LCA of trailing edge maintenance – a case study of graphene nanoplatelet-based coating

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Madrid, Oct.14th

EASN 15th International Conference
on "Innovation in Aviation & Space towards sustainability today and tomorrow"

Funded by
the European Union

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GIANCE

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A glimpse of GIANCE

GIANCE: Graphene Alliance for Sustainable Multifunctional Materials to Tackle Environmental Challenges

Type of Action: HORIZON-IA
Technology development up to TRL 6

Duration of the project: 3 years

Start date: 1 October 2023

23 partners / 10 countries

Total cost: 9.5 Mio Euro
(8 Mio Euro - EU contribution)

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GIANCE TECHNOLOGY – EXPECTED IMPACTS

- Increased conductivity, durability and toughness
  - Increased damage resistance, repairability and recyclability compared to conventional embedded metallization approaches
  - Extended life of composite structures by preventing lightning strike damage
  - Reduced maintenance / Extended maintenance intervals: part replacement and painting frequency
    → Affect the consumption of resources
- Lighter coating
  - Decreased part weight (10%, highest amount from the coating)
    → Less fuel consumption
- Reduced waste treatment and increased potential for material recycling and recovery
    → Affect the consumption of resources

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OBJECTIVE OF THIS ACTIVITY

Life Cycle Assessment (LCA) of the Graphene-Related Materials (GRM) applied to the new aircraft lightning strike protection (LSP) system of a trailing edge

1. Screening LCA (done)
2. Full LCA (on going)

Figure 5: Lightning protection and strike damage
Clockwise from upper left: Lightning damage to a horizontal stabilizer, rudder, antenna, and bond jumper.

SCOPE OF THE STUDY

- **GOAL**:
  - **Full LCA**: Evaluation of the environmental impact of the GIANCE and current lightning strike protection (LSP) systems of a trailing edge
  - **Screening LCA**: Main differences and improvements expected from GIANCE new solutions

- **FUNCTIONAL UNIT**:
  - 1 m² of LSP layer providing equivalent lightning strike protection per 1,000 flight hours or years)

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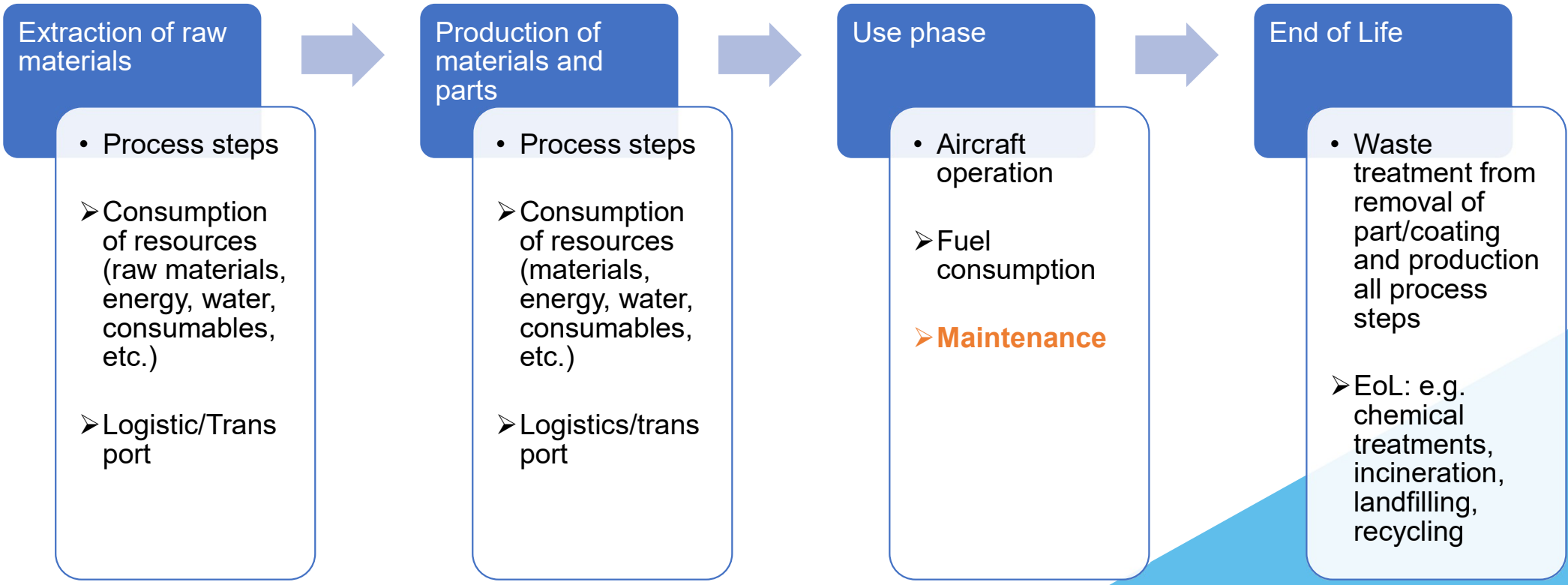
SYSTEM BOUNDARY



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MAINTENANCE

➢ **Lightning strike** may result in serious damage and extensive repairs → Unscheduled maintenance (AOG – Aircraft on Ground events)

Lightning strike

- Coating, painting and part damaged
- ➢ Frequency of events: ≤2.5 strikes per year OR 1 strike per 1,000 flight hours
- (Depend on aircraft type, routes, and seasons)

Maintenance AOG

- Check and detailed inspection
- Removal, repair, restore
- Cleaning of components
- Replace part damage and recoating
- ➢ Use of devices, water, chemicals, etc.;
- ➢Logistic /Transport

Production of materials and parts

- Process steps
- ➢ Consumption of resources (materials, energy, water, consumables, etc.)
- ➢Logistic /Transport

Extraction of raw materials

- Process steps
- ➢ Consumption of resources (raw materials, energy, water, consumables, etc.)
- ➢Logistic /Transport

End of Life

- Waste treatment from removal of part/coating and production all process steps
- ➢ EoL: e.g. chemical treatments, incineration, landfilling, recycling
- ➢Logistic /Transport

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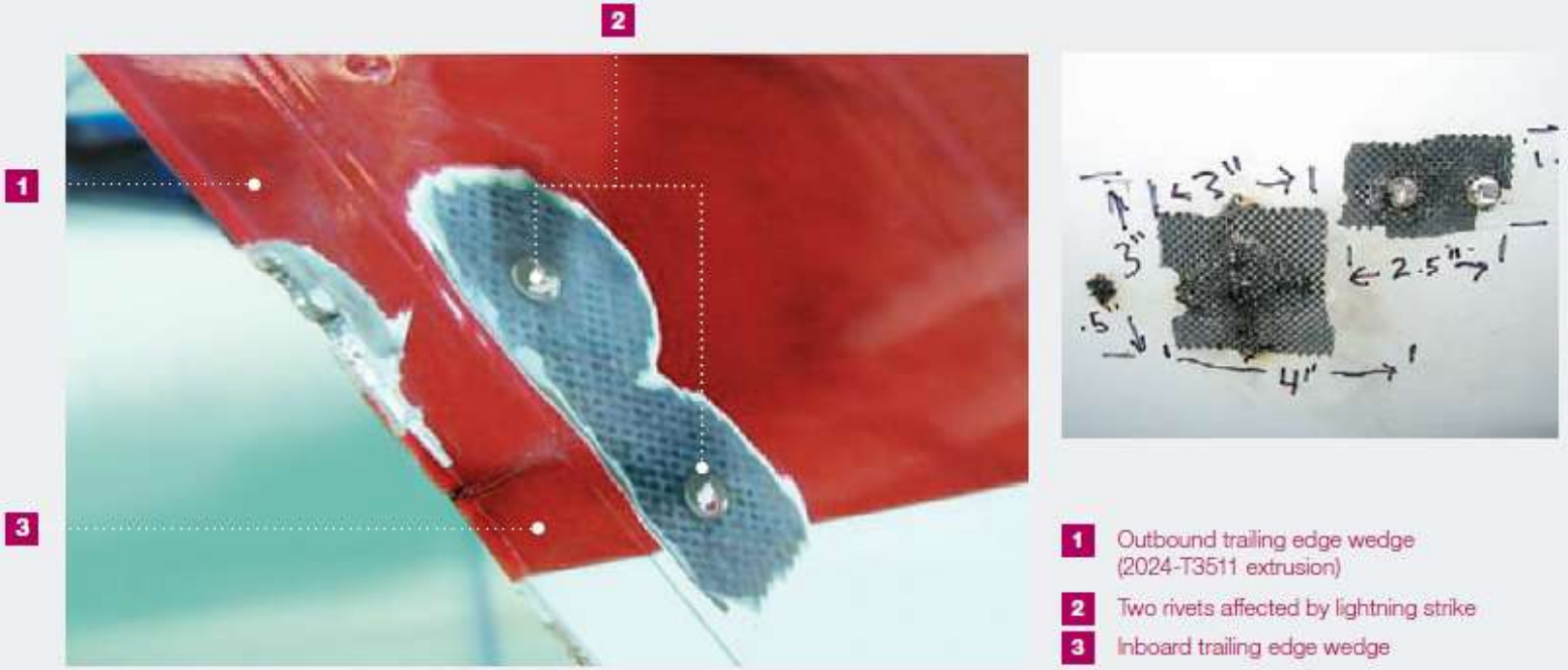
LIGHTNING STRIKE DAMAGE ON A TRAILING EDGE

Figure 7: Lightning damage to a composite airplane

Composite structures are less conductive than metal, causing higher voltages. This is the type of damage that can occur if a lightning protection finish is not applied or is inadequate.



1. Outbound trailing edge wedge (2024-T3511 extrusion)
2. Two rivets affected by lightning strike
3. Inboard trailing edge wedge

BOEING

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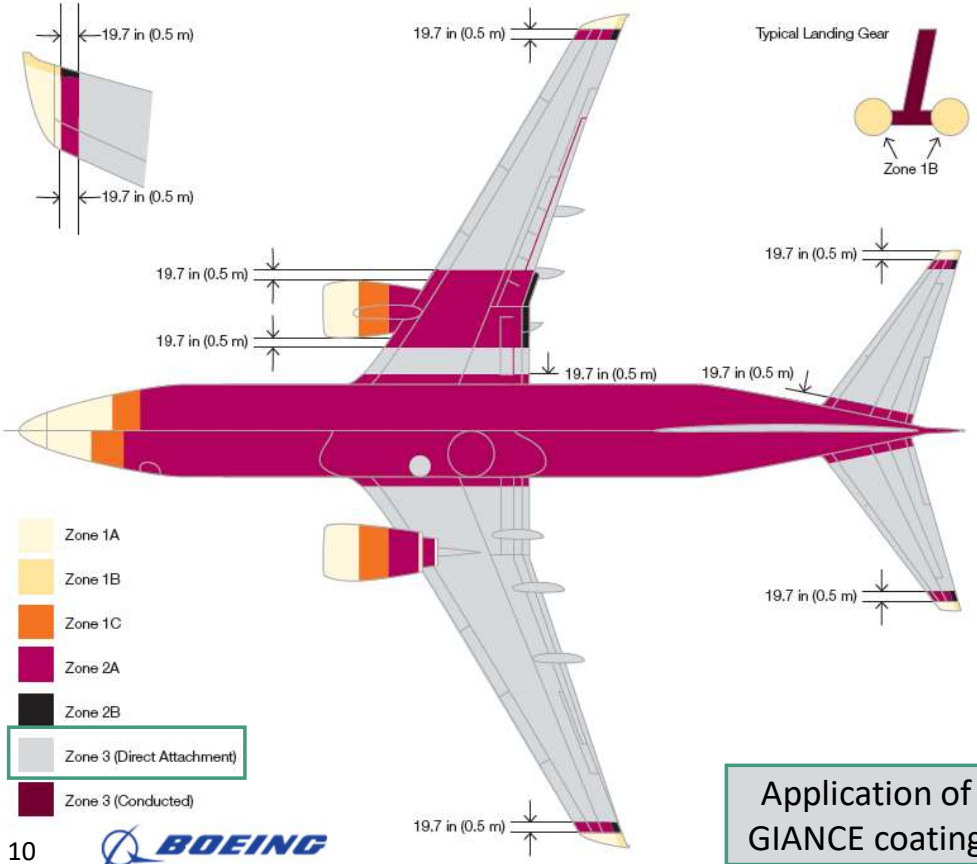
GIANCE TECHNOLOGY – AIRCRAFT PART

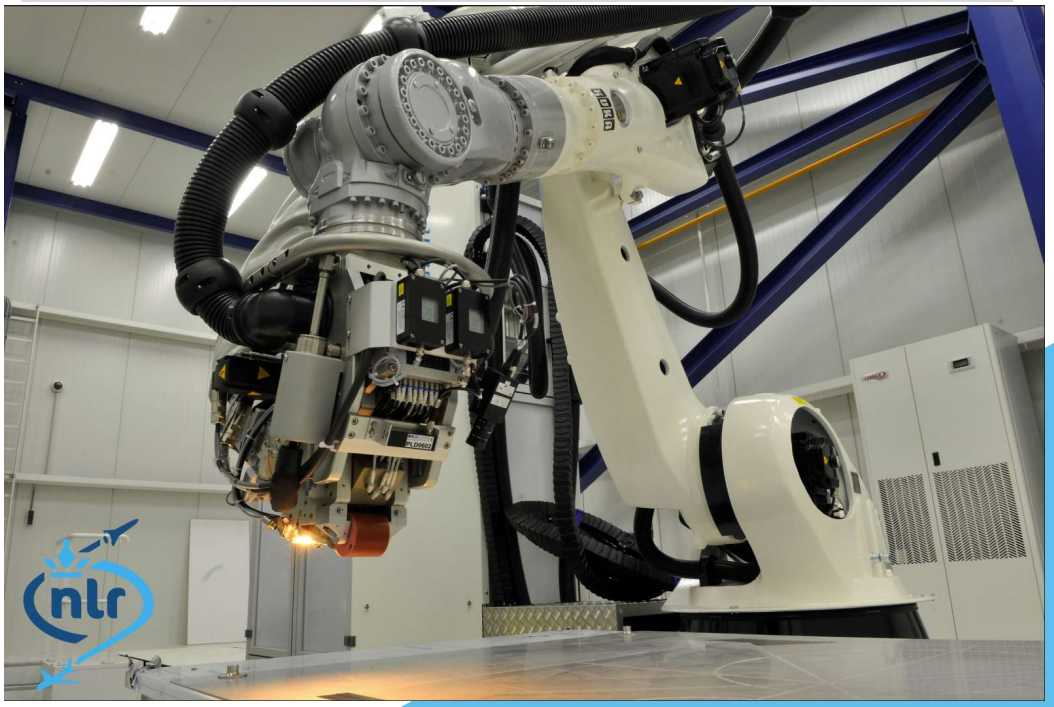
Figure 9: Airplane lightning zones

Areas of an airplane that are prone to lightning strikes are indicated by zone. Zone 1 indicates an area likely to be affected by the initial attachment of a strike. Zone 2 indicates a swept, or moving, attachment. Zone 3 indicates areas that may experience conducted currents without the actual attachment of a lightning strike.



Application of GIANCE coating

Production of CFRP panel – Automated Fiber Placement:



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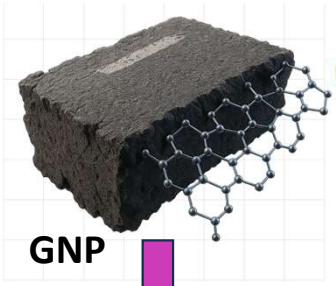
COMPOSITION OF THE LSP SOLUTIONS

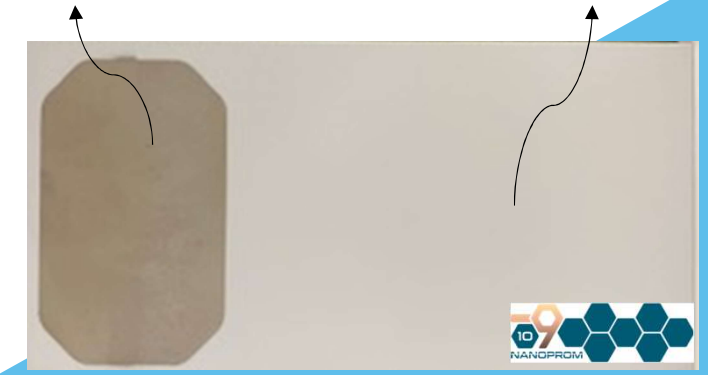
State of the art	GIANCE LSP
Top coating paint layer (PU-cyanate cured, white)	Top coating paint layer (silica sol-gel, white)
2nd primer (epoxy-amine cured)	LSP (coating) and primer: silica sol-gel with silver and graphene nanoplatelet (GNP)
1st primer (epoxy-amine cured)	
LSP: Al metal mesh with epoxy (prepreg)	
Thermoset composite material: epoxy pre-impregnated GF/CF carbon fabrics (prepreg)	Thermoplastic composite material: LM-PAEK pre-impregnated UD carbon tape



UNIVERSAL MATTER
ADVANCED MATERIALS

GNP-metallic powder sol-gel coating

Sol-gel paint layer (white)



LSP Lightning strike protection
GNP graphene nanoplatelet
CF LM-PAEK: Carbon-Fibre-Reinforced Low-Melting polyaryl ether ketone
UD Uni-directional

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STATE OF THE ART COATING

- **Material composition**: Amine-epoxy primers, solvent polyurethane based, cyanate cured top coating, both dissolved in solvents such as toluene, xylene etc.
- **Production steps**: base component and curing agent in mechanical mixing
- **Application processes**:
  - Thermoset composite materials: laid up and cured in autoclave
  - Metal mesh: co-cured/co-bonded with the prepreg in autoclave
  - Two layers of primer and topcoat: Spraying

GIANCE COATING

- **Material composition**: graphene nanoplatelets (GNPs) dispersed in a silica-based matrix; butyl acetate solvent and metal particles
- **Production steps**: high-shear mixer; mechanical mixing and ultrasonication
- **Application processes**:
  - Thermoplastic composite materials: Automated Fiber Placement (collation) and autoclave (consolidation)
  - Coating and topcoat: Spraying (spray booth) - Improved application techniques to reduce overspray and waste (electrostatic spray gun)

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STATE OF THE ART COATING

- **Remove the coating**: chemical stripping and washing (chemical strippers or abrasive methods; use of water or solvents for rinsing and cleaning)

- **End of life**: disposal of primer residues and contaminated materials; Treatment of chemical waste; Composite panels with embedded Al mesh are difficult to recycle due to mixed materials

GIANCE COATING

- **Remove the coating**: Bicarbonate blasting and washing (to collect silver and silica)

- **End of life**: removed GNP silver coating potentially recyclable; less damaged part to be treated

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PRELIMINARY RESULTS

FU: 1 m² of LSP layer providing equivalent protection	REFERENCE technology	GIANCE technology	Benefits & Drawbacks
Coating production			
Mass per m²	0.27 kg of Expanded aluminum foil (GIANCE data)	0.01-0.05 kg GIANCE coating (GIANCE data)	GIANCE is ultra-thin coating
Energy Consumption	175 MJ/kg (Al foil primary, Europe, LCA DB)	Graphene: Confidential GIANCE data Metal: 975 MJ/kg (GLO, LCA DB)	GIANCE has higher energy consumption per kg
Global Warming Potential (GWP) / FU	3.9 CO_2e (based on LCA DB)	1.7 – 8.6 CO_2e (based on GIANCE and LCA DB)	GIANCE: min application of coating **0.0225 kg/m²** → same CO_2e emission as REF
Part production			
Global Warming Potential (GWP) / FU	1260 CO_2e (based on LCA DB)	1100 CO_2e (based on GIANCE and LCA DB)	GIANCE less GWP emissions

Extraction of raw materials → **Production of materials / coatings** → **Manufacturing of aircraft parts** → **Use phase** → **End of Life**

Preliminary results

Ongoing work

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NEXT STEPS

- Further investigation of advantages of GIANCE coating compared to current solution
  - Testing of composite panels will be carried out before and after lightning strike testing
  - The damage will be analysed in terms of geometry (affected area, depth, etc.)

- Investigation of recyclability of the graphene and damaged thermoplastic part

- Consideration of the environmental impact of maintenance and EoL on the LCA study

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CONCLUSIONS

Screening LCA of GIANCE coating solutions Vs. State of the art

- **Change on material level, part manufacturing and coating application phases:**

  showed positive trend, indicating potential reduction in environmental footprint

Eco-design and LCA: support R&D projects ensuring responsible innovation

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Thanks for listening!

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Acknowledgement:
The GIANCE project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101119286 and UKRI under Grant Agreement No 10090645 and No 10101683

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