IrNDT –the Solution for Aircraft Inspection

Modular State of the Art System for Non-Destructive Testing

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AT's History of Aircraft Inspection

2005 Delivery of the first JetCheck System to Lufthansa Technik

2007 First JetCheck System for Boeing

2006 FAA Approval for B737 Hull-Inspection

2008-2009 Delivery of 4 mobile JetCheck Systems to German Airforce

2007-2009 Delivery of 31 mobile NDT kits for AIRBUS

2009 Systems for NASA and SpaceX

Lufthansa Technik | Boeing | Official Approval | Luftwaffe | AIRBUS | NASA | SpaceX

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Current Activities

- Research-Project for the Development of system for in-line inspection of large area composite parts
- Development of a mobile Inspection System for composite materials (with focus on A350 and B787), partners: Airbus, Boeing, Lufthansa Technik and University of Hamburg

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CURRENT SITUATION

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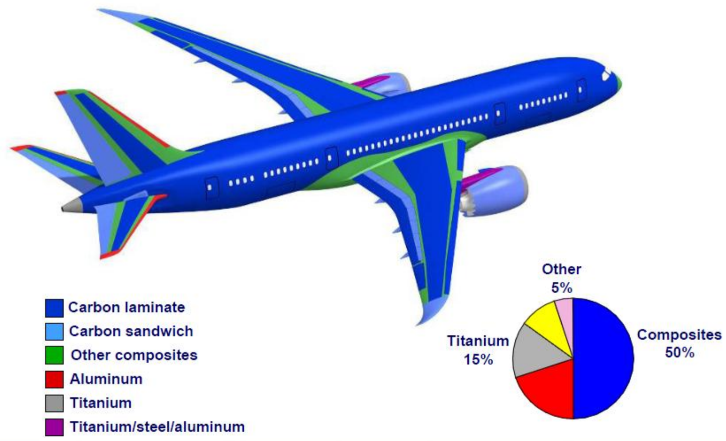
Examples for New Generation Civil Aircrafts

Composite Structure Development B787



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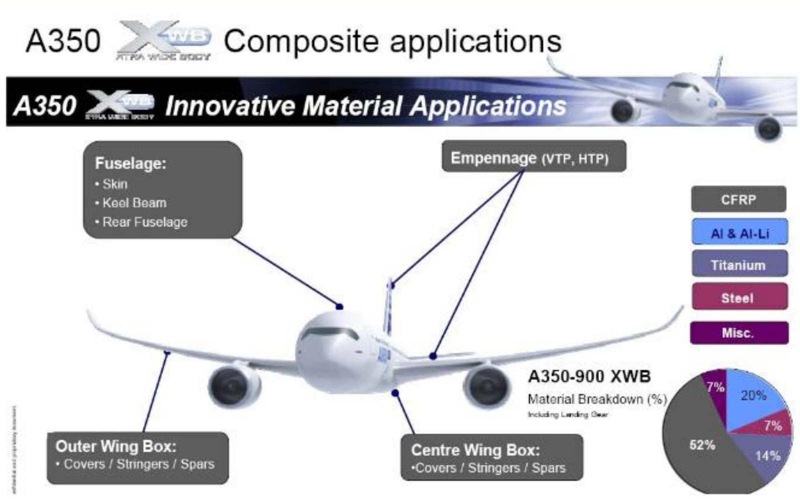
Examples for New Generation Civil Aircrafts

A350 XWB Composite applications



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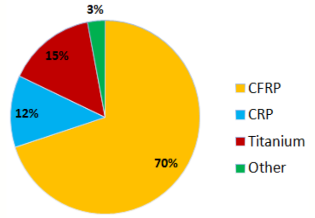
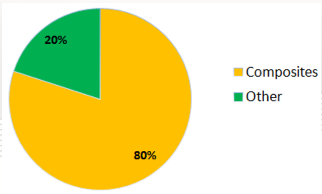
Examples for New Generation Military Aircrafts

Eurofighter Typhoon



Tiger Helicopter



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Scenarios for Damages & Defects
Collisions with Ground Vehicles and Equipment

Incidental contact / collisions with ground vehicles and equipment can result in blunt impact damage

- significant source of damage to commercial aircraft
- extensive sub-surface damage is often <u>not externally visible</u>

Source: H. Kim, CACRC Meeting Nov. 12-16, 2007 Wichita, KS

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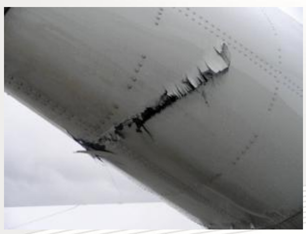
Scenarios for Damages & Defects
Collisions with Ground Vehicles and Equipment



An Airbus A330 from Air France damaged the tail of an A380 (also from Air France) that was parked at Charles de Gaulle Airport (November 2010).

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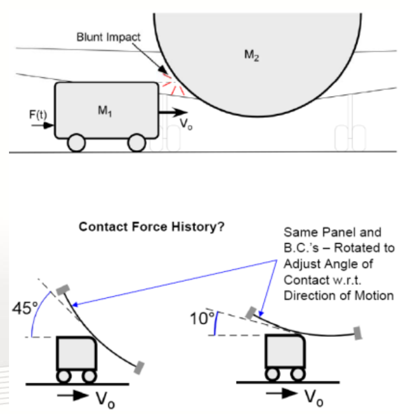
Scenarios for Damage & Defects
Collisions with Ground Vehicles and Equipment

Many variables are important
- "impactor" can be different types of ground vehicles
  or equipment, and various locations on these equipment (e.g., corner, long edge, or flat face)
- "target" can be the many locations of the aircraft
  - fuselage, nacelles, wing skins, control surfaces, etc.
  - impacts can be at or near internal stiffeners, or away from them, thereby greatly affecting the local stiffness of the structure
- incidence angle between "impactor" and composite panel surface plays major role in nature of contact force history



NDE need: Quick detection of internal damage over wide areas

Source: FAA Presentation at CACRC Main Committee Meeting October 29, 2008 (Minneapolis, MN)

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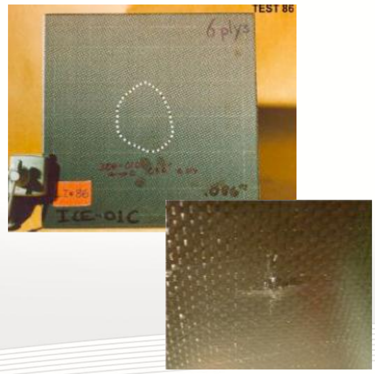
Scenarios for Damage & Defects
Hail ice Thread



Source: Halpin & H. Kim, CACRC Meeting Nov. 12-16, 2007 Wichita, KS

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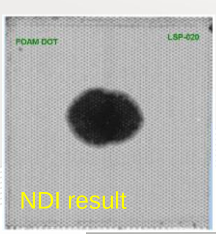
Scenarios for Damage & Defects
Lightning Strikes



Source: FAA Composite Damage Tolerance & Maintenance Workshop, Amsterdam, Netherlands May 9-11, 2007

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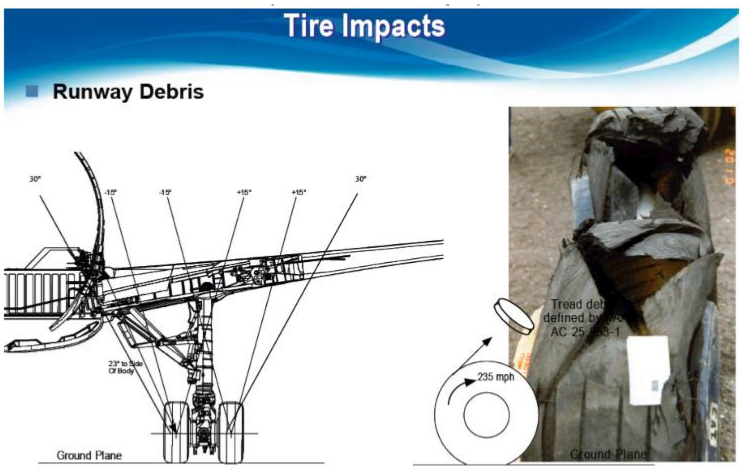
Scenarios for Damage & Defects



Source: Halpin & H. Kim, CACRC Meeting Nov. 12-16, 2007 Wichita, KS

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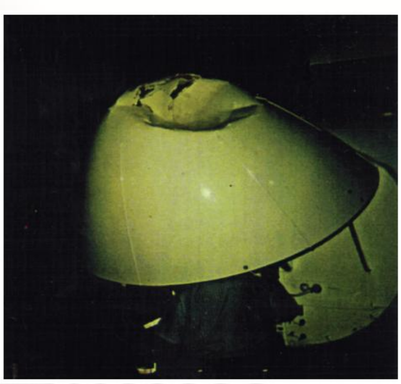
Scenarios for Damage & Defects
Bird Strike



Source: Allen J. Fawcett, CACRC Meeting May 2007, Amsterdam

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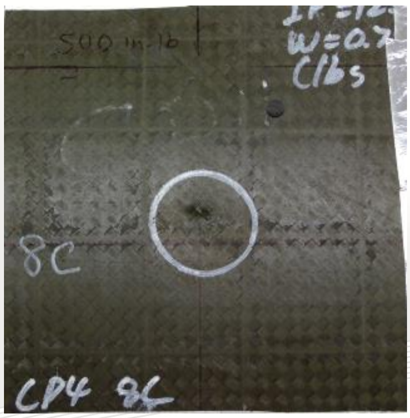
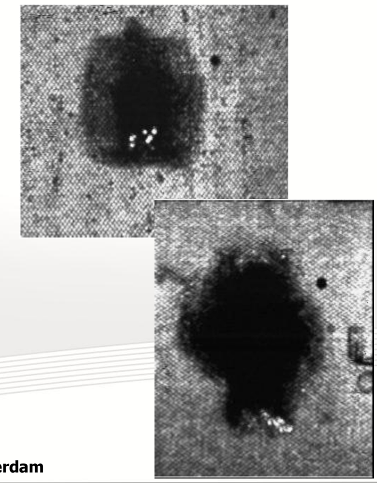
Scenarios for Damage & Defects
Fluid Ingression





Source: Allen J. Fawcett, CACRC Meeting May 2007, Amsterdam

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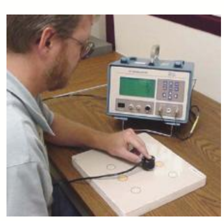
Conventional NDI Devices

Manual Tap Hammer



Ultrasonic

Mechanical Impedance Analysis

Automated Tap Hammer

<u>Human Factor</u>: Results depend significantly on the experience of the inspector, attention to detail, proper deployment

- Only for point-wise measurement
  -> Scanning of large areas is very time consuming
- No automated documentation of the results, e.g. for preparing a repair
- No implementation of a database for quality assurance, trends assessment

Source: Dennis Roach, Sandia National Labs, CACRC Meeting Nov. 12-16, 2007 Wichita, KS

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Wide Area and C-Scan Inspection Methods

- Complicated and time consuming setup
- Requires considerable expert knowledge of the inspector
- Not well dedicated for in-field measurements
- Not for wide area rapid inspections
- Reduced mobility due to large and heavy equipment
- No automated documentation of the results, e.g. for preparing a repair
- No implementation of a database for quality assurance, trends assessment
- Expensive equipment

Source: Dennis Roach, Sandia National Labs, CACRC Meeting Nov. 12-16, 2007 Wichita, KS

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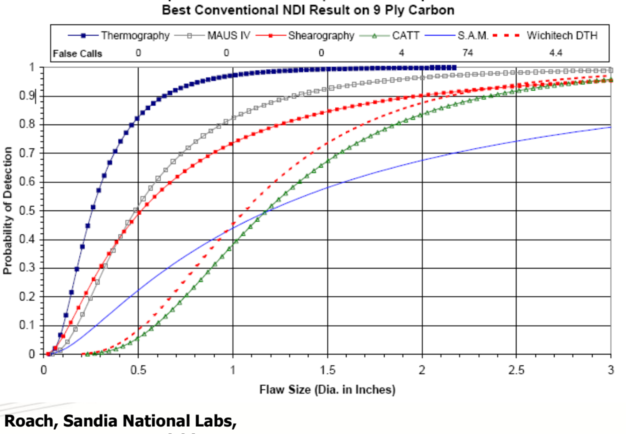
Performance of Multiple Devices for a Single Type of Test Specimen



Source: Dennis Roach, Sandia National Labs, CACRC Meeting Nov. 12-16, 2007 Wichita, KS

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IR-NDT: THE SYSTEM

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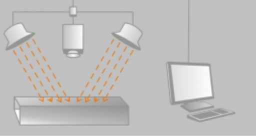
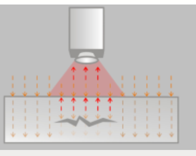
Basics of Infrared Imaging NDT

Thermal stimulation of themeasuring object with A modulated heat source, e.g.

- Thermal emitters
- High power flash lamps
- Ultrasound
- Microwaves
- Hot air
- Eddy current



Recording of the thermal response at the surface of the measuring object as a function of time with an infrared camera



Analysis of the temperature signal

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Basics of Infrared Imaging NDT

Aspects about non-destructive testing with active thermography

Reasons for growing importance

- Non-contact, large-area scans
- Very fast inspection method
- Introduction of new exotic materials
- Introduction of new technologies for fabrication and new techniques for joining parts

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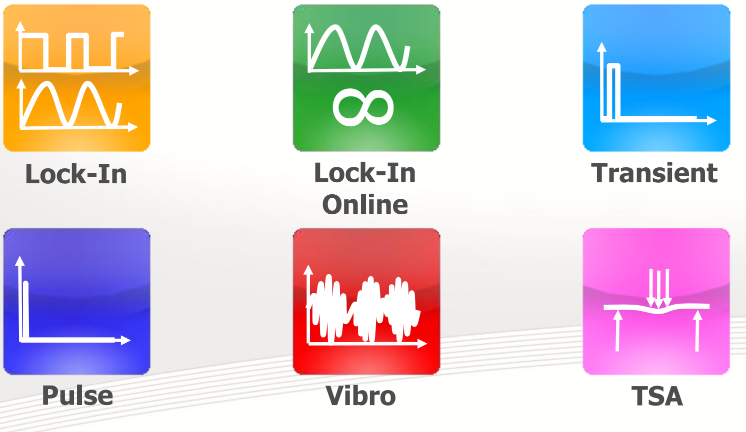
IrNDT Base: Main Features

Supports all known measuring techniques



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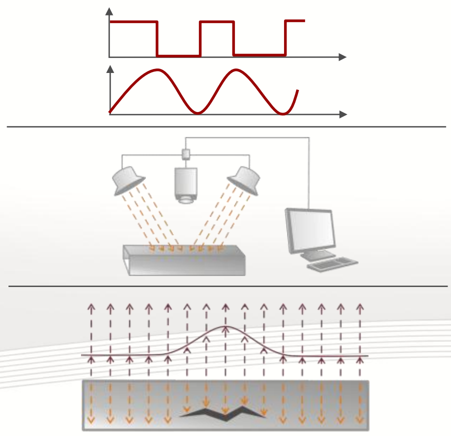
Lock-In Thermography

Measuring Principle

Procedure

- Stimulation of the component with modulated thermal energy
- Measurement of the thermal response as a function of time with an infrared camera
- Signal analysis



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Lock-In Thermography

Measuring Principle

Main Advantages

- Applicable for large-area measurements
- Affordable heat source (e.g. halogen lamps)
- Easy setup
- Low thermal load to the inspected component

Main Disadvantages

- Long measuring times
- Detectability depending on the geometrical orientation of the defects (not suited for defects oriented vertical to the surface)
- Applicable only for parts with low thermal diffusity

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Lock-In Thermography

Measuring Principle

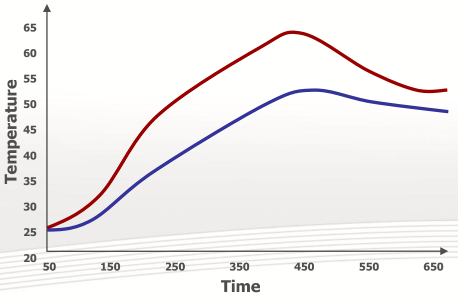
Example

Lock-In measurement of a CFRP Part with sinusoidal excitation:

Typical temperature signals at the surface

Blue curve: Position without defect

Red curve: Position with defect (delamination)



Lock-In Thermography

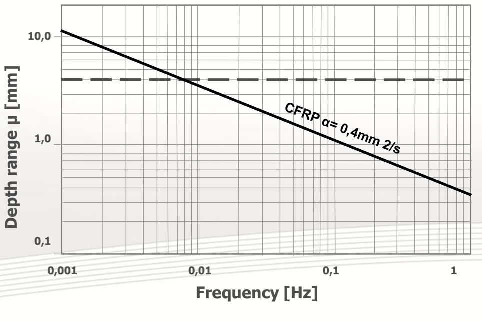
Measuring Principle

Example

- Thermal diffusion length μ over Modulation frequency f for CFRP
- Orientation perpendicular to fiber direction

$$\mu = \sqrt{\frac{2\lambda}{\omega\, p\, c}} = \sqrt{\frac{2\alpha}{\omega}}$$

α = Thermal diffusivity
ω = Angular frequency (ω = 2pf)

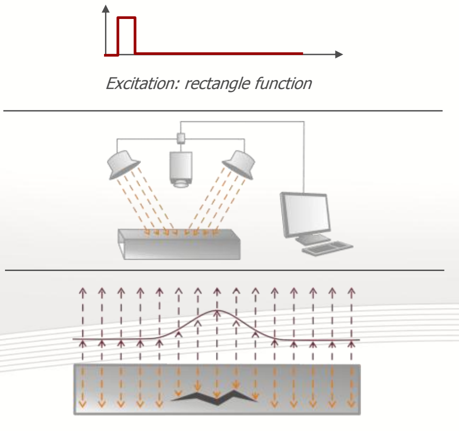


Transient Thermography

Measuring Principle

Procedure

- Transient thermal stimulation of the component
- Measurement of the thermal response as a function of time with an infrared camera
- Signal analysis



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Transient Thermography

Measuring Principle

Main Advantages

- Applicable for large-area measurements
- Short measuring times
- Affordable heat source (e.g. halogen lamps)
- Easy setup
- Low thermal load to the inspected component
- Ability to perform depth resolved inspections

Main Disadvantages

- Detectability depending on the geometrical orientation of the defects (not suited for defects oriented vertical to the surface)
- Applicable only for parts with low thermal diffusity

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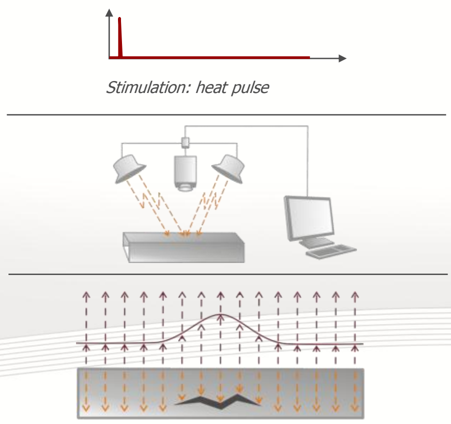
Pulse Thermography

Measuring Principle

Procedure

- Thermal stimulation of the component with a short heat pulse
- Measurement of the thermal response as a function of time with an infrared camera
- Signal analysis



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Pulse Thermography

Measuring Principle

Main Advantages

- Very short measuring times
- Ability to perform depth resolved inspections
- Excellent perfomance for inspection thin layers and for the detection of near-surface defects

Main Disadvantages

- Depth range limited to near-surface defects
- Detectability depending on the geometrical orientation of the defects (not suited for defects oriented vertical to the surface)
- Limited inspection area due to the energy of the flash lamps

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Pulse Thermography

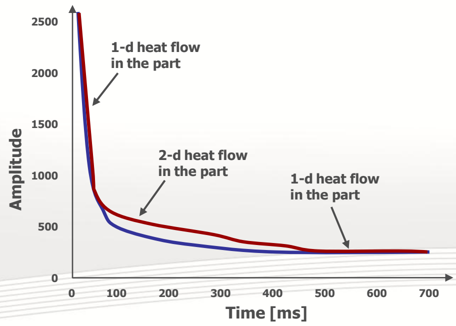
Measuring Principle

Example

Typical temperature signal at the Surface of a part after applying a heat pulse

Blue curve: Position without defect

Red curve: Position with defect (the defect acts as a heat source)



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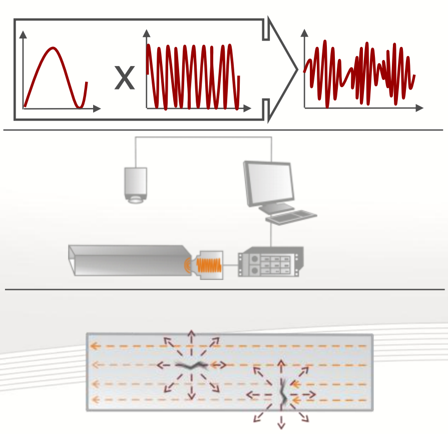
Ultrasound Lock-In Thermography

Measuring Principle

Procedure

- Stimulation of the component with modulated high-power ultrasound energy
- Measurement of the thermal response as a function of time with an infrared camera
- Signal analysis



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Ultrasound Lock-In Thermography

Measuring Principle

Main Advantages

- Defect selective response (dark field method), only the defects are displayed in the result image
- Well suitable for the detection of cracks
- Detection independent from the geometrical orientation of the defect
- High depth range

Main Disadvantages

- High load at the position, where the ultrasound energy is applied to the part (danger of damage)

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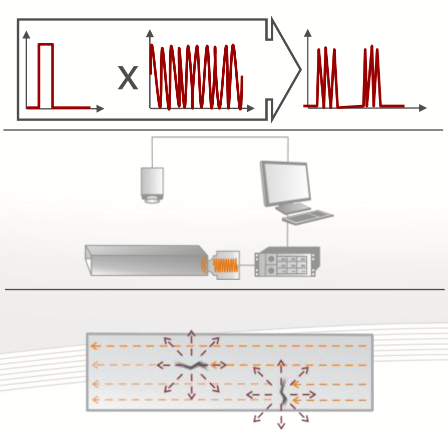
Ultrasound Pulse Thermography

Measuring Principle

Procedure

- Stimulation of the component with pulsed high-power ultrasound energy
- Measurement of the thermal response as a function of time with an infrared camera
- Signal analysis



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Ultrasound Pulse Thermography

Measuring Principle

Main Advantages

- Defect selective response (dark field method), only the defects are displayed in the result image
- Well suitable for the detection of cracks
- Detection independent from the geometrical orientation of the defect
- High depth range
- Short measuring times

Main Disadvantages

- High load at the position, where the ultrasound energy is applied to the part (danger of damage)

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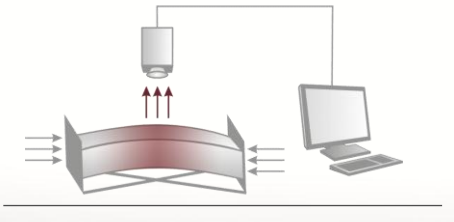
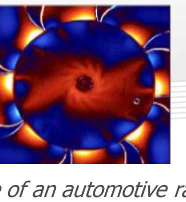
Thermal Stress Analysis

Measuring Principle

Procedure

- Stimulation of the component with mechanical energy
- Measurement of the thermal response as a function of time with an infrared camera
- Signal analysis





Stress image of an automotive radiator fan

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Thermal Stress Analysis

Measuring Principle

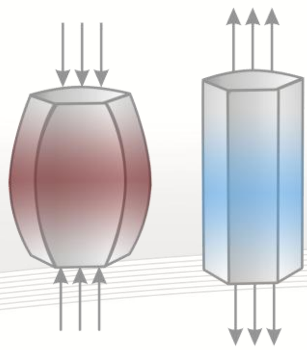
Procedure

Measurement of the stress in a Part as a result of a cyclic load, a random load or an impact load

Thermoelasiticity:

$$\Delta T = \frac{-\alpha T}{\rho C_\rho} (\Delta\sigma_x + \Delta\sigma_y)$$

α = Coeficient of thermal expansion
T = Absolute Temperature
P = Density
$C\rho$ =Specific heat
$\Delta\sigma_x$, $\Delta\sigma_y$ = Stress Amplitudes



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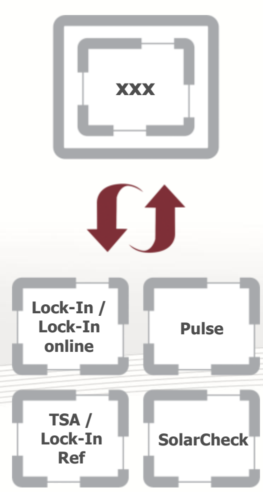
IrNDT: Software Concept

Modular concept: IrNDT Base + Evaluation Modules

Evaluation modules

- **IrNDT Lock-In / Lock-In online**
  Analysis module for lock-in measurings
- **IrNDT Pulse**
  Analysis module for measurings with pulse or transient excitation
- **IrNDT TSA / Lock-In Ref / Lock-In Ref Online**
  Analysis module for lock-in measurings with reference signal / forthermoelastic stress analysis
- **IrNDT SolarCheck**
  Analysis module for inspections of photovoltaic cells



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IrNDT: IRX-Box

Features

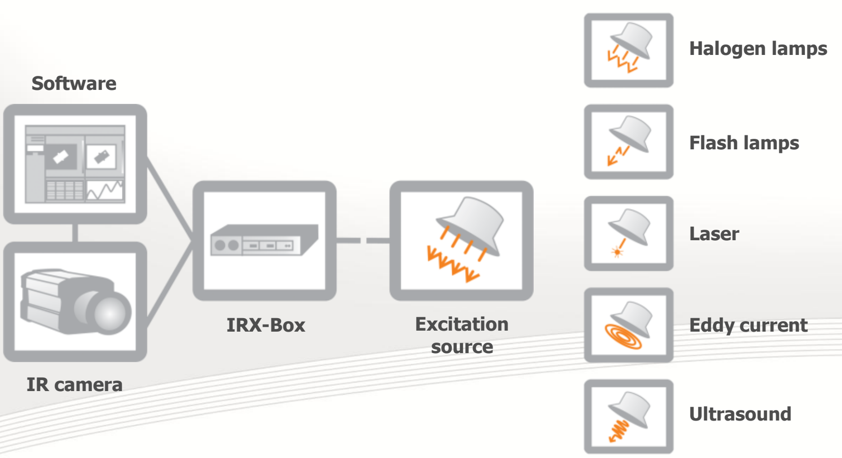
- Interface electronics between camera, software and excitation source
- Exact hardware synchronization between camera and excitation source (Modes: „Camera Master" or „camera Slave")
- Digital I/O's for control functions
- Hardware Platform: National Instruments standard components
- Modular concept for easy extensibility
- Available with PCI-board or with USB-box
- Very easy upgrading of the firmware

IRX-Box PCI

IRX-Box USB

IrNDT: All-In-One

Supports all kind of excitation sources



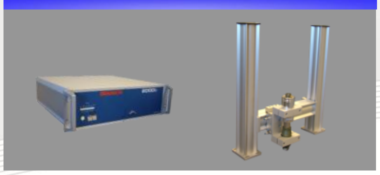
IrNDT: All-In-One

Supports all kind of excitation sources

High Power Flash Lamps

High Power Lasers

Ultrasound



Halogen Lamps

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IrNDT: All-In-One

IrNDT is a modular system consisting of soft- and hardware

Excitation and Inspection methods

	Lock-in online	Lock-in	Pulse/Transient		TSA	Inspection task
			short	long		
Halogen lamps/R emitter	✓	✓	✗	✓	✗	- Composite materials (disbondings, delaminations, etc.) - Foamed materials (cavities, etc.)
Flash lamps	✗	✗	✓	✓	✗	- Metals (welded seams, corrosion, etc.) - Composite materials (disbondings, delaminations, etc.)
Ultrasound	✓	✓	✗	✓	✗	- Detection of cracks and delaminations
Laser LED-Panel Current/Voltage	✓	✓	✓	✓	✗	- high-precision excitation - SolarCell Inspection, DLIT, ILIT - Inspection of small components
Eddy current	✓	✓	✗	✓	✗	- Detection of cracks in Metals
Mechanical excitation	✗	✗	✗	✗	✓	- Thermal Stress Analysis (TSA)

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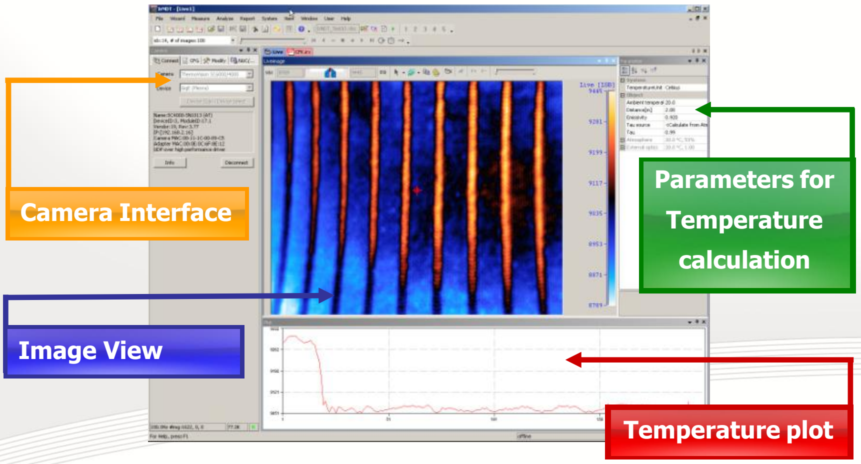
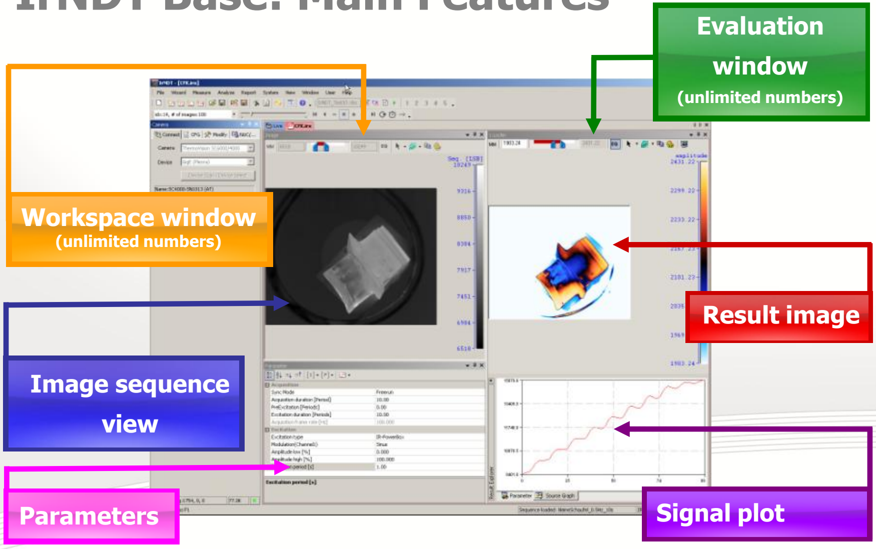
IrNDT Base: Main Features



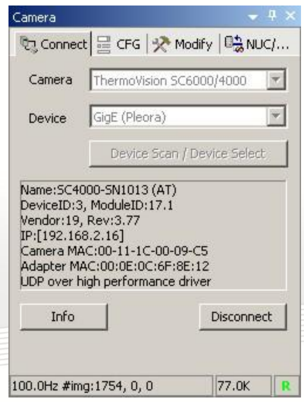
IrNDT Base: Main Features



IrNDT Base: Main Features

Camera connectivity

- Easy to use camera interface with access to all camera functions
- Supports nearly all cameras from FLIR Systems
- High speed recording with full frame rate



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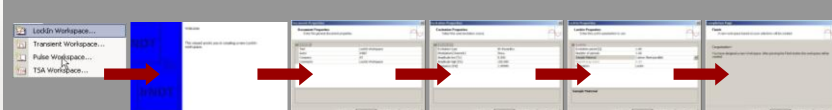
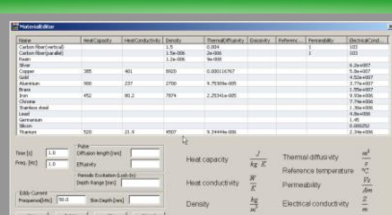
IrNDT Base: Main Features

Various functions for supporting the user, e.g.

Wizard for creating workspaces



Material editor for most common materials



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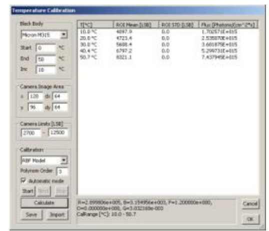
IrNDT Base: Main Features

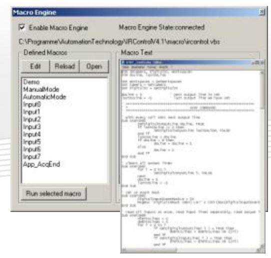
Integrated Calibration Tool

- **With direct control for Mikron Blackbodies**



Macro Engine

- **For handling complex measuring tasks**
- **Control via digital Inputs**



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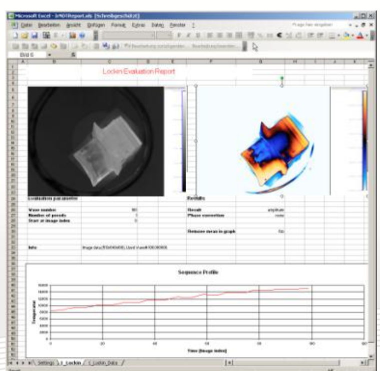
IrNDT Base: Main Features

Further features

- All settings are stored in workspace files
- Different user levels, protected by password
- Export of data to Matlab, etc.
- COM/DCOM Automation inteface for data exchange and control
- Excel based Report Generator



Report Generator

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MOBILE SYSTEM CONFIGURATIONS

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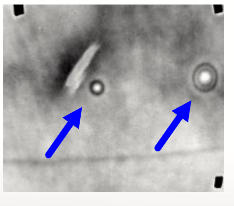
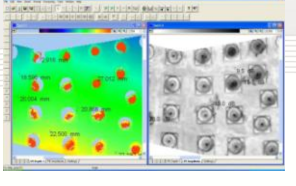
System example: MIL-JetCheck

Active Thermography module: for the fast and flexible inspection of larger areas of the aircraft (up to 1 m^2)

Side rudder of a Tornado



Imaging Ultrasound module: for the specific material inspection at the aircraft



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MIL-JetCheck

Active Thermography

1. Infrared camera with very high thermal sensitivity
2. High-power encapsulated heat-sources (halogen & Flash lamps) with pressurized-air-cooling, for operation even in harsh & dusty environments

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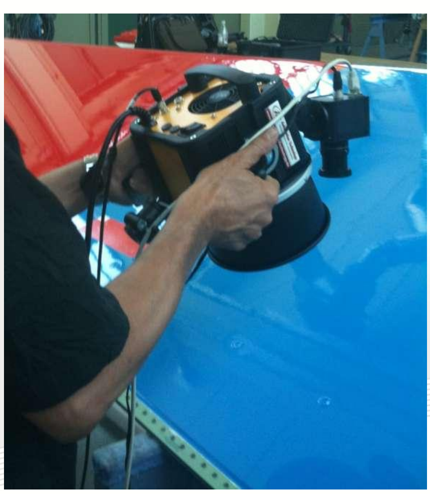
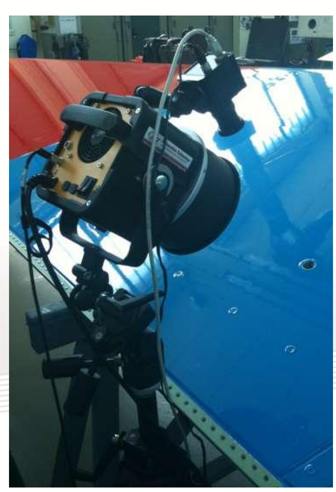
"C-Check" a compact system for inspection of composites





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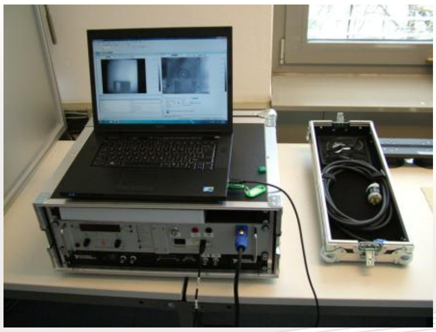
Mobile Systems



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Flightcase

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Mobile Rig for Lab Systems

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