

Aérotrain, high speed rail and nuclear technology: the lessons of Jean Bertin

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A truth that has determined the fate of many civilizations now catches France. It is the simple universal physical principle that makes that any society or person, that doesn't progress, lags behind.

While French president Nicolas Sarkozy can be proud of the sale of French EPR nuclear power equipment in the world and while our transportation minister fronts for the real commercial successes represented by the construction of high speed TGV lines in China, Argentina and Northern Africa, time has nevertheless come to open our eyes and those of our citizenry.

If today, France is the uncontested champion of these efficient and highly useful technologies, we're obliged to face the fact, without hurting our national pride, that in these domains our nation is tragically lagging behind. And we think in particular about fourth generation nuclear equipment, air cushioned vehicles (ACV), Magnetic levitation, etc.

However, a major even, comparable to the choc provoked by the Russian launching of Sputnik in 1957 could wake us up.



Indeed, since January this year, the great nation of China has joined France, Germany, Japan and Korea as the fifth nation capable of constructing high speed rail trains, while not having as much experience as the other four nations in that the Europeans or Japan. Note also here that in December 2003, a Japanese made maglev (a train without wheels suspended by magnetic levitation) broke the world record of speed on rails with 581 km/h. The French TGV holds the record of 574 km/h, but as a train on wheels...

As usual, reality offers us two choices. We can look the other way and take a nap on the comfortable cushion of national pride. Typical of that approach was an article published by the French daily *Le Figaro* on December 27 reporting the Japanese decision to invest 32 billion euros in a Maglev line linking Tokyo to Nagoya (290 km) planned to be operational as of 2025.



Japanese magnetic levitation (maglev) train without wheels.

Le Figaro: “The Maglev resurfaces. This electromagnetic levitation train, about which one talks since thirty years and only functions for the moment in China” (...) “Otherwise, projects are regularly studied before they are abandoned. The [German maglev] Transrapid was a competitor with classical TGV for the liaison between Shanghai and Beijing, but the classical trains have been chosen. From their side, Germany considers since several years a Maglev line connecting the inner city of Munich with its airport, as well as a line between Berlin and Hamburg. But it seems the costs of such a line have brought the German authorities to drop it.”

Le Figaro then adds with bumptiousness: “There is hardly any chance a Maglev arrives in France ever. A project of a train on aircushions called ‘Aérotrain’ was studied at the beginning of the seventies as a possible alternative for the TGV, but was not adopted”

because “such type of train is not made to operate in France.”

Reality today forces us to consider that in a couple of years from now, many nations will buy high speed rail, not made in France, but made in China or Japan and the same is coming true for the German maglev.

This lagging behind in innovation and applied technology, which has already provoked great damage in other areas of our economy, will have tragic consequences for the European industry. Are we ready to become a museum of perfume and wine and to learn the beautiful Chinese language to be able to sell postcards to the new tourists, or are we capable of mobilizing our creative potential with a real industrial policy based on the best of R&D?

Hence, the great European civilizations don't lack great inventors and visionary discoverers but suffer from a residua of feudalism, scientism and oligarchic physiocrats, whose appears often as some sort of “synarchy” always on top, committed, when failing to halt progress, to slower its pace, as to manage it in their interest.

The lost chances of Germany

France is not the only country among industrial nations to fail in this respect. In Germany, for example, beginning 1961, the Jülich research centre constructed a “pebble-bed” high temperature reactor (HTR). This revolutionary device, whose efficiency and security is largely superior to the current pressured water reactors (PWR), was abandoned in 1988 without any real scientific or economic reason. South-Africa, who worked on HTR technology since 1993 signed a cooperation agreement with China in 2005 on this technology which they will afterwards jointly commercialize



Another German tragedy: the Transrapid magnetic levitation train. Developed jointly by Siemens and Thyssen Krupp on the basis of a concept invented in 1934, the first trial track was only operational in 1987 in Lathen, Lower Saxony where the vehicle reached the impressive speed of 500 km/h.

Invoking « a prohibitive price », the German government dropped in January 2000 the

project of a 248 km transrapid maglev connection between Berlin and Hamburg. After a human originated accident in 2006, when 23 persons got killed when the Transrapid hit a smaller maintenance vehicle still on the track, the media cried for war against maglev technology. The Frankfurter Rundschau called it a “technical vision of another age” and blasted what it called the obsession of the German authorities always willing to favor a technology which certainly “can always go faster and further, but at costs always higher”. The budgetary argument is the one opposed the most for the construction of the line between Munich and its airport and so far, it is only the Chinese decision to construct the 30 km connection between Shanghai and its international airport at Pu Dong which gave birth to a commercial transrapid line in March 2004.

The United States

In respect to the United States, one measures the inertia blocking that country when one reads today the optimistic articles that appeared in the US press in the early nineties. Donald M. Itzkoff, in *Railway Age* of Sept 1990, in an article called: “*Washington puts high speed rail on a fast track*” reported how “*maglev mania*” was taking over the US: “*The surge began in May 1989, when the Argonne National Laboratory released its study urging the benefits of replacing short-haul airline flights with a national maglev network hubbed at major airports. The next month, in June 1989, the Maglev Technology Advisory Group (MTAC)—which included Grumman, General Dynamics, and other aerospace and technology interests—reported to the Senate Committee on Environment and Public Works that maglev represented a « crucible within which we can measure America’s competitive resolve as we enter the next century. » MTAC urged a multi-year \$750 million program to develop a next generation superconducting maglev prototype to surpass our foreign competitors, thereby reasserting American technological leadership.*”

But also there, it never was enacted.

The tragedy of the French Aérotrain



L'ingénieur Jean Bertin.

In France, it was the scrapping of the Aérotrain project, a Tracked Air Cushion Vehicle (TACV), sometimes called “hovertrain”, developed by visionary engineer Jean Bertin (1917-1975), which represents the kind of error we have to avoid at all costs.

Let's be courageous. When one takes a wrong direction at the cross road, one sometimes has to go back to that crossing to finally head on in the right direction. If today, specialists admit that France, with Germany, would have been the world's leading producer of Maglev technology if the Aérotrain project had been continued, the scrapping of that TACV technology has installed in the mind of many Frenchmen the extremely unfavorable prejudice. For the man of the street, it is very simply inconceivable that in such a reasonable and rational country as France, a viable, cheap and secure transportation technology could have been abandoned without reason.

If we will detail its history here, it is not out of nostalgia for the sixties, but to learn the lessons of errors done yesterday and continued today. If the technological choices of those days can be surely perfected, we remain convinced that a return to the "spirit of Jean Bertin" has to be considered with great urgency. Recreating a culture of scientific and technological discovery where each individual takes pleasure in perfecting the society with those contributions useful for the wellbeing for the current and future generations: that is a real source of inspiration capable to get us away from the current dominant pessimistic existentialism that leads nowhere.

Away with nostalgia, melancholia and the bitterness that paralyses those great men and women who partook this adventure.

Jean Bertin, the "American"

□

In *L'Aérotrain ou les difficultés de l'innovation* [The aerotrain or the difficulties of innovation » (*1), Jean Bertin tells the story of this battle.

Immediately after the Second World War, he writes, the French government was strongly willing *"to regain the ground lost during the war in the area of science and technique", and therefore was willing to "furnish the necessary financial means and equipment"*.

Working as the technical director in charge of special studies on engines and propulsion of the team of project leader engineer Raymond Marchal at the Société d'Etudes et de Construction de Moteurs d'Aviation (SNECMA) [National Construction Company for Aircraft Motors] between 1944 and 1955, Bertin was a passionate scientist and a French patriot.

Convinced one never had *"to undertake anything without studying its technical, industrial, financial, but also historic and political environment"* he travelled a lot, *"mainly to England and the United States of America, whose aircraft came extremely powerful out of the war"*. *"In 1938, when I entered the Ecole Polytechnique, I held the conviction that a 'new society' was being constructed at the other side of the Atlantic..."* *"America more particularly, fascinated me,"* he writes.

If a great number of discoveries had been made since the beginning of the century, it was only FDR's victory program launched in 1938 to defeat Hitler which translated these discoveries, blocked till then, into technological leaps.

While visiting the US in the immediate aftermath of the war, Bertin notes with irony how he was intrigued by the *"apparently casual way the Americans deal with equipment problems."*

For a Frenchman used to see electric and telephone poles nicely lined up with well tended lines, the spectacle one could admire in nearly all the suburbs mushrooming around Los Angeles were astonishing. The lines were sometimes suspended by trees in the gardens. The electric meters were standing in open air (...) The walls of the factories were generally constructed with the most elementary materials left unpainted” and “My astonishment reached a peak when I saw a powerful construction wharf for aircraft motors entirely in the open air except the testing cabins.”

Interrogated by Bertin, the American managers nearly all gave two answers to justify such “casualness”: investment was defined by the necessity not to waste money and this inside a framework of high competitiveness and very rapid change. Why waste money building nice factories if five years from now they will be too small anyway? All this brings Bertin to complete his training in law, political economy and as a metal turner.

Against “the scandal of pick and shovel”: the “relativity of energy”

With a degree of the Ecole Supérieure de l’Aéronautique in 1943, he realizes the huge progress that represented the reaction-propulsion engine compared to a piston engine. If its energy efficiency of a reaction engine is below that of its predecessor, it represents a major advantage: its permanent rotation eliminates those vibrations inherent to a piston engine. More over, its power makes enables airplanes to fly much higher doubling the height to eight to ten thousand meters. Flying that high, where the air’s density is smaller, reduces significantly the planes energy consumption and consequently increases the flying distance. The understanding of the principle of how increased power increases work brings Bertin to the comprehension that “any choice established on the unique criteria of energy consumption derives from a wrong economic approach.” This physical principle, that unites physical science with physical economy, will be defined with great precision in an article written by Bertin for the magazine L’ingénieur of 1967 (*2), “The relativity of energy”.

Uplifted with what he saw in the United States, Bertin “the American” attacks in the article what he calls “the scandal of pick and shovel” still dominating France at that time where a great number of workers from the countryside, while possessing a second hand car and sometimes a washing machine, spent five or six day a week working with their bare hands, for lack of modern machinery.

Besides the hardness of unqualified labor, Bertin identifies the economic consequences: *“If the productivity of an individual is insufficient, or what comes down to the same, his labor is insufficiently amplified by the means of a form of energy different from his manual labor, the charge of providing his household with consumption goods and equipment is transferred on others”.*

The cause of this state of affairs, adds Bertin, is the old French reflex which consists in wanting to spare energy and costly machines, an obsession *“which often leads to the acceptance of human labor without realizing its real social cost.”*

According to Bertin, *“the problem of energy [converted into work via machines] is sometimes not really understood” (...)* *“I would like to tell certain engineers: you have too much tendency to consider energy as associated by itself to a certain result. In fact, that’s not what has to be considered, but rather the criteria of the furnishing of energy which are*

power on the one side, and the modalities of its application over time on the other side. The integral power/time gives indeed energy but that is secondary because with equal energy the practical result can differ in an extraordinary fashion depending on the power employed. The fantastic level of power one can produce by concentration the emission of energy on infinitely small units of time can give you results completely without relation to the quantity of energy consumed which remains, as such, unbelievably limited. If one wants to clarify even more that aspect, one can say that one should never ignore examine the case where one increases more and more the power made available to man, since it might happen, besides even the case where this permits man to accomplish things he couldn't before, that he can succeed doing something, already possible, but this time with total energy consumption that is less. That's not a paradox."

Applied to physical economy, Bertin concludes that « *seen the continuous elevation of the cost of labor in modern societies* » (...) « *it will become ever more beneficial to replace human labor progressively with a certain consumption of energy [i.e. machines]* » (...) *"That's where progress lies and not in the saving of energy considered in itself."*

Bertin the "inter-mediator"

Bertin, the « American », animated by the spirit of relaxed freedom, observed that at his job of building aircraft motors, engineers in reality rediscovered techniques for which the car industry had to spend fortunes in foreign patents. In those days, the separation of industrial sectors was radical and *"the industrialists of the car industry were totally ignorant about what was going on in aerospace."* (...) *"Little by little, I realized the oddness of this situation but also the economic lesson it carried with it. There was a function to fill in, in a consistent future"* (...) *"to construct a bridge among these different industrial branches"* (...) *"One had to call into existence some sort of inter-mediator".*

If far more limited in scope, it was somehow in the spirit of Colbert's seventeenth century's Academy of Sciences, thanks to which the German philosopher Leibniz could work with the Dutch scientist Huygens in Paris, Bertin thought that *"the moment had certainly arrived to envision the creation of a Society whose objective would be the transfer of acquired knowledge among industrial branches."*

Putting his idea into action, Jean Bertin, without too much financial means, left the security of his well paid job at the SNECMA and founded with his friend Benjamin Salmon, the Société Bertin & Cie, a real "bureau of grey matter", on February 27, 1956. A dozen of engineers, industrial designers and specialized workers and technicians rapidly joined the company. Over the years, the number of employees raised with the rising benefits of the company.

Eight years later, in a publicity brochure for the company, Bertin says the firm *"has taken a major place in the area of industrial and applied research"* (...) *"with 85 engineers active in eight major departments who regularly work as well as for the private as for the public sector: external aerodynamics (aviation); internal aerodynamics and compressors; Science of heat and Energy; Propulsion and soundproofing; Physics of the atmosphere; Rockets (directional control and propulsion); Isotopical separation and physics; Magneto-hydrodynamics."*

Note here that there never existed an "air cushion" department, since Bertin thought that

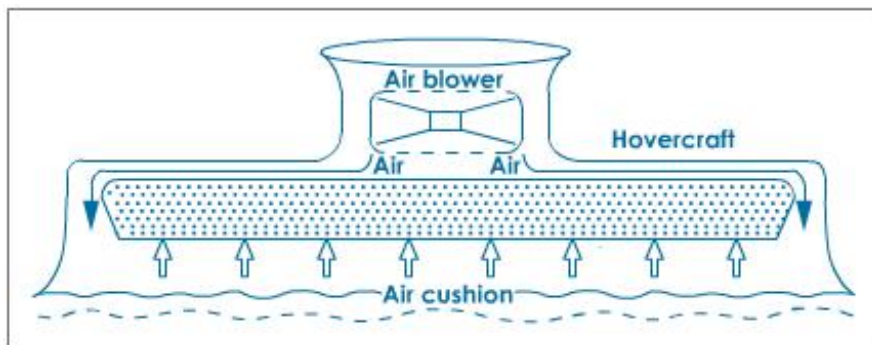
his personnel, in stead of “being integrated in an industrial branch, they are integrated in a branch of physics. Their temporary association with industrial teams gives these teams the required complementary qualifications as demanded by the problems of the moment. But their contribution is generally not limited under this direct form.”

Bertin’s firm will grow as one of the most important private research facilities of Europe and register, over more then a decade, an average of 40 patents per year, i.e. nearly one every week! Bertin’s name is quoted as inventor or co-inventor of 163 patents. In 2003, the aerospace magazine Aviation Week included Bertin among the list of the 100 greatest inventors having contributed to aerospace for his invention of the thrust reverser, a “motor brake” device commonly used by almost all larger airplanes.

Bertin & Cie’s professionalism in the domain of the mechanic of fluids was called on by the large state programs originating from the French state planning of those days. His firm participated at the construction of the Isotopic Separation Facility of Pierrelatte and the thermal protection of the nuclear power reactors. For the Defense Department, Bertin developed the missiles conceived to do the scientific measurements inside the radioactive clouds created at the testing phases of France’s force de frappe over the Pacific.

From Terraplane to Aérotrain by way of the Hovercraft

It is from this enthusiastic and daring « polytechnical » vision that the Aérotrain will spring. In 1957, one of Bertin’s collaborators, Louis Duthion, while working to soundproof an aircraft engine, identifies what is called “ground effect”, an aerodynamic effect due to a flying body’s proximity to the ground, i.e. the physical principle of the air cushion.



This aerodynamic effect can be generated by increasing the pressure of the air located inside a bell-shaped area separating a vehicle from the ground. The compressed air will tend to escape in all the remaining available directions. The science of Aircushion vehicles will consist of compensating the loss of air by a permanent injection of low pressure air and to manage the flows of leaving ear.

Bertin, Duthion and Salmon will file a patent for their discovery on July 16, 1957, but realize rapidly, while doing theoretical studies on the phenomenon, that (without the technological improvements they will craft later) “ground effect vehicles, aimed at traveling on uneven grounds where wheels are inefficient or on water” ... “had no chance of economic success”, since, according to their judgment, to cross a one meter high obstacle, “the size of the diameter of lets say a circular vehicle should be between 100 and 200 meters.”

Since patents were expensive, and since Bertin and his crew lacked funding, they consequently, decided to withdraw their demand for the patent which was done on July 10, 1958.

But the filing of a patent had a good side effect, since it offered its initiator to get access to a certain amount of research accomplished by others on the same subject. *“The past”, wrote Bertin, “even in the case of technological progress, is a very precious lesson; digging out that past had become for us some kind of reflex and we never missed an occasion, when hazard confronted us with phenomena that were unknown to us.”*

Bertin and his team, working through the archives of industrial property, discovered that *“our ground effect was not new at all.”*

Being relatively modest, Bertin never wanted to be attributed the originality of the discovery. As he outlined in December 1971 during a speech *“Some reflections on the relations between research and industry”, he estimates that “the success of research is sometimes the fruit, not of a quantity of directly measurable work, but of intellectual and progressive maturation of the question” and that the solution to certain problems considered to be unsolvable at a given moment “can come from technological progress accomplished in the mean time in other branches.”*

“An extreme example of this last category is well represented by air cushion vehicles. Some might think this is a recent invention. It is not. The nineteenth century is full of attempts to realise air cushion vehicles both terrestrial and maritime. In respect to the Aérotrain in particular, I got the chance to put a hold on the memoir of Louis Girard. This French engineer proposed already in 1860 a train sliding on an air cushion. Very rapidly, he realized that the technological means available at his times would not permit the compression of air as required. He then turned his attention to water, a liquid that is incompressible, which largely simplified his problem while complicating it a little otherwise (recuperation of leakage water). Under these reservations, nearly everything stated in that memoir, applies to the Aérotrain.”

Convinced that old concepts had to be re-examined permanently *“at the light of those new means of realization that fell into our hands thanks to technical and industrial progress”, Bertin told the audience, that, based on the same principle, “six years ago, we even renewed studying the steam engine.”*

Bertin also found out that an Austrian with the name of Müller von Thomamhul had build during the First World War an air cushion ship, reaching 75 km/h, which he projected to become the model for a patrol boat torpedo tube. In 1921, it's the Frenchman Gambin who filed a patent for some very special type of air cushion ship.

Air cushion vehicles (ACV) have to be necessarily very light and Bertin notes that at the time of his precursors *“light alloys as well as powerful motors were inexistent”* and this state of affairs condemned their attempts to failure.

However, thanks to the spectacular development of modern aircraft design, new materials could offer far more satisfying results.



One year passed, and at the end of 1958, a British inventor Christopher Sydney Cockerell announced a new type of vehicle called *Hovercraft*.

Less than a year later, in 1959, the first hovercraft SRN-1, an air cushion vehicle using a peripheral design, crossed the Channel. It had been built in total secrecy by the National Research Development Corporation (NRDC), a British state institution.

This event was highly stimulating for the French team, since all their convictions were put into question. They went back to work and developed aerodynamically what became known as “flexible skirts” capable of managing the out flowing air while keeping the ground effect that offers the required sustentation for the vehicle.

But time had come to find new contracts and raise funds to develop the company. To do so, Bertin sent a letter to those French industrials susceptible to show interest in the construction and use of ACV technology in which many foreign car and ship builders were investing.

In that letter, Bertin proudly states that his team *“was the first in France to demonstrate, as early as beginning 1957, the ground effect phenomenon with annular jets on which these new vehicles evolve and to study them systematically. We have contributed various ameliorations notably a very important increase of the efficiency of the system. We are otherwise specialized in that particular domain of aerodynamics since quite a long time.”*

“While in that time many companies worked already on the ‘Hovercraft’, we received, as an answer to the twelve letters we had mailed out, only one mark of interest. And even that answer was limited to an agreeable conversation without any follow-up”, Bertin complains.

It was only after his encounter with *“a very dynamic man”,* chief engineer Massacrier, during those days leading the engineering division of the French army’s Direction des études et des fabrications d’armement (DEFA), that in 1961, a terrestrial air cushion vehicle

will be crafted, the BC-4.

This experimental vehicle will permit Bertin to test out the “flexible skirt” technique which will insure the viability of those hovercrafts that crossed the Channel for a generation. Bertin wrote that his invention became a great success “not in France, but in Britain” since the British will imitate his design and will get congratulated by the press for the *“flexible skirt scheme”*...

Bertin obviously know that you don’t get a patent on a physical principle, but on a device that enables you to use such a principle. He writes: *“All this is normal; this little war of imagination is even a necessary condition for progress. What is less acceptable, in the simple domain of ethics, is the absence of any reference to our contributions which has always characterized since that moment, British style, any presentation of the development of the hovercraft.”*

The difference, he says, is that we *“have spent about 300000 FF, while, from the British side, it was between 15 to 20 millions”* since over there, *“it is the public authority that financed the costs, while in France, it was our firm that had to act alone on a private level.”*

Bertin immediately considered using ACV technology for civilian purposes, especially in those countries he called “new countries” of the southern hemisphere lacking roads and having large needs for all-roads trucks. In an expose presented in Montreal, *“A philosophy of transportation in the developing countries ‘the Terraplane’”*, he outlined the usefulness of the trucks he developed combining wheels and ACV technology.

The scientific breakthroughs accomplished during the realization of the BC-4 Terraplane, equipped with “flexible skirts” and capable of clearing obstacles, will give birth to the concept of the Aérotrain, since, *“once we got the concept, we became aware it could also operate, in absence of obstacles, at extremely low flying heights on its pathway, which would have been unacceptable with the solid structures of the initial design for air cushioned vehicles. Under these conditions, the power needed for sustentation could be lowered to very low figures; hence it became possible to conceive vehicles circulating on pretreated tracks, free of any obstacle, similar to a vehicle with wheels but with a set of advantages, which when reflected upon, for us, seemed of great interest.”* (See box)

Innovation versus conservatism

As one realizes here, Bertin was a citizen of exception because he behaves as a normal human being. As a passionate scientist, it is essentially the use of scientific discoveries for the benefit of all of society that interested Bertin, a scientist who saw himself more as an innovator. Note here, that at that time, any person presenting himself as an “inventor” was considered not serious at all. It also the time that Charles De Gaulle, in a burst of anger had stated publicly that in France, *“researchers that research”* were easy to find, *“but researchers that find, one is searching them...”*

In any case, when in 1957, the creation of the Common Market in Europe will open up the borders among European countries and creates shocks on markets that operated so far in relative autarky many suddenly realized that the hour of competitiveness had arrived.

Bertin noted that “for any industry, competition is a hard law, analogous to a war; one needs a strategy.” For him, two fundamentally different attitudes exist. “One of the possible options corresponds to the conventional concept (...) to make as best as possible, a known product; the clients will prefer it because it has the best finishing, it will have the best paint, etc.; however, the number of criteria of those clients is so large that the efforts to be the best on the market requires an industrial power on the size of the competitor...” and victory is only obtained, as in war, by methodic application, preciseness and discipline.

The other option, adds Bertin, is the one of innovation. “It means refusing the battle on the conventional level –at least partially I mean – and to try to offer products incorporating elements of novelty sufficient to change those criteria defining the choice of the client. Innovation is a concept of action, which, in the end, gives a chance to intelligence and thinking over mere power and discipline. On condition not to abuse of it, it can be a useful method for certain French industries.”

However, even before starting the promethean project of the Aérotrain, five obstacles arose in front of Bertin: the British, the press, the banks, conservatism and the inherent inertia of a public authority that has drifted away from its original mission to become an instrument to protect the privileges of an oligarchy.

The Aérotrain : some definitions

As one observes in his terminology, for Bertin, an Air Cushion Vehicle (ACV) on land or on water, **flies**.

In a conference at the Ecole Polytechnique on January 23, 1963, Jean Bertin even said that “on could also say that it [the Aérotrain] is some kind of extension of aeronautics to which it owns a lot: building technique, general aerodynamics, motors and propulsions, etc... A simplified image would be to say that it is an ‘imprisoned’ airplane, flying without wings tight to the ground.”

In stead of trying “to ameliorate trains” by adding new technologies, Bertin will rethink the whole concept of land and sea transport from the higher standpoint of aerodynamics.

The Aérotrain is a Tracted Air Cushion Vehicle (TACV) which “hovers” and is guided by both horizontal and vertical aircushions. It advances on a concrete monorail in the form of a reverted T, large 3.40 m and 90 cm high. Propulsion can be of all kind: with airplane motors (reaction motors or propellers), with a silent LIM (Linear induction Motor), or with electric motors acting on a rack railway or by pressuring tires against the central guiding rail. The choice of a unique monorail and the simplicity of sustentation and guidance by aircushions offer ideal conditions for very high speed, since the absence of “physical” contact, besides air, reduce friction to nearly nothing.

If the energy consumption of the vehicle depends of its motorization, its direct energy consumption tends to remain elevated. This cost is largely compensated by the much lower cost for the construction and maintenance of the concrete monorail track itself, whose cost is estimated to be two or three times lower then for normal rail. The little weight of a TACV, whose weight is 300 kg per passenger, in stead of 1000 kg per passenger of a normal train, offers a double advantage. First, the air cushion exerts hardly any pressure on the track

escaping rapid wear. Second, the track can be of light fabrication itself, and can be constructed on pillars. In this way, the track will cost less because the number of expropriations, level crossings, bridges and tunnels can sharply be reduced.

The anchoring of the vehicle around the central vertical guiding track makes derailing close to impossible and the low weight of the vehicle makes very short breaking distances possible. The thrust reversal of the propeller (engine braking), in case of normal breaking, can be complemented by brake shoes gripping the central vertical rail (similar to a car's disc brake) and total cutting off of the sustentation motors. In that case, the security shoes of the vehicle will energetically hit the track and produce a powerful slowdown.

Hence, according to the French *Revue des Chemins de Fer* of January 1973, the emergency brake distance required by a TGV, when driving at 240 km/h is 2300m. For an interurban Aérotrain carrying 80 passengers (I-80), driving at 250 km/h, the emergency brake distance was only 900 m, 2300 meters being the non-emergency brake distance! Furthermore, the non-emergency brake distance of a current TGV running between Paris and Lyon, at 270 km/h is estimated to be 8200 meters.

These performances result from the proportion between the vehicle and the track, since the operational stability of a high speed vehicle is more favorable when its mass is proportionally smaller to the track on which it runs. At the time of Bertin, a 116 tons locomotive was supported by 7.5 tons of rail track, i.e. 15.4 ton of vehicle per ton of rail. From his side, the I-80 Aérotrain only weighed 20 tons and was supported by 50 tons of track (without pillars), a proportion thirty times more favorable.

Concerning comfort, the 13013 passengers that were transported by the I-80 during the testing period over 59140 km were overwhelmed. Comfort was such that one decided to indicate speed in the cabin since most passengers refused they were traveling at a speed of 400 km/h...

Aérotrain: born in the slums of the Paris banlieu

Now the viability of the system had to be demonstrated. After a stay at his friend Gabriel Voisin rue des Paturages in Paris, Bertin and his friends moved to a small mansion located in a forgotten area of the bidonville area of Garenne Colombes in the Paris banlieue, in "one of those numerous streets of the Paris region which were certainly not planned to see one day automobiles run through them" he later recalled.

It is there, that Paul Guienne, an engineer that participated in the experimental work on the BC-4 Terraplane ACV vehicle was ordered to build a scale model of one meter fifty of the Aérotrain, functioning with an air compressor and a real air cushion.

A journalist of the weekly Paris Match that was sent down to write a story reported "*Joyous blue collar workers, with a Paris accent and a cigarette sticking in the corner of their mouths, were sending the model from one side to the other of a wooden constructed monorail.*"

It was this "dynamic" scale model that will, at first, "*convince the whole team of Bertin & Cie of the viability of the concept*" and later "*many French and foreign personalities*" which sometimes even failed to find the workshop, since going to the location was quite an adventure.

To convince the government, the scale model was transported and *“was received with great honors at the Hotel Matignon where the prime minister had some fun, giving a little acceleration to the model, to send it over ten meters of the track. He was readily convinced: air cushion, no contact, so no friction, that’s where the entire miracle lies.”*

There is no deafer man then he that doesn’t want to listen

Looking for eventual partners, Bertin immediately thinks about the public transportation companies and contact the French national railroad company SNCF and the Paris subway company RATP. Since the latter hadn’t modernized, neither tracks nor wagons since the outbreak of the war, the Paris metro had become so noisy that buildings eventually collapsed from the vibrations. Bertin suggested them that by *“taking out tracks and ballast, it would be possible to operate with the Aérotrain without noise and vibrations offering great comfort to passengers without the cost of maintenance of infrastructure.”*

In 1971, at a conference at the International Air Cushion Engineering Society on the theme of *“The place of transport in Modern Society”*, Bertin observes that nobody in those days contested the idea of building tunnels underneath inner cities to install public transportation systems. However, by extending this network to the periphery of the city, the cost of investment of a tunnel increases compared to a diminishing number of passengers. Bertin then outlines his concept of trans-urban Aérotrain transport, running in tunnels under the inner city but moving on pillars once outside the city while easily accessible from a normal metro station. In short, the type of organization Parisians know well with the Réseau Express Régional but operated by ACV technology at 200 km/h.

However, says Bertin, *“nothing could shake the absolute convictions of these officials and engineers, according to whom only the wheel could offer an answer to their needs.”*

Confronted with this refusal, Bertin focalizes on intercity links between 100 and 500 km where speed is a determining factor. On December 4th, 1963, a high level delegation of the national railroad company SNCF visits Bertin’s *“not that splendid”* factory wharf at la Garenne Colombes. Although a certain degree of interest appeared over the discussion and that the delegation finished admitting that on 300 to 500 km distances, this type of transport could beat the airplane, in particular connecting Paris with Lyons, the SNCF categorically refused to spend a penny to study such a project. *“I hit into a clear refusal: we were proposing a new technique; it was up to us to prove its interest for that connection. That was pretty hard, but we only could accept.”*

Bertin’s team then will work day and night to produce a detailed study exploring all the technical and economic aspects and the commercial exploitation of a fast speed rail connection between, Paris and Lyons: *“the number of vehicles and in what frequency; security braking, repair, auxiliary propulsion, weather conditions where snow and ice cover the track, etc.”*

Confronted with the most frequent objection against the Aérotrain, the one saying that it was *“too much inspired by the spirit of aeronautics and could not be convenient for the conditions of land transport”*, Bertin, who had seen the revolution is aeronautics by the

going from propellers to reaction motors, became more and more convinced about the “*necessity for such an inter-branches operation as ours [Bertin & Cie] for which this was precisely its mission*”

Adding ridicule to stupidity, the SNCF, at the end of 1964 claimed that “*there existed no foreseeable increase of traffic susceptible to justify a new connection putting the two cities [Paris and Lyons] at a 1hour15minutes distance including one or two intermediary stops*”, before making clear she didn’t want to follow up on the matter!! [For non-Frenchmen one has to note here that today, the TGV travel time between Paris and Lyons (450 km) is 2h...]

Territorial planning



When looking for credits to finance his projects, Bertin realizes with shock that the Department in charge of land transportation had no budget for R&D ! and that an innovation could only be financed by the “Fonds d’Intervention pour l’aménagement du territoire (FIAT)” [State intervention fund in charge of territorial planning], a newly created public credit facility “*whose primary objective, says Bertin, was to permit a certain unblocking of our French society. I think that that point, among many others, shows how much the idea of progress of public transportation was uncommon.*”

However, a large national debate will give new chances to the Aérotrain. In front of the mushrooming growth of the Paris urban agglomeration, city planners evoked the necessity to structure new urban nucleuses, called “Villes Nouvelles” or artificially seeds of new cities.

Paris Match magazine noted in may 1965: “Bertin didn’t answer. He knew he had the key of one of the most frightening problems of our time. The question is already a problem for the Americans living on the east coast. A couple of weeks ago, *Fortune* magazine published the dramatic results of its investigation. The whole region that goes from Boston to Washington is hit by apoplexy. The construction of 5 or even 6 or 8 lane highways did nothing. The truth of the matter is there and evident: individual transportation is fatally condemned in the large suburbia, after it was condemned in the inner cities. It will be the unstoppable comeback of public transportation so timidly imagined in Paris with the “blue bus line”. Of course, this public transport should not be of another age. Remains that at the Paris Saint Lazare train station, for example, the largest part of trains serving the suburbs are fifty years old steam engines... (...) millions of Parisians are packed up each day in wagons dating from the times of President Fallières”. [elected in 1906]

Bertin succeeded nevertheless to convince French President Charles De Gaulle, Prime Minister Pompidou and his minister Olivier Guichard, that the Aérotrain, by doubling and even tripling the speed of transportation, could “spread human activities over an area four to ten times larger without demanding the people to spent more time for transportation than what they spent already with the current system.”

France in action

The government facility of Olivier Guichard, in charge of the task and directly under the supervision of the Prime Ministers office and intervening vertically at all levels of state power, is a study case for what Lyndon LaRouche in the Unites States and Jacques Cheminade in France call “public productive credit”

Hence, at the initiative of Guichard, it was on November 3, 1965 that the Délégation à l’Aménagement du Territoire et à l’Action Régionale (DATAR) [Department in charge of territorial planning and regional action] signed a contract with the Société de l’Aérotrain which brought in some private capital willing to take the risk of the adventure.

The public funding made it possible to build a first experimental vehicle, called 01, and the construction of 6.7 km long trial track between Gometz-la-Ville and Limours (Essonne, south of Paris) on an unused railroad track connecting Paris and Chartres.

Bertin knew from the beginning that the ideal vehicle for a medium range distance connection as Paris-Lyons (450 km) or Lyons-Grenoble had to offer 80 seats, be 20 meters long and weight between 18 and 20 tons and gather average speed 400km/h despite frequent halts at regular intervals.

For the experience to be conclusive the test vehicle was conceived to be at ½ scale and it finished having 10.11 meters long, weighting only 2.6 tons and it had to reach 200 km/h

Times of record

In less then two months, Bertin and his team constructed what was necessary and the

experience could start on December 1965 when the vehicle was installed on the track. As soon as February 1966 the planned speed of 200 km/h was reached, and on December 23 of the same year, the amazing speed of 303 km/h was established.

Bertin's target was to reach 100m per second (i.e. 360 km/h). To reach that speed, he mounted on the experimental vehicle a rocket and later a power reaction motor. It was this motorization that permitted the crew to "fly", on November 1967 at 345 km/h.

If the Aérotrain 01 proved the workability of the Tracked Air Cushion Vehicle (TACV) technology, the next experimental vehicle 02 was immediately elaborated to reach the high speed objective. Equipped with a rocket and parachutes for braking, it was the Aérotrain 02, on January 22, 1969 that established the world record of TACV flying at 422 km/h at a 5mm height above the ground. The trial pilots we spoke with told us that on a longer track an even higher performance could have been reached without major difficulties.

Six months later, on July 20, 1969, Neil Armstrong, while putting his foot on the Moon declared: *"That's one small step for man, one giant leap for mankind."* But, some might argue, that was a different epoch.

Then, in 1969, Bertin constructed again another experimental vehicle, this time for the suburban traffic, capable to connect airports to inner cities, or the northern (Roissy Charles De Gaulle) with the southern (Orly) airport of Paris and the Paris modern business district La Defense with a "new city" Cergy. The new vehicle will have 44 seats and the risky task was taken up to make it operate with a silent Linear Induction Motor (LIM) at that time in its very shaky early takeoff.

Taken all together, the experiences were very encouraging and the French state finally accepted to finance a single straight 18 km track in the north of Orleans between Ruan and Saran, aimed as an initial segment of a Paris-Orleans connection. This time, the track was a concrete monorail elevated on pillars 5 meters above ground level. The track was completed in September 1969.

Elevated in that way, few obstacles could hamper the ride. Infrastructure costs were greatly lowered because few space of the ground surface is occupied by such infrastructures. The number of required tunnels, bridges, and level crossings was reduced and expropriation costs limited to the minimum,

While at each end of the track a special platform was installed so that the vehicle could make a turnaround, in the middle of the track there was a central platform with a hangar where the vehicle could be stored and repaired.

The Aérotrain I-80 (interurban 80 passenger capacity) weighted 24 tons. It was powered by twin Turboméca Turmo III E3 turbine engines through a ducted propeller with seven blades. A 14 turbo engine powered the air compressors. The vehicle was installed on the track on September 10, 1969 and reached 250 km/h three days later. While the initial run was successful, it was just not fast enough, so the machine was upgraded with a Pratt & Whitney JT8 D11 turbofan. It subsequently broke the land speed record for railed vehicles at 430.4 km/h on the 5th of March 1974.

What had been a dream had now become a reality. If one recalculates traveling times on a 200km/h basis for suburban and on a 400 km/h on inter-urban connections, the physical world in which we operate looks quite different. In a little brochure, written nine years before the splendid performances of the Aérotrain, Paul Guienne, the engineer that constructed the initial small scale model, envisioned the following travel times:

Lyon – Grenoble	87 Km	20 à 26 min
Paris – Orléans	120 Km	25 à 35 min
Lyon – Givors – Saint-Étienne	55 Km	14 à 16 min
Metz – Nancy	57 Km	15 à 17 min
Paris – Orly	12 Km	4 à 5 min
Le Bourget – Paris-Nord	30 Km	10 à 12 min
Marseille – Marignane	25 Km	6 à 18 min
Paris – Lyon	450 Km	1h10 à 1h30
Rennes – Lorient – Quimper – Brest	260 Km	1h à 1h10
Bordeaux – Angoulême – Périgueux	175 Km	35 à 40 min

Aérotrain : Fly to New York

The media coverage given to this vast open air scientific experience of a new transportation technology attracted more than just the curious. On September 7, 1972, the US democratic Secretary of Transport John Volpi, and the mayor of Los Angeles came to France to assist personally to the test rides, as did representatives and transport specialists from over 18 countries sent to France to study and report on these developments.

At least two dozen countries became highly interested in the project and Bertin's Société de l'Aérotrain conducted pre-construction studies for a dozen of them, of which China-Taiwan (KeeLung – Ka Hsiung), Japan (Tokyo – Narita airport), Argentina, Brasil (Sao Paolo – Rio de Janeiro), Italy (Rome – Milan), South Korea, Canada (Montreal – New York), Sweden, Belgium, Switzerland (Brussels – Geneva) and the Netherlands (Amsterdam – Schiphol airport).

While the French press ran articles titled "*The Aérotrain crosses the Atlantic*", the US press wrote "*Aérotrain: Fly to New York*".

US industrialists engaged to build this new technology. Rohr Corporation in California, at that time already working on Maglev technology and financed by the Urban Mass Transportation Administration (UMTA) decide to build an Aérotrain vehicle under a French Bertin license. The vehicle was tested successfully in California, where it is carefully conserved.

The “new countries” as Bertin called them, the African nations starting to be freed of colonial rule and became highly interested in acquiring TACV technology, since no large power grids were required to operate the system. All these projects were waiting for one single event: the construction of a commercially operated Aérotrain connection in France.

If you want to kill your dog, accuse it of rabies

The revolution of a train without wheels provoked wild oppositions. Bertin, when protected by De Gaulle and Pompidou identified this opposition as coming, not from the people or the higher echelons, but from the “intermediate bodies”.

It is useful to examine, with time having gone by, the so-called arguments against the Aérotrain, since they are identical with the arguments opposed to today’s Maglev. Seen from 2008, it is easier to see their absurdity and their dishonesty.

Let’s take them one by one:

1) The Aérotrain is incompatible with the existing rail infrastructure. This handicap makes it harder to penetrate urban agglomerations and will be costly. The users will have to first go outside the city to get access to this mode of transportation.

- **TRUE:** TACV transports needs its own track.
- **UNTRUE:** If the French high speed TGV train can run on a conventional track, any high speed train needs a special track for such a purpose.

2) All transport tries to reduce “intermodality”, the switching from one mode of transportation to another one which implies a loss of time and energy. Adding the Aérotrain increases the switching instead of reducing them.

- **UNTRUE** since the Aérotrain can directly reach inner cities by tracks and tunnels.
- **TRUE,** since a new mode of transportation. However, this attitude can lead to sterile conservatism. Where airplanes or ships refused for this reason?

3) The Aérotrain consumes too much fuel, and energy becomes expensive, especially after the “oil shock”

UNTRUE since oil reserves have remained far larger than the insane prophecies of the Club of Rome. By obliging the Aérotrain to adopt the Linear Induction Motor (LIM) at its early stage of development, the enemies of the Aérotrain tried to kill the project by increasing the cost of its development. Alternative modes of motorization did exist already at that time but were discarded. Second, as Bertin himself scientifically demonstrated, direct energy consumption is only one cost factor among many others and economic viability has to be evaluated by taking all factors into account, and not only one.

4) The Aérotrain is expensive

- **TRUE,** since all new technologies need an initial investment.
- **UNTRUE:** If direct energy cost for high speed traveling and the construction of the track represent a relatively high investment, maintenance costs of “zero friction”

TACV technology are extremely low for both vehicle and track, estimated to be two and three times less than conventional rail systems. As Bertin underlined, the investment in power always pays off. How much money did we lose in terms of lost working hours due to the absence of these rapid transportation systems?

5) The Aerotrain pollutes the environment and traumatizes cows and other animals.

- **UNTRUE:** The media have played up the images of the noisy prototypes that were powered by noisy rockets and airplane motors. They were nothing but prototypes and not planned for commercial use.
- **TRUE:** Bertin, a specialist in noise reduction technology for airplanes had many on shelf solutions ready to solve these problems. Especially today, electric Linear Induction Motors would make TACV technology entirely noiseless.

6) The Aérotrain is a mode of transportation for the wealthy; building it might give “a bad example”.

- **TRUE:** The impression was given that people had the right to develop! How shocking!
- **UNTRUE:** This argument came up to oppose the construction of the connection between the two Paris airports, Roissy and Orly, a project Bertin ultimately accepted only because all doors had been closed for any more promising project such as the Paris-Lyons connection.

In respect to the Aérotrain being a privilege for the rich, one has to remember that the Paris metro still had 1st and second class wagons till August 1991... Also, in its beginnings, the bike, the car, the airplane and also the TGV were presented as for rich people only...

As soon as 1970, one can find all these fallacies of composition in a condensed form in the arguments employed by M. Coquand, President of the “Groupe fonctionnel voyageurs” at the Transport Commission of the “Commissariat general du plan et de la productivité”, in his written answer that highlights the conclusions of the report of the commission in charge of studying the servicing of the Paris-Orléans connection.

In that letter, M. Coquand pretends that “seen the cost of the access into urban areas, whose evaluation remains problematic, the infrastructure for the Aérotrain will cost about 20% more than that of the conventional railroad” [that existed already!]

On top, the commission estimated that “the total cost per passenger/km by Aérotrain at 250 km/h seems to be 30 to 40% more elevated than the TurboTrain (of the SNCF), and that cost would be even higher at 400 km/h (...) the time gain would not compensate this difference [of cost] but for those passengers that estimate that their time has a relatively high value – more than 30 FF per hour...”

The “higher cost” calculation was nothing but a trick, since:

- The commission itself admitted that SNCF would benefit from preexisting infrastructure to penetrate inner city areas, while the new Aerotrain infrastructure had to be constructed.
- Costs for that infrastructure were not calculated employing the same criteria. A

footnote of the report says that “value added tax was not included in the cost of infrastructure for SNCF (a state company), since the latter could deduce the cost of VAT.”

- The same applied for the cost of fuel. SNCF benefited from tax free domestic diesel fuel, while Aérotrain paid the full price for it...
- Without any real reason, the price of the commercial Aérotrain vehicle was overestimated by 25% in respect to its theoretical cost, while each prototype had entirely respected the fixed amount of credits it had received.

In short, those that want to kill their dog, accuse it of rabies. Besides the fundamental economic error of confusing a short term “financial accountants” approach with long term real economic profitability deriving from the impact of its spin-offs in the global physical economy, the case of the opposition to the Aérotrain demonstrates the horrors of the feudal vision that still dominates our technocrats.

Despite all these maneuvers and oppositions, an initial contract for the construction of rapid Aérotrain connection servicing La Défense and Cergy Pontoise was signed in March 1971, a project that both Brasil but also Japan, among others, were closely watching since eager to build such systems at home.

A media campaign took off to demolish the positive image of the Aérotrain and its inventor Bertin, now a symbol of progress. The images of the noisy prototypes were shown again and again to nourish a public outcry in defense of the environment.

At the center of this international offensive, the Hamburg based “Club of Rome”, founded on April 8, 1968, four days after the assassination of Martin Luther King, by a high official of NATO Aurelio Peccei and a British civil servant at the OECD Alexander King, obsessed with the rising proportion of colored people on the planet. The Club of Rome brought together economists, professors, government officials and industrialists willing to take into consideration “the complex problems facing our societies, industrial societies as well as developing ones.”

After the killing of American President Robert F. Kennedy in June 1968, this image became nothing but a mask to impose a “post-industrial” society promoting financial speculation now possible by the destruction of the Bretton Woods monetary agreements decided by president Nixon in August 1971.

The normal preoccupation of the population for an healthy environment was politically exploited and became an instrument for emotional control by the financial oligarchy as a buttering ram against the right of development of nations, especially those of the southern hemisphere.

Nearly a bible for the newly born green movement, the first report of the Club of Rome, “The Limits to Growth” (1972) was followed in October 1973 with the Yom Kippur war. Following that war, even if the Suez Canal was blocked since 1967, the oil producing countries decided to increase by 70% the price of a barrel of oil leading to the first “oil shock”. Then, in 1974, the Club of Rome published its second report: “Beyond the age of waste” that launched a real psychosis of scarcity of energy.

Giscard d'Estaing and the Schneider synarchy

Despite this growing hostile environment against progress, and after endless administrative obstacles, the green light was given to construct the Cergy-Pontoise connection on June 21, 1974.

Some weeks earlier, in May 74, Valéry Giscard d'Estaing was elected as President of the French Republic. Three weeks after the initial "definitive" signature to build the project, and directly from the Elysée, on July 17, Giscard stopped the whole program and *Le Monde* hypocritically wrote that the Aérotrain was "sacrificed by the austerity policy"

Jean Bertin, who had a cancerous tumor, sick and overworked after a decade of endless efforts, died one year later, on December 1975. In 1977, the project is definitely abandoned and the I-80 Aérotrain will make its last trip on December 27, 1977.

Why such a passion against the Aérotrain? The president's wife, born Anne-Aymone de Brantes, was the granddaughter of Eugène Schneider, the "maitre de forges of Le Creusot" and co-founder with François de Wendel of the famous "Comité des Forges" [Coal, iron and steel cartel], ancestor of the current UIMM, finally investigated for decade long corruption. The Schneider family, pronounced "Schneidre", are an old family of the worst synarchist tradition.

If it is seen as highly likely that the "Empain-Schneider Empire" was a major campaign contributor to Giscard's presidential election, the Schneider dynasty have been and are still a pillar of the history of the French railroad and steel industry. Hence, the innovation of the Aérotrain (to be built by the aircraft industry) would not, in the short run, have made them more wealthy and one can easily imagine that a train without wheels does not get much enthusiastic approval of the feudal wheel producers.

One also has to note here that the Empain-Schneider group, through its subsidiary Framatome-Creusot-Loire owned the Westinghouse license of the Pressured Water Reactors (PWR), the only type of technology chosen for the French state's nuclear power equipment under the Giscard presidency. Some sources indicate that Giscard's cousin, Jacques Giscard d'Estaing was in 1975 the director of SOMAIR, the company controlling the uranium mines of the Air region in Niger and in a similar position in Gabon before concluding his career at the Cour des Comptes [French state budget verification office]. According to an article published in 2003 by the weekly *l'Expansion*, "The Brotherhood of Giscard d'Estaing's", Jacques' son, Antoine Giscard d'Estaing, was a financial director at Lyonnaise des Eaux before becoming financial director of today's Schneider Electric.

While Giscard d'Estaing, already as finance minister during the Pompidou government, was blocking the development of the TGV high speed rail, as president he was obliged to accept such high speed rail; for the Aérotrain experiments had made it the standard and proven to be real. Some even claim that the only reason there exists today a stop of the TGV at the small 26.500 habitant city of Le Creusot, the cradle of French steam powered locomotives, is that its mayor was Eugène Schneider, Anne-Aymone's grandfather...

While Rohr industries in the US carefully stored its Aérotrain in Colorado, financing of the project was suspended. In France, on July 17, 1991, the S-44 Aérotrain prototype was destroyed by fire in its storage facility at Gometz-la-Ville and in 1992 the unique I-80 Aérotrain stationed in Chevilly is destroyed by arson, in an ultimate attempt to prevent any comeback of the Aérotrain concept.

The tragedy of the Aérotrain as the failure of territorial planning (since one out of four Frenchmen still lives in the giant Paris area), do nothing but revealing the tragedy of an entire epoch.

After thirty years of uninterrupted growth known as the « glorious thirty », a financial mafia took over the control of our nations. They imposed a radical counterculture praising the search of immediate individual pleasure as opposed to a collective project of the pursuit of shared happiness. From the gems of optimism emitted by the Apollo space colonisation program, achievement as the French Caravelle airplane, Concorde or the Aérotrain, we fell into the pessimism of the Club of Rome and the narcissist vomiting of Jean-Paul Sartre. Time is overripe to catch up and we are confident that the spirit of Jean Bertin will inspire us in that task.

Notes :

(*1) Jean Bertin et Raymond Marchal, « L'Aérotrain ou les difficultés de l'innovation scientifique », Bibliothèque Aviation International, Société des Amis de Jean Bertin, republished in 1989.

(*2) Jean Bertin, « De la relativité de l'énergie » [On the relativity of energy], *L'Ingénieur*, Organe de l'Union Régionale des Ingénieurs Dauphiné-Savoie, 1^{er} trimestre 1967, 19ieme année, N° 73.

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