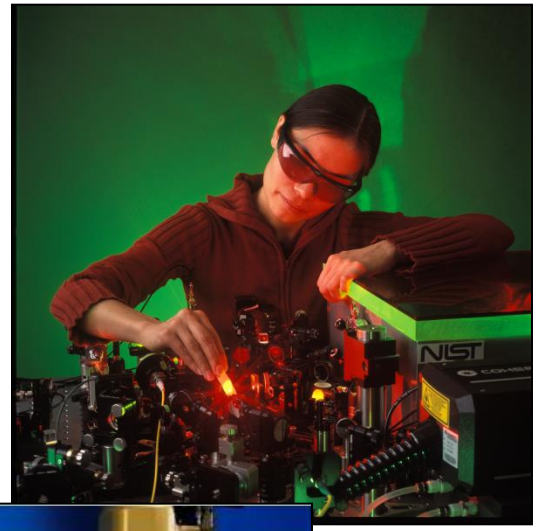
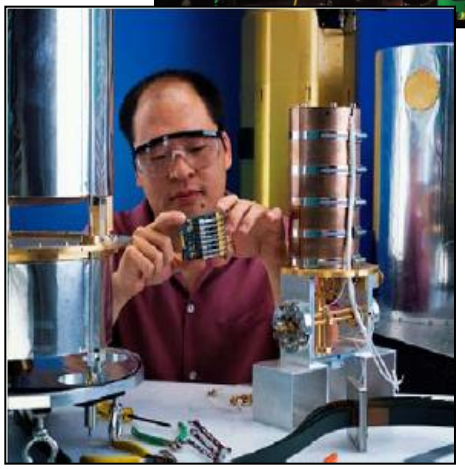
Welcome to the
Department of Commerce
Boulder Laboratories

NIST Boulder Laboratories

NIST's mission is to promote U.S. ***innovation***…

Key roles enabling innovation, education, and infrastructure for investments in the future…





NIST Boulder assets include (*approximate* values):

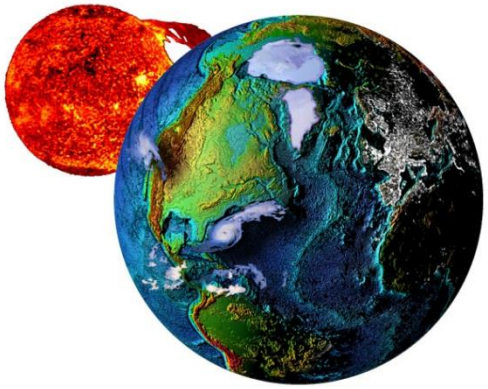
- 375 employees.
- 350 associates.
  - Postdocs, grad & undergrad students, contractors, guest researchers, etc.
- $100 million annual operating budget.
  - Appropriations, other agency reimbursements.
- About 20% of NIST Laboratory programs overall.
- Plus JILA.

Department of Commerce Boulder Laboratories

National Oceanic and Atmospheric Administration (NOAA)

1,100 employees and affiliates

- Atmospheric and climate research.
- Space “weather.”
- Satellite data processing.
- National Weather Service.



Institute for Telecommunications Sciences
National Telecommunications and Information Administration

90 employees and affiliates

- Promote and manage use of radio spectrum.
- Improve emergency responder communications.

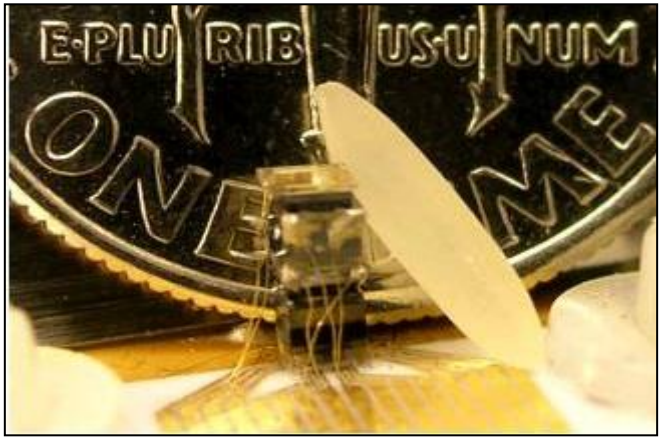
NIST Boulder: Microfabrication and Characterization

Boulder MicroFabrication Facility

Photon detectors: Microwave to gamma ray

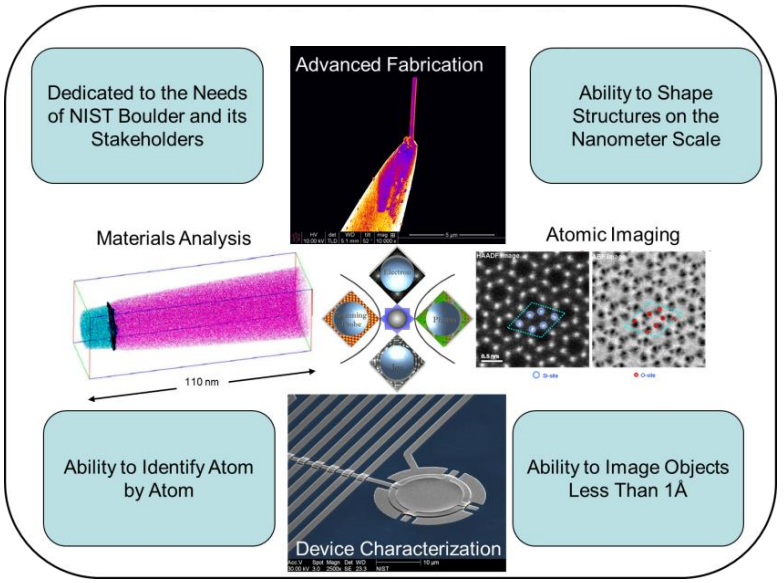
Technical strengths include:

- Superconducting electronics
- MEMS
- Fabrication of unique devices.
- Nanoscale measurements.
- Applications.



Ultraminiature atomic clock

NIST Boulder: Microfabrication and Characterization



Aberration corrected TEM

Focused ion beam / SEM

Local electrode atom probe

Helium ion microscope

Sample prep / inspection

NIST Boulder: Lasers and Optoelectronics

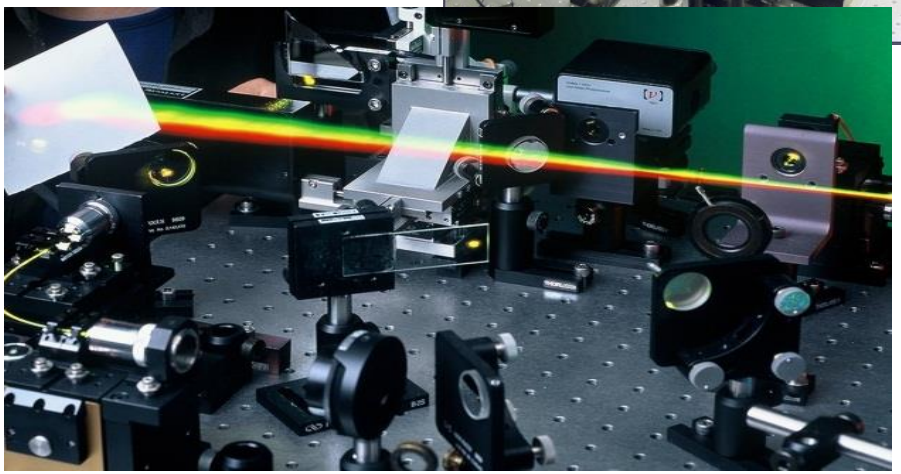
NIST Boulder technical strengths include:

- Traceable laser power:
  - From 1,000s of watts to 0.000 000 000 000 001 watt.
  - Ultraviolet to infrared.
  - Industrial, medical, defense, etc.

- New laser technologies for precision measurements.
  - Telecommunications
    - Real-time video/Telepresence
    - Ubiquitous data access
  - “Breathalyzer” disease detection.
  - Greenhouse gas monitoring.
  - Explosives detection.
  - Many others…

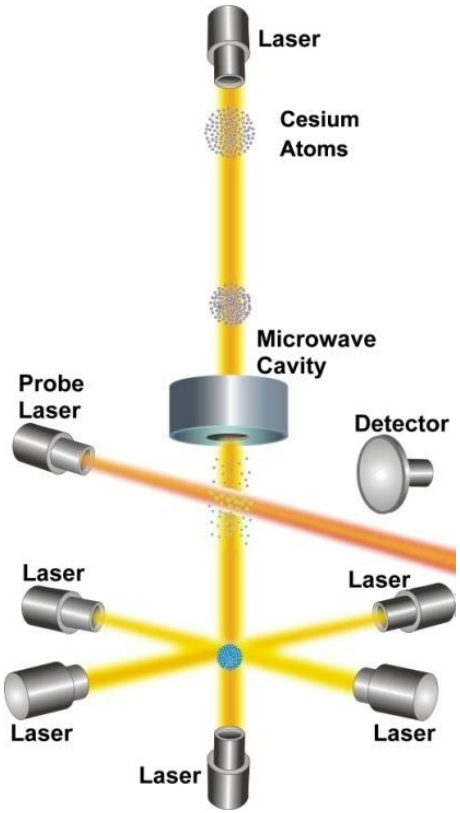
Laser power calibration

2005 Nobel Prize



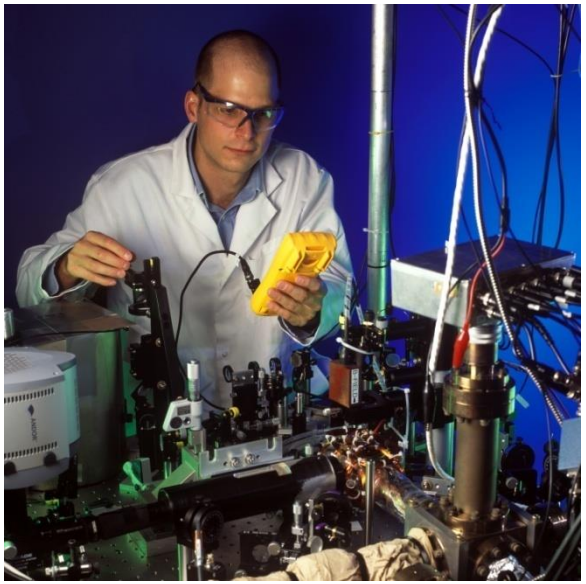
Laser frequency combs

NIST Boulder: Time & Frequency Metrology



NIST Boulder technical strengths include:

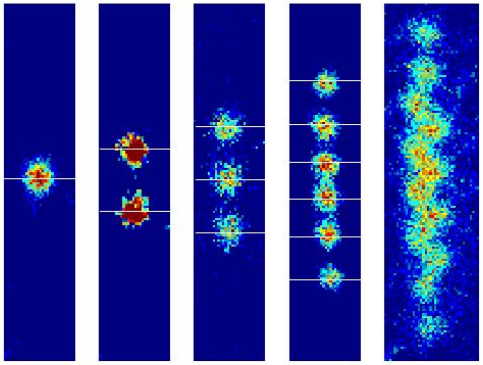
- NIST-F1 laser-cooled atomic clock:
  - Current accuracy 3×10^{-16} second
- NIST research on future atomic clocks
  - Accuracy 8×10^{-18} second and improving
- NIST Internet Time Service
  - **> 12 billion** synchronizations **each day**

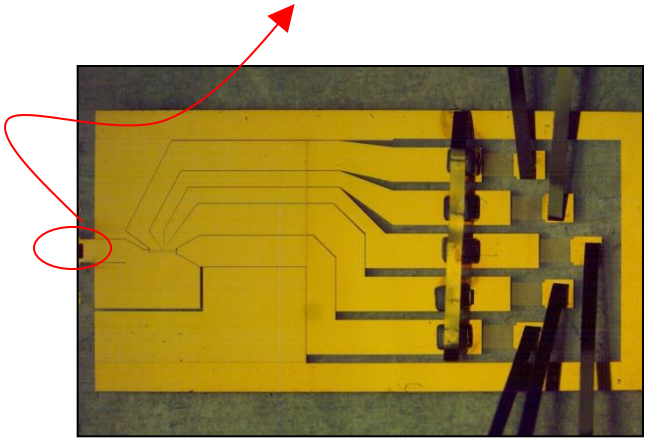


NIST Boulder: Quantum Information and Communications

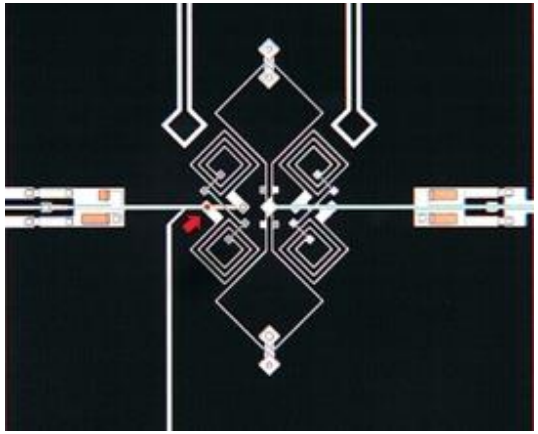
NIST Boulder technical strengths include:

- Quantum information.
  - Vastly more powerful computers.
  - Completely secure communications.
  - New quantum-based ultra-precision measurements.





Trapped ion quantum computing



Superconducting Josephson junction quantum computing

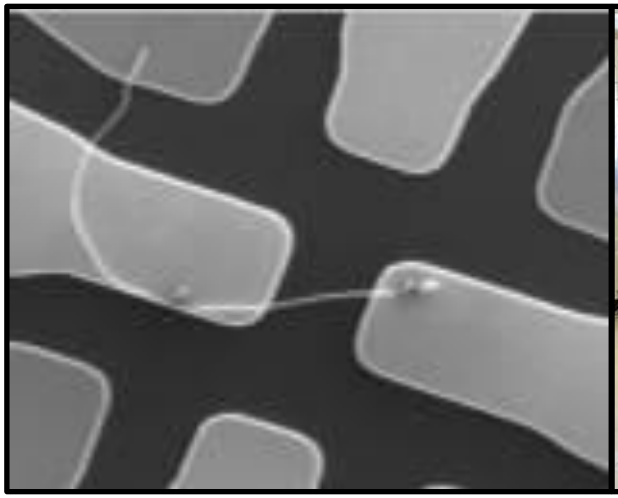
2012 Nobel Prize

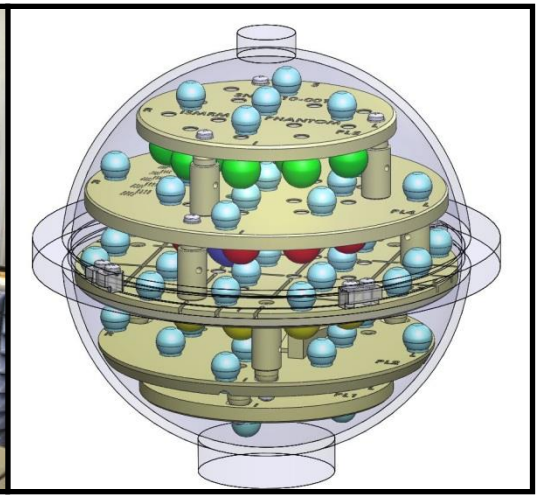
NIST Boulder: Electromagnetics

Anechoic chamber for highest-precision radiowave measurements

NIST Boulder technical strengths include:

- Fundamental microwave measurements
- High-speed electronics, nanoscale devices
- Advanced telecommunications
- Microwave remote sensing
- Nanomagnetics, spin dynamics
- Standards for biomagnetic imaging



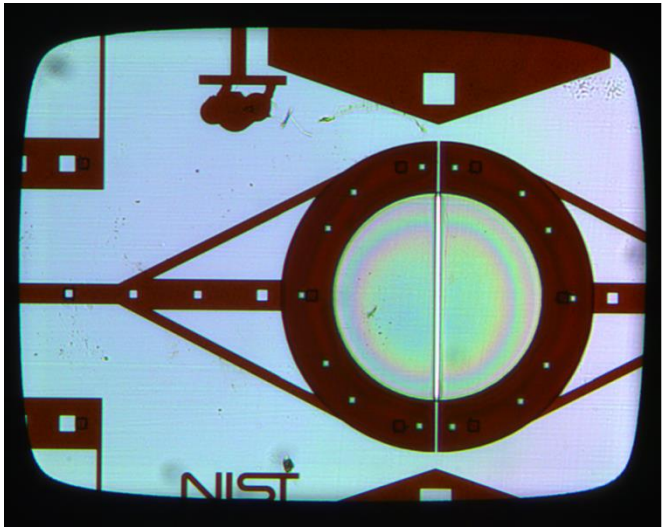


NIST Boulder: Materials Properties

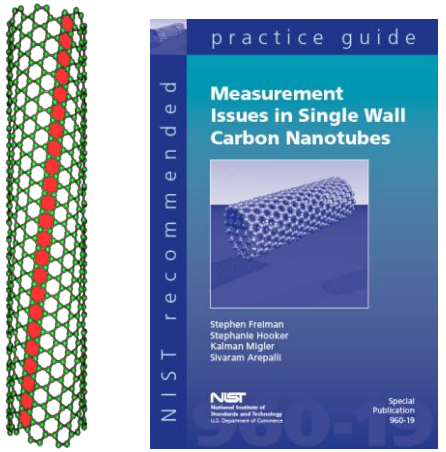
NIST Boulder technical strengths include:

- Materials properties, from largest structures to smallest.
  - Infrastructure measurements.
  - Microscale/nanoscale measurements.
  - Biological materials.

Testing of infrastructure



BioMEMS test platform for single cell measurements



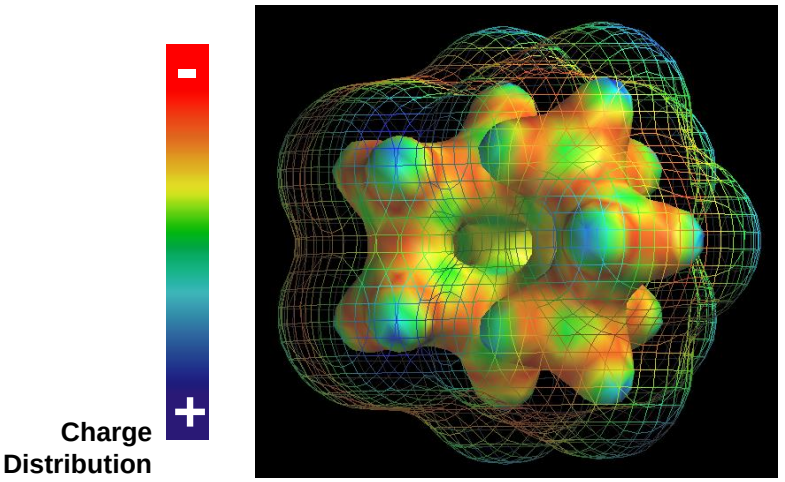
Characterization of carbon nanotubes

NIST Boulder: Chemical Properties

NIST Boulder technical strengths include:

- Physical and chemical properties.
  - Thermodynamics.
  - Fluid properties
  - Cryogenics.

$C_{10}H_{16}$



Comprehensive characterization of JP-10 jet fuel leads to accurate numerical models

Characterization of biofuel – first detailed distillation study

JILA

- Joint institute of CU and NIST.
- Founded 1962 as “Joint Institute for Laboratory Astrophysics”
- Physically located on CU campus.
- 29 JILA Fellows (CU and NIST).
  - NIST JILA Fellows hold CU Adjoint Faculty appointments.

- 250 personnel, mostly students and postdoctoral fellows.
  - Three Nobel Physics Laureates.
- Leading center for:
  - Atomic, molecular, optical physics.
  - Measurement science.
  - Consistently #1 atomic/optical physics graduate education program.

Brief History of DoC Boulder Laboratories

1911 – National Bureau of Standards (NBS) made the first measurements at radio frequencies.

1917 – Radio communication played an important role in WWI.

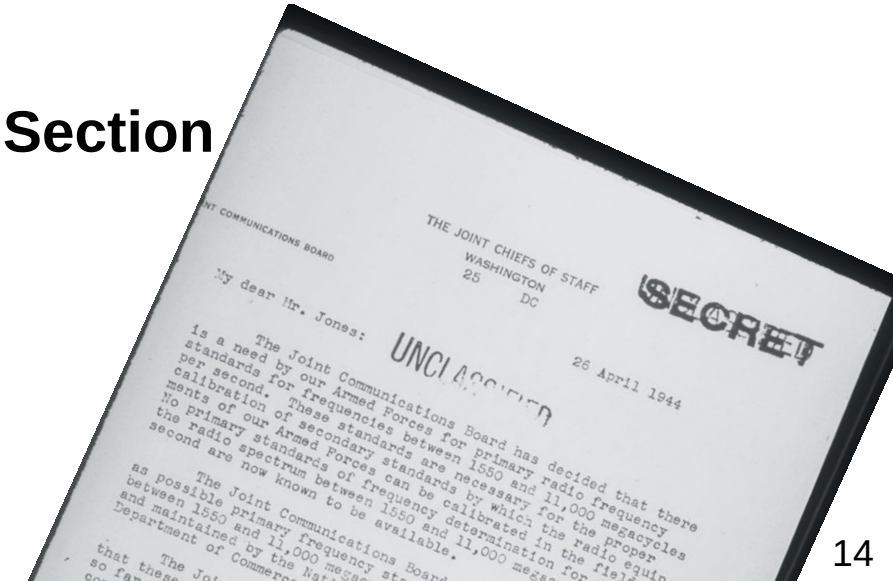
1928-33 – NBS air beacon system. Complete air navigation system by radio, over long distances, in adverse weather.

1941 – WWII aircraft, communications, and missiles relied on radio science.

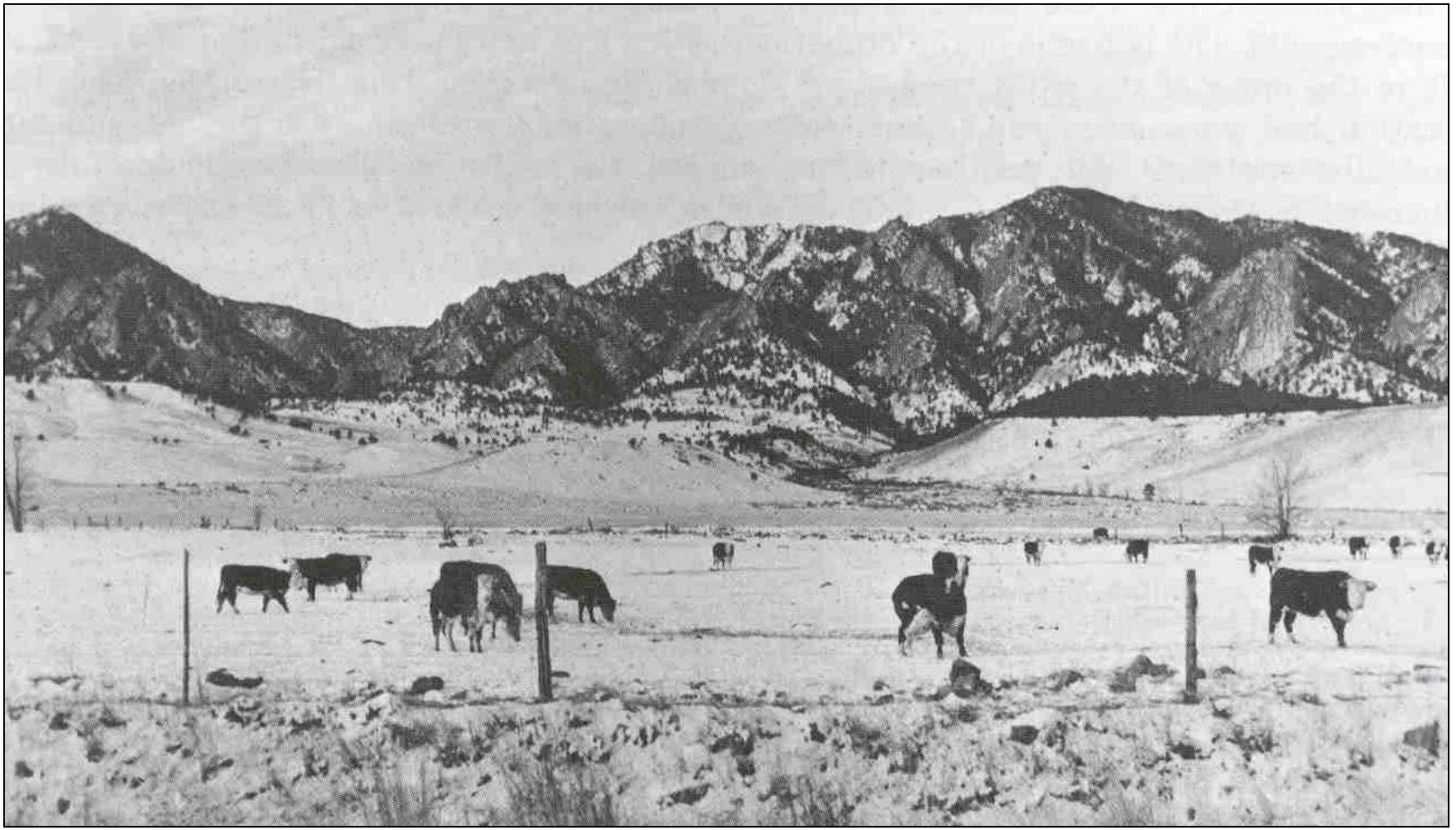
1946 – The expanding NBS Radio Section became the Central Radio Propagation Lab (CRPL).

New site needed.

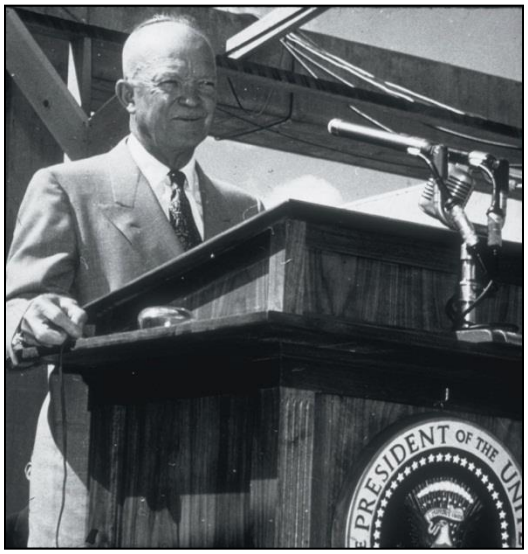
Nationwide competition.



DoC Boulder Laboratories ca. 1950



Brief History of DoC Boulder Laboratories



1950 – Citizens of Boulder raised funds to buy 217 acres of ranch land.

1954 – President Dwight D. Eisenhower dedicated the newly completed National Bureau of Standards Radio Building to "the welfare of humanity—in America and throughout the world."

1965 – CRPL was moved to join other agencies in the new Environmental Science Services Administration (ESSA).

1967 – ITS (Institute for Telecommunication Science) was created; continued the research of the former CRPL.

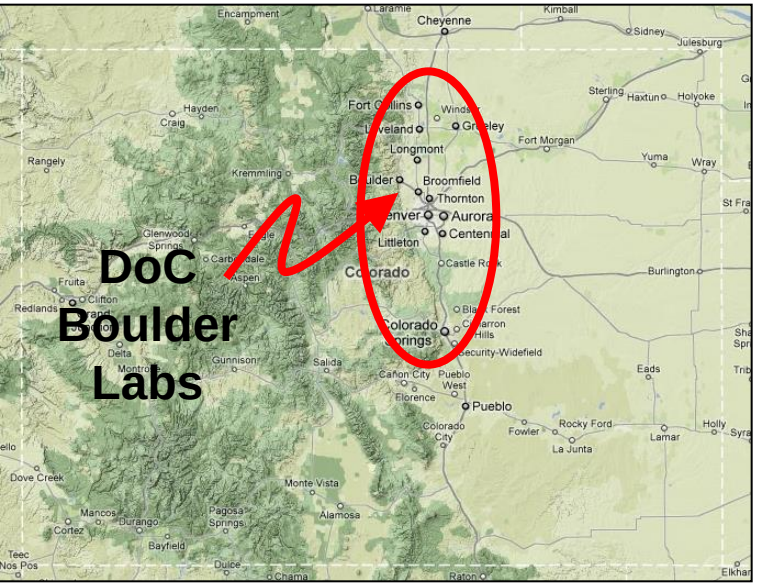
1970 – ESSA became NOAA.

1988 – NBS renamed NIST.

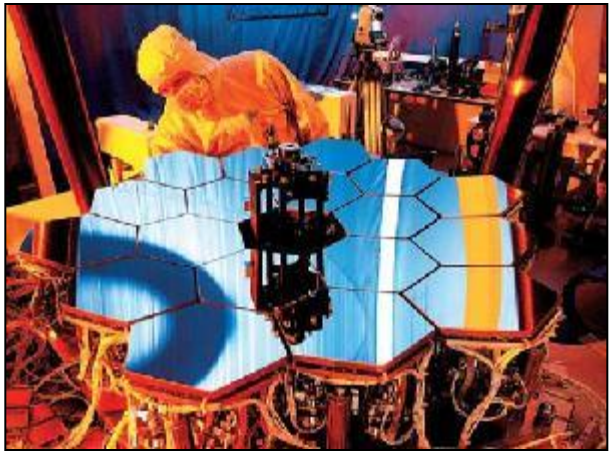
1998 – David Skaggs Research Center completed.

2005 – NOAA Earth Systems Research Laboratory established.

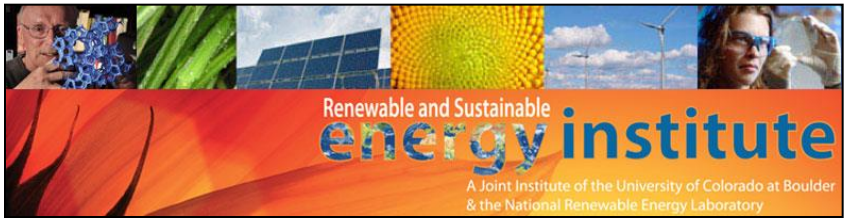
Colorado Front Range Technology Leadership



- Industry / academia / government partnerships.
- Rapidly growing biotechnology industry and R&D.
- Rapidly growing clean energy industry and R&D.
- #2 in the nation for aerospace industry.
- A world leader in telecommunications.
- A world leader in climate science.
- #8 in US for venture capital investments (#22 population).
- Many other high-tech areas benefitting from industry/academia/government partnerships.



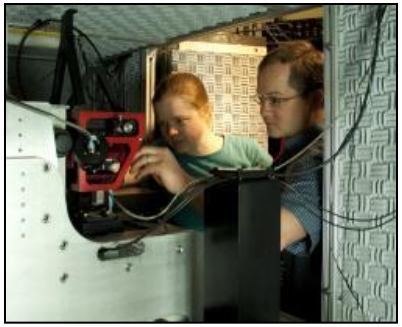
Ball Aerospace



CIMB
Realizing Research Today
COLORADO INITIATIVE IN MOLECULAR BIOTECHNOLOGY

NIST Boulder Laboratories

Innovation:
World-leading measurements, science, and technology to enable advances in manufacturing, networks, health care, many other areas.

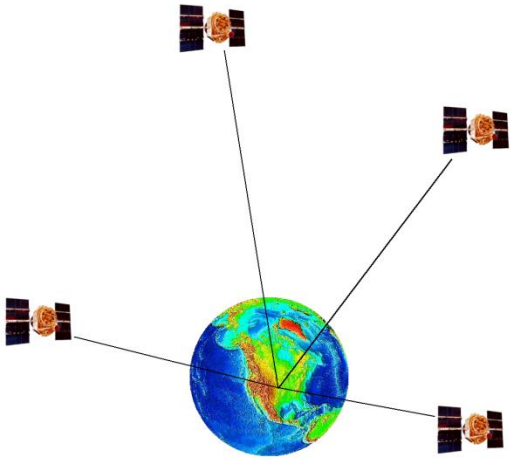


Education:
- Advanced education in science and technology for future scientists and engineers in industry, universities, national laboratories.
- Largest US graduate program in atomic, molecular, optical physics, consistently ranked #1 in quality.

Infrastructure:
- World-leading measurements to enable accurate evaluation and testing of civil infrastructure, networks, etc.
- Innovation and measurements to enable new infrastructures: advanced energy, advanced transportation, etc.

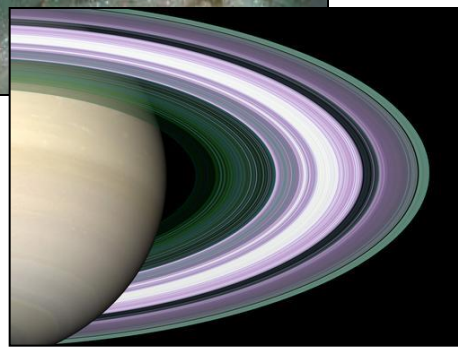
Impact of NIST Measurements and Standards

Telecommunications



GPS

Electrical Power



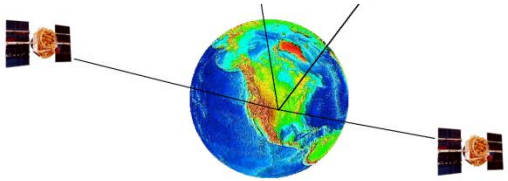
Fundamental science
Space exploration

Impact of NIST Measurements and Standards

2012 projected:
$2.3 trillion worldwide

Telecommunications

2008: $250 billion worldwide
(civilian only)
Defense/security: Priceless



GPS

2011: $370 billion US
Future: Smart Grid

Electrical Power

Fundamental science
Space exploration

Invest in the future

Economic Impact of NIST Measurements and Standards

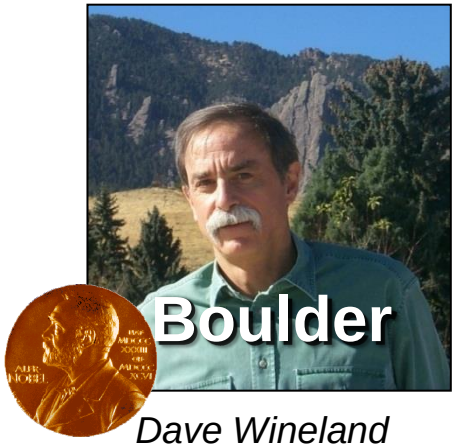
Electric power and energy calibrations
41:1 benefit-to-cost ratio

Standards for measuring sulfur in fossil fuels
113:1 benefit-to-cost ratio

Radiopharmaceutical standards
97:1 benefit-to-cost ratio

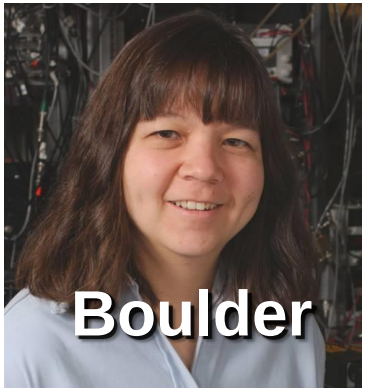
NIST Technical Staff: Members of the National Academy of Sciences

Anneke Sengers
Thermodynamics



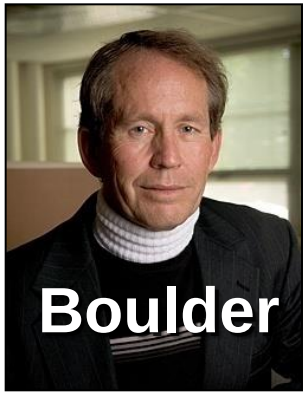
Dave Wineland
Quantum computing
Nobel Prize in Physics

Jan Hall
Precision laser measurements
Nobel Prize in Physics

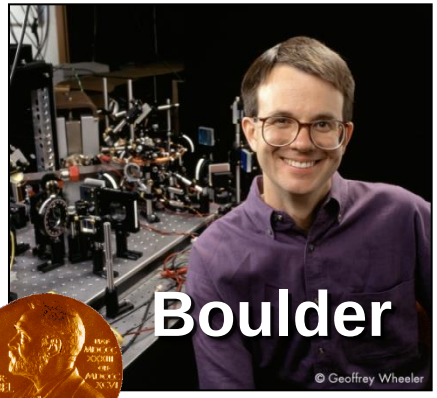


Debbie Jin
Ultracold atoms
L'Oreal-UNESCO Award for Women in Science

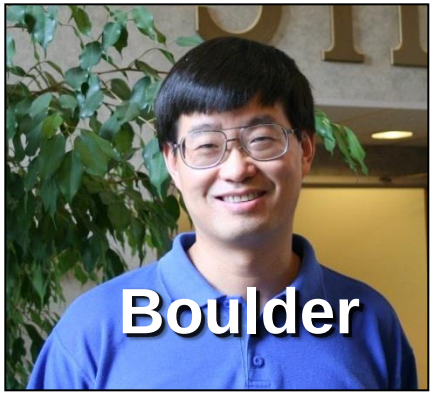
Bill Phillips
Laser cooling
Nobel Prize in Physics



Jim Bergquist
Atomic clocks



Eric Cornell
Bose-Einstein condensate
Nobel Prize in Physics



Jun Ye
Laser applications
Newest NAS Member