**What is U-233?**

Uranium-233 (or U-233) is a special form of the element uranium. It is not found in nature.

**How much U-233 is there? What is its status?**

America has a globally unique inventory of about 400 kg of U-233 at Oak Ridge National Laboratory (ORNL) that is being destroyed as part of a program that started 18 years ago.

**What are the uses of U-233?**

1. Thorium fuel cycle.
2. Source of medical radioisotopes – Th-229, Ac-225 and Bi-213.
3. As a tracer material in nuclear research.

**How is U-233 made?**

By shining the element thorium with subatomic particles called *neutrons*.

**When and where was the American inventory of U-233 made?**

It was created in weapons production reactors at Hanford and Savannah River between the years 1964 and 1970.

**What happened to other inventories of U-233?**

Other inventories of U-233 from Idaho National Lab (INL) and ORNL were disposed of at the Nevada Nuclear Security Site (NNSS) in violation of DOE's own safeguard and security requirements and NNSS' waste acceptance criteria.

**What was the historical cost of making U-233?**

A 1999 report by ORNL estimated historical cost of U-233 at $3 – $6 million per kg (in 2021 USD). Thus, the 400 kilos cost between **$1.2 – $2.5 billion** to create and store.

**What is the cost of making new U-233?**

The same study suggested that without the production reactors of the Cold War era operating today, production of U-233 would cost ~$46M per kg (in 2021 USD).

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**Which countries are pursuing thorium reactors?**

China, India, and Russia among other nations are pursuing thorium reactor programs.

**When did the Chinese thorium reactor program begin?**

Chinese Academy of Sciences (CAS) announced the Thorium Molten-Salt Reactor (TMSR) program in January of 2011. Local news in Tennessee reported a marked increase in Chinese visitors to ORNL in the years leading up to the announcement.

**What is the program budget?**

TMSR program began with a startup budget of $350 million which has since grown to $3.3 billion.

**What is the purpose of such a large budget?**

China is aiming to build thorium-powered aircraft carriers.

**What are some achievements of the program?**

The program has revived needed ancillary technologies such as lithium-7 separation, graphite manufacturing etc. In association with the Australian Nuclear Science and Technology Organization, the program created a new class of corrosion-resistant alloys. These developments clearly demonstrate that the CAS program is aimed at establishing a supply chain and signify China's intentions on commercializing the technology.

**Evidence of China's progress and commitment?**

Video from 2012 where CAS director discusses program objectives.

CAS promotional video from 2018 discussing developments in TMSR program.

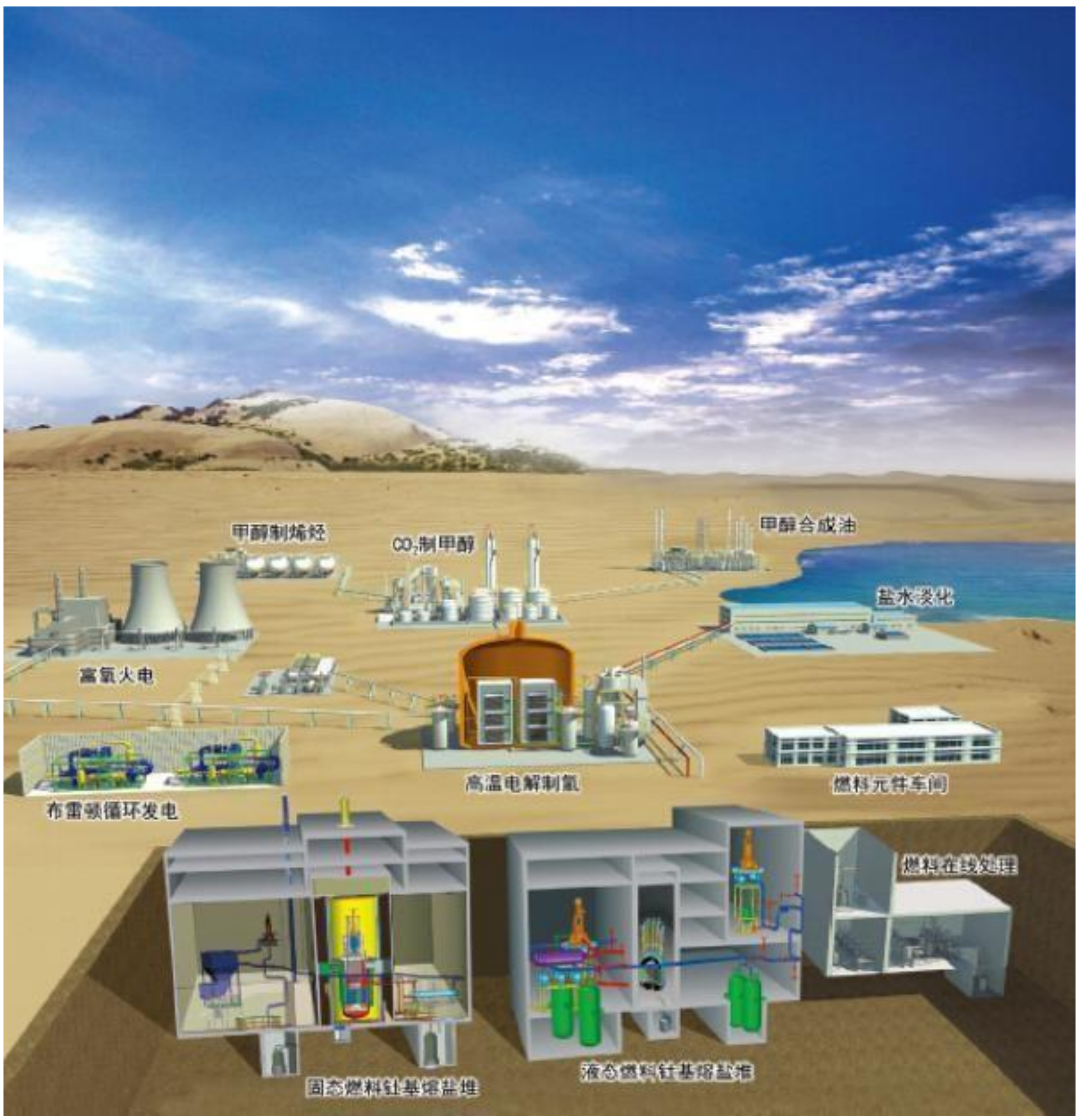


*Figure 1. Chinese TMSR plant concept (source: handout by Shanghai Institute of Nuclear and Applied Physics).*

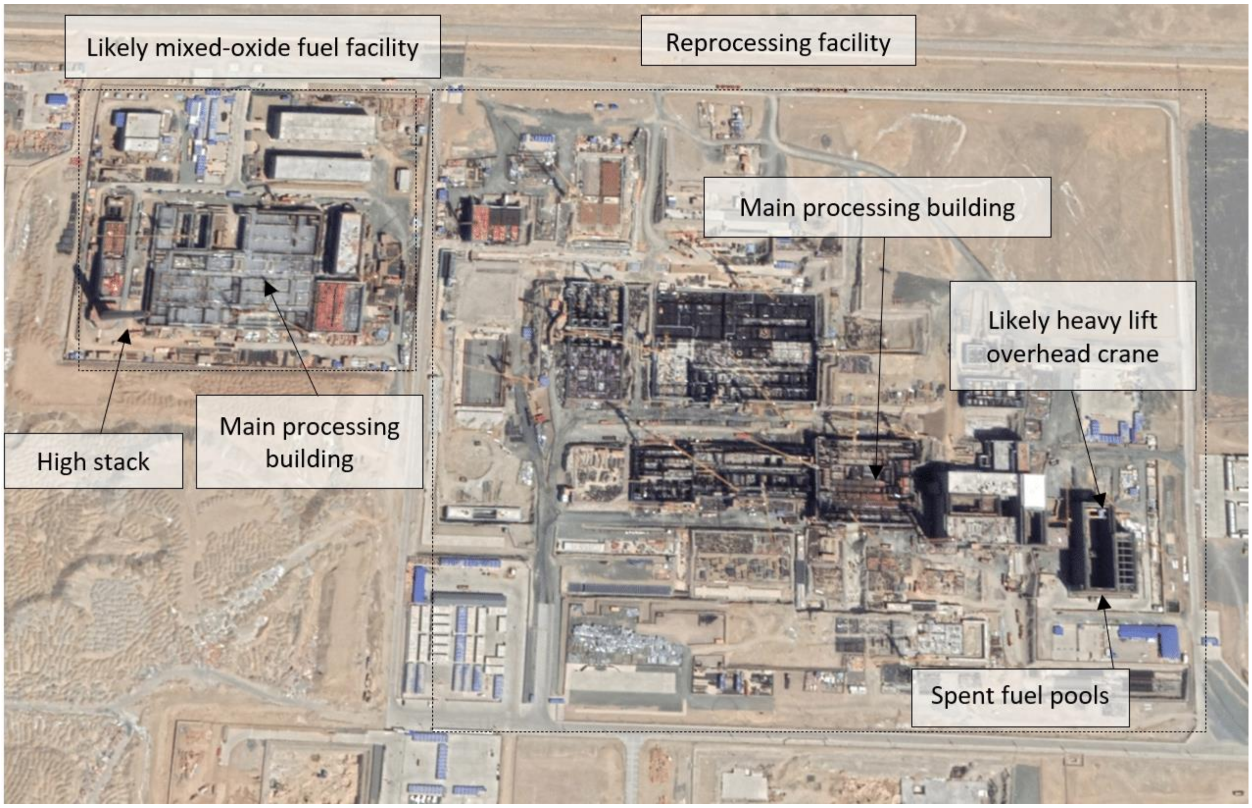


*Figure 2. Satellite image showing construction of Chinese nuclear industrial park [in Gansu where thorium reactors] are being developed (source: [Bulletin of Atomic Scientists], image credit: Google Earth).*


*Figure 3. Screenshot from promotional Chinese video on thorium reactors touting partnerships with major American institutions.*

**How did America become involved?**

The Department of Energy initiated a memorandum of understanding (MOU) with Chinese Academy of Sciences to aid in the development of thorium reactors.

**Does the US have an active thorium reactor program?**

No.

**How can the US cooperate with another country on a reactor we currently do not study?**

This question was raised by several journalists in the wake of the MOU. Links: 1, 2, 3.

**Who initiated the MOU?**

Former Assistant Secretary of the DOE, Dr. Peter Lyons started the MOU. Dr. Lyons even visited Shanghai to reaffirm commitment and served as the executive co-chair of the MOU committee.

**What did Lyons have to say about thorium reactors?**

Dr. Peter Lyons, on two separate occasions (2011 & 2014) told Congress that there was no advantage to pursuing thorium reactors, even though he initiated the MOU with China in 2012.

**Evidence of U.S. collaboration with China on thorium reactors**

DOE was reticent on discussing the MOU with China which led to a Freedom of Information Act (FOIA) request by advocates.

ORNL issued a press release in 2015 saying that as part of a 10-year agreement they are receiving $5M annually from the CAS for research. The statement also nonchalantly explained that the CAS is providing the entirety of the funding for the "cooperative" agreement.

A book published in 2017 by author Victoria Bruce[1] discusses the Chinese thorium program and America's involvement at length. The following relevant quotes are taken from the book:

A top molten-salt reactor expert at ORNL is quoted as saying, "It's true, China will be paying my salary." He goes on to say that "[the Chinese] are going to do a lot of testing that we simply don't have the money for," and that the Chinese are going to get a lot of experienced ORNL scientists to "help provide some guidance."

The book quotes **Chen Kun**, who acted as liaison between the Chinese and Americans on the MOU, as saying that "the collaboration isn't exactly a partnership," because "the funding contributions are not equal."

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**When did the U-233 disposition program begin?**

The U-233 disposition program was initiated in 2003 following a recommendation by the Defense Nuclear Facilities Safety Board (DNFSB) in 1997 to ensure safe storage of American U-233

[1] Victoria Bruce, *Sellout: How Washington Gave Away America's Technological Soul, and One Man's Fight to Bring It Home*, Chapter 21 – The First to Eat a Crab, Bloomsbury Publishing USA, 1st Edition (Jun 2017).

inventories. The DNFSB is not a regulatory body and did not recommend disposition. DNFSB considers the DOE program to be an extension of its recommendation. DOE had cited that additional inventories of U-233 at INL made the ORNL inventory excess.

**What does the chosen disposition pathway of "down-blending" entail?**

Down-blending will convert the solid U-233 into a nitrate liquid, mix it with depleted uranium nitrate, and dry and package the waste with cement into a solid form for ultimate disposal at the NNSS.

**Cost hikes and delays**

Early estimates of the program that started in 2003 very quickly turned out to be overly optimistic as noted by a 2005 Congressional report citing **a 3.5X increase**. In 2007, a GAO report criticized the DOE program for failing to make sufficient progress and noted that the estimated cost had risen to **$433 million**.

In a 2008 special report, then-DOE IG Gregory Friedmann recommended DOE to reconsider the U-233 disposition program due to its uses for harvesting medical isotopes and its importance in developing thorium reactors. In his report, the IG states that **"there is potential for [U-233] to contribute to vital national interests,"** and that **"should the nuclear renaissance expand to include thorium cycle reactors, this material could be vital."** The IG concluded that the **disposal plans provided no assurance that U-233 or its progeny isotopes would be available to support U.S. fuel cycle and medical research needs**. In addition, the IG pointed out that the INL inventory that DOE cited as being sufficient to support future research needs had already been disposed of by 2008 when the report was written. DOE management ignored the report citing lack of Congressional directive.

In a second report in 2010, IG Friedman which focused on delays and escalating costs. The report concluded that "the Department's uranium-233 disposition project had encountered a number of design delays, may exceed original cost estimates, and will likely not meet completion milestones." By 2012, baseline estimates had ballooned to **$511 million**. Late last decade, the project was modified to add an option to make an exclusive sale of valuable medical isotopes to a third party. The project is still underway with $648 million spent and a total contract value of **$935 million.**

**Previous attempts at preserving U-233**

Dr. John Snyder, a retired manager from INL, tried to consolidate the U-233 at INL.