Brigadier General Putt
United States Air Force
Director of Research and Development
Office, Deputy Chief of Staff, Materiel
Washington 25, D. C.

Dear General Putt:

Please refer to your letter of 18 November 1948 relative to the "flying object" problem and to Mr. Collbohm's reply dated 24 November 1948. In paragraph (b) of the reply, Mr. Collbohm promised (among other things) to send a discussion of the "special design and performance characteristics that are believed to distinguish space ships."

This present letter gives, in very general terms, a description of the likelihood of a visit from other worlds as an engineering problem and some points regarding the use of space vehicles as compared with descriptions of the flying objects. Mr. Collbohm will deliver copies to Colonel McCoy at Wright-Patterson Air Base during the RAND briefing there within the next few days.

A good beginning is to discuss some possible places of origin of visiting space ships. Astronomers are largely in agreement that only one member of the Solar system (besides Earth) can support higher forms of life. It is the planet Mars. Even Mars appears quite desolate and inhospitable so that a race would be more occupied with survival than we are on Earth. Reference 1 gives adequate descriptions of conditions on the various planets and satellites. A quotation from Ref. 1 (p. 229) can well be included here.

> "Whether intelligent beings exist to appreciate these splendors of the Martian landscape is pure speculation. If we have correctly reconstructed the history of Mars, there is little reason to believe that the life processes may not have followed a course similar to terrestrial evolution. With this assumption, three general possibilities emerge. Intelligent beings may have protected themselves against the excessively slow loss of atmosphere, oxygen and water, by constructing homes and cities* with the physical conditions scientifically con-

*"Not too large or they might be visible. Perhaps underground, where the atmospheric pressure would be greater and where the temperature extremes would be reduced."

cloudy atmosphere would discourage astronomy, hence space travel. The remaining Solar planets are such poor prospects that they can be ignored.

In the next few paragraphs, we shall speak of Mars. It should be understood that most of the remarks apply equally well to Venus.

Various people have suggested that an advanced race may have been visiting Earth from Mars or Venus at intervals from decades to eons. Reports of objects in the sky seem to have been handed down through the generations. If this were true, a race of such knowledge and power would have established some form of direct contact. They could see that Earth's inhabitants would be helpless to do interplanetary harm. If afraid of carrying diseases home, they would at least try to communicate. It is hard to believe that any technically accomplished race would come here, flaunt its ability in mysterious ways and then simply go away. To this writer, long-time practice of space travel implies advanced engineering and science, weapons and ways of thinking. It is not plausible (as many fiction writers do) to mix space ships with broadswords. Furthermore, a race which had enough initiative to explore among the planets would hardly be too timid to follow through when the job was accomplished.

One other hypothesis needs to be discussed. It is that the Martians have kept a long-term routine watch on Earth and have been alarmed by the sight of our A-bomb shots as evidence that we are warlike and on the threshold of space travel. (Venus is eliminated here because her cloudy atmosphere would make such a survey impractical). The first flying objects were sighted in the Spring of 1947, after a total 5 atomic bomb explosions, i.e., Alamogordo, Hiroshima, Nagasaki, Crossroads A and Crossroads B. Of these, the first two were in positions to be seen from Mars, the third was very doubtful (at the edge of Earth's disc in daylight) and the last two were on the wrong side of Earth. It is likely that Martian astronomers, with their thin atmosphere, could build telescopes big enough to see A-bomb explosions on Earth, even though we were 165 and 153 million miles away, respectively, on the Alamogordo and Hiroshima dates. The weakest point in the hypothesis is that a continual, defensive watch of Earth for long periods of time (perhaps thousands of years) would be dull sport, and no race that even remotely resembled Man would undertake it. We haven't even considered the idea for Venus or Mars, for example.

The sum and substance of this discussion is that if Martians are now visiting us without contact, it can be assumed that they have just recently succeeded in space travel and that their civilization would be practically abreast of ours.

The chance that Martians, under such widely divergent conditions, would have a civilization resembling our own is extremely remote. It is particularly unlikely that their civilization would be within a half century of our own state of advancement. Yet in the last 50 years we have just started to use aircraft and in the next 50 years we will almost certainly start exploring space.

Thus it appears that space travel from another point within the Solar system is possible but very unlikely. Odds are at least a thousand-to-one against it.

This leaves the totality of planets of other stars in the Galaxy as possible sources. Many modern astronomers believe that planets are fairly normal and logical affairs in the life history of a star (rather than cataclysmic oddities) so that many planets can be expected to exist in space.

To narrow the field a little, some loose specifications can be written for the star about which the home base planet would revolve. Let us say that the star should bear a family resemblance to the Sun, which is a member of the so-called "main-sequence" of stars, i.e., we eliminate white dwarfs, red giants and supergiants. For a description of these types, see reference 2, chapter 5. There is no specific reason for making this assumption except to simplify discussion: we are still considering the majority of stars.

Next, true variable stars can be eliminated, since conditions on a planet attached to a variable star would fluctuate too wildly to permit life. The number of stars deleted here is negligibly small. Reference 3, pages 76 and 85 indicate that the most common types are too bright to be in nearby space unnoticed. Lastly, we shall omit binary or multiple stars, since the conditions for stable planet orbits are obscure in such cases. About a third of the stars are eliminated by this restriction.

As our best known sample of space we can take a volume with the Sun at the center and a radius of 16 light years. A compilation of the 47 known stars, including the Sun, within this volume is given in reference 4, pages 52 to 57. Eliminating according to the above discussion: Three are white dwarfs, eight binaries account for 16 stars and two trinaries account for 6 more. The remainder, 22 stars, can be considered as eligible for habitable planets.

Assuming the above volume to be typical, the contents of any other reasonable volume can be found by varying the number of stars proportionately with the volume, or with the radius cubed, $S_e = 22 \times (\frac{r}{16})^3$, where S_e is number of eligible stars and r is the radius of the volume in light years. (This formula should only be used for radii greater than 16 light years. For smaller samples we call for a recount. For example, only one known eligible star other than the Sun lies within eight light years).

Having an estimate of the number of useable stars, it is now necessary to make a guess as to the number of habitable planets. We have only one observed sample, the Solar System, and the guess must be made with low confidence, since intelligent life may not be randomly distributed at all.

The Sun has nine planets, arranged in a fairly regular progression of orbits (see reference 1, Appendix I) that lends credence to theories that many stars have planets. Of the nine planets, (one, the Earth) is completely suitable for life. Two more (in adjacent orbits) are near misses: Mars has extremely rigorous living conditions and Venus has an unsuitable atmosphere. Viewed very broadly indeed, this could mean that each star would have a series of planets so spaced that one, or possibly two, would have correct temperatures, correct moisture content and atmosphere to support civilized life. Let us assume that there is, on the average, one habitable planet per eligible star.

There is no line of reasoning or evidence which can indicate whether life will actually develop on a planet where the conditions are suitable. Here again, the Earth may be unique rather than a random sample. This writer can only inject some personal intuition into the discussion with the view that life is not unique on Earth, or even the random result of a low probability, but is practically inevitable in the right conditions. This is to say, the number of inhabited planets is equal to those that are suitable!

One more item needs to be considered. Knowing nothing at all about other races, we must assume that Man is average as to technical advancement, environmental difficulties, etc. That is, one half of the other planets are behind us and have no space travel and the other half are ahead and have various levels of space travel. We can thus imagine that in our sample volume there are 11 races of beings who have begun space explorations. The formula on page 3 above now becomes

$$R = 11 \times (\frac{r}{16})^3$$

where R is the number of races exploring space in a spherical volume of radius $r \geq 16$ light years.

Arguments like those applied to Martians on page 2 need not apply to races from other star systems. Instead of being a first port of call, Earth would possibly be reached only after many centuries of development and exploration with space ships, so that a visiting race would be expected to be far in advance of Man.

To summarize the discussion thus far: the chance of space travelers existing at planets attached to neighboring stars is very much greater than the chance of space-traveling Martians. The one can be viewed almost as a certainty (if the assumptions are accepted), whereas the other is very slight indeed.

In order to estimate the relative chances that visitors from Mars or star X could come to the Earth and act like "flying objects", some discussion of characteristics of space ships is necessary.

To handle the simple case first, a trip from Mars to Earth should be feasible using a rocket-powered vehicle. Once here, the rocket would probably use more fuel in slowing down for a landing than it did in initial takeoff, due to Earth's higher gravitational force.

A rough estimate of one-way performance can be found by adding the so-called "escape velocity" of Mars to that of the Earth plus the total energy change (kinetic and potential) used in changing from one planetary orbit to the other. These are 3.1, 7.0, and 10.7 miles per second, respectively, giving a total required performance of 20.8 miles per second for a one-way flight. Barring a suicide mission, the vehicle would have to land and replenish or else carry a 100% reserve for the trip home.

Let us assume the Martians have developed a nuclear, hydrogen-propelled vehicle (the most efficient basic arrangement that has been conceived here on Earth) which uses half its stages to get here and the remaining stages to return to Mars, thus completing a round trip without refueling, but slowing down enough in our atmosphere to be easily visible (i.e., praotically making a landing). Since it is nuclear powered, gas temperatures will be limited to the maximum operating temperatures that materials can withstand (heat must transfer from the pile to the gas, so cooling can't be used in the pile). The highest melting point compound of uranium which we can find is uranium carbide. It has a melting point of 4560°R. Assume the Martians are capable of realizing a gas temperature of 4500°R (= 2500°K), and that they also have alloys which make high motor pressures (3000 psi) economical. Then the specific impulse will be I = 1035 seconds and the exhaust velocity will be c = 33,400 ft/sec (reference 5). Calculation shows that using a single stage for each leg of the journey would require a fuel/gross weight ratio of 0.96 (for each stage) too high to be practical. Using two stages each way (four altogether) brings the required fuel ratio down to 0.81, a value that can be realized.

If, by the development of strong alloys, the basic weight could be kept to 10% of the total weight for each stage, a residue of 9% could be used for payload. A four stage vehicle would then have a gross weight $\frac{(100)^4}{9}$ = 15,000 times as great as the payload: thus, if the payload were 2,000 pounds, the gross weight would be 30 million pounds at initial takeoff (Earth pounds).

Of course, if we allow the Martians to refuel, the vehicle could have only two stages* and the gross weight would be only $(\frac{100}{9})^2 = 123$ times the payload, i.e., 250,000 pounds. This would require bringing electrolytic and refrigerating equipment and sitting at the South Pole long enough to extract fuel for the hourney home, since they have not asked us for supplies. Our oceans (electrolysis to make H_2) would be obvious to Martian telescopes and they might conceivably follow such a plan, particularly if they came here without foreknowledge that Earth has a civilization.

Requirements for a trip from a planet attached to some star other than the Sun can be calculated in a similar manner. Here the energy (or velocity) required has more parts: (a) escape from the planet (b) escape from the star (c) enough velocity to traverse a few light years of space in reasonable time (d) deceleration toward the Sun (e) deceleration toward the Earth. The nearest "eligible" star is an object called Wolf 359 (see reference 4, p 52), at a distance of 8.0 light years. It is small, having an absolute magnitude of 16.6 and is typical of "red dwarfs" which make up more than half of the eligible populations. By comparison with similar stars of known mass, this star is estimated to have a mass roughly 0.03 as great as the sun. Since the star has a low lumihosity (being much cooler and smaller than the Sun) a habitable planet would need to be in a small orbit for warmth.

Of the changes of energy required as listed in the preceding paragraph, item (c), velocity to traverse intervening space, is so large as to make the others completely negligible. If the visitors were long lived and could "hibernate" for 80 years both coming and going, then 1/10 the speed of light would be required, i.e., the enormous velocity of 18,000 miles per second. This is completely beyond the reach of any predicted level of rocket propulsion.

If a race were far enough advanced to make really efficient use of nuclear energy, then a large part of the mass of the nuclear material might be converted into jet energy. We have no idea how to do this, in fact reference 6 indicates that the materials required to withstand the temperatures, etc., may be fundamentally unattainable. Let us start from a jet-propellant-to-gross-weight ratio of 0.75. If the total amount of expended material (nuclear plus propellent) can be 0.85 of the gross weight, then the nuclear material expended can be 0.10 of the gross. Using an efficiency of 0.5 for converting nuclear energy to jet energy and neglecting relativistic mass corrections, then a rocket velocity of half the velocity of light could be attained. This would mean a transit time of 16 years each way from the star Wolf 359, or longer times from other eligible stars. To try to go much faster would mean spending much energy on relativistic changes in mass and therefore operating at lowered efficiency.

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* Actually three stages. On the trip to Earth, the first stage would be filled with fuel, the second stage would contain partial fuel, the third would be empty. The first stage would be thrown away during flight. On the trip back to Mars, the second and third stages would be filled with fuel. The gross weight of the initial vehicle would be of the order of magnitude of a two-stage rocket.

To summarize this section of the discussion, it can be said that a trip from Mars is a logical engineering advance over our own present technical status, but that a trip from another star system requires improvements of propulsion that we have not yet conceived.

Combining the efforts of all the science-fiction writers, we could conjure up a large number of hypothetical methods of transportation like gravity shields, space overdrives, teleports, simulators, energy beams and so on. Conceivably, among the myriads of stellar systems in the Galaxy, one or more races have discovered methods of travel that would be fantastic by our standards. Yet the larger the volume of space that must be included in order to strengthen this possibility, the lower will be the chance that the race involved would ever find the earth. The Galaxy has a diameter of roughly 100,000 light years and a total mass about two hundred billion times that of the Sun (reference 4). Other galaxies have been photographed and estimated in numbers of several hundred million (reference 2, p. 4) at distances up to billions of light years (reference 7, p. 158). The number of stars in the known universe is enormous, yet so are the distances involved. A super-race (unless they occur frequently) would not be likely to stumble upon Planet III of Sol, a fifth-magnitude star in the rarefied outskirts of the Galaxy.

A description of the probable operating characteristics of space ships must be based on the assumption that they will be rockets, since this is the only form of propulsion that we know will function in outer space. Below are listed a few of the significant factors of rocketry in relation to the "flying objects".

(a) Maneuverability. A special-purpose rocket can be made as maneuverable as we like, with very high accelerations either along or normal to the flight path. However, a high-performance space ship will certainly be large and unwieldy and could hardly be designed to maneuver frivolously around in the Earth's atmosphere. The only economical maneuver would be to come down and go up more or less vertically.

(b) Fuel reserves. It is hard to see how a single rocket ship could carry enough extra fuel to make repeated descents into the Earth's atmosphere. The large number of flying objects reported in quick succession could only mean a large number of visiting craft.

Two possibilities thus are presented. First, a number of space ships could have come as a group. This would only be done if full-dress contact were to be established. Second, numerous small craft might descend from a mother ship which coasts around the Earth in a satellite orbit. But this could mean that the smaller craft would have to be rockets of satellite performance, and to contain them the mother ship would have to be truly enormous.

(c) Appearance. A vertically descending rocket might well appear as a luminous disk to a person directly below. Observers at a distance, however, would surely identify the rocket for what it really is. There would probably be more reports of oblique views than of end-on views. Of course, the shape need not be typical of our rockets; yet the exhaust should be easy to see.

One or two additional general remarks may be relevant to space ships as "flying objects". The distribution of flying objects is peculiar, to say the least. As far as this writer knows, all incidents have occurred within the United States, whereas visiting spacemen could be expected to scatter their visits more or less uniformly over the globe. The small area covered indicates strongly that the flying objects are of Earthly origin, whether physical or psychological.

The lack of purpose apparent in the various episodes is also puzzling. Only one motive can be assigned; that the space-men are "feeling out" our defenses without wanting to be belligerent. If so, they must have been satisfied long ago that we can't catch them. It seems fruitless for them to keep repeating the same experiment.

Conclusions:

Although visits from outer space are believed to be possible, they are believed to be very improbable. In particular, the actions attributed to the "flying objects" reported during 1947 and 1948 seem inconsistent with the requirements for space travel.

Very truly yours,

J. E. Lipp
Missiles Division

JEL:sp -

References

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