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Chapter 16

The Contribution of Robert Esnault-Pelterie to Astronautics[1]

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The pioneering work of Robert Esnault-Pelterie is distinguished by its exceptional scope in the field that he covered—the whole of aeronautics and of astronautics—the range of technology that he has enhanced, and the variety of his abilities as an engineer who was as gifted for theoretical work as for experiments.

To speak very rapidly of a subject which does not form part of the agenda of our Congress, we should simply recall that Esnault-Pelterie numbered among the brilliant young men of several nations who achieved the first powered flights at the start of this century. For this reason, the Aeroclub of France awarded him retroactively French pilot's license No. 4 when licenses were instituted in January 1909. He is known particularly to many of my compatriots as the inventor of the joy-stick, the lever with two degrees of freedom that allows a pilot to control simultaneously, with one hand only, the ailerons and the elevator of his aircraft. But a much more important side of his work related to the general design of the aircraft and of its engine, for example, the radial engine and the use of metal that he pioneered to build the airframe and the propeller.

It is remarkable to see that a man who had contributed so decisively to the strides made in aviation, and who might have devoted a glorious career to its development and progress, immediately looked further ahead. The bounds that man was starting to make successfully into the lower layers of the atmosphere were, in his eyes, only a stage in the great upsurge that would tear him from his natal planet one day and bear him up to the

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stars. This was the problem to which he was to devote his whole life in an environment of skepticism which was completely general, at least at the start. He presented a paper to the French Physics Association in 1912, which he had to camouflage under the low-profile title of (to use his own expression) "Considerations and Results of an Infinite Lightening of Engines," and in which he affirmed his confidence in the possibility of interplanetary traveling. He allowed his ideas to ripen for a long time and compared them with those of foreign rivals that he appreciated—Oberth, Hohmann, Goddard—and published in 1930 a major work "Astronautics," which is a veritable epitome of knowledge at the time in a field that greatly benefited by his original contribution. The variety of subjects that he dealt with, the accuracy of his views, and the reliability of his forecasts, today remain a subject of astonishment.

But Esnault-Pelterie was not only a brilliant theoretician. He was also an engineer passionately attached to proving the accuracy of his concepts by experiments. It was, in this case, the technique of the rocket which was the key to astronautics. It was the development of this technology that he was to devote his work during the greater part of the ten years between 1930 and 1940. He set up a test installation at Boulogne; government assistance, which was at first very limited, gradually developed thanks to the influence of one of his most faithful supporters, General Ferrié, who knew and appreciated him since the time of his military service, and whose prestige, as the creator of wireless telegraphy, opened many doors to him.

Esnault-Pelterie first used what we call today a single propellant, tetranitromethane. An accident that deprived him of three fingers of his left hand led him to prefer another propellant which he first believed to be less reliable, the liquid oxygen/petroleum ether pair. It was ambitious to approach cryogenic propulsion at the start, but Esnault-Pelterie overcame all the difficulties and rapidly succeeded in developing a rocket that delivered about 100 kg of thrust for one minute with a very reasonable specific impulse on the order of 230 sec.

The thermal problems were solved by cooling the engine with running water, and all the subsequent efforts of Esnault-Pelterie were directed to a more operational system, based either on liquid-oxygen cooling or on a non-cooled system that made use of highly refractory materials. He made the greatest efforts in this second direction but also encountered a number of difficulties—melting, perforation, galloping corrosion at temperatures where, as he said, "everything combines with everything else." Resolved not to be overcome by any difficulty, he invented electrical furnaces in order to make his own materials. When his personal activity ended with the Nazi invasion in 1940, he left a rich harvest of experiments to the men who were to continue his work, Professor Montagne and Colonel Barré. He himself followed the development of astronautics after the war, but as a spectator. Esnault-Pelterie saw the brilliant confirmation of his ideas in the launching of the first Sputnik, shortly before his death.

The Ideas of Esnault-Pelterie on Piloting and Navigation

Problems of piloting and navigation figure among the subjects on which the most personal and possibly the most original viewpoints are furnished by Esnault-Pelterie.

When examining the possibility of sending a projectile or an inhabited vehicle to the Moon, Esnault-Pelterie realized after a brief calculation of errors that the necessary precision would not be attained by the very strict heading and velocity imposed at the start. He understood that a corrective engine was needed, that it would operate on data supplied by a navigation system—and which might be the engine used later for moon landings. The engine had to be orientable but it would be simpler to use it to orient the vehicle itself. The nozzle was therefore mounted on a universal joint and operated by a control with two degrees of freedom—evidently a joy-stick—allowing the thrust to be offset in relation to the center of gravity in order to create the torque required for correct steering. He believed that an electric control system would be the best means of maintaining orientation.

Esnault-Pelterie then understood that it would be necessary to control attitude, even when the engine was not operating, either to make an astronomic observation or for reasons of habitability. This could be done by means of "small adventive rockets" that could be operated when required but, to economize fuel, it would be better, he thought, to use the effect of reaction of small electric motors fitted at right angles. Then compared with systems actually used today, this description only lacks the idea of the engine being essential to assist a motor that has reached its maximum speed when it has to counteract a disturbing torque of significant average value for too long a time.

Trajectory correction assumes that the exact position of the vehicle is known. Bearings taken on planets offered a possibility, but were of insufficient accuracy. Esnault-Pelterie then thought of the principle that we today call inertial navigation. He described the problem in particularly clear terms:

> Given a point "*m*" that is mobile from a position that we take as the origin and in relation to three axes of coordinates that we consider as fixed, is it possible to design an instrument which can indicate at any instant the position of the mobile point in relation to the axes, with no link, either material or immaterial, between the mobile point and any part of the system of fixed coordinates?

He immediately produced a theoretical solution to the problem:

> If we possess a means of linking, to the mobile point "*m*," a system of auxiliary axes of coordinate axes which remain parallel to the fixed axes while following the point in its movement, and three components of acceleration along the three axes, we shall know at each instant the values of:
>
> $$\frac{d^2x}{dt^2}, \frac{d^2y}{dt^2}, \frac{d^2z}{dt^2}$$
>
> and, if we possess a means of twice integrating these time functions, we shall know at any instant the coordinates of the mobile point in relation to the fixed system.

Esnault-Pelterie then reflected on the possibilities of designing the method practically. He immediately imagined several principles of an accelerometer that would carry out the first integration, that is, supply the components of the velocity vector.

—The first operates by viscosity. A mass caused to move along one of the axes is subject to a perfectly-linear braking force that is sufficiently powerful for its movement in relation to the mobile piece to remain very small when compared with the distance covered. Its final movement is proportional to the velocity.

—The second system is an off-balance gyroscope. The torque applied to the gyroscope is proportional to the acceleration and thus to the precession rate also. The angles through which it has precessioned are therefore proportional to the velocity.

—The third system is a little more complicated and is inspired by the classical measurement of gravity by the pendulum method, with the counting of oscillations supplying the desired effect of integration. Because the oscillation frequency is not proportional to gravity but to its square root, he had the idea of linearizing the system by making the apparent gravity act on a pendulum retained by a spiral spring and therefore with a natural frequency that the acceleration would only modify by a small quantity.

This natural frequency is finally eliminated by the use of two opposed pendulums, one with its equilibrium point stable and the other with its equilibrium point unstable in the direction of the acceleration component that it is desired to integrate. Each controls rotation of a gear train through an escape mechanism taken from clock systems. The outputs of the two systems act in reverse directions on a differential of which the spindle indicates the velocity attained by the vehicle, by the angle through which it has rotated since the start.

Esnault-Pelterie seemed to favor the latter system, because he immediately saw the advantage that he could gain from it to carry out the second integration. Let us replace, in an instrument based on the same principle, the force due to the apparent gravity by a force applied proportionately to a previously-measured velocity component, for example, by the action of a spiral spring of which the other end is moved in relation to the result of the first integration. The output of the second instrument will supply a position coordinate. A variant using a torsion pendulum, of which the stiffness is modulated proportionately to the variable to be integrated, appeared to him to exhibit certain advantages.

Esnault-Pelterie then gave attention to another aspect of the problem—the construction of a constant-orientation platform that would have to carry these various instruments. He recognized that it was possible to do so by means of two gyroscopes controlling electric motors, but this method appeared to him to be "enormously complicated." He then realized that acceleration of the vehicle is directed along the axis of the nozzle, and that it simply had to be measured along this direction. The orientation of a nozzle axis is itself reconstituted by double integration based on the information given by two angular accelerometers. (It is curious that he appeared to overlook the possibility of directly gauging the angular velocity by means of gyrometers and of reconstituting attitude by one integration only.) The method remained mysterious to him, and he admitted that he had not had the time to examine it more deeply.

He finally examined the problem posed by the existence of a gravitation field to which the accelerometer is insensitive, but which has a fundamental influence on gauging the trajectory. He very soon saw that, if the field is known as a function of position, it was simply necessary to add, at each state of integration, the acceleration as measured by the accelometer to the gravity acceleration calculated for the position immediately preceding and suitably extrapolated. He gave no indication of a mechanical device that would be able to cope with this complication. The problem can only be resolved, in effect, by means of the enormous facilities that were later supplied by on-board digital computers.

The ideas presented by Esnault-Pelterie on the subject of navigation are incontestably original in that he certainly did not take them from any of his predecessors. He would not have failed to have said so if he had, for he took great care to cite his sources. This of course does not mean that other workers in other countries did not have similar concepts at the same time, or earlier, and without his knowing. In any case, the history of astronautics and the technology of military missiles soon manifested their full value. The three principles of measuring acceleration that he proposed have been used effectively. The last even constitutes, in a slightly different form, one of the most advantageous present-day designs for an integrating accelerometer. He simply followed the evolution of the clock-maker's art. The hinged pendulum and spring is replaced by an elastic vibrating rod and the oscillations are counted by electronic methods.

The two methods of application of inertial navigation envisioned by Esnault-Pelterie (a stabilized platform or use of accelerometers directly connected to the structure) have both been used and are still today in competition. What a satisfaction would it have been for our pioneer if he had been able to anticipate that the two systems that he had imagined would be used in association, one as a normal system and the other as a standby system in the Apollo program, that was to realize his dreams, in flight to the Moon.

Conclusion

To recall the contribution of Esnault-Pelterie in a very specific sector, in order to illustrate the variety of his talents, I would not like to fail to speak of the fundamental role that he played in the promotion of international cooperation in the field of astronautics. We know that in 1929 he founded an international prize for astronautics with his friend, the banker Hirsch, and that his first gesture was to award it to Hermann Oberth. Yet, Oberth was a rival in the scientific field and, at the same time, a national of a country whose relations with France were still scarred by a recent and cruel war. Oberth expressed his gratitude in terms that remained printed in all the editions of the work that he published a little later, in spite of events that were again so tragic.

Esnault-Pelterie believed that astronautics is a subject sufficiently ambitious and fascinating to justify a coordinated effort by the whole of humanity, with the hope of perhaps turning man away from his traditional conflicts. This is the spirit that today animates our International Federation of Astronautics, the IAA, which has the duty of particularly honoring the memory of one of the most unquestionable originators of this noble ambition.