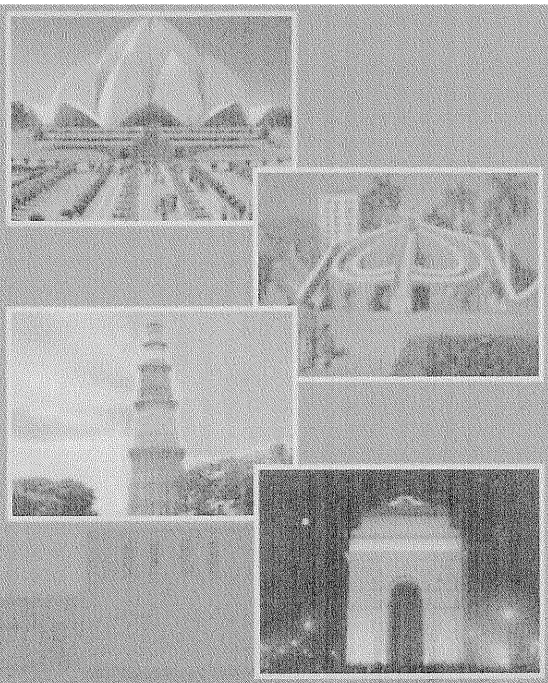

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Materials Science Research in India: A Quantitative Study, 1993-01

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Abstract:

Describes the importance of materials science and the current efforts in India in R&D. Discusses the status of materials science research output in India during 1993-01, with a view to analyze its publication size and growth, media of communication, strong and weak areas of research, quality of research output, nature of collaboration, and institutional productivity and quality.

Introduction:

Materials science has been defined variantly. According to the Summary Report of the Committee on the Survey of Materials Science and Engineering (COSMAT) of the United States National Academy of Sciences (1974), materials science has been defined as a multidisciplinary field concerned with the fundamental nature of materials and their applications, with the generations and application of knowledge relating to the composition, structure, and processing of materials to their properties and uses. This definition recognizes three basic elements in the study of materials – (1) structure and composition, (2) processing and properties.

The Committee on Materials Science and Engineering of the National Research Council (1990) in its report "Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials" provided another definition in which it added the fourth element –performance. According to this report materials science is defined as the study of materials for controlling the four basic elements—(1) properties, (2) structure and composition, (3) synthesis and processing, (4) and performance, and understanding the strong inter-relationships among them.

Prof. C.N.R Rao, India's one of the leading science policy makers considers the use of advanced technology materials as an index of development. Such has been its contributions to the society that materials science is now recognized as a subject of special importance. Prof. Rustom Roy says, "New materials are clearly are the fountainhead for new materials science".

Materials science research has been thus become one of the major driving forces for change in the modern era. Moreover, in order to maintain or create global competitiveness all countries all countries are interested in substantial amount of their budget in R & D in this new area.

With the hope of creating new industrial opportunities, India has also started major research programs in the materials science area, involving a large number of universities, research institutions, institutes of national importance and other organizations Most of the funding for research in India comes from the various government agencies, such as DST, CSIR, DRDO, CSIR, AICTE, UGC, etc. Under DST, Scientific and Engineering Research Council (SERC) have promoted major research programme in frontline materials science areas

Need for the Study:

Materials science is an important area of research in India contributing more than 20% of the total Indian research output. It has also a number of industrial applications and contributing to the industrial growth of the country In view of the importance of this area in Indian context, a need was felt to have a quantitative survey of its research output in India. Very few studies had been conducted in this area in the past.

Objectives of the Study:

The main objectives of the present study is make an assessment of the status of materials science research in India during 1993-01, with a view to analyze its (i)publication size and growth, (ii) media of communication, (ii) strong and weak areas of research, (iv) quality of research output, (v) nature of collaboration, and (vi) Institutional productivity and quality.

Methodology:

The results presented in the study are based on raw bibliographical publication data extracted and downloaded in February 2004 from the *Science Citation Index - Expanded Version* (SCIENCE) (Web of Science) of the Thomson-ISI. The data pertains to the period from 1993 to 2001, The delineation of the broad and narrow subject areas in research publications was based on a set of journals assigned by the Thomson-ISI to relevant subject categories. For impact factor data, I have used list of journals with impact factor provided by ISI-Thomson Press every year A number of absolute and relative indices are used for analyzing performance of research in materials science in India. For mapping materials science research, the absolute and relative indicators used include: (i) publications count, (ii) average IF per paper, (iii) share of collaborative and international collaborative papers, (iv) activity index. The activity index measures the extent to which institutional share in the given sub-field compares with the country share in the same sub-field. It is a relative measure and its average value is taken as one. The values of activity index, if more than one, indicate that the publications activity in the respective sub fields is above the country average. For values of activity index less than one, it indicates that the publications activity in the respective sub fields is below the country average.

India has a long tradition of undertaking quantitative studies on various subject fields as a part of library and information discipline. The number of studies in this area has been steadily growing over the years, as can been seen in bibliographies published on library and information science literature and reviews appearing in the field. Some of the studies published in India are reviewed here.

In the area of materials science, only two studies have been undertaken so far. Kochhar and his colleagues[1] developed a database and analysed the status of Indian materials science output (8273 papers) covering metals and alloys, aluminum, ceramics, composites, glass, polymers, and wood during 1979 to 1989, on behalf of TAIFAC, Department of Science and Technology project.. Mohan, Gupta and Dhawan[2] have analysed the international collaborative output in materials science in India during 1995-1999, based on papers covered in Material Science Citation Index.

Results and Discussions:

Publications Size

Publications data derived from *Web of Science* revealed that India published a total of 9545 papers in materials science during 1993-2001. At sub-field level their distribution shows wide variations in publications count. For example, multidisciplinary materials science accounts for the largest share (76.6%) in the total country output in materials science, followed by ceramics (5.76%), textile (4.27%), coatings & films (4.06%), materials characterization & testing (3.03%), biomaterials (1.48%), and wood (0.68%) (Table 1)

Table 1: Publications Output from India in Materials Science: 1993-2001

Subject	Publications Count	Av. IF per Paper	% Share in Total Papers
Biomaterials	141	0.979	1.48
Ceramics	550	0.897	5.76
Characterization & Testing	289	0.296	3.03

Coatings & films	388	1.034	4.06
Composites	376	0.446	3.94
Multidisciplinary	7328	0.909	76.77
Textile	408	0.212	4.27
Wood	65	0.333	0.68
Total	9545	0.638	100.00

Growth Rate

The country has achieved an average growth rate of 7.09% annually during 1993-2001, which marginally increased to 7.61% during the last five years, 1997-2001. It demonstrates that materials science research in the country is not stagnant, but growing steadily. At sub field level, average annualized publications growth rate is much higher, ranging between 10.4% and 242.5%, the lowest being 10.4% for ceramics and the highest being 242.5% for textile (Table 2).

The relatively higher growth in materials science at the sub-field levels compared to country growth rate of 7.09% due to wide differences in publication sizes at the subfield level and at the main field level. Secondly, it is also due to their publications sizes (at sub field levels) in single to double digits. Any small change in publications size from single digit to double digit on year-to-year basis is enough to reflect steep rise in growth rate. For example, biomaterials showed rise from 6 to 19 papers between 1994 and 1995, and this small change by just 13 papers has reflected 216% rise in one year. On the other hand, in multidisciplinary science the publications output has shown rise from 673 in 1993 to 692 in 1994, but this increase by 19 papers in one year has caused growth by just 2.82%.

Table 2: Publications Growth in Materials Science for India: 1993-2001

Pub. Year	Bio-materials	Ceramics	Characterization & Testing	Coat-ings & films	Com posites	Multi-disciplinary	Textile	Wood	Total
1993	9	43	15	30	36	673	12	8	826
1994	6	38	23	25	24	692	2	15	825
1995	19	55	24	40	32	754	41	5	970
1996	12	61	32	36	17	772	48	4	982
1997	17	54	43	26	30	922	50	5	1147
1998	11	56	34	49	34	781	53	8	1026
1999	17	81	28	45	65	895	57	8	1196
2000	25	79	48	43	59	874	64	3	1195
2001	25	83	42	94	79	965	81	9	1378
Av Ann. Gr Rate	31.81	10.44	18.22	25.00	19.85	5.12	242.54	27.92	7.09

Table 3: **Publications Growth in Different Sub Fields in Materials Science: 1993-2001**

Subject	Publications Count			Growth Rate
	1993-95	1996-98	1999-01	93-95 to 99-01
Biomaterials	34	40	67	97.06
Ceramics	136	171	243	78.68
Characterization & Testing	62	109	118	90.32
Coatings & films	95	111	182	91.58
Composites	92	81	203	120.65

Multidisciplinary	2119	2475	2734	29.02
Textile	55	151	202	267.27
Wood	28	17	20	-28.57

Comparing growth on cumulative three years data, textile has shown the fastest growth in materials science (267.2%) during the period from 93-95 to 99-01, followed by composites (120.6%), biomaterials (97%), coating & films (91.5%), materials characterization and testing (90%), and multidisciplinary areas (29%). In wood research, the country showed decline in its publications growth by 28.5% during the same period (Table 3).

It demonstrates that biomaterials, coatings & films, composites, characterization & testing, and textiles are the fast growing areas of research in materials, which have shown annual growth rate of 18.4% to 31.8%. Research activity in wood is not significant and growth in ceramics is comparatively slow.

Sub-field Wise Publications Activity Analysis:

Publications activity of the country in materials science was studied sub-field wise to examine and compare to what extent its publications size in each sub-field under different periods of study is comparable with its overall publications size in materials science. In this analysis, data were computed for measuring publications activity index. It is a relative measure and its average value is taken as one. The values of activity index, if more than one, indicate that the publications activity in the respective sub fields is above the country average. For values of activity index less than one, it indicates that the publications activity in the respective sub fields is below the country average.

Table 4: Publications Activity of Sub Fields in Materials Science: 1993-2001

% Share of Total Output	Subject	Activity Index		
		1993-95	1996-98	1999-01
97.06	Biomaterials	0.88	0.86	1.20
78.68	Ceramics	0.90	0.94	1.12
90.32	Characterization & Testing	0.78	1.14	1.03
91.58	Coatings & films	0.89	0.87	1.19
120.65	Composites	0.89	0.65	1.37
29.02	Multidisciplinary Science	1.05	1.02	0.94
267.27	Textile	0.49	1.12	1.25
-28.57	Wood	1.57	0.79	0.78
100	Overall	1	1	1

The publications activity in multidisciplinary science, though, has been seen as rising at 29% sexennially, but compared to the overall publications activity in materials science it has been declining from 1.05 in 1993-95 to 1.02 in 1996-98, and to 0.94 in 1999-01. The publications activity in wood compared to national average in materials science has also been declining gradually, from 1.57 in 1993-95 to 0.79 in 1996-98 and to 0.78 in 1999-01. In all other sub-field areas publications activity has been gradually rising. The same trend is also reflected by the growth rate in publications output in these sub fields (Table 4).

It demonstrates that growth in ceramics is comparatively slow but its publications activity has been above the country average. The other areas in which publications activity has been above the country average are biomaterials, characterization & testing, coatings & films, composites, and textiles. As shown above these have also been the fast growing areas of research in materials which have shown annual growth rate of 18.4% to 31.8%.

Media of Communications:

Indian scientists published papers in materials science in 108 journals (both Indian and foreign) during 1993-01. Of these the top 10 journals accounted for 58.79% papers, top 20 journals for 76.93% papers, top 30 journals for 85.52% papers, and top 40 for 90.94% papers of the total output in materials science. It implies that the country output in materials science is highly scattered in nearly 68 journals.

Impact of India's Publications Output in Materials Science

The average impact factor per paper for the country output in materials science is not high (0.638) since nearly 91.74% of its output was published in low impact journals (IF 0.001 – 1.999), and 2.7% output in zero impact journals. Its output appearing in medium impact journals (IF 2.000 – 3.999) and high impact journals (IF 4 and more) was not very significant (3.57% and 1.58% respectively). This trend is uniform across all sub-fields in materials science. However, the quality of research output in materials science is showing marginal rise with time. Comparing the publications share of the country in different categories of journals during 1993-95 and 1999-01, it was seen that the country's share of papers reported in zero impact and low impact journals have shown decline (from 2.97% to 2.70% and from 94.24% to 91.74%), whereas in medium and high impact journals, the country share has shown marginal rise (from 2.44% to 3.57% and from and 0.34% to 1.98% respectively). This indicates that the quality of research in materials science has marginally increased over the years (Table 5).

Table 5: Research Output in Difference IF Range during 1993-95 to 1999-01

IF Range	Total Papers			Total Papers	
	93-95	96-98	99-01	93-01	% Share
0.00 – 0.00	78	138	42	258	2.70
0.01 – 1.99	2470	2879	3408	8757	91.74
2.00 – 3.99	64	117	160	341	3.57
4 and more	9	21	159	189	1.98
Total	2621	3155	3769	9545	100

Collaborative Research Profile of India in Materials Science

Of the total 9545 papers reported by India in materials science during 1993-01, 2910 (30.49%) were through collaborative research. The country showed significant rise in collaborative papers from 346 (13.2% share) to 1620 (42.9% share) during 1993-95 to 1999-01 (Table 4.16). The rise in collaborative research output (368.2%) was greater than the rise in country output in materials science research (7.09%) during the corresponding period.

Table 6: Publications Output by Nature of Collaboration in Materials Science

Period	TP	TCP	TNCP	TICP	TCP%	TNCP%	TICP%
93-95	2621	346	236	122	13.20	9.00	4.65
96-98	3155	944	713	285	29.92	22.60	9.03
99-01	3769	1620	1152	565	42.98	30.57	14.99
93-01	9545	2910	2101	972	30.49	22.01	10.18
TP=Total Papers; TCP=Total Collaborative Papers; TNCP=Total National Collaborative Papers; TICP=Total International Collaborative Papers							

India had collaboration in materials science research at national and international level. Of the total 9545 papers in materials science, 2101 (22%) were through collaborative research at national

level and 972 (10.2%) through collaborative research at international level. The rise in collaborative research at national level was higher (from 236 to 1152 papers, 9.0% to 30.56% share) than the rise in collaborative research at international level (from 132 to 565 papers, 4.65% to 14.99% share) during 1993-95 to 1999-01. The collaboration through bilateral participation was greater (859 papers, 88.37% share) than collaboration through multilateral participation (113 papers, 11.62% share). However, bilateral research showed decline (from 94.26% to 86.72%) and multilateral research showed rise (from 5.74% to 13.27%) during 1993-95 to 1999-01 (Table 6).
The share of national collaboration papers in total materials science subfields output ranged from 9.23% to 27.39%, with an average of 22.01% Only three sub-fields, namely composites, coatings and textiles contributed more than average share(Table 7)
On analysing the growth in share of national collaborative publications during 1993-95 to 1999-01, the largest growth was observed in composites (from 9.78% to 35.96%) followed by multidisciplinary materials science (from 8.82 to 25.37%), etc(Table 7)
The share of international collaborative papers in total materials science sub-fields output ranged from 4.50% to 18.04%, with an average of 10.18%. Only coating, wood, ceramics and multidisciplinary material science subfields contributed more than the average share(Table 7)
On anaylsing the growth in share of international collaborative publications during 1993-95 to 1990-01, the largest growth was observed in coating & films (from 10.53% to 26.37%), followed by composites (0% to 14.78%), etc.(Table 7)

Table 7: Growth of collaborative Research Output in Different Subfields of Materials Science

Subfields	National Collaborative paper share		International Collaborative paper share	
	93-95	99-01	93-95	99-01
Biomaterials	8.82	25.37	2.94	13.43
Ceramics	8.09	19.75	5.88	13.99
Characteristic & Testing	6.45	22.88	1.61	5.08
Coating & Films	12.63	28.02	10.53	26.37
Composites	9.78	35.96	0.0	14.78
Multidisciplinary Materials Science	8.87	32.52	4.72	15.76
Textile	16.36	20.79	3.64	0.56
Wood	0.0	25.00	0.00	20.00

Institutional Productivity & Quality:

A total of 933 institutions belonging to Universities & Colleges, R&D, Institutes of National Importance, Industry and others participated in materials science research during 1993-01 O the total participating institutions only top 10, 20 and 88 institutions contributed 50%; 71% and 80% of the total publications output (9545 papers) in materials science in India during 1993-01.

Among the top 20 participating institutions.

(a) Seven belongs to institutions of national importance and they together contributed 3717 papers constituting 34.75% of total materials science output in India during 1993-01. The major institutions under this category in order of ranking are Indian Institute of Sciences (IISc) Bangalore, (995 papers), Indian Institute of Technology (IIT) Kharagpur (695

papers), IIT-Madras (495 papers), IIT-Bombay (426 papers), IIT-Kanpur (357 paers) and IIT-Delhi (349 papers)(Table 8).

(b) Nine belong to R & D sector and they together contributed 2492 papers constituting 26.10% of the total materials science output during 1993-01. The major institutions under this category in order of ranking are Bhabha Atomic Research Centre (BARC), Mumbai *487 papers), Indira Gandhi Center for Atomic Research (IGCAR), Kalpakkam (405 papers), Defence Metallurgical Research Laboratory (DMRL), Hyderabad (298 papers), Indian Association for The Cultivation of Science (IACS), Kolkota (281 papers), Centre for Glass and Ceramic Research Institutes (CGCRI),Kolkota (256 papers), National Physical Laboratory (NPL),New Delhi (250 papers), National Chemical Laboratory (NCL),Pune (205 paper), Electrochemical Research Institute (CECRI), Karaikudi (156 papers) and Regional Laboratory, Trivendrum (154 papers)Table 8).

(c) Five belong to Universities & Colleges sector and they together contributed 946 papers constituting 9.91% of the total materials science output during 1993-01. The major institutions in order of ranking under this category are Shivaji university (SHIVUK), Kolhapur (230 papers), Banaras Hindu University (BANAUV), Varanasi (227papers), Institute of Technology (Coll-IT), Varanasi (166 papers), Anna University (ANNUM), Madras (162 papers) and University of Delhi (DELHUD), Delhi (161 papers)(Table 8).

Table 8: Productivity of Leading Institutions in Materials Science during 93-01

S No.	Institute Code	Total Papers		
		Total	Cumulative Total	Cumulative%
1	IIS-BANG	995	995	10.42
2	IIT-KHAR	695	1690	17.70
3	IIT-MADR	495	2185	22.89
4	BARC-MUMB	487	2672	27.99
5	IIT-BOMB	426	3098	32.45
6	IGCAR-KALP	405	3503	36.70
7	IIT-KANP	357	3860	40.44
8	IIT-DELH	349	4209	44.09
9	DMRL-HYDE	298	4507	47.22
10	IACS-KOLK	281	4788	50.16
11	CGCRI-KOLK	256	5044	52.84
12	NPL-DELH	250	5294	55.46
13	SHIVUK-KOLP	230	5524	57.87
14	BANAUV-VARA	227	5751	60.25
15	NCL-PUNE	205	5976	62.61
16	COLL-IT-VARA	166	6142	64.34
17	ANNAUM-MADR	162	6304	66.04
18	DELHUD-DELH	162	6465	67.63
19	CECRI-KARI	156	6621	69.36
20	RRL-TRIV	154	6775	70.97

It was found that there was no correlation between publication productivity and quality. On one hand, we find that NCL Pune has secured first rank in quantity having IF/papers as 1.275 in contrast to 15th rank in publication productivity (205 papers). On the other hand altogether IIT Delhi has secured 8th rank in publication productivity but 20th rank in quality having IF/paper as 0.531 only(Table 9).

Among the various institutions, R & D sectors institutions have performed much better in publication quality as reflected in impact factor (IF) per paper. Among the top 20 productive institutions, the 1st, 3rd, 5th, 6th, 8th and 11th have been taken by R&D institutions, such as NCL (Pune), DMRL (Hyderabad), BARC (Mumbai), IACS (Kolkota), NPL (Delhi) and CGCRI (Kolkota) in terms of publication quality, altogether their publications productivity rank were 15th, 9th, 4th, 10th, 16th and 11th respectively(Table 9).

The Universities & Colleges sector institutions have also performed better in quality compared to their publications productivity. Among these institutions, BANAUV (Varanasi) and Coll-IT-Va (Varanasi) have secured 3rd rank and the 7th rank in IF/paper compared to their 14th and 16th rank in publication productivity(Table 9).

Among all the participating institutions, the Institute of National Importance (except IISc-Bang) have shown the least impact and quality. On one hand IIT (Kharagpur) and IIT(Madras, IIT (Bombay), IIT (Kanpur) and IIT (Delhi) have secured 2nd , 3rd, 5th , 7th and 9th rank in publications productivity but they secured 9th, 10th, 14th, 19th and 20th rank in IF/paper(Table 9).

Table 9: Productivity and Impact of leading Institutions in Materials Science During 1993-01

S No.	Institution code	Total Papers		IF/Paper	
		Total	Rank	Actual	Rank
1	NCL-PUNE	205	15	1.275	1
2	IIS-BANG	995	1	1.189	2
3	DMRL-HYDE	298	9	1.176	3
4	BANAUV-VARA	227	12	0.991	4
5	BARC-MUMB	487	4	0.948	5
6	IACS-KOLK	281	10	0.939	6
7	COLL-IT-VA	166	16	0.850	7
8	NPL-DELH	250	12	0.814	8
9	IIT-KANP	357	7	0.790	9
10	IIT-KHAR	695	2	0.781	10
11	CGCRI-KOLK	256	11	0.779	11
12	IGCAR-KALK	405	6	0.772	12
13	RRL-TRIV	154	20	0.773	13
14	IIT-BOMB	426	5	0.741	14
15	SHIVUK-KOLP	230	13	0.733	15
16	CECRI-KARI	156	19	0.690	16
17	DELHUD-DELH	161	18	0.682	17
18	ANNAUM-MADR	162	17	0.679	18
19	IIT-MADR	495	3	0.648	19
20	IIT-DELH	349	8	0.531	20

Conclusions :

As seen from publications data in *Web of Science* for the period 1993-01, India published 9545 papers in materials science during 1993-2001. Much of the published output in materials science relates to multidisciplinary science (76.6% share). The other areas of research are ceramics, textiles, coatings & films, materials characterization & testing, biomaterials, and wood. Their share in the country output in materials science is smaller ranging between 0.68% and 5.76%.

It has been seen that research in materials science in the country has been growing steadily at about 7% per year. However, publications growth rate at sub field level is much higher, ranging

between 10.4% and 242.5%, the lowest being 10.4% for ceramics and the highest being 242.5% for textile. It demonstrates that biomaterials, coatings & films, composites, characterization & testing, and textiles are the fast growing areas of research in materials science research with annualized growth rate of 18.4% to 31.8%. Research activity in wood is not significant and growth rate in ceramics is comparatively slow.

The quality of research output in materials science, measured in terms of impact factor per paper, has not been high (0.638). This is mainly because high percentage share of the country output (91.74%) is published in low impact journals (IF 0.001 – 1.999), besides 2.7% output in zero impact journals. The country output in medium impact journals (IF 2.000 – 3.999) and high impact journals (IF 4 and more) has not very significant (3.57% and 1.58% respectively). This trend has been uniform across all sub-fields in materials science.

The publications output by India in materials science during 1993-01 was published in 108 journals (both Indian and foreign), but majority share of the country output (58.79%) was published in top 10 journals. The top 40 journals accounted for 90.94% papers of the total output in materials science. As many as 68 journals account for very small share of the country output in materials science, nearly 9.06%. It implies that the country output in materials science is highly scattered in nearly 68 journals.

The collaborative research in materials science has been growing faster (368.2%) than the country research in materials science (7.09%). The bilateral participation in materials science research is greater (accounting for 88.37% share) than collaboration through multilateral participation (11.62% share). The collaborative research output of the country at sub-field level ranged between 16.9% and 37.6%. It was the highest in coatings, followed by composites, multidisciplinary materials science, biomaterials, ceramics, textiles, characterization, and wood. Composites has been the stronger area for collaborative research as rise in collaborative research output in composites was the highest (38%). The collaborative research activity was the least in ceramics.

The pockets of excellence in materials science research are localized to select few institutions even though a total of 933 institutions participated in materials science research during 1993-01. Of these, top 83 institutions accounted for 80% research output and the remaining 850 for just 20% research output. Of the top twenty institutions, 12 have been academic institutions (IIS, IIT-KHAR, IIT-MADR, IIT-BOMB, IIT-KANP, IIT-DELH, SHIVUK, BANAUV, COLL-IT-VA, ANNAUM, DELHUD, and RRL-TRIV) and the remaining 8 have been mission-oriented institutions (BARC, IGCAR, DMRL, IACS, CGCRI, NPL, NCL, and CERI).

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