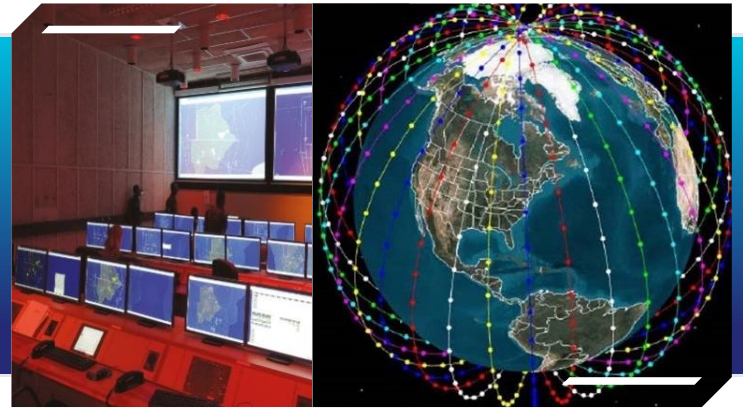


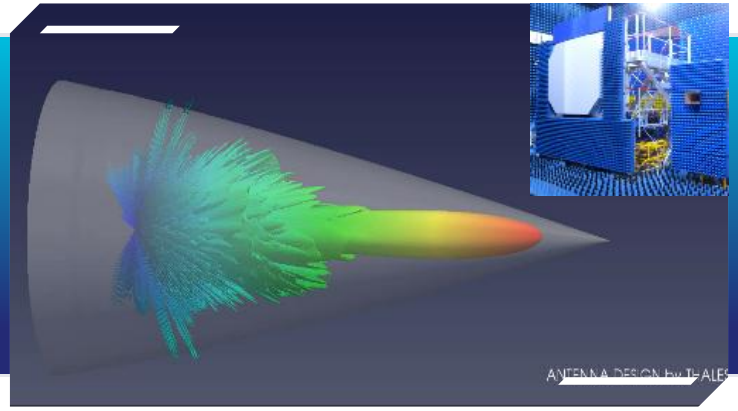
THALES
Building a future we can all trust

Quantum computing for Radar applications

Rami KASSAB
Head of Innovation for Surface Radars
www.thalesgroup.com

Quantum algorithms advantages for applications at scale







> **Complex problems non tractable in human time with supercomputers**

New operational capacities and services

> **Existing problems solved faster than with classical computers**

Performance improvement for augmented engineering

> **Cost, weight and energy advantage of quantum computing**

Reduction of carbon footprint and energy consumption

TLASFR-2026-00144513_000 – 15/10/2026 Thales LAS France / Template: 87211168-COM-GRP-EN-007

This document may not be reproduced, modified, adapted, published, translated, in any way, in whole or in part or disclosed to a third party without the prior written consent of Thales © 2026 THALES. All rights reserved.

Quantum algorithms use-cases: Engineering & in Operations



CONSTRAINTS ON PERFORMANCE
(integrity, accuracy,...)

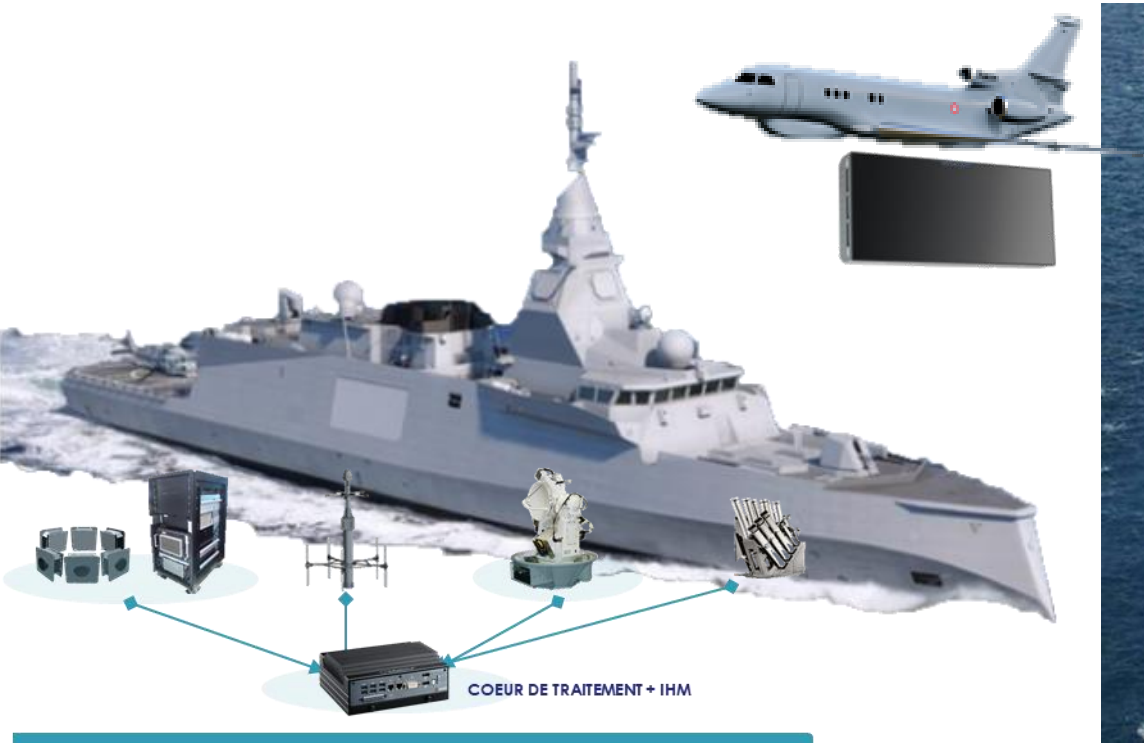
Quantum Code Analysis and Verification for Industrial and Military Critical Systems



CONSTRAINTS ON LOW LATENCY
(OODA loop acceleration)

TLASFR-2026-00144513_000 – 15/10/2026 Thales LAS France / Template: 87211168-COM-GRP-EN-007
This document may not be reproduced, modified, adapted, published, translated, in any way, in whole or in part or disclosed to a third party without the prior written consent of Thales © 2026 THALES. All rights reserved.

Use case: intensive electromagnetic simulation for design optimization and performance gains





Overcoming current limitations in EM simulation to address new technological challenges (optimized design, ultra-wideband, stealth, optimized platform payload, etc.)

TLASFR-2026-00144513_000 – 15/10/2026 Thales LAS France / Template: 87211168-COM-GRP-EN-007

This document may not be reproduced, modified, adapted, published, translated, in any way, in whole or in part or disclosed to a third party without the prior written consent of Thales © 2026 THALES. All rights reserved.

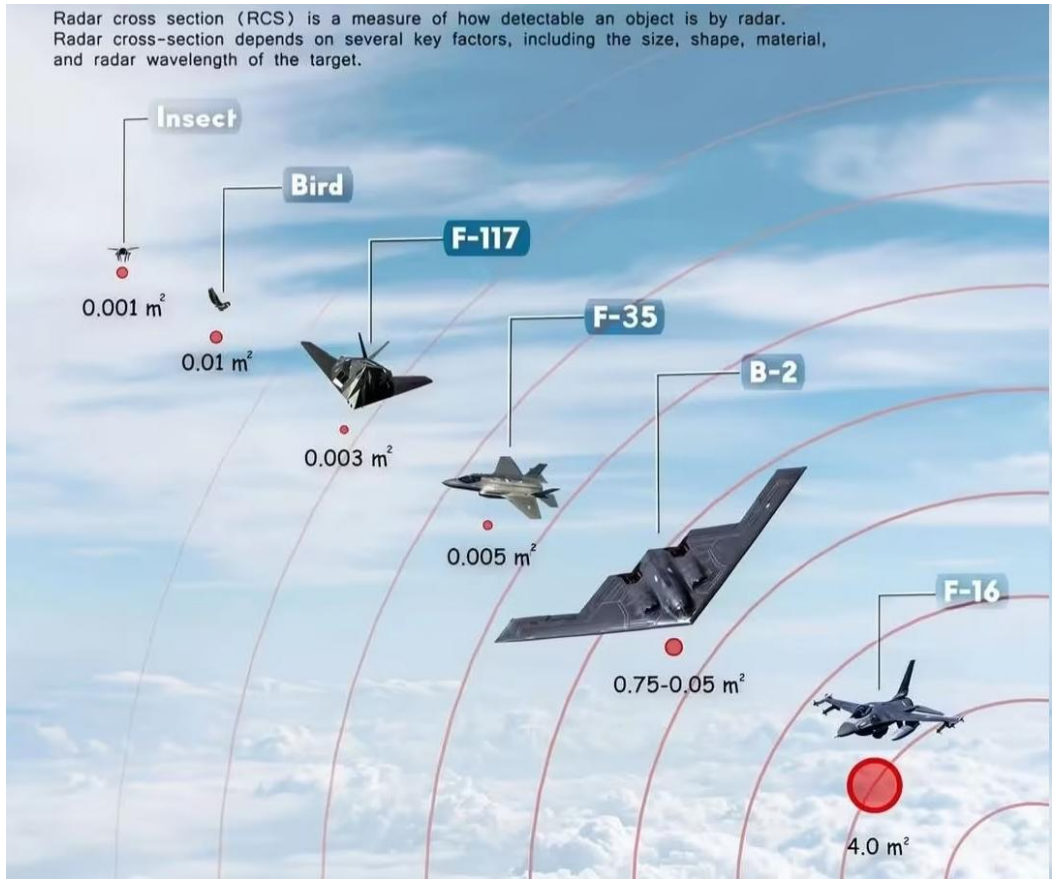
THALES
Building a future we can all trust

Radar Cross Section Estimation using the Variational Quantum Linear Solver Algorithm



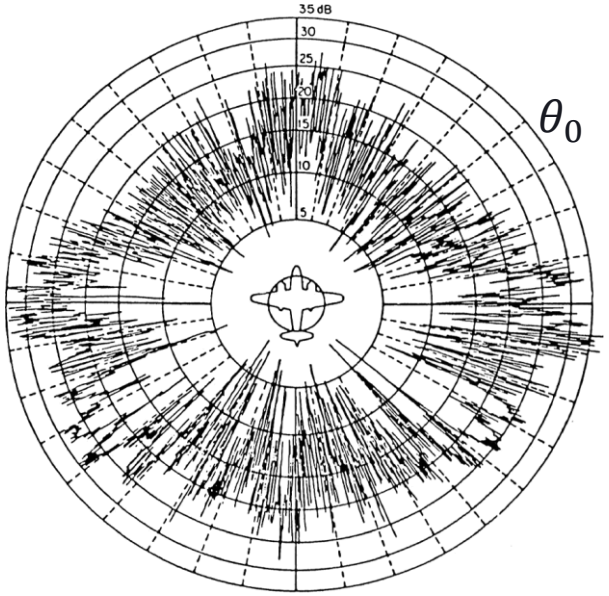
www.thalesgroup.com

Radar Cross Section σ



$$R^4 = \frac{P_t G^2 \lambda^2 \overline{\sigma}}{(4\pi)^3 L\, k\, T_0\, B\, F\, SNR_{min}}$$

$$\sigma(\theta_0) = \lim_{r_0 \to \infty} 4\pi r_0^2 \frac{|E_{sc}(r_0, \theta_0)|^2}{|E_0|^2} \quad [m^2]$$



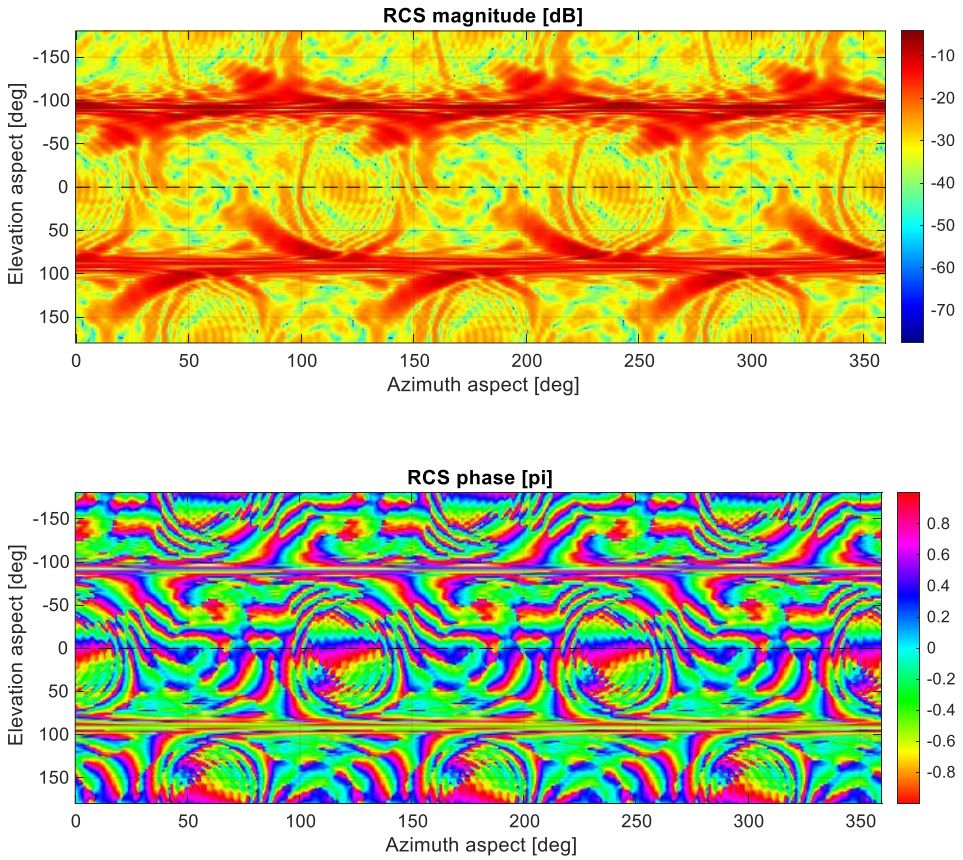
Statistical properties (Swerling cases)
→ for **detection**

But also **target signature** for classification

TLASFR-2026-00144513_000 – 15/10/2026 Thales LAS France / Template: 87211168-COM-GRP-EN-007

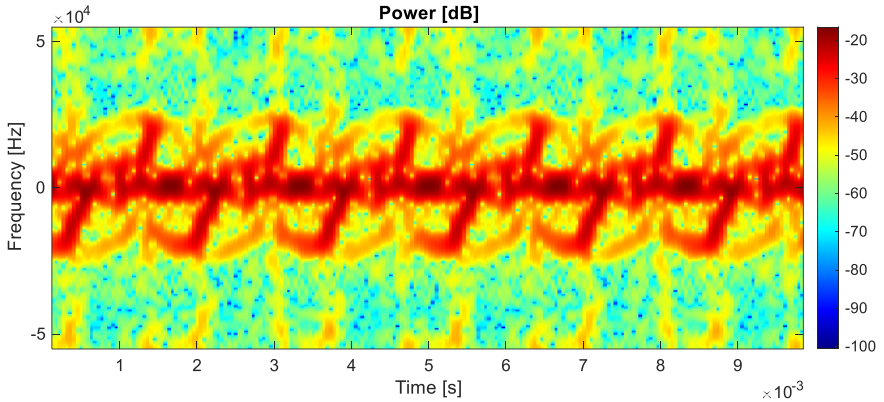
This document may not be reproduced, modified, adapted, published, translated, in any way, in whole or in part or disclosed to a third party without the prior written consent of Thales © 2026 THALES. All rights reserved.

Radar Cross Section → Target signature





Larger and more complex geometries and different materials → Maxwell → Finite Element Method (FEM)



Simulated micro-Doppler spectrogram for 2 rotations, PRF = 110 kHz @ 0° elevation aspect

3-bladed rotor (PEC) complex RCS estimate using MoM @ 24 GHz, HH-pol.

TLASFR-2026-00144513_000 – 15/10/2026 Thales LAS France / Template: 87211168-COM-GRP-EN-007

This document may not be reproduced, modified, adapted, published, translated, in any way, in whole or in part or disclosed to a third party without the prior written consent of Thales © 2026 THALES. All rights reserved.

Finite Element Method

> For full wave EM applications

Maxwell

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t},$$

$$\nabla \times \mathbf{H} = J + \frac{\partial \mathbf{D}}{\partial t},$$

$$\nabla \cdot \mathbf{D} = \rho,$$

$$\nabla \cdot \mathbf{B} = 0.$$

with,

$$\mathbf{D} = \epsilon \mathbf{E},$$
$$\mathbf{B} = \mu \mathbf{H},$$
$$\mathbf{J} = \sigma \mathbf{E} + \mathbf{J}_{\text{source}}$$

Helmholtz equation

With time dependency $e^{-i\omega t}$, we can write,

$$\mathbf{E}(\mathbf{r}, t) = \Re\{\mathbf{E}(\mathbf{r}) e^{-i\omega t}\}, \quad \mathbf{H}(\mathbf{r}, t) = \Re\{\mathbf{H}(\mathbf{r}) e^{-i\omega t}\}$$

Such that E-field becomes (fully Helmholtz),

$$\nabla \times \mu^{-1}(\nabla \times \mathbf{E}) - \omega^2 \epsilon \mathbf{E} = i\omega \mathbf{J}$$

Or simplified to,

$$\nabla^2 \mathbf{E} + k^2 \mathbf{E} = 0, \text{ with } k^2 = \omega^2 \mu \epsilon$$

when we would assume:

- *no sources:* $J = 0$.
- *homogeneous materials:* μ, ϵ *constant*
- *isotropic:* μ, ϵ *scalar*

Weak form

3D volume (target + environment) is e.g. a tetrahedral mesh. Field is linear combination of Nédélec base functions $\{\mathbf{N_j}\}$: $\mathbf{E} \approx \sum_j e_j \mathbf{N_j}$. Testing with $\mathbf{N_i}$ (Galerkin) and integration yields:

$$\sum_j \left[\int_\Omega (\nabla \times \mathbf{N_i}) \cdot \mu^{-1} (\nabla \times \mathbf{N_j}) \, d\Omega \bullet \omega^2 \int_\Omega \mathrm{b} N_i \cdot \epsilon \mathbf{N} j \, d\Omega \right] e_j = i\omega \int \Omega \mathbf{N_i} \cdot \mathbf{J} \, d\Omega.$$

TLASFR-2026-00144513_000 – 15/10/2026 Thales LAS France / Template: 87211168-COM-GRP-EN-007

This document may not be reproduced, modified, adapted, published, translated, in any way, in whole or in part or disclosed to a third party without the prior written consent of Thales © 2026 THALES. All rights reserved.

Finite Element Method

> For EM applications

To matrix form

$$\sum_j \left[\int_\Omega (\nabla \times \mathbf{N_i}) \cdot \mu^{-1} (\nabla \times \mathbf{N_j}) \, d\Omega \bullet \omega^2 \int_\Omega \mathrm{b}N_i \cdot \epsilon \mathbf{N}j \, d\Omega \right] e_j = i\omega \int \Omega \mathbf{N_i} \cdot \mathbf{J} \, d\Omega$$

Define:

$$M_{ij} = \int \mathrm{b}N_i \cdot \epsilon \mathbf{N_j} \, d\Omega \qquad K_{ij} = \int (\nabla \times \mathbf{N_i}) \cdot \mu^{-1} (\nabla \times \mathbf{N_j}) \, d\Omega$$

$$f_i = i\omega \int \mathrm{b}N_i \cdot \mathbf{J} \, d\Omega \quad \text{(source vector)}$$

We obtain,

$$(K - \omega^2 M) e = f$$

which rewrites to,

$$A\, x \;=\; b$$

Classic state of the art methods offer at best $\mathcal{O}(N\kappa)$

With N system dimension (e.g. number of edges) and κ the condition number of A. Note that A is sparse.

Exponential speed up in quantum if we encode in amplitude:

$$\mathrm{x} \rightarrow |\mathrm{x}\rangle$$
$$\mathrm{b} \rightarrow |\mathrm{b}\rangle$$

$$A|\mathrm{x}\rangle = |\mathrm{b}\rangle$$

$$\rightarrow \; \mathcal{O}(\log(N)\, \kappa^2)$$

TLASFR-2026-00144513_000 – 15/10/2026 Thales LAS France / Template: 87211168-COM-GRP-EN-007

This document may not be reproduced, modified, adapted, published, translated, in any way, in whole or in part or disclosed to a third party without the prior written consent of Thales © 2026 THALES. All rights reserved.

Quantum Linear System Problem

$$A|x\rangle = |b\rangle \rightarrow |x\rangle \propto A^{-1}|b\rangle$$

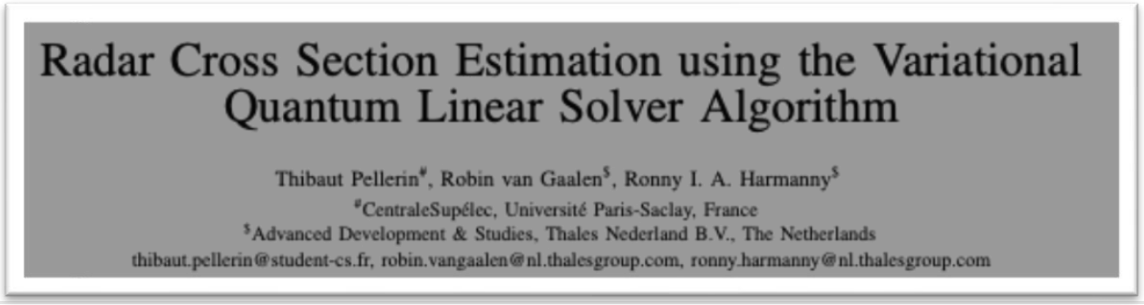
HHL: $\frac{1}{2}\,|\mathbf{Tr}\,|x_0\rangle\langle x_0| - |x\rangle\langle x||\, \leq \epsilon$

Computing electromagnetic scattering cross section of a target (Clader et al., 2013).

Resource analysis of HHL algorithm by Scherer et al. (2017):

$$N = 332{,}020{,}680, \quad \epsilon = 0.01,$$

341 qubits, 10^{25} gates, and 10^{21} measurements.



Radar Cross Section Estimation using the Variational Quantum Linear Solver Algorithm

Thibaut Pellerin[#], Robin van Gaalen[$], Ronny I. A. Harmanny[$]
[#]CentraleSupélec, Université Paris-Saclay, France
[$]Advanced Development & Studies, Thales Nederland B.V., The Netherlands
thibaut.pellerin@student-cs.fr, robin.vangaalen@nl.thalesgroup.com, ronny.harmanny@nl.thalesgroup.com

Variational Quantum Eigensolver for this NISQ era

Some conditions

- A is *invertible* ($\kappa < \infty$)
- $|b\rangle$ can be *efficiently prepared*, $U|0\rangle = |b\rangle$.
- Decomposition of the matrix A into a *polynomial linear combination* of L unitaries of the form

$$A = \sum_{l=1}^{L} c_l A_l$$

- Estimate for $|x\rangle$ can be *efficiently prepared and characterized*, $V(\alpha)|0\rangle = |\psi\rangle \approx |x\rangle$.

TLASFR-2026-00144513_000 – 15/10/2026 Thales LAS France / Template: 87211168-COM-GRP-EN-007

This document may not be reproduced, modified, adapted, published, translated, in any way, in whole or in part or disclosed to a third party without the prior written consent of Thales © 2026 THALES. All rights reserved.

THALES
Building a future we can all trust

Conclusion



www.thalesgroup.com

France has running-ahead technology assets to be among the global leaders of the quantum computer race… and Thales is playing a key role in this game

1

AVANT-GARDE

As a QPU early adopter, pioneering at scale the quantum computing based applications

2

DUAL TECHNOLOGIES

As a dual company, synergizing quantum algorithms for civil and defense use-cases

3

QUANTUM HUB

As a global hub of partnerships, connecting startups, major companies and research organizations around quantum machines, algorithms and real use-cases

4

QPU BENCHMARK

As a leader of the French / European benchmark initiative, structuring the evaluation methodologies and standardization metrics for quantum computers and applications

TLASFR-2026-00144513_000 – 15/10/2026 Thales LAS France / Template: 87211168-COM-GRP-EN-007

This document may not be reproduced, modified, adapted, published, translated, in any way, in whole or in part or disclosed to a third party without the prior written consent of Thales © 2026 THALES. All rights reserved.

Quantum Computing for Radar Engineering

> References:

[1] Chih-Kang Huang, Giacomo Antonioli, Frédéric Barbaresco, A Quantum Spectral Framework for Solving PDEs, arXiv:2604.25825v1 [quant-ph]

[2] Elise Fressart, Michel Nowak, Nicole Spillane, Adaptive mesh refinement quantum algorithm for Maxwell's equations, arXiv:2504.01646v1 [quant-ph]

[3] Elise Fressart, Michel Nowak, Nicole Spillane, Quantum Domain Decomposition for Preconditioning the Finite Element Method, arXiv:2605.26090v1 [math.NA]

[4] Timothe Presles, Cyrille Enderli, Gilles Burel, El Houssain Baghious, Phase-coded Radar Waveform Design with Quantum Annealing, arXiv:2305.17953v2 [cs.ET]

[5] Timothe Presles, Cyrille Enderli, Gilles Burel, El Houssain Baghious, Quantum Computing for Partition Function Estimation of a Markov Random Field in a Radar Anomaly Detection Problem, arXiv:2501.01154v1 [cs.ET]

This document may not be reproduced, modified, adapted, published, translated, in any way, in whole or in part or disclosed to a third party without the prior written consent of Thales © 2026 THALES. All rights reserved.

THALES
Building a future we can all trust

Thank you

www.thalesgroup.com