OPtimisation for low Environmental Noise impact AIRcraft - OPENAIR

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ABSTRACT

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OPENAIR is currently the main Level 2 European project working on aircraft noise reduction. As such, it is a key element of the European aircraft noise research roadmap as developed by the X-NOISE Coordination Action which aims to reduce Aircraft Noise by 10 dB per operation as set by the ACARE 2020 Vision.

Over the years, a significant effort has been conducted in the field of source noise reduction technologies, marking a first step towards the achievement of the ACARE targets through the Silence(R) project.
As part of the European 7th Framework Program, OPENAIR started on 1st April 2009 as a program on aircraft noise reduction with a total budget of 30 million Euros, 60% funded by the European Commission. OPENAIR aims to deliver a 2.5 dB noise reduction for both engine- and airframe noise sources, beyond the SILENCE(R) achievements. To do so, OPENAIR focuses on the validation of new technologies at TRL5, such as electronically assisted solutions, designs exploiting improved Computational Aero-Acoustics, new affordable absorbing materials and airframe noise solutions. In order to keep an unbiased view on results, OPENAIR uses the Aircraft Noise Technology Evaluation process ANTE. A summary of the OPENAIR research topics will be provided.

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1. INTRODUCTION

In the late 90's, several aircraft noise projects made significant progress under the coordination of the X-Noise network. Projects like RAIN (airframe noise), RANTACC (Nacelle acoustics) and RESOUND (turbomachinery noise) delivered results up to TRL3. For a next step, to achieve TRL5-7, these projects and several others were combined into a follow-up project called SILENCER that ran from 2001 to 2007. While SILENCER delivered about 10 fully matured "Generation 1" technologies, it also performed some work on more advanced methods and techniques. These so-called "Generation 2" technologies were based on continuously improved Computational Aeroacoustics as well as electronically assisted solutions. The OPENAIR project, coordinated by Snecma, has continued this work started in SILENCE(R),while incorporating a multi-disciplinary design approach. The paper describes the OPENAIR objectives, major technologies and the technology evaluation method applied for final assessment.

2. OBJECTIVES

The aerospace industry has significantly grown over the years as more and more people are using air transport to travel for business or pleasure. These growing numbers of airplanes have put pressure on the public acceptance with respect to its environmental impact and in particular the noise aspects.

Although enormous noise reductions have been achieved in the past, continued improvement of the noise climate is required to mitigate annoyance as much as possible. Therefore, in the year 2000, a "group of personalities" had formulated a number of challenging goals for the aerospace industry, including several environmental goals. For "noise" an objective for 2020 was set to reduce noise caused by aircraft by half. ACARE (the Advisory Council for Aeronautics Research in Europe) then translated this objective in a 10 dB reduction per aircraft operation (departure or arrival). This objective is now known as one of the ACARE noise objectives for 2020.

Progress towards the noise objective up to now has been achieved thanks to many projects that have been completed since the year 2000. A large contribution came from the SILENCE(R) project that proved a 5 dB reduction, based on 10 new noise technologies, combined with the application of improved noise abatement procedures. OPENAIR now aims to achieve another 2,5 dB reduction based on a new set of technologies that could provide a step change in source noise reduction. This step change is pictured in Figure 1, where the "generation 2" technologies from OPENAIR, together with results from new engine – and aircraft architectures are foreseen to complete the gap to the achievement of the ACARE noise goal. OPENAIR plans to validate these technologies up to TRL5.

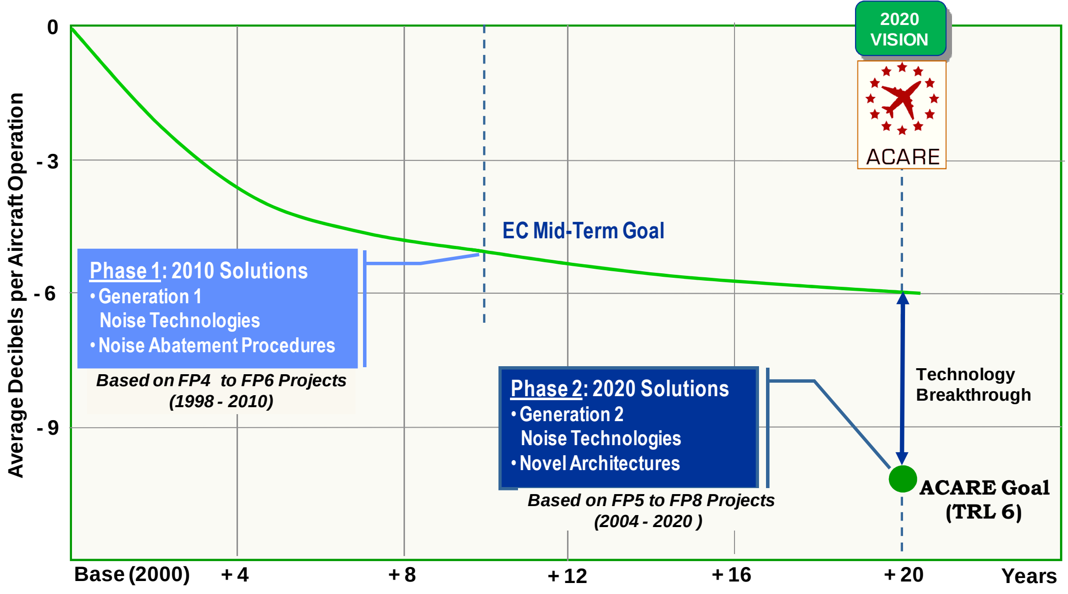

Figure 1: Steps to ACARE Noise goal

Besides these quantitative objectives, OPENAIR also aims to verify the practical applicability of its technologies over a range of products.

3. PROJECT SCOPE

OPENAIR is bringing together a multi-disciplinary partnership, operating across several complementary axes:

1. An Integrated Propulsion System Design sub-project supported by cycle studies, turbomachinery and nacelle aerodynamics, acoustic liner design and manufacturing
2. An Electronically Assisted Propulsion System Technologies sub-project which will study and assess Active / Flow Control techniques involving actuation devices, control algorithms, powerplant component mechanical design, composite materials, nozzle aerodynamics
3. An Airframe sub-project concerned with landing gear and wing systems mechanical design, high lift device (HLD) aerodynamics, aircraft controls etc.
4. A Technology Evaluation (TE) activity is running in parallel to the noise reduction work to assess the environmental impact of the individual technologies as well as the global integrated result.

3.1 Engine Noise Technologies

The engine noise reduction was covered in the 2 of OPENAIR sub-projects and includes both engine source noise reduction techniques as well as noise suppression techniques among which nacelle modifications. Under the Integrated Propulsion System Design sub-project, the following technologies were developed:

3.1.1 MDO Outlet Guide Vanes (OGVs) and Lined OGVs.

Both the Multi Disciplinary Optimized (MDO) OGVs and the Lined OGVs have been designed with a large reduction of the number of vanes (~10) compared to the traditional configuration (~40). This allowed design space for (thin) special shapes as explored under the MDO OGV design, or (thicker) designs that allow internal space for acoustic liners as seen for the lined OGVs. Design objectives balance aero performance and acoustic design. Both broadband- and tonal noise sources were lowered while leaving the aero performance unchanged. All designs were tested on a fan rig.

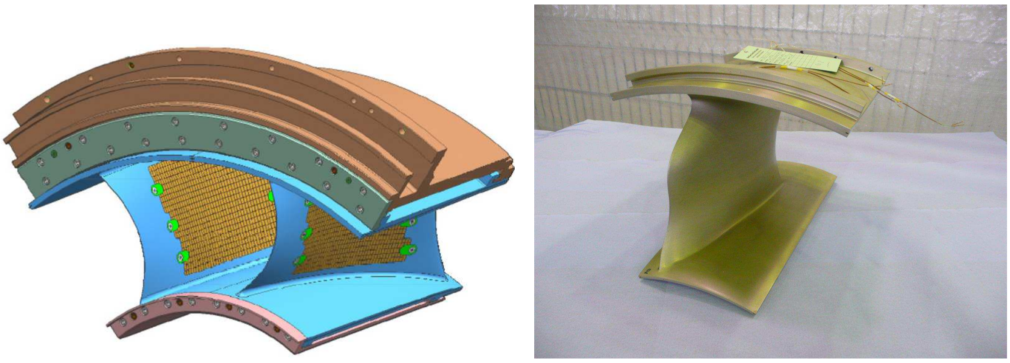

Figure 2: Lined- and MDO OGVs

3.1.2 Intake Technologies

Various new inlet liner concepts, based on recent advancements in Computational Aero Acoustic (CAA), have been developed and tested on a fan rig. Among the configurations tested are a “Folded Cavity Liner” which has a geometry that allows low frequencies to be damped through a large space that is folded behind the conventional liner. In this way lower nacelle thickness can be used compared to conventional designs. A “Segmented Liner” has also been tested where the first 25% of the inlet lining (measured from the fan face) was configured as a conventional deep liner. Forward fan noise reductions have been achieved, besides a significant reduction of the buzz-saw noise, which is an annoying noise source audible in the cabin.

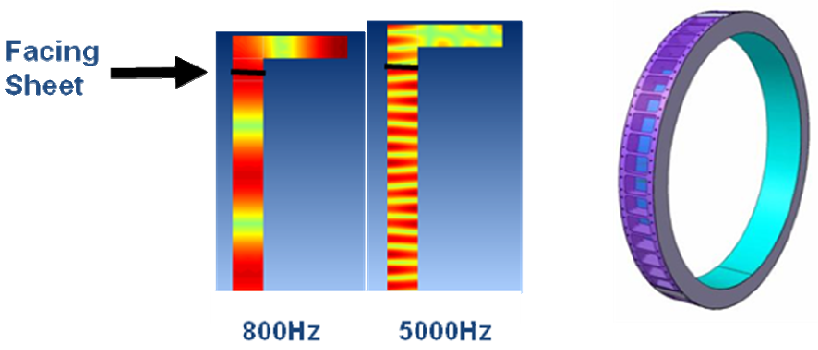

Figure 3: Folded-cavity liner impedance model and fan rig liner design

3.1.3 Highly Curved Bypass duct

The highly curved bypass duct seeks to push out the duct earlier to a higher radius. As the duct cross sectional area is conserved this results in a reduced height duct with a greater liner area per unit length. Reduced height ducts are more effective at noise absorption. These attributes allow a shorter nacelle to be used giving significant reductions in weight and drag.

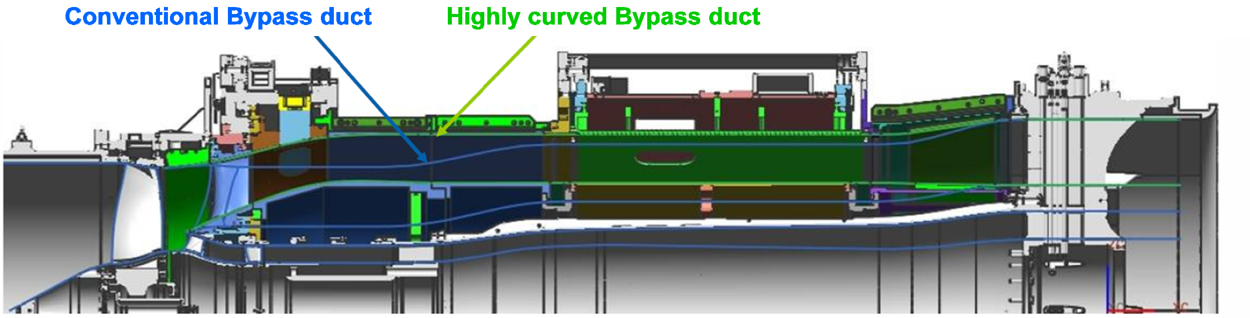

Figure 4: Highly Curved Bypass duct configuration in Anecom fan rig

3.1.4 Acoustically lined splitters

Many configurations of supplementary liner area in the bypass duct were designed and several were tested. Bringing extra structures in this area come with new challenges, but may provide a solution to the acoustic area loss when shorter nacelles are desired in the future. OPENAIR has tested both “splitters”, who fully cover the height between the inner and the outer wall, as well as so-called “fins”, who protrude from the outer wall up to halfway the duct height.

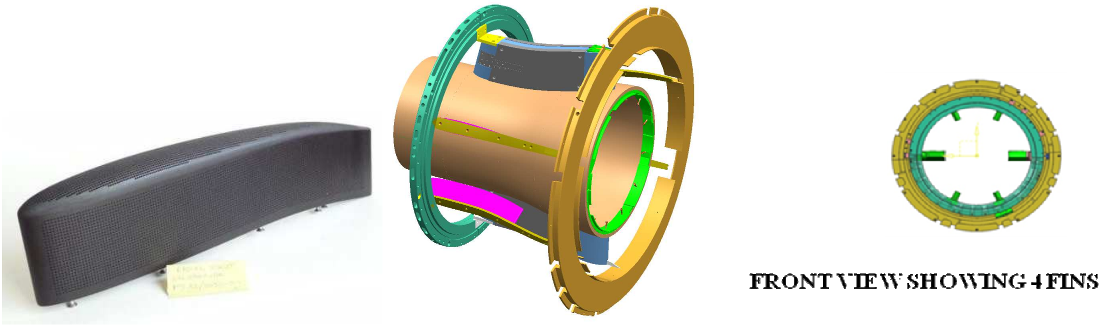

Figure 5: Lined Fin and fin/splitter locations

3.1.5 Negatively Scarfed Nozzles

The scarfed nozzle have been designed for the secondary nozzle of both short- and long cowl nacelles. The scarfed shape is changing the directivity of the rearward radiated fan noise to higher angles and provides a global reduction on the total engine noise. The test vehicle in the QinetiQ Noise

Test Facility was equipped with a hot air primary jet stream and water cooled speakers in the secondary duct for fan noise simulation.

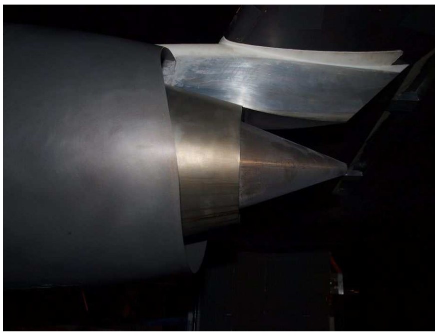

Figure 6: Scarfed nozzle demonstrator

Under the Electronically Assisted Propulsion System Technologies sub-project, a number of active control technologies were developed:

3.1.6 Active Stator

Following a successful start of the research efforts on this active noise control technology in the SILENCE(R) project, OPENAIR followed up with improved actuators, sensors and algorithms. Objectives were extended to include also rearward fan noise control, besides the already demonstrated forward fan noise control. The new system has been validated in the RACE fan rig. Integration aspects of this technology have been largely matured through full scale demonstrator OGVs.

Figure 7: RACE fan rig for system demonstration and full scale demonstrator OGV

3.1.7 Active Nozzle

Under the Active Nozzle jet noise technology activity various active flow/noise control concepts have been explored before selecting one for large scale testing at the CEPRA19 facility in France. The validated concept concerned the “Microjet” technology based turbulences caused by air blowing at the nozzle exit. Extensive integration studies have been performed on the air supply through the nacelle to the primary and secondary nozzle.

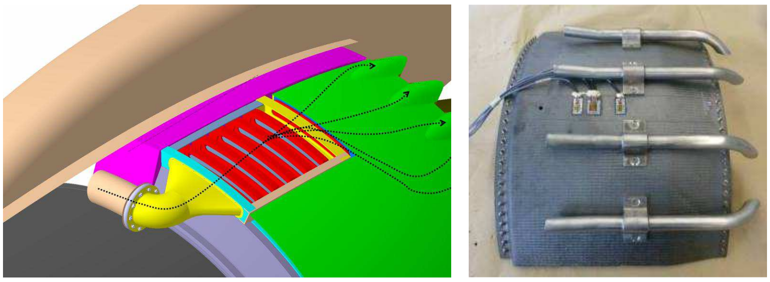

Figure 8: Active Nozzle integration study and demonstrator panel

3.2 Airframe Noise Technologies

Under the Airframe Noise sub-project, technologies were developed that focus on the main landing gear and on wing slats and flaps:

3.2.1 Deceleration Plate

The deceleration plate (DP) is an object placed on the downstream side of complex gear structures. Strategically placed, these objects will reduce the velocity upstream in the gear structure and thereby reduce noise generation without negative flow displacement effects. Reductions were found in the broadband noise of the landing gear.

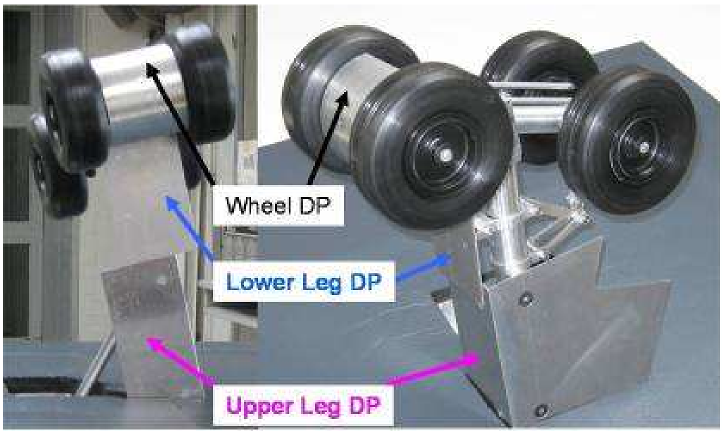

Figure 9: Preliminary landing gear testing at small scale

3.2.2 Low noise gear

This OPENAIR technology groups all efforts to adapt the detailed design of all landing gear components to a noise and aero optimized configuration. Besides technologies from the TIMPAN project (Hub caps and brake fairings), the test gear was equipped with a rectangular torque link in front of the leg, Electric dressings and solid covers for drag stay and leg cavity. Tests at full scale at the DNW LLF facility were carried put on both wing mounted, as body mounted landing gears.

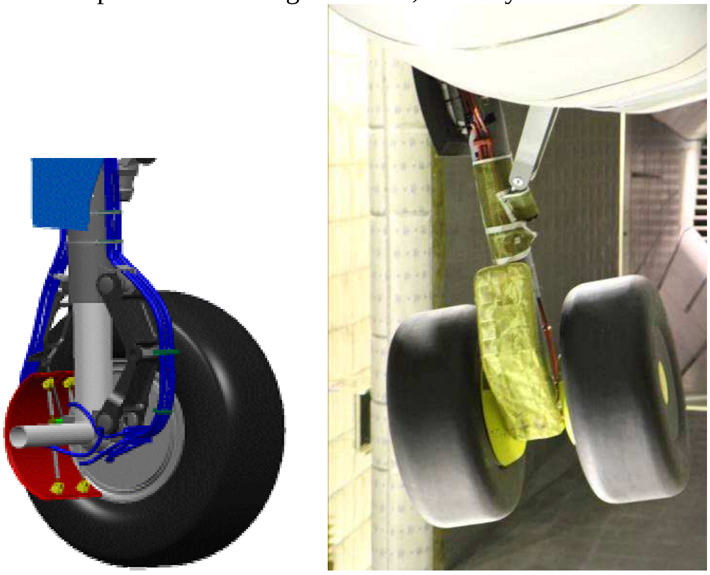

Figure 10: Deceleration plate and torque link mesh fairing (TIMPAN)

3.2.3 Adaptive slats

In the adaptive slat concept, the trailing edge of the slat is a flexible morphing structure that can fully close the gap between the wing and the slat. In normal operation with low angle of attack, the gap is closed and quiet. When Cl_{max} is required or high angles of attack, the gap opens for maximum aircraft performance.

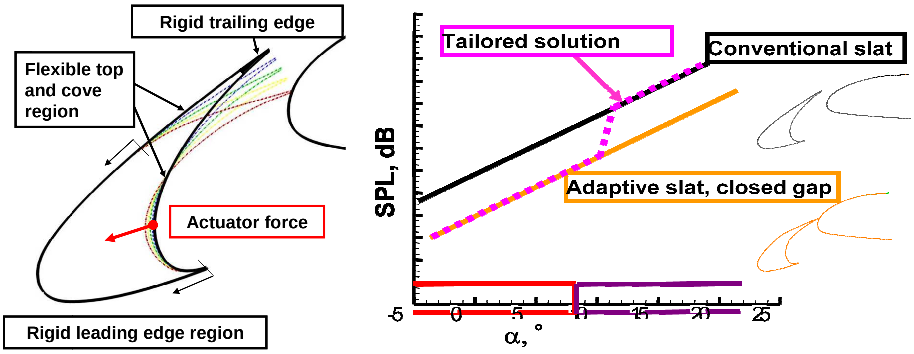

Figure 11: Adaptive Slat geometry and aero performance

3.2.4 Low Noise Slat Settings

In this non-morphing concept, the slat/wing gap/overlap is optimized for aero- (Cl_{max}) and aeroacoustic performance

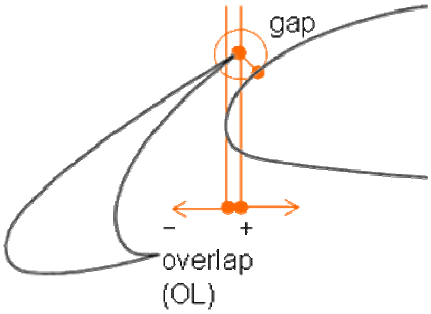

Figure 12: Gap/overlap optimization for wing slat.

3.2.5 Porous flap-side edge

Various acoustically porous materials were evaluated for their environmental (certification) requirements before a final selection was manufactured for large scale acoustic testing at the DNW LLF windtunnel.

Figure 13: Porous flap side edge in DNW windtunnel

4. TECHNOLOGY EVALUATION

All technologies that have successfully matured to TRL5 during the project have been subject to the technology evaluation process. By using performance and noise models, the TE process has evaluated the benefits of the new technology concepts developed in the project with the integrated technologies fitted into “Virtual Platforms” representing current and potential future market segments.

Depending on the characteristics of engine or airframe in the evaluation matrix, a technology package will be adapted to each virtual platform.

Since 2001, this approach has proven to be a valuable tool for decision making, as it allows assessment of the environmental benefits of the low noise technologies, in balance with aircraft performance and design constraints over a wide range of typical engine/aircraft configurations. It is also able to determine the maximum noise reduction achievable by a package of low noise technologies on current or future products with minimum weight, performance and industrial risk. In order to identify potential global benefits from the OPENAIR project, the TE process has concluded with an airport impact assessment on a major European airport.

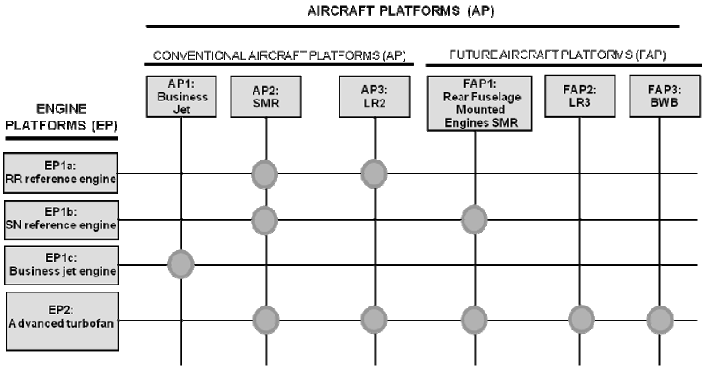

Figure 14: Virtual platform configuration matrix

5. CONCLUDING REMARKS

With the project officially ending at the end of September 2014, the acoustical benefits are in the process of consolidation at the time of the writing of this paper. Although some results are available, the current paper only mentions the key technologies that have emerged from the project at a high TRL. Future publications are expected to report more about the acoustical benefits.

REFERENCES

1. Giacche D et all. Acoustic optimisation of ultra-low count bypass outlet guide vanes. AIAA Aeroacoustics Conference 2013_2243.
2. Project webpage: http://openair.xnoise.eu
3. Burak O et all. Experimental and numerical investigation of a novel Acoustical liner concept. AIAA Aeroacoustics Conference 2010 Stockholm.
4. Kroeger G. et all. Optimised aerodynamic design of an OGV with reduced blade count for low noise aircraft engines. ASME Turbo Expo 2012 Copenhagen.
5. Genoulaz N. et all. Experimental Valoidation of an Active Stator Technology Reducing Modern Turbofan Engine Noise. AIAA Aeroacoustics 2007, Rome.
6. Cadot-Burillet D. et all. Technology Evaluator - A global way of assessing noise reduction technologies. AIAA Aeroacoustics confernce 2007 Rome.

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