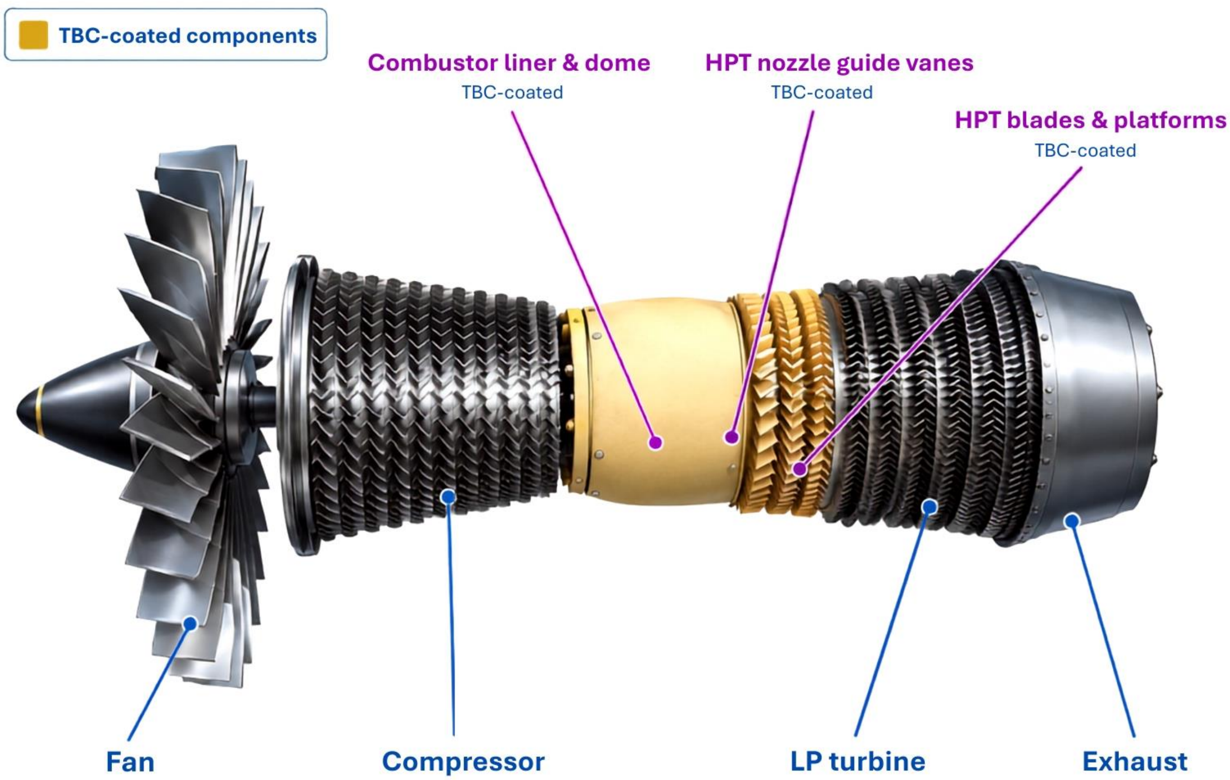
Thermal Barrier Coating Inspection

Terahertz Technology for Non-Contact TBC Thickness Measurement, TGO Monitoring and Hidden Defect Detection

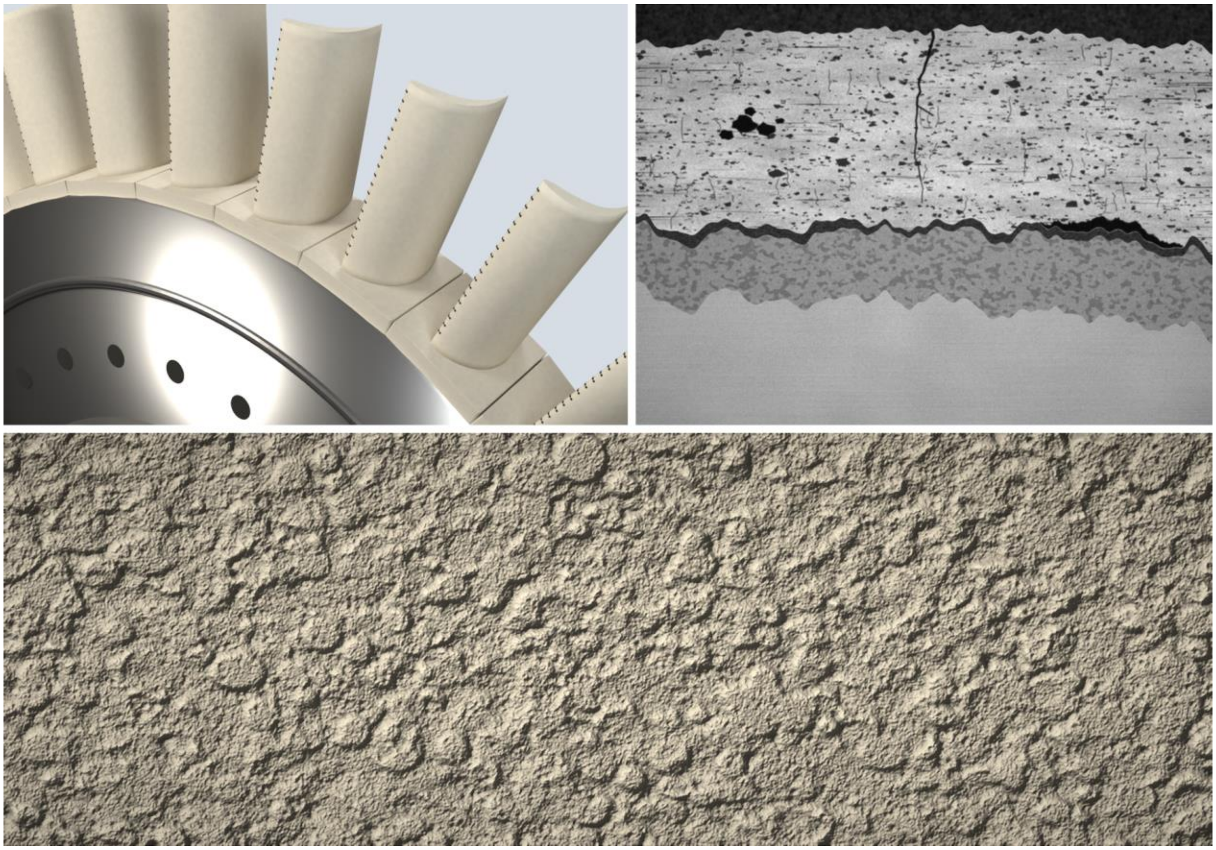
Thermal Barrier Coating (TBC) is applied on critical gas-turbine hot-section components in aerospace and power generation sectors. The TBC coatings protect metallic surfaces from extreme thermal, and environmental conditions thereby increases their lifespan. TBC performance depends on topcoat thickness, microstructure, porosity, thermally grown oxide (TGO) and coating–bond-coat interface integrity, which can evolve during processing and service.

TeraNIM-Aero™ uses Terahertz Time-Domain Spectroscopy (THz-TDS) to provide non-contact, non-ionising and non-destructive inspection of suitable TBC systems. It enables surface coating thickness assessment, interface evaluation and defect indication without sectioning or couplants—across **turbine blades, vanes, combustor liners, shrouds and transition ducts**.



Why Thermal Barrier Coatings need Non-Contact Inspection?

- Multilayer structure: ceramic topcoat, TGO, bond coat and metallic substrate
- TGO growth and ageing hidden beneath the ceramic topcoat
- Delamination, voids and air-filled cracks at unknown depth near the interfaces
- Porosity and microstructure that vary with the APS / EB-PVD process and thermal history

- Thickness variation and erosion across curved blade and vane surfaces
- 

Conventional TBC Inspection & Challenges

BORESCOPE / VISUAL

Surface-visible inspection; no subsurface assessment.

EDDY CURRENT

Ceramic TBC is non-conductive; measurements are sensitive to probe spacing, geometry and multilayer effects.;

ULTRASONIC

Contact/couplant requirements; challenging for thin, porous coatings.

IR THERMOGRAPHY

Indirect subsurface assessment; requires controlled heating.

X-RAY / CT

Specialised infrastructure and radiation controls.

SEM / SECTIONING

Detailed characterisation, but destructive method.

How Terahertz Technology Works for TBC Inspection

THz pulses penetrate the ceramic topcoat and reflect from material interfaces. The time delay between reflections provides information about coating thickness and interface depth.

Delamination, voids and air-filled cracks alter the reflected THz waveform, producing changes in amplitude, phase or arrival time that can indicate defect presence and depth. The metallic substrate provides a strong reflection defining the coating boundary.

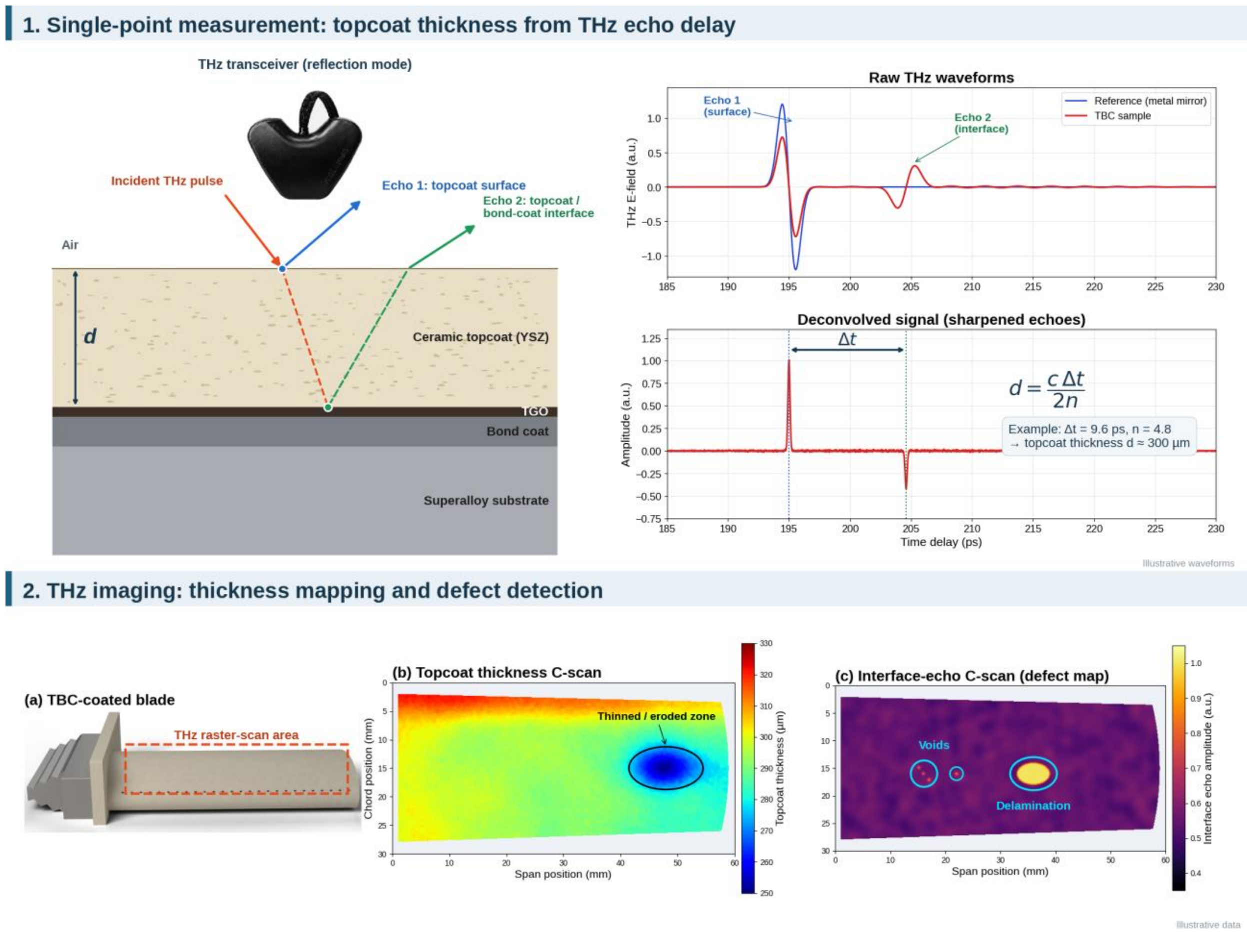
Advanced signal processing separates overlapping reflections, enabling extraction of coating and interface information from calibrated structures.

Air → Ceramic Topcoat → TGO → Bond Coat → Metallic Substrate

Terahertz Inspection Capability Across TBC Systems

TBC system	Thickness mapping	Interface & delamination	Porosity & structure	Erosion & ageing
Lamellar plasma-sprayed TBCs **APS and APS-DVC · 7–8YSZ**	● Topcoat thickness maps	● Air gaps and delamination	● Porosity from pulse broadening	◐ Erosion loss; TGO growth
Columnar TBCs **EB-PVD, SPS and PS-PVD · 7YSZ**	● Thickness maps on curved parts	◐ Delamination indications	◐ Column and gap structure	◐ Erosion loss; TGO growth
Advanced low-k and CMAS-resistant TBCs **Rare-earth-doped zirconia; $Gd_2Zr_2O_7$ or zirconate on YSZ double layers**	◐ Total and per-layer thickness	◐ Layer interfaces and delamination	◐ Microstructure indicators	◐ Erosion loss; TGO growth
Service-exposed TBCs (MRO) **Any process, after engine running**	● Remaining topcoat thickness	● Spallation and delamination maps	◐ Sintering and densification	○ TGO growth and ageing state

● Demonstratable with THz-TDS ◐ Need validation on coupons ○ Indirect, needs advanced analysis



TeraNIM Thermal Barrier Coating Inspection Workflow

STEP 1 — SCAN

Direct a THz pulse onto the coated component in reflection mode and acquire reflected signals across the defined inspection area using single-side, non-contact scanning with controlled stand-off.

STEP 2 — DETECT

Identify reflections and signal changes associated with the topcoat surface, TGO and bond-coat interfaces, and internal discontinuities such as delamination, voids, porosity changes and coating loss.

STEP 3 — ANALYSE & REPORT

Determine topcoat thickness, TGO and ageing indications, and defect location, generate 2D B-scan / C-scan coating maps, flag low-confidence pixels and provide the Pass / Fail inspection result.

Key Advantages for Aerospace and Power-Generation OEMs

- **Non-Contact —** No probe contact, no couplant on the coated surface.
- **Non-Destructive and Non-Ionising —** No sectioning of the coating, no radiation facility.
- **Metallic Substrates —** Reflection mode works on opaque turbine alloys.
- **Thickness & TGO Monitoring —** Topcoat thickness and TGO-related changes from the same waveform.
- **Delamination Detection —** Air-filled defects alter the reflected THz signal.
- **Automation Ready —** Integrates with scanners, robots and cobots for curved parts.

Thermal Barrier Coating Quality Control with TeraNIM™

TeraNIM-Aero provides a non-contact and non-destructive approach for inspecting validated thermal barrier coating systems. By combining THz reflection measurement, coating-specific refractive-index calibration, signal processing and automated scanning, the system can support topcoat thickness measurement, TGO growth monitoring, porosity indication, delamination detection, erosion mapping and automated hot-section component inspection.