tonnage of space hardware over the next 5-15 years.

Oct. 23: U.S. Space Command Chief Gen. John Piotrowski warns that the Soviets have already developed ground-based lasers powerful enough to destroy low-orbiting satellites and damage those farther away.

Oct. 26: French satellite pictures confirm U.S. Pentagon reports that the U.S.S.R. has built at least two new ABM, ground-based laser testing stations.

Nov. 15: Leading West German SDI proponent and INF Treaty opponent Jürgen Todenhoefer resigns from all official posts.

Nov. 19: The Club of Rome's Council on Economic Priorities issues a report which concludes that the SDI will undermine the American economy.

Dec. 1: In a nationally televised interview on NBC, Gorbachov admits that the Soviet Union has an SDI program.

After Weinberger, an uncertain future for SDI

by Robert Gallagher

Despite some promising advances in the development of the free electron laser (FEL) this past year, it is likely that, as it did in late 1986, the laser program will again suffer a setback, when the Strategic Defense Initiative Organization (SDIO) reprograms its funding for 1988. Congress has cut SDI funding from the $5.9 billion that the adminstration requested, to a mere $3.9 billion. With Caspar Weinberger's resignation as defense secretary, and Gramm-Rudman automatic budget-cutting in force, even that $3.9 billion is not secure.

Weinberger resigned after failing to reverse administration policy in three areas directly related to SDI: 1) the defense budget, 2) the treaty with Moscow on intermediate-range nuclear missiles in Europe, and 3) whether to interpret the ABM treaty the way Moscow wants, or the way it is written. With Weinberger gone, the SDI has lost its most intelligent spokesman within the administration. As he resigned, the past year's trend away from research in directed energy weapons continued.

In October 1986, after Congress slashed the Defense Deparment's budget request for SDI from $4.8 billion to $3.2 billion, SDI management decreased the portion of research and development funding going into directed energy weapons from 30% to 25% of the research budget, in order to shift limited resources into engineering technology required for early deployment of a partially effective defense based on miniature space-based rockets, known as "kinetic energy weapons." Then, in its budget request for 1988, SDIO dropped the directed energy portion of its R&D funding to 21%.

Now that Congress has passed what amounts to a "zero growth" budget for SDI (a total of $3.9 billion for 1988, compared to $3.75 in 1987), it is expected by the national labs and defense contractors, that the directed energy program will get short-changed even more.

Over the past year and a half, SDI management gave priority to developing and deploying a poor man's version of Danny Graham's "High Frontier" system of kinetic-kill weapons to intercept Russian ballistic missiles in the boost phase of their trajectory, where the missiles are most vulnerable. The system is being designed to be able to destroy at most 10% of the missiles Russia would fire in a preemptive strike against U.S. military targets. SDIO hopes that the system will be able to destroy 50% of the heavy Russian missiles, those capable of destroying fortified military targets like missile silos. They hope to accomplish this by selective targeting of heavy missiles, such as the SS-18s and SS-19s, something that may be difficult on their shoestring budget.

The Pentagon plans on deploying about 3,000 space-based interceptors in the system. That is less than one-third the number that the Marshall Institute reported would be required in December 1986. The space-based portion of the system is to be complemented with ground-based anti-missile missiles for destroying warheads while they are in the mid-course phase of their trajectory, or as they are reentering the atmosphere, the so-called "terminal" phase of their trajectory.

Last summer, the Pentagon planned to take the system into production in 1990 and begin deployment in 1993. By 1995, they plan to have deployment of this initial system completed.

In the meantime, funding for directed energy is getting the axe. It appears that the program to develop the x-ray laser, primarily funded by the Department of Energy SDI program, will be the hardest hit by ongoing budget cuts. Congress slashed funding for the Department of Energy SDI from $514 million in 1987 to about $300 million for 1988.

One can only guess how the cuts will affect the free electron laser program. Last year's cuts led to cancellation of one project and a decision to take only one type of FEL technology to a larger scale engineering phase at White Sands Missile Testing Range. Which of the two FEL technologies is chosen for the engineering phase, presently depends on a "horse race" between Lawrence Livermore and Los Alamos between now and July 1988.

All this is occurring despite some very promising laboratory results during 1987.

Free electron laser results. In February 1987, scientists at Stanford University High Energy Physics Lab and TRW, Inc. produced coherent blue-green laser light, the shortest wavelength of radiation ever generated from an FEL powered by a high power linear electron accelerator. In June, Boeing Corp. achieved lasing at the same wavelength with their FEL. At Stanford, the peak power achieved inside the laser was 260 megawatts at the blue-green wavelength of one-half one

millionth of a meter (0.5 microns). The team achieved this with a 115 million volt electron beam. This work demonstrates that the same high powers achieved by FELs at Los Alamos in producing longer-wavelength infrared radiation, can also be achieved in producing more lethal, shorter wavelength laser light.

Radiation of shorter wavelengths is more lethal because the intensity of action of electromagnetic radiation increases as it becomes more concentrated. But the future of the Stanford program has been uncertain since the budget cuts of October 1986. As one scientist put it, "Nobody knows where they stand."

Livermore made limited progress in amplifying an infrared laser beam from a carbon dioxide laser over the past year.

The Livermore Beam Research Group had predicted at the 1985 Particle Accelerator Conference in Vancouver, B.C. that they would be able to amplify a 1 million watt laser pulse by a factor of 30, with an efficiency of 2%, using a magnetic "wiggler" that is five meters long. But the July 1987 issue of the lab's *Energy and Technology Review* reported that so far, the device has only been able to amplify the input laser beam pulse by about 50%, one-sixtieth of what they had hoped. The efficiency beam is less than one-tenth of one percent.

The big effort for FEL scientists working on the radio frequency type of device, revolves around the Boeing project. If Boeing can achieve significant progress over the next six months, it will demonstrate the capability to build the engineering model at White Sands. Boeing turned on its machine for the first time last year. Recently, it reengineered its FEL to generate 0.63 micron radiation, a slightly longer wavelength than that which achieved lasing last summer.

Meanwhile, the FEL oscillator under development at Los Alamos is undergoing extensive modifications to enable the device to produce 160 to 200 million watts (megawatts) in peak *output* power of infrared laser radiation with an efficiency of 8 to 10%.

Los Alamos plans to combine such a radio frequency linear accelerator-driven FEL oscillator, which generates radiation, with a radio frequency linear accelerator-driven FEL amplifier, to amplify the output of the oscillator and achieve gigawatt power levels.

Los Alamos is funding another FEL laboratory at Stanford, headed by John Madey, to test the oscillator-amplifer concept on a laboratory scale with FEL hardware available there. After this work is completed, it is expected that Madey will leave Stanford, due to political problems at the university. His company, Sierra Lasers, is reportedly building a radio frequency FEL for Vanderbilt University for medical applications. The short picosecond pulses produced by a radio frequency FEL have been found to be preferable for treating tissue because their action is nonthermal.

Finally, SDI funding for development of radio frequency weapons has begun to pay off. Lawrence Livermore National Laboratory and the Air Force Weapons Laboratory at Kirtland Air Force Base have both produced pulses of radiation in the radio frequency spectrum with powers of billions of watts with a device called a "virtual cathode oscillator" (vircator). A photo of the vircator at Kirtland appeared in *Aviation Week and Space Technology* in December, and shows that the entire device can be housed in two or three large camper vehicles. This is only two to three times larger than prototype Russian radio frequency weapons, a nice accomplishment for a program that only started in 1984.

A good year for the Soviet space program

by Marsha Freeman

This past year the Soviet Union marked some important milestones in its space programs—both civilian and military. On the public side of space activities, the *glasnost* policy opened a window into previously quiet aspects of Soviet space plans and operations, including the first admission that the Soviets are developing a reusable space shuttle vehicle.

A multi-day extravaganza in Moscow at the beginning of October called Space Forum, for the 30th anniversary of Sputnik, gave the Soviets a captive audience of about 450 foreign scientists, many of whom had their expenses paid by the Soviet Academy of Sciences. At the meeting, the Soviets presented an unusually candid picture of their future unmanned science missions, new modules to be added to the Mir space station, and some of the new technology they are developing for the manned space program.

In order to procure U.S. government participation at the conference, and undoubtedly in step with pre-summit preparations, Soviet Space Institute head Roald Sagdeev promised that SDI-bashing would not be included on the agenda of the three-day space science conference. The Soviets have accelerated their drive to entice U.S. and European participation in their ambitious space science programs. They have gotten a sympathetic hearing, due to the dreary state of advanced planning for Western space missions.

On May 15 the Soviets surprised the world with the first test launch of its Energiya rocket. This booster, with a 220,000 pound payload capacity, was launched the day after Soviet leader Gorbachov visited the Baikonur Cosmodrome, along with the Soviet minister of defense. Energiya gives the Russians the ability to launch massive payloads into Earth orbit,