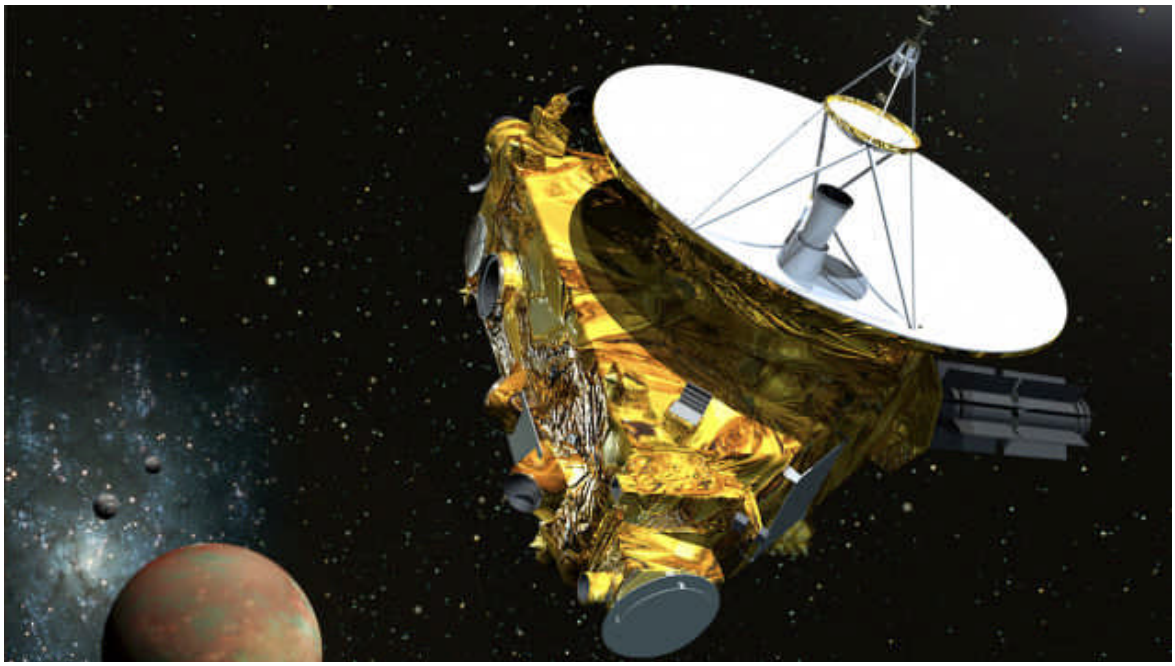
GIZMODO

We're Running Out of the Nuclear Fuel That Powers Space Travel

Sarah Zhang
Filed to: ROSETTA 12/02/14 12:30pm



Rosetta's lander lasted just 60 hours on a comet after it bounced into the dark shadows of a cliff, w ldn't power the vehicle. Why didn't it carry a more reliable power source, say a nuclear battery li ly fueled Voyager for decades? It's a simple question with a fascinating answer, one that begins with the Cold War and ends with the future space exploration.

When it comes to space travel, plutonium-238 is the perfect fuel: long-las , as I'll e lain later, relatively safe. Without it, we have no hope of going much further than Mars, after which it simply becomes too dark to rely on solar panels, the most common alternative power source in space. But the world is rapidly running out of plutonium-238. Because we've stopped making nuclear weapons.

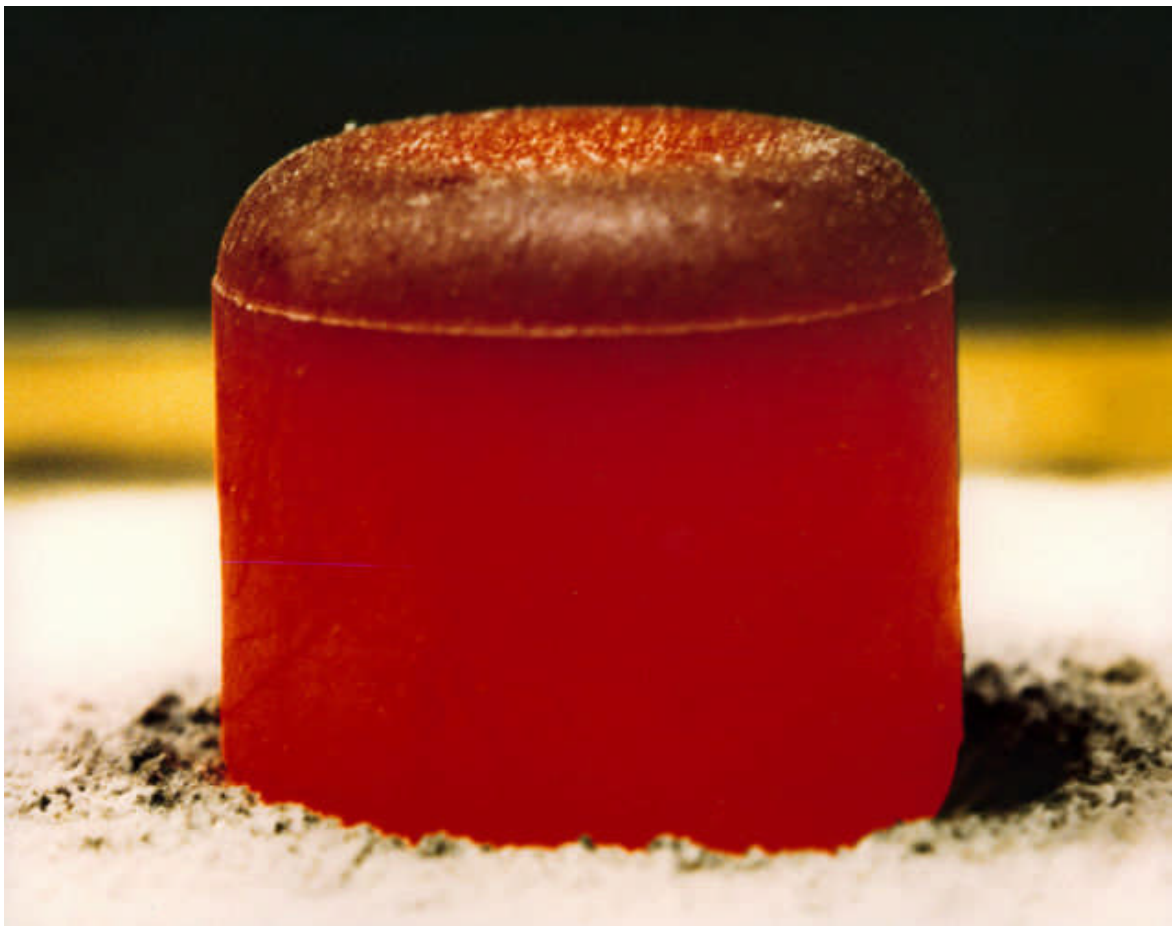
Cold War origins

Plutonium-238, you see, is a byproduct of producing plutonium-239, better known as the main ingredient in nuclear weapons. During the Cold War that birthed the space race, this was a rather convenient fact. The Savannah River Site in South Carolina that made plutonium-239 for bombs also turned out plutonium-238 for satellites and space probes. A

1980s (only to linger as an environmental disaster), NASA began buying plutonium-238 from Russia.

NASA has sent since pellets of plutonium-238 on the two Voyager spacecraft, the Curiosity rover on Mars, and several other space probes exploring the dark outer reaches of our solar system.

Plutonium-238 also happens to be the perfect fuel for spacecraft. Although highly radioactive, the kind of radiation it emits does not easily penetrate through other material, making it safe. Wrapped in iridium metal, pellets of plutonium-238 glow red hot, giving off plenty of heat. As long as these pellets don't crack, radiation is not a concern. The pellets are placed in radioisotope thermoelectric generators (RTG), which turn the heat into electricity. It can last years, even decades in the case of Voyager now exploring interstellar space.

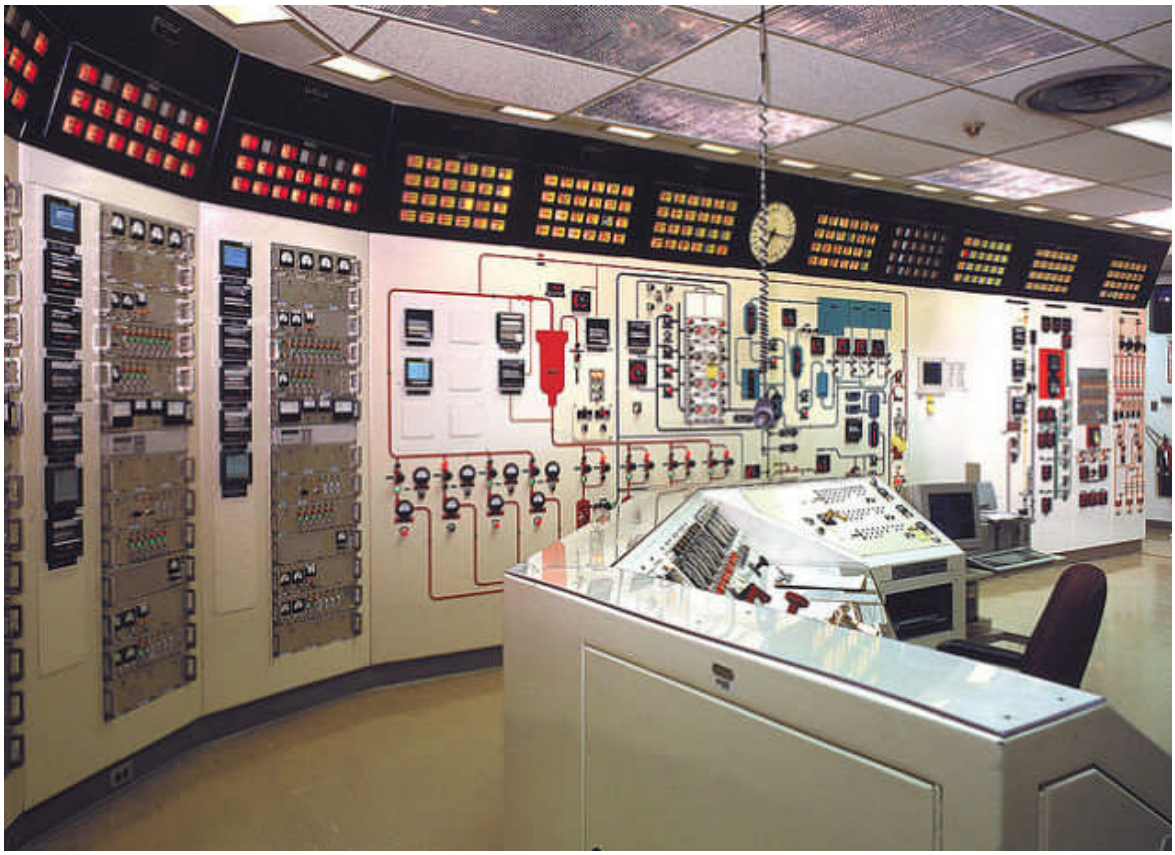


A pellet of plutonium-238 that was made for the RTG of either the Cassini mission to Saturn or the Galileo mission to Jupiter. Credit: DOE

Back on Earth, however, our plutonium-238 supply is running out. According to a recent article in *Nature*, NASA has only 35 kilograms, or about 77 pounds of plutonium-238 left—left in its aging stockpile, less than half of which is up to grade to use as fuel. The next Mars mission launching in 2020 will use up 11 pound of it. Russia is no longer selling plutonium-238, possibly because they too have run out or are running out.

The isotope doesn't occur naturally. No one else on Earth has plutonium-238.

Making plutonium-238 (again)



The control room for the High Flux Isotope Reactor used to make plutonium-238 at Oak Ridge. Yes, it's old. Credit: ORNL

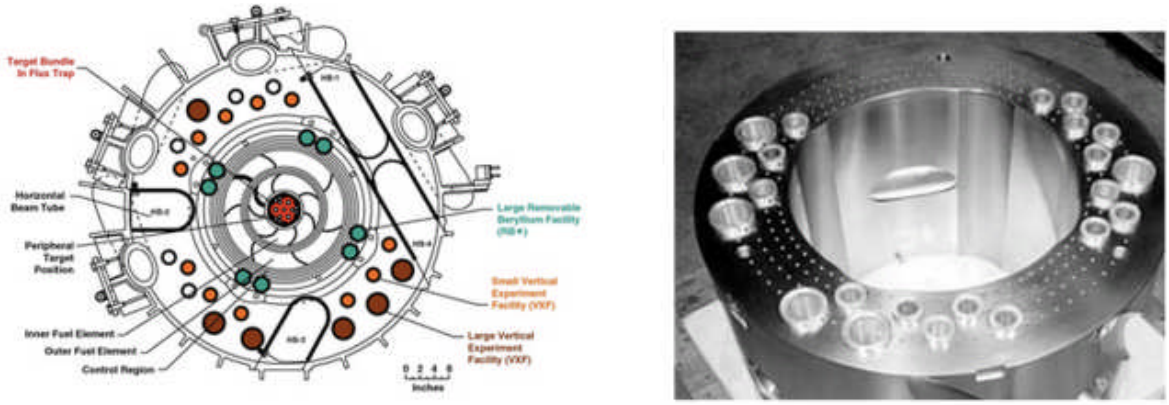
But there is a plan now. In 2013, NASA began paying the Department of Energy $50 million a year to develop a program to make plutonium-238 again. With the facilities that once manufactured and handled the waste long shut down, it will not be easy. And it will be slow. Even if everything goes according to plan, the DOE will be making 1.1 kilograms, about 2.4 pounds, of plutonium-238 by 2021.

The production plan, for now, involves hopping between no fewer than three DOE labs all o .

- Idaho National Laboratory: The precursor material, neptunium-237, is extracted from nuclear reactor fuel.

- Oak Ridge in Tennessee: A reactor irradiates neptunium-237 to make plutonium-238. T -238 and any remaining neptunium-237 are extracted to be used as fuel and recycled, respectively.
- Los Alamos in New Mexico: Plutonium-238 is pressed into pellets and stored.

Two near cross-country trips later, we finally have plutonium-238 that is ready to use. (For more technical details about plutonium-238 production and a nifty map, head over to *Nature.)* There are also plans to turn Idaho into a second facility for irradiating neptunium-237, though the exact procedure for how to do that are still being worked out.



A cross section (left) and photograph (right) of the High Flux Isotope Reactor used to make plutonium-238 at Oak Ridge National Laboratory. Credit: ORNL

In fact, much of the plan's latter half is still TBD. A DOE spokesperson confirms that Oak Ridge scientists are just now starting to test the chemical processes for extracting plutonium-238 and neptunium-237 after the irradiation procedure. And then there is the tedious but crucial work of scaling up the entire production process. It's expected to be fully underway seven years from now.

The uncertain future

With NASA's current stockpile and the DOE production plan, the U.S. has enough plutonium-238 to fund two missions a decade for the next couple of decades.That's certainly better than nothing, but it puts into perspective just what a li lear fuel for space exploration really is.

In light if all that, it makes sense why the Rosetta mission wasn't a good candidate for a RTG. Most practically ld have to buy plutonium-238 from the U.S. or Russia, neither of whom are eager to part with the precious resource. And solar panels here were at least option, unlike, say, with NASA's upcoming New Horizons mission to Pluto, where it is too dark to rely on the sun for power.

The Cold War jumpstarted space exploration, and Cold War-era nuclear fuel still powers our modern spacecraft. Historical ties are not so easily severed, but out of the ugliness of the Cold War and the horrible environmental disaster that was nuclear fuel production, we at least got the opportunity to transcend the smallness of Earth and gli

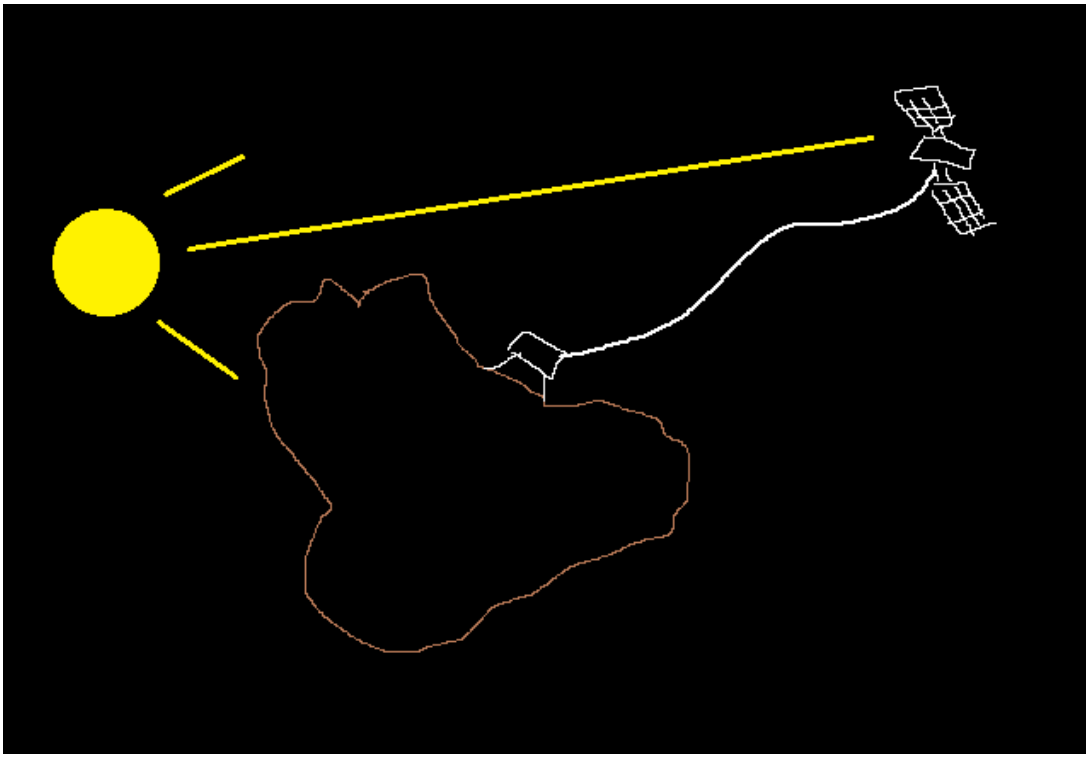
(JHUAPL/SwRI)

CaptainJack ▸ Sarah Zhang
12/02/14 12:39pm

As a fun fact, when I was 14 I worked an after school job printing blueprints (when blue-lines technically) and one of the projects I printed up complete plans for was for the Savannah river site (also various nuclear middle silos and prisons). In hindsite it has always amazed me that more countries have not had plutonium production capabilities, considering that security was loose enough for a teenager to have full access to the prints in the 80s.

stavosws6 ▸ Sarah Zhang
12/02/14 1:04pm

So next time, they should make a tethered orbiting solar panel that connects to the lander and power it via the cable. Allow me to MS paint it.



Sarah Zhang ▸ stavosws6
Is this chart bad?
12/02/14 5:04pm

stavosws6 ▸ Sarah Zhang
12/02/14 8:48pm

No. Actual art was used ;)

x TomcatXx ▸ Sarah Zhang
12/02/14 12:47pm

How do they "press" the pellets? That has to take some serious pressure considering the density.

Brianorca ▸ xXTomcatXx
12/02/14 1:10pm

Density is not the problem. Lead and gold are relatively soft materials. I don't know anything about plutonium specifically, but this article seems to indicate it's pretty soft. It also has a low melting point.

xXTomcatXx ▸ Brianorca
12/02/14 1:57pm

Found it, here. Page 181. It looks like most of the process happens at pretty high temperatures (around 1500 degrees C). The pressure seems to be around 190 standard atmospheres. I think the difference is that Plutonium fuel is in Plutonium Oxide that has undergone calcination. As opposed to straight plutonium metal (uncalcinated Plutonium Oxide). From what I've read, calcinated metals tend to increase in weight. Pretty interesting to note though, is that the whole process seems to take about 31 hours. I'm assuming it's done in batches like the picture on the last page shows. Pretty neat stuff.

Sarah Zhang ▸ xXTomcatXx
12/02/14 5:05pm

This is my favorite comment thread today

Moonshadow Kati aka Lady Locksmith ▸ Sarah Zhang
12/02/14 2:57pm

Out of curiosity, why does it matter how safe it is? If there is some technique in which it can be safely handled long enough to create the unmanned probe or rover (or whatever), w
leaks into space?

Sarah Zhang ▸ Moonshadow Kati aka Lady Locksmith
12/02/14 5:09pm

We still need to get it to space. The safety concern is when humans are handling it and transporting it while on Earth.

Two Echo ▸ Sarah Zhang
12/02/14 3:44pm

In that link about the Savannah River Site, the first picture is of H-tank farm where all the waste was stored in underground tanks built in the 1950s. I worked there, at the H-tank complex, right out of high school around 2003. It was a living nightmare. The whole place was spooky; abandoned reactor buildings dotting the skyline, and hundreds acres of landfills filled with everything from radioactive locomotives to hand equipment. The tanks were constantly leaking and they would bring in pipefitters and other construction crews to patch them up. These guys would get their yearly radiation limit (It was around 5 REM for critical personal) within two weeks and then lay them off. Wash, rinse, repeat.

Sarah Zhang ▸ Two Echo
12/02/14 5:11pm

Oh shit, what were you doing when you worked there?

Two Echo ▸ Sarah Zhang
12/02/14 7:48pm

I was a sheetmetal apprentice at the time. Fortunately, all we did was hook up temporary ventilation filters for the guys actually working on the tanks. It was still hellish though, we had to hook huge filters and blowers up into the yellow containment tents wearing a gas mask, and protective gear. Basically what you the Ebola doctors doing. And this place was an asphalt jungle, so it was probably 110 in July, with no shade.

I only did it for 2 years until I got into IT. My dad has some crazy stories from the 90s when the Cold War was winding down and everyone was in a hurry to decommission everything, about black spores in the ducts at the naval fuels facility that would kill you if you got a leak in your plastic air

suit. About how in some of the very old areas of the plant, in the oldest buildings, the radiation levels would be so high that the radiological techs with the geiger counters would give you a map on what needed to be fixed, and they would wait at the airlock because they wouldn't go any further. Dad said if your flashlight went out, the only way to find your way back was to follow your air hose.

The whole plant had an oppressively gloomy atmosphere, but the most unsettling parts of the area was the 5 colossal reactors. They pretty much dominated the skyline, and as much as you saw above ground, there was more underground. They were all built in the 50s, and basically the only safe ones are C & K I believe, the rest where shut down in the early 80s. R reactor is the worst off, it barely lasted 10 years, they abandoned due to a cracked reactor shield. From what I've heard, they only go near R every couple of years to check the ambient radiation levels. Pretty much a 1 mile fauna dead-zone around that particular reactor.

Pictured, one of the reactors. I've never been anywhere else that felt as oppressive as SRS, and I hope I never do. Doom, Fallout, all of those games probably got inspiration from SRS; it really is a science fiction horror setting come to life.

Tim_T ▸ Sarah Zhang
12/08/14 9:08am

Hi Sarah, I lead a project funded by the European Space Agency on the development of an alternative to Pu238, Americium 241. In the UK there are significant amounts of this material that could be made available. It has properties not dissimilar to the Pu238 but without the need for its manufacture in a reactor. If you search "space nuclear power tinsle les. Please feel free to contact me if you wish to know more. Kind regards. Tim

Sarah Zhang ▸ Tim_T
12/08/14 11:16am

Hi Tim — Why don't you drop me an email? sarah AT gizmodo.com

Tim_T ▸ Sarah Zhang
12/13/14 6:44am

Thanks, I have. Tim