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THE DEVELOPMENT OF ROCKET TECHNOLOGY AND SPACE
RESEARCH IN POLAND⁺

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FROM THE EARLIEST BEGINNINGS TO THE END OF
THE 19TH CENTURY

The first rockets were designed in China after black powder was invented, probably not earlier than the 10th century and not later than in the second half of the 12th century.¹ The first known military application was during a military engagement around Peking in 1232. In Europe, rockets were used for the first time by the Tartars, probably during the battle of Legnica (Dolny Slask - Silesia) in 1241, as reported in a book by the Polish 15th century history writer, Jan Długosz.² The Tartars used the poison gases coming out of dragon heads mounted on long sticks. A little church was built on the battleground near Legnica. On the walls inside of the church a fresco shows the battle³ (Figure 1). T. Przykowski³ also found that a monk Seweryn (about 1380), living in the same monastery, had written on the application of powder to propel the "tubes," which probably were rockets. If this is true, it would be the first written statement on rocket application in Poland.

The first Polish description of rocket production appears in the book of M. Bielski, published in 1569,⁴ (Figure 2). According to his own experience and experiments, the author provided exact descriptions of how to produce military powder rockets (Figure 3). The next Polish author to deal with rocket problems was Walenty Sebisch (1577 - 1657), from Raduszkowice by Olawa (Silesia). He was the military architect of Wrocław. His manuscripts, discovered by T. Przykowski,³ date from about the year 1600 and contain sketches of rockets with delta-type stabilizers (Figure 4), conic nozzles in rockets, a rocket battery (Figure 5), and a device similar to the two-stage rocket (Figure 6).

The most outstanding early work is the manuscript of A. Dell'Aqua (1584 -- after 1654) Praxis reczna działa (Hand Production of Guns). Dell'Aqua came to Poland from

⁺Presented at the Sixth History Symposium of the International Academy of Astronautics, Vienna, Austria, October 1972.

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134
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Malewida ściana w klasztorze wspaniałym na polu bitwy pod Legnicą obroną używaną przez Tatarów głowy świeco posiadające ognie i dymy na głowy walczących wojsk. Być może, że dla przedobrania stopnia tych dymów i gwałtu używane również paciorki prochowych lub rakiet. W tym klasztorze przebywający mnich Seweryn w 1380 r. czynił próby „rachowej rury przy pomocy prochu” będącej prawdopodobnie rakiety na paliwo stałe.
(Foto T. Prądkowski)

Fig. 1

Venice in 1613 and remained in the service of the Polish King and the Polish princes up to the end of his life.⁵ His manuscript was written in Polish over a period of five years, between 1630-35. At least five copies survive. In Part III of the manuscript (p. 389, K 187, Cz. 383) is found Figure 171. The rockets G-H are combined in a two-stage rocket (Figure 7). The second stage H, a rocket battery, contains five little rockets.

Kazimierz Siemienowicz occupies a distinguished place in the history of rocket technology. He was made a Polish General of Artillery by the King Władysław IV, and served during the first half of the 17th century. He wrote the well known and outstanding book *Artis Magnae Artilleriae . . .*, published in Amsterdam in 1650,⁶ and translated later into many European languages. The chapter concerning rockets contains the sketches of a multistep rocket, a rocket battery, the conic rocket nozzles, and delta-type rocket stabilizers⁷ (Figure 8); the multistage combined rocket is shown in Figure 9. It is not certain if these rocket conceptions are those of Siemienowicz. It is possible that all these conceptions are earlier than those of Siemienowicz, Dell' Aqua, Schmidlap, Biringuccio or Haas.⁷ Similar rocket conceptions were advanced, independently it seems,

179. *Kieleski* *Pieczęć*
SŁAWA DZ.
 cesarza wedlug postępu y
 zachowania starego obyczaju Kró-
 mskiego/ Greckiego/ Macedońskiego-
 go/ y innych Narodow pierwowzego y niniey-
 szego Wiekę/ tól Pogánsta iako y Krześ-
 ciansta/ z rozmarządny *Wielki* *Wojewoda* / Lu-
 chytanin y Władce Ludziom Dy-
 cesum pożyteczna.
 Królestwi ná ośm Cześci
 rozdzielone.
Wielki *Wojewoda* *Prinlegio* S. R. M.
W Kraslowic:
 Drukowano v Matrukska Siabeneys
 szczy/ Roku Pánstwego: 1569.

Fig. 2

74
Spráwach Pustárstich.
 bádé obfyt płocnem furwym mocnym/ oboto spytat
 wierzdu na fudat/ aby tej grocu ielajnego bylo widac
 nie o/ nasyt acfya prochu/ smoy/ slarzi/ Saletry/ por-
 trofi: wofyftiego rowno/ obciagni to niciami moenia-
 mi oboto spyt/ zatusi ciopel v wierzdu wozdnac trza-
 ba y omocyt v smole / gdy masz strzelic v fusie albo v
 brotky batornic ite tym spytam/ zapalaj lernwey ob-
 ecy diurci / Nad ciopel wymiess / strzelsie tparam gólu
 ch. esz zapalik / ityby wznal na dachu.
 Racc tál diutiac/ nátrac trabel pástronnych w formis
 na to wiononey/ samowyná toncu kálda / idy tchko
 diurcica mala zofala/ nabyta tego spytutem w for-
 mie prochem nie ostanowionym mialim co ná puciere
 jedza Saletry/ zaprawa ná toncu tle. em albo cásstham/
 przywólilascie do niego pod waga/ coby tál las: iczka
 wozyla iako y Raca/ zapalac ob diurci/ foydse wozora z
 lasic iczka/ poydise y po mci daleko gdy do niego cewocze
 ta przywólil.
 Tymis tej Pustarye Smotl ogniste tálowymie pios zmozi zgdó-
 chem przyprawionym/ trazy latáta fo wierzyc/ dylara
 szc za sworez / ale to nie poiytchino fu potrzybie.
 Garnce/ krece surm obbajia/ tál chymia. Talsy Garnce surm
 pa w garniec prochu u Rusnicnego/ potym nástáda w
 on garniec miedy prochu rurci ielajnych broctich iako
 palec / a tchak miaszich iako flucz samowoy / w kálda
 rurci wozyc dwa cłoty ielajny z salromac Slosary ma-
 oba tóhca / a w poyryjdbu ma wytrzas diurci ite mias
 la/ kora fo u armis prochu rusnicne ma nátrac / a
 bádúe pedna rurka: Wozie tálch rurci wozyc w ledon
 garniec tops albo wozycy albo mniy / wozdug wozidob-
 dzi garniec. Potym nástyc w on garniec pedno prochu
 rusnicne

Fig. 3

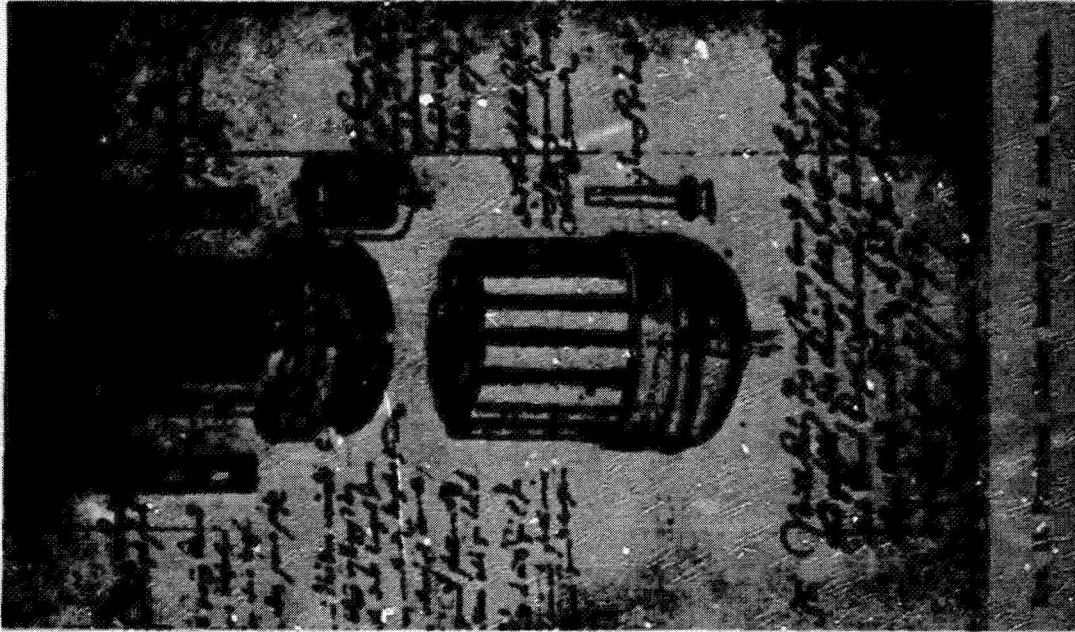


FIG. 5

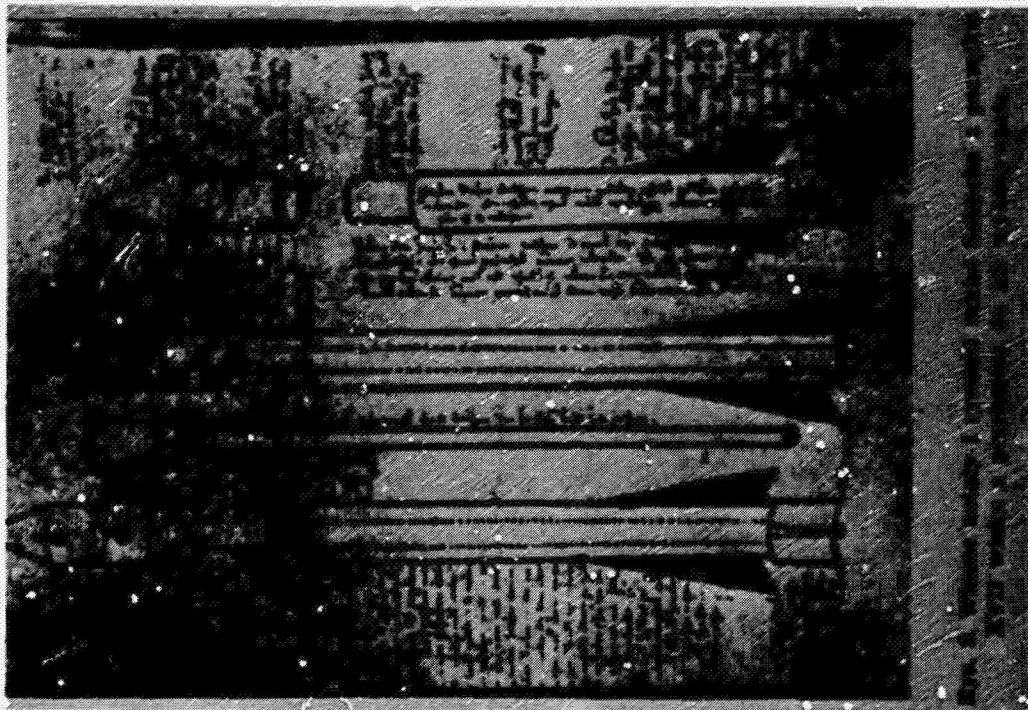


FIG. 4

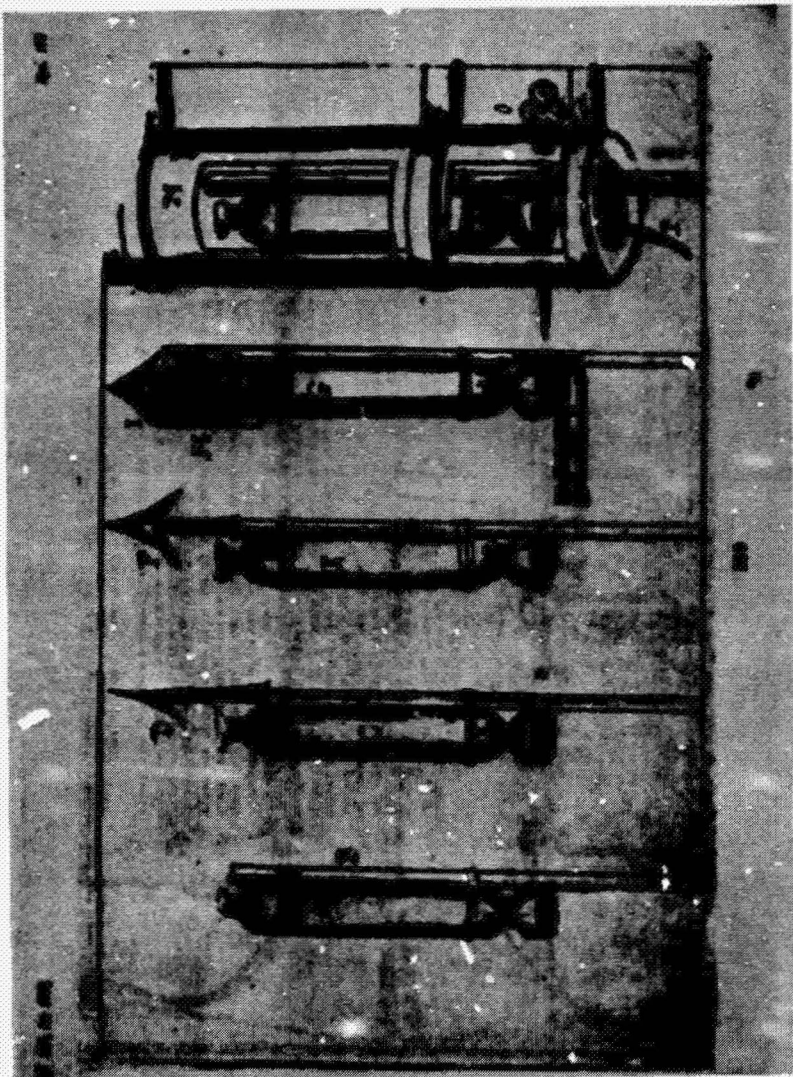


FIG. 7

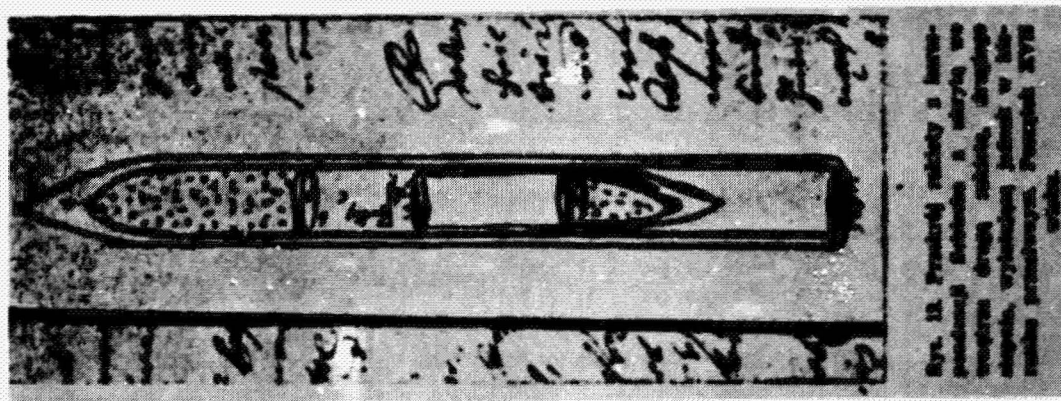


Fig. 13. Product of activity of bacteria
producing cellulose & other
polysaccharides from glucose, fructose,
sucrose, xylose, and other
simple carbohydrates. Produced by
Bacterium

FIG. 6

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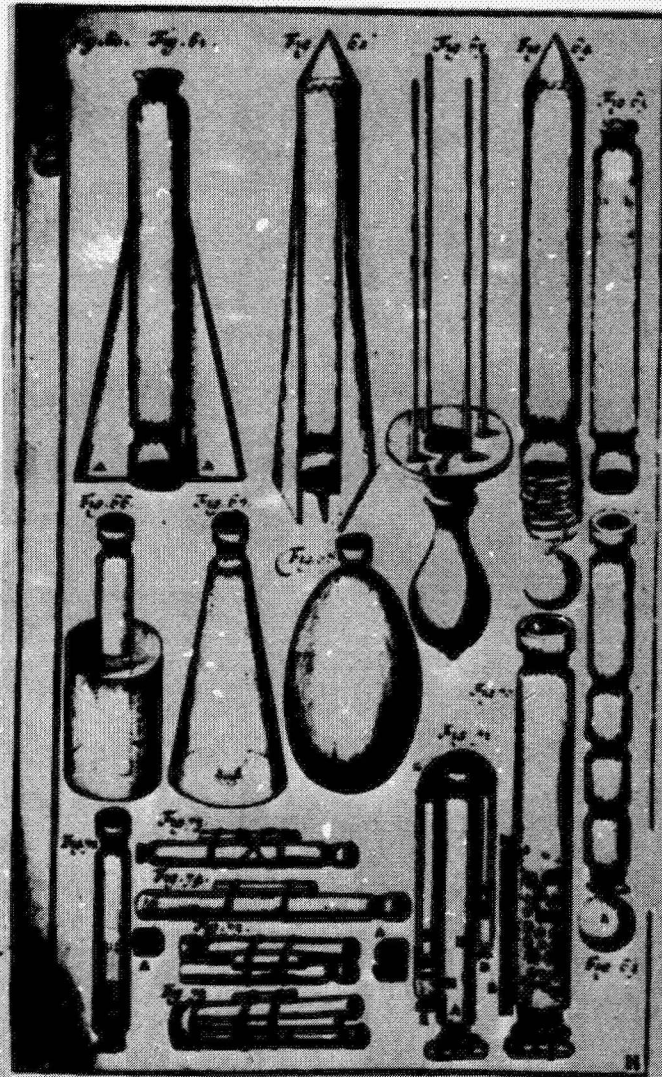


Fig. 8

by different authors before and after Siemienowicz. In any event, his book was the top achievement in the history of the rocket sciences up to the 19th century, namely, to the time of publication of Britain's William Congreve. As far as the priority of the rocket construction ideas is concerned, it is probable that a link between the authors mentioned above and other unknown authors may have existed, e.g., an earlier author.

Besides the ingenious Polish rocket pioneers of the 17th century, we should mention also an excellent forerunner of airplane designers: Titus Livius Borattini (or Boratyni, 1617-1682),⁸ who was born in Italy. He came to Poland in 1641 and appeared on the King's court from 1650. Apart from his state activity (as tenant of the Kings

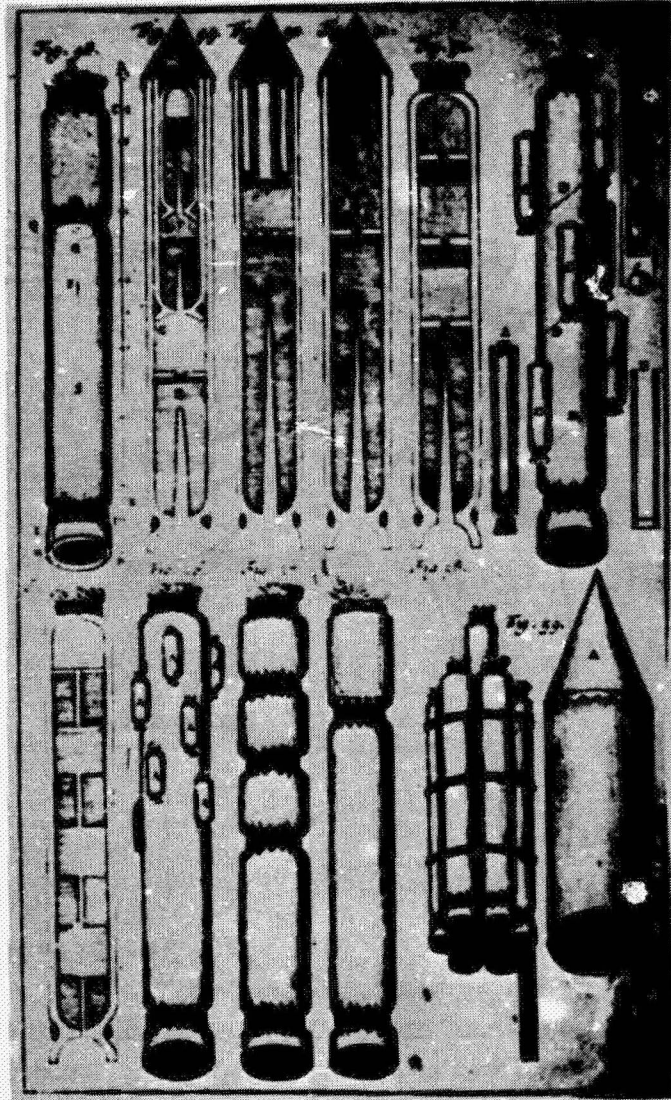
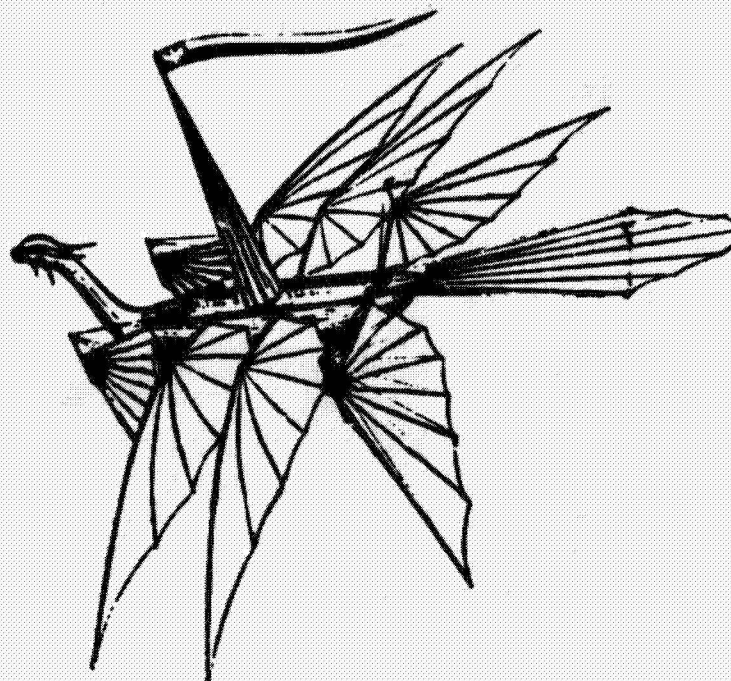


Fig. 9

mint), he also conducted research work in science and technology; he invented a new balance, proposed a new and general system of units in time, length and weight, and constructed models of heavier-than air flying ships (Figure 10). His invention separated two different functions in the flying apparatus: lift force (now supplied by the wing) and thrust force (now supplied by the propeller or the jet engine). The frame of the wings was built of bones and covered with textiles. Human muscle provided the power.

Rockets used in fireworks and for military purposes were described by W. Ryzranowski, 1749.⁹ Later, Captain Józef Bem, in 1820, provided many technological



„SMOK LATAJĄCY” Boratyniego
wg rys. J. B. Cynka.

Fig. 10

descriptions of how to prepare raw materials, machines and apparatus to produce the military rockets.¹⁰ He also summarized the results of field experiments carried out with rocket weapons. Bem gave an account of the bombardment of Gdańsk in 1813 by the English fleet using fire rockets.

LAST YEARS OF THE 19TH CENTURY THROUGH WORLD WAR II

From 1895 to 1903 a young man M. Wolfke (1883-1947), later a professor of physics in the Warsaw Technical University (Figure 11), dealt (in Warszawa) with the problem of communications with other planets. In his first work, Planetostat, he proposed two possible ways of achieving cosmic flight. One used a reaction space ship (planetostat). The forward motion of the space ship was to be realized by the reaction of solid projectiles or gases leaving the nozzles with great velocity (Figure 12).¹¹ This is



MIECZYSLAW WOLFKE

Fig. 11

probably the first written statement of a Polish author on the application of the reaction principle to cosmic flight. (We should mention in this context the name of K. E. Tsiolkowsky [1857-1935] the founder of scientific astronautics, and a great Russian and Soviet scientist of Polish-Russian origin [his father was a Pole, his mother, a Russian woman]. Tsiolkowsky confirmed this himself in a letter to the Polish astronomer, Professor T. Banachiewicz, (Figures 13, 14).

The idea of using charged particles (namely, electrons) as the jet mass in a space rocket was formulated by A. F. Uliński,¹² probably for the first time in the scientific literature (Figure 15). The source of electron energy was the energy radiated from the sun and converted in thermoelectrical batteries to supply the voltage of about 250 KV. Uliński, a Pole living in Austria, studied rocket problems after 1913 while

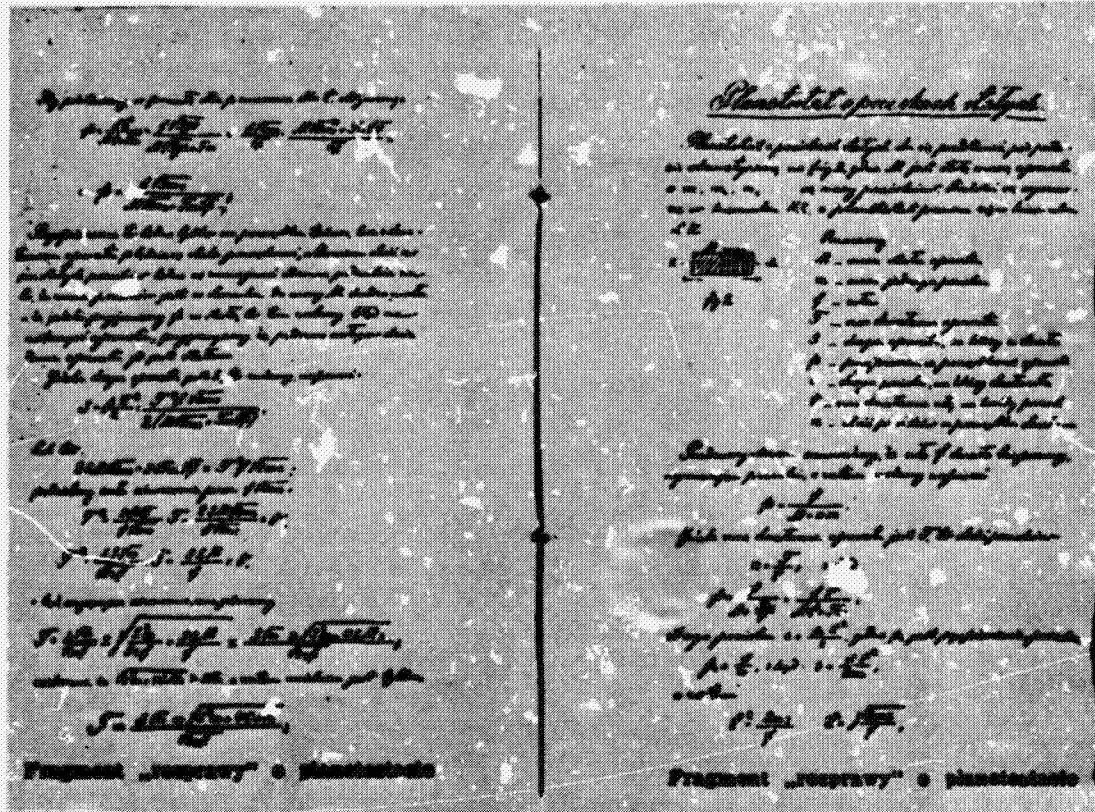


Fig. 12

serving in the Austrian army. The principles of rocket propulsion and the problems of space flight were also described by F. Burdecki (1929)¹³ in what was probably the first Polish scientific-popular book on space flight.

Now we shall consider some technical and scientific papers published in the 20th century in Poland. In 1931-32, W. Vorbrodzki¹⁴ published some papers on the military applications of rockets, on flight to the moon, and out of the Earth's gravitational field. Z. Krzywoblocki, between 1934-39, also published some theoretical papers on the military applications of rockets and the rocket propulsion of aircraft. Together with H. Stankiewicz and others, he performed some tests with rocket engines, aiming at stable flight of a winged rocket. G. Mokrzycki (1935), in a popular book,¹⁵ discussed the application of rockets to the purpose of communications on Earth and to space flight beyond the Earth. Of special interest are the theoretical papers of T. Olpiński, P. Demiańczuk and K. Zarankiewicz, dealing with the efficiency of propulsion, dynamics and the mechanics of flight, ballistics of rocket projectiles, and applications of rockets to space flight. K. Zarankiewicz¹⁶ analysed the vertical flight of rockets in

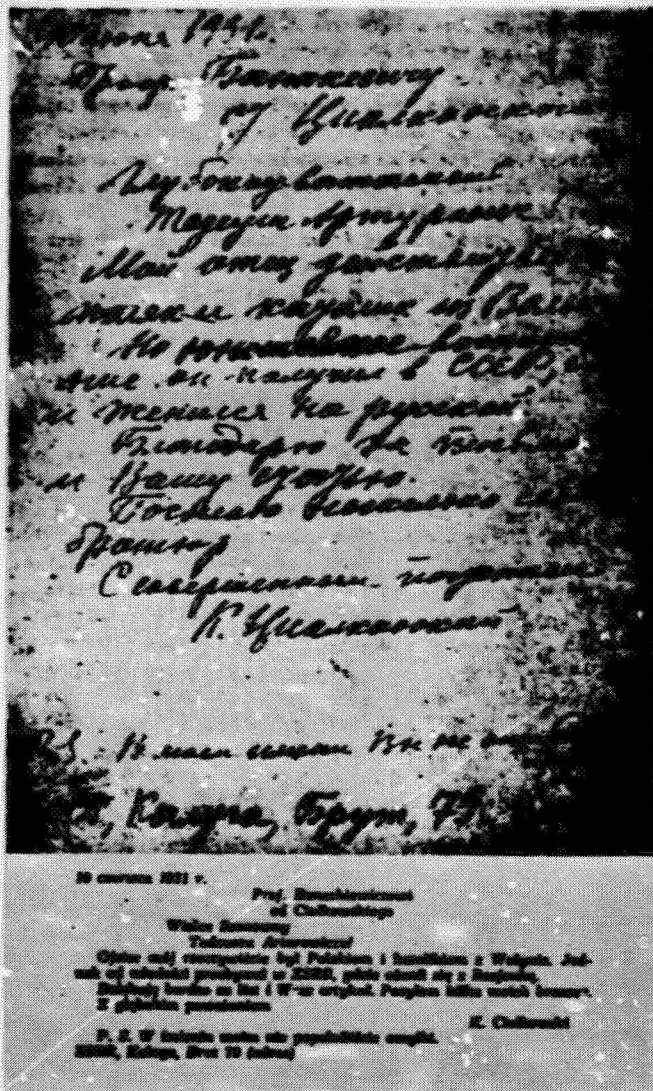


Fig. 13

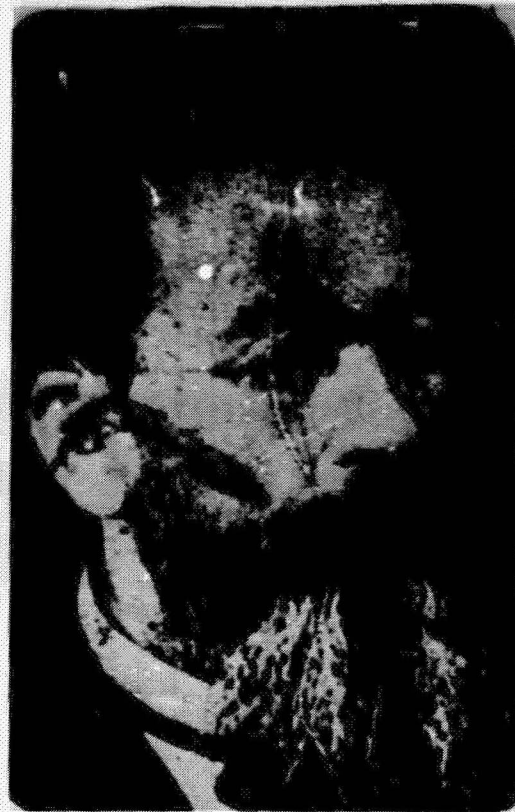


Fig. 14

an Earth gravitational field, in vacuum, and in the atmosphere, taking the empirical formula for the relation of atm. here drag to different velocities. He calculated the time necessary to reach the proper parabolic velocity as a function of the accepted model of the atmosphere, the shape of the rocket, the burnout velocity of the gases, and the variation of the rockets mass (Figures 16, 17). The paper presents the exact mathematical solution of the problem.

In 1936 Oderfeld, Sachs, and Bernadzikiewicz¹⁴ set a model jet propulsion engine in operation. Systematic work on the development of rockets was possible after

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gdzie

$$\frac{(h+1) 9,81}{n \cdot 1000}$$

$$b = n \cdot 1000 \cdot 1000; \quad h = 3; \quad n = 3;$$

To równanie całkowitą będący w przedziale $0 \leq t \leq 70$ sek.

Całą równania (22) przy warunkach początkowych dla $t = 0$, $f(0) = 1$, jest funkcja

$$f(t) = \left| 1 - \frac{1}{b} \int_0^t f \cdot dt \right|$$

Cała, występująca w tym wzorze, jest obliczona przy pomocy reguły Simpsona, rachunek liczbowy przedstawia w skróconym tabelo

TABELA 7.

t	f(t)	t	f(t)	t	f(t)
00	0,1000	20	0,0701	40	0,0400
10	0,2074	30	0,0509	50	0,0267
60	0,1363	70	0,0341	80	0,0200

Obliczenia, odczytując z tej tabeli (8) dla $t = 330$ sek., możemy przewidzieć, że raketa, jak wyżej, rozpoczyna swój ruch z masą o ciężarze 9210 kg wysłana prędkości paraboliczną, przy uwzględnieniu oporu powietrza, z masą o ciężarze 136 kg; lub uwzględniając opór powietrza (patrz tabela 1) uzyskałaby prędkości paraboliczną z masą o ciężarze 143 kg.

Obliczony tak-żo ruch paraboliczny prędkości na pewnym czasie będzie symulował, np. przy pomocy ampuł obliczone

TABELA 6.

t	f	f'	f''	f'''	f''''	f'''''
1	0,000002	0,000000	0,000000	0,000001	0,000001	0,000000
5	0,000071	0,000000	0,000001	0,000001	0,000000	0,000000
10	0,000205	0,000000	0,000001	0,000001	0,000000	0,000000
15	0,000407	0,000000	0,000001	0,000001	0,000000	0,000000
20	0,000609	0,000000	0,000001	0,000001	0,000000	0,000000
25	0,000811	0,000000	0,000001	0,000001	0,000000	0,000000
30	0,001013	0,000000	0,000001	0,000001	0,000000	0,000000
35	0,001215	0,000000	0,000001	0,000001	0,000000	0,000000
40	0,001417	0,000000	0,000001	0,000001	0,000000	0,000000
45	0,001619	0,000000	0,000001	0,000001	0,000000	0,000000
50	0,001821	0,000000	0,000001	0,000001	0,000000	0,000000
55	0,002023	0,000000	0,000001	0,000001	0,000000	0,000000
60	0,002225	0,000000	0,000001	0,000001	0,000000	0,000000
65	0,002427	0,000000	0,000001	0,000001	0,000000	0,000000
70	0,002629	0,000000	0,000001	0,000001	0,000000	0,000000

Dla przedziału czasowego $70 \leq t \leq 330$ sek. przyjmujemy, że ruch rakety odbywa się w próżni, to jest że równaniem określającym funkcję $f(t)$ nie jest (22), lecz wzór (14) gdzie stała C należy obliczyć przyjmując dla równania (15), jako początkowe warunki ruchu dla $t = 70$ jest $f(70) = 0,3624$ (wartość uzyskana z powyższej tabeli)

Wówczas wartość

$$C = 0,95375$$

jest trywialnym, przez który należy pomnożyć wartość funkcji $f(t)$ zawarte w tabeli 1, dla $t = 70$ sek., aby otrzymać z nich wartości funkcji $f(t)$ dla rakety. Można przeliczyć przez wartość powietrza, a dalej, jak robiliśmy, powietrze się w próżni.

W ten sposób, jako należy czytać tabelę 4, otrzymamy jej wartości, liczone (tab 7) funkcji $f(t)$ dla rakety. Można przeliczyć wartość powietrza uwzględniając równanie paraboliczne opór: po 70 sekundach ruchu powietrze się już nie byłoby było w próżni.

spekulacji, może by się okazało prędkości 300 m sek. na przesłonie 1500 m w próżni, to masa rakety rakety parabolicznie by się do 157 kg. Według, że rzyk na powierzchni wody lotniczy rakety (przy uwzględnieniu prędkości parabolicznej) jest bardzo niewielki, z drugiej strony nie są liczą budowy ampuł rakietowych, sągajemy na wysokość 1500 m (np. przy zmianie stanu góry), byłoby odpowiednim.

LITERATURA

C. Czerny, Lehrbuch der Ballistik, 3 tom, Berlin 1926.
 E. Esnault Paterson, L'exploration par fusée de la haute atmosphère et la possibilité des voyages interplanétaires, Aubertemps, Paris 1928.
 H. Goddard, A method of reaching extreme altitudes, Smithsonian Institution, Washington 1919.
 W. Hohmann, Die Erreichbarkeit der Marsbahnen, Mitteilungen der VFW, Berlin 1925.
 W. Isac, Die Möglichkeiten der Weltumfliegerei, Leipzig 1928.
 H. Oberth, Wege zur Raumfahrt, München-Berlin 1929.
 M. Vukobratović, Rakiety, Warszawa 1933.
 A. G. Scherwinski, Die Rakete für Fahrt und Flug, Berlin 1929.

Fig. 17

building a rocket test stand at the Warsaw Technical University, begun in 1938 under direction of T. Felsztyn together with A. Kowalczewski, Z. Paczkowski, D. Smoleński, W. Stolarek and Z. Tulodziecki.¹⁴ The contributions of A. Szternfeld, born in Sieradz (1905), also must be counted among the achievements in Polish space research. He studied at the Jagiellonian University in Cracow, and later in Nancy in France. The main parts of his well known book Introduction to Cosmonautics¹⁷ were written in France (1929-32)

and in Poland (1932-1933). A. Szternfeld moved to the Soviet Union in 1935 where he continued his successful scientific work in astronautics. His book¹⁷ was published in an extended version in the USSR in 1937.

We should also pay a tribute to the Polish underground movement during World War II that informed the Allies in England about German work on rocket development in Peenemünde on the Szczecin-Bay, and on the V-2 rocket flying tests in Middle Poland. One fired rocket was recovered by Polish partisans and sent without damage to England for careful scientific and technological investigation. Some parts of the rocket were also investigated in occupied Warsaw by Polish scientists and engineers.

FROM 1945 TO THE PRESENT

After World War II several countries pursued the development of rocketry, and scientific and practical applications were achieved in communications, meteorology, military, and the exploration of the Solar System. Many investigations were also performed in Poland.

At the beginning we shall mention some of the workers and papers on rocket technology. Propellants were investigated by L. Heger, W. Bozdaniuk and S. Ciborowski;¹⁴ liquid propellants by S. Wójcicki; ballistic properties of solid propellants were investigated by D. Smoleński, M. Zembrzusi, M. Dybek, W. Kowalczyk, J. Deweryniak, E. Woźniak, M. Parulska, J. Grzegorzewski and J. Jórczak. Thermodynamics and rocket internal ballistics were the subjects of the work of Z. Paczkowski (in a monograph Rocket Flight Mechanics), D. Marchel, F. Wolnica and R. Odolinski; stability of the flight of rockets with stabilizers Z. Paczkowski and L. Wasilewska; measurements in rocket technique, K. Kowalewski, J. Pakleza, W. Styburski and M. Zembrzusi; rocket guidance, S. Sławiński, R. Dmowski, A. Lizoń, K. Holejko, E. Olearczuk, Z. Katliński and S. Paszkowski; some military rocket applications were developed by S. Wojciechowski, A. Arciuch, W. Kozakiewicz, J. Wiśniewski, S. Zukowski, Z. Paczkowski, S. Paszkowski, T. Burakowski, A. Sala, S. Hornung et al.¹⁴

In the Rocket and Satellite Research Department of the Polish Hydrological-Meteorological Institute (IHM), measurements are conducted on the direction and velocity of the wind at different heights, and the temperature of the troposphere and stratosphere. Pictures are received of cloud fields transmitted by meteorological satellites as well as pictures in the infrared part of the spectrum. Atmosphere sounding is performed with the meteorological rockets "Meteor-1, 2, and 3." These investigations were begun by J. Walczewski, G. Pawlak and J. Kibinski.¹⁴ O. Wolczek and M. Subotowicz have worked on the theory of the nuclear, ion, and plasma rocket engines. M. Bielecki, W. Dudonis, R. Janiczek, Z. Kotliński, B. Korner, K. Makowski, E. Olearczuk,

Z. Paczkowski, M. Subotowicz, K. Zarankiewicz, W. Zakowski, et. al, have concentrated on the theory of the rocket flight. In many papers, M. Subotowicz investigated the theories of classic and relativistic multistep rockets. He also generalized the well-known formula of Ackeret, of the velocity of the one step relativistic rocket on the case of the multistep relativistic rocket.¹⁸ Different rocket parameters, and the general characteristics of the rockets and spaceships, were investigated in the papers of M. Subotowicz, R. Szymański, R. Vogt and S. Wójcicki.

The popularization of rocket and astronomical problems has been performed by E. Bialoborski, K. Borun, Z. Brodzki, J. Gadomski, W. Geisler, A. Marks, J. Salabun, M. Subotowicz, O. Wołczek, K. Zarankiewicz, et al. The following people are dealing with the history of rocket and space research in Poland: W. Geisler, E. Olszewski, T. Przykowski, T. Nowak, M. Subotowicz, J. Thor, et. al.

The possibility of using new rocket techniques for space research stimulated Polish scientists. At the beginning, this work was concentrated in the Astronautical Department of the Polish Academy of Sciences (PAN), directed by K. Zarankiewicz (1955-59). In 1960 the monograph of M. Subotowicz Astronautyka¹⁸ was published, covering progress in astronautics up to 1960. In 1964 the Committee of the Research and Peaceful Use of the Space was established in PAN; rocket and satellite investigations of the Sun were realized under J. Mergentaler, and of the interaction of primary cosmic rays with matter under M. Miesowicz. Also, a regular service was organized to observe artificial satellites of the Earth.

The investigations of J. Gadomski¹⁹ on the ecospheres of the stars at distances of about several light years around the Sun has become widely known. The ecosphere around a particular star means the "life zone," where the thermal conditions exist near the planets, enabling macro-molecules to develop of essential biological importance in the development of living organisms. It follows from the analysis of J. Godomski that at a radius of about 17 light years around the Sun there exist 14 stars of solar spectral class that possess ecospheres. But there are only three stars of astronomical interest.

An interesting project was suggested by O. Wołczek²⁰ to investigate the cosmologic processes in space by exploding hydrogen bombs beyond the Earth's atmosphere. Different problems of space physics were investigated in the papers of W. Fiszdon and J. Jateczak (cosmic ray physics), K. Kordylewski (the matter of the libration points of the Earth-Moon system), and A. Januszajtis, M. Lunc, A. Marks, M. Subotowicz, O. Wolczek, and J. Walczewski. Some suggestions concerning the possible verification of the general theory of relativity using astronautical methods were presented by M. Subotowicz. This same author presented some proposals to detect antimatter in a Moon laboratory.

The references concerning all the papers mentioned in this section may be found either partly in reference 14, or in the scientific and popular astronomical journals published in Poland: Technika Rakietowa (1957-63), Postepy Astronautyki (from 1967), Technika Lotnicza i Astronautyczna, Biuletyn Informacyjny of the Polish Astronautical Society (1956-57), and Astronautyka (from 1958). We have not considered here the papers on space medicine directed by Kaulbersz, Bilski, J. Walawski, S. Barański, Z. Jethon, Z. Kaleta, or papers on space law directed by M. Lachs, J. Machowski, J. Sztucki and others. All these papers should be referred to separately.

In Poland, the Polskie Towarzystwo Astronautyczne (Polish Astronautical Society), founded on December 30, 1954, and Komitet d/s Badań i Pokojowego Wykorzystania Przestrzeni Kosmicznej Polskiej Akademii Nauk (Committee on Space Research and its Peaceful Use of the Polish Academy of Sciences), deal with problems concerning scientific and popular work in astronautics. The Polish Astronautical Society (PTA) has about 800 members and publishes the scientific quarterly Postepy Astronautyki, and the scientific-popular bimonthly Astronautyka. Every two years PTA organizes Scientific Conferences on the Rocket Technique and Astronautics, and represents Poland during the International Astronautical Federation (IAF) Congresses and in the Commissions of the IAF and the International Academy of Astronautics in Paris. PTA also sponsors the scientific research in astronautics and popularizes astronautical achievements. In 1976 the Polish Academy of Sciences established the research in close cooperation with the socialist countries program "Intercosmos," including manned and unmanned flights around the Earth, and to the Moon and planets.

REFERENCES

1. V. N. Sokolsky, Iz istorii awiacji i kosmonawtyki, AN SSSR, 1968, wyp. 6, str. 77
2. J. Długosz, Historia Polonica, vol. 1, part. VII, 1455-1480, p. 811-812
3. T. Przypkowski, Technika Rakietowa, 5, 1963, Nr 13, p. 75
T. Przypkowski, Astronautyka, 2, 1959, Nr. 1-2 /8-9/, p. 5
4. M. Bielski, Sprawa Rycerska, Kraków, 1569, slega 8 "O sprawie puzkarskiej"
5. A. Dell' Aqua, Praxis Reczna Działa, rękopis /manuscript/ 1630-1635; printed 1969, Wrocław, Ossolineum, introduction and comment of T. Nowak
6. K. Siemienowicz, Artis Magnae Artilleriae, pas I-ma, Amsterdam, 1650
7. M. Subotowicz, Kwart. Hist. Nauki i Techn. No. 3, 1957, 435-513 Kwart. Hist. Nauki i Techn. 13, 1970, 805, No. 4
8. C. D. Waard, ISIS, 24, 1935/36 125 E. Jungowski, Problemy, 24, 1968, 39, No.1
9. W. Bystrzanowski, Informacje matematyczne rozumnie ciekawego Polaka - świat cały, neibo y ziemia, Lublin, 1749, str. 500

10. J. Ben, Erfahrungen über die Congrevschen Brand-Raketen bis zum Jahre 1819 in der Königlischen Polnischen Artillerie gesammelt . . . , Weimar, 1820
11. J. Szpecht, Wśród fizyków polskich, Lwów, 1939
12. F. A. Uliński, Der Flug / Sonderheft/, Dezember, 1920
13. F. Burdecki, Podróże międzyplanetarne, Lwów-W-wa, 1929, str. 93
14. Z. Paczkowski, red., Materiały dokumentacyjne, Technika Rakietowa, 5, 1963, zesz. 13
15. G. Mokrzycki, Przeszłość, teraźniejszość i przyszłość lotnictwa, Warszawa, 1935
16. K. Zarankiewicz, Przegląd Techn., 77, 1939, 139-145, No. 4
17. A. Szternfeld, Wprowadzenie w kosmonawtykę, Moskwa, 1937
18. M. Subotowicz, Jet Prop., 28, 1958, 460
19. M. Subotowicz, Proc. X th Int. Astron. Fed. /IAF/ Congress, London, 1959, p. 852-864; and M. Subotowicz, Astronautyka, PWN, Warszawa, 1960, p. 1-586
20. J. Gadomski, Proc. IX/1959/, X/1960/, XI/1961/, XII/1962/IAF Congresses, Springer Verlag, Wien, Austria
21. O. Wołczek, Proc. IX IAF Congress, Wien, 1959, p. 67