A KEY ROLE
TECHNOLOGICAL RESEARCH AT THE SERVICE OF INDUSTRIAL & ECONOMIC DEVELOPMENT

In all times, great scientific breakthroughs and their applications were drivers for the industrial development, bringing progress and wealth to societies. It is this fact that, today, urges emerging countries to develop training, research and technological innovation to make them ground-bases for their economic growth and the path towards better living conditions. How did France historically set up the conditions for a lively and efficient research? On what principles is this research operating today?

Audrey HENRIOUD
and Jean RANNOU

POST-WAR AWARENESS

In France, technological research becomes a national priority by the end of Word War II. At this "refounding" time, everything, or so, is to be done in the scientific field, for already delays had been stacking up for many years. Moreover, France was ravaged by five-year occupation. CNRS (see below) creation, on October 19th 1939 only, finally demonstrated what unpreparedness degree the country had reached: as innovative armament-programs in general, the CNRS was coming too late to "organize the scientific war effort and contribute to Reich victory". Thus one discovered that research was necessary to support the war effort, – but one month after we had declared it –, whereas Germany had for a long time made research a national priority. Besides she had, first, understood the key-role scientific research could play in developing and maturing technologies for the benefit of industry. By the end of the 1930's, Germany was on the verge of taking a decisive industrial advantage on the other (European) countries. Learning lessons from what had been successful elsewhere, several technological research institutes were therefore created by the end of the war to extend CNRS action.

> "Technological research remains the compulsory path towards programs to come (…) skipping this stage can generate delays and overcharges with no common measures with the investments that could have helped avoid them."

Photo above:
Created just after the Second World War, the Modane-Avrieux center gathers a set of wind tunnel facilities. Thanks to its geographical position, hydraulic energy is used. (© ONERA)

These new institutes came in between fundamental (or academic) research and industry to setup the indispensable connection between them. Their mission was already clear: they were to develop scientific knowledge and technologies required for achieving great projects that had been decided for rebuilding France and place it back in front of great nations. Several factors concurred to providing success for such an undertaking. Belonging to a long-term political view and founded on achieving very ambitious scientific and industrial projects, with time it profited by a consistent state direction that knew how to maintain the national momentum to reach targets set. Besides, it rested on the shared conviction that success demanded an unprecedented technological effort, which Gen. De Gaulle promoted as soon as he was back to power.

NEW CLOTHES FOR RESEARCH

Though this policy had produced spectacular results for thirty years, effort began to ease up in several industrial sectors from mid 1970's onwards. Consequences did not appear immediately, all the more so they had been softened by social measures and public-employment increase. They really became visible by the beginning of 2,000's, when it was no longer possible to balance commercial deficit. Finally, as with other European countries, financial and economic crisis and the explosion of public debt caused the magnitude of problems to appear in full daylight. To find a way out from such a situation, more and more numerous decision-makers realized it was urgent to create productive value and jobs anew. The only way for so doing: an energetic revival for the technological research effort and innovation, aiming at providing industry with increased competitiveness. One way or another, preserving the environment and the depletion of natural resources impose the same step: research therein is doubly vital. This research yet has to be properly organized and used.

In France, initiatives were multiplied for a few years, to give a new impetus to technological research and innovation, but they do not seem to have produced the results expected. We probably lack some clear direction and an imposing authority, as was the case through the 50's and 60's, to come out with a consistent system, able to federate initiatives and avoid effort being dispersed. This does not mean refunding some rigid Colbert-type policy [protectionism & developing industry and outer trade], but relight some "competitive consistency" that seems to be lacking. Furthermore, demand for quick results naturally leads to favoring developments and production at the detriment of the indispensable effort for maturing and validating the technologies that have to be made upstream. So as to refund some sustainable research, it then seems useful being aware anew of what technological cycles imply.

Aerodynamicists visit to S1 wind tunnel facility of Modane in 1937.(© ONERA)

★ Main technological institutes created in France

- November 17th 1943: Institut français du pétrole (IFP - French Petroleum Institute).
- May 4th 1944: Centre national d'études des télécommunications (CENT - National Center for Telecom Studies).
- October 18th 1945: Commissariat à l'énergie atomique (CEA - Atomic Energy Commission).
- May 3rd 1946: Office national d'études et de recherches aéronautiques (ONERA - National Office for Aerospace Studies and Research).
- May 18th 1946: Institut national de la recherche agronomique (INRA - National Institute for Agricultural Research).

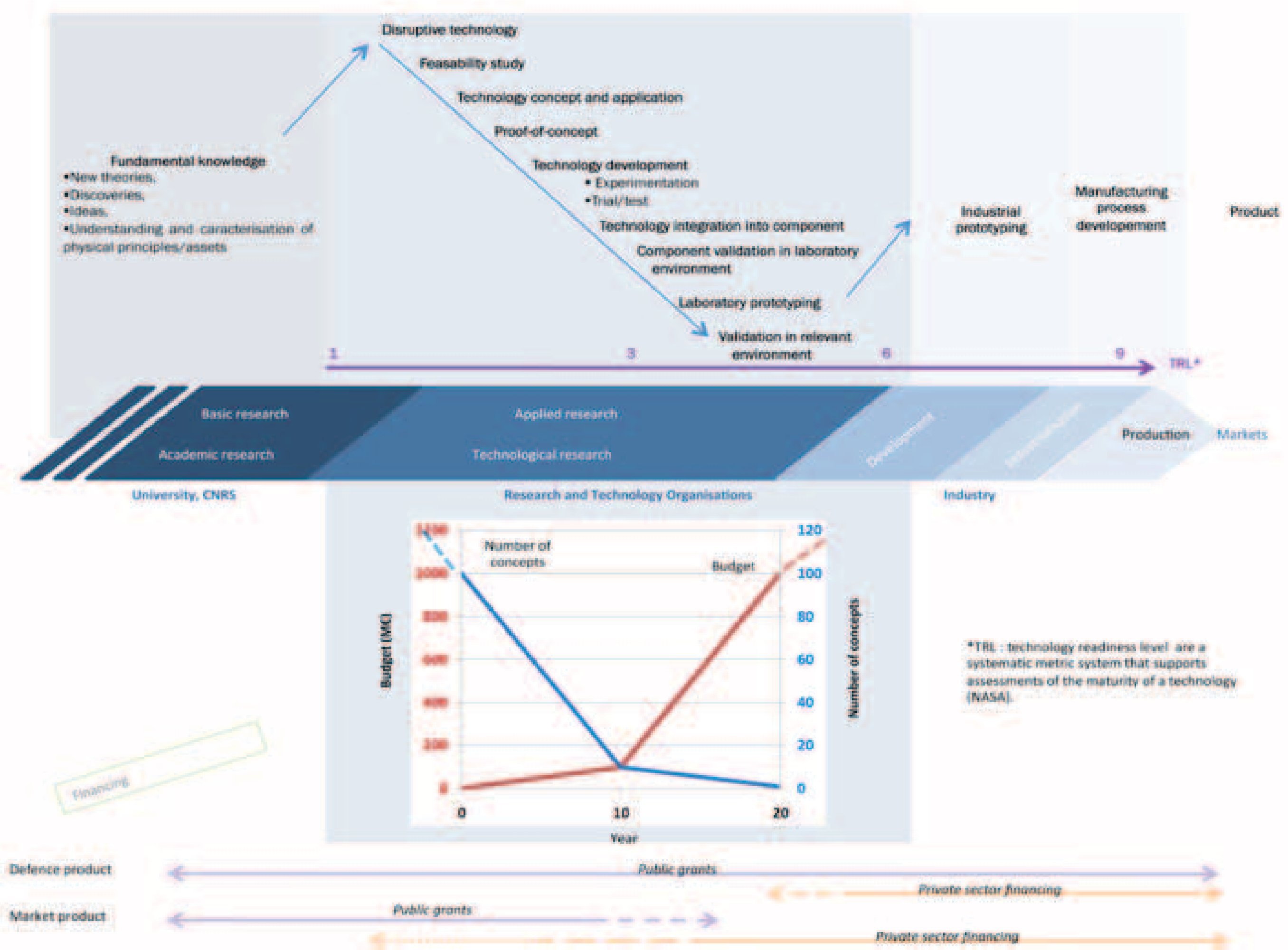
To meet new requirements, ONERA missions are extended to aerospace research in 1963, when the CNES (National Space Agency) is created. INSERM (National Institute for Health and Medical Research) was created in 1964, then IRIA (Datamation Research Institute) in 1967, which becomes the INRIA (National Institute for Research in Computer Science and Control) in 1979. All scientific and industrial activity sectors are concerned with the creation and, some organizations, among which CEA and ONERA have a twofold civilian and military calling as early as they have been created. CEA is provided with a Military Applications Directorate. ONERA is place under the aegis of the Defense ministry. Besides, defense-research, outside CEA, is placed under the direct authority of the DGA (French procurement agency). The latter sets directions, provides funding and, at the time, carries out itself part of research works, especially as far as navy, army fields and armaments are concerned.

FROM RESEARCH TO PRODUCT: A THREE-STEP CYCLE

Such cycle, presented in diagram below, holds technological innovation as the determining element to obtain a competitive advantage and/or a performance leap when new products are being developed by industry, for this is the one that is founded on the technological research effort, on technological breakthroughs. Other innovative ways, founded on industrial developments, are also possible using already-proven technologies to ensure new functions or services. When going from research to product, the necessity of the first step entrusted with fundamental research is properly understood in France and largely funded. Besides, it is controlled by a ministry and, nowadays, is associated with upper education, which is consistent with practices in other countries, but, yet presents the risk to take it away from industrial and economic realities. The third step – product development by industry – has been France's strong point for a long time, it was due to the excellent training of its engineers. Its importance is perfectly perceived by all decision-makers and numerous financial efforts, tax research credit and now the Great Loan, have been made to support industrial developments. On the contrary, the intermediate step, the one achieved by technological research, in France, comes out as the poor relative, while it plays a capital role in developing new technologies derived from ideas and findings from fundamental research, to make them available for industry. This is what Germany understood before other in the 1920's. And such truth is still standing: those who make most efforts for technological research enjoy better industrial performances, especially with export.

TECHNOLOGICAL RESEARCH KEY-ROLE

Designing a new product that is more competitive on the marketplaces, or combat-decisive when defense capabilities are issues, supposes one knows how to select the best "technologies" that can be envisioned, and then, bring them to maturity



From research to product: life cycle and funding of aerospace. (© CEIS)

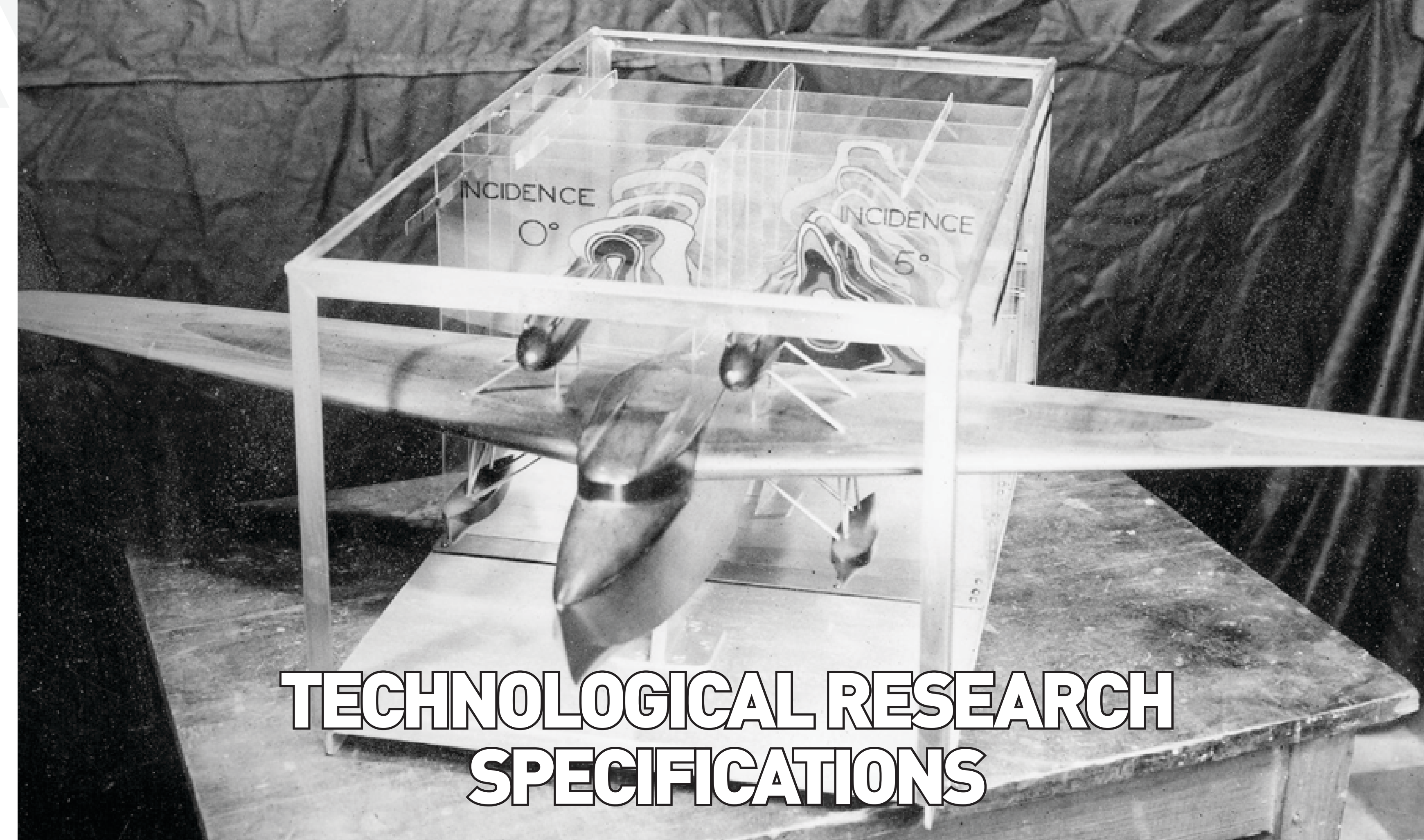
within deadlines that are compatible with requirement being satisfied. Both these scientific capabilities – selection and maturation –, are crucial, for if they are lacking, one cannot detect and, then, control technologies that will emerge. One, then, is confronted with a dilemma: either one is too conservative or one is too ambitious. In the first case, the new product being developed will not be competitive and, in the second one, it will stack delays and overcharges. Many industries did not survive such a dilemma.

"Technology" as term, covers pretty different, tangible and intangible realities, going from:

– technological bricks:
  • New basic technologies (molecules, materials, alloys, manufacturing process, software technology, etc.),
  • Components (processor, memory, algorithm… assembly technology, etc.) ;
– to products:
  • Component assemblies for producing objects or equipment as such (mobile-phone… computation code, model, etc.) or that can be integrated into a system,
  • Systems (architecture, equipment assemblies, … integration process).

Controlling these capabilities means one has the knowledge, scientific competencies and the tools to lead both these phases within the process, successfully to an end.

The first phase – selecting – implies lab-research works to check or demonstrate a new technology derived from some discovery is feasible, and, then, check that components it will help manufacture will indeed meet previsions and expectations. That is: explore the field of emerging technologies to keep those that are likely to be applied. With a new concept as case, studies will come and complete lab-research works. Selections being carried out, the second phase – maturation – includes deeper studies and lab-works to develop and adjust base-technologies, then components (modeling, simulation, experiments, trials) to come out with validation, first at lab-level, then in a simulated pertinent environment or in a environment that is close to actual employment conditions. At this stage, one is using small- or even real-size demonstrator. Duration for scientific works achieved during this selection-&-maturation step for technologies, can be short – two years for an electronic component – or much longer – until fifteen to twenty years for a new material –, but in all cases, it is indispensable to succeed in integrating these technologies into the further development for a product, equipment or system. One must add this core-step cannot be separated, nor from fundamental research or from industry. Its role is even essential to bridge both, upstream to direct searchers to meet expectations from companies and direct technological selections downstream from emerging technologies. Technological research, implemented in France by the end of World War II, remains the compulsory path towards programs to come. It is the key for selecting and developing the right technologies and making them available to industry with the best guarantees as far as their performances, reliability and costs are concerned. Difficulties that some great projects are meeting, in France or abroad, are here to remind that skipping this stage can generate delays and overcharges with no common measures with the investments that could have helped avoid them. ■



TECHNOLOGICAL RESEARCH SPECIFICATIONS

Guy RUPIED
Managing director of GIFAS,
and Cécile ROUSSEL.

Aeronautics, then aerospace changed the view men had on the world and the universe. Fly and go into space, see the earth from above… vertiginous perspectives that had never been achieved before suddenly revealed themselves. For these prowesses's to transform into promises, scientists and engineers however had to invent and ceaselessly innovate to imagine and develop very numerous technologies, very different from what existed so far. They required time and perseverance, steadfastness often, for aerial and spatial systems are long to develop as well as very complex. This quest is far from being achieved. Human dreams are far from being completed. Scientists and engineers will have to carry on their efforts, all the more so the relationship with scientific progress has been modified in its spirit and requirements: safety and best performances are ever required, especially with regard to environment.

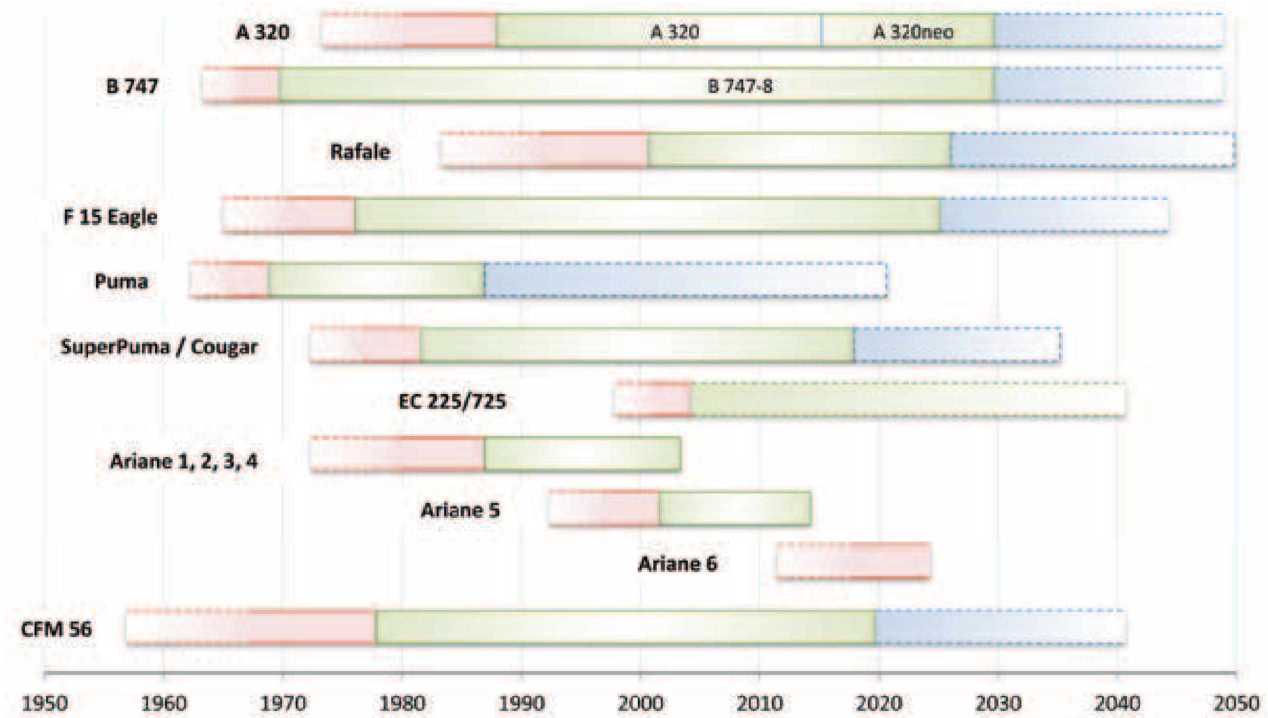
> “The importance of the aerospace sector, when one looks at its impact – so much on economy as strategy, as well as the weight of related technologies –, is highlighting the necessity to play a driving role in developing and mastering these technologies.”

LONG CYCLES, A "TECHNOLOGICALLY SUSTAINABLE" CULTURE

Systems manufactured by the aerospace industry are part of very long cycles. Best sold transport aircraft have a life-cycle whose life-time can close up with the century. Much up-stream time is required to lead studies and technological maturation, then design, develop and manufacture new aircraft and new missiles. This life-time being costly on account of its duration and of the complexity of systems manufactured, they have to be flown and sold during long enough to obtain return(s) on investment.

Thus, Airbus A320, entered into service in 1988, will be manufactured at least till 2030 in its neo version, and will remain operational beyond 2050. Its competitor, Boeing 737 could remain in service 80 years if remotorizing it is made up, just as with the Boeing 747. When one adds up studies and development, the total life-cycle is close to the century. On their side, combat aircraft have slighter shorter life-cycles, but they will go beyond 60 years for the Rafale and 75 years for the American F15. Orders of magnitude are the same with helicopters. As for engines, which as a whole are changed once during aircraft life-time, one must highlight that the CFM56, that powers the A320 and the B737, will be manufactured for at least 45 years and spares even longer. Furthermore, new engines

Photo above:
A seaplane project in the 30's. (© ONERA)



Life cycle of aerospace programmes. (red: R&D phase; green: production and exploitation phase; blue: exploitation phase). (© ONERA)

demand longer study-&-development times than aircraft. Finally, with space, rockets of the Ariane-type naturally have a life-cycle that is shorter than airplanes, but successive series profit by the experience acquired with previous ones. Yet, Soyuz as launcher is already 45 years old since it was first launched in 1966.

ANTICIPATION AND TECHNOLOGICAL MATURATION REQUIREMENT

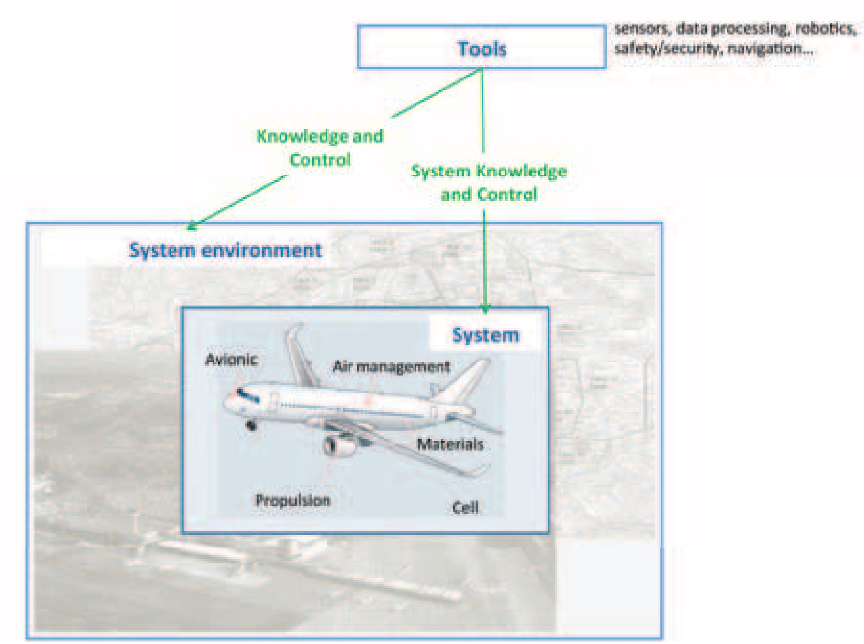
Long-time consequence for technological research is twofold. Some anticipation and expertise are required, for good technological choices have to be made, quite upstream. Mistakes are difficult to be made good and always costly; instances are many since the beginning of aviation that illustrates this reality. Conversely, good technological choices and innovations obviously are at the heart of great successes, A320, CFM56 and Falcon 7X are the demonstration thereof. Long lifetime then imposes some good control of the maturation process for technologies, so that they are available for a good while, knowing that these maturation times are quite variable in their nature. It can exceed 20 years for a new material making some technological breakthrough possible. Such dual requirement, choice and technological maturation, transforms technological research into a natural bridge between fundamental research on one side and industry on the other. One, indeed, has to be able to identify and assess emerging technology as early/upstream as possible, which imposes some great proximity with fundamental research. One then has to know how to appreciate the time required for technological maturation – as well as associated risks and costs –, to optimize future industrial choices, which supposes some perfect understanding of industrial needs. As one can see, the problem, here, pertains to working out some cultural continuum between upstream and downstream. Great industrial nations are those that master but also see to this continuum upkeep.

COMPLEX SYSTEMS

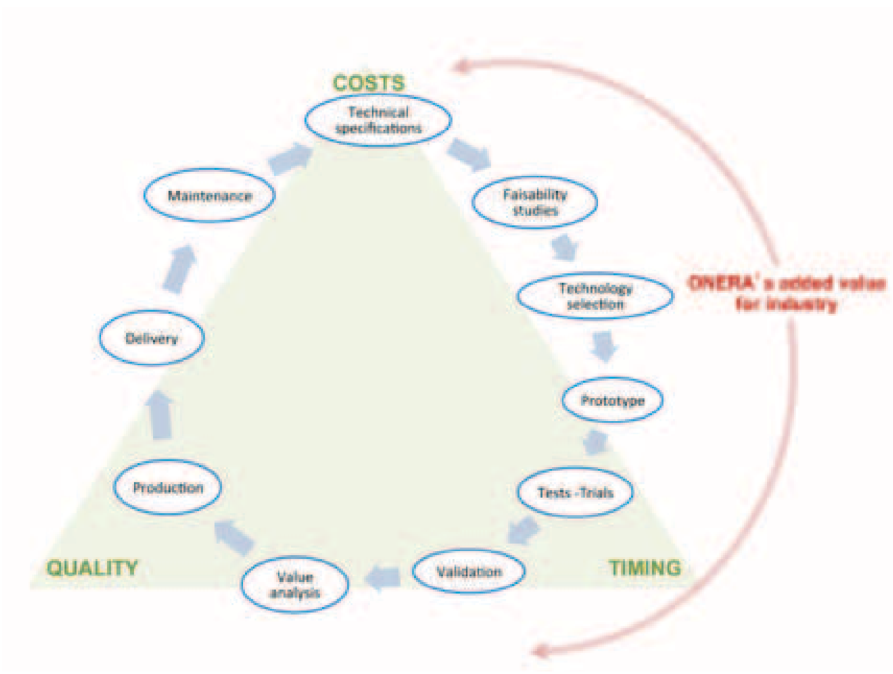
This dual requirement is all the more delicate as aeronautical and space products are complex systems. They are made up of intrinsically complex technologies, components, equipment and subassemblies, which, furthermore, one has to know how to combine and integrate them to design and manufacture an optimized system. An aircraft (or a missile) besides, is quite varied as far as its subassemblies are concerned: cell and structure, engines, landing, steering, navigation, flight management, power production and distribution, air-conditioning systems... The number and diversity of knowledge and scientific & technical competencies, of modeling & simulation tools as well as test-&-trial means involved therefore is enormous. An ambitious but structured approach, based on the virtuous circle "experience-modeling-simulation-validation" helps validate each breakthrough and reduces the risks related with conducting so complex projects. Moreover, these systems are likely to progress through a constantly evolving milieu, which sometimes is so hostile that it rapidly endangers flight safety. They can be aggressed by lightning, icing conditions, heavy rain, strong winds, turbulences, or even military attack systems. Consequently, system status and environment require to be known on a permanent basis for steering to be ensured real-time and mission pursued optimally: best course, stability and flight safety whatever the outer conditions. These parameters and constraints therefore call on additional technologies being integrated, increasing system complexities all the more so. Naturally, such complexity will also increase too with time under the combined effect of technological evolution on one side, and of improvement of design and integration capabilities on the other. The future henceforth is for systems that are very much integrated as early as they were designed and able to carry out a greater number of functions. The necessity of mastering vanguard scientific and technological competencies in all fields can then be perceived. They are necessary for developing components, equipment and subassemblies making up those systems. In parallel, one must be able to cross these competencies around each new project so that its global consistency and optimization can be secured. Such crossing with competencies cannot however produce fruit unless founded on some "system vision" shared by teams in charge of technological research on one hand and development on the other.

TWO FACTORS FOR COMPLEXITY AND TECHNOLOGICAL DEVELOPMENTS: FLIGHT-SAFETY AND RESPECT FOR THE ENVIRONMENT

If the need for security and operation reliability of aircraft was born with aviation; taking into account its impact on environment happened more progressively. It started with noise reduction, then that of polluting releases and hot-house effect gases. One became interested in the nature of materials being used, on one side to contribute to reducing polluting releases (reduce weight to reduce fuel-consumption), on the other to avoid any risk when they are being used, then to recycling by life-time end. Safety, first and foremost, is concerned with air-craft themselves. It relies on the perfect and permanent control of the flight, as well as the reliability of critical components on-board, reliability being prominent with missiles. Improving safety calls on scientific and technological competencies already described previously, but also requires specific works to define and design those sensors that are necessary for the permanent knowledge of the aircraft and its environment. Competencies have then to be developed to merge all data together and make them available to the crew for flight-management. This supposes man-machine relationship to be excellent. At the same time, crew has to be discharged of the elementary tasks related to steering by defining and implementing the most appropriate automatisms. With air-transport, flight safety is more directly depending on management and control on-course, near-by and on airports. The European research program SESAR (Single European Sky Traffic Management Research) has set itself the ambitious goal of multiplying flight-safety by 10 over the next decades. In this respect, certification today is playing a key-role with flight-safety. Critical component reliability in the aeronautical field thus is ruled by regulations set up at international, European or national level, better and better. But, here too, this improvement does not go along without calling on specific competencies, at the same time technological and industrial, required for defining those relevant criteria to be retained for certifications. Then, competencies and test-means to bring technologies and systems to the level required by certification are needed. They have to be maintained therein over time. As far as environment impact is concerned, goals to be reached by air-transport are henceforth defined, as well as on the European level as on the national one. Goals defined by the Advisory Council for Aeronautics Research in Europe – ACARE –, can be quoted; Clean Sky, as European organization, is in charge of implementing them. These goals have been taken up by European Union countries. In France, the Council for civilian aeronautics (CORAC) is in charge thereof, via a "technological roadmap". The European regulation REACH (Registration, Evaluation, Authorization and Restriction of Chemical substances) that installs control on chemical substances in materials used with industrial products can also be quoted. Complying with certifications, regulations and European targets as a whole imposes reinforcing technological research competencies in many scientific and technical fields. First, with those already presented concerning performances of aerospace systems; first goal: reduce fuel consumption and therefore operating costs and releases. The second effort focus is concerned with noise, especially that of helicopters for which room is plentiful for improvements, but goes through technological breakthroughs. Besides, a specific study on condensation drags and their impact on environment has been undertaken. A world of research and trial work is to be pursued on the composition of



Transport aircraft, a complex system in a complex environment. (© D.R.)



ONERA's added value for industry.

materials being used by the aeronautical and space industry, to suppress, or at least, reduce their production costs. Finally, alternative and economically viable fuels, whose release balance would be more favorable than the present ones, have to be developed. Thus, technological research is not behind us as some are thinking, quite the contrary, since its scope of actions and competencies continues to widen. This can be checked, in particular from the fact that new possibilities are being opened through knowledge evolutions and scientific tools, but also through the growing requirements of societies as far as performances and safety are concerned. Technological research must therefore comfort and develop scientific knowledge and competencies, modeling and simulation tools, as well as test and trial means required for maintaining industrial capabilities in the aerospace sector. Finally, one must remind that requirement levels are so high that few countries, so far, have successfully reached them. Wind-tunnels, a special case and test-means by excellence for aeronautical research, are emblematic of the role and importance of aerospace research centers. The engagement of emerging countries to acquire them translates their ambition thereon, as with India or China. The latter country, so far depending on western facilities, launched into building wind-tunnels with French wind-tunnels acknowledged being the first ones as model. In the United States, after a stagnation or even recession period, investments on wind-tunnel stock, on the rec-ommendation of a think-tank gathering the greatest national aircraft-manufacturers, the American Congress recently voted a M$ 600 over 10 years for upgrading facilities and related competencies (program ATP). On its side, in 2009 Europe funded a first project, ESWIRP – 7.7 M€ –, for modernizing its wind-tunnel stock.

> “All countries that have successfully developed an aerospace industry relied on research, and especially on technological research institutes, as NASA, German DLR or ONERA. "New-comers" are following the same track.”

ONERA: AT THE HEART OF FRENCH AEROSPACE RESEARCH CAPABILITIES

Thence, stakes and necessity to have research capabilities in the aeronautical and space field available and to maintain them are easily perceived. In France, ONERA (National Office for Aerospace Studies and Research), in this respect has a central position. Supervised by the Ministry of Defense since it was created in 1946, it is the French center for aeronautical research, and since 1963 that of space research (when the CNES – national space re-search center – was created). It provides the link between fundamental research (up to level TRL 3), achieved within universities and research centers such as the CNRS (French National Center for Scientific Research), and the industrial research-&-development (from level TRL between 6 & 7). This particular position, equivalent to that of the CEA (French Atomic Energy Commission) and to Alternatives Energies (CEA) or the INRA (national agronomic research institute), implies it is working on technological niches targeting technological innovation and its industrial application, which can be defined as finalized research. ONERA role is threefold. It comes in as an expert for the benefit of civilian state DGAC (French Civil Aviation Authority) or defense DGA (French procurement agency) entities. It supports industrials with prospective reflections, in working out specifications, defining system architectures, making technological choices, tests and trials... Finally, it actively takes part in training next scientific generations. The importance of the aerospace sector, when one looks at its impact – so much on economy as strategy, as well as the weight of related technologies –, is highlighting the necessity to play a driving role in developing and mastering these technologies.

This is where maintaining national capabilities, such as those held by ONERA, within a European cooperative logic, makes up a major goal, except if we give up playing a role in the aerospace adventure. ■

ONERA AND PARTNERSHIP TOOLS

Jacques LAFAYE
Special advisor to the Chairman of ONERA.

Cooperation and partnership with the aerospace industries and research labs are a priority for ONERA. Closing-up industry and the research world also make up a priority for the State that favored new tools to be created these latest years. In this respect, ONERA is a founder-member of the three aerospace competitive clusters: ASTECH in Ile-de-France (around Paris), PEGASE in Provence-Alpes-Côte-d'Azur and AEROSPACE VALLEY in Midi-Pyrénées. The clusters help closing up large groups, SMEs, research centers and higher education establishments around projects, bringing in value to be add to industry within a few years. Another innovative tool: the Carnot Label. This label, rewarding the ONERA in 2007, distinguishes the pubic research organizations/establishments that are most able, in precise contract terms, to meet research needs expressed by industry. Directly inspired from the German model, e.g. the Fraunhofer Institutes, the Carnot Institute as network is mainly devoted to increasing technology transfers and partnerships between public labs and private firms. In April 2011, the ministry for research and higher education launched Carnot 2 as network; it extends and deepens the first experiments. In this respect, the ONERA label was renewed, along with 33 other institutes. As a whole, these 34 Carnot 2 institutes represent 15 p. cent of the French public research personnel, who carries out 50+ p. cent research contracts with industry. The Carnot label also demonstrates that scientific excellence and an attentive ear to industry requirements go along together. Carnot operating principle is simple: each one institute receives funding directly from the national research agency (Agence Nationale de la Recherche). Its amount is computed as a function of contractual performance of the institute with industry. Such resource contributes to research steps dedicated to preparing the future and, in fine, reinforces scientific excellence.

> “ONERA main target within the Carnot network is to build up research proposals as close as possible to the requirements of the aerospace industry by associating relevant labs in the network.”

ONERA main target within the Carnot network is to build up research proposals as close as possible to the requirements of the aerospace industry by associating relevant labs in the network. Also concerned – beyond the Carnot network proper – associating oneself with the best competencies to be found in academic research labs. The aeronautic - airspace - defense industry/ies call(s) on a wide array of scientific disciplines for its research and technological requirements. The target in view is to make up some alliance among Carnot institutes around ONERA, and be able to build up a research offer able to provide a competitive edge for the French and European industry. ■

Photo above:
Calculation of turbulent flow generated by a landing gear through acoustic analysis. ONERA-NASA cooperation. (© ONERA)