and from Eqs. 20*a* and 20*b* we get

$$t_0 = 2\frac{c^2}{P}\mathcal{M} \qquad (27a)$$

and

$$x_0 = \frac{c^3}{2P}(\mathcal{M}-2) \qquad (27b)$$

If, for example, we fail to fulfill requirement 25 by a factor of 10^6 (if we have 40 power plants plus 6000 transmitters, weighing, in all, 10 tons—still a fantastic value), then $b = 10^{-6}g$, and it would take 2.3 millions of years for the crew to approach the velocity of light to within 2 percent.

Or, to put it the other way round, if one wants to get an acceleration of, say, $b = 100g$, in order to take full advantage of having a deep-frozen crew, then 100 times the weight of the equipment mentioned in requirement 25 must not total more than 10 tons; this means that power plants plus transmitters should have an output of 6000 megawatts per gram. Purcell (*4*) has arrived at similar conclusions from a study of the requirements of relativistic rockets. There is no way of avoiding these demands, and definitely no hope of fulfilling them.

Conclusion

The various questions dealt with in this article have not led to the definitive answer that interstellar space travel is absolutely impossible. We have found simply the minimum travel times given by different assumptions, and we have found the requirements needed for reaching these limits. This is, at present, all we can do, and the final conclusion as to the feasibility of such ventures is up to the reader. The requirements, however, have turned out to be such extreme ones that I, personally, draw this conclusion: space travel, even in the most distant future, will be confined completely to our own planetary system, and a similar conclusion will hold for any other civilization, no matter how advanced it may be. The only means of communication between different civilizations thus seems to be electromagnetic signals (*5*).

References and Notes

1. S. von Hoerner, *Science* **134**, 1839 (1961).
2. A different derivation of Eq. 20, connecting V and M, has been given by J. R. Pierce [*Proc. I.R.E. (Inst. Radio Engrs.)* **47**, 1053 (1959)] together with a good explanation of the so-called clock paradox. Pierce also investigates interstellar matter as fuel, with the same negative result as that given in this article.
3. *Space Handbook: Astronautics and its Applications* (U.S. Government Printing Office, Washington, D.C., 1959), p. 113.
4. E. M. Purcell, *Brookhaven National Laboratory Lectures, No. 1.*
5. I wish to thank F. D. Drake for reading the manuscript.

News and Comment

Military in Space: Air Force Seems To Have Won Argument For Expanded Program

The Administration has denied that it is planning a major role for the military in space, but at the same time it has explained that it is taking out "necessary insurance against military surprise in space."

The dilemma that faces it on the military's role in space is an enormously complex one, with no simple answers ready at hand. In many respects the dilemma is similar to the one faced by the Truman Administration when it wrestled with the pros and cons of developing the hydrogen bomb. The decision in that case was that the United States could not afford the risk of denying itself destructive capacity of a new order unless there were an assurance that the Soviets would also forego development of the weapon. There was, of course, no such assurance, and U.S. efforts were spurred on by uncertainty about what the Soviets were up to, while the Soviets also went ahead, presumably figuring that it was too dangerous for them to stay out of the race.

It would have been astonishing if the H-bomb question had been decided otherwise, for the sad fact is that technological developments with military applications have inevitably ended up in military hardware. As far as a military space role is concerned, the principal impediment is that the role is not yet clearly visible, at least, not from this country's vantage point. In other words, there is not yet any certainty about what you can do in space to hurt an enemy or prevent him from hurting you that could not be done just as well—and more cheaply—from the earth.

This uncertainty need not remain indefinitely, for it is a fair assumption that, with the investment of enough money and talent, military functions can be developed for space. Among those that seem most feasible are surveillance and rendezvous techniques aimed at destroying hostile space vehicles; a more remote possibility, but getting some thought, is orbiting bombs.

Against this background the Administration has been trying to maneuver in the very limited area between accelerating the arms race and coming out second to the Soviets in military space technology. At the outset, the dominant view in the Administration seemed to be that the Soviets were not forging ahead with military space work, and that therefore the United States would only touch off a new line of arms competition if it undertook a major military space program. This was the view held by the civilian managers of the Department of Defense, and it seemed to be shared by Kennedy. Strongly opposed was the Air Force, which argued that the Soviet Union had never demonstrated any interest in refraining from weapon development. Furthermore, the Air Force argued, the great lead times required to develop space equipment should rule out any wait-and-see policy.

The effect of these arguments, possibly reinforced by intelligence findings that have not been made public, has been to move the Administration in the direction of the Air Force's

thinking. Just what the outcome will be is something on which the Administration itself appears to be undecided at this point, but unless the United States is going to depart from precedent, the likelihood is that the Air Force is bound for space. The unsettled question seems to be the rate of speed.

In contrast to the H-bomb question, which spilled over from the closed councils of government to produce a bitter public debate and, ultimately, the Oppenheimer case, the future of the military in space has not become a major policy question. It has excited the Air Force, the space industry and its trade press, but otherwise has generated little debate inside government and virtually none outside. Some explanation for this may lie in the fact that while the H-bomb was a clearly definable undertaking, even the Air Force has to concede that the role of the military in space is bounded by counsiderable uncertainty. In addition, opposition to the development, or at least a crash-basis development, of the H-bomb was generated by highly placed scientists who were concerned about the weapon's strategic and moral implications; their opposition produced the debate. These men included conscience-stricken members of the A-bomb development team who felt compelled to speak out on the great issues involved in the H-bomb question. No similar group exists to take a stand in opposition to expanding the military into space; to a large extent this is simply because space work is far more fragmented than nuclear weapon development. There is no one man or small group of men who can command the public's attention on the policy questions of space, a situation that does not exist in the atomic field, where any significant utterance from major figures instantly receives broad attention.

One result has been that the Air Force and those within the Administration who favor its position have not been confronted by a positive opposition. Their task, rather, has been to persuade people whose attitude has been one of neutrality underpinned by a willingness to be convinced by a good case.

The pressure for a military role in space has had to work against the Administration's fervent desire to promote peaceful space undertakings with the Soviets. Joint ventures such as weather and communication satellites and magnetic field studies do not necessarily exclude a simultaneous military effort, but the cooperative programs inevitable partake of much of the technology that would go into a military space effort; once space becomes a military arena, the room left for cooperative efforts would be considerably reduced.

The Administration's simultaneous moves toward cooperation and an expanded role for the Air Force have been accompanied by efforts to cut down publicity on military space efforts. Under a directive which itself is classified, the Air Force over the past few months has clamped down on news about its space work, particularly in connection with the highly classified reconnaissance satellites. One aim of this news policy is said to be to avoid giving the Soviets a pretext for feeling provoked, but it is likely that the Soviets can find the means to determine whether or not they should feel provoked by our space efforts.

Up until now the military has not been altogether excluded from space work. In the fiscal year just ended, the Defense Department reports, its funds for space projects of all sorts totaled $1.1 billion; for the new fiscal year, the total has been increased to $1.5 billion. The availability of these vast amounts would seem to undercut the argument that the Air Force space program is financially undernourished, but the money is used in an area where a great deal usually goes only a short way. In addition, not all of it goes to the Air Force, since the other services get a share, and the total itself comes out to be less than half of what is provided for the civilian space effort.

The Air Force has not stated how much it wants, but in congressional testimony last spring, Lt. General James Ferguson, Air Force deputy chief of staff for research and technology, outlined a broad area of interest, including the development of manned spacecraft for "self-contained flight to and from space." He also said the Air Force saw a possible need for manned space stations.

The most effective opposition to the Air Force's space plans originally came from the civilian heads of the Department of Defense, who took the position that, as far as could be seen, the military had no role in space. This did not exclude spending some money —not enough, in the Air Force's opinion—to keep the matter under investigation, but as far as any intensive effort was concerned, the Defense Department was in opposition to the Air Force.

Over the past few months, however, the opposition has shown signs of weakening. Last May, for example, Roswell Gilpatric, deputy secretary of defense, said in an address that cooperation with the Soviets for the peaceful use of outer space was "still the national goal," but that "we would be very ill-advised if we did not hedge our bets." Gilpatric added: "We ought to be ready to anticipate the ability of the Soviets at some time to use space offensively." He also disclosed that, while no decision had been made on expanding the military space role, the Administration planned an "analysis in depth" in preparation for the next military space budget.

Similar speeches and remarks by Administration officials have since followed, and while no one has said publicly that the Air Force will get the go-ahead for an expanded space program, the impression has been created that the Administration is thinking in that direction.

That the Defense Department feels uneasy and unsettled about the issue would seem to be indicated by its denial last month of a New York *Times* report which stated: "The Defense Department is embarking upon a man-in-space program to prevent military control of space by the Soviet Union." The *Times* account went on to say: "After years of reluctance and opposition, the department has finally accepted the need for a military space program aimed at control of space as well as its exploration."

The denial, however, lost some of its cogency after a congressional appearance by Harold Brown, Defense Department director of research and engineering. Testifying before the Senate Aeronautical and Space Sciences Committee, Brown did not move on to the Air Force position, but he indicated that the Defense Department was no longer of the opinion that the military had no role in space.

"During the last year," he said, "military space activity expanded both in volume and scope as the Department of Defense research and development program reflected a growing appreciation of the prime importance of space technology to national defense posture. . . . At this point in time, it is difficult to define accurately the specific char-

acteristics that future military operational systems of many kinds ought to have. We must, therefore, engage in a broad program covering basic building blocks which will develop technological capabilities to meet many possible contingencies. In this way, we will provide necessary insurance against military surprise in space by advancing our knowledge on a systematic basis so as to permit the shortest possible lag time in undertaking full scale development programs as specific needs are justified."

Brown did not go into what factors will figure in achieving the "shortest possible" lag time, a matter on which he and the Air Force could have widely differing opinions, and which is probably at the heart of the question of just how quickly and to what extent the military will be permitted to proceed into space.

The "presently definable military needs and requirements" in space, he said, include satellites for communications, reconnaissance, early warning, navigation, and weather forecasting. In the other areas he described, he said that the military space role at present is limited to the development of "building blocks," including the technology for "intercepting passive or uncooperative satellites" and establishing and maintaining space stations. The underlying principle of the Defense Department space program, he said, "is to develop systems rapidly where there is a clear and urgent military need," and to use the "building block" approach to "provide a foundation for moving rapidly into those military systems which may be required on short notice."

The explanations offered by Brown and other members of the Administration still leave open the question of just how far the Defense Department intends to go in military space developments. With East-West relations on earth soured by 15 years of Cold War, the hope has grown that the costly adventure of space exploration might provide a meeting ground for the Soviet Union and the United States. Against this hope the Administration has to balance the fact that it cannot afford to wake up one day and find the Soviets 5 years ahead of this country in military space developments. And complicating the matter is the fear that efforts that are intended merely to keep us in the race may actually speed up the race.—D. S. GREENBERG

Announcements

The National Academy of Sciences has completed the construction of a west wing, to be known as the Equitable Life Assurance Society **Hall of the Life Sciences**. The $1,000,000 wing, financed by Equitable, will be used to house the various activities of the Academy and its National Research Council in the biological, medical, and behavioral sciences. The first floor contains a conference room, a refectory to be used as a cafeteria or a banquet hall, and eight offices; on the second floor are another conference room and 14 offices.

Of the additional $3,200,000 required to complete a proposed east wing and a 700-seat auditorium, $1,200,000 has been given or pledged by private foundations and industry.

The **Board of Microbiology** of the American Academy of Microbiology is accepting applications for certification in the fields of public-health and medical-laboratory parasitology, bacteriology, immunology, microbiology, mycology, and virology. (G. I. Wallace, American Board of Microbiology, P.O. Box 897, Vero Beach, Fla.)

Chartered flights are being arranged for those who plan to attend the 3rd International Meeting of Forensic Immunology, Medicine, and Pathology, and the 1st International Meeting of Forensic Immunology and Toxicology, to be held in London from 16 to 24 April 1963. The round-trip fare will be $210; reservations should be accompanied by a $50 deposit. (Milton Helpern, 55 East End Ave., New York 28, N.Y.)

Flights are also available for the meeting of the International Association of Traffic Accident Medicine, to be held from 25 to 30 April in Rome. The fare from London to Rome will be $89.90; from Rome to Paris, $60.50. Further details on this meeting are available from C. Gerin, Instituto di Medicina Legale, Università degli Studi, Viale dell'Università 32, Rome, Italy.

Grants, Fellowships, and Awards

Essays on the **historical development of rocketry and astronautics** are eligible to compete for the $200 Robert H. Goddard national award, recently established by the National Rocket Club. Entries may cover any significant aspect of the development of rocket technology, revealing new information or casting a different light upon events or individuals influencing the field in the United States. Deadline: *1 November*. (Goddard Historical Essay Competition, National Rocket Club, Suite 32, 1745 K St., NW, Washington 6, D.C.)

Funds for **study and research in the Soviet Union** during the 1963–64 academic year are available to American faculty members and graduate students under 40 years of age. Applicants must have a knowledge of the Russian language adequate for their research purposes. Individual grants, covering periods from one semester to 15 months, will vary according to applicants' needs and resources. Deadline: *16 November*. (Stephen Viederman, Inter-University Committee on Travel Grants, Indiana University, Bloomington)

The Optical Society of America has established the **C. E. K. Mees International Medal**, in honor of the late founder of Eastman Kodak Research Laboratories. The award, the society's first to be specifically international, will recognize the "extension of the frontiers of optics as Mees himself extended photography." The first recipient of the medal, to be selected by a five-member committee, will be honored on 4 October during the society's fall meeting in Rochester, N.Y.

The Explorers Club is offering grants-in-aid, generally under $1000, for **exploration and scientific field work**. Applicants need not be members of the club. (Executive Director, Explorers Club, 10 W. 72 St., New York 23)

Students or graduates who obtained their last academic degree within the past 7 years are eligible to apply for research support in **logistics or related areas**, sponsored by the Office of Naval Research. The award, which is for an individual undertaking, will be made on the basis of an unpublished manuscript on networks, scheduling, and combinatorial methods of importance to mathematical development in the field. The research may be undertaken at any institute in the United States acceptable to the ONR. Support will begin between 1 March and 3 June 1963, and will continue for one year at a salary