Abstract—For more than five decades, Radioisotope Power Systems (RPSs) have enabled space missions to operate in locations where the Sun's intensity is either too dim, obscured, or otherwise inadequate for solar power or other conventional power-generation technologies. The natural decay of the radioisotope plutonium-238 ($^{238}$Pu) provides the heat source used by an RPS to generate electricity (as well as heat to keep key subsystems warm) for National Aeronautics and Space Administration (NASA) missions such as Voyagers 1 and 2, the Cassini mission to Saturn, the New Horizons flyby of Pluto, and the Mars Curiosity rover. The United States has not produced new $^{238}$Pu since the late 1980s. RPS–powered missions have continued since then using existing $^{238}$Pu inventory managed by the U.S. Department of Energy (DOE), including material purchased from Russia. NASA and DOE have determined that a new domestic supply is needed to ensure the continued availability of RPSs for future NASA missions. Using funding provided by NASA since 2011, DOE is currently executing a project to reestablish a $^{238}$Pu supply capability using its existing facilities and reactors. The project, known as the Plutonium-238 Supply Project (PSP) is led by the DOE Oak Ridge National Laboratory (ORNL). This paper will provide an overview of the PSP approach, its progress to date, and the potential benefits to NASA of missions that could be enabled by the new production of $^{238}$Pu.

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1. INTRODUCTION

The Department of Energy (DOE) is responsible for maintaining the national capability to support the design, development, production, deployment and safety of Radioisotope Power Systems (RPSs) for National Aeronautics and Space Administration (NASA) and national security missions. DOE and its predecessor agencies have been producing radioisotope power systems for over fifty years. Radioisotope power systems uniquely enable missions that require a long-term, unattended source of electrical power and/or heat in harsh and remote environments. These systems are reliable, maintenance–free, and capable of producing heat and electricity for decades. $^{238}$Pu serves as the heat source for all RPS launched by the United States. Figure 1 shows where the missions have been able to explore and move beyond the known edge of the solar system.
Radioisotope Power Systems have enjoyed highly successful use in the United States, having been used on 27 space missions to date. NASA, in partnership with DOE, has deployed RPSs on breathtaking missions to the Moon, Mars, and the outer planets. Four active RPS-powered missions continue to provide information at Mars, Saturn, Pluto, and beyond the boundary of our Solar System. 

Planetary science investigations have performed many survey missions in a flyby mode of planetary objects throughout the solar system; now scientists are conducting additional missions to make measurements in more detail by orbiting to take longer duration observations, and in limited cases, some in situ missions have begun to be conducted. A growing diversity of target destinations and differing mission power system needs requires development of a variety of RPS capabilities to match the potential mission usage (Fig. 1).

The planetary science community is asked to conduct a decadal survey to aid NASA in establishing the highest value priorities for robotic exploration of our solar system. The most recent decadal survey culminated in a 2011 report by the National Research Council (NRC). The report identified both mission priorities and enabling technologies. Missions envisioned by the community included continued exploration of Mars, including a Mars sample return to Earth; a focused study of Europa, a moon of Jupiter; and an orbiter with probes to explore Uranus. Furthermore, the study results identified objectives to explore other planetary bodies throughout our Solar System such as sampling comets, conducting a rendezvous with Trojan asteroids, sending probes to study the moons of Saturn, and returning to the Earth’s Moon to explore the Aitken Basin and to assess the overall geophysical activity of our closest neighbor.

To explore this diverse set of potential targets, the spacecraft and surface systems will require reliable and long-lived power. Extended trip times, locally challenging extreme environments, and acquisition of long-duration scientific research measurements all contribute to the ongoing need to provide such missions with radioisotope power. And to provide RPSs for the missions, there is a continued need for $^{238}$Pu as their heat source. The NRC observed: “Without a restart of $^{238}$Pu production, it will be impossible for the United States, or any other country, to conduct certain important types of planetary missions after this decade”. 

The $^{238}$Pu production process consists of the fabrication of neptunium-237 ($^{237}$Np) targets, irradiation of the targets in a nuclear reactor, and recovery of $^{238}$Pu from the irradiated targets through chemical extraction. In the past, $^{238}$Pu was produced at DOE's Savannah River Site (SRS) in South Carolina on an incremental basis during large-scale production of weapons-grade Pu, using reactors that have since been shut down. The last $^{238}$Pu production in these reactors occurred in 1988. After DOE stopped producing $^{238}$Pu, DOE's remaining inventory, supplemented by...
purchases from Russia, has been used to continue to supply power systems. NASA and DOE have begun a multi-year project to re-establish the capability to make \(^{238}\text{Pu}\) using existing DOE facilities. This paper describes that project and the status of the effort.

2. BACKGROUND

Production of \(^{238}\text{Pu}\) requires irradiation of \(^{237}\text{Np}\) in a nuclear reactor with a high neutron flux to enable reasonable production rates. DOE has selected two research reactors with sufficient flux — the Advanced Test Reactor (ATR) at Idaho National Laboratory (INL) and the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) for this purpose.

Figure 2 outlines the production of \(^{238}\text{Pu}\) which involves the following five steps:

1. \(\text{NpO}_2\) in storage at INL must be put into shipping containers and shipped to ORNL for use in producing \(^{238}\text{Pu}\).
2. \(\text{NpO}_2\) that has been in storage requires purification to remove its decay daughter, \(^{233}\text{Pa}\), which emits a low-energy gamma ray that contributes to worker dose during subsequent target fabrication activities. Purification and recycling of neptunium require conversion to an oxide form for target fabrication.
3. Targets are fabricated by blending \(\text{NpO}_2\) with aluminum powder and pressing the mixture into a pellet. Multiple pellets are then clad in an aluminum tube and sealed by welding.
4. Targets are irradiated in either ATR or HFIR. Irradiation times vary from one to six cycles, depending on the specific location in the reactor core and the buildup of undesirable isotopes such as \(^{236}\text{Pu}\).
5. Irradiated targets go through a series of chemical processing steps to recover and purify both neptunium and plutonium. Plutonium is shipped to the Los Alamos National Laboratory (LANL), and neptunium is recycled back to target fabrication.

While \(^{238}\text{Pu}\) was produced at the SRS site, there are modifications to the processes necessary in order to use existing DOE infrastructure. The two major areas requiring development are:

1. A new small, dense target for irradiation of \(\text{NpO}_2\) must be developed. The SRS targets were very large and not very dense (only 6 vol% \(\text{NpO}_2\) in the aluminum matrix). Current DOE research reactors have a much smaller volume and must be loaded to a density of ~20 vol% \(\text{NpO}_2\). The problem is that a small portion of the \(^{237}\text{Np}\) fissions releasing significant amounts of fission heat. The targets must be designed to operate at temperatures lower than the melting point of aluminum (~650°C).

2. Research staff at both Savannah River National Laboratory\(^{2,3}\) and INL\(^4\) identified process improvements to reduce costs and wastes using solvent extraction to recover \(\text{Np/Pu}\) instead of the anion exchange process used originally at SRS. This process modification requires additional development and testing.

Furthermore, the process chemistry is affected by the \(^{238}\text{Pu}\) concentration as well as the presence of fission products. The high radiation fields cause the chemicals used in the processing to degrade. The efficiency of separation and recovery is impacted significantly by these changes in process chemistry. This paper will describe current status of development underway to test and scale up the various process steps required to produce \(^{238}\text{Pu}\).
3. STATUS OF DEVELOPMENT

This project plans to develop a robust set of processes modified to account for this particular combination of Pu/Np so that an average annual production level of 1.5 kg/yr of bulk Pu oxide can be sustained for many years. A testing program was developed so that the various parts of the overall project could be demonstrated at small (mg to g) levels and scaled up to the kg/yr. level. Currently, the testing program is scheduled to be complete and transition into pilot operations at the end of 2018. Final scale up to 1.5 kg/yr. is anticipated to be complete by 2023. The following sections describe development efforts to date.

Neptunium transfer—Most of the nation's supply of separated 237Np resides in storage vaults at INL. Neptunium target feed material will be shipped to ORNL from INL on a just-in-time basis in Department of Transportation (DOT) 9975 shipping containers. The DOT 9975 container represents a robust package for confinement of the 237NpO2. The DOT Certificate of Compliance for this container has been updated to include the 237NpO2 payload. The containers are approved for up to 6 kg of 237NpO2 with up to ~0.5 g 238Pu present. INL has recently installed a new capability to remove containers of NpO2 from the storage vault, repack into 9975 containers, and ship to ORNL. Containers of NpO2 have been shipped from INL to ORNL and this part of the effort needs no further development.

Target Fabrication—The production target consists of a stack of cylindrical pellets containing the Al 237NpO2 cermet material sealed within an aluminum tube (clad) shown in the exploded view in Figure 3. The 237NpO2 is blended with aluminum powder and formed into pellets by pressuring the material in a die at high pressures. Pellet quality control requires fabricating pellets to carefully controlled weights and dimensions. All weights and dimensions are measured by hand on a one-pellet-at-a-time basis. The cermet pellets are loaded into the aluminum tubes, and the ends of the tubes are welded to form a single target assembly. Individual targets are placed into target holders to form target arrays, with the number of targets per array assembly dependent upon the irradiation space. Currently irradiations are based on bundles of seven targets in the HFIR. Eventually, positions at the ATR will be used for additional capacity. ORNL is in the process of developing automated equipment to increase the rate of pellet fabrication and plans to install new equipment during 2016. The new equipment is expected to significantly decrease costs of target fabrication.

To date, eighty-four targets containing a total of about 2.7 kg of NpO2 have been fabricated and irradiated. Those targets will be used in chemical processing tests to validate process chemistry.

Target Design, Testing, and Qualification—Figure 4 shows the irradiation pathway to produce 238Pu. 237Np oxide is used as the feedstock. The optimal neutron flux is a thermal neutron flux on the order of 10^{14} n/s.cm^{2}. High energy neutrons and photons (greater than 6MeV) result in production of 236Pu (shown on the left hand side of Fig. 4) which is undesirable. Thermal neutron irradiation of 237Np results in a neutron capture followed by a beta decay which makes 238Pu. There are additional neutron captures indicated on the right-hand side of the figure that make 239Pu and 240Pu as shown in the upper right corner of figure 4. The targets and irradiation conditions are designed to maximize 238Pu and minimize other isotopes. The goal of the irradiation scheme is to produce Pu that consists of >85% 238Pu. Most of the balance is 239Pu and 240Pu, while 236Pu is measured in parts per million.

![Figure 3. Illustration of NpO2/Al cermet target used to produce 238Pu.](image)

The pressing of the oxide target material with the substrate aluminum base material forms a ceramic/metallic component typically referred to as a cermet. Currently, enough NpO2 and aluminum powder for single pellets are weighed into individual vials by hand. The vials are then mixed, dispensed by hand into a die, and pressed to make a pellet. The pressing of the oxide target material with the substrate aluminum base material forms a ceramic/metallic component typically referred to as a cermet. Currently, enough NpO2 and aluminum powder for single pellets are weighed into individual vials by hand. The vials are then mixed, dispensed by hand into a die, and pressed to make a pelleted. Pellet quality control requires fabricating pellets to carefully controlled weights and dimensions. All weights and dimensions are measured by hand on a one-pellet-at-a-time basis. The cermet pellets are loaded into the aluminum tubes, and the ends of the tubes are welded to form a single target assembly. Individual targets are placed into target holders to form target arrays, with the number of targets per array assembly dependent upon the irradiation space. Currently irradiations are based on bundles of seven targets in the HFIR. Eventually, positions at the ATR will be used for additional capacity. ORNL is in the process of developing automated equipment to increase the rate of pellet fabrication and plans to install new equipment during 2016. The new equipment is expected to significantly decrease costs of target fabrication.

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![Figure 4. From feedstock (237Np) to production (238Pu) due to neutron irradiation and isotope decay in HFIR.](image)

The bottom right side of Figure 4 depicts fission of 237Np and 238Np occurring during irradiation. This fission generates heat which must be removed to keep targets below the melting point of aluminum (650°C).

Although targets were successfully irradiated at SRS, the NpO2 content of those targets was low at ~6 vol%. Due to the limited irradiation volume in the existing DOE reactors,
the loading goal was set to 20 vol% in order to achieve 1.5 kg/yr. PuO₂; however, data on target performance during irradiation were not available to qualify the targets as safe (that is, there are no predicted target failures). Target failures occur due to breaching, which can happen due to excessive pressure caused by fission gas release or melting of Al at high temperatures. To qualify prototypic targets in the HFIR, an irradiation test program was developed. The irradiation test program consisted of four phases (color coded in Figure 5) that provided an incremental approach intended to reduce the risk of target failure during testing and lead to a prototypic target design. Additionally, post-irradiation examination (PIE) results from each phase served as hold points and were used to guide the course of the subsequent irradiations.

Irradiation characteristics of ²³⁸Pu production in HFIR of particular interest are as follows:

- pellet dimensional changes
- fission gas release
- heat generation rates
- product yields (how much ²³⁸Pu is created)

Figure 5 illustrates how irradiation cycles were used in the testing.

Data collected during PIE included pellet dimensional changes, fission gas release, pellet clad interaction, and Pu yield. Data on dimensional changes were used as input to model these dimensional changes as a function of fission density. This model is based on tests used for uranium oxide/aluminum cermet fuels where the fuel can either shrink or swell depending on the fission density. New data was required for this particular mixture of NpO₂ and aluminum to develop a safety envelope for irradiation in both HFIR and ATR. The model is based on the sum of an exponential shrinking term and a linear swelling term. The sum is plotted as a function of fission density and is shown in Figure 6. Data collected during PIE tests are also plotted as data points, and in general, the combination of linear swelling and exponential shrinking provides a bounding estimate of pellet dimensional changes. This new model then allowed calculation of heat transfer characteristics and pellet centerline temperatures to qualify as prototypic targets for eventual production targets. The thermal-hydraulics models show that the target centerline temperatures will not exceed the melting point of aluminum, and thus the targets are qualified for production. The current target design is sufficient for production of ~1.0 kg/yr. PuO₂ in the HFIR. Additional work is required to develop a target design for the ATR.
Chemical Processing—Chemical process steps at ORNL are being tested independently of each other using existing materials (i.e., plutonium and neptunium). These preliminary tests establish nominal process parameters which will be refined by the results of an integrated end-to-end process demonstration started in summer 2015 using irradiated targets produced from this project. As additional irradiated targets become available, they will be used in additional testing. The end goal is to conduct multiple separations test in order to validate the ability to process at the 1.5 kg/yr. level. The chemical process steps are shown in Figure 7. Note that several steps are coded with numbers that are used to explain the status of development of those steps below.

(1) Aluminum dissolution—Aluminum dissolution is exothermic and requires careful process controls to avoid overheating the reaction mixture. To test existing process controls, dummy targets were fabricated of aluminum only to the expected dimensions of production targets and dissolved using standard caustic dissolution techniques. The tests provided data on full-scale process control and dissolution time requirements. During September of 2015, twenty prototypic targets containing new $^{238}$Pu were dissolved using parameters derived from the dummy target dissolutions. Aluminum dissolution is at a prototypic level.

(2) Actinide and fission product dissolution in nitric acid—After aluminum has been dissolved and this solution removed, the actinides ($\text{Np}^{+}\text{Pu}$) oxides, as well as many of the fission products, are dissolved in a solution of concentrated nitric acid. The dissolution takes place at $\sim100$–$110^\circ\text{C}$ over many hours. After dissolution, the chemical valences of both plutonium and neptunium are adjusted prior to solvent extraction. Actinide dissolution will need to be tested several more times at a prototypic level.

(3) Plutonium/neptunium separation using solvent extraction—Previously, separation and purification of Np/Pu was accomplished using large anion exchange columns at SRS. Thompson$^{[2,3]}$ recognized that switching to solvent extraction for Np/Pu recovery and partitioning could lead to a reduction in operating costs and waste generation as compared to anion exchange. Thompson obtained a limited set of data on partitioning and recovery, but the yields were lower than desired and the timeframe for conducting the separations was judged to be too short for operations at that time. Later, Todd$^{[4]}$ conducted a computational study which confirmed Thompson’s observation. Recently, results from Taylor$^{[5]}$ have provided insight into mechanisms of neptunium redox reactions which can be used to develop a viable flowsheet for partitioning and recovery. Effective separation of the plutonium/neptunium/fission product (FP) mixtures requires control of the valence states of both plutonium (which can exist as $\text{Pu}^{+3}$, $\text{Pu}^{+4}$, and $\text{Pu}^{+6}$) and neptunium (which can exist as $\text{Np}^{+4}$, $\text{Np}^{+5}$, and $\text{Np}^{+6}$). Techniques for valence control are being tested and validated. In tests performed to date, an existing supply of $^{238}$Pu were used along with an existing supply of neptunium and trace FPs to make a surrogate feed in the same proportions and concentrations expected from production targets.

The equipment used for the separations is a three-bank set of small-volume mixer settlers. The separations flowsheet, as depicted in Figure 8, begins with adjusting the valences as closely as practical to $\text{Np}^{+6}$ and $\text{Pu}^{+4}$. The Np/Pu/FP
mixture enters the middle of the top bank, or A-bank. Both the Pu\(^{4+}\) and Np\(^{6+}\) are extracted into the organic phase which flows from right to left and into the middle of B-bank. The fission products, along with any Np\(^{5+}\), flow to the right and exit as waste. However, conditions in the A-Bank are controlled to favor oxidation of Np\(^{5+}\) to Np\(^{6+}\) to minimize loss of Np. In the B-bank, a reductant is added to reduce Np\(^{6+}\) to Np\(^{5+}\). The Np\(^{5+}\) is stripped from the organic phase back into the aqueous phase, and exits as neptunium product. The Pu\(^{4+}\) remains in the organic phase along with any remaining Np\(^{6+}\) and exits on the left-hand side. That stream enters C-bank, where the Pu\(^{4+}\) is reduced to Pu\(^{3+}\) and stripped from the organic phase into the aqueous phase exiting as plutonium product on the right-hand side. Methods of valence control have been developed to hold valences in specific states, while monitoring valences to see if disproportionation occurs. Initially the use of ultra violet-visible spectroscopy was employed to monitor valence states and examine kinetics of disproportion in glove-box tests. Similar equipment will be used in the hot cell facility to support scale-up to production-level operations. Data from the tests will be used to establish scale-up requirements. In tests conducted to date, valence control has been moderately successful. The Np product is relatively free from Pu. However, the Pu product contains significant amounts of Np and requires further purification. Further tests will be needed.

(4) Plutonium Purification—ORNL is currently working closely with LANL to ensure that the product purity of the newly generated PuO\(_2\) is adequate for use in the LANL process that produces the encapsulated PuO\(_2\) pellets. Testing conducted to date indicates that plutonium product from the solvent extraction step will have too much Np for use as final product. Current efforts focus on adjusting the valences so that valences are Pu\(^{4+}\) and Np\(^{5+}\). The solution will be passed through a column containing cation exchange resin, and Pu will load on the resin while Np will flow through. Once the resin has been loaded to full capacity, any remaining traces of Np will be washed out. All of the Np passing though the resin will be joined with the neptunium product. The resin will then be air dried. This has been somewhat successful on small quantities but has not been tested at prototypic levels.

(5) Plutonium Conversion to Oxide—The column containing cation resin loaded with plutonium will be placed in a furnace and heated to >500\(^\circ\)C to destroy the resin and produce an oxide product. This has only been tested at ~ 5 g levels and will need to be scaled up to ~ 50 -100 g.

![Figure 8. Current desired flowsheet for co-extraction and partitioning. Organic streams are shown in blue, while aqueous streams are shown in green. Plutonium and Np(VI) are designed for co-extraction in A-bank, and B-Bank is designed to reduce Np(VI) to Np(V) and remove it as neptunium product. C-Bank reduces Pu(IV) to Pu(III), where it is stripped from the organic to the aqueous and collected as plutonium product (r.h.s.).](image-url)
(6) Plutonium Product Shipment—Plutonium oxide will be placed in small screw-top containers and transferred out of the cell bank. The containers will then be placed into a container which is compatible with storage requirements at LANL. The container will be welded shut and transferred into a shipping package which is then shipped to LANL. Design efforts are underway to develop capability to ship ~100’s of gram.

(7) Neptunium Purification—Based on initial test results, Np from the solvent extraction step is expected to contain only 10’s of ppm of $^{239}$Pu, which is acceptable for target fabrication. To date, our solvent extraction tests have not challenged the separation step with a full complement of fission products, so there may be too many fission products, and sodium in the neptunium product from solvent extraction to allow use in target fabrication. We plan to use anion exchange to remove any sodium and remaining fission products. This process will be tested during the first end-to-end chemical processing demonstration currently in progress.

Since neptunium decays to $^{233}$Pa, which has a 27–day half-life and emits ~300 keV gammas as it decays. The small amount of $^{233}$Pa must be removed before target fabrication. If not removed from the $^{237}$Np, its activity would result in significant doses to the target fabrication staff. $^{233}$Pa is removed by passing an aqueous neptunium nitrate solution through a column of glass beads. The glass beads absorb $^{233}$Pa leaving a relatively low-dose Np nitrate solution which is transferred out of the cell on a just-in-time basis.

(8) Neptunium Product Oxide Conversion—After $^{233}$Pa removal, the aqueous solution of neptunium in nitric acid is transferred to a glovebox facility. Ammonium nitrate is added to the solution as part of the feed adjustment. The solution containing neptunium is then denitrated in a rotary kiln to convert the neptunium to oxide (NpO$_2$) in a process called “modified direct denitration (MDD)” The MDD process was originally developed to convert uranium to an oxide suitable for another project. At the beginning of the Plutonium-238 Supply Project, ORNL tested and made changes to the existing MDD process to allow production of NpO$_2$. The MDD process was then scaled up to a rate of 80 to 100 g/h. of NpO$_2$, which is the expected scale for full-scale production operations. The unit has been in place and working since 2013 although it is currently only operated in ~100 g batches due to limits on target fabrication rate.

4. OPTIMIZATION

ORNL is also in the process of optimizing the overall flowsheet to increase production rate and decrease unit costs. There are two major efforts which started in 2016:

(1) Modified target design—a target containing only NpO$_2$ pellets encapsulated in a zircaloy clad is being tested. This target design has the potential to increase $^{238}$Pu production, decrease the number of targets required for irradiation, and eliminate aluminum dissolution.

(2) Enhanced chemical processing—A model of material flows throughout the entire process was developed to identify bottlenecks. Aluminum dissolution was identified as a major bottleneck. Successful completion of the modified target design described above should increase production and decrease unit costs. Additional process bottlenecks will be identified as data is developed. The model will be used to optimize production by increasing yield and decreasing unit costs.

5. SUMMARY

ORNL is reestablishing the supply of $^{238}$Pu. The demonstration phase is well under way to develop and validate target fabrication, target irradiation, and PIE of test targets, as well as to conduct chemical separations to test neptunium/plutonium recovery and purification. The status of activities is as follows:

- Target fabrication has been scaled-up to prototypic targets; these targets have been qualified and irradiated for two cycles.
- Aluminum and actinide dissolution steps have been successfully tested on 20 targets.
- Solvent extraction testing on material from irradiated targets occurred in late 2015. More tests are needed to show consistent results.
- Laboratory tests of cation exchange separation have been successful in removing large quantities of Np from the Pu product. Future tests will be conducted in hot cells at larger scale.
- Anion exchange purification of neptunium solutions will be done to complete the first production campaign.

ACKNOWLEDGEMENTS

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**BIOGRAPHY**

**Robert Wham** is a Ph.D. Chemical Engineer whose research focus is radioisotope production and radiochemical separations including recycle of used nuclear fuel. He currently serves as Technical Integration Manager for the Pu-238 Supply Project within the Nuclear Security and Isotope Technology Division.

Previously, he served as Technology Integration manager for the Nuclear Science and Technology Division (NSTD) and was responsible for six groups within NSTD. The groups covered diverse areas such as radiochemical processing, robotics, stable isotope production, radioisotope production, and design of remotely operated equipment.

Prior to that, he managed several radiochemical processing programs at the Radiochemical Engineering Development Center (REDC). His experience in hot cells and radioisotope production comes from working on the production of heavy elements in the Transuranium Element Program, as well as the recovery of plutonium, americium and curium from targets irradiated at the Savannah River Site. Both of these took place at REDC. He was Facility and Program Manager for REDC from 1991 to 1997.

**Mr. Thomas Sutliff** has been employed at the NASA Glenn Research Center in Cleveland, Ohio for over 30 years. Mr. Sutliff currently is Deputy Program Manager of the Radioisotope Power Systems Program, supporting NASA’s Science Mission Directorate. He has extensive experience in program and project management at NASA, including flight system leadership for space station and shuttle microgravity science payloads.

Prior to his project management roles, Tom managed Glenn’s Research Center’s Structural Dynamics Laboratory, conducting vibration tests and data analyses in that laboratory, as well as performing structural analyses and mechanical system designs.

**Becky Onuschak** is the Program Director for Infrastructure Capabilities in the Office of Space and Defense Power Systems at the US Department of Energy. She manages programs to support NASA and national security radioisotope power systems production, including the resumption of domestic $^{238}$Pu production. She has worked at DOE since 1994, with a professional focus on establishing technical management structures and processes and developing project teams. She has been involved in space nuclear power since 2002. She is certified both as a PMI project management professional and an INCOSE systems engineering professional.