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Securing and Simulating Nuclear Technology: Secure Web-Based Architecture and Physics-Based Simulation in 'RTG Reality' for Public Science Advocacy

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Abstract

Many public misconceptions get in the way of implementing peaceful nuclear technologies and efforts to promote space exploration missions. The research team of Al-Saeed University, Taiz, Yemen, designed an interactive Web-based scientific simulation, RTG Reality, that aims to compensate for these cognitive shortcomings by providing the design and mathematics of the simulation along with the security protocols needed for its implementation. Application was awarded the first prize among the Yemeni universities and was acknowledged at the Asian level in the 2026 "Myth Smashers: Nuclear Science App Challenge", organized by the Asian Network for Education in Nuclear Technology (ANENT) and the International Nuclear Science and Technology Academy (INSTA) under the IAEA auspices. The simulation successfully converts complex concepts of thermodynamics, radioisotopic decay and complex safety containment issues of Radioisotope Thermoelectric Generators (RTGs) into a high fidelity interactive framework. The platform, designed with a secure-by-design cybersecurity approach, utilizes static site generation, an isolation of client-side deterministic state-machines, and strict input validation to provide the integrity of telemetry and prevent compromise of educational infrastructure from cyber threats. RTG Reality provides a proven and safe approach to nuclear education and public engagement through a stringent physics-based telemetry model along with an integration of historical accidents telemetry.

Keywords: RTG Reality, IAEA, Nuclear Education, Myth Smashers

Introduction

Global policy making, educational programs and research efforts are hindered by the gap between the scientific community's understanding and popular views on nuclear technologies. The lack of a clear conceptual separation of explosive supercritical fission processes with controlled critical fission power generation and passive subcritical radioisotopic decay increases the prevalence of public apprehension, which is sometimes referred to as “radiophobia.” This is especially evident in the public debates on deep space exploration and space missions with scientific objectives that require power sources other than solar energy, such as Radioisotope Thermoelectric Generators (RTGs). The RTGs harness the thermal energy generated by the natural alpha decay of Plutonium-238 (^{238}Pu) and transform it into electrical energy using the Seebeck effect [1-3] to achieve very reliable electrical power.

Despite their safe operation for over 60 years and many notable space missions, public fears about the possibility of a nuclear detonation or a widespread environmental contamination from a launch failure or atmospheric re-entry are still common. To overcome this gap, current nuclear pedagogy has developed into active learning model teaching, with a focus on the computer-based simulation of the fundamental principles of nuclear and serious games. These interactive modalities allow the user to manipulate variables, observe the variations of the telemetry in real time and understand complex physical phenomena by experiencing them through manipulation, greatly improving the retention of the cognitive content and the understanding of the concepts involved when compared to the passive learning techniques [1,4,5].

The IAEA, with the support of ANENT and INSTA, hosted "Myth Smashers: Nuclear Science App Challenge" in 2026, to further this educational model. The international competition invited academic institutions to come up with creative digital platforms to combat the popular nuclear myths. RTG Reality is the application designed by Al-Saeed University in Yemen, which is available at https://alsabriym-rtg-myth.vercel.app/, and is carefully designed to debunk the misconceptions about the safety of RTG in space exploration [6].

One of the unique features of this development is the architectural design. The app, created by a cybersecurity student, recognizes that public education sites geared toward high-risk industries like nuclear technology are “the perfect target” for malicious actors to spread “digital misinformation, deface sites, or cause denial of service attacks” to amplify public fear. Accordingly, RTG Reality is built around a "secure-by-design" web architecture, which separates computational states, checks for input validation bypasses, and assures the most complete integrity of the simulated physics telemetry. This manuscript outlines the mathematical principles, structural engineering, safety evaluations and secure web implementation of the RTG Reality application [3,7,8].

Ensure the security of the system design and web implementation

Sensitive nuclear concepts should be taught by educational instruments that are high availability, responsive, and resistant to potential exploitation. If an opponent manages to breach an educational simulation or control the telemetry from the simulation to show "abnormal behavior," such as a simulated RTG core exploding, or thermal decay causing a breach in containment, then the educational goals of the simulation would be defeated and the myths perpetuated by the simulation would be reinforced. Thus RTG Reality is based on a modern and secure-by-design front-end architecture [1,7].

Using Static Site Generation and CDN Decoupling

The application is built using Next.js and React and then distributed across a Content Delivery Network (CDN) using the Vercel infrastructure. All of the UI and basic computational models are statically pre-compiled into HTML, CSS and highly optimized JavaScript during build, taking advantage of the Static Site Generation (SSG) capabilities. There is no need for an active server-side database or server-side runtime environment in this methodology, which helps prevent typical server-side web vulnerabilities like SQL Injection (SQLi), Cross-Site Scripting (XSS) and Remote Code Execution (RCE) [7].

Client Side State Isolation and Input Validation

All physics simulations are contained within the user's web browser and are controlled by isolated React state hooks that set mission time (t), remaining fuel mass (m), temperature difference (ΔT), and electrical efficiency (η). The application has strict client-side validation procedures to prevent potentially dangerous or unfeasible user inputs that might trigger buffer overflows, application crashes or incorrect scientific results. Manual time overrides are tightly bound by a state-management framework and limited to a maximum of 200 years ($MAX = 200\,\text{YRS}$). This means that if the user has made a manual change to the Document Object Model (DOM) or tries to put in other numbers in the input box, the state machine will sanitize it, and return to a secure, physically valid range [2,6].

Multi-Language Localization & Accessibility

RTG Reality is designed to be as effective as possible in diverse educational settings, and may be configured with a client-side localized toggle, which supports both Arabic and English languages. This feature ensures learners in Yemen and the broader Middle Eastern region can access the scientific information in their native tongue, thus closing the language gap in nuclear education. The translated JSON files are stored separately from the running app, preventing the possibility of language injection or other runtime string manipulation attacks.

Mathematical Modeling of Radioisotope Thermoelectric Generators

The accuracy of RTG Reality depends on the mathematical engine used to model phenomena such as radioactive decay, thermal transport, solid-state thermoelectric conversion, and so on [9].

Radioisotopic Decay Kinematics

The 4.8 kg of Plutonium-238 dioxide (PuO_2) fuel model is the simulated power source. The decay of plutonium-238 to the ground state of uranium-234 (^{234}U) is by alpha (α) emission.

$$^{238}_{94}\text{Pu} \rightarrow\, ^{234}_{92}\text{U} +\, ^{4}_{2}\alpha + 5.59\,\text{MeV}$$

These alpha particles absorb into the fuel form of ceramic and the heat produced by this process is modeled over time following the radioactive decay law:

$$P(t) = P_0 e^{-\lambda t}$$

The thermal power of the thermal power plant is P(t) at elapsed time t (in years), initial thermal power is P_0 (at t=0) = $2000\,\text{W}_{\text{th}}$ and the decay constant of ^{238}Pu is λ. The half-life ($T_{1/2} = 87.7$ years) gives rise to the decay constant:

$$\lambda = \frac{\ln(2)}{T_{1/2}} = \frac{0.69315}{87.7} \approx 0.00790\,\mathrm{yr}^{-1}$$

The thermal power decreases the remaining mass of ^{238}Pu fuel, m(t):

$$m(t) = m_0 e^{-\lambda t}$$

Where $m_0 = 4.8\,\mathrm{kg}$. These values are calculated on the fly as the user moves the mission timeline slider.

Thermoelectric Power Conversion and the Seebeck Effect

RTGs use a series of thermocouples composed of very highly doped semiconductor materials to transform this decay heat into electricity. If a temperature difference, $\Delta T = T_{\mathrm{hot}} - T_{\mathrm{cold}}$ between the "Hot" and "Cold" surfaces of the thermocouple is maintained, a thermoelectric voltage (V) will be generated [10]:

$$V = -S \cdot \Delta T$$

Where S is the Seebeck coefficient of the material ($\mathrm{V} \cdot \mathrm{K}^{-1}$). A dimensionless thermoelectric material performance parameter called the dimensionless figure of merit (ZT) [11] is used to evaluate the performance of a thermoelectric material.

$$ZT = \frac{S^2 \sigma T}{\kappa}$$

Where σ is the electrical conductivity ($\mathrm{S} \cdot \mathrm{m}^{-1}$), κis the thermal conductivity ($\mathrm{W} \cdot \mathrm{m}^{-1} \cdot \mathrm{K}^{-1}$), and Tis the absolute mean temperature ($T = \frac{T_{\mathrm{hot}} + T_{\mathrm{cold}}}{2}$). Thermal conductivity in semiconductors is composed of the electronic (κ_e) and lattice/phonon (κ_p) components. According to the Wiedemann-Franz law, the electronic thermal conductivity is directly linked to electrical conductivity [10]:

$$\frac{\kappa_e}{\sigma} = LT$$

Where $L \approx 2.44 \times 10^{-8}\,\mathrm{W} \cdot \Omega \cdot \mathrm{K}^{-2}$ is the Lorenz number. Reducing the lattice thermal conductivity (κ_p) while maintaining a high electrical conductivity (κ_e) is very important to achieve the highest ZT. The important operational parameters of some of the commonly used thermoelectric materials in Table 1.

Table 1.
Operational parameters of some thermoelectric materials used in RTGs.

Thermoelectric Material	Optimal Operating Temp (T_{hot})	Seebeck Coeff (S, $\mu V \cdot K^{-1}$)	Peak Figure of Merit (ZT)	Key Space/Terrestrial Applications
Bismuth Telluride (Bi_2Te_3)	$300\,K$	-220(p-type)	1.0@ $300\,K$	Low-temperature terrestrial cooling and energy harvesting
Lead Telluride (PbTe)	$600\,K$	-180@ $600\,K$	1.5@ $600\,K$	Legacy SNAP-19 and SNAP-27 space missions
Silicon-Germanium (SiGe)	$1000\,K$	-250@ $1000\,K$	0.7@ $1000\,K$	Standard GPHS-RTGs (Voyager, Galileo, Cassini)
Skutterudites ($CoSb_3$-based)	$873\,K$	$-200$to -300	$1.1$to 1.4	Enhanced MMRTG (eMMRTG) upgrades for future Mars missions

The system conversion efficiency (η) of the RTG is modeled by combining the Carnot cycle efficiency with the material efficiency factor:

$$\eta = \left(\frac{T_{\text{hot}} - T_{\text{cold}}}{T_{\text{hot}}}\right) \frac{\sqrt{1+ZT} - 1}{\sqrt{1+ZT} + \frac{T_{\text{cold}}}{T_{\text{hot}}}}$$

The baseline model in the virtual laboratory of RTG Reality determines $\Delta T = 700\,\text{K}$ as an operational temperature difference. The electrical power output $P_e(t)$ is computed with a system efficiency (η) of 5.5% in the dynamical state engine as:

$$P_e(t) = P(t) \cdot \eta = 2000\,\text{W}_{\text{th}} \cdot 0.055 = 110\,\text{W}_{\text{e}}$$

Simulation Workflow and Active Telemetry Mechanics

In RTG Reality, the user experience is designed as an interactive scientific adventure, giving the user the freedom to explore radioactive systems safely and see their behaviour when subject to the changing conditions of the environment.

Dynamic Mars Telemetry Simulation

In Phase 2 of the application, the user is shown a scenario for landing on Mars. The spacecraft's initial power is based largely on its solar array, producing a steady total of $600\ W_e$. At $T + 13$ seconds into the simulation, however, a significant environmental event occurs: A large dust storm on the surface of Mars (SYS_STORM: ACTIVE).

The solar power generation decreases quickly to zero (SOLAR_OBS_SYS: INACTIVE) due to the dust in the atmosphere blocking the incoming sunlight, threatening complete power loss to the spacecraft's scientific payloads. The onboard RTG is switched on by a manual system override command (CMD: ACTIVATE RTG) prompted by the user. The simulated state engine moves the load to the RTG which generates a continuous, reliable $110\ W_e$ output, showing the importance of its independence from sunlight to maintain a mission in extreme environments.

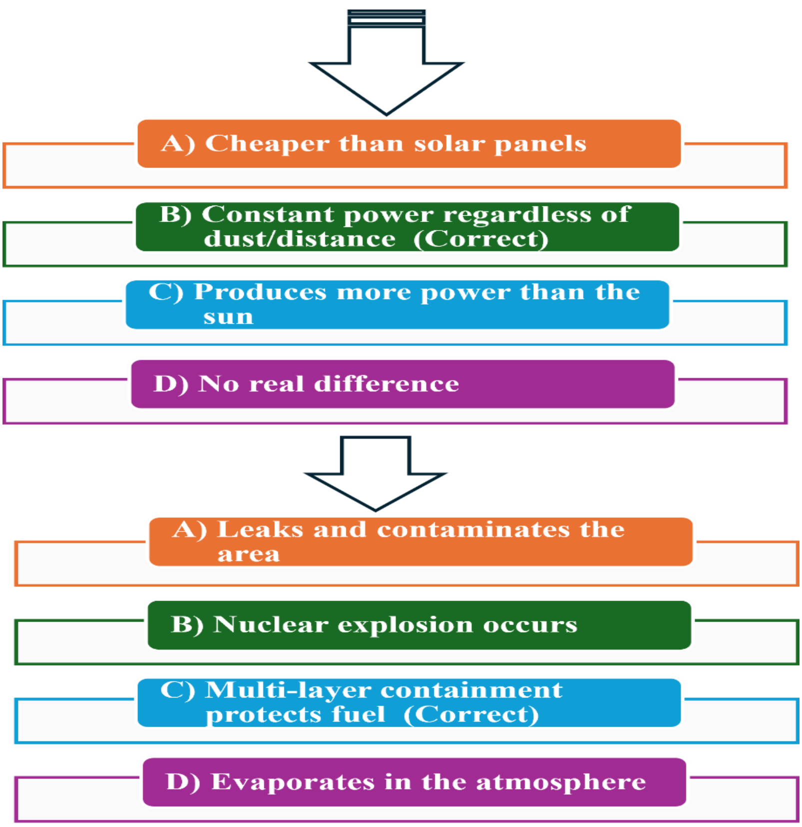

Figure 1: Feedback Loops for Educational Verification.

Educational Verification Loop

The simulation challenges the cognitive retention of the concepts and techniques introduced during the telemetry exercises by incorporating real-time interactive "System Queries". The knowledge and understanding of the learning phases in Figure 1 are to be attained by solving these evaluation points correctly.

These immediate feedback loops make the simulator not only a step-by-step simulator, but one in which the user has to understand the thermodynamic and engineering aspects behind the system [12].

Comparative Nuclear Physics: Weapons, Reactors, and RTGs

These immediate feedback loops make the simulator not only a step-by-step simulator, but one in which the user has to understand the thermodynamic and engineering aspects behind the system .[12]

The key pedagogical goal of RTG Reality is to remove the general public misunderstanding that an RTG may cause a nuclear explosion or a meltdown like the one in a reactor. The simulation does this by visually and mathematically comparing the essential physics of nuclear weapons, critical fission reactors and subcritical radioisotopic power systems. In Table 2 they are compared in terms of their operating parameters [9,13].

Table 2.

Comparison of nuclear weapons, fission reactors, and radioisotope power systems.

Operational Parameter	Nuclear Weapons	Nuclear Fission Reactors	RTGs
Physical Mechanism	Prompt supercritical fission chain reaction	Controlled critical fission chain reaction	Spontaneous, non-chain-reacting alpha decay
Fissile / Isotope Fuel	High-Enriched Uranium (^{235}U > 90%) or Plutonium (^{239}Pu)	Low-Enriched Uranium (^{235}U 3-5%) or MOX fuel	Plutonium-238 Dioxide (PuO_2) ceramic pellets
Multiplication Factor (k)	Supercritical ($k \gg 1$)	Critical ($k = 1$)	Subcritical ($k \approx 0$; no chain reaction possible)
Control Interface	Non-existent (designed for instant release)	Active control via neutron-absorbing rods and coolants	Completely passive; non-adjustable thermal decay
Meltdown / Explosion Risk	Designed for explosive release	Prevented through active safety systems and coolants	Physically impossible due to subcritical, passive decay

The second requirement for nuclear weapons is prompt supercriticality ($k \gg 1$), in which a very large mass of fissile isotopes (such as (_^{235}U or ^{239}Pu) is quickly squeezed into a supercritical geometry. This configuration starts an uncontrolled exponential fission chain reaction via prompt neutrons, liberating tremendous energy in microseconds.

Commercial nuclear reactors run at a criticality of $k = 1$, keeping a controlled fission chain reaction that sees the production of exactly one neutron for each fission, which triggers another fission. Reactors produce high power but require more complex, active coolant systems and neutron-absorbing control rods to ensure stability and prevent thermal excursions or core melting.

In stark contrast, RTGs are completely subcritical systems ($k \approx 0$). No fission chain reaction, no need for any neutrons to maintain power generation. The heat is generated only by a spontaneous, unadjustable alpha decay of individual ^{238}Pu atoms. This decay rate is only dependent upon the physical half-life of the isotope, so the thermal output does not rise exponentially, change with demand, or be turned off. An RTG is physically impossible to fail spectacularly, such as in the case of meltdowns or nuclear explosions, thus making it an inherently safe space power source [9,13].

Accident Containment Analysis and Safety Engineering

Although it is physically impossible to cause nuclear explosions in an RTG, a key priority is to prevent localized radioactive contamination in the event of launch failures, atmospheric re-entry, or high-velocity terrestrial impact. A good example of this is the 3D visualization of contemporary General Purpose Heat Source (GPHS) multi-layer containment modules [6] (Figure 2). The containment layers used in the RTGs are presented in Table 3, along with their roles in mechanical or thermal Protection at high-temperature limits.

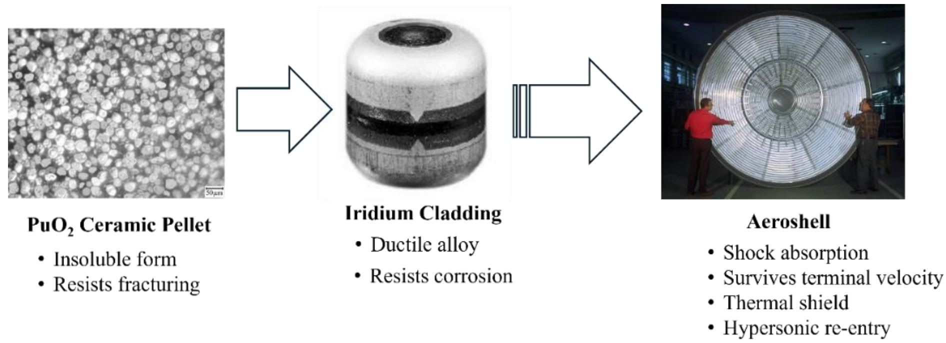

Figure 2: Visualization of GPHS Multi-layer Containment Modules.

The PuO_2 Ceramic Fuel Pellet

The first line of defense is the physical condition of the fuel. Instead of the low melting point, highly reactive metallic plutonium that is used in other RTGs, the RTG used plutonium-238 in ceramic dioxide (PuO_2) form. Like ceramic mugs in homes, this material will not break into small dust particles when subjected to high impact loads and it is very non-biological soluble in both fresh and salt water if damaged in the ocean by a spacecraft [14].

Iridium Alloy Cladding

The ceramic pellets are individually enclosed in an iridium alloy clad shell, called the "fueled clad". Iridium is chosen because of its ability to resist chemical corrosion, its high melting point (≈ 2443°C), and high temperature ductility. This cladding is a first line of defence for confining the plutonium dioxide even in the event of severe mechanical deformation [15].

Table 3.

Composition of the Containment Layers of RTGs and their role in Mechanical or Thermal Protection at High-Temperature Limits.

Containment Layer	Material Composition	High-Temperature Limit (˚C)	Primary Mechanical / Thermal Protection Role
1. Isotopic Fuel Form	Plutonium Dioxide (PuO_2) Ceramic	≈ 2400°C	High-temperature containment; chemically insoluble and fracture-resistant to mitigate aerosol hazards.
2. Encapsulated Clad	Iridium Alloy cladding	≈ 2443°C	Corrosion-resistant mechanical barrier; retains ductility under severe high-impact deformation.

Containment Layer	Material Composition	High-Temperature Limit (˚C)	Primary Mechanical / Thermal Protection Role
3. Impact Absorber	Fine-Weave Pierced Fabric (FWPF) GIS	≈ 3000˚C (sublimation)	Kinetic energy absorber designed to withstand land or water impacts up to 55 m/sterminal velocity.
4. Thermal Insulator	Carbon-Bonded Carbon Fiber (CBCF)	≈ 3000˚C	Insulates the internal cladding to prevent thermal shock from aerodynamic re-entry heating.
5. Aerocasing Shield	Graphite Composite Aeroshell	≈ 3000˚C	Structural outer shell engineered to survive reentry heating up to 2000˚Cand subsequent debris impacts.

Graphite Impact Shell (GIS)

Two fueled clads are surrounded by a Graphite Impact Shell (GIS) to protect the ductile iridium cladding from mechanical impact loads during explosion on the launch pad or ballistic impact in ground. The GIS is made of Fine-Weave Pierced Fabric (FWPF), a carbon-carbon composite designed to absorb kinetic energy in high velocity impacts up to a terminal velocity of 55 m/s[15].

Aeroshell and Thermal Insulation

The outer layers of GPHS include the aerocasing or aeroshell which contains the GIS assemblies. The aeroshell is surrounded by Carbon-Bonded Carbon Fiber (CBCF) insulators that give the aeroshell structural integrity and thermal protection. The multi-layered graphite-composite structure is to be able to resist the very high thermal shock and friction-induced heating (≈ 2000°C) that occurs during accidental hypersonic atmospheric re-entry [16].

Empirical Validation: Historical Space Mission Incident Analysis

The safety models developed in the application are checked against actual space-vehicle incidents involving extreme launch and re-entry stress on the RTG containment systems from various sources [3,6,13,17,18]. These are summarized in Table 4.

Table 4.

Analysis of Some Important Historical Space Mission Incident.

Space Mission	Launch Date	RTG Model	Incident Details	Containment Performance	Environmental Impact
Transit 5BN-3	April 21, 1964	SNAP-9A	Failed to achieve orbit; reentered atmosphere over Indian Ocean.	Intentionally vaporized at high altitude (≈ 50 km) as designed.	Dispersed ≈ 17,000 Ciof ^{238}Puglobally; minimal health impact.
Nimbus B-1	May 18, 1968	SNAP-19 (2 units)	Range safety destroyed booster at 30 kmaltitude over Pacific Ocean.	Survived explosion and ocean impact intact; recovered from ocean floor.	Zero radioactive release; fuel recovered and recycled.
Apollo 13	April 11, 1970	SNAP-27	Lunar mission aborted; lunar module reentered Earth's atmosphere.	Survived atmospheric re-entry intact; sank in the Tonga Trench.	Zero release; contained ≈ 3.8 kgof ^{238}Puunder 6000 mof water.

The SNAP-9A High-Altitude Dispersal Paradigm (1964)

The Transit 5BN-3 navigation satellite was launched on 21 April 1964 and is significant because it was designed to be contained. Larger fragments were avoided by early space-nuclear designs, which used high altitudes where sublimation would limit contamination. The SNAP-9A RTG burned up over the Indian Ocean when the vehicle failed to reach orbit, scattering about 17,000 curies (0.6 PBq) of Plutonium-238 in the stratosphere as submicron particles.

Initially this spread led to higher plutonium concentrations in the stratosphere worldwide, but over time these amounts were mixed and decayed, producing virtually no radiation doses to the global population (estimated at ≈ $0.04\,\mu$rem whole-body, over 50 years, and not associated with adverse health effects). This event, however, led to a paradigm shift in the design approach which moved from ‘vaporization' designs to ‘absolute containment' designs [3].

The Nimbus B-1 Recovery Success (1968)

The absolute containment paradigm was proven effective on May 18, 1968, when the launch of Nimbus B-1 failed. The satellite's two RTGs from the SNAP-19 system plunged into the ocean when the range safety officer destroyed the rocket due to a guidance fault over the Santa Barbara Channel .

The fuel capsules came through the explosion and high velocity water contact without any damage. The intact RTG units could be recovered after five months without leakage of radioactive material and the Plutonium-238 fuel could be safely extracted and processed and reused for future space missions [13].

The Apollo 13 Deep-Ocean Submergence (1970)

The most well-known RTG safety containment test was during the abort mission of the Apollo 13 in April 1970. The Lunar Module Aquarius was used as an emergency lifeboat for the crew to return to Earth after an explosion in the oxygen tank in the Service Module. A SNAP-27 RTG with 3.8 kg of plutonium dioxide ceramic fuel [17] was attached to the landing stage of the module.

The Lunar Module's re-entry was planned to destroy it over the South Pacific Ocean when it returned on April 17, 1970. The hypersonic re-entry heat did not destroy the containment shell of the SNAP-27 graphite cask and it splashed into the Tonga Trench, at a depth of some 6000 "meters". The post-reentry radiation survey confirmed that no localized release of radiation had occurred and that modern GPHS barriers were able to withstand extreme thermomechanical stresses[18].

The pedagogical impact, cognitive efficacy, and public advocacy

The design and international recognition of RTG Reality illustrate how an online interactive simulation can help to promote public understanding of nuclear issues [4].

The use of Bloom's Taxonomy in the context of Serious Games

Typical teaching approaches focus on bottom-up learning tasks that emphasize memorization and understanding of concepts. In contrast, the concept of RTG Reality building is based on interactive mechanics which help to lead users to higher order cognitive domains [3,5,19,20]:

- **Knowledge and Comprehension:** Explore the interactive onboarding phases to learn about the thermoelectric principles of the Seebeck effect and about basic radioisotopic decay kinetics and half-lives.
- **Application and Analysis:** In the simulated Mars dust storm, users will need to analyze as solar grid telemetry decreases and determine the risks to spacecraft power systems, acting to ensure that the spacecraft systems remain powered on by using secure over-ride to override RTG failures.
- **Evaluation:** In Phase 3 users will use the interactive comparative matrix to explore the fundamental differences between critical fission reactions

and passive alpha decay, and thereby demonstrate why RTGs cannot cause nuclear explosions.

This paradigm of active learning has been proven to enhance the conceptual understanding of the students about passive safety mechanisms and system integration over conventional lecturing.

Trust, Inclusivity, and Global Nuclear Advocacy

Digital serious gaming also provides an opportunity for countries with significant educational challenges and no physical nuclear facilities, such as Yemen, to introduce advanced concepts in STEM and nuclear engineering, but in an accessible, inexpensive manner. Secure, cloud-based platforms allow students around the world to engage in hands-on science training, while removing the need for scientific simulations from physical laboratories.

Further, gamification features in public advocacy reduce emotional impediments, change the concept of radiophobia to scientific facts and create an environment that allows for public discussion of the peaceful uses of nuclear technology. The international attention garnered by the RTG Reality at the 2026 "Myth Smashers" challenge demonstrates the potential of secure, browser-based simulations for global education and scientific communication.

Conclusion

This award-winning interactive, browser-based application, RTG Reality simulation developed by the Al-Saeed University team, Yemen, is a successful example of how interactive applications can boost public scientific literacy and help promote international nuclear advocacy. The application combines strict mathematical equations based on the decay of Plutonium-238 and thermoelectric energy conversion, and gives a hands-on scientific experience.

The nuclear weapons comparison of the fission reactor compared to the radioisotopic decay system effectively debunks common safety myths by showing that a supercritical chain reaction can't exist in a subcritical radioisotopic decay system. Besides, the simulation has empirical proof of present containment engineering from the various space-mission accident cases studied, including the intact re-entry of the Apollo 13 SNAP-27 generator into the Tonga Trench.

Importantly, the secure-by-design front end architecture of the application supports high availability and integrity of telemetry, and it is resilient to digital exploits, creating a benchmark for digital nuclear pedagogy. This work, endorsed by international organisations such as ANENT, INSTA and the IAEA, demonstrates that secure, interactive tools can be used to reduce barriers to education, to facilitate factual public discussion and to inspire a new generation of nuclear scientists and security professionals around the world.

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