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The most impressive nuclear-propulsion program the US has yet conducted is in serious danger of collapse. This despite a near-perfect record in meeting or exceeding all technical, cost/effectiveness, and budgetary goals during its ten-year life. The program is Pluto, and its goal is development of a nuclear-ramjet engine that could be used in a revolutionary new strategic system. The Pluto vehicle is an unmanned weapon of global range and awesome destructiveness. It would fly at Mach 3—more than 2,000 mph—on the deck, carrying a greater load of thermonuclear weapons than a Polaris sub or a dozen Minuteman ICBMs to any point on the globe. With the technology now available, Pluto is caught up in a battle between Congress and the Defense Department. The battle raises questions about the future of the program. . . .

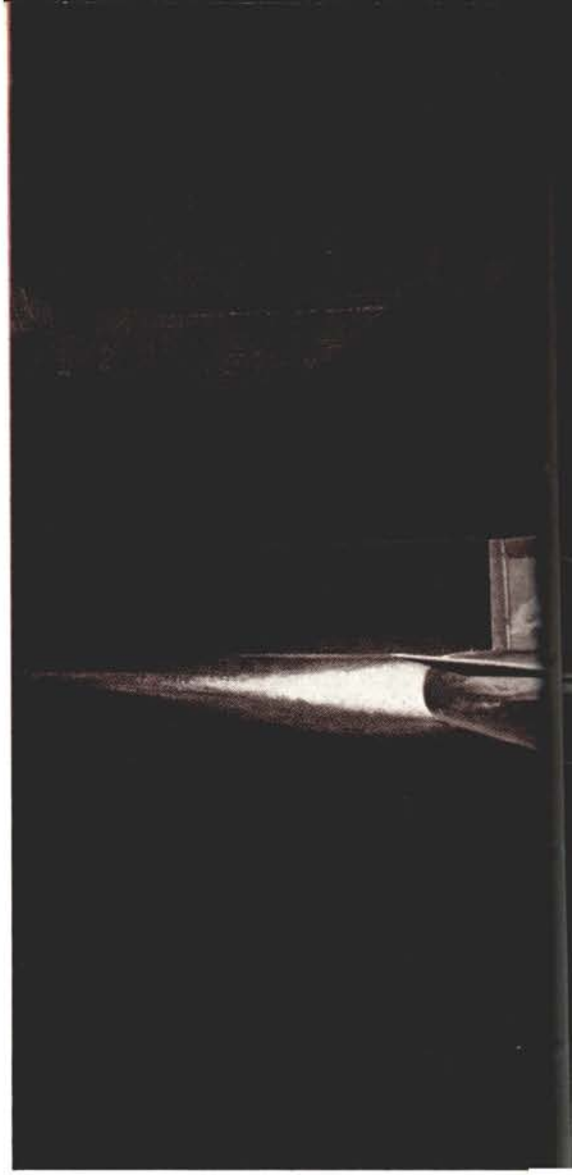

Illustration by Gordon Phillips

PLUTO...

A New Strategic System or Just Another Test Program?

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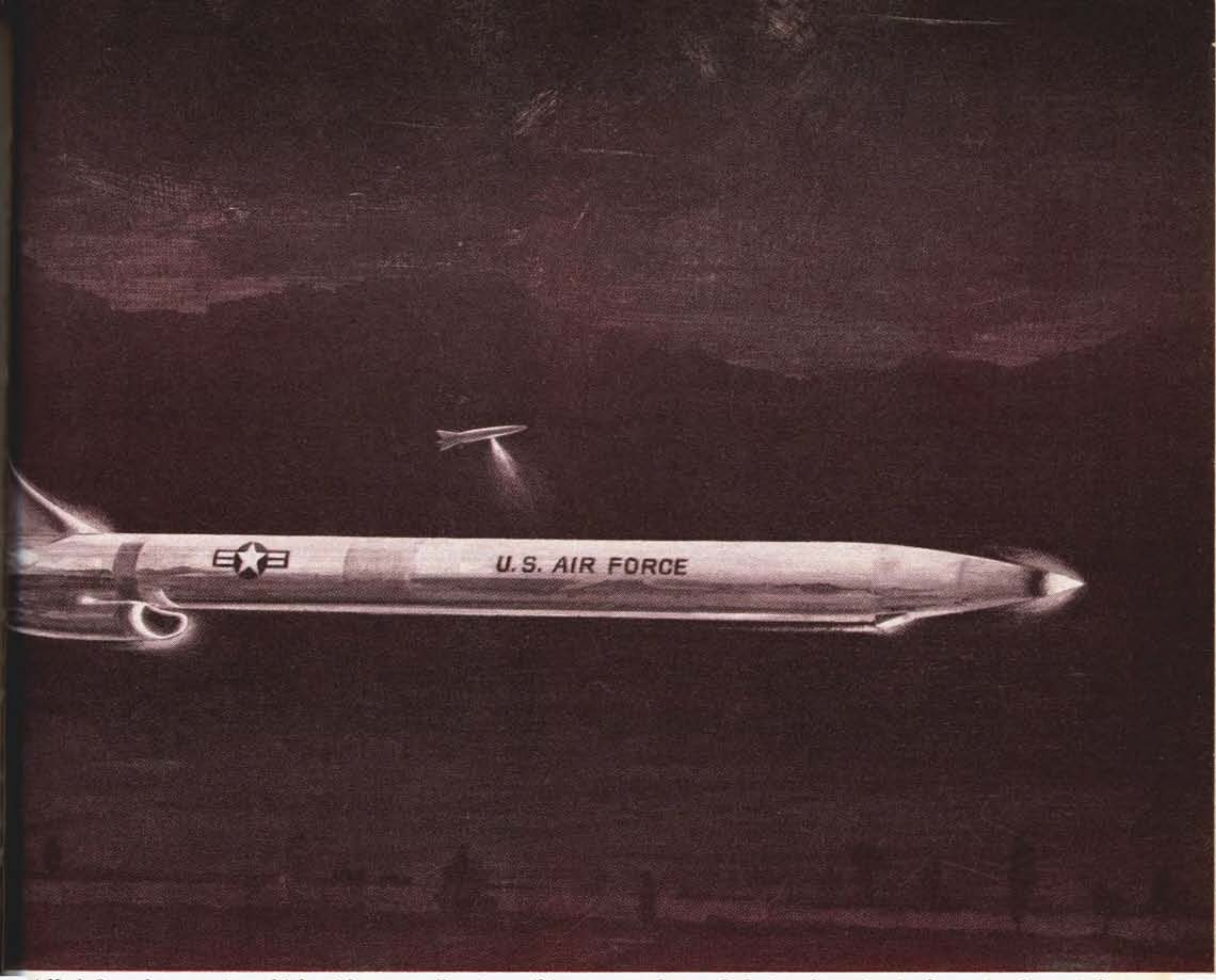
THE most impressive nuclear propulsion program to date, and indeed one of the most impressive US technology-building programs of all time, is on the verge of collapse. It is not a victim of failure—quite the contrary: It has achieved an essentially perfect record in meeting or exceeding all technical, cost/effectiveness, and budgetary goals over its ten-year life.

The program is Project Pluto. It is aimed at proving the feasibility of the nuclear-ramjet engine. It has become a key test case in a running fight between the executive and legislative branches of the government over how to manage advanced technology programs. In this test-case role, despite its extremely fine record and great future potential for weapon systems, Pluto is in imminent danger of being mothballed.

Congress has wholeheartedly supported Pluto in the past and continues to praise both its technical achievements and potential. But Congress is now using Pluto to goad the Administration into clarifying its advanced technology philosophy and military requirement system as currently practiced.

The immediate target under congressional attack is an Atomic Energy Commission request for $8 million to be spent in fiscal year 1965 to make ground tests of the new flight-weight Pluto reactor, the Tory II-C, and



A Mach 3 nuclear ramjet vehicle with more offensive striking power than a Polaris submarine is shown in the artist's conception above ejecting a small nuclear weapon. The Tory II-C reactor could power this 100-foot long, 200,000-pound vehicle. Its payload of more than 50,000 pounds could accommodate dozens of small nuclear weapons and several large ones.

to begin work on an improved version, the Tory III.

Late in April the Joint Committee on Atomic Energy recommended a $1.5 million reduction in the AEC's Pluto request. The Joint Committee explained that it wanted to fund the complete series of Tory II-C tests, but was not going to back any Tory III development. It agreed fully with the vast majority of its technical witnesses, who stated that Tory II-C tests would prove the feasibility of the nuclear-ramjet engine as well as it would ever be proven on the ground without flight tests. In other words, Congress is trying to speed up flight testing by withholding funds for further, and unnecessary, ground-based development.

Administration spokesmen, including Dr. Harold Brown, DoD Director of Research and Engineering, have supported a continuation of Pluto study work and ground tests at a low level of funding (approximately $20 million per year total from USAF and AEC budgets) to keep the technology "progressing."

The Joint Committee, after several years of criticizing this philosophy, now completely rejects it. The Committee believes it would be grossly wasteful to continue a policy that has consumed a little more than $200 million in nearly ten years and kept the program creeping at a minimum pace.

Most Joint Committee members agree with Dr. Theodore Merkle of the AEC's Livermore Laboratory, the program's technical leader. Late in 1958 Dr. Merkle said flatly that a nuclear ramjet could be built with technical knowledge that then existed. According to him at that time, "It is just a question of do you want it or not?" Pluto work during the past five years has proved Dr. Merkle's contention, and the committee is maneuvering to get the Administration to answer his question, "Do you want it or not?"

After cutting the FY '65 budget to allow only the completion of the Tory II-C tests, the Joint Committee stated in its report, "Unless a decision is made within the next year to flight test the Tory II-C device, it is an unavoidable conclusion that the [Pluto] program should be terminated."

In effect such a decision would mean that the break-up of the Pluto development team of scientists and engineers would begin on July 1, at the end of FY '64. Many design and laboratory specialists not directly connected with the Tory II-C tests would have to be switched to other programs because the Tory III would not be funded.

The Department of Defense, in an effort to prevent the Pluto break-up, is studying plans for a flight-test program which would satisfy a number of diverse factions in the DoD as well as the congressional critics. Date for a decision was scheduled for July 1, although there is little likelihood that this schedule will be met —or that the decision will be announced at that time even if made. The decision must be a tricky one, with great import for the military. The program will cost between $200 and $500 million, depending upon its sophistication and the number of flight vehicles involved.

If tests should prove successful it would be difficult to explain why development of an operational system should not be authorized. It is generally agreed that major strategic weapon systems in the future will be very expensive and few in number, so the Navy and the Air Force, as well as DoD, have an intense interest in any potential system which is receiving large development funds. Many atmospheric, spaceborne, and underseas systems are competing for the Administration's blessing as the next major strategic weapon system and to advance from the relatively cheap ground-test stage into a major test program in the operational environment.

The chances of DoD coming up by July 1 with a Pluto flight-test program that will be acceptable to the Joint Committee have to be rated as slim. During the past three years the only clear position that has emerged from the Pentagon's third floor is that new strategic weapons really aren't of interest. The current systems, especially the ICBM and the Polaris missiles, are considered to be invulnerable for far into the future. Development of improved systems to overcome weaknesses in these weapons and to present new defensive problems to an enemy generally have been described as unnecessary and wasteful by Mr. McNamara.

Consequently, it appears highly unlikely that this policy will be altered to produce a Pluto flight-test program of which the Joint Committee will approve. The Joint Committee objective, before considering the authorization of further funding, was to obtain reasonable assurances that the DoD wanted to go ahead with weapon-system development and could get all the information it needed out of the prototype flight vehicles.

Early in June a more formidable congressional challenge seems to have dashed all hope that Joint Committee pressure could have brought about a Pluto flight-test program. This new challenge is based largely upon the fact that the first full-power run of the Tory II-C on May 22 was a complete success. This was the first of several such runs planned next year for the Tory II-C test program which the Joint Committee funded.

The challenge came from the powerful House Appropriations Committee in a report issued on June 11. The Committee said that the May 22 test "amply demonstrated the successfulness of the ramjet propulsion reactor powerplant. Since there is still no military system or requirement for this powerplant and no engine system or vehicle to carry it has been developed up to this time, the Committee sees no reason why further development and testing work is necessary." The Appropriations Committee thereupon cut $5.5 million from the Joint Committee's authorization and said, "The $1 million which has been allowed for this program is for the purpose of 'mothballing' the project until such times as there is a military system and a requirement for it."

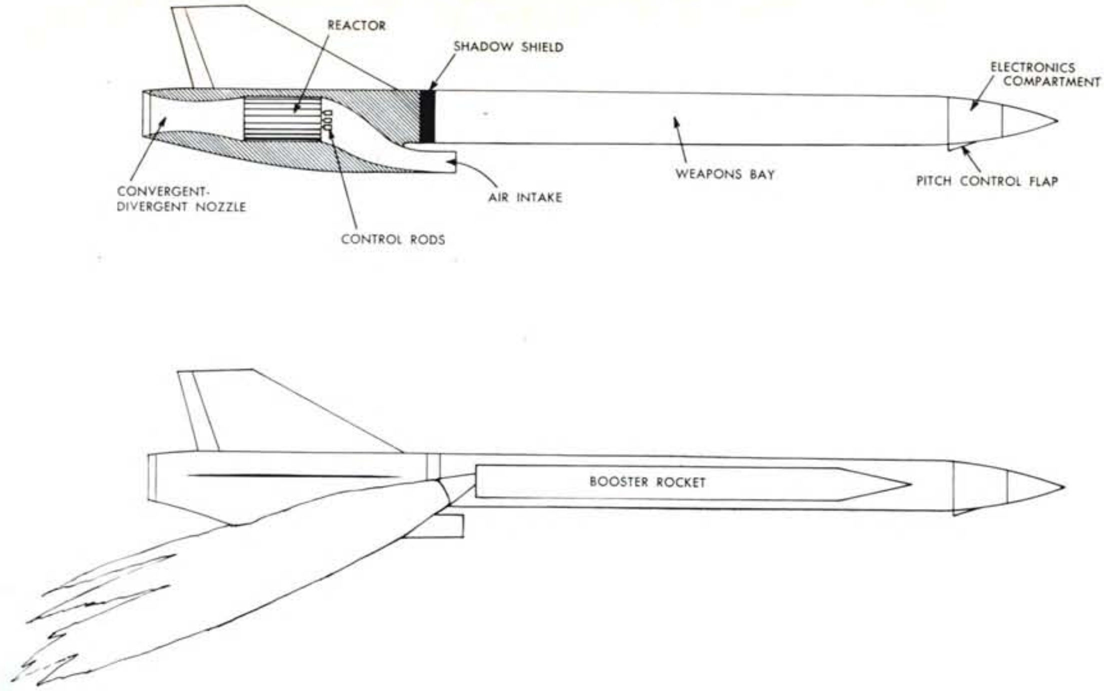
In calling for the generation of a weapon-system requirement before further funds are made available, the Appropriations Committee has given Mr. McNamara the task of coming to Capitol Hill and explaining his policy, unless he wants Pluto to die at once. Mr. McNamara must also justify his entire technology-building policies. Many congressmen do not believe that the Secretary is getting maximum effectiveness from his R&D dollar when he continues to call for $20 million a year for a system that is never going to be an operational weapon. They cite Mr. McNamara's own extensive statements about the overriding need for conserving technical resources and investigating the widest variety of concepts and systems to ensure US technical superiority into the future. The Congress certainly agrees with this basic objective, but few of its members will continue to support the expenditure of hundreds of millions of dollars on systems that the Administration is going to ignore after they are tested successfully and proven feasible.

It is no accident that the Congress is using Project Pluto to challenge the Administration. Pluto is revolutionary in every sense.

Militarily, it opens the possibility of operating bombardment/reconnaissance vehicles in a completely new speed-altitude regime—Mach 3, or about 2,300 mph, at altitudes as low as 500 feet. For practical purposes the range can be considered as infinite, because there is no technical doubt that the nuclear-ramjet vehicle could operate for at least twenty-four hours before radiation and heat would begin to deteriorate any of its subsystems. Therefore, the vehicle could travel around the world at the earth's maximum diameter while making extensive dogleg maneuvers. No nation is close to possessing a defense which could intercept such a high-speed, low-altitude vehicle attacking from any direction. Developing such a defense would be difficult and costly, at least in the same class with an anti-ICBM system.

The cost/effectiveness rating of Pluto vehicles must be very high compared to existing systems. One major advantage is that a low-altitude nuclear-ramjet vehicle has by far the largest payload of any flight system yet envisioned. Over twenty-five percent of its weight could be carried in the form of weapons or other payload. A Mach 3, low-altitude, vehicle powered by a Tory II-C type reactor would weigh 150,000 to 200,000 pounds or more, and its payload would be more than 50,000 pounds. It could carry more nuclear weapons, and larger weapons if desired, than a Polaris submarine, which has a normal complement of sixteen missiles each with a warhead of under ten megatons. By the same reasoning one Tory II-C powered vehicle could be more potent than a dozen or so Minutemen.

A second major advantage is a very high guidance accuracy rating for the low-altitude vehicle, even better accuracy than is being attributed today to the iner-



Simplicity of nuclear ramjet vehicle is illustrated at left. A small shadow shield protects the payload of weapons and the communications and navigation equipment from radiation. Booster rockets accelerate the vehicle nearly to cruise speed. At Mach 3, the body provides adequate lift. Eliminating the wings increases payload weight and reduces heating problems.

tially guided ICBM. The system consists of a programmed inertial system which is corrected at regular intervals by measuring the differences in height of prominent terrain features along the vehicle's route. Distances from the vehicle to the geographic features also are measured, and the distance and height differential information is fed into a computer which determines the vehicle's exact position and corrects the inertial system.

Ling-Temco-Vought, Inc., developers of the equipment for correcting an inertial-guidance package, already have tested it successfully in flight under all-weather conditions.

These two features—a large payload and an exceptionally high guidance accuracy—combine to give the nuclear-ramjet vehicle a high-effectiveness rating compared to current strategic missile systems. The nuclear vehicle also has aircraft-type advantages in that it can be recalled or given alternate assignments after a flight has been initiated. And it is vastly superior to the manned aircraft in range and speed at low altitude and, consequently, in ability to penetrate enemy defenses.

Initial cost of a Tory II-C powered vehicle purchased in quantity probably would be considerably less than a B-52 bomber—say $5 million or less. This estimate seems valid despite the ramjet's requirement for a large quantity of expensive nuclear fuel. The extreme simplicity of the nuclear ramjet, plus the fact that its total empty weight would be considerably less than that of a B-52, would have a controlling influence on cost.

Operational costs also should be relatively low. Keeping such unmanned vehicles in a state of constant readiness certainly would be much cheaper than operating a submarine or a large bomber and probably comparable to the cost of operating one missile silo.

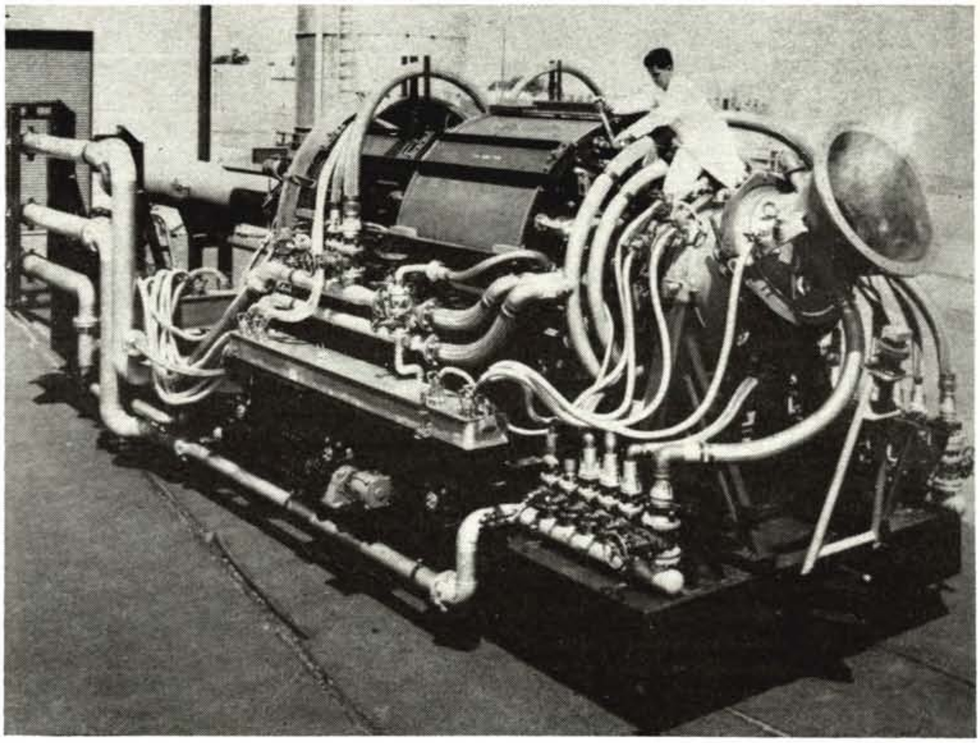
Many perils are inherent in drawing cost/effectiveness generalizations when a great deal of detailed information is not available on the weapon system in question, the other offensive systems it must be rated against, or estimates of the military environment it would have to operate against in the next five to fifteen years. However, the information available on low-altitude nuclear-ramjet vehicles, reviewed above, indicates that the Pluto system offers some unique cost/effectiveness advantages.

For instance, it appears that a force of 100 nuclear-ramjet vehicles could be produced for a total cost of under $1 billion in new funds. Such a force would have a striking strength equivalent to a fleet of sixty Polaris submarines or more than the entire complex of 950 Minuteman missiles that is in operation or on order. A nuclear-ramjet vehicle force also would have another great advantage. It could not be stopped by any existing air defense or any AICBM system which might be under development. Therefore, it would place a new and highly complex problem on the shoulders of enemy defense planners. In contrast, all new offensive system proposals which are pure ballistic or semiballistic with lifting, maneuverable warheads would be vulnerable to any successful anti-ICBM system.

Technically, the Pluto case is strong in support of the cost/effectiveness arguments. First and foremost, the project's research-and-development record has been virtually spotless so far. Pluto has not been plagued by failures and technical setbacks such as those which hindered the nuclear-aircraft program and continue to hinder the nuclear-rocket development.

Compared to the other nuclear propulsion programs Pluto has been a low-priority project with limited funding. Most of its effort has gone toward reactor development. The primary objective has been to prove that it is feasible to power a Mach 3 low-altitude vehicle with a nuclear ramjet. The scientists and engineers at the AEC-University of California Lawrence Radiation Laboratory and their principal contractors, Ling-Temco-Vought and Marquardt Corporation, have exceeded this original objective. Their Tory II-C reactor design has been proven in full power tests at the Nevada Test Station at Jackass Flats. Its detail design

The first major Project Pluto test device was the Tory II-A reactor at right. Its purpose was to test a ceramic core of the same type needed in an operational engine. It was not flyable because it had a thick graphite moderator jacket, shielded control rod actuators, and other heavy components. The first Tory II-A tests were run in 1960.



has stood up to the rigors of a 1,060-degrees-Fahrenheit, 50,400-pound-per-square-foot airstream, the same as would pass through the reactor during Mach 3 flight.

As a flight-weight reactor the Tory II-C has several features which distinguish it from stationary power reactors on the ground, or reactors used in submarines, aircraft carriers, or merchant ships. Most important is a very high power-to-weight ratio. Powerplants in high-performance flight vehicles must deliver high power for minimum possible weight. Nuclear-powered vehicles are no exception.

Power-to-weight ratios for nuclear powerplants are sensitive information. But it is known that the nuclear turbojets in the nuclear-powered airplane program were about fifty times better from the power-to-weight standpoint than the engine system in the *Nautilus*, the first nuclear-powered submarine, and about 200 times better than the atomic-powered merchantman, the *NS Savannah*. The Pluto powerplant's power-to-weight ratio is many times superior to any planned for the nuclear airplane. One major reason is the difference in shielding weight. The airplane had to carry more than 100,000 pounds of shielding to protect the crew. Pluto vehicles need only a "shadow" shield *(see page 33)* weighing a few thousand pounds to stop radiation from streaming directly from the reactor into the payload bay, the guidance system, automatic pilot, cooling system, etc., all of which are thousands of times more resistant to radiation than are humans.

Pluto also gets a weight advantage because it is a throw-away unit. It is intended to operate for about twenty-four hours at the most and then to be either incinerated in an enemy target or to be sent to the bottom of the sea on command from base. There are no plans to bring a Pluto vehicle back to a base, service it, and use it again. The requirements for a long service life and ground maintenance added many thousands of pounds to the nuclear airplane.

Another weight advantage falls to Pluto because its reactor wall temperatures must be around 2,200 degrees Fahrenheit or higher. This is at least 500 degrees Fahrenheit hotter than the wall temperatures required in nuclear turbojets powering a high subsonic-speed airplane.

The nuclear ramjet must operate at around Mach 3 to have enough ram pressure to overcome the high pressure losses associated with airflow through the reactor. At this speed the air enters the engine at 1,000 degrees Fahrenheit, and the reactor must be much hotter to produce the required thrust. Thrust-to-weight ratio of the nuclear ramjet depends heavily upon the maximum wall temperature achieved in the reactor. If it could be pushed up to 2,500 degrees Fahrenheit, then the payload percentage probably could go up to more than fifty percent of the total vehicle weight.

The high temperature requirement meant that Pluto reactors could not be made of the low melting point metals used in aircraft, shipboard, and ground power reactors. And the ramjet reactor could not be made of graphite, the nuclear rocket reactor material that operates to very high temperatures in the 3,000-degree-Fahrenheit range. Graphite and most other high-temperature materials oxidize and deteriorate rapidly when exposed to hot air. The nuclear environment also imposed severe requirements, and the materials which conceivably could be used in the ramjet reactor were severely limited.

Beryllium oxide, a ceramic, was virtually the only candidate. It has two serious disadvantages, and a large percentage of Pluto funds have gone toward overcoming them. First, beryllium oxide is extremely brittle. Yet it has to withstand terrific thermal shock loads during reactor start-up, and heavy gust loads and vibrations during Mach 3 flight at sea level in rough air. The key technical accomplishments of the Pluto program have been to improve the mechanical properties of beryllium oxide and to devise design techniques which would hold the brittle reactor together for at least one trip around the world.

The second problem is that beryllium oxide releases fission fragments, radioactive particles, into the airstream when the reactor is hot. Reportedly, the rate of release has been reduced to the point that there would be no hazard to persons on the ground because the particles would be released over a very large area by a Mach 3 missile.

Successful use of beryllium oxide has resulted in a relative light, high-power density reactor compared to any manned aircraft system. The Tory II-C reactor is only 4.7 feet in diameter and 8.5 feet long yet it produces 600 million watts of power.

Much of the low cost, light weight and relatively high payload percentage of the nuclear-ramjet vehicle can be attributed to the fact that low-altitude, Mach 3, vehicles have no need for wings. Under these flight conditions a body of approximately cylindrical shape has as high an aerodynamic efficiency (lift-to-drag ratio) as the best winged aircraft. Usually the wings account for ten to fifteen percent of the total weight of an aircraft. If they are removed the payload can be increased by this percentage. On Mach 3 vehicles there is the added bonus of reducing the structural heating problems when the wings are eliminated.

The Tory II-C reactor, measuring 4.7 feet in diameter and 8.5 feet in length is in the test ducting at right. It is a complete flight weight unit which produced 600 megawatts of power last May for five minutes under simulated Mach 3, sea-level flight.

Pluto also has benefited from significant advances in high-temperature airframe structures. Eight years ago there would have been some legitimate doubts about building even a wingless airframe which would hold together for twenty-four hours of rough sea-level flight under the combined heating effects of a Mach 3 airstream and heavy nuclear radiation. Today, it is considered within the state of the art to build the Pluto vehicle out of sheet steel that formerly was available only to turbine wheel designers.

All subsystems needed in Pluto vehicles have been reported in congressional testimony to be ready or well within the state of the art. Some of them, such as the basic inertial-guidance system, have been developed to a high state of perfection outside of the Pluto program. Others have been studied intensely with project funds. One of these is an automatically controlled air-inlet system with low reaction time, and a wide range of allowable operating conditions which compensate for the low power response time of the reactor. Another is a pneumatic actuator which sits on the front of the reactor and controls its power output by moving hafnium control rods into and out of the core. All the electronic components necessary for Pluto's communication, navigation, and bombing system have been developed in the project or in the nuclear airplane program.

Expert testimony before the Congress has indicated that Pluto cannot make any more significant progress without flight tests. Studies of military vehicles such as the SLAM (Supersonic Low Altitude Missile) and LASV (Low Altitude Supersonic Vehicle) also are at the point of bogging down without more definite data from Pluto flight tests.

Most congressmen familiar with the program are highly critical of the Administration because no formal requirement has been generated in the Department of Defense. Undoubtedly, the House Appropriations Committee will have substantial support in its move to cut off Pluto funds unless a requirement is generated.

Rep. Melvin Price (D.-Ill.) reflected the general tenor of the Congress when he recently discussed the point. He said. " . . . consistently, the Department of Defense and the Air Force have stated that one of their main requirements is a low-altitude, supersonic aircraft manned or unmanned. . . . They have stated this year after year. They still state it. They stated it again in the military posture hearings this year. . . . So they do have a requirement for it. Whether they state it as a requirement officially or not, they certainly have stated it many times in presentations before the Armed Services Committee of both Houses of Congress."

In backing the Pluto development for several years Representative Price and most of his colleagues believed they were meeting a military requirement. Now that there is considerable doubt about this point they apparently are going to push for clarification of the military requirements that actually exist today and of DoD policies used to establish requirements. Until such clarification Project Pluto seems destined for cold storage.—End