I. From the Pencil Rocket to the KAPPA-8

-- Hideo ITOKAWA --

1. Beginnings

Three events which led to research on sounding rockets of this Institute are outlined below. One is the AVSA research group, organized in 1954, at the Institute of Industrial Science; another is the granting in the same year of research funds for industrial tests by the Ministry of International Trade and Industry to the Fuji Precision Industries Ltd., and finally, participation in the International Geophysical Year (IGY) program. Since the AVSA research group is treated in detail in the August 1955 edition of the Seisan Kenkyu [Monthly Journal of the Institute of Industrial Science] (Vol. 7, No. 8) on page 174, it will not be described here.

The author was in the United States from January to June 1953. On my first visit to the U.S. there were many things to see and ask about, but what caught my attention more than anything else was not medical or acoustical engineering (which were the specialities reaping the most profits in research) but rather the awakening inspiration of a group of American scientists in developing space science. Although 8 years ago, in 1953, Japan was economically on the road to recovery, the scars of the Second World War were still in evidence; and it was still a period of turmoil and confusion. In this year, the San Francisco Peace Treaty was signed and Japan once again became an independent nation. Also, the ban on aeronautical research, which had been in effect since the end of the war, was lifted. At this time, active research in rockets and space was underway at the University of California, Johns Hopkins, MIT and other leading universities. Those aircraft companies that I chanced to visit were all paying particular attention to the changeover from airplanes to rockets, and in the book stores, I saw shelf after shelf of new books on space physics and space medicine. I strongly felt that the exploitation of the universe -- the next objective of mankind -- was approaching reality. When I boarded the plane in San Francisco to return to Japan, my state of mind was such that I wanted to shout "Do not forget to open your eyes to the road that leads to the universe (space)", regardless of the situation in Japan, where the ban on aeronautical studies had just been lifted. However, upon returning to Japan, the situation was not as simple as I had imagined. There was vacillation over whether new projects should finally be started on aircraft, and even to mention rockets seemed entirely out of the question. Although I wrote predictions of what rockets would be like in 5 years and what they would be doing, and sent the manuscript to a magazine, it was rejected as being too difficult to follow and too presumptuous. The "Enlightenment Movement" was a previous decision. Within the Institute of Industrial Science, the AVSA was a definite trend in the right direction. One fortunate event in the founding of the AVSA was that professors Hoshiai, Takagi, Sawai, and Saito (of the Electronic Engineering Research Group of the Institute) took the initiative. Here, there was a pioneer spirit to open new fields in electronic engineering. In the beginning, practically every meeting of the AVSA was made up entirely of electronic scientists. However, as time went on, former researchers in aeronautics began to participate actively, and the receipt of 400,000 yen as a research grant from the Ministry of Education in 1954 was responsible for new enthusiasm among the members.

Because it was necessary to seek both the interest of the members in the Institute and the cooperation of industry, this was not a simple matter. From August to December 1953, I went on a public relations tour which took me as far away as Kyushu. It was fortunate that at that time we received assistance for the tour from the Federation of Economic Organizations. However, their response to the proposal to begin rocket research was surprisingly aloof and lacking in enthusiasm. Another discouraging fact was that the interest, of industrial circles, in rocket research was confined only to guided missiles.

Only one person at that time was willing to gamble on the universe and rockets. That was Mr. Ryoichi Nakagawa, chief of the Technology Department of Fuji Precision Industries. The following year, Fuji Precision Industries received a grant of 2,300,000 from the Ministry of International Trade and Industry (MITI) for research purposes. This coincided with the 400,000 yen awarded to the Institute by the Ministry of Education.

In our discussions with Mr. Nakagawa we agreed that rocket research should emphasize the peaceful use of rockets with the focus primarily on a transport rocket. Although this is in agreement with the results of the AVSA plans, it was a conclusion reached through industrial and economic considerations. This is especially surprising in view of the fact that at that time the sole interest of (others) was the military application of rockets.

The IGY event was sudden and undreamed of in comparison with the two above events. In 1954, the AVSA research group established the following objectives:

A. Facilities for experimenting in supersonic aerodynamics.
B. Study of solid and liquid rocket engine fuels.
C. Study of telemeters and radar.
D. Flight tests on small objects.
E. Testing and flight of sounding rockets.

The final goal was flight outside of the atmosphere, i.e., a rocket transport. However, the research objectives over a four year period were to construct a sounding rocket to study the physics, physiology, medicine, etc., outside of the atmosphere and to take the first steps in making a space flight. Please refer to the article by Professor Maeda on the approach of the IGY officials.

According to AVSA plans, the period in which Plan E (the launching of a sounding rocket) was to take effect was expected to be 1957. This coincided with IGY plans for a sounding rocket in 1957-58, and seemed as if AVSA had planned it that way. The AVSA research group decided to cooperate with the IGY around February 1955.

2. The Change-Over to IGY Plans

Although there were no significant changes in the framework of AVSA plans in its changeover to IGY plans, it was necessary to make several changes in their details. First of all, the name AVSA was changed to SR (Sounding Rocket) research group. Second, we revised plan B and postponed research on liquid fuel engines until after 1957. According to plan B, we had been conducting research on both solid and liquid fuels, but due to the time factor involved in the IGY, a choice had to be made and we decided to emphasize solid fuels for the time being. (The SR research group, in cooperation with the engineers from Fuji Precision Industries had completed full-scale plans for the manufacture of the present KAPPA 6 with a liquid fuel engine. There were few secrets about the liquid fuel engine, since the data on the V-2 was available in every country, after the war, in PB reports. Thus, it was comparatively easy to design a liquid fuel engine.) The conclusion was that, for IGY purposes, a solid fuel system should be used.

Since solid fueled-rockets are a new development, access to information on them is difficult to acquire. In another sense, however, this facilitated research.

Considering the fact that the sounding rockets used during and after the IGY, the French MONICA, the British SKYLARK, and the American NIKE, CAJUN, EXOS, and the Soviet meteorological rockets all use solid fuels, we can say that the decision of our group to follow suit was correct. The decision in 1955 to change over to solid fuels was an exceedingly quick one and was actually regarded very highly at international conferences.

Please refer to the article by Professor Takagi regarding Plan C.

No changes were made in Plan D, which remained almost as in the original. The development of a remote-control technique appeared in the form of the ROCKOON (balloon-launched rocket) ignition, and KAPPA rocket (safety destruction system). Later, the development of automatic control and gyro-techniques were scheduled for the SUN-FOLLOWER and other sounding equipment. Thus, this plan was almost the same as reported in Vol. 7, No. 8 of this magazine on page 175.

In Plan E, the altitudes of the sounding rockets were to be in six stages of 20 km, 50 km, 80 km, 120 km, 200 km, and 500 km. This plan also was carried out almost as conceived, the only difference being that the 120 km altitude was omitted, and 300 to 400 km of the KAPPA 9 between the 200 to 400 previously planned, was added.

3. Organization and Composition of the Study Group

In organization of research, there is a vertical and horizontal system. In the case of the vertical system in a private company, work is carried out in vertical order, namely with the following heirarchy: president, department head, section head, and chief clerk, that is -- department, section, and clerical office. In the horizontal system individual members of an independent, already existing vertical system, are arranged horizontally to form a group. The SR research group adopted the horizontal system.

A good point in the horizontal system is that it is as new a technique as the study of observation rockets itself, and possesses flexibility in the face of constantly changing conditions in a type of research where much probing in the dark must be done, and there is uncertainty as to what will occur next. In other words, there is no rigid heirarchy and any member, whether he be from within the Institute or from outside, can participate in the planning of the organization of research. One drawback, however, is that the position of responsibility is unclear, and it is difficult to include new members in the budget when required for new plans.

Since there are no administrative restrictions in the horizontal system, there must be harmony and solidarity among members in order for the organization to proceed smoothly. Also it is necessary to guard against carelessness, such as slovenliness in management. In order to avoid the shortcomings of the horizontal system, overall management was monitored, regulated and in order to decide on basic policies, the manager system was established. In the beginning, the SR research group was composed only of professors Tamaki and Saito, and assistant professor Mori, and in addition, the representative of the administrative office was officially included (a head official or administrative manager). For a discussion of the handling of the administrative aspect of the observation rocket, see the article by Mr. Shimoura, administrative official.

Actually the activities of the SR research group were in the planning council, and the council of the flight group and the members were not invariable. The councils were made up according to the needs of a particular time, the members being connected with planning, design, and the testing of flying bodies. Also, the membership was not confined to the Institute alone, but the participation of the most suitable people from all of Japan was hoped for.

Within the Institute a Liaison Committee on Sounding Rocket Research was set up, as well as a Specialist's Committee and several specialist committees within the Special Committee on Rocket Sounding of the Science Council. (See article by Professor Maeda.) This shows that the above intention to include members from outside the Institute was realized.

However, the most important thing required in promoting research by this type of teamwork, is the cultivation of specialists in each field necessary. Frankly speaking, however, when the SR group first started in 1955, there were no rocket experts available in any field. Although there were some who had read texts and literature on the subject, there was no one, including the author, who had any knowledge of actual rocket technology. Moreover, it takes time to train specialists. The organization of research means to determine those fields where training is needed, search for people both suitable and willing to work in them, and while training them as specialists, each of them is given an orientation to their role in the team. Also, it is a usual custom to seek directly the advice of specialists in other fields of technology and obtain good ideas from them. For example, we can cite the advice of Asst. Prof. Ando on ship welding techniques, in the manufacture of the KAPPA 7 engine, and Professor Kato's advice on the selection of materials for the tail pipe.

One final remark I wish to make in regard to the composition of the KAPPA Team, is its coordination with industrial circles. Naturally a close tie-up with industry and manufacturers was necessary, since the project was not only pure research, but included testing sounding rockets, manufacture and launching operations. Moreover the outcome of everything was closely related to it. The following order was used to determine which item and which factory or company to coordinate with. First, an investigation of each factory and company believed suitable was carried out. Then, at the same time that researchers conducted an investigation on location, they made sure of their willingness to coordinate with the company. Then the coordination was established by selecting that company which possessed the highest technical skills, willingness, and responsible engineers.

It is most fortunate that factory selection proceeded ideally, just as if painted in a picture. The reason was that rocket technology was too new and there was no case where a company tried to sell itself by out-bidding others. Actually since the founding of the SR group there have been absolutely no cases where we were high-pressured by the factories. The reason for this was that they did not know what items were important. To cite an example, when we were determining the method of manufacturing the engine for the KAPPA 7, we visited all specialized factories in Japan, and conducted a close, wide-scale investigation and finally the Muroran Factory of the Japan Steel Works and the Kobe Shipyard of the new Mitsubishi Heavy Industry were selected. Moreover, we pay close and constant attention to the constantly advancing industrial world, even in the case of materials already selected, for example, when titanium would be usable as a material for rockets and where good solid fuels were being developed.

In addition to the companies mentioned above, the following participated in planning and did not hesitate to render their cooperation. The Nippon Oil and Fat Industry Limited (Nippon Yushi Kogyo), Imperial Heat Processing and Manufacturing Limited (Teikoku Kakohin Seizo K.K.), the Showa Fireworks Ltd. (Showa Kayaku Kogyo K.K.), Ito Precision (Ito Seiki), Yushiya Manufacturers, Nippon Electric Company, Toshiba, Myojo Electric, Mitsubishi Electric Machine Co., Kubota Meteorological Instrument Co., Tokyu Vehicle Manufacturing Co., The Matsushita Communication Industries, Yokokawa Electrical Machinery Plant.

4. The Merits and Demerits of the PENCIL Rocket and the BABY Rocket

In April 1955, the SR group's first task was a test of the PENCIL rocket. The length of the PENCIL, an extra small rocket, was 23 cm with a weight of 230 gr. and a maximum speed of 200 m/sec. For fuel, a double-base unrestricted fuel was used. However, the PENCIL rocket did not use conventional fuel, but for the first time used a cast double-base or composite and we can say that almost all of the fuels then under development were tested. There are two criticisms of the PENCIL rocket, namely, that it is a mistake to hold any great hopes for the success of the rocket, while at the same time it is meaningless to consider it as a test of no value.

The first flight of the PENCIL rocket was on April 12, 1955 at an abandoned rifle range in Kokubunji outside of Tokyo. The results are as follows:

1. Although small, all of the important elements are contained in the rocket. Therefore, a table of elements for a future sounding rocket has been made, containing information on fuselage, engine parts, fuel, heat resistors, nozzle, tail, tail pipe, aerodynamic stability, center of gravity, launcher, and length of launcher.

2. By the flight test of a small rocket on a horizontal range, we established a system for obtaining material for the design of a large rocket and dispersion wave length was one of the objectives in our study of the PENCIL rocket. It also served as a model for later low-angle launching tests of the FT, ST, and SP small rockets. Also, a method for obtaining flutter and stability data was discovered.

3. This was a good on-the-spot test of teamwork operation by the horizontal system. In this sense, people connected with electronics participated in this test of the pencil rocket, which had no electronics and served as the ground work for training specialists later on in the special fields of the flight testing of the KAPPA rocket, optical tracking, launcher crews, and the general affairs group. There were many types of pencil rockets and of 200 constructed, 150 flew. The initial rockets were tested at Kokubunji, and around June they were moved to the grounds of the Institute, into a water basin used as a horizontal range (previously used for ships).

The BABY rocket (Fig. 1) basically is an enlargement and extension of the PENCIL rocket. Its overall length was 1m30cm1m50cm, a rocket about the same height as a human being. The only difference was that while the PENCIL rocket was the forerunner of a horizontal flight test rocket, the BABY was the first rocket to be launched vertically into the sky. Although small, it fulfilled all the functions of a rocket and was an improvement over the PENCIL rocket. Not only was it the first one to carry a telemetering system but it had a rocket-borne camera (see another article) which took photographs above the earth and even had a recovery installation for pick-up at sea. In August 1955, the three BABY-S (simple) which flew at a launching angle of 65° served as a trial test of a vertically launched rocket and for the establishment of a rocket testing ground. In September, five BABY-T (telemeter) served as trials for a rocket telemeter and the three BABY-R (recovery) from October to November were a challenge to the difficult technique of recovering the nose section at sea.

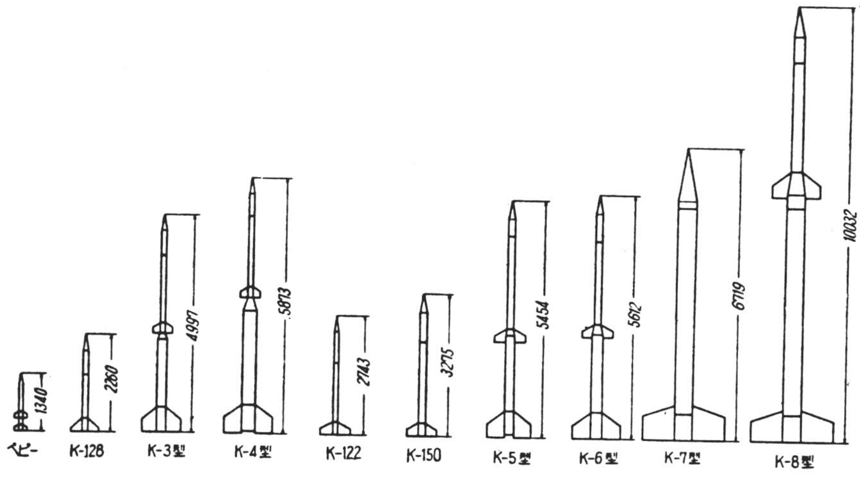

Figure 1

5. Why was Akita Selected?

Since there was no possible launching ground for rockets in the country at the time that the research on observation rockets was begun, a pessimistic air was prevalent among the specialists who considered it was a waste of time even to build a rocket. This explanation was circulated as the conclusion of an investigation in Japan by the Ministry of Defense at that time. In Japan where there is no desert area such as White Sands in the U.S., or Woomera in Australia, it was thought that perhaps the ocean surface could be used, but this was almost impossible. For a rocket testing ground, the three conditions of air, sea and ground must be uniform. First of all, there must be no obstructions in the air (no aircraft, of course), clouds are an obstacle, and even dragonflies can be an obstruction (in experiments with an infrared detector the pulse from a dragonfly flying close by, due to the infrared rays emitted by a distant flying rocket, causes a great amount of noise). In other words the air must be clear and the vicinity of air routes is out of the question. A strong factor in the choice of White Sands was that there are practically no clouds there throughout the entire year. Secondly, there must be no obstacles on the ocean. Passenger ships, freighters, fishing boats, pleasure boats -- boats of any kind, as well as islands, and even dolphins are an obstacle (during recovery operations).

Thirdly, a safe and secure place is desirable on land, with no railroads or highways nearby. Also, transportation and communication should not be inconvenient. The nearest city of any size should be fairly distant. In order to select a spot meeting these requirements, this problem was referred to the Council of Vice-Ministers in June 1955 which passed items of agreement for each ministry to facilitate sounding rocket research. The next step was for the Ministry of Education to take the lead and on the basis of the agreement of the Council of Vice-Ministers, to establish a liaison council with each ministry and department concerned on the subject of sounding rockets.

Then, the entire coast was thoroughly searched, the Civil Aeronautics Bureau looking for a spot where no air routes existed, the Ministry of Transportation providing data on the rate of ship traffic, the Fisheries Agency and Maritime Safety Agency providing data on the rate of fishing vessels going out to fish, and the Autonomy Agency data on suitable conditions on land. The Pacific side was the first to be eliminated because of the air and sea routes there. Next, the Sea of Japan side was investigated and finally the shores of Akita Prefecture remained as most suitable.

The problem remaining was the cooperation of the local people. We were fortunate in having the resolute and willing leadership of Mr. Masami Kojima of the Governor's office and we received the close cooperation of everyone from Governor Kobata to authorities in each prefectural office, the authorities of Iwashiro-cho down to all of the local authorities. The equipping of the Akita rocket testing grounds progressed favorably, providing an ideal Tokyo University rocket testing area. We had already predicted in the beginning that since the distance across the Japan Sea is only 800 km, when the altitude of our rockets reached 400 km, it would become necessary to reconsider the use of the Pacific side. That time will probably be 1961.

In the above manner the decision was made to choose Akita. We may assert that there is no place in Japan as suitable as Akita. However, we cannot say that no problems whatsoever exist, since (in spite of their scarcity) there are fishing grounds, and fishing boats do go out on fishing trips, and negotiations with the fishing unions become intolerable. Another hindrance is the fact that the climate is bad in winter and throughout the year west winds are prevalent, depreciating the effective launching angle and making it quite difficult ot acquire significant altitude.

6. The Name KAPPA

The question is often asked as to why the name KAPPA was selected. There are rather clearly defined complications in this matter. When tests of the BABY rocket were finished in October 1955, the problem arose as to what to name the next rocket. As explained later, since the plan was to have a series of steps from the BABY and PENCIL leading up to the final sounding rocket, a proposal was made to name them in series and to select a set of names that would be internationally understandable. Therefore, it was proposed and decided, to use the Greek letters, Alpha, Beta, Gamma, Delta, etc. in alphabetical order. The present KAPPA was selected from plans for a series of rockets Alpha, Beta, etc.

Since the sound "Kappa" -- with long final $\bar{a}$ -- can be confused with "copper", it is correct to give the final $\breve{a}$ a short value. Since "Kappa" sounds the same as the word "water imp" it is easy to remember and since it begins with a consonant, it is clearly distinguishable over the telephone. As the KAPPA rocket reaches types 9, 10 and further, the size will increase and grow to the point where they will not even remotely resemble the original rocket. For this reason, the name should be changed to Omega, Lambda, etc.

7. The Course to Type 6

Now to give a description of the total weight, maximum velocity, and maximum altitude of the sounding rocket. Figure 2 is a graph of the time, type of rocket constructed, and increase in total weight of each rocket from the BABY rocket to the KAPPA 8. Figure 3 in the same manner is a graph of the maximum velocity and altitude. It is interesting to note that the rockets' maximum velocity increases each year almost in a straight line with the maximum altitude, and that the graph was not consciously planned to be that way.

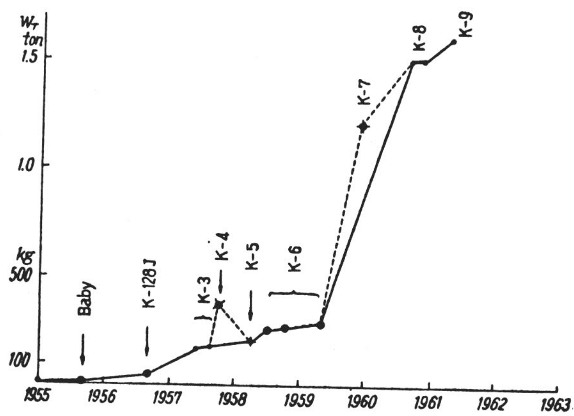

Figure 2

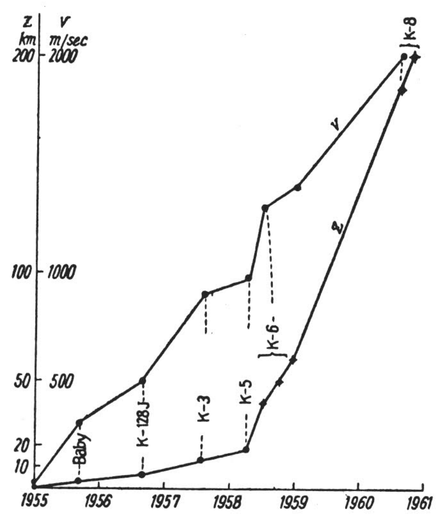

Figure 3

However, the technical difficulties encountered with the rockets generally can be considered proportional to their speed. For example, when the speed of sound is passed at the so-called sonic barrier, stability and vibration problems occur, and as the supersonic barrier is entered the problems of stability and aerodynamic heating become more difficult. Therefore, the fact that velocity V in Figure 3 increases every year almost in a straight line can be looked upon as proof that the research group continued research at an almost constant tempo.

Since the altitude is the transformation of the energy of the velocity into potential energy, it should be proportional to the square of the velocity. The fact that the altitude each year increases parabolically explains this. Another problem is the change in total weight in Figure 2. As a result, it can be seen that we selected the weights so that the speed increases each year in a straight line. The cost of constructing one rocket is generally determined by its weight. Also, since the amount of fuel is proportional to the total weight, the latter determines the nature of the fuel (propellant) and the manufactured installation. It is also a factor in the transportation and handling of the rocket, and since it determines the amount of instruments that can be carried, it is a powerful limiting factor in the sounding rocket.

The objective we had in mind when the BABY rocket tests were completed and the KAPPA plans were being carried out, was when to reach the one ton weight line. At the time that we had constructed the BABY rocket with a total weight of 8 kg, the idea of a total weight of 1 ton was only a distant dream. We even had vague apprehensions about the figure "1 ton". We reached the one ton line in 1960, as shown on the graph. This was 5 years after beginning our research.

In Stockholm, in August 1960, there was a special sectional meeting of the SSR (Small Sounding Rocket) group, a part of the I.A.F. (International Astronautical Federation). Although there was no standard definition of the word "small" it appears that one ton was limit. Although the KAPPA 6 was small, it would be better to put the KAPPA 8 into the category of a middle class sounding rocket.

Four stages were passed in progressing from the PENCIL rocket to the KAPPA 6. The first step was the PENCIL and the BABY, the second research in a one stage rocket; the third a study of a 2 stage rocket, and the fourth was the construction of a rocket to be used in the IGY program, being a coordination of the results of all the research done in the previous stages. We called the one stage rocket in the second step the KAPPA-1. Of this type, three rockets were tested, having diameters of 128 mm, 122 mm, and 150 mm respectively. On the basis of the external diameters and dimensions, we called them the K-128, K-122 and K-150. Flight tests took place from late 1956 to 1957, and a comparison was made of rapid burning, high acceleration and a slow burning, low acceleration type engines. At the same time, research was done on the electronics of telemetering, radar, and measuring instruments as well as studies in aerodynamics and structural dynamics. The K-122 was used especially for every type of antenna test, and in comparative tests of propellants.

In general we may say that there were no major technical problems involved in the one stage rocket. The only exception was that in the K-128 No. 2, we believe that a flutter developed in the tail fin, which provided valuable data for further research. Generally speaking, technical progress was marked after the flight tests mentioned above, and when they went too smoothly there was little progress.

The first 2-stage test was the KAPPA-3, which took place in April 1957 and the final one was the KAPPA-5 in May 1958. The three two-stage test rockets up to the KAPPA-6 were the KAPPA 3, 4, and 5. As shown in Figure 2, the increase in total weight of the KAPPA 3, 5, and 6, show a smooth line in respect to each year, while as the broken lines show, the KAPPA 4 and 7 deviate from the curve of the graph. Problems occurred in the flight testing both of types 4 and 7. In both of them partial damage occurred to the fuselage, which was the greatest problem in flight tests. A full investigation and study was made of aerodynamic stability, aerodynamic heating, aerodynamic vibration, mechanical vibration, steel stability, elastic stability, combustion stability, etc. to determine the causes of damage. In summary, the two stage-rockets were technically more difficult than the one stage rocket, and many problems arose when experimenting with them. The first problem in the KAPPA 3 was engine combustion stability. When the engine used in the one stage rocket was employed in the two stage, complications arose such as poor ignition and flame-out.

As a result, the KAPPA 5 in addition to solving many of the problems involved in the 3 and 4, gave the smoothest performance of all two stage rockets in flight tests. Then, in June, 1958, with only 6 months remaining until the IGY, the KAPPA 6 constructed as a sounding rocket flew, and on June 30th, first success was obtained in measuring temperature and wind. We began work in the IGY and working at a rapid pace until its close, we obtained success in soundings which will be described later on.

8. The Propellant

A solid fuel propellant is essentially a mixture of a fuel and an oxidizer. There are two types, one with the fuel and the oxidizer existing together in the same element, and a heterogeneous mixture with the compound containing the oxidizer separate from the fuel compound. The former, with the fuel and oxidizer together, is called a homogeneous or double-base propellant. The name "double-base" means that the chief compounds in the propellant are two substances such as nitroglycerine and nitrocellulose. The latter heterogeneous propellant is called a composite, the oxidizer being supplied in the form of calcium ammonium perchlorate or saltpeter. A binder is combined with the fuel, and the finished product is in stick form. The PENCIL and BABY used a double-base propellant, while the KAPPA 6 and 8 used a composite propellant. In the KAPPA 3, 4, and 5, both types were used together. For example the booster (the rocket of stage one) had a double base and the second stage used a composite or at times vice versa.

Research in both types of propellants is being carried on at the same time. We have not discarded the double-base, even though the KAPPA 6 and 8 are using a composite.

There are two ways of manufacturing double base propellant, by extension under pressure and casting. Since there is a probability that the casting method will yield a high performing propellant, predictions at this time can not be made.

When the propellant in a unit of time, burns w kg of fuel and produces T kg of thrust, the ratio

$$\frac{T}{W} = I_{sp}$$

is called the specific impulse (I_{sp}) and is used as a measure to indicate the performance of the propellant. The unit is expressed as time in "seconds". The I_{sp} of the propellant developed during research on the KAPPA rockets was from 180 seconds to 230 seconds.

Since we cannot say whether high specific impulse propellants are necessarily suitable for use in sounding rockets, when the increase in I_{sp} is bound to the increase in pressure due to combustion, a problem arises in balance due to sacrifices made due to increase in weight as a result of increasing the thickness of the engine wall.

Another important factor to be considered in a propellant is its burning rate. In general the burning rate is 5 to 10 mm per second, but in certain cases a very low rate is required and some times, on the other hand, a high burning rate is needed. Recently engineer Yoshiyama of the first section of this Institute has been carrying on noteworthy research on these two problems. The next important problem in the design of the propellant is its geometric form. The relationship between time and impulse determine this. Another determining factor is whether the burning will be stable or become unstable. Unstable burning will cause either burn-out or explosion due to extreme rise in pressure. Research assistant Akiba of the first section of this Institute is carrying out systematic research on the theoretical solution to this problem.

In order to use a propellant in a sounding rocket after research on it has been completed, first of all physical and chemical tests of a sample are made, its mechanical strength is tested and then after repeating several ground tests, first with a small engine and then with a large engine, the performance of the the propellant is ascertained, the final step being a flight test of it in a previously tested rocket. For ground testing, the Institute has two small testing stands on its grounds, and in Akiba there are two large ones. Moreover, the Fuji Precision Industries' test stand at the Imperial Fire Works Manufacturing Co. in Kawagoe is being used.

9. Engine

Four tests were made on the construction of an engine using drawn steel pipe, welded steel plate, light alloys and plastics. Drawn steel pipe can be processed accurately and has an advantage in that its strength is great, but one fault lies in the fact that its maximum size is limited by steel pipe manufacturing equipment. Also in the case of light alloy (aluminum alloy) an engine using seamless pipe has the same restriction. Of course, from the standpoint of construction and weight, there is an advantage in using alloys since they are lighter. However, when the size of the rocket is greater than a certain point, a defect is involved whereby the amount of propellant carried must be reduced, due to an increase in the thickness of the engine wall, its advantage over steel thus being reversed.

In the case of welded steel plates, considerable accuracy is obtained if close attention is maintained during manufacture. It has the great advantage that it can be used in any size. However, this is technically difficult to achieve. The plastic system was studied in 1957, and tests were made at the Kozu Factory of the Japan Metallurgical Industries (the present Showa Fireworks), and although a certain degree of usefulness was ascertained, research was stopped. Later research was conducted in America, and plastics were utilized in the rocket for the ECHO satellite, the SCOUT. The steel seamless pipe was used in the KAPPA on 1, 3, and 4, and on the K-122, K-150, K-5, K-6, an alloy type engine was studied. The KAPPA-6 used an aluminum alloy engine, and KAPPA 8 used a welded steel plate engine. For further details refer to the article by Professor Mori.

10. System

All of the KAPPA rockets carried radar and transponders. In other words, a system was used in which radar waves were not directly reflected from a surface, but were first picked up by the transponder, intensified, and then sent back. For this purpose there is a limitation in the minimum dimensions of the rocket, but it does not require a large radar system. Recently the miniaturization of sounding rockets such as the American /URKES/ [phonetic] has become popular. However, in the case of extremely small rockets, a transponder cannot be carried, and radar tracking is chiefly done by skin reflection. Since the rocket and the surface area are small, extremely high power is required for the ground radar. In other words even though the rocket is made smaller and cheaper, a great amount of money must be spent on the radar. In the case of KAPPA rockets, ti was concluded that the transponder system was the most economical and efficient of all systems. However, one defect in transponder tracking is that if an accident occurs to any of the parts carried by the rocket, it becomes impossible to track the rocket at all. The optical tracking system was emphasized in the KAPPA plans in order to overcome this difficulty.

In rocketry, there are the staging and cluster systems, the cluster system being used in the Australian rockets. However, all of the results of former studies of the KAPPA have shown the cluster system to be unpractical, and the staging system was therefore adopted. In the future type 9 three-stage and type 10 four-stage tests will probably be carried out, and it is felt that it would be necessary in the end to do research on a five-stage system.

The propellants have undergone the history cited above and although at the present time solid propellants are under investigation, this does not mean that investigations are not being made of the packed system, canned system, and the liquid engine system with the simplified storage recently developed in America. Moreover, in preparation for the future, basic research is being done on non-chemical engines (ion, plasma). Also the time is close at hand when research must be done on atomic powered engines.

11. Operation

Rocket launching operations in Akita were a problem, and it is necessary to make a study of the systems involved. It is necessary to limit as far as possible the number of personnel involved in launching operations. Although in other countries, sounding rockets are all launched by military personnel, in Japan it was decided that only university people should be able to do the launching.

Table 1 shows the operation schedule up to the time of launching according to a time axis, and is similar to an orchestral score. In order to construct this time schedule, first of all a time study was made of each operation of each group, the amount of time required calculated, and every operation was organized so that each was organically related to another. Then, a rehearsal of all operations was once made on this basis, and on the basis of its results, revisions were made and the final edition produced. (For a discussion of the operation system in its entirety refer to the article by Professor Shimomura.)

At the present time, the total number of personnel required is 100 including 35 to 70 dispatched personnel. In the future this must be simplified, and along with a study of the reduction of personnel, it will be necessary to train specialists in launching operations. For the purpose of study (and for the record) the operations were monitored by 16 mm camera, and compiled in the form of a documentary movie. The documentary films previously made are kept in the form of a film library at the Institute, and are shown at learned societies and elsewhere.

Public relations movies generally last about twenty minutes, and usually the cost of making one is from three million to five million yen. the KAPPA documentary films, however, cost from one hundred thousand to two hundred thousand yen each. The fact that they are often shown at international meetings indicates one phase of KAPPA research. For a discussion of research on launchers, please refer to the article by Professor Mori.

Table 1

Time Schedule for the K-8-4 (IC)

Group	X-300 min.	X-195 min.	X-160 min.	X-145 min.
Headquarters	--	--	Test of jeep launcher manual control	Count practice Lead wire check (igniter pellet)
Rocket launcher	--	Begin main assembly	Begin loading booster on launcher	--
Telemeter and instruments	Begin nose assembly	Nose section to rocket crew	--	--
Radar	Begin nose assembly	Nose section to rocket crew	--	--
ID	Begin nose assembly	Nose section to rocket crew	--	--
Cosmic rays	Begin nose assembly	Nose section to rocket crew	--	--
Observation camera	--	--	--	--
Communications	--	--	--	--

Group	X-125	X-115	X-114	X-110
Headquarters	--	--	--	Telephone switch transmission test begun
Rocket launcher	Complete leading booster on launcher	Complete main assembly	Bring out trailer for transmission test	--

Table 1 (continued)

Group	X-125	X-115	X-114	X-110
Telemeter and instruments	--	--	--	T. sw. on for beginning transmission test
Radar	--	--	--	T. sw. on for beginning transmission test
I D	--	--	--	Begin transmission test
Cosmic rays	--	--	--	Begin transmission test
Observation camera	--	--	--	--
Communications	Akita Observatory prepares	--	--	--
Group	**X-108**	**X-106**	**X-104**	**X-102**
Headquarters	--	--	Telephone back to original condition	--
Rocket launcher	--	--	Transmission test over. To main assembly shack	Begin loading main on launcher, begin coupling of main-booster, begin joining lead wires
Telemeter and instruments	--	sw. on	sw. off, transmission test over	--
Radar	Begin ground transmission	sw. off	Transmission test over	--
I D	--	sw. on	Sw. off, transmission test over	--

Table 1 (continued)

Group	X-108	X-106	X-104	X-102
Cosmic rays	--	sw. on	Sw. off, transmission test over	--
Observation camera	--	--	--	--
Communications	--	--	--	--
Group	**X-80**	**X-75**	**X-74**	**X-65**
Headquarters	Prep. for complete power source load test	Pump off, lights out, complete power source load test, siren check, patrol ship, radioman warning, official, explosives, (flares) rescue squad r.r. officials	Pump, heater, lights on again	Release balloon for wind, air temp., air press.
Rocket launcher	--	Main and booster coupled, lead wires connected, main release duct check, begin notching	--	--
Telemeter and instruments	--	Begin coupling lead wires to launcher	--	Finish connecting lead wires to launcher
Radar	--	Begin coupling lead wires to launcher	--	Finish connecting lead wires to launcher

Table 1 (continued)

Group	X-80	X-75	X-74	X-65
I D	--	Begin coupling lead wires to launcher	--	Finish connecting lead wires to launcher
Cosmic rays	--	Begin coupling lead wires to launcher, begin install gamma source	--	Finish connecting lead wires to launcher, complete installation of gamma source
Observation Camera	--	--	--	Check cloud altitude, track balloon
Communications	--	--	--	--
Group	**X-60**	**X-58**	**X-50**	**X-49**
Headquarters	Launcher angular indicator, Contact patrol ship, visitors sit down, check patrol RR car	Chute crew ready	--	Remove chute from launching point
Rocket launcher	Notch finished. Begin transport of launcher	--	--	Transport over, begin horizontal set, place dome
Telemeter and instruments	--	--	--	--
Radar	--	--	--	--
I D	--	--	--	--
Cosmic rays	--	--	--	--

Table 1 (continued)

Group	X-60	X-58	X-50	X-49
Observation camera	--	--	Check field of vision, cloud altitude, and fishing boats	--
Communications	Contact patrol ship, begin observations at Akita Observatory	--	--	--

Group	X-39	X-36	X-31	X-30
Headquarters	--	Check fishing boats	--	Start transmission test, B flag siren, pump, heater off, check warning
Rocket launcher	Horizontal set over, start to remove dome, set timer, start switch, place timer connections on airframe, cover hole	Dome removed	Make sure of stopper pin	--
Telemeter and instruments	T. sw. on	Begin connecting lead wires	Lead wires joined and checked	--
Radar	--	Begin connecting lead wires	Lead wires joined and checked	Sw. on
I D	--	Begin connecting lead wires	Lead wires joined and checked	--

Table 1 (continued)

Group	X-39	X-36	X-31	X-30
Cosmic rays	--	Begin connecting lead wires	Lead wires joined and checked	--
Observation camera	--	Check fishing boats	--	--
Communications	--	Check sea patrol	--	--
Group	**X-29**	**X-28**	**X-27**	**X-26**
Headquarters	--	--	--	--
Rocket launcher	--	--	Main pad, band removed	Begin angle set
Telemeter and instruments	--	Sw. on	Receiver check sw. on (launching off point)	Power source for switch, confirm off
Radar	Start ground transmission	--	Sw. off (ground also)	Power source for switch, confirm off
I D	--	Sw. on	Sw. off	Power source for switch, confirm off
Cosmic rays	--	Sw. on	Sw. off	Power source for switch, confirm off
Observation camera	--	--	--	--
Communications	--	--	--	--
Group	**X-20**	**X-17**	**X-15**	**X-12**
Headquarters	Check controller, Check balloon, launching, wind,	--	--	--

Table 1 (continued)

Group	X-20	X-17	X-15	X-12
	air-temp., air pressure, taking shelter, warning train schedule			
Rocket launcher	--	Angle set, begin removing booster band	Band removed, begin connection of all igniter wires	Complete all igniter wiring, begin measuring igniter circuit resistance
Telemeter and instruments	--	--	--	--
Radar	--	--	--	--
I D	--	--	--	--
Cosmic rays	--	--	--	--
Observation camera	Field of vision check	--	--	--
Communications	--	--	--	--
Group	**X-10**	**X-9**	**X-7**	**X-6**
Headquarters	Ground and sea check, warning check	--	--	Silence all communication
Rocket launcher	Complete measurement of igniter resistance	Confirm first intermediate switch off, begin igniter connection	Igniter connection finished	Confirm first intermediate switch off
Telemeter and instruments	--	--	--	--
Radar	--	--	--	Transponder switch on

Table 1 (continued)

Group	X-10	X-9	X-7	X-6
ID	--	--	--	--
Cosmic rays	--	--	--	--
Observation camera	--	--	--	--
Communications	Contact Akita Observatory	--	--	Communication silence
Group	**X-5**	**X-4**	**X-3**	**X-2**
Headquarters	--	--	Everyone takes cover	Confirm shelter
Rocket launcher	First intermediate switch on, take shelter	--	Cover taken, lead wire brought	Circuit, resistance check
Telemeter and instruments	--	Sw. on	--	Confirm receiving
Radar	Ground transmission begun	Confirm reception	--	--
ID	--	Sw. on	--	Confirm receiving
Cosmic rays	--	Sw. on	--	Confirm receiving
Observation camera	--	--	--	--
Communications	--	--	--	--
Group	**X-90S**	**X-70S**	**X-60S**	**X-30S**
Headquarters	Flare shot	Confirm second intermediate switch off	Controller start	Second intermediate switch on
Rocket launcher	--	--	--	--

Table 1 (continued)

Group	X-90S	X-70S	X-60S	X-30S
Telemeter and instruments	--	--	--	--
Radar	--	--	--	--
Cosmic rays	--	--	--	--
Observations camera	--	--	--	--
Communication	--	--	--	--
Group	X	X-10	X-15	
Headquarters	Rocket launched	B flag lowered, controller reset, wind, air-temperature, air-pressure, pump, heater again turned on	Siren, two fire works announce completion	
Rocket launcher	--	--	--	
Telemeter and instruments	--	--	--	
Radar	--	--	--	
ID	--	--	--	
Cosmic rays	--	--	--	
Observation camera	--	--	--	
Communication	--	--	--	

Schedule of Trains Passing through Proving Grounds

Coming	802	Passenger	19.19[5]	Going	551	Freight	21.02
Going	67	Freight	19.36	Going	891	Freight	21.16[5]
Coming	564	Freight	19.56	Coming	58	Freight	21.54[5]
Going	827	Passenger	20.22	Coming	874	Freight	22.13
Coming	512	Passenger	20.35	Going	883	Freight	23.08

12. The KAPPA 6 and the IGY

The KAPPA 6 is a two stage, solid fuel sounding rocket, the instruments carried weighed 7 to 10 kg. At a launching angle of 80 degrees, it has a climb capability of 60 km (by radar observation, with no wind correction). The booster diameter is 240 mm, length 2,660 mm, diameter of the second stage rocket is 150 mm, length from 3 to 3.5 m, overall length from 5.4 to 6.0 m, and the total weight is approximately 360 kg. Table 2 is a list of its firings. For details, please refer to the article by Professor Maeda.

Table 2

List of Firings of KAPPA-6

Date of Firing	Name of Rocket	Launching Time	Angle of Launcher	Altitude (km)	Flight Duration (sec)	Instruments
16 June 1958	K-VI-1	11 : 36	75°			flight test
20 June 1958	K-VI-2	15 : 15	78°	40-50	200"	flight test
24 June 1958	K-VI-TW-1	10 : 51	78°	25	21"	temperature and wind
30 June 1958	K-VI-TW-2	16 : 52	75°	45	75"	temperature and wind
12 Sept 1958	K-VI-3	10 : 31	78°	40	208"	flight test
14 Sept 1958	K-VI-4	11 : 40	78°	40	207"	flight test
25 Sept 1958	K-VI-RS-1	14 : 50	78°	40-50	240"	solar radiation
25 Sept 1958	K-VI-TW-3	11 : 55	78°	50	100"	temperature and wind
26 Sept 1958	K-VI-TW-4	12 : 50	78°	50	100"	temperature and wind
28 Sept 1958	K-VI-CP-1	12 : 05	78°	36	205"	cosmic ray and pressure

Table 2 (continued)

Date of Firing	Name of Rocket	Launching Time	Angle of Launcher	Altitude (km)	Flight Duration (sec)	Instrument
29 Nov 1958	K-VI-RS-2	12 : 05	78°	40	130''	solar radiation
30 Nov 1958	K-VI-CP-2	13 : 00	78°	49	230''	cosmic ray and pressure
23 Dec 1958	K-VI-TW-5	12 : 03	80°	60	120''	temperature and wind
17 March 1959	K-VI-RS-3	10 : 35	80°	56	240''	solar radiation
18 March 1959	K-VI-TW-6	11 : 45	80°	50	104''	temperature and wind
19 March 1959	K-VI-RS-4	10 : 15	78°	50	215''	solar radiation
20 March 1959	K-VI-TW-7	11 : 50	80°	50	104''	temperature and wind

After the completion of the IGY, improvement in the performance of KAPPA 6 was continued, the length of the booster increased about 50%, and in addition to radar and transponder, it was reconstructed and tested as the KAPPA 6-H, which can carry a doppler radar-transponder. Its first flight was in September 1960. It is presumed that the result of KAPPA 6-H will be a climb of 85 km at an angle of 80°.

13. The KAPPA 8

As explained above, research on the KAPPA rocket was started in close relation to the IGY program. The budget for 1959 was less than half of the budget for 1958 during the IGY. As a result, since a marked restriction was imposed on the number of tests and observations were discontinued in 1959, and it was decided to exert our main effort in the development of a sounding rocket. In this manner, research began on the KAPPA 7 and 8.

The conception of the KAPPA-8 began in December 1958 at the close of the IGY. The basic idea was to add a new booster to the already perfected KAPPA 6 sounding rocket in order to make a three-stage rocket.

The emergence of a large engine with an outer diameter of 420 mm, to be used for a new booster, came as a result of a large scale optimization study, in which plans were made for changing the diameter of each engine from 280 to 700 mm, and in which research was done on center of gravity, weight, performance and natural vibration. The revolutionary steel plate welding techniques of the Kobe Ship Yard of the New Mitsubishi Manufacturing Co. were of great service. New propellants suitable for a wide aperture were studied. In this manner the engine developed was called the 420B used in the designs of the

KAPPA 7 as a one stage rocket, the KAPPA 8 as a two stage rocket in combination with the booster (245B) of the KAPPA 6-H, and the KAPPA 9 as a three stage rocket in combination with the 6-H. The total weight of the KAPPA 8 was 1.5 tons, its total length was 10 meters. It had its first flights in July and September 1960, attaining an altitude of 200 km and was useful in ionosphere sounding. This was higher than the 160 km record attained at the end of 1959 by the English SKYLARK and surpassed the altitude of 170 km attained by the American two-stage rocket the NIKE-CAJUN. At the present time, the KAPPA 8, we may say, has the highest performance of any two stage sounding-rocket in any country.

Another characteristic of the KAPPA 8 is the large size of its payload. For an altitude of 200 km it can carry up to 35 kg, and can carry up to 60 kg for an altitude of 180 km. Also since the capacity of the payload chamber is large, it can be used for every type of space observation instrument. Actually, simultaneous observation of ionosphere and outer space was made with the KAPPA 8, Nos. 3 and 4. Also worthy of mention is the fact that the possibility of animal experiment and space medicine research (in plan E of the AVSA) with the KAPPA 8 are now on the point of being realized. The flight time of the K 8 is about 7 minutes, and it has shown excellent performance in zero gravity tests.

14. Future Problems

The three stage KAPPA 9 and four stage KAPPA 10 are planned as future rockets. Especially in the 10, there is a significance in the challenge of the large diameter single grain engine. The K-6H will be used for low altitude observation, the K-8 for an altitude of 200 km. As the objectives of observation increase, the new fields of space physics will grow in prominence, including noctilucence, electron density, and earth magnetism research. In this respect, aspect control and tele-control techniques will become necessary, and research will be done on a mid-flight explosion safety system. The new development of every type of instrumentation is hoped for. Another problem is that as rocket performance improves, the Sea of Japan will become narrower, and it will become necessary to construct a new testing ground on the Pacific Ocean side.

In summary, there are four future objectives. First, the cultivation of new ideas. Examples are the parametric amplifier in the field of electronics, the bulb type engine -- in all fields original ideas are necessary. In space science, which is on an international scale, evaluations are made at international conferences. It is hoped that each country will contribute new and original ideas.

Second is the refinement of rockets already built. This means not to abandon old rockets when new ones are made, but to improve them. The KAPPA-6 is an example of this.

Third is observation, or the periodic and irregular observation of the universe. Sooner or later, it will be necessary to observe the universe constantly.

Fourth is the testing of coming rockets, or taking steps in the development of types 9, 10, and 11, etc. In carrying out these objectives, it is hoped that the non-military nature of the projects and international cooperation will not be destroyed.

Finally, all the members of the KAPPA team express their deepest thanks to the many people who are cooperating to ensure progress in these ventures.

(December 6, 1960)

II. The Rockoon

-- Osamu HIRAO and Tomo OKAMOTO --

Penetrating a dense layer of air at supersonic speeds causes a strain on the rocket fuselage and affects its flight performance. Several methods to overcome this difficulty have been conceived. One such method is the ROCKOON, first tested by Professor Van Allen and the Rockoon Research Group at the University of Iowa in 1952. A rocket was suspended from a balloon, and after the balloon had slowly drifted up to a comparatively thin layer of air, the rocket was ignited and launched. It was a complex task because a large polyethylene balloon was used and the rocket was ignited several minutes after launch at a low temperature and low pressure. The first rocket used, the DEACON, had a total weight of 90 kg and only reached an altitude of 30.5 km. When the rocket was launched from an altitude of 20 km, it reached 91 km. Therefore, the balloon system certainly is worthy of consideration.

In Japan, several plans for a Rockoon were outlined since 1956. Since this is described in detail in an article by Shigeo Nakagawa (Vol. 12, No. 3) I will not go into it here. Instead, I will outline the progress from 1959, the year I took over the present program at the Institute. Also, I will mention some objectives for the future.

From the beginning, we had three objectives:

I: To launch a rocket accurately and safely without letting the rocket or timer strike the ground.

II: To study the temperature of the rocket propellant when floating in the air and when launched from the balloon; in other words, devise a method for maintaining the temperature of the propellant at about 20° C.

III: To manufacture a safe and accurate timer and telemeter.

During the experiments we encountered several problems. The experiments, which were performed over a two year period, are listed in Table 1.

1. Launching Test

This experiment corresponds to No. 1 of Table 1. The large balloon used for the rockoon was made of polyethylene with a fixed capacity. The hydrogen, which is put into the balloon before it is released from the ground, takes up only about 1/10th of the total capacity (reached when the floating altitude is 20 km). The method of checking the buoyancy by weight and balance was difficult because the slightest gust of wind proved dangerous even though the balloon was tied down with control ropes. At the present