



Innovative aerial service
robots for remote
inspections
by contact

(02/2010 – 01/2013)

www.airobots.eu

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PART 1

CONTRIBUTION OF THE PROJECT TO STEP CHANGE

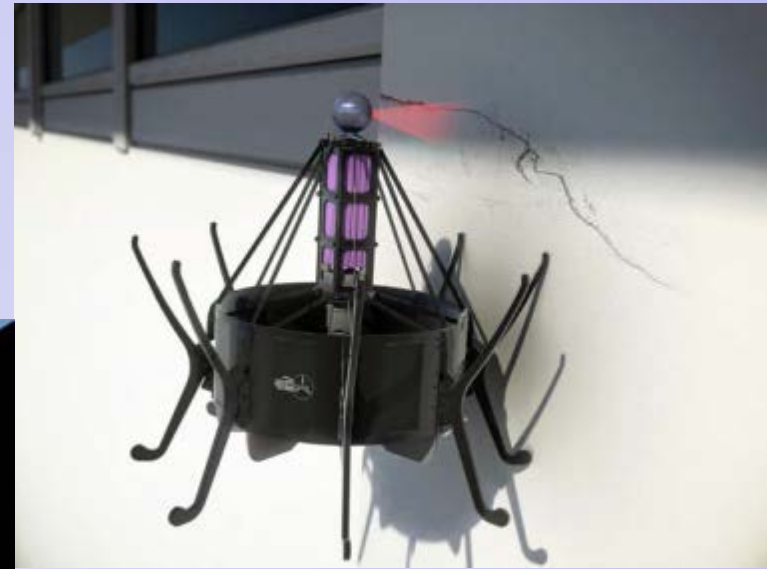
Key contributions



- To develop aerial vehicles able to interact with the human world in order to accomplish typical robotic tasks in air rather than constrained on ground
➔ Aerial Service Robotics
- To develop advanced automatic control strategies and “human-in-the-loop” strategies which allow an intuitive tele-operation of the vehicle by means of haptic devices
➔ “Flying hand” of the operator

AI Robots: The vision

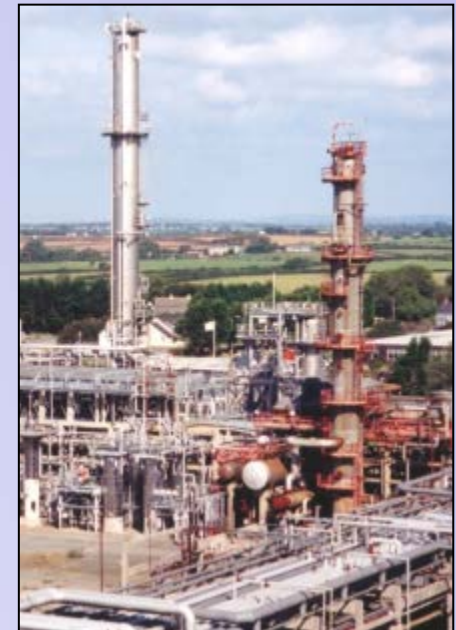
- Physical Interaction
- Flying hand



Driving industrial scenarios

Strong involvement of the end user :

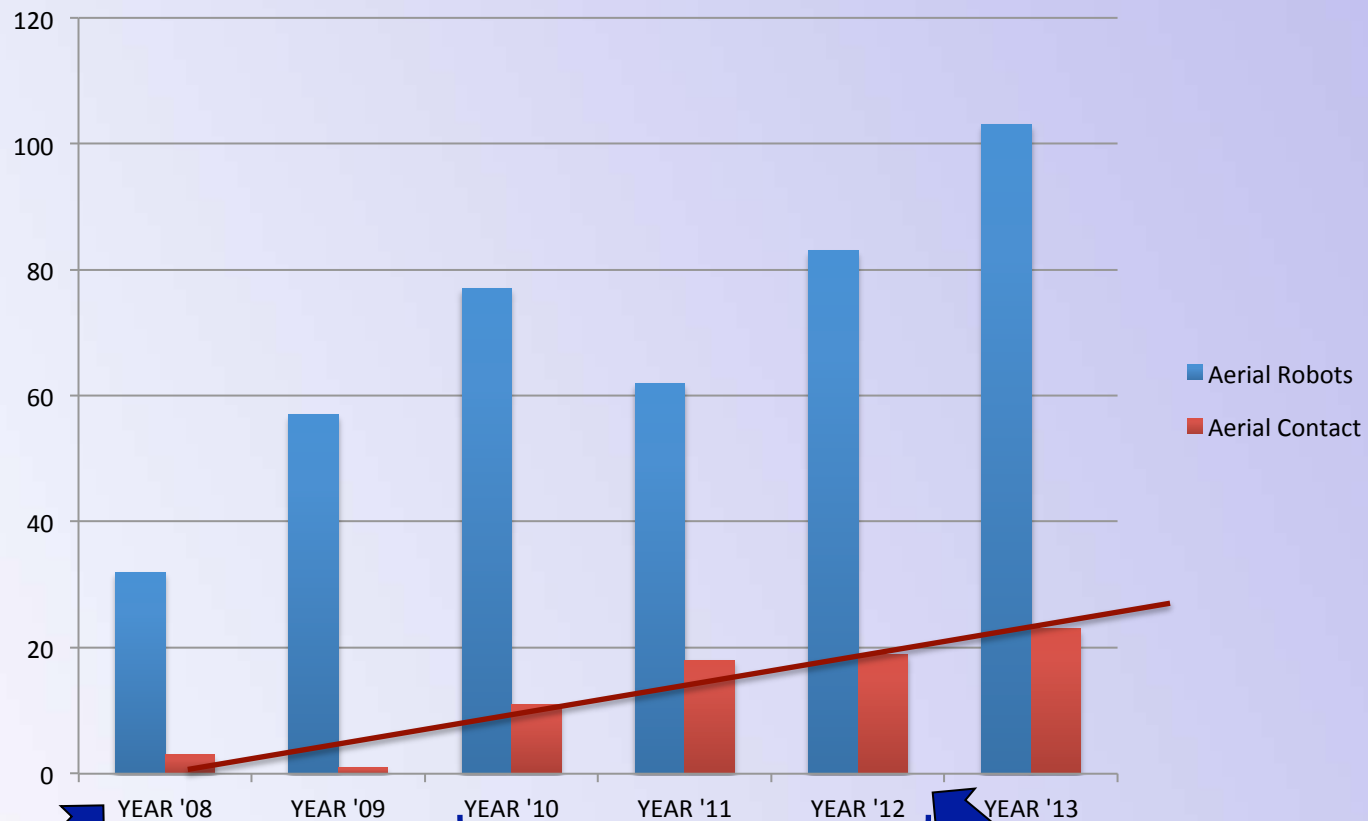
- Inspection of power plant structures (boilers, environmental filters, etc.)
- Inspection of structures within oil and gas industry (large scaled chimneys, flare systems, refining columns, pipelines and pipewebs)
- Cleaning of infrastructures



Trend of the idea

NUMBER OF PAPERS (ICRA + IROS) ABOUT "AERIAL ROBOTICS" AND "AERIAL CONTACT"

SOURCE: IEEE EXPLORER



PRELIMINARY
DISCUSSIONS
WITHIN THE
CONSORTIUM



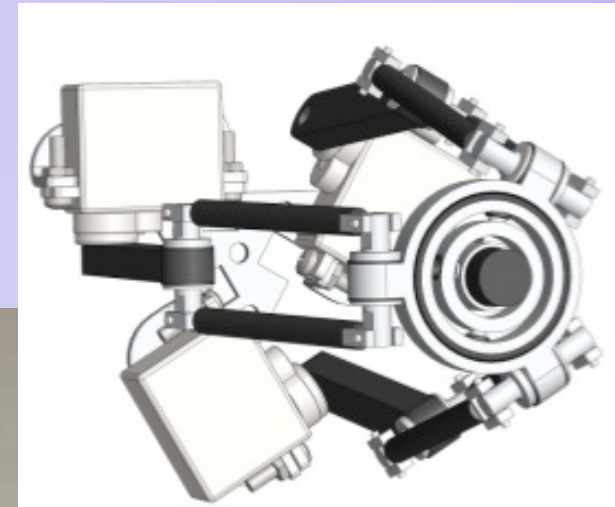
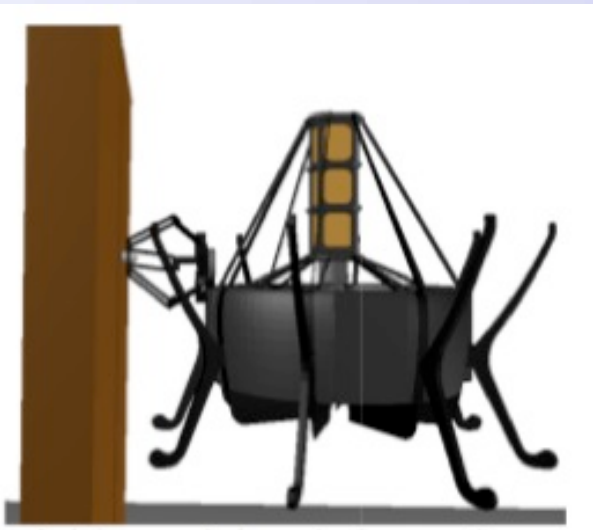
AIROBOTS



START OF INDUSTRIAL
EXPLOITATION

- Robot abilities:
 - **Interaction** (ability to physically interact) and **collaboration** (continuum between autonomous behavior and supervision)
- Technology clusters:
 - **Improving Design and Systems** : innovation in the aerial platforms
 - **Better machines: Control** (complaint behavior during the impact)
 - **Improved Human-Robot interaction**: Flying hand
 - **Better action and awareness**: Perception, Navigation
- Goals
 - **Building systems that support excellent research** (70 publications in AIRobots)
 - **New markets** (inspection of big plant by contact)

Improving Design and Systems



Better machines: Control



Critical feedback

- Strong involvement of the end-user
- Targeted TR Level changed dynamically during the project

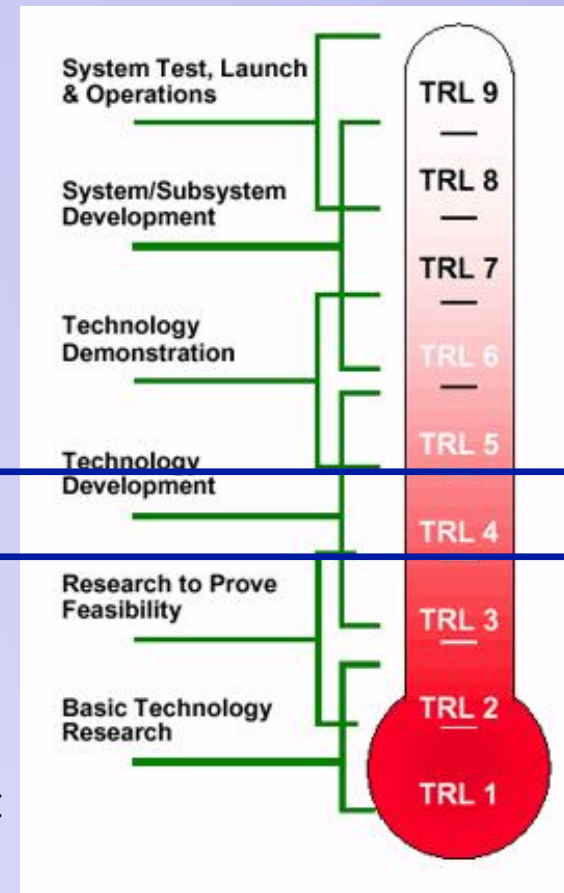
TRL4

Technology
validated in lab



TRL5

Technology Validated
in Relevant Environment



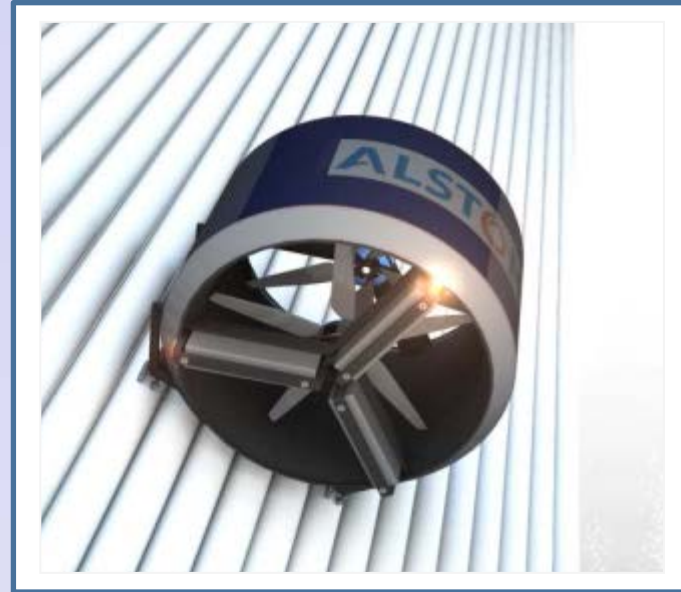
- No companies involved in the UAV design and construction involved in the consortium at the start

PART 2

USE OF RESULTS: “Step Changes” for the user perspective



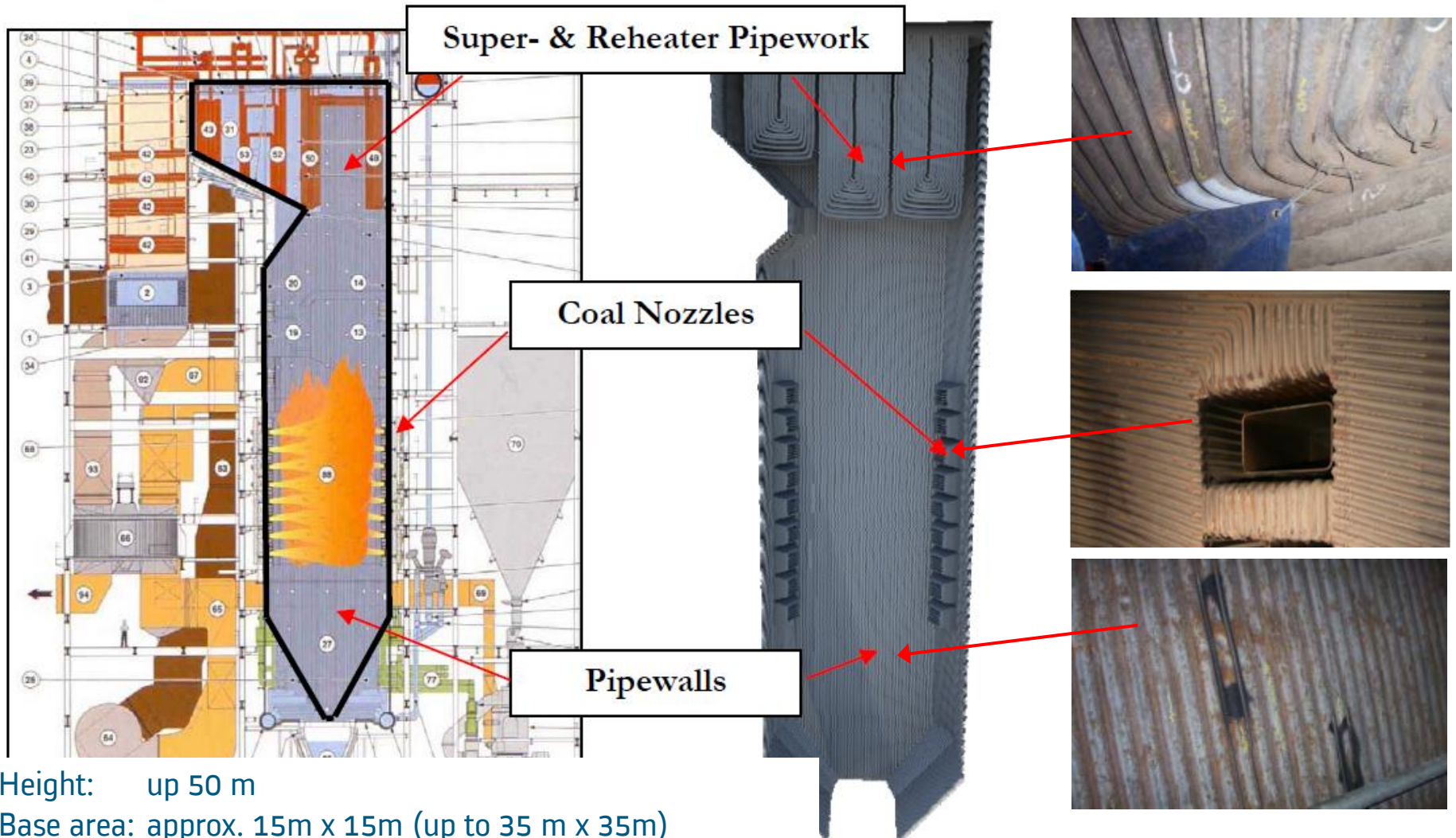
**Human Inspector
today**



**Aerial Robot Inspector
2015**

Ekkehard Zwicker
CEO, ALSTOM Inspection Robotics

ALSTOM Case - Boiler Inspection



Case Visual Inspection of Boilers

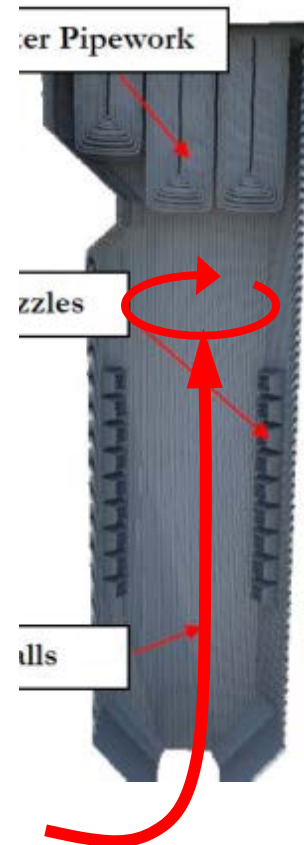
Human in the loop - intuitive tele-operation

— Visual (pre) inspection

- Visual detailed inspection using a on board video camera

— Features required:

- Path specification:
 - the visual inspection is performed along a user specified grid
- Navigation:
 - the system follows the specified path (according the specified grid) in a certain distance to the boiler wall
- Data Processing:
 - low resolution video stream transmission,
 - high resolution vide stream storage linked with position data
- Obstacle handling
 - Openings / Coal Nozzles
 - Super Heater Pipework hanging into the boiler from top
 - Cables and other means to support inspection & maintenace



Case Non Destructive Inspection of Boilers

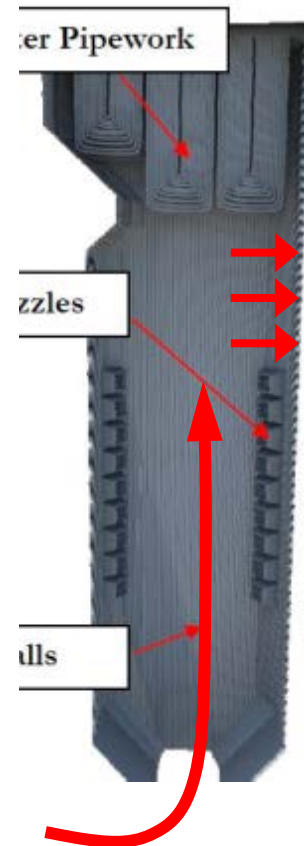
Physical Interaction with real world structures

— Non destructive detail inspection (Ultrasonic)

- Objective is to dock with the system to the boiler in order to perform visual or nondestructive inspection tasks.
- The system is equipped with a NDT system or a manipulator.

— Features required

- teach in the point(s) in the boiler where the system has to be placed for inspection
- Approaching the points along a specific path
- Landing at the boiler wall, clamping (probably magnetically) to the boiler wall automatically
- Move the NDT sensors with a manipulator or directly with the flying system
- De-clamp and leave from boiler wall
- Obstacle handling



— State of the art

- Scaffolding of the boiler (3 d)
- Visual (pre)inspection (1 d)
- NDT inspection of the zones of interest (3 d)
- Un-scaffolding (3d)

— Flying Inspection

- Visual (pre)inspection (1 d)
- NDT inspection of the zones of interest (2 d)
- Selective scaffolding / un-scaffolding (4d)
(in case of repair)

The alternative

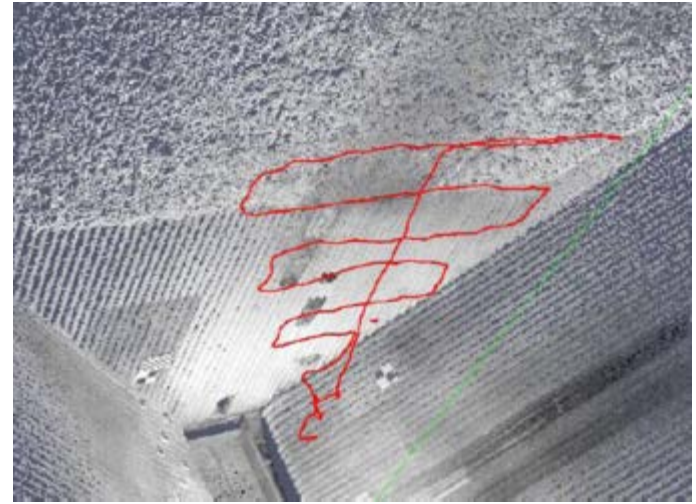


**tremendous
risk exposure!**

Saving: 7 d / 70%

Saving: 3 d / 30%

Test Missions to verify business case



Goal

- Proof of concept and verification of the business case

Sites

- Smaller, aged boiler in Spain
- Larger, new boiler in Germany

Focus

- Visual inspection
- Human in the loop / intuitive tele-operationon

Statements from ALSTOM Management & Customers

ALSTOM Upper Management

- AI Robot project results have a disruptive potential for ALSTOM Thermal Service Business
- Key technology to shave down costs and risk exposure

ALSTOM Customers

- Break through technology to shave down time and to reduce risk exposure
- Support for continuous industrialization by adapting inspection procedures

Strategic Decision in ALSTOM R&D

- Stepwise industrialization and commercialization of flying inspection using AI Robots project results focusing
 - 1st step: human in the loop / intuitive tele-operation to enable a extensive use by field service personal
 - 2nd step: physical interaction to enable non destructive testing

Industrialization & Market Launch

— Focus

- Application: (1) Visual Inspection, (2) contact free NDT, (3) NDT by contact
- Navigation: (1) manual, (2) semiautonomous, (3) full autonomous

— Scope of the steps

- **1st step “manual visual inspection” -> “semi autonomous visual inspection”**
 - **off-the-shelf manual visual inspection**
 - Application of the available flying system for operator guided (piloted) visual inspection using a fully integrated system, commercially available
 - Test missions to gain experience and to show the potential
 - **Industrialization of the AIRobots navigation capabilities (by a ETH Spin Off)**
 - Industrialization of the AIRobots navigation capabilities and integration into the commercially available open flying platform
 - Optimization in operator guided tests and pilot missions in plants (visual inspection)
- **2nd step: -> “autonomous contact free NDT inspection”**
 - Integration of contact free NDT / reverse engineering applications onto the system
 - Further improve navigation to allow a fully autonomous visual inspection
- **3rd step: -> “autonomous NDT inspection by contact”**
 - Proof feasibility of making a flying machine docking onto a vertical surface
 - Industrialization and integration of contact based NDT (Ultrasonic, deep penetrating EC)

2013/14

2015

2017