Aerial robotic manipulation for inspection and maintenance

The industrial relevance

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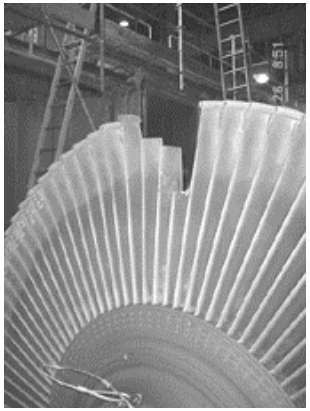
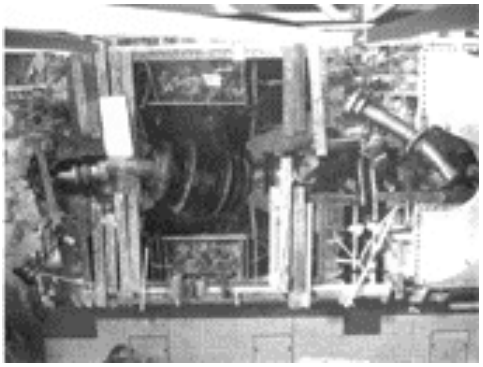
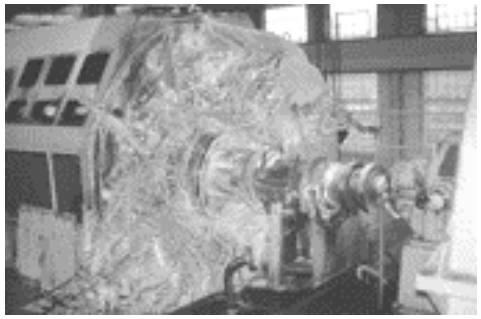
When things go terribly wrong … the economic impact

Steam Turbine

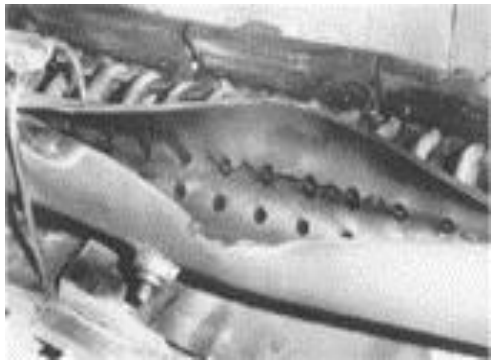




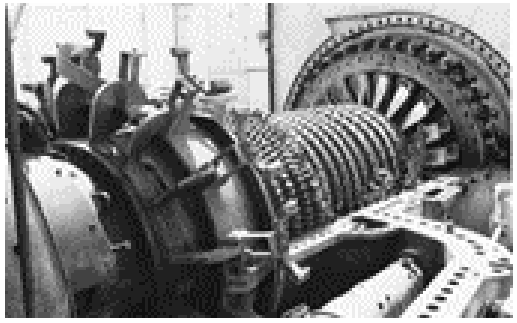
Generator

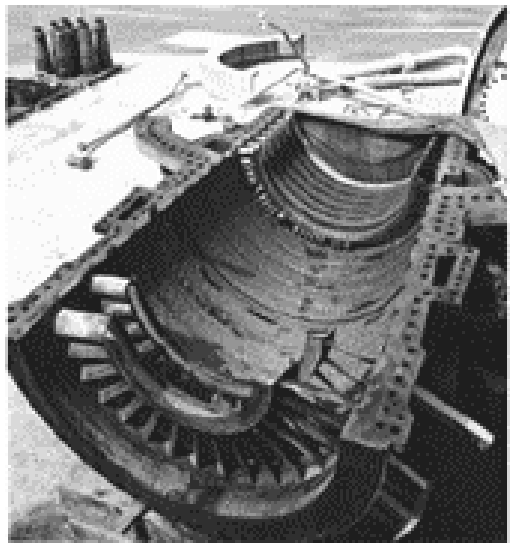


Boiler



Gas Turbine





Average Power Plant age ≈ 35 years
300 MW off the grid unplanned ≈ 1 Mio € / d

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When things go terribly wrong … the environmental impact

Hazardous Emissions

Hazardous Spillage

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When things go terribly wrong … human safety

Human safety risk exposure due to

working in height

working confined spaces

hazardous environment

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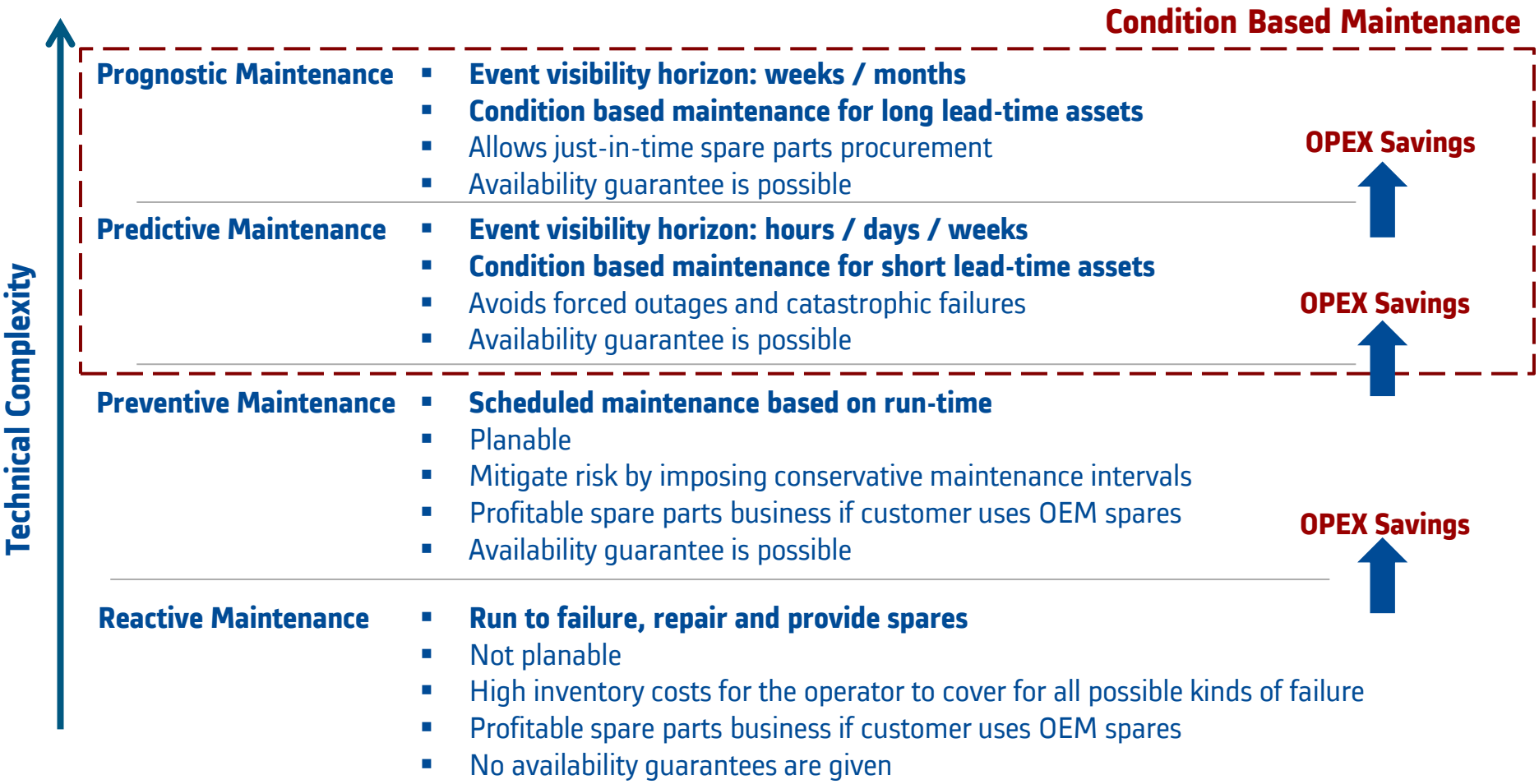
Inspection & Maintenance – Trends and Strategies



- **Condition Based Maintenance requires reliable inspection data**
- **Permanent installed sensors are getting more and more common**

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Business Drivers – Robotic Technology

Business Driver		Robotic Technology
Reliable inspection data – High precision & resolution – Repeatability – More coverage		
Reduced outage time		
Enhanced human safety – remote operation – autonomy		
300 MW off the grid unplanned ≈ 1 Mio € / d		
	Speed – **quick setup / installation**	▪ design to use / plug & play ▪ auto navigation replaces add. install.
	Speed – **high speed operation**	▪ high speed robotics ▪ dedicated navigation to operate the high speed robot safely ▪ NDT integration (data acquisition & processing)
	Repeatability / Accuracy	▪ absolute positioning ▪ path planning & navigation
	Accessibility	▪ remote operation ▪ obstacle handling / climbing ▪ autonomous operation
	Versatility	▪ Based on the platform various applications can be configured
	Robustness	▪ Reliable and save operation even in harsh environments

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Current Practice

Manual Inspection & Maintenance

- Laborious -> long down times / high costs
- Dangerous -> risk of accidents
- Failure prone -> risk of unreliable data





Case - Petrochemical Industry

Pressure vessels

Storage Tanks

Pipework

Offshore and Marine Structures

Heat Exchangers

Rotating

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Inspection of Pipework

- Pipework requires inspection for:
  - Internal condition:
    This results in many measurement locations (hundreds of thousands in a large refinery, periodically inspected)
  - External Condition:
    requires complete removal of insulation; very costly
- Cost determined by access:
  - Scaffolding
  - Digging up road crossings
  - Digging up buried, unpiggable lines

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Roles for Robots on Pipework

- Access inspection points without scaffolding
  - Crawling; flying, and deploying the inspection tool
- Inspect insulated pipework
  - Crawling, flying robot
  - Drilling through insulation ….
- Local point repair
  - Remove old point/corrosion
  - Apply new paint
- Enter pipework to reach at buried sections

Trend:

- ➢ Permanent installation of sensors > installation & maintenance
- ➢ Mobile robots for larger area inspection > set up on remote locations

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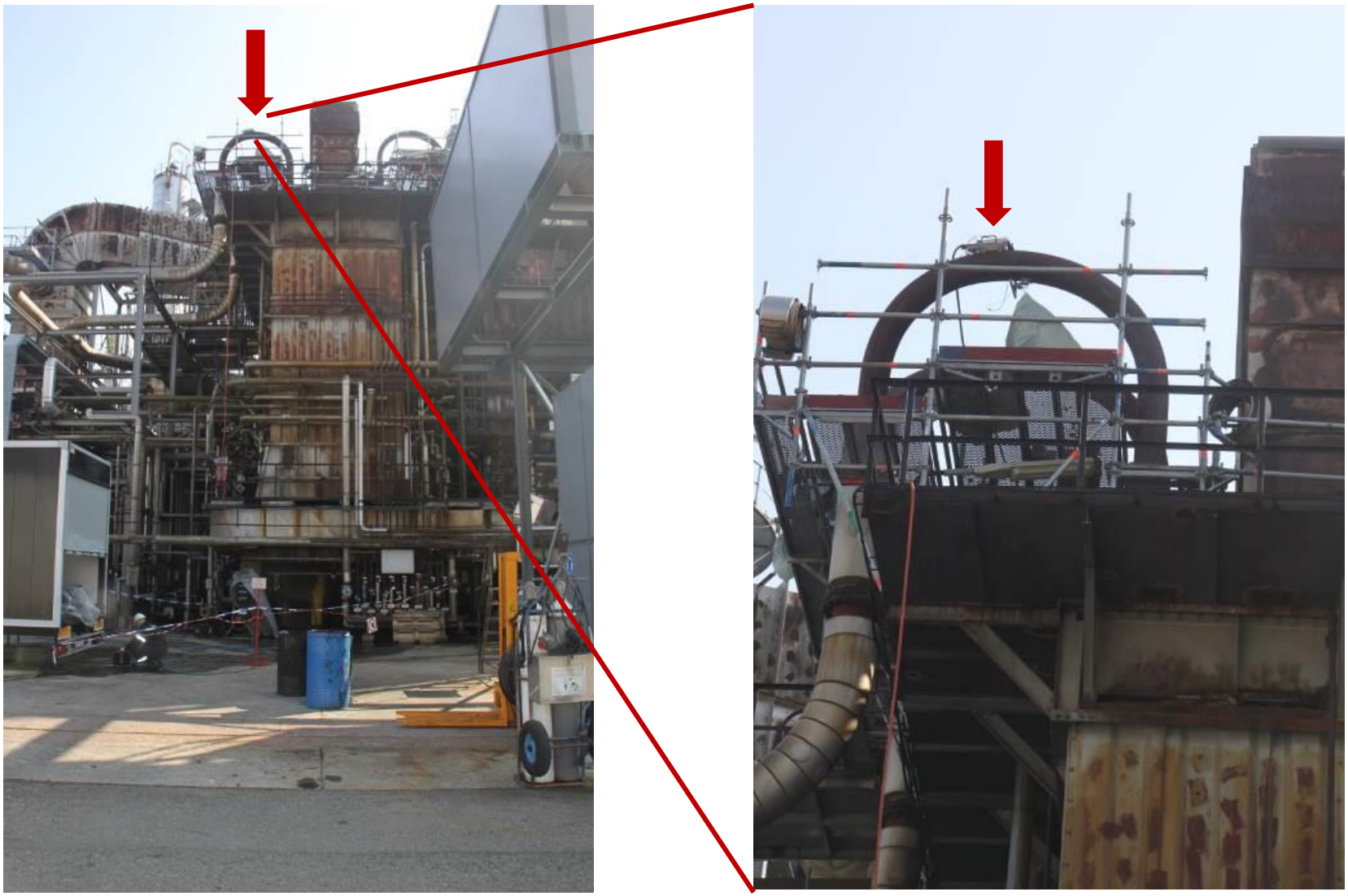
.... Manual?
– not really an option!

Mobile Robots …. need scaffolding



Business Figures ….

2008 Worldwide HPI maintenance spending by equipment and materials				
%	**Item**	**U.S.**	**O.U.S.**	**Worldwide**
5	**Piping**	$ 274.000.000	$ 846.000.000	$ 1.120.000.000
8	**Vessels**	$ 383.600.000	$ 1.184.400.000	$ 1.568.000.000
6	**Boilers**	$ 328.800.000	$ 1.015.200.000	$ 1.344.000.000
10	**Heat exchanges**	$ 548.000.000	$ 1.692.000.000	$ 1.568.000

…. we don’t talk about peanuts!

Source: HPI market data

Conclusion

- Obviously there is a very strong need and business case
- Remote visual inspection by “drones” nor mobile robots solve the problem completely
- **Approach**
  1. **Areal workers:**
     Aerial robotic manipulation by the flying robot directly
  2. **Areal workers + mobile robotics:**
     Transporting & maintenance of mobile robots by flying robots

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On what we are working on …

… mobile robots which can be handled by areal robots

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AIR Modular Robotic Platform Concept – The FAST Platform

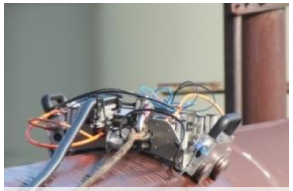
FAST Modular Robotic Platform

+

Modular Controller Platform

Fully **A**utomated In**S**pection **R**obot

Pipe Inspection

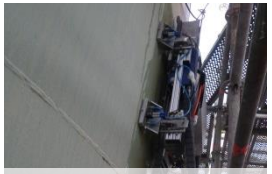


VARO Refinery, Cressier/CH

Pressure Vessel - Cleaning & Inspection

SHELL Gas Processing Plant Mordijk / NL

Pressurized Tanks - UT Inspection



Evonik Pressurized Tanks Frankfurt/DE

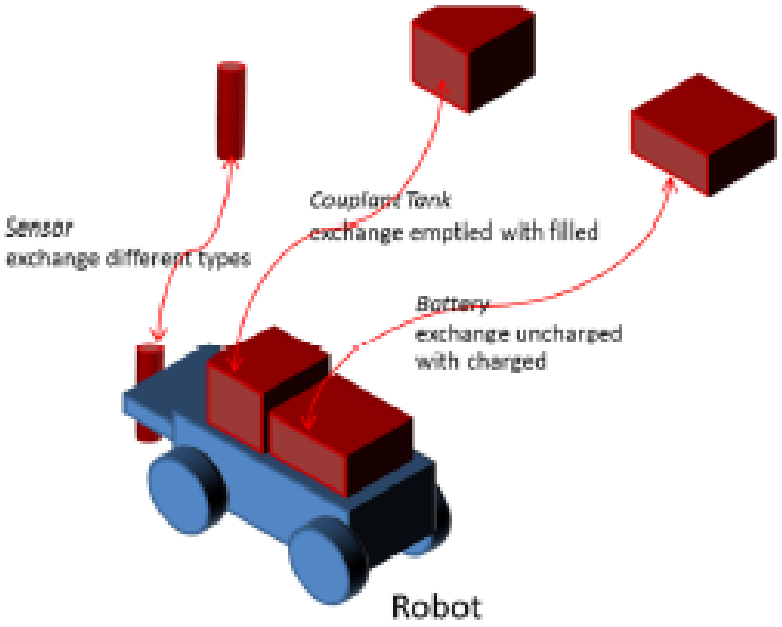
Steam Drum Inspection

ALSTOM TS R&D Lab, Windsor / US

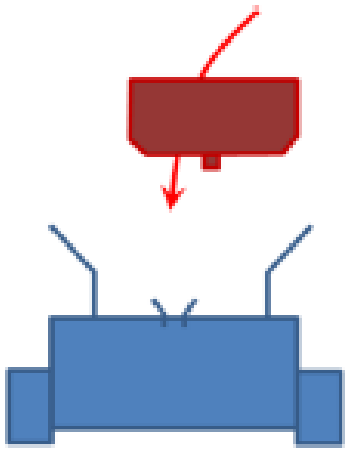
Robotic design to support maintenance and handling using a flying robotic arm

Challenges -> Goals

- Weight
- Autonomy (power & control)
- Integration of NDT sensors
- Assembly & Disassembly by dexterous robotic arms



Basic Principle



Assembly supporting design

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