Influence Intervals of Solar Eclipses on Spacecrafts Deployed in Some Typical Space Orbits

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***Abstract*—Energy supply is one of the essential concerns for spacecrafts in space, which directly effects the expected lifespan of the spacecrafts. Solar energy, which is just second to nuclear energy, is almost the most convenient and secure sources of energy for spacecrafts in orbit. Main Influence intervals of solar eclipses on spacecrafts deployed in some typical space orbits are simulated, wherein variation of altitudes in space is taken into account as one of the main factors leading to differences in influence intervals of solar eclipses. The space regions include those for sunsynchronous orbital satellites,those for middle altitude orbiting satellites,those for geostationary orbiting satellites, and those for inclined geosynchronous orbiting satellites.The influence intervals of solar eclipses will provide one of the key constraints of spacecrafts' mission plannings. The simulation results have shown that the higher altitude, the longer duration of solar eclipses.**

Keywords-solar eclipse; orbit; spacecraft; mission

I. INTRODUCTION

For most spacecrafts, which are deployed near the Earth, it is almost unavoidable that solar energy will be used to keep onboard devices functioning. As an exception, nuclear energy seems to be popular for deep space exploration. Therefore, solar lighting condition has become one of the most important factors for spacecrafts' orbit designings[1]. It is obvious that the sunsynchronous orbit is the most proper choice for purpose of energy availability. But sunsynchronous orbit has limitings of altitudes and inclinations. Therefore, sunsynchronous orbit can not fully meet all demands of all space missions. Geosynchronous orbit， inclined geosynchronous orbit, middle altitude orbit become alternatives for specific purposes of space missions. For example, geosynchronous orbit is usually proper for communication satellites, which can provide a much greater coverage of ground users; inclined geosynchronous orbit is proper for some specific navigation satellites or communication satellites; middle altitude orbit is usually proper for navigation satellites, GPS satellites and BeiDou satellites being cases in point.

II. SOLAR ECLIPSE MERCHANISM

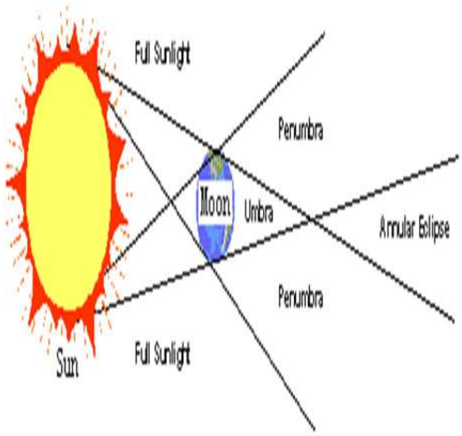

FIGURE I. SOLAR ECLIPSE DEVELOPINGS

In fig.1, when a spacecraft (S/C) crosses the space zones marked with umbra, penumbra, solar intensity will be attenuated, even to zero. The event when the S/C crosses the space zones marked with umbra, penumbra is referred to as a solar eclipse[2]. Solar eclipses happen almost randomly, but they can be predicted. According to the predictions, S/C missions might skip the interval when solar eclipses happen so that unpleasant failures of S/C might be avoided.

III. SIMULATIONS OF SOLAR ECLIPSES FOR S/C IN VARIOUS TYPICAL ORBITS

Most S/C are deployed in geosynchronous orbit (GEO), inclined geosynchronous orbit (IGSO), middle altitude orbit (MEO) or sun-synchronous orbit (SSO). Here, all these four typical space orbits are considered in the simulation. During the simulation, a solid year between 1 Jul 2015 12:00:00.000 Greenwich Mean Universal Time (UTCG) and 1 Jul 2016 12:00:00.000 (UTCG) is taken into account. Simulations of solar eclipses for S/C in various typical orbits are carried out. Simulation results are as follows.

TABLE I. YEARLY SOLAR ECLIPSES FOR GEO

Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
12 Sep 2015 9:28:28.474	12 Sep 2015 0:06:16.215	2268
13 Sep 2015 1:47:48.010	13 Sep 2015 2:45:19.902	3452
13 Oct 2015 5:08:49.463	13 Oct 2015 6:11:53.813	3784
13 Oct 2015 0:48:35.309	13 Oct 2015 1:27:44.059	2349
9 Mar 2016 04:03:44.734	9 Mar 2016 04:52:33.476	2929

From table 1, the simulation for solar eclipses of GEO has shown that there are five solar eclipses every year; the solar eclipses happen twice in September, twice in October, and once in March. The average solar eclipse lasts average 2956 s. Influence interval of 2956 s might lead to severe consequence for S/C energy balance if we ignore the existence of solar eclipse events.

TABLE II. YEARLY SOLAR ECLIPSES FOR IGSO

Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
15 Aug 2015 1:13:21.511	15 Aug 2015 2:12:07.376	3526
13 Sep 2015 6:12:37.372	13 Sep 2015 6:31:03.231	1106
12 Oct 2015 4:54:39.494	12 Oct 2015 5:59:53.822	3914
11 Nov 2015 9:27:25.886	11 Nov 2015 9:43:36.184	970
9 Feb 2016 00:33:34.514	9 Feb 2016 00:56:29.755	1375
7 Apr 2016 07:56:33.221	7 Apr 2016 08:25:52.119	1759

Table 2 lists the simulation for solar eclipses of IGSO. It has shown that there are six solar eclipses every year; The solar eclipses happen once in August,once in September, once in November, once in Febuary, once in April. The average solar eclipse lasts average 2108 s. Influence interval of 2108 s might lead to severe consequence for S/C energy balance if we ignore the existence of the solar eclipse events. Compared with S/C in GEO orbit, S/C in IGSO orbit seems to experence more frequent eclipse events with less interval.

TABLE III. YEARLY SOLAR ECLIPSES FOR MEO.

Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
13 Sep 2015 7:49:21.077	13 Sep 2015 8:12:01.842	1361
12 Oct 2015 0:51:17.504	12 Oct 2015 1:21:20.317	1803
7 Apr 2016 07:31:39.475	7 Apr 2016 08:01:20.294	1781

In table 3, the simulation for solar eclipses of MEO has shown that there are three solar eclipses every year; The solar eclipses happen once in September, once in October, once in April. The average solar eclipse lasts average 1648 s. Influence interval of 1648 s might lead to severe consequence for S/C energy balance if the existence of the solar eclipse events is ingored. Compared with S/C in either GEO orbit or IGSO orbit, S/C in MEO orbit seems to experence fewer eclipse events with much less interval of solar eclipses.

TABLE IV. YEARLY SOLAR ECLIPSES FOR SSO

Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
13 Sep 2015 6:08:39.485	13 Sep 2015 6:33:05.366	1466
13 Sep 2015 7:41:47.213	13 Sep 2015 8:08:53.220	1626
9 Mar 2016 01:33:38.660	9 Mar 2016 01:47:42.181	844
9 Mar 2016 02:14:19.296	9 Mar 2016 02:29:23.276	904

In table 4, the simulation for solar eclipses of SSO has shown that there are four solar eclipses every year; The solar eclipses happen twice in September, twice in March. The average solar eclipse lasts average 1210 s. Influence interval of 1210 s might lead to severe consequence for S/C energy balance if the existence of the solar eclipse events is ingored. Compared with S/C in GEO orbit and that in IGSO orbit, S/C in SSO orbit seems to experence the fewer eclipse events with much less interval.

IV. CONCLUSION

Solar eclipses simulations for S/C in four typical orbits, i.e., geosynchronous orbit, inclined geosynchronous orbit, middle altitude orbit and sunsynchronous orbit, have shown that the longest duration of a solar eclipse happens in case of GEO orbit with the average eclipse interval of 2956 s, and the shortest duration of a solar eclipse happens in case of SSO with the average eclipse interval of 1210 s. The duration of a solar eclipse in case of IGSO with the average solar eclipse interval of 2108 s is second only to that of GEO with the average solar eclipse interval of 2956 s. The duration of a solar eclipse in case of SSO with the average solar eclipse interval of 1210 s is second to that of IGSO with the average solar eclipse interval of 2108 s. It seems that the higher altitude, the longer duration of solar eclipses. Different kind of orbits has different influence interval of solar eclipses, which might lead to severe consequence for S/C energy balance if the existence of the solar eclipse events is ingored. It is recommended that as one of the important factors, solar eclipse events should be taken into account when S/C mission plannings are made.

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