne Duberly, and Phil Johnson, *Organization Theory: Challenges and Perspectives* (United Kingdom: Pearson Education Limited, 2007); Richard Scott and Gerald Davis, *Organizations and Organizing: Rational, Natural, and Open System Perspectives* (new Jersey: Pearson Prentice Hall, 2003); Amitai Etzioni, "Organizational Control Structure," in *Handbook of Organizations* (Chicago: Rand McNally & Company, 1965), 1247.
[20] The logic of this argument has been summarized in: Martha Crenshaw, "Terrorism Research: The Record," *International Interactions: Empirical and Theoretical Research in International Relations* 40 (4) (2014), pp. 556–67.
[21] Ackerman, "Designing Danger: Complex Engineering by Violent Non-State Actors: Introduction to the Special Issue." p.2
[22] In drafting this scenario – while remaining realistic – we portrayed a scenario that does not needlessly complicate the project. This way, we avoid exaggerating the impact of *organizing* this endeavour.
[23] There is, however, research on more simple enrichment methods – although this is primarily focused on state nuclear projects. See, for instance, at Scott Kemp, "The Non-proliferation Emperor Has No Clothes: The Gas Centrifuge, Supply-Side Controls, and the Future of Nuclear Proliferation", *International Security* 38(4) (2014), pp. 39-78.
[24] Levi, *On Nuclear Terrorism*. p.23. Obviously, there are scenarios with assistance by rogue elements within the state apparatus, or circumstances where the state might be inclined to help terrorists (e.g. when the regime is in dire danger). Yet, we limit ourselves to the 'most-likely scenario.' This scenario is confirmed by a survey with 83 nuclear experts. Richard Lugar, "The Lugar Survey On Proliferation Threats and Responses," (Survey, June 2005), https://fas.org/irp/threat/lugar_survey.pdf.
[25] Supporting this claim are, for instance, Levi, *On Nuclear Terrorism,* p.15-18. And Matthew Bunn, "Guardians at the Gates of Hell: Estimating the Risk of Nuclear Theft and Terrorism and Identifying the Highest-Priority Risks of Nuclear Theft" (Massachusetts Institute of Technology, 2007), p.214.
[26] See, for instance: Zimmerman and Lewis, "The Bomb in the Backyard"; Bunn, "Guardians at the Gates of Hell: Estimating the Risk of Nuclear Theft and Terrorism and Identifying the Highest-Priority Risks of Nuclear Theft"; Mark et al., "Can Terrorists Build Nuclear Weapons?"; Ferguson and Potter, *The Four Faces of Nuclear Terrorism*. Albert Narath, "The Technical Opportunities for a Sub-National Group to Acquire Nuclear Weapons," XIV Amaldi Conference on Problems of Global Security, April 27, 2002.
Building on the publicly available literature, "small" refers in this case to a range of people between 5 and 20.
[27] Zimmerman and Lewis, "The Bomb in the Backyard."
[28] Henry Mintzberg, *Structure in Fives: Designing Effective Organizations* (New Jersey: Prentice-Hall, 1983).
[29] People did not focus on the enrichment of fissile material at "Los Alamos."
[30] "Establishing Los Alamos; 1942-1943" (U.S. Department of Energy, n.d.), https://www.osti.gov/opennet/manhattan-project-history/Events/1942-1945/establishing_los_alamos.htm.
[31] Leslie Groves, *Now It Can Be Told: The Story of the Manhattan Project*, 2nd ed. (United States of America: Da Capo Press, 1983). pp.66-67
[32] Lawrence Badash, Joseph Hirschfelder, and Herbert Broida, eds., *Reminiscences of Los Alamos, 1943-1945*, Studies in the History of Modern Science (USA, UK, The Netherlands: Reidel Publishing Company, 1980). p.68
[33] Lillian Hoddeson et al., *Critical Assembly: A Technical History of Los Alamos During the Oppenheimer Years, 1943-1945* (United Kingdom: Cambridge University Press, 2004). p.9
[34] Brian Michael Jackson, "Technology Acquisition by Terrorist Groups: Threat Assessment Informed by Lessons from Private Sector Technology Adoption," *Studies in Conflict & Terrorism* 24 (3) (2001): 183–213.
[35] Bent Flyvbjerg, "Five Misunderstandings About Case-Study Research," *Qualitative Inquiry* 12 (2) (2006)., p.234.
[36] Firsthand accounts by various scientists and participants of Los Alamos can be found in 'Lawrence Badash, Joseph Hirschfelder, and Herbert Broida, eds., *Reminiscences of Los Alamos, 1943-1945*. This book provides testimonies by John Dudley, Edwin McMillan, John Manley, Elsie McMillan; George Kistiakowsky, Joseph Hirschfelder, Laura Fermi, Richard Feynman & Bernice Brode. Another important source of information was the 'Voices of the Manhattan Project' (to be retrieved via: http://manhattanprojectvoices.org/). This contains various interviews with scientists and participants of, amongst others, Los Alamos. Interviews with Robert Oppenheimer, Hans Bethe, Robert Serber, Harry Allen and Robert Van Gremert, Norris Bradbury and others are available. Moreover, this article draws upon other bibliographical sources, such as 'Leslie Groves, *Now It Can Be Told: The Story of the Manhattan*

Project', and 'Luis Alvarez, *Adventures of a Physicist*, vol. Alfred P. Sloan Foundation Series (New York: Basic books, inc., Publishers, 1987)'. Finally, there is a variety of secondary literature on the internal dynamics of Los Alamos, such as: David Hawkins, "Manhattan District History: Project Y, The Los Alamos Project"; Hoddeson et al., *Critical Assembly: A Technical History of Los Alamos During the Oppenheimer Years;* Edith Trustlow, *Manhattan District History: Non-scientific aspects of Los Alamos Project Y 1942 through 1946* (United States; 1973).

[37] The limited amount of words allowed in this article also made us opt for an in-depth reflection of one case, rather than a potentially superficial reflection on two cases.

[38] Although working in an inductive fashion, we are ineluctable guided by a theoretical background. Where appropriate, we thus rehabilitate existing concepts. In this context, we primarily make use of the concepts suggested by Hymans ("Resource support", "High levels of autonomy" and "Clear and compelling goals"). To my knowledge, he is the only author who more systematically adopted an organizational approach to state nuclear projects. Yet, Hymans did not analyse 'Los Alamos' (or the Manhattan Project), and we place, for instance, more emphasis on the importance of "information-sharing" and the relationship between *effectiveness* and *efficiency*.

[39] Stephane Groueff, J. Robert Oppenheimer's Interview, 1965.

[40] Ibid.

[41] Groves, *Now It Can Be Told*., p.150.

[42] Ibid., p.149.

[43] Hoddeson et al., *Critical Assembly: A Technical History of Los Alamos During the Oppenheimer Years, 1943-1945*., p.9.

[44] Luis Alvarez, *Adventures of a Physicist*, vol. Alfred P. Sloan Foundation Series (New York: Basic books, inc., Publishers, 1987)., p.126.

[45] David Hawkins, "Manhattan District History: Project Y, The Los Alamos Project" (Los Alamos Scientific Laboratory, December 1, 1961).

[46] "Los Alamos: Beginning of an Era 1943-1945: Part 4" (Los Alamos Scientific Laboratory, 2008).

[47] Jacques Hymans, *Achieving Nuclear Ambitions: Scientists, Politicians, and Proliferation* (United States: Cambridge University Press, 2012)., p.51.

[48] People were, for instance, limited in their use of telephones, surrounded by a chain-link fence, and facing poor housing conditions.

[49] "Los Alamos: Beginning of an Era 1943-1945: Part 2" (Los Alamos Scientific Laboratory, 2008).

[50] Hymans, *Achieving Nuclear Ambitions: Scientists, Politicians, and Proliferation*., p.51.

[51] John Manley, "A new laboratory is born", in Badash, Hirschfelder, and Broida, *Reminiscences of Los Alamos, 1943-1945*.

[52] "The Manhattan Project: Making the Atomic Bomb" (United States Department of Energy, January 2010)., p.80.

[53] Hawkins, "Manhattan District History: Project Y, The Los Alamos Project."

[54] George Kistiakowsky, "Reminiscences of wartime Los Alamos", in "Badash, Hirschfelder, and Broida, *Reminiscences of Los Alamos, 1943-1945*.

[55] Hoddeson et al., *Critical Assembly: A Technical History of Los Alamos During the Oppenheimer Years, 1943-1945*., p. 162.

[56] Hymans, *Achieving Nuclear Ambitions: Scientists, Politicians, and Proliferation*., p.52.

[57] Hoddeson et al., *Critical Assembly: A Technical History of Los Alamos During the Oppenheimer Years, 1943-1945*., p.167.

[58] Irving Janis, *Groupthink: Psychological Studies of Policy Decisions and Fiascos* (New York: Houghton Mifflin, 1982), p. 9.

[59] Richard Rhodes, *The Making of the Atomic Bomb* (New York: Simon & Schuster, 1986)., p. 476.

[60] Hawkins, "Manhattan District History: Project Y, The Los Alamos Project." p. 32.

[61] Ibid. p. 33.

[62] John Manley, "A new laboratory is born", in Lawrence Badash, Joseph Hirschfelder, and Herbert Broida, eds., *Reminiscences of Los Alamos, 1943-1945*.

[63] Hawkins, "Manhattan District History: Project Y, The Los Alamos Project." p. 34.

[64] Ibid. p. 33.

[65] Joseph Hirschfelder, "Scientific-Technological Miracle at Los Alamos", in Lawrence Badash, Joseph Hirschfelder, and Herbert Broida, eds., *Reminiscences of Los Alamos, 1943-1945*, p. 85.

[66] Hymans, *Achieving Nuclear Ambitions: Scientists, Politicians, and Proliferation*., p. 53.

[67] Rhodes, *The Making of the Atomic Bomb*., p. 460.

[68] Letter from Franklin D. Roosevelt to Robert J. Oppenheimer, 29th of June 1943.

[69] "The Manhattan Project: Making the Atomic Bomb"; Badash, Hirschfelder, and Broida, *Reminiscences of Los Alamos, 1943-1945*., pp. 161-163.
[70] Mintzberg, *Structure in Fives: Designing Effective Organizations*., p. 2.
[71] Gareth Jones, *Organizational Theory, Design and Change: Text and Cases*, 4th ed. (Pearson Prentice Hall, 2003)., p. 10.
[72] Mintzberg, *Structure in Fives: Designing Effective Organizations*.; Eliot Freidson, *Professionalism: the Third Logic* (United States: John Wiley & Sons, 2001).
[73] Eliot Freidson, *Professionalism: the Third Logic,* p. 12.
[74] Mintzberg, *Structure in Fives: Designing Effective Organizations*., p. 255. The different ideal-types in his design are: the simple structure, a machine bureaucracy, a professional bureaucracy, and a divisionalized form. See Mintzberg for more information.
[75] Ibid. pp. 253-255.
[76] Ibid. p. 276.
[77] Levi, *On Nuclear Terrorism*. p.5
[78] Ibid. p.142
[79] Ibid. p.6
[80] Max Abrahms, "Why Terrorism Does Not Work?," *International Security*, 2006. p.76
[81] For an extended framework on the different goals of terrorist organizations, see: English, *Does Terrorism Work: A History*. He, for instance, also identified various tactical goals. Reflecting on nuclear terrorism, one could think about, e.g. operational success, prestige and/or outbidding of opponents. The identified inefficiencies are also applicable to these goals.
[82] This is a notion used by Max Weber. In contrast to the instrumental rationality – which I adopt throughout this article – this notion refers to pursuing actions because of the value of these actions themselves.