Terahertz Inspection

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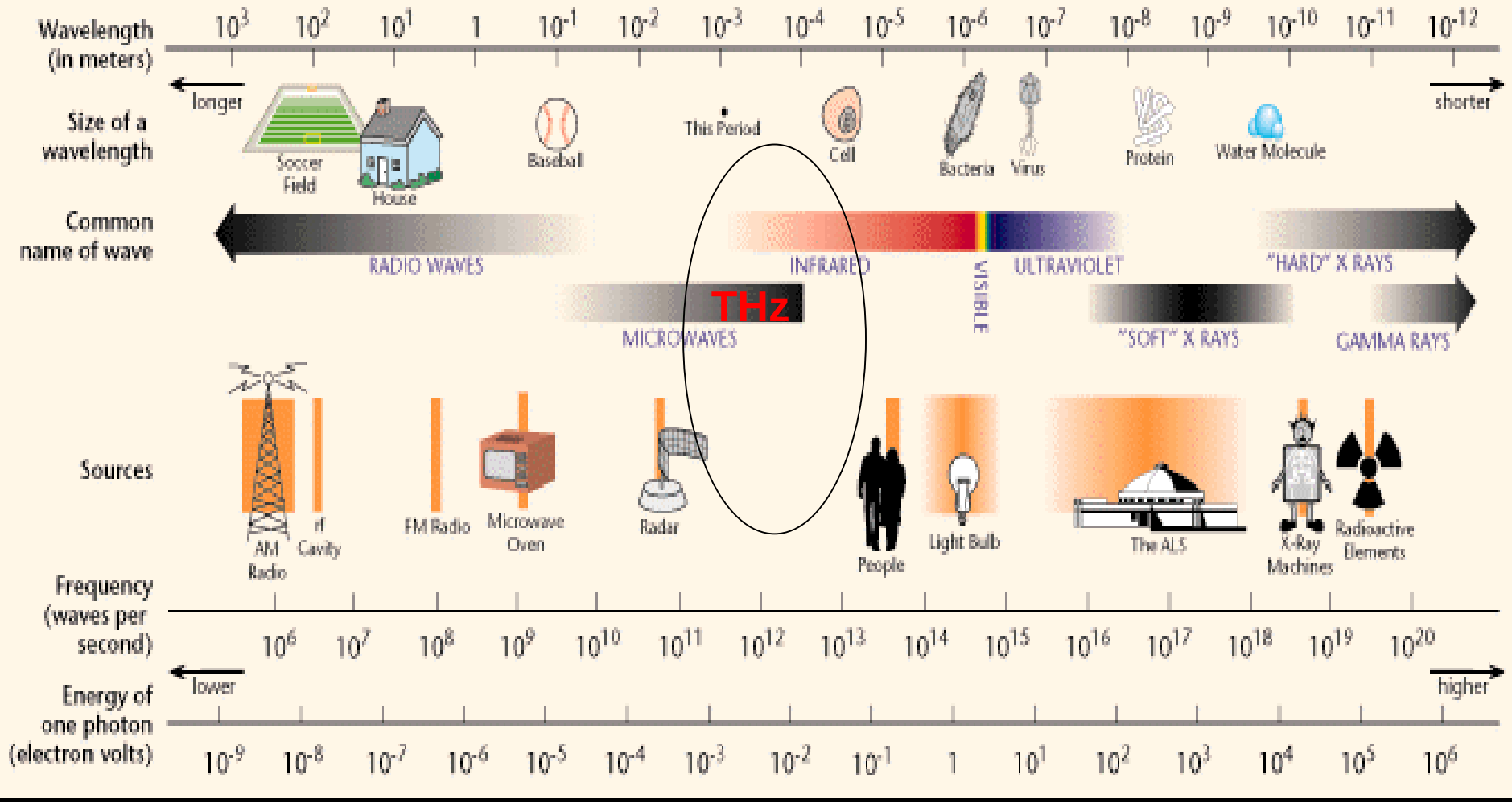
Dutch Terahertz provides THz inspection services for monitoring and detection of volume defects (i.e. **voids, delamination, porosity**) in **dielectric composite** material (particular foam, honeycomb structure, epoxy, glass fiber) manly used in **marine** and **aerospace** industry

Dutch Terahertz
SPACE QUALITY INSPECTION

NOVA

esa
business incubation centre
Noordwijk
managed by SBIC

THE ELECTROMAGNETIC SPECTRUM



Terahertz Instruments for Space

- Terahertz instrumentation is originally designed to deal with cosmic radiation with a very high frequency from 100 GHz till 3 THz:
  - Herschel Space Observatory launched by European Space Agency in 2009
  - International ground based mission ALMA Atacama Large Millimeter Array (NOVA)

NOVA Netherlands Research School for Astronomy

- These missions are designated to investigate the birth and death of stars, research physics of the cold Universe and directly image the formation of planets
- Terahertz instrumentation has also great potential in inspection of composite materials
- Terahertz non-destructive testing method was born on the technological arena after NASA Columbia Shuttle Catastrophe in 2003

TeraHertz vs Ultrasound

- The behavior of THz TD waves is similar to ultrasonic waves, with only fundamental difference that THz radiation propagates via composite specimen as an electromagnetic wave and ultrasound as a mechanical wave
- It implies that phenomena, such as diffraction, reflection and refraction are valid both for ultrasonic and THz waves
- Ultrasonic inspection suffers from "shadow effect", where a smaller crack situated behind a larger crack could not be detected. In contrast, there is no such limitation with terahertz
- At higher THz frequencies - on the border with IR - under certain conditions the quantum phenomena, such as entangled photons, might be observed. That opens a revolutionary way of developing quantum images based completely on a new principle, i.e. where one photon interacts with a specimen under test, and another photon - which does not interact with a substance at all - is used to construct the image

Ref: G.B. Lemos, V. Borish, G.D.Cole, S. Ramelow, R.Lapkiewicz, A.Zeilinger, "Quantum imaging with undetected photons", Nature 2014/08/28/print, 512, 409–412.

TeraHertz and Composites

- Non-conducting composites, such as glass fiber reinforced plastic, foam, epoxy, ceramics, balsa wood, Kevlar, Nomex honeycomb sandwich, SOFI foam, etc. are transparent in THz frequency range

- Carbon fiber based composites are conductive and highly reflective in THz frequency range

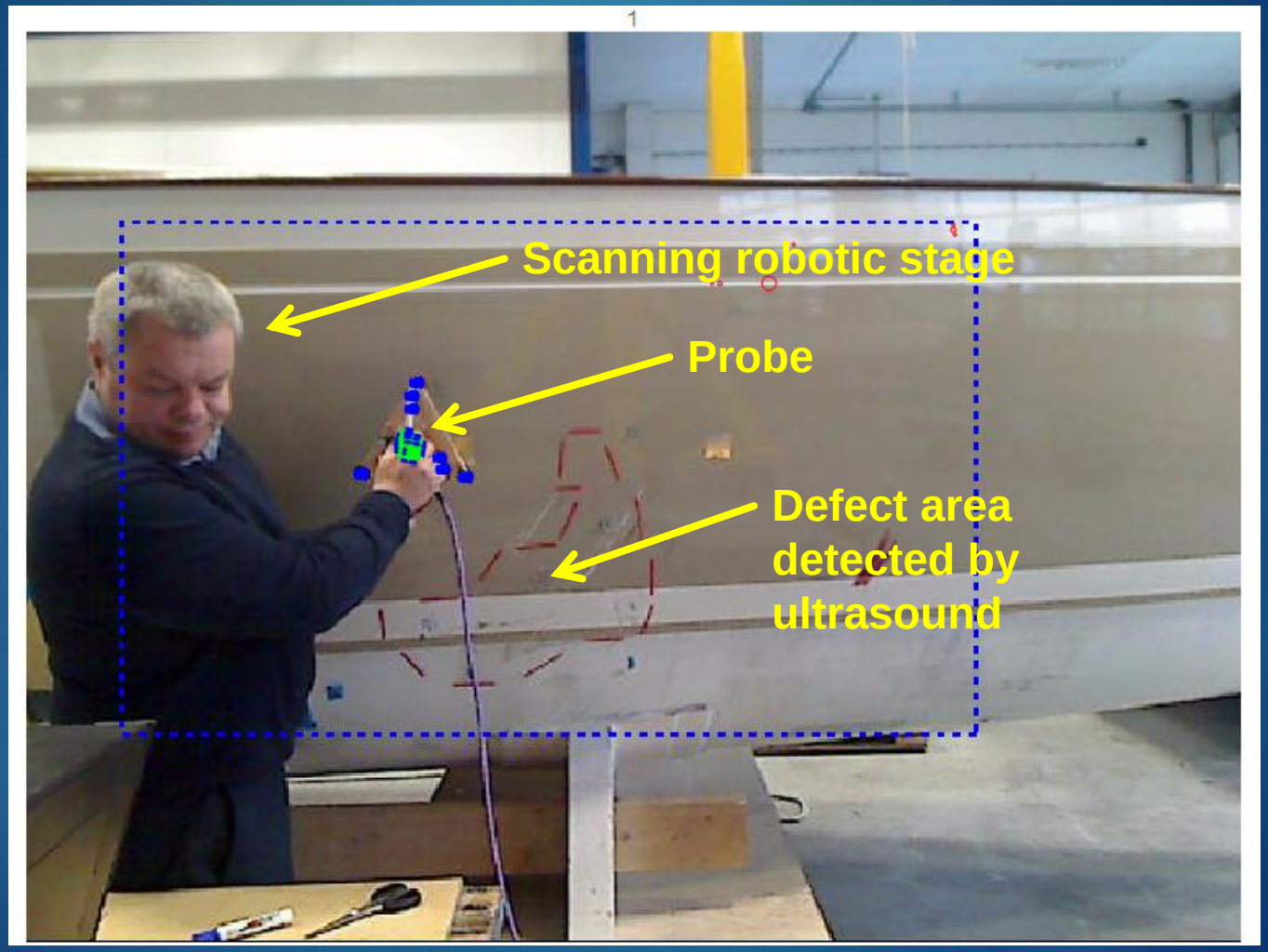
  - In a unidirectional CFRP laminate highly anisotropic electrical conductivity $\sigma_l \gg \sigma_t$ is observed, e.g. longitudinal conductivity (σ_l) varies from $1x10^4$ to $6x10^4$ S/m versus transverse conductivity (σ_t) from 2 to 600 S/m
  - Reflectivity will depends on fiber orientation and polarization of the incident THz radiation
  - This property of THz radiation behavior is used to assess various heat damage levels in CFRP materials

Terahertz Inspection

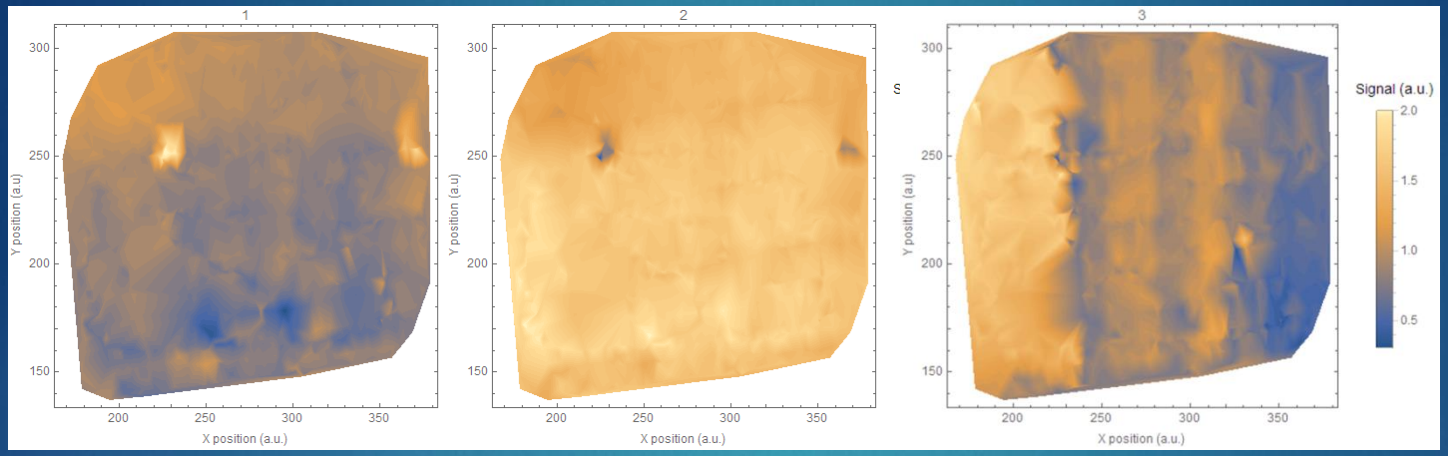
- A marine composite assembly under test, where the upper layer is GFRP, followed by foam attached by epoxy resin to monolithic CFRP hull

- We need to identify the following defects: porosity, delamination, voids and weak bounds

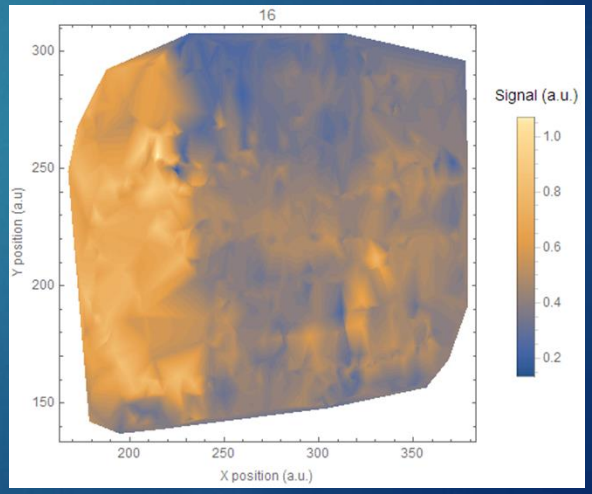
Terahertz Inspection Process



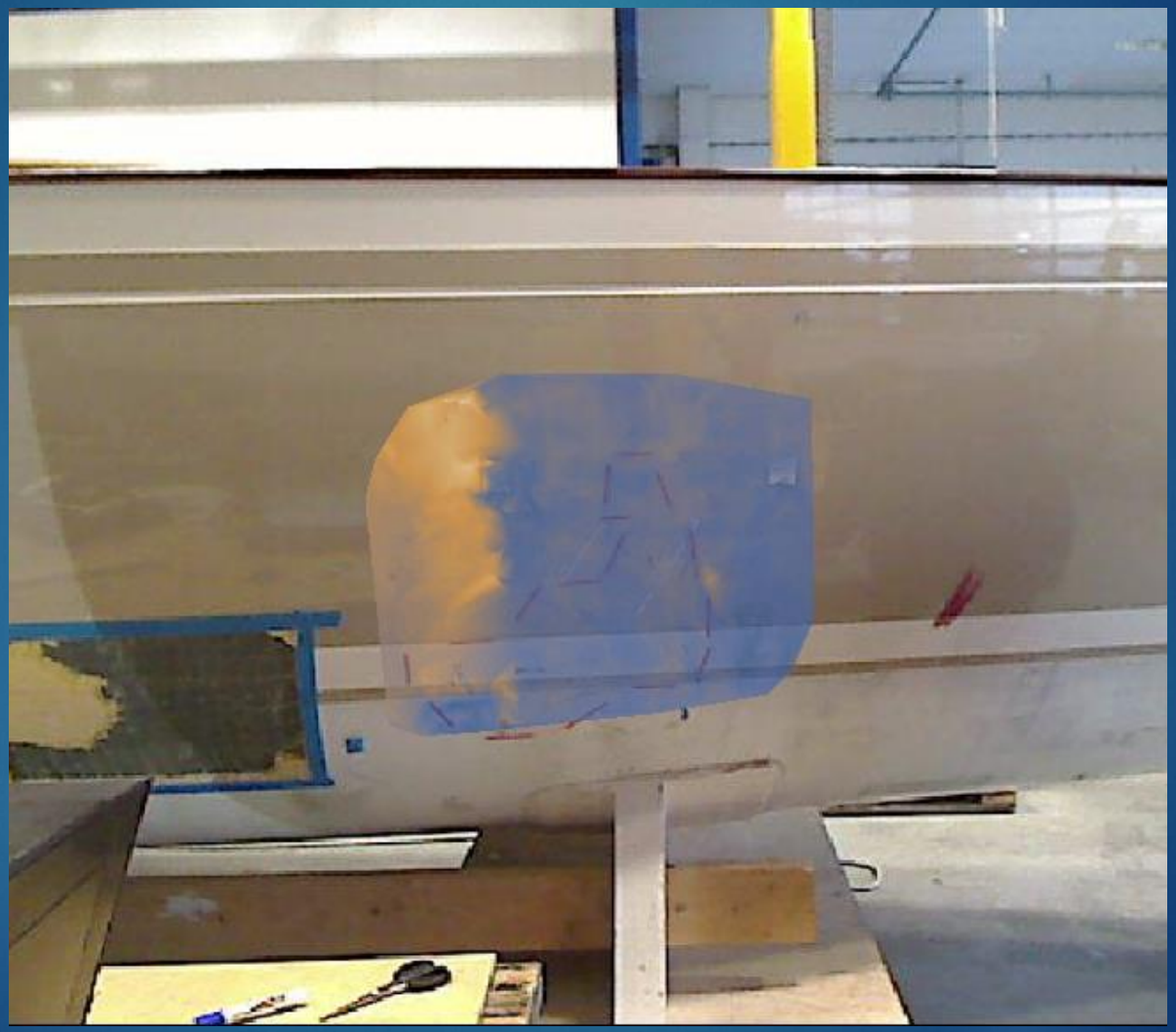
Terahertz Images



- Reflected THz signal. ‘Dark blue’ areas indicate the presence of the defects and ‘yellow areas’ indicate the ‘0’ defect zone. Reflective tape markers used as reference points are clearly visible at coordinates (230,250) and (370,250).

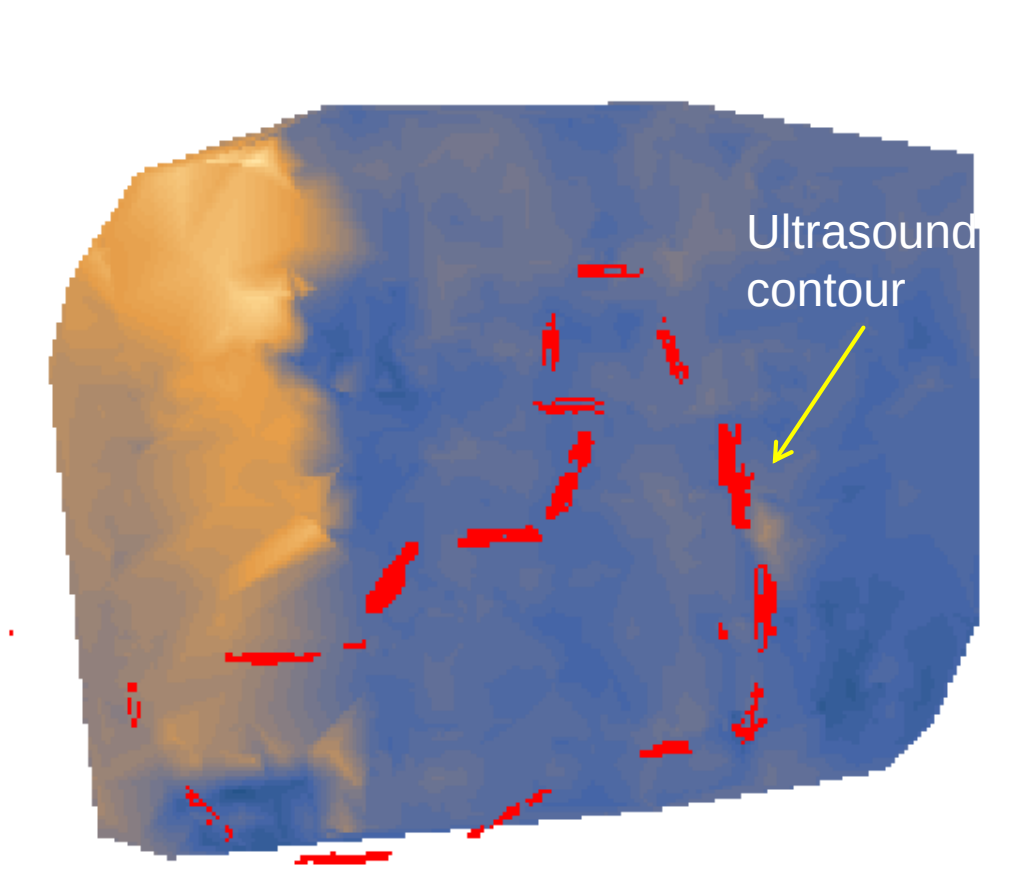


THz Overlay over RGB image

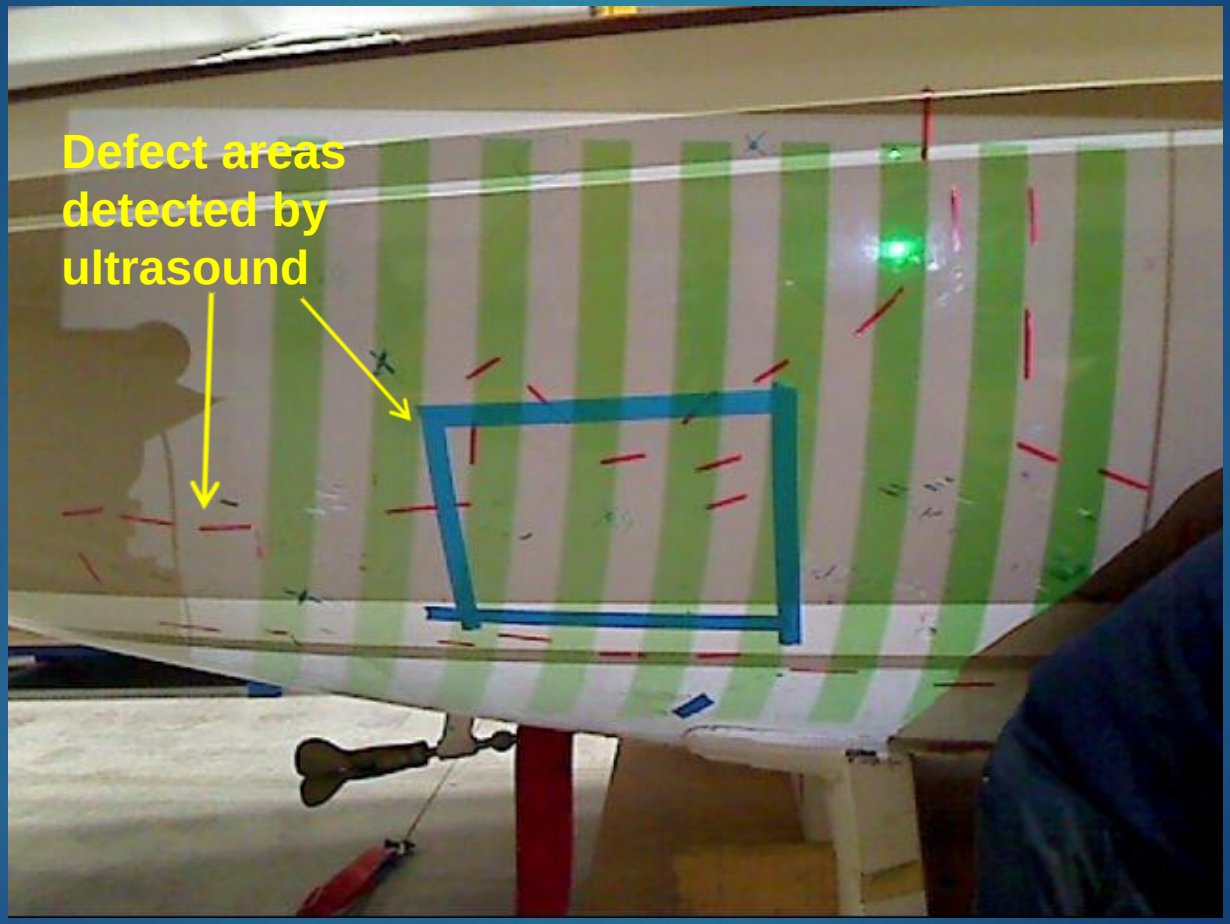


Group Delay THz Image vs Ultrasound

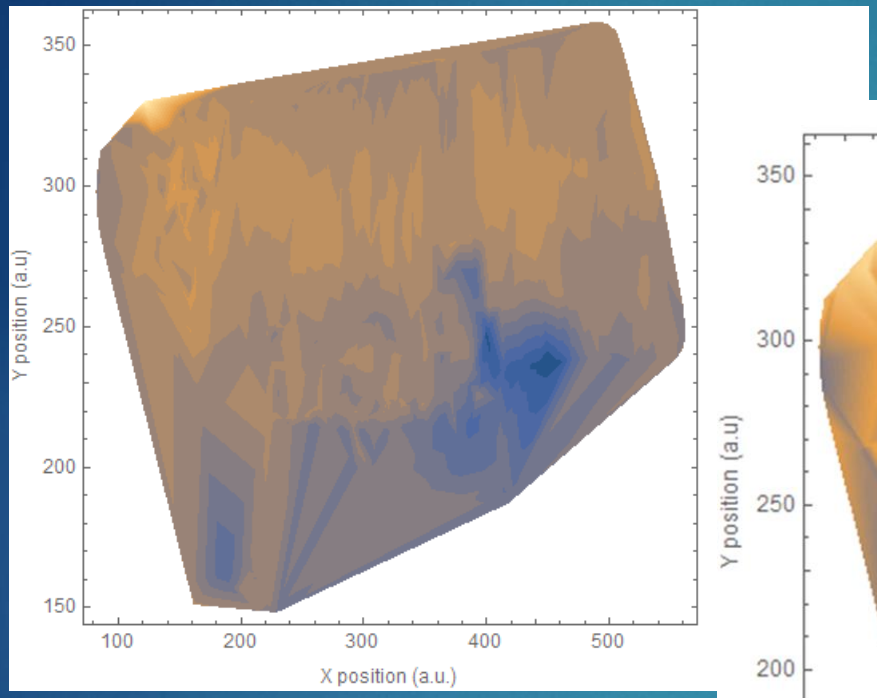
Shows dielectric constant/reflectance distance variations

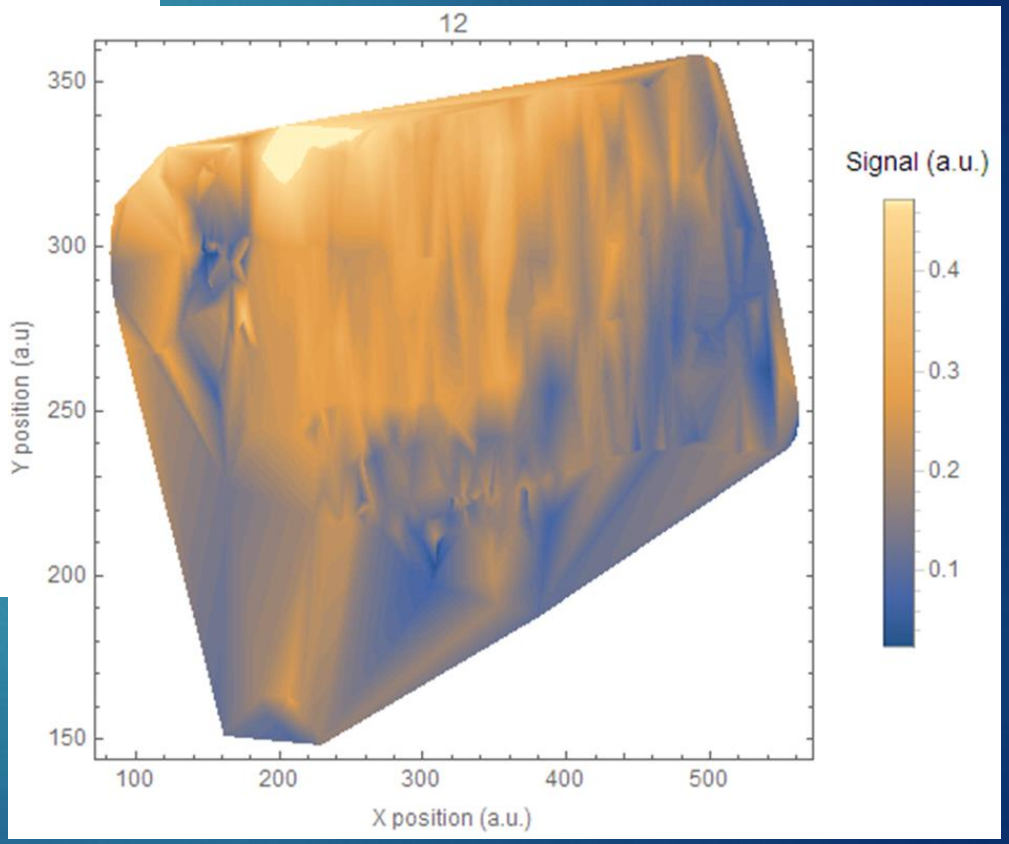


Ultrasonic Analysis: Zone 2



THz Images





❖ **Group Velocity Image**

THz Overlay over RGB Image

Summary

- **THz** technology is a new **promising** technology
  - for non-destructive testing of **dielectric** materials used in aerospace, particular for **foam**, **honeycomb** structure and **glass fiber**
  - as well as for estimating **thickness** and **quality** of the individual paint layer in multi-layers paint and coating, corrosion under paint
- **Dutch Terahertz** has advanced **THz expertise and** instrumentation, i.e. **sources** and **detectors** (cryogenic and at room temperature, e.g. superlattice device) within a range of **100-1980 GHz** for monitoring and detection of volume defects (i.e. **voids, delamination**) in **dielectric** material

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