LLNL-CONF-674576

LAWRENCE LIVERMORE NATIONAL LABORATORY

Antarctica Radiological Source Removals - Complex US-Russian Cooperative Effort

S. Porter

July 14, 2015

Antarctica Radiological Source Removals - A Complex US-Russian Cooperative Effort
Indian Wells, CA, United States
July 12, 2015 through July 17, 2015

Antarctica Radiological Source Removals - A Complex US-Russian Cooperative Effort

Authors: Stephen J. Porter[1], Andrew Hallock[2] , Victor Pomelov[3] ,Valery Lukin[3], Alexander S. Grigoriev[4] .
[1]Lawrence Livermore National Laboratory, Livermore, CA, USA, [2]Department of Energy/National Nuclear Security Administration, Washington, DC, USA, [3]Arctic Antarctic Research Institute, [4]Kurchatov Institute, Moscow, Russian Federation.

ABSTRACT

In order to meet the power requirements for scientific experiments in Antarctica during and after the Soviet era, the Soviet Antarctic Expedition (SAE) deployed radioisotopic thermoelectric generators (RTGs). The RTGs provided long term reliable autonomous power, using Strontium 90 as a radiological heat source (RHS). These RTGs have since exceeded their service life, and are no longer serviceable. However, the radiological heat sources (RHS) within the RTGs are still active and present a security risk, as well as a potential environmental hazard. As part of an international cooperative effort to recover the more than 800 Russian RTGs, it was decided to repatriate the RTGs from Antarctica back to the Russian Federation for disassembly and final disposition. Because most of the international and Russian laws were written for countries, and Antarctica is a continent with special international status under the Treaty of Antarctica, the legal preparation and obtaining the necessary licenses and permissions was exhaustive and complex. Moreover, approvals for ports of call and crossing territorial waters with equipment housing radiological material also presented numerous challenges. Of the remaining RTGs to be recovered one (1) was located far within the interior of Antarctica and had become buried deep into the ice pack. This required a special expedition consisting of trained subject matter experts from various Russian entities, and special technologies, such as ground penetrating radar, ice cutting equipment, and retrofitted vehicles to transport the RTG back to one of the coastal stations. The RTG was then loaded by helicopter onto a ship with the other RTGs. It was a true cost-sharing effort as the Russians provided the use of one of their ships to repatriate the RTGs back to Russia, while the US funded retrofits to the ship, training, equipment, and other related activities.

BACKGROUND

During the 1970s and 1980s the Soviet Antarctic Expedition (SAE) deployed a network of automated meteorological and geophysical stations throughout Antarctica. To provide power to these remote stations they needed a reliable, standalone power source, so they looked to radioisotopic thermoelectric generators (RTGs) that were designed to supply a constant steady source of power. These RTGs were part of a larger deployment of RTGs by the then Soviet Union, as more than 1,000 RTGs were installed at navigational, meteorological, and other remote sites across the Soviet Union, which included the Northern Sea Route, Baltic Region, Russian Far East, and inland locations. These RTGs used radioactive strontium-90 (Sr-90) for the production of electricity by thermoelectric conversion. Each RTG contained one or more stainless-steel capsules of Strontium 90, or radioactive heat sources (RHSs) as they are called. RHS radioactivity was extremely high by design, as the higher the activity the greater amount of heat was released during decay, therefore producing a greater amount of electrical power.

Russian RTGs had a service life of at least 10 years, according to their passport data. Often this service life was extended after confirmation that the unit was still operational, which in some cases prolonged the service life another 5 to 10 years. These devices with their high activity radioactive sources were deemed not only an environmental concern; but also posed a significant security threat, since the large quantities of radioactive material in the RHSs could be used in a radiological dispersal device (RDD) or so-called 'dirty bomb'. Over the three plus decades RTGs were deployed, there were numerous reported cases of vandalism and unauthorized activity to dismantle RTGs, primarily for their non-radioactive components and non-ferrous metals. This raised concerns that the radioactive strontium contained in the RHSs might be pulled from the RTGs and used for malicious purposes.

A variety of RTGs were designed and manufactured during the Soviet era, each with varying levels of activity (# of RHSs) and associated power output. The largest RTG is an IEU-1 having an initial activity level of 465,000 curies (Ci), and the smallest being a Beta-M/S with an activity of 35,700 Ci. The types of RTGs remaining in Antarctica are of the Beta-M/S variety.

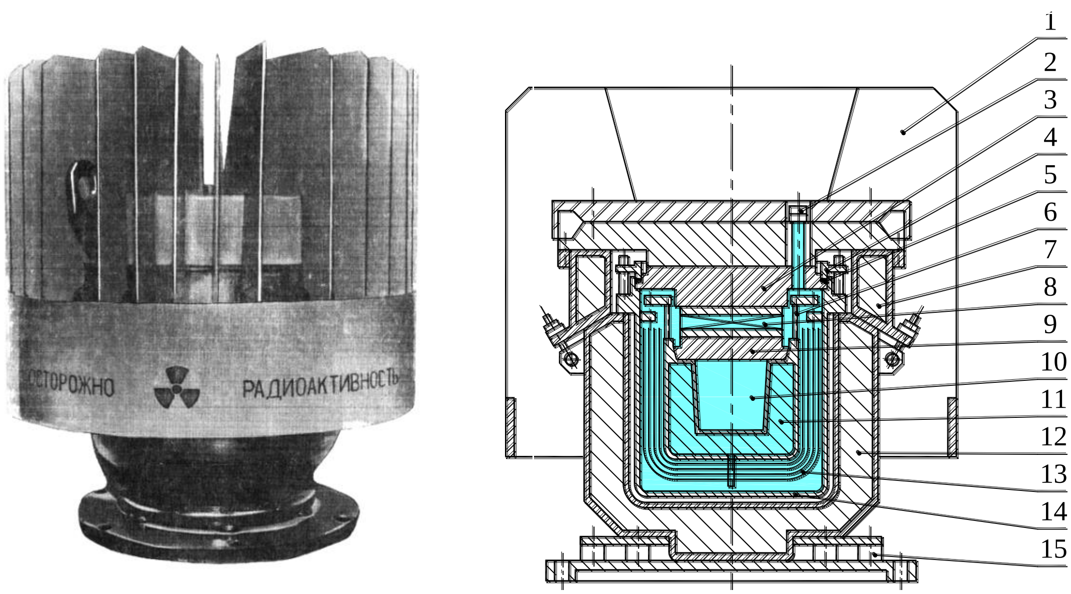

Figure 1. External view and cross-section of a Beta-M/S RTG:

1—radiator; 2—electrical lead; 3—lid; 4—flange; 5—lining;
6—radiation source support; 7—radiation shielding;
8—thermoelectric unit; 9—lid; 10—heat source; 11—protective unit;
12—radiation shielding; 13—screens; 14—housing; 15—base

By the early 2000s, nearly all RTGs deployed in the field had exceeded their original service life, so it was determined the RTGs needed to be decommissioned and disposed of. The autonomous operation of RTGs was originally viewed as a benefit; however, it later became apparent this autonomy was more of a liability, as it provided relatively unfettered and undetected access to radiological sources. Efforts to decommission RTGs were delayed by a number of factors, including a lack of financing, and available technologies to replace the reliable low-maintenance RTGs, where autonomous power was still needed for the majority of site installations in remote locations.

Most of the RTGs deployed in Antarctica had been recovered and decommissioned after their initial service life expired. However, four RTGs still remained in Antarctica, and their removal and subsequent disposal proved to be a challenge in the post Soviet Union era. One RTG was located at the Novolazarevskaya station, while two others resided at the Molodezhnaya field base, and another was buried deep in the ice pack in the interior of Antarctica near Dome B. Shown here in Figure 2 are the locations of the four remaining RTGs in the continent of Antarctica and potential routes for their recoveries.

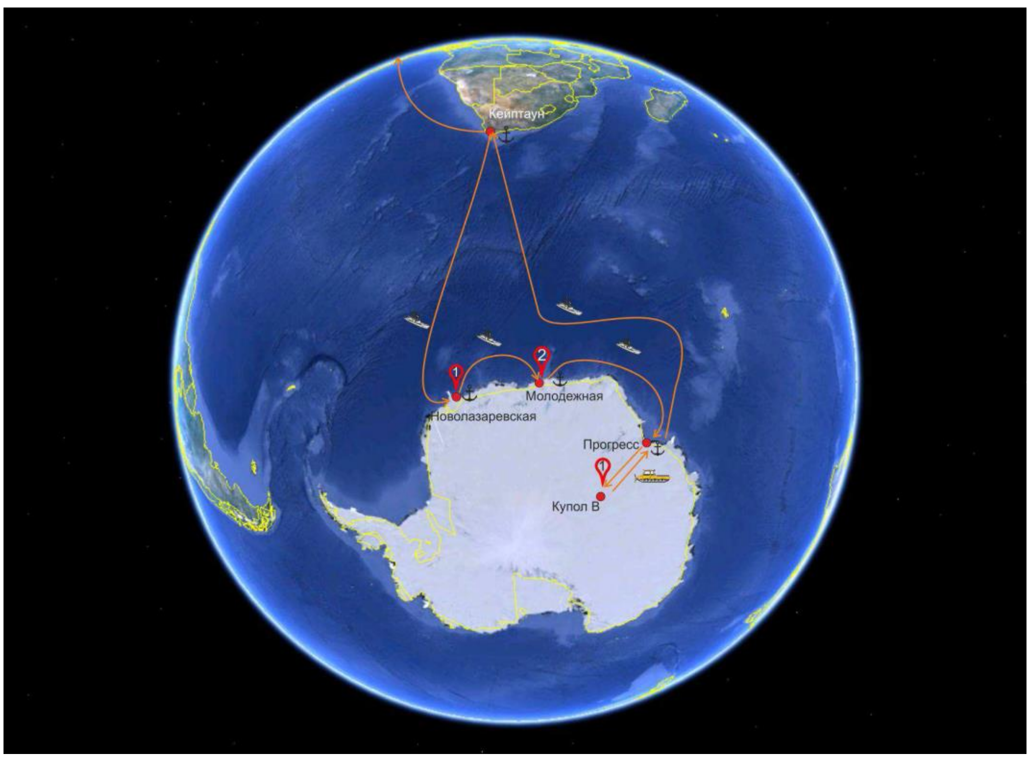

Figure 2. Remaining RTGs on continent of Antarctica

FEASIBILITY STUDY

Due to the many obstacles facing the recovery and repatriation of the remaining RTGs in Antarctica, The U.S. Department of Energy's National Nuclear Security Administration

(DOE/NNSA) determined a study should be performed as to the feasibility of the effort. The project team at Lawrence Livermore National Laboratory (LLNL) negotiated an agreement on February 2, 2012 with the Russian National Technical Physics and Automation Research Institute (NIITFA) to perform the feasibility study. NIITFA was the logical choice to perform the study as it was their experts who designed and initially deployed the RTGs in Antarctica. NIITFA collaborated with the Arctic Antarctic Research Institute (AARI) on the study.

NIITFA completed the study on February 11, 2013, and its results showed that it was feasible to recover and repatriate the remaining Antarctica RTGs back to the Russian Federation for disassembly and final disposition. The report recommended the project be performed in two phases. Phase I would involve the radiological survey and preparation of the RTGs for certification, and include the recovery of the RTG buried in the ice pack at Dome B. Phase II would involve picking up the RTGs at their collection points, loading them onto the AARI research vessel (Akademik Fedorov), and repatriating them back to the Russian Federation for disassembly and final disposition.

The study also included details regarding the logistics, training, and equipment needed to recover the one RTG buried near Dome B. The expedition team would require special training to not only withstand the harsh Antarctic elements, but also in the handling of radioactive devices. Special equipment for the expedition included ground penetrating radar, a special 12 position ice cutting blade for extracting the RTG, a retrofitted sled to carry the RTG, two specially equipped vehicles, arctic rated diesel fuel, additional fuel tanks, and an overpack for the RTG in case it was damaged. Figure 3 shows the location of the RTG near Dome B, and the planned route to take it back to the Progress Station for subsequent loading onto the AARI vessel.

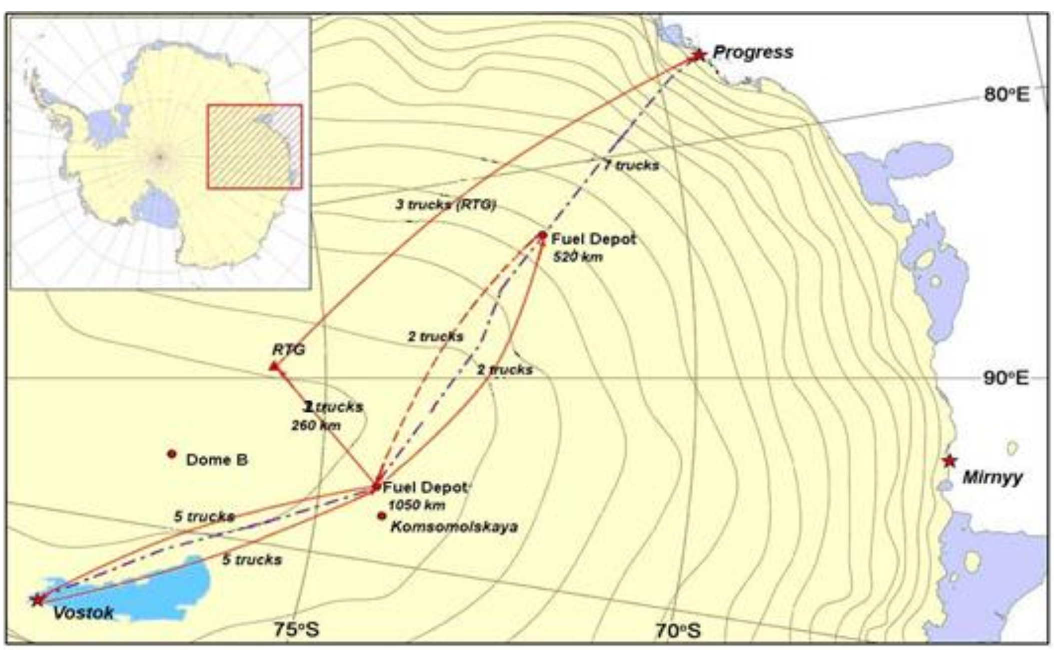

Figure 3. Proposed recovery route of RTG near Dome B to Progress Station

PREPARATION

Because the RTGs were deployed during the Soviet era, current ownership of the RTGs was uncertain. This presented a problem with respect to contractual agreements, as it was necessary to identify the State Operator as defined in Russian law. In addition, most Russian laws pertinent to this type of effort were written with regard to activities in the Russian Federation or in other countries, not for areas with extra-national status like Antarctica. This was uncharted legal territory, which also included the liability component; where both LLNL and DOE/NNSA require indemnification to conduct such operations internationally. This necessitated the engagement by the legal counsels of DOE/NNSA, LLNL, Roshydromet, AARI, and NIITFA.

When it was determined that AARI was the owner or State Operator under new Russian law, a contract for the recovery of the four RTGs was entered into between LLNL and NIITFA. AARI was listed as a sub-tier contractor, while NIITFA was primary since they were the most experienced with RTGs, and had contracting experience with the US. However, due to indemnification concerns that kept resurfacing, the DOE/NNSA and LLNL legal counsels asked that the roles be reversed to make AARI the primary contractor. Since AARI had never entered into such agreements with the US, the LLNL procurement and legal staff had to work extensively with the AARI legal staff to execute a new contract.

Figure 4. AARI vessel Akademik Fedorov in dry dock, Turku, Finland

Due to the legal complexities, the recovery contract was delayed by almost six months and finally signed on May 25, 2014. In order to accommodate the tighter project timelines resulting from missing a previous sailing, the two proposed phases were combined into one in order to be ready for one sailing, scheduled for November 1, 2014. This included the long lead time items, such as, manufacturing of special equipment, licenses, permissions, ports of call requests, retrofits to the vessel, safety inspections, approvals, and sub-tier contractual agreements.

Upon the return of the vessel (Akademik Fedorov) from its previous sailing to Antarctica in 2013-14, retrofits were performed at the Turku, Finland shipyard. The US team visited the ship in Turku on October 24, 2014 to observe the retrofits (reference Figure 4).

The Akademik Fedorov is a one-of-kind ship, as it is not only a scientific vessel, but has a hardened hull and other special ice breaker characteristics, that in the words of ship's Captain, "it cannot get stuck in the ice." The ship functions as a research, cargo, passenger, and tanker vessel with permanent helicopter basing. An ice-strengthened vessel with ice class L6 (Russian Maritime Register classification) allows it to move with a speed of 2 knots in ice 120 cm thick. Only icebreakers have a higher ice class (L7). The ship's hull was retrofitted with anchoring devices to secure the RTGs during transit, temperature monitors, and scheduled radiation monitoring. Also, in preparation for the recovery effort, station managers and members of the expedition team took part in radiological training classes in St. Petersburg, Russia.

RECOVERY

The Akademik Fedorov set sail for Antarctica from the port of St. Petersburg on November 8, 2014, and made a port of call in Bremerhaven, Germany to pick up supplies and equipment, and another stop in Cape Town, South Africa. Specialists from NIITFA and AARI flew separately

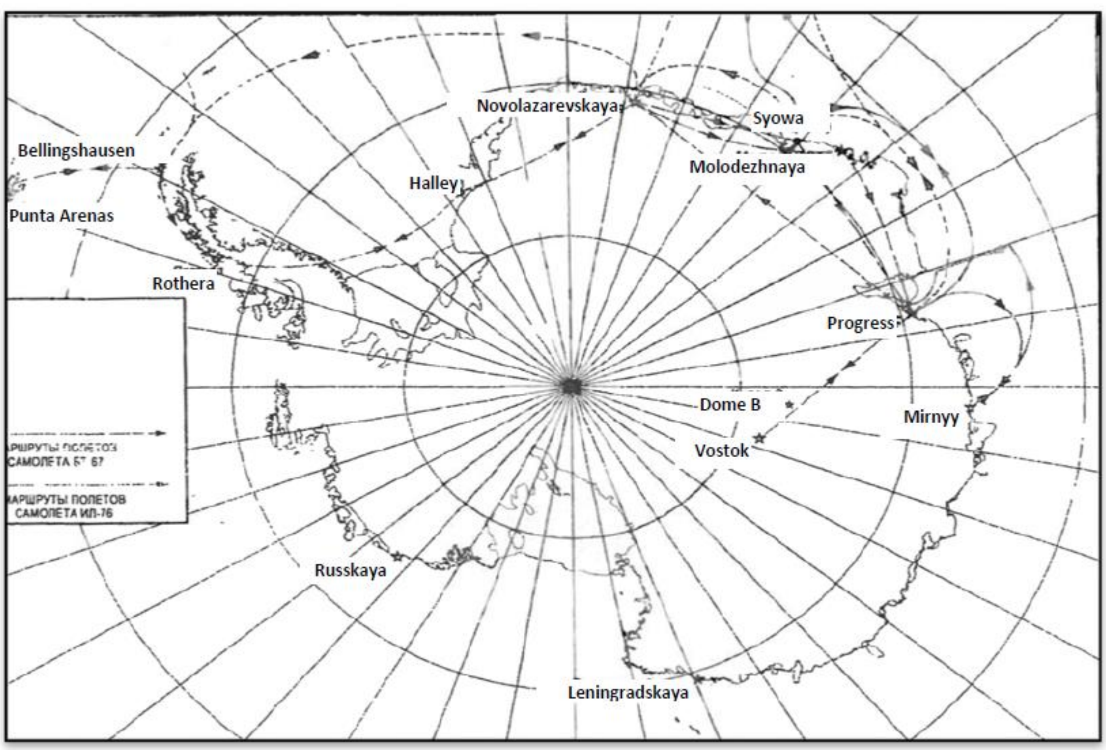

Figure 5. Locations of remaining RTGs, collection points, and coastal pick up routes

via Cape Town, South Africa to join the rest of the Russian Antarctic Expedition (RAE) crew in Antarctica. The team visited Molodezhnaya station first, where they surveyed the two RTGs, and then placed them in transportation containers. The team then traveled to Novolazarevskaya station where they surveyed the third RTG and prepared it for transit.

Figure 6. RTG being placed into transportation cage at Molodezhnaya

Figure 7. Two RTGs at Molodezhnaya prepared for transit

Figure 8. Follow-on survey of RTG at Novolazarevskaya as part of final preparation for repatriation to the RF

Figure 9. Airlifting RTG onto Academik Fedorov at Novolazarevskaya station

The special expedition team then assembled at the Progress station where they underwent additional extensive training before beginning the three and half week journey to Dome B for the recovery, survey, and transport of the fourth RTG back to Progress station. Traversing the continent to Dome B and recovering the ice-encased RTG was the most dangerous part of the whole mission, due to the harsh conditions and dangerous terrain. The ground penetrating radar was used to safely traverse the Antarctica terrain to avoid hidden crevasses underneath the ice pack. The expedition team split from the main group heading to Vostok station at the 1050 km point and moved toward Dome B (reference Figure 3).

Figure 10. Special expedition traversing interior of Antarctica to recover RTG at Dome B

Two vehicles took part in the recovery of the RTG near Dome B, and their engines remained running at all times due to the extreme cold and harsh environment. Figure 10 shows the vehicles towing the additional fuel tanks, as well as the teams mobile housing unit, and sledge carrying the cage and special overpack. Reaching the site they then methodically cut through six meters of compressed snow/ice and successfully extracted the RTG. The technical experts surveyed the RTG, examining it for damage and radiation leaks, before placing it in the transportation cage and hoisting it onto the sledge. The RTG was then successfully transported back to Progress station.

The Akademik Fedorov revisited each of the aforementioned Russian research stations along the coastal boundaries of Antarctica, where the RTGs were air lifted by helicopter from the collection points, then lowered into the ship's retrofitted hull for repatriation back to the Russian Federation. At time of recovery, the combined Strontium 90 radioactive activity of the four RTGs was 80,000 curies. Due to the dangerous nature of the radioactive material placed on-board the ship, special permissions and approvals were needed for traversing international waters and ports of call, as it returned to the Russian Federation.

The Akademik Fedorov arrived back at the Port of St. Petersburg on May 18, 2015, where AARI and U.S. Team members were available to witness the RTGs successfully offloaded, then placed on a flatbed tractor-trailer truck for transport to an interim storage facility. After the RTGs were inspected and all the paperwork completed, the RTGs were transported by a secure convoy to a facility outside Moscow for disassembly and preparation for disposition of the RHS sources.

Figure 11. RTGs moved from ships hull to a container on its deck at Port of St. Petersburg

Figure 12. Container with RTGs being loaded for transport to interim storage

CONCLUSION

This was an extremely difficult operation due to the unique legal, geographical, technical, and environmental obstacles. The project was a true partnership between Russia and the United States. The Russian Federation provided their specialists and use of their unique sailing vessel to repatriate the RTGs, while the United States funded the preparation, retrofits, special equipment, training, logistics, and final disposition of the radioactive sources. This cooperative effort resulted in the removal of 80 thousand curies of radioactive material. This successful removal of radioactive material from the continent of Antarctica not only enhanced the security, safety, and environment of Antarctica, but also contributed to the larger international goal of strengthening global nuclear and radiological security.

REFERENCES

1. NRC Kurchatov Institute. Master Plan for Decommissioning, Replacement with Alternative Power Sources and Disposal of Radioisotope Thermoelectric Generators of the Russian Federation. Moscow, 2007.
2. Specification and Operation Manual for Beta-M RTG. eN3.110.000. TO. Moscow, 1980.
3. G8 Global Partnership: Assessment and Options for Future Programming in the Fields of Nuclear and Radiological Security (Moscow Conference, November 21-23, 2012).
4. Results of Ten Years of Successful Russian-American Cooperation in the Decommissioning of Russian Radioisotope Thermoelectric Generators (RTGs) INMM #577, July 2014
5. In early June 2015 the Delegations of the Russian Federation and the USA presented a joint Information Document on the results of this Project at the XXXVIII Antarctic Treaty Consultative Meeting in Sofia (Bulgaria), June 2015

Prepared by LLNL under Contract DE-AC52-07NA27344