A scientometric analysis of recent aerospace research

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Aerospace science and technology is a major research area for nations because of its economic and strategic importance. Gangan Prathap[1] analysed aerospace research in India using the Scopus database and the keywords AERO* and INDIA in the field of affiliation. While Scopus is an extensive database, it includes conference papers which are not considered archival. In the present analysis, we have used ISI Web of Science as the search database and only AERO* in the address field. The objective is to analyse international aerospace research. We have also limited the time interval to the period 2000–08 in order to bring out recent trends in research, and identify the emergence of new countries and institutions in aerospace research. The ISI Web of Science shows 52,555 publications under AERO* during this period in the last week of April 2008. The 'Analyze' tool in the Web of Science has been used to evaluate the nations and institutions.

National origin

The analysis of publications was first conducted to identify the top countries. Table 1 shows the top 25 countries in terms of per capita publications. It can be seen that Singapore ranks first and Israel ranks second in this list, while India ranks 25th. Many of the European countries are also major contributors to aerospace research, with The Netherlands being the highest among them in per capita terms. USA accounts for about 44% of the world's publications in aerospace, and is therefore the dominant source of published aerospace research. China is a distant second, with about 12% of the publications.

Institutions

Table 2 shows the top 50 institutions in terms of publications. The Beijing University of Aeronautics and Astronautics (BUAA), China occupies the first rank in terms of number of publications during 2000–08. NASA occupies the second position. The third position is occupied by the Nanjing University of Aeronautics and Astronautics (NUAA), China and the fourth position by Seoul National University, South Korea. Clearly, there is a strong contribution from Asian institutions in aerospace research during recent years. This phenomenon of the rise in Asian research as a general trend in science was recently profiled by Arunachalam[2]. However, only two Indian institutions make it into this list. The IITs hold the 33rd rank and the IISc holds the 49th rank. Here the IITs consist of those campuses with aerospace departments i.e. at Kanpur, Mumbai, Kharagpur and Chennai. We should also point out that more aerospace papers were published by BUAA (2041) than by India (1559) during 2000–08.

Table 1. Top 25 countries in aerospace research during 2000–08, ranked by per capita publications

Rank	Country	Record count	Percentage of publications	Population in millions	Papers/million
1	Singapore	1321	2.51	4.6	287.17
2	Israel	946	1.8	7.3	129.59
3	The Netherlands	1291	2.46	16.4	78.72
4	Australia	1644	3.13	21.4	76.82
5	USA	23349	44.43	304.8	76.60
6	Sweden	681	1.29	9.2	74.02
7	England	3537	6.73	50.8	69.63
8	Switzerland	504	0.96	7.6	66.32
9	Finland	351	0.67	5.3	66.23
10	South Korea	3179	6.05	48.2	65.95
11	France	4094	7.79	64.5	63.47
12	Scotland	319	0.61	5.1	62.55
13	Canada	1897	3.61	33.3	56.97
14	Germany	4618	8.79	82.2	56.18
15	Belgium	571	1.08	10.6	53.87
16	Greece	553	1.05	11.1	49.82
17	Taiwan	845	1.61	23	36.74
18	Italy	1958	3.73	59.6	32.85
19	Japan	3733	7.10	127.7	29.23
20	Spain	906	1.72	46.1	19.65
21	Russia	1668	3.17	141.9	11.75
22	Brazil	941	1.79	187.5	5.02
23	China	6593	12.54	1325.5	4.97
24	Turkey	320	0.61	70.6	4.53
25	India	1559	2.97	1136.6	1.37

Table 2. Top 50 aerospace research institutions

Rank	Institution	Country	Record count	Percentage of publications	Citations	*h*-index
1	Beijing University of Aeronautics and Astronautics	China	2041	3.88	5841	28
2	NASA	USA	1579	3.00	13416	48
3	Nanjing University of Aeronautics and Astronautics	China	1442	2.74	2382	18
4	Seoul National University	South Korea	1257	2.39	4245	22
5	ONERA (French Aerospace Lab)	France	1243	2.36	6089	29
6	Nanyang Technological University	Singapore	1128	2.14	1934	14
7	Japan Aerospace Exploration Agency	Japan	1070	2.04	3129	21
8	University of California, San Diego	USA	982	1.87	7711	35
9	University of Colorado	USA	942	1.79	11954	47
10	Caltech	USA	927	1.76	12012	45
11	University of California, Los Angeles	USA	914	1.74	9020	41
12	Princeton University	USA	887	1.69	7583	35
13	University of Michigan	USA	834	1.59	6127	30
14	University of Sydney	Australia	807	1.53	3891	24
15	Max Planck Institute for Aeronomy	Germany	781	1.49	8195	35
16	CNRS	France	749	1.43	5824	32
17	University of Florida	USA	680	1.29	3069	21
18	University of Tokyo	Japan	674	1.28	4229	26
19	Georgia Institute of Technology	USA	668	1.27	3799	27
20	German Aerospace Center	Germany	657	1.27	5649	30
21	MIT	USA	652	1.24	5300	30
22	Delft University of Technology	Netherlands	644	1.22	2432	20
23	Cornell University	USA	615	1.17	5499	31
24	University of Missouri	USA	615	1.17	2243	19
25	DLR	Germany	611	1.16	6217	31
26	National Oceanic and Atmospheric Administration	USA	610	1.16	9682	43
27	Aerospace Corporation	USA	606	1.15	3935	26
28	Rensselaer Polytechnic Institute	USA	601	1.14	3354	19
29	North Carolina State University	USA	588	1.12	3069	26
30	US Air Force	USA	582	1.11	2575	21
31	Russian Academy of Sciences	Russia	579	1.10	2205	20
32	University of California, Davis	USA	579	1.10	2817	25
33	Indian Institutes of Technology	India	575	1.09	1338	15
34	University of Southern California	USA	562	1.07	4644	32
35	Chinese Academy of Sciences	China	557	1.06	2133	18
36	University of Illinois	USA	543	1.03	3391	25
37	University of Texas	USA	534	1.02	3377	26
38	University of Maryland	USA	532	1.01	4490	27
39	Texas A&M University	USA	515	0.98	2791	24
40	University of Manchester	UK	503	0.96	1418	16
41	University of California, Irvine	USA	494	0.94	3666	26
42	Arizona State University	USA	475	0.90	2995	26
43	Imperial College of Science, Technology and Medicine	UK	470	0.89	2410	19
44	Technion Israel Institute of Technology	Israel	456	0.87	1310	15
45	Korea Advanced Institute of Science and Technology	South Korea	447	0.85	1233	14
46	Stanford University	USA	445	0.85	3081	26
47	Tohoku University	Japan	442	0.84	2234	17
48	University of Paris 6	France	433	0.82	4507	31
49	Indian Institute of Science	India	431	0.82	1333	16
50	Purdue University	USA	418	0.79	1587	16

Table 3 shows the distribution of aerospace-related institutions in different countries. The dominance of the USA in terms of publications is largely due to a disproportionately large number of good institutions. Other countries have 1–3 institutes in this list. Among the top 50 institutions, 27 are located in the US. For France and Germany, the ONERA and DLR respectively, are the national aerospace laboratories which produce most of the published research. There appears to be an ambiguity in Web of Science about 'DLR' and the 'German Aerospace Center', which are actually the same institutions. For Japan, the Japanese Aerospace Exploration Agency is responsible for the maximum number of publications and is followed by the University of Tokyo.

The number of publications is probably the best measure of academic research productivity[3]. However, citations of publications are a good indicator of the impact made by the published work. The 'Citation Report' feature of Web of Science has been used to obtain the citations

Table 3. Distribution of aerospace-related institutions in different countries

Country	Number of institutions in the top 50
USA	27
China, France, Japan	3
UK, South Korea, India, Germany	2
Russia, Netherlands, Israel, Singapore, Australia	1

Table 4. Top six Indian aerospace research institutions

Rank	Institution	Record count	Percentage of Indian papers	Citations	*h*-index
1	IISc, Bangalore	431	27.64	1333	16
2	NAL, Bangalore	308	19.75	992	16
3	IIT Kanpur	203	13.02	477	10
4	IIT Madras	125	8.02	229	8
5	IIT Kharagpur	122	7.82	220	7
6	IIT Bombay	107	6.86	253	7

and *h*-index of each institution. In terms of citations, NASA holds the first rank, followed by Caltech. Another measure of impact[4] is the *h*-index. For example, BUAA has an *h*-index of 28, which means that 28 papers from this university were cited at least 28 times. The combined IITs have an *h*-index of 15 and for IISc it is 16. In terms of *h*-index, NASA is the number one institution with value of 48. We see that NASA has the highest impact on aerospace research in terms of citations and *h*-index, while BUAA publishes the maximum number of papers.

Table 2 shows that many Asian institutions have lower citations levels and *h*-index for a given number of papers, compared to Western institutions. However, it should be pointed out that citations are often driven by familiarity with research and perceived 'brand' of the institutions, and not just by technical impact. This is particularly true in aerospace research, where national professional societies and conferences play an important role. Asian institutions need to publish in high impact journals and engage in research in new areas of aerospace science to increase their *h*-index. In addition, collaborative research between universities is often useful for making work more visible, and thereby increasing its impact. Intra-Asian collaboration and exchange programmes are needed to expose Asian researchers to each other's work. IISc has an *h*-index of 16, which is the same as that of Purdue University. However, other institutions such as Stanford University have an *h*-index of 26, with a similar number of papers.

Indian institutions

Table 4 shows the top six Indian institutions in terms of aerospace publications. We see that IISc published about 28% of the Indian research work, followed by NAL with about 20%. The four IITs together total about 37% of the papers in the country. IIT Kanpur is the leader among the IITs in aerospace research, as measured by publications, citations and *h*-index. We see that the Indian institutions need to increase their productivity to world levels to address the shortfall in basic aerospace research. However, there is an upper limit to the work that a few institutions can do. Therefore, there is a need to start aerospace engineering departments in other IITs as well as in the new ones being set up, and to expand aerospace education and research to select National Institutes of Technologies. There is also a need to start dedicated aerospace universities in line with BUAA and NUAA, whose papers appear to be flooding the journals and whose impact in terms of citations and *h*-index is also quite high.

We should note that not all the research revealed by using the keyword AERO* can be classified as classical aerospace engineering research. For example, some departments have combined mechanical and aerospace engineering and some institutions listed do considerable basic science including atmospheric science. However, a qualitative idea about the performance of nations and institutions in aerospace related research has been obtained.

Closing remarks

The aerospace research done by the industry and defence laboratories is often not published in the open literature, but can have a significant impact on the strategic capabilities of a country. This leads to an ongoing debate in the aerospace circles about the value of journal articles published in the open literature. However, in the long run, countries which publish in the open literature appear to have an advantage in terms of their assimilation of knowledge and creation of new ideas. The process of writing papers improves the logical thinking process required for research and is also the best way of teaching research skills to graduate students. Since most papers are published based on the work of Ph D students, the number of papers is also an indicator of the training level of the next generation of researchers. Furthermore, the peer review process allows feedback from international experts in the field, which can be used to improve the papers and can be a source of new ideas for further research. Papers can be thought of as a leading indicator of engineering products to come. In this sense, the emergence of China as the second most prolific country in the world in aerospace research shows that future innovations may come from China, and may have significant economic and strategic consequences on other countries. In general, basic research of the type which is published in archival journals is often the precursor of disruptive technologies.

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3. Balaram, P., *Curr. Sci.*, 2008, **94**, 289–290.
4. Hirsch, J. E., *Proc. Natl. Acad. Sci. USA*, 2005, **102**, 16569–16572.

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