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Technical Communication Practices of Dutch and U.S. Aerospace Engineers and Scientists: International Perspective on Aerospace

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Technical Communication Practices of Dutch and U.S. Aerospace Engineers and Scientists: International Perspectives on Aerospace

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Abstract— **As part of Phase 4 of the NASA/DoD Aerospace Knowledge Diffusion Research Project, studies were conducted that investigated the technical communications practices of Dutch and U.S. aerospace engineers and scientists. The studies had the following objectives: (1) to solicit the opinions of aerospace engineers and scientists regarding the importance of technical communication to their professions, (2) to determine the use and production of technical communication by aerospace engineers and scientists, (3) to investigate their use of libraries and technical information centers, (4) to investigate their use of and the importance to them of computer and information technology, (5) to examine their use of electronic networks, and (6) to determine their use of foreign and domestically produced technical reports. Self-administered (mail) questionnaires were distributed to Dutch aerospace engineers and scientists at the National Aerospace Laboratory (NLR) in the Netherlands, the NASA Ames Research Center in the U.S., and the NASA Langley Research Center in the U.S. Responses of the Dutch and U.S. participants to selected questions are presented in this paper.**

THE PRODUCTION, transfer, and use of technical information is of paramount importance to the process of technological innovation. Rosenbloom and Wolek [1], for example, noted: "How well [the] objectives of research and development (R & D) are met, and at what cost, depends to an important degree on the ability of engineers and scientists to acquire the technical information needed to do their jobs." Haeffer [2] noted that "Technical progress is mainly due to the utilization by engineers and scientists of generally disseminated and easily accessible [and understood] technical information for the creation and development of new products, methods, and processes." A number of studies have established strong relationships between the communication of technical information and technical performance of engineers and scientists both at the individual [3, 4, 5] and group [6, 7, 8] levels. However, while a substantial body of literature exists, few if any comparative studies have investigated the technical communication practices of engineers and scientists at the international level. The need for these studies becomes increasingly important as industries such as aerospace become increasingly international and collaborative in scope and operation [9, 10].

To remain competitive in a global economy and in a multinational manufacturing environment, aerospace producers have to push forward with new technological developments, maximize the inclusion of those developments into the R & D process, and maintain and enhance the professional competency of their engineers and scientists. Meeting these objectives in timely fashion and at a reasonable cost depends on a number of factors, but largely on the ability of aerospace engineers and scientists to communicate (i.e., produce, transfer, and use) technical information.

To learn more about international technical communication in aerospace, researchers at the NASA Langley Research Center, the Indiana University Center for Survey Research, Rensselaer Polytechnic Institute, and institutions in selected counties are studying the technical communication practices of aerospace engineers and scientists. These studies comprise the NASA/DoD Aerospace Knowledge Diffusion Research Project, a four-phase study of the organization, culture, and communications within the national and international aerospace communities [11], [12]. This research has included exploratory studies of the technical communication practices of aerospace engineers and scientists in Israel [13], Japan [14], [15], selected Western European countries [16], Russia [17], and the U.S. [18].

This article presents selected results of a recent project undertaking, a study of the technical communication practices of Dutch and U.S. aerospace engineers and scientists at three similar research facilities in Holland and the United States. The Dutch/U.S. study included the following objectives:

1) to solicit participants' opinions about the importance of technical communication
2) to determine the participants' use and production of technical communication
3) to investigate their use of libraries and technical information centers
4) to investigate their use of and the importance to them of computer and information technology
5) to examine their use of electronic networks
6) to determine their use of foreign and domestically produced technical reports

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Research Design and Methodology

The research was conducted at comparable aeronautical research facilities: the National Aerospace Laboratory (NLR) in the Netherlands, the NASA Ames Research Center in the U.S., and the NASA Langley Research Center in the U.S. The three facilities share similar missions and clientele. The NLR serves European and other aircraft industries, civil and military aircraft users, space agencies, and non-aerospace industries; the NASA Centers serve many of the same types of clients, the focus being on U.S. producers. Aerospace engineers and scientists at the three facilities work in similar aerospace subdisciplines and document their research findings.

English-language, self-administered (self-reported) mail surveys were used to collect data from study participants. The instrument had been used previously in several other Western European countries and in Japan and Russia in adapted form to address sociocultural differences. The instrument was pretested before being distributed to 200 researchers at the NLR. A total of 109 surveys was received by the established cut-off date, for a completion rate of 55%. Questionnaires were distributed to 558 researchers at the two NASA Centers, and 340 were received by the established cut-off date, for a completion rate of 61%. A follow-up survey containing additional questions about technical communication training, technical report use, and foreign language proficiency was distributed to the U.S. respondents. (These questions were initially included in the Dutch questionnaire.) Of the original 320 U.S. respondents, 287 completed and returned the follow-up survey. The study at NLR was conducted during November and December of 1992, and the studies at the NASA installations were conducted during July and August of 1992 with the follow-up in December 1992.

For purposes of this study, "technical communication" was broadly defined to include the full range of activities, processes, procedures, and technologies associated with the production, transfer, and use of technical information. Ordinal scales were used to measure the majority of the responses. Importance and language proficiency (i.e., reading and speaking) were measured on a 5-point scale (1.0 = very unimportant; passably and 5.0 = very important; fluently). A two-tailed t-test was used to determine statistical significance involving mean (1) importance, (2) number of hours, (3) number of information products used, and (4) the percentage using electronic networks. The complete research design and methodology are contained in NASA Technical Memorandum 107693 [19].

Descriptive Findings

This article presents selected results from the Dutch and U.S. studies, with the Dutch responses presented first, followed by the U.S. responses. Demographic data are presented first, followed by data dealing with the importance of technical communication, workplace use and production of technical communication, use of libraries and technical information centers, use of computer and information technology, use of electronic networks, and use of foreign and domestically produced technical reports.

TABLE I
Survey Demographics [n = 109; 287]

	Netherlands		U.S.	
Factors	%	(n)	%	(n)
Professional Duties	28	(30)	6	(21)
Design/Development	3	(3)	11	(37)
Administration/Managenient	63	(69)	82	(279)
Research	6	(17)	1	(3)
Other				
Organizational Affiliation	100	(209)	100	(340)
Government				
Professional Work Experience	38	(41)	15	(52)
1 - 5 years	15	(17)	22	(74)
6 - 10 years	22	(24)	28	(95)
11 - 20 years	25	(27)	34	(115)
21 - 40 years	0	(0)	1	(4)
41 or more years				
Mean Years Work Experience	12.2		16.8	
Median Years Work Experience	9.0		14.0	
Education				
Bachelor's Degree Or Less	20	(22)	27	(91)
Graduate Degree	80	(87)	73	(249)
Educational Preparation				
Engineer	74	(81)	80	(273)
Scientist	25	(27)	17	(58)
Other	1	(1)	3	(9)
Current Duties				
Engineer	75	(82)	69	(234)
Scientist	22	(24)	27	(92)
Other	3	(3)	4	(14)
Member of A Professional/ Technical Society	46	(50)	78	(265)
Gender				
Female	4	(4)	15	(50)
Male	96	(105)	85	(290)

Demographic Information About the Survey Respondents

Survey respondents were asked to provide information about their professional duties, years of professional work experience, educational preparation, current professional duties, and gender. These demographic findings appear in Table I.

Comparing the Dutch and U.S. groups reveals that the respondents differ significantly in terms of organizational affiliation and professional/technical society membership; they are similar in years of professional work experience, current professional duties, amount and type of educational preparation, and gender.

The following "composite" participant profiles are based on the demographic data. The Dutch survey participant works as a researcher (63%), has a graduate degree (80%), was trained as an engineer (74%) and currently works as an engineer (75%), has an average of 12 years professional work experience, and reads and speaks two foreign languages with considerable fluency. The U.S. survey participant works as a researcher (82%), has a graduate degree (73%), was trained as an engineer (80%) and currently works as an engineer (69%), has an average of 17 years of professional work experience, and belongs to a professional/technical society (78%).

Time Spent Communicating Technical Information

Dutch aerospace engineers and scientists spent an average of 9.10 hours per week writing technical information and an average of 6.49 hours communicating technical information

TABLE II(a)
TECHNICAL COMMUNICATION PRACTICES OF AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND UNITED STATES: HOURS SPENT WEEKLY PRODUCING AND RECEIVING INFORMATION

	Netherlands		U.S.	
Factors	%	(n)	%	(n)
Hours Spent Weekly *Writing* Technical Information:				
0	0.0	(0)	2.4	(8)
1 - 5	42.2	(49)	43.2	(155)
6 - 10	33.0	(36)	33.8	(115)
11 - 20	21.1	(23)	17.9	(61)
21 - 40	3.7	(4)	2.7	(9)
Mean	9.10		8.27	
Hours Spent Weekly Communicating Technical Information *Orally*:				
0	3.7	(4)	2.9	(10)
1 - 5	52.2	(47)	39.9	(136)
6 - 10	30.3	(33)	35.8	(121)
11 - 20	13.8	(15)	17.6	(60)
21 - 40	0.0	(0)	3.8	(13)
Mean	6.49*		8.71*	
Hours Spent Weekly Working With *Written* Technical Information *Received From Others*:				
0	0.0	(0)	1.8	(6)
1 - 5	48.6	(53)	49.6	(169)
6 - 10	40.4	(44)	30.6	(104)
11 - 20	8.3	(9)	16.2	(55)
21 - 40	2.7	(3)	1.8	(6)
Mean	7.36		7.70	
Hours Spent Weekly Working With Technical Information *Received Orally From Others*:				
0	7.3	(8)	3.2	(11)
1 - 5	70.7	(77)	57.9	(197)
6 - 10	18.3	(20)	29.2	(99)
11 - 20	3.7	(4)	8.8	(30)
21 - 40	0.0	(0)	0.9	(3)
Mean	4.28*		6.27*	

* $p \leq 0.05$.

orally; U.S. aerospace engineers and scientists spent an average of 8.27 hours per week writing technical information and an average of 8.71 hours communicating technical information orally. See Table II(a).

Dutch aerospace engineers and scientists spent an average of 7.36 hours per week working with written technical information received from others and an average of 4.28 hours per week working with technical information received orally from others. U.S. aerospace engineers and scientists spent an average of 7.70 hours per week working with written technical information received from others and an average of 6.27 hours per week working with technical information received orally from others.

Importance of Communicating Technical Information and Change Over Time

As indicated in Table II(b), about 89% of the Dutch and about 91% of the U.S. aerospace engineers and scientists indicated that, in their work, the ability to communicate technical information effectively is important.

About 60% of the Dutch and 70% of the U.S. aerospace engineers and scientists indicated that, compared to five years ago, the amount of time they spend communicating technical information has increased. As they have advanced professionally, 50% of the Dutch aerospace engineers and scientists indicated that the amount of time spent working with technical information received from others had stayed the same and 45% indicated that the amount of time had increased. Sixty-five percent of the U.S. aerospace engineers and scientists indicated that the amount of time spent working with technical information received from others had increased, and 26% indicated that the amount of time had stayed the same.

TABLE II(b)
TECHNICAL COMMUNICATION PRACTICES OF AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND UNITED STATES: IMPORTANCE AND CHANGE OVER TIME

	Netherlands		U.S.	
Factors	%	(n)	%	(n)
In Your Work, Communicating Technical Information Is:				
Unimportant	2.9	(1)	7.7	(26)
Neither Important Nor Unimportant	8.3	(9)	1.8	(6)
Important	88.8	(69)	90.5	(308)
Mean	4.40		4.53	
Compared to 5 Years Ago, The Amount Of Time You Spend Communicating Technical Information Has:				
Increased	60.0	(66)	70.0	(239)
Stayed The Same	35.0	(38)	24.0	(80)
Decreased	5.0	(5)	6.0	(21)
As You Have Advanced Professionally, The Amount Of Time You Spend Working With Technical Information *Received From Others* Has:				
Increased	45.0	(49)	65.0	(221)
Stayed The Same	50.0	(54)	26.0	(87)
Decreased	5.0	(6)	9.0	(32)

TABLE III(a)
TECHNICAL COMMUNICATION PRACTICES OF AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND UNITED STATES: COLLABORATIVE WRITING PRACTICES AND PRODUCTIVITY

	Netherlands			U.S.		
Factors	$\bar{X}$%	%*	(n)	$\bar{X}$%	%*	(n)
Writing Practice:						
Alone	64.8	24	(26)	61.1	15	(50)
Groups of –						
1	20.1	65	(71)	20.7	72	(246)
2 to 5	12.6	49	(54)	15.6	61	(208)
More Than 5	2.5	10	(11)	2.1	14	(47)
Same Group	—	49	(53)	—	47	(161)
Different Group	—	27	(30)	—	38	(129)
Writing Productivity With Group:						
More	—	28	(31)	—	32	(110)
About The Same	—	19	(21)	—	31	(107)
Less	—	25	(27)	—	20	(68)
Difficult To Judge	—	4	(4)	—	2	(5)

* Percentages do not total 100.

Collaborative Writing—Practices, Productivity, and Group Size

Survey participants were asked whether they wrote alone or as part of a group. The results are found in Table III(a).

Approximately 24% of the Dutch respondents and 15% of the U.S. respondents write alone. Although a lower percentage of the Dutch than the U.S. respondents writes with a group of 2 to 5 people or with a group of more than 5 people, writing appears to be a collaborative process for both groups.

Of the respondents who wrote collaboratively, 49% of the Dutch group and 47% of the U.S. group worked with the

TABLE III(b)
TECHNICAL COMMUNICATION PRACTICES OF AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND UNITED STATES: NUMBER OF PEOPLE AND NUMBER OF GROUPS

	Netherlands			U.S.		
Factors	Mean	Median	(n)	Mean	Median	(n)
Number of –						
People In Group	4.96*	3.00	(53)	3.21*	3.00	(161)
Groups	2.87	2.00	(30)	2.82	3.00	(129)
People In Each Group	3.47	3.00	(30)	3.03	3.00	(129)

*$p \leq 0.05$.

TABLE IV
MEAN (MEDIAN) NUMBER OF TECHNICAL INFORMATION PRODUCTS *PRODUCED* (ALONE OR IN A GROUP) IN THE PAST 6 MONTHS BY AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS

	Alone		In a Group		Average Number of Persons Per Group	
Information Products	Mean	Median	Mean	Median	Mean	Median
Abstracts	14.34	(0.00)	0.38	(0.00)	2.71	(2.50)
Journal Articles	0.08	(0.00)	0.03	(0.00)	2.33	(2.00)
Conference/Meeting Papers	0.37	(0.00)	0.39	(0.00)	3.28	(2.00)
Trade/Promotional Literature	0.13	(0.00)	0.07	(0.00)	5.00	(5.00)
Drawings/Specifications	0.96	(0.00)	0.44	(0.00)	3.17	(2.50)
Audio/Visual Material	0.87	(0.00)	0.07	(0.00)	2.60	(2.00)
Letters	9.63	(4.00)	0.82	(0.00)	2.29	(2.00)
Memoranda	2.30	(1.00)	0.41	(0.00)	2.70	(2.00)
Technical Proposals	0.54	(0.00)	0.69	(0.00)	3.32	(2.00)
Technical Manuals	0.17	(0.00)	0.17	(0.00)	3.46	(3.00)
Computer Program Documentation	0.52	(0.00)	0.35	(0.00)	3.06	(2.00)
In-house Technical Reports	0.95	(0.00)	0.37	(0.00)	2.69	(2.00)
AGARD Technical Reports	0.04	(0.00)	0.04	(0.00)	3.50	(3.50)
Technical Talks/Presentations	1.41	(1.00)	0.14	(0.00)	2.40	(2.00)

same group when producing written technical communication, as reflected in Table III(a). And as indicated in Table III(b), the average number of people in the Dutch group was 4.96; in the U.S. group, 3.21.

Twenty-seven percent of the Dutch respondents worked in an average number of 2.87 groups, each group containing an average of 3.47 people. Thirty-eight percent of the U.S. respondents worked in an average of 2.82 groups, each group containing an average of 3.03 people.

Dutch and U.S. aerospace engineers and scientists were asked about the influence of group participation on writing productivity. As shown in Table III(a), only 28% of the Dutch respondents and 32% of the U.S. respondents indicated that collaborative writing is more productive than writing alone. Nineteen percent of the Dutch respondents and 31% of the U.S. respondents found that collaborative writing is about as productive as writing alone; 25% of the Dutch respondents and 20% of the U.S. respondents found that collaborative writing is less productive than writing alone.

Technical Information Production

From a prepared list, both groups were asked to indicate the number of times they had produced, either alone or as a member of a group, specific technical information products. As individual authors, the Dutch respondents most frequently produced abstracts, letters, memoranda, technical talks/presentations, and drawings/specifications (Table IV).

TABLE V
MEAN (MEDIAN) NUMBER OF TECHNICAL INFORMATION PRODUCTS *PRODUCED* (ALONE OR IN A GROUP) IN THE PAST 6 MONTHS BY AEROSPACE ENGINEERS AND SCIENTISTS IN THE UNITED STATES

	Alone		In a Group		Average Number of Persons Per Group	
Information Products	Mean	Median	Mean	Median	Mean	Median
Abstracts	0.66	(0.00)	0.66	(0.00)	2.67	(2.00)
Journal Articles	0.26	(0.00)	0.35	(0.00)	2.74	(2.00)
Conference/Meeting Papers	0.54	(0.00)	0.59	(0.00)	2.79	(3.00)
Trade/Promotional Literature	0.06	(0.00)	0.01	(0.00)	2.50	(2.50)
Drawings/Specifications	2.04	(0.00)	0.64	(0.00)	3.02	(2.00)
Audio/Visual Material	2.61	(0.00)	1.30	(0.00)	2.95	(2.00)
Letters	6.89	(4.00)	0.65	(0.00)	2.32	(2.00)
Memoranda	9.07	(2.00)	0.64	(0.00)	2.55	(2.00)
Technical Proposals	0.42	(0.00)	0.22	(0.00)	2.61	(2.00)
Technical Manuals	0.12	(0.00)	0.11	(0.00)	3.11	(3.00)
Computer Program Documentation	0.62	(0.00)	0.13	(0.00)	2.35	(2.00)
In-house Technical Reports	0.47	(0.00)	0.19	(0.00)	2.89	(2.00)
AGARD Technical Reports	0.04	(0.00)	0.03	(0.00)	3.43	(3.00)
Technical Talks/Presentations	2.27	(1.00)	0.94	(0.00)	3.46	(3.00)

TABLE VI
MEAN (MEDIAN) NUMBER OF TECHNICAL INFORMATION PRODUCTS *PRODUCED* IN THE PAST 6 MONTHS BY AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND THE UNITED STATES

	Netherlands		U.S.	
Information Products	Mean	Median	Mean	Median
Abstracts	14.72*	0.00	1.32*	1.00
Journal Articles	0.11*	0.00	0.61*	0.00
Conference/Meeting Papers	0.76	0.00	1.14	1.00
Trade/Promotional Literature	0.20	0.00	0.07	0.00
Drawings/Specifications	1.40*	0.00	2.68*	0.00
Audio/Visual Material	0.95	0.00	3.91	1.00
Letters	10.45	4.00	7.53	4.00
Memoranda	2.72*	2.00	9.71*	2.00
Technical Proposals	1.23*	1.00	0.63*	0.00
Technical Manuals	0.34	0.00	0.23	0.00
Computer Program Documentation	0.87	0.00	0.74	0.00
AGARD Technical Reports	0.07	0.00	0.07	0.00
In-house Technical Reports	1.32*	1.00	0.65*	0.00
Technical Talks/Presentations	1.55*	1.00	3.21*	2.00
Grand Mean	36.8		32.5	
Grand Median	14.0		22.0	

*$p \leq 0.05$.

As part of a working group, these Dutch aerospace engineers and scientists most frequently produced letters, technical proposals, drawings/specifications, memoranda, and conference/meeting papers. The average number of persons per group ranged from a high of 5.00 to a low of 2.29.

As individual authors, U.S. respondents most frequently produced memoranda, letters, audio/visual materials, technical talks/presentations, and drawings/specifications (Table V).

In groups, U.S. aerospace engineers and scientists most frequently prepared audio/visual material, technical talks/presentations, abstracts, letters, drawings/specifications, and memoranda. The average number of persons per group ranged from a high of 3.46 to a low of 2.32. Table VI contains a comparison of technical information products produced by both groups.

Technical Information Use

Abstracts, journal articles, conference/meeting papers, letters, and drawings/specifications were the technical informa-

TABLE VII
MEAN (MEDIAN) NUMBER OF TECHNICAL INFORMATION PRODUCTS *USED* IN THE PAST 6 MONTHS BY AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND THE UNITED STATES

Information Products	Netherlands		U.S.	
	Mean	Median	Mean	Median
Abstracts	24.76*	1.00	8.41*	1.00
Journal Articles	15.95	10.00	12.26	5.00
Conference/Meeting Papers	9.18	5.00	9.99	6.00
Trade/Promotional Literature	2.06*	0.00	4.99*	0.00
Drawings/Specifications	7.16	0.00	8.24	1.00
Audio/Visual Material	1.30	0.00	7.13	0.00
Letters	7.79	0.00	10.72	4.00
Memoranda	6.36*	4.00	14.00*	3.00
Technical Proposals	2.08	0.00	2.13	0.00
Technical Manuals	5.74	0.00	3.33	0.00
Computer Program Documentation	5.48	1.00	8.02	1.00
AGARD Technical Reports	2.05	0.00	0.92	0.00
In-house Technical Reports	4.95*	3.00	3.10*	0.00
Technical Talks/Presentations	2.87*	2.00	7.36*	5.00
Grand Mean	97.8		100.6	
Grand Median	50.0		63.0	

*$p \leq 0.05$.

TABLE VIII
USE AND IMPORTANCE OF THE ORGANIZATION'S LIBRARY TO AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND THE UNITED STATES

Use[a]	Netherlands		U.S.	
	%	(n)	%	(n)
0 times	5	(5)	11	(37)
1 - 5 times	20	(22)	43	(145)
6 - 10 times	28	(30)	21	(72)
11 - 25 times	35	(38)	14	(49)
26 - 50 times	6	(7)	7	(22)
51 or more times	6	(7)	1	(4)
Does Not Have A Library	0	(0)	3	(11)
Mean	18.5*		9.2*	
Median	10.0		4.0	
Importance	Netherlands		U.S.	
	%	(n)	%	(n)
Very Important	78.0	(85)	68.3	(232)
Neither Important nor Unimportant	15.6	(17)	15.6	(53)
Very Unimportant	6.5	(7)	12.9	(44)
Do Not Have A Library	0.0	(0)	3.2	(11)
Mean	4.1		4.0	

[a]Use equals the number of visits to the organization's library in a 6-month period.
*$p \leq 0.05$.

TABLE IX
INFORMATION SOURCES USED IN PROBLEM SOLVING BY AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND THE UNITED STATES

	Netherlands		U.S.	
	%	(n)	%	(n)
Personal Store Of Technical Information	98	(107)	99	(337)
Spoke With A Coworker Or People Inside My Organization	98	(107)	99	(338)
Spoke With A Colleague Outside Of My Organization	79	(86)	94	(318)
Used Literature Resources Found In My Organization's Library	95	(104)	91	(310)
Spoke With A Librarian Or Technical Information Specialist	74	(81)	80	(274)

tion products most frequently used by these Dutch aerospace engineers and scientists (Table VII).

On the average, they used 25 abstracts, 16 journal articles, 9 conference/ meeting papers, 8 letters, and 7 drawings/specifications in a 6-month period. Technical proposals, technical talks/presentations, Advisory Group for Aerospace Research and Development (AGARD) technical reports, trade/promotional literature, and audio/visual materials were the technical information products least frequently used by these Dutch aerospace engineers and scientists during a 6-month period.

Memoranda, journal articles, letters, conference/meeting papers, and abstracts were the technical information products most frequently used by U.S. aerospace engineers and scientists (Table VII). On the average, they used 14 memoranda, 12 journal articles, 11 letters, 16 abstracts, 10 conference/meeting papers, and 8 abstracts during a 6-month period. AGARD technical reports, technical proposals, in-house technical reports, technical manuals, trade and promotional literature were the technical information products least frequently used by U.S. aerospace engineers and scientists during a 6-month period.

Libraries and Technical Information Centers—Use and Importance

Almost all of the respondents indicated that their organization has a library or technical information center. Unlike the U.S. respondents (9%), about 44% of the Dutch respondents indicated that the library or technical information center was located in the building where they worked. About 56% of the Dutch and 88% of the U.S. respondents indicated that the library or technical information center was outside the building in which they worked and that it was located near where they worked. For 56% of the Dutch, the library or technical information center was located 1.0 kilometer or less from where they worked. For about 81% of the U.S. respondents, the library or technical information center was located 1.0 mile or less from where they worked.

Respondents were asked to indicate the number of times they had visited their organization's library or technical information center in the past 6 months (Table VIII).

Overall, the Dutch respondents used their organization's library or technical information center more than their U.S. counterparts did. The average use rate for Dutch respondents was 18.5 visits during the past 6 months, compared to 9.2 visits for the U.S. respondents.

A majority of both groups indicated that their organization's library or technical information center was important to performing their present professional duties (Table VIII). About 78% of the Dutch aerospace engineers and scientists indicated that their organization's library or technical information center was important or very important to performing their present professional duties. About 68% of the U.S. aerospace engineers and scientists indicated that their organization's library or technical information center was important or very important to performing their present professional duties.

Problem Solving and Technical Information Use

From a list of information sources, survey participants were asked to indicate which ones they routinely used in problem solving (Table IX).

TABLE X
USE OF COMPUTER SOFTWARE BY AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND THE UNITED STATES TO PREPARE WRITTEN TECHNICAL COMMUNICATIONS

	Netherlands		U.S.	
Software	%	(n)	%	(n)
Word Processing	89	(97)	96	(327)
Outliners and Prompters	20	(22)	14	(46)
Grammar and Style Checkers	24	(26)	30	(103)
Spelling Checkers	74	(81)	88	(299)
Thesaurus	35	(38)	37	(127)
Business Graphics	26	(28)	15	(52)
Scientific Graphics	61	(66)	91	(308)
Desktop Publishing	19	(21)	48	(162)

In addition to personal knowledge, upon which they relied greatly, the U.S. aerospace engineers and scientists in this study displayed information-seeking behavior patterns similar to those of U.S. engineers in general. The information-seeking behavior of the Dutch respondents did not vary greatly from that of their American counterparts. U.S. participants used their personal stores of technical information, coworkers in the organization, colleagues outside the organization, literature resources found in the organization's library, and a librarian or technical information specialist. Their Dutch counterparts used their personal stores of technical information, spoke with coworkers in the organization, used literature resources found in the organization's library, spoke with a colleague outside the organization, and spoke with a librarian or technical information specialist.

Use of Computer and Information Technology

Survey participants were asked if they use computer technology to produce technical information. Approximately 91% of the Dutch respondents use computer technology to produce technical information. Almost all (98%) of the U.S. respondents use computer technology to produce technical information. About 56% of the Dutch respondents and about 73% of the U.S. respondents "always" use computer technology to produce technical information. A majority of both groups (83% and 98%) noted computer technology had increased their ability to communicate technical information. About 66% of the Dutch and 80% of the U.S. respondents stated that computer technology had increased their ability to communicate technical information "a lot."

From a prepared list, survey respondents were asked to indicate which computer software they used to produce written technical information (Table X).

Word processing software was used most frequently by both groups. With the exception of outliners and prompters and business graphics, the U.S. respondents made slightly greater use of computer software for producing written technical communication than did their Dutch counterparts.

Survey respondents were also given a list of information technologies and asked, "How do you view your use of the following information technologies in communicating technical information?" Their choices included "already use it"; "don't use it, but may in the future"; and "don't use it and doubt if I will." (See Table XI.)

TABLE XI
USE, NONUSE, AND POTENTIAL USE OF INFORMATION TECHNOLOGIES BY AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND THE UNITED STATES TO PREPARE WRITTEN TECHNICAL COMMUNICATIONS

	Already Use It		Don't Use It, But May In Future		Don't Use It, And Doubt If Will	
Information Technologies	Dutch %	U.S. %	Dutch %	U.S. %	Dutch %	U.S. %
Audio Tapes and Cassettes	6	13	16	30	79	57
Motion Picture Films	4	17	21	29	75	55
Videotape	25	63	42	31	33	7
Desktop/Electronic Publishing	28	60	51	32	22	8
Computer Cassettes/Cartridge Tapes	45	44	24	32	31	24
Electronic Mail	37	83	51	15	13	2
Electronic Bulletin Boards	11	36	57	48	32	17
FAX Or TELEX	95	91	4	8	1	1
Electronic Data Bases	42	56	50	40	8	4
Video Conferencing	0	37	46	54	54	10
Teleconferencing	13	53	50	40	38	7
Micrographics and Microforms	30	23	16	42	54	34
Laser Disk/Video Disk/CD-ROM	11	19	59	68	30	14
Electronic Networks	58	76	35	19	7	5

The Dutch and U.S. aerospace engineers and scientists in this study use a variety of information technologies. The percentages of "I already use it" responses ranged from a high of 95% (fax or telex) to a low of 0% (video conferencing) for the Dutch respondents. Similarly, the U.S. responses ranged from a high of 91% (fax or telex) to a low of 13% (audio tapes and cassettes). A list, in descending order, follows of the information technologies most frequently used.

Netherlands		United States	
Fax or telex	95%	Fax or telex	91%
Electronic Networks	58	Electronic Mail	83
Computer Cassettes/		Electronic Networks	76
Cartridge Tapes	45	Videotape	63
Electronic Data Bases	42	Desktop Publishing	60
Electronic Mail	37		

A list, in descending order, follows of the information technologies "that are not currently being used but may be used in the future."

Netherlands		United States	
Laser Disk/Video Disk/		Laser Disk/Video Disk/	
CD-ROM	59%	CD-ROM	68%
Electronic Bulletin Boards	57	Video Conferencing	54
Desktop/Electronic		Electronic Bulletin Boards	48
Publishing*	51	Micrographics and Microforms	42
Electronic Mail*	51	Electronic Data Bases	40
Electronic Data Bases*	50		
Teleconferencing*	50		
Video Conferencing	46		

* Denotes tie

Electronic Networks—Use and Importance

Survey participants were asked if they use electronic networks at their workplace in performing their present duties. Approximately 65% of the Dutch respondents use electronic networks and about 35% either do not use or do not have access to electronic networks. About 89% of the U.S. respondents use electronic networks in performing their present

TABLE XII
USE AND IMPORTANCE OF ELECTRONIC NETWORKS TO AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND UNITED STATES

Use[a]	Netherlands %	Netherlands (n)	U.S. %	U.S. (n)
0	0.0	(0)	1.2	(4)
1 - 25	47.7	(52)	52.9	(180)
26 - 50	10.1	(11)	16.8	(57)
51 - 75	0.0	(0)	7.6	(26)
76 - 99	5.5	(6)	8.8	(30)
100	1.8	(2)	1.5	(5)
Do Not Use or Have Access to Electronic Networks	34.9	(38)	11.2	(38)
Mean	22.1*		30.1*	
Median	10.0		20.0	

Importance	Netherlands %	Netherlands (n)	U.S. %	U.S. (n)
Very Important	35.7	(39)	65.0	(221)
Neither Important nor Unimportant	21.1	(23)	11.2	(38)
Very Unimportant	8.3	(9)	12.6	(43)
Do Not Use or Have Access to Electronic Networks	34.9	(38)	11.2	(38)
Mean	3.7*		4.1*	

[a]Use is a percentage of a 40-hour work week.
*p ≤ 0.05.

duties and about 11% either do not use or do not have access to electronic networks (Table XII).

Respondents were also asked to rate the importance of electronic networks in performing their present duties (Table XII). The U.S. respondents rated electronic networks almost twice as important as their Dutch counterparts did. U.S. participants were less ambivalent about the importance (neither important nor unimportant) of electronic networks than were their Dutch counterparts (about 11% vs 21%). Respondents were also asked how they accessed electronic networks (Table XIII): mainframe terminal, personal computers, and workstations. Access via personal computer was most frequently reported.

Respondents using electronic networks were asked to indicate the purpose(s) for which they used them (Table XIII). Both the Dutch and U.S. respondents indicated that electronic file transfer, electronic mail, remote log in for design/computational tools, and connecting to geographically distant sites represented their greatest use of electronic networks. Also noticeable for both groups is the lack of electronic network use for accessing and searching library catalogs, acquiring (ordering) documents from the library, and searching (bibliographic) data bases.

Survey participants who used electronic networks were asked to identify the groups with whom they exchanged messages or files (Table XIII). The Dutch respondents displayed a consistent pattern of message and file exchange both within and outside of their organization. Overall, the U.S. group exhibited higher percentages of network use for exchanging messages or files than did their Dutch counterparts. The U.S. respondents did not display as consistent a pattern of use as the Dutch respondents did.

Foreign and Domestically Produced Technical Reports—Use and Importance

To better understand the transborder migration of scientific and technical information (STI) via the technical report, survey participants were asked about their use of foreign and domestically produced technical reports and the importance of these reports in performing their professional duties (Table XIV).

TABLE XIII
ACCESS AND USE OF ELECTRONIC NETWORKS AND THE EXCHANGE OF ELECTRONIC FILES BY AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND UNITED STATES

Access	Netherlands %	Netherlands (n)	U.S. %	U.S. (n)
Mainframe Terminal	12.8	(14)	13.5	(46)
Personal Computer	26.6	(29)	49.1	(167)
Workstation	7.3	(8)	26.2	(89)
Some Combination of the Above	18.4	(20)	a	a
Do Not Use or Have Access to Electronic Networks	34.9	(38)	11.2	(38)

Purpose	Netherlands %	Netherlands (n)	U.S. %	U.S. (n)
Connect to geographically distant sites	36.7	(40)	53.2	(181)
Electronic mail	33.9	(37)	81.5	(277)
Electronic bulletin boards or conferences	8.3	(9)	36.8	(125)
Electronic file transfer	58.7	(64)	83.5	(284)
Log on to remote computers	37.6	(41)	63.8	(217)
Control remote equipment	9.2	(10)	8.8	(30)
Access/search the library's catalog	10.1	(11)	29.1	(99)
Order documents from the library	3.7	(4)	9.4	(32)
Search electronic (bibliographic) data bases	11.9	(13)	33.5	(114)
Information search and data retrieval	24.8	(27)	35.9	(122)
Prepare scientific and papers with colleagues at geographically distant sites	19.3	(21)	32.9	(112)

Exchange With --	Netherlands %	Netherlands (n)	U.S. %	U.S. (n)
Members of Own Work Group	37.6	(41)	81.5	(277)
Others In Your Organization But Not In Your Work Group	27.5	(30)	77.9	(265)
Others In Your Organization, Not In Your Work Group, At A Geographically Distant Site	33.9	(37)	56.8	(193)
People Outside Your Organization	33.0	(36)	58.8	(200)
Do Not Use or Have Access to Electronic Networks	34.9	(38)	11.2	(38)

[a] Not asked of U.S. participants.

Both groups reported the greatest use of their own technical reports (96% of the Dutch use NLR reports and 97% of the U.S. group use NASA technical reports). Other than their own reports, the Dutch use NASA (82%); NATO AGARD (71%); German technical reports (69%); and British technical reports (50%).

Other than their own reports, the U.S. group uses AGARD (82%) and British (54%) technical reports. Neither group makes particular use of Japanese, Indian, or Russian technical reports. Survey participants were also asked about technical reports series access. Overall, the Dutch appear to have better access to foreign technical reports than do their U.S. counterparts; the exception, of course, is access to NASA technical reports.

Both groups were asked to rate the importance of selected foreign and domestic technical reports in performing their present professional duties. The average (mean) importance ratings are shown in Table XIV. The Dutch rated the importance of U.S. NASA reports ($\overline{X}$ = 3.69) second only to their own ($\overline{X}$ = 4.32), followed by German technical reports ($\overline{X}$ = 3.22) and NATO AGARD reports ($\overline{X}$ = 3.18). The U.S. group

TABLE XIV
USE AND IMPORTANCE OF FOREIGN AND DOMESTICALLY PRODUCED TECHNICAL REPORTS TO AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND UNITED STATES

Use	Netherlands %	Netherlands (n)	U.S. %	U.S. (n)
Country/Organization				
NATO AGARD	70.6	(77)	82.2	(236)
Britian	49.5	(54)	54.0	(155)
ESA	44.0	(48)	5.9	(17)
India	7.3	(8)	6.3	(18)
France	43.1	(47)	41.1	(118)
Germany	68.8	(75)	36.2	(104)
Japan	11.0	(12)	11.5	(33)
Russia	0.9	(1)	8.4	(24)
The Netherlands	96.3	(105)	19.9	(57)
U.S. NASA	81.7	(89)	96.5	(277)
Importance	**Netherlands Rating $\bar{X}$**	**(n)**	**U.S. Rating $\bar{X}$**	**(n)**
Country/Organization				
NATO AGARD	3.18	(108)	3.42	(282)
Britian	2.87	(105)	2.89	(266)
ESA	2.35*	(108)	1.44*	(242)
India	1.46	(101)	1.40	(241)
France	2.36	(107)	2.25	(257)
Germany	3.22*	(108)	2.20*	(247)
Japan	1.57	(104)	1.63	(239)
Russia	1.31*	(97)	1.60*	(231)
The Netherlands	4.32*	(109)	1.81*	(246)
U.S. NASA	3.69*	(108)	4.26*	(285)

*$p \leq 0.05$.

TABLE XV
FOREIGN LANGUAGE FLUENCY AMONG AEROSPACE ENGINEERS AND SCIENTISTS IN THE NETHERLANDS AND UNITED STATES

Language	Netherlands n = 109				U.S. n = 287			
	Read %	Speak %	$\bar{X}$ Ability[a]		Read %	Speak %	$\bar{X}$ Ability[a]	
English	100	100	—	—	[b]	[b]	—	—
French	92	92	2.5	2.1	32	22	1.7	1.6
German	100	99	4.0	3.4	22	15	1.7	1.6
Japanese	7	6	1.0	1.0	4	5	1.7	1.7
Russian	8	5	1.0	1.0	7	5	1.6	1.6

[a]A 1 to 5 point scale was used to measure ability with "1" being passably and "5" being fluently; hence, the higher the average (mean) the greater the ability of survey respondents to speak/read the language.

[b]English is the native language for these respondents.

rated NASA reports most important ($\overline{X}$ = 4.26), followed by AGARD reports ($\overline{X}$ = 3.42).

Foreign Language Skills—Reading and Speaking Competencies

Survey respondents were also asked to provide information about their foreign language skills, specifically their reading and speaking competencies in the languages used by major international aerospace producers. These findings appear in Table XV.

All of the Dutch respondents (100%) read and speak English and German and read and speak French to a lesser extent (92%). The U.S. respondents reported little fluency in any foreign languages. Neither group reported particular fluency in either Japanese or Russian. The mean ($\overline{X}$) ability to read and speak German and French was higher for the Dutch than for the U.S. group. The mean ($\overline{X}$) ability to read and speak Japanese and Russian, although low for both groups, was higher for the U.S. group.

DISCUSSION

The literature associated with the communication of technical information and technological innovation supports Fischer's [20] conclusion that "The communication of technical information is central to the success of U.S. technological innovation, in general, and the management of R & D activities, in particular." However, as Solomon and Tornatzky [21] point out, "While technical information, its production, transfer, and utilization, are crucial to technological innovation and competitiveness, linkages between technical information and the various sectors of the technology infrastructure are weak and/or poorly defined." The inability to define or explain the linkages may be due, in part, to the fact that decisions regarding the use of technical information in the process of technological innovation are driven by economic considerations which, in turn, are often shaped by labor, tax, and trade policies, laws, and regulations.

In this era of international competitiveness and global economies, there is rising concern that engineers and scientists in other countries might be better able than their counterparts in the United States to utilize technical information for product and process development. Two recent studies concerned with global competitiveness in the large civil aircraft (air frame) market state that U.S. competitors have decreased the time it takes to apply technological advances in existing product lines [22, 23].

Multiple explanations exist; two are offered. Branscomb [24, 25] states that certain countries, notably Germany and Japan, have implemented what he refers to as "diffusion or enabling" technology policies directed at creating and utilizing technological capabilities. Diffusion-oriented technology policy invests heavily in the technology infrastructure; it emphasizes the professional competency of the engineering and scientific workforce and the integration of systems responsible for the production, transfer, and utilization of technical information into the R & D process. Vernon [26] states that the past 20 years have witnessed the tendency of technical information to cross national boundaries. This "boundary-spanning" tendency of technical information is due mainly to improvements in communication and transportation and the fact that other nations are spending more for R & D. These nations are becoming greater consumers of technical information, are developing the infrastructure needed to acquire and disseminate technical information, and are willing to allocate the resources needed to acquire the technical information they do not possess.

If true, these two explanations should ultimately affect the communication of technical information by engineers and scientists. Our investigation of the technical communications practices of Russian aerospace engineers and scientists supports Branscomb's views regarding the importance of technology policy [27]. Unfortunately, the results of the Russian investigation illustrated how technology policy can have a deleterious effect on the communication of technical information at the individual, group, organizational, and national levels. Our investigation of the technical communications practices of Japanese aerospace engineers and scientists supports Vernon's position regarding the positive outcomes of investing in a technology and information infrastructure and supports the generally held assumption that the communication of technical information is affected, to an undetermined degree, by language and culture [28].

Given this background and the technological complexity and uncertainty of aerospace, we expect the technical communication practices of the Dutch and U.S. aerospace engineers and scientists to reflect the dynamic and robust nature of the discipline. Given the limited purposes of this exploratory study, the overall response rates, and the research designs, no claims can be made regarding the extent to which the attributes of the respondents in the studies accurately reflect the attributes of all aerospace engineers and scientists in the Netherlands and the United States. A much more rigorous research design and methodology and a larger sample size would be needed before any claims could be made; however, a comparison of the responses does provide insight into the nature of technical communication among aerospace engineers and scientists in the Netherlands and the U.S.

Communicating Technical Information

The number of hours spent weekly communicating (i.e., producing and receiving) technical information are comparable. Statistical differences were noted, as shown in Table II(b), between the two groups regarding the hours spent weekly communicating technical information orally and working with technical information received orally from others. The ability to communicate technical information effectively is important to Dutch and U.S. aerospace engineers and scientists. About 90% of the Dutch and U.S. aerospace engineers and scientists in these studies indicated that the ability to communicate effectively is a significant factor in their professional success. Compared to five years ago, the amount of time spent communicating technical information has increased for both groups. As they have advanced professionally, the amount of time they spend producing and working with technical communications has increased for almost one-half (45%) of the Dutch respondents and about two-thirds (65%) of the U.S. respondents, as can be seen in Table II(b).

Collaborative Writing

Slightly more than 60% of both groups produce written technical communications alone. The remainder (those who write in groups) write with the same group or with one other person. A slightly higher percentage of the U.S. (32%) than Dutch respondents (28%) find collaborative writing more productive than individual writing. Further, the number of groups and the relative number of people in each group are comparable. However, as shown in Table III(b), a statistically significant difference was found between Dutch and U.S. respondents when the number of people in each of the collaborative writing work groups was compared.

Both groups of respondents frequently produce the same types of materials whether they write as individuals or collaboratively. For the Dutch, abstracts and letters were produced most frequently alone; letters and technical proposals were produced most frequently in collaboration (Table IV). For the U.S. respondents, letters and memoranda were produced most frequently alone; audio/visual material and technical talks/presentations were produced most frequently in collaboration (Table V).

Technical Communication Production and Use

The number of technical information products produced individually and collaboratively was totaled and a mean (median) was calculated for each information product (Table V). A grand mean (median) was calculated for the total number of technical information products produced by both groups. Statistically significant differences were found to exist between both groups for the production of abstracts, journal articles, drawings/specifications, memoranda, technical proposals, in-house technical publications, and technical talks/presentations. No statistically significant difference was found when the total productions (for example, technical information products produced) of both groups were compared.

The mean (median) number of technical information products used by both groups was calculated (Table VII). A grand mean (median) was calculated for the total number of technical information products used by both groups. Statistically significant differences were found to exist between both groups for the use of abstracts, trade/promotional literature, memoranda, in-house technical publications, and technical talks/presentations. No statistically significant difference was found when the total uses (for instance, technical information products produced) of both groups were compared.

Library Use and Importance and Problem Solving

Statistically, Dutch aerospace engineers and scientists made far greater use of their organization's library than did their American counterparts (Table VIII). However, the importance of the organization's library was about equal for both groups. To solve technical problems, the Dutch and U.S. aerospace engineers and scientists in these studies appear to rely on personal knowledge, discussions with colleagues within and outside their organization, and literature resources found within the organization's library (Table IX). Neither group routinely consults librarians or technical information specialists for information when solving problems. Although both Dutch and U.S. respondents indicated that libraries and technical information centers are important information repositories, the Dutch respondents make greater use of them than do the U.S. aerospace engineers and scientists who participated in this study. More Dutch aerospace engineers and scientists had a library or technical information center located in their building than did their U.S. counterparts, which may or may not account for the greater use reported by the Dutch respondents.

Use of Computer and Information Technology

More U.S. respondents used computer technology to prepare technical information than did their Dutch counterparts, although a majority of both groups indicated that computer technology had increased their ability to communicate technical information. The two groups displayed notable similarities in terms of the information technologies they use presently and those that they anticipate using in the future.

Use and Importance of Electronic Networks

Statistically, the U.S. aerospace engineers and scientists in this study reported greater use of electronic networks than did their Dutch counterparts (Table XII). Further, the U.S. respondents rated the use of electronic networks twice as important as their Dutch counterparts rated them, a statistically significant difference, although more than 90% of both groups anticipate using electronic networks in the performance of their work (Table XI). The preferred method of accessing electronic networks is by personal computer (Table XIII). Both groups reported similar types of use (purpose) for electronic networks; however, use of electronic networks to access the library's catalogue and order documents from the library was low for both groups. The Dutch respondents display a more consistent pattern than U.S. respondents of message and file exchange both within and outside of their organization.

Use and Importance of Foreign and Domestic Technical Reports

The U.S. and Dutch survey respondents reported the greatest use of domestically produced technical reports and ranked them highly in terms of importance in performing their professional duties (Table XIV). The U.S. respondents indicated extensive use of NATO AGARD reports (82%) and British technical reports (54%), all of which are available in English. The Dutch also indicated extensive use of NASA reports (82%), NATO AGARD reports (71%), German technical reports (69%), and British technical reports (50%), all of which are available in languages in which the Dutch respondents report fluency. Statistically significant differences were noted in the importance ratings for German technical reports, European Space Agency (ESA) reports, and Russian technical reports, as well as Dutch NLR reports and U.S. NASA reports.

The Dutch respondents read and speak fluently three foreign languages in addition to their native Dutch, whereas the U.S. respondents report fluency only in their native language: both groups read and speak English fluently, but the Dutch also report fluency in French and German. Neither group reports fluency in Japanese and/or Russian.

Concluding Remarks

Despite the limitations of this investigation, these findings contribute to our knowledge and understanding of the technical communication practices among aerospace engineers and scientists at the national and international levels. Such an understanding should contribute to the process of technological innovation, thus enhancing the competitive positions of nations in a global economy.

The results of this exploratory study reinforce the findings from the literature about the essential role that effective communication plays in technological innovation, and they provide a comparative view of technical communication among individuals working in the same discipline in similar institutions in different countries. Although similarities do exist, differences appeared among the survey respondents in communicating technical information orally, in the size and number of groups involved in collaborative writing, in the types of technical information products they produced and used, in their use of libraries and electronic networks, in the importance to them of technical report literature, and in their foreign language competencies and skills. Further exploration of these differences could provide the nucleus for a research agenda using a variety of research designs and methodologies to investigate (1) communication and technological innovation, (2) technical communication at the individual, group, and organizational levels, (3) collaborative writing within the inherently collaborative discipline of aerospace, (4) the impact of language and culture on technical communication, and (5) information source selection and use in R&D projects. We hope others will join in this research challenge.

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