Mon. Not. R. Astron. Soc. **262,** L35–L36 (1993)

Impact probabilities on artificial satellites for the 1993 Perseid meteoroid stream

Martin Beech[1] and Peter Brown[2]

[1]*Department of Astronomy, University of Western Ontario, London, Ontario N6A 3K7, Canada*
[2]*Department of Physics, University of Western Ontario, London, Ontario N6A 3K7, Canada*

Accepted 1993 March 24. Received 1993 March 22

ABSTRACT

It is argued that the new but short-lived maximum in the activity profile of the Perseid meteor shower may yield an enhanced meteoroid flux in 1993 August. An estimate of the impact probability of Perseid meteoroid stream particles with Earth-orbiting satellites is presented. The impact probability for objects comparable in size to the *Hubble Space Telescope* and the Space Shuttle is found to be small but non-negligible. The probability of meteoroid impacts on the proposed Space Station is also discussed.

Key words: artificial satellites, space probes – meteoroids.

1 INTRODUCTION

Travelling with a velocity of order 60 km s^{-1}, a typical Perseid meteoroid with visual magnitude $+2.5$ and mass ~ 2.5 mg has 4.5 kJ of kinetic energy. Should such a meteoroid strike an artificial satellite, it is likely that the satellite would suffer severe damage. Indeed, the empirical formula of Laurance & Brownlee (1986) suggests that an impact crater some 5 cm in diameter might result from such a collision.

Under 'normal' circumstances, the number density of large microgram meteoroids, both shower and sporadic, is so low that satellite impacts with such objects are highly unlikely (McKinley 1961). Any impact is expected to be with space-debris generated in the process of space exploration itself (Klinkrad & Jehn 1992; Rossi & Farinella 1992).

Since the launch of the *Sputnik* space probe in 1957 October, the only substantive meteor storm in which the visual meteor rates were in excess of several thousand per hour was that of the 1966 November 17 Leonids (Kronk 1988). The population of Earth-orbiting satellites has increased dramatically since 1966, and consequently the possibility of satellite damage under meteor storm conditions deserves to be examined carefully. The urgency for such a study is highlighted by the possibility of an enhanced meteor display from this year's Perseid meteor shower.

2 THE PERSEID METEOROID STREAM

The Perseid meteor shower is one of the most prominent of all the annual meteor showers. Its ability to return with nearly constant visual meteor rates each year indicates that the stream is an old and well-established one (Lovell 1954). Periodic comet Swift–Tuttle (Comet 1862 III, and 1992t) was long ago established as the stream's parent body (Kronk 1988).

During the past several years, the International Meteor Organization (IMO) has conducted extensive global watches of the Perseid meteor shower. These studies have revealed a prominent but short-lived (of order 1 h) secondary maximum in the visual meteor activity profile (Roggemans 1989; Koschack & Roggemans 1991). This enhanced activity spike has been identified with material recently ejected from Comet P/Swift–Tuttle (Brown, Gyssens & Rendtel 1992). Observers in China and Japan reported zenithal hourly rates (ZHR) possibly in excess of 1000 visual meteors per hour in 1992 (Pin-xin 1992, but see also Znojil 1992) when the Earth encountered the new Perseid activity spike.

The impact geometry for the Earth and the Perseid meteoroid stream this year places the Earth inside and behind Comet Swift–Tuttle (Brown et al. 1992). Geometrical encounters of this kind between the Earth and Comet Tempel–Tuttle have previously produced spectacular meteor storms from the Leonid meteoroid stream (Yeomans 1981). The likelihood of an enhanced display from the Perseid meteoroid stream this August 12 is therefore high, although the peak strength is uncertain as little is known about the dust distribution around Comet Swift–Tuttle. On the assumption that the solar longitude of the 1992 activity spike remains the same, it is estimated that the 1993 outburst will begin at about 1 h UT on August 12.

3 IMPACT PROBABILITIES UNDER STORM CONDITIONS

The Perseid meteor shower typically produces a peak visual ZHR of order 100. Koschack & Roggemans (1991) have shown that this rate is equivalent to 180 meteoroids capable of producing a meteor of magnitude +6.5 or brighter per 10^9 km^3. In mass terms, the +6.5 or brighter magnitude limit corresponds to those meteoroids of mass ≥ 1 mg. Under storm conditions, the visual ZHR will be much higher than 100. During the 1966 Leonid meteor storm, approximately 40 visual meteors per second were recorded at maximum activity (Kronk 1988). The 1833 Leonid meteor storm, although not so well documented, is generally believed to have had an even greater ZHR than that recorded in 1966. Should the 1993 Perseid outburst produce meteors at about the same rate as the Leonid storms, a ZHR of order 10^5 visual meteors is possible. High meteor activity was noted for the Perseid returns in 1861 and 1863 during Comet Swift–Tuttle's last passage, but precise strengths are not well determined (Kronk 1988).

The duration of any enhanced activity from the Perseid stream this August can only be guessed at the present time. Pin-xin (1992) recorded enhanced meteor activity for about an hour during the 1992 encounter with the Perseid activity spike. During the 1966 Leonid storm, however, the ZHR remained above 10^5 for between 20 to 40 min. On the other hand, the maximum ZHR of the Draconid meteor storm of 1946 remained near its peak rate for about 10 min (Lovell 1954). It is possible, therefore, that any enhanced activity from the 1993 Perseids might last from between ~500 to ~2000 s.

Using the particle density derived by Koschack & Roggemans (1991), the meteoroid flux ('meteoroid' in this case means a meteoroid capable of producing a meteor of absolute visual magnitude greater than +6.5) corresponding to a Perseid ZHR of 100 is 1×10^{-11} meteoroids m^{-2} s^{-1}. We note that this is less than the total meteoroid flux, which contains the many smaller meteoroids that do not produce visual meteors. Under storm conditions, the meteoroid flux may increase by a factor of order 10^3: the resulting collisional probabilities for Perseid stream meteoroids are presented in Table 1. Given the uncertainty in our knowledge of the possible peak meteoroid flux, and the likely duration of any meteor storm, we believe that the real impact hazard could be larger or smaller by a factor of 10 than that shown in Table 1.

Table 1. Impact probabilities (in per cent) for Perseid meteoroids, given several combinations of storm duration and impact area.

	Area (m^2)			
Storm Duration (s)	5	10	50	100
500	3×10^{-3}	6×10^{-3}	0.03	0.06
1000	6×10^{-3}	0.01	0.06	0.1
2000	0.01	0.02	0.1	0.2

For small satellites with surface areas of order 5 m^2 the Perseid impact probability is small, but given the large number of objects in this size range (several thousand: Maley 1991) the possibility of some impact damage exists. For larger objects, with surface areas of order 100 m^2, the impact probability is still small but is certainly non-negligible. We note in particular that the *Hubble Space Telescope* (*HST*) and the Space Shuttle have exposed surface areas approaching 100 m^2. Shara & Johnston (1986) have estimated that there is a 0.1 per cent probability of the *HST* being struck by a 1-m sized artificial Earth satellite in a 17-yr period. This is comparable to the impact probability with a Perseid meteoroid during a storm lasting ~10 s.

The meteoroid impact probability grows in proportion to the surface area of the target. In the near future it is very likely that large space structures will be deployed in Earth orbit, and we note that the surface area of the proposed Space Station is of order 10^3 m^2. When habitable structures of this size become common in Earth orbit, the consequences of meteoroid impacts need to be considered carefully. Under Perseid meteor storm conditions, for example, the impact probability on a structure as large as that for the proposed Space Station will rise to several per cent. Indeed, the meteoroid impact probability for the Space Station during a Perseid meteor storm lasting ~2000 s with a ZHR of 10^5 is of order that expected from collisions with space-debris over a 30-yr exposure time (Klinkrad & Jehn 1992).

4 CONCLUSIONS

We find that the impact probability of Perseid meteoroids, under possible meteor storm conditions, with Earth-orbiting satellites is small but non-negligible. The impact probability with objects the size of the *HST* and Space Shuttle is about 0.1 per cent.

REFERENCES

Brown P., Gyssens M., Rendtel J., 1992, WGN, 20, 192
Klinkrad H., Jehn R., 1992, ESA Journal, 16, 1
Koschack R., Roggemans P., 1991, WGN, 19, 87
Kronk G. W., 1988, Meteor Showers: A Descriptive Catalog. Enslow Publishers Inc., New Jersey
Laurance M. R., Brownlee D. E., 1986, Nat, 323, 136
Lovell A. C. B., 1954, Meteor Astronomy. Oxford Univ. Press, Oxford
McKinley D. W. R., 1961, Meteor Science and Engineering. McGraw-Hill Company, New York, Section 10-5
Maley P. D., 1991, Icarus, 90, 326
Pin-xin X., 1992, WGN, 20, 198
Roggemans P., 1989, WGN, 17, 127
Rossi A., Farinella P., 1992, ESA Journal, 16, 339
Shara M. M., Johnston M. D., 1986, PASP, 98, 814
Yeomans D. K., 1981, Icarus, 47, 492
Znojil V., 1992, WGN, 20, 244