The Mercury-Atlas-6 Space Flight

John H. Glenn, Jr., describes his astronomical, meteorological, and terrestrial observations. John A. O'Keefe comments on the scientific results of the flight.

Glenn's Observations

Luminous particles

Coming out of the night on the first orbit, at the first glint of sunlight on the capsule, I was looking inside the capsule to check some instruments for probably 15 or 20 seconds. When I glanced back out the window, my initial reaction was that the capsule (spacecraft) had tumbled and that I was looking off into a star field and was not able to see the horizon. I could see nothing but luminous specks about the size of the stars outside. I realized, however, they were not stars. I was still in the attitude that I had before. The specks were luminous particles that were all around the capsule. There was a large field of spots that were about the color of a very bright firefly, a light yellowish-green color. They appeared to vary in size from maybe just pinhead size up to possibly ⅜ of an inch. I would say that most of the particles were similar to first-magnitude stars; they were pretty bright, very luminous. However, they varied in size, so there would be varying magnitudes represented. They were floating in space at approximately my speed. I appeared to be moving through them very slowly, at a speed of maybe 3 to 5 miles an hour. They did not center on the capsule, as though the capsule was their origin. I thought first of the lost Air Force needles that are some place in space, but they were not anything that looked like that at all.

The other possibility that came to my mind immediately was that snow or little frozen water particles were being created from the peroxide decomposition. I don't believe that's what it was, however, because the particles through which I was moving were evenly distributed and not more dense closer to the capsule.

As I looked out to the side of the capsule, the density of the field to the side of the capsule appeared to be about the same as directly behind the capsule. The distance between these particles would average, I would estimate, some 8 to 10 feet apart. Occasionally, one or two of them would come swirling up around the capsule and across the window, drifting very, very slowly, and then would gradually move off back in the direction I was looking. This was surprising, too, because it showed we probably did have a very small flow field set up around the capsule or they would not have changed their direction of motion as they did. I do not recall observing any vertical or lateral motion other than that of the particles that swirled around close to the spacecraft. It appeared to me that I was moving straight through a cloud of them at a very slow speed. I observed these luminous objects for approximately 4 minutes before the sun came up to a position where it was sufficiently above the horizon that all the background area then was lighted and I no longer could see them.

After passing out of them, I described them as best I could on the tape recorder and reported them to the Cape. I had two more chances to observe them, at each sunrise; it was exactly the same each time. At the first rays of the sun above the horizon, the particles would appear. To get better observation of these particles and to make sure they were not emanating from the capsule, I turned the capsule around during the second sunrise. When I turned around towards the sunrise, I could see only 10 percent as many particles as I could see when facing back toward the west. Still, I could see a few of them coming toward me. This proved rather conclusively, to me at least, that I was moving through a field of something and that these things were not emanating, at least not at that moment, from the capsule. To check whether this might be snowflakes from the condensation from the thrusters, I intentionally blipped the thrusters to see if I was making a pattern of these particles. I could observe steam coming out of the pitchdown thruster in good shape, and this didn't result in any observation of anything that looked like the particles. I had three good looks at them, and they appeared identical each time. I think the density of the particles was identical on all three passes.

I would estimate that there were thousands of them. It was similar to looking out across a field on a very dark night and seeing thousands of fireflies. Unlike fireflies, however, they had a steady glow. Once in a while, one or two of them would come drifting up around the corner of the capsule and change course right in front of me. I think this was from flow of some kind, or perhaps the particles were ionized and were being attracted or repelled. It was not due to collisions, because I saw some of them change course right in front of me without colliding with any other particles or the spacecraft. If any particles got in near enough to the capsule and got into the shade, they seemed to lose their luminous quality. And when occasionally I would see one up very close, it looked white, like a little cottony piece of something, or like a snowflake. That's about the only description of them I have. There was no doubt about their being there, because I observed them three different times for an extended period of time. I tried to get pictures of them, but it looks like there wasn't sufficient light emanating from them to register on the color film.

The High Layer

I had no trouble seeing the horizon on the nightside. Above the horizon, some 6 to 8 degrees, there was a layer that I would estimate to be roughly 1½ to 2 degrees wide. I first noticed

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it as I was watching stars going down. I noticed that as they came down close to the horizon they became relatively dim for a few seconds, then brightened up again, and then went out of sight below the horizon. As I looked more carefully, I could see a band, parallel to the horizon, that was a different color than the clouds below. It was not the same white color as moonlight on clouds at night. It was a tannish color or buff white, in comparison to the clouds, and not very bright. This band went clear across the horizon. I observed this layer on all three passes through the nightside. The intensity was reasonably constant through the night. It was more visible when the moon was up, but during that short period when the moon was not up, I could still see this layer very dimly. I wouldn't say for sure that you could actually observe the specific layer during that time, but you could see the dimming of the stars. But, when the moon was up, you very definitely could see the layer, though it did not have sharp edges. It looked like a dim haze layer, such as I have seen occasionally while flying. As stars would move into this layer, they would gradually dim; dim to a maximum near the center, and gradually brighten up as they came out of it. So, there was a gradient as they moved through it; it was not a sharp discontinuity.

Parameters for the First United States Manned Space Flight, 20 February 1962

Orbit parameters	
Perigee altitude (statute miles)	100.03
Perigee altitude (nautical miles)	86.92
Apogee altitude (statute miles)	162.17
Apogee altitude (nautical miles)	140.92
Period (minutes, seconds)	88:29
Inclination angle (degrees)	32.54
Maximum conditions	
Altitude (statute miles)	162.17
Altitude (nautical miles)	140.92
Space-fixed velocity (feet per second)	25,732.0
Earth-fixed velocity (feet per second)	24,415.0
Landing point	
Latitude	21°26′N
Longitude	68°41′W

Nightside Observations of the Earth

Over Australia, they had the lights of Perth on, and I could see them well. It was like flying at high altitude at night over a small town. The Perth area was spread out and was very visible, and then there was a smaller area south of Perth that had a smaller group of lights but they were much brighter in intensity—very luminous. Inland, there was a series of about four or five towns that you could see in a row, lined up pretty much east and west, that were very visible. It was very clear; there was no cloud cover in that area at that time.

Knowing where Perth was, I traced a very slight demarcation between the land and the sea, but that's the only time I observed a coastline on the nightside. Over the area around Woomera, there was nothing but clouds. I saw nothing but clouds at night from there clear up across the Pacific until we got up east of Hawaii. There was solid cloud cover all the way.

In the bright moonlight you could see vertical development at night. Most of the areas looked like big sheets of stratus clouds, but you could tell where there were areas of vertical development by the shadows, or lighter and darker areas on the clouds.

Out in that area at night, fronts could not be defined. You can see frontal patterns on the dayside. In the North Atlantic you could see streams of clouds, pick out frontal areas pretty much like those in the pictures from earlier Mercury flights.

With the moonlight, you are able to pick up a good drift indication, using the clouds. However, I don't think it's as accurate as the drift indications during the day. The drift indication is sufficient that you can at least tell what direction you're going at night, within about 10 or 15 degrees. In the daylight, over the same type clouds, you probably could pick up your drift down to maybe a couple of degrees.

The horizon was dark before the moon would come up, which wasn't very long. However, you can see the horizon silhouetted against the stars. It can be seen very clearly. After the moon comes up, there is enough light shining on the clouds that the earth is whiter than the dark background of space. Well, before the moon comes up, looking down is just like looking into the Black Hole at Calcutta.

There were a couple of large storms in the Indian Ocean. The Weather Bureau scientists were interested in whether lightning could be seen or not. This is no problem; you can see lightning zipping around in these storms all over the place. There was a great big storm north of track over the Indian Ocean; there was a smaller one just south of track, and you could see lightning flashing in both of them, especially in the one in the north—it was very active. It was flashing around, and you could see a cell going and another cell going and then horizontal lightning back and forth.

On that area, I got out the airglow filter and tried it. I could not see anything through it. This, however, may have been because I was not well enough dark adapted. This is a problem. If we're going to make observations like this, we're going to have to figure out some way to get better night-adapted in advance of the time when we want to make observations. There just was not sufficient time. By the time I got well night-adapted, we were coming back to daylight again.

Dayside Observations

Clouds can be seen very clearly on the daylight side. You can see the different types—vertical developments, stratus clouds, little puffy cumulus clouds, and altocumulus clouds. There is no problem identifying cloud types. You're quite a distance away from them, so you're probably not doing it as accurately as you could looking up from the ground, but you can certainly identify the different types and see the weather patterns.

The cloud area covered most of the

area up across Mexico, with high cirrus almost to New Orleans. I could see New Orleans; Charleston and Savannah were also visible.

You can see cities the size of Savannah and Charleston very clearly. I think the best view I had of any area during the flight was the clear desert region around El Paso on the second pass. There were clouds north of Charleston and Savannah, so I could not see the Norfolk area and on farther north. I did not see the Dallas area that we had planned to observe because it was covered by clouds, but at El Paso I could see the colors of the desert and the irrigated areas north of El Paso. You can see the pattern of the irrigated areas much better than I had thought we would be able to. I don't think that I could see the smallest irrigated areas; it was probably the ones that are blocked in by the larger irrigated areas, both around El Paso and at El Centro, which I observed after retrofire.

The western part of Africa was clear. That is a desert region where I mainly saw dust storms. By the time we got to the region where I might have been able to see cities in Africa, the land was covered by clouds. I was surprised at what a large percentage of the track was covered by clouds on this particular day. There was very little land area which could be observed on the daylight side. The eastern part of the United States and an occasional glimpse of land up across Mexico and the desert area in Western Africa was all that could be seen.

I saw what I assume was the Gulf Stream. The water can be seen to have different colors. Another thing that I observed was the wake of a ship as I came over recovery area G at the beginning of the third orbit. I had pitched down to below retroattitude. I was not really thinking about looking for a ship. I was looking down at the water, and I saw a little V. I quickly broke out the chart and checked my position. I was right at area G, the time checked out perfectly for that area. So, I think I probably saw the wake from a recovery ship; when I looked back out and tried to locate it again, the little V had gone under a cloud and I didn't see it again. The little V was heading west at that time. It would be interesting to see if the carrier in area G was fired up and heading west at the time.

I would have liked to put the glasses on and see what I could pick out on the ground. Without the glasses, I think you identify the smaller objects by their surroundings. For instance, you see the outline of a valley where there are farms, and the pattern of the valley and its rivers and perhaps a town. You can see something that crosses a river, and you just assume that it's a bridge. As far as being able to look down and see it and say "that is a bridge," I think you are only assuming that it's a bridge more than really observing it. Ground colors show up just like they do from a high-altitude airplane; there's no difference. A lot of the things you can identify just as from a high-flying airplane. You see by color variations the deep green woods and the lighter green fields and the cloud areas.

I could see Cape Canaveral clearly, and I took a picture which shows the whole Florida Peninsula; you see across the interior of the Gulf.

Sunset and Sunrise Horizon Observations

At sunset, the flattening of the sun was not as pronounced as I thought it might be. The sun was perfectly round as it approached the horizon. It retained its symmetry all the way down, until just the last sliver of sun was visible. The horizon on each side of the sun is extremely bright, and when the sun got down to where it was just the same level as the bright horizon, it apparently spread out, perhaps as much as 10 degrees each side of the area you were looking at. Perhaps it was just that there was already a bright area there and the roundness that had been sticking up above it came down to where, finally, the last little sliver just matched the bright horizon area and probably added some to it.

I did not see the sunrise directly, only through the periscope. You cannot see that much through the scope. The sun comes up so small in the scope that all you see is the first shaft of light. The band of light at the horizon looks the same at sunrise as at sunset.

The white line of the horizon is extremely bright as the sun sets, of course. The color is very much like the arc lights they use around the pad.

As the sun goes on down a little bit more, the bottom layer becomes a bright orange and it fades into red, then on into the darker colors, and finally off into blues and black as you get further up toward space. One thing that was very surprising to me, though, was how far out on the horizon each side of that area the light extends. The lighted area must go out some 60 degrees. I think this is confirmed by the pictures I took.

I think you can probably see a little more of this sunset band with the eye than with a camera. I was surprised when I looked at the pictures to see how narrow-looking it is. I think you probably can pick up a little broader band of light with the eye than you do with the camera. Maybe we need more sensitive color film.

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O'Keefe's Comments

This paper discusses the preliminary attempts to explain the observations made by astronaut Glenn during the MA-6 flight. Analysis of Glenn's observations is continuing and is not yet complete. This paper is intended only to indicate the direction which the analysis is taking, not to provide the final explanations. The theories presented are mine, not the astronaut's. In some cases, final verification of these theories must await further Mercury flights.

Three principal points are to be considered in the field of space science as a result of the MA-6 flight. They are (i) the luminous particles (the Glenn effect), which are probably the result of the flaking off of paint, or possibly the condensation of moisture from the spacecraft heat exchanger; (ii) a luminous band seen around the sky and possibly due to airglow or aurora but probably due to reflections of the horizon between the windows of the spacecraft; and (iii) the flattened appearance of the sun at sunset (this is not attested by the visual observations but appears fairly clear in the photographs).

Luminous Particles

Glenn observed a field of small, luminous objects surrounding his spacecraft at sunrise on all three orbits. He compares them to fireflies, especially in color, remarking that they were very luminous and variable in size.

Some of these particles came close to the spacecraft so that they got into the shade, as evidenced by a marked loss in brightness and a change in color from yellow-green to white. The change in color is comprehensible as being due to passage from illumination by direct sunlight to illumination by bluish light scattered from the twilight all along the horizon. Passage into the shadow is a clear indication that the particles involved were genuinely close at hand. It indicates that the particles were within the range of stereoscopic vision, so that Glenn's distance estimates are meaningful. It follows that his estimates of relative velocity are also meaningful: these estimates were 3 to 5 miles per hour—that is, 1.3 to 2.2 meters per second relative to the spacecraft. Glenn stated that the overall impression was that the spacecraft was moving through a field of these particles at a speed of 3 to 5 miles per hour.

This observation indicates that the luminous objects were undoubtedly associated with the spacecraft in their motion. The spacecraft velocity was approximately 8000 meters per second; the velocity of the particles was identical with that of the spacecraft in all three coordinates within about 1 part in 4000. Rough estimates show that this implies that the orbital inclination was the same for the particles as for the spacecraft within ± 0.01 degree. The eccentricity was the same within ± 0.0002. In particular, the spacecraft was at that time descending toward perigee at the rate of approximately 50 meters per second. The particles were descending at the same rate within $\pm$ 2 meters per second. Thus, from considerations of velocity alone, there is a very convincing demonstration that the particles were associated with the spacecraft.

In addition, it should be noted that the height at that time was 160 kilometers. It was thus at least twice the height of the noctilucent clouds (which apparently consist of ice particles and must therefore be considered). At this level, the atmosphere has a density of the order of 10^{-10} gram per cubic centimeter; it is completely unable to retard the fall of any visible object. Hence, there is no reason to expect any layer of particles to be sustained at this level. Anything at this height must be in orbit.

Size of the Field

An important consideration is the fact that the field of particles could not have been of very great extent. If, for example, we suppose that there were two or three of these "very luminous" particles within 3 meters of the window (the spacing being estimated by Glenn at 6 to 10 feet, or 2 to 3 meters), then in the next 3 meters there should have been 12 particles, averaging one-fourth as bright, so that the contribution to the total illumination from the second 3-meter group would have been the same as that from the first 3-meter group, and so on. Had the field extended to a distance of "several miles" —that is, say 10 kilometers—the total light would have been some 3000 times that of the individual nearby particles, and Glenn would have spoken of an intensely luminous fog. Since he saw the particles for times of about 4 minutes, during which he traveled about 1920 kilometers, the field, if a part of the environment, would have been of this length, and the particles would have covered the sky solidly in this direction, so that it would have looked like a cloud or a snowfield. This sort of calculation is well known in astronomy, under the name of Olber's paradox. It establishes with certainty that the particles did not extend far in any direction from the spacecraft. The fact that Glenn did not see a local concentration around the spacecraft means that there was no large increase in density within the range of stereoscopic vision, but it does not conflict with the idea that the field extended, at most, a few hundred meters in any direction.

Size and Brightness

With respect to the brightness of the particles, conversations with Glenn have established that the most significant brightness estimate is the comparison with fireflies. T. J. Spilman, of the Smithsonian Institution, states that the available measures of light of *Photinus pyralis*, the common firefly of the eastern United States, indicate from 1/50 to 1/400 candle when the light is turned on. At a distance of 1 meter, a candle has a brightness of about -14; the firefly at 2 meters would be 200 to 1600 times fainter, or would have a brightness between about -8.3 and -6. At distances of the order of 20 meters, it would have a brightness between -3.3 and -1, comparable to that of planets or the brightest stars.

The full moon (brightness -12.6) is plainly visible on several of the photographs taken in orbits. The particles may possibly also be visible; but if so, they are not more than 1/10 the brightness of the full moon, and hence are not brighter than about -10. Of course occasionally a large particle may have come close, but the run of the mine must have been of brightness -10 or fainter.

A white object 1 centimeter in diameter, at a distance of 2 meters in direct sunlight would be of about -13.9 magnitude; if of pinhead size (2 mm in diameter) it would be -10.4. If we allow a reduction to 1 millimeter on account of the known fact that bright objects seem larger than they are, we find a brightness of -9, which is of the same order as that of the firefly at the same distance.

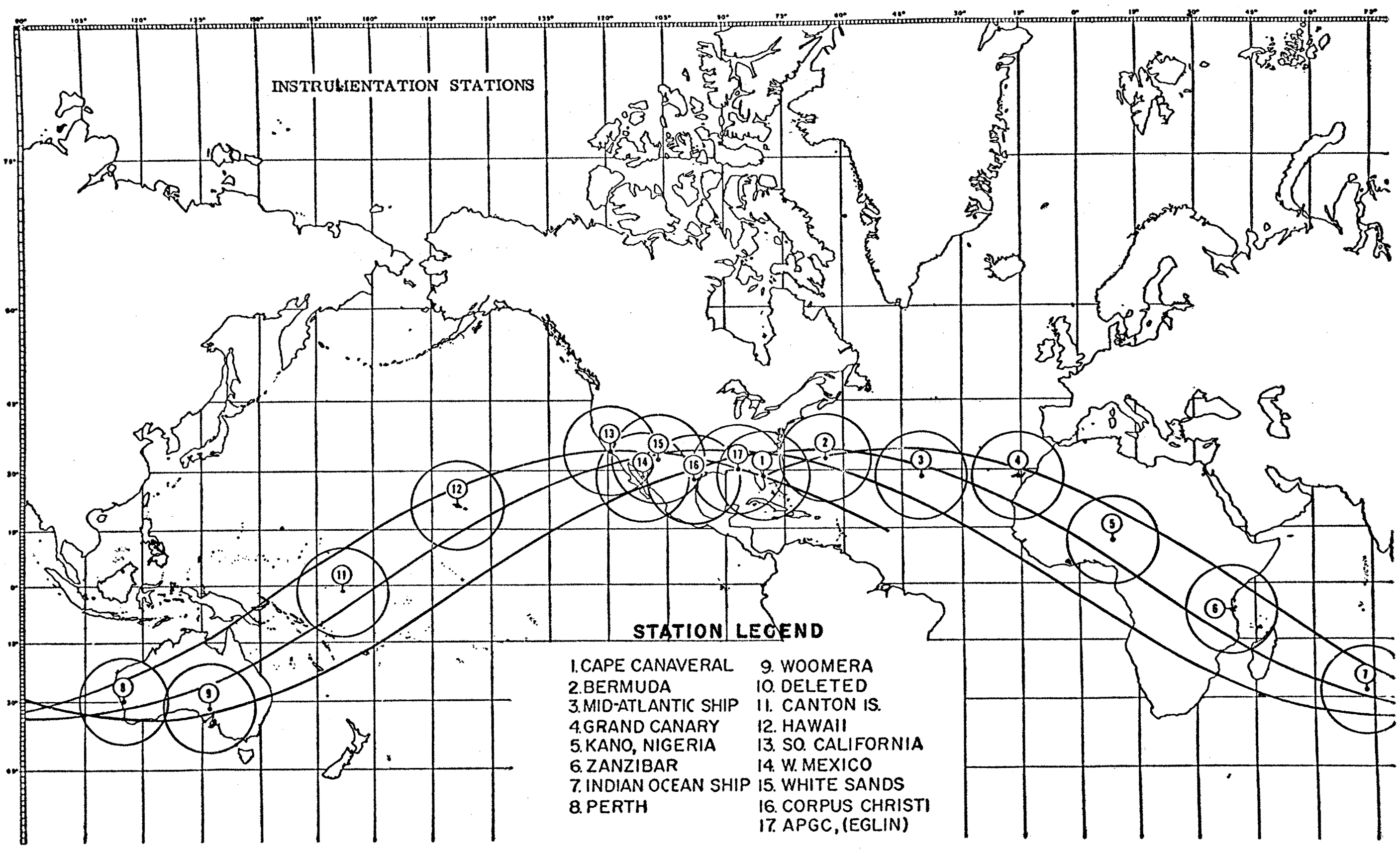
Probable Cause of Motion

The next question is, what is the agency which is causing the particles to move with respect to the spacecraft? The possibilities are electrical, magnetic, and gravitational fields; light pressure; and aerodynamic drag. Of these, the electrical forces can be discarded for mass motion over a large area, since we are in the lower *F*-region of the ionosphere and space is essentially a conductor. The magnetic fields can be divided into terrestrial and spacecraft fields. The spacecraft field is certainly too small, at reasonable distances, to account for the acceleration, and the terrestrial field cannot accelerate a dipole, because the field gradient is too small. Gravitational fields will act in almost precisely the same way on the spacecraft as on the particles. The acceleration will be in one direction for particles below the spacecraft and in the other direction for those above it; thus the gravitational fields will make the particles seem to go around the spacecraft with a steady motion rather than to move past it.

Light pressure and drag have similar effects at sunrise, but at heights of the order of 160 kilometers, drag is about 1 dyne per square centimeter, while radiation pressure is less by many orders of magnitude. Hence, the most probable source of the acceleration is aerodynamic drag.

Nature of the Particles

Important information about the nature of the particles is furnished by their behavior under the influence of drag forces. At sunrise, the spacecraft was a little above its minimum altitude of 160 kilometers. At this height, the density of the air is roughly 1.3×10^{-12} gram per cubic centimeter; the spacecraft velocity is about 8×10^5 centimeters per second; the drag pressure is thus about 1 dyne per square centimeter. Since Glenn states that he appeared to be moving slowly through a relatively stationary group of particles, it is evident that the particles could not have been greatly accelerated while they were in the near vicinity of the spacecraft. In comparison, a snowflake with a diameter of 1 millimeter and the usual density of 0.1 will be subjected to a force of about 0.01 gram per square



Map of orbital paths and ground stations.

centimeter of frontal area. It will thus be accelerated at the rate of 100 centimeters per second per second, and its velocity will exceed the velocities estimated for the particles after only 2 seconds, when it has gone 2 meters. We cannot escape from the problem by supposing the snowflakes to be much larger—say, 1 centimeter in diameter—because, though occasional particles may have been as large as this, the majority must have been smaller, since they did not give strong photographic images. Glenn tells us that their average separation was only about 6 to 10 feet, so that at any given moment one of the particles would be expected to be within a few meters of the spacecraft window, and hence brighter than the full moon.

A few particles, which came close to the window and could be examined in detail, appeared large and cottony. These were very probably snowflakes. They were seen to accelerate perceptibly in the airstream.

We are now in a position to attempt to decide what the particles were composed of. It is clear at once that we are not dealing with any sort of gas fluorescence or gas discharge, such as might be produced by the motion of the spacecraft through the ionosphere, because the lights were not visible until sunrise. They were, therefore, shining by reflected light. Solid or liquid particles are more efficient than gases in reflecting light, by factors of millions; hence the particles must be assumed to have been solid or liquid. Their sizes were probably in the millimeter range, as judged from their apparent brightness. Their densities must have been much higher than 0.1. The highest density one could reasonably assume would be about 3; in that case the particles would be accelerated at 3 centimeters per second per second, and would reach a velocity of 2 meters per second after a time of 1 minute, when they would be 50 meters away, and their velocities would be difficult to estimate accurately.

Possible Sources of Particles

It can be shown at this point that the particles could not have come from the sustainer (the launch vehicle), which was over 100 kilometers away at the first sighting and about 300 kilometers away at the third sighting. If accelerated over this distance at the lowest reasonable rate—namely, 3 centimeters per second per second—they would have passed the spacecraft at 135 meters per second, a velocity which cannot be reconciled with the observations. Any small particles observed at this altitude moving with low relative velocity must have been released from the spacecraft itself, and not very long before they were observed.

Another significant item is the total mass. With a separation of the order of 3 meters (10 feet), as reported by Glenn, there would be about 1 particle per 30 cubic meters; the particles apparently weighed about 3 milligrams each. If a 100-meter cube were filled with such particles, there would be about 30,000, with a total weight of about 1 kilogram. If we assume them to be 1-centimeter snowflakes, of mass 100 milligrams each, the total weight would be 30 kilograms. Since Glenn reports the field as extending widely, it is clear that the denser, smaller particles are more probable.

Among the materials known to have come off the spacecraft, only three appear to have had sufficient volume: (i) a considerable amount of paint and other materials in the area between the heat shield and the pressure vessel; (ii) water from the hydrogen peroxide thrusters; (iii) water from the cooling system.

Of these possibilities, the second can be discarded at once—first, because Glenn himself directly studied this possibility in flight by watching the output of the pitchdown thruster. He noted at that time that the jet of steam, which was visible, was entirely unlike the observed particles. In the second place, the velocity imparted to the steam as a necessary part of the thruster operation would have taken the steam away immediately.

The water from the cooling system may well have been responsible for a few of the large snowflakes which Glenn described. This water, after being used to cool the spacecraft, is released through a hole, about 2.5 centimeters across, into the space between the spacecraft bulkhead and the heat shield. This space is approximately 10 centimeters in depth and extends over the back of the heat shield, which is about 2 meters in diameter. The volume is thus roughly 3×10^5 cubic centimeters, or 300 liters. From this space, the water emerges through ten or more holes, each about 1 centimeter in diameter, spaced around the heat shield.

This system appears likely to produce snowflakes. During tests, the clogging of the 2.5-centimeter pipe by ice was a common occurrence. On the MA-6 flight this condition was indicated, by warning lights. It seems likely that vapor which got through the 2.5-centimeter pipe to the space back of the bulkhead would expand against the low pressure inside the bulkhead and cool. Ice crystals would form, but these might not leave the spacecraft for some time, because of the smallness of the ports relative to the size of the space. This situation, where a low gas pressure may be sustained for a considerable period, is very helpful in explaining the growth of snowflakes as large as 1 centimeter in diameter. It is hard to see how such flakes could grow in empty space.

As a result of the relatively low temperatures, the large size of the pipes, and the cooling and condensation back of the bulkhead, the gas pressure at the ports would be expected to be very low, so that the snowflakes would emerge with low velocities, as described by Glenn. It is easy to imagine a flake formed in this way drifting down past the spacecraft window slowly, in the manner described. As long as it was back of the heat shield, it would not encounter the airstream; but eventually, as described by Glenn, it would drift up into the airstream and then start moving up to the rear. Such particles would look like white cottony snowflakes because they were cottony snowflakes. Their color in direct sunlight would be different from their color in the shadow for the same reason that shadows at sunset are sometimes blue (*1*): the light that gets into the shadow is the light from the long twilight arc on the earth, and this is predominantly blue.

The total quantity of water available from this source is about 1 kilogram per hour. In view of the very short time that it could remain in the vicinity of the spacecraft and the relatively large total amount required to fill a reasonably large area around the spacecraft, it appears somewhat unlikely that ice was the material of the particles, though the possibility that dense ice crystals were involved cannot be entirely excluded.

Another possibility is that the particles were of solid material such as paint. Millimeter-size particles of this type would have densities of the order of 3 and masses of the order of 3 milligrams. Within a sphere of 10-meter radius, with the spacecraft at the center, there would be 140 such particles, with a total mass of about ½ gram. Within a sphere of 100-meter radius there would be particles with a total mass of about ½ kilogram. Let us suppose that particles of this type are liberated primarily at sunrise, possibly because of some cracking or stretching of the spacecraft skin that occurs at that time. In that case, liberation of not much more than 1½ kilograms of material during the whole flight would have been required for a particle-cloud of the size observed, especially if the density was somewhat less in the outer portions of the cloud. This figure is perhaps not inconsistent with the amount of material which could have flaked off. It is necessary to emphasize the extremely tenuous character of these figures, which depend on estimates of the cloud size, since the mass of material required varies with the cube of the diameter of the cloud.

To sum up, it appears that the Glenn effect is due to small solid particles, mostly about 1 millimeter in diameter, but with a few larger bodies in addition. The brightness of the majority of the particles was about -9 at a distance of 2 meters. They were probably at least as dense as water; higher densities are more likely. They were certainly not a part of the space environment but were something put in orbit as a result of the MA-6 flight. They were almost as certainly related to the spacecraft, not to the sustainer. There are two reasonable possibilities: (i) ice from the cooling system or (ii) paint or other heavy material which flaked off the spacecraft under the low pressures of the space environment. Of these, the paint is the more probable because its higher density explains the orbital behavior better, and because we can understand why paint might be liberated only at sunrise, while ice would be liberated throughout the flight (thus, very large quantities of ice would be needed, as compared to the required amounts of paint).

In short, the most probable explanation of the Glenn effect is that it arose from millimeter-size flakes of material liberated at or near sunrise by the spacecraft.

The Luminous Band

Glenn reports a luminous band on all three revolutions, at a height of 7 to 8 degrees above the horizon, tan-to-buff in color, and more luminous when the moon (then full) was up. He also states that the band was faintly and uncertainly visible when the moon was down; at such times he saw the horizon clearly silhouetted against the stars.

After the flight it was noted that many photographs of the twilight showed a luminous band parallel to the horizon. Photographs of the sky in full daylight showed a faint luminous zone extending all the way up from the horizon. The faintness of the band on daylight photographs was probably due to the automatic reduction of the exposure in strong light.

The focal length of the camera lens was 50 millimeters. The photographs were enlarged about 6.8 times for study; the scale was then about 0.17 degrees per millimeter. The height of the band seen on the enlargements was about 75 millimeters, corresponding to 12.6 degrees.

The band seen on the photographs had not been noted in the spacecraft. It was therefore thought at first to be perhaps a camera effect. However, the circular form of a camera lens makes it difficult to explain a band parallel to the horizon.

The most probable explanation of the luminous band seen on the photographs is that it results from multiple reflections within the spacecraft window system. The spacecraft has an inner and an outer window, which are inclined with respect to one another. The angle of inclination was found, by measuring the blueprints, to be about 6 degrees. Light passing through the outer window and reflected by the inner one back to the outer window, and then back again into the spacecraft, would have been turned through an angle of about 12 degrees, in a direction away from the top of the spacecraft, which in flight points near the horizon. This probably accounts for what was seen in the photographs. The existence of these reflections has been directly verified in the Mercury procedures trainer at the Mercury Control Center. It was further found, in spacecraft No. 18, that one of the reflections (there were two) was a light tan in color, like the band observed by Glenn.

Since it is a spacecraft phenomenon, the luminous band produced by reflection must also have been present in the night sky, especially after moonrise. It may have been the band observed by Glenn. The color which he remarked on may have resulted from an antireflectant coating which had been applied to the windows.

(*Addendum*. This supposition does not explain the disappearance of stars as they reach the level of the luminous band. However, let us note Glenn's comments on stars disappearing during the time between sunset and moonrise. During that time, the bright planet Venus set. It is possible that what Glenn saw was the disappearance of the reflection of Venus as it reached the level of the reflection of the horizon.)

If the band is not due to reflection, it may be possible to attribute it to some auroral phenomenon. There is a line in the auroral spectrum at 5577 angstroms. This line is known from rocket measurements to stop at 100 kilometers. A height of 100 kilometers would appear, at the spacecraft height of 250 kilometers, as a false horizon at an angular altitude of about 3 degrees. It would be green in color and would be more difficult to see after moonrise. In height and color it does not agree with the luminous band.

There are, in addition, two auroral red lines, at 6300 and 6464 angstroms, respectively, which are known to come from a height greater than any so far reached by rockets sent to observe them. From theory we estimate that they ought to be at a height of about 240 kilometers. These might be reconcilable with the observed luminous band, though they ought not to be easier to see after moonrise. They would explain the tan-to-buff color observed. On the other hand, these lines are much fainter than the line at 5577 angstroms, so it is hard to understand why they would be observed while it was missed.

On the whole, the balance of probability is that the luminous band was due to reflection in the spacecraft window. The outstanding reason for connecting the two is the belief that the inclined windows would have given a ghost image.

Glenn reports that the sunset appeared to be normal until the last moment, when the sun appeared to spread out about 10 degrees on either side, and to merge with the twilight band. Glenn specifically states that he did not see the sun as a narrow, flat object.

On the other hand, three consecutive photographs of the setting sun can be well interpreted in terms of the theoretically predicted sausage shape. In two of these there is some slight spreading of the image, evidently partly photographic and partly due to motion, and in the third the motion is considerable. All, however, appear to indicate a solar image of about ½ degree in its greatest dimension, as required by theory, rather than a much shorter image, as would have been the case if the sun, setting, had looked as it does from the ground.

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The Scientific Establishment

The American system gives scientists in government a freedom and influence unmatched in other countries.

Don K. Price

Now that the federal government is spending more money on research and development than its total budget before Pearl Harbor, American scientists find it hard to figure out their new role in society. They used to assume that democracy would never be a patron of the sciences, and even after the Second World War the Executive had to urge the support of research on a skeptical Congress. But even though the last Administration started to cut back on expenditures for science, it ended by quadrupling them. And this was by no means for defense alone; over those 8 years the Congress multiplied the budget of the National Institutes of Health more than ninefold, giving them each year more than the President recommended. It is almost enough to make one try to apply to politics the theory of Henry Adams that science, as it becomes more abstract, increases in geometrical progression the power that it produces (*1*).

In his farewell message President Eisenhower warned the nation against the danger that "public policy could itself become the captive of a scientific-technological elite." Even though he quickly explained that he was not talking about science in general, but only those parts allied with military and industrial power, this was a shock to the scientists (*2*). To one who believes that science has helped to liberate man from ancient tyrannies—who, in short, still takes his political faith from Franklin and Jefferson and the Age of the Enlightenment—it is disconcerting to be told that he is a member of a new priesthood allied with military power.

Yet the plain fact is that science has become the major Establishment in the American political system: the only set

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