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37. We use the word *invariant* to include both those residues in the region usually designated the common region of the antibody molecule and those in the "variable region" which are invariant.
38. The argument that the "interaction sensing unit" must be invariant is independent of the assumption that it is complementary to the receptor antibody.
39. This conclusion depends on the assumption that the "interaction sensing unit" is complementary to the receptor antibody. We believe this to be the only plausible hypothesis in the case of paralysis, since the receptor is the only molecule which specifically recognizes the antigen and can, therefore, be the only molecule which specifically transmits a signal to the cell. For induction the signal could be transmitted through either the receptor antibody or the carrier antibody, or both. We favor the last alternative, since the carrier antibody must be recognized in order to be mandatory for induction, and since the antigen must, according to the model for paralysis, cause a conformational change of the receptor on binding it. This hypothetical scheme has the added attraction that it ensures that cells which are nonparalyzable because the receptor is unable to transmit the paralytic signal will be noninducible.
40. These considerations are consistent with the existence of allelic exclusion at the level of the antigen-sensitive cell. In an animal homozygous for a particular class of antibody molecules, an individual antigen-sensitive cell is expected to express receptors for only one of the two alleles. If both alleles were expressed, and if they coded for antibodies of different specificity, as is to be expected, the induction of antibody could not be specific, as the interaction of antigen with one of the two kinds of receptor present would lead to induction of both alleles. The argument presented above thus demands allelic exclusion at the level of the antigen-sensitive cell if the antibody-secreting plasmacyte is to be unispecific. The above argument for allelic exclusion has been made for a homozygous animal, but it can be reasonably extended to animals heterozygous for a particular class of antibody molecule. A system in which the "interaction region" is allotype-specific leads to difficulties; if the "interaction region" is not allotype-specific, the argument applies to heterozygous animals with the same force that it applies to homozygous animals. These considerations also show that an antigen cannot interact with a "stem cell," which possesses receptors of very many different kinds, to provide a signal for the cell to differentiate into a unispecific cell, as proposed by B. D. Brondz and N. E. Goldberg, *Folia Biol. (Praha)* **16**, 1 (1970).
41. We predict that no anti-U will be induced in spite of the fact that the hapten could in principle provide a carrier determinant to induce anti-U. We base this prediction on the fact that more than one carrier site is, in most cases, required to get a measurable response, as discussed in the text.
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Administering and Managing the U.S. and Soviet Space Programs

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The American and Soviet space programs have, from the management and organizational standpoint, much in common. Yet there are a number of fundamental differences. Because of some of these differences the United States has so far reaped greater benefits, in a social sense, from its space efforts than has the Soviet Union. Because of others, however, the scales could tip in favor of the Soviets. The fundamental issue is whether the United States will continue willing to do the things necessary to match the continuity, purposefulness, and concentration of effort that characterize the Soviet approach.

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Features in Common

Complexity and resources. The two programs have been roughly equal in complexity and in input of resources. If, as has been asserted, the U.S. moon undertaking represented a task equal in technological complexity to the total of all the great tasks performed by man from the building of the pyramids through explosion of an atomic bomb, hardly less can be said of Soviet space enterprises. So far, the U.S.S.R. has not aimed at anything that quite matches the moon landing. It has, however, in numerous other particulars been the pioneer, working at the cutting edge of space knowledge and exploration. In its space efforts it has had to penetrate the unknown as much as the United States has, if not more. Many of the pathfinding firsts were Soviet achievements. Beyond this, the U.S.S.R. has kept pace with the United States in the continued development and improvement of general capabilities to operate in space, including the range of capabilities that made possible the U.S. moon landing.

For one program as much as the other, the space task has presented problems for which no solution was available. Each program, over and over again, has required doing something for the first time, with a high degree of uncertainty as to what was needed to do it or as to the precise results that would follow. Each has required working against long lead times, in which it takes years to move from the conception of a mission to its realization. Each has required the development of new tools and new ways of using tools, new mechanisms of propulsion, new systems of life support, new guidance systems, new computer technologies, and all with a degree of reliability never before attempted in human undertakings.

We have no way of determining how Soviet budgetary figures compare with the $33 billion the United States will have spent on its civilian space activities by the end of the current fiscal year and the added $23 billion for related military programs, for a total of something over $56 billion. We can nevertheless be reasonably sure that the Soviet investment has been comparable to that of the United States, if not substantially greater. This follows

from the *scale* of the Soviet effort. Charles S. Sheldon II of the Legislative Reference Service of the Library of Congress has pointed out in a series of studies (*1*) that, from the physical standpoint, Soviet space activities have remarkably paralleled the space activities of the United States. Whether we think in terms of number and sophistication of missions, booster capabilities developed (including Saturn V), launch facilities, space ships, research and development efforts, or whatever, the Soviet investment of human and material resources adds up to very much the same total as the U.S. investment. This of course represents a relative burden on the Soviet national economy more than double that placed on our economy by our own space effort.

Some in this country tend to discount the magnitude of the Soviet space investment on grounds that it has been a "by-product" of ongoing military efforts. Certainly the Soviet space program has been intimately tied in with military programs. However, the effort has encompassed much more than would be needed to meet ordinary military needs. *Ekonomicheskaia Gazeta* (*2*) has spoken of the "gigantic efforts of the multimillion army of scientists, engineers, and highly qualified workers, who are creating the meteorological, radio-relay, geodetic and other satellites." While this is doubtless a considerable exaggeration, it suggests that the total of 600,000 individuals engaged in U.S. programs at their 1966 peak is probably considerably smaller than the total of workers continuously engaged in the Soviet program. This surmise is strengthened by the fact that the productivity of American scientists and technologists is acknowledged by the Russians to be appreciably greater than their own—twice as great, according to the estimate of Soviet Academician Peter Kapitsa (*3*).

Utilization of existing organizations and expertise. Both programs have depended for success not so much on the development of the new as on the more effective organization and utilization of the existing, and both have required extensive organizational and administrative innovations and new management techniques.

In the United States the National Aeronautics and Space Administration (NASA) was created through the welding together of many ongoing operations and organizations. These included the long-established National Advisory Committee for Aeronautics as a hard core, a variety of existing government laboratories and research institutes operating around the country, and elements of other government agencies as needed for many specific jobs. In developing and carrying forward its program of activities, NASA has not brought into being new manufacturing enterprises or new scientific and research expertise but has relied upon those already available in the nation's industrial complex and in the universities. As former NASA administrator James E. Webb summed it up (*4*, p. 42):

> Seldom in history has a large and complex undertaking been so widely spread over existing organizations and institutions as has been the case with NASA. . . . The NASA program has involved about 20,000 industrial prime and subcontractors and suppliers, 200 universities, and almost 400,000 non-governmental workers.

Although the Soviet space program has not been spread so widely over the nation's industrial and other competencies, quite clearly it has drawn upon many diverse industrial ministries and enterprises, segments of the U.S.S.R. and Republic academies of science, many research and design organizations, and various other organizations and institutions. The "multimillion army" engaged in the Soviet program has not been mobilized within a single massive organizational structure but remains dispersed over a wide variety of particular establishments. It appears, in fact, that the U.S.S.R does not even have a "space agency" on the order of NASA, and that central direction is effected principally through various coordinating devices, it being left to existing organizations, particularly within the military establishment, to carry on most of the directional activities that, in the United States, have been centralized in NASA.

Similarly, in both programs most of the basic scientific knowledge and technology has not been newly created but already existed. The task in each case has centered primarily on organizing for new purposes that which was already at hand. It involved drawing together and regrouping and redirecting capabilities that had been built up in such fields as aeronautics, missile rocketry, electronics, cybernetics, and communications, as well as in the basic sciences. Many new and difficult scientific and technological problems have had to be solved as the respective programs advanced from one level of accomplishment to another. But, here again, organization rather than traditional "inventiveness" has been the key: solutions have been effected through purposefully organizing and utilizing existing knowledge and technology to create new knowledge and technology as needed.

Although utilizing old organizational forms and structures and leaning heavily on scientific and technological advances already achieved, the Russians, as much as the Americans, have had to adopt essentially new ways of doing things to effect their space successes. They have given few details as to how they have run their space program, but from what they have said it is clear that they have not been bound by the standard bureaucratic approaches characteristic of Soviet economic management in general. They, like the Americans, have cut across boundaries of diverse organizations and have marshaled the variety of disciplinary skills and resources needed to perform specific space tasks. Here a comparison of authoritative descriptions of the U.S. and Soviet approaches might be illuminating.

For the United States (*4*, p. 19):

> The type of job with which NASA was charged . . . is clearly beyond the capability of a traditional bureaucratic establishment. It requires above everything flexibility. It cannot be accomplished by an organization that is rigid either in structure or methods. It can be done only by an organization that is truly adaptive, that has the capability to deal with the unknown, to operate under conditions of rapid change in a turbulent environment, to secure and act upon instantaneous feedback from both its own performance and its environment, to use and where necessary generate new knowledge and new technology, to combine and recombine highly trained experts of differing backgrounds and disciplines, to adjust to varying levels of support, to speed up and slow down, to change directions in mid-course, to constantly improvise, invent, and innovate.

For the U.S.S.R. (*5*):

> There was never any departmental approach, though hundreds of different departments took part in the work. . . . Planning is continuous, flexible, and it changes in connection with the results of the work. . . . These development projects were done so thoroughly, exhaustively, and in such a multifaceted way that the construction and putting into operation of new, very complicated lines of production proceeded rapidly, without delays. In the course of several years, problems of colossal difficulty were solved. . . .

For either the Soviet or American operation the description could accurately be recast in terms of the stan-

dards set by Warren Bennis (*6*) for "tomorrow's organizations": adaptive, problem solving, temporary systems of diverse specialists, linked together by coordinating executives in organic flux.

The Soviet and U.S. programs parallel each other to a surprising extent in the use of the systems approach and its various subelements, such as systems analysis, systems engineering, and systems management. The Russian procedures are often less sophisticated than the American, but they work in essentially the same way and yield essentially the same results. And in both programs, of course, computer science and computer technology play the same key role in planning, in data storage and processing, and in real-time informational and feedback systems, although the quality of U.S. hardware and U.S. applications is appreciably higher.

Military and nonmilitary objectives. In both programs, organization and management have been complicated by the necessity of serving both military and nonmilitary objectives and by the pressures of diverging national interests.

The Soviet program is run by the military establishment, but under the close supervision and control of the Council of Ministers and the Politburo of the Party Central Committee, and with a nonmilitary input into the decision-making process at nearly all levels. The American program is run predominantly by a civilian agency (NASA) and subordinately by the Department of Defense, but with close coordination and interaction between the two. Both programs, including the civilian as well as the military side for the United States, encompass activities and capabilities directly related to ground-based military needs. While the Soviet program has appeared to be more directly aimed at fully exploring possibilities of a strategic breakthrough in space, the U.S. program has certainly also aimed at keeping the United States in a position to guard against, or offset, such a breakthrough. At the same time, both programs have objectives that lie outside, or go beyond, the military sphere. In the case of the United States, these objectives quite clearly have been and remain predominant. In the case of the Soviets, there has been an accelerating buildup of activities and capabilities that appear highly unlikely to be of military usefulness, in either the near or the foreseeable future.

In the United States there have been numerous—and, on several occasions, quite severe—clashes between "military interests" and "civilian interests" over conduct of the program. We have no direct evidence of similar clashes in the U.S.S.R., but we do have evidence of almost constant struggle over resource allocations and the establishment of priorities within the space program and between the space program and regular military programs. It is clear that civilian-oriented projects got short shrift within the Soviet space program for a long time, but growing emphasis on planetary probes, scientific experimentation, and space applications for meteorology, earth resources, and communications indicates a substantial change in recent years.

Organizational triumphs. Both programs represent organizational triumphs of a high order.

An aspect of the American moon landing that is now generally forgotten is that a number of knowledgeable people were convinced it could not be done. The thought was not that the scientific and technological barriers were insurmountable, but that man did not yet know enough about how to marry the relevant science and technology to the problems of space exploration to be able to compress within any predictable time period the succession of advances needed to move from basic knowledge to an operational space system that could get men on the moon and return them safely to earth. Man probably would someday go to the moon, but only through a block-building or one-step-at-a-time process. How could a program possibly conceptualize, design, contract, and get production started on the intricate and complex Saturn-Apollo system before the primitive Atlas-Mercury system and the follow-on Titan-Gemini system had each been fully developed and proved out? That NASA succeeded in doing just this sort of thing, and at the same time succeeded in building, in spread-eagle fashion, the all-round capabilities necessary to enable the United States to go forward, if it wishes, to the accomplishment of almost any task that might be set in space, can only lead to wonderment on the part of any observer.

But what of the U.S.S.R.? Americans today appear somewhat shamefaced over the extremes to which they went in the wake of Sputnik in assessing the prowess of the Russians in mastering and utilizing advanced technology. And well they might. Who likes now to recall the orgy of self-denigration in which we as a nation indulged as we contemplated the first Soviet space achievements? The pendulum, however, may have swung too far back. We can again speak with assurance of a general technological gap between the United States and the U.S.S.R. But we cannot speak of a gap in the area of space. The success of Apollo, together with some recent Soviet setbacks, clearly put the United States ahead. This, however, does not alter the fact that the Russians, with far less in the way of basic resources, have achieved their own great and expanding successes, and that through doing so they, as well as we, have demonstrated an ability to organize the use of technology to generate new technology for the performance of the most complex and difficult of tasks in space.

The Differences

In the two countries the management of the space programs has reflected and strengthened the differing political, social, and economic systems.

Those who adhere to the theory that the United States and the U.S.S.R. are converging might well feel that the parallel in the ways in which the two nations have conducted their space programs provides convincing evidence of the correctness of their views. Some believe that, in both the U.S. and the Soviet space programs, and indeed in all enterprises involving the use of advanced scientific knowledge and complex technology, forces are at work that are incompatible with existing institutions and their traditional methods of decision-making and control and hence are leading to an essentially uniform new way of running things in both countries.

The reasoning is relatively straightforward: Science and technology have become so complex, and the problems and ramifications of their use so involved, that they are beyond the comprehension of ordinary rulers of states and their administrators, whether of a Marxist-authoritarian or a democratic-representative variety. Only a scientific-technological elite, which alone has the knowledge and training necessary to understand what the business is all about, can cope with the intricacies of a great technological enterprise. Whatever the appearance, therefore, the scientists and technologists are making the real decisions and determining the ac-

tual direction of these enterprises, and these scientists and technologists, in consequence, are gradually reshaping the fundamentals of the system within which they are operating.

Sidney Hyman in a fascinating contribution to the "Man on the Moon" issue of the *Bulletin of the Atomic Scientists* (*7*) had this vision of the way the process has worked in the American space effort.

> New things had to be created for all aspects of the program—new tools, new industries, new environments, new men to produce the tools and environment, new men newly grouped around the world to direct the movements of the whole business. Here, by itself, in the mere act of organizing and executing the man-in-space program was a wholly new world, created by government, managed from within by a new elite brotherhood of scientists and technicians with their own special focus of interest, their own heroes, their own urge to maintain themselves as an elitist brotherhood. The very existence of the new world of collective mental effort—of a special society within a society—may have as great a political impact on the shape of the future as any other kind of fallout from the space program.

Others have visions of a similar process for the Soviet space program: A doting Party apparat looking on and paying the fare and basking in the glory—but not quite understanding either the why or the how, or able really to do anything about it—while a new breed of technocrats, whether in military or civilian garb, dreams up and executes their complex projects for their own reasons and in their own ways. Here too, as the vision would have it, the technocrats constitute "a special society within a society," and, here too, as a special society they are exerting mounting pressures on the larger society to remake itself in their own image. And in support of the vision can be cited such things as Academician Andrei Sakharov's description (*8*) of the "anxiety" of the Soviet "scientific and scientific-technological intelligentsia" that "is nourished by a realization that the scientific method of directing policy, the economy, arts, education, and military affairs still has not become a reality," and his accompanying appraisal of the strength of the forces that "demand" the substitution of rule by the scientific method for the oppressive and irrational methods inherited from Stalin.

There is much of high fantasy in these visions. On the Soviet side, it is true that stirrings among scientists and technologists have been manifest for some time. Many Americans, ourselves included, can bear witness to expressions of dissatisfaction by a wide range of individual Soviet scientists-technologists—frequently surprisingly frank expressions. Discontent in various guises has also been increasingly evidenced in Soviet professional journals and other media. For the most part the target is failure to fully use the potential of science and technology. But within this general line of attack a sub-theme has emerged. This is the need for what Sakharov calls "democratization": for greater freedom of Soviet scientists-technologists to engage in interchanges with their fellows abroad; for greater mobility among scientists and technologists within the Soviet Union itself; and, above all, for a greater and more decisive voice for scientists and technologists—as such, rather than as party or government funtionaries—in the country's decision-making processes.

The Soviet regime has tolerated expressions of discontent among scientists and technologists. It has even encouraged such expressions when the concern has been, or appeared to be, greater efficiency. It has not, as far as one can tell, even taken any sort of punitive action against Sakharov for his extraordinary utterances. But the regime has only tolerated, not responded. It has stuck tight, and across the board, to the fundamentals of the system that is being criticized.

"The system." To the Soviet regime, and indeed to the nation at large, the name of the game in space has been "the system," not scientific and technological excellence as such. "Victorious socialism" made possible the triumphs of the sputniks. Capitalism was "much too narrow" to accomplish such feats. The whole world could see that "socialism must triumph over the decaying system of yesterday." Reversing the traditional slogan, they said, "Let the capitalist countries catch up with our country if they can."

Soviet exuberance over the success of the Soviet system in opening the space age cannot be discounted as mere propaganda, although it proved extremely effective as propaganda. An unmistakable ring of genuine belief has been evident throughout the chorus of self-praise. For the first time the Soviets had something concrete to which they could point in support of their claims of superiority. While events in space of the last few years have clearly knocked some of the boastfulness out of Soviet leaders, nothing from the Soviet side suggests any lessening of the basic assurances regarding the correctness of their way of doing things that they drew from their space triumphs. There is less conviction that the American system is breaking down as the Soviet system goes forward, but no less conviction that the Soviet system is inherently superior and will, if fully and effectively utilized, ultimately triumph over its rival.

How has the Soviet system actually worked for the space program? Hardly a whit differently from the way it has worked since Stalin's day for other major projects in high-priority areas.

On the one side we find:

1) The best in the way of material and human resources that the country can provide or that can be obtained from abroad.

2) Highly favorable work conditions for those engaged in the program.

3) A large measure of individual and collective freedom in pursuit of inquiries and with respect to initiatives (the dialectic has long since been stopped at the edge of crucial enterprises).

4) A free flow of needed information within and from without.

5) Flexibility and adaptiveness in problem solving.

6) Prestige and privileges for the scientists-technologists involved, comparable to those enjoyed at the highest level of the ruling caste.

On the other side we find:

1) Policies set, decisions made, priorities established, and resource allocations determined arbitrarily by the party-government establishment, with participation of scientists-technologists only as they have attained status and authority as party-government officials.

2) Work done mainly within the confines of artificially erected space and defense compounds.

3) No regard for public opinion and no popular involvements.

4) The ever-watchful eye and total authority of an all-powerful and all-pervasive Party apparat.

5) Above all else, the mania for secrecy.

6) No professional interchanges between scientists-technologists in the space and nonspace fields.

7) No exchanges with foreigners.

8) Compartmentalization of planning, work, and information, wherever possible within the endeavor itself.

9) No public discussions or revelations about what is going on in the program, what it is all about, the names

of individuals involved at even the highest levels, participating organizations, the location of operations or launch sites, future plans, costs, technical discoveries, research and development efforts and results, or anything else except successful missions.

But can the system continue indefinitely to operate in so authoritarian a fashion? What of the restiveness of the Soviet scientists-technologists who are in part regimented within the space and space-related programs and in part excluded from any contact with them? Have not resentments built up to a point where the regime will have no choice but to yield to the "democratization," or the shared rule, that Sakharov, and doubtless others, would like to have?

Unfortunately, the evidence suggests that the number of dissidents among Soviet scientists-technologists is relatively small, and that the nature and scope of their dissatisfactions are not such as to motivate significant activist efforts toward change. And certainly the evidence does not justify the expectation that scientists-technologists as a group have either the will or the ability to mount effective pressures on the regime.

A leading Soviet intellectual, Andrei Amalrik, has written pointedly to this issue. Although bent upon presenting as sweeping an array as possible of the weaknesses of the current regime and its system, and the dire consequences likely to follow, Amalrik virtually dismisses the significance of oppositionists. "Much of the overt and covert protest in the Soviet Union," he asserts, "has the character of the dissatisfaction of a junior clerk with the attitude of his superior." He judges that "the vital elements of Soviet society are about as opposed to any real change in the existing order as the ruling elite itself, although for different reasons" (*9*).

With respect to the United States, Sidney Hyman's thoughts, cited above, about the nature and effects of "the new world of collective mental effort" seem to us far more appropriate to the Manhattan Project than to the space program. The A-bomb effort was indeed carried on by a "society within a society." Evidently also it did result in something of a "new elite brotherhood" that has sought both to perpetuate itself and to gain, on the basis of its superior insights, a special place for itself in the shaping of public policy.

There was a period during which it appeared possible, perhaps even likely, that the U.S. response to the Soviet space challenge would take a form that would involve a break with our traditional way of doing things under our representative-democratic system in favor of a forced-draft, Soviet-like authoritarian effort. Spurred by the alarms raised by the first Sputniks, and particularly by the first Soviet manned space flight, insistent voices throughout the nation and in the Congress demanded a "suspend the rules and get on with the show" crash program on the order of the Manhattan Project. Congressman James Fulton reflected something of a national mood when he asserted, after Gagarin's flight, that he would "work the scientists around the clock and stop some of the WPA scientific business." So did Congressman Anfuso of New York in proclaiming, "I want to see our country mobilized to a wartime basis because we are at war; I want to see our schedule cut in half; I want to see what NASA says it is going to do in 10 years done in 5."

National Aeronautics and Space Act. The majority of Congress, backed by the Administration, rejected, however, a privileged effort that would have involved bypassing regular legislative procedures and controls. The Manhattan Project had been all very well and good, in view of wartime needs. But once was enough. The Congress, in adopting the National Aeronautics and Space Act, refused the panic-button approach. The Act itself reflected the operation of the representative process at what could be called its best, and provisions of the Act subjected space activities to continuing congressional control in accord with long-established processes. Regular reports would be submitted by the space agency; there would be annual authorization and appropriation of funds; special committees and subcommittees would exercise continuing oversight of the program as a whole and the various elements making it up. The program, except for sensitive military components, would be conducted entirely in the open, continuously within public view.

The Act left the way open for NASA to adopt, if it should wish, a Manhattan-Project-type organizational approach—that is, to bring together in a single monolithic government organization the scientists, technologists, and other skilled and unskilled workers needed for the program and to sequester, for its exclusive use and control, requisite industrial resources. NASA deliberately rejected this course. It decided to spread the NASA job over as wide a range of existing resources and institutions as possible. It would rely on industries operating in their regular ways, and on universities, with their personnel working, on campuses or at campus-related laboratories, in accord with their own norms and continuing with their regular academic activities.

Something more, however, than the usual governmental contractual system, with its reliance on legal and accounting mechanisms, would be used to insure that the space jobs were done as they needed to be done. First, NASA built up an in-house scientific, managerial and engineering capability that enabled it to plan and administer, to watch over and assist the research and development and production being done on the outside. In its laboratories, regional centers, and headquarters it maintained the competence to speak and understand the language and thinking of those on whom it relied, to know as much about the problems they were dealing with as they did, to check and supplement their work in its own laboratories, to step in with the necessary specialists when this was required, and, in some cases, to help untangle snarled situations (*4*, p. 43). Second, NASA has taken advantage of legally permitted exceptions to standard contracting and patent procedures, and of special provisions of the Aeronautical and Space Act itself, to insure that its contractees—industry and the university—benefited from their space work to a degree commensurate with their contributions.

In these and other ways, the space effort represented a new sort of partnership between government, industry, and universities—a partnership that has benefited and strengthened each of the participants without impinging on their interests and integrity.

Whatever one may think of the wisdom and value of the U.S. space program as a national venture, any objective observer must concede that it has had an important result: It has given a convincing answer to those who question "the capacity of the democratic, representative systems of government to cope with the problems raised by the scientific revolution" (*10*). It is difficult to conceive of a requirement's being raised by the scientific revolution that will exceed the space venture in complexity, involve greater unknowns and uncertainties, be more dependent for success on the mysteries of science

and advanced technology, or require a larger degree of faith and trust on the part of the people and their elected representatives. The space job has been successfully carried out through the workings of the representative systems and without damage to the basic institutions and long-term values of the American system.

Impact on the national economy. Because of the way in which it has been operated, the Soviet space effort has so far had less impact on the national economy, and on society generally, than the U.S. effort has had.

One of the massive ironies of the U.S. and Soviet space experiences is admirably summed up by a sentence from *The Economist* of 8 February 1969: "Looking at the Russians' achievements in space, one finds it hard to believe that one of their obsessions at home is with the technological gap between themselves and the United States, and how to close it."

In relating their space successes to the presumed superiority of their system, Soviet spokesmen have thought in terms of a two-way street. The socialist system, or the socialist mode of production, because of its unique characteristics made possible the space successes; at the same time, the socialist mode insured, in a way impossible for the capitalist mode, that the scientific and technological achievements that went with the successes would redound to the general benefit of the economy and would spark an overall advance of Soviet society in all its parts. The matter was succinctly stated in the Party Program adopted at the 22nd Party Congress in October 1961:

> All in all, capitalism is increasingly impeding the development of the contemporary productive force. Mankind is entering a period of scientific and technical revolution. . . . But the relations of production under capitalism are much too narrow for a scientific and technical revolution. Socialism alone is capable of effecting it and applying its fruits in the interest of society. . . .

Soviet successes in space served as the takeoff point for exultant Soviet predictions of the late 1950's and early 1960's that the U.S.S.R. would surpass the United States in various categories of production, in per capita terms, within a specified and astonishingly short span of years. Because of the same technological competencies that had enabled the Soviets to outdistance the Americans in space, Khrushchev boasted in 1959, they would surpass the Americans in "the per capita production of meat, butter and milk" within "two or three years," and in area after area after that. Such grandiose claims were raised to the level of dogma in the Party Program of 1961.

The implicit promise of these pronouncements was that the Soviet regime, through its command system, could and would bring about a transfer of the scientific, technological, organizational, managerial, and other advances incident to space and space-related activities to the needs of society generally. The trouble with the promise was that, as a practical matter, the Soviet leadership until quite recently was not particularly concerned with concrete domestic benefits from the space effort. The conquest of space as a feat in itself, and as a demonstration of the high level of Soviet science and a guarantor of a leading place for Soviet science in the world of the future, appeared to be sufficiently important to justify the effort. In practice, then, the space program, with its all-pervasive secrecy, has tended to strengthen the traditional compartmentalization of the Soviet economic system, and thus to raise, rather than lower, the barriers against the diffusion of knowledge and technology.

Computer technology, The Soviet space program, like the American, has been dependent on a rapidly advancing computer technology. Yet Soviet sources have frankly revealed continuing grave shortcomings in computer technology and hardware available for use in the economy as a whole. Party boss Brezhnev singled out for special emphasis at the 1966 Party Congress "the poor use of electronic computers" in production and in scientific research. Three years later *Izvestiya* reported that "plants, ministries, and scientific research organizations are clamoring" for computers, and urged that their output be increased three- to fivefold. It also reported an acute shortage of specialists able "to develop new computers and use them competently" and concluded that "the situation for computer technology is rather grave and merits comprehensive discussion." Also, in 1969, A. M. Rumyantsev, vice president of the Academy of Sciences of the U.S.S.R., cited the lack of computer resources as a factor inhibiting long-term planning for Soviet science: "There is no developed theory for such planning, no appropriate economic-mathematics, and, finally, no essential electronic computing and informational system." And in October 1969, *Pravda* reported that Soviet higher and technical schools were setting up, *for the first time*, courses to train "specialists in automatic systems of control, construction and production of computing apparatuses, applied mathematics, and automated production and distribution of electricity." (Reportedly a group of Soviet scientists recently told the top leadership, "As for the use of computers in the economy, here the gap [between U.S. and Soviet achievements] is so wide that it is impossible to measure it. We simply live in another epoch.")

Secrecy versus dissemination of results. Soviet scientists and technologists not directly engaged in the space program have neither first- nor secondhand knowledge of technical discoveries and innovations effected in the program. They do not know with any exactness—much less have available for their own use—the research tools and techniques employed. When commenting on space achievements and prospects, the run-of-the-mill Soviet scientist generally has to draw on U.S. or other Western sources rather than on Soviet sources. Evidently, also, there is no flow of information about new materials and new products from the space program into the mainstream of Soviet economic life. Generally, the situation, as in so many other instances in the Soviet Union, is one of two self-contained and contrasting worlds existing side by side.

The advantage the United States derives from the openness of its space activities and the spread of space tasks over the spectrum of U.S. competencies and the consequential opportunities for a free flow of the results into the marketplace is obvious. Even more important, however, is the fact that the built-in purpose of the U.S. space program—first, in terms of the Space Act itself and, second, in terms of NASA policies and operating procedures—to promote actively the dissemination and utilization of space-generated technologies to the advancement of the general capabilities and well-being of the nation, has no parallel in the Soviet Union.

An excellent illustration is provided by the situation in higher education. There was a time when it was assumed in this country that Soviet advances in space and education went hand in hand—were, as a matter of fact, two aspects of the same thing. Yet, on 1 September

1969, *Pravda* discussed plans for the upcoming academic year—that is, the current academic year—in terms which indicated that there had so far been, on the one hand, little relationship between (i) training and research activities in higher educational institutions and (ii) requirements of programs involving the use of advanced scientific knowledge and technology, and, on the other, little impact of such programs on course offerings and course content, on expertise and interests of faculties, on the focus and techniques of research assignments and activities, or on instructional and research materials and tools within higher educational institutions. Similarly, extensive commentaries in the Soviet press regarding current deficiencies in the area of Soviet science and technology heavily emphasize the low level of performance and the general lack of usefulness of the work being done by university faculties and in research institutes connected with universities and higher specialized schools.

Certainly nothing has happened in the Soviet Union that compares with the interchange of knowledge and resources between the government and industry, on the one hand, and universities, on the other, in connection with the American space program. Also, there is nothing to compare with NASA's deliberate effort to expand and strengthen the capabilities and resources of American universities in areas related to space science and technology. This effort has included support of doctoral training for several thousand scientists and engineers; support of training and research programs looking toward furtherance of the interdisciplinary approach; support for construction of new laboratories and other facilities on university campuses for research and training in the aerospace sciences; encouragement and support of research by graduate students and faculties in NASA laboratories and regional centers; and pressures to secure the integration of work being done on space projects at university campuses and regular training and research programs.

Also, NASA's well-rounded and imaginative program to foster and facilitate the dissemination and utilization of new processes and products, the new scientific knowledge, and the new managerial technologies developed in the space program has no parallel in the Soviet Union. The Soviets have a system for surveying world scientific and technical literature and for abstracting and publishing the results. They also have a system—or rather some 60 separate systems for different branches of the economy—for identifying and disseminating significant published and unpublished items of scientific-technical information. Neither of these systems, however, encompasses information from the space-military sector. This is, of course, in sharp contrast to the elaborate and steadily growing system developed by NASA to store and retrieve all scientific and technical information produced in the U.S. space program and to facilitate its movement to potential users throughout the economy by means of various abstracting and reporting services.

The Soviets themselves are evidencing increasing agitation over their inability to match the United States in transferring "great prestige" and "great accomplishments" in science and technology to meet the general needs of society. Peter Kapitsa sounded the keynote in a report to the Academy of Sciences of the U.S.S.R. in December 1965:

> . . . We must quickly find a way for overcoming the lag [of Soviet science behind American science]. If in the near future we will not increase the labor productivity of our scientists, will not improve the conditions for assimilating by industry the achievements of science and technology, then the problem of catching up with America, of course, cannot be solved. If we decisively and capably utilize the great advantages our socialist system provides in organizing our science and industry, then this lag in growth will only be a temporary hitch.

There has subsequently been both intensive discussion of the issues involved and mounting concern on the part of the post-Khrushchev leadership. A Party-Government decree in October 1968 reorganized the Soviet structure for administering scientific and technological affairs in the economy as a whole and introduced material incentives for scientific workers. The directing and coordinating authority of the State Committee for Science and Technology was greatly strengthened, but there was no indication that its jurisdiction was extended into the closed and militarily oriented preserve of space. How effective the reorganization has been remains to be seen. As recently as December 1969 the journal *Voprosy Filosofii* lamented: "Regrettably it is necessary to admit that today we know much more about the problems which must be solved for raising the effectiveness of scientific activity than about the means for their solution. . . ."

Priorities. Regardless of whether the Soviets can solve their knowledge-transfer problems, their space program, in growing contrast to the situation in the United States, clearly retains top priority in terms of the availability of human and material resources.

In all the public discussion regarding science and technology in the Soviet Union, no finger has been pointed at the favored position of the space program, or at the way it is run, as a source of difficulties. Although the situation may be different on the inside, public statements give no indication of pressures similar to those in the United States for a diversion of funds from the space effort to other requirements, or for results from the effort other than continued progress in the space arena itself. The overall feeling evidently is that, despite the transfer problem, the Soviet Union, and indeed Soviet science and technology as a whole, is reaping great benefits from space accomplishments. As for the running of the program, the very fact that the compartmentalized management system has yielded such great successes in the past —and is relied upon to regain Soviet leadership in the future—has doubtless contributed to the regime's reluctance to take effective action to bring the program and its potential into a closer relationship with the rest of the economy. This may well continue to be the case indefinitely, since, under the Soviet system, major state objectives are ends in themselves, not to be jeopardized by lesser considerations.

It appears that, rather than tamper with the space program, the Soviet leadership will rely principally on stepped-up investments to get the greater "productivity" from science and technology that it is seeking. Despite current complaints about shortcomings, the general line in the Soviet Union is that investments in science and technology yield greater returns to the growth of the national income than any other form of investment. *Ekonomicheskaia Gazeta* estimated in July 1968, for example, that "expenditures on science and the assimilation of its results are approximately 3.5 times more effective than the usual capital investments." Over the past 10 years the rate of increase in expenditures on science and technology has been greater than

the rate of increase in expenditures in any other area. Authoritative statements indicate an intention to increase expenditures even more rapidly within the next few years—in fact, by a factor of about 3 during the 1970's.

The outlook for the United States is uncertain. For several years—since fiscal 1966, as a matter of fact—the trend has been steadily downward for expenditures on the space program, and more recently sharp reductions have been signaled for other areas of research and development, including reductions in the support of advanced training of personnel. Basic to all else, the prevailing national mood seems to be moving strongly against investments for the future in favor of maximum utilization of resources for the immediate betterment of conditions of life.

Conclusion

This raises a fundamental question about the management, in its largest sense, of the U.S. space program and the other activities undertaken in response to the Sputnik experience. Has the whole operation represented but another highly successful one-shot exercise in crisis management, or has it represented incorporation into American society of a new way to organize, systematically and purposefully, the development and use of scientific and technological resources to the furtherance of national goals? It is too early to discern the answer to this question. But how it is answered will heavily weight any final appraisal of the comparative results of the U.S. and Soviet space programs.

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NEWS AND COMMENT

Science under Nixon: Influence Has Declined in National Affairs

The scientific presence in Washington that grew up after World War II was never so potent as alarmed political traditionalists made it out to be; nor was it ever so unheeded and abused as many scientists made it out to be. But a look into science's Washington outposts after 2 years' absence quickly confirmed my impression that, however powerful the community may once have been in national affairs, 20 months under Nixon have inflicted upon it a gigantic loss of influence, visibility, and confidence. The decline, of course, can be dated from budgetary restraints under Lyndon Johnson and the frost that developed between his administration and the universities. But Johnson, as legislative architect of the space program, beneficiary of cardiac therapy, and self-styled "teacher-president," at least partially subdued his political instincts and created the impression that, however erring scientists might be in opposing the war, he at least saw an indispensable value in their profession. The recognition did not show up in the form of the continuous financial growth that researchers had become accustomed to in the postwar years, but budgetary disappointments were at least accompanied by requests for patience and expressions of sorrow from the White House.

The difference under Nixon, of course, is that, despite a few cordial words now and then, there is little to suggest that the President accords scientific activity any special or privileged role in national life, and there is a good deal to suggest that the President, as well as many of his closest advisers, regard the scientific community as having succeeded in making unwarranted claims on national resources and political sympathy.

Perhaps the first clue to this attitude came when the White House vetoed the appointment of Franklin Long as director of the National Science Foundation (NSF) after it was noted that Long was on record as opposed to the development of an antiballistic missile system. The ensuing outcry against political screening of this normally apolitical post (Alan T. Waterman, after all, was appointed NSF director by Truman, served under Eisenhower, and retired after 2 years under Kennedy) led to Nixon's making a formal apology befor the National Science Board. But it should be noted that the veto was instinctive—the apology, calculated.

Both calculation and instinct, however, are to be found in a minor footnote to the early days of the administration, when Nixon circulated to his staff a paper, "Alienation and Relevance in Higher Education," by S. J. Tonsor, of the University of Michigan. Underlined and with marginal notes in the President's own hand, the paper was accompanied by a covering memo that said that Tonsor's views reflected his own and would be reflected in the administration's dealings with higher education.

Proceeding from the thesis that "the most important problem which higher education faces today is the wave of irrationality and anti-intellectualism which has caught up large numbers of both students and professors," Tonsor went on to express doubt about the suitability of much research on campus. "The only sound test," he wrote, "is whether or not research enhances or diminishes the primary teaching function of the university. And it must be confessed that in spite of the brave talk to the contrary and considerable administrative legerdemain, research has become the tail which in many instances wags the dog. Faculty members on fractional appointments who spend the greater part of their time in other than teaching activities distort and confuse the educational purposes of the