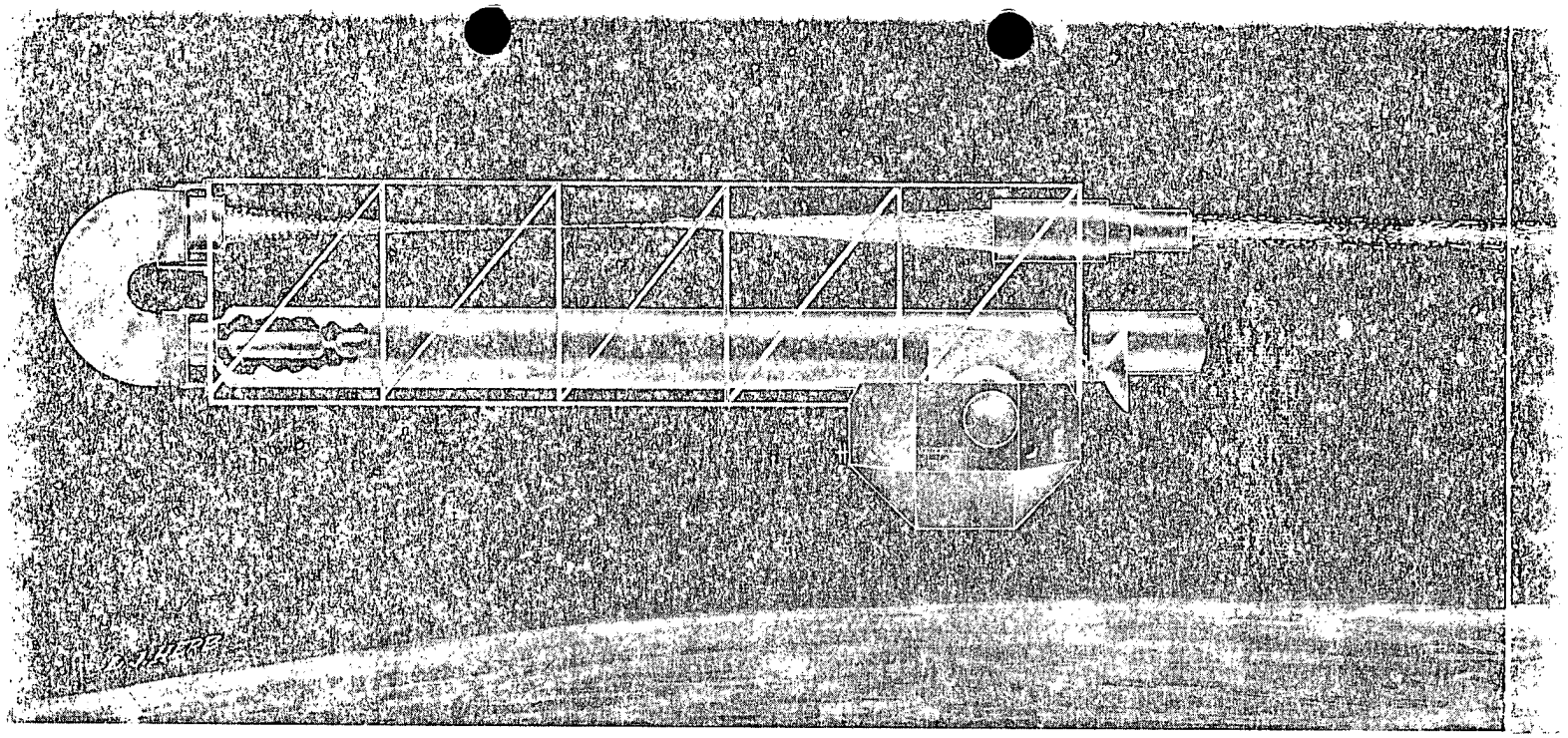

Concept of a charged-particle beam weapon is based on the design of a negative hydrogen beam that is accelerated and neutralized by passing the beam through a charge-exchange cell. In this ballistic missile defense concept, the collimated charge-particle beam is directed

Soviets Push for Beam Weapon

USSR developing charged-particle device aimed at missile defense, exploring high-energy lasers as satellite killer

By Clarence A. Robinson, Jr.

Washington—Soviet Union is developing a charged-particle beam device designed to destroy U.S. intercontinental and submarine-launched ballistic missile nuclear warheads. Development tests are being conducted at a facility in Soviet Central Asia.

The Soviets also are exploring another facet of beam weapons technology and preparing to test a spaceborne hydrogen fluoride high-energy laser designed for a satellite killer role. U.S. officials have coined the term directed-energy weapons in referring to both beam weapons and high-energy lasers.

A charged-particle beam weapon focuses and projects atomic particles at the speed of light which could be directed from ground-based sites into space to intercept and neutralize reentry vehicles, according to U.S. officials. Both the USSR and the U.S. also are investigating the concept of placing charged-particle beam devices on spacecraft to intercept missile warheads in space. This method would avoid problems with propagating the beam through the earth's atmosphere.

Because of a controversy within the U.S. intelligence community, the details of Soviet directed-energy weapons have not been made available to the President or to the National Security Council.

Recent events have persuaded a number of U.S. analysts that directed-energy weapons are nearing prototype testing in the Soviet Union. They include:

- Detection of large amounts of gaseous hydrogen with trace of tritium in the upper atmosphere. The USAF/TRW Block 647 defense support system early warning satellite with scanning radiation detectors and infrared sensors has been used to determine that on seven occasions since November, 1975, tests that may be related to development of a charged-particle beam device have been carried out in a facility at Semipalatinsk.
- Ground testing of a small hydrogen fluoride high-energy laser and detection of preparations to launch the device on board a spacecraft. Some U.S. officials believe the test of the antisatellite laser may be related to recent Soviet activities on a manned Salyut space station.
- Test of a new, far more powerful fusion-pulsed magnetohydrodynamic generator to provide power for a charged-particle beam system at Azgir in Kazakhstan, near the Caspian Sea. The experiment took place late last year in an underground chamber in an area of natural salt dome formations in the desert near Azgir and was monitored by the TRW early warning satellite stationed over the Indian Ocean.
- New test site at Azgir under the direct control of the Soviet national air defense force (PVO Strany), commanded by Marshal of the Soviet Army General P.F. Batitskiy. Since the PVO Strany would be responsible for deploying a beam weapon to counter U.S. ICBM warheads, Marshal Batitskiy's role indicates a near-term weapons application for these experiments, U.S. officials believe.
- Point-by-point verification by a team of U.S. physicists and engineers working under USAF sponsorship that the Soviets had achieved a level of success in each of seven areas of high-energy physics necessary to develop a beam weapon.
- Shifts in position by a number of experienced high-energy physicists, who earlier discounted the Soviet capability to develop the technology for a charged-particle beam device. There is now grudging admission that the USSR is involved in a program that could produce such a weapon.
- Recent revelations by Soviet physicist Leonid I. Rudakov during a tour last summer of U.S. fusion laboratories that the USSR can convert electron beam energy to compress fusionable material to release maximum fusion energy. Much of the data outlined by Rudakov during his visit to the Lawrence Livermore Laboratory has since been labeled top secret by the Defense Dept. and the Energy Research and Development Administration, but it gave a clue to U.S. scientists that the USSR is far ahead of the U.S. in controlled fusion by inertial confinement (compression of small pellets of thermal nuclear fuel) and weapons based on that technology.

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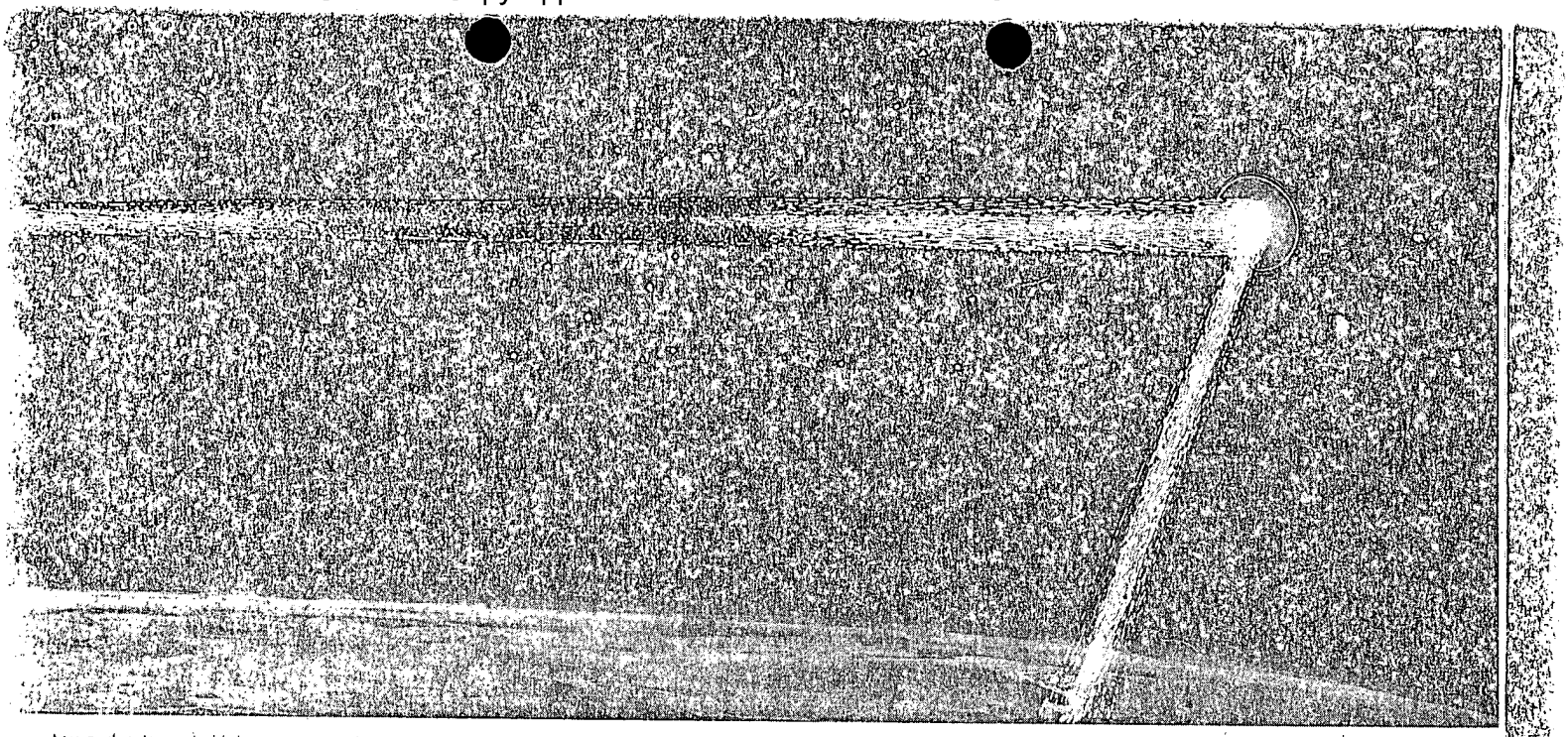

toward a target. Using a space-based design for a charged-particle beam weapon avoids effects of the earth's magnetic field on the beam and the task of propagating the beam through the atmosphere. Both the USSR and U. S. have space-based experimental concepts.

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Pattern of activity in the USSR, including deployment of large over-the-horizon radars in northern Russia to detect and track U. S. ICBM reentry vehicles, development and deployment of precision mechanical/phased-array anti-ballistic missile radars and massive efforts aimed at civil defense.

There is little doubt within the U. S. scientific or intelligence communities that the Soviets are involved in developing high-energy technology components that could be used to produce a charged-particle beam weapon, but there is a great difference of opinion among officials over whether such a device is now being constructed or tested in the USSR.

In increasing numbers, U. S. officials are coming to a conclusion that a decisive turn in the balance of strategic power is in the making, which could tip that balance heavily in the Soviets' favor through charged-particle beam development, and the development of energetic strategic laser weapons.

Most of the controversy centers on what tests are being conducted in an unusual research facility about 35 mi. south of the city of Semipalatinsk.

In the face of mounting evidence of Soviet efforts aimed at developing a charged-particle beam weapon for anti-ballistic missile defense, the Air Force's Scientific Technical Intelligence Committee (STIC) has scheduled a fall meeting to review new data.

The Semipalatinsk facility where beam weapons tests are taking place has been under observation by the U. S. for about 10 years. The central building at the facility is believed by some officials to contain a collective accelerator, electron injectors and power stores.

The building is 200 ft. wide and 700 ft. long, with walls of reinforced concrete 10-ft. thick, the entire facility, with its associated support equipment, is estimated to have cost $500 million.

The test site is at the southern edge of the Semipalatinsk nuclear test area, and it is separated from other test facilities. It is surrounded by a series of security fences.

The total amount invested by the USSR in the test project for the 10 years' work there is estimated at $3 billion by U. S. analysts.

The U. S. used high-resolution photographic reconnaissance satellites to watch as the Soviet technicians had four holes dug through solid granite formations not far from the main large building at the facility. Mine heads were constructed over each opening, and frames were built over the holes. As tons of rock were removed, a large underground chamber was built deep inside the rock formation.

In a nearby building, huge, extremely thick steel gores were manufactured. The building has since been removed. These steel segments were parts of a large sphere estimated to be about 18 meters (57.8 ft.) in diameter. Enough gores for two complete spheres were constructed. U. S. officials believe the spheres are needed to capture and store energy from nuclear-driven explosives or pulse-power generators. The steel gores are believed by some officials to be among the earliest clues as to what might be taking place at the facility.

The components were moved to the nearby mine heads and lowered into the chamber.

Some other U. S. physicists believe the steel gores are designed for underground storage of unused nuclear fuel for a

Debate Seen on Charged-Particle Work

Washington—Senior U. S. scientists and engineers believe that this nation is on the verge of a heated debate over the strategic implications of charged-particle beam development in the Soviet Union and the U. S.

"That debate is just getting under way and it is likely to rival the 'Fortress America Great Defense Debate' in 1952 involving Taft [Sen. Robert A. Taft], the B-36 bomber and strategic defense policies," one U. S. official said.

Some observers see an ominous parallel between the attitude of some U. S. scientists toward beam weapons and that of the late Dr. Vannevar Bush toward the feasibility of intercontinental ballistic missiles in the mid-1940s. The highly respected scientist, who had directed the U. S. military research effort during World War 2, testified bfore a Senate committee in December, 1945: "There has been a great deal said about a 3,000-mi. high-angle rocket. . . . In my opinion, such a thing is impossible. . . . I say technically I don't think anybody in the world knows how to do such a thing and I feel confident it will not be done for a very long period of time to come."

Within eight years, the U. S. would initiate its own massive effort to develop long-range ballistic missiles, and within 10 years, the Soviet Union would be testing just such a long-range ballistic missile.

[illegible] Squadron Flies to German Base

First operational squadron of Air Force/McDonnell Douglas F-15 fighter aircraft flew from Langley AFB, Va., to Bitburg Air Base, West Germany, last week in a single movement designed to show USAF capability to reinforce NATO forces rapidly. The flight involved 23 F-15s, including two TF-15 trainers.

The 525th Tactical Fighter Squadron, led by Brig. Gen. Frederick C. Kyler, commander of the 36th Tactical Fighter Wing, arrived at Bitburg after a 7-hr flight with four in-flight refuelings. Three of the unit's F-15s already were in place. Two additional F-15 squadrons are to move to Bitburg by the end of the summer to bring the wing to full strength.

Gen. Kyler reported on arrival to Gen. Franz-Joseph Schulze, commander-in-chief of Allied Forces, Central Europe. The 525th squadron was trained in the U. S. and was operational on arrival.

The flight was made with the aircraft grouped in three cells of six aircraft and one cell of five, with about 30 min. separation between cells. Flight routing was along the U. S. and Canadian east coasts to Newfoundland, then across the Atlantic, Britain and Belgium to Bitburg.

STAT Maintenance personnel were in place at Bitburg before the squadron arrived, with some having been trained in the U. S. and some at Bitburg.

magnetohydrodynamic or closed cycle gas core fission process needed to power beam weapons or for storing waste products from the fission process.

One of the major problems in gaining acceptance of the concept within the U. S. scientific community was to convince high-energy physics experts that the Russians might be using nuclear explosive generators as a power source to drive accelerators capable of producing high intensity proton beams of killing potential.

Initially, some U. S. physicists believed there was no method the Soviets could use to weld together the steel gores of the spheres to provide a vessel strong enough to withstand pressures likely to occur in the nuclear explosive fission process, particularly when the steel to be welded was extremely thick. U. S. officials later discovered that the Russians invented a process called flux welding and had been using it for years in producing pressure spheres. The flux welding process, according to some U. S. officials, makes the bonded material weld as strong as, or stronger than, the steel walls.

U. S. officials, scientists and engineers queried said that the technologies that can be applied to produce a beam weapon include:

- Explosive or pulsed power generation through either fission or fusion to achieve peak pulses of power.
- Giant capacitors capable of storing extremely high levels of power for fractions of a second.
- Electron injectors capable of generating high-energy pulse streams of electrons at high velocities. This is critical to producing some types of beam weapons.
- Collective accelerator to generate electron pulse streams or hot gas plasma necessary to accelerate other subatomic particles at high velocities.
- Flux compression to convert energy from explosive generators to energy to produce the electron beam.
- Switching necessary to store the energy from the generators in large capacitors.
- Development of pressurized lines needed to transfer the pulses from the generators to power stores. The lines must be cryogenically cooled because of the extreme power levels involved.

For several years, Air Force Maj. Gen. George J. Keegan, who until his recent retirement headed USAF's intelligence activities, has been trying to convince the Central Intelligence Agency and a number of top U. S. high-energy physicists that the Soviets are developing a charged-particle beam weapon for use in an antiballistic missile role.

Evidence was gathered by Air Force intelligence from a variety of sources, including early warning and high-resolution reconnaissance satellites, published USSR papers on high-energy physics and visits between Soviet and Free World physicists. In contacts with scientists deeply involved in developing components necessary for beam weapon application in both the USSR and the U. S., data was gleaned that clearly showed the Russians to be years ahead of the U. S. in most areas of technology, one U. S. physicist said. He added that it became increasingly clear that the Soviets were making a concerted effort to develop the technology in each area so that, if it was pulled together, a beam weapon and possibly related laser weapons could result.

All of the evidence that Gen. Keegan and his small team gathered about Soviet designs on charged-particle beams was presented to the CIA and its Nuclear Intelligence Board, which has so far rejected their conclusion that beam weapons development is evident.

Most of the evidence had been gathered over a four-year period and involved the entire spectrum of facilities for test and experimentation, research laboratories, power generation, electron injection, collective acceleration and beam propagation—all areas where the Soviet Union has outpaced the U. S., according to a U. S. official.

Some scientists and engineers refused to accept information that the installation at Semipalatinsk had anything to do with beam-generation tests or that levels of energy required for these experiments could be attained. And even if somehow the energy could be generated, it could not be harnessed for beam application, they said.

Energy Levels Required

Typical levels of energy required for use with a beam weapon are 10^{12} joules per pulse, with the energy of a particle of the beam from 1 to 100 giga electron volts. It is these levels of energy required that still cause some skepticism among high-energy physicists.

"Keegan refused to accept CIA's evaluation of the USAF intelligence data," one U. S. official said. "So, he systematically set about acquiring talented young physicists to analyze the information and to probe the basic physics of the problem—an area in which U. S. scientists were notably deficient."

One scientist in particular, a USAF civilian employe at Wright-Patterson AFB, Ohio, was influential in providing Gen. Keegan with an assessment of the information, which said that it appeared the facility at Semipalatinsk was being developed for use for nuclear power generation related to beam weapon work. His assessment was made very early in the observation of the facility, long before atmospheric data of possible beam weapons testing was obtained.

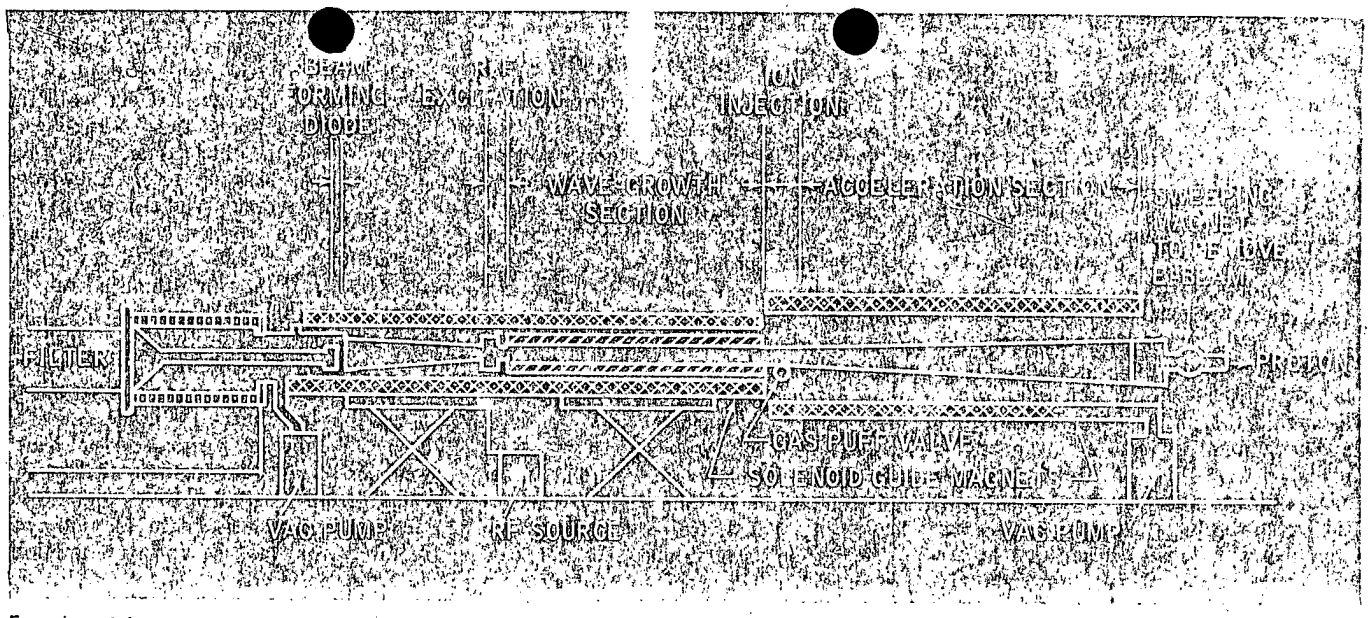
"These young physicists gathered to his cause by George [Gen. Keegan] were a very sharp group of young turks, and some have since gone on to gain stature within the high-energy physics crowd," one official said.

It was anticipated by Gen. Keegan and his advisers that the USSR would be forced to vent gaseous hydrogen from the experiments at Semipalatinsk and that early warning satellites could detect it.

Underground Testing

Liquid hydrogen in large amounts is believed by some officials to be utilized to cushion the nuclear explosive generator sphere and for cryogenic pumping of large drift tubes nearly a kilometer in length through which the beams are propagated for underground testing. In both cases, large amounts of gaseous hydrogen are formed and released into the atmosphere, probably carrying large amounts of nuclear debris or radioactive tritium that can be exploded at altitude and dispersed to avoid harming the people below, according to some U. S. scientists.

"Explosions of such gaseous hydrogen discharges are now being detected with regularity from Soviet experiments," a U. S. official said, "and scientific studies



Experimental auto-resonant accelerator concept shows the hardware configuration in diagram. The design is to determine whether the accelerated plasma wave can be grown in a laboratory and whether collective acceleration of protons can be achieved. The illustration shows that the more efficient acceleration of particles may be possible using the concept where a traveling wave in an electron beam traps and accelerates protons. The relativistic beam is more than simply a medium for propagation of the wave. It is the active medium that serves as the power source for reinforcing the electric field of the wave and for accelerating the ions.

of the gas releases and explosions have confirmed their source as being near the Semipalatinsk facility."

USAF intelligence developed an acronym—PNUT—to refer to the test area at Semipalatinsk. The letter P is for possible, and the other letters stand for nuclear underground test. The CIA still refers to the site as URDF-3—unidentified research and development facility three.

In recent public pronouncements, Gen. Keegan has taken the CIA to task for having rejected Air Force intelligence information about Soviet beam weapon development. He also has spoken bitterly about a number of top U.S. physicists who refuse to accept even the possibility that the Soviets are involved in beam weapon development. Most of the physicists who would not accept the data were older members of the scientific community who had been involved in research and development from the early days of a project called Seesaw.

Project Abandoned

The U.S. attempted unsuccessfully to develop a charged-particle beam device under the project code named Seesaw. It was funded by the Defense Dept.'s Advanced Research Projects Agency but abandoned after several years.

A number of influential U.S. physicists sought to discredit Gen. Keegan's evidence about Soviet beam development. The general attitude within the scientific community was that, if the U.S. could not successfully produce the technology to have a beam weapon, the Russians certainly could not. "It was the original not-invented-here attitude," one U.S. physicist said.

There were about 20 hypotheses advanced by these physicists and the CIA's Nuclear Intelligence Board as to what the facility at Semipalatinsk was being used for by the USSR. One theory was that it was a supersonic ramjet test site and another was that it was a nuclear reactor test site for commercial applications. That was based on the layout, which resembled some reactors in the USSR.

"There is now no doubt that there is dumping of energy taking place at the site with burning of large hydrogen flames," one official said. "What bothered the Nuclear Intelligence Board at first was that it was hard to imagine that some seven technologies critical to the weapons concept could be perfected there within the time frame presented and not be detected by us.

"In each case, the Air Force was able to disprove the theories advanced, at least to USAF satisfaction," one U.S. official said. "But along the way Keegan became an outcast within CIA and the Defense Intelligence Agency. This was despite the fact that many times in the past it turned out that his intelligence information proved correct when it was not accepted at first. He [Keegan] made some great intelligence breakthroughs," another official said.

As evidence of Soviet intent mounted, the Air Force convened a munitions panel of its Scientific Advisory Board to examine the problem. The panel met at Livermore Laboratory for three days to study the data of Gen. Keegan and his technologists. Some members of that panel also were involved in the Seesaw project before it was halted.

"The panel of experts rejected vitually all of the Air Force's hypotheses. In an emotional meeting, they denigrated all suggestions of nuclear explosion generation, power storage, power transmission and collective acceleration," an official explained. "The bottom line was that the panel said there is no way to control or stabilize such a beam if a weapon is produced. The net result is that evidence about possible beam weapons development was rejected."

Later, some of the same physicists who rejected the charged-particle beam data realized the Soviets had made progress in many separate areas of required technology for beam weapon application. Some physicists involved sought funding from the National Science Foundation and Energy Research and Development Administration for nuclear power and beam generation studies, one official said.

In an effort to prove that USAF intelligence estimates were correct, Gen. Keegan and his young physicists set about trying to prove Soviet technology exists in areas necessary for beam weapons.

Theoretical Blocks Isolated

After isolating the theoretical roadblocks identified by the Scientific Advisory Board's munitions panel, the physicists, along with several new groups recruited by Gen. Keegan, went to work exploring possible USSR technologies.

Within a few months the team, under the direction of a young Air Force physicist, found that all the munitions panel's objections could be overcome "and had already been solved in the Soviet Union. Several breakthroughs in high-energy physics were involved," an official said.

Explosive generation was solved in the USSR by Soviet academicians Andrei Terletsky, who was once a KGB agent in Sweden, and Andrei Sakharov, who was instrumental in developing the Soviet hydrogen bomb and is now a dissident.

Soviet physicist Rudakov visited the

U. S. in July, 1976, and outlined his major advances in electron beam fusion. ERDA immediately tried to cover up the ideas he presented at Livermore in response to a taunt by a Western scientist. It was all considered highly secret in the U. S. and "those seated there had to sit with their mouths open and not respond to Rudakov's outline," one U. S. physicist said.

"His idea startled the U. S. physics community by its magnitude—transforming laser and electron beams to soft X-rays to compress fusion fuel at low energy levels. This is a real scientific breakthrough," the physicist said, "and could allow them to produce large amounts of fusion power to be used in producing energy for a beam weapon." Rudakov had such good results in using relativistic electron beams to achieve fusion that he now is developing a $55-million machine funded for this purpose in Russia called Angara 5, a physicist added.

Gen. Keegan and his physics team quickly determined that the next problem to be resolved was flux compression needed to convert energy from explosive generation to electrical energy to power an accelerator.

"Through open sources they learned that the Soviets had long since solved that problem," one expert said.

U. S. scientists meeting at Livermore objected and said that power pulses generated could not be conducted over known cabling without burning it up until Gen. Keegan's researchers discovered that pressurized gas lines invented in the U. S. years earlier by ITT and General Electric were available and in use by the USSR.

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Reconnaissance Data

Pipes at the Semipalatinsk site leading from the underground chamber were spotted by reconnaissance satellite, but they were discounted by the CIA and munitions panel as being there for another application, possibly to exhaust supersonic ramjets. Photographs from satellites also revealed a number of tank cars near the test site loaded with liquid hydrogen. USAF intelligence officials believed it was being used by the Soviets for cryogenic pumping of beam drift tubes. This was considered impossible by U. S. scientists because they believe liquid hydrogen is too volatile and dangerous for cryogenic use. Again, however, papers have been published in the USSR on the subject, and liquid hydrogen has been used for years for that purpose, one official said.

Officials believe that cabling leading from the underground granite chamber at Semipalatinsk carries power from a fission explosive generator to nearby transformers where it is stepped up. The power is cabled into giant capacitors inside one end of the large thick-walled building, they believe. Along the 700-ft. side are located the electron injector gun and the collective accelerator, according to their theory. The power is fed into them to produce a proton beam. The beam is bent at an angle by magnetic mirrors and propelled near the speed of light along the drift tubes running underground about a kilometer, they believe, and the drift tubes are evacuated to simulate operating the beam in space and are used only for beam propagation testing.

At one time, there were five concentric rings constructed around the building about 5 km. (3.1 mi) apart. At each 5 deg. of arc, a vertical sensor was placed. At first, U. S. analysts believed this arrangement was to monitor movement of gaseous hydrogen clouds. The geometry was so precise, however, that some believed the sensors were located to measure beam impact or for beam tracking.

Storing energy to manage its flow was the next area of technology that Gen. Keegan and his scientists investigated. They discovered that the Soviets had solved the problem earlier by using large water capacitors to store energy. Dense fields of energy/electricity can be stored using pressurized water as a dielectric with pressure to 100 atmospheres. This is considered another breakthrough by U. S. physicists, because the USSR can store 40 times the density of energy that can be stored in the Free World, one official explained. "This technology is now being developed in the U. S.," he added, after it was completely verified under a contract with the Defense Nuclear Agency.

For the past 15 years there has been an open and free exchange between the U. S. and the USSR in the high-energy physics area, one U. S. physicist explained. That exchange is related mostly to projects for nuclear power generation for commercial application, but by its very nature, the development of energy or offshoots of the technology has application to the beam weapons field, the official said.

"This is a field where to our knowledge there are few secrets. We go freely to their [USSR] laboratories and have few doors barred to us," a U. S. high-energy physicist said, "and the same thing is true for them in this country." This does not apply to laboratories where weapons development is being carried out.

Gen. Keegan's scientific team set out to prove the feasibility in another area of Soviet technology required for beam weapons use—switching. Switching the energy from its storage capacitors to the electron injector is a major element required for the weapon to function, according to U. S. experts.

A small U. S. company has devised a breakthrough in switching technology, a U. S. scientist explained, and has patented it. Theoretical feasibility has now been fully established, the scientist added.

The electron injector was the next area of investigation on which the team focused its attention. For this to be successful, several engineers have explained, a generator is needed to provide a steady stream of rapidly pulsed plasma of 100 million electron volts per pulse at levels of 10^7 megajoules/sec.

"This is pure Buck Rogers to the physicists at Livermore Laboratory, who refused to accept that the Soviets could accomplish it," one U. S. official said. U. S. scientists since have been able to confirm that Soviet high-energy institutes long ago solved problems of electron injection that place them years ahead of U. S. technology. "At the Institute of High-Energy Physics in Novosibirsk, U. S. scientists have found generator technology that, when scaled up, can be used as an electron injector." Such equipment is now being exported to the U. S. for commercial use. The Soviet technology involved is at least 10 years ahead of anything under development in the U. S.

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CIA Chief Informed

In 1975, Gen Keegan disclosed his findings on Soviet technology related to beam weapons development to William Colby, then head of the CIA, and to a number of its nuclear scientific advisers.

"On the strength of Keegan's information that the Soviets were on the verge of developing a weapon to neutralize our ICBMs and SLBMs, Colby directed the formal convening of the CIA's Nuclear Intelligence Panel to consider the disclosures," according to a U. S. official.

In a final meeting last year with the panel, Gen. Keegan and his associates presented evidence over a three-day period to the panel. The panel went into executive session to study the data and then wrote its report. No copy of the report was ever presented to USAF intelligence.

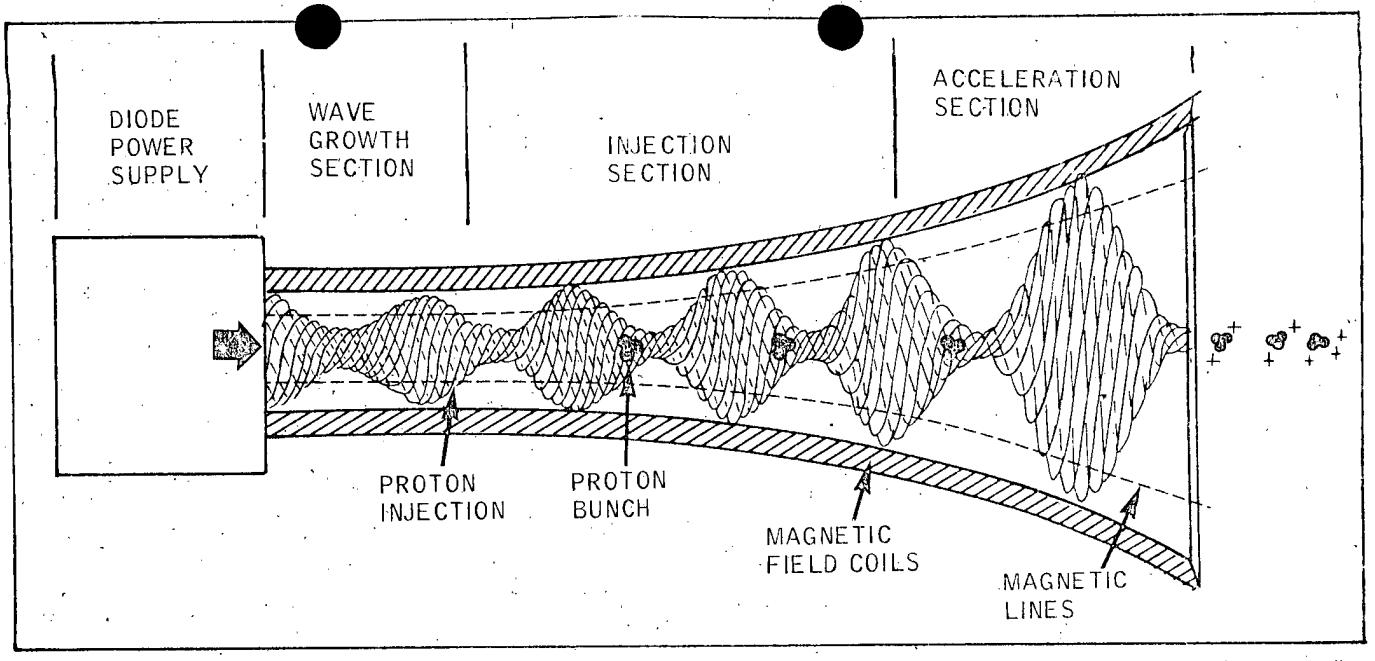
In-House Research

Washington—U. S. Air Force and Navy are expected by Fiscal 1978 to cut in-house research and exploratory development to approximately 35%, with 65% being contracted out, a Defense Dept. official told Congress.

This is approximately the goal set a year ago (AW&ST June 7, 1976, p. 47), John L. Allen said during testimony before the House Armed Services subcommittee on research and development. Allen is deputy director of Defense research and engineering for research and advanced technology.

Earlier, the Navy agreed to a cut of 3,000 persons and the USAF to a reduction of 1,000. These reductions were to be accomplished within each service's research and development staff and were not limited to in-house laboratories.

The goal for the Army was placed at 2,900 employes, a figure to which that service has not yet agreed, although discussions are in progress. Allen acknowledged that the Army is "heavily in-house" oriented and would have to shift personnel from laboratory work to achieve the 35% goal.



Collective accelerator principle in a schematic drawing shows that more efficient acceleration of particles may be possible when a traveling wave in an electron beam traps and accelerates the protons.

That is standard, one official said, because copies of the report are routed only to those in authority within the CIA.

"What the report said was that there were no technological errors in USAF's analytical work. It was agreed by the board that there is a massive effort in the USSR involving hundreds of laboratories and thousands of top scientists to develop the technology necessary for production of a beam or other energy weapon for use against U.S. ICBMs and SLBMs," an official said. The report also said the board was unable to accept USAF's detailed conclusions regarding the experimental site at Semipalatinsk. It reasoned, according to several sources, that since none of the key subtechnologies involved had been perfected in the U.S., it was implausible that the Soviets could be so far ahead. In any event, the U.S. scientific advisers to CIA were unwilling to concede that the Soviets could harness such advanced technology into a working weapon or demonstration system.

They were willing to accept that the technology had been developed independently, but not that it has been used in series for weapons work at either Semipalatinsk or Azgir, officials said.

Colby wrote a letter to former Secretary of State Henry Kissinger just before he left on a trip to negotiate with the Soviets about strategic arms limitations and mentioned that there "was a facility related to nuclear functions that were unknown but that it might have high scientific application," one official said. With that exception, none of the USAF intelligence data has ever been made available to the President, the secretary of State or the National Security Council, he added.

The major argument now raging within the intelligence community is whether the facility at Semipalatinsk is experimental in nature and whether it will require a major effort by the USSR over many years to build more such facilities to use for weapons purposes.

"One of the problems is that some U.S. intelligence officials and scientists have difficulty in understanding the concepts involved. The technology is simply beyond their comprehension," an official said. The facility at Semipalatinsk is an example, the official continued. It depends on how it is visualized. "This is a case where the experimental hardware is identical to the equipment necessary to destroy an ICBM. If they can generate the charged-particle beam to test the device, and large amounts of hydrogen being burned there indicate they are, then they can generate for weapons use."

The giant vacuum drift tube underground at the facility is used only to simulate upper atomspheric and space conditions for the tests; in operational use, the weapon's beam would be fired from the collective accelerator front end.

"After 10 years of work at the site and after developmental testing of the beam for over a year, the only thing required is to scale the device for weapons application," he said. That could be accomplished by as early as 1978 with a prototype beam weapon, and it could be in an operational form by 1980, some officials believe.

Another big objection offered by some U.S. physicists and other scientists is that the beam from such a weapon will have to be propagated and bent to intercept incoming warheads in reentry vehicles, an extremely difficult task.

One possible solution is that a "magnetic mirror" can be used for beam bending to intercept reentry vehicles.

Despite strenuous objections from U.S. scientists over the feasibility of beam bending, USAF intelligence established a Soviet solution to the problem for the Soviet beam concept, an official said.

Precise pointing and tracking may not be required. "All that is needed is for the Soviet long-range precision radars now deployed in violation of the ABM agreement to detect avenues or windows for reentry vehicle trajectories against targets in the USSR. By aiming rapidly pulsed proton beams into these windows, ICBMs and SLBMs could be quickly saturated and destroyed," he explained.

The windows would be located from 1,000 to 2,000 naut. mi. out in space. "With this method, many acquisition and tracking problems could be overcome. By using the window concept to scatter the beam over a wide area through which warheads must transit, it is believed that not many beam weapon devices would be required to protect the USSR from a U.S. retaliatory strike," the official said.

Many deployment schemes of great simplicity are open to the Russians. One such scheme would be to place the collective accelerators vertically inside silos that the USSR now claims are for command, control and communication.

There are at least 150 of these silos that the U.S. is now overlooking by accepting the Soviet definition as command and control centers for their use. Using nearby silos linked to those with the accelerator for containment of the explosive generator, the Soviets could deploy such a system within a few years, an official said.

"Since the necessary radars are nearing operational readiness, all of the needed system components could be emplaced," he added.

"The one thing that George [Gen. Keegan] finds so pernicious about this whole thing is that CIA and other top

U. S. officials scoff at the idea that the backward Russians can develop technology that we have been unable to develop in the U. S. ," one official said. "He [Keegan] admits that he could be wrong, but he is not wrong about the Soviets' will to produce such a weapon and about the national assets they are devoting to it."

"From all of this evidence we have a good idea of where the Soviets are in development and where they are headed with beam weapons and high-energy lasers. Not much has been done in this country since Seesaw," a U. S. physicist said. "But there is certainly a lot of new interest now within the scientific community."

There is an effort under way to establish an agency in the U. S. to coordinate the development of directed-energy weapons. Some congessional staff members as well as officials within the Administration are pressing for this to be accomplished.

Fragmented Development

"Development is now fragmented with various factions from a number of agencies and laboratories trying to compete for funding. What is needed now is for a control point to be set up with some cohesion and orderly planning to develop the various components of technology required for weapons," one House staff member said.

John L. Allen, deputy director of Defense research and engineering for research and advanced technology, said:

"Science fiction writers have been fascinated with the concept of a directed-energy weapon that beams energy directly to a target, obviating the need for bombs, missiles or projectiles. A weapon of this type now appears not only to be possible, but we may even have a choice of the beams that can be used . . . electrons or other fundamental particles.

"These beams travel at or near the speed of light [186,000 mi./sec.] so that the delivery time is negligible, an attractive attribute for a weapon. The beams can also be moved rapidly from one target to the next. Thus, for defense against nearly simultaneous multiple attackers, directed-energy weapons are appealing."

He added that high-energy lasers are the most advanced of the directed-energy devices. "About 10 years ago, it became apparent that the generation and propagation of damaging levels of energy might be feasible," Allen explained. "However, the technical problems foreseen were formidable. High power is needed for useful lethal ranges. The achievement of such high power requires a strong foundation of basic knowledge of the physics and chemistry of highly excited gases, coupled with, in some systems, sophisticated high-volume, high-velocity gas flow technology. The flow rates involved in gas dynamic high-energy lasers are like those from a jet engine. The physical size is also comparable to a jet engine."

Allen said the Defense Dept.'s Advanced Research Projects Agency and the services are investigating the application of high-energy lasers. "Both the Army and Navy are pursuing terrestrial applications. The Air Force is pursuing airborne applications, and the Defense Advance Research Projects Agency is looking at the possible application of lasers in space defense with emphasis on chemical lasers. It is still too early to determine the potential cost effectiveness of high-energy lasers as weapons, but the next two or three years will yield a great deal of insight."

Problems Cited

"Particle beams—beams of electrons, for example—are not directly affected by the weather and may provide longer ranges than high-energy lasers in adverse weather. However, they have other problems. Charged-particle beams have a tendency to be unstable. They also are deflected by magnetic fields, so pointing and tracking uncertainties exist. If these problems can be solved, a viable weapon could result. We believe that charged-particle weapons might, in some applications, present a useful alternative or complement to the high-energy laser for giving us 'zero time of flight' weapons. We are pursuing projects at an exploratory level," Allen told the House Armed Services research and development subcommittee.

The Navy is seeking $6 million in Fiscal 1978 for a program called Chair Heritage to continue exploratory development of beam weapons, mostly related to accelerator development. It plans to transition to advanced development in Fiscal 1979. Navy is now working on a scaled-down advanced test accelerator. The design for the device was selected in July, 1976, and experiments with the accelerator are slated for completion in August, 1978.

The auto-resonant accelerator, a number of knowledgeable physicists believe, offers the potential for generating low-cost, extremely intense beams of high-energy heavy particles. The device is believed capable of generating beams of ions in the giga electron volt range. Power levels would be in the range of 10^{13} w. with pulse lengths on the order of a microsec., i.e., single pulses with an energy of 1-10 megajoules.

From the military application standpoint, the auto-resonant accelerator has the potential for being used to deliver the equivalent of pounds of TNT to blast targets at long range at the speed of light. The effects of neutron, hot X-ray and gamma radiation would have an equally destructive impact on warheads. Austin Research Associates is doing basic research with the auto-resonant accelerator.

With a program of technology development, senior experts in physics believe, substantially higher energy levels can be delivered to targets at longer ranges.

The auto-resonant accelerator is not limited to pulsed operation. That limitation now is from the design of associated electron-beam diodes and power supplies. If E-beam diodes and power supplies can be developed that can be repetitively pulsed at the rate of 100-1,000 pulses/sec. for several seconds, average beam powers in the 1,000-megawatt range are believed possible.

"A number of military applications are possible by changing the total energy requirements and repetition rates. Some of these missions are close at hand," a U. S. physicist said.

Under current funding, U. S. officials are convinced that M. L. Sloan and William E. Drummond will complete their mathematical model for the auto-resonant accelerator by July. In a paper on the accelerator concept, Sloan and Drummond explain the principle: a conceptually simple and compact method of generating pulsed ion beams in the multi-ampere current range.

This accelerator scheme combines the basic concepts of traveling wave and collective acceleration. While the traveling wave is used for the acceleration process, the wave is a collective eigenmode of the electron beam-magnetic guide field cylindrical guide system rather than a vacuum wave guide mode as in a conventional traveling wave accelerator.

Economy in Size

Because of the collective nature of the medium of propagation, much higher effective accelerating fields can be sustained than in a conventional accelerator, allowing for economy in the size of the machine. This is extremely important in a weapons application.

The cyclotron wave used in the auto-resonant accelerator is a negative energy wave so that in the acceleration process where energy is delivered to the ions, instead of being degraded, the electric field energy of the wave actually grows.

If the auto-resonant accelerator achieves only a few percent efficiency in conversion of electron beam energy to ion energy, pulsed currents in the tens of amperes range or larger are anticipated.

The name auto-resonant accelerator is derived from the process involved—the novel feature is that as the cyclotron eigenmode delivers energy to the accelerated ions, it automatically extracts energy from the relativistic electron beam. Power is thus automatically fed from the relativistic beam to the resonant ions.

To provide the accelerating medium, the electron beam is propagated in a vacuum over a distance of several meters. The relativistic electron beam is the accelerating medium and is used to accelerate protons to high energies.

A puff of hydrogen can be allowed into the front or injector end of the auto-resonant accelerator. When the electron beam is turned on, the ionization process will strip the hydrogen atoms to bare

protons at a predetermined [redacted], depending on the ambient hydrogen pressure and volume and the electron beam energy, current and cross-section. Juggling these quantities can adjust the production rate.

There are other promising concepts for collective accelerators at U.S. laboratories and research centers, but they are not all being actively pursued because of a lack of funding and coordination within the high-energy physics field, according to U.S. officials. These include:

- Traveling potential well accelerator at Sandia Corp. funded by the Energy Research and Development Administration and the USAF Office of Scientific Research. Craig Olson at Sandia has developed the concept for controlling the acceleration of a potential well using an intense light source or lasers beamed into a low-pressure gas for a two-step photo ionization process. Olson uses laser beams at different wavelengths for ionization and cesium vapor for the gas.
- Self-synchronized pinch model accelerator concept by Sidney Putnam at Physics International in San Leandro, Calif. This concept was proposed by Putnam in 1972, but no experimental work has been accomplished in the U.S. The Soviets, however, have picked up this concept and accomplished theoretical work with it. The concept uses a space non-charged neutralized electron beam, which contracts in an envelope around ions as it moves through the accelerator. This is based on local magnetic pinch effects.
- Collective bunching model accelerator being developed under the Naval Research Laboratory along with a traveling wave accelerator using a slow space charge wave. Cornell University is doing the simulation work for the Navy.
- Toroidal storage ring accelerator concept by Norman Rostoker at the University of California at Irvine. This concept provides for a small torus about four meters in diameter. A cloud of electrons is stably confined in the machine to trap ions inside a ring to focus them.
- Electron ring accelerator at the University of Maryland under National Science Foundation sponsorship. This is a variation on the USSR smoke ring accelerator theme proposed years ago.

"Many possibilities are open for the U.S. but remain unexplored," a senior U.S. official said. "Whether this results from lack of interest, lack of funds for research, lack of national focus for efforts in this field, or a belief that the possibility that such weapons may adversely effect detente is unclear. It does seem that the Soviets have taken a very different course which may eventually prove most U.S. planners and analysts to be wrong. If this proof comes early enough, it may then be too late for our research and development establishment to catch up on what may finally be agreed to be a very long Soviet lead in this field of strategic defense."

Carter Strategic Weapon Funding Backed in House

By Katherine Johnsen

Washington—House of Representatives last week supported President Carter's strategic nuclear weapons program in passing a $35.7-billion authorization for Fiscal 1978 military research and development and procurement to buttress the Administration's posture on a new strategic arms limitation talks (SALT) agreement with the USSR (AW&ST Apr. 18, p. 16).

After two days of debate, the measure was approved by a vote of 347 to 43, without any change in the aerospace program recommendations of the House Armed Services Committee (AW&ST Apr. 11, p. 21). The authorization increases the Administration's request for procurement programs by a net $793 million. This is offset by a net reduction of $777 million in research and development programs.

B-1 Debated

The pros and cons of the controversial USAF/Rockwell International B-1 program were argued on the House floor. But neither the advocates of accelerating the program, nor the advocates of canceling it, challenged the President's decision to procure five of the strategic bombers in Fiscal 1978. The Ford Administration had proposed a buy of eight.

Senate Unit Cuts F-14A

Washington—Senate Armed Services Committee last week reduced the Navy/Grumman F-14A procurement program from 44 aircraft to 36 during action on the $35.7-billion Fiscal 1978 authorization for weapons systems.

Both the Ford and Carter Administrations recommended $941 million for the buy of 44. The Senate committee's action would reduce the Fiscal 1978 funding by $200 million.

The committee also adopted language that would:

- Limit the Fiscal 1979 buy of F-14s to 36, instead of the 60 aircraft programed by the Navy.
- Direct that the two-year saving, estimasted at a total $550 million, be applied toward any shortfall in the McDonnell Douglas F-18 program (AW&ST Mar. 28, p. 14).

The Navy solution to funding problems was to permit a year's slippage in the F-18 program and cancel the Lockheed P-3C program in Fiscal 1979.

Congressmen claim the Navy wants to cancel the F-18 program.

Last week the House approved the funding proposed by the Carter Administration, for both the F-14 and F-18 programs. The Senate committee's target is to complete action on the authorization May 6.

Rep. Ronald V. Dellums (D.-Calif.) offered an amendment to eliminate $134 million for the USAF MX advanced ballistic missile system and cancel the program. But only 11 House members supported the amendment. The other 89 members present voted against it.

The mobile MX will only decrease U.S. security, Rep. Dellums said. "The greater accuracy of the missiles will pose a constant threat to the Soviet ICBMs, thus increasing the chances of a preemptive first strike."

Estimating the total MX program cost at $40-50 billion, Rep. Dellums said: "That is a lot of money for a weapon that has been called 'an arms controller's nightmare.' President Carter has already expressed his desire to ban it altogether. But owing to the verification problems it will cause, it may be too late to ban it after we have developed it."

Challenging Rep. Dellums, Rep. Jack F. Kemp (R.-N.Y.) told the House:

"The premise upon which the [Dellums] argument is based is that the U.S. is provocative and that the Soviets have not developed mobile land-based missiles. That is wrong. They do have right now a 3,000- to 4,000-naut.-mi range mobile SS-20. If they combined the SS-20 with the SS-16, it gives them a mobile intercontinental ballistic missile. It would have hard-target capabilities. It is the SS-20 that is destabilizing, not our MX research and development program.

SALT Flexibility

"We should be giving the President the flexibility to go into SALT 2 negotiations with the support of this Congress by not tying his hands in this important weapons program, stopping it unilaterally," Rep. Kemp said.

The Carter Administration reduced the $294 million proposed by the Ford Administration by $160 million to the $134 million.

Meanwhile, the Carter Administration has delayed implementation of its decision proposing outright cancellation of Minuteman 3 production, announced by Secretary of Defense Harold Brown Feb. 22. This will require the submission to Congress of a request to rescind Fiscal 1977 production funding. This request has not yet been submitted.

The House authorized $325 million for

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