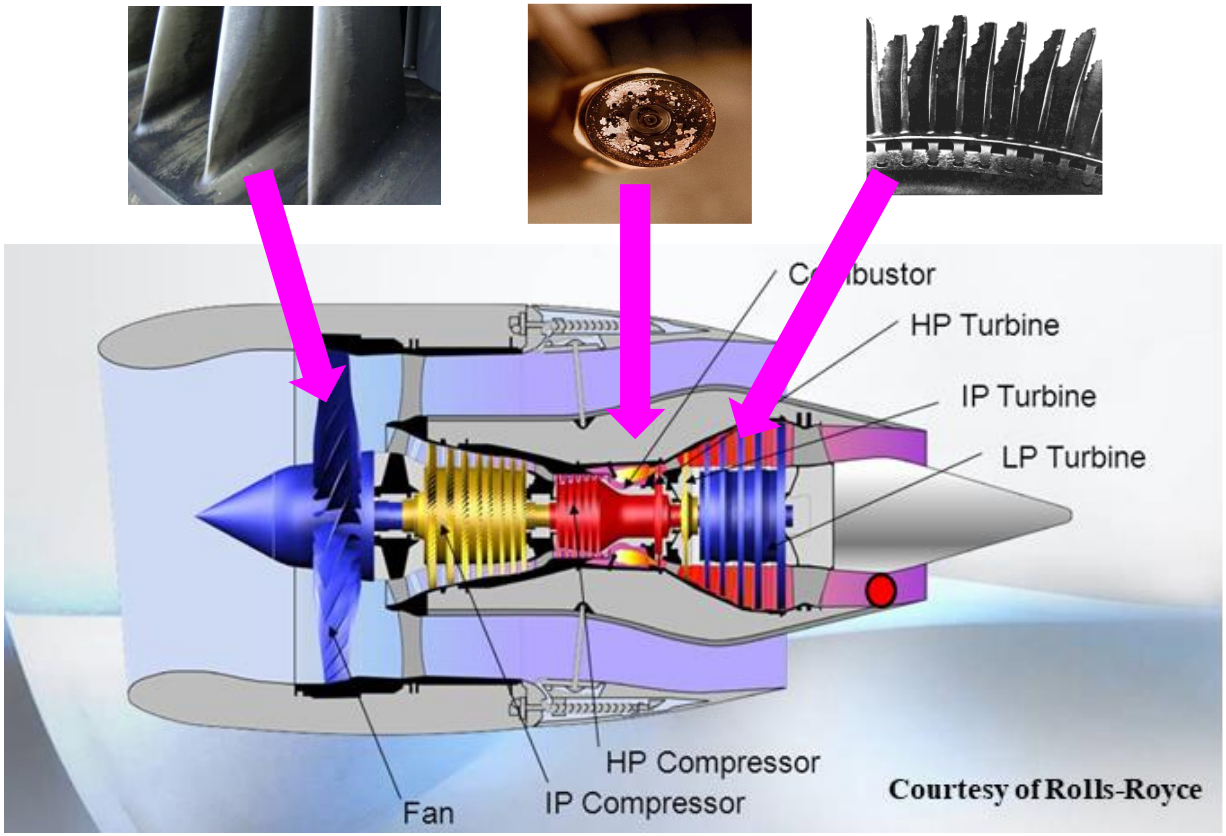
Gas Turbine Condition Monitoring Techniques

Performance-based monitoring



Gas path measurements: P, T, PCN, mf

Visual inspection

External visual inspection

leaks of gas and oil, security of pipes, control linkage, etc.

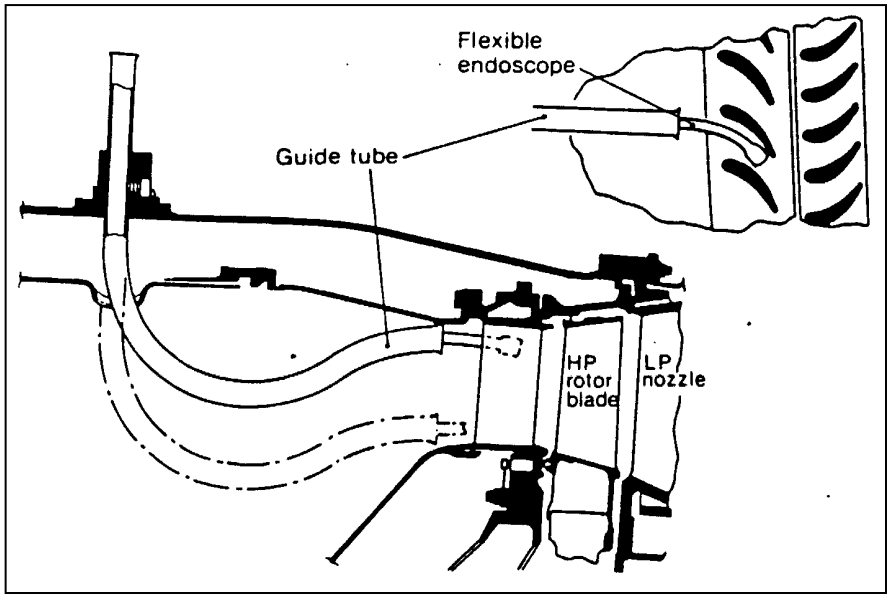
Status of fan (LP compressor), LP turbines, nozzle, etc.

Internal visual inspection using endoscopes

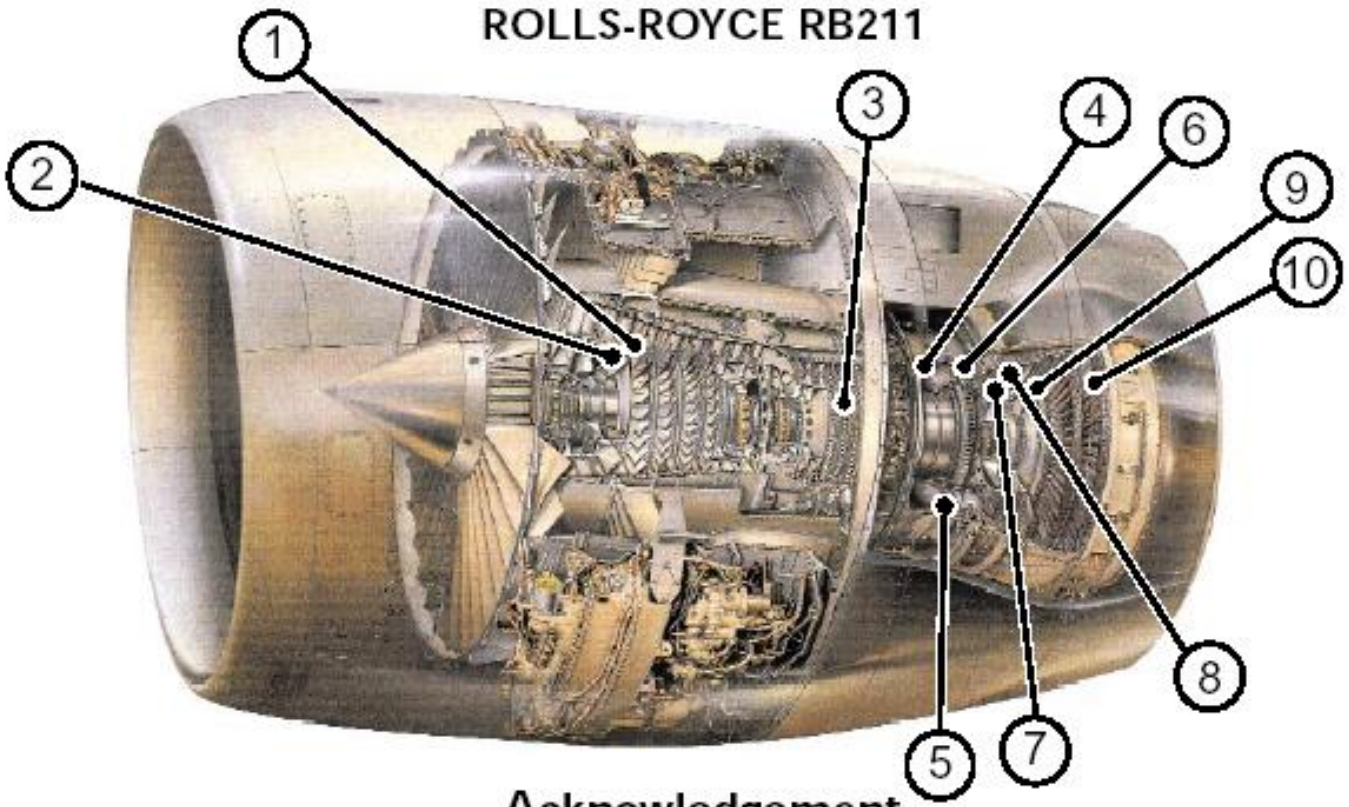
Rigid endoscopes – sometimes referred to as borescopes, rigid endoscopes

Flexible endoscopes – sometimes referred to as fibrescopes, flexible endoprobes

http://www.olympusindustrial.com/index.cfm/



A typical endoscope & application



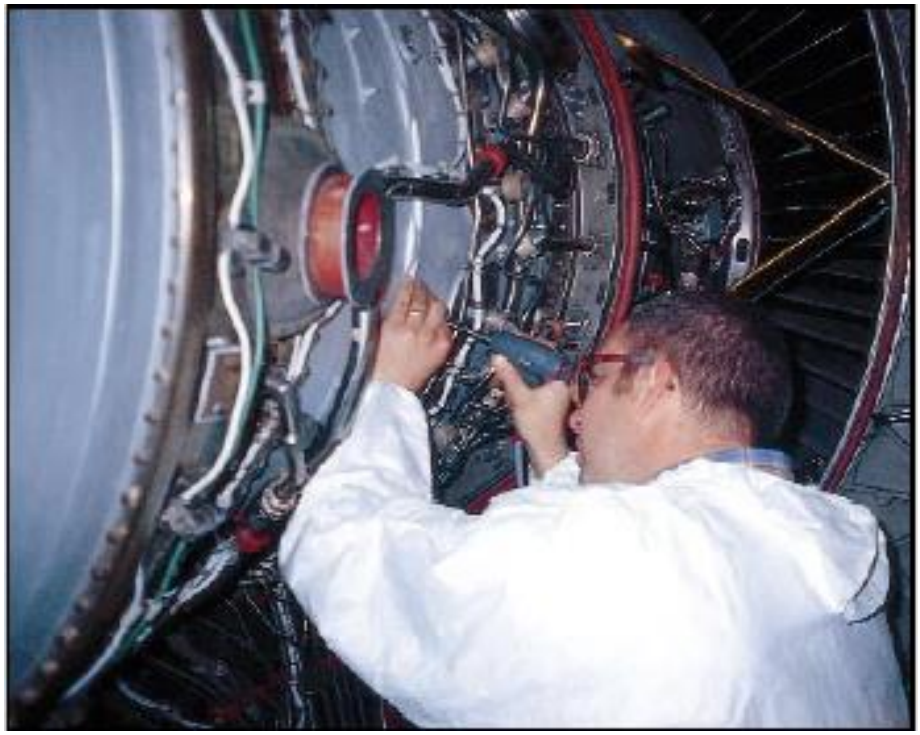
Acknowledgement

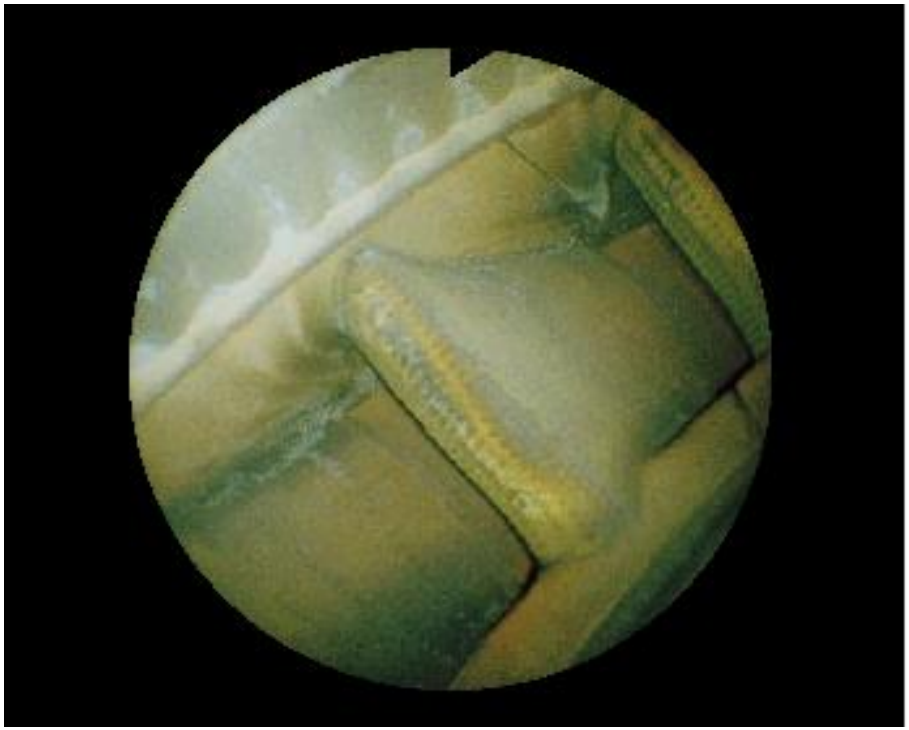
Diagram courtesy of Rolls-Royce plc.

Numbers refer to inspection areas.

http://www.olympusindustrial.com/downloads/files/SI5045690.pdf

A typical endoscope & application





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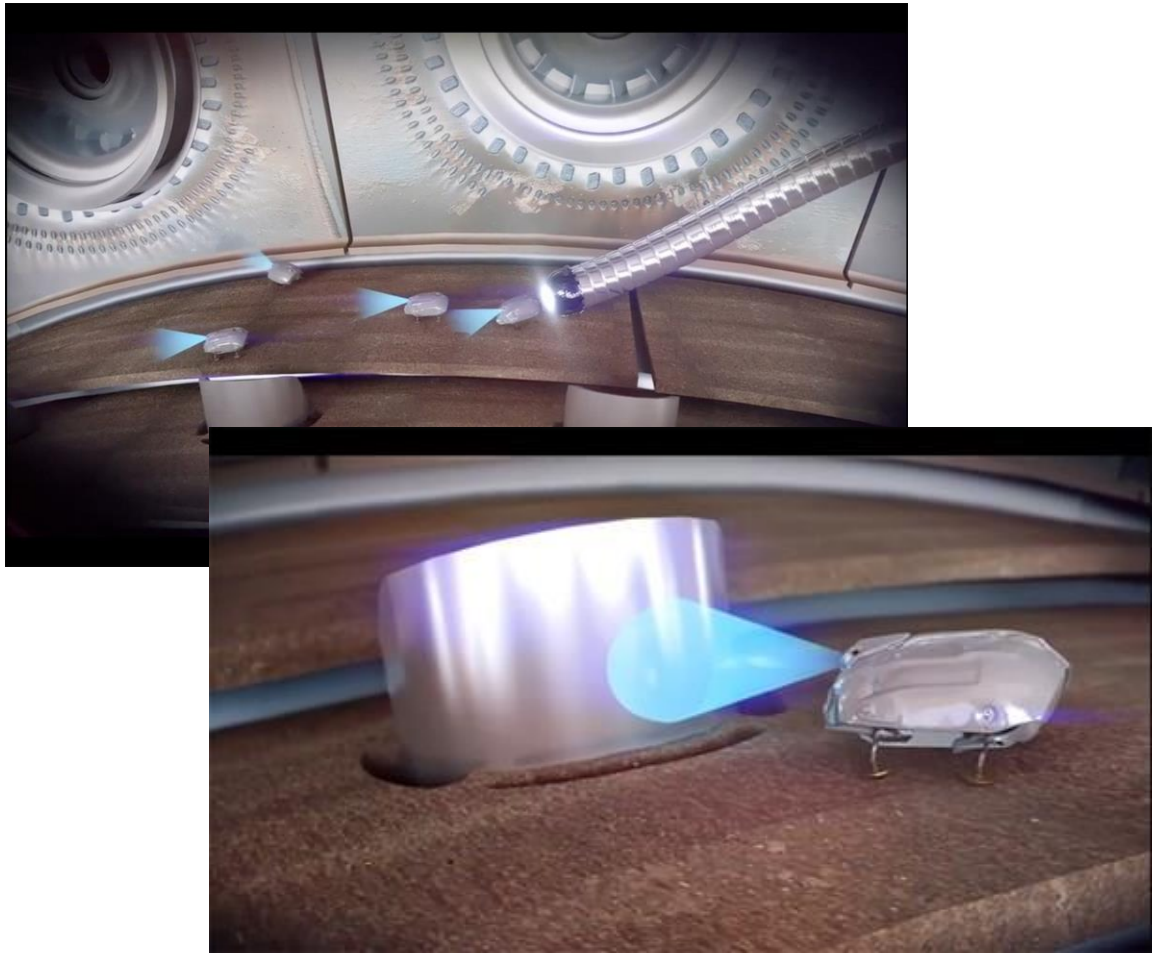
Visual inspection

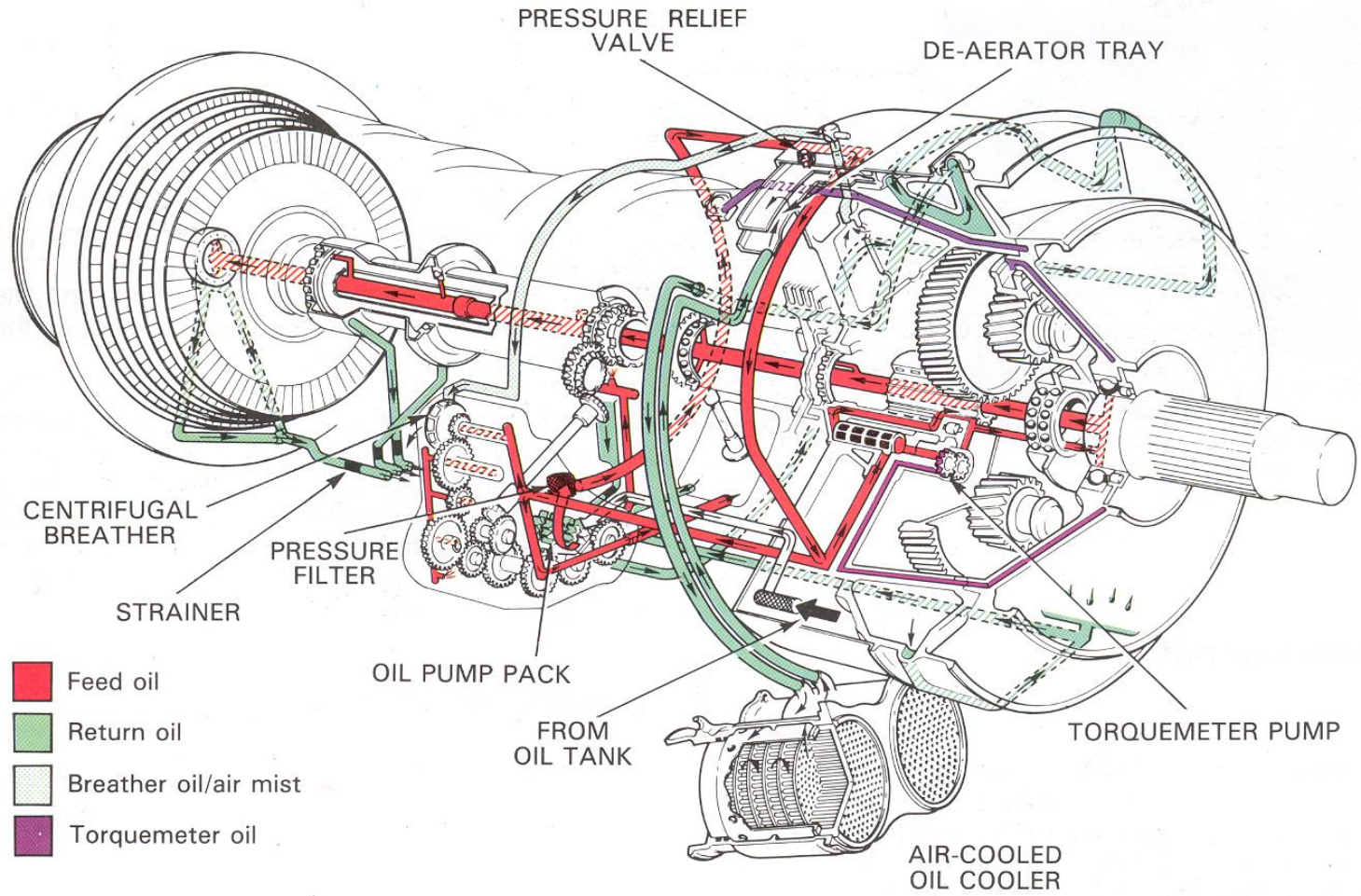


(www.aerosociety.com)

Courtesy of Rolls-Royce

Artistic impression of SWARM robot

Oil system monitoring



(Courtesy of Rolls Royce <<Jet Engines>>)

Oil system monitoring

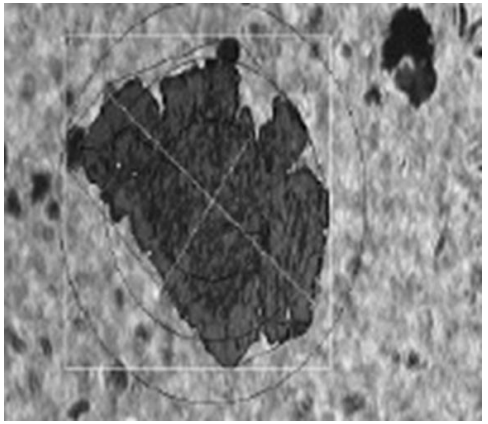
Royal Air Force Maintenance Engineer performing post-flight oil check

http://www.mildenhall.af.mil/photos/mediagallery.asp?galleryID=1405&?id=-1&page=11&count=48 –(visited on the 03.02.2011).

Oil system monitoring

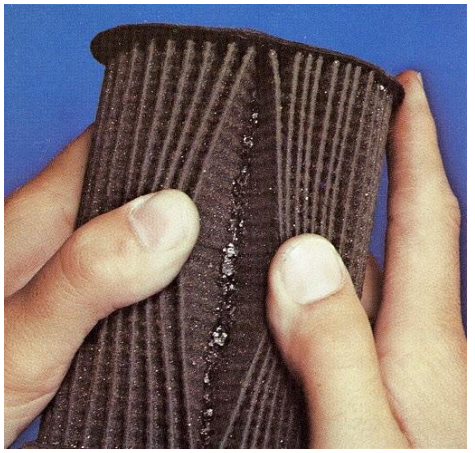
Oil /Wear Debris monitoring

- **Size** – indicate wear severity
- **Quantity** – indicate wear rate
- **Distribution** – indicate wear zone
- **Shape** – indicate wear modes and types
- **Composition** – indicate debris source



Courtesy of MA Khan and AG Starr (CM 2007)

Magnetic Chip Detectors



Oil Filter showing trapped Debris

Oil system monitoring

Oil condition/quality monitoring

Spot check - oil degradation & consumption

Laboratory tests:

- physical condition of oil

  such as contaminants, viscosity, acid number, etc.

- chemical properties of oil

Oil system monitoring

Oil system operation monitoring

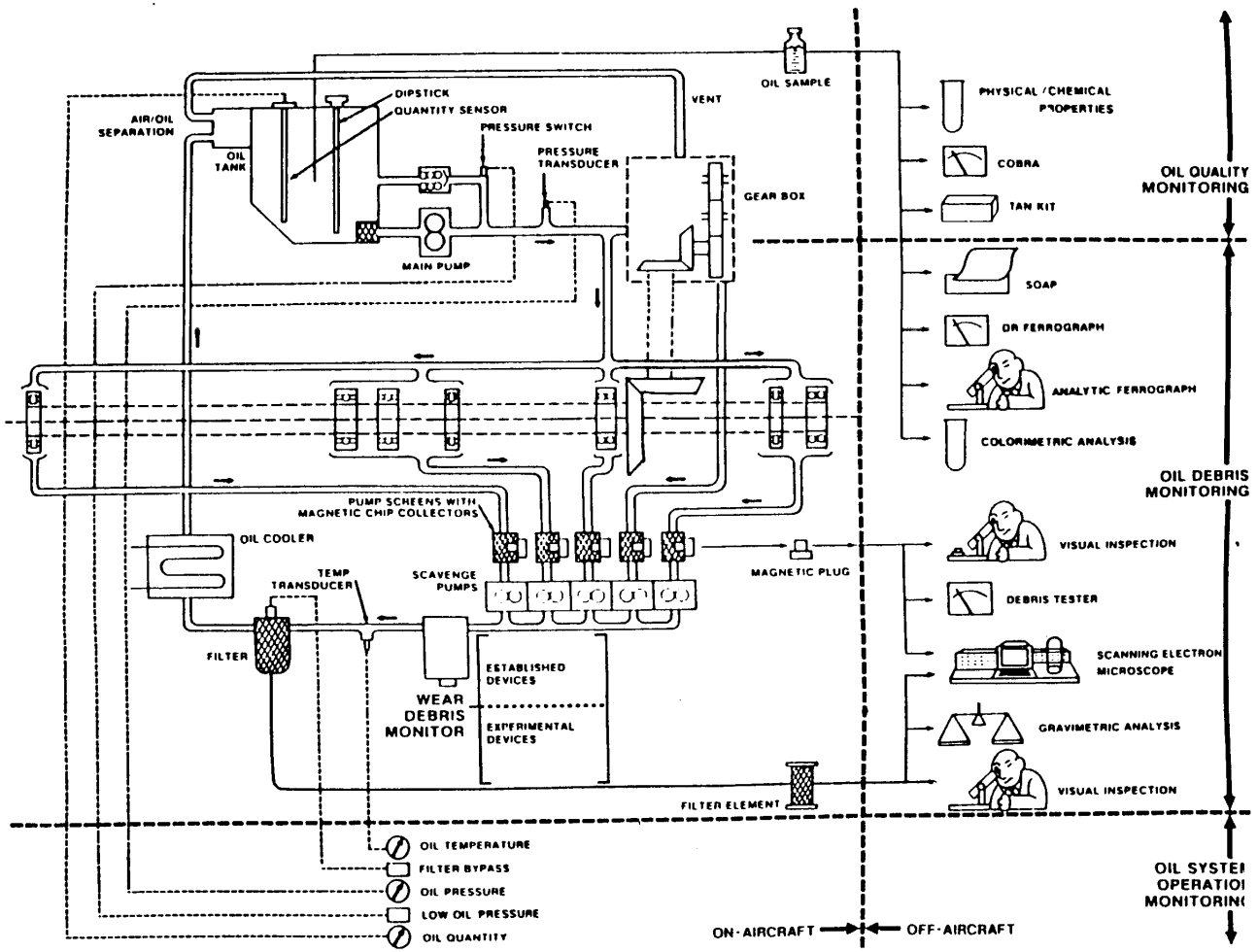
Oil temperature

Oil pressure

Oil quantity

To monitor the functioning of oil system

Oil system monitoring



Oil condition monitoring

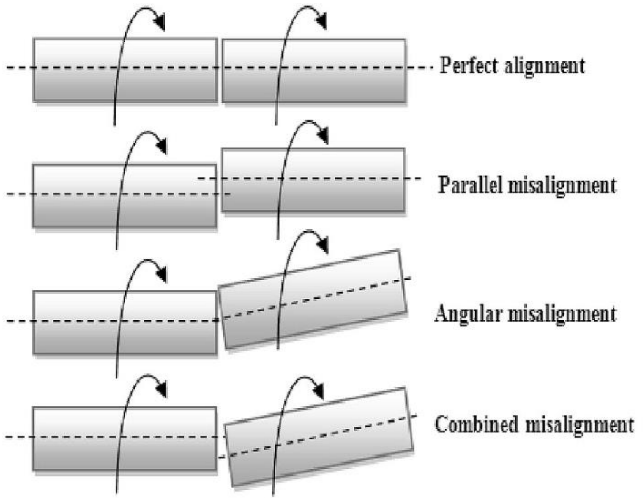
Oil debris monitoring

Oil system operation monitoring

Vibration monitoring

Vibration causes:

* Unbalance
* Misalignment
* Bearing problems



(https://www.researchgate.net/figure/Types-of-misalignment-shaft_fig1_342188040)

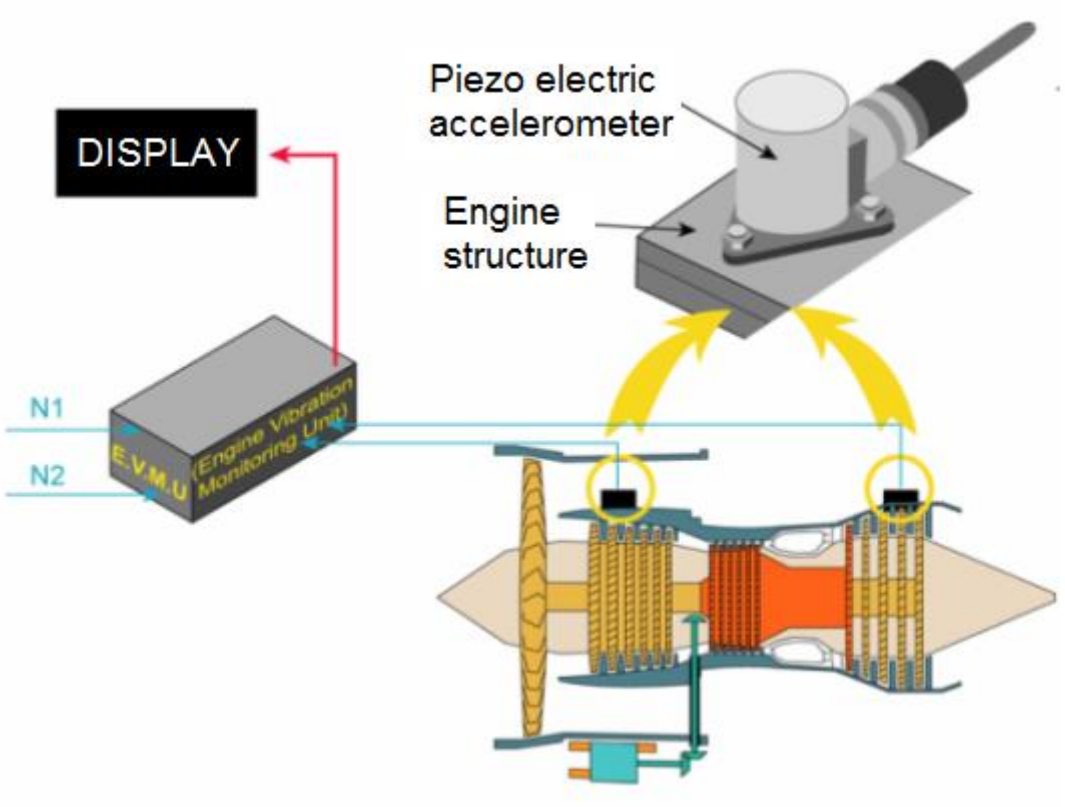
Vibration contributors:

Rotors, blades, discs, bearings and gears

Vibration can detect:

* Out of balance
* Damaged bearings
* Damaged or worn gears
* Misalignment, bent shaft
* Mechanical looseness

Vibration monitoring



(https://elearnstation.com/scenari/STARTING%20AND%20IGNITION%20SYSTEMS/co/module_EGINE_INDICATING_SYSTEMS_3.html)

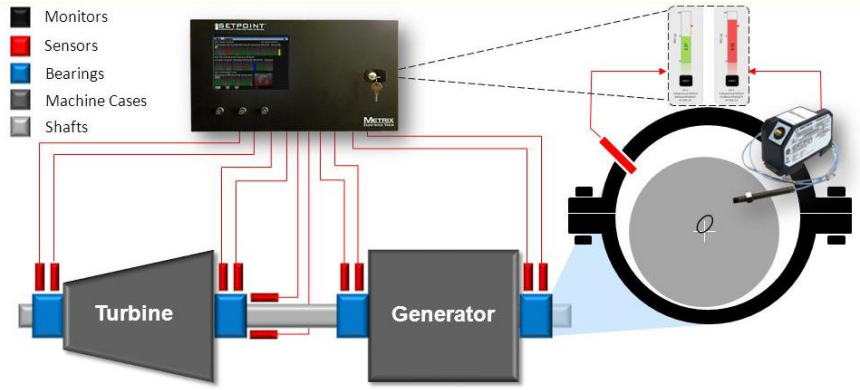
Vibration monitoring

Vibration measurement:

Six components need establishing:

1) DISPLACEMENT (proximity sensor)
2) ACCELERATION (accelerometers)
3) VELOCITY (velocity sensors)

4) FREQUENCY
5) AMPLITUDE
6) PHASE

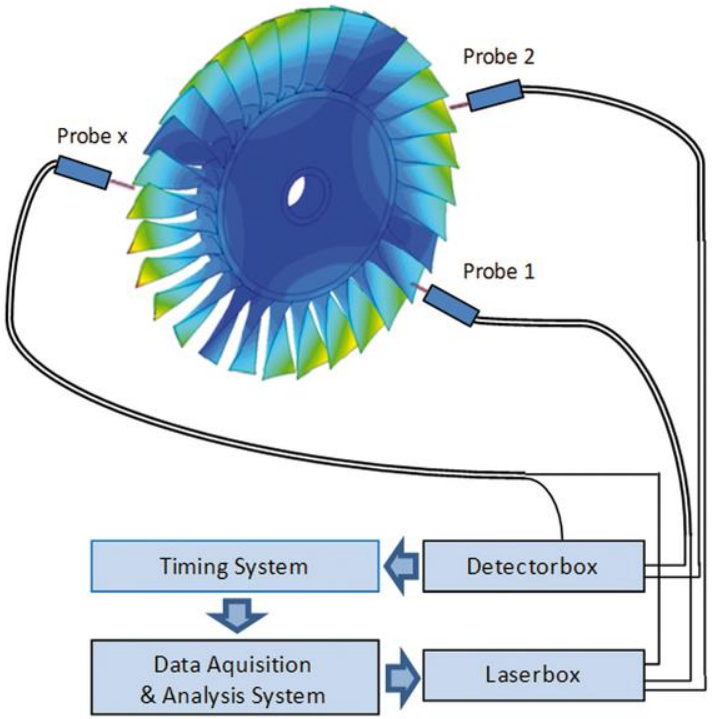


Courtesy of SETPOINT (https://slideplayer.com/slide/3921450/)

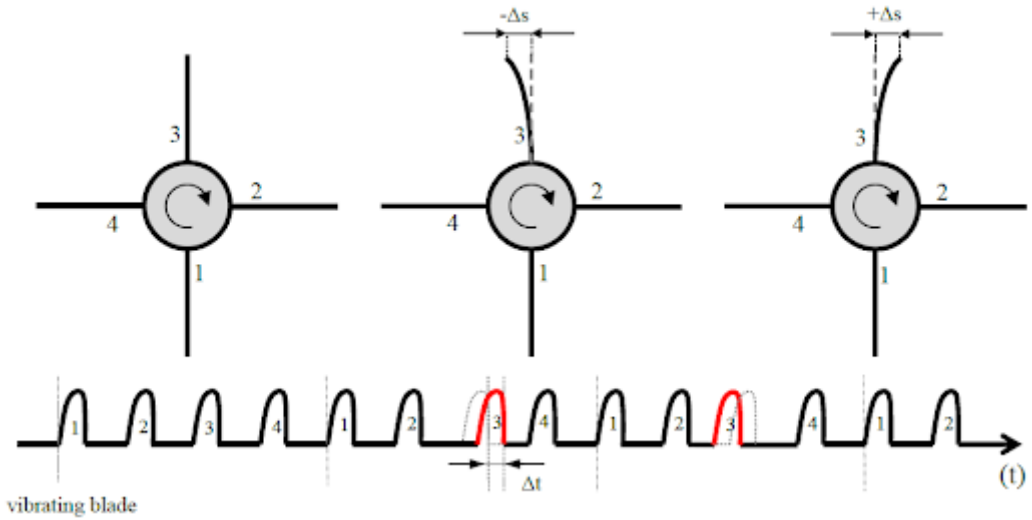
Vibration safe limits setting:

based on statistics & experience

Vibration monitoring – Blade Tip Timing

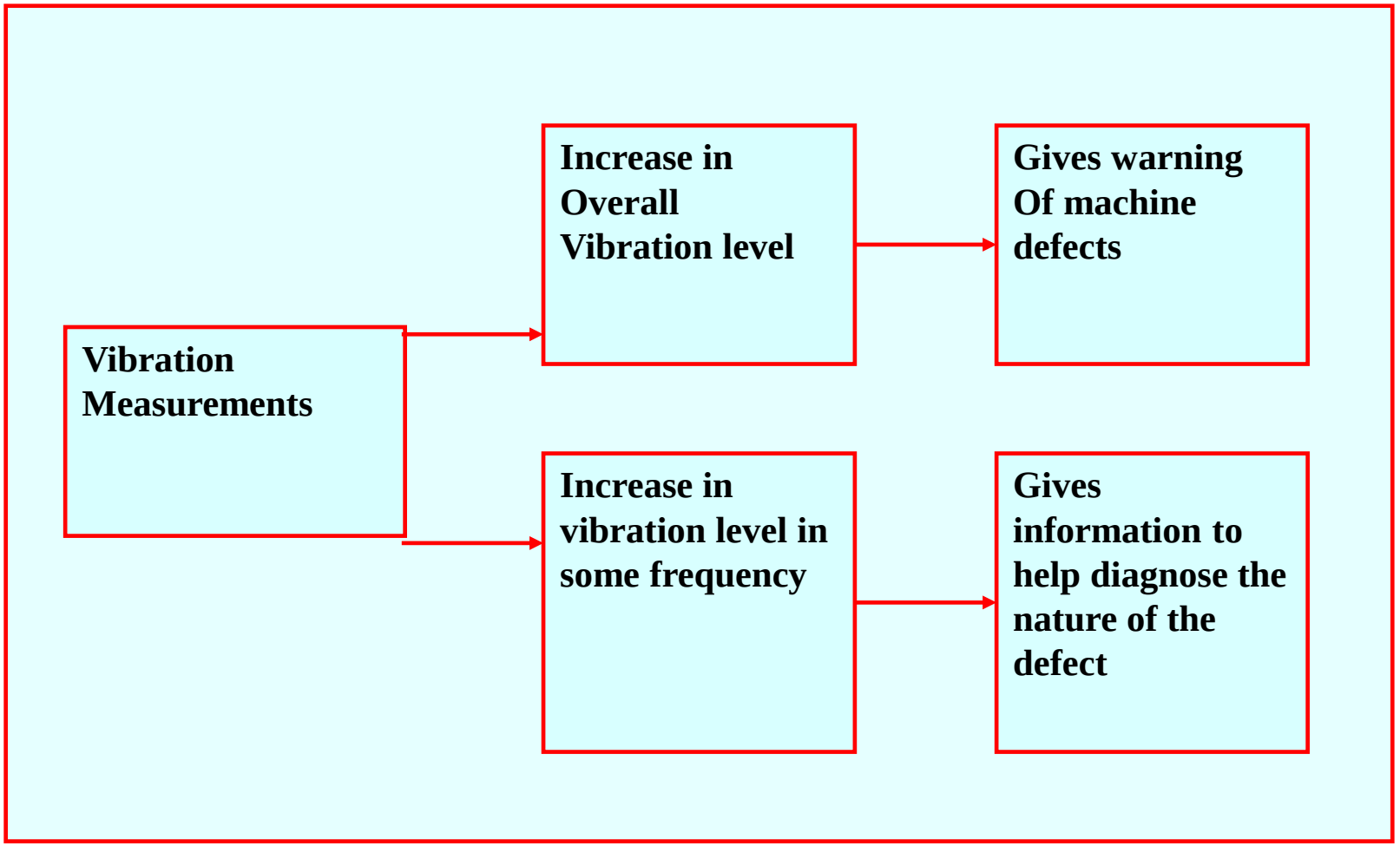


Courtesy of Institute of Turbomachinery and Fluid Dynamics, Leibniz Univ Hannover



Courtesy of American Journal of Sensor Technology. **2014**, 2(2), 13-19 doi:10.12691/ajst-2-2-1

Vibration monitoring



Acoustic monitoring

Acoustic emissions: "Sudden change of stress by, for example, the formation of cracks, plasticity, and phase transformation - emit elastic waves"

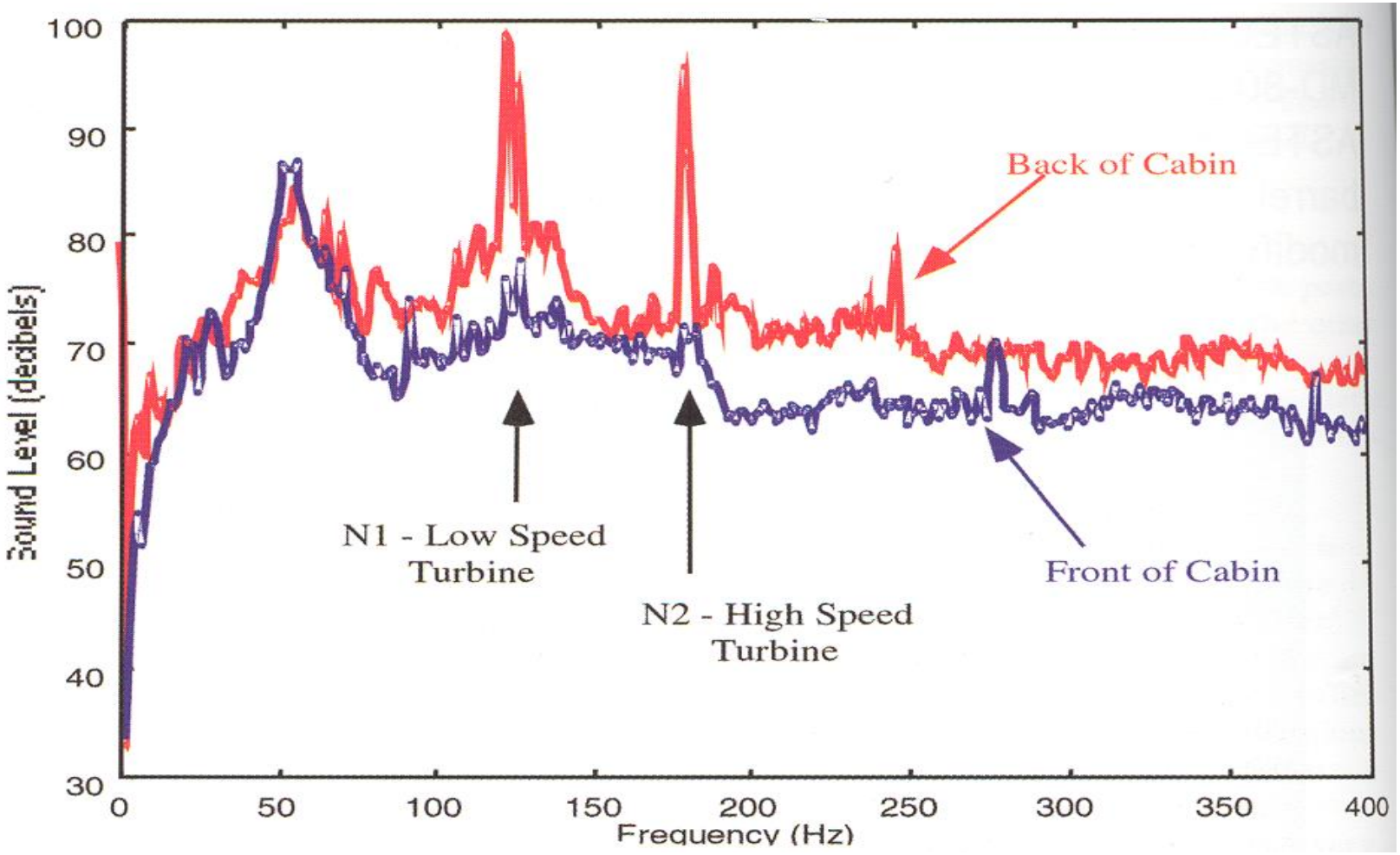
Sources of acoustic emissions:

- **Mechanical systems - related to vibration**
- **Aerodynamic systems - related to flows**

Acoustic monitoring can detect:

- **Changes in mechanical conditions of individual components**
- **Rotation imbalance**
- **Change in flow field – performance degradation**

Acoustic monitoring



(Courtesy of "Turbomachinery" magazine)

Engine usage monitoring

GT components are lifed subject to:

- **Mechanical stress**
- **Thermal stress**

GT component life is mainly determined by:

- **Creep**

  – plastic deformation due to long time high temperature operation.

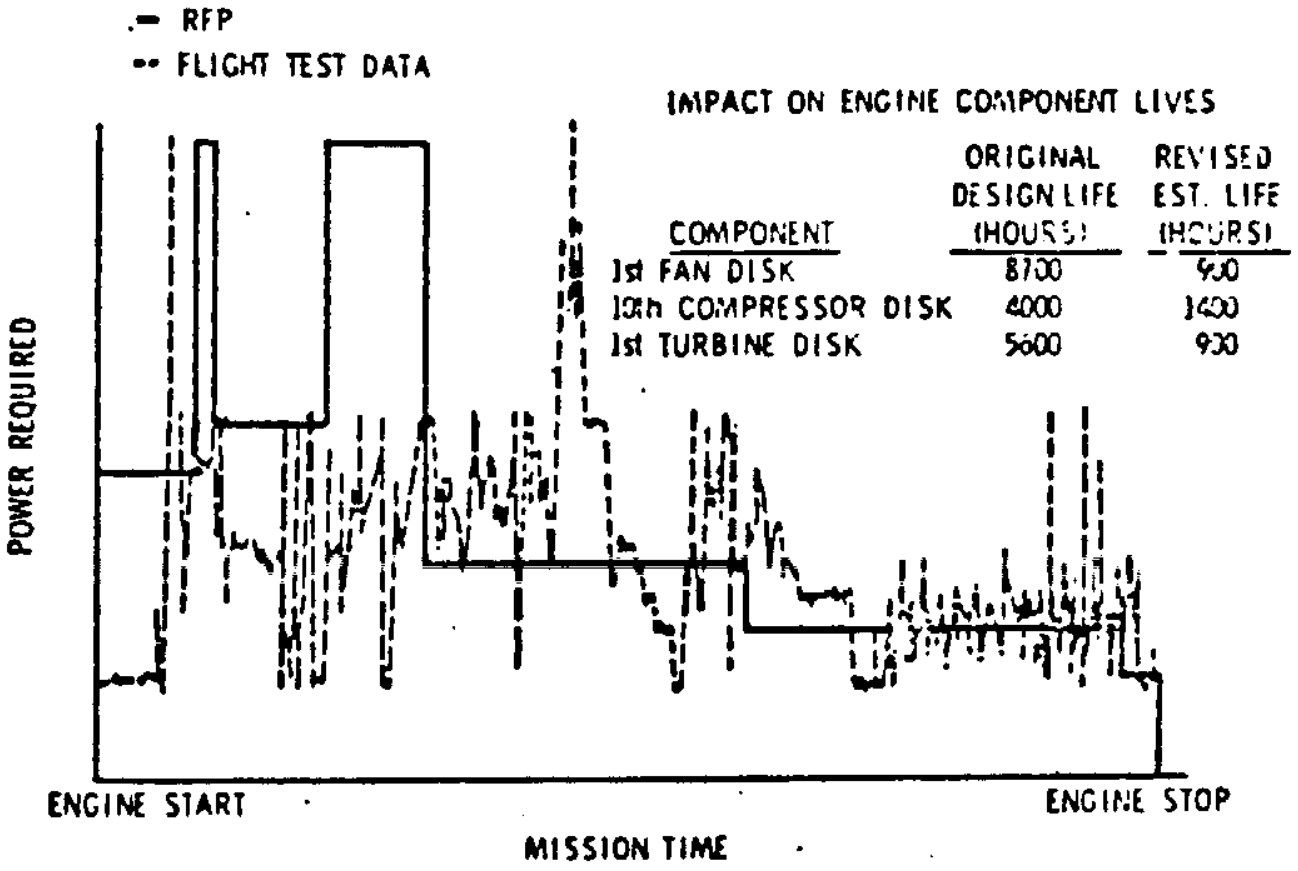
  -- Function of centrifugal stress, temperature and time.

  -- Common modes of turbine blade failure.
- **Low cycle fatigue.**

  -- LCF life is calculated with an assumed load history.

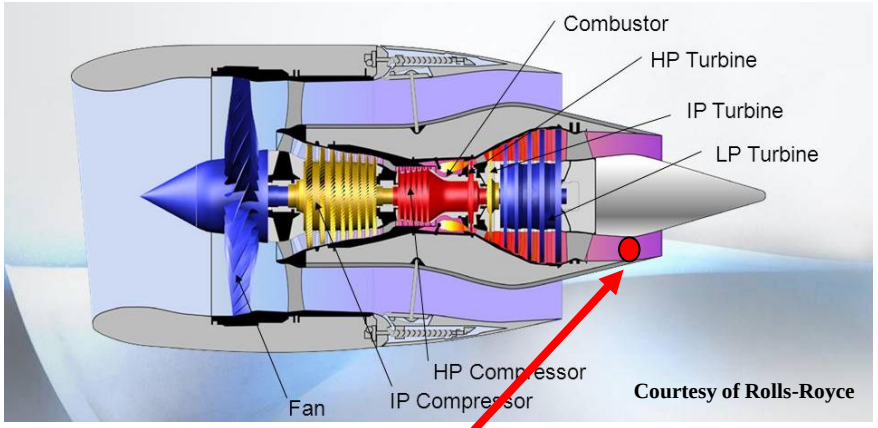
Engine usage monitoring

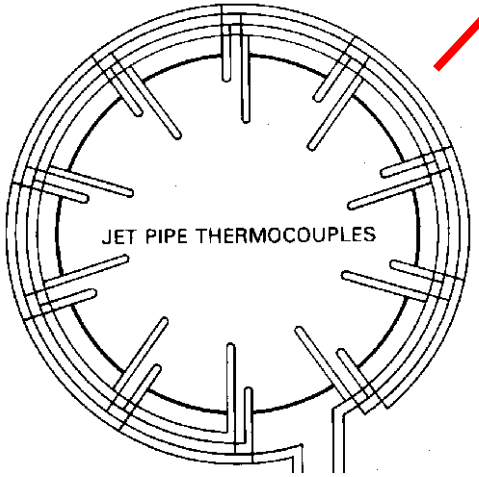
Two important factors: (a) Creep; (b) Low Cycle Fatigue (LCF)

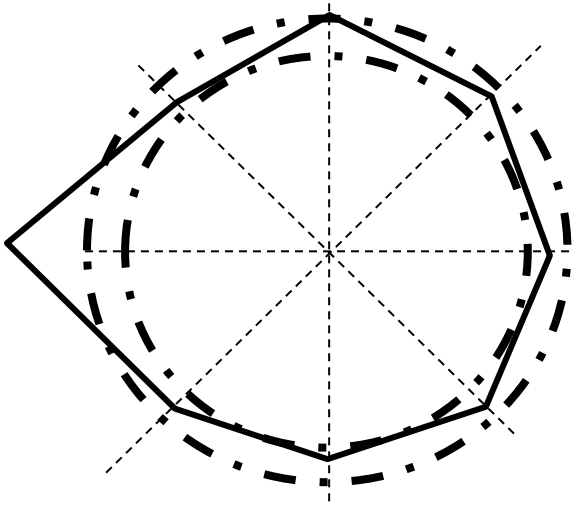


Turbine exit spread monitoring

- Using equal-spaced thermal couples
- To carry out continuously under steady state conditions,
- To monitor combustion system and turbine components







Limited transient monitoring

During start-up:

Higher EGT or ***power turbine entry temperature*** may indicates fuel system drift, starting system shortfall or combustion system deterioration

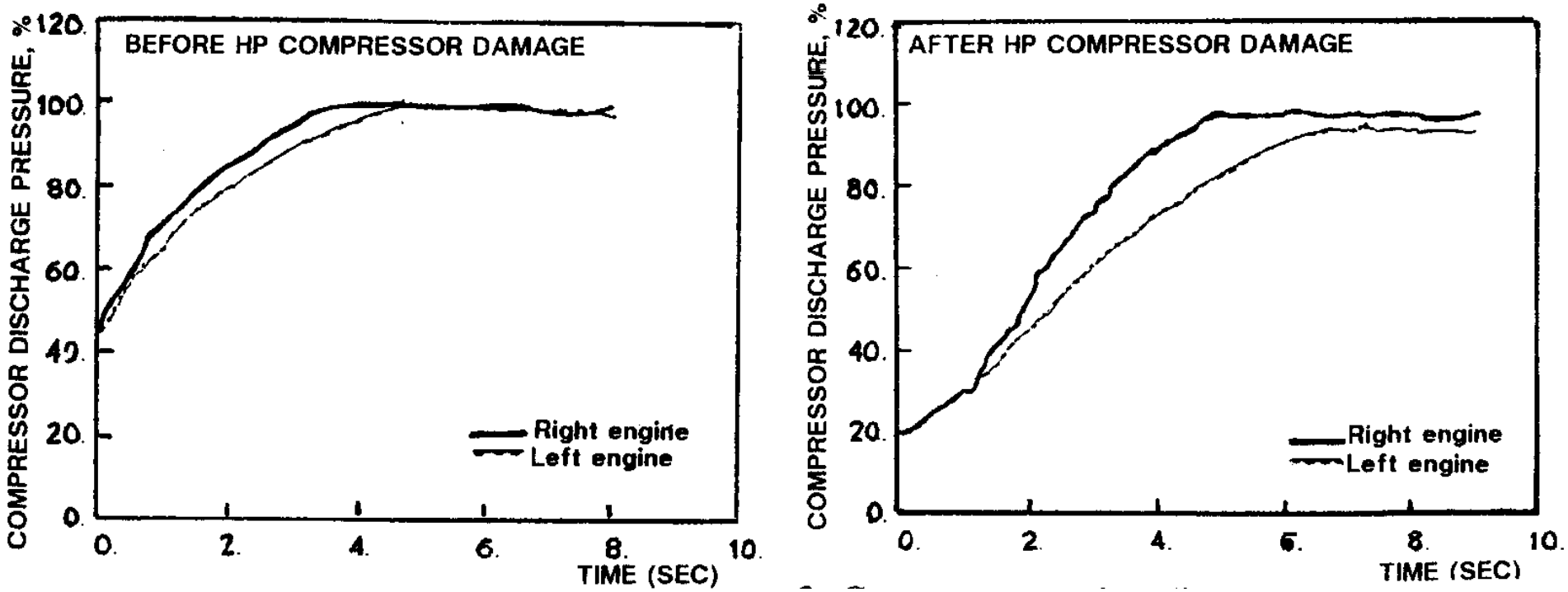
Longer start up time: bearing or other rotating part faults

Run-down time:

Short run down: It gives an indication of mechanical problems both on main spools and or directly coupled accessories.

Long Run down: It usually indicates that fuel is still entering the combustion system after shutdown due to problem in the fuel system, such as shut off valve leak, control system malfunction or governor problem

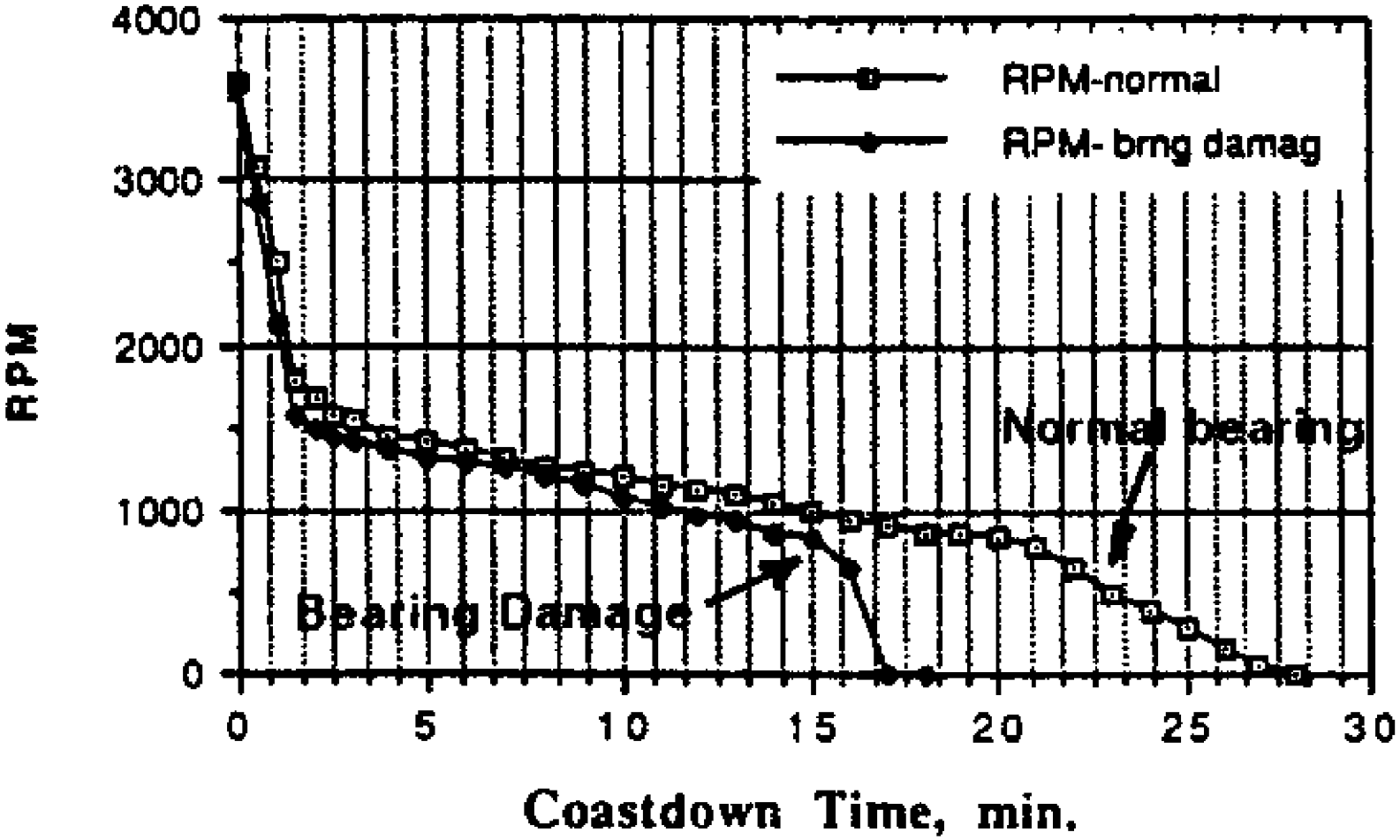
Limited transient monitoring



(Cue R.W. & Muir D.F., ASME 90-GT-357)

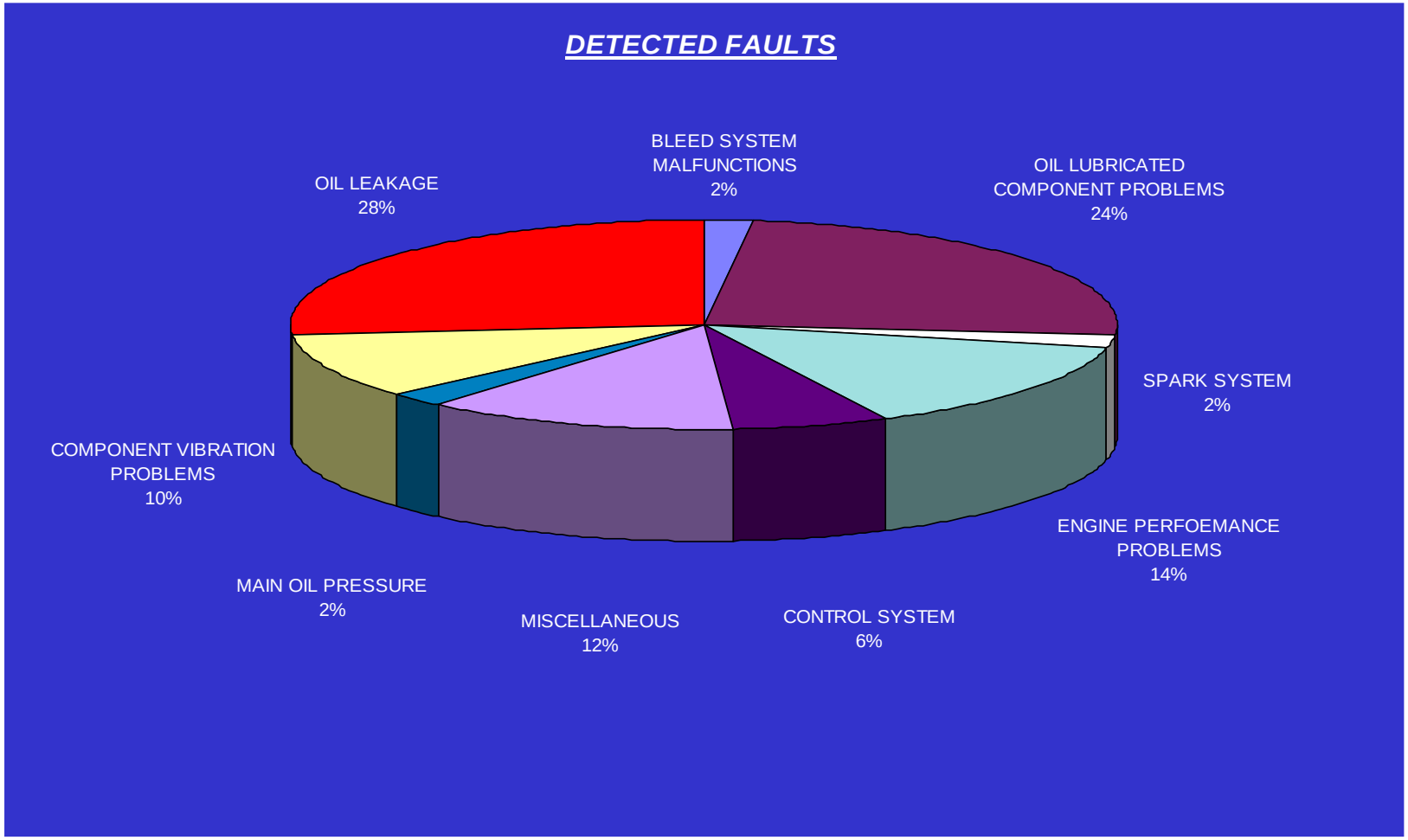
A compressor discharge pressure traces
(damage of HP compressor in left engine)

Limited transient monitoring

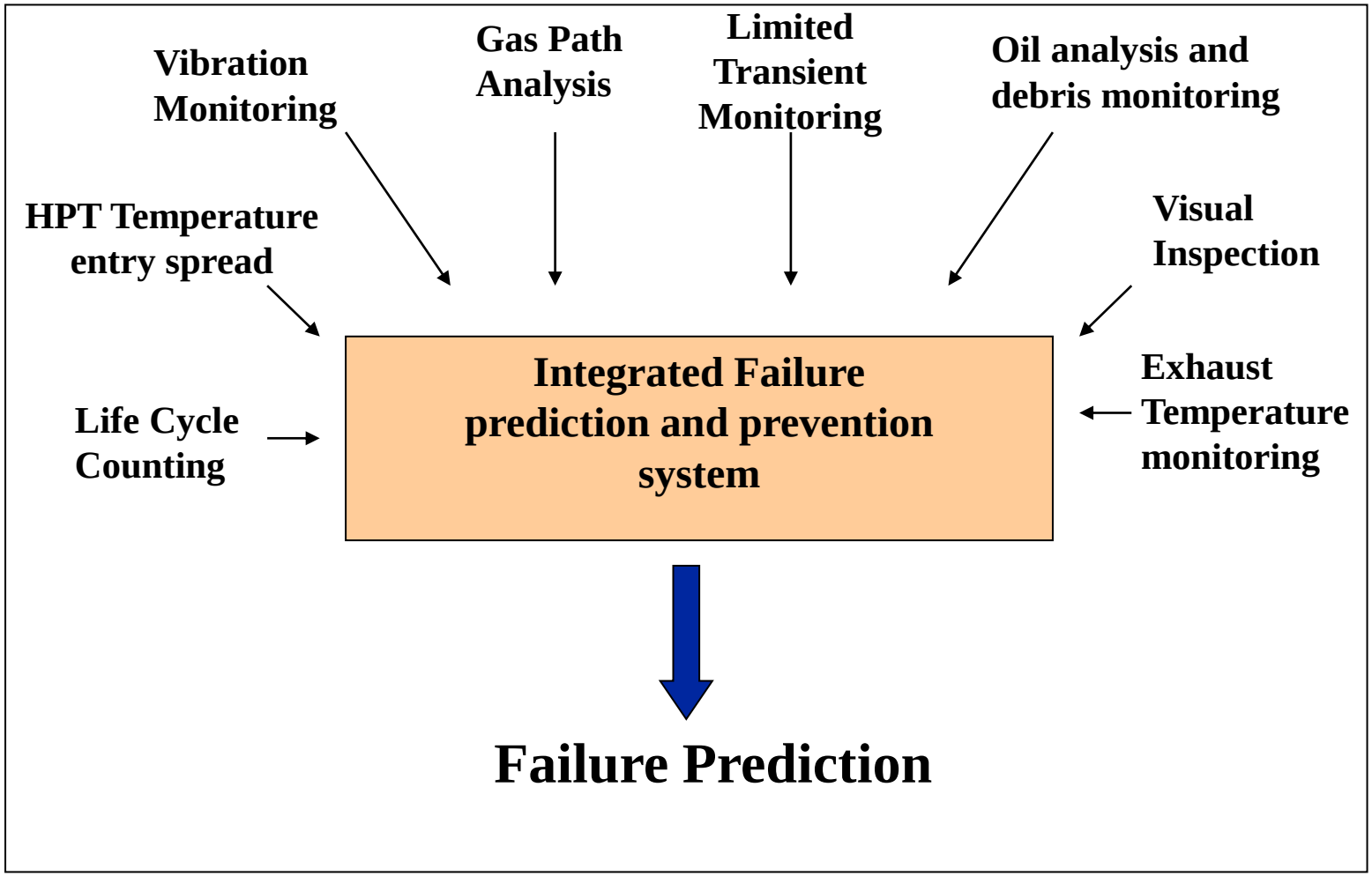


(Meher-Homji C.B. and Bhargava R., ASME 92-GT-100)

Breakdown of faults detected for a typical gas turbine



An integrated diagnostic system



How can condition monitoring benefit us?