# EFFECTS OF METEOR-IMPACTS ON STATIONARY SATELLITES

K. Purbosiswojo

Bosscha Observatory, Lembang (Java), Indonesia.

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*ICHTISAR*

*Dalam tulisan ini diperbintjangkan, pengaruh tertumbuknja meteor² pada satelit stasioner. Pada prinsipnja orang dapat mengetahui ada tidaknja korelasi antara massa dan ketjepatan meteor dari perubahan² orbit satelit tersebut. Djuga ditundjukkan bahwa pada prinsipnja orang dapat mendjabarkan dari perubahan² jang tersebut kepadatan ruang dan vektor ketjepatan suatu aliran meteor jang dilintasi satelit. Tetapi hasil² numerik membuktikan bahwa pengaruh meteor dapat diabaikan sama sekali.*

*ABSTRACT*

*In this paper the changes of the orbital elements of stationary satellites due to meteor impacts are discussed. From these changes in principle one should be able to draw the conclusion whether or not there exists a correlation between meteor-mass and velocity. It has been shown here, how to detect and estimate an increase in space-density and the velocity-vector of any meteor stream T which the satellite traverses. Numerical results, however, show that effects of meteor-impacts can be neglected at all.*

## INTRODUCTION

Suggestions have been made to place stationary satellites into orbit. These satellites should be stationary above one point of the earth surface in the equatorial plane. Since stationary satellites can be employed for television and telecommunication purposes investigations about perturbations on their orbital elements will be worthwile. These perturbations has an influence in the stability conditions of the orbit. Due to its extreme height, i.e. 35,787 km from the surface of the earth, airdrag is practically zero. There exists however another kind of drag, due to plasma surrounding the satellite. And lastly we have to investigate effects of meteor-impacts on the elements of the orbit and on the spin of the satellites. We need not emphasize other kinds of perturbations such as the unexpectedly high pressure of the radiation of the sun in space, perturbation from the sun and moon, which may or may not knock the satellite out of its original orbit.

Despite all of these things there is one condition which favors the observer, i.e. that the satellite can be observed continuously by radar or by optical means. The currently advancing technology on lasers may allow us in the future to observe faint reflected light from the satellite. Thus one may observe continously perturbations experienced by the satellite, and may analyze it effectively. The present paper discusses the effects and problems arising from meteor-impacts.

## METEOR IMPACTS

The problem of meteor-impacts is not a simple one. This is due to lack or inadequacy of observational data. Since the time rockets and satellites have been launched this situation is improved a great deal.

It is a well known fact that meteors are not distributed evenly in space. Sporadic increases in the number of meteor-impacts, has been confirmed by, for example Sputnik III (McCracken and Alexander, 1963). Especially at greater altitudes from the earth surface, there is indeed a large dispersion in the numerical data (Nazarova, 1963). At the moment we may assume meteor conditions summarized as follows:

1. There is a dust envelope about the earth (Whipple, 1961).
2. Meteor-impacts is a function of height h. The approximate upper limit of N at each h higher than 2000 km is propertional to $h^{-1}$ (Whipple, 1961).
3. The impact-rate at 2000 km altitude is approximately $10^{-3}$ $m^2$ per second. This number is again an upper limit approximation. The minimum meteor mass is taken to be $10^{-8}$ gms.
4. The mass distribution of meteoric particles is approximately $N(m) = k. m^{-0.5}$ (Moroz, 1962). We again take the upper limit approximation of the exponent.

Using these assumptions we obtain a mean meteor mass of

$$m_o = \frac{\int_{m_{min}}^{\infty} m dN}{\int_{m_{min}}^{\infty} dN} = 1/3.\ 10^{18} \text{ gms.} \qquad \ldots\ldots(1)$$

at 2000 km altitude. Thus the mean mass at 360,000 km is approximately $1/54.\ 10^{-8}$ gms.

From meteor data we do not have any idea of the mean of meteor impulses at a height of $36.\ 10^3$ km. Hence we have to resort to the mean of mv, in which we use the mean $m_o$ of m and the mean of meteor velocities in a geocentric system. Meteor velocities above the atmosphere are ranging between 11 and 72 km/sec. (McCracken and Alexander, 1963). Thus we may take for the mean velocity the value of 40 km/sec. (compare Whipple, 1961). The relation between the means mv, $m_0$ and v ia as follows:

$$\overline{mv} = m_0 v + \text{cov } [m, v] \tag{2}$$

where cov [m,v] is the covariance of m and v. Actually, in our case, the covariance cannot be defined as the product of correlation of mass and velocity, times the variance of mass by the variance of velocity, as in the case of normal distributions. The covariance term is here a notation to indicate the difference of $\overline{mv}$ and $\overline{m}.\overline{v}$ in case m and v are not correlated.

The impulse transferred by an impact is used both for a change in the linear velocity and a change in the spin angular momentum of the satellite. Since there is no preference between linear velocity and spin, it is likely that the probabilities of both mentioned changes are the same. Thus one half of the transferred impulse is used for a change in the linear velocity, and the other half for a change in the spin. Assume further that the impact is completely elastic. It is to be noted here that a non-elastic impact will lessen the impulse transfer, and reduce the perturbation. Therefore the total impulse transferred to the satellite's linear velocity can be expressed by:

$$-\triangle I = (\tfrac{1}{2}\, NAvm_0 + NA\text{cov}\,[m,v]\,)\triangle t \tag{3}$$

where A is the cross-sectional area of the satellite. If the satellite's mass is M then

$$-\triangle v = \left(\frac{\tfrac{1}{2}NA}{M}\, vm_0 + \frac{NA}{M}\, \text{cov}\,[m,v]\right)\triangle t \tag{4}$$

The velocity-time spectrum is as follows:

$$t - t_0 = -\frac{2M}{NAm_0} \log \frac{\tfrac{1}{2}v + \text{cov}\,[m,v]}{\tfrac{1}{2}v_0 + \text{cov}\,[m,v]} \tag{5}$$

If the velocity-change by meteor-impacts were large, we should be able to see whether there exists a mass-velocity correlation or not, by plotting velocity versus time. A numerical result shows however that it will be undetectable (see later section).

We shall now take the changes of the satellite's orbital elements under consideration:

major axis: $\triangle a = \dfrac{2a^2}{GM_\oplus} v \triangle v$ .............................. $\alpha v^2$

eccentricity: $\triangle e = 2(a + \cos f)\dfrac{\triangle v}{v}$ .......................... $\alpha v^0$

mean motion: $\triangle n = 3v\triangle v \left\{ -\dfrac{1}{GM_{\oplus}\sqrt{a}} - \sqrt{\dfrac{1-e^2}{GM_{\oplus} r(1+e\cos f)}} \right\}$ ................ $\alpha v^2$

perigee : $\triangle w = \dfrac{2\sin(f-w)}{e}\,\dfrac{\triangle v}{v}$ ..................... $\alpha v^0$

Thus we see that the eccentricity and the mean motion practically do not undergo a change. Suppose that the satellite traverses a meteor stream. The velocity and the density N will differ here for those in the space outside the meteor stream. Theoretically (though not neccesarily detectable), we should be able to deduce what the velocity-vector and space density of the stream is by using the formula:

$$-d\left(\frac{\triangle v}{\triangle t}\right) = \tfrac{1}{2}\,\frac{NA}{M}\,m_o dv + \tfrac{1}{2}\,\frac{Av}{M}\,m_o dN$$

together with formulas for the change in inclination, major axis and eccentricity (compare formulas in Seifert's (1959) table 8-4). This is carried out theoretically by substituting the values of N, A, M, $m_o$ and v for at least two points of the orbit, and solve the equations for dv and dN.

It is easy to see that oscillations due to the orbital velocity of the satellite with respect to the earth velocity towards the earth apex are nilled after each revolution of the satellite, and similarly the effects of impulse-transfer to the spin angular momentum. Thus they need no further discussions.

## NUMERICAL RESULT AND CONCLUSION

Meteor impacts will reduce the velocity of a satellite and thus will perturb the orbit continuously. This is similar to the influence of air-drag. The question arises whether this has such an effect as to endanger the stability of the orbit of the satellite within only a few years. To answer this question we can, for example, made an estimate of the change in the major axis of the orbit. We have the relation

$$\triangle t = \frac{GM_{\oplus}M}{aNAv^2m_o}\,\frac{\triangle a}{a}$$

Substituting $A = 1\ m^2$, a 5% change of the major axis, an impact rate $N = 1/18\ 10^{-3}\ m^{-2}\ sec^{-1}$ and $v = 40$ km/sec., we obtain a time of the order of one billion years, per gram mass of the satellite.

Thus we may conclude that we have no reason to worry about the influence of meteor-impacts on stationary satellites. From this result we have to resort to sensors and detectors in the satellite to solve for example the question of the correlation of mass and velocity of meteors. Lasers can in the future perhaps help to solve this problem.

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