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Scientometric analysis of orbital debris research publications

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Abstract
This paper examine on scientometric analysis of orbital debris research publications during 2002 to 2016, This study aims to evaluate the research productivity of orbital debris, growth of year wise publications, document types, sources wise, authorship pattern, top ten countries contribution, and top ten institutions contributed in this research. The study reveals that, The year wise analysis found that 2015 has occupies first place, 2005 has occupies second position with 30 papers, 2016 has occupies third place with 25 papers and so on. The document types found that majority of papers were published in Conference paper, article has 27.49 percent, and the remaining three documents were published least number of papers. The orbital debris research papers contributed by 754 authors during the study period, among the 754 authors Liou, J.C. has occupies first position with 16 papers contributed and so on.

Keywords: orbital debris, debris population, satellite population, scientometric

Introduction
The number of man-made debris objects orbiting the Earth, or orbital debris, is alarmingly increasing, resulting in the increased probability of degradation, damage, or destruction of operating spacecraft. Due to the increasing debris population it is reasonable to assume that improved capabilities for on-orbit damage attribution, in addition to increased capabilities to detect and track small objects are needed (Englert, C.R. *et al*., 2014) [1]. The space environment presents many hazards for satellites and spacecraft. One of the major hazards is hypervelocity impacts from uncontrolled man-made space debris (Marshall Polk. *et al.*, 2015) [7]. Low earth orbit has become increasingly congested as the satellite population has grown over the past few decades, making orbital debris a major concern for the operational stability of space assets (Percy. T.K., Brian Landrum. D, 2013) [8].
The orbital debris modeling can build evolutionary models as essential tools to predict the current or future orbital debris populations. The orbital debris modeling can also devise an effective search strategy applicable for breakup fragments in the geostationary region using ground-based optical sensors, and to evaluate the effectiveness of space-based measurements of objects not tracked from the ground, both to contribute to space situational awareness. Another application of the orbital debris modeling is to estimate attitude motion of space objects to be removed for environmental remediation (Hanada. T, 2013) [3].

Scientometrics
Scientometrics, according to Garfield, "the study of the measurement of scientific and technological progress" (Garfield 1979) [2]. Its origin is in the quantitative study of science policy research, or the science of science, which focuses on a wide variety of quantitative measurements of science at large. Scientometrics is related to and has overlapping interests with Bibliometrics and Informetrics. The terms Bibliometrics, Scientometrics, and Informetrics refer to component fields related to the study of the dynamics of disciplines as reflected in the production of their literature (Hood & Wilson. 2001) [4].

Materials and Methods
The data have been collected from the Scopus database; the study period is during (2002-2016). The search string was used 'Orbital debris' in the Title search box, field were used, the time span field were select from 2002 to 2016. A total of 291 records were retrieved, the data downloaded and analyzed using MS office -Excel as per objectives of the present study. The present study helps to find in orbital debris research publications.

Relative Growth Rate (RGT) and Doubling Time
The Relative Growth Rate is the number of publications/pages per unit of time. Hence, one year is taken as the unit of time. The mean relative growth rate R (1-2) over a specified period of interval can be calculated from the following equation suggested by Mahapatra (1985) [6].

$$R(1-2) = \frac{W2 - W1}{T2 - T1}$$

Where,
R = Mean relative growth rate over the specify period of interval
W1 = log W1 (Natural log of initial number of publications/ pages)
W2 = log W2 (Natural log of initial number of publications/ pages)
T2-T1 = Unit difference between the initial time and final time.

Therefore,
R (a) = relative growth rate per unit per of publication per unit of time (year)
R (p) = relative growth rate per unit per of pages per unit of time (year

The corresponding Doubling Time for publications and pages can be calculated by using the following formula:

$$\text{Doubling time (Dt)} \frac{0.693}{R}$$

Therefore,

$$\text{Doubling time for publications Dt (a)} \frac{0.693}{R(a)}$$

Lotka's Law

The Lotka's Law is applicable to author productivity; it can be used in the field of Library and Information Studies research. Lotka's law was made in Lotka's 1926 journal article, "The Frequency Distribution of Scientific Productivity": "...the number (of authors) making *n* contributions is about *l/n2* of those making one; and the proportion of all contributors, that make a single contribution, is about 60 percent (Lotka A J, 1926)".

Objectives

The following objectives of the present study are:

- To find Orbital debris research publications from 2002 to 2016
- To find authorship pattern in Orbital debris research publications
- To find out top ten authors contributed in Orbital debris research publications
- To identify the top ten countries contributed in Orbital debris research
- To find top ten sources published in Orbital debris research papers
- To find out top ten institutions contributed in Orbital debris research

Table 1: Year wise orbital debris research publications

Sl. No	Year	No. of Records	Percentages
1	2002	5	1.72
2	2003	15	5.15
3	2004	16	5.50
4	2005	30	10.31
5	2006	13	4.47
6	2007	6	2.06
7	2008	17	5.84
8	2009	21	7.22
9	2010	23	7.90
10	2011	23	7.90
11	2012	22	7.56
12	2013	21	7.22
13	2014	22	7.56
14	2015	32	11.00
15	2016	25	8.59
	Total	291	100.00

Table 1 shows that, year wise orbital debris research publications during from 2002 to 2016, during the study period 291 papers were published in orbital debris research, among the fifteen years 2015 has occupies first position, 2005 has occupies second position with 30 papers, 2016 has occupies third place with 25 papers, followed by 2010 and 2011 has 23 papers, 2012 and 2014 has 22 papers, 2009 has 21 papers, 2008 has 17 papers, 2004 ahs 16 papers, 2003 has 2015 papers, 2006 has 13 papers, 2007 has 6 papers and 2002 has 5 papers last place but starting was start with least publications.

Table 2: document types wise orbital debris research publications

Sl. No	Document types	No. of records	Percentages
1	Conference Paper	201	69.07
2	Article	80	27.49
3	Book Chapter	6	2.06
4	Review	3	1.03
5	Book	1	0.34
	Total	291	100.00

Table 2 indicates that document types wise orbital debris research publications during the study period, 291 orbital debris research papers published in five document types, among those conference paper type has occupies first place with 201, article type has second place with 80 papers, Book Chapter type has 6 papers, review type has 3 papers, book type has single papers.

Table 3: source types wise orbital debris research publications

Sl. No	Source types	No. of Records	Percentages
1	Conference Proceedings	181	62.20
2	Journals	100	34.36
3	Books	7	2.41
4	Trade Publications	2	0.69
5	Book Series	1	0.34
	Total	291	100.00

Table 3 shows that source Types wise orbital debris research publications published during the study period, Conference Proceedings has published 181 papers, Journals has 100 papers, Books has published 7 papers, Trade Publications has published 2 papers and Book Series has 1 paper.

Table 4: language wise orbital debris research papers

Sl. No	Language	No. of Records	Percentages
1	English	286	98.28
2	Chinese	5	1.72
	Total	291	100.00

Table 4 shows that language wise orbital debris research papers, 219 papers were contributed only two languages, 286 papers were in English and remaining 5 papers are in Chinese language.

Table 5: authorship pattern in orbital debris research publications

Sl. No.	Authorship pattern	No. of Records	Percentages
1	Single	27	9.28
2	Double	34	11.68
3	Three	56	19.24
4	Four	61	20.96
5	Five and Above	113	38.83
	Total	291	100.00

Table 5 indicates that authorship pattern in orbital debris research publications, among the 291 papers, 113 papers were contributed five and above author collaborative contributions, 61 papers were published four author collaborative contributions, 56 papers were published three author collaborative contributions, 34 papers were contributed two author collaborative papers, and moreover 27 papers are only contributed single authors.

Table 6: top twenty authors contributed in orbital debris research publications

Sl. No	Author Name	No. of Records	% of 291
1	Liou, J.C.	16	5.50
2	Christiansen, E.L.	12	4.12
3	Johnson, N.L.	10	3.44
4	Krisko, P.H.	9	3.09
5	Fahrenthold, E.P.	8	2.75
6	Hanada, T.	8	2.75
7	Ryan, S.	7	2.41
8	Stansbery, E.G.	7	2.41
9	Matney, M.	6	2.06
10	Pardini, C.	6	2.06
11	Abercromby, K.J.	5	1.72
12	Burchell, M.J.	5	1.72
13	Corsaro, R.	5	1.72
14	Drolshagen, G.	5	1.72
15	Giovane, F.	5	1.72
16	Lear, D.M.	5	1.72
17	Schonberg, W.P.	5	1.72
18	Stansbery, E.	5	1.72
19	Williamsen, J.	5	1.72
20	Williamsen, J.E.	5	1.72

Table 6 shows that top twenty authors contributed in orbital debris research publications during the study period contributed 291 papers among the contributed by 754 authors were contributed in this research, Liou, J.C. has occupies first position with 16 papers contributed, Christiansen, E.L has second position with 12 papers contributed, Johnson, N.L. has third position with 10 papers contributed, followed by Krisko, P.H. has contributed 9 papers, Fahrenthold, E.P. and Hanada, T. Has contributed 8 papers respectively, Ryan, S. and Stansbery, E.G. has contributed 7 papers respectively, Matney, M. and Pardini, C. Has contributed 6 papers, Abercromby, K.J., Burchell, M.J., Corsaro, R., Drolshagen, G., Giovane, F., Lear, D.M., Schonberg, W.P., Stansbery, E., Williamsen, J., and Williamsen, J.E. they have contributed 5 papers contributed 5 papers, moreover the remaining 734 authors were contributed less than 5 papers in this research during the study period.

Table 7: top twenty countries contributed in orbital debris research publications

Sl. No	Countries	No. of Records	% of 291
1	United States	80	27.49
2	China	22	7.56
3	United Kingdom	20	6.87
4	Canada	18	6.19
5	Germany	14	4.81
6	Italy	14	4.81
7	France	10	3.44
8	Japan	9	3.09
9	Russian Federation	9	3.09
10	Australia	7	2.41
11	Netherlands	7	2.41
12	India	6	2.06
13	Spain	4	1.37
14	Iran	3	1.03
15	Hong Kong	2	0.69
16	Sweden	2	0.69
17	Ukraine	2	0.69
18	Belgium	1	0.34
19	Brazil	1	0.34
20	Colombia	1	0.34

Table 7 top twenty countries contributed in orbital debris research publications, totally 79 countries were contributed by in this research during the study period, among the 79 countries top twenty countries were listed in this table, United States has occupies first position with 80 papers, China has second place with 22 papers, United Kingdom has third position with contributed 20 papers, followed by Canada has 18 papers, Germany and Italy has 14 papers respectively, France has seventh place with 10 papers, Japan and Russian Federation has contributed 9 papers respectively, Australia and Netherlands has contributed 7 papers, India has twelfth place with 6 contributions, Spain has 4 contributions, Iran has contributed 3 papers, Hong Kong, Sweden and Ukraine have 2 contributions, Belgium, Brazil and Colombia has contributed 1 papers in this research, moreover the remaining 59 countries also contributed single papers.

Table 8: top twenty institutions contributed in orbital debris research publications

Sl. No	Institutions name	No. of Records	% of 291
1	NASA Johnson Space Center	50	17.18
2	Lockheed Martin Corporation	12	4.12
3	Naval Research Laboratory	11	3.78
4	National Aeronautics and Space Administration	10	3.44
5	NASA Marshall Space Flight Center	8	2.75
6	University of Texas at Austin	8	2.75
7	Institute for Defense Analyses	8	2.75
8	Engineering and Science Contract Group (Jacobs Technology; Houston, TX)	7	2.41
9	Kyushu University	7	2.41
10	Consiglio Nazionale delle Ricerche	7	2.41
11	Lawrence Livermore National Laboratory	7	2.41
12	Aerospace Corporation	7	2.41
13	Istituto di Scienza e Tecnologie dell'Informazione A. Faedo	7	2.41
14	NASA Goddard Space Flight Center	6	2.06
15	University of Kent	6	2.06
16	Boeing Corporation	6	2.06
17	ESTEC - European Space Research and Technology Centre	6	2.06
18	US Naval Academy	6	2.06
19	Technische Universitat Braunschweig	5	1.72
20	Beijing Institute of Technology	5	1.72

Table 8 shows that top twenty institutions contributed in orbital debris research publications, among the 291 papers 50 papers were contributed by 'NASA Johnson Space Center' and also it has occupies first place, 'Lockheed Martin Corporation' has second place with 12 contributed, 'Naval Research Laboratory' has third place with 11 papers contributed, followed by 'National Aeronautics and Space Administration' has contributed 10 papers, 'NASA Marshall Space Flight Center', 'University of Texas at Austin', and 'Institute for Defense Analyses' has contributed 8 papers, 'Engineering and Science Contract Group (Jacobs Technology; Houston, TX)', 'Kyushu University', 'Consiglio Nazionale delle Ricerche', 'Lawrence Livermore National Laboratory', 'Aerospace Corporation', and 'Istituto di Scienza e Tecnologie dell'Informazione A. Faedo', has contributed 7 papers respectively, 'NASA Goddard Space Flight Center', 'University of Kent', 'Boeing Corporation', 'ESTEC - European Space Research and Technology Centre' and 'US Naval Academy' has contributed 6 papers, 'Technische Universitat Braunschweig', and 'Beijing Institute of Technology' has contributed 5 papers with nineteenth and twentieth place respectively.

Table 9: top twenty sources published in orbital debris research papers

Sl. No	Source Title	No. of Records	% of 291
1	Advances in Space Research	29	9.97
2	Proceedings of The International Astronautical Congress, IAC	24	8.25
3	European Space Agency Special Publication ESA	22	7.56
4	Advances in the Astronautical Sciences	21	7.22
5	Acta Astronautica	15	5.15
6	The International Academy of Astronautics and The International Institute of Space Law	8	2.75
7	Journal of Spacecraft and Rockets	8	2.75
8	61st International Astronautical Congress 2010, IAC 2010	7	2.41
9	Collection of Technical Papers – AIAA/ ASME /ASCE/ AHS/ ASC Structures Structural Dynamics And Materials Conference	7	2.41
10	62nd International Astronautical Congress, 2011	6	2.06
11	AIP Conference Proceedings	6	2.06
12	IEEE Aerospace Conference Proceedings	6	2.06
13	International Journal of Impact Engineering	6	2.06
14	Proceedings of SPIE The International Society for Optical Engineering	6	2.06

15	Science And Technology Series	6	2.06
16	AIAA 57th International Astronautical Congress, IAC 2006	5	1.72
17	International Astronautical Federation 59th International Astronautical Congress 2008, IAC 2008	5	1.72
18	Procedia Engineering	4	1.37
19	Handbook of Cosmic Hazards and Planetary Defense	3	1.03
20	International Astronautical Federation 56th International Astronautical Congress 2005	3	1.03

Table 9 shows that top twenty sources published in orbital debris research papers, totally 100 sources were published 291 papers, among the 20 sources 'Advances in Space Research' has occupies first position with 29 papers, 'Proceedings of The International Astronautical Congress, IAC' has second place with 24 papers, 'European Space Agency Special Publication ESA' has third place with 22 papers, followed by 'Advances in the Astronautical Sciences' forth place with 21 papers, 'Acta Astronautica' has fifth place with 15 papers, 'The International Academy of Astronautics and The International Institute of Space Law', and 'Journal of Spacecraft and Rockets', have published 8 papers respectively, '61st International Astronautical Congress 2010, IAC 2010', and 'Collection of Technical Papers – AIAA/ ASME /ASCE/ AHS/ ASC Structures Structural Dynamics And Materials Conference', have published 7 papers, '62nd International Astronautical Congress, 2011', 'AIP Conference Proceedings', 'IEEE Aerospace Conference Proceedings', 'Proceedings of SPIE The International Society for Optical Engineering', and 'Science And Technology Series' have published 6 papers respectively, 'AIAA 57th International Astronautical Congress, IAC 2006', and 'International Astronautical Federation 59th International Astronautical Congress 2008, IAC 2008, have published 5 papers respectively, 'Procedia Engineering', have eighteenth position with 4 papers, 'Handbook of Cosmic Hazards and Planetary Defense', and 'International Astronautical Federation 56th International Astronautical Congress 2005, has nineteenth and twentieth place respectively 3 papers. This table as evidence to majority of papers were published in Conference Proceedings in the research during the study period.

Table 10: author contributions in orbital debris research publications

Sl. No.	Number of Contribution	No. of authors	Percent age	Cumulative Percentage
1	1	415	55.04	55.04
2	2	288	38.20	93.24
3	3	19	2.52	95.76
4	4	12	1.59	97.35
5	5	10	1.33	98.67
6	6	2	0.27	98.94
7	7	2	0.27	99.20
8	8	2	0.27	99.47
9	9	1	0.13	99.60
10	10	1	0.13	99.73
11	12	1	0.13	99.87
12	16	1	0.13	100.00
	Total	754	100.00	

Table 10 shows that author contributions in orbital debris research publications; it reveals the contribution of research based on author productivity levels. It is clear from the table that 55.04 per cent of the authors have made single contribution in the field of orbital debris. 288 authors were contributed 2 papers, 19 authors were contributed 3 papers, 12 authors were contributed 4 papers, 10 authors were contributed 5 papers, 2 authors were contributed 6, 7 and 8 papers respectively, one (single) author were contributed nine, ten, twelve and sixteen papers in this research during the study period.

Table 11: Lotka's Law of author productivity

Sl. No.	Number of Publications/ Contributions	Observer No. of authors with n (an) or F	Observed % of authors 100/an/a1	Expected no. of authors (an=al/n2) P	Expected % of authors predicated by Lotka's/100n	(F-P)2/P
1	1	415	100.00	415	100	0
2	2	288	89.72	80.25	25	537.82
3	3	19	5.92	35.66	11.11	7.78
4	4	12	3.74	20.06	6.25	3.24
5	5	10	3.12	12.84	4	0.62
6	6	2	0.62	8.91	2.77	5.36
7	7	2	0.62	6.55	2.04	3.16
8	8	2	0.62	5.01	1.56	1.81
9	9	1	0.31	3.96	1.23	2.21
10	10	1	0.31	3.21	1	1.52
11	12	1	0.31	2.22	0.69	0.67
12	16	1	0.31	1.25	0.39	0.05
	Total	754			X^2	51.29

Based on the above discussion, it is appropriate to examine and analyze the implications of Lotka's law in relation to author productivity on orbital debris research study. Table 11 shows the Lotka's law of author productivity. Lotka's law explained that the number of persons making two contributions is about one fourth of those contributing one. It explains that the number of authors making "n" contributions is about $1/n^2$ of those making a single contribution and

proportion of contribution that makes a single contribution is about 86.38 per cent. In other words, for every100 authors making one contribution each, there would be 25 others contributing 25 articles each (100/22 =25) and about 11 contributing three articles each (100/33 =11.11) about 6 contributing four articles each (100/44 =6.25), and so on. In this study, the productivity of orbital debris study research scientists is examined. At the first observation, the analyzed data invalidate Lotka's findings that the proportion of all contributions that make a single contribution is 55.04 percent. Further 754 authors published 291 papers; Lotka's chi-square model confirms the source trend. It explains the fact that the calculated x^2 value is 51.29, which is less than the tabulated value at 5 percent level of significance. Thus, the present analysis clearly validates the Lotka's finding. In the present analysis, productivity is attributed to several factors. If a complete publication detail of an author is taken, the Lotka's Law testing may present a different picture.

Conclusion

Conclude from this study, among the fifteen years the starting year was started with 5 papers end of the year 2016 end with 25 papers in this research. The orbital debris research papers were published various five document types, among those Conference Paper has 201 papers, Article has 80 papers the remaining three documents were published least number of papers. Orbital debris research papers published only in two languages, in English 286 papers, and in Chinese 5 papers were published. The authorship pattern in orbital debris research publications, collaborative contributions were high compare with single author contribution. Totally 79 countries were contributed in orbital debris research during the study period, United States has occupies first position with 80 papers, China has second place with 22 papers, United Kingdom has third position with 20 papers contributed. It found the top twenty sources published in orbital debris research papers, Advances in Space Research is a journal it has occupies first position with 29 papers. It is remarkable to note that when the number of contributions increases, the number of decreases authors. It points out the fact that a greater level of research performance is noted among few authors.

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