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Thank you for participating,

Gregory Hamilton
President
Aviation Week Network

Acknowledged, agreed, and submitted by

Nominee's Signature: Erlantz Cristóbal　　　　Date: 5th June 2023

Nominee's Name (please print): ERLANTZ CRISTÓBAL

Title (please print): EXECUTIVE DIRECTOR OF TECHNOLOGY AND ENGINEERING, ITP AERO

Company (please print): ITP Aero

NOMINATION FORM

Name of Program: Intermediate Pressure Turbine (IPT) for Rolls-Royce's UltraFan

Name of Program Leader: Abel Jiménez

Phone Number: +34 610 267 334

Email: louisjon.trollope@itpaero.com

Postal Address: Bizkaia Science and Technology Park, building 300, Zamudio (Bizkaia) 48170, Spain.

☒ Customer Approved

- Date: 2nd June 2023
- Customer Contact (name/title/organization/phone):
  - Shorney, Andrew. Ultrafan Demo Chief Design Engineer, Rolls- Royce

X Chief Design Engineer – Ultrafan®

A Shorney
Ultrafan Demo Chief Design Engineer
Signed by: Shorney, Andrew

  - O'Sullivan, Bill. Communications Manager, Rolls- Royce. Bill.Osullivan@Rolls-Royce.com

☐ Supplier Approved (if named in this nomination form)

- Date: ____
- Supplier Contact (name/title/organization/phone): ______________________

PLEASE REFER TO PROGRAM EXCELLENCE DIRECTIONS AS YOU COMPLETE THIS FORM.

EXECUTIVE SUMMARY: Make the Case for Excellence
Value: 10 points
Use 12 pt. Times Roman typeface.

What is the vision for this program/project? What unique characteristics and properties qualify this program for consideration?

[LIMIT YOUR NARRATIVE TO THIS PAGE.]

In order to meet the challenges of the transition towards decarbonisation of aviation in the most efficient and sustainable way, ITP Aero is working intensively on the design and production of more efficient new engine architectures to reduce the environmental impact of air transport. Additionally, ITP Aero is also developing proprietary technology for hybrid-electric and hydrogen-based aeronautic propulsion systems.

Among the latter is the project we now present, which involves **the design, production, assembly and delivery of the first Intermediate Pressure Turbine (IPT) for Rolls-Royce's UltraFan® technology demonstrator. This turbine is essential as part of the British company's sustainability strategy with the capability to play a key role in the decarbonisation of aviation and will be able to run on 100% sustainable fuel**. In addition, these advanced engines will reduce fuel consumption by up to 25% compared to currently in service engines, and will reduce perceived noise by 35%.

To this end, the turbine developed by ITP Aero features major innovations such as the use of additive manufacturing technology, based in 3D printing of high temperature alloys, for the manufacture of the TBH (Tail Bearing Housing), one of the main structures of the engine. This innovative tool allows complex components to be produced with reduced amounts of raw materials and lower cost tools. More specifically, removable acoustic attenuation panels have been incorporated reducing the noise emitted by the turbine.

This remarkable improvement in efficiency is a milestone of great importance for ITP Aero and the Spanish aeronautic sector, as a large part of the process has been carried out at the company's headquarter facilities in Zamudio (Bizkaia, Spain) and Ajalvir (Madrid, Spain).

But not only that, this turbo machine will soon mark a firm step forward in the commitment to decarbonisation acquired by ITP Aero after joining the United Nations 'Race To Zero' programme, becoming the first aeronautical company in Spain to commit to achieving net zero carbon emissions by 2050. Moreover, the improvement of the turbo engine is a real game changer in the context of international aviation, with the capability to run on both sustainable aviation fuels and traditional jet fuels, with research active into hydrogen and hybrid electric capabilities.

The turbine is currently at the Rolls-Royce facilities in the UK, where tests are being carried out on the full prototype demonstrator engine. The promising results expected made the solution developed by ITP Aero a solid foundation for the sustainable engines of the future that will help shape a more efficient aviation industry.

DIRECTIONS

- **Do not exceed 10 pages in responding to the following four descriptions**.
  - Allocate these 10 pages as you deem appropriate, but it is important that you respond to all four sections.
- DO NOT REMOVE THE GUIDANCE PROVIDED FOR EACH SECTION.
- Use 12 pt. Times Roman typeface throughout.
- Include graphics and photos if appropriate; do not change margins.

VALUE CREATION
Value: 15 points

Please respond to the following prompt:

➢ **Clearly define the value of this program/project for the corporation; quantify appropriately**

It could be said that, thanks to this ITP Aero project, an engine technology demonstrator has become a reality with the capability to open the door to cleaner and more efficient aviation, in line with the goals set by the Advisory Council for Aeronautics Research in Europe (ACARE), which aims to reduce aircraft noise by more than half by the year 2050. Furthermore, UltraFan is set to play a key role in the decarbonisation of the aviation sector by contributing to the gradual replacement of fossil fuels with other more environmentally friendly fuels that can reduce CO2 emissions by up to 70% on a lifecycle basis.

This project is also a technological and business milestone, as it opens the door to a new type of product for ITP Aero. In addition, each of the technologies developed to design and produce the turbine have value in themselves for possible applications in other products, such as materials that withstand higher stresses and temperatures. These are suitable for use in traditional turbines, improving their performance. In short, this is a turning point for ITP Aero and for the aviation sector, in Spain, as UltraFan will certainly be the precursor of a new, more sustainable aeronautical era, maintaining the company's commitment to lead the transition to a world of zero net emissions.

ITP Aero's purpose is to develop the technology to drive change towards a more sustainable mobility, always based on the development of proprietary technology as its main competitive advantage. The technology provided by the company will significantly improve the efficiency of the UltraFan engine, which has the capability to be the most efficient on the market once it enters service. Similarly, the weight reduction achieved thanks to the advanced manufacturing techniques used will improve in the overall efficiency of the aircraft, which will undoubtedly make it more attractive on the market.

ITP Aero has thus positioned itself as a strategic supplier for the sector, as more than half of the world's aircraft are equipped with its products. This commitment is also transferred to its entity as a founding member of the European Union's Clean Aviation programme, a public-private partnership created in 2021 between the European Commission and the aeronautical industry that works with joint lines of action to try to improve the sector's ecological performance, that is, to reduce noise and carbon emissions and other gases to combat climate change.

- **Clearly define the value of this program/project to your customer**

The Intermediate Pressure Turbine produced for the UltraFan demonstrator prototype is the germ of a potential family of Rolls-Royce engines that will feature improved capabilities and a new architecture that is 25% more efficient –with lower fuel consumption– than the first generation of traditional Trent engines and 10% more efficient than the Trent XWB, the most efficient large engine in service. In aviation, this 10% improvement in efficiency is a significant contribution to today's technology solutions, and, more importantly, it is a leap that ITP Aero, jointly with RR, can make in the near term.

Weight and noise will also be significantly reduced in this new model, being manufactured with lighter composite materials and minimising the perceived acoustic power by more than half. All in all, this will be the largest engine in the market, with a fan diameter of 140 inches -a standard underground train could pass through the fan circle- and more than 30,000 parts, but it will be lighter, quieter and more efficient.

In line with what was mentioned before, this project not only offers answers to the customer's current needs, which have materialised in the design and manufacture of this new type of product and have met all the specifications required by Rolls-Royce. In addition, it has opened up a path of opportunities for its possible future application to other elements that withstand greater stresses and temperatures. ITP Aero has made a firm commitment to develop and incorporate all the new technological solutions foreseen for the UltraFan turbine, without fear of taking risks and acquiring the necessary commitments to carry out this work with the best results.

- **Clearly define the value of this program/project to members of your team; quantify if possible**

ITP Aero has developed the UltraFan IPT merging its technology development strands with the standard turbine product development process. This has allowed technology developers to be exposed to the product development process, understanding the difficulties of manufacturing and supply chain management and logistics, complying with aeronautical quality standards.

On the other hand, the turbine design and development community has been exposed to the technology development methods and processes learning to accommodate new technical solutions (new materials, turbine architecture, aerodynamics, noise suppression technologies, sealing strategies) into the turbine design and manufacturing, assessing the remaining risks while the technologies were being matured. In total, more than 500 engineers and technicians have participated in the development of the IPT and its supporting technologies.

While developing the UltraFan IPT, and in spite of being a demonsrator (with very short production series), ITP Aero has “remained loyal” to its production and engineering organization, articulated in Operational Units (formerly Centres of Excelence). As a consequence, the IPT has been developed by a multinational, multi-site, multidisciplinary team from ITP Aero sites in Madrid, Basque Country and Mexico. The whole team has enjoyed and benefited from the high technological challenge, enriching their knowledge, skills and competences. The team has also acquired significant knowledge and experience in product digital integration through the use of Rolls-Royce engine integration digital tools creating a “design in context” framework.

For some team members, this has also been an opportunity for cultural exchange as some members of ITP Aero in Mexico were temporarily deployed in Spain.

- **Clearly define the contribution of this program/project to the greater good (society, security, etc.)**

The UltraFan IPT is the main ITP Aero contribution to a sustainable mobility in the next decades. While some of the revolutionary alternative technologies for aircraft decarbonisation progress in the technology maturity ladder are in a position to yield substantial sustainability improvements, the UltraFan IPT comprises a number of maturities that are nearing their technology demonstration completion and that could be available to new or improved engine products in the next few years, allowing for a significant reduction of fuel consumption and emissions.

While having been conceived from the beginning to be compatible with sustainable aviation fuel operation, this allows for an enhanced expectation of emissions reduction. Moreover, UltraFan will be adaptable to run on hydrogen in the future.

The UltraFan architecture is scalable, being suitable for application in narrow and wide body aircraft, therefore having the capability to provide a wide spread whole fleet efficiency improvement.

ORGANIZATIONAL BEST PRACTICES AND TEAM LEADERSHIP

Value: 35 points

Use 12 pt. Times Roman typeface

Please respond to the following prompts:

- ***15 points:*** **Describe the innovative tools and systems used by your team, how they contributed to performance and why**

As mentioned, ITP Aero's participation in the new UltraFan family has materialised in the design, manufacture and assembly of a hyper-instrumented Intermediate Pressure Turbine, i.e. equipped with a system that extracts more data on its operation. This is the first one manufactured by the company, a world leader in Low Pressure Turbines, the main difference between the two being that the first one rotates at a higher speed, has more power, is subjected to higher temperatures, and requires new technologies for its creation, different turbine architecture and new manufacturing methods.

The adaptation of the ITP Aero Turbine design system to the high speed/high temperature conditions of the UltraFan IPT has been particularly relevant, enhancing our design tools to extend their design space into new ranges of airfoil lift, Mach numbers, Reynolds numbers, coupled analysis (fluid-thermal-mechanical), cooling systems, and tip leakage control.

Noise prediction tools have also been enhanced allowing for application of a wider range of turbine noise reduction technologies. Availability of these tools has proven to have a high synergy with the advanced additive manufacturing technologies, that allowed for the design and manufacturing of complex noise liners geometries whose performance could be perfectly predicted.

The UltraFan IPT has also been a catalyser for improving ITP Aero´s tools for flutter and forced response prediction, for different airfoil architectures; as well as for furhter developing lifing methodology capturing more complex and coupled phenomena (wear, fretting, creep & thermomechanical fatigue interaction, surface condition effects …).

A key aspect of this project has been the use of additive layer technology (3D printing), implemented to manufacture the TBH, using the additive layer manufacturing method. First, the 3D model of the component is digitally divided into individual layers and a laser melts the superalloy powder into the component layer by layer. This method allows complex components to be produced with fewer materials or toolds, and the result has been the incorporation of removable sound attenuation panels that are lighter and reduce the amount of output power emitted by the turbine, in addition to enabling the use of 100% sustainable fuels and a significant reduction in fuel consumption compared to current models. ITP Aero's own design and manufacturing criteria also allow for a 25% material saving compared to other production processes currently in use.

- ***10 points*: Define the unique practices and process you used to develop, lead and manage people?**

ITP Aero is well known by the stability of their project teams along project development. This is key in a top technology project like the UltraFan IPT as this is a process of continuous learning where having experienced and understood the problems and decisions made along the project becomes vital in order to construct a solid base of knowledge.

The project key roles (chief engineer, chief design engineer, chief functional engineer, chief validation engineer and main component engineers, have remained unchanged since the project started in 2015. The stability of the team made possible an environment of full mutual trust and commitment (and even friendship). Project leaders made a continuous effort to keep the team up to date in overall programme progress and expectations.

These practices are all in line with ITP Aero People's policies and processes. In 2022, ITP Aero was recognised for HR best practice, by the Spanish specialist media outlet, Equipos & Talento, in collaboration with Cegos Consulting. ITP Aero's "Development of a High Performance Culture" project encompassed the company's initiatives to reinforce the company's culture in areas such as: new values, continuous feedback processes, 'recognition awards', the hybrid working model and the I.T.P. Leadership model.

At ITP Aero we have launched various global initiatives aimed at reinforcing the values and behaviours that we want to see grow in people. The transformation of our performance process, the new recognition model and the integration of remote work are, among others, clear examples of the firm commitment that ITP Aero is making to cultural transformation.

All these policies and initiatives have had straight impact on ITP Aero's UltraFan demonstrator IPT project, in line with the company's purpose to "*develop the technology to drive change in the aerospace industry, towards a more sustainable mobility*".

- ***10* points: How did you leverage skills and technologies of your suppliers?**

It is ITP Aero's strategy to develop, support and be supported by local supply chain, as much as possible. However, in the aeronautic industry it is certainly unavoidable to make use of a wider-global supply chain for some specific components.

ITP Aero has made use of this project to develop some local and global suppliers with whom ITP Aero is intending to develop a long term strategic relationship (forging, castings, machining, fabrications, special processes). The main criteria used to conform the supply network of the project has been the willingness, proactivity and commitment expressed by the supplier. In many cases this has led to the selection of smaller – not as developed suppliers to whom we have assigned parts of very high technical difficulty, in many cases implying the assumption of a technology "delta" in their processes and product portfolio. This strategy implied a very close interaction and follow up of the product development with them. The result has been entirely satisfactory, as most of these suppliers are currently supporting ITP Aero production programmes.

In some specific cases joint technology development plans were established for parts procurement, going beyond a customer-supplier relationship. This was the case for the development of some critical rotative parts made in a new high temperature alloy, were the supplier and ITP Aero jointly characterized the forging material (including post machining properties) and validated its use as engine critical part.

Some parts were provided to the project in the frame of European technology development programmes, such is the case of the IPT casing, manufactured from astrology powder by means of a hot isostatic pressure powder under the FUTURALVE programme, with participation of the industrial partners that will in the future support the production of those parts.

The CFAA (Centro de Fabricación Aeronáutica Avanzada – Advanced Aeronautics Manufacturing Centre) located in Zamudio, (Basque country, Spain), developed and carried out part of the above mentioned astrology IPT casing machining process, refinining it along the manufacturing of the first part.

New honeycomb plate joining processes (brazing materials and application) were also developed together with suppliers.

DEALING WITH PROGRAM COMPLEXITY
(VOLATILITY, UNCERTAINTY, COMPLEXITY, AMBIGUITY, or VUCA)
Value: 25 points
Use 12 pt. Times Roman typeface

Please respond to the following prompts:

- ***10 points:*** **Describe UNIQUE areas of VUCA faced by your program and why. (Please avoid the issues surrounding Covid-19 pandemic, which was faced by all programs.)**
  VUCA, short for volatility, uncertainty, complexity, and ambiguity.

One of the main concerns of the project was the difficulty to engage technically proven suppliers of castings, machining and fabrications given the extremely short production series. As discussed above, this was partly solved by relaxing the expectactions on technical capabilities and prioritizing willingness and commitment as supplier selection criteria.

Difficulties to engage casting suppliers in the manufacturing of the Turbine Bearing Housing were “replaces” by assumption of a higher degree of technical risk replacing discarding casted solutions and adopting the strategy to design and develop the parts in additive manufacturing. This was the first time that an engine part of this size and structural importance was manufactured using this technology. By following a thorough manufacturing process, with validation and inspection of the parts (or samples) and subassemblies at every step (printing, polishing, ready to wel, weld subassembly, weld assembly, heat treatment at different stages, repairs …) the team managed to achieve a compliant assembly in time for the project.

A similar decision was made to manufacture the TBH noise liners in additive manufacturing instead of using conventional fabrication techniques.

Given the fact that several airfoil special processes were perfomed in UK based companies, Brexit customs enforcement introduced significant delays in parts transfers, and more worrying, uncertain return times. This was managed by processing sets in smaller batches, transferring parts as soon as units were coming out of the previous manufacturing step and trying in that way to create a continuous steady flow. Support from the suppliers, who agreed to work under this less efficient but safer schedule, was crucial.

Casting of airfoils with complex geometries and materials (single crystal, cooled and hollow airfoils) was another important challenge that required the casting suppliers and the design team to engage in a close interaction, launching numerous trials and assessing their viability practically part by part. ITP Aero castings specialists supported the process proposing strategies to fix the different issues.

- ***15 points:*** **Explain how your team responded to these challenges. What changes did you make, what were the results?**

Please refer to the section right above.VUCA areas and solutions are both explained above.

METRICS
Value: 15 points
Use 12 pt. Times Roman typeface

Please respond to the following prompts, where predictive metrics indicate items that provide a view of how yesterday's actions and today's actions will affect the future timeline, cost or other requirement.

Provide charts/graphs that illustrate performance to these metrics:

- **What are your predictive metrics?**

With the project goal set in designing and developing an IPT architecture and enabling technologies that support the higher level objective of developing a new engine with undisputable competitive advantages, the most reasonable predictive metrics are the main intermediate pressure turbine KPI´s, which were monitored all along the project.

These are, as for any other aero-engine module, efficiency, weight, noise, reliability and product cost. Safety is not considered a KPI, compliance with safety requirements is simply a must. The engine OEM, as responsible for the integration of all modules and for the performance of the overall engine, assigns to the different modules their respective targets in an iterative process, trying to achieve a balanced distribution of the level of challenge assumed by each module. This is a live process, where targets are re-discussed and redistributed along the development process, as technical challenges and opportunities are better understood and also allowing for some degree of update of customer (airframer) requirements.

The project, started in 2015, has been managed through yearly budget plans.

- **How did you perform against these metrics?**

As the development process progressed, the IPT design was adjusted to the project objectives for efficiency and weight. The turbine efficiency has been validated by means of rig tests performed in the aero-tunnel of the CTA (Centro de Tecnologías Aeronáuticas – Centre for Aeronautical Technologies) based in Zamudio (Basque Country, Spain), a research centre close to ITP Aero's main headquarters.

Test campaigns were carried out for front stages, rear stages, full turbine and noise liners, collecting an extensive set of data that allowed to validate the design methodology, the airfoils design itself and the overall performance of the turbine in terms of efficiency and noise. The results have been extremely satisfactory, fully validating the aerodynamic design of the turbine.

Particularly remarkable is the turbine noise behaviour, where specific features designed in the airfoils combined with the TBH noise liners provide a comfortable margin with respect to specific turbine noise requirements. Moreover, the TBH noise liners, provide an extremely powerful tool to create additional margin in case the overall engine compliance could be compromised.

On top of the excellence in the gas path design, additional improvements in turbine efficiency were achieved by adopting new generation high temperature materials in the casing and the rotative parts exposed to the highest temperatures, which allowed for cooling flow reductions with a positive impact in efficiency. Rotatives parts cooling was also optimized by embracing significant manufacturing challenges and development of new coating processes.

Regarding weight, this being a completely new architecture, there was no valid prior reference to benchmark against, so the only reference were the project targets. These were met by embracing a number of technology challenges in individual components:

- Great use of additive manufacturing technology in static parts that allowed for optimized designs, achieving a significant weight reduction with respect to alternative designs based on casting technology.
- Advanced airfoils design (light and slender) by enhancing ITP Aero design tools for a better representation of dynamic effects.
- High temperature materials, delaying properties degradation, allowing for lighter designs at higher temperatures.

As for reliability, the IPT has been designed considering final product requirements. Relaxations in the manufacturing conceded in order to protect the schedule and the higher benefit of the early availability of the demonstrator engine have been collected, discussed and agreed in the project technical reviews, not having identified any unsurmountable issue compromising the ability of a future product to comply with requirements.

Product cost understanding was refined along the project as the demonstrator design and make was maturing and as the supply chain frame evolved. Technical cost (energy consumption, materials consumption, machine-process time, labour) was continuously monitored and managed-optimised.

Along the development, the project team was able to adjust the expenditure to the available budget, achieving the project milestones. This was controlled not only by the company management mechanisms, but also by the Clean Sky 2 (CS2) Joint Undertaking project discipline. This being a project funded by the EU under the CS2 programme, is tightly controlled through various mechanisms: procurement rules, periodic reporting, accounting and economic audits, technical reviews (project general progress, risks management, milestones and deliverables status …).

- **How do your predictive metrics drive action toward program excellence? Please provide examples.**

The IPT design fundamentals are settled and the demonstrator engine test campaign has started. It is now time to focus on a future product development. The tests will validate the overall architecture, efficiency and reliability; and renewed efforts will be applied to identify weight and cost reduction opportunities. The IPT turbine will be benchmarked against itself in an attempt to better support making the engine more competitive and appealing to airframers, triggering their decission to launch new aircraft products featuring the UltraFan. The configuration of the supply chain will be part of this exercise, paying special attention to those components or parts were specific constraints (suppliers limited number, previous experience, market position) have been identified along the development of the demonstrator engine.