By The Dawn's Early Light

Nuclear Science and the Key to Conquering America's Challenges

Design: Hrair Aprahamian

APS physics

This Brochure is prepared by the American Physical Society's Division of Nuclear Physics.

ARUNA

Association For Research At University Nuclear Accelerators

Florida State University John D. Fox Accelerator Laboratory
Ohio University John E. Edwards Accelerator Laboratory
Texas A&M University Cyclotron Institute
TUNL Triangle Universities Nuclear Laboratory
University of Kentucky Accelerator Laboratory
University of Notre Dame, ISNAP, Institute for Structure and Nuclear Astrophysics
University of Washington CENPA Center for Experimental Nuclear Physics and Astrophysics

GRIPPER

nuclear physics and society

Nuclear Science

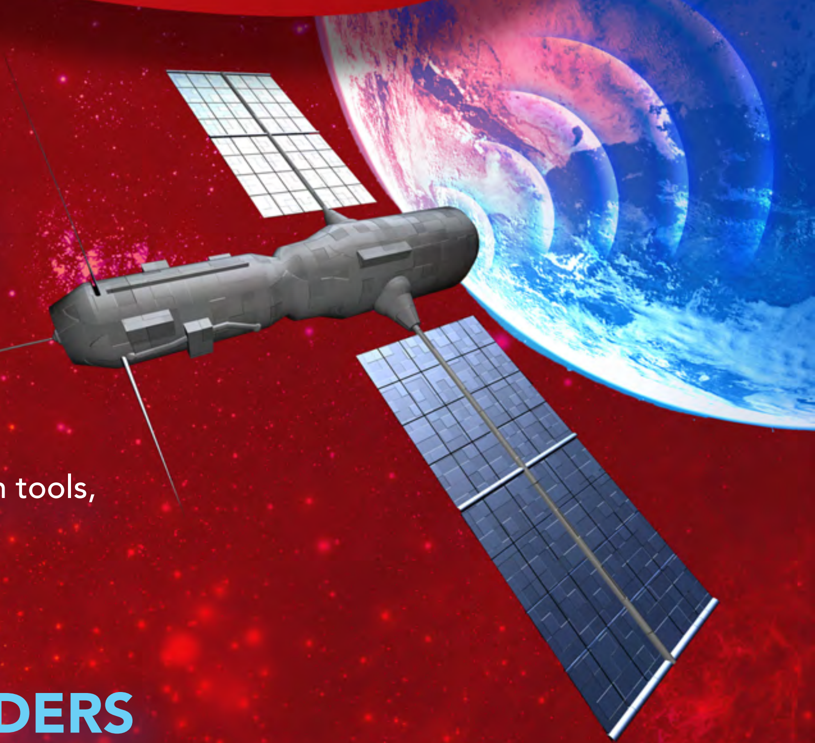
The remarkable discoveries of nuclear science continue to play a significant role in the frontiers across all of the American landscape.

DEFENSE AND SECURITY
ENERGY AND CLIMATE
HEALTH AND MEDICINE
INNOVATION AND ECONOMY
ART AND FORENSICS

Technological advances of tomorrow, still being analyzed and tested today in national and university nuclear science laboratories across the country, represent still greater opportunities that will cascade throughout the economy and industries of the United States of America.

Keep this area blank.
This area will not be printed

GRIPPER

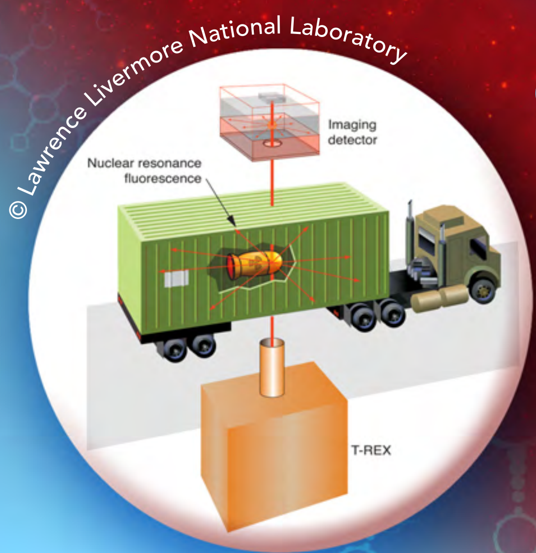


Nuclear science discoveries and technologies have the potential to make significant contributions to the national security and defense in key areas, such as stockpile stewardship, physical data, understanding of extreme environments in high-energy-density conditions, cargo inspection and interrogation, production and implementation of radioactive isotopes, nuclear forensics, simulation tools, and the training of a skilled workforce.

- **NATIONAL DEFENSE**
- **PROTECTION OF BORDERS**
- **WEAPONS OF MASS DESTRUCTION**
- **STOCKPILE STEWARDSHIP**

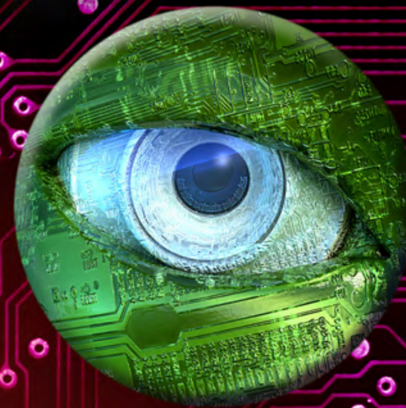
Physical Data

National security and defense programs have a critical need for the highest quality data on the interaction of radiation with various materials.



Cargo Inspection and Interrogation

Security priorities of the last decade have focused on deterring the threat from subnational organizations. Nuclear techniques are crucial to non-intrusive complete composite scans of merchandise and cargo thereby allowing for safer shipment without impacting economic efficiency.

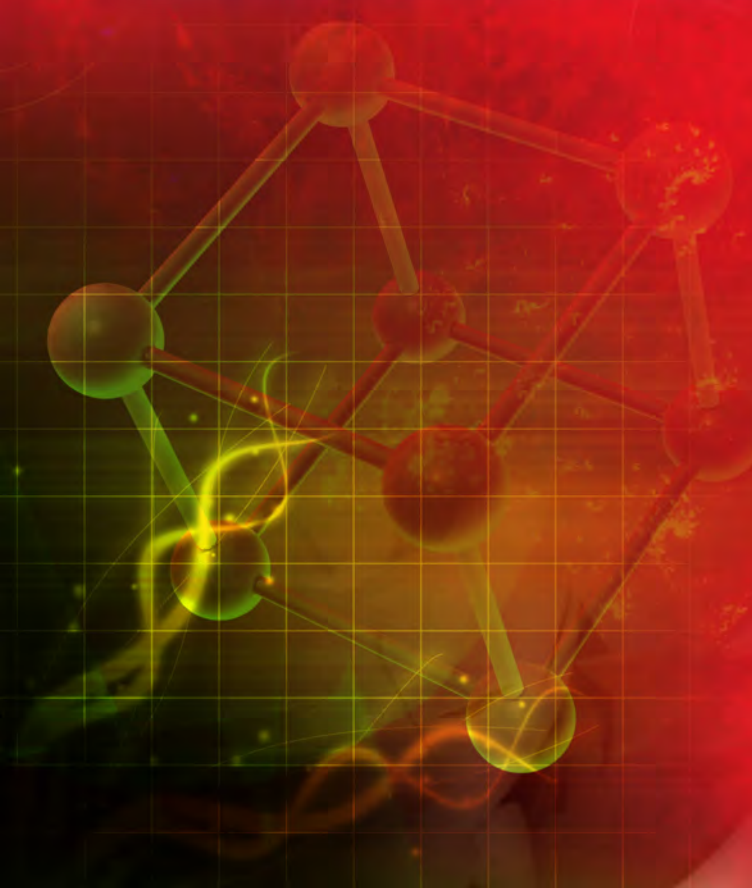


Nuclear Forensics

Currently nuclear forensic analyses require intensive and time-consuming chemical separations using mass spectrometers and other instruments. Reducing the time required for these analyses and moving the instrumentation to a field laboratory would have significant advantages.

Compact, Fieldable Accelerator Systems

A clear need exists for compact, robust accelerator systems that can be deployed in the field. Currently, vibrations and temperature swings affect most accelerator-based technology, and components and infrastructure occupy a large space. All of these components require integration into a single compact unit that can withstand the challenging environments associated with field use. This is especially critical for the forensics area of security and defense, where detection, characterization, and decontamination operations need to occur quickly.



Simulation Tools

Nearly all projects use extensive numerical simulation analyses to optimize designs and reduce cost and risk. Many tools in use today are based on work developed in the 1970s albeit with a recent shift to massive parallel systems with hundreds of thousands of processors. Many if not most of the tools developed in those research programs have not trickled down to the broader nuclear science community or to industry. Often, the problem is a lack of user friendliness and communication. Code development and adaptation to computer architecture require a concerted effort between government and industry.

Accelerators for America's Future ***by Department of Energy***

Institute for Structure and Nuclear Astrophysics
at University of Notre Dame

Energy and Climate

Nuclear physics has the extraordinary potential to address the energy and environmental challenges of the 21st century. Confronting growing energy demand while reducing the environmental impact of greenhouse gases will be of paramount importance in the coming decades.

Nuclear technologies have the ability to tackle these challenging developments by providing us with a reliable, economical, and clean source of power while shrinking our carbon footprint. Reducing our national dependence on foreign oil.

Reactors for Energy

Nuclear reactors provide over 20% of our electricity and account for 70% of our emission-free power. Modern nuclear reactors create energy by inducing a chain reaction in a fissionable material like uranium. Bursting neutrons from the nucleus of a uranium atom bump into other nuclei and create a chain reaction all throughout the fissionable material producing enormous amounts of energy in the process. However, nuclear physics has found a new way to develop inexpensive power that confers several advantages over fission based reactors. Subcritical reactors utilize a non-fissionable material such as natural thorium, an element that is four times as prevalent as uranium in the earth's crust. Use of these subcritical reactors can halve the volume of radioactive waste and of toxic actinides produced.

Spent Fuel Transmutation

Nuclear reactors typically produce 100,000 tons of spent nuclear fuel over their lifetime, the byproducts of which are toxic and must be properly contained, disposed, and accounted for. Safe and stable storage containers, which may last only for hundreds of years, must be couple with geographical characteristics that isolate these spent fuels after the containers have decayed. However, nuclear accelerators can transmutate these fuels and reduce the lifetime of these toxicity characteristics from 300,000 years to merely 500.
This vastly reduced toxicity profile is also safely within container guide-lines and thereby poses an admirable solution to nuclear waste storage and maintenance.

Water Purification

Particle accelerators play an important role in the purification of drinking water and treatment of waste water. The technology is widely available globally but has not yet become fully adopted in the United States. The primary means of processing water with nuclear technologies is electron-beam irradiation, a process that has many advantages over traditional water purification and treatment methods. The irradiation method is not impeded by the presence of solids or other adsorptive compounds in the water. What's more, as concern grows about the presence of chemicals and pharmaceuticals that traditional water purification systems can't remove, nuclear science offers the cleanest and most efficient choice.

Cleaner Air with Electrons

Electron beams can serve us not only in cleaning up our water but also our air. As we become increasingly aware of the detrimental effects that gases from smokestacks and factories have on the environment, we can utilize nuclear technologies to clean these emissions before they hit the atmosphere.

Currently, emissions are treated in a complex limestone scrubbing process in order to remove sulfur dioxides and nitrogen oxides. The process requires multiple applications and creates undesirable waste water. Electron-beam technology is faster, requiring only a single application, and it doesn't create any waste products but rather ammonium sulfate and ammonium nitrate byproducts, that can be sold as fertilizer.

Accelerators for America's Future ***by Department of Energy***

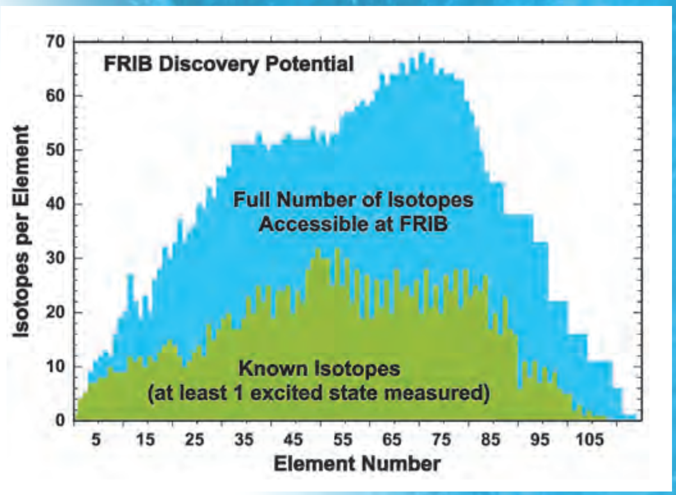
The Physics of Climate ***by Professor Micheal Wiescher at University of Notre Dame***

The bold and innovative technologies of particle accelerators have created powerful tools for medicine.

Accelerator technologies are critical to many vital medical applications. Tens of millions of patients receive diagnoses and therapy as a result of nuclear science medical breakthroughs.

Isotope Production

Radioisotopes have numerous applications in medicine and biology. Their greatest promise lies in aiding medical diagnosis and therapy. The methodology is simple: isotopes emitting x-rays, gamma rays, or positrons are delivered to a point of interest in the patient's body and serve as diagnostic probes. Instruments located outside the patient image the radiation distribution thereby gaining knowledge of the underlying biological structures and fluid motion.



The sources for these hundreds of different isotopes are nuclear reactors or accelerators.

Imaging

Radioactive isotopes are used to image internal organs for diagnosis of disease and evaluation of proper function.

Therapy

Every year, one million new cases of cancer, the nation's second largest cause of death, are diagnosed in the United States. Half of these patients undergo radiation treatment and therapy, the technology for which is under continuous improvement and promises to deliver many exciting breakthroughs in the coming years.
Particle beam therapies maximize the dose to tumor tissue while minimizing damage to healthy cells.

Innovation and Economy

Universities and national laboratories are discovery engines in all of the sciences in general and in nuclear physics in particular. Our modern industrialized economy depends on the innovations that trickle down from research to the market place.

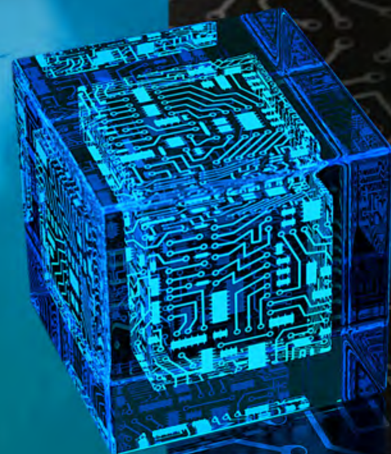
Electron-beams modify and prepare industrial ceramics and plastics by cross-linking polymers; they also irradiate our food and sterilize pathogens in our medical equipment. Ion-beams are in heavy use in microchip manufacturing and surface treatments for artificial joints. In order to take advantage of the potential to increase existing markets and to develop new applications, industry and government will need to address the existing barriers to expansion.

Cross-linking Polymers

One of the most common industrial applications for nuclear technologies is the cross-linking of polymers, a process which renders materials undissolvable while eliminating the use of volatile organic solvents.

Replacing Thermal Processes

Nuclear technologies, in particular electron and ion-beam accelerators, have the potential to revolutionize many manufacturing processes. Among these include many heat-based processes such as the curing of inks and coatings with less energy consumption and waste.



Producing Biofuel

Instead of driving up the prices of arable land and edible food crops like corn in order to produce biofuels such as ethanol, electron beams can break down nonedible plant products to use as ethanol-producing fermentation stocks. This method also produces zero toxins without diverting corn from the food supply.

Ion Beams

Ion beams are prevalent in computer chip manufacturing. In a process called doping, silicon wafers are impregnated with atomic impurities to modify their conductivity profile, enabling manufacturers to make faster and smarter chips.

Accelerators for America's Future ***by Department of Energy***

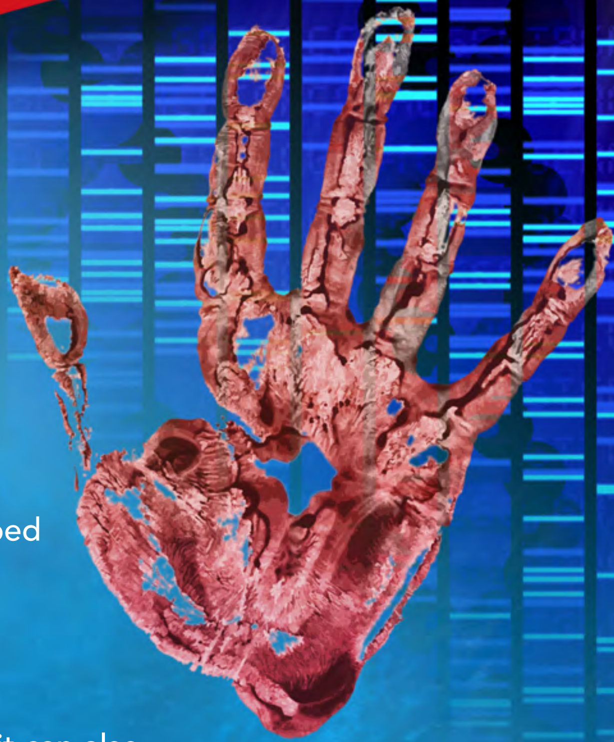
Art and Forensics

The spheres and domains that nuclear physics impacts are constantly expanding. Art and criminal forensics have recently tapped into the benefits of nuclear science which helps these disciplines analyze paintings, manuscripts, sculptures and unearth crime scene data that standard investigative methods cannot diagnose.

Art Forgeries

Passing off forged paintings and art pieces as authentic is a lucrative business, turning virtually worthless objects into highly-prized and desired objects. With so much to gain, the art industry has been trying to utilize expert art inspectors and historians though such methods are not always accurate and occasionally identify genuine works as forgeries while actual forgeries go undetected. Ion beams to analyze works of art with proton-induced x-ray emission (PIXE) and accelerator mass spectroscopy (AMS) have transformed the art market. Scientists can now determine the origin of the canvas, frame, pigments and even the climate during the piece's creation, allowing them to compare it to known samples and identify anomalies, thereby being able to proclaim a given art object as a forgery. Accelerators developed to study the properties of the atomic nucleus can now be used to further many other fields of study from archeology, architecture, sociology, and history.

The true origin of archeological objects is a major factor in their physical and chemical "fingerprint", these objects also pick up microscopic debris from the climates they've been exposed to and can clue researchers in to the movements and migrations of objects over time. For example, analysis of the ruby eyes of a Babylonian statue showed that the rubies came from a mine in Vietnam, proving that a mature trade economy had developed between those distant regions over 4000 years ago.



Criminal Science

Nuclear science and the technologies that have evolved from it can also be used by criminal forensics teams to identify criminals. Gunshot residue is composed of small metallic particles that lodge themselves into the skin and clothing of shooters; they are nearly impossible to wash and get rid of them in the aftermath of a shooting. Researchers can place this clothing in ion beam accelerators and identify the "fingerprint" of the residue and therefore determine the origin. The chemical composition of the bullet and gunpowder, ultimately lead to the apprehension of the criminal.

Notre Dame physicists use ion beams to detect art forgery by Marissa Gerhard

Ion Beam Cop: Forensic science and analysis, Dr Melanie Bailey, Ion Beam Centre, University of Surrey