LALP-95-106
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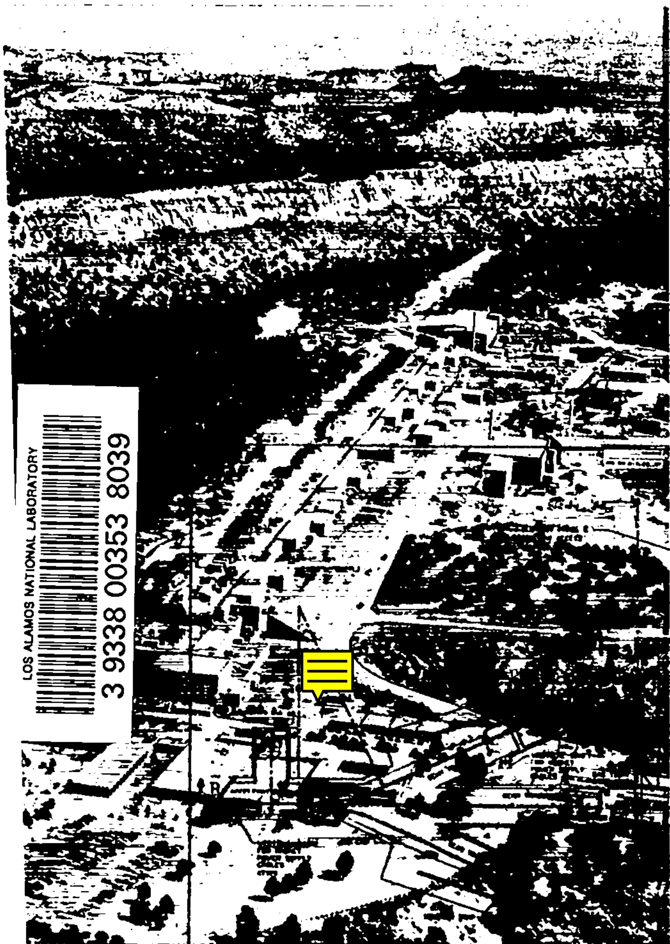
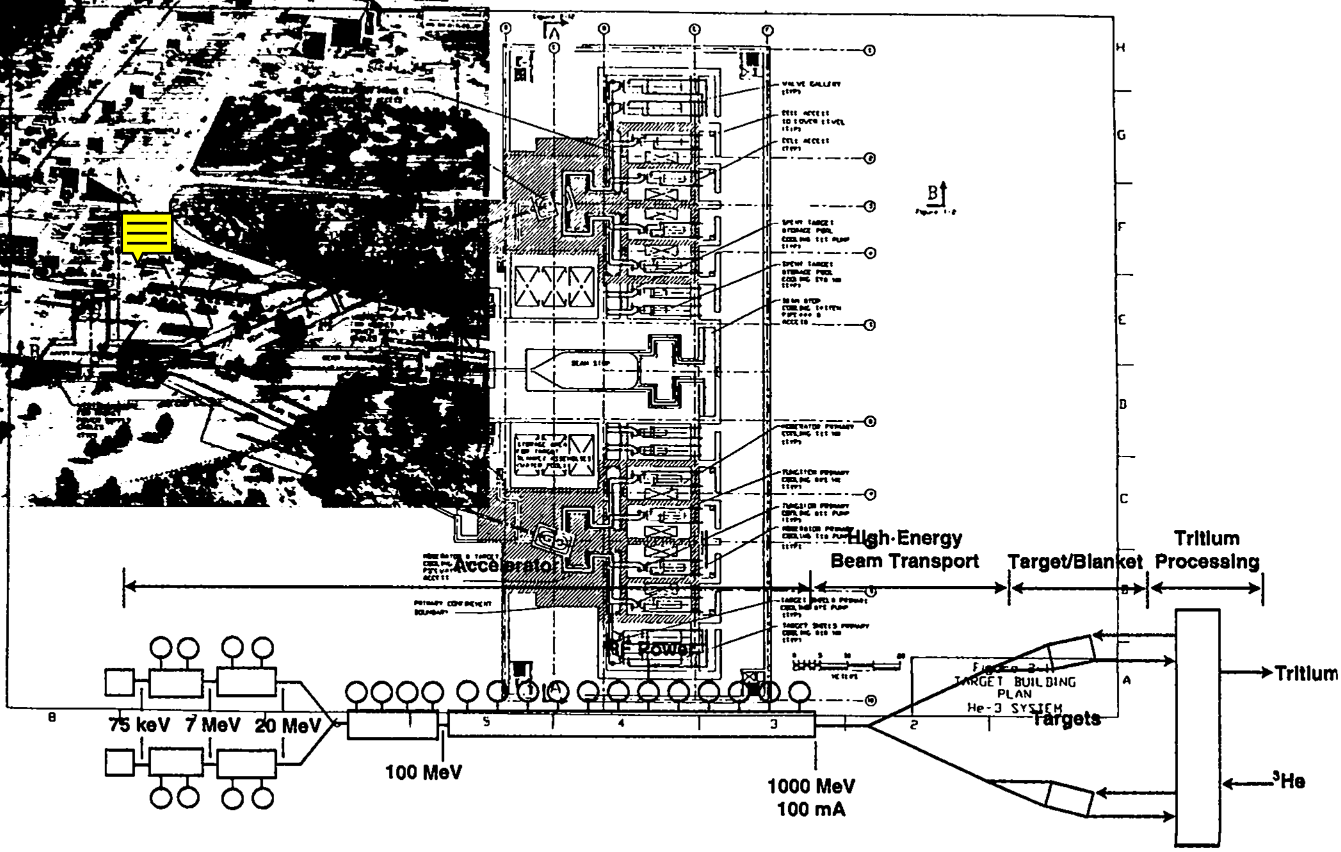
Accelerator Production of Tritium

An Assured Source for Nuclear Deterrence



The Los Alamos Meson Physics Facility, where APT components are being tested. The APT facility will be built elsewhere.



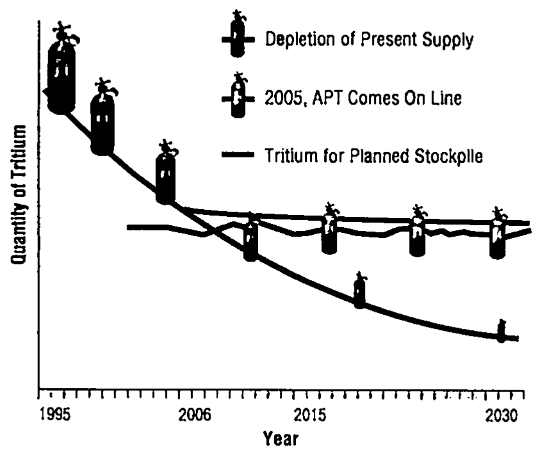
Tritium Is an Essential Element to Sustain the Nation's Defense

APT technology can be used elsewhere to

- *study radiation damage for materials*
- *make heat sources for space power applications such as the Galileo mission*
- *aid in using accelerators to destroy radioactive wastes*
- *aid in producing nuclear energy without nuclear waste*
- *produce medical radioisotopes*

For 50 years the existence of nuclear weapons has been an important component of the United States' strategy to deter major international war. Today, maintaining an adequate defense through both conventional and nuclear arms remains the best means to ensure continued peace. A reliable supply of tritium is necessary to maintain the nuclear part of our defense structure. Since tritium decays (to ^3He) at the rate of 5.5% per year, it must be continuously replenished. Present tritium requirements are being met through excess supply and the reuse of tritium recovered from dismantled nuclear weapons, but this will not be sufficient for future needs. The Department of Energy (DOE) estimates that in order to maintain the strategic nuclear weapons remaining in the enduring stockpile, a tritium production capability must come on line in 2005.

The DOE released a Programmatic Environmental Impact Statement (PEIS) in March 1995 that considers several types of nuclear reactors and an accelerator for the new source of tritium. Reactors can certainly produce tritium, but they face institutional issues associated with their potential impact on the environment, safety, and health. A better alternative is APT, in which neutrons produced in a linear accelerator can be used to produce tritium.



Tritium is lost to radioactive decay at the rate of 5.5% per year. In the time frame 2005–2012 new supplies of tritium must be produced to maintain the nation's nuclear stockpile.

An Accelerator System Is a Clean, Environmentally Sound Source of Tritium

Production of tritium at a sufficient quantity requires an abundant source of neutrons. APT can produce the required neutrons without fissile materials or chain reactions. Neutrons and tritium are generated only while the accelerator is operating. When the accelerator is shut down, there are no runaway fission processes than can generate energy and lead to an accident. Further, the amount of radioactivity produced and confined in the target is much less than from any other source of tritium. There is no chance of a criticality accident, and no high-level radioactive waste is produced.

Accelerator Production of Tritium	Reactor Production of Tritium
no fissile materials	*fissile material (uranium)*
minimal environmental effects	*significant environmental effects*
more easily sited	*difficult to site*
no high-level radioactive waste or spent nuclear fuel	*high-level radioactive waste and spent nuclear fuel*
immediate shutdown, little residual heat from radioactive decay	*slower shutdown, larger amount of residual radioactive heat—requires continuous, active cooling*
easily scaled up or down to meet stockpile needs	*more difficult to scale up or down*
constant extraction of tritium does not allow tritium to build up so potential for significant release is minimized	*tritium allowed to build up, potential for large release*
no chance of a criticality accident	*chance of a criticality accident*
confinement accomplished simply	*numerous, complicated containment systems necessary*
engineering simplicity provides for inherent safety advantages	*engineering complexity provides for complex safety issues*
low up-front funding and lower capital costs	*high up-front funding and higher capital costs*

How an Accelerator System Produces Tritium

In order to make the necessary, abundant source of neutrons to produce tritium, the APT facility will produce protons in a linear accelerator and use them to bombard a heavy-metal target, such as tungsten or lead. The resulting neutrons are then captured in helium (^3He) gas flowing through the target to react with the neutrons to make tritium. In the extraction/purification subsystem the tritium is extracted from the ^3He gas and separated from impurities for use in the stockpile. (This process has already been demonstrated on a scale much larger than that required for the APT system.) In the APT design, this process takes place continuously. Unlike in reactors, tritium does not accumulate in the target system, thereby avoiding major releases of tritium in an accident; and the tritium is provided to the stockpile rapidly, minimizing loss from natural decay.

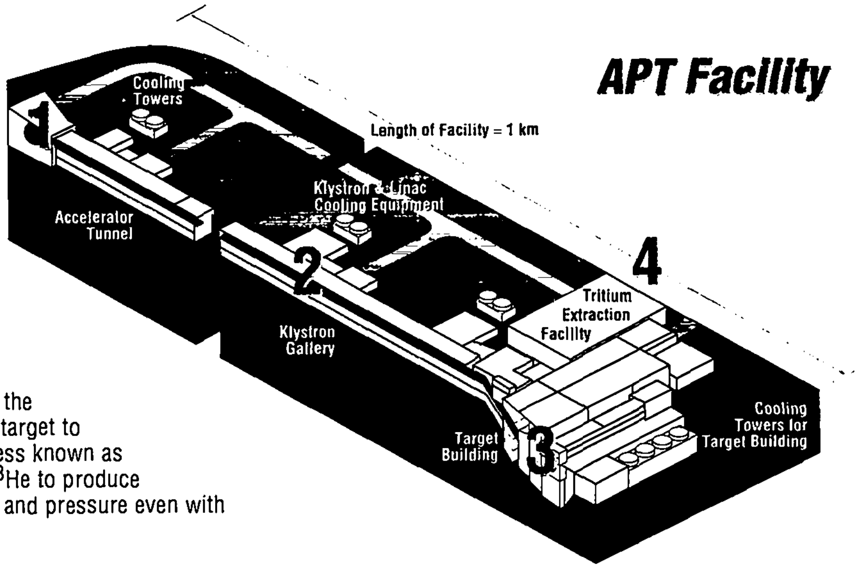
1 ***Injector Section*** The proton beam that is used to produce tritium begins in the APT injector. This beam is formed by ionizing hydrogen atoms and accelerating them to form a low-energy proton beam.

2 ***Accelerator Section*** Here the proton beam is accelerated until it ultimately reaches 95% the speed of light. The accelerator is approximately 1 kilometer (0.7 mile) long and uses well-tested technology to assure that the final energy is reached.

3 ***Target/Blanket Section*** At the accelerator exit, the beam is expanded to distribute the protons evenly across the face of the target. The expanded proton beam strikes a tungsten and lead target to produce about 26 neutrons per proton through a nuclear process known as "spallation." Neutrons are then slowed and finally captured in ^3He to produce tritium. The APT target/blanket will operate at low temperature and pressure even with 100 MW of proton beam power.

4 ***Tritium Extraction Facility*** The tritium produced in the target/blanket is extracted continuously and purified. The technology for this process has been successfully demonstrated at full scale for the fusion energy program. In addition, the process has been designed and tested to prevent release of radioactive tritium to the environment.

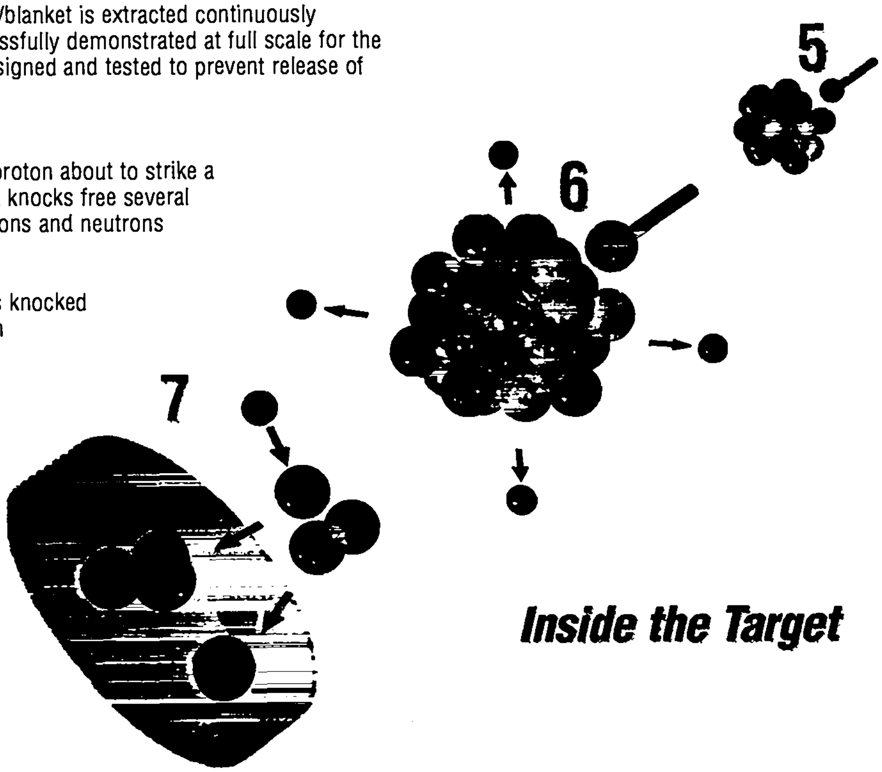
APT Facility



5 ***Proton Striking Tungsten Nucleus*** This illustration shows a proton about to strike a tungsten nucleus. Because of the high speed of the proton, it knocks free several neutrons and protons from the tungsten nucleus. Those protons and neutrons have somewhat lower energies than that of the initial proton.

6 ***Spallation Process*** In this case, one of the energetic protons knocked out in the initial collision is shown striking a second tungsten nucleus. The process described in illustration 5 above is repeated, producing a "cascade" of neutrons, protons, and other light particles. The spallation process is further enhanced by neutrons "evaporated" from the residual nuclei. Tungsten neutron sources using the spallation process have operated successfully at Los Alamos over the past 20 years.

7 ***Moderation and Capture*** Neutrons are captured in ^3He to make tritium much more efficiently if they are going at low speed. This is done in APT by moderating them in heavy water. Once slowed down, they strike a ^3He nucleus and are absorbed to form tritium.



Inside the Target

APT Offers a Highly Reliable Source of Tritium for the Future

Because of tritium's importance to the U.S. nuclear deterrent posture, any new production method must provide confidence that the technology can work and that the schedule requirements can be met. A national laboratory/DOE/industry team has accomplished a design study, provided input to the DOE PEIS, made comparisons with other technologies, and had many positive independent reviews. National laboratory partners Los Alamos, Brookhaven, Livermore, and Sandia will continue to confirm the low environmental impact of APT and will complete the essential technology demonstrations.

The system design behind the APT facility is based on well-established, existing technology in the areas of operational accelerators, tritium extraction, and neutron targets. Its dual, redundant target systems assure a reliable supply of tritium.

Scientists will verify the production efficiency of APT using prototype targets at low power in the Los Alamos Neutron Science Center. At the same time, they will fabricate and operate an engineering model of the accelerator to be used at the plant to verify its long-term performance. Industry will contribute to a detailed conceptual design, will lead the engineering design and construction of a full-scale plant (at a site to be determined in the future), and will contribute to its conceptual design and serve as a partner in the technology demonstrations. The system design behind the APT facility is based on well-established, existing technology in the areas of operational accelerators, tritium extraction, and neutron targets. Its dual, redundant target systems assure a reliable supply of tritium. In the words of the 1995 JASON Review, "APT is a viable option for meeting the U.S. needs for tritium production."

"APT is a viable option for meeting U.S. needs for tritium production." —JASON review 1995

APT Scheduling and Costs Are Reasonable

The timetable calls for a project start after a Record of Decision by the DOE in FY1996 with technology demonstrations and concurrent design activities over the following four years. Site preparation and facility construction will begin in FY2000 followed by operation and tritium production in FY2005.

The total operating cost of the plant will be between $120M and $200M, depending on the cost of electricity. Although reactor options for tritium production could potentially generate revenue through power production, non-proliferation issues and a prohibition against DOE competition with private-sector utility companies have led to very little income from government reactors in the past. Without power generation income, the annual cost of reactor- and accelerator-produced tritium are similar.

The APT development team includes the DOE, national laboratories, the DoD, and industrial partners.

Program requirements for APT in FY1996 are $75M to begin the design and technology demonstrations. The total estimated cost of the facility, including the four-year work preceding construction, is $2.5B. APT has a lower capital cost and smaller construction expenditure rate than other proposed new tritium facilities.

Project Office

For more information on APT, please contact:

APT Project Office
Phone 505-665-5523
Fax 505-667-4344
e-mail apt_po@at.div.lanl.gov

Los Alamos
NATIONAL LABORATORY
Los Alamos, New Mexico 87545

LALP 95-106

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