Washington Internships for Students of Engineering

Tritium: Commercial Cultivation of the U.S. Nuclear Weapons Program

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Prepared for the
American Nuclear Society and the
Washington Internships for Students of Engineering

August 3, 2000

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About the Author

Jason Wilds is currently a senior at Tennessee Technological University studying chemical engineering. The research for this paper was conducted for the Washington Internships for Students of Engineering (WISE) program during the summer of 2000. His participation was sponsored by the American Nuclear Society.

Washington Internships for Students of Engineering

The WISE program is a ten-week internship program designed for fourth year students of engineering who possess interests in public policy and its effects upon technical issues. The students learn how public policy and technology affect each other and the role engineers have in the political process. The summer consists of meetings with various government agencies and organizations directly relating to technology and policy. Committee hearings and other events pertaining to student interests are also attended throughout the summer. The program culminates into a research paper of interest to the student and the sponsoring society which allow him or her to perform a technical analysis of a public policy issue while utilizing the unique sources available in the Washington D.C. area.

Acknowledgments

The author would like to express appreciation to the American Nuclear Society and the Washington Internships for Students of Engineering Steering Committee members for their interests and efforts in supporting WISE and for the opportunity to participate in the program.

Appreciation is also expressed to Dr. Alan Levin for his gracious assistance as a mentor. Thanks also goes out to Dr. Robert Whitesel for support and help in research and Dr. Gail Marcus. The Faculty-in-Residence, Dr. Gil Brown was also instrumental in supplying support and assistance throughout the internship.

A special thank-you goes to the Nuclear Energy Institute and its wonderful employees for their hospitality and supplying office space.

Specifically, Sherry Reilly who served as a mentor and friend throughout the summer, and Leslie Barbour, David Modeen, Samantha Strauss, Ellie Shaw, Jim Hagan, Kimberly Lengerhuis, Vince Gilbert, Rob Dubrow, Joe Colvin, CEO, Angie Howard, and the NEI "Rad Boyz" softball team. Another thanks is in order for Dr. Patricia Dycus, Tennessee Technological University, for her help and encouragement in participating in the WISE program.

Executive Summary

The United States Nuclear Weapons program has been in existence since nuclear weapons were first invented during World War II. The responsibility for maintaining this arsenal is under the jurisdiction of the Department of Energy. In the past, nuclear weapons components and special nuclear materials were manufactured within the department. However, it is very costly to properly maintain a nuclear facility and most DOE facilities capable of producing these components have been shutdown for various reasons.

One major component of these weapons is tritium gas, an isotope of hydrogen. Tritium is used in modern thermonuclear weapons which make-up the entire U.S. stockpile. Tritium production ceased in 1988 after the Savannah River K reactor was shutdown for safety concerns. Originally, new production capabilities were not implemented because existing supplies were replenished with recycled tritium from dismantled nuclear warheads. However, tritium production quickly became a topic of concern when Strategic Arms Reduction Treaty (START) talks slowed and because tritium has a relatively short half-life of 12.3 years and decays rather quickly.

The Department of Energy sought out different proposals to determine the best solution for tritium production. Constructing a new reactor, building an accelerator, purchasing irradiation services from an existing reactor, or restarting a previously shutdown reactor were the options considered. The department analyzed each of these and then issued the decision to produce

Several issues were reflected upon prior to the outcome and will continue to affect the program. The Tennessee Valley Authority heavily lobbied for the DOE to complete construction of its Bellefonte reactors instead of using the existing reactors at Watts Bar. However, the Watts Bar option was eventually chosen. The accelerator was also pursued for its many different capabilities including accelerator transmutation of waste and medical isotope production. The accelerator would have possibly avoided some political issues but cost of construction was high compared to commercial reactor production of tritium.

Many public policy issues are applicable to producing tritium in a commercial reactor. Nonproliferation and the policy of separating commercial and defense nuclear capabilities are areas of imminent concern. Commercial and defense separation has been an important U.S. policy. For instance, President Carter banned reprocessing spent fuel because he believed that doing so would make it easier for a proliferant to obtain special nuclear materials. The Hart-Simpson Amendment to the Atomic Energy Act also prohibited the use of special nuclear material from commercial reactors for defense purposes. Commercial and defense nuclear separation has been an important governmental policy but the use of Watts Bar, for some, appears to be a step in the wrong direction.

Nonproliferation issues are also of imminent concern with tritium production. Tritium is used in a nuclear weapon in which it boosts the destructive capacity. This has the potential to attract proliferation issues among co-signers of the Nonproliferation Treaty. Fortunately, since

Tritium production is essential for maintaining the U.S. nuclear weapons stockpile. Several options for production are available, however, cost and changing demands weighed heavily upon the decision makers. The Department of Energy made the correct choice in using Watts Bar when considering all the necessary issues. The decision was not easy and definitely controversial since it involved nuclear weapons. In the future, nuclear weapons stockpiles may no longer exist and tritium production for defense issues will no longer be necessary.

Tritium: Commercial Cultivation of the U.S. Nuclear Weapons Program

Issue Definition

The responsibility of maintaining the nuclear weapons stockpile is essential to national security and falls under the jurisdiction of the Department of Energy. However, in 1988 it closed down its last means for producing tritium, a necessary component in all U.S. nuclear weapons. A new means for tritium production then became a top priority for the DOE. Several options for producing tritium were available and the cost and political issues of each were evaluated.

This report is an analysis of the issues associated with tritium production. The objective of this report is to analyze the decision made by the Department of Energy and look at all public policy issues effected by the decision. The report is designed to educate those interested in the status of the nuclear weapons stockpile and present the reader enough information to understand the DOE's decision and allow them to reach their own conclusion.

Introduction

Tritium is a major component of the United States nuclear weapons arsenal and its production will invoke many political issues. Traditionally, manufacturing weapons materials has been an "in-house" task for the Department of Energy (DOE), however, in the past several years, lemmas were the main issues in the DOE's decision to produce tritium in a commercial light water reactor.

Nuclear weapons have been in the forefront of concern since the public became aware of their existence. The Department of Energy's decision to produce tritium is no exception, thus invoking two key political dilemmas. First, commercial and defense nuclear functions have traditionally been separated. Some individuals feel producing tritium in a private, utility owned reactor crosses this "line". Conversely, others believe that since tritium is not a special nuclear material under the Atomic Energy Act, as are the fissile materials plutonium and uranium-235 and 233, a problem does not exist.[1] The Department of Energy's decision to use a Tennessee Valley Authority (TVA) reactor simply complicates the issue even further. The Tennessee Valley Authority is a private utility, however, it is a federally-owned organization utilized for defense purposes since its establishment in 1933. Second, nonproliferation issues have been a key concern as well. Tritium is not a special nuclear material. However, its use intensifies the destructive capacity allowing for a reduction in size and weight of the weapon.[2] As a result, based on varying opinion, tritium exudes certain characteristics of a special nuclear material thereby incorporating nonproliferation issues. No existing laws or treaties will be broken, so the only long-term repercussions concerning nonproliferation issues may be to the U.S. nuclear reputation.

It is obvious that difficulties in tritium production are not encountered from technological concerns. Tritium is easily manufactured by several different methods. The dilemma unfolds when the federal government realized in 1995 that a new form of production must be established after stockpile levels fell below minimum requirements and earlier means of production had been

History

The nuclear race began during World War II when American scientists believed that Adolf Hitler was attempting to develop a nuclear weapon. Scientists from the United States as well as those who fled their respective countries from the Nazi regime helped construct the first nuclear weapon. The first weapons test was completed in 1945 at the Trinity test site. Soon after two atomic bombs were dropped on Japan to end World War II. The first, Little Boy, was a gun-type weapon, which propelled two pieces of uranium together causing a nuclear explosion.[3] The second bomb, Fat Man, imploded a critical mass of plutonium. The nuclear weapons race and the eventual cold war accelerated weapons development. A third bomb known as the hydrogen or thermonuclear bomb is where tritium is utilized. This bomb uses the same implosion techniques as Fat Man, but contains more components. The bomb first implodes a central core causing a fission "trigger" reaction, which activates a fusion explosion from a mixture of tritium and deuterium.[4]

What is Tritium

Tritium is a heavy isotope of hydrogen containing a proton and two additional neutrons, thereby tripling its mass. Its existence is so rare in nature that it can not be separated and must be manufactured. The half-life of tritium is 12.3 years or a 5.5% rate of decay per year.[5] It was last produced in 1988 at the Savannah River Site K-Reactor in South Carolina.[6] There are also peaceful uses of tritium, albeit in small quantities, such as glow in the dark materials and airport runway lights.

Reduction in Tritium Supply

The United States and the newly formed Russia signed the first Strategic Arms Reduction Treaty (START I) in Washington, D.C., on July 31, 1991. The treaty is designed to diminish the excessively large number of nuclear weapons, bombers, and ballistic missiles contained in the Russian and United States stockpiles.[7] Initially, the decaying tritium supply was replenished with recycled tritium from dismantled nuclear weapons due to the implementation of START I. Under current conditions, approximately three kilograms of tritium need to be produced on an annual basis by the year 2005.[8] (Exact quantities are classified; 3 kilograms is the requirement for new technologies.) START II, an extension of the first treaty that further reduces weapons stockpiles, was ratified by the U.S. Senate in January 1996. The treaty, after ratification by Russia, will cut the number of allowable warheads in half and only 1.5 kilograms of tritium per year will be necessary and production could be postponed until 2011.

Nuclear disarmament was the original reason for delay in obtaining new production capabilities for tritium since recycled tritium was used to replenish the existing stockpile. Tritium's relatively short half-life continues to complicate matters. The lack of production compounded by the steady decay of existing supplies has heightened the sense of urgency within the DOE.

Tritium Production Prior to 1988

Defense supplies of tritium have always been produced in a government-owned DOE reactor. Prior to 1988, tritium was produced in the K reactor at the Department of Energy's Savannah River Site until the reactor was shut down because of safety concerns, thereby halting boiling, will be required by the Department of Energy. Savannah River K reactor was a heavy water reactor, which is a reactor that uses deuterium as a coolant and is fueled by natural uranium, produced weapons materials and did not operate at higher temperatures and pressures as do power generating reactors. These differences in reactors require new technological developments. Tritium will be produced in pre-existing reactors and new tritium producing components must be manufactured to avoid any significant impact on the operation and safety of the plant. The production of tritium comes from neutron bombardment of lithium six and its eventual decay into tritium and other by-products. The same scientific principles used for tritium production at Savannah River are being used in development for future tritium production.

Background on the Issue

After the cessation of tritium production in 1988, a new means of acquiring the hydrogen isotope was delayed, due to disarmament, until the early nineties. The Department of Energy considered several different options for tritium production including:

- construction of another nuclear reactor
- building an accelerator
- purchasing irradiation services from an existing reactor, or
- restarting the Fast Flux Test Facility.

Many different alternatives for tritium production were examined when it became apparent to the Department of Energy that it would need to resume tritium production. The possibility of building a new reactor was pondered, however the extremely high cost and negative environmental impacts from building a new reactor were major areas of concern. Constructing a new materials, including plutonium and tritium, have been permanently shut down

The Fast Flux Test Facility (FFTF) located at the Hanford Site, near Richland, Washington, was also considered for tritium production on a short-term basis. The FFTF is a 400-megawatt sodium-cooled research reactor used until 1992. The possibility of using this reactor was mentioned, but was met with strong opposition from environmentalists and lawmakers.[9] The FFTF is located on a highly used nuclear weapons site and its restart might add to the existing problem.[10] The necessity to fuel the reactor with special nuclear materials would make its use even more difficult. This is because it could lead to more nonproliferation concerns and only to produce enough tritium for START II level requirements. After initial considerations FFTF production was quickly abandoned as an option.

Accelerator Production of Tritium

The back up to reactor production, as selected by DOE, is accelerator production of tritium (APT). Accelerator production of tritium has been very controversial since the Department of Energy began discussing tritium production. The accelerator brings an important twist to the tritium program. Accelerator construction cost is at least 2 billion dollars and electricity consumption would be very costly.[11] APT differs from reactor production because the nonproliferation issues concerning an accelerator are not yet defined.

Constructing an accelerator as a defense facility would avoid many of the proliferation concerns associated with a reactor. However, the accelerator has the potential to produce special nuclear material in quantities of proliferation concern.[12] Nonproliferation problems with an accelerator are different from a commercial use reactor. However it is possible that they could be-

Accelerator construction has a number of potential uses beyond tritium production. A recent report from The Senate Energy and Water Appropriations Subcommittee directs the Office of Nuclear Energy, Science, and Technology to establish an Office of Advanced Accelerator Applications to conduct research on accelerator transmutation of waste, material science, and as a backup to the tritium production program.[13] Accelerator transmutation of waste will allow reactor waste to be broken down into safer materials using an accelerator to split up the radioactive components. Medical isotope production has also emerged as a very profitable capacity of an accelerator. These isotopes are used for diagnosis and cutting edge treatments. The accelerator project for tritium was only chosen as a back up and its complete design was all that was called for concerning tritium. Coincidentally, if the triple mission had been used as justification for accelerator construction, its dual use would have raised proliferation issues similar to commercial reactor production.

DOE's decision: Complete Bellefonte or use Watts Bar

When DOE first issued requests for proposals on June 4, 1997, for commercial production of tritium, many commercial utilities expressed interest.[14] But when the public began to show signs of resistance, TVA emerged as the only utility to submit a bid to produce tritium for DOE. Initially, TVA saw this as an opportunity to finish construction of its Bellefonte reactors. Bellefonte Nuclear Power Plant construction began in February 1975, but construction was postponed in 1988 citing a lower electricity load forecast for the future.[15] Currently, one pressurized water reactor is 60% complete and the other is 90% complete.[16]

Fortunately, TVA's bid contained two proposals. One was to complete the Bellefonte

Bellefonte was completed, its initial use been for defense purposes, nonproliferation issues might have been avoided. If tritium demands dwindled in the future, converting Bellefonte from a defense reactor into a commercial power reactor would have avoided the difficulties associated with the defense use of a commercial facility at Watts Bar as well.

The bidding process between DOE and TVA was quite heated. At one point, TVA removed its bid for Watts Bar production of tritium. The economic advantages of completing the idle reactors at Bellefonte were very important to TVA. However, early in December of 1998 the Tennessee Valley Authority resubmitted their bid for Watts Bar production of tritium. The decision concluded when Secretary of Energy Bill Richardson announced the commercial light water reactor at Watts Bar as the chosen tritium production site on December 22, 1998. Low cost was cited as the overwhelming reason for choosing this option. The cost of approximately $2.0 billion for the completion of Bellefonte or construction of an accelerator was also the estimated cost of a current life-cycle contract for producing tritium at Watts Bar.[17] Even though the decision made by the Department of Energy was not the one most appealing to TVA, due to the lower cost and flexibility of using an existing CLWR, it was certainly justified.

CLWR Production of Tritium

After months of deliberation, the commercial light water reactor was selected as the primary source for tritium production. Several criteria were used when contemplating the best means for tritium production. Environmental, scheduling, cost, capacity, and reliability risks were cited as important requirements considered in the final decision.[18] The CLWR was named the best option because it met each of these requirements. Flexibility was a major component of

Other political concerns, including nonproliferation were seen as manageable risks. The DOE considered as many factors as possible when making the decision. Looking at the feasibility of each option, the easiest choice was fairly obvious. However, with any political decision many unseen factors must also be considered. The United States has been the predominant party in promoting commercial and defense separations of nuclear uses. Even though commercial production was more attractive considering the large costs of a new facility, the ramifications to foreign policy have the potential to be even more costly.

Technology Associated with Tritium Production in CLWR

The technology necessary to upgrade the existing reactors was not initially available since tritium production ceased at the Savannah River heavy water K-reactor. Only pressurized water reactors will be used for tritium, which are different from the heavy water reactor used at Savannah River. Watts Bar tritium production only necessitates changes in the burnable absorber rods (BAR) used in the reactor. Traditionally, a boron rich BAR is used in CLWRs. However, to produce tritium, a special burnable absorber rod containing an isotope of lithium, Li^6, must replace the boron in the BAR. These BARs are referred too as tritium-producing burnable absorber rods (TPBARs) and absorb excess neutrons in a nuclear reactor to keep the chain reaction under control. The only current restriction dealing with the use of these new bars is the time frame desired for the first shipment of tritium and deterioration of the absorbing rods. Over time boron BARs become less effective at absorbing the excess neutrons in a nuclear reactor unlike TPBARs, which retain their initial absorption capabilities throughout the fuel cycle.[19] Neutron absorption is even enhanced during the fuel cycle because tritium begins to decay into hereplaced during refueling.[20] If 2000 TPBARs or less are used in each reactor most difficulties involving fuel assembles can be avoided. Fuel enrichment is also an important concern because commercial reactors use uranium at 5% enrichment or less, and if too many TPBARs were used, a higher level of enrichment would be necessary causing problems with licensing amendments from the Nuclear Regulatory Commission. This poses the need to use more than one reactor, Sequoyah Reactors I and II. Under START I requirements it is necessary to irradiate four thousand TPBARs per year or 6000 over an 18-month average fuel cycle; START II would cut the tritium production requirements in half.

Currently, the tritium production office with-in DOE is testing 32 TPBARs at the Watts Bar reactor. In October of 1997 these TPBARs were placed in the reactor and irradiated until February of 1999.[21] The TPBARs were then shipped to Argonne National Laboratory-West where they will be nondestructively examined and then selected TPBARs will be destructively examined at Pacific Northwest National Laboratory.[22] TVA and Watts Bar will begin licensing amendments with the Nuclear Regulatory Commission in the fall of 2000 and plan to begin producing tritium in 2003, so it will be available in 2005.

Public Policy Issues

Commercial and Defense Nuclear separation

The use of nuclear energy has been a controversial issue ever since its inception. The first large-scale display of such a powerful source of energy was a result of defense productions. Initially, there was a debate as to whether all nuclear capacities should be classified or if its capabilities for producing power should be shared. The United States quickly emerged as a leader clear energy. In the meantime, the Soviet Union and the U.S. were concurrently emerging as nuclear super powers and beginning the cold war.

The United States demonstrated its commitment to nuclear and defense separations by allowing public utilities to build nuclear power plants and preserving its own defense reactors within the Department of Energy. One key example of this commitment was President Jimmy Carter's decision to prohibit the reprocessing of spent nuclear fuel in 1979. Reprocessing spent nuclear fuel drastically reduces the large volumes of radioactive waste and allows for recycling of unused uranium. President Carter wanted to prevent the theft of this reprocessed material and encourage other countries, by U.S. example, to do the same. Reprocessed waste has the potential of being used in a nuclear weapon and the President wanted to deter other countries from possibly stockpiling this material. The President's decision was certainly understandable, but no foreign countries have followed our lead due to the financial repercussions encountered by not recycling spent nuclear fuel.

Another example of separation is the Hart-Simpson Amendment to the Atomic Energy Act which prohibited the use of special nuclear material obtained from commercial reactors for defense purposes in 1983, which reaffirmed the separation of commercial and defense nuclear activities.[23] This illustration of separation clearly shows the government's commitment to maintain the separation among nuclear capabilities.

The civilian/military separation has not been definitive. For example, the Hanford-N reactor sold excess steam to power companies in order to profit from its energy, while producing weapons-grade plutonium. Uranium enrichment suppliers have produced uranium for military and civilian uses in the past, however the United States Enrichment Corporation is now limited

One could avoid the issue of defense and commercial separation because TVA is a government entity and is warranted in producing defense materials in its reactors. The Tennessee Valley Authority Act specifically mentions "in the interest of national defense" as one of the reasons for its inception. In case of war, the United States has reserved the right to repossess TVA for war purposes, and TVA is charged with the responsibility of producing explosives for the United States Army and Navy, as mentioned in the Act.[25] Nevertheless, the Tennessee Valley Authority functions as a private utility and should be treated accordingly. The Department of Energy, instead of avoiding this area of the issue actually names this as a constructive argument for using Watts Bar. By choosing to not construct a significant new weapons facility, which would be looked upon as building up our weapons production capabilities, the U.S. can underscore to other nations its continuing pursuit of smaller nuclear weapons stockpiles.[26] This approach does allow more room for rationalization of using TVA facilities.

Nonproliferation Implications

Throughout the entire decision-making process concerning tritium, perhaps the most overwhelming fear was nonproliferation reprimands. Technical matters and economic dilemmas were easily evaluated and clarified. Tritium production in a commercial reactor and its use in nuclear weapons create the sensitivity of the topic.

After the rapid development of nuclear weapons in the United States during World War II peaceful uses of nuclear power were soon developed. These developments were strongly encouraged by President Dwight D. Eisenhower's *Atoms for Peace* address presented to the United Nations in 1953.[27] He called for a united effort among world nations to promote peaceful uses

The International Atomic Energy Agency (IAEA), an organization within the United Nations, is the central body responsible for scientific and technical cooperation in the nuclear field. However membership and all inspections in a member country are on a voluntary basis.[28] It is an impartial entity that inspects nuclear facilities of member countries to ensure that special nuclear materials are not being manufactured. The IAEA, fortunately, has confirmed that there is not a legal impediment with U.S. production of tritium in a facility eligible for IAEA inspections, which includes all commercial nuclear power plants in the United States.[29]

Nonproliferation is an extremely important issue for many nations. Under the Nonproliferation Treaty only the United States, Russia, United Kingdom, France, and China are classified as nuclear weapons states while the other one hundred and eighty-two members are non-weapons states. It is quite clear why so many nations have a justification to be concerned with the United States nuclear weapons program. Every non-weapons state, as classified by the Nonproliferation Treaty, has an imminent desire to see the termination of nuclear arms considering their respective nations security concerns and inability to possess nuclear weapons.

The nonproliferation issues and foreign policy repercussions may be the most detrimental affects of the tritium decision. Future relations with individual countries could be effected. The tritium production program might give other nations the idea that the United States was not serious about nonproliferation and they could again justify using commercial facilities for weapons purposes. The U.S. has strongly persuaded other nations to follow its lead in peaceful uses of nuclear energy. However, producing tritium in a commercial reactor may cause other nuclear powers to reconsider the United States role in nonproliferation talks.

Concerns within the Industry and the American Nuclear Society

The American Nuclear Society and professionals within the industry do not have a uniform opinion on this issue. Individuals working on both sides of tritium production are members of the American Nuclear Society, so a formal position was never taken. Educators at American universities and those in the industry are also divided concerning this decision. Many feel that the decision to use TVA was justified for one of two reasons. First, the separation of commercial and defense nuclear power has been crossed so many times the separation has become blurred. Second, TVA already functions as a government entity. The controversy dealing with tritium is warranted due to the obvious separation of opinions among those dealing intimately with the industry.

Conclusion

The decision of how and where to produce tritium for the Department of Energy was not an easy one. The judgement was based on varying opinions and could not only be based on simple hard facts and figures. First, the United States must maintain its nuclear weapons arsenal. The country was the first nuclear superpower and will continue to be as long as nuclear threats exist. In the future, perhaps Strategic Arms Reduction Treaty talks will continue and nuclear arms will cease to be a national concern.. Nevertheless, the weapons stockpile, in order to function as designed, must be supplied with tritium. Therefore, the United States is required to manufacture tritium, regardless of production technique.

Second, the Department of Energy was somewhat limited as to how it was to obtain tritium. It was the opinion of those within DOE that the risks associated with constructing a new much cheaper compared to the same price for a twenty-five to forty year contract for purchasing irradiation services in a commercial light water reactor.

The Department of Energy faced a difficult predicament when charged with the task of producing tritium. Cost to the taxpayer and foreign policy consequences probably weighed most heavily upon the decision-makers. Whether or not the right decision was made, the reasoning behind the final result was definitely logical.

Researching the political decisions involving the upkeep of our nuclear weapons stockpile has posed many difficult questions. The complexity of this issue initially appears rather straightforward, yet quickly becomes difficult and complex. In discussing tritium production among professionals within the industry, representatives of the federal government, and knowledgeable, concerned citizens one sees many opinions arise without any sign of consensus.

The entire debate centralizes into one simple question. It is not can we, but should we produce tritium and if so, by what means? The Department of Energy was issued the responsibility of answering this question despite a vast array of opinions. Nevertheless, DOE made a decision which I believe they considered was in the best interest of the country. I agree with their decision based upon costs to the taxpayer and future reductions in nuclear weapons.

The decision to produce tritium or nuclear weapons is not a glamorous position to uphold. In the interest of the country, the Department of Energy has been issued with this responsibility. Given the facts and policies available, DOE made the most appropriate decision to produce tritium at Watts Bar. Someday all facets of nuclear energy may be used for peaceful purposes and nuclear weapons will no longer be a threat to world stability.

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