6.5 FINAL REMARKS

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My summary will certainly leave out much fine work but will stress a few of the points that impressed me.

First, I note remarkable progress since 1967 when I last worried about the interplanetary complex, particularly the new observations from space and of very small particles. I am delighted to see the ground based Zodiacal Light observers, like Weinberg and Dumont, converging on their observations both of polarization and of intensity. The larger particles are clearly the major contributors particularly away from the Sun. This forces the theoreticians and the laboratory people to find out how these larger particles produce the observed polarization including the negative polarization. Theoreticians always can prove the answer when it is known.

The law of intensity variation from the Sun has been summarized. There is a discrepancy with the Pioneer 10 particle measures. I think that observations of the Zodiacal Light in space will be of more value near the Sun than farther away. No north-south asymmetry remains and it is now completely proven, I think, that the Zodiacal particles are concentrated with respect to the fundamental plane of the solar system, by the Apollo 15, 16, 17 observations. The high reflectivity in the very far ultraviolet is of great importance and, as Dr. Elsässer mentioned, observations are needed in the infrared as well as in the ultraviolet.

Skylab indicates no short-term intensity variations. Levasseur and Blamont find evidence for near-Earth variations produced by meteor streams. My own personal opinion: MAYBE?

Observations from space have proven conclusively that the Gegenschein is an optical phenomena of back-scattering by particles. As for observed clouds of particles in the Lagrangian points of the Earth-Moon system I again say MAYBE.

Delsemme has given a fine account of the comets as a source of the interplanetary particles and I agree with his conclusion. There is a great deal of mass to be contributed by comets and Dohnanyi's evidence against the asteroids confirms my own opinion.

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Next we have the exciting discovery of beta-meteoroids, beta representing a finite ratio of solar light pressure to gravity. Berg and his co-workers have proven their point. With the HEOS, Fechtig and his group have proven finally that there is a strong tendency for particles to break up near the Earth to produce little clusters and groups. With regard to the refractory Hemenway particles generated in the Sun, I think it is very important to look for them. Here I have my own opinion: MAYBE?

On the atmospheric collection of small particles I think Dr. Brownlee and his group well deserve the resounding congratulations already given them for capturing what are almost certainly cometary particles that we can hold in our hands and study. The structure is truly remarkable for these sub-micron clusters. They look like fish eggs. They will certainly be of extreme importance in determining the nature of the formation of comets.

The Moon crater work is really extremely impressive to me, that such detailed studies can be made of craters down to submicron size. The same is true of the other laboratory studies on lunar samples. I congratulate the workers and stress that in the laboratory some genius must find a method for accelerating low density, fragile particles or clusters of small particles to velocities of kilometers per second. Otherwise calibration of craters versus meteoroid velocity and mass remains obscure. But I do congratulate the group here on their very fine work on laboratory crater formation.

There appears to be a big question as to whether the rates of impacting debris on the Moon at the present time are greater than they were 50,000 years ago. That question was answered in the positive by one worker and in the negative by another. The question revolves around dating processes on the Moon by means of high-energy particles from solar flares. The problem demands resolution.

With regard to the interstellar dust observed in space, particularly by Pioneers 8 and 9, I must say I began looking for interstellar meteors in 1933 when I made some calculations identical in principle to those by Tomandl. I calculated the radiants of meteors coming from a great cloud around the star Sirius, following Öpik's proof in 1931 that a cloud of particles could be stable over billions of years against the passage of stars at great distances from a star. My calculations led nowhere. They were never published and I could never find any clear evidence of any hyperbolic particles. I hope he has better success than I.

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The experiments on the Moon have proven there are mobile charged dust particles on the Moon. I do wish that Berg and Rhee could agree whether they were going from the light side plus-to-minus or from the dark side minus-to-plus but I am sure this will be resolved. Continued studies of this phenomena should yield very important results.

Over thirty years ago I asked the question "Does the Moon gain or lose mass by impact accretion?" The question is still not answered, at least by concensus. There seems to be some strong evidence on both sides. Laboratory studies show that the crater debris won't go out fast enough. Some lunar evidence, not discussed here at this meeting indicate that there must be some loss of mass.

Paddock and Rhee have at last produced some good theory and laboratory work on the spin up of small particles in space by solar radiation, mentioned so many years ago by Öpik. With the experimenters I feel that you can spin them fast but you can't break them up that way. If they are fragile enough to break they will not last long after they are released from a comet. But there is clear evidence that meteor dust is revolving rapidly: the Soberman experiment. I congratulate the group with HEOS 2 in finding dust from Comet Kohoutek. Their calculated rate of loss of matter from that comet is amazingly large. If finally confirmed the result will give us food for thought about the surfaces of new comets. Can we ever observe this phenomenon again in other comets?

It is very encouraging to see good theories for the antitails of comets fitting so well with observation. I think the resultant particle size distribution among meteoroids has been discussed adequately except for one point. I believe it is now firmly established that reduction in slope, or nearly a "stillstand", occurs on the upgoing curve of log (cumulative number) versus log (mass curve). This indicates a drop off in the normal particles of cometary origin around 10^{-8}-10^{-9} grams. Then there is a build-up of the smaller particles which may or may not extend out to 10^{-18} grams or further, probably due to fragmentation. I think this is enormous progress since 1967 when we had no knowledge of what went on much below about 10^{-7} grams.

The particle density clearly varies inversely and only statistically in some fashion with particle size. Is the explanation a) survival of the fittest in the collisional processes or b) that the interiors of great comets contain harder material with more coherence than material from the outer layers? The answer bears heavily on the processes of comet formation.

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In meteor streams the time arrow is very clear. Meteor streams from comets start out very narrow and compact and continuously spread out, violently in conflict with the jet-stream concept of Alfvén and Trulsen. The fact that the densities of meteoroids also correlate with the ages, further shows that the jet-stream theory among cometary meteor streams is wrong. On the other hand, I must congratulate Trulsen that this theory provides such a fine relationship between the inclinations and the eccentricities among the asteroids in the early <u>dissipative</u> stages.

I am delighted to see the clear-cut relationship between meteors and the solar cycle finally established by Lindblad. I worried about such a relationship so many years ago and could never prove a correlation.

From the theories presented this morning, small conducting particles with an imaginary term in the index of refraction will definitely spiral away from the Sun, counter to the Poynting-Robertson effect. Dielectrics will spiral on into the Sun. It is a very interesting question whether indeed we have any pure silicates, dielectrics, in mixed material that must be the basis of a comet. There must not be any pure crystals of any sort, or are there? Iron must surely be reasonably abundant to produce opacity. The particles must be radiation damaged, and that, I understand, will produce some opacity, following Harwit's experiments. Finally it seems to me that close to the Sun, when the particle begins to warm up and the vapor pressure becomes significant, then the particle will begin to radiate and therefore to absorb. Thus it is difficult to believe that any particles will spiral into the Sun. Nevertheless, I think that we need more theory and more laboratory work on the problems of light pressure on tiny particles, particularly those with very irregular shapes.

Now to summarize some of the jobs to be done. We need both laboratory work and theory on the radiation problem just mentioned and desperately need them on the polarization and reflectivity problems of particles as functions of irregular shapes, varying sizes, phase angles, etc. Such data are most important for the larger particles in the millimeter range, which contribute most to the Zodiacal Light.

Also at last, electric charge is beginning to count with regard to these very tiny particles in space. In 1940 I first calculated the likely charges but they turned out to be only a few volts, unimportant for sizeable particles (unpublished). Now I think we must watch for

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charge effects, particularly on these particles that break up near the Earth.

Laboratory experiments on projecting low-density particles to very high velocities to study crater formation are especially important.

With regard to the Zodiacal Light there is a plea for more observations with respect to latitude, longitude, elongation from the Sun and, as Dr. Elsässer mentioned, in the far infrared. Lillie's very interesting results in the far ultraviolet below 2,000 angstroms demand more observations from space, again as a function of solar distance.

I see I have 20 seconds left. In this time I make a plea for space missions to comets and to asteroids. I am of the opinion that many of the atoms in our bodies come from comets, perhaps a major portion, and many from asteroids. Life on Earth may exist only because of comets in the early history of the solar system. Thus in situ studies of comets may be critical to studies of life in the universe.

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