



Operated by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Forum Presentation

A Roadmap for Discoveries for Africa

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The African School of Fundamental Physics and its Applications

Dakar, Senegal

16 August 2014

Outline

Applied and Basic Research, Time, and Discovery

How the most simple became the most complex

A very few Pioneers

What is the value of pursuing truly new knowledge?

A Road Map for Africa

Investment, Future Value, and Impact

Some Applied Research is closer to solving a problem of a specific and well defined Issue.

What method is best for extracting oil from oil shale ?

Fundamental Research does not have so true a focus because the questions are sometimes broader.

An example would be:

What laws of nature determine the course of future history and constrain other research efforts or our understanding of the truth?

How large is the universe?

It often takes time to pursue the individual answers to research questions and often substantial resources.

So the problem could be defined as resources over time and gauging the impact of solving a particular problem, or even better, making a discovery.

Industry supports the applied research effort mostly, and the society often supports the academically motivated and more basic research effort.

Is the investment better because we have an expected outcome?

DISCOVERY

Extracting and understanding a phenomena for the first time!

Leading to answers and often more questions

Usually a piece of a puzzle that took some time to ascertain

Often connecting many separate fields of study.

Long-term Benefits:

- * Knowledge is the foundation of future technology
- * Technology drives economic growth
- * Fundamental Research → Innovation → Prosperity
- * Physics research produces transformative discoveries and contributes positively to the health of a national scientific structure.
- * Examples:
 - * Faraday's experiments on electricity → electric light
 - * H E P communication needs → World Wide Web
 - * Superconducting wire → new machines

Cost and benefits of public investment have been shown to be a positive outcome.

Near-term (~ our lifetimes):

- * Employment
- * Procurement
- * Technology Transfer, Knowledge Transfer

Examples:

The European Physical Society four year study on the contribution of physics to the economies of Europe:

The physics-based industrial sector generated over 15% of the total turnover and 13% of overall employment within Europe's business economy. (*ref*)

It is estimated from a study regarding CERN business contracts, approximately 38% return on investment was realized over a period of 20 years totaling nearly 1.3 billion Swiss francs.

There are similar estimates for regional economic impacts due to laboratories in the USA.

Benefits of Fundamental Physics Research

- **Increase our understanding of nature and how it works**
- **Technological spin-offs –**
- **much of today's economy is based on late 1800s – early 1900s research on the electron**
→ **TV (accelerator) & communications**



Brookhaven National Lab

Credit: BNL Photo Files



CERN Laboratory

Fermi National Accelerator Laboratory



The Road Map

Capacity development in human potential as well as institutional development is crucial to the continued and increase participation of Africa in Discovery Science. We have pioneered the use of decommissioned research equipment for use in some schools in the USA. These educational institutions used the QuarkNet Program focused on the LHC. This type of effort can also be considered for some student institutions represented in this African School for Fundamental Physics Research. We already have efforts in this direction regarding computing processors that were donated from CERN and elsewhere.



As an agricultural chemist, Dr. Carver discovered hundred of uses for Peanuts and hundred more for: Soybeans, Pecans, Sweet potatoes, and made them into: adhesives, bleach, buttermilk, sauces, axle grease, fuel briquettes, ink, metal polish, paper, plastics, synthetic rubber, and many more..

Dr. George Washington Carver USA Library of Congress LC J601-302

However, Dr. Carver only applied for three patents:
paints and stains from soybeans
#1,522,176, 1/06/1925, Cosmetics & Plant Products
#1,522,178, 1/06/1925, Paints & Stains
#1,632,365, 6/14/1927, Paints & Stains



Lincoln University, 1946

Courtesy: Leo Baeck Institute, New York & The Albert Einstein Estate



Research has provided long-term benefit through applied physics:

The quantum theory of solids leading to semiconductors and computer chips

Nuclear Magnetic Resonance leading to MRI imaging

Particle accelerators leading to particle beams for cancer treatment.

Could Dr. Einstein's theories of special and general relativity also be connected to current day benefits?

Relativity plays a key role in the multi-billion dollar industry
concentrated around the
Global Positioning System (GPS)



Military Navigation amounts to \$10 billion effort

24 atomic clock satellites in orbit at 14000 km/hr and 20,000 km above the Earth

Gravity is ~ four times weaker

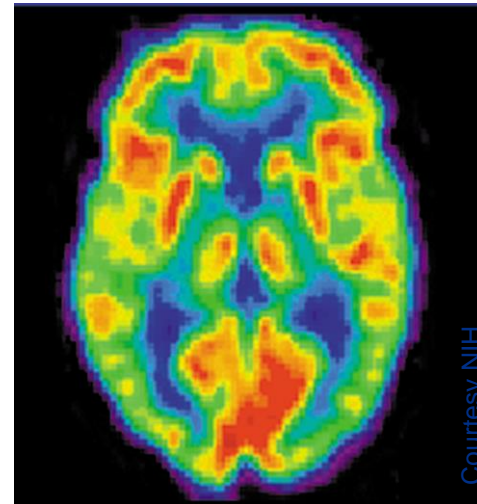
The GPS clocks run faster than earth based clocks.

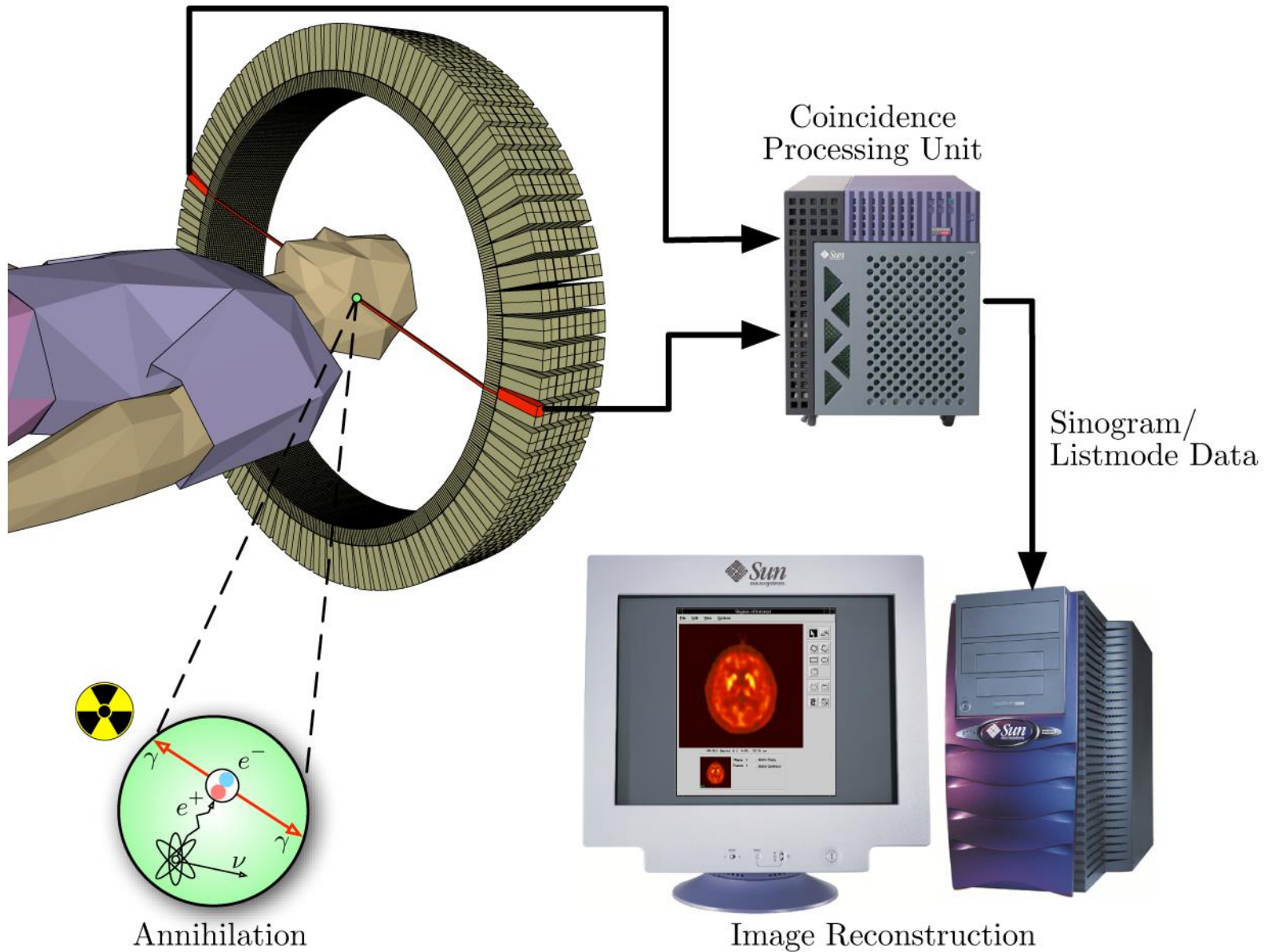
Relativity is needed to adjust the time
by **38** micro-seconds/day

What Value?

Antimatter can be used for

- PET Scans





Ideas can be implemented in any country.
Collaborations and cooperation for mutual benefit is the true basis of executing pioneering research.

The models of CERN, SESAME, and collaborations around the world working on complex research projects are primary examples.

We want to suggest this structure for countries in Africa. It is possible to establish an international structure where resources are shared among regional African nation states and directed toward scientific and technical research and education training.

Within this structure, interdependence could produce and operate research, knowledge, and data centers that would be the basis of group collaboration with regional, non-regional and world scientific efforts.

The models of CERN and other research organizations worldwide are clear models that could be studied to consider applicable aspects. In this example, it is acknowledged that memoranda of understanding, as well as nation states treaties would be helpful, and for some efforts required.

The results of such long-term development and commitment would be transforming in the world, and make it possible to enhance and directly address technical and particularly emergency issues that arise.

Office of Science Laboratories

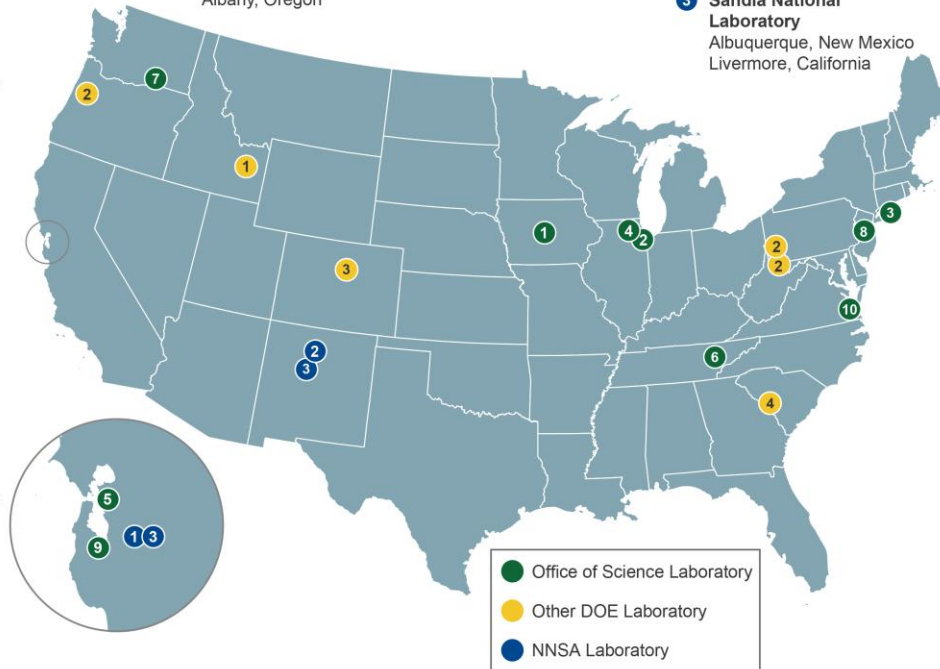
- 1 Ames Laboratory
Ames, Iowa
- 2 Argonne National Laboratory
Argonne, Illinois
- 3 Brookhaven National Laboratory
Upton, New York
- 4 Fermi National Accelerator Laboratory
Batavia, Illinois
- 5 Lawrence Berkeley National Laboratory
Berkeley, California
- 6 Oak Ridge National Laboratory
Oak Ridge, Tennessee
- 7 Pacific Northwest National Laboratory
Richland, Washington
- 8 Princeton Plasma Physics Laboratory
Princeton, New Jersey
- 9 SLAC National Accelerator Laboratory
Menlo Park, California
- 10 Thomas Jefferson National Accelerator Facility
Newport News, Virginia

Other DOE Laboratories

- 1 Idaho National Laboratory
Idaho Falls, Idaho
- 2 National Energy Technology Laboratory
Morgantown, West Virginia
Pittsburgh, Pennsylvania
Albany, Oregon
- 3 National Renewable Energy Laboratory
Golden, Colorado
- 4 Savannah River National Laboratory
Aiken, South Carolina

NNSA Laboratories

- 1 Lawrence Livermore National Laboratory
Livermore, California
- 2 Los Alamos National Laboratory
Los Alamos, New Mexico
- 3 Sandia National Laboratory
Albuquerque, New Mexico
Livermore, California



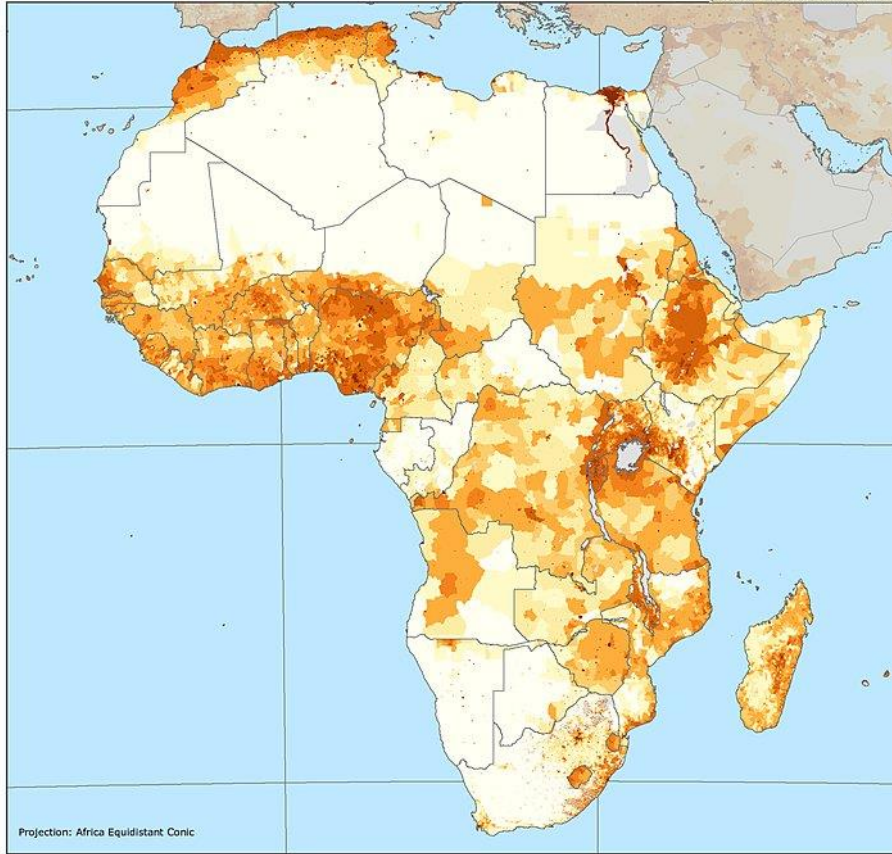
The DOE Laboratory System

Office of Science is the steward of 10 of the 17 DOE laboratories
A number of facilities are in or near population centers of the country.

Population, Landscape, and Climate Estimates, v3: Population Density 2010, Africa

National Aggregates of Geospatial Data Collection

PLACE III
Population, Landscape, and Climate Estimates



The data in this map represents 2010. These Population Density layers, for 1990, 2000, and 2010 were developed for the Global Rural-Urban Mapping Project, Version1 (GRUMPv1). They were created by dividing the 1990, 2000, and 2010 UN-adjusted population (POP) count grids by the land area (LA) grid. The pixel values for the resulting grid layers, one each for 1990, 2000 and 2010, were then aggregated to form the 12 population density classes. Source information:

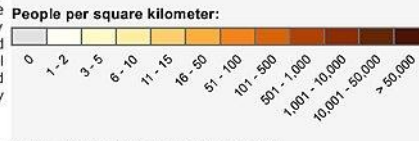
<http://sedac.ciesin.columbia.edu/gpw/>.

Center for International Earth
Science Information Network
Earth Institute | COLUMBIA UNIVERSITY



© 2012, The Trustees of Columbia University in the City of New York. Center for International Earth Science Information Network (CIESIN)/Columbia University, 2012. National Aggregates of Geospatial Data Collection: Population, Landscape, and Climate Estimates, Version 3 (PLACE III). Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). <http://sedac.ciesin.columbia.edu/data/set/nagdc-population-landscape-climate-estimates-v3>.

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March 2012



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Population centers in Africa could also be a start of potential locations for research, information, and cooperative education centers.

The World Wide Web

For decades, HEP physicists shared preprints through the mail.

The USA government created ARPANET, (Advanced Research Projects Agency Network) linking academic institutions and research centers

1983 network split into

.....Government

.....Civilian branch

1995 The civilian branch was renamed the **Internet**, an international network of computers connected by the same communications protocol.



About 25 years ago, physicist **Tim Berners-Lee**, at the **CERN Lab** created the Hyper Text Transfer Protocol (**HTTP**)

In very large science research, we often solve problems that we do not know we have. The **Web** was created to manage data using the internet and provided a solution to handling information that was not considered before. This led to a major impact on the quality of life in our present world, influencing the way we work, play, control commerce, and govern.

Clearly of great value to some, and unpredictable!

If you have some protons to spare, one makes neutron beam for cancer therapy :



Fermilab also built a proton Therapy accelerator for Loma Linda, California. More than 350,000 treatments so far!



Particle accelerators: invented for pure research, then applications come.

An example of the research with accelerator light sources that have an impact on Africa.

Information from Hamburg, 29, November 2012:

Using the world's most powerful X-ray laser, scientists revealed a blueprint for a modified molecule that would block the vital enzyme of the parasite *Trypanosoma brucei*, rendering it inactive and thereby killing the parasite.

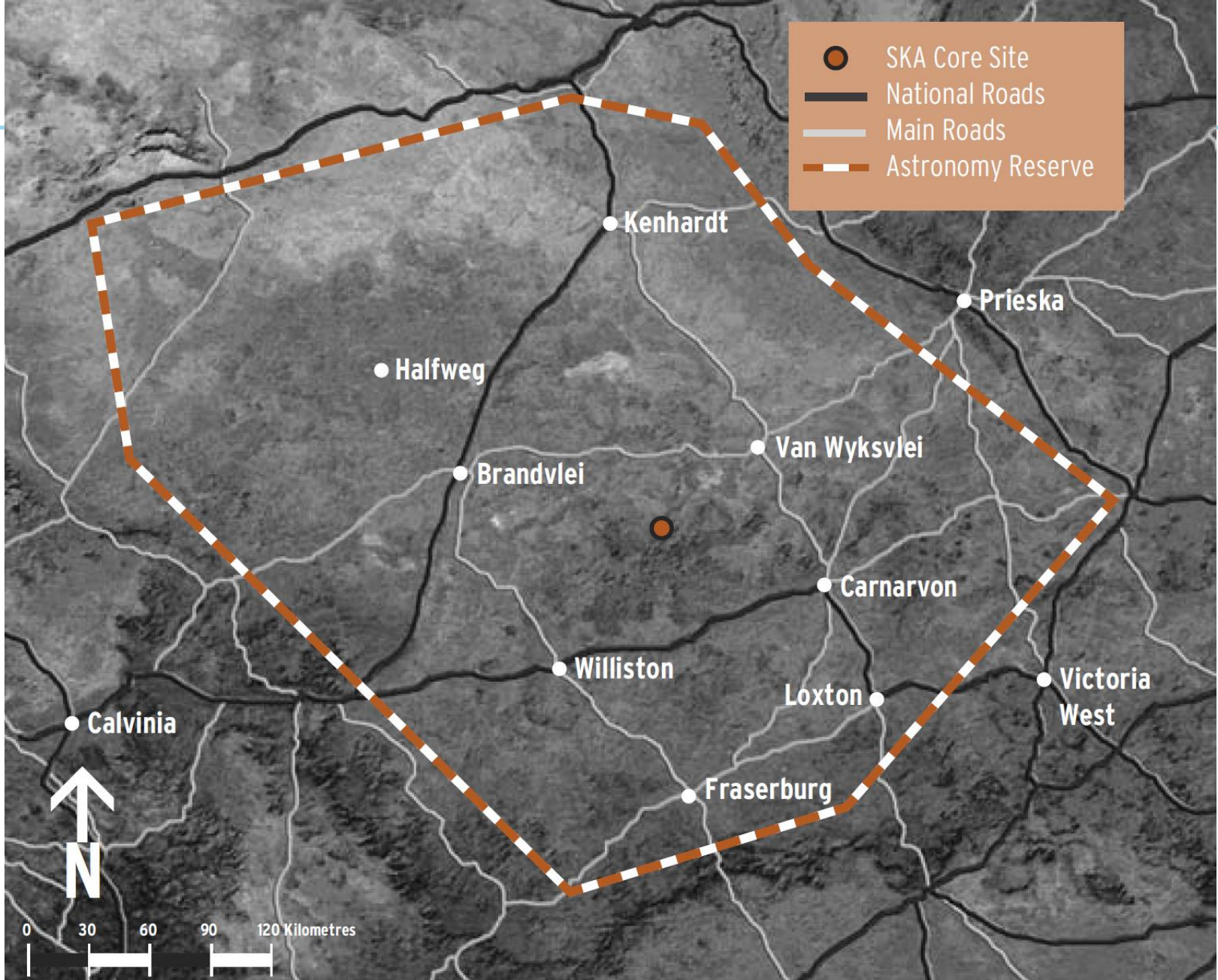
This is the sleeping sickness parasite that threatens more than 60 million people in sub-Saharan Africa. This is reported to be the first new biological structure solved with a free-electron laser.

Other researchers investigated tiny crystals of the parasite's enzyme at the SLAC laboratory in the USA, using their coherent light source report direct effects as well.

The researchers Lubeck et. al. are quoted as reporting: "The knockdown of this essential enzyme in the parasite did cure the infection in mice."

(Results are reported in Science Magazine).

There are of course many other science topics that can be addressed when a facility is available.





The configuration of the SKA core and remote stations throughout Africa.

I wish also to thank our hosts and organizers for an outstanding effort in making this conference and school such a success.

My best wishes to

Professor Oumar Ka , Faculté des Sciences et Techniques
University Cheikh Anta Diop, Dakar-Fann, Senegal

And in particular the entire local organizing committee.

What do the Economists tell us ?

- Economic Studies
 - CERN
 - Vancouver BC
 - USA

- A costly study to get the data, and more costly to fit a model.

- In these cases as well as the primary studies at the CERN lab, other studies for TRIUMF, and the Lawrence Berkeley National Lab, the economic impact primarily focused on direct regional economic activity and was measured in terms of economic growth.
- . The results indicate that there was a positive impact on the GDP for these **regional** economies. The outcome more specific to our field is the question of indirect economic impact from particle physics research activity.
- The long-term effect of creating research equipment, research experiments, and educating trained technical personnel requires a lengthier time to evaluate and quantify
- Beyond the direct economic impact from experimental research, there is also the auxiliary and absolutely complementary technical activity that must be successful in building unique one of kind equipment that is specialized for a rare environment.

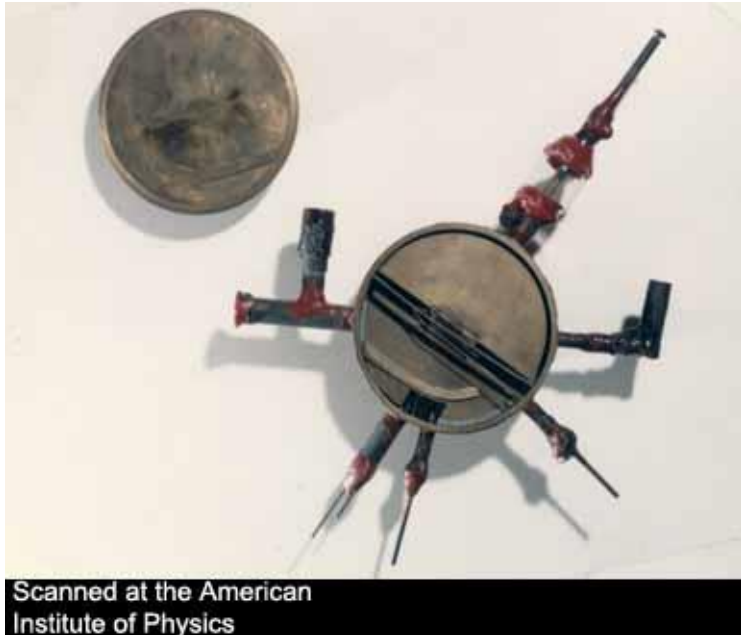
- There are a number of studies conducted over a few decades concerning the CERN laboratory operations and development. These reports include the impact of CERN contracts, knowledge transfer and technology transfer. CERN is a particle physics laboratory, and it is important to note that evaluation of economic impact for discovery science is more precise for direct spending and less precise as previously presented for indirect research activities. The European Physical Society completed a four year study on the contribution of physics to the economies of Europe, and concluded that the physics-based industrial sector generated over 15% of the total turnover and 13% of overall employment within Europe's business economy. (*ref*)
- They also reported that in the physics-based sector within Europe the level of employment represented more than 13% of the total business employment exceeding 15 million people, and that each physics-based job generated 2.73 jobs to support that activity.

- The CERN studies in both 1975 and in 1984 consisted of estimating the economic utility resulting from CERN contracts. (*ref*) There were additional studies concentrating on knowledge transfer and technology transfer to industry and society. These studies attempted to quantify the technical and economic benefit to the manufacturing industries involved in CERN contracts.

- The conclusions of the study indicate that the return on investment for the CERN contracts over a period of nearly 20 years generated a return of nearly 4.8 billion Swiss francs, compared to 3.5 billion Swiss francs invested into CERN.
- One difficulty in this calculation is that the total return on the investment must be known to accurately quantify the economic impact
- In many of these cases the measurement metric included intellectual property copyrights and patents. At the end of 2012, CERN's patent portfolio contained 238 patents.

- In the British Columbia Institute of Technology (BCIT) (2007) study(*ref*), the impact of the technical output of this institution covered some of the same topics that have been listed before. However in this study the impact of the research work is directed at a specific regional geographical area and quantified in terms of gross domestic product (GDP) and tax revenues exceeding the operating budget and influencing the local economy.
- The applied research component was more difficult to quantify, and was estimated to return nearly half of the initial funds spent on operations. The return on government investment was quantified in terms of regional economic activity (three times the tax revenue) and job created (84 jobs per \$1M tax dollars invested). The overall economic impact of BCIT in this study was close to a half billion dollars

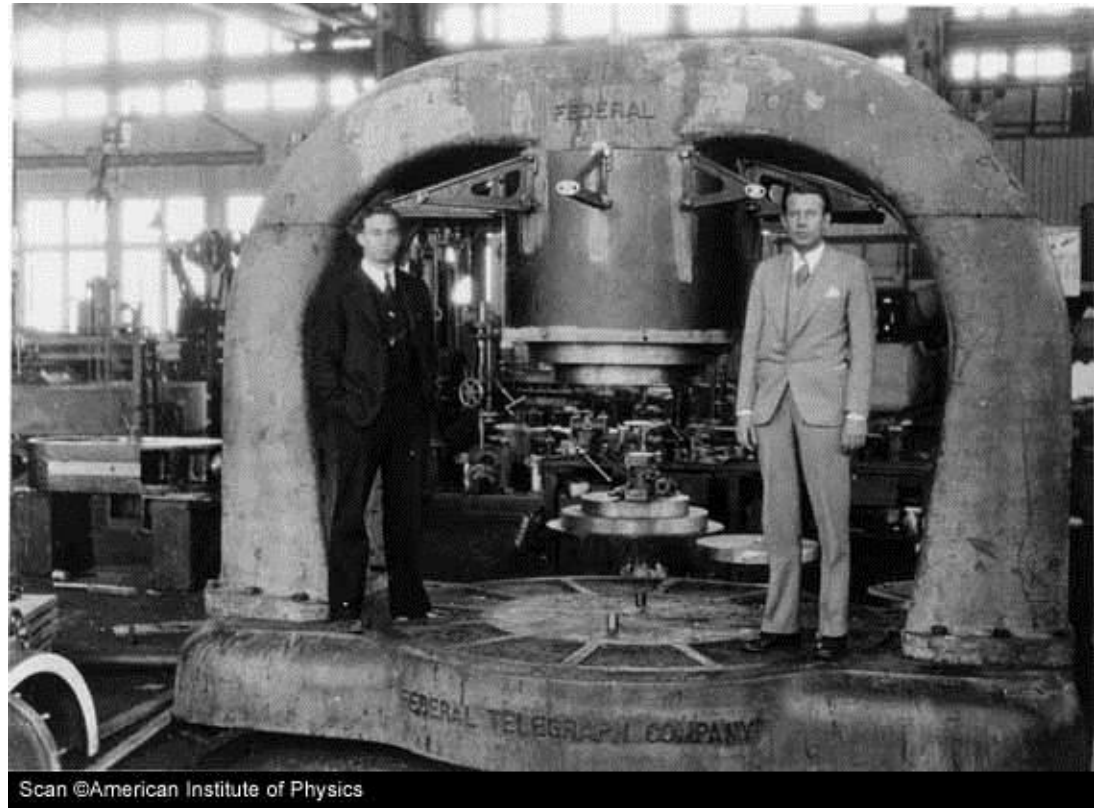
The First Accelerators



Scanned at the American Institute of Physics

Lawrence and Livingston began developing this 4.5-inch cyclotron in 1929-30.

Courtesy: Adrienne Kolb, Fermilab



Scan @American Institute of Physics

Livingston (left) and Lawrence with the magnet of the 27-inch cyclotron, operating in 1932 at 3.6 MeV.



Congressman Jerrold Nadler of New York's 8th Congressional district
Congressman Chaka Fattah of Pennsylvania's 2nd Congressional district



Congressman Randy Hultgren of Illinois' 14 Congressional District



Secretary of Energy Steven Chu
March 2013

Fermilab

- * 6,800 acres of mostly open land.
- * A federally funded research facility part of the U.S. Department of Energy that is managed and operated by Fermi Research Alliance, LLC.
- * A vital part of the Kane and DuPage County communities and of the growing northeastern Illinois economy.
- * Employs ~ 1,912 people and hundreds of subcontractors.
- * Provides research facilities for ~ 2,500 particle physicists including students.
- * Hosts thousands of visitors each year, who take advantage of educational, recreational and cultural opportunities.

- Cost and benefits of public investment have been shown to be a positive outcome as suggested in The National Academy Study: [Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future](#) (The National Academies Committee on Science, Engineering and Public Policy, National Academies Press, 2005).

Near-term (~ our lifetimes):

- * Employment
- * Procurement
- * Technology Transfer, Knowledge Transfer

FY 2009 Statistics:

✦ Employment ~1,912 employees, not including subcontractors

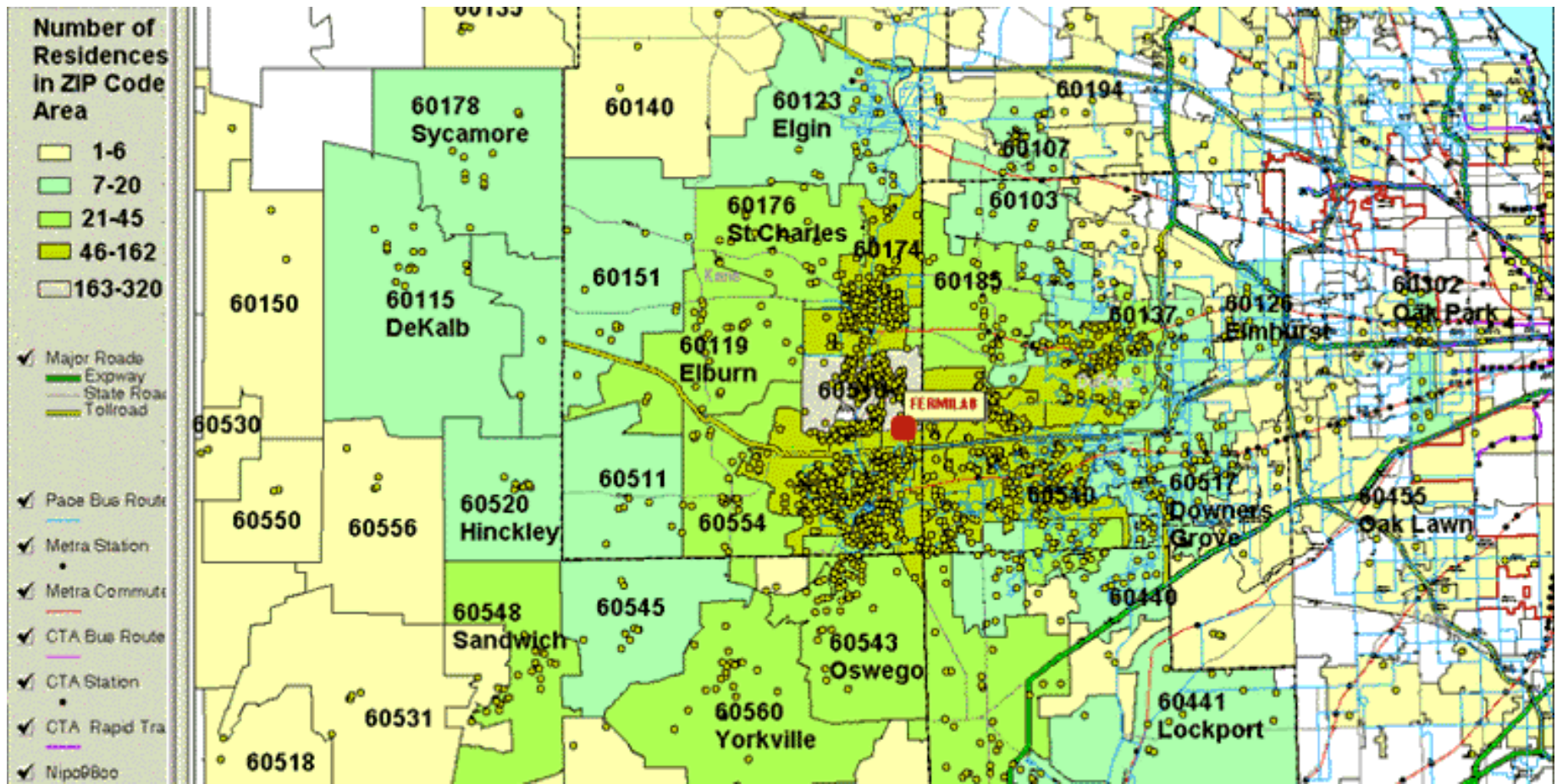
✦ Payroll \$141M + \$43M fringe = \$184M

✦ IL income tax \$4.1M withheld (CY 2009)

✦ Approximate employment mix by job categories:

Administrative & Clerical	280
Computer Professionals	284
Engineers, Engineering Physicists	298
Scientists	365
Technicians, Technical Specialists	465
Drafters, Service Workers, Skilled Trades	<u>220</u>
Total	1,912

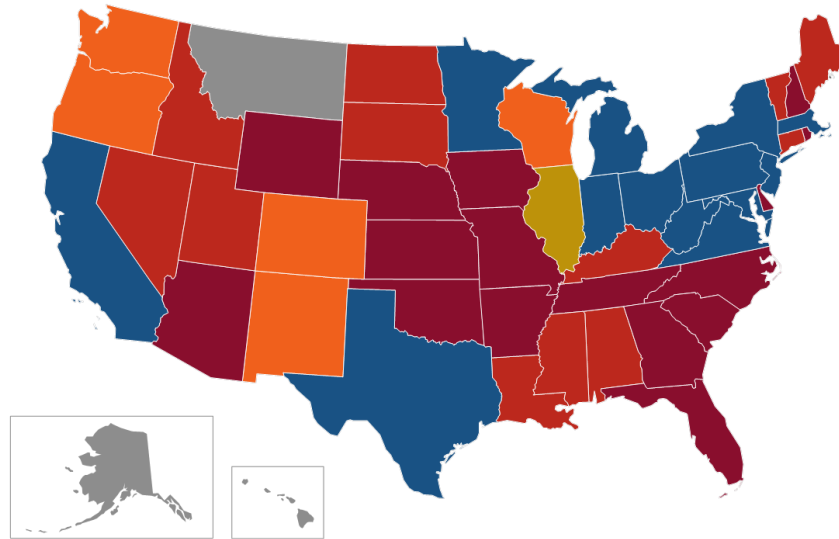
(473 employees with PhDs)



Fermilab Employee distribution

Science at Fermilab Fermilab Procurements

In FY2008 Fermilab spent \$90.8 million in the United States to purchase goods and services in 47 states and the District of Columbia. Procurements in Illinois accounted for 46 percent of spending.



\$0

Alaska, Hawaii, and Montana sold no goods or services to Fermilab in FY2008.

\$100-\$100,000

Alabama, Connecticut, Idaho, Kentucky, Louisiana, Maine, Mississippi, Nevada, North Dakota, South Dakota, Utah, Vermont

\$100,001-\$500,000

Arizona, Arkansas, Delaware, Florida, Georgia, Iowa, Kansas, Missouri, Nebraska, New Hampshire, North Carolina, Oklahoma, Rhode Island, South Carolina, Tennessee, Wyoming

\$500,001-\$1 million

Colorado, New Mexico, Oregon, Washington, Wisconsin

\$1,000,001-\$10 million

California, District of Columbia, Indiana, Maryland, Massachusetts, Michigan, Minnesota, New Jersey, New York, Ohio, Pennsylvania, Texas, Virginia, West Virginia

More than \$10 million

Illinois*

* Fermilab purchases, 46 percent, or \$41.8 million, of its goods and services from Illinois businesses. A large portion of the spending pays for support for day-to-day operations such as cafeteria service and housekeeping, as well as on-site construction.