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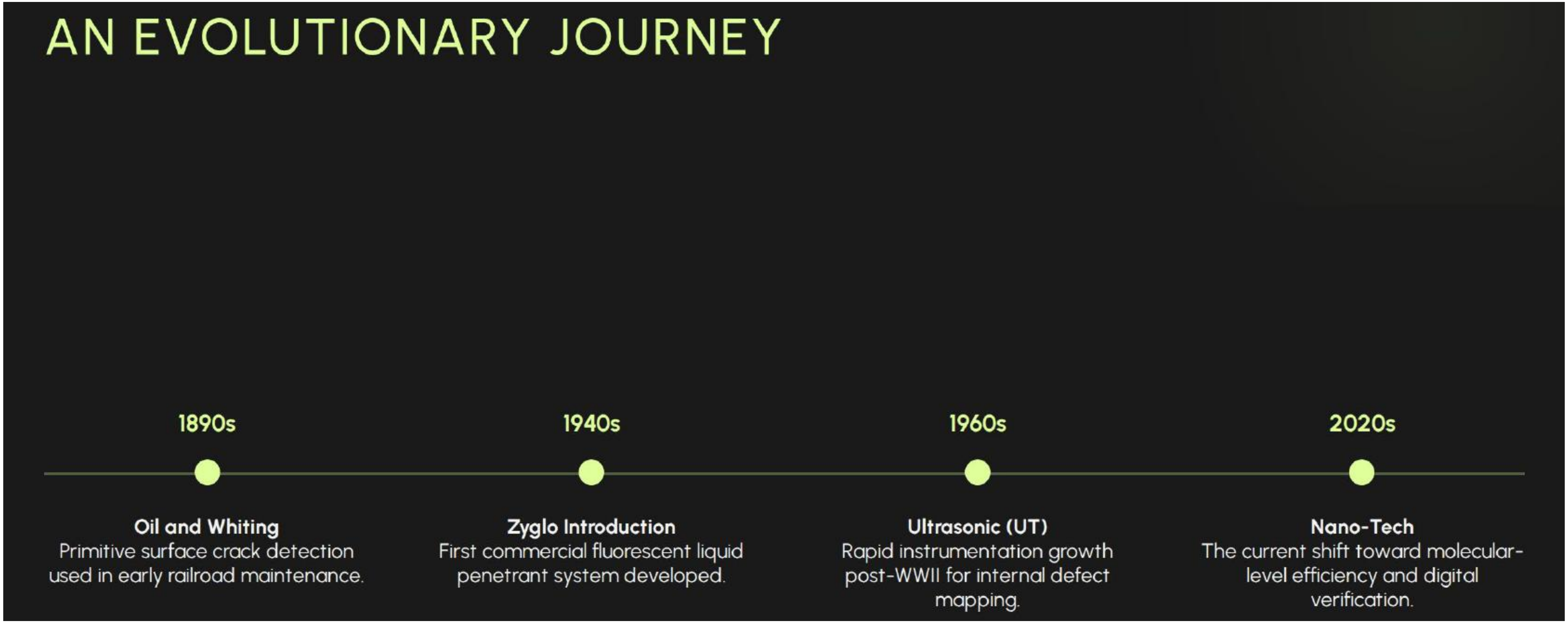
Beyond the Capillary: The Evolution of Surface Inspection From Ancient Metallurgy to Nano Liquids and Digital Physics..

20+ Years in Aviation, Marine, and Industrial TIC Driving Global Innovation through Strategic Solution Partnerships

Passionate about scaling startups and global known inspection projects

100%

of open surface inspection techniques will be transformed into Digital& Smart Nano liquid systems ?



Early Precursors: Practical “NDT Thinking” Before NDT Had a Name

Non-Destructive Testing is a mindset as old as the first forge. It was born from a craftsman's obsession with integrity:

Ancient LPI: Before "Quality Assurance," blacksmiths used oils and ash to let capillary action reveal hidden flaws in their steel.

Ancient UT: Long before transducers, masters used Acoustic Inspection ringing the metal to hear a crack before the eye could ever see it.

We’ve been "listening" to our work for 2,000 years..

When we talk about Non-Destructive Testing today, we usually picture lab coats, high-frequency transducers, and complex digital scans.

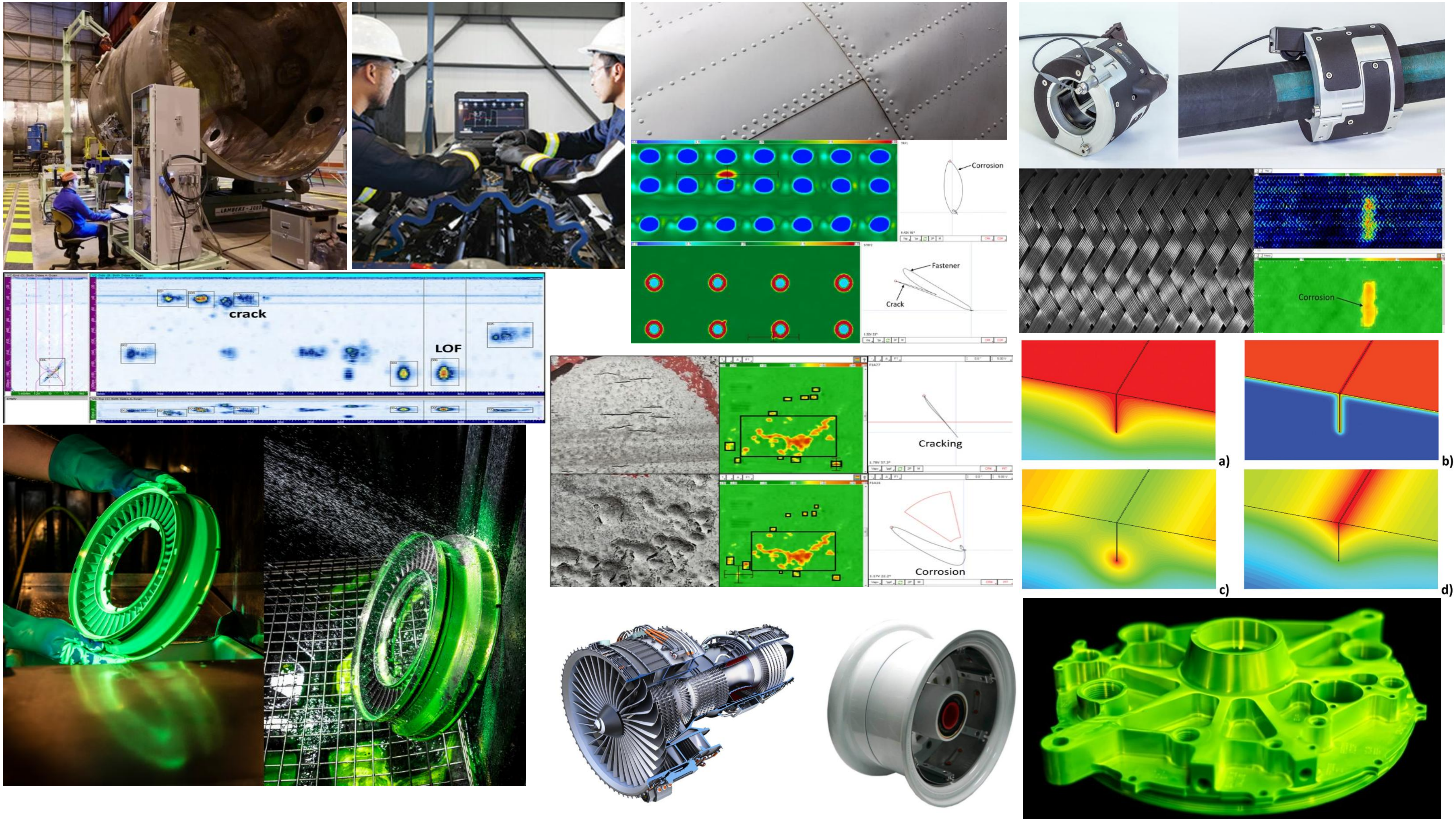
But NDT isn't just a suite of tools It's a mindset that's been part of the human story since the first forge was lit. ⚒️

From Traditional Foundations to the Frontier of Nano-Technological Efficiency

Rail inspection was a painstaking, manual process; it’s the very foundation upon which our modern surface techniques were built.

The progress made in surface inspection methods over the last century has been truly remarkable.

How did we evolve from these foundations?


crack
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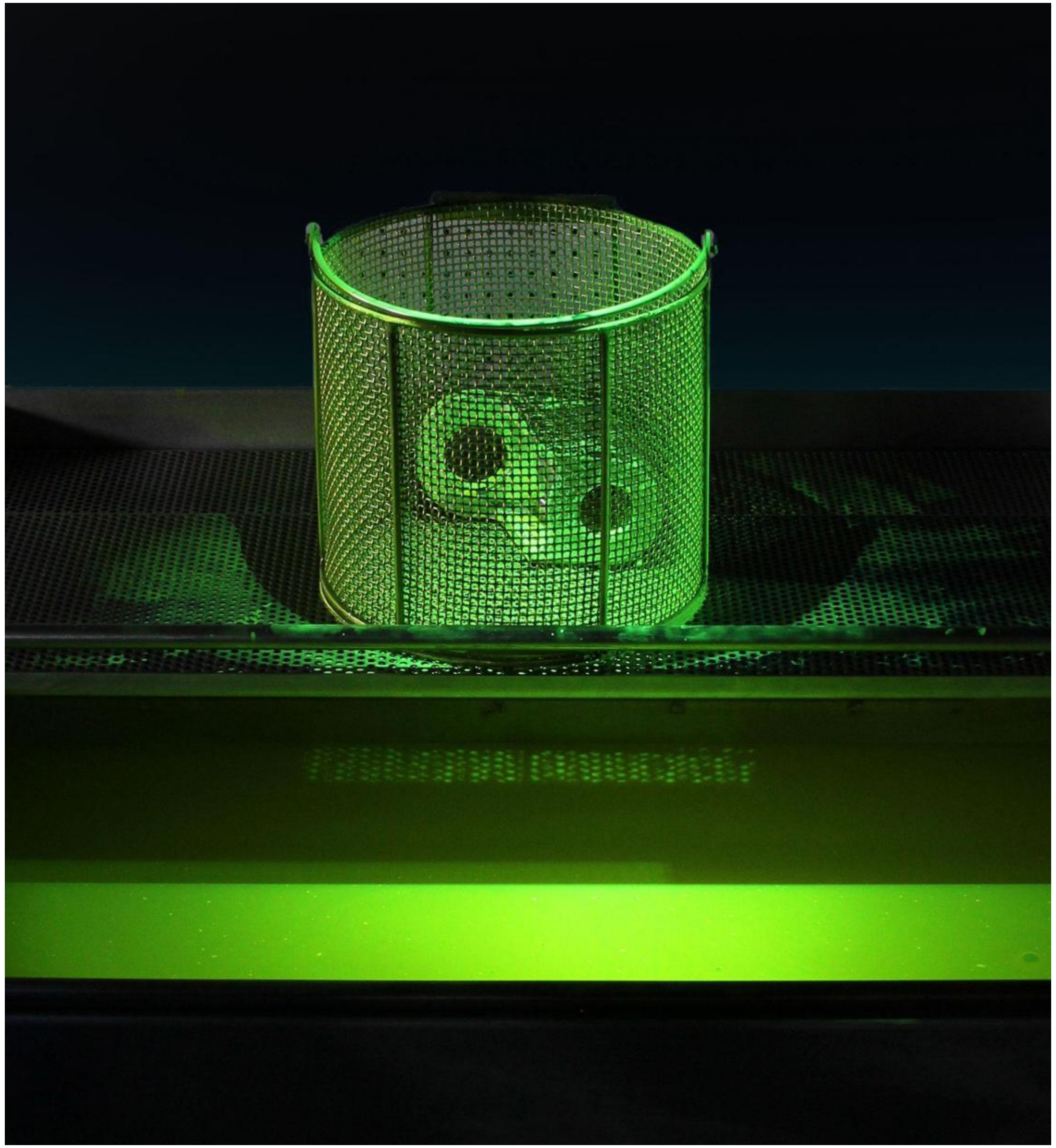
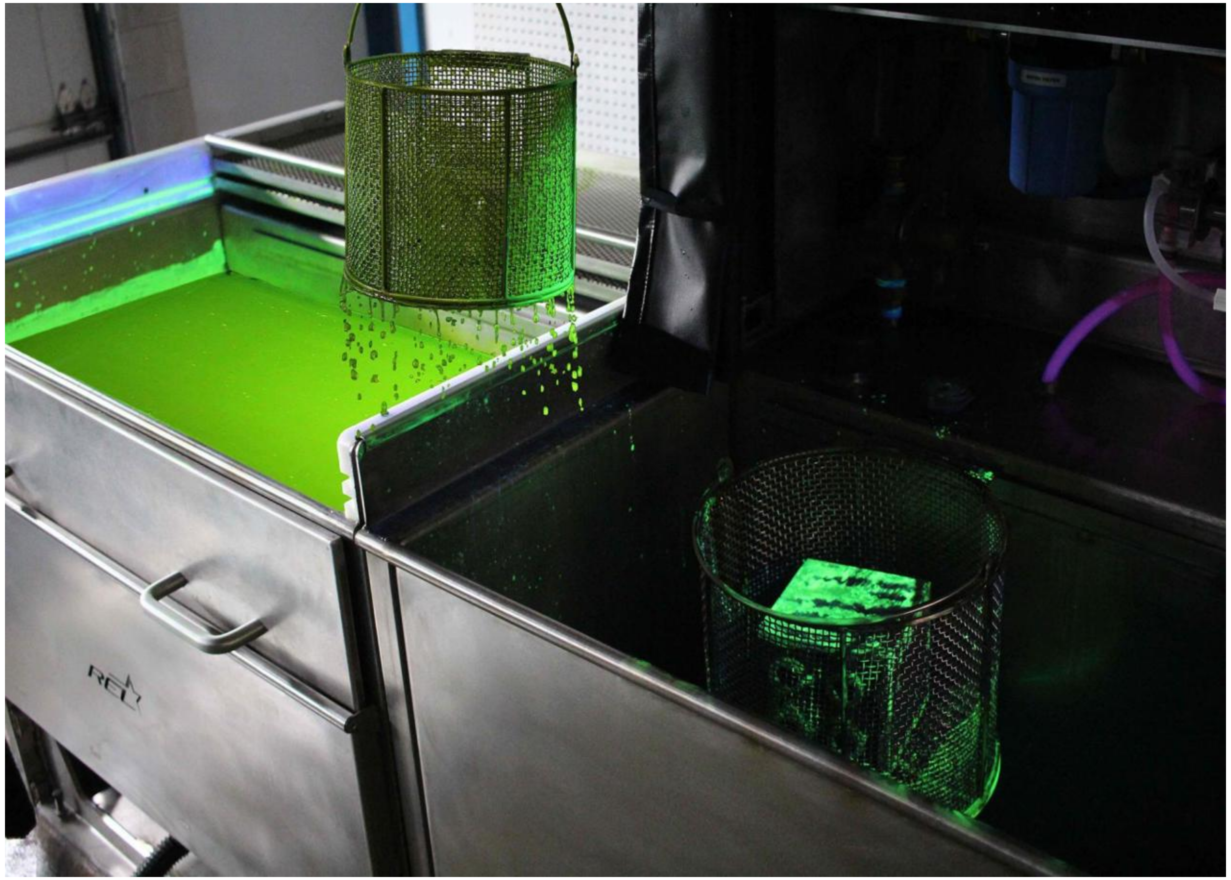
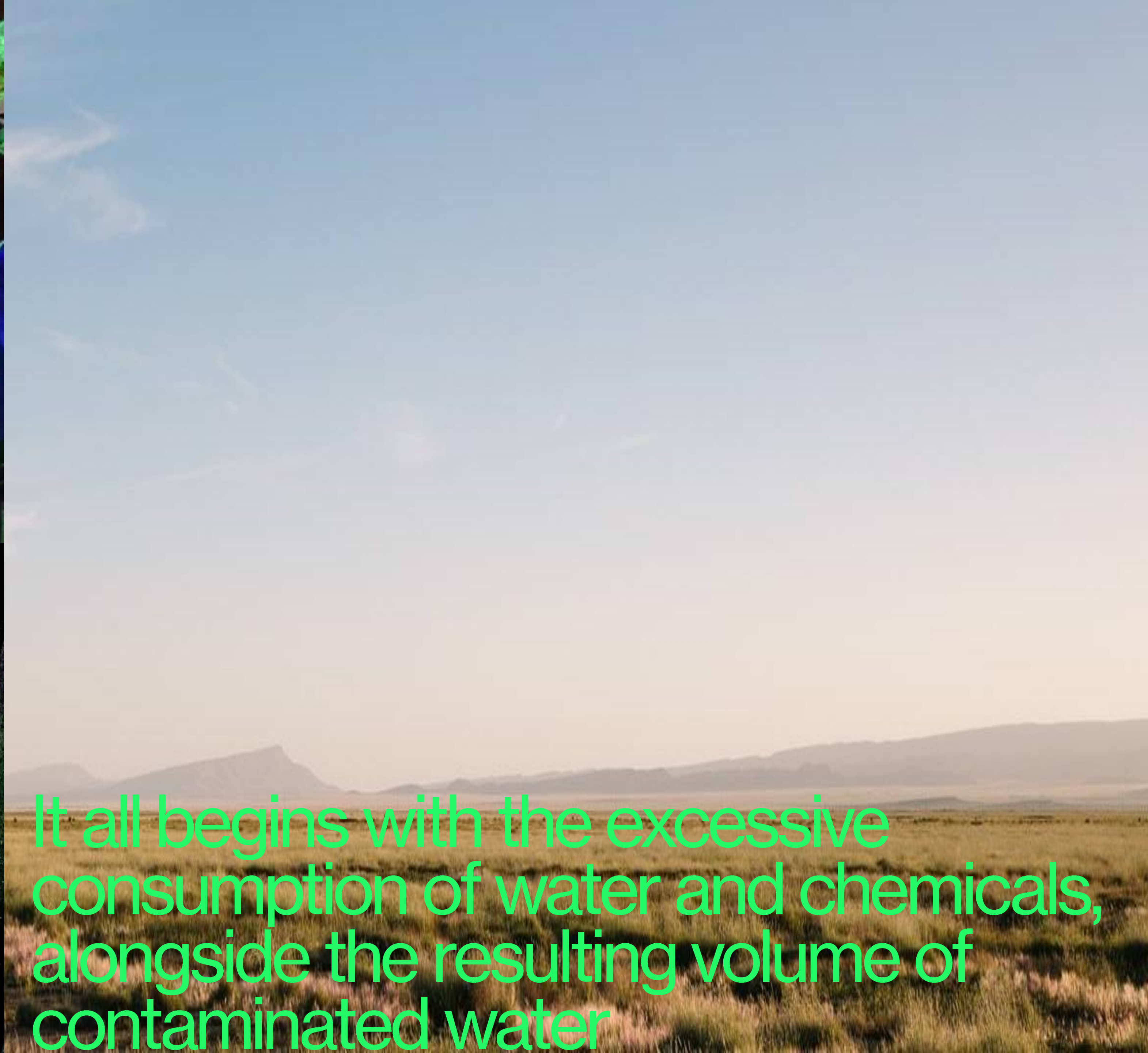
What if we were to pivot our approach by integrating innovative open surface methods through new nano-smart solutions and digital techniques?





The LPI process on its own is arguably one of the most complex NDT techniques we employ.



It all begins with the excessive consumption of water and chemicals, alongside the resulting volume of contaminated water

Method A with Digital Monitoring:

Water Consumption:

Reduced by ~50% via smart-rinse cycles

Chemical Waste:

Petroleum-free formulas allow for direct-drain disposal

Accuracy:

Digital AI verification ensures that "Green" doesn't mean "Less Safe."

Method	Physical Principle	Quantifiability	Non-Contact?	Key Aviation Benefit
Nanoliquid LPI (Method A)	Capillary action	Qualitative / Visual	No (Requires wetting)	Best for complex-geometry
ECA (Eddy Current Array)	Electromagnetic Induction	High (3D Mapping)	Near-contact (Coated parts OK)	High-speed mapping of wing skins
Ultrasonic Rayleigh Waves	Surface Acoustic Waves	High (Crack Depth)	No (Requires couplant)	Measuring precise depth of fatigue cracks
Laser-Pulse Thermography	Thermal Diffusivity	Medium (Digital Image)	Yes (Full Remote)	Fast screening for composite delamination

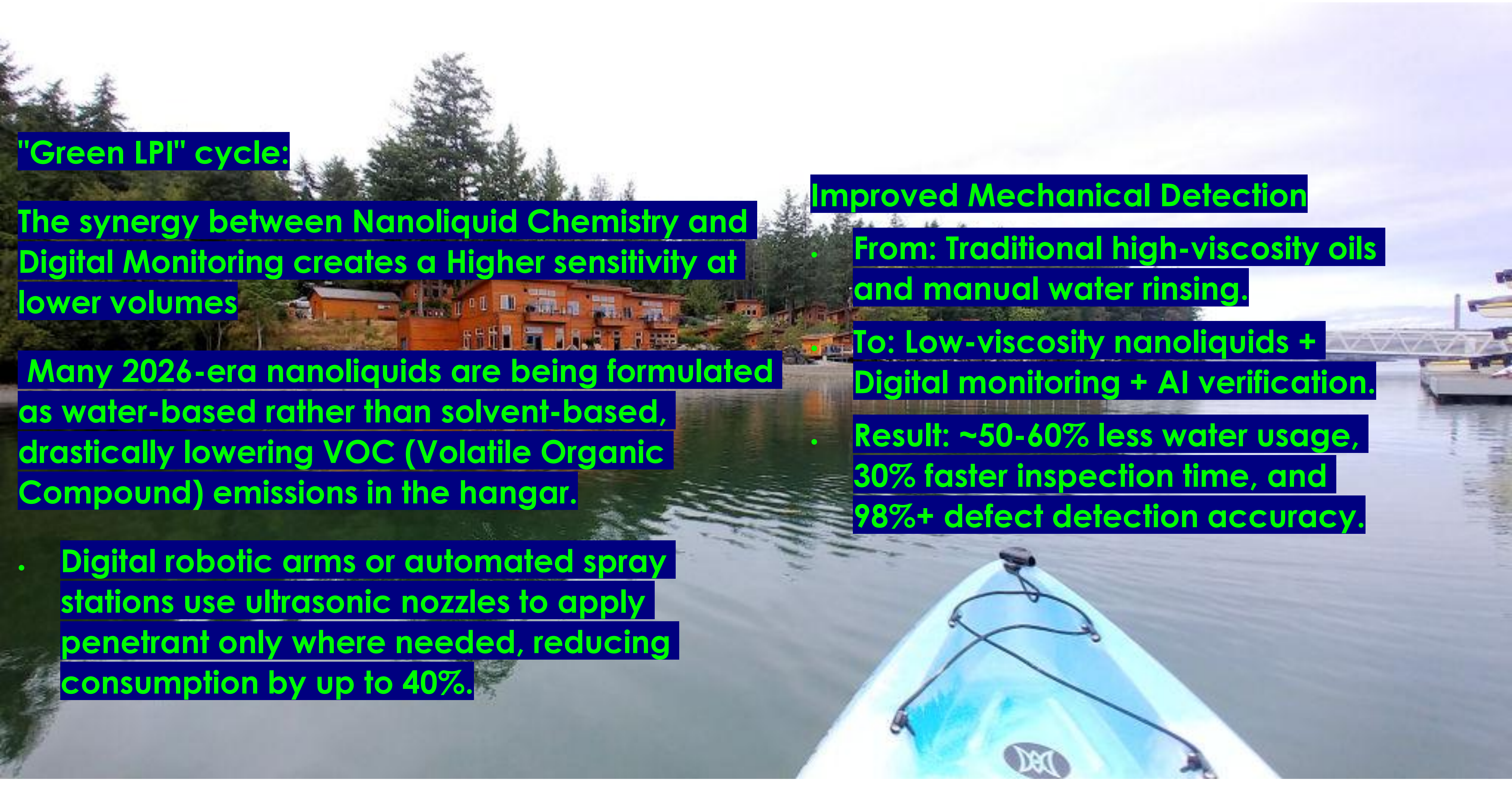
Open Surface Comparison Matrix

Digital Integration in Method A

Digital technologies act as the "guardrails" for Method A, ensuring that the speed of the process doesn't compromise the safety of the aircraft parts.

Digital Tool	Role in Method A	Environmental/M-Day Benefits
Smart Rinse Sensors	*Monitors the fluorescence level in the rinse water in real-time.*	*Automatically stops the rinse the moment surface excess is gone, preventing over washing +*
Robotic Spray Path	*Uses LiDAR to map the part geometry (e.g., an Aluminium wing spar).*	*Applies the exact volume needed, reducing chemical waste by 30-40% +*
AI Indication Scoring	*AI compares the fluorescent glow against a database of known material defects.*	*Eliminates "inspector fatigue" and provides a digital record of the crack's exact dimensions +*

Method A Optimisation Chart AI



"Green LPI" cycle:

The synergy between Nanoliquid Chemistry and Digital Monitoring creates a Higher sensitivity at lower volumes

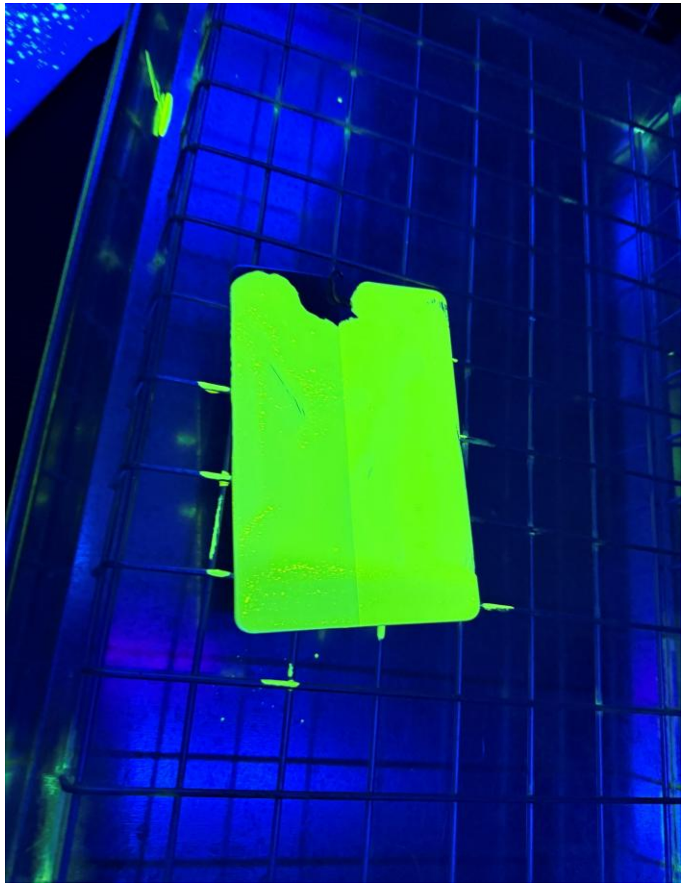
Many 2026-era nanoliquids are being formulated as water-based rather than solvent-based, drastically lowering VOC (Volatile Organic Compound) emissions in the hangar.

- Digital robotic arms or automated spray stations use ultrasonic nozzles to apply penetrant only where needed, reducing consumption by up to 40%.

Improved Mechanical Detection

- From: Traditional high-viscosity oils and manual water rinsing.
- To: Low-viscosity nanoliquids + Digital monitoring + AI verification.
- Result: ~50-60% less water usage, 30% faster inspection time, and 98%+ defect detection accuracy.

Would it still be possible to enhance the nano-solutions to achieve less than 0.1-5% excess in the cleaning process?



Research Study

With reverse engineering of 'Beyond Capillary' Yes ;

Embrace change.

Lead the future.

There is always room for improvement +

References:

1. Core Industry Standards (The Rules)
SAE-AMS 2644 (2026): The primary spec for penetrant materials. Reference the QPL for "Green" nanoliquid compliance.
ASTM E1417 (2025): Standard practice for LPI; provides new guidelines for automated spray and rinse cycles.
REACH Regulations (2026): EU limits on toxic chemicals; identifies nanoliquids as the primary replacement for old formulas.

2. Technical Innovation & MRO Sources (The Science)
HCLTech/GE Whitepaper (2026): Confirms AI-assisted inspection increases detection by 34% and slashes false alerts.
Aerospace Materials Performance Journal (2025): Documents how pH-neutral nanoliquids prevent micro-corrosion in Aluminum "blind holes".
Journal of NDE (2025): Proves nanoliquids achieve high sensitivity without the chemical intensity of traditional emulsifiers.
DLA Qualified Product Database (2026): The source for verifying officially approved NDT materials.

3. Sustainability & Digital Integration (The Vision)
ICAO / WEF Global Outlook (2026): Highlights NDT's role in Net-Zero 2050 goals via automation and waste reduction.
Airbus DDMS: A real-world benchmark for integrating Digital Twins and AI into the hangar.
Industry 4.0 Integration Report (2026): Details using AR overlays to guide technicians through dwell and rinse phases.

4. High-Value Data Points (For your "Slogan" or Callouts)
Smart Rinse Effect: Digital sensors reduce water waste from 1,000L to under 400L per shift.
The Source-Reduction Model: MRO facilities using AI (like YOLOv8) are reducing total wastewater by 60%.

Recent studies (2024–2026) emphasize a move away from the "pollute-then-treat" model of inspection to a **"source-reduction"** model.

- **Nanofluidics & Penetration Mechanics:** Research in the *Journal of Non-Destructive Evaluation (2025)* indicates that nanoliquid formulations overcome the "surface tension barrier" in high-strength Aluminum alloys (2024/7075). Unlike traditional fluids, nanoliquids use sub-micron particles to ensure that **Method A** (Water-Washable) achieves the sensitivity once reserved only for Method D, without the chemical intensity of secondary emulsifiers.
- **Digital Guardrails for Sustainability:** The *Global Aviation Sustainability Outlook (2026)* highlights that automation is the primary driver for reducing water waste. By using **AI-powered computer vision** (e.g., YOLOv8 models) and **smart-rinse sensors**, MRO (Maintenance, Repair, and Overhaul) facilities are reducing wastewater by up to **60%**, as the system stops the wash cycle precisely when the background fluorescence reaches a threshold, preventing "over-wash" and excess water use.
- **Aqueous-Base Evolution:** The shift toward **AMS 2644 Class W** (Water-based) penetrants is a major theme. Literature shows these formulas are not only safer for the environment (low VOCs) but also "material-friendly," preventing the micro-corrosion often caused by solvent residues in porous aluminum castings.

Resource Category	Key Document / Source	Significance for Your Content
Industry Standard	SAE-AMS 2644 (Updated 2026)	The "Bible" of penetrant materials. Reference the latest QPL (Qualified Product List) for nanoliquid compliance.
Technical Guide	ASTM E1417 / E1417M	Standard practice for Liquid Penetrant Testing. Crucial for validating Method A (Water-Washable) workflows.
Sustainability Report	ICAO Global Aviation Sustainability Outlook (2026)	Provides data on how NDT efficiency contributes to broader "Net-Zero 2050" aviation goals.
Digital Integration	Airbus DDMS (Digital Design Manufacturing & Services)	A real-world example of how major OEMs are integrating digital twins and AI into inspection.

Thank you

Q&A

Panel discussion session

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