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STRATEGIC ALLIANCES AS AN ADVANTAGE IN FACING THE CHALLENGES OF FUTURE AIRCRAFT ENGINE DEVELOPMENT

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Abstract

Over the last decades, aircraft engine design has become an increasingly complex project. The complexity of an engine's design can be considered from two perspectives: technical and organizational. The technical challenges presented by aero engines design have been known since the very beginning of aviation history, as these are the challenges that an engineering team needs to deal with on a daily basis. They evolved over time, together with engine design development, but were always considered part of the process. Today these problems may be bypass ratio, high pressure, high temperature, pollution and noise emissions, but also the technical solutions' impact on durability, reliability and maintenance. The organizational aspect however, is not so clear and obvious to determine. The importance of this issue depends on the scale of the project, the source of funding or various political influences. There is also a mid-position perspective connecting the technical and organizational ones – the technological readiness of the organization planning the new project.

It is essential to consider these challenges, to evaluate them and to include them in the risk management plan at an early stage of the design program to ensure that the organization will obtain the final result: an operational and competitive aircraft engine. The solution proposed in this paper is for the organization to find a strategic partner or partners in order to limit risk and maintain a competitive position. A prime example of the creation of such a strategic alliance and of its benefits is the partnership between the General Electric Company (GE) and the Institute of Aviation in Poland. The authors provide the timeframe and the investment needed to organize several key R&D centers. They also provide details about laboratory equipment and the potential of the R&D centers/laboratories. All these figures are based on 15 years of experience gained while working on building the strategic alliance between the Institute of Aviation and General Electric, co-organizing in Poland engineering offices for GE Aviation, GE Power & Water, GE Oil&Gas, and GE Aviation Systems. Combining the authors' experience and knowledge, this paper is a unique compilation of technical and strategic management information about technical and organizational challenges. The authors also put forward the idea that such strategic alliances may be a solution, or part of a solution, to the organizational challenges mentioned above.

Keywords: engine design; durability; cost; investment; alliance; risk.

1. INTRODUCTION

In the contemporary, globalized aircraft industry the engine design process is becoming more complex and ever larger investments are needed to overcome the challenges during this process, as well as to optimize the risk level associated with this activity. One of the effects of this increasing complexity and need of funding is the necessity for cooperation between different science or R&D centers. There is significant literature (especially in Strategic Management) describing the advantages of cooperation between entities, but only a small number of scientific publications is devoted to the cooperative relations with R&D centers.

The issues of cooperation have been discussed for over a hundred years, although the beginnings of these relationships are found in the area of military strategies and concepts already two and a half thousand years ago in Sun Tzu's treatise [1] Joint-ventures were known in Ancient Egypt, Babylon, Phoenicia and Syria [2]. Great expeditions to conquer new land and establish trade routes from the 15th until the end of the 19th century could be carried out due to established alliances [3, 4]. A significant growth of interest in cooperation is dated back to the 1980s [5]. Initially, research was concentrated on individual cooperative relationships – strategic alliances [6-10]. In the last decade researchers focused their efforts on multilateral relationships – network relations [11-15].

Cooperation has been the subject of conceptual works based mainly on achievements of both transaction cost theory and game theory. In transaction cost theory it was considered as a hybrid form of inter-organizational relations limited between two extremes: market transactions and hierarchical structures [16-20]. Each of these extremes has its typical transaction costs. Market transactions generate costs related to understanding and controlling a new market situation, supporting information with research and persuading partners. Hierarchical structures however have to face up to bureaucratic costs of agency, evasion, free riding, measurement and coordination. These costs are caused by such factors as: specific assets, uncertainty and complexity of the environment, information limitations, continuity of transactions and bureaucratic costs [21, 22]. The failures of hierarchical structures and market transactions induce an organization to establish cooperative relationships [23]. However, cooperation requires the creation of earmarked assets which are protected by long-term contracts and mutual trust [24]. The exchange of assets ensures mutual safeguards against transaction risks by creating a situation of mutual hostages [19].

In game theory cooperation is perceived as a non-zero-sum game. It is based on the prisoner's dilemma [17]. The players are encouraged both by the repeatability of movements and the tit for tat strategy (based on reciprocity [25]), as well as shadow of the future [26]. Cooperation is more advantageous if it has a strategic character [27, 28]. It reduces the opportunistic behavior of the players [29].

Cooperative relationships occur in sectors with considerable uncertainty of demand and rapid changes of knowledge and technologies. Uncertainty of demand occurs mainly in high-tech sectors: ICT, biotechnology, aerospace including aircraft engines, nanotechnology and materials. Environment uncertainty is related to competition growth and the occurrence of symptoms of hypercompetition [30] and globalization [31]. Reducing the product lifecycle, intensified attacking actions (and their retortions), (open and secret) price wars result in the erosion of competitive advantages [32]. Empirical research by Thomas III [33], M. Harvey, M. M. Novicevic and T. Kiessling [34] proves that one of the effective ways for enterprises to survive and develop in the hypercompetitive globalized environment is to grow their innovation and cooperation competences [35].

This article focuses on examples from the aerospace industry and in particular on the challenges that companies and R&D centers have to face developing new products on the aircraft engines market.

As was mentioned above, the constant development of new technologies, new materials, and new processes has rendered the designing of a new aircraft engine a very complex endeavor, and if current trends continue, this complexification will only intensify with time. In addition to the traditional technical perspective on aircraft engine design, this growing complexity can be viewed from an organizational perspective as well. While it can be said that generally the technical complexity scales with the size of the project, the organizational complexity depends not only on the size of the project, but also upon factors such as the source of funding or the various political pressures that may impact the project. A third aspect to consider consists of the technological readiness of the organization undertaking the project.

It is essential for an organization planning the development of a new aircraft engine to carefully and fully assess all of these aspects of the design process and to integrate all the challenges and risks arising from them into their project planning and their risk management plan. Without this approach, and taking into account the extreme complexity of modern aircraft engines, it will be very difficult to achieve such a project's goal: to bring a competitive and safe aircraft engine to market.

As soon as the design organization that considers developing a new aircraft engine assesses all the challenges it faces, it should classify them all. The key/method described above may be used to divide the challenges into technical and more organizational ones. As a next step the organization should plan and review possible solutions to address these challenges. This is particularly important because at present no company, including the major players on the market of aircraft engines, such as Pratt&Whitney, Rolls Royce or General Electric, do not even consider new product development on their own. Long established organizations such as these concentrate on key resource usage optimization or dedicate their own people to supervise key activities using external resources where possible. They also endeavor to share the risk connected to challenges (both organizational and technical). It is necessary to stress the fact that all these companies are proceeding in this way despite each of them being capable of performing this kind of development on their own. Organizing all kinds of cooperation, including strategic alliances, is one of the methods to decrease the level of risk and in this way to survive in such a demanding high technology market like aircraft engines [7].

If we consider the fact that even such players as General Electric, Pratt&Whitney, or Rolls Royce see the advantage coming from cooperation with other businesses present on the market, we may arrive at the conclusion that other organizations, research institutes or universities cannot ignore such opportunities if they want to play any significant role in this sector of the market. The Institute of Aviation in Poland can be considered a prime example of a research organization which has benefited greatly from cooperation in the form of a strategic alliance with a major foreign corporation. .

The Institute of Aviation was founded in 1926 as a research and development organization responsible for the elaboration, but also the evaluation and support in incorporation of ideas for the aerospace industry in the freshly revived Republic of Poland. At the beginning of its existence the Institute of Aviation took full advantage of government subsidies and additionally could rely on a group of patriots animated by the spirit of their country's independence after the WW I. During the 20 years between the World Wars the Institute of Aviation developed, tested or successfully incorporated a great number (around 100) of structures and technical solutions. Examples of aircraft from this period are PZL P. 7a, PWS – 26, PZL P.24, P-11c, RWD 14, and many others aircraft and gliders.

After World War II, the Institute of Aviation was the leader for research and development for aircraft and aircraft engines in Poland and one of the most important players in the so-called Eastern Bloc. The overall situation after the war in Poland and in particular the willingness to rebuild a ruined country based on in-country capability were factors that allowed the Institute to build its role and position. The geopolitical situation in the region was also an important factor. In effect, the Institute could use almost unlimited resources. As a result many airplanes and aircraft engines were developed during this time. The most famous in region are perhaps the jet trainers ISKRA and IRYDA. The latter was never introduced to service in the air force due to political and economic turmoil following the fall of communism in Poland, even though it was one of the best in its class at the time. As to aircraft engines, the Institute worked on many different technologies and products like the SO-01, SO-03 or K-15 jet engines. Many piston or rocket engine technologies were also developed and tested at that time.

After the Eastern Bloc collapsed the situation of the Institute changed dramatically: The end of the trainer jet fighter Iryda program connected with a rapid cut off from financial subsidies from the government caused that the Institute could not even think about new programs and had to focus on its survival. In 1999 the Institute management came to the conclusion that without a strategic partnership with industry and/or other scientific organizations it would not be possible to survive in the demanding market of aerospace research and development. In early 2000 an opportunity to turn the situation around appeared – a strategic alliance partner was identified – the General Electric Company.

The General Electric Company is one of the oldest corporations and since the very beginning has been actively present on the high technology market. It has been operating continuously since 1891. During the course of the year 2000 GE Management came to the conclusion that in order to stay competitive it would be necessary to globalize their area of research and development and agreed to make strategic alliances in this scope. This resulted in the creation of the Engineering Design Center in Poland, which is a strategic alliance between General Electric and the Institute of Aviation.

The Institute of Aviation created similar alliances, although on a different scale, with other companies active in the aerospace market as well as with scientific or research and development organizations like the Warsaw University of Technology, the Military University of Technology and many others. Since that time the Institute of Aviation has returned to the group of the world's best research and development organizations working on solutions for recent challenges in aircraft engine design.

2. EXAMPLES OF TECHNICAL CHALLENGES DURING AIRCRAFT ENGINES DESIGN

The challenges faced during aircraft engine design that are presented below illustrate the complexity of these problems and their associated costs and risks, and the way the Institute of Aviation has overcome them thanks to its strategic alliances with different organizations.

2.1. Engine design and testing on a detailed component level

In order to be able to design and test aircraft engines on a detailed component level it is necessary to have, except for qualified and experienced personnel of course, sufficient office capability, including accurate computational power, and sufficient laboratory capability. It is necessary to mention here that in the meaning of office capability in this context is not just a good computer, a desk and some office equipment, but also a computational cluster consisting of thousands of processors that are necessary to conduct Computational Fluid Dynamics (CFD) analyses, Heat Transfer (HT) analyses or dynamic analyses. Another cost that needs to be considered during design group organization is the cost of software – purchase and maintenance. Therefore the approach to the design as well as the software selection should be decided before the beginning of any engineering work. The cost of investment is generally dependent on the scale of the project.

The development of a test capability for bearings used in aircraft engines (one of the smallest but at the same time one of the most important engine components) or for engine fans (these are at the other end of the scale as to the size of the component, but they are just as important for engine

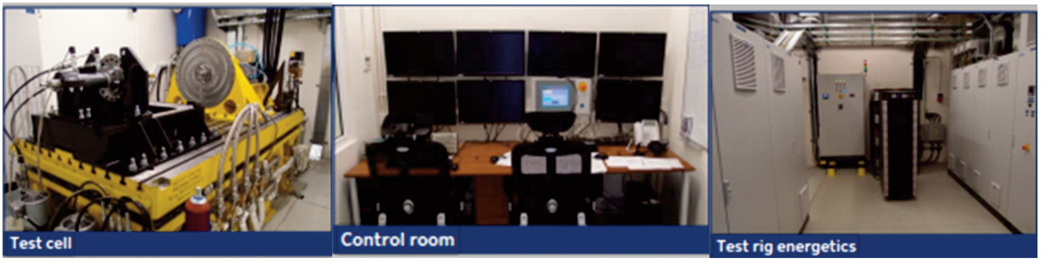
performance and safety as the bearings) can be a real challenge. Of course as in every project the test stand/laboratory organization has to have its own budget and resources. Some evaluations state that to organize a modern, two stand laboratory for bearing testing there is a need for 4 million US dollars, a minimum one year of time and essential help from somebody who's done it before (or much more time and money to gain the required experience).
To organize an engine fan test laboratory it is necessary to have about 10 million US dollars, two years of time and significant support from experienced experts. The difference in time and cost between bearing and fan labs does not result only from the size difference but also from different test natures and types (over speed, fan blade out, bird injection).

2.1.1. Bearing Lab

Two fully automated, flexible test platforms designed to test jet engine bearings, oil scoops, seals, gear boxes, AOS, etc. performance, endurance, functional tests flexible testing platforms.

Bearings Test rigs in numbers:

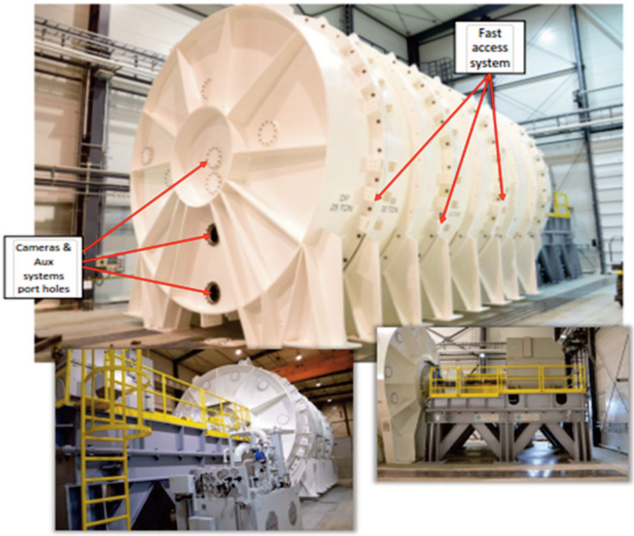
- Drive system (up to): 150kW; 22 000 rpm, dynamics 1000 rpm/s
- Lube oil system (up to): 120 l/min, 40 bar, 150°C, 4 feeding lines
- Oil scavenge system (up to): 6 lines, chip detectors, 0,28 bar(a)
- Load system (up to): 210 bar, 2-100kN, 4 hydraulic cylinders
- Hot air (up to): 0,9 kg/s, 6,21 bar, 550°C
- Control & data acquisition system: 700 I/O ch, up to 25kHz sampling frequency, measurements of temps, flows, speeds, pressures, stains



Picture 1. Bearing test laboratory in the Institute of Aviation in Poland

2.1.2. Engine Fan Test Rig details

- **Vacuum chamber**
  Size: 280CBM (5,5m in dia, ~12m - long),
  Weight: 170 tons
  Pressure: 1mbar(a) – 1 bar(a) in up to 40min
- **Drive system**
  6MW of power
  Two GBX (max 3k rpm, max 12k rpm)
- **Highly advanced DAQ**
  HSI (High speed imaging)
  Advanced time synchronization
  Explosives
  Slip ring + telemetry



Picture 2. Rotating components test stand in the Institute of Aviation in Poland

2.2. Detailed components cooling based on combustion chamber example

The combustion chamber by is seen by many (including the authors) as the heart of the jet engine (and any engine for that matter) [36, 37]. The processes taking place inside it have a direct impact on all key parameters specific to the engine. We are talking about, for example, carbon dioxide, nitrogen oxides, the chemical energy of the fuel conversion efficiency and thus the efficiency of the entire system. Pressure and temperature inside the combustion chamber are the highest observed in the entire engine, the temperature distribution at the outlet has a critical impact on durability of the rotating elements located behind it - the turbine [38]. To design a combustion chamber capable of meeting the expectations of the market, a laboratory is needed, in addition to the design office equipped as in the example on the design of components. This laboratory will evaluate the phenomena occurring inside the chamber as well as validate the theoretical calculations. Such a lab at the Institute of Aviation lab is called the Laboratory of heat transfer and flow mechanics (HT & FML) and was established in 2 years with an effort of about 2 million US dollars.

2.2.1. HT & FML design and methodology development MAIN ACTIVITIES

- Combustors flow checks (also with cross flow)
- Shroud, Hanger & Nozzle flow checks
- Shroud-Nozzle impingement cross flows
- Heat transfer tests, e.g. HTC
- Film cooling
- CFD validation
- Flow visualization

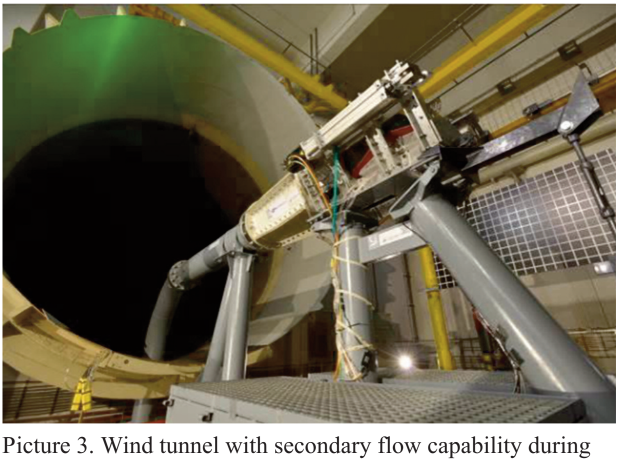
2.2.2. HT & FML TECHNICAL PARAMETERS

- Main working medium – Compressed Air
- Cold line – Air, up to 2kg/s@ 5 bar@T^{amb}. (4.4 pps@72psi)
- Hot line – Air, up to 1kg/s@ 5 bar@560°C (2.2 pps@72psi@1020°F), Planned

- ~70 measurement and control channels installed (>200 planned)
- Automatic & Manual test control mode
- Flow measurement range from 0.00075 up to 2kg/s (4.4pps)
- Pressure measurement accuracy <0.1%
- Flow uncertainty <1%
- Professional Equipment: NI DAQ system, High quality pressure transducers, PT100, TC's, Liquid
- Crystals, Pressure Sensitive Paint, CO_2 installation, Constant T Anemometry-Hot Wire, IR Camera

2.3. Detailed flow structure and cooling conditions in engine components on an entire system/module level

The key to verifying the product before putting it on an aircraft is studying the cooling process and the interaction of different flows in major components - modules of the engine and at the level of the entire system. Understanding the detailed workings of the flow of air or of combustion products within the complex structure of the jet engine is of extreme importance for its performance/efficiency as well as its reliability and hence safety. The cooling of components such as turbine blades or sections of the liner of the combustion chamber could be tested in a relatively small lab in a small scale. However, leakages from the compressor for cooling the hot parts of the engine, the anti – ice system or correct operation of the new generation thrust-reverser shall be tested in its entirety or, if this is not possible, the largest sections of these modules. For such testing/analyses it is necessary to have a wind tunnel installation and if possible an installation equipped with more than just one, major flow – secondary or tertiary flows if possible. The main flow in the tunnel represents the air stream flowing outside the engine and the secondary air flow simulates the internal flow inside the module. If there is a capability to add a third flow of different temperature for instance, we may simulate the cooling by impingement flow or cross flow heat transfer. These kinds of installation are still rare, which could be caused by the huge investment necessary to build them.. However the need for such laboratories with multiple flow capability should increase in the near future because the competition in aircraft performance forces about a race after any kind of (even the smallest) percentage in efficiency or improvement in reliability. The approximate cost of an accurate air installation with a measurement and data acquisition system is about 5 million US dollars (assuming we already have a wind tunnel capable of accommodating the additional installations).



Picture 3. Wind tunnel with secondary flow capability during test setup for a thrust reverser test.

2.3.1. Wind tunnel in numbers.

D=5m,
L=6,5m
V = 90m/s
P=5,6MW
M2=45kg/s
M2'=1,2kg/s. T=250°C
M3=6kg/s
PIV 3D system, High Speed Camera, tufts, smoke, etc...

2.3.2. Wind tunnel flow capabilities.

Upgraded in 2015, this low-velocity wind tunnel is a closed-loop tunnel, with an open measuring space, which has 5 meters in diameter and is 6.5 meters long. The dimensions, engine power (5.6 MW) and wind speed of 90 m/s place this tunnel among the world's leading low-velocity wind tunnels.

Additionally the wind tunnel is equipped with an innovative SF400 and SF80 secondary flow systems generating additional air flows, with the maximum mass flow rates of 45 kg/s and1.2 kg/s accordingly. The SF80 system also allows the air temperature to be raised to 250°C. This unique system permits the testing of an aircraft engine's internal components or their models under simulated takeoff and landing conditions and in increased exhaust gas temperatures.

Currently, the tertiary flow installation TF150 is being installed, with an approximated air mass flow rate of 6 kg/s.

2.3.3. Multi - flow Wind tunnel test capability.

- Secondary Flow tests: engine inlets, blocker door thrust reverser
- Flow visualization: PIV 3D system, High Speed Camera, tufts, smoke, etc.
- Measurements of velocity and turbulence distribution in the boundary layer.
- Cooling effectiveness in real conditions (cross flows, leakages, impingement factor, etc.), but also standard tests like:
- Aircraft models - aerodynamic characteristics of stability and maneuverability, pressure distributions.
- Aerodynamic load measurements on models of aircraft.
- Hinge moment measurements on control surfaces.
- Investigation of flutter characteristics, vibration frequency, critical speed, damping.
- Store trajectory tests including forced drop for cockpit fairing and underwing attachments.
- Buffeting tests.
- Helicopter model tests with rotor up to 3 m.
- Car and car model aerodynamics.
- Buildings, bridges, ships, trains - measurements of loads, pressure distribution, aero elastic stability and dynamic response.

2.4. Materials engineering – general testing.

Engine aircraft development requires a high end materials laboratory with word class specialists, even though the material properties of metals used in the aerospace industry are generally known, and that no new material compositions/alloys will be created.

This kind of capability is necessary to evaluate, among other things, samples in conditions that we assume they will work in in our new engine design, or to evaluate the construction after durability/performance tests – so called failure analysis. The minimum for test techniques that the organization considering engine design should be familiar with are given below.

2.4.1. Techniques used in the materials laboratory of the Institute of Aviation

- Non-destructive testing: Fluorescent and Dye Penetration Inspection (FPI and DPI), Magnetic Particle Inspection (MT), visual inspection (VT), Eddy-current testing (ET), Radiographic Testing (RT), Computer Tomography Testing (CT), Ultrasonic testing (UT)
- Sample preparation: Sample cutting equipment, sample mounting (cold & hot), Polishing equipment, Ultrasonic cleaner
- Etching: Electro-chemical and chemical etching installation
- Macro- and microscopic techniques: Macro and stereo photography, Optical Microscopy, Confocal microscopy, Scanning Electron Microscopy with EDS
- Chemical analyzers: Spark Spectrometer for quantitative chemical analysis, carbon and sulfur analysis for metallic materials, EDS detectors for semi-quantitative chemical analysis build in SEM microscopes
- Hardness testers: Macro Vickers, Micro Vickers, Brinell and Rockwell
- Measurements equipment: 3D Blue light scanning, Image Dimension Measuring System, etc.
- Mechanical testing: tensile, LCF, HCF, creep and impact testing machines
- Field Investigation: hardness, microscopy

Picture 4. Examples for materials test laboratory in the Institute of Aviation in Poland.

2.4.2. Test performed in the material laboratory

A materials lab possessing such capabilities will be able to conduct the following tests, which are necessary during the design and evaluation of new aircraft engines:

- Bearing failures (rolling and sliding)
- Material cleanliness and grain size evaluation
- Coating/microstructure evaluations
- Creep evaluation
- Roughness testing
- Pitting evaluation
- Stress rupture
- Characterization of modes of failures (tensile overload, LCF, & HCF, IGO, IGA)
- Crack and discontinuity detection by non-destructive method (FPI)
- Chemical analysis/composition, phase identification
- Crack initiation in frame elements
- Corrosion/Erosion in oil, fuel and hydraulic manifolds

- Disk failures and spools failures
- Fatigue crack propagation, thermal mechanical fatigue
- Corrosion attack evaluation

A laboratory possessing such capabilities is expensive, requiring an investment of about 12 million US dollars, extensive experience or the time to gain it as well as the time for the investment realization – 2 years is an absolute minimum.

2.5. Electronic systems and software

Electronic systems and software are treated here as one area, even though each of them, as part of the aircraft engine development process, could be the subject for a book or of a lifetime of research. As in the case of mechanical design, here there is also a need for multimillion investments for hardware and infrastructure and there is a need for time to gain experience. The factors that differentiate these subjects from mechanical engineering are: speed of changes or new technologies/solutions appearance but also the fact that there is a need for people of totally different skillsets and ways of thinking as compared to the average mechanical engineer. An additional difficulty may be the fact that and error or drawback in combustor chamber design, for instance, may be identified based on physical tests finding a crack, a burned hole, a coating spallation or a based material discoloration. This is not so obvious for electronic systems. The problem is even deeper in the case of software verification because of its immaterial nature. Therefore, special laboratories are created to test electronic systems and software and operate based on special rules and procedures. Safety critical software verification is a science on its own and is also the main activity for many institutions. The financial investments to organize just the basis for such testing capability amount to about one million US dollars. It took the Institute of Aviation almost 4 years to understand and incorporate processes and procedures in a way that builds trust in customers and certification agencies. Since most people working in this area are young or very young compared to the mechanical engineering teams, keeping them in one team for the long term and thus keeping their expertise in-house is a separate problem and causes an additional need for resources to attract and retain them.

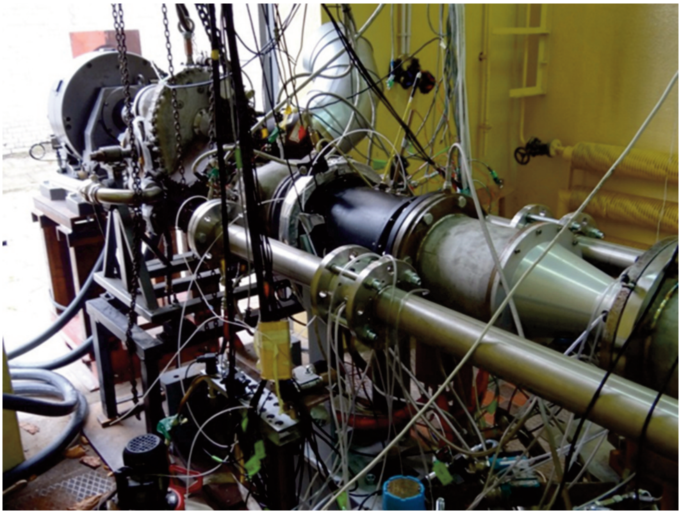
3. THE NEED FOR NEW TECHNOLOGIES

The few examples given above show how large the financial and organizational investments are necessary in order to be able to participate in research and development in the area of aircraft engines. Problems like vibrations or engine acoustics were not even discussed. IT was just mentioned, as was the need for durability tests of the entire system or components test evaluation in material laboratory after such a durability test is finished. Multi-cycle endurance tests are necessary to ensure the durability of the engine and to avoid the consequences of releasing to the market a defective/ unreliable engine or even worse an engine/product that is not safe. All the research and tests mentioned above address engine development based on solutions that are already known.

Technology development in this area is very fast and it is necessary to discover new solutions, break the limits, to go beyond and above. This kind of approach brings even more risk of failure but in the case of success the prize will be great – competitive advantage and in affect gain of and/or preservation of market position.

3.1. New technology example – detonation combustion

An example of new technology research could be experiments on engines with a detonation combustor chamber. In theory a detonation combustor engine can be 15 or even 20 percent more efficient that a "traditional" jet engine. Additionally, since the detonation propagates parallel to the engine axis [36, 37] a more compact design is possible, that will have a positive impact on mass savings. Unfortunately, although many have tried this before and still continue work in this direction, detonation combustion is difficult to be fully controlled for more than few minutes [38]. In effect, non-controlled pressure impulses cause damage to elements behind the combustion chamber, such as turbine blades. Below is a picture showing an example for a test stand to examine an engine with a detonation combustion chamber.



Picture 5. Test stand for an engine with detonation combustion.

3.2. New technology example – electric propulsion

Another example, and also a recent trend, are all the research programs on hybrid or full electric propulsion system and their application for airships. It is a relatively new area and although there is a strong enthusiasm and positive feedback from actual research, there is a long way to go before such a technology is applied to passenger aircraft. Current challenges related to high energy density storage, high power demand in different flight cycles, and other issues still place traditional combustion aircraft engines as a most reliable and most efficient way to power aircraft.

4. SUMMARY AND CONCLUSION

This paper highlighted the need for incurring extremely high financial investments associated with the need to control many, often different aspects of technology development (materials engineering, flow simulation, software, etc.) which must be considered by anyone who wants to enter the market of research and development of modern aircraft engines. From the investment standpoint there are very few entities capable of executing a new engine project with no cooperation. The data given above covers just hardware investment but one needs to consider even bigger numbers to invest in infrastructure and later the equipment and infrastructure maintenance costs. Additionally, in the technology and software area, both hardware and software become obsolete very quickly and the majority of investment need to be repeated every few years. Therefore possessing external funding from the commercial market brings additional risk. No one can guarantee that the research work will be successful. Even if the results are sophisticated and create a competitive advantage over the products of others, the product life cycle is hard to predict and with high probability it is going to be shorter than assumed. Technology solutions are aging much faster than they were in the 80's or 90's – this concerns both the laboratory equipment and the product being developed. Return on investment calculations need to consider this fact. An additional factor is the coordination of different activities like design, analyses, tests, certification reports, etc. within different areas of technology: statics, dynamics, mechanics, flow dynamics, heat transfer, material engineering, electronics, vibrations, etc. Many companies apply the model of being just the design coordinator and all the detailed activities are outsourced. A perfect example of such a model is Airbus and its latest project A350XWB where Airbus was an integrator of component design activities and assembly. A similar model is applied for engine design where companies like GE, Pratt&Whitney, or Rolls Royce keep key component design and outsource all external engine systems and nacelle design. Even then, for core design these companies try to share the risk by engaging research institutes, universities or other companies. This creates additional value of specialization.

Another challenge is associated with a trained and capable team – there is investment need in training, international trips to expand their knowledge and salaries of course – this fact increases in time since more experienced specialists require more attention from the organization for many reasons. Globalization brought several factors like tool unification and easy access to the workplace (fast trains, low cost airlines), which is even easier now thanks to the Internet – more engineering activities can be conducted remotely. All this creates risk for high attrition and/or additional cost to maintain huge resources.

The only reasonable solution in this situation is to look for some serious and reliable partners and establish cooperation. There are different models of cooperation but the most efficient for all parties involved are long-term relations – the highest is the initial cost of investment (material and non-material). The example of the strategic alliance between the Institute of Aviation and General Electric proves the benefits for both partners. It does not however guarantee success, since the market can be put in turmoil by the unexpected arrival of a totally new technology or of new player, but at least it increases the chances of becoming successful.

Companies both large and small have come to realize that cooperation in research and development is inevitable if they want to keep playing on such a demanding market as the design and development of modern aircraft engines.

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ALIANSE STRATEGICZNE JAKO PRZEWAGA W STAWIANIU CZOŁA WYZWANIOM W ROZWOJU SILNIKÓW LOTNICZYCH W PRZYSZŁOŚCI

Abstrakt

Przez ostatnie dekady, projektowanie silników lotniczych stało się coraz bardziej złożonym przedsięwzięciem. Złożoność projektowania silnika może być oceniana z dwóch stron: ze strony technicznej i ze strony organizacyjnej. Wyzwania techniczne związane z projektowaniem silników lotniczych są obecne od zarania historii lotnictwa, gdyż są to wyzwania, z którymi zespoły inżynierów zmagają się na co dzień. Ewoluowały one razem z rozwojem technologii lotniczych, ale zawsze były uważane za część procesu. Dzisiaj te wyzwania mogą się objawiać w postaci współczynnika dwuprzepływowości, wysokiego ciśnienia, wysokiej temperatury, zanieczyszczenia środowiska czy emisji hałasu, ale również w postaci wpływu rozwiązań technologicznych na trwałość, niezawodność i serwis. Nie jest równie łatwo opisać stronę organizacyjną. Jej waga zależy od skali projektu, źródła finansowania, oraz od różnych wpływów politycznych. Istnieje również spojrzenie pośrednie, łączące stronę techniczną i stronę organizacyjną – gotowość technologiczna organizacji planującej nowy projekt.

Niezmiernie ważne jest aby spojrzeć na te wyzwania, przeanalizować je, i ująć w planie zarządzania ryzykiem na jak najwcześniejszym etapie programu, aby zapewnić organizacji otrzymanie pożądanego produktu, jakim jest operacyjny i konkurencyjny silnik lotniczy. Rozwiązanie zaproponowane w tym artykule ma pomóc organizacji znaleźć strategicznego partnera lub partnerów w celu ograniczenia ryzyka i zachowania konkurencyjnej pozycji. Bardzo dobrym przykładem stworzenia takiego strategicznego aliansu i jego zalet jest partnerstwo pomiędzy General Electric Company (GE) i Instytutem Lotnictwa w Polsce. Autorzy przedstawiają ramy czasowe i finansowe konieczne do zorganizowania szeregu kluczowych centrów badawczo-rozwojowych. Przedstawiają również szczegółowy opis wymaganego sprzętu laboratoryjnego oraz potencjału tych centrów B&R/laboratoriów. Wszystkie te liczby są oparte na piętnastoletnim doświadczeniu zdobytym przy budowaniu strategicznego aliansu pomiędzy Instytutem Lotnictwa i General Electric, przy współtworzeniu biur inżynierskich dla GE Aviation, GE Power & Water, GE Oil&Gas, and GE Aviation Systems. Niniejszy artykuł naukowy, będący wynikiem połączenia doświadczenia i wiedzy autorów, jest unikalnym zbiorem technicznych i strategicznych informacji managerskich o wyzwaniach natury technicznej i organizacyjnej. Autorzy przedstawiają ideę, że tego rodzaju alianse strategiczne mogą być rozwiązaniem, lub częścią rozwiązania, wyżej wymienionych wyzwań organizacyjnych.
Słowa kluczowe: projektowanie silników, wytrzymałość, koszt, inwestycje, alianse, ryzyko.