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Planetary Contamination II: Soviet and U.S. Practices and Policies

Quarantine can be neither absolute nor unilateral; U.S. policy should acknowledge Soviet practice.

Bruce C. Murray, Merton E. Davies, Philip K. Eckman

In the accompanying article (page 1501), Horowitz, Sharp, and R. W. Davies have examined the COSPAR recommendations in the light of new environmental knowledge of the surface of Mars. We now wish to examine the matter from a different point of view: How similar, in fact, are U.S. and Soviet practices and policies? And, what is the likelihood that viable terrestrial microorganisms have already been transported to Venus and Mars as a result of these practices?

We shall show that U.S. and Soviet policies differ completely. The United States continues a strict interpretation of the COSPAR agreement despite past burdens and formidable cost and lead-time implications for its future programs. The Soviets, on the other hand, who attempted entry capsule missions at least 5 years before the United States, have adopted less stringent measures —partial sterilization procedures and modest risk of unintentional impact by other elements of the spacecraft system.

We conclude that Soviet practice has already led to the transfer to Venus, and probably to Mars, of a considerable number of viable terrestrial microorganisms (*1*). Thus, both the COSPAR recommendations and current U.S. planetary quarantine policy should be reviewed and modified to reflect the probability of such transfer.

U.S. Actions and Stated Policies

The NASA planetary quarantine policy became formalized at the end of 1960 and was applied initially to lunar probes. However, technical difficulties with sterilization of the first three Ranger probes launched toward the moon were accompanied, in late 1962, by abandonment of sterilization requirements for the remainder of the Ranger program. Sterilization procedures were also abandoned for the Surveyor lander program, except that "clean room" assembly practices were retained (*2*). These actions were justified on the basis that (i) heat and other kinds of sterilization had resulted in a significant reduction of the reliability of spacecraft, and (ii) the surface environment of the moon was felt to be sufficiently hostile to preclude propagation of any form of terrestrial life.

United States quarantine policy for planetary flyby probes was also modified in late 1962 sufficiently to provide that the probability of landing one or more viable terrestrial microorganisms with either spacecraft or final-stage booster should be less than 10^{-2} for Venus and 10^{-4} for Mars. The application of this quarantine policy to the 1962 Mariner flyby spacecraft launched toward Venus does not appear to have influenced its reliability or its objectives. That spacecraft was not heat-sterilized, nor was the initial aiming point biased away from the planet (*3*).

The Mariner flyby launched toward Mars in November 1964, on the other hand, was initially aimed 600,000 kilometers away from Mars, although the final aiming point was to be only 10,000 kilometers from Mars (*4*). A precise midcourse trajectory correction was then carried out to bring the spacecraft close to the nominal targeting point beside the planet. The a priori calculated probability that this procedure would result in impact on Mars of the unsterilized flyby vehicle was 6.1×10^{-5}, within the 10^{-4} requirement referred to above (*4*). The trajectory requirement placed on the Mariner mission to meet the U.S. interpretation of COSPAR recommendations required additional resources to execute an already high-risk project (*5*). The only future U.S. Mars venture firmly under way at present, the 1969 Mariner flyby, is required to meet the more recent 1966 constraint of a probability of impact of less than 3×10^{-5}.

The quarantine constraint has been set an order of magnitude lower for the 1967 Mariner Venus flyby, a value reflecting the inferred lower probability of contamination of Venus because of anticipated high surface temperatures (*6*). This latest U.S. Venus policy does illustrate that the United States can

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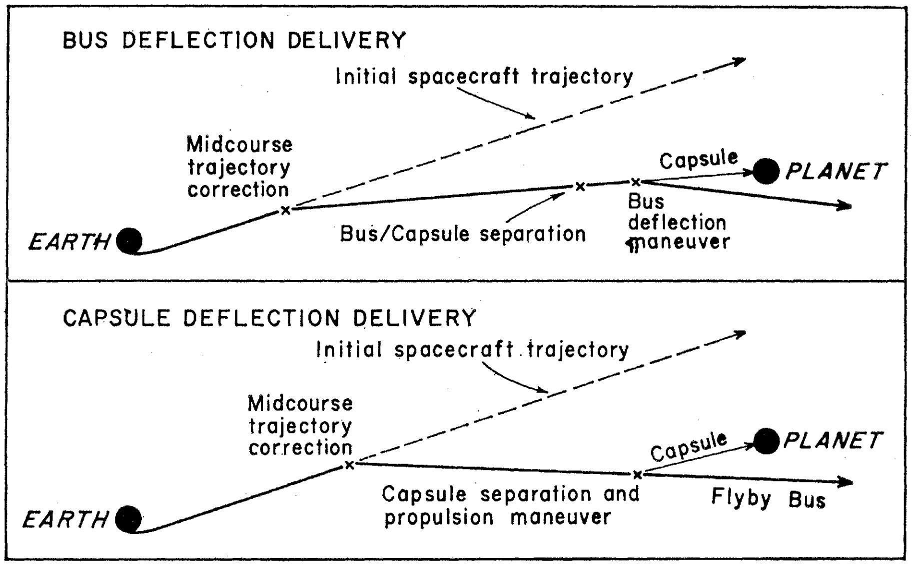

Fig. 1. Capsule delivery techniques.

reinterpret the COSPAR recommendations in light of changing environmental information.

Despite high priority in NASA planning as early as 1962, the U.S. has not yet attempted to deliver a capsule into the atmosphere of Mars or Venus; such a venture is at present under serious consideration for Mars in 1971 and 1973 and is included in future plans for Venus in 1972. Studies of the 1964, 1967, 1969, and 1971 (*7, 8*) opportunities illustrate U.S. quarantine policy regarding such a capsule mission, and reveal significant differences between this policy and Soviet practice on similar missions.

One clear-cut difference is a difference in attitude toward bus-deflection and capsule-deflection delivery techniques. As illustrated in Fig. 1, bus deflection involves placing the flyby bus and the capsule on an impact trajectory with the planet at the time of the midcourse trajectory correction maneuver, mechanically separating the capsule from the bus some days before arrival, and then deflecting the bus away from impact by means of the same maneuvering system that has already performed the midcourse trajectory correction maneuver. Capsule deflection, on the other hand, involves supplying the capsule (near encounter) with the necessary velocity increment for impact while the flyby bus continues on its original non-impact trajectory. In this mode, there is no requirement for a terminal maneuver by the bus. However, the capsule must contain its own small rocket motor and propellant, and it must be pointed accurately while still joined to the flyby bus. Generally, if the capsule lacks an independent stabilization and orientation system, there is a requirement for the capsule to be "spun-up" before separation from the flyby bus, and it must separate in such a way as not to damage the flyby bus during ignition of the capsule rocket. Bus deflection is simpler and generally preferable, from an engineering point of view, for first-generation capsule missions, particularly if resources are limited. The primary advantage of capsule deflection is that, in case of total failure of the flyby bus *after* the midcourse trajectory correction and *before* encounter, the unsterilized flyby bus will not impact the planet, as would be the case with bus deflection.

One means of circumventing the quarantine-based objection to bus deflection and yet permit use of the simpler and less costly technique would be to carry a failsafe abort rocket aboard the flyby bus. A self-contained timing system would be set to ignite the abort rocket automatically before the encounter unless an overriding command were sent from Earth. Hence, if the terminal maneuver failed, or if control of the flyby bus were lost after the bus had performed its midcourse trajectory correction, the flyby bus automatically would be deflected off the impact trajectory by the impulse from the abort rocket. If the terminal maneuver were successful, then, of course, a command would be sent to override the timer on the abort rocket. Such an approach was first suggested for a proposed 1964 Mars capsule mission, and was analyzed in exhausitve detail in a study of a possible 1969 Mars capsule mission (*8*). This analysis demonstrated that incorporation of the abort-rocket approach could reduce the probability of accidental impact of the planet by an unsterilized flyby bus to a level compatible with the COSPAR recommendations. Yet the "climate of opinion" at that time must have been especially conservative regarding the bus-deflection approach, inasmuch as R. W. Davies [who, incidentally, introduced the concept of numerical sterilization standards (*9*, p. 495)] concluded (*8*):

> . . . perhaps the most difficult problem is that of convincing people and demonstrating that the Mars contamination constraint can be satisfied with bus deflection. . . . A more elaborate analysis and design study is certainly required and will be more mathematically convincing. Nevertheless, it will be very difficult to ever prove the quoted reliability. Not only is the combined environment impossible to duplicate on Earth, but the number of tests required to statistically prove the system reliability will be so large that the cost and time required would be prohibitive. One might be tempted to rule out the entire concept on this basis, but it should be remembered that all aspects of the sterilization program are hampered by the same problem. No one will be able to *rigorously* prove that a given heat sterilization cycle will sterilize a given lander capsule to the required level. It will always be necessary for reasonable men to make reasonable assumptions, extrapolations, and calculations from a limited body of knowledge and experience in order for Mars exploration to take place at all.

Insofar as we are aware, none of the subsequent studies of later Mars missions have included bus deflection as a possible alternative. In effect, U.S. evaluation of proposed Mars capsule missions has reflected quarantine criteria more stringent than those recommended by COSPAR. It is likely that this attitude has contributed to, but is not solely responsible for, the postponement of a U.S. capsule mission, particularly in the case of the 1969 Mars opportunity.

The most ambitious concept of the future U.S. program for unmanned planetary exploration is organized around the proposed use of Saturn 5 vehicles to launch large, multiple payloads toward Mars, and eventually Venus, in order to carry out complicated scientific experiments, especially chemical and biological ones directly on the surface. Present U.S. policy guidelines continue to require complete heat sterilization of the entire lander system—retropropellant, electronics, power supply, and so on. Inasmuch as many essential components at present will not perform reliably after heat sterilization, an entire new technology of heat-sterilizable spacecraft components, sterile assembly, and launch operations must be developed if Voyager landers are ever to become a reality under present U.S. quarantine policy.

Some efforts in this direction have been under way for the last several years, but the main costs still lie ahead. The cost for heat-sterilizable landers is not yet known, but it will be considerably greater than the cost would be if heat sterilization were not required (perhaps half again as large).

In addition, planetary program lead times are lengthened even further because of an extra test phase for sterilization—both for components and for entire systems—and the development of special facilities (see Fig. 2). For instance, NASA has indicated that major spending must start in the second half of the 1967 calendar year if a Voyager lander mission in 1973 is to be carried out. There can be little doubt that both the cost and the time scale for Voyager will be considerably increased because total heat sterilization remains U.S. policy (*10*).

In summary, U.S. policy for Mars continues to require total sterility of entry bodies, and therefore complete heat sterilization. Nonsterile bodies must be targeted and maneuvered in a manner to keep their probability of impact below 3×10^{-5}. This policy has placed certain additional burdens on U.S. flyby missions. Postponement of U.S. attempts to perform even simple Mars capsule missions can be partly attributed to this policy. Much more serious are the implications of total heat sterilization for the cost and lead times of the more ambitious Mars and Venus lander missions, such as those currently being planned in the Voyager program.

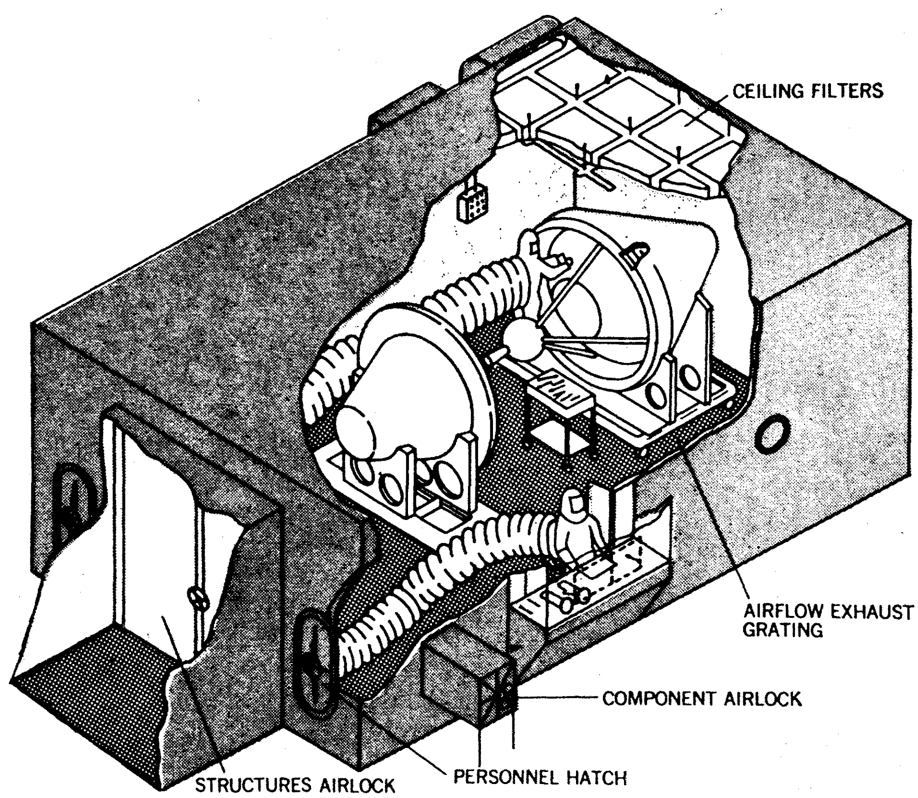

Fig. 2. One concept of a special facility required to heat-sterilize and provide access to a moderate-sized lander. The spacecraft would be placed in a sealed container and could not be removed from the container before launch without having to go through the heat-sterilization cycle again. Access for test, adjustment, and repair could only be effected by the "human glove box" shown. [Reproduced, with permission, from an article by H. G. Lorsch which appeared in the November 1966 issue of *Space Aeronautics*.]

Soviet Practice and Implied Policies

To understand Soviet quarantine policy, it is helpful to examine the Soviet planetary missions (*11*) in the light of the decisions faced by the U.S.

It is now clear that (i) Soviet flyby spacecraft are not intentionally biased away from the intended aiming point; (ii) bus deflection rather than capsule deflection is used; and (iii) no abort rocket capability has been provided. As a result, a Soviet flyby bus impacted Venus in at least one case, due to total failure just before terminal maneuver. There is a significant chance that Mars similarly was impacted by an earlier Soviet flyby bus. These flyby busses certainly were not heat-sterilized, although they may have been subjected to other sterilization measures. Furthermore, the capsules intended for planetary entry apparently have not been completely heat-sterilized either.

It is evident that Soviet practice differs significantly from U.S. practice regarding planetary quarantine. Either the Soviets believe that partial heat sterilization, combined with gaseous sterilization and other nondestructive techniques, actually satisfies the COSPAR recommendations or else they have concluded that those recommendations, if taken literally, are so severe as to preclude serious planetary exploration at present. Official Soviet releases and technical articles, and especially the detailed Soviet description of the recent Venus 2 and Venus 3 flights, afford ample evidence of the Soviet Union's less stringent quarantine practice regarding that planet (*12*). It is also possible to assess their practice regarding Mars, as is shown below.

The Soviet automatic space station Venus 2 (Fig. 3) was a photographic flyby virtually identical to the earlier Soviet photographic flybys, Zond 3 (1965) and Mars 1 (1962) (*12*, p. 8; *13*). The Soviet description of the flight *12*, pp. 12, 14) states,

> The "Venus-2" station was launched on November 12, 1965, with the objective of flying past close to Venus. To do so it was necessary to ensure that it flew past Venus from the side illuminated by the Sun at a distance of no more than 40,000 kilometres from its surface. . . . The processing of the trajectory measurements made after the station was put into interplanetary orbit, showed that the "Venus-2" trajectory was close to the one estimated. The minimum distance of its flight past the planet would be 24,000 km. from the surface and it would pass over the illuminated part of the planet. Thus, the conditions of the fly past fully met the requirements and there was no necessity to correct the "Venus-2" trajectory.

This procedure is to be compared with the intentional initial trajectory bias of Mariner 4 of 600,000 kilometers away from Mars. The next U.S. Venus flyby in 1967 will also be biased away from the nominal aiming point near the planet, because of U.S. quarantine policy.

Although preliminary Soviet press releases (*14*), stated that Venus 3 carried somewhat different instruments and would pass on the side of the planet opposite to that on which Venus 2 passed, after the encounter the Soviets revealed (*12*, p. 9) that there was actually a much more significant difference; the "special compartment" (see Fig. 3), instead of containing the Venus 2 camera and film system, was a

> detachable vehicle in the form of a sphere with a diameter of 900 millimetres. The surface of the sphere has a heat resistant coating which protects it against high temperatures during drag in the dense layers of the atmosphere of Venus. The detachable vehicle carries transmitters in the decimetre waveband which were designed to transmit to the Earth basic data on the atmosphere and the surface of the planet as recorded by the instruments. The landing on the surface is by means of a parachute system.

The capsule contained the Soviet emblem and a special survivable globe identifying the probe and the country of origin. In addition, "before launching, the detachable vehicle of the 'Venus-3' station was thoroughly sterilized, which is necessary in order to destroy all microorganisms of terrestrial origin and prevent the possibility of their transfer to Venus" (*12*, p. 9).

No other reference to sterilization was made in this article; therefore, by implication, it appears that the flyby bus was not sterilized because it was to be maneuvered to miss Venus. However, the last scheduled radio contact with Venus 3 was unsuccessful, as was the attempt 3 days earlier to contact Venus 2. As a result, the only reasonable conclusion is that the bus-deflection maneuver was not carried out and both the unsterilized flyby bus of Venus 3 and its sterilized detachable capsule impacted Venus on 1 March 1966, as shown in Fig. 4.

It now becomes important to know precisely (i) what is meant by the Soviet term "thoroughly sterilized" capsule, and (ii) to what extent clean room assembly and other partial sterilization measures were employed in the manufacture and preparation of the flyby bus. However, the Soviets have never specified what procedures were used on any planetary flight. The only indirect references we have been able to locate are two papers given at the COSPAR sessions in May 1966. In one (*15*) it is stated,

> To sterilize spacecraft physical, chemical and mechanical methods are used. Hot air and ionizing radiation find the greatest application. The method of filtration is also used, ultraviolet rays are employed in assembly shops.

The other reference (*16*) is somewhat more specific:

> At present a single sterilization method for sterilizing spacecraft as a whole cannot be used as the materials employed for spacecraft construction have rather different properties and the methods for sterilization have a different sterilizing power. To sterilize separate components, instruments and assemblies of spacecraft various conditions for dry heat sterilization can be recommended within the limits of from 115 to 200°C taking into account the thermostability of article materials. The sterility of some materials and articles (rubber, lubricants, radio-electronic apparatus) can be achieved by means of gamma rays at a rate of 2.5 million rad. The liquids utilized in spacecraft are sterilized by means of filtration through asbestos filters which are used in medical industry. The final stages of sterilizing the surfaces of a spacecraft is its sterilization effected by the gas method.

It seems clear from the above that the Soviets also find heat sterilization incompatible with reliable operation of some components, as U.S. designers have. Significantly, "radio-electronic apparatus" contained in the capsule of Venus 3 is sterilized by gamma irradiation. Perhaps this is how the problem of sterilizing batteries (which the capsule necessarily contained) was resolved, a problem which has been particularly vexing to U.S. engineers. Thus, from what the Soviets have disclosed on this matter, we are led to conclude that various sterilization techniques, rather than total heat sterilization, have been used to reduce the microorganism content as much as possible, consistent with available materials.

This, then, is presumably what the Soviets mean by the term "thoroughly sterilized." Under present U.S. policy, however, this does not constitute adequate procedure. It is clear that the Soviet Union and the United States are exploring the planets under different (self-imposed) ground rules.

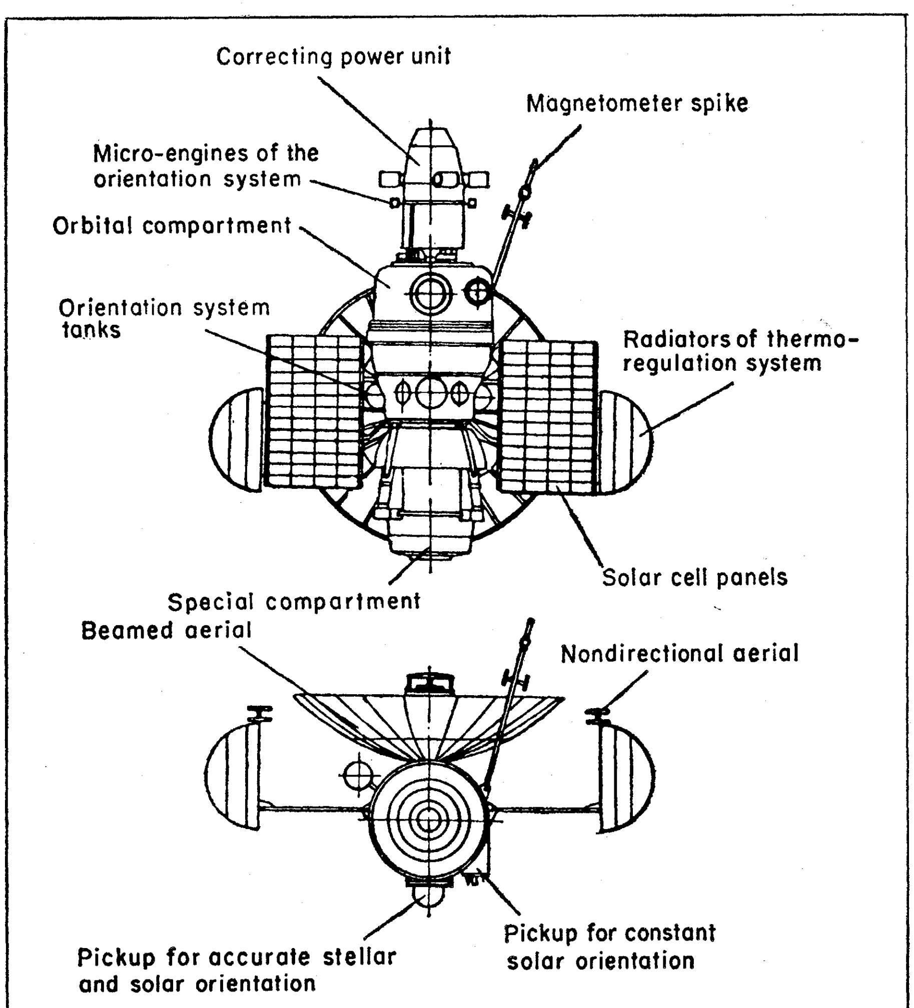

Fig. 3. Standard Soviet planetary spacecraft. This diagram is reproduced directly from the Soviet (English-language) description of the Venus 2 and Venus 3 missions of 1966. It is nearly identical to that released at the time of the Soviet Mars 1 flight in 1962.

What was the nature of the two remaining Zond probes which were launched by the Soviets? These were of the same type as the Venus 2 and Venus 3 probes, but the Soviets have never indicated whether they were photographic flybys or capsule missions. Zond 1 was launched on 2 April 1964, toward Venus, with an estimated flight time of 107 days (*17*). It made two successful midcourse trajectory corrections, the second on 14 May, 42 days after launch (*18*). Shortly thereafter contact was lost. By comparison, the flight time for Venus 3 was 104 days, and the midcourse maneuver was carried out 40 days after launch. It is possible that Zond 1 also was an attempted bus-deflection mission that failed, like Venus 3, and that Zond 1 may also have impacted the planet. Even the first Soviet planetary flight, on 4 February 1961, Venus 1, was intended to impact (*19*), although this spacecraft almost certainly did not actually hit Venus (*13*).

Zond 2 was launched toward Mars on 30 November 1964 and experienced some initial difficulties with its electrical power supply (*20*). However, six plasma engines used for stabilization were successfully tested, and "stable" radio contact was maintained for some time (*21*). The probe oriented itself properly with regard to the sun and the earth on radio command (*18*).

No midcourse correction was announced, although Jodrell Bank in England tracked the probe until at least the middle of February. At that time Bernard Lovell asked a leading Soviet scientist, M. V. Keldysh, who was visiting the United Kingdom, if the probe was indeed on a collision course, as the Jodrell Bank tracking data suggested. Keldysh indicated that the probe would miss Mars by 1500 kilometers, a distance which was within the range of uncertainty of the trajectory computation made at Jodrell Bank (*24*). This would suggest that a midcourse correction had indeed been effected by that time (about 77 days after launch). Radio contact was lost permanently on 4 May 1965 (*23*). Thus, two questions arise. Was Zond 2 a bus-deflection mission? Did Zond 2 impact Mars?

Analysis of the trajectory suggests that Zond 2 was indeed a capsule mission, because, unlike all other Soviet or U.S. planetary flights to date, the trajectory of Zond 2 was not selected to minimize injection energy out of earth orbit, or the communication distance, or total time of flight. Rather, it minimized the relative velocity of approach at Mars. These relationships are illustrated in Fig. 5. This appears to be a conspicuous clue to intent, because the very thin atmosphere of Mars poses the difficult problem of providing adequate atmospheric braking so that the probe will have time to transmit data before impact, or to reach terminal velocity in order to survive impact. Hence, it is essential for any Mars capsule mission to reduce relative approach velocity, even at the expense of reduced communication capability and increased time of flight.

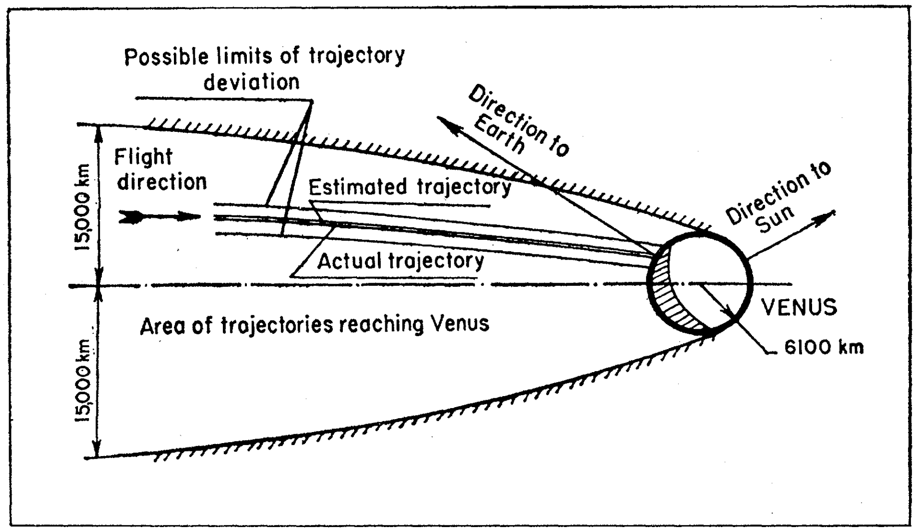

Fig. 4. Soviet illustration of the impact of the capsule-carrying spacecraft Venus 3 on 1 March 1966. There had been a loss of radio contact 3 days earlier, preventing the intended deflection of the unsterilized flyby bus away from the planet.

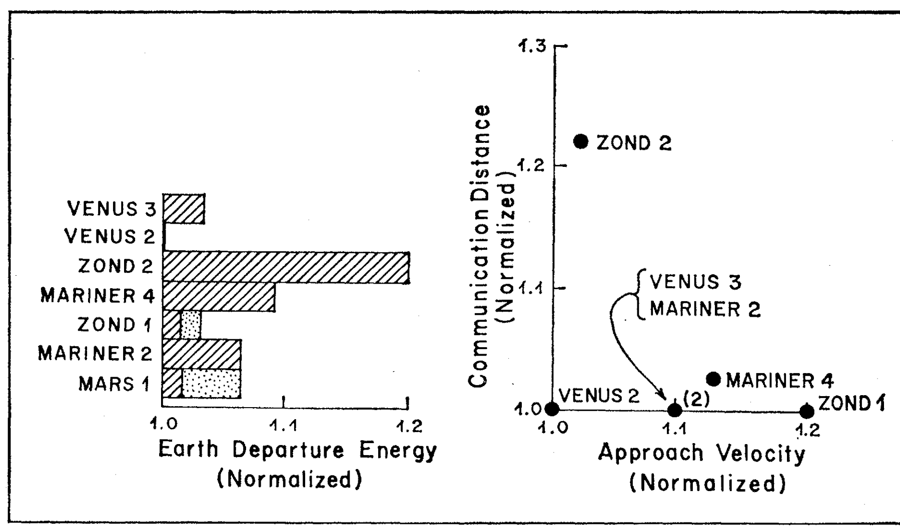

Fig. 5. Trajectory parameters of Zond 2. (Left) The normalized earth-departure energy (*vis viva*) of Zond 2 is compared with that of other planetary flights made to date. Normalization in each case is with respect to the minimum value possible during the launch window. It is apparent that the choice of the Zond 2 trajectory reflects some objective beyond simply traveling from Earth by the easiest route available. (The dotted part of the range for Mars 1 and Zond 1 indicates uncertainty in trajectory information.) (Right) the normalized communication distance and approach velocity for each mission are compared. Normalization is with respect to the minimum value possible for the actual launch energy employed for each mission. It may be seen that the Zond 2 trajectory differed from all others in the excessively large communication range. Since maximum information rate decreases inversely as the square of communication range, a significant penalty in communication capability was accepted in the choice of the Zond 2 trajectory. Unfavorable choices of Earth-departure energy and communication distance evidently were required by the need to reduce approach velocity to the minimum value possible. This is evidence of a planned attempt to eject a capsule into the atmosphere of Mars.

But what about Keldysh's reported statement that the probe would miss Mars by 1500 kilometers? As noted above, the Soviets initially announced that Venus 3 would "pass by" the planet, even though it was being placed on an impact course at that time. Thus, this statement about Zond 2 may have referred to the expected miss distance *after* the terminal bus-deflection maneuver was accomplished. Due to coverage and other photographic factors, it seems unlikely that the Soviets would have intentionally aimed a first photographic flyby of Mars so close to that planet. Mariner 4 passed about 10,000 kilometers from Mars, and Zond 3 passed about the same distance from the moon on its test flight. Venus 2 passed 24,000 kilometers from that planet. Even the second-generation Mariner Mars flyby in 1969 probably will not be aimed closer than about 3000 kilometers from Mars.

Since the Soviet Union has indicated that Zond 2 was of the Venus 2 or Venus 3 type (*12*, p. 8), it seems highly likely that Zond 2 was a capsule mission like Venus 3, especially in the absence of any plausible alternative explanation for the deliberate choice of minimum approach velocity. Although we do not know with any certainty that the midcourse correction was effected, the Jodrell Bank results indicate that this was probably the case; otherwise, the injection from parking orbit by the launch vehicle would have been of unprecedented accuracy. Thus we are led to the conclusion not only that Zond 2 was a capsule mission of the Venus 3 type but also that it failed *after* being maneuvered onto an impact trajectory with its planetary target.

This conclusion has profound significance for quarantine policy. J. O. Light (*24*) has shown, by use of the published trajectory errors of the Venus 2 and Venus 3 missions, that, if Zond 2 were a capsule mission of the Venus 3 type and did effect a midcourse maneuver, it almost certainly impacted Mars. Thus, as in the case of Venus, there is already a high probability that viable terrestrial microorganisms have been transported to Mars. Furthermore, the very basis of the COSPAR recommendation for Mars is undermined, since now there is a reasonable probability that the number of terrestrial microorganisms already transported to Mars greatly exceeds the total originally expected by COSPAR from all unmanned exploration in the next 20 years.

Conclusions

The accompanying article of Horowitz *et al.* concluded with the view that the COSPAR recommendations regarding Mars should be adjusted to reflect new environmental information. Specifically, it was concluded that viable terrestrial microorganisms which are transported to Mars inside solid components in sealed spaces have a low probability of being released to the surface or atmosphere, and that, if any are released, they are not likely to infect the planet. We suggest, in addition, that both the COSPAR recommendations and U.S. planetary quarantine policy should be altered to take into account past and continuing Soviet practice regarding the exploration of Mars and Venus. No amount of analysis by COSPAR, or of costly, self-imposed restrictions by the U.S. on its own planetary exploration program, can reduce the probability of contamination of either Venus or Mars below what the Soviets have already made it, or will make it as they continue their large planetary effort. All that U.S. policy can accomplish is to insure that U.S. efforts do not significantly increase the probability above that level. Any recommended policy which would require the U.S. to apply significantly more stringent restrictions is illogical in that, in effect, the U.S. would be asked to increase greatly the cost and complexity of its planetary program without achieving any significant reduction in the probability of actual contamination.

There exists some parallelism between the problem of planetary quarantine and that of radioactive fallout from atmospheric nuclear testing, although the desirable solution to the quarantine problem is not merely to stop all activity. Both are multilateral problems, and individual national policy necessarily must reflect the policy of other nations. Thus, the real questions that must be faced by COSPAR, and by the U.S., are, (i) What is the probable number of viable terrestrial microorganisms already transported to Venus and to Mars? and (ii) What is the total number to be expected in the next decade or so from foreseeable Soviet efforts alone? Then COSPAR can recommend, and the U.S. can decide, that the total U.S. contribution should be equal to some specified fraction of the total present and future Soviet contribution.

This approach in turn suggests that every effort should be made to induce the Soviets to supply additional details on the Zond 2 and Venus 3 mission and trajectory and, particularly, on the procedure used for sterilizing the components and assembly of both spacecraft. With such information, the probable number of viable terrestrial microorganisms deposited on Venus and Mars could be estimated well enough to permit a realistic quantitative analysis of what U.S. policy and practice should be. However, if more complete information on Soviet practice cannot be obtained, then, it seems to us, the U.S. has no logical alternative but to permit greater engineering freedom in lander delivery technique and to accept gaseous and other nonthermal sterilization procedures, where necessary, in its own program. By relying on the demonstrated U.S. spacecraft reliability to insure that the U.S. contribution to planetary contamination will remain significantly less than the Soviet contribution, we could reduce significantly the cost and time required to carry out serious scientific investigations of the surfaces of Venus and Mars.

References and Notes

1. Note that the preceding article concluded that such transfer is not likely to result in actual biological infection. Hence we do not wish to contribute to the idea that the Soviets actually have *contaminated* either Venus or Mars, but merely point out that it is very likely that transfer has taken place. Inasmuch as U.S. policy pertains only to *transfer*, Soviet practice must be recognized regardless of what the actual chance of contamination might be.
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5. B. C. Murray and M. E. Davies, *Science* **151**, 945 (1966).
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7. R. Sehgal *et al.*, "Mariner B Capsule Propulsion Study," *Jet Propulsion Lab. Tech. Mem. 33-86* (1962).
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9. R. W. Davies and M. G. Comuntzis, *Proceedings 10th International Astronautical Congress, London, 1959* (Springer, Vienna, 1960).
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11. In our analysis of Soviet planetary efforts we have disregarded the possibility of intentional hoaxes or deliberate falsification of descriptions of spacecraft or missions. This attitude proved suitable in an earlier analysis (see *5*), where we correctly predicted the possibility of a Soviet flyby capsule attempt at Venus in early 1966. Subsequently, a report which appeared in *Pravda* on 6 March 1966 (see *12*) proved to be a remarkably detailed document and represents a major departure by the Soviets in the reporting of planetary missions. Finally, we note that the most spectacular and widely questioned Soviet deep-space achievement, the return of photographs of the back side of the moon by Luna 3 in 1959, has been corroborated recently by photographs from the U.S. Lunar Orbiter 1. Soviet reporting of lunar and planetary flights has been charac-

terized by abundant sins of omission, and an occasional intentional vagueness, but not, so far as we can determine, by sins of commission.
12. "Flight of automatic interplanetary stations 'Venus-2' and 'Venus-3,'" Moscow *News*, 26 Mar. 1966 (original Russian version appeared in *Pravda*, 6 Mar. 1966).
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15. V. I. Vashkov and A. G. Prishchep, "The effectiveness of sterilization by means of the mixture of ethylene oxide and methyl bromide," abstract of paper presented at COSPAR meeting, Vienna, 1966.
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17. "Zond 1 en route to Venus?" *Flight Intern.* (18 June 1964), p. 1039.
18. *Pravda* (19 May 1964).
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25. This article is contribution No. 1441 of the Division of Geological Sciences, California Institute of Technology, and Rand Corporation paper P-3517. Any views expressed here are our own; they should not be interpreted as reflecting the views of the Rand Corporation, the views of the California Institute of Technology, or the official opinion or policy of any governmental or private research sponsors.

The Modern University: Concerns for the Future

University administrators must do more than cope with exigencies; they must divine the future and plan.

Samuel B. Gould

The American university, it has been said, represents one of society's great potential instruments for change. The actuality has rarely been true in the past, however, and few signs are emerging to cause much more hope for the future. Change, unprecedented change, is inevitable, but to attribute it to the initiative of the university is to read into the institution strengths and forces that may be more apparent than real.

It is perhaps more accurate to say that these days our universities are too busy being successful to give too much thought to the distant future. The university is now, after all, the recipient of all that the most affluent society on earth can bestow upon it. Success may not have spoiled the institution, but neither do these golden days encourage the necessary soul-searching. Success need not produce mindlessness; indeed, our constant preoccupation with the enormous tasks of providing quality education for the millions can and should prompt deep and serious thought about what lies ahead.

There is little question that national destiny is shaping today's universities, rather than the other way around. But, once we have successfully solved the problems of academic quality in mass education, we shall still face other hurdles to which we have barely addressed ourselves; these will rapidly become central to the modern university's future ability to accommodate to change, and even to become also an effective initiator of change.

Our present methods of responding to the changing needs of the world are more closely characterized as a patchwork approach, rather than one of bold and inventive planning. With all the ingredients present to tell us what the world has in store, we are still adapting old methods and making minor revisions and emergency moves; we are still desperately trying to pour new wine into old bottles instead of recognizing that the new vintages may require quite different sorts of receptacles. In the face of the thousands upon thousands of students pouring onto the campuses of the universities, those of us who are responsible for the educational advancement of these thousands are still clinging to everything traditional—to our curricula, to our internal organizations, even to our prejudices. We patch here and there, but we still procrastinate about meeting the issues squarely. Only now, years later than it should have happened, do we see a general stirring, a growing sense of urgency among educational leaders regarding the need for clearly establishing the philosophy of their institutions and systematically planning their long-range futures. Only now is there an increasing awareness that, given the rapidly changing world we live in, we can no longer expect anything to remain the same, even educational anythings.

The process of planning starts with some effort to predict the nature of our society and of the world 50 years from now, the needs that will emerge from mankind who must live in that world, and the kind of institution that can best prepare for it. The longer one explores these elements of the process, the more clearly one sees the inadequacies of what we are now doing and the dangers inherent in our continuing to do it. Under such circumstances, one would think it unnecessary to plead for a continuing and visionary process of planning, but the fact is that only now are some of our colleges and universities giving attention to it.

The failure to plan exposes another characteristic of our universities generally: this is the tendency to follow rather than lead. Too much of the initiative for new programs, innovative efforts, or experimental approaches comes from outside the universities today—from foundations, from government agencies, sometimes even from individuals. Since this initiative is usually accompanied by large amounts of money, temptingly available, universities find it hard to resist. Without really meaning to, they can suddenly find themselves fully embarked on a course of action or extraordinarily involved in study areas that were not previously an important part of their mission as an institution. Or, to put it another way, a new and happily coincidental flexibility develops in the mission that puts within the university's purview almost anything an outside agency is willing to support. Carried to a high point of development, this tendency can soon lead to the situation in which the university no longer shapes society

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