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China's S&T Information Policy Discussed

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[Article by Qiu Yunping [6726 0971 1627], Department of Information Science, Harbin University: "Some Issues in Information Policy in China"]

[Text] Abstract. The current status of information policy in China, as well as problems and their causes, are discussed, and the principles, system structure, procedure and content of research on information policy are examined, along with the main current tasks and measures.

Information policy consists of the guiding principles and standards of procedure that are formulated with reference to the organizational and management principles of the information field in order to achieve specific objectives and solve objective problems. It consists of the strategic and tactical principles that determine the direction of development of the scientific and technical information field and guide all information activity. In general terms, its subject matter includes the study, drafting, implementation and evaluation of information policy. Under the current new situation, comprehensive, profound research on problems of information policy in China and the improvement and implementation of correct information policy constitute both a major topic of theoretical research in information science and an urgent and arduous task that China faces in developing the information field. Based on this understanding, the present paper attempts a preliminary investigation of information policy in China.

1. Current Status and Problems of Information Policy in China

The problem of information policy is a basic problem that permeates the entire development of the information field. China's scientific and technical information activity began in 1956, and experience indicates that its development requires the support of policy. In the last 30-odd years, the functional and administrative departments concerned with scientific and technical information, and such organizations as the Chinese Institute of Scientific and Technical Information, have conducted research on information policy and have made great efforts in drafting and implementing a series of correct information policies in each historical stage, which have promoted the development of information activity in China. For example, in 1956, the document "12-Year Long-Term Program for Scientific and Technical Development," drafted with the leadership and support of Premier Zhou Enlai, clearly stated China's tasks in the scientific and technical information field, then established a top-to-bottom information management system with unified duties and functions, thus constituting a vertically and horizontally organized national information circulation network. The "Program for Scientific and Technical Information Activity" issued by the State Council in 1958 was an important policy document of epoch-making significance. The first national science and technology information conference stated the requirement that scientific and technical information must give extensive, rapid, precise, correct service to socialism; the second conference, held in 1961, expressly affirmed it as China's general policy on scientific and technical information activity. In 1963, the national 10-year program for scientific and technical information gave a timely statement of the entirely new topics of machine retrieval, machine transformation, microforms, and reproduction technology and organized research and vigorous practical efforts for the modernization of information activity. In response to the shift in the national focus of activity, the fifth national scientific and technical information conference, held in 1980, stated the new policy that scientific and technical information activity must effectively serve economic development and gave timely guidance for the development of the information field in China. In 1984 the State Council announced the creation of the State Science and Technology Commission Information Office, which had the responsibility of formulating nationwide general and specific on scientific and technical information activity, with the result that the study, formulation and management of information policy in China took a turn for the better. The international scientific and technical information policy conference and the symposium of domestic experts that were held in 1986 by the State Science and Technology Commission Information Office expounded the problems of state information policy and issued the document "Key Points in China's State Scientific and Technical Information Policy." At the same time, the information-consciousness of Chinese society has increased considerably, understanding of information activities is growing by leaps and bounds, and the awareness that information activity is a major activity of strategic importance to overall development is gradually increasing. Thus, we may state that a certain foundation for information policy has now been laid down.

But we must also be clearly aware that China's information policy is still not capable of meeting the entire society's requirements regarding information activity of the development needs of the information field itself under the new circumstances. Strictly speaking, China's information policy system still has not fully taken shape, research in the field is rather behindhand, and policy benefits are still not adequate. The main problems in this area are as follows.

a. The guiding concepts are not sufficiently liberated and there is an overemphasis on stability; the reform of the information system and the opening up of policy are proceeding slowly; and to a certain extent, there is still a problem of inadequate understanding and of halfhearted leadership.

b. The information policy research system is inadequate, and the responsibilities of the organizations and personnel are unclear; information-science academics have not been sufficiently involved in it and have not had a chance to discuss it thoroughly. As regards the subject matter of research, investigations of the theory of information policy and of policy conceptions has been entirely lacking, so that the line of demarcation between policy and theory is rather blurred, which has created certain difficulties for information reform and information activity. For example, there is no theoretical guidance regarding the compensated information services that are universal in the information field, policy provisions regarding them are not sufficiently clear, and personnel working at the basic levels are afraid that they do not understand them clearly and implement them correctly, so that in some cases they are hesitant to act. There is insufficient quantitative analysis of research methods and policymaking procedures, so that there is a danger of their being influenced by subjective and artificial factors, and there is an urgent need to make them more scientific and standardized.

c. The information policy system has not fully taken shape, and the relevant policy mechanisms need improvement; information policy is not sufficiently legislatively mandated, stable or authoritative. To date, there are no legislative documents that give a systematic article-by-article survey of China's information policy. As a result, information activities have thus far been hesitant and changeable owing to changes in the political situation or shifts in organizational leadership, and progress in the information field has suffered.

d. In the process of drafting and implementing information policy, as a rule the focus is only on formulating policy clauses, and the necessary inspection, oversight and implementation work are neglected. For example, meetings, surveys and work reports have an insufficient policy content; the functional departments and publications very seldom deal with problems of information policy; and in certain cases no one checks to see that higher-level policies are being carried out on the lower levels.

e. There is a definite gap between Chinese information policy research and that in other countries. In recent years, many countries have attached great importance to information policy research and have drafted uniform information policies in order to improve the management of information activities and to increase their effectiveness. Currently, the international information community regards the drafting and implementation of information policy and the evaluation of its effectiveness as one of the four major trends in the information field. China's behindhandedness in this area is expressed primarily in such respects as information-consciousness, the place accorded to information activities, the degree of sophistication of information policy, and the scientific character of policymaking methods. For example, internationally, scientific and technical information has been regarded as a "secondary resource," or it is even thought that "economic progress depends on science and technology, and scientific and technical progress depends on flexible scientific and technical information." Some developed countries recognize and establish the position of information activities in terms of the intrinsic connections and mutual constraints of the above three factors and consequently make the development of information activity a basic state policy and fix it in legal form as a basis for guiding and managing information activity. But some Chinese information policy documents fail to treat this matter at a sufficiently high level or thoroughly enough.

The above problems have two main causes, namely, factors internal to the information system and external influences and constraints. Subjectively, there are problems of understanding and problems of information policy research and policy activity, but the major problem is the influence of the social environment and the constraints of objective conditions. China is in the initial stage of socialism and in the key period of reform, and its entire social structure and economic system are being altered. In the new situation, the new and old systems are intertwined and coexist; state information policy, economic policy and production policy will all influence each other, and some overall policies and programs will be temporarily unclear. These external circumstances unavoidably have an affect on information policy. At the same time, such basic problems as the information management system and society's information-consciousness can also constrain the improvement and development of information policy.

2. Principles of the Formulation of Information Policy in China

Policy formulation is an important aspect of information policy in China. To formulate a correct information policy, not only must the various internal relationships within the information field be correctly handled, but in addition the interconnections and mutual effects of information policy with scientific and technical policy, economic policy and social policy must be harmonized. As a consequence, the following principles must be followed in drafting information policy in China.

a. Consistency With Other Policies. Because scientific and technical information is an important state activity, information policy is unquestionably an organic component of state policy. Thus, information policy must follow state political principles and submit to the requirements of the state's development of science and technology and invigoration of the economy. In other words, information policy must be consistent with other state policies such as scientific and technical policy and economic policy.

b. Scientific Character. Research in information science makes it clear that the development of the information field and information services has its own inherent laws, characteristics and scientific standards. When drafting information policy, a conscientious effort must be made to investigate and strictly adhere to the laws of information activity, because this is the only way to draft correct information policy that is in accordance with objective laws. If, instead, we proceed only in terms of subjective wishes and fail to consider objective laws, the information field will encounter setbacks and will fail as a result of policy errors. When drafting information policy scientific methods should be selected and used in order to assure that information policy is highly scientific and correct.

c. Specificity. The consideration of information policy must focus on China's circumstances and actual requirements and on its different objectives and tasks in order to draft a Chinese-style information policy in accordance with China's distinctive circumstances. Countries differ somewhat in their information management systems and patterns of work, and differ greatly in their information-consciousness and information requirements; as a result, every country formulates and implements an information policy based on its own realities. For example, because such developed countries as the United States and Japan possess economic power and a strong scientific and technical base and have both the urgent need and the ability to develop high technology, they have formulated information policies that encourage the collection and analysis of technological information. On the other hand, certain developing countries have an urgent need for applied technology, and their policies therefore encourage the provision and analysis of applied technology information. In China, we must make an integrated analyses of the country's information management system and information management model, the foundations of information work, the society's information-consciousness, user information requirements, existing information collection practices and the like. Only by consistently taking realistic approach will it be possible to formulate a practicable information policy that is reasonably consistent with China's real circumstances. The implementation of such an information policy will be relatively smooth. Note that in addition to emphasizing the principle of specificity when drafting state information policy, we must also adhere to the principle when considering regional or departmental information policies.

d. Integration. Information policy is a policy system that is made up of overall policy and various specific policies. It is obvious that there are necessary relationships between the various policies. Although the specific objectives, subject matter and range of application of the various policies may differ, they must all be subordinated to the general orientation, general objective and general task involved in developing the information field. They should be mutually complementary and mutually supportive. Consequently, when drafting specific information policy, we must proceed with reference to the information field as a whole, with integrated consideration and analysis. For example, when drafting a policy on contracting activities by information organizations, consideration must also be given to the policy on funds allocation for the information field, policy on compensated information services and the like. This is the only way to realize the overall benefits of information policy.

e. Fairness. Policies generally affect individuals, groups and schools of thought. According to the principles of fairness, a fair approach must be taken when drafting or implementing information policy, so that the affected groups or individuals receive their proper benefits without any partiality; overall plans must be made, and consideration of one aspect at the expense of another must be avoided. For example, the principle of fairness must be followed when drafting information policy, policy on distribution of benefits, and technical promotions and awards policy. Only a fair policy can help to find a rational solution to problems and effectively motivate information personnel.

f. Stability. In a specific historical period and under specific policy preconditions, information policy must maintain relative stability, avoiding frequent or arbitrary changes. A stable information policy helps to increase the sense of responsibility of information organizations and personnel toward the policy and enhances the authority of the policy, and avoidance of vacillation and of detours will assure that the information field in China will develop in healthy fashion.

g. Continuity. Information policies drafted at different times must have continuity. If every advance in information activity, information work and the information field is inseparably connected with the original foundation, there will be appropriate continuity; consequently, when we draft new information policies, we must consider the original policy foundation in order to maintain definite policy continuity. If today's policy departs too much from past policy, so that there is a discontinuity, then the new information policy is unlikely to be successful.

h. Adaptability. A scientific information policy not only must be rather strongly based on principle, but also must have a certain amount of flexibility and be able to adapt to circumstances and to changes in them. China's information policy must adapt to the overall development strategy of the information field, to the degree of development and resilience of the information society, to the objective conditions affecting the information system and its operation. In addition, as a national information policy, it must also adapt itself to the overall international information system and to international information policy.

3. System Structure of China's Information Policy

Because information is a universal social phenomenon, information activity and information work affect a wide area, have some relationship to almost all members of society, and produce a certain influence on every field of study and every production department. In different historical periods and stages of development, information work will face differences in situation and in information requirements, in its service orientation, and in subject matter, physical facilities, personnel competence, paths of development and the like. As a result, in addition to formulating each information policy with reference to general principles and to the complexities of the situation, we must also adjust, revise or replace information policies in response to the continuously changing situation. Thus, in a national information system, information policy must constitute a policy system. The information policy system consists of the information policies of each development period, each application area, and each aspect. Consequently, each component information policy must be geared to a specific, limited policy objective, but their totality must form a complete, organic system. Analyzed from different angles, the information policy system reveals different aspects. For example, in terms of development stage, China's information policy system includes the information policies of the period of the country's foundation and of the period of its development. In terms of policy time frame, it includes long-term information policy, mid-term information policy and short-term information policy; in terms of its period of applicability, it includes previous information policy and current information policy; and in terms of area of application, China's current information policy system includes the following categories.

a. National Information Policy. This is a national-scale, universally applicable information policy that is based on the overall development of the national information field. A national information policy must be broad and comprehensive and must be drafted on the basis of system studies; it must focus on effective handling of the relationships of the information system with the external environment, and of information activity with other state activities, and must keep the objectives of information activities consistent with national interests. In addition, care must be taken to coordinate it with international information policy. This type of information policy generally consists of overall information policy with a high degree of integration, broad statement of principle, general applicability, and authority. In the broad sense, national information policy should include national scientific and technical information policy, social science information policy, information-industry policy and the like, and it must provide national unified guidance and unified coordination for such fields as scientific and technical information, social science information, and economic information. China's national information policy is the pattern and basis for scientific management by China's information sector; it is the principal means of overall, macro-scale organization, guidance and coordination of information activities; and it is an essential guarantee that state information activity will be able to develop smoothly.

b. Departmental Information Policies. These are also called sectorial information policies. They consist of the various regulations, rules and procedures that the sectorial management departments draft in order to guide and coordinate sectorial information activities. The main distinguishing characteristic of this type of information policy is its sectorial orientation and specialization. The formulation and implementation of departmental information policies by the various sectorial management departments and other functional departments of China's national economy has a positive effect in promoting the development of the departments' specialized information activity. For example, the Ministry of the Chemical Industry issued the document "Provisional Regulations on Scientific and Technical Information Activity in Chemical Engineering," which vigorously promoted the construction of a chemical engineering information network. In December 1985 the ministry also issued to chemical engineering leadership organs and information departments at all levels nationwide the document "Some Views on Strengthening Chemical Engineering Information Work," which emphasized that "All chemical engineering information departments must respect the general policy of 'developing information resources and serving the four modernizations' and must conscientiously take an attitude of service to the development of chemical engineering." The document also established clear guidelines regarding key points in chemical engineering information work, information funding sources, and compensated information services.

c. Regional Information Policy. Guided by the principles of the national information policy, the provinces, autonomous regions and economic zones should draft and implement regional information policies based on their specific circumstances and requirements. This is because in the huge expanse of China's territory, the provinces and regions differ in their natural geographic conditions and are uneven in their economic, scientific and technical, cultural and educational development, and in social information awareness, information requirements; as a result, different information policies are needed. For example, the information policies of the coastal zone and the interior, of the economic development zones and the ordinary provinces will each have some particular emphasis. Relatively speaking, the development of the coastal region and the special economic zones requires more advanced, up-to-date information work, emphasizing the use of modern information technology, rapid, correct collection of international market intelligence, management information, financial information, advanced technology information and the like; while information activities in the provinces and regions of the interior place more emphasis on information related to the development of their local resources and to applications technologies. Although regional information policy is limited in scope, its specific content should deal with all aspects of information activity and should provide detailed specification of the program for regional development of information activity, its service orientation, the focus of its work, bonuses and the like, and should be correct, practical and feasible. Drafting and implementing the appropriate regional information policy is important for the establishment and development of a region's information activity.

As regards policy objectives and scope, China's information policy includes general information policy and specific information policy. The former is basic policy drafted with reference to the overall development of the information field in China, while the latter is specific policy drafted with reference to a certain aspect or function of information activity. The subject matter of China's general information policy should include: establishing the legal position of information activity in China; establishing standards of information activity; establishing a management system for the information sector; specifying general objectives and general principles for information work; and drafting a development strategy and general program for the information field. The subject matter of specific information policy is extremely diverse; it must include at least the following aspects.

a. A Policy of Contract Operations by Information Organizations. Under the new situation, China's information organizations are in the process of changing over from being pure service organizations to being service-oriented business operations. In the information sector, instituting the contract responsibility system is the key to making the reform of the information system more thorough. Consequently, an appropriate contracting policy must be drafted, with clear policy specifications of principles, objectives, subject matter, rewards and penalties, and earnings distribution for contract operations by information organizations, and with treatment of the relevant legal questions.

b. A Funds Allocation Policy for the Information Sector. According to the spirit of the CCP Central Committee Decision on Reform of the Science and Technology System, the state institutes a fund contracting system for the science and technology information sector. As the economy develops, with a concurrent steady rise in the costs and expenses of information activities, the state and the cognizant departments at all levels must appropriately increase information funding; they must make studies and determine appropriate proportionalities of information funding in state scientific research funds and the percentage of the gross national product to be allocated; they must establish an incentive policy and vigorously assist information personnel to apply for scientific research funds and other special allocations; they must clearly specify the percentage of earnings from compensated information services that is to be used for development; and they must strive to obtain aid from the relevant groups and individuals and increase funding sources through all channels in order to assure the continuous development of the information sector.

c. Document Resource Policy. Document resources are the foundation of information work. Drafting a policy on document resources is an important guarantee of effective documentation work and of increased efficiency in document resource development and utilization. Document resource policy should include the following: principles and procedures for the acquisition of domestic and foreign documents; rational allocation of document resources and coordinated division of labor; standardization of document processing; organization and coordination of a document search publication system and support for its development; development of interlibrary cooperation to form a document network, to accelerate the circulation of information and to establish sharing of resources; and support for the integrated development and utilization of documentary sources.

d. Information Service Policy. Information service is one of the basic tasks of information units. Information service policy must specify the overall goals, service orientation, program, content, forms and measures of information services. In addition, a policy of priority service to key scientific research projects and core users; and a policy for the collection, evaluation and rewarding of results arising from information services must be drafted in order to increase the social effectiveness of information services.

e. Policy on Compensated Information Services. Currently, most information services in China are either uncompensated or compensated. Compensated information services are a new service form that has arisen recently in the course of reform and which raises numerous policy questions that merit investigation and are urgently in need of solution. They include, for example, the scope of compensated information services, quality requirements, fee standards, distribution of earnings and the like, all of which require uniform, clear policy specifications. Otherwise there will be cases of arbitrary or unreasonable collection of fees, which would impair the reputation of information services and do serious harm to the further development of the information sector.

f. Policy on Information Research. In the broad sense, information research includes information analysis, surveys and studies, and theoretical research on information science. In the area of information surveys and studies, policy should guide and coordinate the selection of topics, organization of personnel, and the evaluation and dissemination of results. A combination of planned and free topic selection should be applied to information surveys and studies; a policy of topic contracting and voluntary cooperation should be implemented with respect to surveys and studies; and a central management policy should be applied to information publications and research results. In theoretical research on information science, the scientific system of information science and its development strategy should be studied, and the policy of establishing a national information science research center and research network and training and supporting new personnel in information science in order to promote healthy development and improvement of information science in China should be formulated.

g. Policy on Modernizing Information Technology. Modernizing information facilities is one of the strategic objectives of China's information sector. In order to assure continuous progress in modernizing China's information technology, we should adopt a vigorous and rapid development policy suited to China's specific situation and circumstances. Information policy should be used to specify objectives and approaches for modernizing China's information technology and methods and procedures for implementing them in order to accelerate the pace of modernization.

h. Policy on International Information Exchange. Under China's opening to the outside world, importing, assimilating and utilizing foreign information and accelerating international information exchange are clearly of particular importance. Policy on international information exchange has the purpose of coordinating China's international information activity and correctly handling the relevant aspects of international information exchange.

i. Policy on Information Education. Information education is the basis for the development of the information industry. Information education includes school education and on-the-job education. Based on the real hierarchical structure, knowledge structure and work requirements of China's information personnel, China's information policy should consist of developing on-the-job education, supporting secondary and specialized education, and planned development of undergraduate and school education. The development policy should include an overall program, rational dispositions, training with reference to requirements, and assurance of quality, with the objective of creating a Chinese-style information education system, and training and developing a large contingent of information specialists in various areas with a high degree of scientific competence.

j. Information Personnel Policy. Information personnel policy includes policy on the training, utilization, management and mobility of information personnel and on structural proportionalities. Specific provisions must be made on status, pay and conditions, qualifications testing, general technical promotion, results evaluation, and awards in order to motivate information personnel and mobilize their creativity to the greatest degree possible.

k. Information Awards Policy. Information awards policy include policy on awards for information results and policy on awards to information personnel. Since information research results have the character of scientific results, information personnel are an important component of the ranks of scientific and technical personnel; consequently, awards should be instituted for the personnel and results that do the most to promote technological advancement and increase economic results.

l. Information Management Policy. Information management is a broad concept, and information management policy therefore has many aspects, including the management system, structural management, resources management, personnel management and results management. Management of China's information sector should involve contract management, objectives management, quantitative management, economic management and the like everywhere. Exercising these forms of management requires appropriate information policy.

Thus the structure of China's information policy system can be summarized as follows:

4. Procedure and Subject Matter of Information Policy Research in China

Research on questions of information policy should deal with the entire process, and its content is consequently rather diverse. But from the current standpoint, earlier information policy research generally overemphasized certain aspects of policy problems and neglected others. For example, there were many introductions to foreign information policy and many discussions of the drafting of information policy, but little attention was paid to such important areas as the demarcation of information policy problems, policy implementation, and policy evaluation. According to the basic principles of policy science, the basic subject matter of information policy research as it relates to policy development should include the following five areas.

a. Identification of Information Policy Problems. In the development of China's information sector, there will inevitably arise many problėms of various kinds. But not all problems are policy problems. The identification of information policy problems is the first step in studying information policy. The term "information policy problem" refers to circumstances that the great majority of people in the information world are aware of or concerned with, which conflict with relevant values, standards and interests, and which the relevant departments must take legal steps to resolve. Policy problems are generally interdependent, subjective, artificial, historical, dynamic, or indeterminate.

b. Information Policy Program Planning. The second procedure in China's information policy research is the planning of an information policy program, i.e., the formulation of a draft policy clause that may solve policy problem. In the stage of information policy program planning, the main subjects that must be investigated are: the distinctive characteristics of information policy program planning, the types of policy program, the organizations and personnel to be involved in program planning, program planning principles and methods, program planning feasibility and effectiveness, program limitations, predicted applications and the like. Solving an information policy problem generally requires the planning of a variety of policy options among which the policymaker can choose; ultimately the policymakers select the most satisfactory policy program that promises the greatest effectiveness as their official result.

c. Legitimation of Information Policy. This refers to the organizations that have the power to formulate or approve policy, and the process by which the drafts proposed by information policy planners are evaluated and passed and become law. The legitimation of policy is an extremely important procedure in the information policy formulation process, by virtue of which the policy becomes binding.

d. Implementation of Information Policy. This refers to the designation of actions to carry out a given policy. Implementation of information policy is the key to its ability to solve the relevant policy problems. It is a dynamic process, the primary factors influencing which are: (1) the distinctive characteristics of information policy problems; (2) the scope of information policy itself; (3) the combination of conditions external to information policy.

e. Evaluation of Information Policy. Policy evaluation is the process by which system methods and objective techniques are used to pass judgment on policy. The objective of information policy evaluation is to provide the necessary conditions for implementation of information policy to analyze its stage. Under the new situation, the smooth development of the information sector poses an even greater requirement for support from information policy and makes new and more demanding requirements regarding information policy research. But as we have stated above, the current status of information policy research in China is not suited to the new situation and to the requirements of the information sector's development; but numerous policy questions urgently require study and solution. In terms of the general objectives and development requirements of an information policy system in China, and with reference to currently existing problems, the current focus of China's information policy research shoud be: research on information policy theory and policy conceptions; research on placing information policymaking methods on a scientific, quantitative, standardized basis; research on establishing a complete information policy mechanism and system; research on the reform of the information system, the contract responsibility system, and compensated-services policy; research on information-industry policy; investigations of the theory and policy of information legislation in China; research on the implementation of information policy, its problems, and ways of dealing with them; research on the theory, methods, subject matter and measures of information policy evaluation; research on methods of organizing and managing information policy research; research on relationships with other policies that bear on information policy, such as scientific and technical policy, economic policy, and industrial policy.

In order to make information policy research in China more profound and to conscientiously strengthen the development of an information policy system, we suggest the following measures.

a. Further strengthen the publicizing of information policy and continue to increase awareness of information policy problems. There is a need both to increase awareness on the part of leadership and policymaking personnel and to enlist the concern of all persons working in the information field, research personnel, and the multitude of users in order to strengthen their involvement and understanding.

b. We suggest the establishment of an information policy planning and consultation center and the gradual separation of policy drafting and implementation functions. According to the principles of policy science, policy drafting or planning units should be separate from implementation organizations in order to assure that the policy is advanced, scientific, and fair. Under China's current circumstances, it is rather difficult to establish a specialized national information policy research center, but we can select several representative advanced schools and institutes and state or regional specialized information research institutes with strong research personnel and set up a combined information policy planning and consultation center that will establish long-term, rather stable cooperative and consulting relationships with leadership and policymaking organizations; and manpower should be provided for research topics, the drafting of information policy programs, and evaluation and analysis of information policy.

c. Formulate and implement a priority development policy, and give priority consideration to information policy research topics in such areas as research topic selection, funding, and awards for results, in order to provide policy-related support and incentives.

d. Strengthen the groundwork for information policy research. Examples include the systematic establishment of several policy document information centers on a national scale, extensive collection of domestic and foreign information policy documents, provision of relevant information services, pursuit of research in policy science, and the like.

e. Extensive development of lateral ties and cooperation, including ties between the various information industries within the information system and cooperation with the relevant fields so as to gradually form an information policy research network in China and thus to comprehensively promote the development of an information policy system.

Figure a.

- Chinese Information Policy System
  - Information management policy
    Information awards policy
  - Information personnel policy
    Information education policy
  - International information exchange policy
    Policy on modernizing information technology
    Information research policy
  - Compensated information services policy
    Information services policy
    Document resources policy
  - Information sector allocation policy
    Information organization contract management policy
  - Specific information policy
  - General information policy
  - Regional information policy
  - Departmental information policy
  - National information policy
  - Short-term information policy
  - Mid-term information policy
  - Long-term information policy
  - Information policy for the development period
  - Information policy for the foundation period
  - Current information policy
  - Past information policy

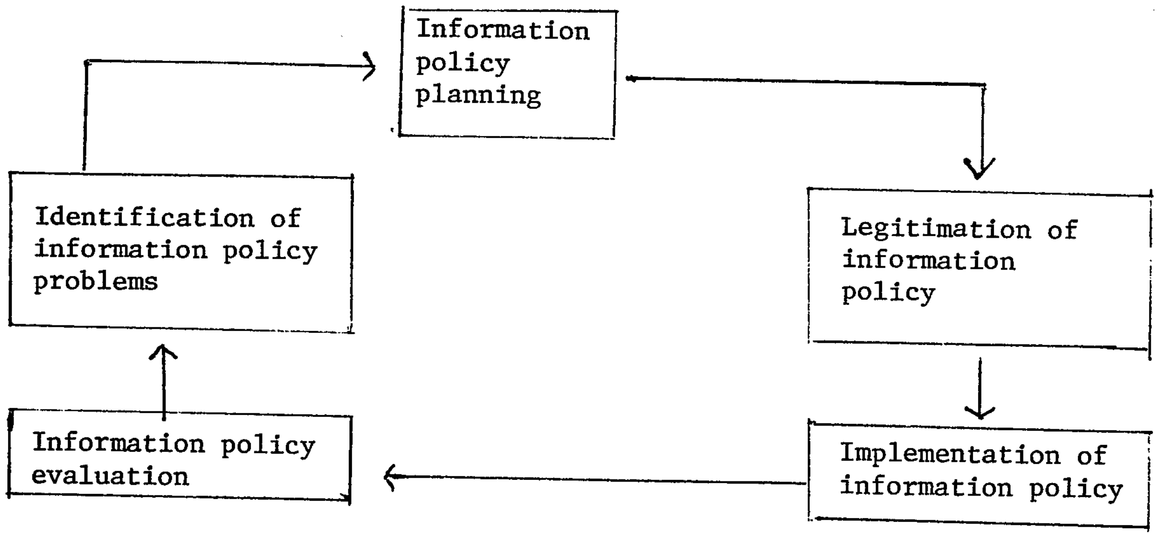

Figure b.

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1989 Beijing S&T Focal Points Listed

40081040c Beijing BEIJING KEJI BAO [BEIJING SCIENCE AND TECHNOLOGY NEWS] in Chinese 13 May 89 p 2

[Article: "1989 Focal Points of Beijing Science and Technology Efforts"]

[Text] The general requirement for Beijing's science and technology efforts in 1989 is that they thoroughly implement the general and specific policy laid down by the Third Plenary Session of the 13th Central Committee, make the reform of the science and technology system more thorough, vigorously promote scientific and technical progress in all fields, and make an even greater contribution to readjusting the economic structure, increasing effective supply, and increasing economic benefits.

1. Further promote and deepen the Spark Plan, with its objective of invigorating the rural economy, increase implementation quality, expand the benefits of scale, and complete the objectives specified by the "Beijing Spark Plan Outline" a year ahead of schedule. Vigorously disseminate a group of scientific and technical results and advanced technologies that will be important in increasing the output of grain and nonstable foodstuffs, effectively organize a major citywide agricultural dissemination project, and effectively carry out the 10-year program of the agricultural modernization project. Proceed vigorously with the construction of 4 to 6 Spark-Plan intensive villages and 100 model Spark Plan enterprises.

2. Accelerate implementation of the industrial vitalization plan. In connection with the readjustment of Beijing's industrial products and industry structure, organize key development efforts centered on Beijing's advantages in developing fast-selling products and export products that create foreign exchange. This year, 100 key projects will be carried out.

3. Continue to organize and carry out the implementation of Beijing's outline science and development program for municipal construction and city management. This year, taking the commemoration of the 40th anniversary of the founding of the state and the 11th Asia Conference as the key objectives, strengthen science and technology breakthrough efforts and dissemination of

applications in connection with the urgent needs of municipal construction and management, focusing on integrated management and development of transportation, municipal environmental protection, municipal construction, municipal government project technology, and municipal computer management projects.

4. Carry out the Torch Plan. This year we must overcome difficulties and proceed energetically so that the Torch Plan will get under way smoothly. Conscientiously implement 40 to 50 high-level, high-benefit projects with export potential.

5. Accelerate the opening up of science and technology. Externally oriented science and technology activity should serve industrial readjustment and the development of an externally oriented economy. In connection with the needs of the city-level key projects and key plans and the creation of foreign exchange through export, effectively carry out the 10 major science and technology cooperation projects and the 50 knowledge importation projects. Undertake the drafting of mid- and long-term technology export programs and strive to have this year's technology and product export double the 1988 figure.

6. Accelerate the establishment of a legal system for science and technology. Legal studies, legislation, legal applications and implementation of laws should be intensified this year. The study and publicizing of scientific and technical laws and regulations should focus on science and technology contracting law and implementation regulations, establish an arbitration structure for establishing technology contracts and drafting arbitration regulations. In addition, the research for and drafting of the "Regulations for Promoting High Technology and Industrial Development" and "Regulations on Promoting Technological Progress in Industry." The focus of legal implementation investigations should be on the laws and regulations in the experimental zones, and in addition there should be a comprehensive checkup on all provisions that have already been issued. An effort should be made to assure that all laws are followed and are administered strictly.

7. Intensify soft science research, and improve topic selection studies so as to increase the success rate, increase practicability and make policymaking more scientific in connection with certain major topics in the capital's economic construction, municipal construction and municipal management.

8. Vigorously and reliably continue the reform of academies and institutes, further improve the three guarantees and one designation, and promote optimized organization in research academies and institutes subordinate to the city. Conscientiously solve the problem of having science serve the industries. Promote the establishment of industrial enterprise technology development organizations, strive to have one-third of the large and medium-size enterprises in the city, and particularly the 100 key industrial enterprises, establish effective science and technology development organizations. Promote reform of the science and technology system in

plant-run institutes, and implement a variety of types of scientific and technical contract responsibility systems. Make the reform of the rural science and technology system more thorough, and consolidate and improve the county and village level science and technology management and services system. Vigorously guide and support the development of privately run scientific research organizations, see to it that they increase in number to about 1,500 this year and assure that the annual business of 20 of them reaches 10 million yuan.

9. Continue effective work in the construction of experimental zones and promote the development of high-technology industries. This year we must continue effective work in the planning and construction of experimental new-technology industry development zones, further improve the market mechanism of the experimental zones, establish new economic systems suited to the development of new-technology enterprises, take a variety of measures to help enterprises to develop as rapidly as possible and gain entry into foreign markets as rapidly as possible, and strive to create $40 million in foreign exchange.

10. To celebrate the 40th anniversary of the founding of the state with deeds, the municipal science and technology committee has decided to mobilize the city's scientific and technical personnel in a "Contributions by the 100 Projects in Commemoration of the 40th Anniversary of the Founding of the State" movement whose main subject matter will include 100 scientific and technical development and applications dissemination projects that produce major economic and social benefits, 100 superior discoveries or patents, and the like.

Key High-Technology Projects Seen Key to Revitalization of Shanghai Industry

40081040b Hong Kong LIAOWEN ZHOUKAN [OUTLOOK WEEKLY--OVERSEAS EDITION] in Chinese No 24, Jun 89 pp 9-10

[Article by Zhang Guoyuan [1728 0948 0337] and Zhang Xuequan [1728 1331 0356]: "The Fourteen Projects of the First Campaign"]

[Text] On 27 May, the leadership groups of 14 key breakthrough efforts in Shanghai held a meeting in the science meeting hall to announce bid solicitation information for the second group of key breakthrough projects. There were no empty seats in the auditorium: prospective bidders were jammed shoulder to shoulder. The first campaign in Shanghai's economic development strategy, consisting of 14 key breakthrough projects whose main objective is to turn high technology into productive industries, had already produced rising expectations of a revitalized Shanghai.

New Opportunities

As we begin the last decade before the 21st century, world economic, scientific-technical, and social development has given rise to intense unrest. The blows of global currency and stock crashes, the economic rise of new industrial countries in Asia, the multifaceted tendencies of economic development in Northern Europe, Western Europe and East Asia, the rapid development of high technology and new technologies, and the resultant highly transnational adjustment and shifts in the world economic structure and production structure, are compelling many countries to find policies and measures to get them out of difficult circumstances or to identify favorable opportunities for development. Both the developed and the developing countries are staking their economic and social development on scientific and technical progress, and whoever can gain primary in scientific and technical progress will become a world power.

This abruptly changing world situation gives Shanghai, with its excellent scientific and technical capabilities, a new opportunity in international competition. Shanghai currently has more than a thousand scientific research organizations of various types, and nearly 400,000 specialists in natural science and engineering and technology; its scientific and technical strength exceeds that of Taiwan, Hong Kong, Singapore, and South Korea. Its total number of scientists and engineers is over 88,000, which is 50,000 more than Singapore; and Shanghai has 30,000 more research and development personnel than South Korea. An analysis of more than 7,000 award-winning scientific and technical results obtained since the country was established indicates that in certain scientific and technical fields Shanghai is actually a world leader.

But owing to the constraints of its system, there has long been a structural disjunction between science and the economy, and Shanghai's scientific advantages have not been fully utilized. A survey indicates that 55 percent of Shanghai's current research organizations, 80 percent of its scientific and technical personnel, and 42 percent of its scientific research funding are outside of enterprises, and that its scientific research work has little relationship to enterprise technical advancement. Statistics indicate that scientific and technical progress accounts for less than 30 percent of Shanghai's total economic growth, while in the developed countries the figure is more than 60 percent. The logical result is that the scientific and technical gap between Shanghai and the developed countries is expanding: it is 10-15 years in the main new technologies and 20-26 years in the main traditional technologies. Statistics on the facilities of enterprises belonging to 28 main industrial offices indicate that their general purpose equipment and technology index is only 1.71 percent of the world figure.

For similar reasons, Shanghai's technological superiority over the various other Chinese provinces is gradually weakening: the percentage of the main general purpose equipment and technology that is advanced by domestic standards has fallen to 10.7 percent, while the percentage that is classified as backward has risen to 30.48 percent. The standards of mechanical engineering products are beginning to fall behind the national average: the percentage of products representing the 1970's or early 1980's level is also lower than the national average. Electronics technology is being used worldwide as the spearhead of high-technology and new-technology development, but the rate of improvement of the quality and consistency of Shanghai's electronics products has fallen to ninth in the country; Shanghai's medium-scale (MSI) and small-scale (SSI) integrated circuits, which accounted for half of national output in the 1970's, currently account for only 20 percent of the total, and its market share has fallen from 50 percent to 10 percent.

Shanghai's top level policymaking organizations were already aware of this problem in the early 1980's. In 1985, the document "Outline Report on Shanghai's Economic Development Strategy," approved by the State Council, clearly stated that extensive use must be made of advanced technology in a focused effort to accelerate the modernization of traditional industry.

In May 1988, a report that concentrated the wisdom of hundreds of experts, scholars and public figures at all levels was sent to Zhu Rongji [2612 3579 1015], who had just become mayor of Shanghai. The report suggested that certain objectives in certain fields should be chosen as citywide key industrial breakthrough projects, that scientific and technical personnel from all quarters be involved in the effort, and that an a [as printed] be made to achieve breakthroughs in 2 to 3 years so as to obtain noteworthy economic benefits, to provide the impetus for a readjustment of the entire city's product structure and production structure, and to bring about a new takeoff of Shanghai's industry.

The report was rapidly approved by the municipal government, and 14 key industrial projects were designated as the first citywide breakthrough projects; Zhu Rongji personally became the head of the citywide breakthrough leadership group. The prelude to the 14 key breakthrough projects came in September 1988.

Twenty-five years before, in 1963, Shanghai had organized a large-scale industrial breakthrough effort which ultimately developed into 6 new industries and 18 major new technologies and brought Shanghai's economy into a new period of development, in which a large group of products that had caught up with the world state of the art appeared. This year too, there are grounds for predicting that the breakthrough effort based on the 14 projects will mean another period of advancement for Shanghai.

Catch-Up Efforts From Advanced Starting Points

The breakthrough effort involving Shanghai's 14 key projects is a catch-up effort from advanced starting points.

Supercritical power plants constitute the first of the breakthrough projects. Supercritical power plant equipment represents the current state of the art in power generating equipment; the large-scale use of this equipment in Japan and the Soviet Union has resulted in their having coal consumption figures of respectively 337.7 and 328 grams per kilowatt-hour, while China consumes 100 g more per kilowatt-hour than these figures. According to statistics, last year China's fossil-fired power plants generated 400 billion kWh, and they thus consumed 40 million more tons of standard coal than they need have. Although its power plant equipment industry is at least 30 years behind the world state of the art, Shanghai has resolved to set out from the advanced starting point of supercritical power generating equipment in order to catch up with the world state of the art; by the 1990's it will strive to create full sets of power plant equipment for export that is highly competitive on foreign markets.

The domestic production of Santana vans is another breakthrough effort that begins from an advanced starting point. A complete van includes 1,556 parts and assemblies, and domestic production of each of them requires up to 18 separate sequences of inspections and acceptance tests by the West German Volkswagen motor vehicle company. Worldwide, general-purpose motor vehicle horns must be able to operate 60,000 times, but the West German company insists that the Chinese side produce horns for the Santana that can sound 100,000 times; it also requires that they be able to operate after immersion in water for 15 minutes. The horns produced as a result of the breakthrough effort not only passed the immersion test, but also operated 120,000 times.

In 1985, when the first lot of Santanas was turned out at Shanghai, only 2.7 percent of the parts were domestically produced; by the end of last year the figure had already reached 30.6 percent, and this year it is expected to exceed 50 percent. Volkswagen's 1988 evaluation was that the quality of Shanghai's Santana products placed it first among the five plants worldwide now producing Santana products.

At the end of last year, at an individually run service shop in Shanghai, several dozen sets of fashion clothing made from a new type of textile that had not been seen before were sold out in short order. The appearance of this product, a "multipurpose coated composite fabric," may well be an epoch-making "new weapon" of Shanghai's textile industry; it represents a third generation, following Shanghai's Dacron of the 1960's and its medium-length fibers of the 1970's. The coated composite was developed jointly by the textile industry, the organic chemicals industry, and the mechanical engineering industry. It is likely to free Shanghai's vigorous textile industry from the need to compete for scarce cotton yarn with its sister provinces and municipalities, enabling it instead to reestablish its own superiority in the textiles market with a variety of new multipurpose coated composite fabrics, while also striving to establish its products on international markets. Of a total of 800,000 meters of coated fabric trial-produced last year, 500,000 m has already entered the United States market.

The true high-technology industries among the 14 breakthrough projects include computers and peripherals, the S-1240 program-controlled telephone exchange, fiber optic communications, and a 600,000-kW nuclear power plant. As a result of the breakthrough efforts on these projects, within the next few years they are likely to develop into respectable high-technology industries. The other 10 projects are also closely connected with high technology. According to statistics from integrated circuit experts, 6 of the 14 projects require a variety of key special-purpose integrated circuits, and as a result, the completion of the 14 projects will bring about the advancement of Shanghai's special-purpose integrated circuit industry. An analysis of domestic production of the Santana indicates that the automotive industry's development will vigorously develop Shanghai's microelectronics, computer, new materials and industrial robot high technologies into industries.

The fourteen projects have attracted involvement by Shanghai's scientific personnel. When the first 136 scientific and technical breakthrough topics under the 14 projects were announced, scientific and technical personnel from nearly 500 research academies and institutes, specialized academies and schools, and industrial units throughout the city flocked to submit bids, the total number of which was 989. The successful bidders on 98 topics included more than 2,000 scientific and technical personnel. Research workers, professors and high-ranking engineers accounted for more than a fifth of the total.

Bold Objectives

Judging by the current situation, work on the 14 breakthrough projects will bring Shanghai splendid economic benefits. It is forecast that by 1992, they will result in an increase of 15 billion yuan in Shanghai's output value, with an increase of 5 billion yuan in profit tax payments, and creation or saving of $1 billion in foreign exchange. By the end of the century, the output of the fully Chinese-produced Santana van will reach 300,000 units; in terms of current prices, this means that the Santana project alone will add more than 50 billion yuan to Shanghai's output value, equivalent to half of the city's current industrial and agricultural output. This will unquestionably put an end to the multiyear revenue slump, will increase Shanghai's financial strength, and will allow it to make an even greater contribution to the country. The breakthrough effort will also become the spearhead of the citywide readjustment of industrial structure and product structure and provide an impetus for the development of numerous related industries.

But the above does not constitute the end objective of the 14 breakthrough projects. The program planners envision an even more attractive long-term project; that the breakthrough effort will ultimately give rise to several domestically and internationally known, economically powerful enterprise groups that will produce well known, fast-selling products that bring good economic benefits and are highly competitive on international markets, so that they enter the great international circulation.

As China's greatest industrial city, in the long term it is dangerous for Shanghai to rely exclusively on large-scale labor-intensive types of industry. Since such products are not well known brands and are not distinctive, an independent sales network cannot be developed for them and in the final analysis it will be difficult to establish them on international markets. While taking the technology-intensive approach is much more arduous and produces smaller short-term benefits, it is the basic way to reinvigorate Shanghai. Shanghai needs to forge ahead.

In view of the above facts, while the effort on the 14 breakthrough projects is under way, Shanghai has taken a series of steps to accelerate the development of high technology into industry. Construction is proceeding feverishly on the Caohejing emerging technology development zone, set up with the provisional approval of the State Council last June. Last November the Shanghai Science and Technology Committee also proposed a Torch Plan aimed at promoting the industrialization of high technology. Shanghai has also drafted the appropriate supporting policies to promote the industrialization of high technology. All of these measures will create an excellent environment for efforts on the 14 breakthrough projects.

Advisor to the Shanghai municipal key breakthrough technology leadership group Gu Xunfang [7357 6064 5364] revealed to a reporter that the 14 projects represent only the first campaign in promoting Shanghai's economic takeoff; there will be a second and a third campaign in the future. We may foresee that a transformed Shanghai will emerge in the not-too-distant future.

Views on Establishment of High-Technology Industry Aired

40081040d Beijing KEJI RIBAO [SCIENCE AND TECHNOLOGY DAILY] in Chinese
5 Jun 89 p 3

[Article by Lu Xingjian [0712 5887 0256] and Ba Fangchen [1572 2455 6591]: "Some Views on Establishing High-Technology Industries in China"]

[Excerpt] Some Thoughts on China's Establishment of High-Technology Industry

1. The establishment of high-technology industry should have the promotion of economic development as its objective. The countries that single-mindedly pursue military power and neglect economic construction have already experienced its bitter result, national decline. With developing the economy as our objective, we should select the high-technology industries that do the most to promote economic development and that give the most direct economic benefits for priority development, and we should make use of the high added value that they produce to accelerate the accumulation of funds for economic development.

2. We should focus on developing the microelectronics industry as a basis for constructing China's information industry. Developing the information industry is the focus and foundation of the development of high-technology industries in almost all countries. The worldwide annual business in information technology products has already reached $655.0 billion, indicating its economic importance.

The information industry is involved in a multitude of fields. For example, computers are used in all areas of industry, agriculture, the service sector and social activity in the developed countries and have produced immense social and economic benefits. In particular, the large-scale development of the information industry has accelerated the economic modernization of traditional industries. China's high-technology industries represent only a very small percentage of its industrial structure, and the traditional industrial sectors will continue for a long time to be the mainstay of its industry. But the overall level of equipment in China's traditional industries is equivalent only to that of the 1950's or 1960's in the developed countries. This indicates the urgency of developing China's information industry.

3. We should adopt a strategy of import replacement, begin with domestic markets, and gradually make exports exceed imports and enter into international competition. Replacement of imports is the strategy universally adopted by the developing countries when they develop high-technology industries. For China, importing technology and using other countries' technological results still is the shortcut to developing high-technology industries. The key to advancing from importation of technology to replacement of imports is increasing our ability to copy, assimilate and innovate.

In developing high-technology industries, we should start with domestic markets. First, China's traditional industries urgently need technical modernization and there are extensive domestic markets. Second, our products will not necessarily be strongly competitive at first, and it will only be by continuously improving them that we can gradually gain a place on international markets. Third, countries that transfer technology inevitably will attach numerous limitations to it in order to prevent us from becoming their competitors. If we begin with domestic markets, we must exercise strict protection: we must adopt various methods of supporting newly established enterprises, and we must prevent foreign products from flooding in and overwhelming native industries.

4, We must put the mechanism for developing high-technology industries in good working order. Foreign experience indicates that in order to develop high-technology industries, several types of mechanisms must be strengthened. The first is the competitive mechanism. China's market economy has not yet established itself, and the supplv of products does not meet demand, so that the government must take steps to introduce the mechanism of competition between enterprises. The second is the funding mechanism. This means providing funding guarantees for all inventions so that successful inventions will be rapidly converted to commodities. The third is the information mechanism. High technology develops at a fast pace and the product life cycle is short, so that without a national or even an enterprise information network it will be impossible to keep aware of domestic and foreign technology and market dynamics, the government will be unable to direct the enterprises, and the enterprises will be unable to compete. The fourth is the marketing mechanism. The products of high-technology industries are primarily innovation products, and in order to sell them rapidly and capture the market, there is a need for smooth marketing channels and for publicity methods; and in addition, production, sales and service must be integrated.

5. We must vigorously promote education and make an effort to train all types of specialized personnel. High-technology industries are technology-intensive, and statistics indicate that knowledge accounts for about 50 percent of the production cost of integrated circuits. It is evident that from the production standpoint, knowledge and personnel are the key to developing high-technology industries. The same is true from the marketing standpoint: even the best product will find no buyers if no one can use it.

CAS Research Team Investigates Xizang Plateau Potential

40081040e Beijing RENMIN RIBAO [OVERSEAS EDITION] in Chinese 21 Jun 89 p 2

[Article: "CAS Multidisciplinary Team Goes to Xizang"]

[Text] A Qinghai-Xizang Plateau interdisciplinary research team organized by the Chinese Academy of Sciences recently entered Xizang to engage in multidisciplinary research on agriculture, forestry and stock raising in the middle sections of the Yarlung Zangbo River, Lhasa River and Nyang Qu River basins and to draft a plan for resource development and economic development in the region during the remainder of the century.

The middle sections of the valleys of Xizang's three rivers comprise 18 counties and county-level cities and districts, among which are Lhasa City and Shannan and Xigaze districts; they have a total area of 65,600 square kilometers, with a population of 760,000 and with 100,000 ha of arable land; their annual grain output is 52.5 percent of the total for Xizang, so that they constitute its main commodity foodstuffs production area. There is more than 40,000 ha of land suitable for reclamation, several million hectares of usable grassland, and a large area suitable for forestry. Water resources are extremely abundant, transportation conditions are good, culture and education are rather well developed, and resource development and utilization will be relatively easy, giving a rapid return and providing major benefits.

The expedition will be conducting research in eight areas: energy, industry, agriculture, forestry, stock raising, water resources, the economy, and information systems. At the end of the year it will submit a development plan for the remainder of the century, including social and economic development and major construction projects. It will provide scientific data and suggest measures for coordinated resource and environmental development, utilization, management and protection in the context of the development project, so as to promote a beneficial ecological cycle and obtain long-term benefits.

Study of Effect of Acute Hypoxia on Human Performance Under Aerospace Conditions

90CF0025A Beijing YUHANG XUEBAO [JOURNAL OF CHINESE SOCIETY OF ASTRONAUTICS] in Chinese No 3, Jul 89 (manuscript received 30 Jun 88) pp 65-70

[Article by Zhang Jingxue [1728 7238 7185], Jia Siguang [6328 0674 0342] Wu Jianmin [2976 1696 3046], Qi Zhangnian [4359 4545 1628], and Yu Qingxiang [0060 1987 4382] of the Institute of Space Medico-Engineering, Beijing]

[Text] I. Introduction

Acute hypoxic conditions encountered by astronauts and aircraft pilots can have adverse effects on human performance or endanger human lives. The human brain is highly sensitive to the level of oxygen supply; therefore, oxygen deficiency may severely affect the brain's function. Numerous studies have shown that oxygen deficiency can alter a person's vision, hearing, motor function, memory, and thought activity[1,2]; however, the evidence is inadequate and inconclusive, and existing experimental results do not convincingly reveal changes in the brain's function. Clearly, such incomplete information will not satisfy the needs of aircraft pilots and astronauts in carrying out their mission. For this reason, a systematic study has been conducted to provide experimental data for a medical support program.

II. Experimental Methods and Results

The human performance measure used in this study is a combination of brain function and activity efficiency. An important aspect of this study is to choose the appropriate performance indices which reflect the level of brain function and activity efficiency. Examples of these performance indices including hearing, vision, motor function, consciousness, thought activity and brain electricity. The objective of this study is to understand the various functions, and then perform a quantitative analysis of the measured data.

(1) Experiment on the Complex Reaction Time of the Human Body. The test subjects included 27 male youths between the ages of 19 and 22 and 37 male laboratory workers between the ages of 22 and 40. These subjects were divided

into four groups: one group on the ground, and three groups flown in a decompressed chamber of an aircraft at altitudes of 1500m, 2500m, and 3000m, respectively; the dwell time at each altitude was 60 minutes. In order to understand the performance characteristics during initial operation, each subject participated only in one experiment of one of the groups, and a total of 64 experiments were conducted.

The subjects were tested for human-bodv complex reaction time under a bicycling load of 27 watts. A human model picture was projected every 10 seconds; each cycle contained 16 pictures or 8 pictures. The results show that during the first cycle, the average reaction times for the 1500m, 2500m and 3000m group do not differ significantly from those of the reference group (Table 1). In the 3000m group, only 2 subjects show significant increase in reaction time ($p < 0.05$).

Table 1. Comparison of First-Cycle Average Reaction Times in a Human Model Experiment

Height (m)	Results of Denison et al.		Results of this experiment			
	16 pictures	8 pictures	16 pictures		8 pictures	
			A	B	A	B
0	1.65	1.90	3.58	3.79	3.49	3.68
1500		2.31[b]	3.61	3.46	3.81	3.79
2500	3.33[a]	2.55	3.62	3.96	3.84	4.09
3000						
# of Subject-trials in each group	4	9,7,8	10	7	7,10	7,6

Notes: A = Lab workers aged 22-40
B = Youths aged 16-22

a: 8000 feet (2438m) relative to ground $P < 0.02$
b. 5000 feet (1524m) relative to ground $P < 0.05$

(2) Short-Term Memory of Numbers and Memory-Related Electric Potential

The test subjects included 11 male youths aged 19-23. They were tested for short-term memory while dwelling 25-30 minutes in a decompression chamber at altitudes of 3000m, 4000m, and 5000m, respectivelv. Every 2 seconds a 3-digit number was displayed for the subject to memorize; a total of nine 3-digit numbers were randomly displayed 90 times, then the test subjects were asked to write down the 9 numbers. At the same time, memory-related electric potentials were recorded from electrodes attached to the forehead. The results are given in terms of the percentage of correct answers, as shown in Table 2; the average result at 3000m is higher by 0.1 percent; at 4000m, it is lower by 8 percent; and at 5000m it is lower by 14.8 percent ($p < 0.05$). The individual percentages of correct answers show both increases and decreases at 3000m and 4000m; however, at 5000m, all test subjects show lower test results. The average amplitudes of memory-related electric potential at 5000m, N_2P_2, show higher values ($p < 0.05$), indicating deterioration of the memory function, which is consistent with the above results.

Table 2. Short-Term Memory Results -- Percentage of Correct Answers

Altitude (m)	3000	4000	5000
Percentage of correct answers — Before ascending	76.4±14.3	76.8±20.8	76.7±11.6
After 25 min. at given altitude	76.5±13.3	68.8±19.7	61.9±5.0*

* $p < 0.05$

(3) Hearing Alertness. The test subjects included 9 male youths aged 19-23. Six-minute hearing alertness tests were conducted in a decompression chamber at 3000m, 4000m, 5000m and 6000m for dwell times of 5-15 minutes and 30-40 minutes. Everv 3 seconds a random 1000-Hz audio-frequency signal or a 1200-Hz non-signal was transmitted via earphones to the test subject; each test subject was instructed to push a key if he detected a signal. The data were processed by a computer to generate performance measures such as focusing ability. discrimination abilitv, time-delay rate, omission rate, and reaction time. The performance curves show that as altitude increases, the rate of correct identification decreases, and the time-delay rate and omission rate increase. At 5000m and 6000m, these parameters reach a clearly defined level; at 3000m and 4000m, the reaction-time delay also reaches a clearlv defined level.

Under moderate hypoxic conditions (3000m, 4000m), the test subjects were still able to discover the errors made during the performance tests; some test subjects still showed α or θ-wave excitation in their brain electricity. Under more severe hypoxic conditions (at 5000m, 5000m), the subjects clearlv had difficulties in maintaining concentration; their reactions slowed down, and the energy of slow brain waves showed significant increases. In a quiet environment, the subjects can easily drift into a state of brain suppression (point A in Fig. 1); they may exit this state by being awakened by others (point B), or by waking up naturally (point C). If a test subject straightens up immediately, he can continue to function for more than 30 seconds. The detailed results of the hearing-alertness tests are reported elsewhere,[3] and will not be repeated here.

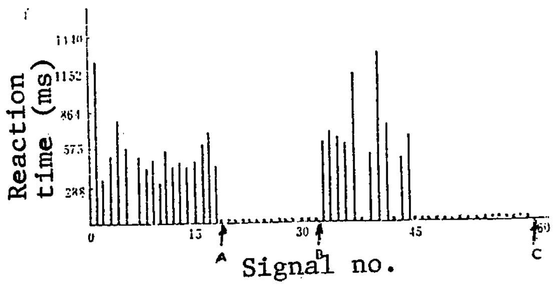


Fig. 1 Variation of Hearing Reaction Time of Mr. Liu for 30-Minute Dwell at 6000m Altitude: A. Drift into brain suppression. B. Awakened by other C. Wake up naturally D. Answer omitted

(4) Manual-Tracking-Skill Experiment. The test subjects and the test conditions are identical to those of the hearing-alertness experiment. With dwell times of 10 minutes and 29 minutes at each altitude, the test subjects were instructed to perform manual tracking functions. Fig. 2 shows a block diagram of the compensation tracking system. u(t) is a reference input random signal, the cut-off frequency is 6 rad/s, and e(t) is the tracking error signal. The error signal was displayed in the form of deviation of a light point from its equilibrium position; the display was located 70 cm in front of the test subject. The test subject tried to reduce the deviation by operating a control stick. The displacement of the control stick was converted by a sensing device into an electronic signal Y(t). The control object was an analog circuit whose transfer function is $\frac{K}{s+1}$. The three signals u(t), e(t), and Y(t) were recorded simultaneously on a magnetic recorder. The dynamic data from the compensation tracking operation were processed by a computer to obtain various parameters which reflect changes in tracking efficiency under acute hypoxic conditions.

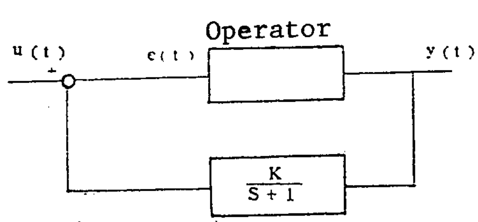


Fig. 2 Block Diagram of a Manually Controlled Compensation Tracking System

1. Control Error. This is given by the expression:

$$E = \left(\sum_1^N e^2(t) \Big/ \sum_1^N u^2(t) \right)^{\frac{1}{2}}$$

E is a measure of the interactions of all the elements in a tracking system; it is a quantitative indicator of the system operating efficiency. Fig. 3 shows that with increasing altitude and increasing dwell time, the error also increases. At altitudes of 5000m and 6000m, and dwell time of 30 minutes, the error increases by 20 percent ($p < 0.05$), which indicates a significant reduction in tracking efficiency.

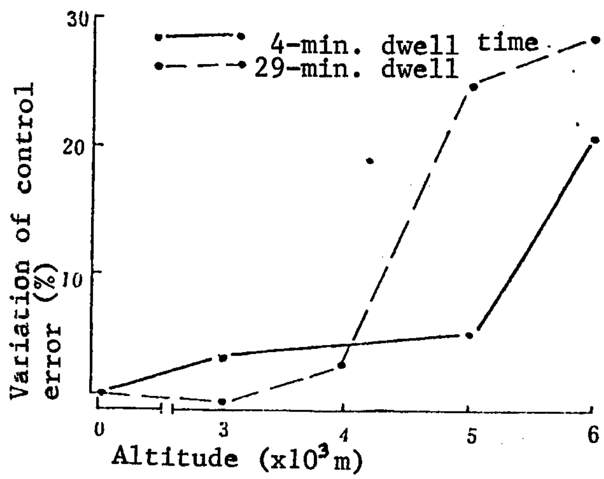
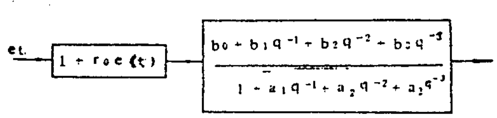


Fig. 3 Variation of Compensation Tracking Error With Altitude

2. Dynamic response of the operator. Under acute hypoxic conditions, the dynamic response of the operator is rather complicated, and contains both linear and non-linear components. In this experiment, a simple Hammerstein model is used to simulate the response of the test subjects:



where r_0 is the non-linear coefficient, q^{-1} is the delay operator, and a_i, b_i are discrete linear model parameters, i=1,2,3.

The model parameters are estimated using an open-loop generalized least-squares approach. The calculated results show that the fit errors for 80 percent of the samples are within 10-15 percent.

3. Steady-state gain of the linear model (K_0). It is given by the expression:

$$K_0 = \frac{b_0 + b_1 q^{-1} + b_2 q^{-2} + b_3 q^{-3}}{1 + a_1 q^{-1} + a_2 q^{-2} + a_3 q^{-3}} \Bigg|_{q^{-1}=1}$$

This is the steady-state output response corresponding to a unit-step input signal. A large value of K_0 facilitates tracking. as shown in Fig. 4. As altitude increases, the steady-state gain clearly decreases; at an altitude of 5000m and 6000m, the average gain reduction is 23 percent ($p < 0.05$). This reflects the severe hypoxic conditions at these altitudes which cause deterioriation of the subjects ability to control errors.

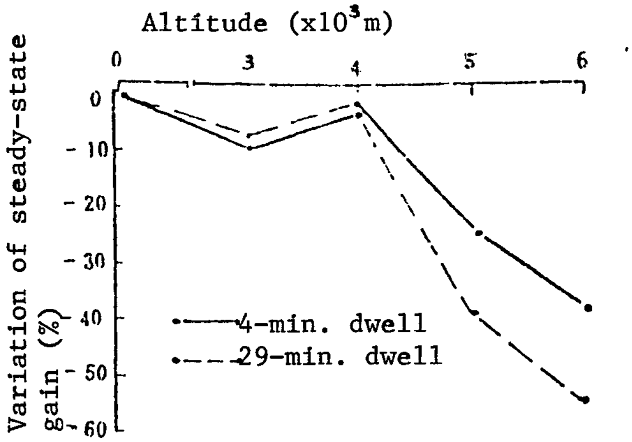


Fig. 4 Variation of Steady-State Gain of the Linear Model of Compensation Tracking System With Altitude

Variation of brain electricity during tracking operation. The results show that conductivity at the forehand is relatively stable but conductivity at the rear section varies with altitude; specifically, the energy distribution ratio of the β_1, β_2 fast-wave increases ($p < 0.05$), whereas the energy distribution ratio of the δ slow-wave ($p < 0.05$) decreases. This may be caused by the temporary excitation of the cortex of visual senses during tracking operation.

(5) Overall Performance. Evaluation of the overall performance under acute hypoxic conditions is carried out using fuzzy set theory. The overall performance (J) is defined as the average change rate, given by the expression

$$J = \sum_{i=1}^{5} q_i \underset{\sim}{V}(u_i) \Big/ \sum_{i=1}^{5} \underset{\sim}{V}(u_i)$$

where u is defined as the domain of focusing ability. discrimination ability, memory, reaction time and tracking error respectively, $\underset{\sim}{V}$ is the fuzzy subset. $\underset{\sim}{V}(u_i)$ is the degree of attachment of each index u_i with respect to the set $\underset{\sim}{V}$, and q_i is the rate of percent change in the ith performance index. whose value is positive if there is an increase, and negative of there is a decrease.

As shown in Fig. 5, the overall performance decreases with increasing altitude. Specifically, it decreases 0.2 percent at 3000m, 6 percent at 4000m, and 34 percent and 40 percent at 5000m and 6000m, respectively (referenced to 100 percent at 0m).

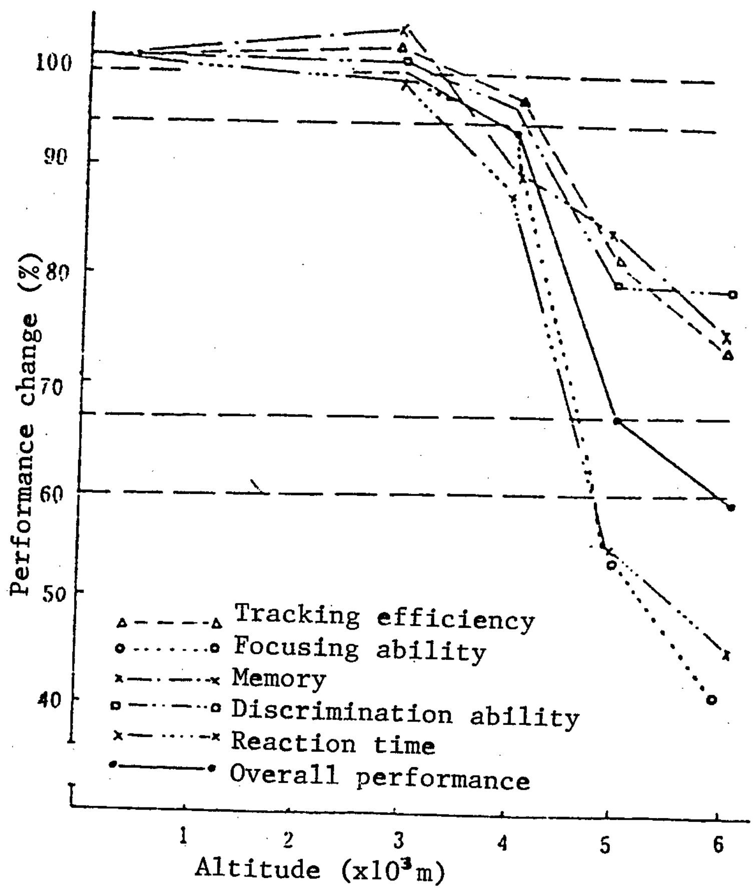


Fig. 5 Performance Change Under Acute Hypoxic Conditions

The above results are summarized below:

1. At altitudes of 1500m, 2500m, and3000m, the first-cycle average reaction time of the human body shows no significant increase compared to that at sea level. The results of Denison are not verified by the results of this experiment. There is no acute hypoxic effect on human performance at 1500m and 2500m.

2. At an altitude of 3000m, the average value of each perfomance index does not show significant change; only the reaction times of individual test subjects show noticeable increase. Basically, there is no hypoxic effect on human performance at 3000m.

3. At an altitude of 4000m, all performance indices show decreases, but the results are not statistically conclusive; this is considered to be a region of acceptable hypoxic performance.

4. At altitudes of 5000m and 6000m, the performance indices of all test subjects decrease to a level considered to be statistically significant.

5. The result of overall perfomance of the test subjects provides a better measure of the effect of oxygen deficiency on human performance.

III. Discussion

In carrying out flight missions, an aircraft pilot must maintain his focusing ability, discrimination ability and decision-making ability; he must also have fast reactions, good memory, good senses and motor function. These abilities all center around brain activities. The brain's state of consciousness, thought process, and its ability to coordinate and control bodily functions directly affect flight performance and safety. Oxygen deficiency may cause performance degradation because it has a direct effect on the brain's functions. Therefore, over the years the problem of human performance under hypoxic conditions has been a central topic of study by many investigators.

This experiment on complex reaction time of the human body model has been conducted to verify the results of Denison. Over the years, most investigators have believed that human psychological activities and state of mind do not show significant changes until a severe condition of decompression and oxygen deficiency is reached at 12,000 ft (3658m). However, the study by Denison et al.[4] showed that a hypoxic condition at 5000 ft (1524m) or 8000 ft (2438m) can affect a human's ability to learn a new topic, although it has no effect on someone who is already proficient. This conclusion has attracted the attention of the British aerospace medicine community. In this study, however, where experiments have been carried out under identical conditions but with larger number of man-trials and improved analysis techniques, Denison's results cannot be verified. Recently, Morgan has reported that moderate oxygen deficiency has no effect on logical deduction ability.[5] Based on the results of this study, we believe that an appropriate altitude threshold for hypoxic effect on human performance should be 3000m.

The tracking operation test involves vision and motor reaction which depend on brain activities. At altitudes of 5000m and 6000m, although the EEG indicates temporary excitation, statistical analysis and model analysis of the test data show large increases in tracking error and significant reduction in steady-state gain; the increase in transient oscillations causes deterioration in control stability and poor tracking response. These results show that tracking operation can provide a quantitative measure of human adaptability and of the brain's function under hypoxic conditions. Clearly, this result is of practical importance for pilot training activities.

The test on hearing alertness involves hearing and motor function which also center around brain activities. For an experiment under moderate and severe hypoxic conditions, it is a very useful performance index. We agree with the conclusion of Cahoon,[6] which states that the deterioration of hearing alertness under acute hypoxic conditions at 5000m and 6000m is not caused by the loss of hearing ability, but by the blockage of the selection and attention channels. In this study, it is further discovered that blockage of the selection and attention channels. In this study, it is further discovered that blockage of the selection and attention channels is expressed in the form of loss of concentration. Oxygen deficiency affects the duration of excitation of the cortex nerve cells, which in turn interferes with the stability of selection and attention; generally, motor function is affected first, then the senses are affected. The results also show that in a quiet environment, the test subject can easily drift into a state of brain suppression; but in this state, the cortex still maintains its ability to excite the brain cells. Therefore, if a pilot discovers that his reactions slow down significantly, he must immediately alert himself of the possibility of oxygen deficiency and take emergency measures.

Short-term memory of numbers is a measure of the basic intelligence activity of the brain; it is an important indicator of the brain's function. This study shows that the first sign of oxygen deficiency is the loss of short-term memory.

The overall performance calculated from the five basic performance indices (memory, discrimination ability, focusing ability, reaction time and tracking ability) provides a more complete picture of the brain function and activity efficiency; it is a better measure in practice. When the overall performance decreases by 34 percent, the human body is considered to be in an unacceptable hypoxic state where performance is severely affected.

IV. Conclusion

At 1500m and 2500m altitude, decompression and oxygen deficiency have no effect on human performance; at 3000m, performance is essentially unaffected; at 4000m there is evidence of performance degradation, but the data is not statistically conclusive; at 5000m and 6000m, performance degradations are considered to be statistically significant. This information can provide a scientific basis for establishing a medical support program for aircraft pilots and for astronauts working inside the space module of performing tasks outside the module in a space suit.

The authors would like to express their thanks to comrades Bo Tiande and Chen Jinshan for assistance in processing the data for this study.

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Design and Implementation of MI/MO Real-Time Computer-Coordinated Force Control System for Swept-Wing Aircraft

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[Text] Abstract

In this paper, a method for designing a three-channel real-time coordinatively controlled load for an electrohydraulic servo system is presented. The coordinative structure of the system with conditional output feedback compensators is quite simple. This coordinative controller is applied to the lift load control system of a variable swept aircraft wing. Our 5,000-repetition test shows that the coordinative method presented in this paper is practical and the results are quite good. It is suitable for real-time computer force-control systems in several aspects such as static and moving structure dynamic load tests.

1. Introduction

In the design of a multi-point coordinated force-control system for a moving object, the system structure is generally very complicated due to the interference of motion parameters of the object under load and the effects of cross-channel interference. In order to maintain coordinated operation and meet system performance requirements, it is necessary to apply effective coordinated-control techniques in addition to the conventional direct-control methods.

The lift of a variable-sweep aircraft wing varies with the angle of back-sweep, as shown in Figure 1. In this paper, our goal is to conduct ground-performance tests of typical flight profiles of variable-sweep aircraft to determine if the swept-wing drive system will function properly under flight load conditions. Based on these results we have designed a force-control system where the lift will vary as the swept-wing configuration changes. The main features of this force system are as follows:

(1) The load spectrum is related to the motion of the swept wing (i.e., the angle of back-sweep α).

(2) The force system is required to reproduce changes in the load spectrum to within a certain tolerance in order to reflect the actual lift variations with the angle of back-sweep during flight.

(3) The magnitude of lift can vary from several tons to tens of tons; it is limited by the strength of the wing structure. The movable wing is operated by a three-point coordinated force system; the tracking error of the resultant force is required to be less than or equal to 5 percent. Because of the symmetry in the wing structure, it is necessary to focus our discussion only on one side.

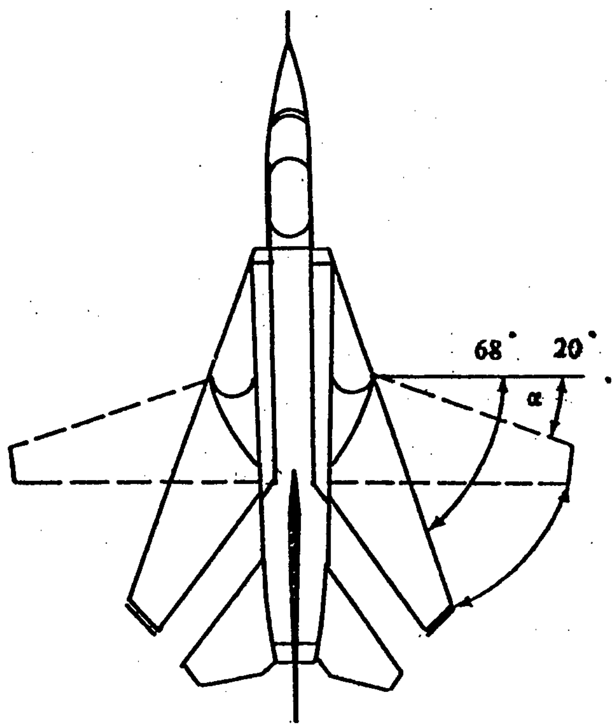

Figure 1. A Fighter Aircraft With Variable-Sweep Wing

A basic requirement of this system is to ensure that tests can be performed safely and reliably.

2. System Components and Model Construction

2.1 System Components

The motion of the variable-sweep wing is in the horizontal direction whereas the lift is in the vertical direction. Simulation of the variation in aircraft lift requires three separate control devices on the ground which are used to drive the operating mechanism and the control system of the wing. The suspended support boom of the three-point force mechanism must move in concert with the swept wing, hence a boom position-control system is required. Another component is the three-point coordinated force-control system used to simulate the lift variation of the aircraft. The operation of the control system is illustrated by the flow chart shown in Figure 2.

The operating procedure of the system is as follows: Based on the input flight altitude H and the Mach number M, the control computer calculates the automated variable sweep function $\varphi(H,M)$, and generates the command signals u_H, u_M; these signals activate the analog regulator $G_c(s)$, and the automated operating system and drive system, thereby setting the variable-sweep wing in motion. The motion of the back-sweep angle α for a typical flight profile is shown in Figure 3.

The value of the back-sweep angle is measured by the angular displacement sensor, A/D converted, and sent to the computer. The computer uses the value of α as a reference to control the motion of the suspended boom so it closely follows the motion of the wing. The value of α is also used to calculate the function $F(\alpha)$ to generate the load spectrum for each channel, $f_{i\alpha}(k)$ (i=1,2,3), and to control the force execution unit to apply the functions $f_{i\alpha}(k)$ to the wing. Each control cycle T is completed within 20 ms. The control computer in this system performs the following functions: calculating the variable-sweep function, collecting system parameters, resolving the three-point load spectrum, controlling the suspended-boom positioning system and the force system, and monitoring the operating condition of the system.

2.2 System Design Parameters and Models

The force-control system shown in Figure 2 consists of three separate channels; except for differences in the load rigidity at the force points and in the piston area of the actuating cylinder, all other components are identical. The design parameters of each channel are as follows:

Power amplification factor:	K_R = 2 mA/V
Pressure gain of servo valve[7]:	K_{pp} = 10.5 kg/cm^2/mA
Piston area of actuating cylinder:	K_A = 37.69 cm^2
Load rigidity at force point:	G_6 = 2506 kg/cm
Flow pressure coefficient:	K_c = 0.8 cm^5/kg·sec
Equivalent modulus of elasticity of hydraulic fluid:	β_e = 1.4x10^4 kg/cm^2
Volume of hydraulic fluid under pressure:	V_t = 1331 cm^3
Load mass:	m = 318 kg/cm^2
Force sensor transfer coefficient:	K_{f6} = 0.00024 V/kg
Rigidity of hydraulic pressure:	$G_h = 4\beta_e K_A^2/V_t$ = 59767 kg/cm

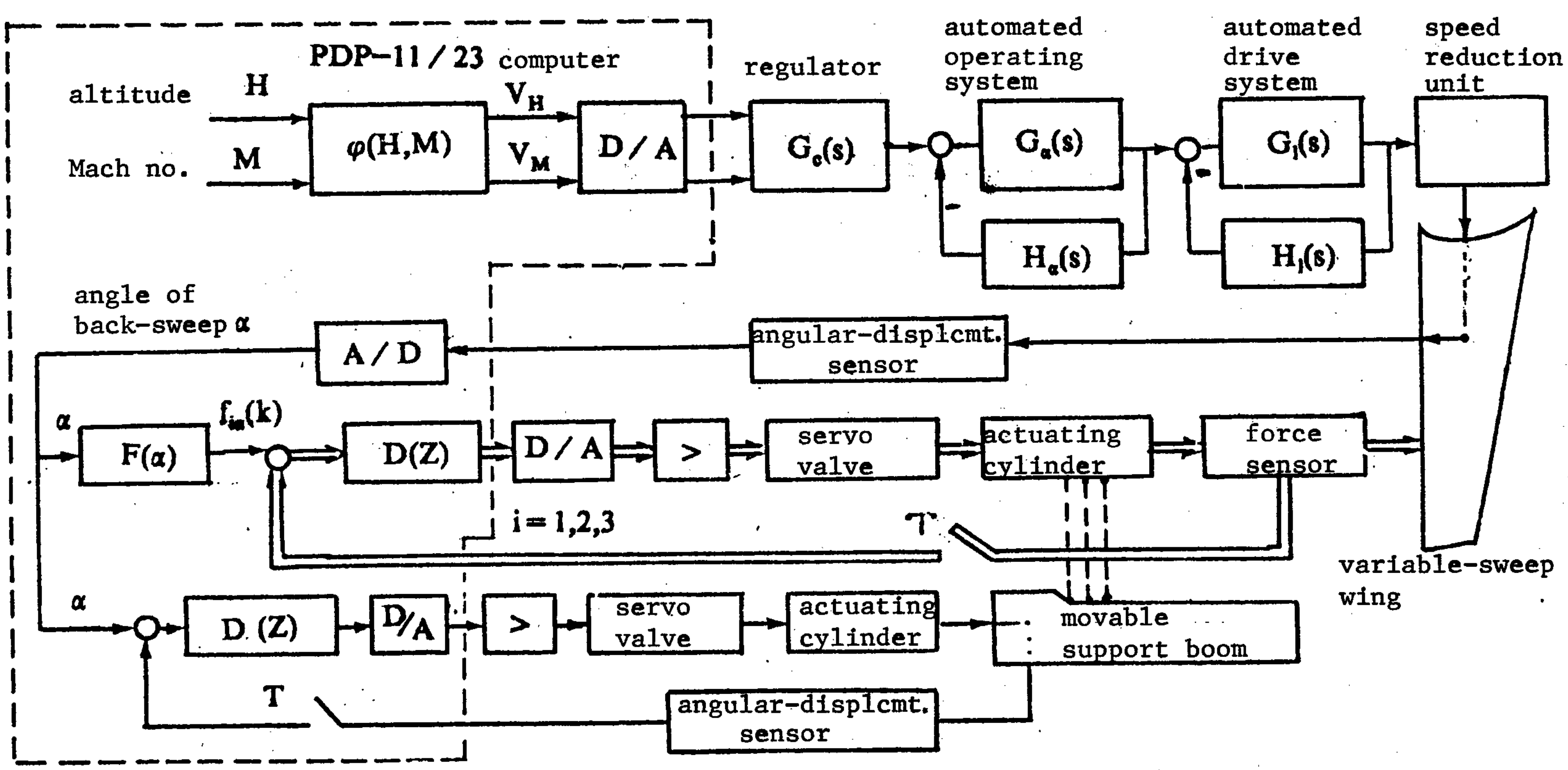

Figure 2. Operation of the Control System

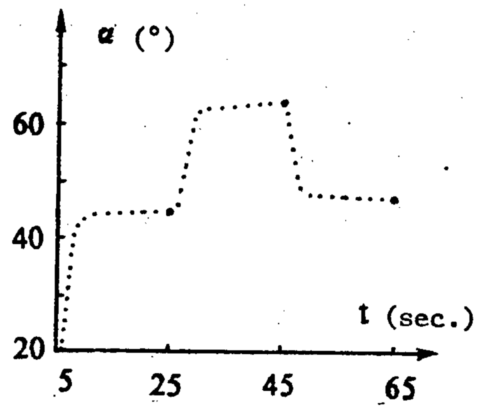

Figure 3. Motion of a Variable-Sweep Wing

Since $G_h >> G_6$, the bandwidth of the DYSF-3P pressure servo valve ($\omega_s > 565$/sec) is much greater than the bandwidth of the load system ($\omega_o = 3$/sec); also, the motions of the force mechanism (in the vertical direction) and the loaded wing do not change significantly, hence the open-loop transfer function of the force system can be approximated by[4]

$$G_6(s) = K/(T_M S + 1) \tag{1}$$

where $K = K_R \cdot K_{pp} \cdot K_A \cdot K_{f6} \cdot K_{g6} = 1$; K_{g6} is specified to be 5.26; and $T_M = (K_A^2/G_6 + V_t/4\beta_e)/K_c = 0.738$ second.

Equation (1) is given based on system design parameters; due to field-installation constraints and structural limitations, it only contains output feedback. The effects of cross-channel interference, wing motion interference and asynchronization between the suspended boom and the wing will be taken into consideration during test-model construction and system integration. We shall first discuss the problem of test-model construction, whose procedure is shown in Figure 2. The command signals issued by the computer cause the swept wing to follow the motion shown in Figure 3; at the same time, the suspended boom is also controlled to follow the same motion. When a step load spectrum (2,000 kg) is applied to the force system, the step response measured by the computer under the condition D(z) = 1 is shown in Figure 4. This response reflects the inherent characteristics of the system; it shows that the object is a 0-type system, which reaches steady-state after 0.6 second, but the steady-state value contains large fluctuations which are attributed to the pulsation of the fluid flow and disturbances caused by the motions of the wing and the suspended boom. By approximating this step response by a smooth curve and using the system structure of equation (1), we can calculate the open-loop time constant of the system to be $T_M = 0.26$ second. Therefore, equation (2) becomes

$$G_6(s) = \frac{1}{0.26s + 1} \tag{2}$$

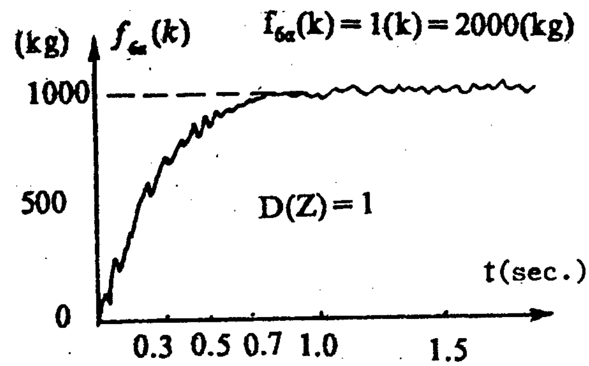

Figure 4. Step Response of the Force System

It should be pointed out that equation (2) includes the effects of sampling and signal preservation on the system dynamic response. However, for safety considerations during field testing, the model construction tests are only performed for each channel independently; hence equation (2) does not include cross-channel interference effects.

3. Design and Implementation of the Digital Controller

The main difficulty with the force-control system described here is that the motion of the swept wing is not affected by external factors, and the force is applied in the form of passive loading; in other words, when the back-sweep angle reaches a certain value α_{ℓ}, the corresponding load $F(\alpha_{\ell})$ must be applied to the wing. Another difficulty is that the wing has rather large elastic deformation, and there are large differences in rigidity at the three force points (1400 kg/cm^2 - 2506 kg/cm^2); also, there is severe cross-channel interference. Furthermore, the test requires that the control of a number of subsystems must be completed in real time. In fact, during one control cycle, T = 20 ms, the control computer must complete the following tasks: data acquisition over 51 channels, closed-loop control over 10 channels, state variable control over 32 channels, and calculation of the variable-sweep function and load spectrum. Therefore, in designing the force-control system, it is necessary to consider the execution time of the entire test. In the three-point coordinated force-control system, a control technique is used which includes PI [proportional-plus integral] control plus conditional-output, dynamic-compensation coordinated control; the block diagram for this control system is shown in Figure 5. In the figure, $D_i(z)$ (i=1,2,3) are the PI digital controllers, $Seti[\cdot]\cdot\hat{D}_i(z)$ are the dynamic compensation coordinator, where $Seti[\cdot]$ are logical variables which represent the set of compensation conditions, and $\hat{D}_i(z)$ are the compensators. $N_{fi}(s)$ denote the interference effects, K_{gi} are the specified coefficients, and K_{fi} are the feedback coefficients of the force sensors.

The design of the digital controller is carried out in two steps: the first step involves the design of $D_i(z)$, and the second step involves the design of $Seti[\cdot]\cdot\hat{D}_i(z)$.

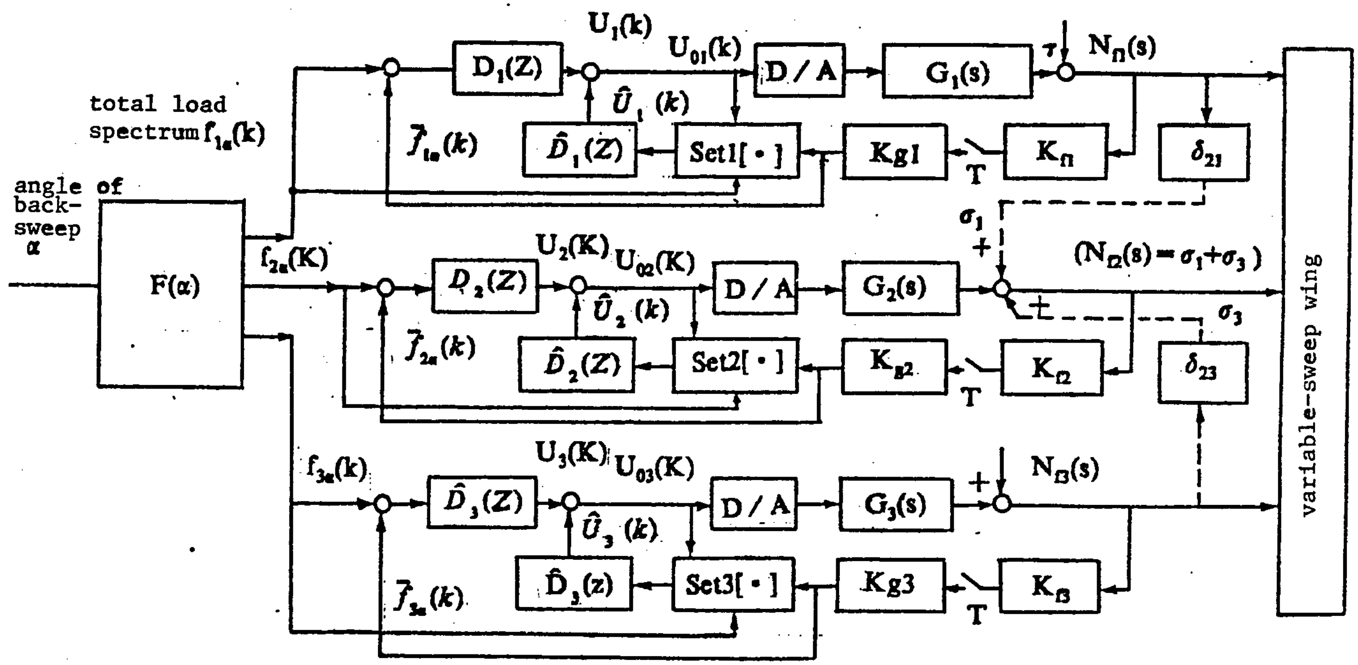

Figure 5. Implementation of the Three-Point Coordinated Force-Control System

3.1 The Design of $D_i(z)$. In designing $D_i(z)$, we first neglect the effects of cross-channel interference, and impose the following performance requirements for each independent channel:

(1) for system stability consideration, the damping $\xi > 0.6$
(2) the adjustment time $t < 0.6$ sec
(3) for a step input ($1(k) = 2000$ kg), the overshoot < 5 percent, and the steady-state error < 2 percent
(4) the tracking error for a triangular wave (slope ± 336 kg/sec) < 60 kg, the maximum coordination force at the inflection point (relative error) < 5 percent.

The control law for a PI controller is

$$u_i(k) = K_{pi}[e(k) + \frac{T}{T_{Ii}} \sum_{j=0}^{k} e(j)] \qquad (3)$$

Since $D_i(z)$ do not consider cross-channel interference effects, i.e., no compensation is required, the implementation of a system shown in Figure 5 is simply $u_{oi}(k) = u_i(k)$. As in the case of test-model construction, the tuning procedure for this system uses a time-dependent test load spectrum. For example, consider channel no. 6, where the parameters are chosen to be $K_{p6} = 2$, $T_{I6} = 0.1$, then the corresponding step response and triangular-wave response are shown in Figure 6. In the case of a step response, the overshoot is 2 percent, and $t_s < 0.6$ sec; in the case of the triangular-wave response, the tracking requirements are met, and the over-coordination force at the inflection point (load = 2351 kg) is less than 50 kg, which is equivalent to a relative error of < 3 percent. Comparison with the results of Figure 4 also shows that the control system clearly has the ability to suppress small fluctuating components.

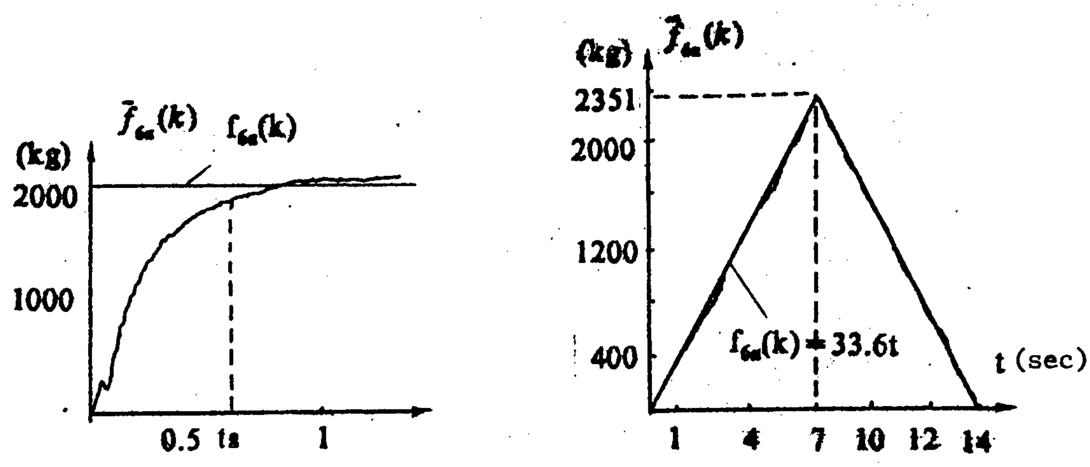

Figure 6. (a) Step Response; (b) Tracking of a Triangular Wave

3.2 The Design of Seti[·]$\hat{D}_i(z)$. In applying the three-point coordinated force, the cross-channel interference level in this system is quite high. In order to eliminate cross-channel interference, first the effects of interference must be detected on a timely basis; this is accomplished by Seti[·]. Then, measures must be taken to eliminate the interference; this is accomplished by $\hat{D}_i(z)$. Because interference cannot be directly measured, an indirect method is used, which is based on the deviation of tracking error between output and input, or based on the error between the slope of the output force and the slope of the input load spectrum. When the errors exceed the performance threshold, the compensator $\hat{D}_i(z)$ comes into play to eliminate the interference. Clearly, if coordinated operation of the system is maintained under the control of $D_i(z)$, then the compensator $\hat{D}_i(z)$ will not be activated. Therefore, this feedback compensation method differs from conventional feedback techniques in that $\hat{D}_i(z)$ does not act on the system directly; its activation depends on the compensation condition.

Seti[·] is a set whose logical value determines the system control $u_{oi}(k)$; when Seti[·] = "true," then

$$u_{0i}(k) = u_i(k) - \hat{u}_i(k) \tag{4}$$

where $u_i(k)$ is given by equation (3)

$\hat{u}_{oi}(k) = \hat{D}_i(z)\bar{f}_{i\alpha}(k)$, and $\hat{D}_i(z)$ is of the form

$$\hat{D}_i(z) = C_0 + C_1 z^{-1} + \cdots + C_l z^{-l} \tag{5}$$

When Seti[·] = "false," it means that coordinated system operation has been achieved, thus $u_{oi}(k) = u_i(k)$.

The value of Seti[·] in each channel determines which of the three channels requires compensation; if Seti[·] = "true" (i=1,2,3), then all three channels must be compensated. The value of Seti[·] is generated in real time; at each step, this information must be updated.

3.3 Definition of Seti[·]. The concept of the expert system has been introduced in the definition of Seti[·]. The variables of the set Seti[·] may incorporate all the information that can be obtained from the system, as well as any special knowledge about the control system, because Seti[·] only provides the compensation condition, not the compensation variables. In this system, three variables $f_{i\alpha}(k)$, $\bar{f}_{i\alpha}(k)$ and $u_{oi}(k)$ are introduced in the definition of the set Seti[·]; they represent all the available information of the system.

Let

$$\triangle f_{i\alpha}(k) = f_{i\alpha}(k) - f_{i\alpha}(k-1)$$
$$\triangle \bar{f}_{i\alpha}(k) = \bar{f}_{i\alpha}(k) - \bar{f}_{i\alpha}(k-1)$$

We shall define Seti[·] to be:

$$Seti[\cdot] = \{\text{true} | [\Delta \bar{f}_{iu}(k) > \Delta f_i(k) + \varepsilon_i] \bigcup [(\Delta \bar{f}_{iu}(k) < -(\Delta \bar{f}_{iu}(k) + \varepsilon_i)) \bigcap u_{0i}(k) < \max u(k)]\} \quad (6)$$

In the above expression, ε_i is the given coordination error, and max u(k) is the maximum energy of the system. The interpretation of equation (6) is as follows: if the slope of the system output exceeds the slope of input by a certain error margin, then compensation is activated to reduce the amount of control for the next step. Therefore, the constraint condition that must be satisfied by the parameters $C_j (j=0,1,\cdots,\ell)$ is:

$$\hat{u}_i(k) > 0 \quad (7)$$

The other situation is exactly reversed, except that information on the control $u_{oi}(k)$ is added; in this case, an increase in the amount of control is required, however. When $u_{oi}(k) > \max u(k)$, it means that the system has exhausted its capability. The constraint condition for parameter selection in this situation is

$$\hat{u}_i < 0 \quad (8)$$

3.4 Test Results. As an example, consider the three-point coordinated force control of the left wing. The control parameters are: $K_{p1} = 3$, $K_{p2} = 2$, $K_{p3} = 2$; $T_{I1} = 0.35$, $T_{I2} = 0.25$, $T_{I3} = 0.125$; $C_0 = 0.2$, $C_1 = -0.2$; $\varepsilon_1 = 22$ kg, $\varepsilon_2 = 22$ kg, $\varepsilon_3 = 82$ kg. Figure 7 shows the tracking of the system for a particular flight profile load spectrum. With coordinated control, the resultant tracking error is less than 5 percent, which satisfies the test requirement.

4. Conclusion

As part of the field tests, a comparison of two different control techniques was made. First, only P2 control was used; while the system functioned normally on some tests, the repeatability was poor. Under severe temperature conditions of 43°C, the system began to deviate from normal operation after several repeated tests. Also, when the absolute value of the ripple in a particular channel $|\bar{f}_{ik}(\alpha)|$ exceeds 500 kg, the entire system fluttered or even diverged. With the implementation of PI control plus Seti[·]$\hat{D}(z)$ compensation, improvements in system performance were observed in the following aspects.

(1) Good repeatability. The system was quite stable after a test of nearly 5,000 repetitions.

(2) Improved interference-rejection capability. Even when sharp changes of $|\bar{f}_{ik}(\alpha)| > 750$ kg occurred in certain channels, the system still functioned normally.

(3) Increased range of PI control parameters. The system functioned normally even when the PI parameters were varied by 50 percent.

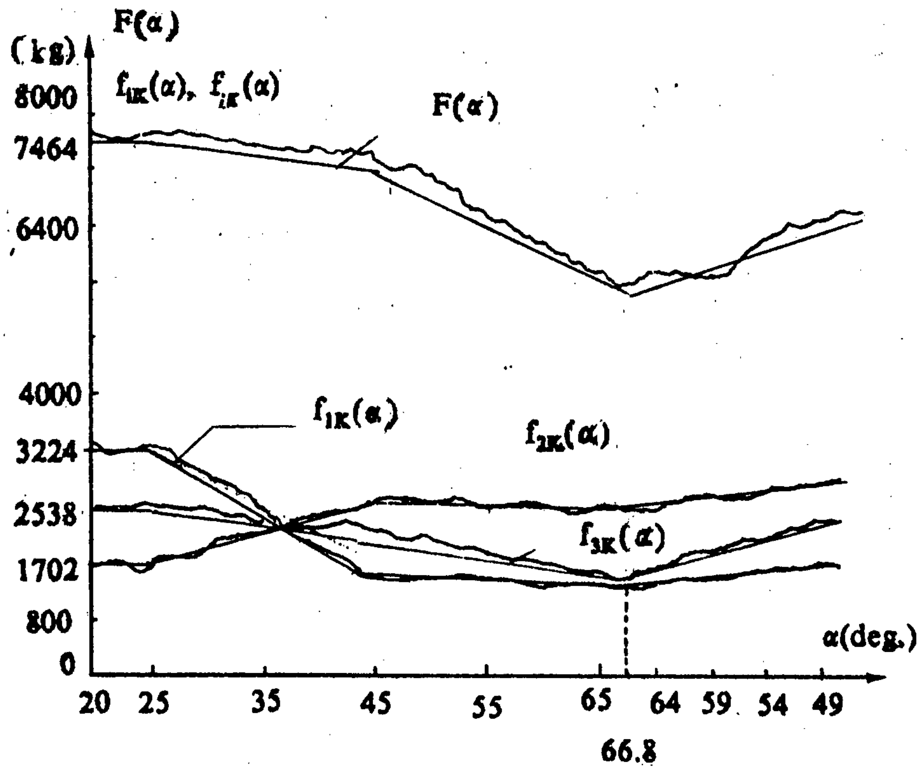

Figure 7. Three-Point Coordinated Tracking Curve

Seti[·]$\hat{D}_i(z)$ provides effective compensation for step-change interference; however, it has practically no compensating effect on slowly varying interference or steady-state errors because in the latter case Seti[·] generally yields a "false" value.

Acknowledgement

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Details of CZ-4 Launch Vehicle Presented

90CF0070A Beijing HANGTIAN [SPACE FLIGHT] in Chinese 26 Sep 89 No 5, pp 1-3

[Article by Li Xiangrong [2621 4161 3837]]

[Text] The "Long March 4" (CZ-4) launch vehicle is a large, three-stage rocket which uses liquid propellant at normal temperature; it has the flexibility of being launched from any launch site in this country. The rocket has a simple propulsion system and a reliable structure. Its launch operation is also simple and efficient.

On 7 September 1988, the CZ-4 successfully launched China's first sun-synchronous experimental weather satellite. Flight test results showed that its performance fully met design requirements. The CZ-4 has two different satellite fairings which can accommodate payloads of different sizes and quality; it is designed to provide launch services for a wide range of satellites, particularly for satellites going into sun-synchronous orbits and polar orbits.

Overview

The original design goal of the CZ-4 was to launch a 1,100-kg payload into a geosynchronous transfer orbit; it primarily uses propellants at normal temperatures. It is a superior launch vehicle in terms of reliability, adaptability, performance and economy. But since normal-temperature propellants have lower energy content than low-temperature propellants, its payload capability is limited. For this reason, a series of key measures were taken in the overall design to enhance the payload capability.

1. The thrust of the first-stage engine has been increased from 4x686 kiloNewtons(kN) to 4x735 kN, which has increased payload capability by 113 kg. The CZ-4 is China's launch vehicle with the largest lift-off thrust.

2. The first-stage fuel tank has been lengthened by 4 m, which increases the propellant capacity by 40 tons, and raises the payload capability by 230 kg; the lift-off thrust-to-weight ratio is 1.2.

3. The third stage has a twin-engine design with 14 tons of propellant capacity; this design increases the payload capability by 116 kg over the single-engine design.

4. In order to reduce structural weight, the third stage uses a fuel tank which is made of high-strength aluminum alloy with a single-layer structure. The traditional large-frame engine-mount design has been replaced by a riveted short engine compartment design in which this compartment is attached directly to the fuel tank; the compact structure weighs only 40 kg, which is 90 kg lighter than the original structure. Through design optimization, the weight of the first stage has also been reduced by 300 kg and the second stage by 50 kg.

5. The third-stage pressurization design uses helium instead of nitrogen for pressure control, and reduces weight by 87 kg.

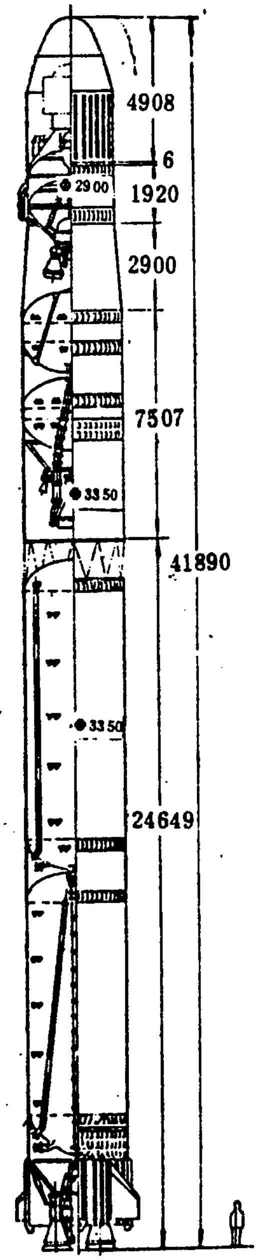
6. The control, telemetry and external measuring systems have been reduced in size. The number of secondary power-supply units of the control system has been reduced to 6; the total volume has been reduced by half and the weight has been reduced by 40 kg. The weight of the telemetry system has been reduced by 30 kg, and the external measuring system by 20 kg.

Through the implementation of these design measures, the CZ-4's payload capability for geosynchronous transfer orbit was ultimately increased to 1,250 kg.

The payload capability of the CZ-4 for sun-synchronous orbit is shown in Fig. 1 as a function of altitude and ellipticity. The overall parameters of the CZ-4 in launching the "Fengyun-1" weather satellite are shown in the following table.

	First stage	Second stage	Third stage
Theoretical length (m)	43.032	18.262	9.840
Diameter (m)	3.350	3.350	2.900
Lift-off mass (tons)	239.942	52.978	13.888
Mass at engine cut-off (tons)	64.836	17.853	2.738

Note: the 1st and 3d stage are not filled to capacity.



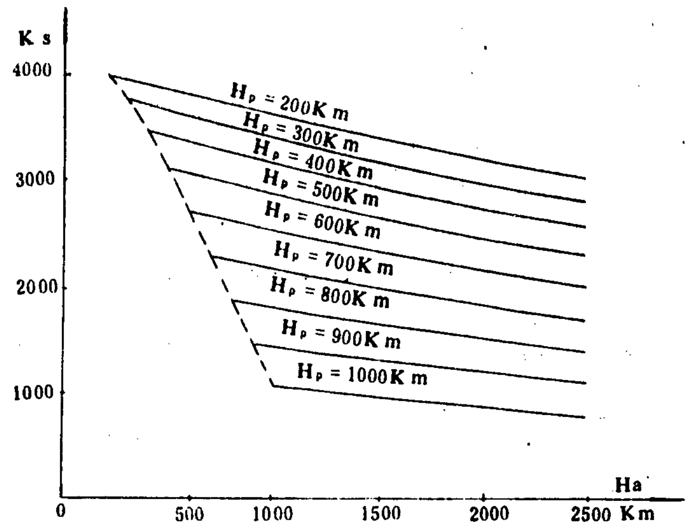


Fig. 1 Payload Capability of the CZ-4

The typical procedure for launching the "Fengyun-1" weather satellite was as follows. Three seconds after ignition, the rocket thrust increases to a point where it exceeds the gravitational force and the launch vehicle lifts off the launch pad. At 7 seconds into the flight, a pre-programmed pitch maneuver in the launch plans is initiated; at 150.807 seconds, the first-stage propellant is exhausted, and the vehicle velocity reaches 2,297.985 m/sec. The on-board control system issues a command for first-stage engine cut-off and second-stage ignition; 1.2 seconds later, the explosive bolts are detonated, and the first stage is pushed away from the second stage, re-enters the atmosphere, and falls back to earth in the pre-designated Shangluo mountain region [in Shaanxi Province]. At 25 seconds after second-stage ignition, the rocket reaches an altitude of 119.135 km, which is near the edge of the atmosphere; at this point, the protective satellite fairing is ejected from the rocket. At 125.852 seconds into second-stage flight, the velocity reaches 4,444.845 m/sec, and the on-board computer issues a command to shut off the second-stage main engine; 9.8 seconds later, the four vernier engines are activated to remove any attitude disturbances caused by second-stage engine cut-off, then they are shut off. One second later, the explosive bolt between the second stage and the third stage is detonated, and the eight solid-propellant retrorockets are ignited to separate the third stage from the second stage. The second stage rocket body is allowed to fall freely into the atmosphere, where it is burned up and broken into small debris which eventually fall into the Xianluo Bay [i.e., Gulf of Thailand]. At 1.2 seconds after separation, the third-stage engine is ignited; at 329.750 seconds into third-stage flight, the velocity and altitude of the rocket achieve orbital conditions, and the on-board computer issues a command to shut off the third-stage main engine. At the same time, it activates the four 471-Newton anhydrous-hydrazine normal-thrust engines to correct any orbit-injection errors caused by third-stage engine shut-down; the attitude of the rocket is controlled and stabilized by the 10 thrust nozzles of the anhydrous-hydrazine attitude-control engine. After shut-down of the normal-thrust engines, the orbital parameters at injection are accurately measured by the tracking system and the external trajectory-measuring system. At 55 seconds after third-stage main-engine cut-off, the explosive bolts connecting the satellite and the rocket are detonated, and 0.2 second later, the two solid-propellant retrorockets are ignited, separating the satellite from the rocket; at this point, the satellite has entered its final orbit. After separation, the third stage continues powered flight until it is far away from the satellite. The rocket travels for a total of approximately 674.368 seconds, during which time it passes over the provinces of Shanxi, Shaanxi, Hubei, Guizhou, and Guangxi, and exits China's airspace at Pingxiang. At the point of orbit injection over Vietnam, it has traveled a ground distance of approximately 2,243 km.

Subsystem Design

1. The Rocket Structure System. The CZ-4 satellite fairing [shown in Figure 2] is a semi-rigid structure which consists of the spherical nose cone, the aft cone and the cylindrical section. The conic sections and the spherical head are covered with fiberglass skins which are transparent to radio signals;

the remaining structure is made of aluminum alloys. The fairing is connected to the third stage by six axially mounted explosive bolts; the two halves of the fairing are connected by three pairs of explosive bolts. During separation, the control system provides the detonating current, and the separating force is provided by three pairs of power-packed ejection tubes, which produce a separation velocity of 4 m/sec.

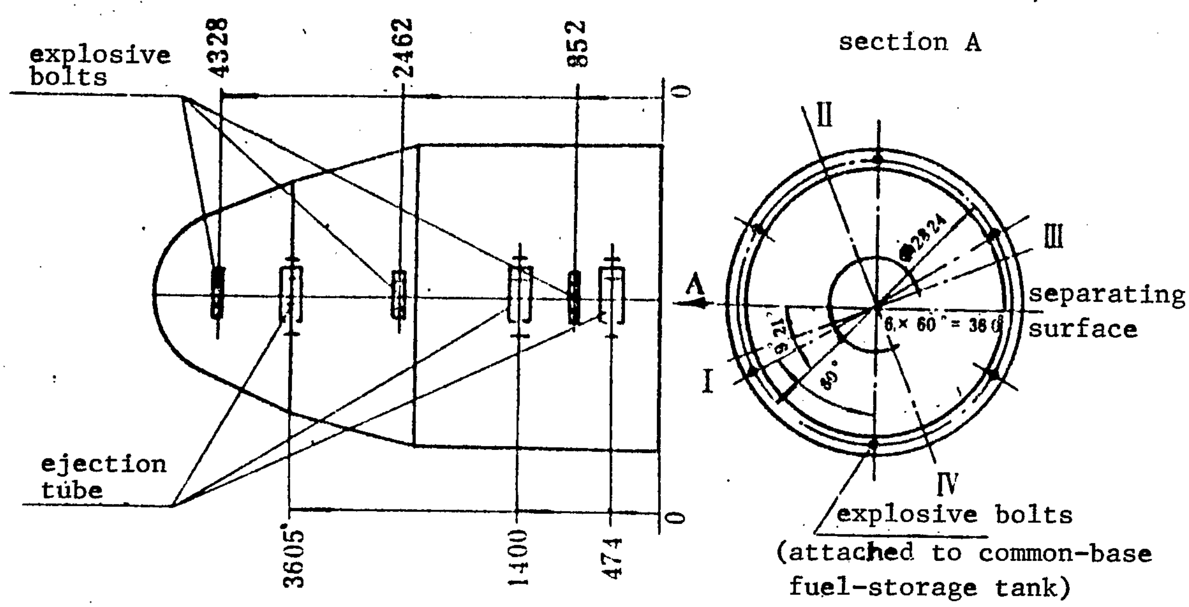


Fig. 2 Satellite Fairing and Separating Mechanism

The fuel-storage tanks of all rocket stages are made of high-strength aluminum alloy LD-10 material. To reduce weight, all three stages use a thin-wall, single-layer structure with a common base. Anti-sloshing plates are installed inside each tank to provide damping of liquid sloshing. The third-stage storage tank is also equipped with cruciform or *-shaped isolation plates to increase the sloshing frequency so that it will not interfere with the control system due to proximity to the control frequency.

The third stage has a riveted conical instrument compartment which contains various instruments, gas bottles and electric cables; it is rigidly attached to the satellite at the top. Attached to the cover of the storage tank is a short engine compartment which contains two third-stage engines, the anhydrous-hydrazine normal-thrust engine and attitude-control engine, the servomechanism support, gas bottles and supply tubes; this compartment is light-weight, structurally compact, and easily accessible. The inter-stage sections and the tail section are all made of aluminum alloys; the first stage is also equipped with an inter-stage frame structure to allow second-stage engine exhaust to escape during first- and second-stage separation.

2. Propulsion System. The first-stage engine of the CZ-4 has been modified from its original design to achieve an increase in unit thrust of 49 kN. The second-stage propulsion system is identical to that of the CZ-3. The third-stage YF-40 engine is a newly developed high-performance upper-stage engine using normal-temperature propellant. Its specific impulse of 303 seconds and its thrust-to-mass ratio of 56.82 kN/kg have both reached state-of-the-art standards. The radiation-cooled niobium-alloy nozzle extension can swivel in two orthogonal directions and has re-start capability. The CZ-4 uses a twin-engine parallel design. The third-stage pressurized supply system has a primary supply line and a secondary supply line; the primary supply line passes through the electromagnetic valve and the pressure reducer, to the storage tank, while the secondary supply line passes through another electromagnetic valve which is controlled by the pressure sensor of the storage tank. The storage tank is pressurized by ten 20-liter normal-temperature helium bottles which provide sufficient redundancy to enhance reliability.

3. Third-Stage Anhydrous Hydrazine Normal-Thrust and Attitude-Control Engine System. This system is used for velocity correction and attitude control after third-stage engine shut-down, and for attitude adjustment prior to satellite orbit injection; the attitude-determination error during the first launch was only 0.2 degree. The system has 14 thrust nozzles which are controlled by electromagnetic valves; it also contains an anhydrous hydrazine fuel-storage tank, a helium pressurization bottle and a pressure reducer. The system uses a surface-tension-network hydrazine tank which was flown for the first time during a flight test; this design eliminates the problems caused by mesh welds and vibration. By making use of the residual effect of a special 3.25x2300 stainless-steel oblique mesh in propellant management, it is possible to achieve an effluency of over 98 percent in a micro-gravity field with a total volume of only 28 liters.

4. Control System. The control system has a platform computer design. The guidance system uses a conjugate function for gravity compensation which is approximated by the coefficients of a second-order curve. The third-stage steering circuit uses variable-coefficient steering, and variable coupling terms from the normal direction are incorporated in the lateral steering circuit. The results of steering accuracy from the first launch showed that they completely satisfied design requirements (see the following table).

Parameter	Allowable value	Flight value
Deviation in orbital period (sec)	±12	-5.241
Deviation in orbital inclination (°)	±0.12	-0.109
Eccentricity	±0.005	+0.00243
Deviation in perigee altitude (km)	-40	-17.958
Deviation in apogee altitude (km)	+40	+17.403

The attitude-control system uses a digital network and digitized zero-adjustment design. The digital circuit has many desirable features including flexibility in changing parameters, adaptability, a high degree of dynamic and static accuracy, and resistance against interference.

The attitude-control system and the guidance system share the same on-board computer. The computer has incorporated horizontal microprogram-design techniques in its logic design; it has also implemented micro diagnostic programs, 8-stage program screens, and a program-selective priority-interrupt system. It can perform not only the functions of guidance and attitude control, but also those of first-stage zero adjustment and pulse generation.

The newly-developed third-stage bidirectional-swivel servomechanism is operated by two actuating cylinders driven by a hydraulic pump. Its weight-to-power ratio is considered to meet state-of-the-art standards.

5. Telemetry System. There are two pulse-code-modulation (PCM) high-speed telemetry units which can telemeter 364 digital and analog parameters of the rocket status. It uses state-of-the-art sensors which can measure micro overloads of the order of 8×10^{-4} gram; the units are also compact in size.

6. External Measurement Safety System. The rocket is equipped with continuous-wave (CW) radar responders and pulse radar responders which can transmit measured ballistic-trajectory parameters to the ground station; it also has a 10-cm beacon which is used by the ground station for rocket guidance. The CW radar responder uses a phase-locked transponding design; it also uses microwave low-noise amplifiers and a high-gain microstrip antenna with small axial ratio. This simple design enhances the interference-rejection capability and improves the accuracy of velocity and range measurements. To avoid causing damages to properties on the ground along the flight path, the system also has the provision for self-destruction in case of a malfunction.

7. Ground Testing, Command and Control System and Other Ground Equipment. The ground testing, command and control system complies with the international CAMAC [computer-automated measurement and control] regulations. The power distribution, testing, and command and control functions are performed by two Z-80 microcomputers and one [Great Wall] 0520 microcomputer and the command and control station; in addition, there is a second test-launch system which consists of the DFS-1 simulation real-time processing system operating in conjunction with the command and control station; this redundant system provides assurance that a launch will always take place within a 30-minute launch window.

There is newly designed ground equipment which includes the laser collimation device, the pressure-difference controlled gas distribution unit, and the automatic pressurization control for the common-base fuel-storage tank.

Free Electron Cyclotron Resonance Laser

90CF0095 Beijing WULI XUEBAO [ACTA PHYSICA SINICA] in Chinese Vol 38 No 8, Aug 89 pp 1215-1224 [MS received 16 May 88]

[Article by Wang Changbiao [3769 2490 2871] of the Chengdu Institute of Radio Engineering [now the University of Electronic Science and Technology]: "Free Electron Cyclotron Resonance Laser"]

[Excerpts] Abstract

This paper presents a new free electron laser (FEL)--the free electron cyclotron resonance laser. Expressions for electron efficiency and start-up resonance current of this laser are given.

I. Introduction

In recent years there has been considerable interest in generating coherent electromagnetic radiation by relativistic electrons.[1-4] The cyclotron[5] and the FEL[6] are two familiar relativistic devices. Important progress[7-16] has been made in research on the [electron] cyclotron [resonance] maser (ECRM) and the free electron laser (FEL). In an ECRM and a circularly polarized FEL, electrons with axial velocity $v_{\parallel}$ and transverse velocity $v_{\perp}$ are in spiral motion. The product of the axial relativistic factor $\gamma_{\parallel} = (1 - \beta_{\parallel}^2)^{-1/2}$ and the dimensionless transverse velocity $\gamma_{\parallel}\beta_{\perp}$, is much smaller than 1.[8,13] ($\beta = v/c$, c is the speed of light in vacuum.) Spontaneous radiation of the electrons is primarily concentrated on the axial fundamental harmonic,[17] resulting in the highest interaction efficiency between the electron beam and the fundamental harmonic.

Usually, there are two ways to raise the operating frequency of the device without changing the pumping field: 1) the Doppler effect and 2) the interaction between the electron beam and higher-order harmonics.

One of the important differences between an ECRM and an FEL is that the dependence of the cyclotron angular frequency of the electrons on energy is not the same. In an ECRM, the cyclotron angular frequency of the electrons is $\omega_c = B_0|e|\gamma_0 m_0$[18] (where B_0 is the applied axial magnetic field, e is the electronic charge, m_0 is the rest mass of an electron, and $\gamma_0 = (1 - \beta^2)^{-1/2}$ is the overall relativistic factor). In an FEL, the cyclotron angular frequency of the electrons is $\omega_0 = 2\pi v_{/\!/}/\lambda_w$ [19] (where λ_W is the spatial period of the applied circularly polarized magnetic field). From classical electromagnetism[20] we know that there is an upward Doppler frequency shift in the forward spontaneous radiation of the cyclotron due to the axial drift motion of the electron. Hence, the operating frequency of the ECRM is $\omega \approx \omega_c/(1 - v_{/\!/}/v_p) < (1 + \beta_{/\!/})(\gamma_{/\!/}^2/\gamma_0)B_0|e|/m_0$ (where v_p is the phase velocity of the electromagnetic wave), and the operating frequency of the FEL is $\omega \approx \omega_0/(1 - \beta_{/\!/}) \approx 4\pi\gamma_{/\!/}^2 v_{/\!/}/\lambda_w$.

Since the dependence of the cyclotron angular frequency of the electrons on energy is different, the energy dependence of the operating frequency of the ECRM is also different from that of the FEL. The operating frequency of the ECRM does not increase as fast as that of the FEL with Doppler effect. Most masers can only operate in the millimeter-wave band[7,8,10] and free electron lasers can operate in the visible region.[12]

In order to shorten the operating wavelength by using higher-order harmonics, the Bernstein-mode quasi-optical cyclotron maser[21,22] was introduced. Based on a theoretical analysis,[23] even when operating in its tenth cyclotron harmonic, the interaction efficiency of the Bernstein-mode quasi-optical cyclotron maser is comparable to that of the fundamental harmonic. Since the Bernstein mode is a quasi-longitudinal wave (static electric wave), one must increase the longitudinal-electric-field component to raise the interaction efficiency. However, the coupling between the Bernstein mode and the electromagnetic mode outside the electron beam is adversely affected when the longitudinal-field component is too strong. Therefore, the power and efficiency of this type of device are severely limited.

This paper introduces a new free electron laser, the free electron cyclotron laser (FECL), which involves the interaction between the electron beam and ultra-high-order harmonics. Figure 1 shows the structure of this laser. The surface of the cylindrical mirror is parallel to the applied uniform magnetic field $B_0\hat{z}$. An electron beam with $v_{/\!/} \ll c$ is gyrating along the axial magnetic field at a relativistic speed $v_\perp \approx c$. The direction of propagation of the wave is perpendicular to the electron beam. In such a structure, because $\gamma_{/\!/}\beta_\perp \approx 1$, $\beta_{/\!/} \ll 1$, the spontaneous radiation of the electron is mainly concentrated in an ultra-high-order harmonic of the order of approximately $(\gamma_0/\gamma_{/\!/})^3$ in a direction perpendicular to the electron beam.[17] The spontaneous radiation is reflected by the mirror and is used to interact with and modulate the electron beam to generate coherent radiation. Because the spontaneous radiation is concentrated at an ultra-high-order harmonic, effective energy transfer between the electron beam and the ultra-high-order harmonic is made possible.

The operating mechanism of the FECL is not exactly the same as that of the Bernstein-mode quasi-optical maser. In the Bernstein-mode quasi-optical maser, although there is relatively strong interaction between the electron beam and higher-order harmonics, the strongest interaction still takes place in the fundamental harmonic. In an FECL, the electron beam can directly interact with an ultra-high-order cyclotron harmonic of the electromagnetic mode. The most intense interaction occurs in a certain ultra-high-order harmonic, rather than in the fundamental harmonic. The FECL is also different from the quasi-optical cyclotron maser[24,25] and induced quasi-optical cyclotron maser.[26,27] The working wavelength λ of these two quasi-optical masers is much larger than the electron cyclotron radium γ_c. Within the cyclotron radius, electrons almost cannot experience any field amplitude changes. In an FECL, $\lambda << \gamma_c$; electrons within the cyclotron radius will experience periodic changes in field amplitude with respect to space. This is the difference which limits a quasi-optical maser to operating in the millimeter-wave and sub-millimeter-wave bands, while an FECL can operate in the visible band.

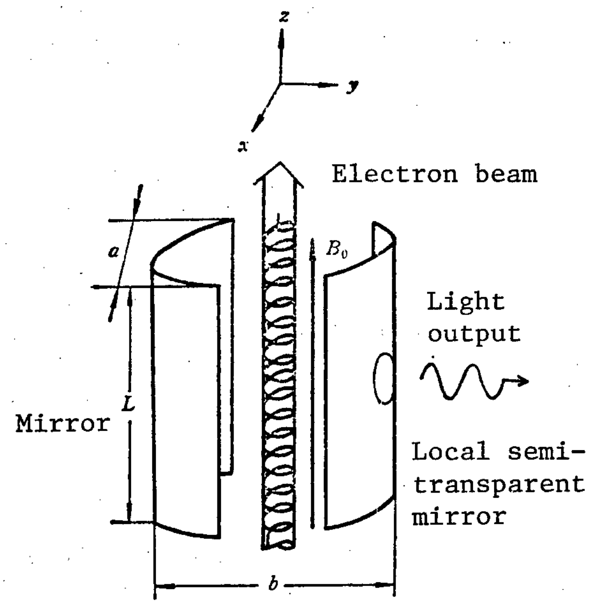


Figure 1. Free Electron Cyclotron Laser

A single-particle model was used to calculate the interaction between a plane wave and an electron beam with a specific momentum. Expressions for linear electron efficiency and start-up current have been obtained.

II. Correction for Spontaneous Radiation and Partial Expansion of the Interacting Optical Field

In the non-self-consistent single-particle theory, people usually assume that a stable interaction field already exists in the cavity and then calculate the mean energy variation of the electron in this region with the Lorentz equation. Based on conservation of energy, this mean electron energy variation is considered as electronic excitation of the field. However, usually the field does not include a correction for the amplitude of the electric field due to spontaneous radiation.[24]

Based on the relativistic electron theory,[17] the spontaneous radiation of an electron in uniform circular motion at a speed v ≈ c is mainly concentrated in higher-order harmonics near the trajectory plane. Based on an observation of the trajectory plane, the amplitude of the electric field in the ℓth harmonic is proportional to $(\beta/\gamma_0)lJ'_l(l\beta)$, where $J'_\ell(x)$ is the derivative of the ℓth-order Bessel function of the first type. For a gyrating electron traveling at an axial velocity of $v_\parallel \ll c$, by means of relativistic transformation and taking $\gamma_\parallel \approx 1$ into consideration, it is not difficult to find on a plane perpendicular to the axis that the amplitude of the electric field of the ℓth harmonic is proportional to $(\beta_\perp/\gamma_0)lJ'_l(l\beta_\perp)$. Hence, when $\beta_\perp$ is small, the maximum amplitude of the spontaneous-radiation electric field of a gyrating electron occurs at a lower-order harmonic. As $\beta_\perp$ gradually increases, this maximum shifts to higher-order harmonics, as shown in Figure 2.

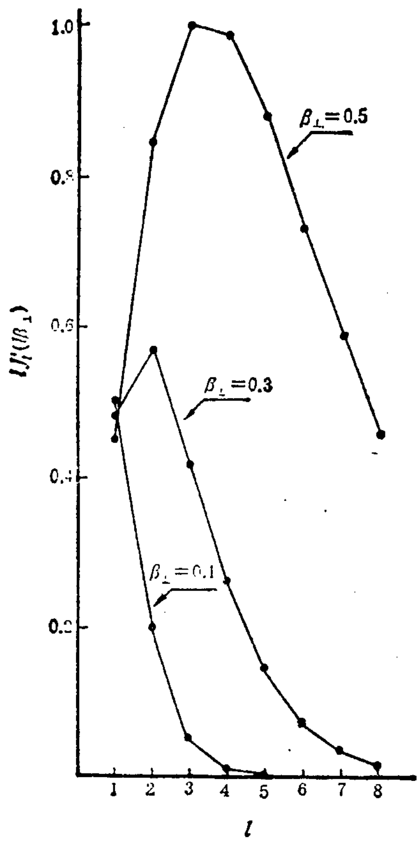


Figure 2. Maximum Value of $lJ'_l(l\beta_\perp)$ Shifting to Higher-Order Harmonics With Increasing $\beta_\perp$

In an FECL, the spontaneous radiation is reflected by the mirror and interacts with the electron beam to create a disturbance to the motion of the electrons. The disturbed electrons produce radiation due to excitation. Since the magnitude of the disturbance depends on the magnitude of reaction force on the electron, the excited radiation field also depends upon the spontaneous radiation field. Since each spontaneous radiation at a specific frequency has a different field amplitude, an excited radiation field also should have a specific amplitude for a certain frequency. Therefore, we should make a correction for the effect of spontaneous radiation on the interaction field in the cavity when we calculate the mutual interaction between spontaneous radiation and the electron beam.

Since the operating frequency of the FECL is very high and the distance between the mirrors is very short (a few centimeters), we can use a plane wave to approximate the interaction optical field. [passage omitted]

Equation (25) shows that the electron efficiency varies with the harmonic factor Y_ℓ, i.e., the FECL efficiency differs at various operating harmonics. Figure 4 shows how Y_ℓ varies with ℓ when $\gamma_\perp = 7$. Table 1 shows the relation between ℓ and $\gamma_\perp$ when Y_ℓ reaches its maximum $(Y_\ell)_{max}$. From Table 1 we find that Y_ℓ reaches its maximum when $\ell \approx 0.39\gamma_\perp^3$. This indicates that the operating frequency of the FECL is $\omega \approx 0.39\gamma_\perp^3\omega_c$.

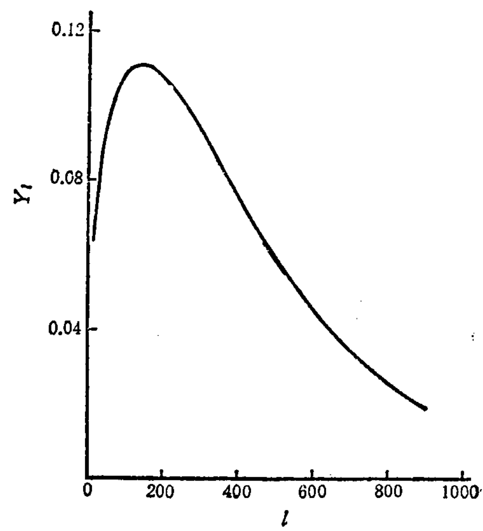


Figure 4. Y_ℓ vs. ℓ when $\gamma_\perp = 7$

Table 1. Relation Between ℓ and $\gamma_\perp$ at Maximum Y_ℓ

$\gamma_\perp$	$\beta_\perp$	$(Y_l)_{max}$	l	$l/\gamma_\perp^3$
7	0.989743	0.111544	138	0.4023
10	0.994987	0.159177	395	0.3950
15	0.997775	0.238654	1318	0.3905
20	0.998749	0.318160	3108	0.3885
25	0.999200	0.397782	6064	0.3881
30	0.999444	0.477116	10490	0.3885

Based on equation (24), the efficiency line width is determined by the factor $-F'(u)$. The efficiency line width of the ℓth order harmonic is approximately $(2N\ell)^{-1}$, as shown in Figure 5. It should be pointed out that the negative efficiency region shown in Figure 5 is because the model itself is non-self-consistent. It does not include a correction to the optical field amplitude due to its interaction with electrons.

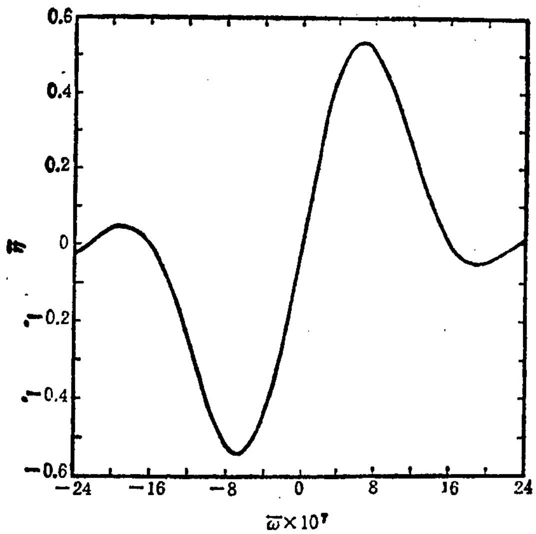


Figure 5. Normalized electron efficiency $\bar{\eta}$ $\gamma_0 = 25$; $B_0 = 80$ kG; $N = 199$; $\ell = 3151$; $\bar{\omega} = (\omega - \ell\omega_c)/\omega$; $\bar{\eta} = -F'(u)$

Assuming the average reflectance of the mirror (see Figure 1) is R, then the quality factor of the resonance cavity can be expressed as:

$$a = \frac{2\pi}{1-R}\frac{b}{\lambda}, \tag{26}$$

where b is the distance between mirrors. With equation (1) and by taking the boundary condition into consideration, the mean energy stored in the cavity is:

$$W = \frac{1}{4}\varepsilon_0 abLc_s^2E_0^2, \tag{27}$$

where ε_0 is the electrical permeability in vacuum and a is the width of the face of the mirror.

Assume that P_b is the power of the electron beam, then the start-up condition is:

$$P_b\eta_{max} \geqslant \frac{\omega W}{a}. \tag{28}$$

Substituting equations (25)-(27) into the above, we get an expression for the start-up current in the ℓth harmonic:

$$I_{st} = 0.59 \frac{\lambda a}{L^2} \frac{\varepsilon_0 m_0 c^3}{|e|} \frac{\gamma_0 \beta_{\parallel}^3}{\langle g_l^2 \rangle \beta_\perp^2} \frac{(1-R)}{J_l'^2(l\beta_\perp)}. \quad (29)$$

IV. Example

As an example, let $\gamma_o = 25$, $\gamma_\perp = 20$, $B_o = 80$ kG,[8] a = 4 cm, L = 20 cm, R = 0.9,[27] $\langle g_\ell^2 \rangle = 0.5$, $E_o/B_oc = 4.2 \times 10^{-4}$, the number of gyrations N = 199, and electron cyclotron radius $r_c = 5.3$ mm. Figure 6 shows the dependence of electron efficiency and start-up current upon ℓ. From Figure 6, when $\ell = 3151$, the linear efficiency is approximately 0.6 percent and the start-up current is approximately 0.36 A. The operating wavelength should be 10.6 microns.

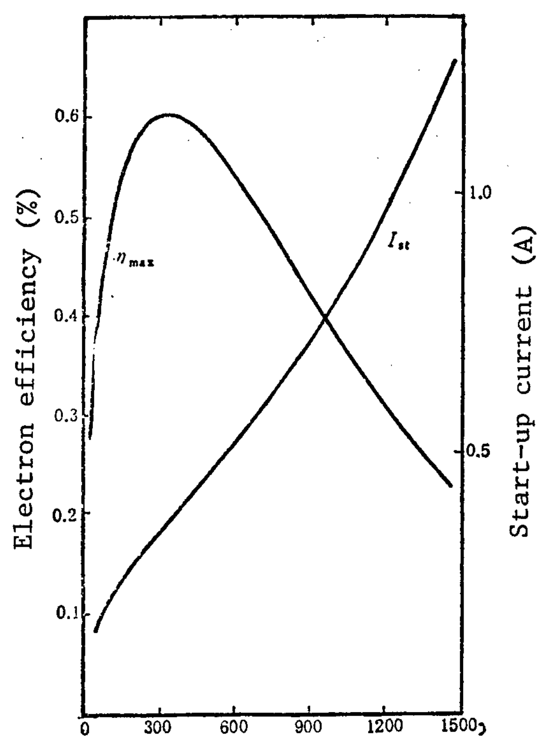


Figure 6. Dependence of η_{max} and I_{st} upon ℓ when $\gamma_o = 25$, $\gamma_\perp = 20$, $B_o = 80$ kG, a = 4 cm, L = 20 cm, R = 0.9, $\langle g_\ell^2 \rangle = 0.5$, $E_o/B_oc = 4.2 \times 10^{-4}$

Figure 6 also shows that the FECL might operate in several modes. However, because the frequency spacing between longitudinal modes is wide and the efficiency line width is narrow, it is possible to suppress them by properly choosing the distance between the mirrors. In addition, a multi-layer mirror[15] could be used to suppress unwanted modes in order to ensure sufficient coherence of the laser output.

V. Conclusions

The free electron cyclotron laser presented in this paper is a type of free electron laser. The working frequency of this laser is $\omega \approx \gamma_{\perp}^{3}\omega_{c}$. It is actually an electronic device which transforms the spontaneous radiation from electrons in forced relativistic circular motion in ultra-high harmonics near the trajectory plane to coherent radiation. Compared to the FEL,[6] the FECL has three attractive advantages. 1) The usable radius of the electron beam is not significantly affected by the applied magnetic field. Consequently, the volume of interaction between spontaneous radiation and the electron beam is greatly increased. In an FEL, the transverse gradient effect of the periodic magnetic field limits the usable electron beam radius to approximately 0.1 λ_w.[15,28-30] 2) Since the direction of wave propagation is perpendicular to that of the electron beam, the slippage between the light wave and the electron beam is eliminated. Thus, the annoying fringe instability in an FEL does not exist.[31-33] 3) The distance between mirrors is short and the quality of light transmission is good. Therefore, the FECL does not require an optical [wave-]guide.[34-36] In addition, because $v_{\perp} \approx c$, the energy transfer between the electrons and the optical electric field is effectively enhanced. Therefore, the FECL is a promising high-efficiency, high-power laser.

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Development of VSAT Satellite Network

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[Article by Tong Weiping [4547 5898 1627]: "A Dedicated Satellite Data Communications System and Its Applications"]

[Text] As the scope of our economic activities expands, the requirements for high-speed and better quality information transfer become more demanding. Long-range computer networking--i.e., high-quality, long-range data transfer--has become an urgent task in communications. In order to satisfy the demand of domestic users, after several years of effort, China Broadcast Satellite Corporation (CBSC) opened a low-speed data communications network, i.e., the V-NET network, in August 1988. V-NET employs VSAT (Very Small Aperture Terminal) equipment imported from the U.S. firm VSI (VSAT Systems Inc.) to transfer data at low speed (1.2 - 9.6 kbps) between two points or from one point to several points via satellite. It is particularly suitable for communications between terminals and from a mainframe to a number of terminals. In addition, V-NET can also be used to provide services such as facsimile, static graphics and telephone communications.

V-NET is being used by State Seismological Bureau, the Ministry of Railways, the Chinese Civil Aviation Administration, the State Planning Commission, the General Administration of Customs, the Ministry of Energy Resources, the State Oceanography Bureau and various financial institutions. Several dozens of terminals have been built in China, and the plan is for 200 terminals to be completed by the end of 1989.

I. Network Structure

The basic mode of V-NET is a star-shaped network, as shown in Figure 1. The ground system consists of a central station (main station) and terminals (VSAT stations). It has an unbalanced structure; this imbalance is reflected by the fact that there are only a few central stations (usually one) and a large number of terminals (several hundreds or even thousands). In addition, the central station usually has a larger aperture antenna (normally 9 m) and the terminal stations use a smaller aperture antenna (around 2.5 m). Since the system has a star structure, each terminal can only be directly connected to the central station. Communications between two terminal stations must go through the central station. For example, as shown in Figure 1, if station A wishes to communicate with station B, station A has to transmit its signal to the central station via satellite and the central station then transmits the signal to station B again via satellite. Thus, communications between two terminal stations must be handled by satellite twice. Although the transfer of information is further delayed, from the system standpoint this allows further down-sizing of the terminal station to lower its cost. Currently, a VSAT terminal station, including a 3-m-diameter antenna, an outdoor transmission unit, a low-noise frequency converter, and an indoor unit together with the associated cables, costs approximately 75,000 yuan.

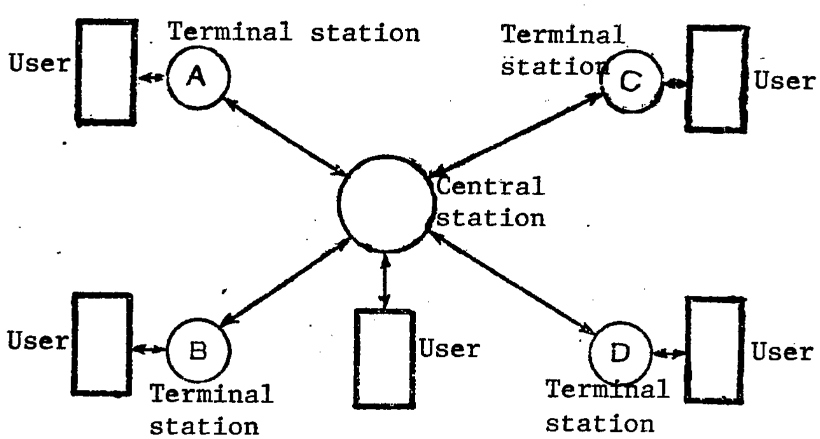

Figure 1. Diagram of Basic Star Network

The construction of a V-NET station is different from that of a conventional satellite communications station. Usually, a conventional station cannot be built in an urban area because it requires considerable space for its large-diameter antenna, its load demand is high, and it is susceptible to microwave interference in the city. The V-NET system is installed at the site of the user. The small-diameter antenna can be installed near the end user (e.g., computer room) or on a rooftop. Satellite equipment and computer equipment are put together; there is no need for a lot of wiring. The quality of the satellite link signal is the quality of the user signal. Another advantage is that the construction cycle of the system is very short.

II. Signalling Mode

V-NET uses the TDM/SCPC [time-division multiplexing/single carrier per channel] signalling mode. The information to be transmitted from the central station to various local stations is combined in a 57.6-kbps data stream to form a TDM signal. This signal is convoluted, spread-spectrumed [frequency expanded], biphase phase-modulated, frequency-converted and amplified before it is transmitted to various stations via satellite. The signal received is converted, demodulated and decoded by every local station and the information needed is located from this data stream (based on physical address) by each individual station and then sent to the local terminals. If the overall transmission rate required exceeds 57.6 kbps, one can increase the TDM carrier wave transmitted by the central station to take care of the problem.

Each terminal station transmits information to the central station at 1.2 - 9.6 kbps. These data also undergo convolution, spread-spectrum processing and biphase phase modulation before being transmitted to the central station on various assigned carrier frequencies, as shown in Figure 2. From a local station to the central station, we use the frequency-division multiple access [FDMA]/SCPC mode. This requires transmitting the same number of carrier waves as the number of terminal stations in the system. The central station has the same number of receivers which decode the data and then send it to the main computer, or the appropriate terminal, or re-transmit it to another terminal station.

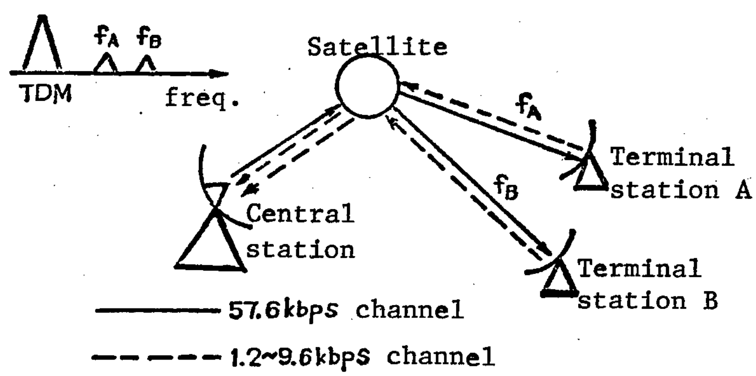

Figure 2. Transmission of Information

III. System Design

1. Spatial Parameters

The satellite used by V-NET operates in the C-band, i.e., the satellite reception band is 5925-6425 MHz and the transmission band is 3700-4200 MHz. It presently uses the eastern hemisphere beam of transponder 24 from Intelsat V located at longitude 66 ° east. We expect to transfer the V-NET operation to the 87.5°E domestic satellite [i.e., "Chinasat 1"] by the end of this year. Table 1 shows the major specifications of the transponders on these two satellites.

Table 1

Parameter	Intelsat V	Domestic Communications Satellite ["Chinasat 1"]
Saturated flux density	-74.6 dBW/m^2	-84 dBW/m^2
G/T value	-7 dB/K	-3 dB/K
Saturated effective isotropic radiated power [EIRP]	31 dBW	32.5 dBW
Transponder bandwidth	72 MHz	54 MHz

2. Central Station

The central station of the network is located at Yungang, a southwestern suburb of Beijing, and has an antenna with a diameter of 7.3 m (or 13 m). It uses a power amplifier which is rated at 3 kW output power and a low-noise field-effect transistor amplifier (LNA) rated at 80 K noise temperature. The design requirement of the system is to have an error rate $P_e \leqslant 1 \times 10^{-7}$ when the normalized signal-to-noise ratio $E/N_o = 8.3$ dB. In order to be able to connect to the main stations (e.g., main stations of computer networks) of a number of clients and to process signals from various terminals, several levels of digital interfaces in the uplink and downlink lines, such as uplink and downlink slave and main interfaces, have been set up.

3. Technical Specifications of Terminal Station

- antenna -

operating frequency: transmission 5925-6425 MHz
reception 3700-4200 MHz

antenna gain: 3 m

transmission 43.0 + 20 log f(GHz)/6(dBi)
reception 39.5 + 20 log f(GHz)/4(dBi)

2.5 m

transmission 41.7 + 20 log f(GHz)/6(dBi)
reception 38.2 + 20 log f(GHz)/4(dBi)

sidelobe characteristics:

first sidelobe: over 14 dB lower than the main lobe.
other sidelobes: over 90 percent of the peaks under the following envelopes:

$G = 52 - 10 \log D/\lambda - 25 \log \theta$ dBi ($\theta \leqslant 48°$)
$G = -10$ dBi ($\theta > 48°$)

polarization mode: single circular polarization, polarization direction variable, may become linear.

axial ratio: $\leqslant 1.3$
duplex transceiving isolation: $\geqslant 75$ dB (with low-pass filter)
feed-source insertion loss: transmission, reception band $\leqslant 0.3$ dB
standing wave ratio at reception, transmission end: $\leqslant 1.3$
antenna control mode: manual

- transmitter -

frequency range: 5925-6425 MHz
saturated output power: 2 W
maximum stray output: -55 dBc
gain stability:

$^{+1.5}_{-1}$ dB (measured $\leqslant \pm 0.5$ dB) (-40°C - +55°C)

- indoor unit -

standard user interface: EIA RS-232C
data rate: 1200-9600 bps

- system error rate -

$P_e \leqslant 1 * \exp(-7)$ when $E_b/N_o = 8.3$ dB

- low-noise frequency converter -

input frequency: 3700-4200 MHz
output frequency: 950-1450 MHz
noise temperature: 80 K
phase noise: -78 dBC/Hz (at 10 kHz)
stray: -40 dBC

4. Connection Circuit

V-NET users in the Beijing area must go through the central station located in the southwest suburb to transmit, collect and relay information. Therefore, we have to consider the connection between the central station and various urban users in the system design. Usually, we can depend upon digital microwave circuits, fiber-optic circuits, or conventional wired circuits with a modulator and a demodulator. Since it is not cost-effective to use optical cable because the data transmission rate is relatively low, and the quality of wired circuits is relatively poor, it was finally decided to adopt a single point(central station)-to-multipoint (urban users) digital microwave connection circuit. In order to avoid interference from the ground microwave trunk-line frequency, the microwave band chosen is 1.5-1.7 GHz.

5. Network Management System

The V-NET network management system located in the central station can monitor the operation of all terminal stations and the central station, test the quality of various channels, and control the entire network on a real-time basis. Its primary functions include:

- monitor on/off of each station
- record incidents taking place in the network
- verify quality of links
- self-test and re-set of network nodes
- initiate link tests
- control on/off of the transmitter at each terminal station
- vary user interface baud rate
- verify network structure

These functions are carried out by a powerful PC-AT computer.

6. Protocol Conversion

The satellite link protocol for V-NET is HDLC (High-Level Data Link Control Procedure), which was designed for synchronous and transparent data transmission at the link level. It consists of three parts, i.e., frame structure, procedure essence and procedure type. It is suitable for point-to-point and point-to-multipoint link structures. It may operate in a semi-duplex or full-duplex mode. Because the computers or other peripheral terminals the users have use different control procedures, in order to allow these signals to be transmitted by V-NET, a protocol conversion card (or interface card) has to be inserted between the terminal station and the user computer, and between the central station and the user computer to accomplish the conversion from various control procedures to HDLC. At the present moment, V-NET supports the following control procedures:

- asynchronous communications protocol
- synchronous character protocol (e.g., BSC, UNISCOPE)
- synchronous bit protocol (e.g., SDLC, UDLC)

In addition, it is capable of transparent data transmission to meet the transmission requirements of a continuous binary data flow signal from a vocoder (2.4 kbps) or a static graphics terminal.

7. Usage of Transponder

When the 66°E Intelsat [V] is used, the central station employs a 7.3-m-diameter antenna and each terminal uses a 3-m-diameter antenna. The system link is calculated as follows:

direction	satellite power used	satellite bandwidth used
terminal → central	EIRPs = -10.3 dBw	28.8 kHz
central → terminal	EIRPs = 10.4 dBw	350 kHz

In the table, the information rate from a terminal station to the central station is 4.8 kbps, and from the central station to a terminal station it is 57.6 kbps. If the information rate is 2.4 kbps for each terminal station in V-NET, a 36-MHz-bandwidth transponder can accommodate thousands of terminal stations. The TDM carrier configuration is dependent upon the operating rate of each terminal station. It is also related to the mode of operation of the terminal stations. If a total re-transmission mode is employed, the system is usually limited by power because of the need to increase the number of TDM carriers. In this case, the diameter of the terminal station needs to be increased to optimize the usage of the transponder.

IV. Equipment

1. Central Station Equipment

Figure 3 [on following page] is a block diagram of the central station equipment. From the figure, one can see that in order to avoid congestion when there are too many users or the volume of data to be transmitted is high, it is possible to use the "intermediate frequency

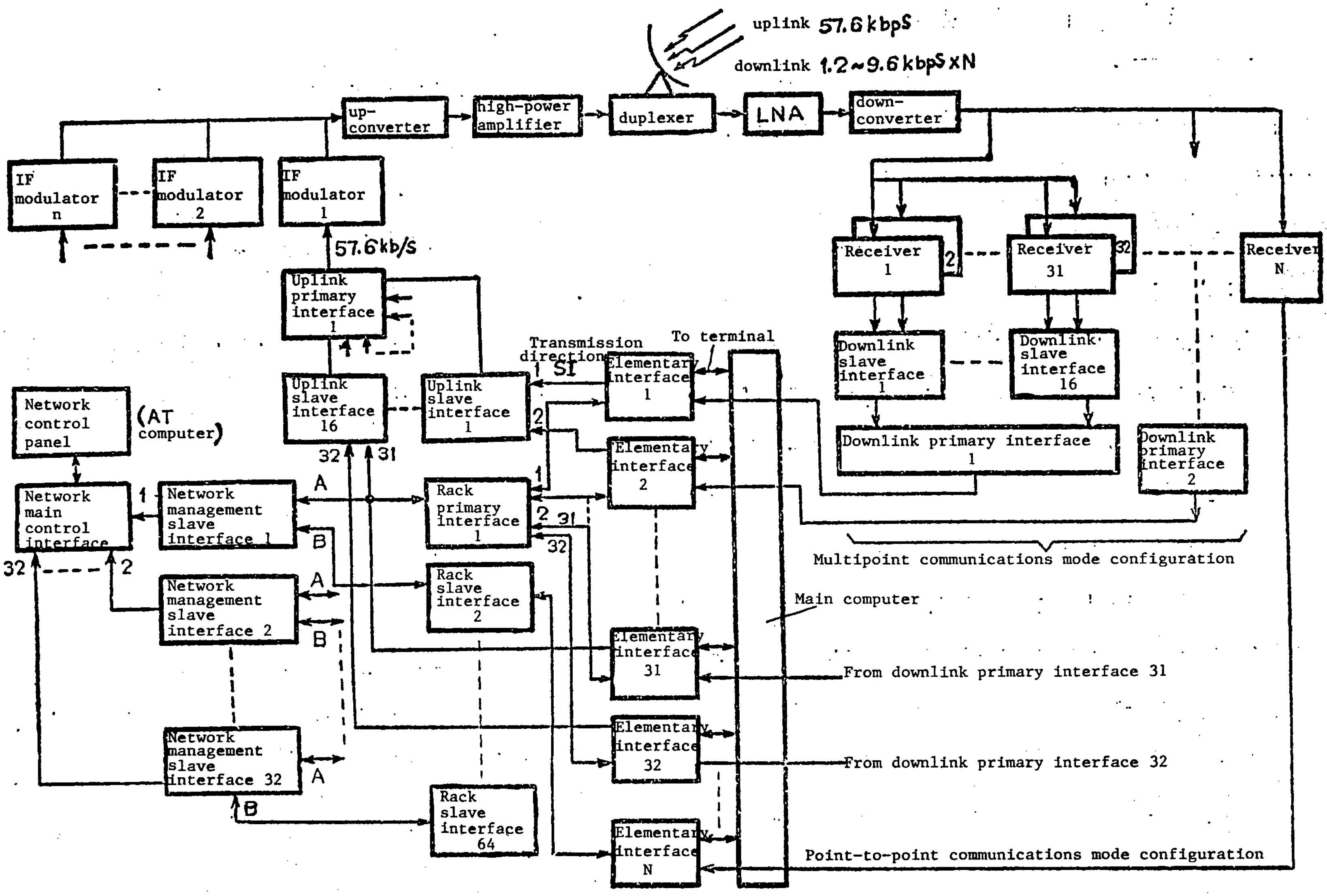

Figure 3. Block Diagram of Central Station Equipment

(IF) modulator 2" and other related devices to expand its capacity. A TDM carrier can have as many as 64 user interfaces (primary). On the receiving end, a main user interface can handle 32 terminal stations. The network control system can handle a maximum of 65,536 terminal stations.

2. Terminal Station Equipment

Figure 4 [on following page] is the block diagram of the terminal station equipment. One can see that it consists of an antenna system, an outdoor radio-frequency unit and an indoor unit. The outdoor unit handles the frequency multiplication (x60) and amplification of the modulated 100-MHz signal. All components are placed inside a 40 cm (high) x 40 cm (wide) x 25 cm (deep) white metal box. In order to minimize transmission power loss, this white box is directly attached to the back of the main reflective surface of the antenna. Its operating temperature is -40 - +55°C. The 3-m-diameter antenna is a Cassegrain type.

The encoding, convolution, spread-spectrum processing and modulation of the uplink signal and the frequency conversion, demodulation, frequency restoration, correction and decoding of the downlink signal are completed by the indoor unit. It also handles protocol conversion. All these devices are placed in a 31 cm (high) x 41 cm (wide) x 43 cm (deep) blue metal box. The front panel contains various alarm and status displays to clearly indicate the operating condition of the equipment and to provide information for the determination and elimination of problems. A terminal station can provide a user with two data interfaces. These two interfaces not only can be directly connected to DCE (data coding equipment, such as a modulator/demodulator) but also to DTE (data terminal equipment, such as a computer). Because of VLSI circuitry, the MTBF (mean time between failure) of the terminal station is above 20,000 hours.

The distance between the indoor unit and the outdoor equipment is limited. Normally, the cable should be under 50 meters. If it is longer, it is necessary to add an appropriate amplifier (no more than two in total) behind the tuner to endure the voltage level at the receiving end. Even with amplifiers, the length of the cable should not exceed 200 meters.

V. Problems Associated with Terminal Station Construction

The key issue in terminal station construction is the selection of antenna location and its installation. Normally, site selection should be based on electrical measurements. If an antenna is to be installed on a rooftop, the foundation must be reinforced. In addition, the

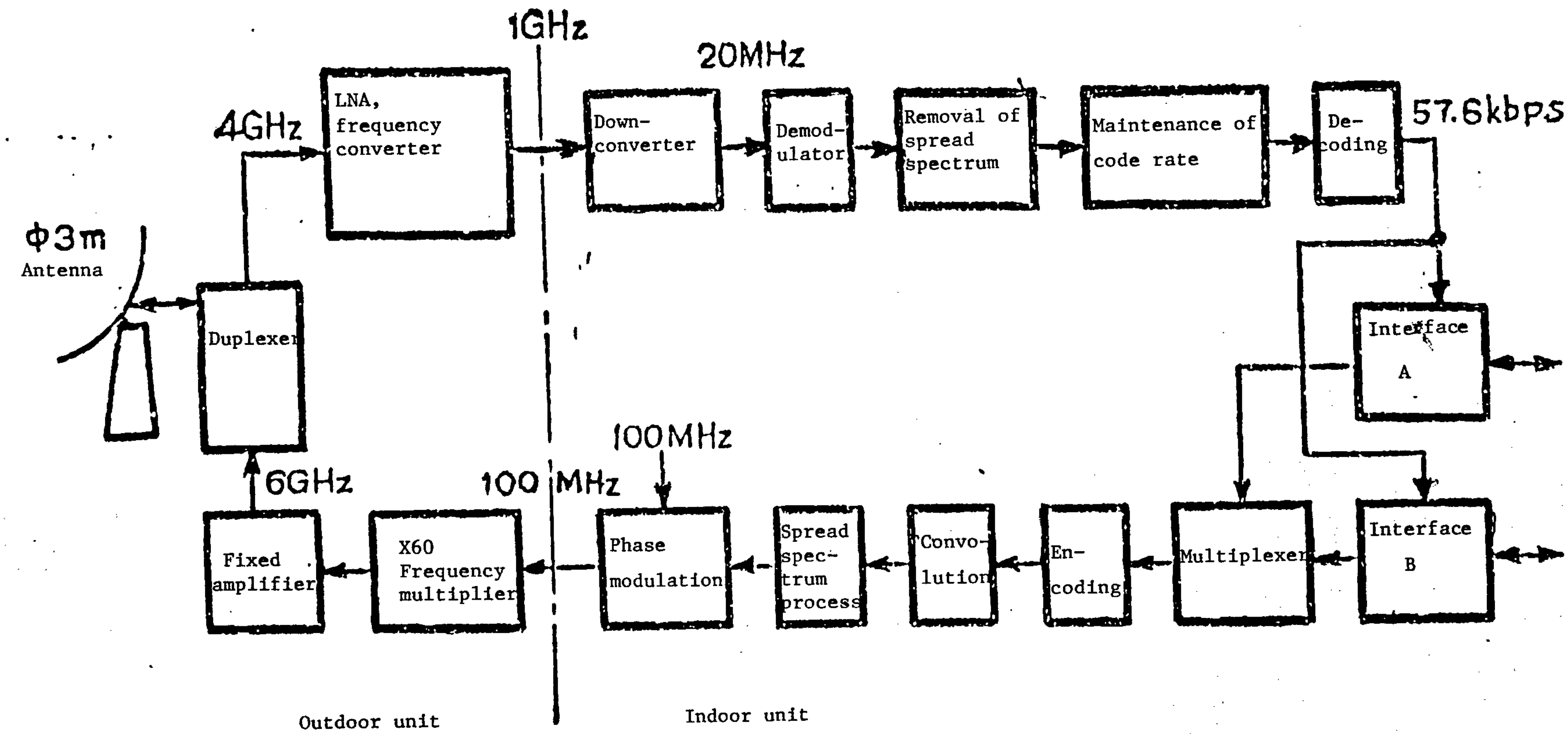

Figure 4. Block Diagram of Terminal Station Equipment

effect of wind load on the added height must be considered as well. The installation of equipment should take the following factors in account:

- avoiding microwave interference in the same band.
- antenna must have a large operating range, i.e., open view in front of the antenna.
- good grounding for antenna and indoor equipment ($R_{ground} < 2\ \Omega$).
- solid antenna foundation; maximum wind load for the 3-m antenna is 1.5 tons and the tip-over moment of force is 3 t·m [ton-meters].
- antenna should be as close to indoor unit as possible, and indoor unit should be located at the same place as the computer and other terminals.

- END -