Research and Development in Communist China

China continues to be a country of the wooden plow and the Bomb.

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It is difficult to place Communist China on a world scale of scientific and technological development. Some think of it as a backward nation, while others list it among the major industrial powers. The paradox is real. Whereas political and social changes have affected the entire population, large segments of the rural population are still untouched by technological change. At the same time China is a significant producer of the world's coal, steel, and electric power and has several other highly developed industries. It continues to be a land of the man-pulled cart, while the rapidly expanding railroad system criss-crosses most of the densely populated regions of the country. China is a country of the simple plow and the Bomb.

There is no term in the Chinese language, and no concept, that is equivalent to our phrase "research and development." Although native sources do discuss "science" and "research," these words, as used in China, refer to activities that are difficult to relate to R & D as we understand it. When one considers this fact, in conjunction with the overall paucity of analytical and textual material and the virtual nonexistence of statistical data, the immediate question is, Why bother? The answer is that even a superficial evaluation of the scope and content of R & D activities in Communist China is vital to any assessment of that country's economic and military potential. Thus, I have tried to draw together some relevant information that will provide a panoramic view of the R & D picture, identify major information gaps, and provide a possible methodological approach for measuring Communist China's R & D effort.

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Political and Social Setting

Politics so permeates all aspects of life in Communist China that we must begin with the role of ideology and the effects of the ever-shifting political climate. One can smile when he reads (*1*) that "Mao Tse-tung's thinking is not only the best weapon for reforming society and remolding people's ideas, but also the best guidance for revealing the secrets of science and technology," but it would be a mistake to ignore this as simply Communist gibberish directed at the uneducated masses. Statements like this are directed at the scientist and the engineer as well; they are not casual statements, and the specialist is expected to accept them and to abide by them. Within the intensely political climate they do have an effect on the individual researcher's thinking and, most important, on his attitude and capacity for work. Therefore, an appreciation of the setting within which R & D activities are undertaken is vital to evaluation of the total R & D picture.

The phrase "walking on two legs," descriptive of many of China's internal policies, means that the country must rely on both the old and the new; on the traditional and the modern; on the slow and the fast. It implies the use of all possible approaches to achieve national goals. It is particularly applicable to science and technology, for the leaders realize the importance of instilling an awareness and an appreciation of science among hundreds of millions of peasants and workers with no scientific and technological tradition (*2*). As a result, *science* and *technology* have become common words in the daily press and are seen in a variety of popular slogans.

An editorial in the *People's Daily* asks rhetorically (*3*): "Is it an accident when an ordinary worker with only three years of primary school education becomes a specialist in the scientific and technical fields of upper space and the origin of light?" The answer, of course, is, "No. In the great era of Mao Tse-tung in our country this is an inevitable phenomenon. . . . Many of our inventions and creations come directly from the hands of the workers; there are even more inventions and creations in which workers play at least some part."

This glorification of the "nonintellectual expert" is almost always accompanied by a slap at the professionals, at the foreign-trained experts, and at foreign science and technology in general. The following example (*4*) is one of hundreds that appear in Communist literature:

> Inspired by Chairman Mao's statement that the downtrodden are often the wisest while the intellectuals are often the most stupid, Shanghai's workers have dared to challenge established authorities and sweep away the foreign dogmas and stereotypes that have shackled the development of production. . . . "We must sweep away the prestige of so-called specialists and authorities who try to overwhelm us with foreign books and stereotypes," said the workers. "We must tear down the bourgeois flag and hoist the great red banner of Mao Tse-tung's thought in the field of science and technology."

The belittling of everything foreign has been particularly evident during the past few years, as part of the big push for self-reliance. The following quotation from an economic journal (*5*) is typical.

> The policy of self-reliance requires that in the cause of building socialism a country must independently develop its economy, national defense, science and technology, culture and education, and other undertakings according to its own concrete situation and its own manpower, material resources and fund supply. . . . A country must not depend upon any other country and become a satellite of another country.

The regime and its media of public communications seldom differentiate between true science and "people's science," or between efforts of professional engineers and of semiliterate technicians. In their efforts to blur class differences and to make every worker a scientist and every scientist a worker, the Communists have undoubtedly created serious morale and performance problems with respect to the professional personnel.

The plight of the Chinese intellectual has been discussed by many authors (*6*). The continuing vacillations of the government's position toward the small professional segment of the population clearly indicate the dilemma that persists after almost 18 years of Communist control. The intellectuals are indispensable for the country's future, but they are still suspect and, presumably, are politically the most unreliable segment of the society. While making every effort to increase the number of highly qualified specialists in the country, the Communists have apparently been unable to produce a professional robot, who can be creative as a specialist yet, at the same time, unquestioningly accept the concentrated unsophisticated political rubbish. Unfortunately for the Communists, a thinking scientist is likely to be a thinking man, and the intense efforts to "wipe out individualistic thoughts" are diametrically opposed to the type of thinking customarily associated with R & D activities.

It is clear that some of the scientific and technical personnel continue to be skeptical about the usefulness of Mao Tse-tung's thought as a guide in scientific experimentation, and they are taken to task by the *People's Daily* (*7*):

> They say: "Going through every page of Chairman Mao's works cannot find an engineering principle or a mathematical formula." It is true that such a principle or formula cannot be found in Comrade Mao's works. But it is in such works that one can find the "formula" that creates the mathematical formula, and the "principle" which points out the engineering principle.

The constant propaganda that emphasizes self-reliance and runs down foreign technology and book-learning is designed to give the Chinese pride and self-confidence and to combat the feelings of inferiority which, presumably, were instilled by more than half a century of foreign domination. According to the *People's Daily* (*8*), "the imperialists and reactionary ruling classes spread the cult of foreign technology and tried to destroy the Chinese people's national pride and make them feel inferior." Although the "China first" line is the one most frequently heard, some of the more serious articles directed at the professional segment of the population occasionally do come out with more realistic statements on science, technology, and R & D. For example (*9*):

> There is a large amount of the world's advanced technology which can be emulated by us. If we are adept in studying and rich in creative spirit, we can shorten the devious road and catch up or even surpass the advanced countries.

In some instances both viewpoints are expressed in the same article; for example (*10*): "China must thoroughly renounce superstitious belief in foreign countries and superstitious belief in books," and, a few pages later, "The absorption and utilization of foreign good experiences and good techniques is necessary at any time for any country."

Soviet versus Western Influences

What little activity in science and technology there was in China prior to 1949 was mainly Western-oriented. Since the turn of the century thousands of Chinese students had received their education in the United States, Western Europe, and Japan, and the reorganizations and reforms of the educational system after 1911 also were largely influenced by Western thought. When the Communists assumed control over the mainland, they immediately repudiated all cooperation with the West and turned to the Soviet Union (*11*, chaps. 7 and 8). However, the long cooperation between China and the West was too solid to be easily and quickly reversed. Western- and Japanese-trained scientists and engineers constituted the backbone of China's professional manpower, many of them occupying key positions in the Academy of Sciences, in the institutions of higher learning, in industry, and in government. The difficulty of redirecting this Western orientation of China's scientists and engineers was ignored by the Communists, except as it touched on political issues. Actually, the shift in language from English, German, and French to Russian posed great problems both for established professionals and for aspiring students. Thousands of Russian texts and reference works were translated into Chinese; thousands of scientists, engineers, and students spent years studying the Russian language—a tongue that does not come easily to the Chinese—and many of the institutions of higher learning adopted Russian materials in their courses (*12*).

This laborious effort of reorientation came to a sudden halt in 1960 with the major political schism between China and the U.S.S.R. China was left with Russian-made factories and Russian blueprints for industrial construction projects, but without the necessary spare parts and without scientific and technical advisors. After some 10 years of intensive Russian influence in science, industry, and education, China once again found herself in the throes of a painful and expensive readjustment—initially a detachment from the Soviet Union and then a gradual and grudging return to a limited form of Western influence in science and technology.

In view of the earlier diatribes against Western science and technology, the drift toward the West may seem a contradiction. In a sense, however, it is just another twist of the "walking on two legs" policy. While the propaganda machine accelerates its denunciations of capitalist science, schools at all levels are introducing more and more courses in English and other Western languages and more and more Western scientific and technical materials are being translated into Chinese (*13*).

The loss of Soviet support, particularly at a time when China's economy was already experiencing a sharp downward trend, had conspicuous economic consequences. Likewise, the current shift from Russian to Western influence and the reorientation in China's educational and scientific systems must be having a braking influence on the country's R & D activities.

Research and Development Goals

Given the above conditions and moods, what can be said about Communist China's R & D goals? As expressed in articles and editorials and as trumpeted by the national and international propaganda media, the aim is clear and direct: in science and technology China must overtake the leading nations of the world. The method is even simpler: under the guidance of the Communist Party's Central Committee and Chairman Mao, the most advanced scientific and technological achievements will naturally follow China's ideological revolution.

The real objectives and their details are much more difficult to ascertain, but for the most part they conform to the following precept (14): "All scientific research is for the purpose of developing production and must be integrated with production practice. Subjects for research must come from production and the results of research, without any exception, must return to production." This theme is stressed again and again. It not only determines the nature and content of R & D but gravely limits all activities relating to true basic research.

Although the degree to which economic goals have determined R & D activities has varied over the years, the emphasis on economic factors has always been there. It is not surprising, therefore, that some of the specific R & D goals can often be ascertained from the overall goals for economic production.

China's First Five-Year Plan (1953–57) for the development of the national economy contained few details dealing with scientific and technical development and only generally discussed the need to raise the level of science and technology in China. It did, however, spell out 11 fields which should constitute the principal work of the Academy of Sciences. Among them were the peaceful use of atomic energy, construction of new iron and steel complexes, research on antibiotics, and research on polymers.

The Second Five-Year Plan (1958–62) was aptly described (*15*) as "stillborn and swallowed up by the Great Leap Forward." As a matter of fact, the full text of the Plan was never published. The draft of the Plan did, however, contain several paragraphs that pertained to science. Once again the emphasis was on the practical needs of national construction and on the building of socialism. The draft stressed the need "to learn from the latest scientific and technical achievements of the Soviet Union and other countries," reasserting the need to concentrate on the science of atomic energy, on electronics, and on the techniques of automation and remote control.

A more important guide to the trends in R & D was the first long-term plan for scientific development, known as the Twelve-Year Plan (1956–67). It was formulated by the State Planning Commission, with the cooperation of the Academy of Sciences and the various industrial ministries, and with the assistance of numerous Soviet advisors. The areas selected for scientific development were in many instances identical to the principal areas of emphasis mentioned in the economic plans. They included the peaceful uses of atomic energy; new electronic techniques; jet propulsion; automation in industry; prospecting for petroleum and other minerals; metallurgical studies; development of fuels and heavy machines; exploitation of the Yellow and Yangtze rivers; modernization of agriculture, with emphasis on mechanization, electrification, and use of chemicals; research on prevalent diseases; and basic research in the natural sciences. Although presumably quite flexible, the Twelve-Year Plan for scientific development was also swallowed up by the Great Leap Forward.

The adjustments that followed the Great Leap cut across all phases of Chinese life. In the areas of science and technology there developed, once again, a more liberal attitude toward professionals and specialists, political control was relaxed, and the emphasis was on quality. Many of the "fly-by-night" institutes were abolished or merged, and the limited scientific manpower was concentrated in research centers which had more adequate facilities. Within the economy, the Communists decreed a major shift of emphasis from industry to agriculture, and it must be assumed that on the scientific and technological front there were similar shifts in policy and a reallocation of scarce capital.

More recently, some of the goals that may be related to industrial R & D have been listed as objectives of the campaign for "technical innovation and technical revolution." These objectives are stated as follows (*16*):

> 1) To speed up the technical reform of all sectors of the economy; 2) to raise labor productivity; 3) to give an impetus to the enterprises so that they will take actions on their own, save investments, and raise output; 4) to improve the quality of industrial products and increase their varieties; 5) to improve labor conditions; 6) to lower cost of products; 7) to enrich and develop scientific and technical theories; 8) to gradually diminish the differences between physical labor and mental labor.

These objectives have been incorporated into the Third five-Year Plan, the details of which have not been published.

Admittedly all such statements regarding objectives are little more than generalities, but they give some idea of priorities and areas of emphasis.

Nature of Research and Development

It may be well to consider Communist China's practical R & D goals in terms of concepts familiar in the West—basic research, applied research, and development. Is it possible to fit Chinese research concepts into these common but comparatively loose categories?

Basic research is a relative term, and the lines between it and *applied research* are often vague and subjective. The American definition for basic research (*17*) makes a special provision for the profit-making organizations by including "original investigation(s) for the advancement of scientific knowledge . . . which do not have specific commercial objectives, although they may be in fields of present or potential interest to the . . . company." Ironically, to adequately describe China's limited basic research, one need only eliminate the word *commercial* and substitute *state* for *company* in the above definition.

In the case of applied research—research directed toward practical application of knowledge—the American specific definition relating to profit-making organizations (*17*) is again applicable, once the word *commercial* is deleted: "Research projects which represent investigation directed to discovery of new scientific knowledge and which have specific (commercial) objectives with respect to either product or process."

According to the American definition (*17*), "development is the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes." All the discussions and descriptions, in Chinese sources, of R & D activities indicate that most of the time and effort is expended in functions that would normally fall into the category of development.

Nevertheless, when one states the view that the volume of basic research in Communist China is insignificant, a frequent response is, "How can that be possible? They produced the Bomb!" The explanation is, simply, that the scientists directed to produce the Bomb had much of the necessary information already available to them. Many of the physicists were Western-trained, they had access to Western literature, and they had considerable Soviet assistance in the middle 1950's. In that sense, a large part of the R & D work involved in production of the Bomb could be considered almost developmental in nature. Other achievements periodically reported in the Chinese press as major scientific breakthroughs are seldom the result of true theoretical research, because in almost every instance the effort is mission-oriented. This statement is in no sense a disparagement of Chinese science but is, rather, an indication of the practical (from the Communist standpoint) philosophy that governs R & D activities. If in the process of pursuing the practical the scientists manage to stray and come up with new findings that extend knowledge but have no immediate practical application, the result may be considered a bonus (*18*). It is the American view (*19*) that "the basic researcher must . . . be able to dream and have faith in his dreams. . . ."; in the view of the Chinese Communist Party, the dream has no part in research.

Over the years, the proportion of basic research to total research seems to have fluctuated in direct proportion to the state's policies toward scientists. Apparently there is a natural pull toward basic research, experienced by most scientists. Whenever the regime relaxes its controls, the scientist drifts toward theory. The more liberal policies never seem to last, however, and are always followed by a harsh reaction in the form of a fierce ideological campaign directed against intellectualism and individualism—two derogatory terms which, to the Communists, have become almost synonymous.

Structure, Performers, Content

It is impossible to present a neat picture of the management and direction of the various institutions engaged in R & D activities. It is known, for example, that the Academy of Sciences with its research institutes is a major performer of research and development. Institutions of higher education not only maintain their own research facilities but also control some facilities that are administratively attached to them. Some universities (and their research facilities) are directly under the Ministry of Education in Peking, while some are under provincial and local administration (see Fig. 1). Research institutes are also maintained by industrial ministries and even by individual plants. To further complicate the situation, industrial ministries and some factories run specialized colleges. The multiple formal and informal controls within this elaborate system appear to be almost limitless. The confusion is accentuated by the numerous reorganizations and politically dictated shifts in management that have occurred over the last 15 years.

Presumably the Scientific and Technological Commission, which was set up under the State Council, sits at the apex of this tangled superstructure and is in some measure responsible for all R & D activities in the academies, in the institutions of higher learning, and in industry. At any rate, this commission, created in 1958 through the amalgamation of the Science Planning and State Technological Commissions, is the highest-ranking scientific and technological body on the mainland (*20*).

Under the Commission is the Chinese Academy of Sciences (Fig. 1), which remains the most important single center for scientific research and development. Through its five academic departments it controls over 100 research institutes. Still other research institutes are found under the regional branches of the Academy, which are located in every province and in most of the major cities. The branch research institutes are under the direct supervision of the provincial, scientific, and technological committees and, with few exceptions, are inferior in terms of both personnel and equipment.

In addition to the Chinese Academy of Sciences there are the Chinese Academy of Medical Sciences, under the Ministry of Public Health, and the Chinese Academy of Agricultural Sciences, under the Ministry of Agriculture. Both of these academies receive some guidance from the Academy of Sciences, share some of the top scientists with the Academy, maintain independent institutes, and operate some research institutes through the parent ministries.

Universities and other institutions of higher education maintain laboratories and other facilities and direct the work of specialized research institutes attached to them. Although there are some notable exceptions, the amount of R & D performed at the institutions of higher education is relatively insignificant as compared to the activities of the Academy and the industrial ministries and enterprises. Probably this is a reflection of the shortage of highly qualified personnel and modern equipment, the more competent personnel and the better equipment being concentrated in institutions which conduct full-time research.

An article in *China Reconstructs* (*21*) states, "In new China, the basic policy for scientific research is service to production." It is therefore not surprising that industry, which is charged with the building of China into a modern power through the "mass movement for technical innovation and technological revolution," plays a paramount role in Communist China's research and development. The National Planning Commission and the National Economic Commission share with the State Scientific and Technological Commission responsibility for much of the planning for, and control over, industrial R & D.

As mentioned above, there are various organizational units at the national, provincial, autonomous district, and municipal levels that conduct R & D in support of industrial needs. There are the research institutes under the direct control of the industrial ministries; there are laboratories and research facilities which are an integral part of the factory; there are specialized colleges which are run by the industries and which contain research facilities; there are also arrangements between plants and Academy research institutes for cooperation on specific research projects. More and more research institutes of the Academy of Sciences seem to be tying their R & D activities to the requirements of specific plants and industries. The evolving picture suggests that, within the system of close cooperation existing between the research institutes under the Academy, the institutions of higher education, and the industries, it is the latter that have the most direct control over much of the content and nature of research. This has been particularly true during the last few years.

Although the overall national R & D goals, like the economic goals, are established at the highest levels through the Scientific and Technological, National Planning, and National Economic commissions, many of the decisions regarding the content of research to be pursued at the plant and institute level are left to the local authorities. This relative freedom of decision at the lowest production levels runs contrary to the usual image of monolithic China, but it is evident in the commune, in the factory, and in the local executive committees. Again and again the leaders declare that research projects must originate from production and that researchers must formulate programs that are compatible with production needs. The authority is unquestionably implied, and sometimes clearly stated.

The functions and responsibilities of what Communist China calls the "design" sector extend considerably beyond what is generally included under "de-

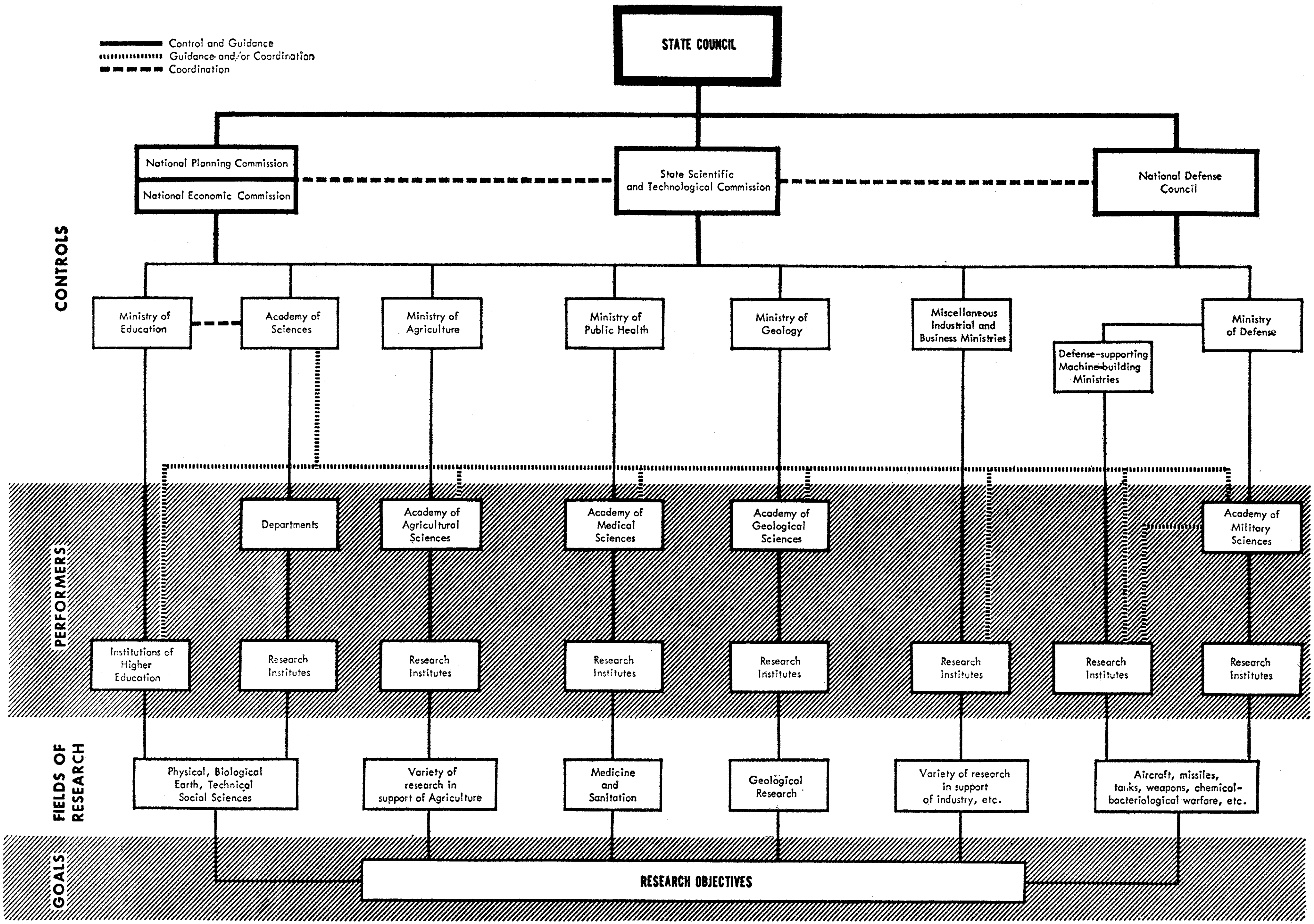

Fig. 1. Organization pattern for research and development in Communist China. The chart reflects more the presumed mechanics of operation than the formal organizational structure (*33*).

sign" in the West. In China, in some instances the terms *design* and *R & D* are used synonymously (*22*). In discussing new technology within the industrial sector, the Chinese speak of "seven barriers"—research, experimentation, design, manufacturing, testing, installation, and usage. According to a Chinese economic journal (*23*), the design sector, approximately in the center of this sequence of functions, understands more about current production needs and realistic conditions than the scientific sector does, and more about foreign technological conditions than the production enterprises do. The design personnel are therefore encouraged to participate in research and experimentation as well as in manufacturing and testing. They are also encouraged to "assign specific tasks" to scientific research units, institutions of higher education, and production units (*24*).

Much of the responsibility for design is relegated to the plant level; this may be construed as an indication of lack of industrial sophistication, for, as long as scientific and technical changes are initiated from the bottom, they are likely to be in the nature of improvements and minor innovations rather than major technological breakthroughs. Relatively little is said about the central design bureaus under the various ministries, which surely employ the more qualified personnel and are likely to be involved in more refined R & D. It is possible that their role is diminishing and that some of the personnel in the central design institutions have been transferred to the plant level, where they will be more aware of the practical problems of production.

Cooperation in research between industries, the universities, and the Academy research institutes has been part of the R & D system for years. The standard procedure, however, has been that of contractual obligation whereby a production enterprise transferred funds to a research institute or a university for work on a specific research problem. Undoubtedly contractual relations between the factory and the institute continue, but recently there has been emphasis on more and more informal integration of research. Thus, during the research and testing stage, personnel from a particular factory are sent to work at the research institute; when the product or device is ready for design, production, or installation, the research personnel from the institute are assigned to work at the factory. This is referred to as the "mutual dispatch of personnel" system.

This discussion would not be complete without at least a mention of military R & D. That the Chinese Communists have been engaging in the development, testing, and manufacture of modern military weapons and equipment is well known, but there is little to be learned from the mainland press with regard to military R & D.

Presumably, prior to 1958 military research was mainly conducted in a few of the suitable facilities of the Chinese Academy of Sciences. In 1958, through establishment of the Military Science Academy, the Ministry of National Defense took direct control over military R & D. The Military Science Academy, in addition to its own research activities, probably directs research in a number of specialized research institutes subordinated to it, some of them perhaps having been transferred from the Academy of Sciences when the Military Science Academy was created.

The ministries of Machine-building, which are responsible for the manufacture of military hardware (including aircraft and tanks) and of the more modern weapons which may be currently in production, must be among the most frequently reorganized institutions in Communist China. Like other industrial ministries, the Machine-building ministries maintain some of the research institutes and educational facilities, which also must be involved in some R & D activities, in many instances in cooperation with the Military Science Academy. In addition, much of the civil research performed in the country has military uses and implications.

Measurement of Research and Development

In view of the complexities of measuring the level of R & D in the advanced countries, it is not surprising that at present it is impossible to measure Communist China's R & D effort with any degree of accuracy. There are no figures on the number of persons engaged in R & D activities, no data on capital invested in R & D, no recent statistics on wages. What follows, then, are some highly qualified and occasionally impressionistic estimates that may help clarify the problems, indicate information gaps, and give a rough idea of the human and capital resources invested by the Chinese Communists in activities more or less conforming to U.S. concepts of R & D.

The volume and level of R & D is of course directly related to the number and competence of a country's scientists, engineers, and technical personnel. The shortage of professional and semiprofessional manpower in Communist China has been a stumbling block and matter of constant concern to the regime. Nevertheless, the progress that was made in expanding the educational system is impressive: it is estimated that, as of January 1965, 1.4 million persons on the Chinese mainland had completed some form of higher education (*25*).

In the analysis that follows I focus on the engineers and the physical scientists, or that body of specialized manpower which constitutes the true accelerating force of a country's scientific and technological development, overall economic growth, and power potential. Omitted from the analysis are research personnel in the life sciences, medicine, and agriculture. Much of the methodology is omitted from the text; unless otherwise stated, the figures are my own estimates (*26*).

It is estimated that, as of January 1965, there were 450,000 engineers in Communist China who had completed some form of higher education. In just 15 years the proportion of engineers increased from one-sixth to one-third of the total number of individuals with higher degrees. It must be pointed out, however, that among the 450,000 are a large number of graduates who are little more than technicians. As part of the "walking on two legs" philosophy, Communist China runs various kinds of higher technical schools—from a 2-year provincial engineering college to the Science and Technology University in Peking, which graduates highly competent engineers after 4, 5, or 6 years of training. It is therefore estimated that there are only 200,000 engineers with sufficient competence to participate in R & D work (*27*).

Whereas there has been a tremendous increase in the proportion of engineers in the population of individuals with higher degrees, the proportion of scientists has actually decreased—another indication of the practical nature of planning in Communist China. As of January 1965 there were an estimated 85,000 scientists in China, exclusive of scientists in medicine and agriculture.

Of this total, perhaps 55,000 are physical scientists.

How many of these engineers and scientists are actually engaged in R & D? As mentioned above, it is difficult to establish such a figure even for the West. Many scientists and engineers devote only part of their time to R & D activities, and even the individuals themselves would find it hard to say exactly when they are engaged in R & D and when in other pursuits. Because of the additional professional and political demands on such people in China, their time is probably even more fragmented. Furthermore, the already tenuous line between engineer and technician would be particularly elusive under a system which produces engineers that are little more than technicians and technicians who may achieve the title of engineer. Where so much of the R & D is production-oriented, it would also be particularly difficult to define the point where R & D stops and production begins.

One possible way to achieve a reasonably accurate estimate of the manpower involved in R & D is to consider each of the three major R & D sectors: research in the institutions of higher education; research at the Chinese Academy of Sciences and all of its branches; and industrial research (work at ministerial research institutes and factories) and R & D at miscellaneous research institutions.

On the basis of educational data, of miscellaneous figures for the size of senior research staff at the Academy of Sciences, and of other directly relevant or tangential data, it is estimated that there were 53,000 scientists and engineers involved in R & D in Communist China in 1965 (*28*). This total is comprised of 27,500 scientists and 25,500 engineers, of whom an estimated 4500 were in institutions of higher education, 3500 were at the Academy of Sciences, and 45,000 were in industrial plants, research institutions under industrial ministries, and other institutions.

In addition to the main body of scientists and engineers, two other major categories of R & D manpower have to be considered: (i) the technicians and laboratory workers (most of whom have at least a secondary education) and (ii) an auxiliary body of workers and employees who range from administrators to custodial personnel. Workers in these two categories are essential to the total R & D effort, and their numbers are important to an estimate of the total R & D wage bill. On the basis of some reported ratios for China and other countries, it is estimated that in 1965 there were 160,000 supporting technical personnel and slightly over 200,000 nontechnical supporting personnel, for a total R & D manpower of some 425,000 (including the 53,000 scientists and engineers). Admittedly the 8 to 1 ratio for supporting personnel and the engineers and scientists working in R & D is high, but this ratio is usually high for less advanced technologies.

In view of the many crude assumptions that had to be made in deriving the R & D manpower figure for Communist China, it would be foolhardy to place too much stock in the final estimate. Yet it is probably not unreasonable to expect the total manpower engaged in R & D in the engineering and the physical sciences to fall somewhere between 375,000 and 475,000.

Measuring the cost of R & D is a tenuous undertaking at best. The cost of research does not appear as an entry in national budgets, and decisions regarding the emphasis to be placed on R & D and the money to be spent on it are made by the department, ministry, or office most familiar with the research requirements, costs, and problems. The only directly relevant figures published by the Chinese Communists are those for the science budget, which are available through the late 1950's. Although originally most of the science budget went to the Chinese Academy of Sciences, larger and larger proportions of the growing science appropriations have been allocated for other uses. Thus, in 1957 the Academy received only 31 percent of the national science budget (*11*, p. 83); the remainder was designated for the support of research and the expansion of physical plant in various other institutions.

In addition to the science budget there are numerous other sources of funds for financing Communist China's R & D effort. For example, part of the scientific research at the universities is supported by appropriations for higher education; industrial ministries finance research in their institutes from operating budgets; most of the defense R & D is financed through the defense budget and through the Ministry of Defense; the Ministry of Public Health sets aside funds of its own for research; limited funds for scientific research are also probably expended by the local provincial and municipal governments. In many cases funds for specific projects may come from several sources, through contractual obligations and direct grants. It is apparently possible, for example, for the Academy of Sciences to provide funds for research done at one of the institutes of the Ministry of Defense at the same time that the Ministry of Defense is financing certain activities of the Academy.

Given the necessary information, the direct approach would call for analysis of all budgetary data in order to derive the cost of China's R & D. Since the necessary facts and figures are lacking, here I take a venturesome shortcut. I have tried to come up with some rough figure for the cost of the total R & D effort from the manpower estimates given above.

Over the years, the Communists have made a number of attempts to standardize the country's wage system, but all these attempts have been unsuccessful and there is little more wage uniformity in China's planned economy than there is in the capitalist countries of the West. The Chinese have not published any comprehensive wage scales for many years, but on the basis of available data it is estimated that in 1965 the total wage bill for R & D personnel was 468,960,000 yuan (*29*). Then, there are various incentives other than wages.

Although the Party line will never admit to it, the Communists have learned, from sad experience, that the way to insure harder work and higher production is to provide financial incentives rather than appeal to idealism (though idealism does exist to a significant degree among the young). There are bonuses for inventions and improvements, bonuses for hard work, rent allowances (or free housing), and other forms of incentives which require funds over and above the basic wages. For example, according to one plant manager, the bonus for superior workers amounts to 8 to 10 percent of the salaries and usually covers 8 or 9 percent of the workers (*30*).

Other expenditures that should be included with wages are specific funds set aside by individual enterprises for labor insurance, medical and health allowances, welfare allowances, and so forth. Bonuses, special wage allowances, and costs of other incentives must be considered part of the total wage bill, which is consequently increased by 15 percent, to 539,304,000 yuan.

The next question is, What proportion of the total R & D cost—which includes land, buildings, equipment, and office supplies as well as materials and processed goods needed to conduct experiments and development prototypes—do wages and salaries represent? In the West, wage and salary costs generally fall within the 40- to 60-percent range. Is this fact pertinent to the estimate for Communist China? Yes—if only to provide a base from which to speculate. This proportion would not change much with changes in the scientific and technological level of an individual country. In general, certain relationships hold: the less developed a nation, the smaller the scientific and engineering manpower resources, the lower the wages, but also the less sophisticated the equipment, the simpler the plant, and the less ambitious the goals. In China the situation is somewhat different. Short of capital, the regime attempts to extract the maximum contribution from its manpower resources at minimum cost. Although there are some built-in nonideological incentives, every effort is made to hold down the salaries of professional personnel in order to prevent a wide gap between their income and that of the ordinary workers and even the peasants.

On the other hand, China's R & D goals are considerably more ambitious than might be expected normally in a country of its economic development. The R & D effort in the area of consumer goods, for example, is small, but scarce resources are poured into research in heavy industry and advanced military technology. Thus, I assume the wage and salary cost, in China's R & D, to be at the bottom of the range, or 40 percent of the total R & D cost. On this basis, the estimate for total R & D cost in Communist China in 1965 is 1350 million yuan.

Is there any way to evaluate this figure—to determine whether it is "in the ball park"? Can it be compared with figures for other countries? Even with the most reliable R & D statistics international comparisons are risky and imprecise, due to differences in concepts, definitions, and data-collection procedures.

One common method of measuring R & D is to express it as a percentage of the gross national product. Since what is covered by the term *gross national product* differs from country to country, this method introduces an additional variable, but it avoids a conversion into dollars, and the cost of R & D is measured within a uniform fiscal and conceptual system. If Communist China's gross national product was 120 billion yuan in 1965 (*31*), the 1350 million yuan spent on research and development would constitute about 1.1 percent of it. If the R & D expenditures were not 1350 million yuan, they probably were within the range of 1200 to 1500 million yuan, and if they did not constitute 1.1 percent of the gross national product, they probably constituted between 1.0 and 1.2 percent. It would be unjustifiable to formulate far-reaching conclusions on the basis of these figures, often derived through rather strained assumptions. Nevertheless, the results do not seem entirely unreasonable, and I offer them in the hope that they may stimulate further discussion and more refined measurement.

Perhaps the most obvious explanation of why a relatively poor country such as Communist China would allocate so much of its scarce capital to R & D is the explanation that this is where the Chinese Communist Party wants to concentrate the country's resources. The Party is determined that China will achieve great power status as quickly as possible. Since, to her leader, "great power" is synonymous with "military power," much of the effort must be directed toward military R & D (*32*). There is no one to question the decisions and no one to suggest that the funds would be better spent in improving the living conditions of the people.

It is customary to conclude by considering the future, but it would be the height of folly to prognosticate about China at the height of the "great proletarian cultural revolution." The one thing that can be safely said is that the current developments on the mainland are not likely to improve China's status in the world of science and technology. The fanatical efforts to purge "bourgeois" thinking, the postponement of the new school term, the determination to increase the proportion of university students from peasant and worker families, and the insistence that peasant and intellectual alike cram into his head the writings of Mao Tsetung—all this must reflect adversely on all scholarly endeavors. The accentuation of the drive to fortify and extend this political control undoubtedly has exacerbated the already latent hostility between the political cadres and the scientists and engineers. These developments may not reduce the expenditures on R & D, but they are likely to affect the performance of the individuals engaged in R & D activities.

References and Notes

1. *Jen-min Jih-pao* [*People's Daily*] (24 Jan. 1966).
2. It must be remembered that, as a nation, China has a long and notable history of scientific research and achievement. See, for example, J. Needham's *Science and Civilisation in China* (Cambridge Univ. Press, New York, 1953–).
3. *Jen-min Jih-pao* (20 Jan. 1966).
4. New China News Agency, 9 June 1966.
5. *Ching-chi Yen-chiu* [*Economic Research*] **1965** No. 7 (20 July 1965); translated in *U.S. Joint Pub. Res. Serv., Pub. No. 34,015* (1966). The demand for self-reliance is only in part directed at international independence. Most of the propaganda was aimed at individual plants and enterprises. Self-reliance had evidently become such a fetish that "some enterprises, though located only a few streets apart and only a wall to separate them, stubbornly refuse to contact one another. Each minds its own business and shuns cooperation" [*Jen-min Jih-pao* (20 Feb. 1965)]. The situation got so bad that, in the spring of 1965, a big push for cooperation between enterprises was initiated.
6. See, for example, T. Hsi-en Chen, *Thought Reform of the Chinese Intellectuals* (Hong Kong University Press, Hong Kong, 1960); R. MacFarquhar, *The Hundred Flowers Campaign and Chinese Intellectuals* (Stevens, London, 1960). The most recent policies are described in J. Munro, *Current Scene* **4**, No. 11 (1966).
7. *Jen-min Jih-pao* (26 Feb. 1966).
8. *Ibid.* (13 Nov. 1965).
9. *Ching-chi Yen-chiu* **1965**, No. 11 (1965); translated in *U.S. Joint Pub. Res. Serv. Pub. No. 33,768* (1966).
10. *Ibid.* **1965**, No. 10 (1965); translated in *U.S. Joint Pub. Res. Serv. Pub. No. 33,403* (1965).
11. Cheng, Chu-yuan, *Scientific and Engineering Manpower in Communist China, 1949–1963* (National Science Foundation, Washington, D.C., 1965).
12. For example, in 1954, in 54 of the 61 courses offered in the science departments of Shantung University, Russian materials were used exclusively.
13. China's interest in Western science and technology is evident in the following incident, reported in the *Wall Street Journal* (5 Feb. 1965): "Not long ago the Massachusetts Institute of Technology library in Cambridge, which exchanges scientific publications with Red China, was briefly baffled by a Communist request for certain papers on atmospheric physics. It turned out that these were to be delivered at an MIT conference months away . . . ."
14. *Jen-min Jih-pao* (20 Jan. 1966).
15. A. Eckstein, *China's Economic Growth and Foreign Trade* (McGraw-Hill, New York, 1966).
16. *Ching-chi Yen-chiu* **1965**, No. 10 (1965); translated in *U.S. Joint Pub. Res. Serv. Pub. No. 35,070* (1966).
17. "Reviews of data on research and development, *Nat. Sci. Found. Pub. No. 33* (1962), p. 8.
18. There is an almost universal conflict between the people who provide the money for basic research and those who are involved in performing the research. It is human nature to expect concrete results and visible benefits in return for expended funds. Consider the following excerpt from an editorial in the New York *Times* (11 July 1966): "The long honeymoon enjoyed by basic researchers in the nation's university and other laboratories appears to be coming to an end. In both the White House and Congress more and more impatience is being exhibited toward research inspired by scientific curiosity rather than by the desire to solve specific well-defined immediate problems." The attitude of the impatient Chinese Communists should not be surprising.
19. H. Selye, *Saturday Evening Post* (24 Jan. 1959).
20. The highly placed chairman of this commission, Marshall Nieh Jung-chen, was recently purged by Mao.
21. *China Reconstructs* **1965**, No. 6 (1965).
22. Frequently, however, the category of "design personnel" includes not only workers in industrial design but workers in architecture, pottery, commercial art, and so on. It is this broad definition of design that makes it

possible for the Chinese to refer to "several hundred thousand design personnel" [*Ching-chi Yen-chiu* **1965**, No. 11 (1965); translated in *U.S. Joint Pub. Res. Serv. Pub. No. 33,768* (1966).
23. *Ching-chi Yen-chiu* **1965**, No. 11 (1965).
24. *Ibid.* **1965**, No. 9 (1965); translated in *U.S. Joint Pub. Res. Serv. Pub. No. 32,793* (1965).
25. After graduation of the 1963 class it was reported (New China News Agency, 14 Aug. 1963) that China had graduated "well over 1.1 million" persons from colleges and universities since 1949. "Post-liberation college graduates include 370,000 engineers, 325,000 teachers, over 110,000 physicians and pharmacologists, over 100,000 agronomists and foresters, and more than 70,000 natural scientists." To arrive at the 1965 estimate an attrition rate was applied to the 1963 data, and adjustments were made, to include persons who graduated prior to 1949 and after 1964.
26. Much of the basic information for these estimates is contained in the study by Cheng (*11*) and by L. A. Orleans, *Professional Manpower and Education in Communist China* (National Science Foundation, Washington, D.C., 1961).
27. There are thousands of experienced workers in China who have worked their way up through the ranks and attained the title of engineer with little formal education. Although excluded from consideration here, some of them may be engaged in R & D.
28. For a more detailed methodology see the original paper from which this article is adapted, in *An Economic Profile of Mainland China* (Joint Economic Committee, Washington, D.C., 1967), pp. 549–578.
29. Although, at the official exchange rate, $1 equals 2.355 yuan, such conversions are rather meaningless and I have avoided them. However, one might say, just for the record, that this figure is roughly equivalent to $110 million.
30. This statement is based on a conversation between Charles Taylor of the Toronto *Globe and Mail* and an official of a Tsinan factory, as reported in the New York *Times*, 8 Aug. 1965. It is precisely this system of incentives that is referred to as "economism" and is being attacked by the leaders of the Great Cultural Revolution. Presumably all incentives have been abolished at least for the present.
31. There are a number of series of estimates of Communist China's gross national product. This estimate is based on data shown in Y. L. Wu *et al.*, *Economic Potential of Communist China* (Stanford Research Institute, Menlo Park, Calif. 1964), vol. 3.
32. China's military budget is a puzzle in and of itself and is certainly outside the bounds of this inquiry. What proportion of the expenditures are in the area of R & D is a question difficult to approach from either the military or the R & D side. The cost of China's nuclear program, for example, is variously estimated at between 1 and 2 billion yuan—a reasonably broad range, considering the nature of the available information. The R & D share of this program should not constitute more than a fraction of the total.
33. Figure 1 is adapted from a chart prepared by Mr. Wang-chi, Science and Technology Division, Library of Congress.

Quasars: Rapid Light Fluctuations

Observed light fluctuations may provide evidence for a recently discussed mechanism for quasars.

W. H. McCrea

Surprising new discoveries about light fluctuations in a particular quasi-stellar object (quasar) may be interpreted as occultation effects, as Cannon and Penston (*1*) were the first to point out. With this clue, I use here the published observations to infer as much as possible about the structure of the quasar. The resulting model is remarkably like one I proposed for quite other reasons. If it is valid, it shows that a quasar may be regarded as an early stage in the formation of a system like the nucleus of a galaxy; at any instant, the optical radiation would come from one or a few temporary stars situated among a very large number of protostars, the occultations being caused by some of these. In the first place, the possible significance of the work is to show that features of these observations may soon lead to much detailed information about the constitution of quasars. Moreover, insofar as the present interpretation is correct, it strongly indicates that the quasar manifestation must be sought in an early stage in the evolution of the type of system considered here and not at a very late stage as suggested from time to time.

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Observational Data

Observations by Sandage (*2*) and by Kinman, Lamla, and Wirtanen (*3*) show that the optical brightness of the quasar 3C 446 was apparently steady during most of 1964 and 1965, that it began to increase in late 1965, and that by mid-1966 it was about 20 times brighter than in previous years. Since then, observations, including those of Wesselink and Hunter (*4*) and of Cannon and Penston (*1*), show rapid fluctuations of brightness. The agreement between the various sets of observations is good, but the picture obtained by combining them is more complex than that obtained from any one set.

The significant features of the rapid fluctuations appear to be the following; the first six were obtained by combining all the available luminosity measurements into a single "light curve." (i) The maximum brightness in every oscillation appears to be the same (about $m_{pg} = 16$) within the uncertainties of the measurements. Without more closely spaced observations, this is perhaps a safer statement than that of Cannon and Penston about the "flat top," although its significance may be similar. (ii) The minima attained seem to have significantly different values. In fact, the oscillations may be described as dips below 16^{m} with depths ranging from about 10 to 70 percent in brightness. (iii) In general, in any fluctuation, both the main fall and main rise in brightness are abrupt (lasting less than a day), and there is no evidence of asymmetry. (iv) During the almost 200 days of the observations, there were some ten clearly discernible dips. (v) A rough estimate of the fraction of the total time spent at or near maximum brightness is 50 percent. Again, a better estimate seems impossible without more closely spaced observations. (vi) Features (iv) and (v) imply that the average duration of a dip is about 10 days. (vii) The radiation in the optical continuum shows a high degree of polarization which does not seem to vary much throughout the observations, although the position angle of this polarization appears to fluctuate somewhat. (viii) Comparison with other quasars, and possibly with 3C 446 itself when it was first observed, shows that 3C 446 has been seen under circumstances exceptionally liable to manifest such fluctuations.