Tsukuba Science City: Japan Tries Planned Innovation

Justin L. Bloom and Shinsuke Asano

Summary. Tsukuba Science City is Japan's new municipal complex of research laboratories and educational facilities. About 30 percent of the nation's government research laboratories and more than 40 percent of its government research manpower are concentrated in the community. A brief history of the monumental project is presented and problems confronting the city are discussed.

Having been in the planning and building stages for more than 20 years, and representing an investment of about $5 billion of public funds, Tsukuba Science City is well known in Japan. It is almost unknown outside Japan, however, except to the handful of foreign scientists, engineers, and others who have visited the city or read about it in the few articles concerning Tsukuba that have appeared abroad. Even its name has been made obscure by the large number of variants that have been employed: Tsukuba Academic City, Tsukuba Newtown, Tsukuba Newtown for Science and Education, and Tsukuba Academic New Town are some of the English versions. The word Tsukuba refers to the location, about 60 kilometers north of Tokyo, where Japan has constructed a planned city designed to consolidate and relocate research and development facilities of the national government previously situated in the Tokyo area. In addition, and equally important in some minds, Tsukuba is the site for Japan's largest experiment in academic revitalization and modernization: Tsukuba University. By plan and in reality, the university and the 43 or so government research facilities located contiguously must be treated as a collective unit.

The Complex Rationale for Tsukuba

Tsukuba grew out of radical thinking about future directions of Japan and the need for change at a pace that would be revolutionary rather than evolutionary. One of the first driving forces was the concept of building a new town from the ground up, near enough to Tokyo to make one of the world's largest cities accessible but at the same time serving to assist in reducing its population. The idea came from planners at the National Land Agency and the Ministry of Construction.

In itself, the idea of constructing a new town was not original; other communities of this nature were also in the planning stage or under construction for a common purpose: to provide better and more economical housing for a country which had applied itself almost single-mindedly to postwar reconstruction of industrial and commercial facilities. Psychologically, the urban planners were faced with overcoming the great desire of the Japanese people to be part of the cultural and social life of the large cities located along the Pacific Ocean side of the island of Honshu—a region embracing Tokyo, Yokohama, Nagoya, Osaka, and Kyoto and containing more than 45 percent of Japan's population. Efforts by private developers to build new residential areas in other parts of Japan were foiled by this psychological barrier, greater extremes of climate to the north and south, and escalation of land values due to a combination of factors which included inflation, increases in real purchasing power, and legal and illegal speculation in land purchases by political and industrial figures.

Consequently, the national government took over a major role in the construction of new towns as suburbs of the larger cities. Among these are Tama New Town on the outskirts of Tokyo, Senri New Town close to Osaka, and Kozoji New Town in the vicinity of Nagoya. What distinguished Tsukuba was the idea of making it a science city, an idea attributed both to the late Ichiro Kono, a former Minister of Construction, and to Kuniomi Umezawa, a former Vice Minister of the Science and Technology Agency (*1*). While the primary motive was dispersion of the population of Tokyo (which increased from 3.5 million in 1945 to 11.4 million in 1970 and since then has remained relatively static), needs for modern research facilities and a new approach to university education were also apparent to central planners. A large number of government research institutions were located in the vicinity of Tokyo. With few exceptions, their physical plants were outmoded or unsafe and were not capable of research and development of the type and intensity that were becoming a critical part of the Japanese industrial and economic development scheme. The decision was made to move these institutions to new quarters in Tsukuba and to build additional laboratories that might otherwise have been situated closer to Tokyo.

Likewise, the national university system of Japan was undergoing reappraisal. Universities in the Western sense were a phenomenon of the Meiji Restoration of 1868 and were modeled after those in Europe. They were operated by the Ministry of Education of the national government and staffed by government employees. In the postwar era, when the imperial universities became national universities and private universities rose to play a competing educational role, the national universities were found to be behind the times by Japanese educators who had been exposed to modern practices, particularly in the United States. Despite considerable resistance from political and educational sectors, the Ministry of Education committed itself to an effort to create a new university philosophy in principle and in actuality by conducting an experiment on a large scale. It decided to transfer the charter of the old Tokyo University of Education—a national university engaged primarily in training secondary school teachers—to Tsukuba and to organize the university more along the lines prevalent in the United States: diminishing the power of chaired professors by strengthening the administrative management, providing better research facilities for undergraduate and graduate students, identifying research departments as distinct from

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educational departments, moderating the rigid entrance requirements of the national system (20 percent of the students at Tsukuba are enrolled on the basis of high school achievement rather than entrance examination scores), and appointing a relatively independent executive policy group (composed of the president and vice presidents for education, research, medical affairs, student affairs, and administration) to formulate university policies.

Birnbaum (*2*), formerly the National Science Foundation representative in the U.S. Embassy in Tokyo, wrote about these plans during the days when Tsukuba University was not yet in operation. Later in this article we will comment on the status of this experiment.

Brief History of the Project

In September 1963, the Japanese Cabinet designated the Tsukuba area as the site of Science City. The designation followed a few years of intensive study by the Prime Minister's Council for Science and Technology, which had recommended relocation of governmental research institutes to a site outside Tokyo "to provide a base for high-level scientific research and education in a new environment" (*3*). In 1966 the Japan Housing Corporation began purchasing land in Tsukuba. The area purchased totaled 1800 hectares, which had been in the possession of 2500 landowners. In June 1969 the Cabinet decided to build facilities for the institutions to be relocated under a 10-year plan starting that year. The decision was an ex post facto one, because in the previous year construction had already begun on a large simulator for earthquake experiments as part of a laboratory of the National Research Center for Disaster Prevention.

In May 1970 the Law for Construction of Tsukuba City for Research and Education passed the Diet. It established the basic policy concerning construction of the Science City. In March 1972 the Research Institute in Inorganic Materials—the first of the 43 institutions selected for relocation—moved to Tsukuba. In April 1973 the Cabinet decided to complete relocation of research laboratories and educational facilities by early 1976, but the target date was later changed to early 1980 when it became apparent that the optimistic initial plan could not be met because of a variety of budget and construction obstacles. In March 1980 all of the 43 research institutes and the university had been completely relocated and were functioning at varying degrees of capacity and efficiency (*4*).

Geographic and Demographic Aspects

The site chosen for Tsukuba Science City is not optimum. As so often occurs in Japan, it is the result of a consensus reached among many factions that may have divergent objectives. The right of eminent domain, although legal in Japan, was not exercised, and the large number of land parcels was acquired by negotiation of prices. The most reasonably priced parcels were those not particularly suitable for agriculture or other purposes, although the region is largely devoted to agriculture. Consequently, the area acquired by the government is highly elongated, stretching about 18 km from north to south and only 6 km from east to west at the widest point. The area encompassed is about 2700 hectares, of which 1500 hectares are designated for research and educational buildings and the remainder for residential and commercial construction.

The city is too far from Tokyo to be considered a suburb, but not far enough to force many of those who work in Tsukuba to sever their ties with the capital. Thus many of those employed in Tsukuba maintain residences in Tokyo or other cities and commute daily. Some senior officials can afford an apartment in Tsukuba and a larger home elsewhere, to which they commute on weekends. This is a sore point with the agencies that administer facilities in Tsukuba, since heavy investments have been made to provide modern housing within the city for everyone who wishes it. Often the quality of the housing available in the new town is substantially better than that elsewhere, but the pattern of commuting persists.

There is no train station in Tsukuba proper (an anomaly in Japan); the nearest train stations are in the towns of Tsuchiura and Arakawaoki and can be reached by bus or taxi. The trip by express train to Ueno Station in Tokyo takes about 45 minutes, and additional travel is needed to reach the suburbs of Tokyo. Automobile transportation is not reasonable, both because of the expense and because a trip to the southern part of Tokyo may take 2 or 3 hours in the usually congested traffic. It is also inconvenient to travel to the new international airport at Narita, about 40 km to the southeast, since there is no direct public transportation in that direction. Foreign visitors would be hard pressed to make the trip to Tsukuba after arrival at Narita unless their Japanese hosts provided a guide. These problems are recognized by everyone associated with the management of Tsukuba, and plans are being made to alleviate them. A national freeway from Tokyo to the northeast region of Honshu will have exits near Tsukuba when completed, and it seems certain that some kind of public transportation, such as a monorail or guideway transit system, will be introduced to link Tsukuba with the two nearby railroad stations. However, improvements in the transportation system will serve to perpetuate the commuter problem by making it easier for Tsukuba residents or workers to reach distant points.

Although part of this sociological problem derives from the characteristic personal association of the Japanese with the location of *furusato*, his ancestral home, there is little doubt that part of it is also due to the comparative lack of social amenities in Tsukuba that are found in the large cities: professional sports activities, concerts, theaters, restaurants, a variety of hospitals and clinics, festivals, historic places of interest, large department stores, and so forth. To the foreigner, however, Tsukuba may seem refreshingly modern, with wide streets, elaborate landscaping, and a general lack of congestion that is a welcome change from the industrial cities of Japan. In time, of course, Tsukuba will become the *furusato* for children born there and will acquire its own identity.

According to data from the National Land Agency, the population of the small towns and farms in the region surrounding the Tsukuba development area was about 78,000 in 1970. It is now about 100,000, and more than 23,000 people have moved into Tsukuba proper as the staff and families of the university and research institutes or as students. Staff members alone number about 11,400, of whom 6,500 are research personnel.

Is Tsukuba the Biggest and Best Science City?

The physical plant of Tsukuba Science City is impressive—in many ways overwhelming to the visitor seeing it for the first time (Fig. 1)—and one immediately tries to think of comparisons. We have not seen the Soviet equivalent, Akademgorodok and the related University of Novosibirsk, but H. Tanimura, an associate professor at Tsukuba University who visited Akademgorodok in 1953, found that the Soviet science city was similar to Tsukuba in having a major university, a number of scientific laboratories, and an almost equal number of working scientists. However, he also noticed a major difference. Whereas the laboratories at Akademgorodok were being "uniformly" operated and managed by a single entity, the Siberian chapter of the Soviet Academy of Sciences, Tsukuba institutions are under the supervision and management of many different government agencies, resulting in managerial inefficiency and, more important, in a lack of interaction between the institutions (*5, 6*). We could argue, however, that too highly structured an administration would reduce the competitive nature of some forms of research and stifle initiative. Probably a balance between the Tsukuba and Akademgorodok approaches would be optimum.

The Science City is divided administratively into five categories: (i) higher education and training, (ii) research institutes of construction, (iii) research institutes of science and engineering, (iv) research institutes of biology and agriculture, and (v) common facilities. The individual institutes and the university are managed and supervised by their parent ministries or agencies as shown in Table 1. The 43 institutions listed occupy 1653 buildings containing 1,788,860 square meters of floor space. It is not possible here to describe each of the facilities (despite many trips to Tsukuba, we have seen only a small fraction of the total plant), and we must therefore limit ourselves to a few specific descriptions of unique facilities or equipment and some more general observations.

Tsukuba University: In Operation but Not Yet Fully Accepted

Tsukuba University celebrated its seventh anniversary of operation on 1 and 2 November 1980 with an open house to show off its progress to the public (Fig. 2). One of us spent a day there on that occasion, touring a number of the laboratories that we had not visited previously and talking to officials and professors. Construction is almost completed. (In fact, some of the buildings constructed earlier are showing signs of excessive wear and tear, probably because insufficient funds are allocated to maintenance, a problem with all Japanese government structures.) Graduate and undergraduate schools are in full operation and some useful research results are beginning to emerge. Enrollment of undergraduates has reached 6556 and that of graduate students 1615, according to Nobuyuki Fukuda, the university president, who is a physicist by profession.

Discussions with other professors at Tsukuba, however, indicate that until some problems are overcome, the university will not achieve the quality ranking given to the leading national universities. The more open admission system, the generally lower average age of the faculty, and the availability of excellent study, research, and recreational facilities have not appeared to attract a student body that is more in rapport with the faculty and more acquisitive in seeking knowledge, as had been hoped. A foreign lecturer who served a 2-year ap-

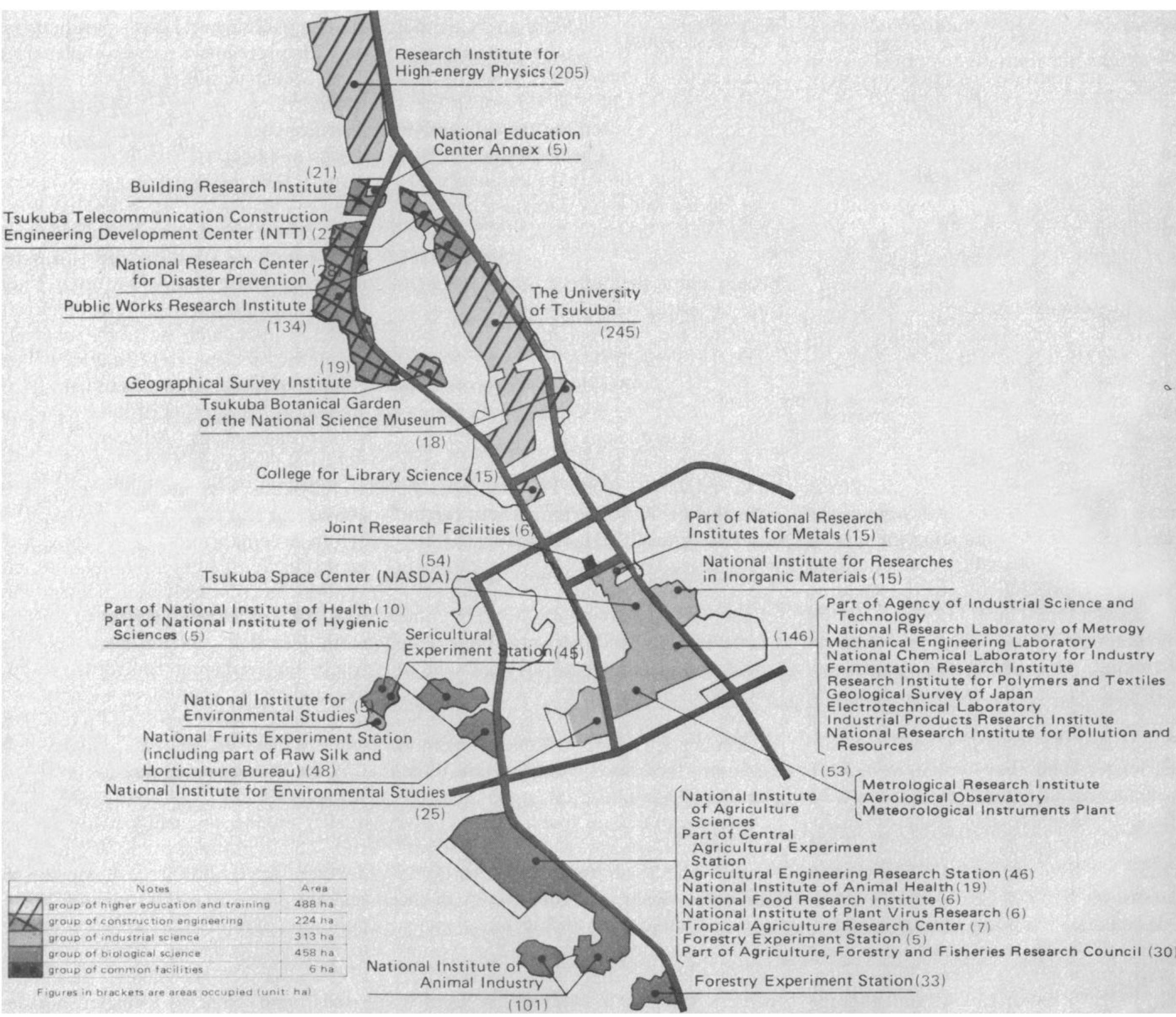

Fig. 1. Layout of the university and surrounding government research institutes in Tsukuba Science City.

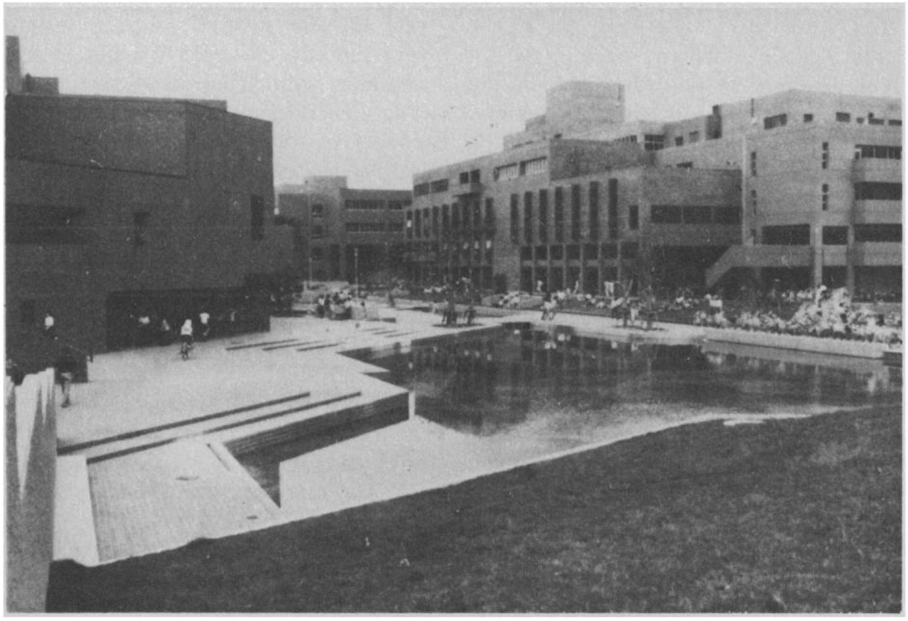

Fig. 2. Tsukuba University's administration building.

pointment at Tsukuba had the same impression as foreign lecturers in other Japanese universities: the students are extraordinarily passive and do not question statements made by their teachers or take the initiative in raising issues, except perhaps in highly informal, small groups. To do so would reflect adversely on the authority and intelligence of the teachers. Most students do not strive for academic excellence, which might isolate them from their peer groups. And the students do not appear to reflect their full capabilities in American-style quizzes and examinations.

Japanese professors at Tsukuba also complain about such factors as the isolation from Tokyo. Those whose families have moved to Tsukuba say they are disturbed by the fact that their children must attend public schools in which a large part of the enrollment comes from rural families with lower academic achievement levels, reducing the quality of primary and secondary education and making it more difficult for the children to compete for entry into high-quality universities. These kinds of problems are not unique to Tsukuba or to Japan and may be overcome in time, but Japanese society does not adapt quickly to social change and the adverse effects may linger longer than they would in a more dynamic social milieu. Thus we are inclined to conclude that some other devices will be needed to make Tsukuba University live up to its designers' aspirations.

It had occurred to us that the physical setting of the university and its modern equipment might be a great inducement for foreign scholars to go there, thereby making the university a unique attraction to Japanese students. However, there are apparently legal, budgetary, and other obstacles to this. Foreigners cannot become tenured faculty members at Japanese national universities, since by definition they would also be government employees, but attempts are being made to change this anachronistic barrier. Also, Fukuda noted that foreign scholars who do not know the Japanese language would find it uncomfortable to live in the Tsukuba community, and that this lack would inhibit their effectiveness in teaching or performing research, notwithstanding the fact that all Japanese students are taught English as a second language and that Japanese professors can communicate in English with various degrees of proficiency.

Another way to enhance the prestige of the university would be to increase the interchange of professionals between the university and the surrounding government research institutes. The rationale for Tsukuba Science City certainly included this as a goal, but it has not come about naturally and there may have to be some sort of contrived arrangement to accelerate the process.

The university occupies 245 hectares of Science City, and its educational and research facilities, including an ultramodern 600-bed hospital, are made available to the public for local, national, and international activities of an educational nature. The 26 research institutes of the university cover most disciplines of the physical, biological, and social sciences, from which the teaching staff is recruited. In addition, there are nine research centers (chemical analysis, computer, accelerator, animal research, mechanics, cryogenics, education, hydraulics, and isotopes). Together, these institutes and centers perform project- and problem-oriented research and provide opportunities for organized interdisciplinary research.

Research Institutes of the Ministry of Construction

A well-known characteristic of Japanese R & D is devotion to the experimental method and to the collection of massive amounts of empirical data which are of value in themselves or from which theories or theoretical extrapolations can be made. The two research institutes of the Ministry of Construction at Tsukuba exemplify this approach. We know of no equivalent elsewhere in terms of size, breadth of interest, or quality of facilities.

The Public Works Research Institute has existed in one form or another for 60 years. It is now the national center for civil engineering and deals predominantly with problems in river engineering, dam construction, erosion control, waste water treatment, highway engineering, structural engineering, and the design and operation of construction machinery. The institute consists of 48 identifiable buildings, test plots, or structures, some of which are truly striking. Dominating its 3-km domain is a paved test track more than 6 km long where design standards for roads can be evaluated. Factors such as traffic capacity, geometric design, road width, surface condition, traffic control, and lighting are studied in the context of kinematics and human engineering. Adjacent to one of the straight stretches of the track loop is a full-scale test tunnel, constructed above grade of reinforced concrete. It is 380 m in length and is used for experiments in ventilation, lighting, fire prevention and control, and noise reduction. Two other related sites are a pavement test field, where heavily loaded trucks under remote control move continuously (and eerily) over a looped road to evaluate the subbase; and a test track where a new system of dual-mode guideway buses is being evaluated.

Facilities for hydraulics and water quality engineering are equally impressive. The largest under-roof laboratory is devoted to hydraulics. A single-span building more than 200 m long with a floor area of more than 10,000 m^2 is used to empirically model mixing and diffusion processes in lakes, reservoirs, ponds, and bays. A smaller adjacent building houses a coastal hydraulics laboratory for modeling erosion, storm surges, tsunamis, and coastal pollution patterns. About 150,000 m^2 of the institute's area is devoted to an outdoor river model test yard, where experiments on a large scale (1:20 to 1:200) can be carried out on river channel improvement, problems of diversion and confluence, flood planning, and civil construction of revetments, bridge piers, and so forth.

A large variety of other test structures and laboratories are being used for studies in sanitary engineering, materials and structural engineering, soil mechanics, excavation and landslide engineering, foundation design, structural vibration, strong-motion earthquake observation, and aerodynamics (*7*).

The second of the ministry's two institutes is the Building Research Institute. Its functions are similar to those of the Building Technology Center at the U.S. National Bureau of Standards, but its facilities are more extensive. The Building Research Institute consists of 20 laboratories. Major ones include a large-structures laboratory, where horizontal static and dynamic loading tests are performed on full-scale buildings (up to eight stories) to study their resistance to ground motion; a full-scale fire test facility; a building elements laboratory; a building materials laboratory; an environmental research laboratory; a wind and rain testing facility; and a geotechnics laboratory. A unique facility at the institute is a center for training students from developing nations in seismology and earthquake engineering. So far, some 500 participants from nearly 50 countries have completed a 1-year course at the institute.

The Building Research Institute's major goals are disaster prevention, improvement of the living environment, development of new building construction materials and techniques, and improvement of the effectiveness of use of energy and other resources (*8*). Its newest attraction is an important experiment in the design of earthquake-resistant buildings being carried out jointly by the United States and Japan. With funding from the National Science Foundation, the Ministry of Construction, and the Science and Technology Agency, a full-scale, seven-story reinforced concrete building is being constructed on the test floor of the large-structure laboratory. It will be fully instrumented with strain gauges, accelerometers, and other instruments to measure the effects induced by hydraulic actuators applying stresses in a horizontal direction to simulate the ground motion of earthquakes.

Table 1. Staffing of institutions in Tsukuba Science City.

Government agency and institution	Research and development	Support	Total
Science and Technology Agency			
National Research Institute for Metals, Tsukuba Branch	64	7	71
National Research Center for Disaster Prevention	59	35	94
National Institute in Inorganic Materials	113	56	169
Tsukuba Space Center of National Space Development Agency (NASDA)	150	35	185
Research Communication Center	0	3	3
Environment Agency			
National Institute for Environmental Studies	200	36	236
Ministry of Education			
Tsukuba University	1431	1801	3232
National College of Library and Information	15	37	52
National Laboratory for High Energy Physics	229	100	329
National Education Center Annex	0	41	41
Tsukuba Botanical Garden of the National Science Museum	10	7	17
Ministry of Health and Welfare			
Tsukuba Primate Center for Medical Science	8	3	11
Branch of National Institute of Hygienic Science	4	11	15
Ministry of Agriculture, Forestry, and Fisheries			
National Institute of Agricultural Sciences	256	126	382
Branch of Central Agricultural Experiment Station	33	30	63
National Institute of Animal Industry	122	111	233
Fruit Tree Research Station	47	48	95
National Research Institute of Agriculture Engineering	69	37	106
Sericulture Experiment Station	199	99	298
National Institute of Animal Health	103	98	201
National Food Research Institute	94	26	120
National Institute of Plant Virus Research	32	18	50
Tropical Agriculture Research Center	53	19	72
Forest and Forest Product Research Institute	285	142	427
Tsukuba Office of Agriculture, Forestry, and Fisheries Research Council	0	85	85
Tsukuba Seed Testing Laboratory	0	9	9
Ministry of International Trade and Industry/Agency of Industrial Science and Technology			
Tsukuba Administration Office of AIST	0	75	75
National Research Laboratory of Metrology	121	66	187
Mechanical Engineering Laboratory	220	87	307
National Chemical Laboratory for Industry	299	103	402
Fermentation Research Institute	62	22	84
Research Institute for Polymers and Textiles	105	27	132
Geological Survey of Japan	223	135	358
Electrotechnical Laboratory	548	155	703
Industrial Products Research Institute	108	35	143
National Research Institute for Pollution and Resources	223	81	304
Ministry of Transport			
Meteorological Research Institute	140	42	182
Aerological Observatory	31	9	40
Meteorological Instrument Plant	19	5	24
Ministry of Posts and Telecommunications			
Tsukuba Telecommunications Construction Engineering Development Center of NTT	132	21	153
Ministry of Construction			
Geographical Survey Institute	0	660	660
Public Works Research Institute	310	186	496
Building Research Institute	121	59	180
Others			
Tsukuba Branch of Japan Information Center for Science and Technology	0	4	4
Tsukuba International Center Japan (International Cooperation Agency)	0	16	16
Marine Oil Pollution Central Research Institute	8	6	14
Japan Automobile Research Institute	136	143	279
Forage Research Institute	49	44	93
Experimental Farm, Japan Agriculture Research Institute	1	8	9
Total	6,432	5,009	11,441

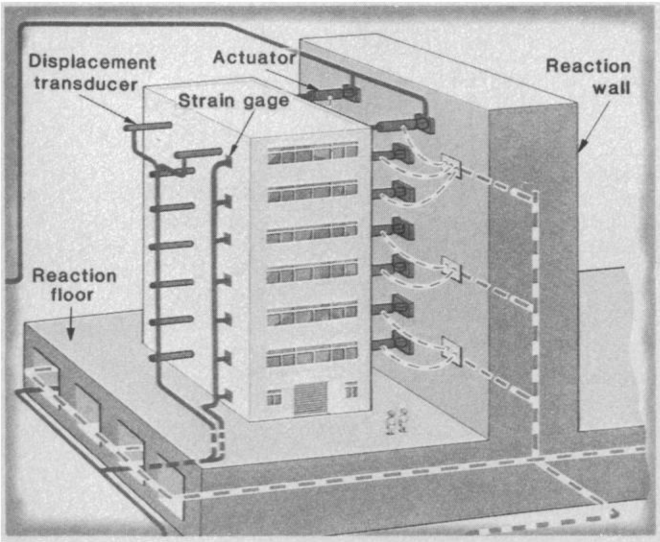

Fig. 3. Artist's concept of the testing facility at the Ministry of Construction's large-structure laboratory in the Building Research Institute. A full-scale, seven-story reinforced concrete building is being constructed within the laboratory and will be subjected to simulated seismic shocks by horizontally mounted hydraulic actuators. The actuators can produce forces in the range of 50 to 100 tons with displacements of the order of ± 30 to 100 centimeters, depending on their size. Displacement and strain measurements are acquired, stored, and read out by an elaborate computer system. The project is being carried out jointly by American and Japanese scientists.

Testing will begin in spring 1981 and will continue until the structure is damaged too severely for useful results to be obtained. Engineers, architects, and earthquake experts agree that tests performed on a full-scale structure will provide a valuable base of information for improving the design of industrial, commercial, and residential buildings in areas prone to earthquakes. The Japanese facility will be used to test the entire building unit; parallel tests of building subunits and assemblies will be conducted at U.S. facilities. Plans are being made to test other types of architectural designs in the same manner (*9*) (Fig. 3).

High Energy Physics in Tsukuba: Catching Up

Not all research in Japan is either applied or empirically based. Many Japanese scientists have had a long-standing interest in basic science, although they have not made the impact that they would have wished. To date, only three Japanese scientists have received the Nobel Prize: Hideki Yukawa, 1949 (physics); Shinichiro Tomonaga, 1965 (physics); and Leo Esaki, 1973 (physics). Esaki was a U.S. citizen at the time he received his prize. For one thing, the accouterments of big science have not been available to them indigenously and a number of them have gone abroad temporarily or permanently. Trying to catch up is difficult and frustrating, and perhaps it is debatable whether it is necessary.

High energy physics is a case in point. Cyclotrons and related equipment built in Japan before and during World War II were dismantled by occupation authorities in the immediate postwar era on the grounds that they might be used for nuclear weapons research. More than 10 years passed before high energy physics could function again as an experimental discipline, and by this time the United States, Western Europe, and the Soviet Union held commanding positions in the field. Only in 1971 could sufficient funds be mustered to form the National Laboratory for High Energy Physics, with the immediate objective of constructing a proton synchrotron at Tsukuba. All truly basic research in Japan is considered to be academic and is under the sponsorship of the Ministry of Education, Science, and Culture. The high energy physics center was no exception, but it was unusual in that it was the first basic research institution to be independent of a national university but have the same status as a university. The center is referred to by the acronym KEK (for its Japanese name, Ko-Energi Butsurigaku Kenkyusho).

The synchrotron was completed in 1976, when a proton beam energy of 8 billion electron volts (8 GeV) was obtained. The beam energy was later raised to the design figure of 12 GeV. Improvements in equipment and operating methods have raised the beam intensity to 4×10^{12} protons per pulse, 200 percent of the design figure. A synchrotron radiation "photon factory" is now under construction at the KEK site. It will consist of a 2.5 GeV electron linear accelerator (linac) which injects into a storage ring 55 m in radius (Fig. 4). Total radiation power is estimated to be 265 kilowatts at wavelengths from 0.1 to 1000 angstroms.

In a logical next move, plans are being made to build a versatile colliding-beam facility with a circumference of 3 km, using the proton synchrotron and the electron accelerator as primary injectors. This project is called by the euphonious name of Tristan (for Transposable Ring Intersecting Storage Accelerators in Nippon), and at various stages of development and construction will be able to study electron-positron, positron-proton, and proton-proton interactions by selection of beams from a set of concentric storage rings and other devices (*10, 11*).

KEK was relatively ignored by foreign physicists until a few years ago, but it is now drawing some international attention. A well-thought-out cooperative research effort has been established under the sponsorship of the Ministry of Education and the U.S. Department of Energy (DOE), with senior scientists such as Wolfgang Panofsky of Stanford, Leon Lederman of Fermi Laboratory, R. W. Birge of Lawrence Berkeley Laboratory, and James Leiss and Bernard Hildebrand of DOE representing the American side. Japan's most distinguished high energy physicist, Tetsuji Nishikawa of KEK, leads the Japanese team.

Space Research and Other Activities

The creation of the National Space Development Agency of Japan (NASDA) in 1969 as an organ of the Science and Technology Agency occurred just in time to permit NASDA to be one of the first to complete a major laboratory at Tsukuba. The Tsukuba Space Center is the focal point for acquisition of satellite tracking data from other stations and it performs the testing and shakedown of satellites and launch vehicle components prior to launch. Although not the equal of NASA's Goddard Space Flight Center or of Caltech's Jet Propulsion Laboratory, it has capabilities commensurate with the size of Japan's space applications program. (Incidentally, in Japan space science research is considered academic and is under the Ministry of Education. A national Institute of Space and Aeronautical Sciences operated by the University of Tokyo is located in Tokyo. For reasons not at all clear, this institute has not been relocated in Tsukuba, although it badly needs new quarters.)

The Tsukuba Space Center houses a variety of types of advanced test equipment, the largest of which is a fine thermal vacuum chamber for simulating the space environment. It was built under the technical direction of Jet Propulsion Laboratory.

Throughout the other research centers of Tsukuba one can find examples of the finest laboratories and laboratory equipment. We cannot describe everything here, but list a few more examples below:

1) There are about 35 wind tunnels in Tsukuba.

2) About 50 electron microscopes have been installed, the largest of which, a 1-million volt machine, is located at the National Institute for Research in Inorganic Materials.

3) The National Research Center for Disaster Prevention has the largest shake table in the world, with a test bed measuring 15 by 15 m. It can handle weights up to 500 tons for horizontal accelerations up to 0.55*g* and up to 200 tons for vertical accelerations up to 1.0*g*. Within the limitation of a maximum amplitude of 60 millimeters, historical records of actual earthquakes may be simulated with the machine.

4) A laser radar and other types of meteorological equipment are in operation at the National Institute of Pollution Research.

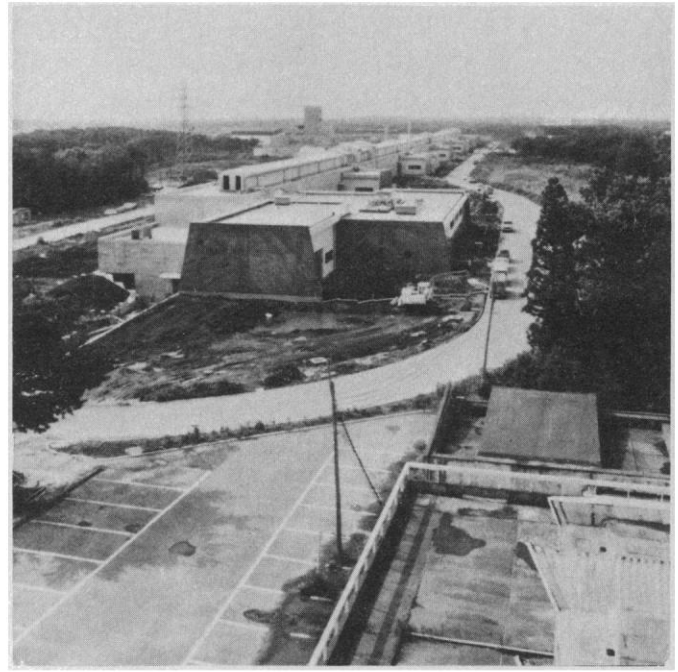

Fig. 4. The 2.5 GeV electron linac building in final stages of construction at the National Laboratory for High Energy Physics (KEK), Tsukuba.

The Tsukuba Government-Industry Focal Point

Of all the government ministries represented at Tsukuba, the Ministry of International Trade and Industry (MITI) is the one most pervasive in its contacts with and influence on private industry and most familiar to students of the close government-industry relationship that exists in Japan. Although the term "Japan, Inc." used so often by foreigners is incorrect in describing the relationship, MITI's functions do typify the harmonious interactions between the two sectors of the society. In the sense of technological cooperation, MITI's Agency of Industrial Science and Technology (AIST) is the link between government and industry. AIST has the status of a semiautonomous entity, dependent on MITI for its budget but relatively free of higher technical direction. Its director-general, Seiichi Ishizaka, is a former science counselor of the Japanese Embassy in Washington and is well known to many Americans engaged in technical management.

Nine of AIST's 16 research institutes or laboratories were moved to Tsukuba in 1979 and 1980. We have not yet visited these institutes in their new quarters, but have heard reports from others which describe them as impressive and probably unique. Ernest Ambler, director of the National Bureau of Standards, and Edward Brady, his associate director for international affairs, found many similarities between the bureau's laboratories in Gaithersburg, Maryland, and AIST's Tsukuba operations, particularly in metrology, standards development, and materials testing (*12*). However, AIST is much more involved in applications than is the Bureau of Standards. For example, AIST has the governmental responsibility for conducting—or sponsoring in industry—the development of non-nuclear energy technology and energy conservation technology. Only a fraction of the work in this particular field is within the Tsukuba complex because of the nature of the facilities required for large-scale demonstration. The Electrotechnical Laboratory (ETL) at Tsukuba, for example, did not move its large magnetohydrodynamics project there and instead is constructing a 100-kilowatt machine at its laboratory in Hyogo Prefecture, in western Japan. ETL is the best-known of the AIST laboratories and has established a large and elaborate complex at Tsukuba equipped with the latest in research instruments, including a 500 MeV electron linac (*13*).

More exotic, however, are some of the other advanced projects at AIST Tsukuba that are not directly related to alleviation of the energy problem. Some of these are discreetly identified as "large-scale projects," meaning that they have been selected because of their importance in solving urgent national problems. One such project that will approach the pilot plant or demonstration phase within the next 6 or 7 years is beginning to attract international attention. Given the cumbersome name of "Flexible Manufacturing System Complex Provided with Laser," or FMC for short, it is an attempt to make a quantum jump in a field already advanced in Japan: automated manufacturing with robotics and other labor-saving devices or processes (Fig. 5). AIST's Mechanical Engineering Laboratory is responsible for FMC, and it has drawn in the big names of Japan's manufacturing industry as consultants and perhaps partial investors. The announced government budget is about $15 million a year at present. The part of the project involving lasers is particularly interesting. Attempts will be made to integrate a continuous-beam 20-kilowatt carbon dioxide laser into the complex to perform metal cutting and welding operations. Other lasers will perform measurement and inspection functions. AIST has been reluctant to reveal details of the complex, probably because of proprietary interests but also because of the large uncertainties about bringing it to a successful conclusion (*14*).

The other Tsukuba institutes of AIST are engaged in national projects and applied research activities too numerous to list. However, the question always arises among foreigners as to the need for performance of industrial research in gov-

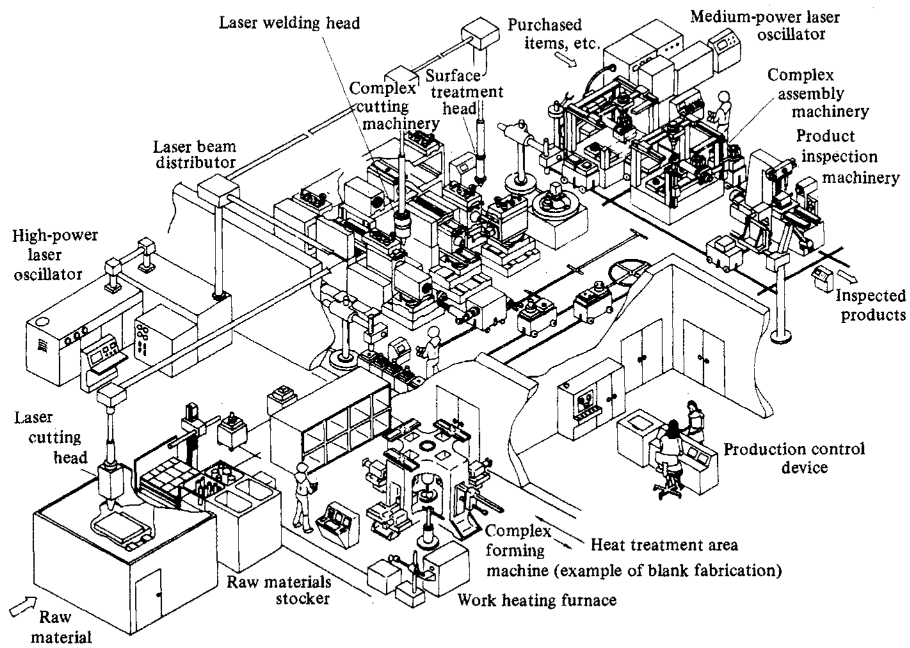

Fig. 5. Conceptual example of a highly automated manufacturing system employing a 20-kilowatt carbon dioxide laser for cutting and welding operations. Components for such a system are under development by the Mechanical Engineering Laboratory of AIST.

ernment laboratories of this kind. Private industrial research is highly advanced and dominates Japan's overall R & D picture. It is certain, however, that the AIST laboratories make a broad contribution to the advancement of industrial technology, as evidenced by AIST's collection of about $1 million in royalties during 1979 for the use of its patents by more than 600 Japanese companies.

Some Other Problems Facing Tsukuba

We already have enumerated some problems faced by Tsukuba, but there are others that warrant mention. Tsukuba is a social experiment as well as an attempt to accelerate innovation, and most of its problems derive from the rigidity of social values in Japan.

One of the characteristics of the Japanese government is its extreme vertical integration. Government agencies do not communicate well with each other, and jealousies abound as they compete for desirable programs and necessary funds. This can be seen vividly at Tsukuba, where very few facilities are shared and there is consequently an excessive duplication of equipment (electron microscopes and wind tunnels, for example). This does not escape the notice of the people involved, but they are inclined to accept it philosophically as the way things are in Japan. It remains to be seen whether the scientists themselves take the initiative and communicate better than they did in their previous surroundings.

There is a shortage of trained professionals to man the fine research laboratories. The existing staffs consist in part of borrowed rather than permanently assigned scientists or engineers. As a result, many of the laboratories are underutilized. We were unable to determine whether this is due to budgetary limitations (there is a freeze in effect on the hiring of additional government employees) or to inability of the institutes to attract personnel to Tsukuba.

One of the objectives of the Tsukuba concept has been to draw industrial research centers to the vicinity of the Science City, encouraging a greater exchange of people and ideas. So far, this has not worked as well as expected. Perhaps private companies fear that they will experience the same personnel problems as the government laboratories. Intel Japan (a U.S.–Japanese joint venture company in the semiconductor business) and Eizai (a Japanese pharmaceutical manufacturer) have constructed new laboratories in the Tsukuba area, and undoubtedly more will follow with suitable inducements from the central government. An indicator of such an effort may be found in the fact that the Japan Automobile Research Institute, a nonprofit organization supported by the automobile industry but probably also dependent on MITI or the Ministry of Construction for financial assistance, has constructed an elaborate proving ground and laboratory on the outskirts of the Science City, although most of the automobile manufacturing plants lie in the belt between Tokyo and Osaka.

To Tsukuba in 1985

Notwithstanding the enormous monetary investment that has already been made in Tsukuba, it is clear that more will need to be done before the city becomes a way of life to its inhabitants. Those concerned with the success and welfare of Tsukuba—politicians, administrators, urban planners, industrialists, and science managers—have reached the typical Japanese consensus on the next step. It is to hold an international science and technology exposition at Tsukuba in 1985. The idea of holding an exposition is said to have come from a senior official of the Science and Technology Agency, who wished to see a large public-oriented project undertaken by the national government which would stress the positive aspects of science and technology.

In November 1979 the Cabinet approved the concept of a science expo and planning funds were authorized in the 1980 national budget. A government-industry association to manage the project was created shortly thereafter, with the well-known industrialist Toshiwo Doko as chairman. The association already has a staff of almost 50 collected from various agencies and companies. Within a year the number will double as general planning moves toward detailed design. In November 1980 the expo was registered as an international event and approved as such by the Bureau of International Expositions in Paris (*15*).

The scale of the expo is as formidable as that of Tsukuba itself. It is estimated to cost in the range of 200 billion yen ($1 billion at current exchange rates), requiring financial participation by the national government, Ibaraki prefecture (where Tsukuba is located), and private industry. The names of those involved in supporting it constitute a Who's Who of Japan.

Rules for holding a formal international exposition require that it be of universal interest but with a specific theme. Foreign participation must be encouraged and permitted. Because of potential conflicts with other expos in the planning stage, the Japanese have selected "Dwellings and Surroundings—Science and Technology for Man at Home" as the theme, which admittedly does not sound too exciting from a scientific viewpoint but which may be a drawing card for the general public. Under the rules, Japan will construct pavilions for foreign participants at no cost to them. Part of the cost of the expo will be recovered through admission fees, but it can almost be guaranteed to lose money. Attendance of about 20 million is anticipated over the 6-month duration of the expo, and the organizers hope that as many as 1.5 million foreigners will come to Japan to attend it.

Ibaraki prefecture is responsible for purchasing land for the expo site from a large number of small landowners. The site is contiguous with the Science City and lies to the south and west. Some thinking is already being done about how the land and buildings might be used afterward. The prefecture wishes to see the area become an industrial park, and there is also talk about additional scientific projects or a museum complex. Planning for the expo will have to take into account the lack of certain amenities in the Science City. Hotels and restaurants, improvements in the road and train system, and increased entertainment opportunities will be needed. There is little doubt that the many visitors will take the opportunity to inspect the Tsukuba scientific complex. The burden to be borne by the residents will be heavy.

Japan has had mixed success with similar expositions in the past. The Osaka expo of 1970 was a success, including the establishment of Senri New Town. The Okinawa Ocean Exposition of 1976 was a technical success but failed to meet financial expectations. Whether these experiences and the different driving force for the Tsukuba Science Exposition will lead the latter to a successful conclusion is uncertain at this time, considering the scale and number of the difficulties involved. However, one thing is certain: Tsukuba Science City will be on the map after 1985, and its identity crisis may be solved.

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17. We are indebted to a large number of colleagues, both Japanese and American, not otherwise cited here, for their encouragement and cooperation in the preparation of this article. Although we take the risk of overlooking someone, we would like to mention in particular Philip Abelson, who visited Japan in 1980, was impressed by what he saw at Tsukuba, and asked that the article be written; Nobuyuki Fukuda, the president of Tsukuba University; Masatoshi Yoshino, Department of Geography, Tsukuba University; Hitoshi Aizawa and Kenichi Murakami, senior officials of the Japan Association for the International Exposition, Tsukuba, 1985; Roger Gale, now with *Energy Daily* in Washington, D.C.; and our patient, hard-working secretaries, Coreen Gusha, Tamaki Sasaki, and Joyce Uchida. Our scientific colleagues in the Embassy, Ebert A. Ashby (NSF Tokyo), Young B. Kim (ONR Tokyo), and Leon H. Fisher (ONR Tokyo), provided valuable advice and background information.