The United States Air Force and the Significance of Basic Research

The many advantages held by the United States Air Force on the battlefields of today and tomorrow are due, in large part, to the technological innovations developed by the extraordinary efforts of countless scientists and engineers.

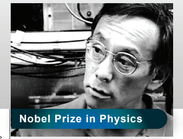
The Air Force Office of Scientific Research (AFOSR) sponsors the work of exceptional individuals who provide basic research; the foundation that underpins the dramatic evolution of Air Force technology. These scientists develop the revolutionary scientific breakthroughs that keep America's Air Force the best in the world.

Among these AFOSR-sponsored scientists and engineers are a select group of 56 researchers who have earned worldwide recognition for receiving the prestigious Nobel Prize for their research contributions in physics, chemistry, medicine and economics. This brochure recognizes these outstanding Nobel Prize winning research scientists.

Revolutionary Results from AFOSR

Air Force Office of Scientific Research funding has played a key role in many discoveries of critical importance to the United States Air Force, the scientific community and the world.

- **Polykarp Kusch and Willis Lamb** made discoveries that resulted in a reshaping of the theory of quantum electrodynamics.
- **John Bardeen** was the co-inventor of the transistor. He laid the foundation for the electronics revolution of the last half of the 20th century.
- **Willard Libby** developed carbon-14 dating which allows accurate determination of the age of artifacts.
- **Robert Hofstadter** pioneered studies in electron scattering of atomic nuclei and opened new explorations into the nature of fundamental particles and allowed for new mechanisms for hardening systems against harmful radiation.
- **Charles Townes** invented the maser, which was the basis for its successor, the laser. He transformed communications, navigation, astronomy, radar, atomic clocks, surgery and numerous industrial procedures.
- **Hans Bethe** was a pioneer in the theory of nuclear reactions - especially his discoveries in concerning the energy production in stars. His work is used to assess survivability from radiation for every Air Force satellite in orbit today.
- **George Porter** invented novel means to study extremely fast chemical reactions. His work contributed to understanding processes related to solar energy conversion and radiation damage control in biological systems.
- **Murray Gell-Mann**, along with George Zweig, advanced the"quark" theory. This classification of elementary particles and their interactions brought order to the chaos created by the discovery of some 100 particles in the atom's nucleus.
- **Ulf von Euler** discovered the neural key to what controls the human body's response to stress and exertion. This research is used to help determine the effectiveness of an individual during sustained operations.
- **Brian Josephson** invented the Josephson Junction. This superconductivity device provides the basis for the world's fastest, lowest power electronic switching elements.
- **Paul Flory** is considered by many to be the founder of polymer science. His work in macro-molecules led to the composites used in many Air Force aircraft, including the F-16, B-2, F-22 and Joint Strike Fighter.
- **Philip Anderson and John van Vleck** are responsible for the fundamental solid-state physics theory. Their research made possible the development of inexpensive electronic switching and memory devices in computers.
- **David Hubel and Thorsten Wiesel** pioneered work on the mechanisms governing the brain's visual system. Many in today's military benefit from their discovery of motion-sensitive cortical cells, which led to how humans detect and track moving targets.
- **Subramanyan Chandrasekhar and William Fowler**'s work in the development of models of nucleosynthesis, thermonuclear and fusion reactions, was critical in the development of the U.S. thermonuclear arsenal and insight into the "Big Bang" origin of the universe.
- **Dudley Herschbach and John Polanyi** opened a new area of research in chemistry-reaction dynamics, which was pivotal in the development of the first chemical lasers.
- **Daniel Tsui** discovered a new form of quantum fluid that led to miniaturized, high-performance millimeter wave components used extensively in surveillance and communications systems.
- **Herbert Kroemer** developed semiconductor heterostructures which resulted in the High Electron Mobility Transistor (HEMT), critical to today's high-speed electronics. He also assisted in the creation of the heterostructure laser crucial to the development of fiber-optic communications.
- **Jack Kilby** invented the integrated circuit. His microchip laid the conceptual and technical foundation for the entire field of modern electronics.
- **John Fenn** received the Nobel Prize for his development of methods for identification and structure analysis of biological macromolecules.
- **John Hall** refined the development of laser-based precision spectroscopy, which ultimately led to even greater accuracy in defining the quantum structure of matter.
- **Robert Grubbs** achieved the first well-defined catalysts for practical laboratory application, which have found very broad use in the chemical industry with the development of new plastics, herbicides, drugs and synthetic pheromones.
- **Roy Glauber**'s work in the field of quantum optics led to the formulation that certain states of light could not be described with classical wave theory. This discovery greatly enhanced the precision of time measurements.
- **Thomas Schelling** proposed the theory that in a conflict a party can strengthen its position by actually weakening or limiting its options.
- **George Smoot** shared the 2006 Nobel Prize in Physics with John C. Mather for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation, which can be applied to space-based surveillance requirements.

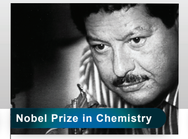


Nobel Prize in Physics

Dr. Steven Chu

recieved the1997 Nobel Prize in Physics. He was one of three physicists sharing the prize for "development of methods to cool and trap atoms with laser light." Funded by AFOSR since 1988, Chu's research provides the foundation for atom interferometers, atom lasers and more precise frequency standards, the basis for ultra-precise clocks. The Air Force will benefit from Chu's research in the following areas:

- Navigation, guidance and control systems (using atom interferometers for accelerometers and rotation sensors)
- Smaller electronic circuits with greater density (using atom lasers)
- Covert and encrypted communications (using precise frequency standards)
- Fundamental physics study, a foundation for future breakthroughs

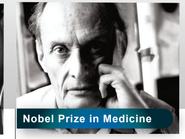


Nobel Prize in Chemistry

Dr. Ahmed Zewail

won the 1999 Nobel Prize winner in Chemistry and pioneered "femto-chemistry," a branch of study in chemistry that allows scientists to understand chemical reactions at the most fundamental level and at the speed at which they occur. Future Air Force applications include:

- Greater understanding and control of the release of energy in chemical reactions in systems such as novel rocket propellants, chemical lasers and the interactions of aerospace vehicles with their environments
- Increased understanding and control of radar signatures from aircraft and rockets; processes that affect chemical erosion in space and the drag placed on satellites by their environments



Nobel Prize in Medicine

Dr. Paul Greengard

shared the Nobel Prize for Medicine in 2000 for discoveries regarding "signal transduction in the nervous system." First funded by AFOSR in 1984, Greengard's research demonstrated the means by which chemicals known as neurotransmitters carry signals between nerve cells. Under AFOSR sponsorship, Greengard experimented with large nerve cells to understand the molecular activity of synapse transmission. This knowledge has led to a better understanding of the brain's function in perception, coginition and action.

- This research benefits the Air Force by providing a solid scientific basis for designing equipment and jobs to match human capabilities and limitations

Nobel Prize in Economics*

Dr. Daniel Kahneman

shared the Nobel Prize for Economics in 2002. AFOSR funded Dr. Kahneman's ground-breaking research on human perception, attention and decision-making beginning in 1971. Along with psychologist Amos Twersky, Kahneman studied the determinants of human choice in risky situations. Kahneman and Twersky showed that a person's decisions depend on how the decision problem is framed or described. This dependence results in decisions that deviate in predictable ways from the rational choice.

- This research directly supports DoD goals for advancement in model perception and cognition for improved human performance

*The Bank of Sweden Prize in Economic Sciences

http://www.afosr.af.mil

Putting it All Together Yields Revolutionary Results...

One program that demonstrates the significant impact of basic research on an Air Force weapons system is the Airborne Laser (ABL). The fields of basic research that ultimately contributed to the realization of the ABL include physics, chemistry, electronics, materials, theoretical mathematics and of course, laser research. Seven AFOSR supported researchers received the Nobel Prize in Physics for their work in lasers, including the development of the theoretical foundation for the laser itself: Charles Townes (known as the father of the laser), Arthur Schawlow, Nicolas Bloembergen, Dudley Herschbach, John Polanyi, Steven Chu and Herbert Kroemer.

While the laser is the cornerstone of the ABL, the research in physics and electronics by Nobel winners John Bardeen, Jack Kilby, Brian Josephson, Philip Anderson, John Van Vleck and Herbert Kroemer provided revolutionary advances in electronic computing capability and communications. Paul Flory's work in macromolecules led to many advanced composites integral to the ABL platform, while Ahmed Zewail's advances in femtochemistry will lead to a better understanding of the Chemical Oxygen Iodine Laser (COIL) that is at the heart of the ABL. The Airborne Laser program continues to be one of the many testaments to the importance of basic research to the Air Force.

Creating Revolutionary Scientific Breakthroughs for the Warfighter

The Air Force Office of Scientific Research (AFOSR), a part of the Air Force Research Laboratory (AFRL), manages the United States Air Force investment in basic research. AFOSR accomplishes this task through strong, productive alliances with a wide array of government agencies, the university research community, industry laboratories and worldwide research establishments.

AFOSR funding is distributed among approximately 1,200 grants and contracts provided to more that 225 academic institutions, 150 commercial firms and more than 240 internal Air Force research efforts performed within AFRL's nine technology directorates. Additionally, AFOSR manages a portion of the basic research investments of the Department of the Defense, the Defense Advanced Research Projects Agency and the Missile Defense Agency.

AFOSR is organized into three scientific directorates: Aerospace, Chemical and Material Sciences; Mathematics, Information and Life Sciences; and Physics and Electronics. These directorates manage programs supporting nearly 40 major research areas.

AFOSR also has two foreign offices: the European Office of Aerospace Research and Development in London, United Kingdom and the Asian Office of Aerospace Research and Development in Tokyo, Japan. In addition, AFOSR maintains the Air Force Research Laboratory's International Office. These offices provide enhanced access to international research opportunities for AFRL's entire technology community.

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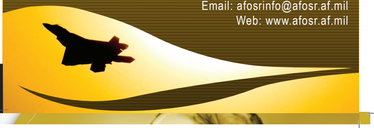


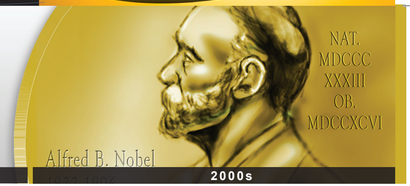
The Air Force Office of Scientific Research Sponsored Nobel Prize Winning Research

AFOSR
THE AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

AFOSR-funded Nobel Prize Timeline

Physics · Medicine · SB *AFOSR Support Began*
Chemistry · Economics

This brochure acknowledges the many Nobel Prize winners whose research was supported by AFOSR. A few examples of the types of research these Nobel winners have explored and the results are included. The extraordinary body of work of this impressive list of researchers has led to scientific breakthroughs that have dramatically affected not only the Air Force, but science and technology around the world. AFOSR is proud of its sponsorship and collaboration with other agencies in supporting these researchers in the many years prior to becoming a Nobel Laureate. AFOSR is grateful for their lasting contributions to the Air Force mission.



1950s

1955
PHYSICS
SB 1954
- **Polykarp Kusch**
  Columbia University
- **Willis Lamb**
  Stanford University
  "their work became one of the foundations of quantum electrodynamics."

1956
PHYSICS
SB 1953
- **John Bardeen**
  University of Illinois
  "co-inventor of the transistor"

1960s

1960
CHEMISTRY
SB 1952
- **Willard Libby**
  University of California
  "developed the carbon-14 method for artifact age determination."

1961
PHYSICS
SB 1953
- **Robert Hofstadter**
  Stanford University
  "pioneered studies of electron scattering in atomic nuclei."

1963
PHYSICS
SB 1958
- **Eugene Wigner**
  Princeton University
  "discovered and applied fundamental symmetry principles of the atomic nucleus."

1964
PHYSICS
SB 1953
- **Charles Townes**
  Massachusetts Institute of Technology
  "invented the maser; laid foundation for the laser."

1966
CHEMISTRY
SB 1952
- **Robert Mulliken**
  University of Chicago
  "the advancement of computer codes with predictive capabilities."

1967
MEDICINE
SB 1959
- **Ragnar Granit**
  The Karolinska Institute, Sweden
  "made discoveries concering visual processes in the eye."

PHYSICS
SB 1953
- **Hans Bethe**
  Cornell University
  "contributed to the theory of nuclear reactions"

CHEMISTRY
SB 1962
- **George Porter**
  Royal Institute of Great Britain, England
  "solar energy conversion."

1968
CHEMISTRY
SB 1966
- **Lars Onsager**
  Yale University
  "complete theoretical description of irreversible processes."

1969
PHYSICS
SB 1958
- **Murray Gell-Mann**
  California Institute of Technology
  "made discoveries concerning the classification of elementary particles and their interactions."

1970s

1970
MEDICINE
SB 1959
- **Ulf von Euler**
  The Karolinska Institute, Sweden
  "introduced discoveries relating to humoral transmitters in nerve terminals."

1972
PHYSICS
SB 1953
- **John Bardeen**
  University of Illinois
  "developed the theory to explain superconductivity,"

1973
MEDICINE
SB 1961
- **Nikolass Tinbergen**
  University of Oxford
  "discoveries concerning organization and elicitation of individual and social behavior patterns."

1973
PHYSICS
SB 1968
- **Brian Josephson**
  Cambridge University
  "his work is the basis for the fastest, lowest power electronic switching elements."

1974
CHEMISTRY
SB1961
- **Paul Flory**
  Stanford University
  "fundamental achievements in the physical chemistry of macromolecules."

1976
CHEMISTRY
SB 1959
- **William Lipscomb**
  Harvard University
  "illuminated the problems of chemical bonding."

1977
PHYSICS
SB 1968
- **Phillip Anderson**
  Bell Laboratories

SB 1964
- **John Van Vleck**
  Harvard University
  "investigations of the electronic structure of magnetic and disordered systems."

1977
CHEMISTRY
SB 1954
- **Ilya Prigogine**
  University Libre de Bruxelles, Belgium
  "the theory of dissipative structures."

1979
PHYSICS
SB 1958
- **Sheldon Glashow**
  Harvard University

SB 1958
- **Steven Weinberg**
  Harvard University

SB 1962
- **Abdus Salam**
  International Centre for Theoretical Physics, Italy & Imperial College of Science and Technology, United Kingdom
  "contributions to the theory of the unified weak and electromagnetic interaction between elementary particles."

1980s

1981
PHYSICS
SB 1975
- **Nicolaas Bloembergen**
  Harvard University

SB1981
- **Arthur Schawlow**
  Stanford University

SB 1956
- **Kai Siegbahn**
  Uppsala University, Sweden
  "contributions to the development of laser spectroscopy."

1981
CHEMISTRY
SB 1962
- **Kenichi Fukui**
  Kyoto University, Japan
  "theories concerning the course of chemical reactions."

1981
MEDICINE
SB 1959
- **David Hubel**
  Harvard Medical School

SB 1959
- **Thorsten Wiesel**
  Havard Medical School
  "discoveries concerning information processing in the visual system."

1983
PHYSICS
SB 1961
- **Subramanyan Chandrasekhar**
  University of Chicago
  "theoretical studies of the structure and evolution of stars."

PHYSICS
SB 1961
- **William Fowler**
  California Institute of Technology
  "studies of the nuclear reactions of importance in the formation of the chemical elements in the universe."

1986
CHEMISTRY
SB 1979
- **Dudley Herschbach**
  Harvard University

SB 1981
- **John Polanyi**
  University of Toronto, Canada
  "contributions concerning the dynamics of chemical elementary processes."

1987
CHEMISTRY
SB 1962
- **Donald Cram**
  University of California
  "development and use of molecules with structure-specific interactions of high selectivity."

1988
PHYSICS
SB 1970
- **Melvin Schwartz**
  Stanford University
  "for the neutrino beam method and the demonstration of the doublet structure of the leptons through the discovery of the muon nuetrino."

1990s

1990
CHEMISTRY
SB 1968
- **Elias Corey**
  Harvard University
  "for his development of the theory and methodology of organic synthesis."

PHYSICS
SB 1961
- **Jerome Freedman**
  Massachusetts Institute of Technology
- **Henry Kendall**
  Massachusetts Institute of Technology
  "development of the quark model in particle physics."

1992
CHEMISTRY
SB 1962
- **Rudolph Marcus**
  California Institute of Technology
  "for his contributions to the theory of electron transfer reactions in chemical systems."

1995
CHEMISTRY
SB 1995
- **Mario Molina**
  Massachusetts Institute of Technology
  "work in atmospheric chemistry, particularly concerning the formation and decomposition of the ozone layer."

1997
PHYSICS
SB 1988
- **Steven Chu**
  Stanford University
  "development of methods to cool and trap atoms with laser light."

1998
PHYSICS
SB 1985
- **Daniel Tsui**
  Princeton University
  "discovery of a new form of quantum fluid fractionally charged excitations."

1999
CHEMISTRY
SB 1986
- **Ahmed Zewail**
  California Institute of Technology
  "studies of the transition of chemical reactions using femtosecond spectroscopy."

2000s

2000
CHEMISTRY
SB 1988
- **Alan Heeger**
  University of California
  "the discovery and development of conductive polymers."

PHYSICS
SB 1995
- **Herbert Kroemer**
  University of California
  "his work was crucial to the development of fiber optic communications."

MEDICINE
SB 1984
- **Paul Greengard**
  Rockefeller University
  " signal transduction in the nervous system."

PHYSICS
SB 1958
- **Jack Kilby**
  Texas Instruments
  "invention of the integrated circuit."

2002
ECONOMICS
SB 1977
- **Daniel Kahneman**
  Princeton University
  "integrated insights on human judgement and decision-making under uncertainty."

CHEMISTRY
SB 1975
- **John Fenn**
  Virginia Commonwealth University
  "identification and structure analyses of biological macromolecules."

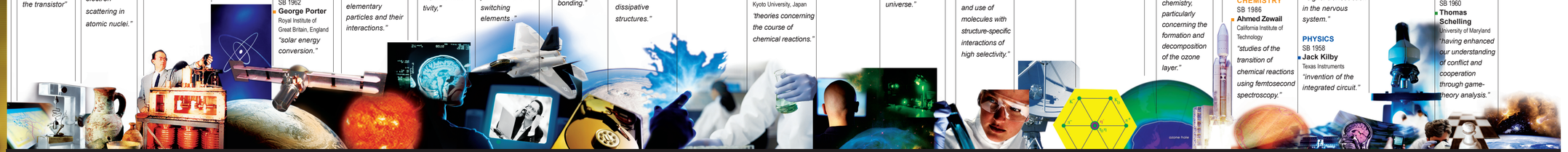
2005
CHEMISTRY
SB 1990
- **John Hall**
  University of Colorado

SB 1962
- **Roy Glauber**
  Harvard University
  "development of laser precision spectroscopy."

CHEMISTRY
SB 1987
- **Robert Grubbs**
  California Institute of Technology
  "development of the metathesis method in organic synthesis."

ECONOMICS
SB 1960
- **Thomas Schelling**
  University of Maryland
  "having enhanced our understanding of conflict and cooperation through game-theory analysis."

2006
PHYSICS
SB 1980
- **George Smoot**
  University of California
  "discovery of the blackbody form and anisotropy of the cosmic microwave background radiation."



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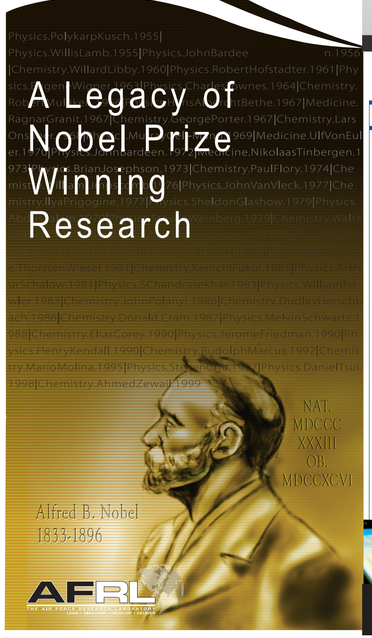
A Legacy of Nobel Prize Winning Research



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