The Elmer A. Sperry Award 2005

FOR ADVANCING THE ART OF TRANSPORTATION

The Elmer A. Sperry Award

The Elmer A. Sperry Award shall be given in recognition of a distinguished engineering contribution which, through application, proved in actual service, has advanced the art of transportation whether by land, sea or air.

In the words of Edmondo Quattrocchi, sculptor of the Elmer A. Sperry Medal:

"This Sperry medal symbolizes the struggle of man's mind against the forces of nature. The horse represents the primitive state of uncontrolled power. This, as suggested by the clouds and celestial fragments, is essentially the same in all the elements. The Gyroscope, superimposed on these, represents the bringing of this power under control for man's purposes."

Presentation of

The Elmer A. Sperry Award for 2005

to

VICTOR WOUK

for his visionary approach to developing gasoline engine-electric motor hybrid-drive systems for automobiles and his distinguished engineering achievements in the related technologies of small, lightweight, and highly efficient electric power supplies and batteries

by

The Elmer A. Sperry Board of Award
under the sponsorship of the:

American Society of Mechanical Engineers
Institute of Electrical and Electronics Engineers
Society of Automotive Engineers
Society of Naval Architects and Marine Engineers
American Institute of Aeronautics and Astronautics
American Society of Civil Engineers

at the
Engineers Week Celebration
Brooklyn, New York

15 February 2007

Victor Wouk

Born the son of Russian Jewish immigrants in the South Bronx in 1919, Victor Wouk (brother of novelist Herman Wouk) earned a bachelor's degree in 1939 from Columbia University and by 1942 had received an MS and PhD in electrical engineering from the California Institute of Technology.

Dr. Wouk spent World War II working on uranium enrichment centrifuges for Westinghouse Research Laboratories in Pittsburgh as part of the Manhattan District Project. Following the war, he worked with North American Philips in New York to develop a 25,000 volt power supply for operating their projection tube. Seeing an opportunity in the industry, Dr. Wouk formed his own company, Beta Electric, that was soon doing $1 million in sales producing test equipment for high-power DC equipment. Bought out by Sorenson and Company in 1956, Wouk then became the chief engineer of Sorenson's power supply section and worked on projects including high power semiconductors. Eager to develop even more sophisticated equipment, Wouk formed the Electronic Energy Conversion Corporation in 1959. With their light weight, low volume and high intensity, his power conditioning units became sought after in the computer industry and in military aviation.

Electronic Energy Conversion Corp. was sold to Gulton Industries in 1963. As head of electronic research for Gulton, Dr. Wouk was approached by Russell Feldman (one of Motorola's founders) about the feasibility of improving the performance of a fleet of Henney Kilowatt electric cars with which he was experimenting at his Connecticut estate. The first electric vehicle using solid-state technology, it was a Renault Dauphine chassis converted to electric power. It was powered by an electric motor rated at 7.1 hp, and used a 36-volt traction battery system based on deep cycle flooded lead-acid "golf-cart" style batteries. It boasted an advertised top speed of 35 mph and a range of 40 miles per charge. Later models of the Kilowatt were upgraded to 72 volt systems and this increased the top speed to in excess of 50 mph. It was priced at US$3,600 in 1961. Approximately 120 were built, and the great majority were sold to their target market of electrical utilities (for electric meter readers). The vehicle was built by the Eureka-Williams company (of Eureka vacuum cleaner fame) at their facility in Conastoga, NY. The actual manufacturing was done by their subsidiary company, Henney Coachworks.

Victor Wouk

Dr. Wouk determined that the electronic control systems of the vehicles were reasonably efficient but the great limitation was the state of battery technology. Russell Feldman then abandoned that project. Later, Dr. Wouk's employer Gulton Industries decided to produce a prototype electric vehicle using the new nickel-cadmium batteries it was supplying to the military. Dr. Wouk built a vehicle based on an American Motors Rambler station wagon but performance remained poor. After consulting with other electronics experts and considering the existing state of battery technology, Dr. Wouk began to consider the possibilities of building a hybrid electric vehicle.

Dr. Wouk explains to New Jersey Congressman Edward Patten the function of the nickel-cadmium batteries in the power system of the Rambler.

In the wake of Congress passing the Clean Air Act in 1970, Wouk left Gulton and, in partnership with Charles Rosen who had been running Gulton's electric-vehicle program, formed Petro-Electric Motors. The duo set out to build a hybrid vehicle that would at least meet and perhaps exceed the Clean Air Act standards. Their demonstration vehicle was a modified 1972 Buick Skylark, which featured a Wankel rotary engine from Mazda and an electric motor that worked in parallel to supply power as needed. "We built the first full-powered, full-sized hybrid vehicle," according to Rosen. "Nobody had taken a full-sized passenger car and made a hybrid out of it."

Dr. Wouk with his 1972 hybrid Buick Skylark at the Environmental Protection Agency's test site.

Dr Wouk's prototype hybrid car was designed with both the limitations of battery power and the limitations of prototype vehicles in mind. He selected a 1972 Buick Skylark as the test bed because the large engine compartment promised plenty of room for additional equipment. He selected a Mazda rotary engine (half the size and power of the Skylark's standard V-8) because it was compact and had a very high power to weight ratio.

The electric motor was used for starting and for extra power during vehicle operation. The car's batteries were recharged during driving by regenerative brakes installed on the vehicle but required an external source to regain their full charge.

Although this design solved the problem of top speed and range that had plagued pure electric vehicles, it was still technically limited and politically controversial. The Wouk hybrid did not fully integrate the internal combustion and electrical propulsion systems and the gasoline engine did not charge the batteries. Also, in the 1960s and 1970s electric vehicle advocates wanted a zero-emission all-electric vehicle. Some opposed hybrid designs because they still produced emissions and betrayed the goal of an all-electric system.

Although Petro-Electric Motors had managed to fabricate a low polluting vehicle (it met the EPA's 1975 vehicle emissions standards) that also achieved twice the fuel economy of a stock '72 Skylark, various bureaucratic and technical issues, as well as political pressures, stymied their project. In 1976, after a failed attempt to raise private venture capital, Petro-Electric folded and Dr.Wouk became a consultant focusing on hybrid vehicles. He worked on electric and hybrid vehicles for the Department of Energy, Tennessee Valley Authority, Booz-Allen, and NASA-Lewis amongst others. He also designed the electric bus system that operated on Roosevelt Island in New York City. For more than 30 years, Dr. Wouk served as a representative of the United States to the International Electrotechnical Commission committee on electric and hybrid vehicles (IEC TC 69).

Dr. Wouk also applied for and received many patents, including a chopper-dropper-booster circuit and an incandescent lamp life extender. His extensive correspondence with his famous brother Herman reveals a host of other concerns, ranging from literature and philately, to space travel and the state of Jewish intellectual life.

During his career Wouk was an inexhaustible communicator. He published over one hundred articles and gave nearly 150 talks to expert and lay audiences. His correspondence is vast and his "letters to the editor" innumerable. The latter also evince the diversity of interests. Despite the gargantuan amount of energy that Wouk put into the development of electric and hybrid vehicles, the range of his activities in both professional and "private" life remained extraordinarily large. Among the organizations in which Dr.Wouk actively participated were the New York Academy of Sciences, the American Association for the Advancement of Science, the Society of Automotive Engineers and the Institute of Electrical and Electronics Engineers (IEEE).

The Achievement

Dr. Wouk's years of experience with high-voltage direct-current control systems uniquely qualified him to solve the problem of electric cars when it was introduced to him.

Since the first battery powered cars were designed in the 19th Century, the vehicles were subject to annoying limitations that offset their great benefits.

Electric vehicles produce no exhaust, and low noise and vibration. Electric motors have very good low-speed torque and produce even power over their entire range. Their cool and smooth operation also promised longer useful life. Before electric starters and automatic transmissions they were also easier to use than their steam and internal combustion counterparts.

On the negative side, electric vehicles had a restricted range and top speed as well as extended recharge times. These restrictions as well as the availability of cheap internal combustion vehicles and cheap gasoline meant that by the 1920s, electric vehicles fell out of general commercial use.

The decade of the 1960s seemed promising for new electric vehicle technologies. Research had established that automotive exhaust was a major cause of photochemical air pollution (smog). Earlier theories that industrial pollution was the major component of such problems were discounted. Meanwhile, the use of electronics in defense, entertainment, and consumer applications was exploding and there were ambitious plans for new urban electric mass transportation systems. These developments suggested to some that automotive transportation might also benefit from some form of electromotive technology.

At this point, when Dr. Wouk began to work on electric cars, the development of semi-conductor chips promised much improved electronic control systems for electric vehicles. These technologies permitted higher top speeds but the low energy density of existing batteries remained an insoluble problem. Dr. Wouk asked the President of his Alma Mater (Caltech) for help in identifying a more powerful battery system. The response was the convening of a seminar on the topic:

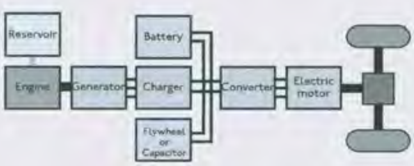
> "Dear Victor, your letter intrigued me. No end to the possibilities." Instead of speaking to Linus [Pauling], he had called a sort of informal seminar on the subject—chemical engineers, electrical engineers, physicists—and came to the conclusion that there are electrochemical couples that have as much or more energy density as [the lead battery]. Usually, though, they are very sophisticated systems—high temperature, very corrosive materials, and so on and so forth.

So two things would have to happen: There would have to be a demand for the performance, and the performance would have to be made available on a commercial scale. That left out electric cars.

After building a prototype electric vehicle which was not commercially feasible, Dr. Wouk decided that the only way to motivate researchers to produce the electrical storage improvements required for a useful electric car would be to build a partially electric car that could actually be sold to consumers. This was to be a dual-powered (or hybrid) gasoline-electric vehicle.

A number of such dual powered vehicles had been built early in the 20th Century and one design had even been called a "hybrid" but they had not seen widespread use. In addition, the popularity of diesel-electric railroad locomotives provided a further example of the possibility of mixed vehicle designs.

By the end of the 20th century, electronics and computer technology had progressed to the point where a commercially viable hybrid vehicle could be manufactured.



Series Hybrid

In a series hybrid design, an internal combustion engine drives an electric generator, instead of directly driving the wheels. The generator both charges a battery and powers an electric motor that moves the vehicle. When large amounts of power are required, the motor draws electricity from both the batteries and the generator. A complex transmission is not needed, as electric motors are efficient over a wide speed range. Some vehicle designs have separate electric motors for each wheel, which simplifies traction control, all wheel drive, and similar features.

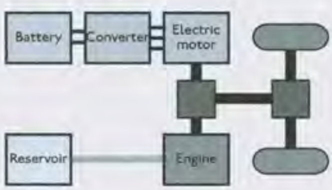
The advantage of a series hybrid is the lack of a mechanical link between the combustion engine and the wheels. The combustion engine runs at a constant and efficient rate, even as the car changes speed. During stop-and-go city driving, series hybrids are relatively the most efficient.

A weakness is that the power from the combustion engine has to run through both the generator and electric motor. During long-distance highway driving, the electrical transmission can be less efficient than a conventional transmission.

The use of one motor per wheel eliminates the conventional mechanical transmission elements (gearbox, transmission shafts, differential). If the motors are integrated into the wheels, the unsprung mass increases, decreasing ride performance. If the motors are attached to the vehicle body, flexible couplings are required. Further advantages of individual wheel motors include allowing lower floors on buses, and simplifying mechanical design in 8x8 all-wheel drive military vehicles.

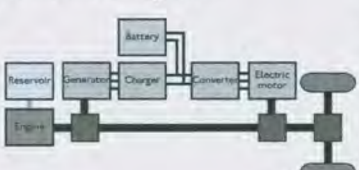
Series hybrids can be also be fitted with an additional rechargeable energy storage system (RESS) for peak power purposes such as a supercapacitor or a flywheel. This can improve efficiency by minimizing the losses in the battery.

Parallel Hybrid



Parallel hybrid systems, which are most commonly produced at present, connect both the electrical and internal combustion systems to the mechanical transmission. They can be subcategorized depending upon how balanced the different portions are at providing motive power. In some cases, the internal combustion engine is the dominant portion and is used for primary power, with the motor turning on only when a boost is needed. Others can run with just the electric system operating alone. Most designs combine a large electrical generator and a motor into one unit, often situated between the internal combustion engine and the transmission, in the location of the flywheel, replacing both the conventional starter motor and the generator or alternator. A large battery pack is required, providing a higher voltage than the normal automotive 12 volts. Accessories such as power steering and air conditioning are powered by electric motors, so that they continue to function when the internal combustion engine is stopped; this offers the possibility of further efficiency gains, by modulating the electrical power delivered to these systems, rather than having them run directly from the engine at a speed which depends on engine speed.

Combined Hybrid



Combined hybrid systems have features of both series and parallel hybrids. They incorporate power-split devices allowing for power paths from the engine to the wheels that can be either mechanical or electrical. The Toyota Hybrid System THS / Hybrid Synergy Drive mode of operation with only a single power split device (incorporated as a single 3 shaft planetary gearset) is a typical example which can also be called Input-Split Hybrid, due to the fact that a fixed amount of torque is transferred via the electrical path from the engine to the wheels. This in turn makes this setup very simple in mechanical terms, but does have some drawbacks of its own. For example the maximum speed is mainly limited by the speed of the smaller electric motor. Also, the efficiency of the transmission is heavily dependent on the amount of power being transmitted over the electrical path, as multiple conversions, each with their own, less than perfect efficiency, lead to a low efficiency of that path (~0.7) compared with the purely mechanical path (~0.98). Especially in higher speed regimes (>120 km/h or 70 mph) the efficiency (of the transmission alone) therefore drops below that of a generic automatic transmission with hydrodynamic coupler.

The main principle behind this system is the more-or-less complete decoupling of the power supplied by the engine (or other primary source) from the power demanded by the driver. Thus a smaller, less flexible engine may be used, which is designed for maximum efficiency (often using variations of the conventional Otto cycle, such as the Miller or Atkinson cycle). This contributes significantly to the higher overall efficiency of the vehicle, with regenerative braking playing a much smaller role.

The differing torque vs. rpm characteristics of the internal combustion and electrical motors operate synergistically; an internal combustion engine's torque is minimal at lower RPMs, since the engine must be its own air pump. Thus, the need for reasonably rapid acceleration from a standing start results in an engine which is much larger than required for steady speed cruising. On the other hand, an electrical motor exhibits maximum torque at stall; therefore this engine is well suited to complement the internal combustion engine's torque deficiency at low RPMs, allowing the use of a much smaller and therefore more fuel efficient engine. Interesting variations of that simple theme, as very well known (implemented in the Toyota Prius) are the addition of a fixed gear second planetary gearset as used in the Lexus RX400h and Toyota Highlander Hybrid. This allows for a motor with less torque but higher power (and higher maximum rotary speed), i.e. higher power density.

The future of hybrid vehicle technology (particularly in mass transit and trucking operations) seems assured but Dr. Wouk's important contribution was to build the first modern hybrid vehicle. Even though it did not gain acceptance in the 1970s, Dr. Wouk continued to advocate in favor of the hybrid principle in the technical committees on which he served and in his writings. Meanwhile, the advocates of all-electric vehicles lost ground as vehicle electric loads increased dramatically for convenience features such as climate control; electric windows, doors, and seats; and electronic entertainment systems, and the long promised advances in battery power density, reliability and recharge time failed to materialize.

Once sophisticated computer-controlled vehicle systems became available by the 1990s and battery prices dropped dramatically, the way was cleared for the modern hybrid vehicles we see today. But those vehicle designers owe a debt to Dr. Victor Wouk who had been there 30 years before. Even back then, Dr. Wouk was known for his view that all-electric vehicles could not perform in a manner that would lead to a significant market share as passenger vehicles. He advocated the development of hybrids as a transition to all-electric or hydrogen powered vehicles. Today, this idea is integral to the market-development strategy of the planet's major auto manufacturers.

Elmer A. Sperry, 1860-1930

After graduating from the Cortland, N.Y. Normal School in 1880, Sperry had an association with Professor Anthony at Cornell, where he helped wire its first generator. From that experience he conceived his initial invention, an improved electrical generator and arc light. He then opened an electric company in Chicago and continued on to invent major improvements in electric mining equipment, locomotives, streetcars and an electric automobile. He developed gyroscopic stabilizers for ships and aircraft, a successful marine gyro-compass and gyro-controlled steering and fire control systems used on Allied warships during World War I. Sperry also developed an aircraft searchlight and the world's first guided missile. His gyroscopic work resulted in the automatic pilot in 1930. The Elmer A. Sperry Award was established in 1955 to encourage progress in transportation engineering.

The Elmer A. Sperry Award

To commemorate the life and achievements of Elmer Ambrose Sperry, whose genius and perseverance contributed so much to so many types of transportation, the Elmer A. Sperry Award was established by his daughter, Helen (Mrs. Robert Brooke Lea), and his son, Elmer A. Sperry, Jr., in January 1955, the year marking the 25th anniversary of their father's death. Additional gifts from interested individuals and corporations also contribute to the work of the Board.

Elmer Sperry's inventions and his activities in many fields of engineering have benefited tremendously all forms of transportation. Land transportation has profited by his pioneer work with the storage battery, his development of one of the first electric automobiles (on which he introduced 4-wheel brakes and self-centering steering), his electric trolley car of improved design (features of its drive and electric braking system are still in use), and his rail flaw detector (which has added an important factor of safety to modern railroading). Sea transportation has been measurably advanced by his gyrocompass (which has freed man from the uncertainties of the magnetic compass) and by such navigational aids as the course recorder and automatic steering for ships. Air transportation is indebted to him for the airplane gyro-pilot and the other air navigational instruments he and his son, Lawrence, developed together.

The donors of the Elmer A. Sperry Award have stated that its purpose is to encourage progress in the engineering of transportation. Initially, the donors specified that the Award recipient should be chosen by a Board of Award representing the four engineering societies in which Elmer A. Sperry was most active:

American Society of Mechanical Engineers
(of which he was the 48th President)

American Institute of Electrical Engineers
(of which he was a founder member)

Society of Automotive Engineers

Society of Naval Architects and Marine Engineers

In 1960, the participating societies were augmented by the addition of the Institute of Aerospace Sciences. In 1962, upon merging with the Institute of Radio Engineers, the American Institute of Electrical Engineers became known as the Institute of Electrical and Electronics Engineers; and in 1963, the Institute of Aerospace Sciences, upon merger with the American Rocket Society, became the American Institute of Aeronautics and Astronautics. In 1990, the American Society of Civil Engineers became the sixth society to become a member of the Elmer A. Sperry Board of Award.

Important discoveries and engineering advances are often the work of a group, and the donors have further specified that the Elmer A. Sperry Award honor the distinguished contributions of groups as well as individuals.

Since they are confident that future contributions will pave the way for changes in the art of transportation equal at least to those already achieved, the donors have requested that the Board from time to time review past awards. This will enable the Board in the future to be cognizant of new areas of achievement and to invite participation, if it seems desirable, of additional engineering groups representative of new aspects or modes of transportation.

THE SPERRY SECRETARIAT

The donors have placed the Elmer A. Sperry Award fund in the custody of the American Society of Mechanical Engineers. This organization is empowered to administer the fund, which has been placed in an interest bearing account whose earnings are used to cover the expenses of the board. A secretariat is administered by the ASME, which has generously donated the time of its staff to assist the Sperry Board in its work.

The Elmer A. Sperry Board of Award welcomes suggestions from the transportation industry and the engineering profession for candidates for consideration for this Award.

PREVIOUS ELMER A. SPERRY AWARDS

1955 To *William Francis Gibbs* and his Associates for design of the S.S. United States.

1956 To *Donald W. Douglas* and his Associates for the DC series of air transport planes.

1957 To *Harold L. Hamilton, Richard M. Dilworth* and *Eugene W. Kettering* and Citation to their Associates for developing the diesel-electric locomotive.

1958 To *Ferdinand Porsche* (in memoriam) and *Heinz Nordhoff* and Citation to their Associates for development of the Volkswagen automobile.

1959 To *Sir Geoffrey de Havilland, Major Frank B. Halford* (in memoriam) and *Charles C. Walker* and Citation to their Associates for the first jet-powered passenger aircraft and engines.

1960 To *Frederick Darcy Braddon* and Citation to the Engineering Department of the Marine Division of the *Sperry Gyroscope Company*, for the three-axis gyroscopic navigational reference.

1961 To *Robert Gilmore LeTourneau* and Citation to the Research and Development Division, *Firestone Tire and Rubber Company*, for high speed, large capacity, earth moving equipment and giant size tires.

1962 To *Lloyd J. Hibbard* for applying the ignitron rectifier to railroad motive power.

1963 To *Earl A. Thompson* and Citations to *Ralph F. Beck, William L. Carnegie, Walter B. Herndon, Oliver K. Kelley and Maurice S. Rosenberger* for design and development of the first notably successful automatic automobile transmission.

1964 To *Igor Sikorsky* and *Michael E. Gluhareff* and Citation to the Engineering Department of the Sikorsky Aircraft Division, *United Aircraft Corporation*, for the invention and development of the high-lift helicopter leading to the Skycrane.

1965 To *Maynard L. Pennell, Richard L. Rouzie, John E. Steiner, William H. Cook* and *Richard L. Loesch, Jr.* and Citation to the Commercial Airplane Division, *The Boeing Company*, for the concept, design, development, production and practical application of the family of jet transports exemplified by the 707, 720 and 727.

1966 To *Hideo Shima, Matsutaro Fuji* and *Shigenari Oishi* and Citation to the *Japanese National Railways* for the design, development and construction of the New Tokaido Line with its many important advances in railroad transportation.

1967 To *Edward R. Dye* (in memoriam), *Hugh DeHaven*, and *Robert A. Wolf* for their contribution to automotive occupant safety and Citation to the research engineers of *Cornell Aeronautical Laboratory* and the staff of the Crash Injury Research projects of the *Cornell University Medical College.*

1968 To *Christopher S. Cockerell* and *Richard Stanton-Jones* and Citation to the men and women of the *British Hovercraft Corporation* for the design, construction and application of a family of commercially useful Hovercraft.

1969 To *Douglas C. MacMillan, M. Nielsen* and *Edward L. Teale, Jr.* and Citations to *Wilbert C. Gumprich* and the organizations of *George G. Sharp, Inc., Babcock and Wilcox Company*, and the *New York Shipbuilding Corporation* for the design and construction of the N.S. Savannah, the first nuclear ship with reactor, to be operated for commercial purposes.

1970 To *Charles Stark Draper* and Citations to the personnel of the *MIT Instrumentation Laboratories,* Delco Electronics Division, *General Motors Corporation*, and Aero Products Division, *Litton Systems*, for the successful application of inertial guidance systems to commercial air navigation.

1971 To *Sedgwick N. Wight* (in memoriam) and *George W. Baughman* and Citations to *William D. Hailes, Lloyd V. Lewis, Clarence S. Snavely, Herbert A. Wallace*, and the employees of *General Railway Signal Company*, and the Signal & Communications Division, *Westinghouse Air Brake Company*, for development of Centralized Traffic Control on railways.

1972 To *Leonard S. Hobbs* and *Perry W. Pratt* and the dedicated engineers of the Pratt & Whitney Aircraft Division of *United Aircraft Corporation* for the design and development of the JT-3 turbo jet engine.

1975 To *Jerome L. Goldman, Frank A. Nemec* and *James J. Henry* and Citations to the naval architects and marine engineers of *Friede and Goldman, Inc.* and *Alfred W. Schwendtner* for revolutionizing marine cargo transport through the design and development of barge carrying cargo vessels.

1977 To *Clifford L. Eastburg* and *Harley J. Urbach* and Citations to the Railroad Engineering Department of *The Timken Company* for the development, subsequent improvement, manufacture and application of tapered roller bearings for railroad and industrial uses.

1978 To *Robert Puiseux* and Citations to the employees of the *Manufacture Française des Pneumatiques Michelin* for the development of the radial tire.

1979 To *Leslie J. Clark* for his contributions to the conceptualization and initial development of the sea transport of liquefied natural gas.

1980 To *William M. Allen, Malcolm T. Stamper, Joseph F. Sutter* and *Everette L. Webb* and Citations to the employees of *Boeing Commercial Airplane Company* for their leadership in the development, successful introduction and acceptance of wide-body jet aircraft for commercial service.

1981 To *Edward J. Wasp* for his contributions toward the development and application of long distance pipeline slurry transport of coal and other finely divided solid materials.

1982 To *Jörg Brenneisen, Ehrhard Futterlieb, Joachim Körber, Edmund Müller, G. Reiner Nill, Manfred Schulz, Herbert Stemmler* and *Werner Teich* for their contributions to the development and application of solid state adjustable frequency induction motor transmission to diesel and electric motor locomotives in heavy freight and passenger service.

1983 To *Sir George Edwards, OM, CBE, FRS; General Henri Ziegler, CBE, CVO, LM, CG; Sir Stanley Hooker, CBE, FRS* (in memoriam); *Sir Archibald Russell, CBE, FRS;* and *M. André Turcat, L d'H, CG*; commemorating their outstanding international contributions to the successful introduction and subsequent safe service of commercial supersonic aircraft exemplified by the Concorde.

1984 To *Frederick Aronowitz, Joseph E. Killpatrick, Warren M. Macek* and *Theodore J. Podgorski* for the conception of the principles and development of a ring laser gyroscopic system incorporated in a new series of commercial jet liners and other vehicles.

1985 To *Richard K. Quinn, Carlton E. Tripp*, and *George H. Plude* for the inclusion of numerous innovative design concepts and an unusual method of construction of the first 1,000-foot self-unloading Great Lakes vessel, the M/V Stewart J. Cort.

1986 To *George W. Jeffs, Dr. William R. Lucas, Dr. George E. Mueller, George F. Page, Robert F. Thompson* and *John F. Yardley* for significant personal and technical contributions to the concept and achievement of a reusable Space Transportation System.

1987 To *Harry R. Wetenkamp* for his contributions toward the development and application of curved plate railroad wheel designs.

1988 To *J. A. Pierce* for his pioneering work and technical achievements that led to the establishment of the OMEGA Navigation System, the world's first ground-based global navigation system.

1989 To *Harold E. Froehlich, Charles B. Momsen, Jr.*, and *Allyn C. Vine* for the invention, development and deployment of the deep-diving submarine, Alvin.

1990 To *Claud M. Davis, Richard B. Hanrahan, John F. Keeley*, and *James H. Mollenauer* for the conception, design, development and delivery of the Federal Aviation Administration enroute air traffic control system.

1991 To *Malcom Purcell McLean* for his pioneering work in revolutionizing cargo transportation through the introduction of intermodal containerization.

1992 To *Daniel K. Ludwig* (in memoriam) for the design, development and construction of the modern supertanker.

1993 To *Heinz Leiber, Wolf-Dieter Jonner* and *Hans Jürgen Gerstenmeier* and Citations to their colleagues in *Robert Bosch GmbH* for their conception, design and development of the Anti-lock Braking System for application in motor vehicles.

1994 To *Russell G. Altherr* for the conception, design and development of a slackfree connector for articulated railroad freight cars.

1996 To *Thomas G. Butler* (in memoriam) and *Richard H. MacNeal* for the development and mechanization of NASA Structural Analysis (NASTRAN) for widespread utilization as a working tool for finite element computation.

1998 To *Bradford W. Parkinson* for leading the concept development and early implementation of the Global Positioning System (GPS) as a breakthrough technology for the precise navigation and position determination of transportation vehicles.

2000 To those individuals who, working at the French National Railroad (SNCF) and ALSTOM between 1965 and 1981, played leading roles in conceiving and creating the initial TGV High Speed Rail System, which opened a new era in passenger rail transportation in France and beyond.

2002 To *Raymond Pearlson* for the invention, development and worldwide implementation of a new system for lifting ships out of the water for repair and for launching new ship construction. The simplicity of this concept has allowed both large and small nations to benefit by increasing the efficiency and reducing the cost of shipyard operations.

2004 To *Josef Becker* for the invention, development, and worldwide implementation of the Rudderpropeller, a combined propulsion and steering system, which converts engine power into optimum thrust. As the underwater components can be steered through 360 degrees, the full propulsive power can also be used for maneuvering and dynamic positioning of the ship.

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Henney Kilowatt car, page 2: Photo courtesy of James Jarrett.

Portrait, page 3: Photo by Jean Raeburn, NY/courtesy Caltech Archives.

Rambler and Skylark, page 4: Photos courtesy of the Archives, California Institute of Technology.

Diagrams on pages 7, 8: Designed by Peter Van den Bossche.

The 2005 Elmer A. Sperry Board of Award

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