equipment.

A qualitative examination of these technolgies shows that *if* these technologies were available in the form required for a beam weapon, then the technologies available to the civilian economy would usher in a new stage of industrial processes, which are almost totally dependent on the narrow range of the electromagnetic spectrum in the infrared (heat), the characteristic feature of these new technological capabilities is that they access the full-range of the electromagnetic spectrum, from x-rays through to microwaves. For the first time, it becomes economical to perform chemical, industrial, and agricultural processes using finely tuned electromagnetic energy rather than "brute force" infrared energy. The impact of this general change can hardly be overestimated. The FEF study has identified several central areas:

1) Energy production: the advent of the plasma age is most dramatically shown by the coming into existence of nuclear fusion energy, the second-generation nuclear technology using heavy hydrogen in the same fuel cycle used by the Sun. This technology, which the Japanese project to be on line in the middle 1990s, produces clean, cheap energy from an unlimited fuel source (water), in intensities 100 times those available at present.

2) Materials processing: plasma torch processing, using matter in its ionized state and magnetic or centrifugal separation, makes astronomical increases in the natural resource base of the world economy. It also creates capabilities for new, high-quality metal refining, waste recycling, and elemental transmutation. Applications of laser-isotope separation, the nearest-term of these technologies, include extraction of rare isotopes, nuclear tailoring of material and alloy properties, and chemical process control.

3) Metal working: the use of beams and lasers for more efficient, higher speed, and more easily automated metal cutting, forming, and welding is a well-established technology which awaits cheap high-power lasers for its widespread application. Less well known, but with perhaps greater impact, are applications of surface heat-treating, differential crystallization, and laser annealing.

4) Chemical processing: chemonuclear processes for the production of synthetic fuels (methane, methanol, and heavier hydrocarbons), hydrogen generation, and coal gasification are dramatic improvements on existing thermal and electrical technologies. These become realistic with the intense energies available from fusion. In addition, the use of lasers for control of specific, complex chemical syntheses and processing are a feature of control of broad ranges of the electromagnetic spectrum with food processing, non-destructive sterilization, and preservation being especially important.

5) Short-time process control: the automation and control technologies for processes which occur on sub-microsecond time scales have applications throughout the plasma industries. The ability to master the very high energy densities and inherently non-steady state properties of plasmas depends on both a diagnostic and control capability.

A 'great enterprise' in NASA's tradition

by Marsha Freeman

The development and deployment of a directed energy-beam defensive weapons system over the next decade will be one of the "great enterprises" the nation must embark on. It will require the kind of government investment that the nation has seen in the past in preparations for war, and in the civilian space program. This federal spending has the potential to stimulate increases in the productivity of the nation's economy because it has the ability to increase the rate at which new technology is introduced into the economy.

Such increases in productivity result from the optimism created by national leadership when great new projects such as the lunar landing are stated as national goals; when the spending on the project puts federal dollars directly into our high-technology industry to accomplish the task; and when industry and agriculture apply government-developed techniques to everyday economic activity.

All three of these effects led to increases in productivity during the 1960s period of the NASA Apollo program. By comparison, *none* of these effects were seen as the space program funding was diverted into Great Society social welfare programs after the death of President Kennedy.

In order to deploy beam weapons in space, our civilian space program will have to be geared up to finally provide the in-orbit manned capability that we do not yet have. Large and complex space-based military systems will have to be maintained, updated, and repaired while in orbit, and specialists located in space stations will have to be on call for this purpose. The funding for civilian space programs will have to increase over the next few years until it regains its 1960s real purchasing power.

This will mean tripling the NASA budget by the end of this decade, for the military and industrial move into space. The technology and productivity development from this funding will add to the shock waves of economic growth the development of the beam weapons themselves will provide.

Lasers for industry

Although we cannot predict all of the new technology that will result from the development of directed energy-beam weapons over the next decade, we know that specific technologies, such as the industrial application of lasers, for example, will be propelled into large-scale use. Electron and plasma technologies will be pushed years ahead, as will the development of fusion energy itself, opening the era of unlimited, intensive energy supplies worldwide.

The use of coherent light sources, in the form of lasers, has been significant in industry for the past decade. Today lasers are used in the welding, cutting, and heat-treating of metals. They can be used for the processing of plastics, rubber, ceramics, glass, and practially all other materials.

The use of highly focused lasers introduced a degree of precision unobtainable from mechanical processing methods, and this precision is evident in the use of lasers in medicine. But due to the collapse of capital investment in industry for the introduction of revolutionary new technologies, laser applications have not penetrated into our basic industries and transformed them on any large scale.

Were the government to announce a full-scale laser-weapon development program, with changes in monetary policy and the investment climate, these technologies would begin to flood into the industrial stream. Research and development would be spurred at great pace and the constraints on the industrial use of lasers would be solved.

According to industry experts, lasers available today are in the low power levels of less than 1,000 watts, or one kilowatt (kwt). Large systems are not reliable and not affordable. If lasers for industrial use were available in the tens of kilowatt range, new applications, such as the heat-treating of semi-finished steel products, would become available.

Steel pieces could be fused with alloying materials on the surface using laser heating, rather than using alloys for the entire piece of metal. Steel pieces could be selectively hardened, or annealed, using laser heating, and processes such as photochemistry could be done on a large scale.

With larger lasers approaching the size of those needed for the beam systems themselves, industry could develop laser drilling techniques for oil and other minerals, and laser tunneling could replace mechanical methods used today.

Further into the future, laser systems will have exciting uses in space. NASA is examining proposals to orbit large nuclear power generating plants. These would produce electricity, which could be used to power a laser. The laser energy would be transmitted from the power station to satellites, space stations, factories, and other facilities in space, which then could operate without their own on-board power supply. Laser energy could also power in-orbit military facilities.

Scientists have developed preliminary designs for laser propulsion systems for deep-space travel. All of these possible future uses of laser technology would be pushed years ahead in their development and use by the directed energy-beam weapon program.

In addition to lasers themselves, the attendant systems design for power handling, optical focusing, materials development, and other areas would stimulate new applications in industry.

The tripling of the NASA budget, to restore the agency to its level of purchasing power during the Apollo period and provide the needed in-space capabilities for a beam program, will bring an entire array of space-manufactured materials to the economy. Man's permanent move into space will create new industries now difficult to foresee.

In addition to the new industrial processes and products that additional space capacities will make available, technologies that have already been "spun off" from NASA spending will begin to penetrate the economy as investment shifts toward high-productivity applications.

Reaping the benefits from space

The increases in NASA funding, which peaked in 1965, spun out new technologies for the economy with the potential to dramatically increase productivity in every area of economic life. For example:

Industrial processing—One of the best known technology spurts from NASA spending was the cheapening and improvement of computers and electronics. Between 1968 and 1971 U.S. textile weaving mills were able to increase productivity between two and three percent by the introduction of a multiplexer circuit connecting a computer to remote terminals developed by NASA's Marshall Space Flight Center for the Saturn rocket.

An ultrasonic testing technique, developed by NASA to qualify delicate materials without destructive effects, is being used in the production of steel, rails, aircraft, nuclear reactors, and automobiles. The original $2 million NASA investment has created a $50 million per year new industry.

High-temperature resistant alloys needed for high-temperature energy and industrial processing were created for spaceship use, and dozens of new materials were created by industry from NASA's basic research. These new materials increased the productivity of existing industrial processes by allowing them, for example, to be run at high temperatures or in more hostile environments, or created wholly new techniques more productive than those they replaced.

Energy—NASA's requirement to work with compact, high-density energy sources, in extreme environments, greatly spurred development possibilities for advanced ground-based energy sources. The NASA ROVER nucler space reactor program, and the NERVA nuclear rocket effort, contributed to the productivity of our civilian technology.

Work done on compact, high-temperature nuclear fission fuel arrays led to the development of composite fuel elements, which have been used in experiments in our liquid fast breeder reactor program. "Beaded" fuel particles developed for NERVA applications are also applicable to next-generation high-temperature gas-cooled reactors which would provide industrial-grade process heat for industry.

Although neither the U.S. breeder nor high-temperature reactor programs have become commercial, the renewed national commitment to frontier military, space, and energy development would pull those NASA spinoffs off the shelf.

The same is true for magnetohydrodynamics (MHD) direct-conversion energy technology. By replacing steam turbines with direct heat-to-electricity conversion, MHD could

Artificial heart shows breakthrough potential

The artificial heart now beating in the chest of Dr. Barney Clark is, in every sense of the word, a spinoff of research and development at the National Aeronautics and Space Administration. It is a monumental demonstration of the impact which the space program has had throughout the economy. It is also a foretaste of the immense effect that the beam weapons program, particularly the X-ray laser, could have on basic biology and aging research.

In 1963, at the height of the Kennedy-era enthusiasm for landing an American on the moon by 1970, Congress voted up funding for drawing up an overview prospectus on artifical heart research. The National Heart Institute went to what was then the center of technical and engineering expertise, NASA. There, Lowell Harmison, a nuclear engineer, and Frank Alturi, a mechanical engineeer with nuclear background, agreed to coordinate a large task force of consultants from various fields, under the auspices of the private consulting firm Hittman Associates.

The summary Hittman report, completed in 1966, envisioned the full development and testing of a completely implantable artificial heart before 1980.

The main problems to be solved were these:

- **Energy source:** the device must ultimately have a fully implantable and long-lasting energy source. The heart must produce a power of 2.5 watts, and pump or contract 30 to 40 million times per year. From the beginning, the most likely source was nuclear. Alturi was involved in developing the plutonium pellets used as electrical generators for some of the earliest space probes. In fact, all of the necessary features which would be needed for human implantation, to guard against spillage in case of a violent event such as a plane crash or a gunshot impact, have already been fully developed by NASA. The heart used in the Utah implantation runs on an external air pump, but can be switched to implanted energy sources as they become available.
- **Geometry of the heart chambers:** clotting occurs if the blood flow pattern is such that some blood pools and remains in an area of the ventricle for a long period of time, or if there is excessive turbulence of the blood as it is pumped. Blood flow dynamics, termed rheology, is a special application of hydrodynamics, and the heart program has relied heavily on experts in the field borrowed from the aerospace industry.
- **Materials:** most of the materials used in artificial hearts are polymer plastics, such as the polyurethane in Barney Clark's Jarvik-7 heart. The space program provided an additional impetus to extend the range of these substances and their characteristics.
- **Monitoring and control devices:** NASA pioneered in the area of automatic computer-controlled sensing of biological parameters such as blood pressure and heart rate, in the course of monitoring the condition of astronauts in space. The computer miniaturization needed for a fully-implantable device is also a product of space research.

Contrary to the predictions of the 1966 Hittman report, the level of funding by the National Heart, Lung and Blood Institute for research around the country has not been $50 million annually, but more in the range of $7-10 million. Despite this severe limitation in funding, which has caused the program to "put many of its eggs in very few baskets," according to a NHI spokesman, the major engineering problems have been solved.

At current funding levels, spokesmen foresee testing implanted energy sources in humans in three to four years, having a dependable implanted energy source in five to six years, and completing final phase testing with large numbers of humans preparatory to mass marketing of the device in another six to seven years. However, since the engineering problems are basically solved, increasing the funding to the orginally charted $50 million per year would predictably shorten the entire rest of development to marketing phase to a total of only **three years**.

The increased longevity and prolonged working lifetime possible with the artificial heart would more than repay society for the social cost of the program. For example, with mass production the cost of the device itself could be brought down to $1,000 easily. Further in the future the device could become the standard treatment for people who survive their first heart attack. Since heart disease is responsible for more than half the 2 million deaths annually in the U.S.A., and since more than half of these people reach a hospital before dying, the potential for the device is enormous.

The long range goal of heart research should of course be non-surgical treatment and ultimately prevention. The development of space-based defense beam weapons involves the production of the X-ray laser, which would revolutionize biology by making possible the microscopic examination of macromolecules such as genes and proteins at far greater magnifications and over far shorter time intervals than is currently possible. It may be possible to observe the action of genes, functioning within living tissue, with a resolution of atomic distances. This would add immeasurably to an understanding of the "unknowns" and guide research not only in atherosclerosis but in cancer and many other areas as well.

increase energy conversion productivity by 50 percent. MHD physics and technology are based directly on space-aged technology, and are yet to be implemented.

Agriculture—Food production, processing, and treatment are some of the greatest potential beneficiaries of space technology. Remote sensing satellites, developed, launched, and operated by NASA, have saved farmers billions of dollars in preventing the spread of plant disease. They have alerted them to possible floods by estimating spring run-off from winter snowfalls.

Farmers have been alerted to impending hurricanes and other damaging weather conditions by NASA-developed weather satellites, and for the first time, global food planning has been possible.

The lack of investment capital for developing nations to build the infrastructure and data handling facilities to make use of Landsat remote sensing data has hampered the full deployment of this great revolution in planning, nurturing, and processing the world's food.

Medicine—The productivity of a nation surely depends on the health and life expectancy of its greatest resource—its people. The artificial heart used to save the life of Dr. Barney Clark just weeks ago was the result of applied NASA resources—both the materials and people that had been developed by the space program created the artificial heart.

Telemetry technology needed to monitor the life functions of astronauts millions of miles away is now used to monitor the life functions of infants in incubators. Infrared scanner devices developed by the Marshall Center during the Apollo effort are used in breast cancer diagnosis as well as in industry. New generations of military sensing techniques will find highly precise medical applications.

Artificial limbs were created by applying the remote handling devices used by NASA in space and by the nuclear industry. Mass spectrometers preset to collect and analyze the atmosphere, a pilot's breath, the space environment, and the soil of Mars are now used in over 200 intensive care hospital units to measure eight critical complements of a patient's breath. All of these applications increase the productivity of the U.S. workforce.

NASA-derived technology led the infusion of new technology into the commercial economy over the 1960s. Advancements from our smaller but yet significant space program of the 1970s, by and large, never entered the marketplace in significant scale. Our productivity over those last twelve years has reflected the fact that we have allowed the by-products of our space investment to sit on shelves or in laboratories, and have not put them to work.

Now, with a national commitment to beam weapon development, a space colonization program, and the introduction of fusion energy and the plasma age, the United States can leap forward in productivity immediately by simply deploying the ready technology of our past research efforts, and plan continuing waves of new technology as these programs go forward.

How beam weapons would spur recovery

by Sylvia Brewda

The economic effect of the U.S. beam-weapon development program put forward by the National Democratic Policy Committee has been analyzed using the LaRouche-Riemann model, the only economic method competent to assess the type of non-linear changes that such a high-technology program would bring about. Model runs produced by the Economics Research Group of the Fusion Energy Foundation led to two simple conclusions:

- Without such a science driver, the U.S. economy is now so ruined that even sane credit policies will not save it.
- With the productivity improvements to be immediately gained from the adoption of the NDPC program, the economy will move rapidly to recovery and growth.

Global productivity impact

An approximate estimate of the global productivity impact of an aggressive beam weapon development and deployment program was devised using the following steps:

1) Estimate of overall efficiency impact of NASA spending during the 1960s as template for estimate of beam weapon program. A large number of correlation studies were done and it was found that close correlation exists between the amount of change of NASA expenditures and the ratio of factor productivity (total tangible profit divided by total tangible input costs) and gross capital investment lagged by one year.

2) A base run of the U.S. economy over the period 1984 to 1989. This base run, even giving very generous estimates for extrapolation of trends that have existed in the U.S. economy and assumptions of maximal efficiency in deployment of existing technologies, shows very slow growth over the coming period. Even after assuming that an initial push could be given to the economy by rationalization, the growth rate levels off to near zero by the end of the period. The accumulated obsolescence and "entropy" in the U.S. economy is too great to overcome by incremental measures.

3) The application of the observed correlation to a beam weapon spending profile that totals $30 billion over 3 years and which grows rapidly between 1982 and 1987, and levels