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Chapter 19

THE PACIFIC ROCKET SOCIETY AND THE FOUNDING OF THE INTERNATIONAL ASTRONAUTICAL FEDERATION, 1944-1960: A MEMOIR*

Edmund V. Sawyer†

BACKGROUND AND EARLY ACTIVITIES

The concept of an astronautical society on the west coast of the United States arose from the pursuit of amateur astronomy which E. V. Sawyer began to study in 1929. This avocation led to his appointment as student instructor at the Pasadena City College Observatory, which possessed a fine 20 inch (50.8 cm) Cassegrainian/Newtonian reflecting telescope, and to six years of dedication to the pursuit of education in the physical sciences. After some research activities at California Institute of Technology, and while employed as an experimental production planner at Lockheed Aircraft Corporation, Sawyer started his own small business in 1938 at 6421 Crescent Street, Los Angeles. The name chosen for the new firm was Crescent Engineering & Research Company (CERC).

Here, in 1939, an attempt was made to fire a rocket engine constructed from a heavy brass manifold, using liquid propane and compressed air. The result was not considered a success, but it did not discourage further experimentation. The business grew and moved to South Pasadena where a small manufacturing complex was established, which included a machine shop and foundry, chemical, electronic and photographic laboratories, a wood shop and electroplating equipment, a welding department and a well-supplied stock room.

A small steel rocket engine was tested in 1943 using liquid propane and gaseous oxygen. It appeared to perform satisfactorily, but after approximately 12 seconds of firing it became overheated and burst. In January of 1944 an accelerated program of rocket experimentation commenced, with the help of several interested CERC employees who enthusiastically assisted in the design and construction of a proposed meteorological sounding rocket which was to be 10 cm in diameter and 2.4 meters in length. This vehicle, the XD-1 Rocket, was to employ a regeneratively

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cooled engine, tanks for liquid oxygen and gasoline (petrol), dual propellant pumps and a turbine driven by pressure supplied by the combustion chamber. As the rocket experimental program became more ambitious, Sawyer founded the South Pasadena Rocket Society on August 14, 1944, with 12 employees as charter members. The officers were: President - E. Sawyer, Vice President - C. Skilling, and Secretary-Treasurer - R. MacCarthy. The headquarters was established in the office of CERC at 1130 Fair Oaks, South Pasadena, California.

The Pacific Rocket Society was founded on February 8, 1946 in South Pasadena, California, U.S.A., and was incorporated in the State of California on April 26, 1946, changing the name of the South Pasadena Rocket Society which was created on August 14, 1944, itself arising from earlier experimentation beginning in 1939. The official purposes of the Societies were: (A) To carry out research, construction and testing of rockets in the interests of scientific knowledge of reaction engines and space flight, and (B) to foster the astronautical education of the public, and to seek support for efforts to conquer space. The headquarters of the Societies were established in the offices and manufacturing facilities of Crescent Engineering & Research Company (CERC), which became the sponsor of the non-profit and non-political societies. The founder of the rocket societies and owner of CERC was Edmund V. Sawyer.

THE MOJAVE TEST AREA

Since rocket engine testing on the premises of CERC was unacceptably noisy and dangerous, Sawyer acquired 160 acres (65 hectares) of land in a remote and uninhabited area of the Mojave Desert. Coincidentally, the adjacent property later became Edwards Air Force Base and the Air Force Rocket Propulsion Laboratory. The land was surveyed in October, 1944 and named The Mojave Test Area (MTA). Work commenced on underground living quarters and a bunker which became the rocket test control center. Twelve rocket engines were tested on the static test stand in 1944 and 1945, as this fixture was gradually improved. Reaction thrust was first registered hydraulically, and later with electronic strain gauges.

The XD-1 rocket engine (Figure 1) was completed and successfully fired during several tests in 1945, supplied by pre-pressurized propellants, but the XD-1 turbine and pumps failed due to pressure stresses and thermal distortions. The XD-1 pumps were abandoned in favor of a concept advanced by Edgar Ewing which was called the "Venturi Injection System," which employed a small primary combustion chamber which sent its jet through a venturi shaped tube connected to the main rocket engine. Fuel and oxidizer ports were mounted in the tubular restriction so that the the venturi effect would carry the needed quantity of propellants into the larger rocket engine. Test engines numbers 14, 15 and 16 were built and 1946 using this principle, and test data from firings at the Mojave Test Area justified Ewing's calculations. At all times, Society regulations restricted experimentation to projects which could point toward eventual space flight. Accordingly, only liquid oxygen was used as an oxidizer and all fuels were required to have high specific impulse factors.

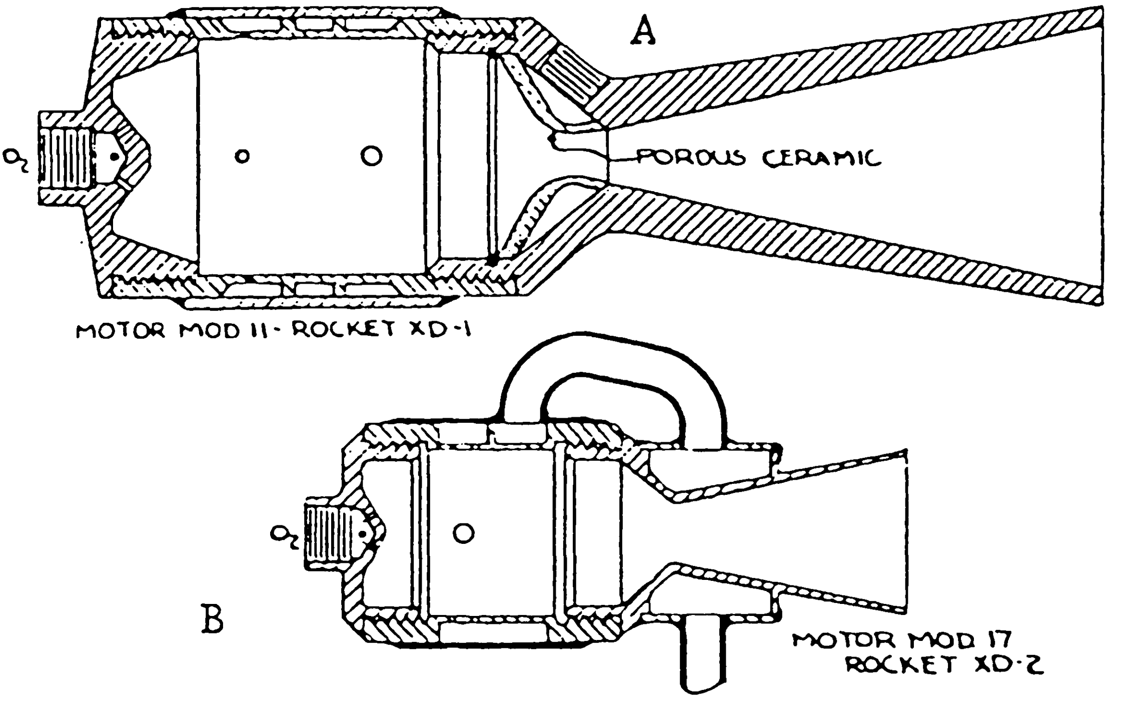

Figure 1 (A) The XD-1 regeneratively-cooled rocket engine was completed and successfully fired during 1945. The ceramic insert was not used. (B) The XD-2 rocket engine detonated on September 8, 1946, and was replaced by the XD-3A design which appeared to fire satisfactorily in October, 1946, but failed on January 19, 1947. The replacement XD-3A engine carried the XD-3 rocket to an altitude of 2,250 feet (686 meters) on June 29, 1947.

FOUNDING OF THE PACIFIC ROCKET SOCIETY (PRS)

The unusual features of the MTA rocket testing activities attracted considerable public attention, which resulted in an increase in Society membership. Newspaper publicity was often helpful in making the work of the Society known, but many published articles reflected skepticism, mirth, or ridicule regarding the goals of space flight and the exploration of the Moon and planets. With the growth of membership and the proliferation of plans, the Pacific Rocket Society was founded by Sawyer to succeed the South Pasadena Rocket Society and to embrace more ambitious plans. On February 8, 1946, the PRS inaugural date, the membership roster consisted of 35 members. However, only the following persons signed the articles of incorporation of the PRS as a non-profit scientific and educational society: E. Sawyer, R. MacCarthy, D. Fry, J. Pettit, R. Marsh, L. Brantley, C. Skilling, J. Coke, S. Rothschild, C. Perryman and P. Bunch. The officers of the PRS were: President - E. Sawyer, Vice President (February-September, 1946) - C. Skilling, (September, 1946 - June, 1947) - R. Marsh, and (June, 1947 onwards) - E. Ewing, Secretary-Treasurer, R. MacCarthy.

PACIFIC ROCKETS

The PRS promptly began to publish a quarterly journal under the editorship of Marsh and the collaboration of all active members. The first issue of *Pacific Rockets*, the journal of the PRS, was printed in June, 1946. By 1948 the membership roster had grown to 81 and the number of subscribers to the journal had increased to over 200. Volume 1, Number 2 of *Pacific Rockets*, published in September, 1946, predicted that, "Manned rockets will complete the round trip to the Moon within approximately two decades." Considerable controversy, even among Society members, arose from this statement. None of the scientists or engineers who were approached by the PRS during 1946 agreed that space flight would be possible during the 20th Century, and many expressed the belief that several hundred years would pass before a trip to the Moon would be possible.

During the earliest years of PRS activity, the only other known astronautical organization which was actively promoting space flight was the British Interplanetary Society (BIS). A growing flow of correspondence was exchanged between the PRS and the BIS, with the latter showing considerable interest in the work of the California society and reporting that no other organization was known to be building and testing rockets with space flight as a goal. Members of the PRS greatly admired the scholarly papers published in the *Journal of the BIS*, and soon an exchange agreement caused 300 copies of the BIS *Journal* to be shipped to South Pasadena quarterly, in exchange for a like number of copies of *Pacific Rockets*.

During 1948, an archive containing more than 50 pictures of rocket experimentation activity in Germany and in the United States was presented to the PRS and 25 of these pictures were reproduced in *Pacific Rockets*, Volume 3, Number 3, through Volume 4, Number 2.

ROCKET TESTING OPERATIONS

Concurrently with the venturi injection tests, a modified rocket was under construction by the PRS which was to employ self-pressurized propellant tanks and mechanical valves. The configuration of the XD-2 Rocket placed the fuel tank in a trailing position for stability. A series of ground tests of the XD-2 Rocket was made, starting on September 8, 1946. The engine (Figure 1), alone, had performed satisfactorily on the static test stand, but during this first flight attempt the XD-2 Rocket engine detonated due to propellant valve icing and leakage. A successful test firing of a modified design called the XD-3 took place on September 16, 1946, but on January 19, 1947, another engine detonation occurred. At this point, Sawyer, who was Test Director, determined that mechanical valves would be eliminated altogether, and the injection ports of the rocket engine combustion chambers be closed by cellulose nitrate plugs which would protrude and be exposed to the pyro-electric ignitor. He proposed that the nitrate plugs be made with rims like those of rifle cartridges, to press against the valve seats and augment sealing. The flame of the ignitor was then to grow for a fraction of a second, burn out the highly flammable cellulose nitrate plugs, and release the propellant fluids into the combustion chamber. MacCarthy suggested that the cellulose nitrate plugs be hollow, so that only the tip needed to be burned off to start a subdued flow of propellants into the combustion chamber. These valves were called "Burnout Plugs" and after a number of refinements they proved so successful that they were used exclusively in flight rockets at the MTA. A new engine (Figure 2), using burnout plugs, was installed in the XD-3 Rocket which, after ground tests, made a successful flight to an altitude of 686 meters on June 29, 1947, using liquid oxygen and propane (a hydrocarbon related to petrol) as propellants.

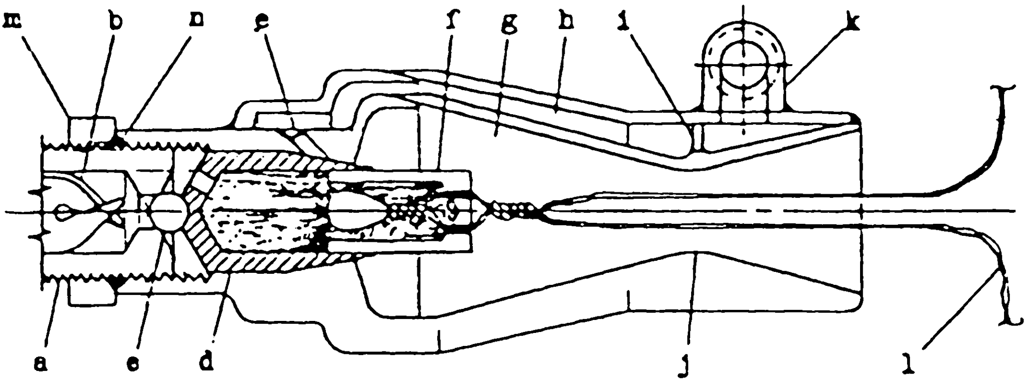

Figure 2 An alternate design among the group of XD-3E engines which were tested between March, 1947 and October, 1949. Two units of the XD-3E design served on flights of the XD-3 rocket at the Mojave Test Area: (a) liquid oxygen injector, (b) oxygen swirl tube, (c) steel ball valve, (d) plastic burnout valve, (e) propane injector orifices, (f) pyro-electric ignitor, (g) combustion chamber, (h) cooling jacket, (i) swirl baffle, (j) nozzle throat, (k) propane inlet, (l) ignitor leads, (m) lock nut and (n) thread seal.

During the period from 1944 to 1951, Society members traveled to the Mojave Test Area on alternate weeks to improve facilities and to carry out rocket tests. A new workshop was constructed, an electric generator installed and the measurement and control equipment improved. In 1948 three remote rocket tracking stations were established which were connected to the control house with cables for communication and for synchronization purposes. The static test stand was given a heavy rock barrier wall and a periscope viewing system.

A new adjustable 14 foot (4.27 meter) launch rack was installed and a dual electric safety system adopted for all firing tests. Protection was built for cameramen and spectators and the entry road was improved. Space was set aside for overnight campers, and was provided with sanitary facilities and water from the MTA well.

PUBLIC EDUCATIONAL ACTIVITIES

An increasing proportion of PRS time and financial resources were devoted to a program to bring astronautical information to the public. During the years of 1944 through 1953, members of the Society gave illustrated lectures to clubs and organizations, and distributed Society literature. Talks about rockets and space flight, and the proposed exploration to the Moon and planets, were broadcast over radio and television stations, generating serious inquiries, skeptical comments, and some new members for the Society. Bi-monthly public meetings were conducted at the South Pasadena Public Library where rockets and engines were displayed, details of plans for space flight discussed, films of rocket tests shown, lectures on astronautical subjects given, astronomical pictures displayed, and question and answer periods held. Qualified speakers were often featured, such as Advisory Member Robert Richardson of the Mount Wilson Observatory. During later years many scientists and engineers from jet aeronautical projects supplied the programs. Perhaps the greatest number of people were reached with the PRS astronautical messages in Southern California by the exhibits which were installed at technical expositions, commercial shows, colleges, county fairs, organizational gatherings and city events. The exhibits were prepared to attract public interest in rockets and space flight, and to provide educational astronautical facts by means of posters, displays and the distribution of literature. A 1/38th scale model of a manned circumlunar rocket was built and often used as the center of attraction at exhibits. This representation of a spaceship was over 2.6 meters in height and 0.6 meter in diameter, and was accompanied by posters giving full specifications and details about the proposed space flight. The PRS estimated that at least an incidental contact was made with more than 100,000 people between the years of 1944 and 1953 with a message about a "new frontier".

THE "XDF" ROCKET DESIGN

In June, 1947, Ewing, who was Vice President of the PRS, proposed that an alternate rocket design be developed as work continued on the bi-liquid propellant XD-3 Rocket. The central feature of Ewing's concept was a rocket engine which would contain its fuel in the combustion chamber and progressively burn this material with injected liquid oxygen, producing a conventional jet and thrust. Behind this proposal was the need to simplify test vehicles for flights at the MTA so that more instrumentation and recovery payloads could be evaluated than had been possible with the infrequent XD-3 flights. Ewing's initial fuel was cellulose, in the form of selected wood, which was regarded doubtfully by Society members. But soon static tests proved the effectiveness of this simplified rocket device, and a flight of the XDF-1 Rocket reached an altitude of 325 meters on October 19, 1947. During 1948 engineering defects were corrected on XDF designs, and in November, the test director established "Standardized Testing Procedures" and required that all XDF rockets employ as fuel either a hydrocarbon or a relatively high specific impulse rated plastic. By the summer of 1949 the reliability of flight rockets had been substantially improved. Of 3 XDF flights carried out during the last half of 1949, all were considered successes (XDF-6, 279 meters, XDF-7, 115 meters and XDF-8, 190 meters of altitude). The XD-3D bi-liquid propellant rocket reached an altitude of 262 meters on October 23, 1949, and was considered a qualified success. Night flights were scheduled, partly because of the ease by which the optical tracking stations could follow the brilliant jets, and partly because desert air was generally quiet at night. Between October, 1947 and June, 1951, 23 XDF-class rockets were launched at the MTA of which 19 were considered successful. Three of these tests took place at night. The XDF-23, which rose to an altitude of 2,630 meters where tracking stations lost sight of the rocket, was a two-stage design with a solid-fueled booster which was jettisoned at approximately 200 meters of altitude.

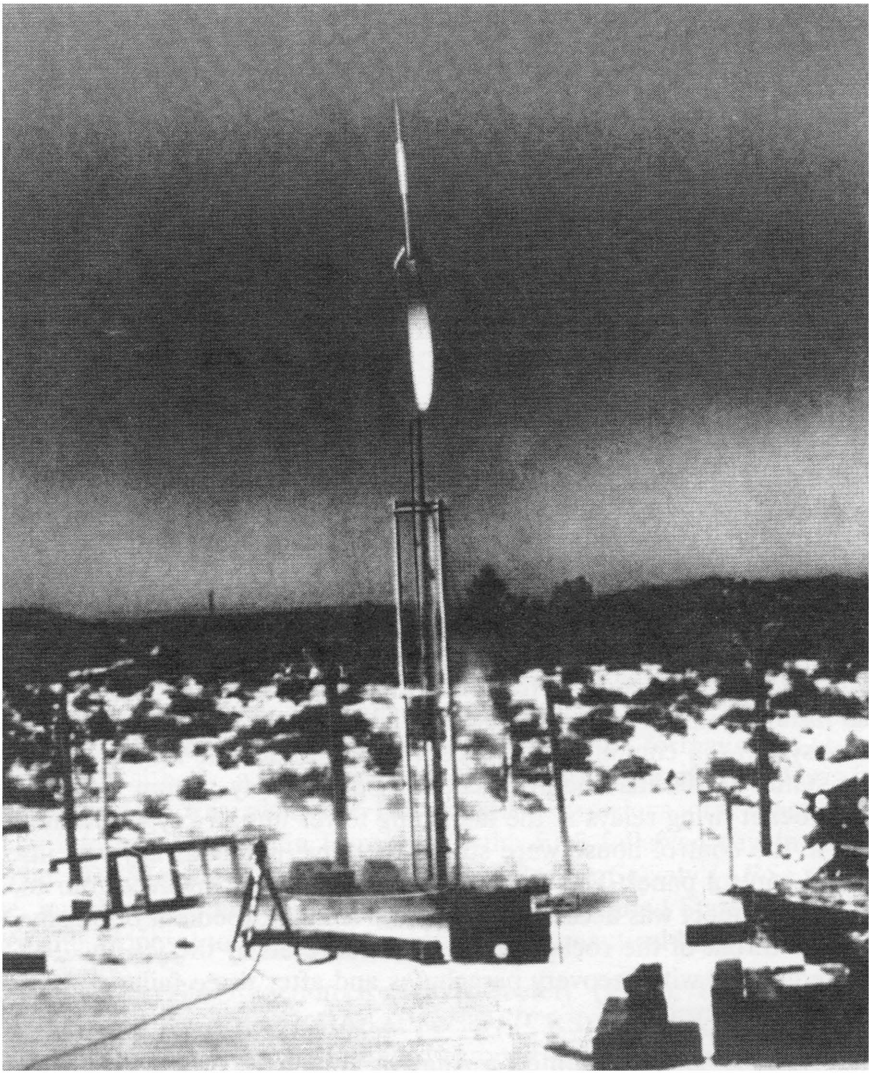

Figure 3 The XDF-21 rocket was launched at the Pacific Rocket Society Mojave Test Area on June 10, 1951. The fuel was ceresin (a hydrocarbon related to petrol) and the oxidizer was liquid oxygen. The rocket reached an altitude of 1,463 meters. (The jet of the XDF-21 rocket was retouched by the photographer.)

Although rocket launchings at the MTA attracted primary attention from members, guests and the news media, a far greater number of static test stand firings took place, either to evaluate rocket engine designs or to carry out pre-flight checks of completed rocket vehicles.

DESTINATION MOON

In 1949 George Pal, creator of Hollywood's Puppetoon pictures, daringly financed a motion picture whose plot was based on "Man's First Trip to the Moon," and called upon the PRS for advisory assistance during the filming of *Destination Moon*. Though skeptical of Hollywood policies, PRS members were soon convinced that a sincere effort would be made to adhere to scientific accuracy. PRS personnel spent many hours on the motion picture set discussing the details of the filming of *Destination Moon* with Director Pichel, Assistant Director D'Arcy, writer Heinlein and artist Bonestell. PRS photographers Crutcher and Linn made numerous pictures of the simulated rocket, the lunar landscapes and the actors. Sawyer, MacCarthy, Curtis and Richardson from the PRS wrote favorable reviews of *Destination Moon* which were published in the 1949 Summer-Fall edition of *Pacific Rockets*. PRS members regarded the production of this motion picture as evidence that the general disbelief in the future of astronautics was waning, and that the wall of incredulity against which the Society had battered for several years was beginning to crumble.

EXPERIMENTAL ACTIVITIES

During 1947 and 1948, L. Reed Brantley, Charter Member of the PRS and Professor of Chemistry of Occidental College, conducted an investigation into the potentials of the element fluorine for use as a rocket propellant. On July 19, 1948, he formally announced the results of his work and gave a demonstration of methods of production, storing and handling of fluorine, and followed with a paper on this subject which was published in *Pacific Rockets*, Volume 3, Numbers 1 & 2.

In the fall of 1947 an improved and more sophisticated electrical control center was installed in the control house at the MTA, providing centralization of all electrical systems, a communications center, and indicators for thrust, temperature and the status of circuits aboard rockets. A dual safety system isolated all power from the rocket firing relays at the launching tower until a key was removed. Firing switches in the control house were still inoperative until this key was inserted into the master control panel. The umbilical wires to rockets involved four to eight circuits, and disconnect was accomplished by the simple expedient of passing the cable beneath the throat of the rocket where it was severed by the jet. By 1948, all rockets were equipped with recovery parachutes and after three failures, "soft landings" were reliably achieved.

During 1949 Ewing invented a rotating parachute for rocket recovery which consisted of nylon ribbons attached to a swivel joint. The rotating canopy of ribbons provided substantially more drag than did a conventional parachute of the same size and weight.

In October, 1949, the optical tracking instruments used by the three rocket sighting stations at the MTA were replaced by recording theodolites built by Skilling. As these new instruments followed rising rockets, altitude, azimuth and time were recorded. During the period beyond 1948, a growing list of "payload" equipment was being carried by flight rockets, including altitude recorders, radio, still and motion picture cameras, tracking smoke flares and peak marker smoke generators. A high percentage of failures of instruments occurred due to the rapid acceleration of rockets and the severe vibration caused by rocket engines. A radio direction transmitter was tested to evaluate this method of tracking ascending rockets, but the accuracy of results failed to compare with that of the recordings of the theodolites. By 1951 a typical two-day rocket testing operation at the MTA involved hundreds of Society members, guests, news personnel and spectators. Permits were required for entry into the MTA and strict regulations enforced. A public address system, warning siren and signal mast made all persons aware of the status of rocket test preparations. Restrictions affecting personnel began with the loading of liquid oxygen into the rocket tank, and became more confining with the completion of propellant loading. The final periods involved a tense countdown. Many of the dramatic experiences attending the firing of the great Saturn Rocket had, in a small way, their counterparts at the PRS rocket launchings.

INAUGURATION OF THE INTERNATIONAL ASTRONAUTICAL FEDERATION

The correspondence and exchange of journals between the PRS and the BIS, which began in 1946, led to a similar relationship between the PRS and the German Gesellschaft für Weltraumforschung (Society for Space Research) known as the GfW. PRS Honorary Memberships were extended to Professor Hermann Oberth and to Messrs. Heinz Gartmann and Heinz-Hermann Kolle of Stuttgart, and GfW memberships were bestowed upon Sawyer, Ewing and MacCarthy of the PRS. The three-way correspondence between the BIS, the GfW and the PRS intensified in 1948 as the formation of an international astronautical association was discussed. All three organizations were strongly supportive of such a plan, and agreed that any such international body would be non-political and non-military. The GfW suggested that, in order to take the first steps toward the formation of an international astronautical body, a preliminary meeting should take place in Paris in 1950. With agreement for this plan, the BIS sought expressions of cooperation from potentially interested groups in Europe and the PRS followed suit in the United States. The PRS inquiry sent to the American Rocket Society (ARS) received no response, but the three newer rocket societies in the United States enthusiastically supported the proposal to form an international astronautical body.

These groups, the Reaction Research Society (RRS), the Detroit Rocket Society (DRS) and the Chicago Rocket Society (CRS), authorized the PRS to represent them both by correspondence and through the service of a delegate to any international conclave. This was, in fact, the first step toward the formation of the proposed American Astronautical Association (AAA) which Sawyer of the PRS was advocating. The Paris Congress of international delegates met in 1950 as planned, with representatives from Britain, Germany, France, Argentina, Italy, and Denmark present*. Mr. Val Cleaver, of the BIS, represented the PRS and its associate

* Editor's note: Representatives of Germany, Argentina, Austria, Denmark, Spain, France, Britain and Sweden were present (order of listing) according to resolution signed on 2 October 1950.

societies at this First Congress. The plan which had been developed by the BIS, GfW and PRS was approved during this meeting and it was agreed that the formal structure of the International Astronautical Federation (IAF) would be developed during the following months and adopted during an official inauguration of the new international organization in London in 1951.

Sawyer, representing the PRS, RRS, DRS and CRS, traveled to London in 1951 carrying a paper from PRS entitled *Landing of Space Craft*, a demonstration of the rotating parachute design invented by Ewing, and a volume of work by Dr. Herrick of Aerojet which proposed to standardize astronautical and rocket nomenclature. The Second Congress of the IAF was called to order in Caxton Hall, in St. Ermin's Hotel, Monday morning, August 27, 1951 by Arthur Clarke of the host society, the BIS (Figure 4). Professor Hermann Oberth was nominated as the Guest-of-Honor at this meeting.

Figure 4 Arthur C. Clarke, host Chairman (standing on rostrum), opens the series of meetings which inaugurated the International Astronautical Federation. This Second Congress of the IAF convened in Caxton Hall of St. Ermin's Hotel in London on August 27, 1951. Eleven delegates were present (seated on the rostrum). Left to right: Mr. Sawyer, U.S.A. (PRS); Lt. Cmdr. Durant, U.S.A. (ARS); Mr. Stemmer, Switzerland; Mr. Casiraghi, Italy; Mr. Haley, U.S.A. (ARS); Mr. Clarke, Britain (BIS; Dr. Sänger, Germany (GfW); Dr. Loeser, Germany (GfW); Mr. Hjertstrand, Sweden: Mr. Ananoff, France and Mr. Tabanera, Argentina (SAI). (Note: last person on the right is not identified).

On the rostrum were delegates from eight nations: Argentina (Mr. Tabanera); Britain (Mr. Clarke and Mr. Cleaver); France (Mr. Ananoff); Germany (Dr. Sänger and Dr. Loeser); Italy (Mr. Casiraghi); Sweden (Mr. Hjertstrand); Switzerland (Mr. Stemmer); and the United States (Mr. Haley and Lt. Cmdr. Durant for the ARS and Mr. Sawyer for the PRS, RRS, DRS and CRS). The genial delegates did not adhere very closely to parliamentary rules, but preparations by the BIS had been thorough and proceedings moved very rapidly at first. The aims, structure and powers of the IAF were quickly established by unanimous votes. But when membership in the IAF and voting privileges were considered, controversies arose which were to delay progress at the conference for more than a day. The ARS delegates who had not responded to a 1950 invitation to participate in the IAF, made a motion that only one organization per nation could be admitted to the IAF as a full representative. This motion was rejected by the vote of all other delegates, and a motion was approved which stated that all groups conforming to the aims and principles of the IAF would be given membership status. The ARS then proposed that voting power within the IAF be delegated with a direct relationship to the number of members claimed by a society. This proposal, too, was rejected by the vote of all other delegates, and the BIS worked diligently to attempt to reach a compromise whereby voting power would be related to a logarithmic factor of the number of members claimed by a society. The ARS delegates announced that they could not participate in the IAF if the BIS plan were adopted. The BIS then pointed out that, if the ARS motion had been adopted, more than half of the voting power within the IAF would be controlled by the ARS and the BIS whose memberships were largely made up of subscribers to their publications. With time running out on the general assembly work, a committee was appointed to seek a resolution to the voting apportionment problem. The committee members were: Cleaver, Tabanera, Loeser, Haley and Sawyer. This committee noted that the definition of membership employed by the ARS allowed all subscribers to their publications to be included in their membership roster, and agreed that all other societies could also list subscribers as members. Nevertheless, the committee agreed to submit a plan to the general assembly by which voting power would be based on increments of 200 member-subscribers, but when this compromise was brought before the assembly, it was rejected and the final decision of the Congress was that each member society would have one vote until further evaluation of the matter could be carried out. D. Elliott of the RRS arrived in London on Tuesday and gave valuable assistance to Sawyer.

The official inauguration of the IAF took place on Tuesday, August 28, 1951, and the signatures of the delegates to the Second Congress of the IAF made the international organization a reality at last. Wednesday was a "free day" to allow delegates and their staffs to tour London, and the Congress re-convened on Thursday when Sawyer exhibited motion pictures of PRS rocket launchings at the MTA. This was followed by the reading of papers from various societies. On Friday the PRS paper, *Landing of Space Craft*, was read and well received, and the rotating parachute was demonstrated. Sänger was elected President of the IAF for the coming year with Loeser to be Vice President, and Stemmer became Secretary. Later a motion was passed to make Haley a second Vice President. The delegates unanimously approved a plan to hold the Third Congress of the IAF in Stuttgart, Germany in 1952, where the refined Constitution would be approved.

The BIS, a generous host, gave a banquet on Saturday evening in Caxton Hall where all controversy was set aside and delegates made lasting friendships. Many pictures were snapped and autographs exchanged. This memorable occasion marked the end of the Second Congress of the IAF and all delegates expressed satisfaction that an international organization had been created which would help coordinate future astronautical work, and play a prominent role in promoting the peaceful conquest of space.

Figure 5 Mr. Sawyer addresses the London Congress of the International Astronautical Federation on August 27, 1951. Left to right: Mr. Sawyer (PRS); Lt. Cmdr. Durant and Mr. Haley (ARS).

CONTRIBUTIONS OF THE PACIFIC ROCKET SOCIETY

During the 1940s very little information was available to guide experimenters with the design and testing of rockets. Therefore, in the PRS, most technical inventions and testing techniques arose from the ingenuity of members. They believed that the refined designs and knowledge gained during their experimentation would eventually contribute, in a small way, to the space programs of the future. However, in review, it is seen that the work of the PRS was so completely over-shadowed in the 1950s by large and well-financed missile and aerospace projects that no definite assertion can be made that specific technical achievements made by the PRS became appreciable contributions to the science of astronautics.

In the area of public education, a claim that the PRS gave some technical preparation for the upcoming "space age" to thousands of people would be on firmer ground, but a clear assessment of the success of the PRS public educational program is impossible. A number of people were inspired by the work of the PRS to become involved in later rocket and space activities, but no specific list of scientists, engineers and technicians has been compiled.

The only well-documented consequence of PRS experimentation which may be considered to have substantially contributed to the building of successful space rocket vehicles and ballistic missiles was the Crescent Engineering & Research Company (CERS) instrumentation program. The history of this development and manufacturing effort shows that major aerospace projects could have been significantly delayed if the PRS experimental activities had not sparked the CERC instrumentation development program. During its rocket test activities, the PRS discovered that rocket components and instrument payloads were often damaged by the severe environmental effects which existed in a rocket vehicle during firing. Many failure arose from vibration and rapid acceleration. The background of rocket testing at the MTA gave awareness that the instrument reliability factor of equipment aboard the German V-2 Rocket would not be acceptable during the operation of high-cost missiles, and could not be tolerated by manned space rockets. CERC, the sponsor of the PRS, made an evaluation of control and measurement devices manufactured in the U.S. and concluded that available sensing instruments, better known as *transducers*, would not meet the requirements of the upcoming aerospace program in the U.S. A development program was initiated by CERC to fill this instrumentation gap and to make available a family of transducers which would both satisfy the electronic specifications and the reliability standards which were essential for the building of successful rocket vehicles. The design engineers were PRS members Sawyer and Fry.

In the U.S., available transducers fell into several classes, all of which were vulnerable to severe shock and vibration conditions. None met all desired specifications of sensitivity, resolution, repeatability, impedance, survival under violent environmental conditions and insensitivity to extraneous phenomena. CERC began the construction of a group of instruments which employed variable permeance (or reluctance) as the basic principle of operation. These transducers represented two legs of an electrical bridge which required excitation by an alternating current. Setting aside accepted design criteria for apparatus involving magnetic fields, CERC built coils on heavy stainless steel tubing and encapsulated these assemblies into thick steel housings. Vacuum "potting" techniques resulted in a solid body which was finally hermetically sealed by welding operations. The moving elements in these transducers were ferromagnetic stainless steel rods protected in the central stainless steel tubing. A typical linear transducer, used to sense position or linear motion, had the appearance of a section of a heavy steel rifle barrel, with a solid steel rod fitted into its bore.

Tests made in 1950 gave evidence that the new transducer designs had achieved the desired performance specifications. Using the same principle of operation and construction features, CERC developed transducers to measure the following phenomena: (A) angular position or rotation, (B) hydraulic or pneumatic pressure, (C) liquid or gaseous flow, (D) acceleration, (E) Torque. Since design specifications emphasized ruggedness and insensitivity to hostile environments, some transducers were built which would operate when immersed in liquid oxygen. Others could be submerged in fuming nitric acid. A design group was built which could perform sensing functions when raised to temperatures as high as 700°C.

By 1951 many of these instruments were ready for customer use, but it was not until the engineering departments responsible for the design of the Atlas Rocket encountered instrumentation inadequacies that CERC transducers were fully evaluated. As a consequence of these tests, the vast Atlas control and measurement systems were built with CERC components. During the testing phase, each Atlas Rocket employed more than 60 CERC transducers and instrument packages. For example, CERC transducers generated the command signals from the Atlas "programmer." Some of these signals were transmitted to the CERC servo-control transducers which were built into, and controlled, the hydraulic actuators which gimbaled the 5 engines on their pitch and yaw axes, thus controlling the course of the rocket. A second illustration of transducer applications was the safety control of pressures in the Atlas fuel and oxidizer tanks, which were separated only by a thin common bulkhead. The CERC pressure transducers employed were required to accurately measure a pressure range of 5 lb/in^2 (3.45 N/cm^2), yet to withstand a test pressure of 1,000 lb/in^2 (689 n/cm^2) without leakage or rupture. Atlas engineers reported that, without the ready availability of CERC instruments, the Atlas program would have been substantially delayed. These products were also employed on the Titan and Polaris rockets. By 1958 numerous other manufacturers were producing duplicates of the transducers originated by CERC and supplying them for use on all rockets produced in the U.S.

The development of CERC instrumentation was a direct result of the PRS rocket testing program. The Pacific Rocket Society should receive credit for providing the knowledge and inspiration which resulted in the invention and early availability of the CERC transducers and instrument packages.

PACIFIC ROCKET SOCIETY - EPILOGUE

Between 1951 and 1954 the rocket testing program of the Society reached a peak of activity, though the experimental nature of this work was diminishing. The refined XDF-class rockets became reliable test vehicles and failures of parachute recovery equipment were rare. Rockets reached altitudes as high as 3,200 meters but by 1955 all testing activities were overshadowed by the interest in the great U.S. aerospace projects. An attempt was made to develop and produce a Standard Research Vehicle (SRV) but opportunities for pioneering work no longer existed. The Society turned to discussion and study pursuits.

During 1951, under the Presidency of J. Nuding, the PRS moved its headquarters to 1305 Ingraham Street in Los Angeles where a large meeting hall was provided. Although the public educational program had been abandoned, meetings were open to all interested parties. Numerous workers in the field of astronautics became available as speakers. Invitations to prominent rocket society members, such as Arthur Clarke of the BIS, brought them to Southern California to lecture the PRS. A branch division of the PRS was active at Northrop Aviation and the new Long Beach Chapter of the PRS flourished. Cooperation existed between the PRS and other U.S. astronautical societies, but the national federation promoted by Sawyer, the AAA, never became a reality.

By 1960 a diminishing membership of the PRS was little more than an enlightened study group which followed the growing achievements of the "space age" with fascination.

At the date of this paper (1980) the PRS, which once claimed a list of 600 members and subscribers, two branch chapters and three affiliates, is only a small group of original members. Three charter members remain active, and the Society now has only two purposes: (A) cooperation with more vigorous astronautical organizations and (B) preparation of a detailed PRS history for the years of 1944 to 1953. This report will contain copies of pictures, publications, drawings and other memorabilia. Each package of historical material contains 744 pages, which include copies of *Pacific Rockets*, the journal of the Pacific Rocket Society. During 1980, copies of the historical report will be delivered to interested astronautical organizations and scholars with the compliments of the PRS.

ABBREVIATIONS

PRS - Pacific Rocket Society

MTA - Mojave Test Area

IAF - International Astronautical Federation

BIS - British Interplanetary Society

GfW - Gesellschaft für Weltraumforschung

ARS - American Rocket Society

RRS - Reaction Research Society

DRS - Detroit Rocket Society

CRS - Chicago Rocket Society

CERC - Crescent Engineering & Research Company.

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