A STRATEGIC INVESTIMENT FOR OUR NATION: EDUCATION ON HELICOPTER ENGINEERING

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Summary: There is no doubt that, regarding the defense industry, the use of helicopters turned into a key-factor for success. This involves military troops transportation and observation roles, and, especially, the helicopter is right now the most important asset to guarantee the effective logistics in the theater of operations in the modern war scene. In civilian applications its applications are even more versatile: they go from the sight seeing so important to the tourism and movie industries, to telecommunications, rescue and recovery in a calamity environment, up to inspections for preserving environmental reserves. ITA has kept a minimum set of courses and a research line in Helicopter Engineering for the last 11 years. The courses aim the formation of the aeronautical engineer and of engineers with a mechanical-like background, and are offered to complement the technical education of both test pilots and test engineers. The substantial growing of the civilian market in the last 10 years, especially in countries like Brazil, demands, at least for the medium term, a continuous and higher investment on education in this field of the aeronautical knowledge, if Brazil indeed decides to acquire a so desired international technological independency. This article analyzes the strategic importance of the education on Helicopter Engineering based on the experience accumulated so far, and points details on how other countries attacked the problem and invested to better their rotorcraft technological knowledge.

Key-words: *Rotorcraft Knowledge, Helicopter Engineering, Centers of Excellence*

1. HISTORICAL SCENARIO

From its humble beginning up today's state-of-the-art technological involvements, the rotorcraft industry went through a continuous learning process. In the 1920s and 1930s, Juan de la Cierva (and his Cierva Company in Spain and UK) was setting high the Cierva brand image, selling his Autogyros both in Europe and in the USA. Sometime prior to the WWII, in the mid-1930s, there was even a campaign throughout the US pushing the idea that every American family would end up with an Autogyro in their garage. There was even and Autogyro, the Pitcairn AC 35, which was certified for public road traffic: after landing in a big field or plaza in the city, the pilot used to fold the blades, lock them up, and start driving the gyro as if it were an automobile (DISCOVERY CHANNEL video, 1990). Igor Sikorsky came to land with his XR-4 in an aircraft carrier only in 1942. This historical shipboard landing marks the closing a long-waited contract with the US Army for selling his aircraft to the US DOD. His historical flights in 1939 in fact demonstrated to the DOD generals and other decision-makers present in the event that the helicopter was a very controllable aircraft in hover. But with its three tail rotors (two with vertical axes and another with a horizontal axis---this, by the way, was the one to survive as part of the classical configuration), though controllability was conquered after years of trial and error development, the aircraft could not fly in forward flight (AMERICAN HELICOPTER SOCIETY video, 1994). Other pioneers involved Louis Breguet and Paul Corny (France, since 1907), Antoine Flettner (Germany, 1940s), Kamov (Russia, 1940s on) and the several other American pioneers who followed Sikorsky: Young (pioneer of the Bell Helicopters), Piazecki (the brain behind the first involvements of Boeing Helicopters); Charles Kaman (founder of Kaman Aerospace), Hiller (who started the Hiller Helicopter Co. by the time he was 17), Hughes (pioneer of Hughes and the future Mc Donnell Douglas Helicopters, today Boeing's). What the legendary test pilots tried to show, by then, is, in fact, that the helicopter was---and still is---the only aerial machine capable of doing some particular operations and involving a suitable tradeoff between performance and financial investment for doing so.

In Brazil, after the establishment of the Technological Institute of Aeronautics (ITA) in 1950, an offshoot of the renowned Technical School of the Brazilian Army (ETE)---today's Military Institute of Engineering (IME)---, the famous Professor Heinrich Focke came to Brazil and stayed from 1951 to 1953 to head the development of the Convertiplane Project (an aircraft which today has an enhanced configuration consolidated in the Bell-Boeing V-22, tiltrotor and its Bell-Agusta BA609 light civil version). Due to lack of funds, Focke went away in 1953, leaving some of the great names of aeronautical design, who belonged to his team, working with the Brazilian Technical Aerospace Center (CTA), like Joseph Kovacs, and Swoboda, who also came from Europe and joined the Convertiplane effort. Eventually, from the late 1950s to the mid-1960s, a spin-off is the Beija-Flor Project, which came up and passed away, inserting itself, anyway, in the Brazilian aeronautical construction and design history as a major milestone.

In fact, the hover capability is responsible for keeping historically the helicopter as an invaluable aircraft to the military. Today the helicopter use involves other important applications: attack, firing stand, observation/scouting and NOE (nap-of-the-earth) flights, search-and-rescue, anti-submarine and mine-finding warfare, armed reconnaissance. It's clear right now that the helicopter is a strategic asset in the war theater of operations: the speed associated with the logistics advancement into enemy territory is now 24-fold the one available during the WWII times, which had the JEEP (**G**eneral **P**urpose Vehicle) as its major driving force. Today's already aging Boeing AH-64 Apaches are worthy 17 state-of-the-art armed tanks, say strategic analysts. Other historical record shall be mentioned: thanks to modern medicine and to the Bell Hueys, more than 99% of the US troops wounded in Vietnam survived (AMERICAN HELICOPTER SOCIETY video, 1994).

In the civilian world, much more applications are available. Helos are used in floods and fires, in the media industry to inform daily traffic jams, in emergency medical services (EMS), search and rescue, as the key-transportation vehicle for the timber industry, in the transportation of bridges and towers, in agriculture pulverization, fertilization and pollination, in the tourism sight-seeing and marketing industry, for monitoring power lines and for the bank-value transportation sector. Two of the most recent applications are the airline transportation (a long-waited dream) and business/corporate services, due to the increase contribution coming from the fractional ownership options available lately for the rotorcraft. In the Brazilian scenario, helicopters can be also employed as an integration machine for the multiple modal transportation industry, linking rivers, harbors and industry plants.

2. TECHNOLOGICAL EVOLUTION AND CURRENT STATUS

From the stability problems in hover and in forward flight faced by Sikorsky in the late 1930s up to now, a long way of conquering technological challenges and innovating are worthy of mention. Technology steps involve engineering and it goes along with manufacturing, operation, world and local market scenarios, funding. One of the best examples showing the involved complexity is mentioned by John F. Zughschwert (Preface of PROUTY, 1985): “In looking at the entire vertical-flight industry of today, one does not find many Sikorskys, Kamans, Hughes, Piaseckis, or Youngs. These men were the original designers, engineers, operators, and salesmen of the helicopter industry. They knew and understood the system from start to finish---from the theory needed to design the aircraft to the expertise needed to actually fly it. How many engineers working in the industry today are also qualified and licensed to fly the machines they are designing, developing, and manufacturing? Conversely, how many operators are fully qualified to design and manufacture their own product?” Early days problems starting with questions like, “Why should I invest in a project like this? What will be its application? What will be the return in doing so?,” when a pioneer tried to get funding for the development of the fully articulated rotor, the swashplate mechanism, the implementation of the cyclic mechanism along with the conventional helicopter configuration with one main rotor and one torque counteracting tail rotor are more than 60 years away already. And one can bet if Juan de la Cierva, Heinrich Focke, and Igor Sikorsky, respectively, were alive and asked “How was it?,” they would say “Well, a drill, but, anyway, it was just like it had happened yesterday!”

It is unquestionable the high-tech contributions coming into the rotorcraft industry scene in recent decades. Just to mention, the high quality and reliability of structural composite frames, the tiltrotor and its folding version, the Joint Strike Fighter, the noise-tuned blades and so on. Right now the buzz-words are “capability create markets”, due to the bent in civil rotorcraft sales, which is closely related to the general aeronautical industry counterpart[9]. The challenge before the rotorcraft industry in special is to deal, without delay, with its long-known dilemma (FLATER, 2002): “Helicopters and tiltrotors can offer answers to national security as well as pressing transportation needs, such as increasing air system capacity and reducing congestion and delays. Yet the markets for rotorcraft---both military and civil---have long been constrained by high acquisition and operating costs, excessive noise and vibration, and perceived lack of safety.”

Obviously, to better understand the necessity of investing in rotorcraft engineering education, one needs to understand what’s in the backstage these days. Technical challenges embedded in the before-mentioned dilemma have been, for years, to reduce costs and weight, to reduce noise, to catch up for human machine interfaces. Experts know already possible ways to go for (FLATER, 2002). To deal with reduction of costs and weight, one shall pursue radically new approaches in materials, processes, and manufacturing. The upcoming nano-phase materials technology can reduce aircraft’s empty weight fraction up to 30 percent. But it has to come along with the makers facing the needs for developing low cost hybrid materials and manufacturing methods suitable to low rate production stack. Options in the sense of reducing parts count and permitting flexible operation, involve the combination of “bearingless” with “swashplateless” rotor systems. To the American public especially, rotorcraft noise is tightly linked to the perception of an inherent lack of safety. To reduce noise by at least 15 dB, the sector needs to pursue self-tuning rotors for optimized variable rpm operation, as well as improved rotor geometries and control strategies with affordable (and reliable) actuation systems. Going into the interior noise, new research and development on quieter gears, pumps and generators, along with lighter and reliable drive shafting are the experts’ choices to be focused in. Human-machine interfaces have recently followed the convergence of digital logic and digital power. The marketer’s ads maximum that “it’s already feasible to imagining you turning on the rotor system, setting in the navigational options, and lie back to relax and just enjoy your helicopter trip till getting into your destination" is still a stretch of the tongue… There's still a long way to go.

To push the envelope, FLATER (2002) goes for an imagination exercise: "Now imagine a new intelligent rotorcraft system, with distributed sensors, processors and actuation devices that actually tailor drag and lift, counter vibration, diagnose faults and implement corrective actions. Consider the possibility of an efficient, active rotor offering continuous control of shape and airflow to achieve near-ideal performance. Techniques to get there include smart material "morphing" blade geometry; swashplateless control; reverse velocity airfoils; active blowing and boundary layer modification; active vibration and noise control; low noise geometry; and variable-speed, intelligent, self-reconfiguring drive systems." And points out that the way to get there is to use Japanese Kawasaki's, Fuji's and Mitsubishi's "technology fusion", in which, for a particular discipline in one industry, revolutionary advances are quickly transplanted to another in a wholly unrelated industry, resulting in enormous gains in productivity.

3. WHAT HAS BEEN DONE IN THIS AREA

Traditionally, the education on Aeronautical Engineering in Brazil throughout the years since the late 1940s and early 1950s---taken care almost exclusively by ITA---has set its core business in the fixed-wing aircraft. And this is not so difficult to understand: historically, aircraft makers push the growing in the sector, and the pioneering aeronautical companies in Brazil were created to project, develop, manufacture and commercialize that type of aircraft. It's not a hard stretch of the mind imagining that things would be different (probably more diversified in terms of the modal-aircraft configuration options) had the Beija-Flor taken off literally…But from the early 1960s trials with Avibrás ("Aviões do Brasil") and Aerotech, were just setting the stage for the future role played by EMBRAER ("Empresa Brasileira de Aeronáutica"), which along the years turned itself a transnational company, located in five continents, one of the giant makers aimed to global airline, defense and corporate markets, recognized worldwide, a real benchmark in the sector.

In the 1970s and 1980s, a course entitled "Helicopter Theory" was already part of the Aeronautical Engineering curriculum. Its objectives involved the opening of the envelope of the rotorcraft knowledge for the aeronautical engineers wannabes, and its contents covered the basic aerodynamic and performance in hover and forward flight regimes of operation, ground effects studies, along with notions of the blade dynamics, stability and control.

In 1992, due to a decision made by ITA's Graduate Studies Division Board, a program involving four courses in Rotorcraft Engineering was established. The courses were: "Aerodynamics and Performance of Vertical Flight Aircraft", "Helicopter and Rotary-Wing Aircraft Aeroelasticity", "Rotorcraft Dynamics, Stability and Control", and "Helicopter Aeroacoustics and Compressibility Effects," supposed to be taught by two professors. Even though the courses were optional for the ITA undergrads, a lot of them took the courses, having as peers flight test engineers and test pilots. With time, due to the loss of availability of one of the faculty, only the first two courses kept being regularly offered. This new scenario forced the customization of the remaining courses. The first course, renamed as "Aerodynamics and Performance of Helicopter and Rotary-Wing Aircraft," now has a new approach: besides offering all the associated basic and intermediate technical concepts, the goal is to give the student a pretty good picture of the historical development of the configurations, civil and military operations, market figures, and discuss the current technological challenges. This rotorcraft scenario summary takes approximately a quarter of the course timeframe. Altogether, the goal in the course is to offer a realistic idea of the rotorcraft industry and its involvements in today's world as an additional complement to the technical aerodynamics and performance theoretical material associated with both the vertical and forward flights of rotorcraft. At least one of the evaluations involves an individual seminar, so the student can enlarge some specific topics that are not covered in the course. While the first course gives a broad view of the rotorcraft sector and technical fundamentals focused in the aerodynamics and performance, the second course goes into details related to real technical challenges involving the rotorcraft, which, to be understood, demands a considerable understanding of the dynamics of rotary-wing aircraft systems. It was renamed as "Dynamics and Aeroelasticity of Helicopter and Rotary-Wing Aircraft." In terms of contents, the course touches aeroelasticity aspects linked to both aerodynamics and structures. It is within this course that the student start touching the real challenges involved in the rotorcraft engineering design. Conventional evaluation, like in-class tests, gives place to home projects and seminars. Currently contents involve dynamic inflow, flapping dynamics, harmonic balance and trim procedures, Floquet theory, multi-blade coordinates analysis, rotor-shaft instabilities, with a detailed discussion and application of a simple ground resonance dynamic model. The references for the current courses in the program are JOHNSON (1980), PROUTY (1985, 1988, 1990, 1993), DOWELL (1994), BRAMWELL (1976), GESSOW AND MYERS (1952), SEDDON (1990), BIELAWA (1992), US ARMY (1972, 1974, 1976).

Along the last 15 years dozens of students had taken the course, most of them ITA aeronautical and mechanical undergrads, flight test engineers, and test pilots. Sparsely in the 1980s and more systematically during the 1990s, some related research lines have been started and developed, like unsteady aerodynamics applying the generalized dynamic wake model; rotorcraft aeromechanics especially applied to the ground resonance phenomenon; helicopter blade flutter instability in hover flight; helicopter performance in autorotation including both hover and forward flight; lift compound helicopter performance analysis; and, more recently, nonlinear analysis of flapping motion of helicopter rotor blades in hover with gust effects, which has a wide application for flight deck operations for the Navy helicopter carriers. Some MSc alumni are working in different fields of the aerospace industry in Brazil, and MSc and Doctor-to-be students are still participating in the academic process. Since 1995, the research work has been supported by the Brazilian Council of Development and Research (CNPq) through Research grants. During the 1995-1997 period an Integrated Project was approved and carried out, and it involved the CNPq grants of 17 scholarships in total for ITA professors, along with undergrad and grad students. Tens of graduate work dissertations, especially involving rotorcraft applications have been produced for the last 20 years. Also, special lectures have been offered with the Flight Tests Division rotorcraft's courses. This is a division with the Aeronautics and Space Institute (IAE), one of CTA R&D institutes, operating like a test pilot and test engineer school, thanks to which a close cooperation with ITA in the rotorcraft technology field has been effectively pursued, turning into a key-factor for validation of theoretical methodologies and for complementing classroom activities. This is the only one of a kind within the World's Southern Hemisphere.

Some attempts to go for innovative helicopter projects happened along these years as well. In 1995, a project of a fertilization and crop-dusting agricultural helicopter was conceived in the University of Taubaté (UNITAU), result of a cooperation involving the Mechanical Engineering and the Agriculture Departments, which had the backing of the Brazilian Army Command located close to the then incipient rotorcraft nucleus. The project was abandoned after losing the desired grant from Brazil's Sc&T Ministry Project and Studies Financing Council (FINEP) in the first version of its program for fostering center of excellence (PRONEX), a just created fostering program. Still, in the 1997-1998 a project of a multi-task light helicopter, having the dynamic set of the Schweizer 300 reciprocating-engine helicopter, which involved international partnership with companies like the Virginia-based Dynamic Engineering Incorporated (DEI) for the conceptual design phase and a ground vibration lab installation, was abandon due to the quitting of a São José dos Campos-based aerospace company from the proposal, after entering in a bad financial situation following the Asia financial crisis of October 1997. São Paulo State Research Fostering Foundation (FAPESP) was on the verge of approving the funding for the project (approximately USD 2.5 million). But to do so, a counterpart from the partner company should be granted, a fact that eventually did not come true.

4. STRATEGIC THOUGHTS

A consolidated view regarding the education on Rotorcraft Engineering, after years of dedication work in this area, is that a strategic planning shall be pursued involving all the stakeholders (Armed Forces, academia and industry) so here in Brazil one would be really prepared to deal, in an effective-way basis, with the activities present in the portfolio of the demanding international market related to rotorcraft.

Regarding the Armed Forces, one way to improve participation and fulfilling the needs is to promote a close relationship between engineers and operators. It seems that the operational interface involvement shall push the investment, because there is no doubt that a good solution to the daily needs can save direct operational costs and open spots for further investment. Seeds have been spread out through courses taught through the Flight Tests Division in CTA for years. In these courses, in addition to the high level of the technical and hands-on contents/activities involved, the opportunity of having around, in a full-time dedication basis, officers from all the Brazilian Armed Forces, has brought a singular environment for professional and personal growth. There is a mutual exchange of experiences, knowledge and work mindset. Because the course has an intense workload, normally there is no spare time for stretching the relations and set new partnership involvements, and, for sure, this is a key-point for taking advantage of the current scenario and guaranteeing effectiveness in the follow-up process.

In the civil sector, there is a pushing coming straight from the market: Brazil has led the ranking for the rotorcraft civil fleet percentage growth worldwide, since 1993. A qualitative and quantitative evaluation of the country's market (CARVALHO NETO, 1996) pointed out where our helos are, which are the major target-public segments, what are their contribution to the overall figures, and what are the most important brands and their respective sizes. Everyone has heard that São Paulo has the world's second largest fleet of helicopters operating in a daily basis. In fact, right now, the total Brazilian civil fleet is just below the first thousand aircrafts, and São Paulo State's contribution nears 70 percent of it. As it has happened mainly in the US, the corporate industry has ceded to the helicopter appealing for responsiveness and traffic jam bypasses. In 2001, a São Paulo-based company called HELISOLUTIONS, a subsidiary of AUDI Helicopters, started its "fractional ownership" services, having its operations focused in the executive transportation within that capital. Richard Aboulafia, an executive with the well-recognized market-oriented tank Teal Group, recognizes that São Paulo Capital is a unique benchmark for this type of services worldwide.

A main issue that easily overlaps the two operational sectors is Aviation Safety. Though the statistics show that the helicopter is by no means less reliable in this respect compared with the fixed-wing aircraft, human-related incidents and accidents still are responsible for something in between two thirds and eighty percent of the total figures. An investment in this area, which is the growing-most sector of prioritization in an internationally scale, is a must.

Whenever an international institution comes to visit CTA and ITA lately, seeking cooperation, the buzz-words invariably involve AVIATION SAFETY AND HUMAN FACTORS. Obviously we need to start a real strategic program based on these areas for fostering the military and civil sectors along with all their operational and logistical involvements. EMBRAER recognizes this as a priority and has started a program for the so-called Human Factors Centered Design Program, led by Paulo Roberto Fernandes Serra, one of its senior engineers, a professional well-recognized by his contributions and experience with "risk assessment" in this field.

Stopping to envision where and how to invest for an effective preparation of human resources in this area is an important point. A first step that comes to mind is: how these challenges have been dealt with by other people? A program that transformed itself into a benchmark regarding the high-tech investment in rotorcraft technology knowledge is that sponsored by the US Army so-called Rotary-Wing Aircraft Centers of Excellence (COEs) (WARTENBERG, 1983). The Army Research Office (ARO) "Centers of Excellence" program started as a way to increase the amount and quality of rotorcraft research at the university level and attract well qualified graduate students to this area of engineering. By 1980, the US Army had set the reasons for funding such a program. Present in the official reasons for such an investment were: rotary-wing aircraft are vital to Army and other military services; rotary-wing aircraft technology is extremely complex and far behind fixed-wing technology, and the need for establishment of a small number of R/C COEs among respected US universities. The RFPs for a nationwide competition went out in 1982. Three institutions were selected: Georgia Institute of Technology (Georgia Tech), Rensselaer Polytechnic Institute (RPI), and University of Maryland. Proposals were received from other 14 well-recognized academic institutions in the aerospace sector, like MIT, Stanford University, Princeton University, and Pennsylvania State University. The explicit objectives for the COEs contained: conduct leading edge research in areas of importance to rotorcraft; provide a continuing source of trained engineers and researchers to industry and government; and make easier the transfer of research results to industry and government for use in rotorcraft design, analysis, and development. Just as an example, in financial terms, in the FY1990, this program brought a total of USD 1.45 million for Georgia Tech, USD 950,000 for RPI, and USD 880,000 for the University of Maryland (US ARMY, 1992). By the start of the third phase of the program, 1993, after the experience demonstrated in the Gulf War of 1991, a status meeting was held at Georgia Tech to evaluate the previous and future investments. The modus operandi in the COEs were well-established by then, and contemplated: (1) offer sufficient R/C specific courses on one campus so as to constitute comprehensive educational programs in rotary-wing aircraft technology; (2) conduct research in areas identified by government and industry as being critical to the advancement of rotary-wing aircraft technology; (3) conduct on-campus operations so as to promote university contribution and undergraduate involvement; (4) conduct periodic on-site reviews with Army Evaluation Panel and respective Advisory Boards of program content and direction; (5) team with other government and industry organizations on research and engineering projects where COE research can feed directly into advancements in rotary-wing aircraft technology and COE research efforts can be "fine-tuned;" (6) conduct special conferences, short courses, symposia and workshops to ease technology transfer of the most recent results to the rotorcraft community; and (7) expand the support of rotorcraft research so as to become self-sustaining. By the same period, concerning future R/C COE's plans, the status document showed: (1) that rotary-wing aircraft are more vital than ever for the military services; (2) made clear the current obstacles to achieving full potential of R/C; (3) that changing world environment dictates closer alliance of rotary-wing community; (4) a need to establish an industry-university international consortium to continue advancement of rotary-wing aircraft technology; (5) a need to gain customer support for Army sustaining funding of R/C COEs. Bottom line, the following issues were disclosed: (a) R/C COE's faculties are strong in rotorcraft technology and a critical multidisciplinary mass has been achieved on these campuses with interdisciplinary research being accomplished; (b) a variety of R/C specific course offering are provided with a breadth sufficient for comprehensiveness and a depth sufficient for cutting edge contribution; (c) outstanding young people are being attracted to rotorcraft studies at the R/C COE's; (d) a large number of graduate are already making significant contributions in the rotorcraft industry and government; (e) many highly capable rotorcraft specific facilities are on line; and (f) research contributions are significantly advancing rotary-wing aircraft technology. Today, Penn State University replaced RPI as the third COE. This American experience is basically unique over the world, having attracted around a thousand international students since its start. US universities outside the R/C COE's, have a hard time in keeping a program of courses involving courses on a regular basis in this field. This scenario is the same for other country's counterparts: normally skilled people in this area are working for the makers or for the government.

Obviously, the scale effect matters: right now our military fleet has less than 400 helicopters; in the US there are more than 9,000. On the other hand, considering the needs of our Armed Forces as a whole, our vast territory, setting aside the difficulty in waging the defense sector, the demand figures are much higher than the ones Brazil has in hands right now. The US counterpart of our approximately 900 civil helos is a figure around 11,000. And, by the way, investment on rotorcraft education can work for both sectors if a solid basis is there. A key-factor here, which also works both ways, is our territory landscape. Experts say that our position, in this regard, is practically second to none!

5. CONCLUDING REMARKS

Helicopter Engineering education is a strategic asset for the future of our nation aerospace and defense sectors. From the first aeronautical project led by Heinrich Focke, "the Convertiplane" to the leading edge technology available today by means of EMBRAER's 170/190 family of regional jets, a solid technical and scientific background has proved to be the cornerstone of the whole process. For sure, in the rotorcraft knowledge embedded along the years within the involved human resources is a paved road for any future investment the country comes to undertake. And this includes even a new helicopter-making company for the future. It's apparent that, comparatively, a critical mass has been built for this and is even more robust than the one available during the pioneer times of the fixed-wing aircraft industry, some 30 to 40 years ago. The point is that many more people shall joint this effort. And the creation of an industry, a initiative that involves a millionaire investment, can grant the necessary impulse. Right now, one can say that it's common sense that the investment in education means costs saving for both the government and the industrial sector in general. Questions like these will have similar answers: Why starting to build some prototype if taking advantage of virtual prototyping a lot of the real design issues can emerge to become clear? Why including in the conceptual design development phase a technique that theoretically proved itself as being ineffective (either in terms of the isolated system or through simulations), by showing itself incapable of improving the overall holistic integrated aircraft performance or flight quality? When a decision-maker comes to realize the return on investment given by a Center of Excellence especially tailored to attend the industry's demands and challenges, it becomes evident to him why some countries opted, a long ago, for prioritizing the educational process.

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