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I. INTRODUCTION

This report is based on a study of the field of atomic and molecular science carried out during 1980-1981 through a comprehensive survey of participants in the field. Its purpose is to establish a quantitative basis for describing the national research effort in this field. Such a basis is needed in connection with several aspects of the planning process: external representation, internal communication and coordination, and a general assessment of the health, strengths, and weaknesses of the field.

A principal attraction of the field is its direct concern with the fundamental properties of matter and its interaction with radiation on a level immediately relevant to the world of ordinary experience. For example, it deals on the most fundamental level with the mechanisms of use of solar energy in the environment and with the most basic biological processes. The field is also a critical resource for all other fields of science that require a knowledge of the properties and interaction of matter and radiation at the atomic and molecular level.

The field of atomic and molecular science includes studies of interactions with each other and with the radiation field of atoms, molecules, and positive and negative ions, electrons, positrons, and other particles, such as muons and pions. To guide respondents in deciding whether their activity was associated closely enough with the field to justify a response, the following inclusive operational definition was adopted:

> Atomic and molecular science incorporates the determination and use of basic physical data about individual atoms and molecules and their various ionic species. It is concerned with interactions of these particles with fields and with each other.

A separate product of this survey is the "Directory of Atomic and Molecular Scientists in the United States," which was distributed on a limited basis in late 1981. It is planned to update this directory periodically.

The study was carried out by the Subcommittee on Atomic and Molecular Survey of the Committee on Atomic and Molecular Science (CAMS), established by the National Research Council to solicit and coordinate information and advice from the community of atomic and molecular scientists for use in planning federal science policy. The committee was originally constituted as the Committee on Atomic and Molecular Physics (CAMP). Its current broader responsibilities are reflected in the new name.

The present study attempts to develop the first comprehensive and statistical description of the broad field of atomic and molecular science in the United States. It thus amplifies and updates materials from previous studies of the field.

Section II of this report discusses the methodology of the survey; Section III is concerned with demographics; Section IV provides a qualitative analysis of the field, perceived from survey returns; Sections V, VI, and VII discuss employment, external support for research, and some miscellaneous findings, respectively; and Section VIII is a summarizing commentary.

II. METHODOLOGY OF THE CAMS SURVEY

The Subcommittee on Atomic and Molecular Survey circulated a general questionnaire (Appendix 1, form OMB-99-S 80001) to all scientists thought to be participants in the field and subsequently distributed a set of eight secondary questionnaires (Appendix 1, 2A-2H) to explore various special aspects of the field in depth.

The Federal Reports Act requires clearance of the justification and plan of surveys supported by federal funds and approval by the Office of Management and Budget of all cover letters and questionnaires prior to their circulation. The entire set of questionnaires and cover letters was approved in May 1980 under OMB-99-S 80001.

GENERAL QUESTIONNAIRE

Questionnaire 1, the general questionnaire, was designed to obtain comprehensive demographics for statistical analysis, for production of a directory of workers in the field, and, in addition, to provide special information for circulation of the secondary questionnaires. Department, institution, address, telephone number, type of employing institution (academic, not-for-profit, federally funded research and development center, or industry), type of position (permanent or temporary) were asked for. The year of highest degree was requested to obtain a profile of professional age. Department and institution of highest degree were asked for to obtain information on sources of workers.

The subcommittee asked scientists to briefly describe their research rather than to select categories from a prepared list, such as the physics and astronony classification scheme (PACS) list, to provide more precise description of individual research. The research was further defined by percentages of effort with experimental and/or theoretical emphasis. Other questions were concerned with allocation of time to active research, supervision, pursuit of funding, teaching, and administration; and the numbers of people supervised in senior, postdoctorate/temporary, student, and support categories. A statement of past or current activity in fields other than atomic and molecular science was requested with the hope of identifying sources of generalists and feeder fields for atomic and molecular science.

The subcommittee was also interested in determining whether the traditional balance of pure versus applied research is undergoing drastic alteration. The former category includes research related to physical constants, precision tests of laws of nature or principles underlying these, tests of general collision theory, and the like. Applied refers to goal-oriented studies and needs for specific types of data for program development. Questions along these lines were directed to the selected respondents of Questionnaires 2A and 2B.

In an attempt to obtain a list of funding agencies (including those not well known to the atomic and molecular community) and an estimate of the total amount of money supporting the field from external sources, scientists were asked to specify sources and amount of funding and duration of contracts. The net response only applies to external support supplied through grants and contracts, as opposed to internal institutional support.

Additional questions in the second set of questionnaires included one intended to ascertain whether the scientist was willing to complete one or more of the specialized secondary questionnaires, concerning unusual facilities used in research, e.g., a facility such as a tokamak or synchrotron not built and operated primarily for use in atomic and molecular science, or an accelerator (>0.5 MeV).

SECONDARY QUESTIONNAIRES

2A. Experimental Goals and Funding. Through this questionnaire, the subcommittee attempted to assess the scientists' attitudes concerning which new and promising or scientifically rewarding established areas should be encouraged by increased support.

2B. Theoretical Goals and Funding. This questionnaire was structured much as was the one above. In addition, the respondents were asked to describe any special problems that they thought theorists might have.

2C. Academic Manpower and Employment Opportunities. This questionnaire explored the availability of academic positions at all levels and requested a general evaluation of the quality of candidates for these positions.

2D. Nonacademic Manpower and Employment Opportunities. This questionnaire probed traits of research scientists deemed useful to nonacademic employers, the perceived competence of young scientists, recent patterns of employment, and estimated number of job openings.

2E. Computer Usage in Atomic and Molecular Physics. To document trends in computer usage, this questionnaire asked for details on the purpose, method, convenience, and adequacy of current computer systems, as well as what changes are desired and why.

2F. Communications. This questionnaire evaluated the perceived effectiveness of current communications mechanisms and factors limiting travel.

2G. Atomic and Molecular Science in Industry. Industrial support of atomic and molecular research has seldom if ever been documented with regard to either subject matter or financial level. Although much of this information is considered proprietary, this questionnaire attempted to explore that part of it that is not.

2H. Atomic and Molecular Science at Unusual Facilities. A significant segment of atomic and molecular research is conducted at what the subcommittee defined as unusual facilities: facilities that have been built and/or are operated for some primary purpose other than atomic and molecular research. Examples are tokamaks, synchrotrons, and high-energy accelerators. A characteristic of these facilities is that they are maintained primarily by funds beyond those mainly allocated for atomic and molecular research. Specific problems associated with shared use are scheduling, cost, and the constraints of research requiring characteristics unique to one facility. This questionnaire probed such problems.

A mailing list was compiled from lists of members of organizations, participants in conferences, and members of associations connected with the field. These included the following:

- The Division of Electron and Atomic Physics of the American Physical Society (DEAP)
- The Division of Chemical Physics of the American Physical Society (DCP)
- International Conference on the Physics of Electronic and Atomic Collisions (ICPEAC)
- International Conference on Atomic Physics (ICAP)
- International Conference on Laser Spectroscopy (FICDLS)
- Gaseous-Electronics Conference (GEC)
- Symposium on Atomic Spectroscopy
- Conference on Applications of Accelerators in Research and Industry
- International Conference on Multiphoton Processes
- IEEE Journal of Quantum Electronics

The general questionnaire was sent to 6500 people working in the United States or temporarily abroad in June 1980. Two months after the mailing a postcard reminder was sent to all persons from whom there was no response. Also, members of the subcommittee identified nonresponding individuals believed to be actively involved in atomic and molecular research from the list of nonrespondents in order that they could be sent a second copy of the questionnaire.

More than 2400 questionnaires were filled out and returned. Of these, the subcommittee judged 158 to be inapplicable. Another 1200 were returned with a statement that the respondent was not involved in atomic and molecular research. Five hundred of the questionnaires were returned unopened, primarily because the address was invalid and occasionally because the addressee was deceased.

The subcommittee planned to send the secondary questionnaires to a limited number of scientists selected randomly from those who responded to the general questionnaire in an appropriate way. In all cases, secondary questionnaires were sent only to people who expressed willingness to respond. With rare exceptions, no more than one secondary questionnaire was sent to any individual. The criteria for selection to receive each secondary questionnaire were as follows:

2A Experimental Goals and Funding: experimental research and at least five years since completion of Ph.D.
2B Theoretical Goals and Funding: theoretical research and at least five years since completion of Ph.D.
2C Academic Manpower: academic institution and supervision of four or more scientists.
2D Nonacademic Manpower: industrial, government, or not-for-profit laboratory and supervision of six or more scientists.
2E Computer Usage: random selection mixing experimental and theoretical, academic, and nonacademic.
2F Communications: random selection mixing experimental and theoretical, academic, and nonacademic.
2G Atomic and Molecular Science in Industry: directors of research of industrial laboratories identified in Questionnaire 1.
2H Unusual Facilities: "yes" response to question 10 of Questionnaire 1.

In the circulation of the secondary questionnaires the selection was random within the criteria stated, but with selection of distribution among the five types of employing institutions--academic, corporate, not-for-profit, federally funded, government--and between experimental and theoretical emphasis, and with research specialty chosen to roughly match the general distribution of respondents in these categories as described in Section IV.

These questionnaires were mailed in October and November 1980. The subcommittee recognized that the randomly chosen recipients of Questionnaires 2A and 2B--Experimental and Theoretical Goals and Funding--were often individuals with limited experience. In order to broaden the base for commentary on the respondents' attitudes, the subcommittee chose a number of leading scientists to receive these questionnaires as well.

The final numbers, sent and received, of the secondary questionnaires are listed in Table II-1.

Simple statistics on demographics were compiled from the 2262 completed returns of the general questionnaire using the computer program Statistical Package for the Social Sciences (SPSS).*

The responses to Questionnaires 2G and 2H are not discussed further in this report. Responses to 2G lend themselves neither to statistical treatment nor to a useful summary statement. The topic addressed in 2H is covered in detail in the Report of the Workshop on Accelerator-Based

*See SPSS, Statistical Package for the Social Sciences, second edition, by N. H. Nie, C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent, McGraw-Hill Book Company, New York (1975).

TABLE II-1. Distribution of Questionnaires

Questionnaire	Total Sent	Total Completed Returns
1	6500[a]	2262
2A	168	100
2B	129	81
2C	72	36
2D	50	20
2E	76	47
2F	66	34
2G	117	29
2H	141	47

[a]The subcommittee had intentionally cast a very wide net (including IEEE and Division of Chemical Physics of APS) with the intent of identifying as many atomic and molecular scientists as possible. Many of the recipients of Questionnaire 1 did not perceive themselves as atomic and molecular scientists and chose not to respond.

Atomic and Molecular Science, New London, New Hampshire, July 27-30, 1980, sponsored by the Atomic, Molecular, and Plasma Physics Program of the Division of Physics of the National Science Foundation.

III. DEMOGRAPHICS OF ATOMIC AND MOLECULAR SCIENCE

The general questionnaire, to which 2262 valid responses were received, provides a basis for characterizing the atomic and molecular scientific population by means of a number of parameters. The subcommittee estimates that the return represents at least three-fourths of the permanent professional U.S. scientists having a primary association with the field. This estimate is consistent with results of several independent checks, including a random sampling of known atomic and molecular scientists and a cross-checking with AIP listings of atomic and molecular scientists in academic physics departments.

Graduate students were not systematically polled, and the 58 forms that they returned are excluded from the data base. The graduate student population is estimated indirectly. The direct representation of postdoctoral and other temporary researchers is also subject to uncertainty. The number of responses received from postdoctorals was 108, but responses from permanent faculty claimed supervision of more than 150 postdoctorals in physics departments alone. Therefore we have omitted postdoctoral returns from the data base and have indirectly estimated their number. Twelve respondents, unemployed at the time they returned their questionnaires, did not report a type of employing institution and are also excluded from the data base.

After excluding graduate students, postdoctorals, and unemployed, the data base from which our statistics were compiled was 2084. Of these 52% were associated with academic institutions, 18% with industrial or corporate research, 15% with federally funded research and development centers (FFRDC), 11% with government (civilian or military) laboratories, and 4% with not-for-profit (NFP) research organizations. Of the total responding, 61% claim that 70% or more of their effort is devoted to experimental research; 31% claim that 70% or more of their effort is devoted to theoretical research; and 8% are heavily engaged (more than 30% effort) in both. Of respondents who indicated they were at academic institutions, about 49% received their highest academic degrees from physics departments, 38% from chemistry (including physical chemistry and chemical physics) departments, and 38% from electrical engineering departments. In corporate, government, and federally funded centers the physics-to-chemistry ratio is a bit higher, and other departments, notably engineering, are more strongly represented. Other cross-correlations are included in tables or in discussion below.

TABLE III-1. Responses by Department of Highest Academic Degree, Showing Category of Current Employing Organization

	Academic	Cor- porate	Govern- ment	FFRDC	NFP	Total
Physics	498	191	147	176	31	1044
Chemistry	369	115	42	84	36	646
Aeronomy	9	11	3	5	5	33
Astronomy	8	2	5	3	0	18
Electrical engineering	29	34	8	9	6	86
Engineering, other	32	25	8	10	1	76
Health	5	0	1	2	0	8
Mathematics	7	2	1	0	0	10
Plasma science	1	1	0	3	0	5
Discipline undetermined/ incomplete response	96	28	15	18	1	158
TOTAL	1054	410	230	310	80	2084

Respondents to the general questionnaire fall into more than thirty different types of departments or divisions. For the purposes of this report we have combined these under nine disciplinary labels. In Table III-1 the field of respondents is represented by academic discipline of the individual's highest degree, and the type of organization by which he or she is currently employed. This characterization is limited by incomplete information. Of the 2084 returns in the data base, 158 do not give the discipline under which the highest degree was obtained. In this and subsequent representations the extent to which the representation is limited by incomplete or uninterpretable information is given on a separate line.

In Table III-2 we characterize the responses in terms of disciplinary emphasis of the department or division by which individuals are currently employed. Because of vagueness in the titles of nonacademic groups, a large percentage of the respondents appear on a line labelled "unspecified."

A particularly interesting product of the survey is the information as to where atomic and molecular scientists are located, organizationally, and in what numbers. It is of interest to see which are the more active university departments and, as well, how broad is the distribution of departments with one or two atomic and molecular scientists. Similarly, it is of interest to see where they are located in industrial, government, and other laboratories. This information is tabulated in detail in Appendix 2.

Table III-3 summarizes characterizations of individual effort in terms of theoretical or experimental emphasis.

TABLE III-2. Response by Current Research Discipline and Category of Current Employing Organization

	Academic	Cor-porate	Govern-ment	FFRDC	NFP	Total
Physics	539	149	96	135	40	959
Chemistry	367	43	16	53	20	499
Aeronomy	13	8	21	4	2	48
Astronomy	15	0	10	1	0	26
Electrical engineering	47	16	2	6	5	76
Engineering, other	48	42	4	14	3	111
Health	7	1	1	3	0	12
Mathematics	5	1	0	3	0	9
Plasma science	4	18	21	31	0	74
Discipline undetermined/ incomplete response	9	132	59	60	10	270
TOTAL	1054	410	230	310	80	2084

Each respondent was requested to briefly summarize his or her scientific specialization, and each response was assigned to a broad area of specialization. Since the spectrum of activities and specializations in atomic and molecular science is quite broad, these assignments were a matter of qualitative judgment in many cases. A

TABLE III-3. Theoretical and Experimental Specializations of Respondents by Category of Current Employing Organization

	Academic	Cor-porate	Govern-ment	FFRDC	NFP	Total
Primarily experimental, 70% effort	566	278	133	208	52	1037
Experimental/ theoretical, 30% each	97	36	20	16	8	177
Primarily theoretical, 70% effort	386	96	65	83	18	648
Unspecified	5	0	12	3	2	22
TOTAl	1054	410	230	310	80	2084

TABLE III-4. Responses by Major Division of Atomic and Molecular Research Specialization and Category of Current Employing Organization

	Academic		Corporate.		FFRDC		Government		NFP		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Structure and properties of atoms and molecules	198	19	33	8	28	9	27	12	9	11	295	14
Collisional interactions	266	25	59	14	62	20	32	14	23	29	442	21
Interactions with electro-magnetic radiation	268	25	87	21	77	25	69	30	21	26	522	25
Techniques and instrumentation	123	12	86	21	71	23	39	17	13	16	332	16
Interface with other areas of science and technology	180	17	140	34	68	22	60	26	12	15	460	22
None specified	19	2	5	1	4	1	3	1	2	3	33	2
TOTAL	1054		410		310		230		80		2084	

Percentages given are column percentages.

listing of about 30 categories was developed first. From this the subcommittee derived a simplified representation in terms of five categories. This is presented in Table III-4. The more comprehensive breakdown is given in Appendix 3. In developing these tables, individual respondents who indicated specializations falling into more than one category contributed equally to those several categories, with total weighting of unity.

For completeness we show the numbers of respondents to the general questionnaire who fall into the academic, corporate, and other research categories who obtained their highest degrees in the United States, and in other countries, in Table III-5.

Questionnaire 1 asked respondents to indicate how their professional effort is divided among several types of activities: research, teaching, committee work, pursuit of funding, etc. Figure 1 represents the results summarized for different types of employing institutions.

TABLE III-5. U.S. Versus Foreign Degree, by Type of Employing Institution

	Academic	Corporate	Government	FFRDC and NFP	Total
U.S. degree	934	378	212	365	1889
Foreign degree	120	32	18	25	195
TOTAL	1054	410	230	390	2084

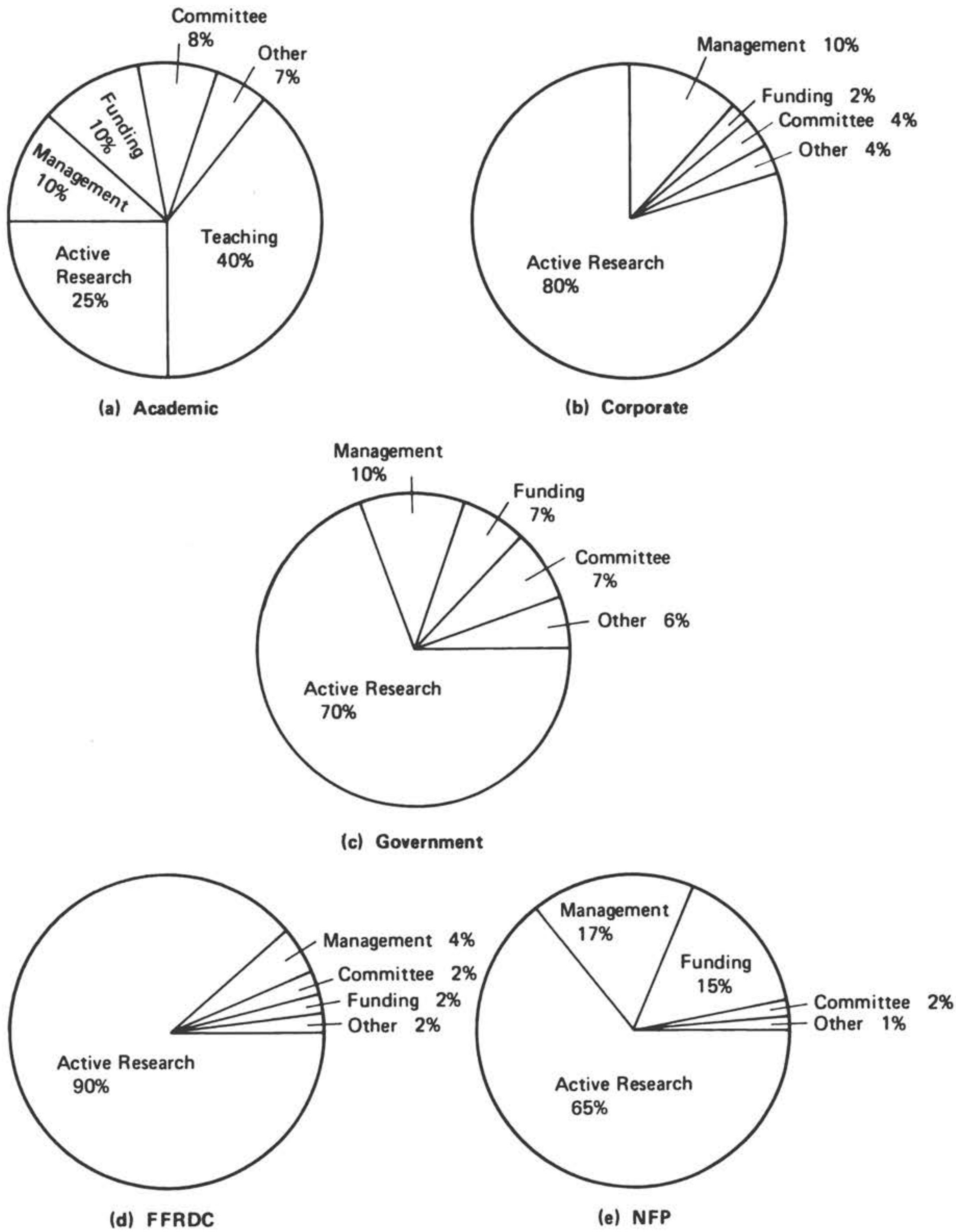

FIGURE 1. Division of time into various types of activity for respondents employed by (a) academic, (b) corporate, (c) government, (d) FFRDC, and (e) NFP institutions.

IV. QUALITATIVE ANALYSIS OF THE RESPONSES

The two principal specialized questionnaires, 2A and 2B, returned by 100 experimentalists and 81 theoreticians, respectively, addressed relatively subjective issues regarding the health of the field, such as its perceived progress, topical trends, and related factors, e.g., current funding practices. This section summarizes attitudes and concerns expressed by the respondents to these questionnaires.

An overall vitality and positive outlook was perceived in experimental atomic and molecular science. Technological advances over the past several decades have had an immense impact. Developments in vacuum technology, source and detection techniques, and electron and ion optics are examples, but above all, the revolutionary parallel developments of the laser and computerized data processing and computational techniques have resulted almost literally in a reinvention of the field. As a consequence, there has been a great improvement in the quality and quantity of the output, which has contributed greatly to the positive attitude of participants in the field.

Our statistics bear out the perception that the laser has revolutionized experimental research in atomic and molecular science. Seventy-four percent of the respondents claimed that the laser has caused a redefinition of research goals and that overall 50% of research time is devoted to laser-related research. In response to the question concerning instrumentation needs, the most common response involved lasers: the need for wider tunability range of single mode lasers; extension into the near and far UV; and better, cheaper, more versatile continuous wave and pulsed lasers.

Almost as universal was the need expressed for better and cheaper data processing systems and computer-controlled experiments; this is a clearly recognized need of essentially all workers in the field.

On the other hand, experimentalists expressed serious concern regarding the growing crisis in funding their needs. Increased experimental sophistication leads to an improved quality of research, but in turn results in a demand for ever more costly equipment. In no area is this problem more severe than in the quest to acquire research-grade lasers.

In general, it seems clear that the laboratories are not adequately instrumented if the existing opportunities in atomic and nuclear science are to be exploited.

Atomic and molecular theorists expressed their feelings about the state of their discipline in the answers to question 2B 5, "Do you perceive theoretical atomic and molecular research has unique problems relative to the rest of theoretical physics research? If so, describe these problems." A number of respondents noted that atomic and molecular theory is as much related to theoretical chemistry as to theoretical physics, emphasizing the strong tendency of atomic and molecular science to form cross-links with neighboring disciplines. Many respondents mentioned the challenge of the intellectual content of the field (e.g., the quantum mechanical and electrodynamic many-body problem), but there was a note of concern in many of the answers by respondents who felt that the fundamental nature of atomic and molecular theory and its promise to contribute significantly to basic physics are not sufficiently recognized.

It was generally felt that theoretical atomic and molecular research remains very much a "small science," while experimental research is rapidly becoming less so. Although small science has its appeal and distinct advantages to the individual researcher, it brings to theoreticians serious operational difficulties in the lack of adequate computational facilities and the benefits that come from large, coherent theory activities at single centers. There is a widespread belief that inadequate computer facilities are an especially serious problem in atomic and molecular science. Thus one respondent said, "The variables in theoretical atomic and molecular science are more numerous than in other fields of theoretical physics. As a result, research in theoretical atomic and molecular science makes heavy use of computers. The needed computational facilities are often not available to many members of the community." Also, "The available computer resources often mold and define the research that is feasible. Certainly all my research has been adapted to the limited resources available." The general problem of computational facilities for theoretical research is addressed in a recent NSF report, "Prospectus for Computational Physics" (see Section VII of this report).

A final major concern expressed by theorists in response to question 2B 5 relates to the nature of the scientific content of atomic and molecular theory. Some atomic and molecular theorists perceive a unique character to the field: it is in its relative tractability, as compared to other subdisciplines. As a consequence, accurate results generally are both expected and forthcoming. This puts pressure on the atomic and molecular theorists to perform reliable numerical calculations, leading to the problems discussed above concerning computational facilities. One respondent stated, "The accuracies demanded of calculation are much higher than would be dreamed of in solid-state theory. On the other hand, the molecule is a beast of low symmetry, which makes both calculations and their description especially complex."

Both experimentalists and theorists expressed serious concerns here summarized approximately in order of decreasing universality: (1) The perception that atomic and molecular science possesses a somewhat lower priority in the scheme of U.S. scientific policy-making than does the field in Western Europe and Japan. The field appears to be growing there, while, because of fiscal pressures, it is declining here. As a result, there is a virtually unanimous belief that the United States is losing its long-held leadership, particularly to West Germany and Japan, and to a lesser extent to France. (In contrast to surveys in the past, our survey did not detect any significant expression of concern over leadership passing to the USSR. Indeed, only a single respondent commented on USSR activities in the field.) (2) The general financial squeeze being felt in all fields is leading to hardships, not only with regard to equipment, instruments, and computational facilities, but in other respects, such as postdoctoral and graduate student support and travel to scientific meetings. (3) Smaller activities (e.g., at smaller educational institutions) are experiencing ever greater threats to their very existence. This problem is of considerably less importance at the more prestigious, larger institutions.

The remainder of this section summarizes the response to specific questions on 2A and 2B received from 100 experimentalists and 81 theoreticians, respectively.

Questions 2A/B1: "Is your current level of funding viable, marginally viable or nonviable?" The results are summarized in Table IV-1.

Question 2A6: "Do you view the current ratio of activity in theoretical as opposed to experimental research as too large, about right or too small?" Of the experimentalists who responded, 70% believe that the ratio is about right; 17% and 13% believe it is too large and too small, respectively.

Question 2A/B3: "In what area(s) is it most important to expand activity and why?" A common response was, stated in various ways, to let the community decide the directions of research for itself through its own choice of problems. A related response effectively condenses to the statement, "back the person, not the topic." Most respondents, however, did single out specific areas in response to this question. Of these, the most prevalent were: the influence of strong electromagnetic fields on atomic and molecular processes, including time-dependence, coherence, and multiphoton effects; laser spectroscopy, including lifetime measurements, superradiance, fluorescence; laser-related reactions, including laser-induced chemistry; plasmas and fusion-related areas, including reaction rates, energy transfer; various aspects of ion scattering, including ion-atom and ion-molecule

TABLE IV-1. The Perceived Viability of Current Funding

	Experimentalists	Theoreticians
Viable	36%	48%
Marginally viable	59%	44%
Not viable	5%	8%

scattering, electron-ion scattering; collisions with atoms and molecules; combustion studies and high temperature reactions; and studies of atoms and molecules in excited states.

Other areas that received positive comments include: astrophysics and related atomic and molecular research; energy transfer, including molecular vibronic excitation transfer; photoexcitation and ionization; the general problem of interaction of low photon fluxes with matter; studies of atoms and molecules in highly excited states (Rydberg systems); nucleation phenomena; areas of atomic and molecular research that are related to other disciplines, particularly nuclear physics; and chemical kinetics and the dynamics of chemical reactions. Among theorists, several areas stood out clearly, in addition to those noted above. These include: study of coulombic and atomic three-body collisions; many-body, e.g., high-Z systems, relativistic effects in many-body systems; and the need to exploit recent advances in mathematical techniques to address the standard atomic and molecular problems (resonance structure, scattering, energy levels, etc.). These advances include group-theoretical techniques, complex coordinates, quantum field theory, and propagation methods.

Questions 2A/B4: "In what area(s) of research is it most reasonable to decrease activity and why?" The responses were too scattered to possess statistical validity and, therefore, are not presented here. We only note one specific danger, mentioned by a number of respondents, concerning the possibility that strong emphasis on certain "hot" fields could mean a decline in interest and support in other areas that are equally important but less fashionable. Such a situation may now exist with regard to the laser: Its ubiquitousness is well deserved, but it may also be prematurely preempting other areas that would have matured in normal scientific fashion. An example could be (according to several respondents) the systematic continuation of the very fruitful area of determining intermolecular potentials from heavy particle collision studies in ground states.

Question 2A/B5: "Do you think the relative emphasis in the field as a whole on 'pure' as opposed to 'applied' research has increased, remained the same, or decreased in the last five years?" The results, summarized in Table IV-2, suggest that the field, as viewed by its practitioners, is becoming more applied.

TABLE IV-2. The Perceived Change in the Ratio of Pure to Applied Research in the Last Five Years

	Experimentalists	Theoreticians
Increased	5%	5%
Remained the same	34%	33%
Decreased	61%	62%

Questions 2A/B7, 8, 9: "How many times in the period 1977-1980 was a grant or contract of yours terminated without renewal? How long prior to the termination were you notified? Discuss the impact of the termination on your research program. What is an appropriate period for project funding without serious review or threat of termination?" We recognize the need for occasional termination of research funding and were primarily concerned with the manner in which terminations were handled. These questions, which are not applicable to scientists not directly supported by grants or contracts, primarily concern academic and not-for-profit researchers. Seventy experimentalists and 71 theoreticians who responded to Questionnaires 2A and 2B, respectively, fall into these categories. Of these, 23 experimentalists and 15 theoreticians lost at least one grant. Eight experimentalists and five theoreticians lost more than one grant (from 2 to 5). The amount of advance notice of termination ranged from two weeks (one such case) to eighteen months (also one case), with a rough average notice over all terminations of about seven months.

The effect on the research was quite varied. Typical comments were: "devastating effect; put us back two years"; "caused redirection of research, some disruption"; "forced a redirection of my entire research program, which was <u>partly</u> benefical"; "more time was spent looking for support; less staff; productivity decrease"; "forced to spend more time in developing new sources of support--proposal writing at the expense of doing research"; "it's part of the nature of the job"; "personnel were transferred to applied programs"; "required complete change of fields"; "not much of an effect--the people supply had dried up too"; "disastrous, had to terminate support for three graduate students and one postdoctoral fellow on short notice . . . greatly reduced level of operation; doing experiments because of what is on hand rather than what's logical and efficient"; "termination forced me to devote much time looking elsewhere for support. The need to be continually concerned with funding--writing proposals, reviewing proposals and worrying--is terribly destructive." There were many more comments along similar lines.

Questions 2A/B11: "What is an appropriate period for project funding without serious review or threat of termination?" We received the following distribution of responses:

Years	1	1-2	2	2-3	3	3-5	5	6
Number of Respondents	2	2	20	20	77	33	3	1

Questions 2A/B10: "Specify kinds of money you consider to be in particularly short supply (e.g., capital equipment, international travel)." Those including 3 or more responses were as follows:

Capital equipment	48
International travel	12
Student salaries	4
Postdoctoral salaries	3
General travel	6

These numbers are consistent with the qualitative picture that emerged from the comments of individual scientists discussed earlier in this section. It is clear that capital equipment heads the list of needs of experimentalists.

We received many other stimulating and pointed comments too lengthy for reproduction in this summary section. Some of these are reproduced in Appendix 4.

V. MANPOWER AND EMPLOYMENT OPPORTUNITIES

This section presents results specifically pertaining to manpower and employment opportunities obtained from Questionnaire 1 and the special employment questionnaires (2C and 2D), which were sent to a limited number of leaders of academic and nonacademic research groups of some size in order to obtain further insights regarding their structure, and clues regarding their evolution. Data were obtained from 41 academic groups (22 in chemistry, 16 in physics, and 3 in electrical engineering), and from 24 nonacademic groups (13 corporate and 11 government or federally funded laboratories).

Figures 2 through 5, based on the results of Questionnaire 1, represent the number of respondents in four organizational categories who received their highest degrees in a given year. These figures represent the scientific age distribution of people in the data base, excluding postdoctorals and graduate students. The data are smoothed by plotting the average of three years, including preceding and subsequent years, at each year.

The most significant feature of each of these figures is the drop in the numbers entering academic and government employment each year from 1970 to the present time. Corresponding declines appear in the corporate, federally funded, and not-for-profit laboratory data only from 1975 to the present. In this connection we note important limitations of the data for very recent years:

1. Some persons who obtained their highest degrees during recent years and are now postdoctorals or graduate students are not included in the data base. These people may later acquire a more permanent status in atomic and molecular science, in various types of employing organizations, and thereby retroactively modify the numbers from those shown in Figure 1, especially for the past two or three years; and
2. persons who entered the field relatively recently are somewhat less likely to have appeared on one or more of the mailing lists on which our survey is based.

To assess the impact of these factors the subcommittee referred to the returns from Questionnaires 2C and 2D, which included a request for a listing of members of their research groups, by nature of appointment, experimental versus theoretical emphasis, etc. These

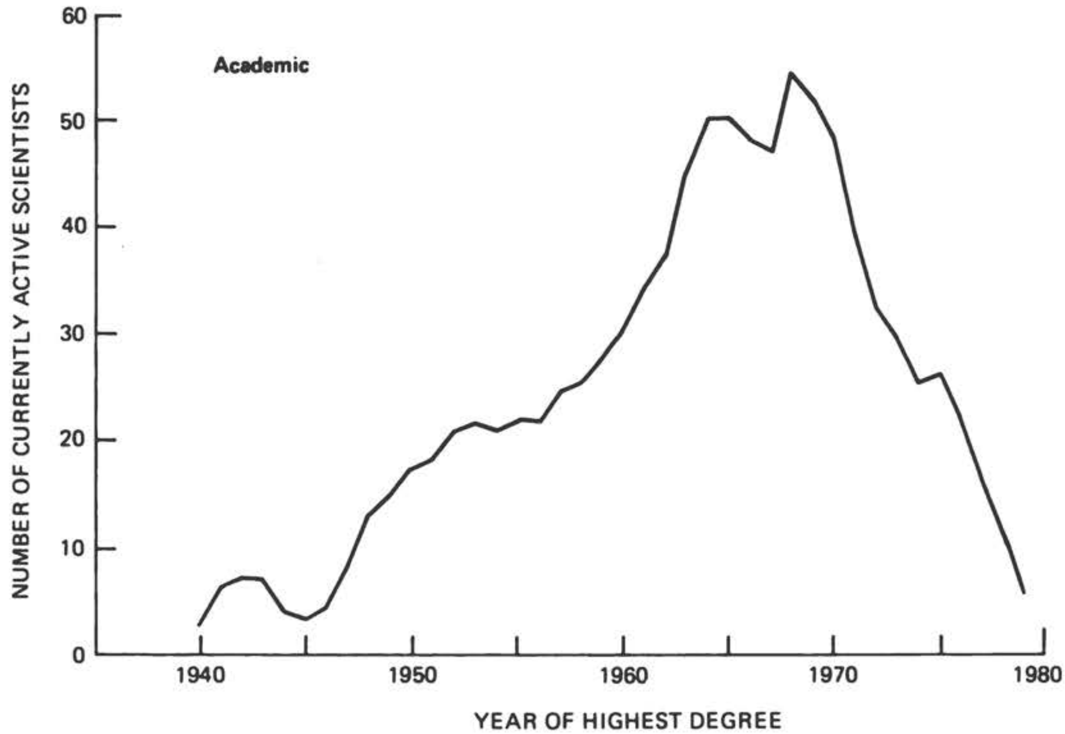

FIGURE 2. Number of respondents currently employed by an academic institution who received their highest degree in a given year.

FIGURE 3. Number of respondents currently employed by a corporate laboratory who received their highest degree in a given year.

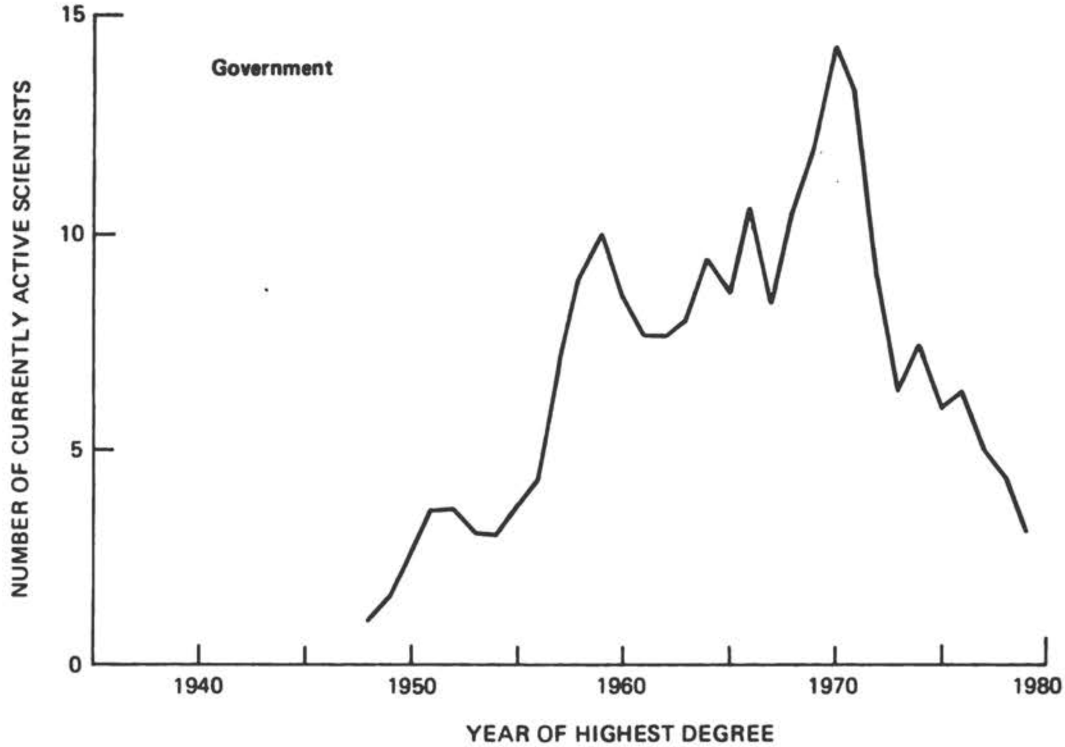

FIGURE 4. Number of respondents currently employed by a government laboratory who received their highest degree in a given year.

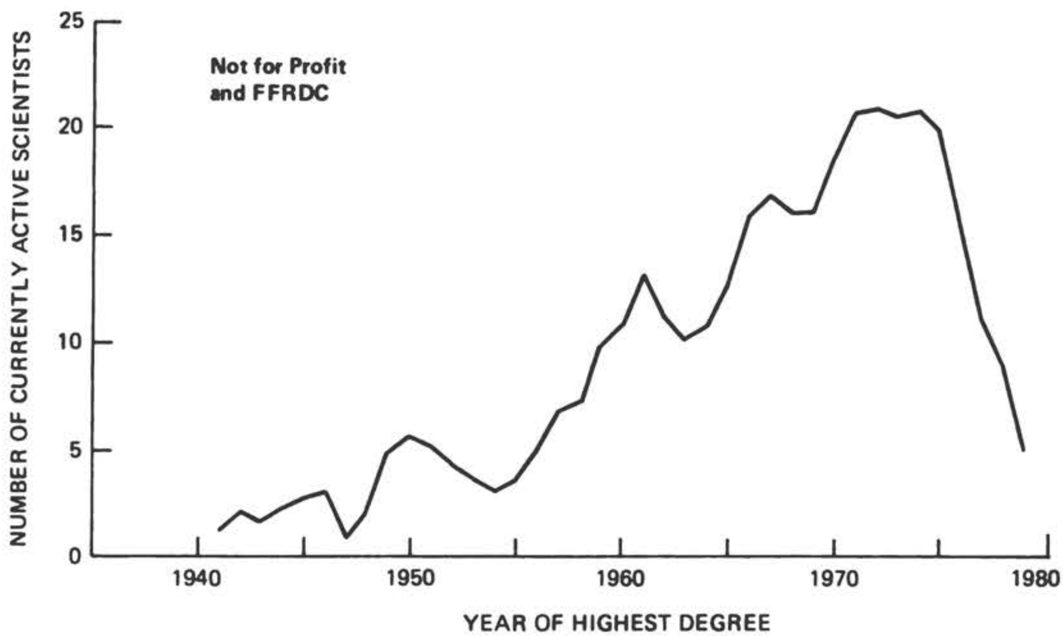

FIGURE 5. Number of respondents currently employed by an FFRDC or NFP laboratory who received their highest degree in a given year.

returns were compared with the individual returns from scientists at those same organizations. For academic research groups, and excluding the postdoctoral and graduate student categories, the correlation was high, indicating a rather complete response from the academic community with Questionnaire 1, and strongly suggesting that the main features of Figure 2 are significant, except for the last two or three years (one mean postdoctoral lifetime).

A different result was obtained from a study of the returns of Questionnaire 2D from nonacademic groups. Typically, only a few members of a given group returned a response to Questionnaire 1. The majority of members of these groups evidently are not or do not consider themselves involved in atomic and molecular science, or they do not participate in those atomic and molecular organizational or scientific communications activities from which our mailing list was compiled. From knowledge of specific cases, the subcommittee recognizes that many members of research groups reported in 2D are, in fact, not primarily involved in atomic and molecular science even though a considerable number in this category were trained in atomic and molecular academic laboratories.

The conclusions that a very severe reduction in the rate of infusion of "new blood" into academic and government laboratories occurred during the period 1970-1975 is quite clear. There is some indication that this trend may have leveled off, after 1975, at a relatively low level. With respect to comparisons with earlier years, it must be remembered that the data include only the "survivors" and do not give a measure of the attrition that occurred to reach this level.

Returns from Questionnaire 2C given some insight into the structure of academic research groups. These questionnaires were sent to 72 respondents to Questionnaire 1 who indicated they had supervisory responsibility for five or more persons. Some additional theoretical groups of smaller size were included since these groups are typically smaller than the experimental research groups. It was apparent from the data that more of the groups with five or more participants are found in chemistry departments than in physics departments. The random distribution of 2C led to responses from 22 groups in chemistry, 16 in physics, and 3 in electrical engineering. On the other hand, Tables III-1 and III-2 show that the physics orientation is stronger among the 2084 individual respondents who make up the data base.

The composition of the 41 academic research groups, which consists largely of postdoctoral and graduate students, is represented in Table V-1. Special attention should be directed to the number of academic trainees who have come from institutions in other countries. (Data on actual national origin were not requested.) The numbers in parentheses represent the subset of the number of persons in a given category who came to their present positions from a foreign institution. The reader is referred to Table III-5 for statistics describing United States versus foreign degrees for all respondents.

In comparison to the academically employed, the number of scientists in corporate, government, or not-for-profit groups responding to Questionnaire 2D who came to their present position from institutions located in foreign countries is quite negligible. The

TABLE V-1. Composition of 41 Academic Research Groups

	Tenure or Tenure Track	Other Perma-nent	Postdoc-toral or Temporary	Graduate Student	Under-graduate	Visitors
Experimentalists	26 (1)	1	21 (13)	88 (1)	9	2 (2)
Theorists	15	4	17 (5)	31 (5)	3	3 (3)
Experimentalists-theorists	6	0	1	3 (1)		2
TOTAL	47 (1)	5 (0)	39 (18)	122 (7)	12	7 (5)

Numbers in parentheses are the number of persons who came to their present positions from a foreign institution.

heavy dependence in the academic community on experimental post-doctorals of foreign origin may reflect a serious supply shortage and a disadvantage in the competition with higher paying corporate, government, and not-for-profit positions. It may also presage a new infusion of foreign trained scientists into the more permanent ongoing atomic and molecular science establishment. On the other hand, nonacademic research groups are showing some preference for hiring directly from the ranks of new Ph.D.'s from domestic universities.

Questionnaire 2D led to responses from 24 nonacademic groups. Virtually all members of the nonacademic groups were listed as permanent. The distribution of emphasis on experimental and theoretical specialization is represented in Table V-2.

Figure 6 shows the overall development pattern of these research groups. The infusion of personnel into government and FFRDC research groups has been modest, with some increased rate in the past five years primarily in the FFRDC groups. On the other hand, the figure suggests considerable new corporate research activity.

TABLE V-2. Experimental Versus Theoretical Specialization of Nonacademic Respondents

	Experi-mentalists	Experimentalists-Theorists	Theorists
Corporate (13 groups including 85 scientists)	60	11	14
Government and FFRDC (11 groups including 80 scientists)	32	3	25

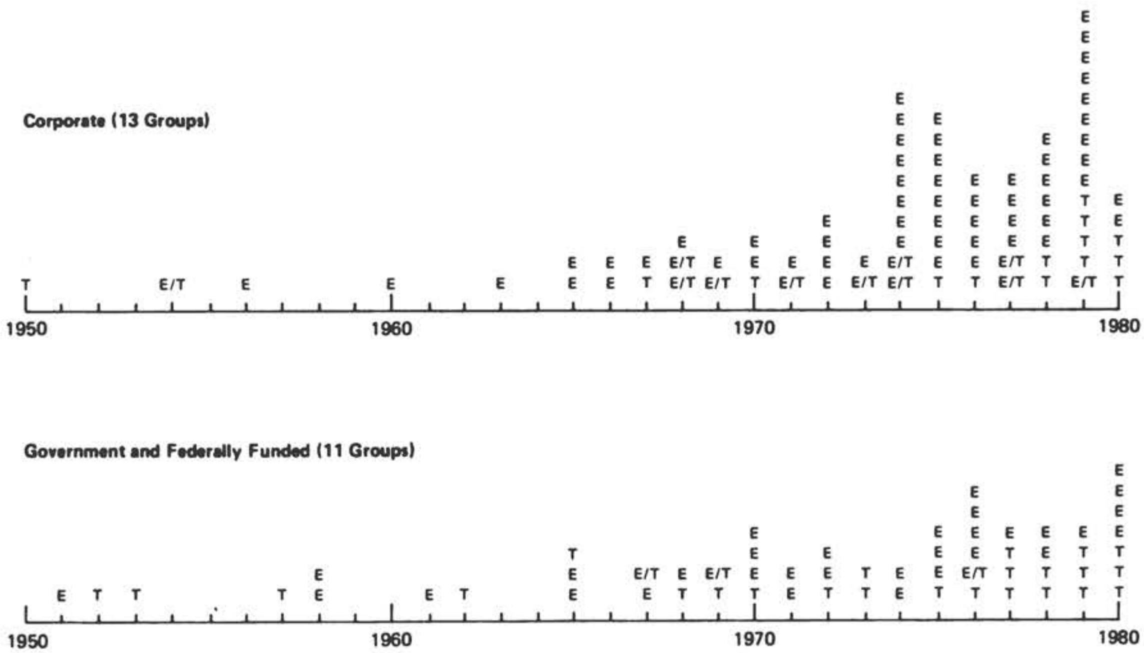

FIGURE 6. Year of hire of current permanent personnel into one of 13 corporate and 11 government and FFRDC groups. E is experimental, and T is theoretical.

There are notably few theoreticians in the corporate groups. Almost all of those who were hired into these groups in the last very few years were hired into two heavily theoretical research groups that carry out contract research for the U.S. government (four or five of the 13 corporate groups appear to be of this type). The heavy reliance of more traditional corporate atomic and molecular science research on scientists capable of a mix of theoretical and experimental work is evident.

An accelerated hiring of experimentalists in recent years is also evident. Again more than half the hiring of experimentalists into corporate groups in the past three to five years can be traced to rapid expansion of two groups, one from a large industrial organization and the other, a contract research laboratory.

Among government and FFRDC atomic and molecular groups, the inclusion of theoreticians is a longstanding practice. The limited data available, for eleven groups in this category, do not reveal any notable patterns in recent hiring.

Departures of permanent personnel are not shown in Figure 6, but data for these groups show that over the past three years departures from nonacademic groups was about two fifths of the number of hires during the same period. Moves out of government and federally funded laboratories were mostly into corporate research. Corporate researchers went to government, federally funded, or other corporate jobs, but few went into universities. About one in five moves reported was within the same organization.

Characterization of employment opportunities on the basis of responses from this limited number of groups is hazardous. One permanent experimental and two theoretical vacancies are cited in total by ten government and FFRDC groups, in addition to a few temporary vacancies. Eleven experimental and three theoretical vacancies are currently listed on returns from thirteen corporate research groups, several of which evidence optimism for the next three-year period. About a dozen current tenure-track experimental and four or five theoretical vacancies are reported in the forty-one responses from academic research groups. However, some of these positions are possibly open to competition from fields of physics or chemistry other than atomic and molecular science.

The special employment questionnaires also invited group leaders to comment on several specific issues. We summarize these responses.

The responses to the question 2C1, "What aspects of your students' training helped them find jobs?" were varied. Most indicated specific experience, usually in the field of their doctoral research. Computer expertise was specifically mentioned by 56% including both experimentalists and theoreticians; laser experience was mentioned by 25%; and electronics experience by 25%. Experience with high-vacuum techniques and laboratory experience in physical chemistry were also mentioned. General qualities were emphasized as frequently as the specific qualities: a broad-based scientific background, ability to plan and execute projects, a problem-solving ability. In complement, nonacademic employers were asked (question 2D1), "In staffing your atomic amd molecular research program, what qualities in training for a Ph.D. in atomic and molecular science do you find attractive?" A similar pattern emerged. Specifically desired qualities were computer experience (50%), laser and high-vacuum expertise (33% each), and electronics experience (25%). Again, general qualities were prominently mentioned: breadth of knowledge, ability to understand and diagnose experimental problems, and verbal skills.

Academics were asked whether there is a shortage of candidates to fill positions at all levels. Without exception, respondents agreed with this statement: "Good graduate students are hard to come by these days." Academics seem able to find enough satisfactory postdoctoral appointees, including the significant influx from foreign countries. For higher-level positions, competition with industrial salaries creates a problem in obtaining qualified people. Of course, this situation depends on the subfield. Inability to anticipate financial support also affects hiring.

In the following paragraphs we present some data that are specific to the <u>academic</u> atomic and molecular research community.

The number of permanent faculty of physics departments from which we received returns was 541. The number of academics in physics departments who specialize in atomic and molecular and chemical physics reported in the AIP book <u>Graduate Programs in Physics, Astronomy and Related Fields, 1980-81</u> was 742. This number was derived from listings in Table A, "Faculty, Enrollments, and Degrees Granted," for each university listed. On inspection of the AIP listings, it is concluded that the figure in the AIP report is somewhat high. In some cases, in

TABLE V-3. Number of Graduate Students and Postdoctorals by Department

Department or Type of Institution	Number of Graduate Students	Number of Postdoctorals or Temporaries
Academic		
Physics	841	246
Chemistry	904	366
Electrical engineering	165	16
Engineering, other	177	35
Plasmas	6	2
Aeronomy	34	18
Health	10	7
Math and computer science	8	4
Astronomy	21	9
TOTAL	2166	703
Nonacademic		
Corporate		136
Government		150
FFRDC		122
NFP		39
TOTAL	2166	1150

VI. SUMMARY OF REPORTED EXTERNAL SUPPORT FOR ATOMIC AND MOLECULAR SCIENCE

In Questionnaire 1, each principal investigator was requested to specify his or her sources and amounts of external funding, i.e., income from grants and contracts. A far more intensive investigation than could be mounted in the present study would have been required to obtain a definitive overall pattern of support of atomic and molecular science. The figures to be presented here, therefore, are approximations. In some cases these have been cross-checked by inquiring directly of the support agencies. However, there are unresolved problems, some attributable to the fact that the definition of atomic and molecular research remains somewhat arbitrary, particularly at the interfaces to other areas: chemistry, plasmas, solid state, astrophysics, atmospheric physics, and quantum optics.

The principal sources of external support for atomic and molecular science have been identified, with rough estimates of available funds. As previously noted, the question of internal support was not addressed.

In compiling these data the subcommittee faced the difficult problem of separating out support for atomic and molecular research from support for other related disciplines that, while listed by respondents, lie outside the field. It is characteristic of the field that many workers devote part of their research time to other disciplines. Where possible, judgments of the respondents as to relevance were honored.

With regard to identification of funding organizations, respondents were not necessarily uniform in their manner of reporting. Some listed only parent organization, e.g., U.S. Army or NIH; others specified a subdivision, e.g., Army Night Vision Laboratory or National Cancer Institute. In general, for simplicity and consistency it was decided to categorize support by major unit only, e.g., Army, DOE. As an addendum, a list of all groups that respondents listed, but without dollar amounts (Appendix 4), is included. For convenience, support sources have been divided into two groups:

Group 1. Private and industrial, and government agencies with relatively modest investment in atomic and molecular science. These include the smaller but highly effective granting institutions, such as the Research Corporation, which are among the best sources for start-up funds. These agencies typically provide smaller grants. Generally they are not intended to supply support continuing beyond a few years, although there are exceptions. But they also carry with them relatively few conditions, reporting requirements, and other formalities of "grantsmanship." Because of the special conditions, total dollar figures are reported here, rather than normalizing per annum as is done with the major agencies. Also included are those government departments and institutes with primary missions elsewhere that do, however, support some atomic and molecular research efforts appropriate to their missions (e.g., NIH, EPA, FAA).

Group 2. Major government granting agencies. These are NSF, DOE, NASA, and DOD, and, listed separately, Army, Air Force, and Navy.

The DOD support includes only agencies that do not identify specifically with one of the armed services (e.g., DARPA). The subcommittee identified individual respondents with six categories of disciplinary affiliation, namely, physics, chemistry, aeronomy, astrophysics, plasmas (including gaseous electronics and transport phenomena in weakly ionized gases), and engineering (including quantum and nonlinear optics). This identification, made partly by using the response to Questionnaire 1, was often judgmental and sometimes somewhat arbitrary.

The data for Group 1, private and industrial, and governmental agencies with modest investments in atomic and molecular science, are summarized in Table VI-1, which presents funding support derived from individual responses to the survey. Here all categories except physics and chemistry are combined as "Other." The total dollar support is given in units of thousands of dollars, and the number of groups, in parentheses. The total support in physics is \$2700K (68), in chemistry \$3600K (108), and other \$1600K (21). The grand total is \$7800K (195).

The funding data for Group 2, major government granting agencies, are presented in Table VI-2a-g. For each of the major funding agencies the data are divided by discipline and by the type of employing institution of the individual receiving the grant. These tables list the total annual support in thousands of dollars for each category derived from individual responses to the survey. Large uncertainties must be attached to the absolute numbers. The most obvious source of uncertainty is from duplication of support reported by investigators sharing the same grant or contract. This problem is most serious for larger grants. In many cases these duplications are easily identified, and the numbers presented in the tables are corrected accordingly. Duplication in relatively smaller grants ($\lesssim$\$200K/yr) is harder to detect, and no corrections have been entered. It is probable that some support was not reported due to individual failures to respond to the survey. Data from nonacademic sectors are probably systematically low, on the basis of a lower rate of response.

Another sizeable uncertainty arises from the obvious fact that some of the larger grants and contracts are used only in part for atomic and molecular science. Some are essentially development projects, and some support work in other related disciplines. For example, projects categorized as "physics" include some very applied programs, such as laser development and diagnostic spectroscopy of plasmas.

In two cases numbers have been compared with summary data provided by the agencies for funding of academic research in atomic and molecular science. In one case the data given here are approximately 10% higher, and in the other (NSF) the data listed here are 150% higher.

Some of the numbers listed under the headings "Government" and "FFRDC/NFP" are in fact allocations by an agency or department to its own laboratories (Argonne National Laboratories, Air Force Geophysics Laboratory, etc.). Support listed for the corporate research sector includes only government contract support and does not reflect in-house funding.

TABLE VI-1. Summary of Support of Atomic and Molecular Science, Not Including NSF, DoE, NASA, and DoD, thousands of dollars

	Physics	Chemistry	Other
Research Corporation	220 (20)	150 (14)	10 (1)
Petroleum Research Fund	60 (3)	770 (39)	30 (1)
Sloan Foundation	20 (1)	40 (3)	20 (1)
Welch Foundation	630 (14)	850 (14)	
Battelle Institution	40 (3)		
Jet Propulsion Lab	20 (1)		
Exxon		200 (2)	
Smithsonian	130 (2)		
Sandia Corporation	130 (1)		
Miscellaneous private	220 (5)	50 (2)	120 (3)
Miscellaneous industrial	360 (5)	240 (4)	
National Institutes of Health	790 (7)	840 (20)	670 (7)
Environmental Protection Agency		(1)	500 (3)
Federal Aviation Administration		10 (5)	50 (1)
Department of the Interior	25 (1)	30 (1)	
Department of Commerce, National Bureau of Standards[a]	100 (5)		100 (1)
Department of Transportation		50 (1)	70 (1)
California Air Resources Board		100 (1)	
TOTALS	2700 (68)	3500 (108)	1600 (19)
GRAND TOTAL	7800 (195)		

[a]Precision measurements grants.

All government grants are in thousands of dollars per year. For private foundations, total funding is given in thousands of dollars. Number of groups is in parentheses.

While the numbers are only approximations, they provide a perspective on the distribution of effort in atomic and molecular science over disciplines and organizational types, and they provide an indication of the scale of the research and development effort in which atomic and molecular scientists are directly involved.

TABLE VI-2a. Funding Statistics: NSF, thousands of dollars

	Type of Employing Institution				
Field	Academic	Corporate	Government	FFRDC/NFP	Total
Physics	12500	200	60	600	13400
Chemistry	8400	400	60	400	9300
Plasmas	700	100	0	0	800
Astrophysics	400	0	0	0	400
Aeronomy	700	0	0	200	900
Engineering	1200	30	0	40	1300
TOTAL	24000	700	120	1200	26000

TABLE VI-2b. Funding Statistics: DoE, thousands of dollars

	Type of Employing Institution				
Field	Academic	Corporate	Government	FFRDC/NFP	Total
Physics	7000	2300	1200	17500	28000
Chemistry	8500	200	100	5000	14000
Plasmas	400	7000	850	6200	14500
Astrophysics	0	0	0	0	0
Aeronomy	50	0	0	1000	1000
Engineering	1100	600	150	0	1800
TOTAL	17000	10000	2300	30000	59300

TABLE VI-2c. Funding Statistics: NASA, thousands of dollars

	Type of Employing Institution				
Field	Academic	Corporate	Government	FFRDC/NFP	Total
Physics	1900	600	1100	1200	4800
Chemistry	700	200	100	40	1000
Plasmas	300	0	0	0	300
Astrophysics	0	0	0	0	0
Aeronomy	700	200	500	600	2000
Engineering	300	100	0	0	400
TOTAL	3900	1100	1700	1800	8500

TABLE VI-2d. Funding Statistics: DoD, DARPA, DNA, thousands of dollars

	Type of Employing Institution				
Field	Academic	Corporate	Government	FFRDC/NFP	Total
Physics	450	1800	1000	700	4000
Chemistry	100	1900	30	0	2000
Plasmas	0	250	0	0	250
Astrophysics	0	0	0	0	0
Aeronomy	0	60	100	0	160
Engineering	100	0	0	0	100
TOTAL	700	4000	1100	700	6500

TABLE VI-2e. Funding Statistics: Army, thousands of dollars

	Type of Employing Institution				
Field	Academic	Corporate	Government	FFRDC/NFP	Total
Physics	1000	900	100	400	2400
Chemistry	600	100	0	60	800
Plasmas	200	500	40	0	700
Astrophysics	0	0	0	0	0
Aeronomy	0	200	0	500	700
Engineering	200	100	40	0	340
TOTAL	2000	1800	200	1000	5000

TABLE VI-2f. Funding Statistics: Air Force, thousands of dollars

Field	Type of Employing Institution				
	Academic	Corporate	Government	FFRDC/NFP	Total
Physics	1800	1600	10000	800	14000
Chemistry	1000	3000	200	600	4800
Plasmas	800	200	0	1000	2000
Astrophysics	0	0	0	0	0
Aeronomy	50	0	5100	150	5300
Engineering	600	230	0	0	800
TOTAL	4200	5000	15000	2500	27000

TABLE VI-2g. Funding Statistics: Navy, thousands of dollars

Field	Type of Employing Institution				
	Academic	Corporate	Government	FFRDC/NFP	Total
Physics	1800	2200	1700	500	6200
Chemistry	800	150	20	140	1100
Plasmas	500	280	0	0	800
Astrophysics	0	0	0	0	0
Aeronomy	100	0	100	0	200
Engineering	250	0	100	0	350
TOTAL	3450	2600	1900	600	8600

VII. RESULTS OF OTHER SECONDARY QUESTIONNAIRES

Questionnaire 2E. Computer Usage in Atomic and Molecular Research

The responses of 46 computer users to Questionnaire 2E are briefly summarized here. The NSF has recently completed a study of the use of computers in theoretical physics, prepared by a subcommittee of the Advisory Committee for the Physics Division. They considered computational needs of all physics subdisciplines, including atomic and molecular physics. Their summary of present computer usage in atomic and molecular physics is presented at the end of the section.

Our subcommittee defined three common types of computing facilities and asked respondents to specify which ones they use:

a. A small computer purchased or leased by a particular individual or group and located in a laboratory or office.

b. A large computer, owned or leased by a university, government, or industrial laboratory, and shared by many research groups, usually located at the same institution as the computer or at a nearby location.

c. Centralized computing facilities accessed by terminals located at many remote locations. (Examples are computers at LASL and Lawrence Berkeley Labs accessed via the ARPANET or commercial phone lines.)

The numbers of respondents in each of these categories or combinations of categories are as follows:

a only	7
a + b	13
b only	21
b + c	1
c only	4

No unusual aspects of computer usage were found. Thus small computers (a) were primarily used for control of experiments and experimental data acquisition, "reduction," and processing. Large computers (b and c) were used primarily for theoretical calculations and computations (modeling and analysis).

Twenty small computer systems in current use were mentioned. Twelve are being operated in universities, six in corporate laboratories, one each in government and FFRDC laboratories. These were all different, ranging in size from 8K to 168K and in cost from $700 to $134,000. The average cost of those owned by universities is $21,000; of those owned by industry $40,000. Eighty percent of these computers were purchased within the period 1977-1980. Eighty percent of owners expect to replace them within the next five years. With three exceptions these computers are dedicated to atomic and molecular research, but are frequently shared with more than one project.

Thirty-four people responded who use local time-share computing facilities (23 academic, 6 corporate, 5 government). Charges to the user ranged from $0 to $400/hour. Five respondents used centralized computing facilities. These were somewhat more expensive than local time-share arrangements. Specific locations of facilities mentioned were NCAR, Boulder, Colorado; LBL, Berkeley, California; LASL, Los Alamos, New Mexico; and ANL, Argonne, Illinois. Eighty percent of the respondents felt that the increased availability of computers has significantly altered their research for one of the following reasons: ability to do more accurate and rapid data acquisition (33%); capability of more detailed (more realistic) modeling (24%); capacity to do more complex theoretical problems (10%).

When asked whether their present pattern of computer usage was adequate to their needs, 25% said it was not. Of these, half indicated financial or financial plus administrative restrictions. Several also mentioned the absence of expertise or unavailability of adequate systems as a limitation in obtaining satisfactory computer usage.

The following statement is taken from a study of computer usage prepared by a subcommittee of the Advisory Committee for the NSF Physics Division.

> Atomic and molecular science today is characterized by rapid advances in experimental technique, especially the ability to prepare and control a wide variety of atomic and molecular states. Highly ionized species, atoms in strong external fields, states with many electrons excited, states with dimensions approximating the macroscopic, and high angular momentum states are but a few examples. The properties of such states and their interactions play a central role in atomic physics research.
>
> The availability of powerful computers has enabled theorists to make significant contributions to the rapid growth of atomic and molecular physics during the past fifteen years. Old methods have been applied to more complex problems, and new methods have been developed for the study of many of the processes that are now amenable to experimental study or are of interest to applied physicists. In the determination of electronic structure, calculations of wave functions for atoms and small molecules have progressed well beyond the Hartree-Fock level. However, present computing power and theoretical techniques are insufficient for accurate multi-configuration calculations

for heavy atoms in which relativistic effects are important. Such calculations will be required in the study of heavy-ion fusion and are needed, for example, for the analysis of the experiments searching for parity-violating atomic transitions. Further development of radiation physics and laser optics will require broader and more detailed studies of photon-atom interactions, often with highly ionized or perturbed atoms. Recent investigations of bremsstrahlung, Rayleigh scattering, Compton scattering and the photo-effect have revealed interesting new phenomena that have been explored by only a few groups with extraordinary access to fast computers. At lower energies better calculations on photoionization will be necessary to interpret the wealth of new data generated with synchrotron light (for ground-state atoms or molecules) and with infra-red or visible lasers (for highly excited states). With respect to larger systems, self-consistent-field calculations can be carried out using the local density or local spin-density approximations on polyatomic molecules, including polymers and weakly-bound clusters, and for molecules adsorbed on surfaces. Calculations by better methods will facilitate the assessment of the accuracy of these approaches, and further applications of these methods should encourage greater collaboration among atomic physicists, quantum chemists, solid-state physicists and biochemists.

In the study of atomic collisons, theory is now capable of verifying and augmenting experimental measurements on many processes in electron-atom collisions. There have been some notable successes in the theory of electron-molecule and ion-atom collisions at both high and low energies. Tremendous problems remain, particularly at intermediate energies and for collisions involving molecules in which electronic or vibrational excitation is important. Useful calculations on rearrangement collisions, energy transfer, excited-state reactions and break-up processes will require new methods and increased computing power. The successful methods should be extended to treat collisions with atoms or molecules on surfaces. Many of the new diagnostic techniques for studying plasmas and solid surfaces involve atomic collisions, and more detailed calculations of the energy, angular distribution and polarization of scattered particles will be needed if these techniques are to be fully utilized. Studies of electron-atom and atom-atom collisions in the presence of a laser field give information not otherwise obtainable. The calculations are necessarily difficult, however, and require extensive computational effort.

Monte Carlo techniques have been introduced into the study of the electronic structure and interactions of atoms and molecules, within quantum, semi-classical and purely classical theories. Simulations are also being used to relate the macroscopic behavior of ionized gases to the properties of the individual atoms and molecules. These simulations have led to significant improvements in transport theory and to a better understanding of swarm measurements of the reactions of atomic ions. However, further studies of energy exchange between molecular ions and neutral ions and molecules are needed. Better-designed simulations would be valuable in the exploration of the many body effects that occur in dense gases, about which very little is currently understood. For example, computer simulations of three-body recombination should help to clarify many of the mysteries concerning combustion at atmospheric pressure. Sir David Bates has already used many hours on the super-computer at Daresbury in England on a preliminary analysis of this problem, but there are U.S. physicists who think they could make forceful advances if given the computer resources.

Questionnaire 2F. Communications

The list of meetings attended by the 36 people who responded to Questionnaire 2F is broad and diffuse, a reflection of the wide range of subjects spanned by atomic and molecular science. Although most of the meetings attended were domestic, 14 people attended foreign meetings.

No clear preference either for large general meetings, or small topical meetings was apparent from the list attended. A preference for poster sessions at large meetings was mentioned by a number of respondents in their general comments. Eighty percent of the respondents felt that their subfield was adequately covered at U.S. meetings.

People were asked to rate time, money, institutional and personal commitments, and subject matter as limitations on professional travel. Ninety-two percent rated money as limiting; seventy-five percent, time; and sixty percent, institutional and personal commitments.

The following statistics emerged concerning sources of professional travel expenses: 22%, full support by employing institution; 22%, full support by outside contract; 25%, support shared by both employer and outside contract; 25%, support by employer supplemented by 10-50% personal funds; 6%, travel funds supplied by conference hosts.

Only 13 respondents commented on needs for critical reviews. Four of these felt their specialty area is adequately covered; nine felt more reviews are needed; some emphasized that many existing "reviews" are inadequate in that they give only cursory, incomplete coverage of a defined subject area. Similarly, only 19 respondents commented on needs for data compilations. Four felt their subject area is adequately covered; fifteen felt that more compilations or updates of existing compilations are needed. Subjects suggested include structural molecular data, electronic states of molecules, molecular spectroscopy update, bond dissociation energies, fluorescence and Auger yields and cross sections, charge transfer cross sections, and ion-molecule reaction rate constants.

Respondents pointed out that on-line bibliographic and data searches are becoming available and desirable, and that exchange of data on magnetic tapes or microfilm is a desirable communication tool. It was noted that a bulletin or list of existing atomic data bibliographies and compilations is badly needed to inform the community of the existing material of which individuals are often unaware.

VIII. COMMENTARY

The purpose of this study was to develop a broad, essentially statistical characterization of the field of atomic and molecular science. To this end the subcommittee carried out the first comprehensive survey of the field. The results, tabulated in this report, provide perspectives that have not been available from any other source. The breadth and scale of funding reported by respondents was not anticipated, even by professionals in the major funding agencies. As a case in point, respondents to the survey report approximately $26M received from NSF for the support of atomic and molecular science. Internal NSF studies lead to identification of about $10M going into direct support of basic atomic and molecular science, strictly defined, from all divisions of the Science Foundation. The difference lies in different perceptions of what constitutes atomic and molecular science, in the inclusion of large grants in applied fields from which only a fraction may be in direct support of atomic and molecular science, and in duplication in the reporting.

For other major agencies--all mission oriented--the problem of definition is at least as important. The results of the survey then serve to emphasize the broad applicability of the field, but in this and other respects the survey does not give a quantitative measure of the health of support for exploratory or innovative basic research. The problem of definition reduces the matter to one of qualitative judgment. A general perception is that the relative emphasis on applications is increasing and that opportunities for work directed toward fundamental research are diminishing or at least not keeping up with increasing costs.

Another category of statistics directly relating to the health of the field is that encompassing the numbers of graduate students and postdoctorals. Ideally, these would include the relationship of supply to demand, and the rate of production of degree students as compared to previous years. The information of this type that can be gained from a single survey addressed to individual scientists is somewhat limited, as has been noted in Section V. We have obtained estimated numbers, given in Table V-3, for graduate students in training, and for the numbers of scientists still in postdoctoral or temporary positions.

A comparison of current data for physics departments with that obtained in a 1968 study (conducted by the Committee on Atomic and Molecular Physics of the NRC, an antecedent of the present committee) suggests that the data are not much different now from what they were 13 years ago. The earlier study was not based on a survey addressed to individual scientists but on data obtained from 53 selected departments that conducted substantial programs in atomic and molecular physics. Responses covered the activities of 302 investigators, compared with the 498 respondents to the present survey from physics departments of a much larger number of academic institutions (see Appendix 3). The graduate student to staff ratio was given as 2.6 in 1968 and is estimated to be 1.7 in 1981, taken over the larger number of institutions, including many that are relatively less active in atomic and molecular physics. The postdoctoral to graduate student ratio taken over 53 departments was about 0.23 in 1968 and is estimated to be 0.29 in 1981, over a larger number of physics departments.

No information is available regarding trends in corresponding data for chemistry and other departments.

No direct information is available on the relationship of supply to demand. Questionnaires 2C and 2D revealed that there are modest numbers of vacancies, present or anticipated, in the 41 academic and 24 nonacademic research groups polled. Comments by respondents put no emphasis on problems of placing their students. Also, it is inferred from the fact that academic scientists are filling postdoctoral positions with candidates from foreign institutions that the competition for new Ph.D.'s by industrial and other types of organizations that can pay attractive salaries may be cutting into the number of domestically produced Ph.D.'s willing to consider undertaking a postdoctoral appointment. There is some suggestion in the hiring pattern of industrial research groups that new Ph.D.'s are often preferred over those with postdoctoral experience.

Respondents frequently expressed concern over the impact of the laser on various important subfields of atomic and molecular physics. Our questionnaires anticipated this concern, and the results show that a large fraction of the scientists in the field have become involved with lasers in one way or another. In light of this concern, it is interesting to consider Table III-4 and the expanded version in Appendix 3, which characterize the distribution of specializations within atomic and molecular science. We do not attempt to identify trends, because earlier data are unavailable. The general area of specialization called "Interactions with Electromagnetic Radiation" may have been very much smaller 10 years ago. Still, there remains a comparable level of activities that fall within the category "Collisional Interactions." The inference is that what has changed is the way research is carried out, at least in part. Atomic and molecular scientists have not been drawn out of their field into optics on any very large scale, but have welcomed the laser as an invaluable tool for pursuing research more effectively and for answering previously unanswerable questions. No doubt there has been some abandoning of important and productive data generation projects as scientists have turned to exciting new possibilities opened up by lasers.

The impression created by a study of the responses to this survey is that the field is generally healthy and that there is a high level of excitement, enthusiasm, and satisfaction, particularly among atomic and molecular experimentalists. It is in the nature of the survey technique that responses tend to represent the attitudes and situations of the scientists currently active in the field. Few responses were obtained from those who had changed to such fields as engineering, teaching in nonresearch environments, administration, or sales. No measure of the scale of that type of movement or of contributions that products of the field have made in such other fields was obtained. No measure of the loss to the productivity of atomic and molecular science research related to such movement was obtained. Responses were received from a number of scientists who have lost research support and who have been able to keep their programs going by changing sponsors. Virtually no responses were received from those who, remaining unfunded, had to drop out of the field. A different type of study would be required to assess impacts of this sort.

The principal products of the survey then reside in the tables and figures of this report, although the interested reader will find fascinating details in the appendixes.

Equally useful is the "Directory of Workers in Atomic and Molecular Science in the United States," prepared from the responses to this survey and distributed separately by the Commission on Physical Sciences, Mathematics, and Resources.

The authors thank the scientists, too numerous to list, who advised the subcommittee on the structure and accomplishment of the survey and all those who, through their response to the questionnaires, contributed to its completion. Thanks are expressed also to Jack Mann, whose diligence in the task of sorting and compiling data contributed immensely to this effort, and to Patti Krog, Pauline Maloni, and Johnnie Foy, who patiently and skillfully typed the drafts and final manuscript.

Appendix 1

Copies of the Questionnaires Used in the Survey

COMMITTEE ON ATOMIC AND MOLECULAR SCIENCE
NATIONAL RESEARCH COUNCIL

QUESTIONNAIRE

Name ____

Department* ______________________________________

Institution ______________________________________

Address ____

____

Phone Number(s) including area code ______________

Year, Degree, Department, and Institution of highest degree ______________

____

If your research activities do not include A&M science as described in the cover letter, check this box. Do not answer the remaining questions, but please return the questionnaire. ☐

*If you are unemployed, check this box and answer all applicable questions. ☐

1. Check the category that describes your institution.
   - ______ Academic
   - ______ Not-for-profit research laboratory (e.g., SRI International)
   - ______ Federally funded research and development center (e.g., Argonne Nat'l Lab)
   - ______ Government (e.g., NBS)
   - ______ Industrial

2. Check the category that describes your position.
   - ______ Permanent faculty (tenure or tenure track)
   - ______ Permanent (other than faculty)
   - ______ Postdoc or temporary
   - ______ Graduate student; anticipated date of Ph.D. ______________

3. Briefly characterize your current research in A&M science.

____

____

____

4. State the percentage of your current A&M research which is:

   ______% Experimental ______% Theoretical

5. We recognize that the reasons scientists want to do research may differ from the reasons agencies support it. State the percentage of your A&M research, as viewed by your supporting agency or institution, intended to produce information for use in program development (such as isotope separation, CTR, and laser development).

_________%

State the percentage of your current A&M research, as viewed by your supporting agency or institution, intended to produce information for specific applications to other branches of physical sciences. _________%

6. Give scientific fields or subfields other than A&M science in which you are currently active or have had extensive experience in the past (specify when).

____

____

____

7. Give the approximate percentages of your total working time you devote to each of these categories.

_____% Active research

_____% Research management/supervision

_____% Pursuit of funding

_____% Teaching

_____% Committee service/administration

_____% Other, specify what ___________

____

8. If you are engaged in research management/supervision, specify the number of people in each of these categories for whom you are immediately responsible (hiring, evaluation, etc.).

______ Permanent or visiting professionals

______ Postdoc/temporary

______ Graduate students

______ Support personnel

9. More detailed aspects of A&M science will be explored through separately distributed questionnaires on goals, manpower, computer usage, communications and user facilities. Would you be willing to respond to one or two of these? ___________(yes or no)

10. In pursuing your A&M research, do you use an experimental facility not built and operated primarily for use in atomic science (such as a tokomak, accelerator or synchrotron)? ___________ (yes or no)

11. Do you use any accelerator ($\gtrsim$0.5 MeV) for your research? _______________(yes or no)

For the completeness of this survey, please give names and addresses of American A&M scientists who may have been missed in our mailing (for example, those on leave or abroad or working in departments such as chemistry or biology). Also use the space at the end of the questionnaire to give any comments you may have concerning this survey. Thank you for your help.

(continued, over)

Support Through Grants and Contracts

Questions 12 through 16 are to be answered by the principal investigators or the equivalent. Please duplicate this section and fill it out for each grant or contract for which you are a principal investigator.

12. Give the name of the agency or foundation providing your grant or contract.

____

____

13. Give its total dollar amount. $________

14. Give the percentages it specifies for theory and experiment.

    _____% Theory   _____% Experiment

15. Give the time period covered by the proposal. ________________________

16. Specify the number of scientists supported by the grant or contract in the following categories:

	Number of people receiving salary support	Equivalent number of full-time positions (M.Y.)
Permanent (faculty or tenure track)	______	______
Permanent (other than faculty)	______	______
Postdoc or temporary	______	______
Graduate students	______	______

please return to:

Jean W. Gallagher
JILA
University of Colorado
Boulder, CO 80309

COMMITTEE ON ATOMIC AND MOLECULAR SCIENCE
NATIONAL RESEARCH COUNCIL

QUESTIONNAIRE ON

EXPERIMENTAL GOALS AND FUNDING

1. Do you feel your current level of funding provides for a research program which is (check one):

    ________ Viable

    ________ Marginally viable

    ________ Not viable

2. Do you feel your area is seriously underfunded in comparison with other areas of experimental A&M research?

    ________ (yes or no)

3. In your opinion, in what area(s) of experimental A&M research is it most important to expand activity in the next five years and why?

____

____

____

____

____

4. In what area(s) of experimental A&M research is it most reasonable to decrease activity and why?

____

____

____

____

____

5. How do you think the relative emphasis in the field as a whole on "pure" as opposed to "applied" A&M science has changed in the last five years? (check one)

    ________ Increased

    ________ Remained the same

    ________ Decreased

6. How do you view the current ratio of activity in theoretical as opposed to experimental research in A&M science? (check one)

    ________ Too large

    ________ About right

    ________ Too small

(over)

7. How many times in the period 1977-1980 was a grant or contract of yours terminated without renewal?

____

8. How long prior to the termination were you notified? ______________________

9. Discuss the impact of the termination on your research program.

____

____

____

____

____

10. Specify kinds of money you consider to be in particularly short supply (e.g., capital equipment, international travel).

____

____

____

11. What is an appropriate period for project funding without serious review or threat of termination?

____

12. If you have any further remarks or opinions concerning the current situation of the totality of A&M research (experimental or theoretical) both in the U.S. and internationally, please express them.

____

____

____

____

____

13. What percentage of your research is laser related? __________%

14. Has the availability of lasers caused you to redefine your research goals? __________ yes or no

If yes, in what way and why?____

____

15. What specific new developments in lasers, computers, or other instrumentation do you expect to have the greatest impact on A&M science and why?

____

____

____

COMMITTEE ON ATOMIC AND MOLECULAR SCIENCE
NATIONAL RESEARCH COUNCIL

QUESTIONNAIRE ON

THEORETICAL GOALS AND FUNDING

1. Do you feel your current level of funding provides for a research program which is (check one):

   __________ Viable

   __________ Marginally viable

   __________ Not viable

2. How do you think the relative emphasis in the field as a whole on "pure" as opposed to "applied" A&M science has changed in the last five years? (check one)

   __________ Increased

   __________ Remained the same

   __________ Decreased

3. In your opinion, in what area(s) of theoretical A&M research is it most important to expand activity in the next five years and why?

   ____

   ____

   ____

   ____

   ____

4. In what area(s) of theoretical A&M research is it most reasonable to decrease activity and why?

   ____

   ____

   ____

   ____

   ____

5. Do you perceive that theoretical A&M research has unique problems relative to the rest of theoretical physics research? If so, describe these problems.

   ____

   ____

   ____ (over)

6. Do you perceive that theoretical A&M research has unique problems relative to experimental A&M research? If so, describe these problems.

7. How many times in the period 1977-1980 was a grant or contract of yours terminated without renewal?

8. How long prior to the termination were you notified?

9. Discuss the impact of the termination on your research program.

10. Specify kinds of money you consider to be in particularly short supply (e.g., capital equipment, international travel).

11. What is an appropriate period for project funding without serious program review or threat of termination?

12. If you have any further remarks or opinions concerning the current situation of the totality of A&M research (experimental or theoretical) both in the U.S. and internationally, please express them.

COMMITTEE ON ATOMIC AND MOLECULAR SCIENCE
NATIONAL RESEARCH COUNCIL

QUESTIONNAIRE ON

ACADEMIC MANPOWER AND EMPLOYMENT OPPORTUNITIES

1. What aspects of your students' training have helped them find jobs? (For example, was it the ability to plan and execute physics research, familiarity with high vacuum techniques or electronics, computer expertise, or other qualities acquired during their graduate student careers?) Answer separately for each of your last three or four students.

____

____

____

____

2. Approximately how many unfilled positions do you have available at each of these levels?

	Now		Total anticipated in the next three years	
	exp	*theory*	*exp*	*theory*
Regular faculty appointment	____	____	____	____
Permanent position (other than faculty)	____	____	____	____
Postdoc/temporary	____	____	____	____
Graduate student	____	____	____	____

3. Is there a shortage of candidates who meet your minimum standards to fill these positions?

____________ (yes or no)

4. Are there candidates available who you could hire only if you compromised your standards?

____________ (yes or no)

5. Is existing manpower in your group adequate in quantity and quality to meet existing opportunities?

____________ (yes or no)

Comment on questions 3, 4, 5: ____________________

____

____

____

____________________ (over)

____

6. Describe the employment situation of all scientists doing A&M research in your group or groject, including yourself, by completing the following table.

Scientist #	Current position (see Table I)	Year hired into current position	Previous position (see Table I)	Previous employer; give institution and department	Currently Experimental(E) or Theoretical(T)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Table I

Type of Position

1. Permant
2. Regular faculty appointment (tenure or tenure track)
3. Postdoc/temporary
4. Graduate student
5. Undergraduate student
6. Not employed

7. Describe the employment situation of all A&M scientists who left your group in 1979 and 1980. Use the numbered definitions given in Tables I and II below.

Scientist #	Position in your group (see Table I)	Position hired into (see Table I)	New employer; Give institution and department	Characterize new position (see Table II)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Table I - Type of Position

1. Regular faculty appointment (tenure or tenure track)
2. Permanent (other than faculty)
3. Postdoc/temporary
4. Graduate student
5. Undergraduate student
6. Not employed

Table II - Characterize Position

1. Jobs directly related to their most recent research
2. Jobs not directly related to recent research, but still in atomic & molecular science
3. Jobs in physics other than atomic & molecular
4. Jobs outside physics

COMMITTEE ON ATOMIC AND MOLECULAR SCIENCE

NATIONAL RESEARCH COUNCIL

QUESTIONNAIRE ON

NONACADEMIC MANPOWER AND EMPLOYMENT OPPORTUNITIES

1. In staffing for your A&M research program, are there particular qualities in training for a Ph.D. in A&M science that you find attractive (e.g., experience in use of lasers, high vacuum techniques, computers, collision theory), and if so, what are they?

____

____

____

2. Can you obtain people from the field of A&M science with adequate training to meet your minimum requirements?

_____________ (yes or no)

3. Can you obtain people who have had training in fields other than A&M science to meet the same requirements?

_____________ (yes or no)

4. Approximately how mahy unfilled positions in A&M research do you have available at each of these levels?

	Now		Total anticipated in the next three years	
	exp	*theory*	*exp*	*theory*
Permanent position	_____	_____	_____	_____
Temporary	_____	_____	_____	_____

5. Please give any additional comments you may have concerning manpower and employment opportunities in nonacademic A&M research.

____

____

____

____

____

6. Describe the employment situation of all scientists doing A&M research in your group or project, including yourself, by completing the following table.

Scientist #	Current position (see Table I)	Year hired into current position	Previous position (see Table I)	Previous employer; give institution and department	Currently Experimental(E) or Theoretical(T)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Table I

Type of Position

1. Permant
2. Regular faculty appointment (tenure or tenure track)
3. Postdoc/temporary
4. Graduate student
5. Undergraduate student
6. Not employed

7. Describe the employment situation of all A&M scientists who left your group in 1979 and 1980. Use the numbered definitions given in Tables I and II below.

Scientist #	Position in your group (see Table I)	Position hired into (see Table I)	New employer; Give institution and department	Characterize new position (see Table II)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Table I - Type of Position

1. Regular faculty appointment (tenure or tenure track)
2. Permanent (other than faculty)
3. Postdoc/temporary
4. Graduate student
5. Undergraduate student
6. Not employed

Table II - Characterize Position

1. Jobs directly related to their most recent research
2. Jobs not directly related to recent research, but still in atomic & molecular science
3. Jobs in physics other than atomic & molecular
4. Jobs outside physics

COMMITTEE ON ATOMIC AND MOLECULAR SCIENCE

NATIONAL RESEARCH COUNCIL

QUESTIONNAIRE ON

COMPUTER USAGE IN ATOMIC & MOLECULAR RESEARCH

A. Physical Description of Computing Facility

1. Computing facilities can usually be described in one of the four following ways:

   a. A small computer purchased or leased by a particular individual or group and located in a lab, office, or home.

   b. A large computer, owned or leased by a university, government or industrial laboratory and shared by many research groups. These research groups are usually located at the same institution as the computer or at a nearby geographical location.

   c. Centralized computing facilities accessed by terminals located at many remote locations. (Examples are computers at LASL and Lawrence Berkeley Labs accessed via the ARPANET or commercial phone lines.)

   d. Other

   Check which of these situations best describes your use of computing facilities.

   a. _____ c. _____

   b. _____ d. _____

   If b, what institution or company owns or leases the computer?

   ____

   If c, what computer facility do you use? ______________________

   If d, what? ______________________________

2. Approximately what percentage of your total computing is applied to each of the following?

   _______% Theoretical calculations

   _______% Computations (modeling and analysis)

   _______% Control of experiment

   _______% Experimental data acquisition, reduction and processing

   _______% Other, what? ______________________

3. Has increased availability of computers significantly altered your research and how? ______________________

   ____

   ____

(over)

B. Costs

If you are a member of a group using a small computer system such as that described in A.1-c, one person from the group should answer question B.1. Name the person who will respond. ____________________

1. Describe your small computer:

   Manufacturer and Model ____________________

   Size of memory ____________________

   If the computer was purchased:

   Price $ __________

   Year of purchase __________

   When will it be necessary to replace it? __________

   Considering the advance of technology, your future research plans, and anticipated funding support, when do you expect to replace it? __________

   What do you anticipate will be the reason for replacing it? ____________________

   ____

   Do you lease the computer (yes or no) __________. Price $__________

   Agencies or institutions paying for purchase or lease. (Give department or division and percentage of your total cost per year each pays.)

   ____________________ __________%

   ____________________ __________%

   ____________________ __________%

   Approximately how many hours/month do you use this system? __________

   How many projects share this computer system? __________

   How many of these are doing A&M research? __________

If you use a time-share system such as described in A.1-b or A.1-c, answer question B.2.

2. Approximately how many hours/month do you use this system? __________

   What is your typical cost/month for computing by this system? $__________/month

   This figure refers to research done by how many people? __________

   Agencies or institutions paying (give department or division and percentage of your total cost/year each pays).

   ____________________ __________%

   ____________________ __________%

   ____________________ __________%

   What institution is paid? ____________________

C. Future Prospects

1. Is your present pattern of computer usage adequate to your needs? ____________
   yes or no

2. How much did these restrictions influence your choice of the system?

	very much	*slightly*	*not at all*
Financial	____	____	____
Administrative	____	____	____
Lack of support staff	____	____	____
Less demanding requirements	____	____	____

   Other (what) ____

3. If restrictions were lifted, what type of system (as described in A-1) would you prefer to use. Rank in order of choice (1 = most preferred)

   1-a ____
   1-b ____
   1-c ____
   1-d ____
   If 1-d, what? ____

4. If restrictions were lifted, what characteristics would be valuable to you.

   Larger memory ____
   Faster processor ____
   More auxiliary storage ____
   Better physical accessibility ____
   More friendly software ____
   Other (what) ____

D. Software

1. Have you (or your group) used a significant amount of software in your research program? ____________
   yes or no

2. Did you buy it, develop it locally or contract out the work? ____________

3. If developed, who did it (e.g., yourself, a student, or a computer expert)?

   ____

4. Why did you choose to obtain the software in this fashion?

   ____

   ____

NAME ____

ADDRESS ____

____

____

please return to:

Jean W. Gallagher
JILA
University of Colorado
Boulder, CO 80309
USA

COMMITTEE ON ATOMIC AND MOLECULAR SCIENCE
NATIONAL RESEARCH COUNCIL

QUESTIONNAIRE ON

COMMUNICATIONS

1. What national meetings and workshops did you attend during the years 1979 and 1980?

____

____

2. What international meetings and workshops did you attend during those two years?

____

3. What was your primary reason for going (for example, to present your own latest results, to hear the new results of other workers in your field, or as a more general learning experience)?

____

____

4a. Which one or two national meetings or workshops are most useful to you?_______________

____

4b. Which one or two international meetings are most useful to you?_______________

____

5. Do you feel important material in your subfield is being adequately covered at U.S. meetings?

_______ (yes or no)

6. If possible, suggest topics for special topic meetings or workshops which are not receiving adequate attention.

____

7. What limits your travel? (check appropriate column for each item)

very limiting	*moderately*	*not at all*	
____	____	____	Time
____	____	____	Money
____	____	____	Institutional commitments
____	____	____	Personal commitments
____	____	____	Need for more varied subject matter at meetings
____	____	____	Other (what)_______________

(over)

8. What percentage of your meeting expenses are paid by each of the following sources?

_____% Research contract or grant support

_____% Employing institution

_____% Personal funds

9. If you have comments on meetings, especially with regard to meeting format (e.g., General APS meeting vs. Gordon conferences), publication policies of meetings, location (e.g., regional vs. international), size of meetings, please give them.

10. Comment on current needs for critical reviews.

11. Comment on current needs for data compilations.

12. Do you perceive some important trends in communications? If so, what are they?

Appendix 2

Number of Respondents from Specific Employing Institutions

Tables A2.1 to A2.7 give a detailed breakdown of number of respondents with regard to employing institution. For academics, Tables A2.1, A2.2, and A2.3 list numbers of permanent faculty reporting from physics, chemistry, and (the sum of all) engineering departments from every college and university from which a response was received. These tables also give the count of graduate students and postdoctorals reported by these faculty members. In addition, Table A2.1 lists the number of faculty associated with atomic and molecular science reported in "Graduate Programs in Physics, Astronomy, and Related Fields, 1980-1981" published by the American Institute of Physics. The AIP numbers are often somewhat higher than those obtained from this survey. This is not surprising because the AIP numbers apparently include some visiting or temporary faculty, as well as people who are not engaged in active research but who identify with A&M as their subject of expertise, while the survey numbers include only permanent faculty engaged in active research. Of course, the numbers obtained from this survey are also somewhat low because 100% response was not obtained. No data comparable to the AIP figures are available for chemistry or engineering departments. Those few respondents, associated with other types of academic departments such as astronomy, computer science, medical schools, are not included in these tables.

Table A2.4 lists the numbers of permanent staff members, and their graduate students and postdoctorals, who reported under their affiliations with interdepartmental institutes and other laboratories which are located at university campuses and are strongly interfaced with the graduate research programs of the university. Some participants in these institutes may have reported under their affiliations with participating departments or other sponsoring organizations, e.g. JILA participants may have reported affiliations with one of the following: CU Physics, CU Chemistry, CU Astrogeophysics, or the National Bureau of Standards. Conversely, some full members of academic departments may have reported under their affiliations with such institutes. In making up these tabulations only one affiliation was used for each respondent.

Table A2.5 lists numbers of employees of all corporate laboratories for which the response to the survey was three or more. Table A2.6 lists all other corporate laboratories employing atomic and molecular scientists from whom a response was received.

Table A2.7 lists numbers of employees of all government laboratories for which the response to the survey was three or more.

Table A2.8 gives similar data for laboratories most accurately labeled as FFRDC or NFP.

Table A2.1. Physics Departments Reporting A&M Research
Alphabetical by State

PHYSICS	Permanent Faculty	Graduate Students	Postdoc-torals	AIP Reported A&M Faculty
Alabama				
Alabama, University of				
Birmingham	2	1	0	0
Huntsville	2	0	0	2
University	1	0	0	5
Auburn University	2	4	0	0
Southern Alabama, University of	1	0	0	---
Alaska				
Alaska, University of	2	3	1	1
Arizona				
Arizona, University of	9	19	5	10
Arkansas				
Arkansas, University of	5	13	0	7
California				
California Institute of Technology				
Physics	1	0	2	1
California State University				
Fullerton	1	0	0	
Long Beach	1	0	2	0
Los Angeles	1	0	0	2
Northridge	2	0	0	1
California, University of				
Berkeley	4	13	2	6
Davis	3	1	0	5
Los Angeles	3	3	0	2
Riverside	1	1	1	1
San Diego	1	1	0	1
Mount St. Mary's College	1	0	0	---
Naval Postgraduate School	1	0	1	2
Pomona College	1	0	0	---
San Diego State University	1	2	0	4
Southern California, University of	6	5	4	7

Table A2.1 (con't)

California (con't)	Permanent Faculty	Graduate Students	Postdoc-torals	AIP Reported A&M Faculty
Stanford University				
Physics	4	22	5	4
Applied Physics	3	9	0	3
Whittier College	1	0	0	---
Colorado				
Colorado School of Mines	1	1	0	2
Colorado State University	2	8	0	0
Colorado, University of	5	4	2	3
Denver, University of	4	0	2	6
U.S. Air Force Academy	2	0	0	---
Connecticut				
Connecticut, University of				
Storrs	7	9	2	7
Torrington	1	0	0	
Fairfield University	1	0	0	---
Weslyan University	1	3	2	2
Yale University	8	14	5	8
Delaware				
Delaware, University of	5	13	1	0
District of Columbia				
American University	1	0	0	2
Catholic University of America	1	0	0	2
Georgetown University	1	0	0	---
Howard University	2	3	1	---
Florida				
Central Florida, University of	1	0	0	---
Eckerd College	1	0	0	---
Florida A&M University	1	0	0	---
Florida International University	1	0	0	---
Florida State University	3	1	0	4
Florida, University of	6	10	6	1

Table A2.1 (con't)

Florida (con't)	Permanent Faculty	Graduate Students	Postdoc-torals	AIP Reported A&M Faculty
Miami, University of	1	2	1	---
Rollins College	1	0	0	---
Georgia				
Emory University	1	2	2	---
Georgia Institute of Technology	5	10	2	7
Georgia State University	2	3	2	3
Georgia, University of	5	2	0	7
Southern Technical Institute	1	0	0	---
Hawaii				
Hawaii, University of	1	0	0	3
Idaho				
Idaho, University of	2	3	0	3
Northwest Nazarine College	1	0	0	---
Illinois				
Chicago, University of	2	5	2	3
Illinois Institute of Technology	1	0	0	---
Illinois State University	1	0	0	---
Illinois, University of				
Chicago Circle	2	3	3	4
Urbana-Champaign	2	6	1	2
Judson College	1	0	0	---
Loyola University of Chicago	1	0	0	---
Northeastern Illinois University	1	0	0	---
Parkes College of St. Louis University	1	0	0	---
Southern Illinois University				
Carbondale	7	20	0	10
Edwardsville	2	7	0	1
Indiana				
Indiana University	1	1	1	2
Indiana University, South Bend	1	0	0	
Indiana University - Purdue University at Indianapolis	1	0	0	---

Table A2.1 (con't)

Indiana (con't)	Permanent Faculty	Graduate Students	Postdoc-torals	AIP Reported A&M Faculty
Notre Dame, University of	3	0	2	2
Purdue University	1	3	0	2
Iowa				
Drake University	1	2	0	---
Iowa State University	1	1	0	---
Kansas				
Emporia State University	1	0	0	---
Kansas State University	8	23	8	10
Kentucky				
Berea College	1	0	0	---
Kentucky, University of	3	3	2	5
Louisville, University of	1	2	0	3
Murray State University	2	1	0	---
Union College	1	0	0	---
Western Kentucky University	1	1	3	2
Louisiana				
Louisiana State University	5	7	3	3
Louisiana Technical University	1	0	0	3
New Orleans, University of	1	1	0	2
Northeast Louisiana University	1	1	0	
Southwestern Louisiana, University of	2	0	0	---
Xavier University	1	0	0	
Maine				
Bates College	1	0	0	---
Maine, University of	2	1	1	4
Maryland				
Johns Hopkins University	3	10	5	3
Maryland, University of				
Physics	2	3	1	1
Chemical Physics	4	11	3	28

Table A2.1 (con't)

	Permanent Faculty	Graduate Students	Postdoc- torals	AIP Reported A&M Faculty
Massachusetts				
Amherst College	1	0	0	---
Boston College	1	3	0	3
Boston University	2	2	0	1
Brandeis University	3	2	0	1
Clark University	1	0	0	2
Harvard University				
Physics	5	12	7	3
Applied Physics	1	5	3	---
Lowell, University of	2	0	0	3
Massachusetts Institute of Technology	7	30	15	4
Massachusetts, University of				
Amherst	3	1	0	5
Boston	1	0	0	
Wellesley College	1	2	0	---
Williams College	2	0	1	---
Michigan				
Central Michigan University	2	2	0	---
Kalamazoo College	1	0	0	---
Michigan State University	4	3	0	2
Michigan, University of	6	20	3	8
Wayne State University	3	2	1	3
Western Michigan University	2	2	0	---
Minnesota				
Minnesota, University of	3	6	1	2
Saint Olaf College	1	0	0	---
Mississippi				
Mississippi State University	1	3	0	4
Mississippi, University of	1	0	0	---
Southern Mississippi, University of	1	1	1	---
Missouri				
Missouri, University of				
Columbia	1	3	1	---
Kansas City	1	1	1	---
Rolla	5	7	4	8
St. Louis	2	2	1	1

Table A2.1 (con't)

Missouri (con't)	Permanent Faculty	Graduate Students	Postdoc-torals	AIP Reported A&M Faculty
Southeast Missouri State University	1	0	0	---
Montana				
Montana State University	2	3	0	1
Nebraska				
Creighton University	1	0	0	1
Nebraska, University of				
Lincoln	8	19	8	7
Omaha	1	0	0	---
Nevada				
Nevada, University of				
Reno	4	4	1	2
New Hampshire				
New Hampshire, University of	2	0	0	5
New Jersey				
Fairleigh Dickinson University	1	0	0	3
Princeton University	3	5	3	2
Rutgers University	3	6	6	2
Saint Peter's College	1	0	0	---
New Mexico				
New Mexico State University	1	0	0	4
New Mexico, University of	3	10	3	3
New York				
City University of New York				
Brooklyn College	4	2	1	6
City College	5	5	0	8
Hunter College	1	1	1	---
Queen's College	1	1	0	---
Staten Island, College of	1	0	0	---
York College	1	0	0	---
Clarkson College of Technology	2	3	1	3
Colgate University	1	0	1	---
Columbia University	1	0	0	5

Table A 2.1 (con't)

New York (con't)	Permanent Faculty	Graduate Students	Postdoc- torals	AIP Reported A&M Faculty
Cornell University				
Physics	2	4	0	---
Applied & Engineering Physics	6	25	6	10
Empire State College	1	0	0	---
Hamilton College	1	0	0	---
New York University	11	24	8	7
Polytechnic Institute of New York	1	1	0	2
Rochester, University of				
Physics	3	4	13	3
Institute for Optics	3	10	2	---
Saint John Fisher College	1	0	0	---
Saint John's University	1	0	0	---
State University of New York				
Albany	2	2	0	6
Buffalo	3	6	1	2
Stony Brook	3	9	3	4
Union College	1	0	0	---
U.S. Military Academy	1	0	0	---
North Carolina				
Duke University	4	6	1	4
East Carolina University	3	2	0	3
North Carolina State University	3	4	1	8
North Carolina, University of Chapel Hill	6	9	4	4
North Dakota				
North Dakota, University of	0	0	0	5
Ohio				
Akron, University of	1	9	0	1
Dayton, University of	2	1	0	---
Kent State University	1	1	0	1
Miami University	1	2	0	2
Oberlin College	1	0	0	---
Ohio State University	0	0	0	4
University of Toledo	4	7	1	5
Wright State University	1	1	0	---

Table A2.1 (con't)

	Permanent Faculty	Graduate Students	Postdoctorals	AIP Reported A&M Faculty
Oklahoma				
Bethany Nazarene College	1	0	0	---
Oklahoma State University	2	6	1	1
Oklahoma, University of	9	14	4	8
Oregon				
Oregon Graduate Center Applied Physics	2	2	0	---
Oregon State University	5	2	2	4
Oregon, University of	4	4	3	2
Portland State University	1	0	0	---
Pennsylvania				
Drexel University	3	4	1	5
Lehigh University	1	1	0	1
Lycoming College	1	0	0	---
Pennsylvania State University	4	7	2	6
Pennsylvania State University				
Capitol Campus	1	0	0	---
Ogontz	1	0	0	---
Scranton	1	0	0	---
Wilkes-Barre	1	0	0	---
Pittsburgh, University of	7	13	4	10
Swarthmore College	1	1	0	---
Temple University	1	0	0	---
Thiel College	1	0	0	---
Rhode Island				
Brown University	1	2	1	2
South Carolina				
Citadel, The	1	0	0	---
Clemson University	1	2	1	---
South Carolina, University of	3	4	0	1
Tennessee				
Fisk	1	0	0	2
Southern Missionary College	1	0	0	---
Tennessee Technological University	1	0	0	---

Table A2.1 (con't)

Tennessee (con't)	Permanent Faculty	Graduate Students	Postdoc-torals	AIP Reported A&M Faculty
Tennessee, University of	7	4	5	5
Tennessee, University of, Chattanooga	1	0	0	---
Texas				
Abilene Christian University	1	0	0	---
Angelo State University	2	0	0	---
Baylor University	1	1	0	1
East Texas State University	4	9	0	---
North Texas State University	4	9	0	6
Rice University	5	25	6	6
Saint Mary's University	1	0	0	---
Texas A&M University	6	14	4	9
Texas Christian University	1	2	0	3
Texas Tech University	2	2	1	4
Texas, University of				
Arlington	2	2	1	5
Austin	4	17	3	10
Dallas (+ Ch for Quantum Electronics)	4	16	0	4
Utah				
Brigham Young University	1	2	0	1
Utah, University of	2	8	5	0
Virginia				
Old Dominion University	3	11	3	5
Virginia Military Institute	1	0	0	---
Virginia Polytechnic Institute and State University	1	2	0	---
Virginia, University of	2	6	2	4
William and Mary, College of	3	5	8	3
Washington				
Pacific Lutheran University	1	0	1	---
Washington State University	1	2	0	---
Washington, University of	7	13	6	7
Whitman College	1	0	0	---

Table A2.1 (con't)

Wisconsin	Permanent Faculty	Graduate Students	Postdoc-torals	AIP Reported A&M Faculty
Lawrence University	1	1	0	---
Marquette University	1	0	0	1
Wisconsin, University of Madison	9	18	1	6

Table A2.2. Chemistry Departments Reporting A&M Research
Alphabetical by State

CHEMISTRY	Permanent Faculty	Graduate Students	Postdoc-torals
Arizona			
Arizona, University of	1	2	0
Arkansas			
Arkansas, University of	1	1	1
California			
California Institute of Technology	5	24	5
California, University of			
Berkeley	10	52	15
Davis	4	5	0
Irvine	2	10	2
Los Angeles	6	20	6
San Diego	1	4	2
Santa Barbara	4	11	7
Santa Cruz	1	4	0
San Diego State University	1	1	0
Southern California, University of	5	16	9
Stanford University	4	27	16
Colorado			
Colorado State University	1	4	3
Colorado, University of	6	22	11
Denver, University of	1	2	1
Fort Lewis College	1	0	0
Connecticut			
Connecticut, University of	2	0	0
Weslyan University	1	4	2
Yale University	1	4	0
District of Columbia			
George Washington University	1	3	2
Georgetown University	1	3	1
Howard University	2	7	2

Table A2.2 (con't)

Florida	Permanent Faculty	Graduate Students	Postdoc-torals
Florida State University	4	3	2
Florida, University of	19	19	6
Miami, University of	2	2	1
South Florida, University of	1	2	0
Georgia			
Atlanta University	1	1	0
Emory University	1	2	1
Georgia Institute of Technology	4	10	3
Georgia Southern College	1	0	0
Morehouse College	1	0	0
Oxford College	1	0	0
Hawaii			
Hawaii, University of	1	1	0
Illinois			
Chicago, University of	5	30	13
Illinois Institute of Technology	2	4	3
Illinois, University of			
Chicago Circle	4	4	2
Urbana-Champaign	4	12	4
Northwestern University	3	11	6
Southern Illinois Edwardsville	3	7	0
Indiana			
Indiana State University	1	0	0
Indiana University	7	18	3
Notre Dame, University of	3	5	7
Purdue University	4	6	1
Valparaiso University	1	0	0
Iowa			
Iowa State University	1	8	1

Table A2.2 (con't)

Iowa (con't)	Permanent Faculty	Graduate Students	Postdoctorals
Iowa, University of	4	9	6
Wantburg College	1	0	0
Kansas			
Kansas State University	2	5	3
Kansas, University of	5	7	5
Kentucky			
Kentucky, University of	1	2	0
Louisiana			
Louisiana State University	2	6	4
New Orleans, University of	1	0	2
Tulane University	1	0	0
Maine			
Maine, University of	1	5	0
Maryland			
Johns Hopkins University	5	9	6
Maryland, University of	4	8	2
Maryland, University of, Baltimore County	1	2	0
U.S. Naval Academy	1	0	0
Massachusetts			
Amherst College	2	0	0
Boston College	1	4	1
Boston University	1	4	1
Brandeis University	3	3	0
Clark University	1	3	0
Harvard University	2	13	4
Massachusetts Institute of Technology	5	22	11
Massachusetts, University of			
Amherst	3	9	1
Boston	2	0	0

Table A2.2 (con't)

Massachusetts (con't)	Permanent Faculty	Graduate Students	Postdoctorals
Suffolk University	1	0	1
Michigan			
Andrews University	1	0	0
Hope College	1	0	0
Michigan State University	2	7	2
Michigan, University of	4	9	2
Oakland University	2	1	2
Wayne State University	2	4	2
Minnesota			
Minnesota, University of	12	38	12
Mississippi			
Mississippi, University of	1	0	0
Tougaloo College	1	0	0
Missouri			
Missouri, University of St. Louis	2	2	0
Nebraska			
Nebraska, University of Lincoln	3	8	3
Nevada			
Nevada, University of	2	1	1
New Jersey			
Drew University	1	0	0
Fairleigh Dickinson University	1	2	0
Princeton University	1	2	1
Rutgers University	3	2	2
Stevens Institute of Technology	1	1	1
New Mexico			
New Mexico State University	1	0	0

Table A2.2 (con't)

New York	Permanent Faculty	Graduate Students	Postdoctorals
Barnard College	1	0	0
Canisius College	1	0	0
City University of New York			
Brooklyn College	4	4	2
City College	1	0	0
Queens College	1	0	1
York College	1	0	0
Columbia University	5	26	6
Cornell University	7	31	19
New Rochelle, College of	1	0	0
Polytechnic Institute of New York	1	2	1
Rensselaer Polytechnic Institute	1	3	1
Rochester, University of	3	6	7
Syracuse University	1	0	0
State University of New York			
Albany	1	5	0
Binghamton	2	6	1
Geneseo	1	0	0
Oneonta	1	2	1
Stony Brook	5	19	11
North Carolina			
Duke University	1	2	0
North Carolina State University	1	0	0
North Carolina, University of			
Chapel Hill	5	17	7
Greensboro	1	0	0
North Dakota			
North Dakota State University	1	2	0
Ohio			
Bowling Green State University	1	0	0
Case Western Reserve University	2	3	2
Cincinnati, University of	3	5	1
Cleveland State University	1	1	0
Oberlin College	2	0	0
Ohio State University	5	12	3

Table A2.2 (con't)

Ohio (con't)	Permanent Faculty	Graduate Students	Postdoc-torals
Ohio University	1	1	0
Toledo, University of	2	0	0
Wright State University	5	8	13
Youngstown State University	1	0	0
Oklahoma			
Oklahoma State University	1	0	0
Oregon			
Oregon State University	2	5	2
Oregon, University of	4	5	3
Pennsylvania			
Carnegie-Mellon University	2	3	1
Drexel University	1	2	0
Pennsylvania State University			
University Park	7	21	4
Hazleton	1	0	0
Monte Alto	1	0	0
Pennsylvania, University of	5	7	1
Pittsburgh, University of	6	19	7
Temple University	1	1	1
Villanova University	2	5	0
Rhode Island			
Brown University	4	7	2
Rhode Island, University of	1	0	0
South Carolina			
Clemson University	1	1	0
South Carolina, University of	1	0	0
South Dakota			
Augusta College	1	0	0
South Dakota School of Mines and Technology	1	0	0

Table A2.2 (con't)

	Permanent Faculty	Graduate Students	Postdoctorals
<u>Tennessee</u>			
Tennessee Technological University	1	0	0
Tennessee, University of	1	1	0
Vanderbilt University	1	1	0
<u>Texas</u>			
Abilene Christian University	1	2	0
Houston, University of	4	10	7
Rice University	6	12	6
Texas A&M University	3	5	8
Texas Tech University	1	1	2
Texas, University of			
Austin	4	14	5
Dallas	2	4	1
<u>Utah</u>			
Brigham Young University	1	2	0
Utah State University	1	1	1
Utah, University of	3	12	4
<u>Virginia</u>			
Christopher Newport College	1	0	1
Virginia Polytechnic Institute and State University	1	0	0
Virginia, University of	2	4	5
Washington and Lee University	1	0	0
William and Mary, College of	1	0	0
<u>Washington</u>			
Central Washington University	1	0	0
Washington State University	1	0	0
Washington, University of	4	12	6
<u>Wisconsin</u>			
Marquette University	2	1	0
Wisconsin, University of			
Madison	10	49	4
Milwaukee	1	0	1
Parkside	1	0	1

Table A2.3. Engineering Departments Reporting A&M Research
Alphabetical by State

ENGINEERING	Permanent Faculty	Graduate Students	Postdoctorals
Arizona			
Arizona, University of	1	2	0
California			
California Institute of Technology	1	6	0
California, University of			
Davis	1	0	0
Irvine	1	3	0
Los Angeles	1	4	1
San Diego	5	9	1
Stanford University	2	13	0
Colorado			
Colorado State University	1	7	0
Colorado, University of	1	0	0
Connecticut			
Yale University	5	9	6
Florida			
Florida, University of	2	1	0
Georgia			
Georgia Institute of Technology	4	1	
Illinois			
Illinois, University of	6	42	0
Indiana			
Purdue University	2	7	1
Kentucky			
Kentucky, University of	1	0	0
Maryland			
Maryland, University of	2	6	1

Table A2.3 (con't)

	Permanent Faculty	Graduate Students	Postdoc-torals
Massachusetts			
Boston University	1	3	0
Harvard University	1	0	0
Massachusetts Institute of Technology	4	18	2
Massachusetts, University of Amherst	2	7	
Michigan			
Michigan State University	1	2	0
Michigan, University of	2	4	2
Wayne State University	2	3	1
Minnesota			
Minnesota, University of	6	31	5
Missouri			
Missouri, University of Columbia	2	7	0
New Jersey			
Princeton University	7	19	4
New Mexico			
New Mexico, University of	1	2	0
New York			
Cornell University	1	0	0
Polytechnic Institute of New York Farmingdale	2	3	0
Rensselaer Polytechnic Institute	2	8	1
Rochester, University of	1	1	0
State University of New York Buffalo	4	23	6
North Carolina			
North Carolina State University	1	2	0
Ohio			
Case Western Reserve University	2	6	3
Ohio State University	1	2	0

Table A2.3 (con't)

	Permanent Faculty	Graduate Students	Postdoc-torals
Pennsylvania			
Lehigh University	1	2	0
Pennsylvania State University	2	9	0
Rhode Island			
Brown University	1	1	0
South Dakota			
South Dakota School of Mines and Engineering	1	3	0
Tennessee			
Tennessee, University of	3	8	2
Texas			
Southern Methodist University	1	4	1
Rice University	1	0	0
Texas Tech University	1	3	0
Texas, University of Austin	3	9	0
Virginia			
Virginia, University of	2	10	2
Washington			
Washington, University of	1	6	2
Wisconsin			
Wisconsin, University of	1	6	1

Table A2.4. Number of Scientists, Graduate Students and Postdoctorals Reporting A&M Research in Academically Related Institutes Outside the Normal Academic Structure

	Permanent Staff	Graduate Students	Postdoctorals
Harvard-Smithsonian Center for Astrophysics Harvard University	13	15	11
Institute for Optics University of Rochester	3	10	2
Joint Institute for Laboratory Astrophysics of the University of Colorado and the National Bureau of Standards	10	16	14
Lawrence Berkeley Laboratory University of California	20	21	5
National Magnet Lab Massachusetts Institute of Technology	5	7	0
Optical Sciences Center University of Arizona	1	3	1
Quantum Institute University of California, Santa Barbara	3	0	4

Table A2.5. Number of Scientists Reporting A&M Research in Corporate Laboratories (More than 2 Scientists Reporting). See Table A3.6.

Laboratory	
Aerodyne Research, Inc.	
Bedford, MA	10
Allied Chemical Corporation	
Morristown, NJ	5
Avco Everett Research Lab, Inc.	
Everett, MA	10
Bell Aerospace Textron	
Buffalo, NY	3
Bell Laboratories	
Holmdel, NJ	11
Murray Hill, NJ	31
Boeing Aerospace Co.	
Seattle, WA	3
Calspan Corporation	
Buffalo, NY	3
E.I. Dupont de Nemours & Co.	
Wilmington, DE	4
Eastman Kodak Company	
Rochester, NY	11
EXXON Research & Development Co.	
Linden, NJ	11
Richland, WA	5
Ford Motor Co.	
Dearborn, MI	6
General Atomic Co.	
San Diego, CA	6
General Electric Co.	
Cleveland, OH	3
Philadelphia, PA	2
Schenectady, NY	8
General Motors Corporation	
Warren, MI	16
General Telephone & Electronic Corporation	
Waltham, MA	8

Table A2.5 (con't)

Laboratory	
Hewlett Packard Co.	
Palo Alto, CA	3
Hughes Research Laboratories	
Malibu, CA	13
International Business Machines	
San Jose, CA	16
Yorktown Heights, NY	13
IRT Corporation	
San Diego, CA	3
KMS Fusion, Inc.	
Ann Arbor, MI	3
Lockheed Aircraft Corporation	
Palo Alto, CA	4
Mathematical Sciences Northwest, Inc.	
Bellevue, WA	5
McDonnell-Douglas Corporation	
St. Louis, MO	9
Northrup Research & Technology Center	
Palos Verdes Peninsula, CA	3
RCA Laboratories	
Princeton, NJ	3
Rockwell International Corporation	
Canoga Park, CA	9
TRW, Inc.	
Redondo Beach, CA	10
United Technologies Research Center	
East Hartford, CT	19
Varian Associates	
Palo Alto, CA	5
Westinghouse Research & Development	
Pittsburgh, PA	22
Xerox Corporation	
Pasadena, CA	2
Webster, NY	6

Table A2.6. Corporate Laboratories Employing A&M Scientists From Which Less Than Three Reported. (See Table A2.5)

Abbott Laboratories
Advanced Kinetics, Inc.
Aerojet Electrosystems Co.
American Science and Engineering Co.
Analytic Sciences Corp.

Barnes Development Co.
BDM Corp.
Bechtel National, Inc.
Bedford Reserach Associates
Beers Associates, Inc.
Bell Laboratories
  Columbus, OH
  Naperville, IL
Block Research and Engineering
Borg Warner Chemicals

Candela Corp.
Charles Evans and Assoc.
Chemical Dynamics Corp.
Chromatix, Inc.
Coherent, Inc.
Communications Satellite Corp.
Cottrell
Coulter Electronics, Inc.

Digital Equipment Corp.
Diverse Air Inc.

Environmental Research and Technology, Inc.
Ethicon, Inc.
Extranuclear Laboratories, Inc.
EXXON Nuclear Co.

Fairchild Camera and Instrument Corp.
Far West Technology, Inc.
Frequency and Time Systems, Inc.

Garrett-Airesearch
General Dynamics/Convair
Grumman Aerospace Corp.

High Voltage Engineering Co.
Holograf
Honeywell
Hughes Aircraft Co.

International Technical Associates

Jaycor

Kuman Sciences

LOM, Ltd.
Lutron Corp.

Marconi Avronics, Inc.
Material Technology Consultants
Maxwell Laboratories, Inc.
Microscope Associates, Inc.
Minuteman Laboratories, Inc.
Mission Research Corporation
Motorola, Inc.

National Research Group, Inc.

Optelcom, Inc.
OptiMetrics, Inc.

Perkin-Elmer Corp.
Phrasor Scientific, Inc.
Philip Morris R&D Center
Physical Dynamics, Inc.
Physical Sciences, Inc.
Polaroid Corp.
Polyatomics Research, Inc.
PPG Fiberglass Technology Center
Proctor and Gamble Miami Valley Laboratories
Proteng

Quantum Technical Laboratories

R&D Associates
Rasor Associates
Raytheon Co.
Research and Laser Technology, Inc.
Rocketdyne
RPC Industries

Science Applications, Inc.
SES, Inc.
Shell Development Co.
Southern Technology, Inc.

Table A2.6 (con't)

Spectra Physics, Inc.
Standard Oil Co. of Ohio
Surface Analytic Research, Inc.
Surface Science Laboratories
Systems, Science, and Software

Tektronix
Terra Nova, Inc.
Tetra Corp.
Texas Instruments, Inc.

Ultra-Violet Products. Inc.
Universal Energy Systems, Inc.

Veeco/Accelerators
Vernon Graphics, Inc.
Vought Corporation

Western Research Corp.
Westinghouse-Bettis Atomic Power Lab.
W.J. Schafer Associates

Xerox Electro-Optical Systems, Inc.

Table A 2.7. Number of Scientists Reporting A&M Research in Government Laboratories (Reporting More Than 2 Scientists)

<u>Department of Commerce</u>	
National Bureau of Standards	
Washington, DC	53
Boulder, CO	9
NOAA	5
<u>Department of Defense</u>	
Air Force	
Air Force Geophysical Laboratory	20
Air Force Weapons Laboratory	
Kirtland AFB	7
Avionics Laboratory	
Wright-Patterson AFB	3
Army	
Armament R&D Command	
Ballistic Research Laboratory	
Aberdeen, MD	4
Missile R&D Command	
U.S. Army Missile Lab	
Redstone Arsenal, AL	8
Navy	
Naval Research Laboratory	
Washington, DC	31
Naval Surface Weapons Center	
Silver Spring, MD	7
NASA	
Ames Research Center	8
Goddard Space Flight Center	18
Langley Research Center	8

Table A2.8. Number of Scientists Reporting A&M Research in Federally Funded Research and Development Centers and Not-for-Profit Laboratories (Reporting More Than 2 Scientists)

Aerospace Corporation	23
Applied Physics Laboratory Johns Hopkins University	6
Argonne National Laboratory	29
Battelle Memorial Institute	
Columbus, OH	5
Richland, WA	5
Brookhaven National Laboratory	20
Jet Propulsion Laboratory	18
Laboratory for Laser Energetics University of Rochester	9
Lawrence Livermore National Laboratory	51
Lincoln Laboratory Massachusetts Institute of Technology	12
Los Alamos Scientific Laboratory	82
Oak Ridge National Laboratory*	48
Princeton Plasma Physics Laboratory	-
Sandia National Laboratory	
Albuquerque, NM	24
Livermore, CA	8
Stanford Research Institute	26
Kitt Peak Observatory	-
Mt. Wilson Observatory	-
National Radio Astronomy Observatory	-
Lick Observatory	-

*Including ORNL Gaseous Diffusion Plant

Appendix 3

Number of Responses Divided by Atomic and Molecular Research Specialization and Category of Current Employing Organization

This table expands Table III-4 by giving a more detailed breakdown by atomic and molecular research specialization. The percentages quoted are column percentages; for example, 14% of the respondents from academic institutions specialize in research on the general structure and properties of atoms and molecules while only 5% of the respondents from corporate organizations associate themselves with this specialty.

	Academic		Corporate		FFRDC		Government		NFP		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
1. Structure and properties of atoms and molecules												
1.1 General structure and properties of atoms and molecules	153	14	21	5	21	7	19	8	7	9	221	11
1.2 Properties and interactions of Rydberg states	8	1	1	0	1	0	1	1	1	1	12	1
1.3 Properties of other special atoms and molecules	21	2	9	2	5	2	2	1	1	1	38	2
1.4 Fundamental properties of atoms and molecules	16	2	2	1	1	0	5	2	0	0	24	1
2. Collisional interactions												
2.1 Atomic and molecular collisions excluding electron collisions	100	9	14	3	22	7	7	3	9	11	152	7
2.2 Electron and positron collisions with atoms & molecules	53	5	11	3	12	4	10	4	3	4	89	4
2.3 Chemical physics excluding photochemistry	113	11	34	8	28	9	15	7	11	14	201	10
3. Interactions with electromagnetic radiation												
3.1 Conventional photon-atom & photon-molecule effects	39	4	3	1	12	4	7	3	3	4	64	2
3.2 Optical and uv spectra	28	3	4	1	8	3	11	5	1	1	52	3
3.3 Infrared, rf, & microwave spectra	25	2	8	2	5	2	7	3	2	2	47	2
3.4 Inner shell transitions including X-ray absorption & emission	21	2	5	1	5	2	9	4	0	0	40	2
3.5 Specifically molecular spectra	33	3	10	2	3	1	9	4	4	5	59	3

	Academic Number	Academic %	Corporate Number	Corporate %	FFRDC Number	FFRDC %	Government Number	Government %	NFP Number	NFP %	Total Number	Total %
3.6 Interactions of laser radiation with atoms and molecules	66	6	35	9	25	8	15	7	4	5	145	7
3.7 Intense-field & multiphoton effects	13	1	2	0	4	1	4	2	3	4	26	1
3.8 Laser chemistry; photo-chemistry	33	3	19	5	14	5	5	2	3	4	74	4
3.9 Interactions of dc fields with atoms & molecules	10	1	1	0	1	0	2	1	1	1	15	1
4. Techniques and instrumentation												
4.1 Quantum & physical optics	44	4	53	13	24	8	17	7	6	8	144	7
4.2 Accelerator-based A&M physics	60	6	15	4	35	11	16	7	6	8	132	6
4.3 Beam technology	10	1	14	3	10	3	3	1	1	1	38	2
4.4 Mass spectrometry	9	1	4	1	2	1	3	1	0	0	18	1
5. Interface with other areas of science and technology												
5.1 Interaction of particles & radiation with surfaces	50	5	41	10	16	5	8	3	5	6	120	6
5.2 Atomic & molecular physics in solids & liquids	35	3	13	3	10	3	2	1	1	1	61	3
5.3 Gaseous electronics	22	2	34	8	4	1	6	3	1	1	67	3
5.4 Atomic & molecular physics in plasmas	30	3	29	7	25	8	13	6	0	0	95	5
5.5 Combustion & other energy-related processes	7	1	9	2	4	1	7	3	4	5	31	1
5.6 Atmospheric & environmental applications	12	1	13	3	6	2	15	7	1	1	47	2

	Academic		Corporate		FFRDC		Government		NFP		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
5.7 Astrophysical applications	17	2	2	1	3	1	8	3	0	0	30	1
5.8 Atomic & molecular physics in nuclear physics	7	1	1	0	0	0	1	0	0	0	9	0
6. None specified	19	2	5	1.2	4	1.3	3	1.3	2	10	33	2
TOTAL	1054		410		310		230		80		2084	

Appendix 4

Reported Agencies and Institutions Supporting Research in Atomic and Molecular Science

Federal Government Agencies

National Science Foundation (NSF)

Department of Energy (DoE)

National Aeronautics and Space Administration (NASA)

Department of Defense (DoD)

Defense Advanced Research Projects Agency (DARPA)

Defense Nuclear Agency (DNA)

U.S. Air Force

U.S. Army

U.S. Navy

Environmental Protection Agency (EPA)

Federal Aviation Administration (FAA)

Joint Service Electronics Program

National Institutes of Health (NIH)

Nuclear Regulatory Agency (NRA)

Solar Energy Research Institute (SERI)

U.S. Dept. of Agriculture (DoA)

U.S. Dept. of Commerce (DoC)

U.S. Dept. of Health, Education, and Welfare (HEW)

U.S. Dept. of the Interior (DoI)

U.S. Dept. of Transportation

U.S. Dept. of the Treasury

U.S. Food and Drug Administration (FDA)

State Government Agencies

Board of Higher Education of New York

California Air Resources Board

Kentucky Center for Energy Research

North Carolina Board of Science and Technology

State of Kentucky Institute for Mining and Minerals Research

University Programs

California Institute of Technology President's Fund

City University of New York Committee on Research Computing

East Texas State University Research Organization

Emporia State University Committee on Faculty Research and Creativity

Faculty Research Award of the City University of New York

Georgia Institute of Technology Foundation

Murray State University Committee on Institutional Studies and Research

Purdue Research Foundation

Research Foundation of the State University of New York

Texas A&M University Center for Energy and Mineral Resources

University of Texas System Organized Research Fund

Private Agencies

American Cancer Society

American Heart Association

American Petroleum Institute

Camille and Henry Dreyfus Foundation

Chemical Manufacturers' Association

Columbia Gas System Service Corporation

Cotton Incorporated

Eaton Foundation

Electric Power Research Institute (EPRI)

EXXON Minerals

Gas Research Institute

Institute for Telecommunication Sciences

Irma T. Hirschl Trust

John A. Hartford Foundation

M. J. Murdock Charitable Trust

National Geographic Society

Petroleum Research Fund of the American Chemical Society

Research Corporation

Robert A. Welsh Foundation

Sloan Foundation

Smithsonian Scholarly Studies

Utah Energy Consortium

Other

North Atlantic Treaty Organization