Nuclear Physics Applications
in industry, medicine, and liberal arts

- Energy Sources
- Nuclear Forensics
- Homeland Security
- Imaging and Diagnostics
- Radiation Treatment
- Material Science
- Art and Archaeology
Physic\textsuperscript{s} Applications

Energy
- ADS \& Transmutation
- Fusion confinement
- Nuclear Waste
- Energy Storage

Nuclear Forensics
- Homeland Security
- Risk Assessments
- Nuclear Trafficking
- Proliferation

Life Science
- Medical Diagnostics
- Medical Therapy
- Radiobiology
- Biomedical tracers

Material Analysis
- Nanotechnology
- Ion Implantation
- Material Structure
- Geology \& Climate
- Environment
- Art \& Archaeology

Nuclear Defense
- Weapon Analysis
- Functionality
- Long-Term Storage

Computation
- Monte Carlo Simulation
- Network Simulation
- Software Development
- Quantum computing
Nuclear Energy

From nuclear power plants

to nuclear pace makers

Accelerator Driven Systems (ADS) for operating sub-critical reactors

1GeV accelerator development ($\sim 10^{15}$ n/s)

ADS for nuclear waste management

- Beam optics & irradiation system development
- Incineration strategies
Fusion Reactors for the Future

The Tokomak approach ITER

The laser approach NIF

Magnet field confined plasma fusion

Laser ignition fusion
Achieving ignition at the National Ignition Facility can be a defining moment for the world’s energy future.

We are developing “LIFE,” a fusion/fission hybrid approach for power generation.
From NIF to LIFE
National Ignition Facility at LLNL
To Laser Induced Fusion Energy
Nuclear Forensics

Driven by terrorism threat & homeland security issues

Trafficcikng of nuclear materials & material loss assessments

Border control & radiation exposure (instrumentation)

Provenance of radioactive material by isotope composition or material structure analysis

- Signature identification,
- Detector array development
- Sensitivity analysis
Airport security - neutron activation techniques for plastic explosive search

\[ ^{14}\text{N} + n \text{ (thermal)} \rightarrow ^{15}\text{N}^* \rightarrow ^{15}\text{N} + \gamma \text{ (10.8 MeV)} \]
Was Napoleon murdered by the British?
Was Napoleon murdered by the British?

Napoleon himself suspected to become a British victim. Chemical analysis of his hair indicated enhanced Arsenic (As) levels which seemed to confirm the murder theory! But!

\[ { }^{75}\text{As}(n,\gamma){ }^{76}\text{As}; \ T_{1/2} = 26.4 \text{ h} \]

\[ { }^{75}\text{As} \text{ is the only stable isotope of As} \]
Nuclear Imaging

Blood flow with radiopharmaceuticals

Tumor mapping & visualization by radioactive isotope accumulation.

Imaging software and analysis

- Gamma Camera
- SPEC & PEP
- Isotopes & Isomers
- Pharmaceuticals

Imaging system development
Brachytherapy  
Gamma therapy  
Neutron therapy  
Heavy ion therapy

Treatment plan with 2 heavy ion fields  
Treatment plan with 9 photon fields IMRT

Radiation Treatment
Material Sciences

Ion implantation into silicon chips for generating micro electronics elements.

Radiation hardening for outer space
Applications from electronics to sails
Isotope analysis in forensics & biology

Isotope studies for provenance, eating habits

- Tooth enamel is formed in early childhood \( \Rightarrow \) origin
dentin & bone changes with time \( \Rightarrow \) death
King of Stonehenge, a German immigrant?

The Daily Express expressed the opinion. "This is as shocking as the discovery that the first cricket players wore leather pants and ate Bratwurst with their tea."
Dating real and false mummies
Increasing slaughter of elephants since 1970 with increased use of automatic weapons.

Ivory trade ban in 1989 to protect elephants from becoming extinct

Growth in poaching and smuggle leading to a decline as high as 90% in certain areas
By using the Bomb Peak

But how to determine the age of ivory carved artifacts on the market, to determine if it was illegally obtained and smuggled?
Nuclear Physics Employment

51% US
80% Male
~5.7 years

Employment of nuclear science students, 5-10 years after Ph.D. award

~49% temporary visa holders