# Eyjafjallajokull

# The impact of volcanic ash on aircraft engines

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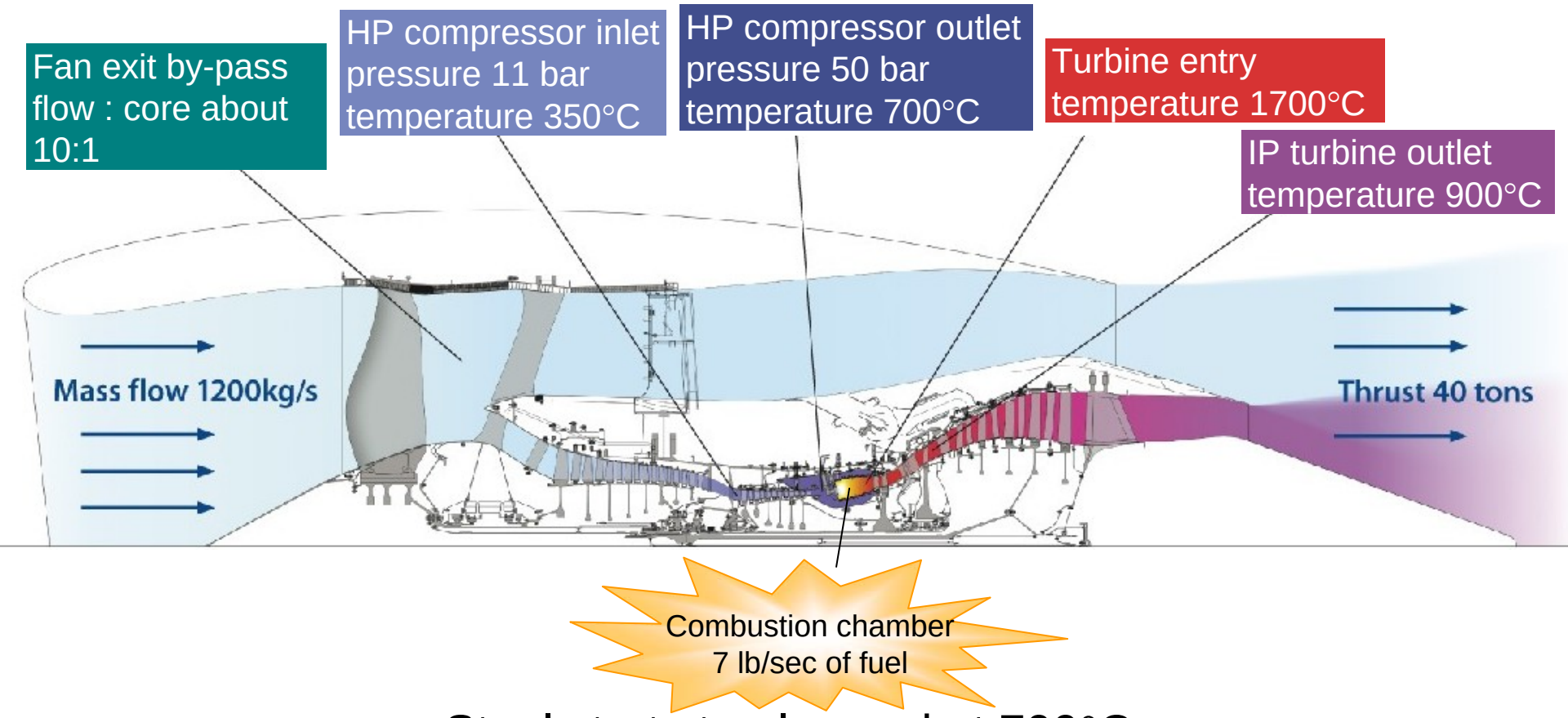
# The impact of volcanic ash on aircraft engines

- Agenda
  - Why is operation in Volcanic Ash an issue ?
    - Engine OEM's understanding
    - Safe to fly
  - Ash & Engines
    - Service Sampling
    - Ash tolerant engine?
  - Conclusions

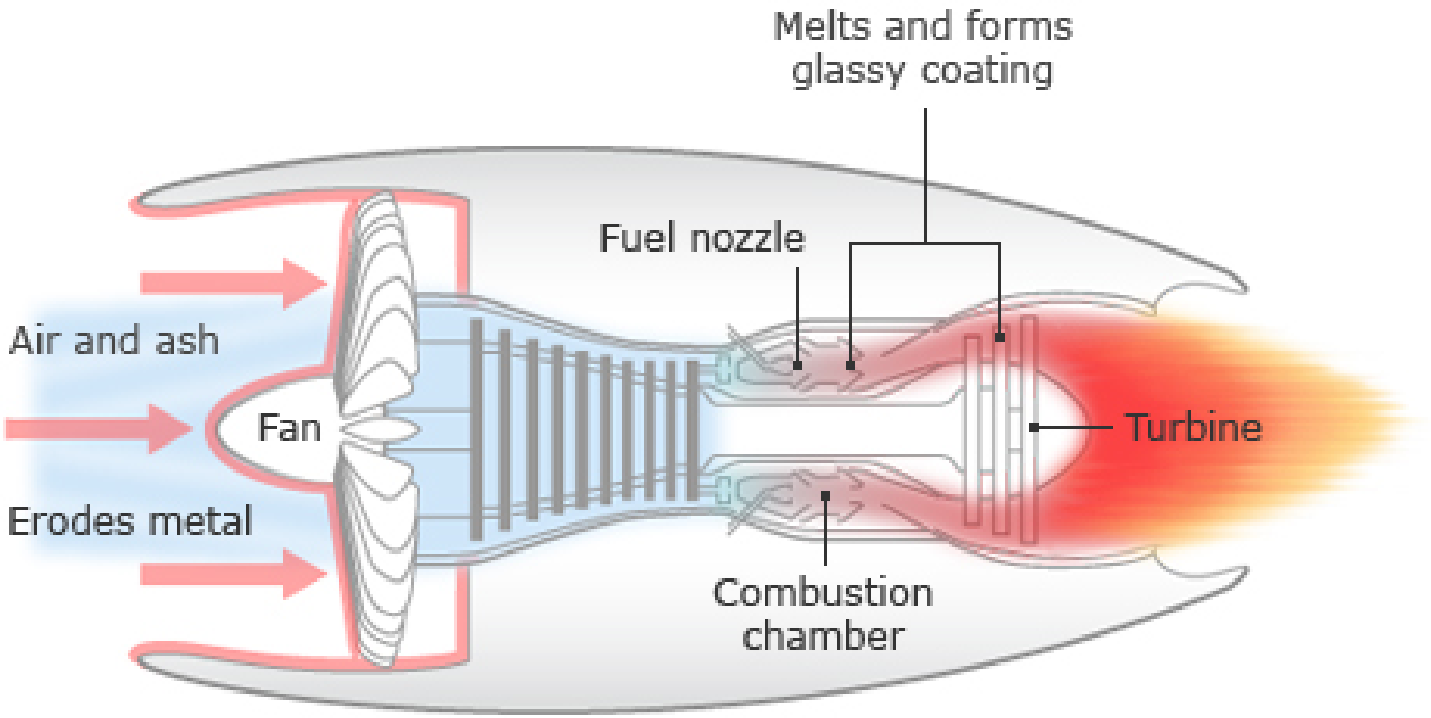
# How engines work

## Operating principle of a modern jet engine and some key figures
## Overall Pressure ratio: ~50




Steel starts to glow red at 700°C

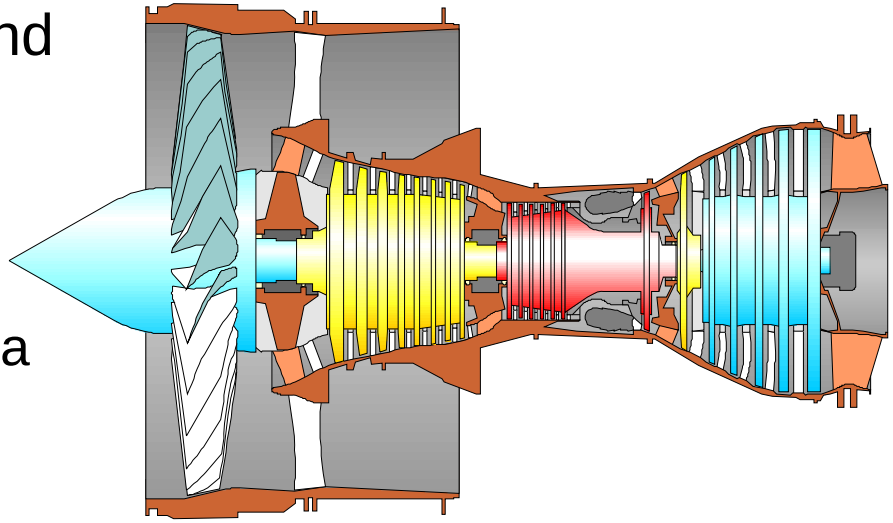
# What does the ash do in the engine ?




Clogs jets fuel and cooling systems

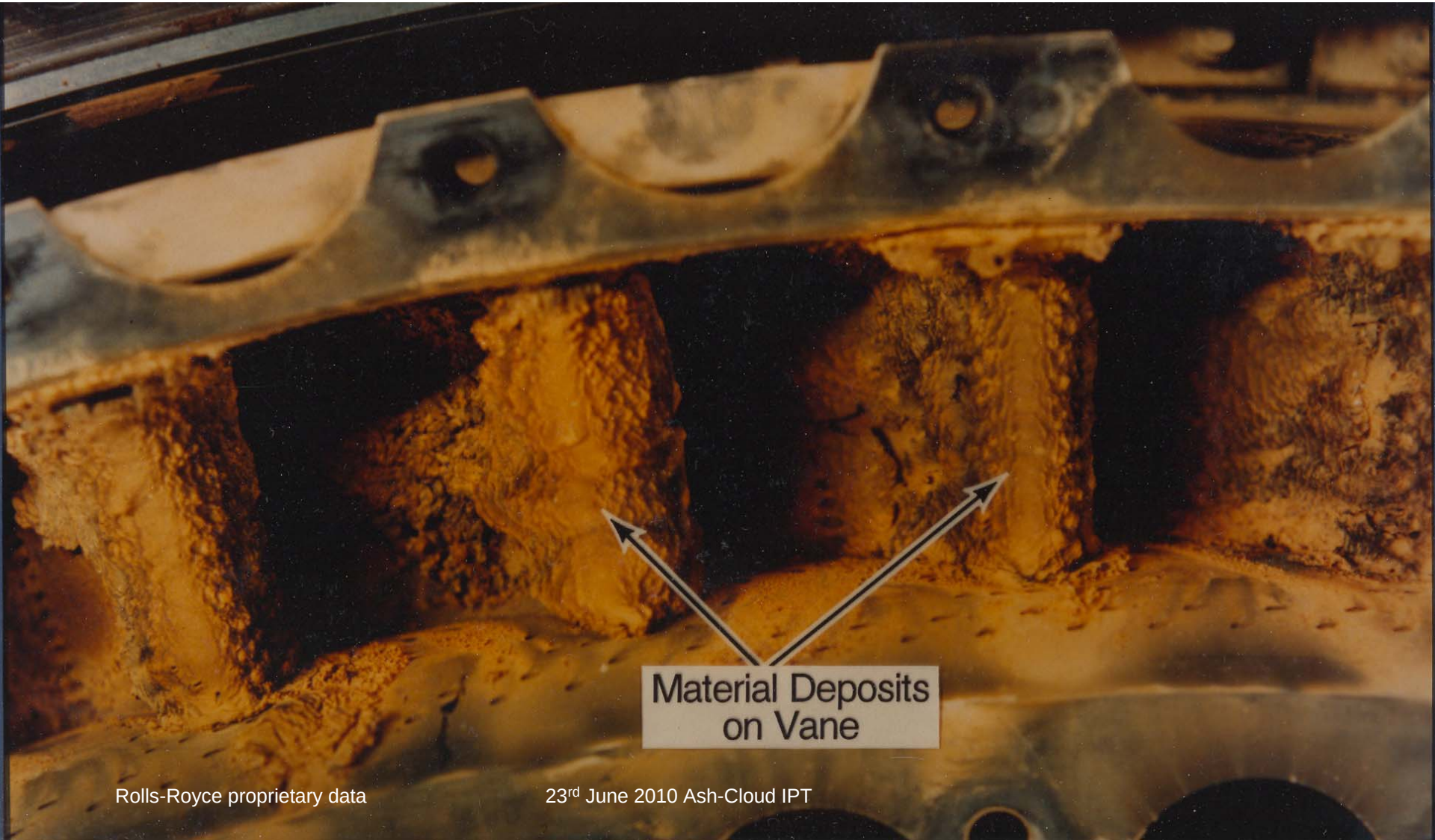
# Why Is Operation In Volcanic Ash An Issue ?

- Erodes compressor blades and linings
- Ash melts in Combustor and deposits in HP Turbine
  - Reduced HPNGV throat area
  - Increased HPC pressure
  - Engine surge
  - Internal cooling airflow blockage
- Fine particles can get in to oil system and damage transmissions components
- Pneumatic controls blocked by small particles

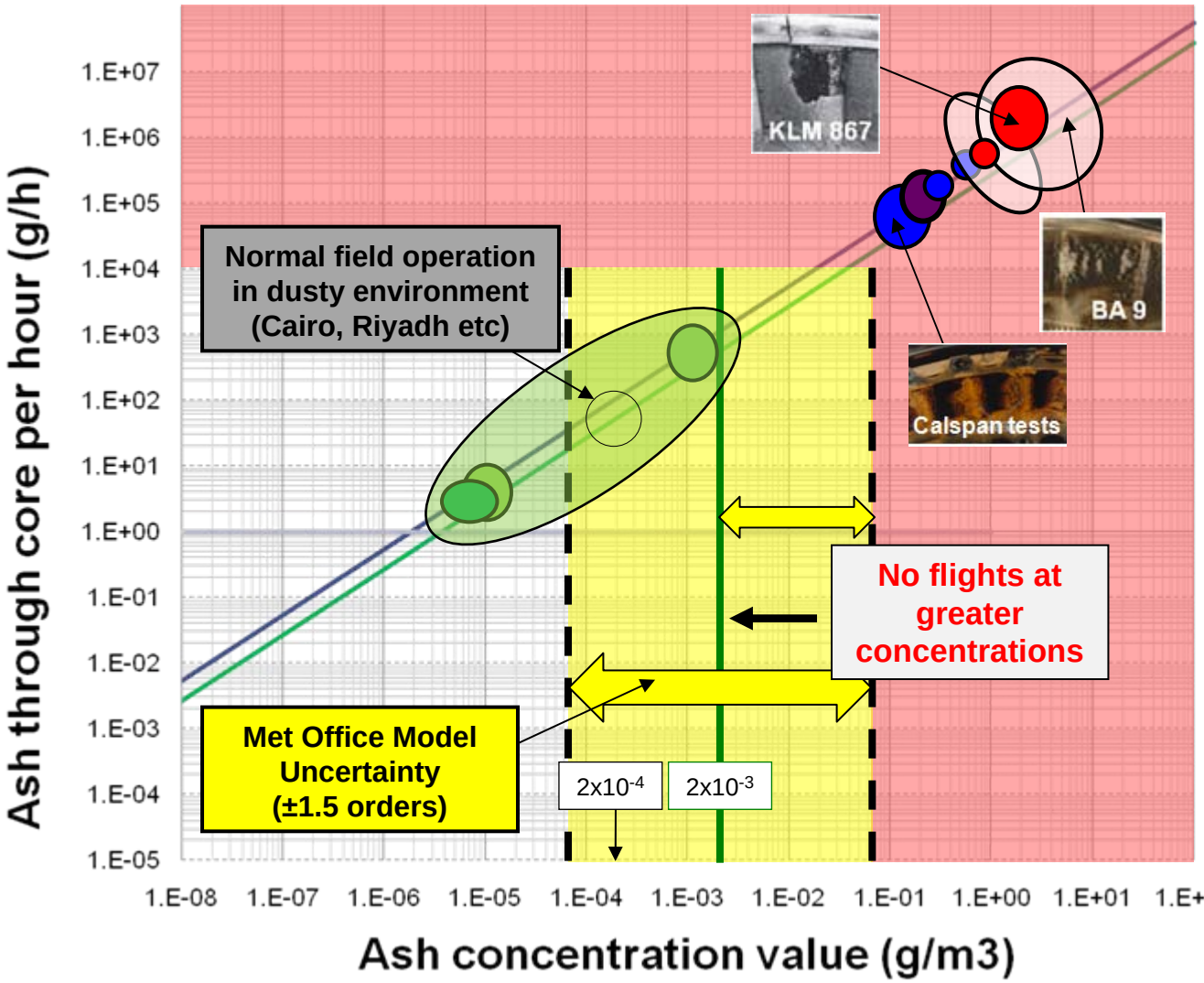


**Heavy HP NGV contamination (BA747, Jarkarta 1982)**

# HPT Vane; After Dust Exposure
## (concentration about >2x10-1 g/m3)
## (exposure around 1 hour)

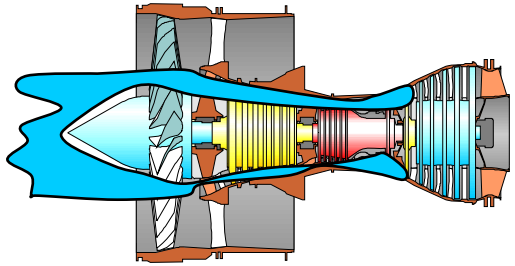


# The Safe to Fly – Chart: 17th May 2010




## Key

- KLM 867
- BA9
- BA / Dornier
- DLR Germany
- GE Earth Mix
- Calspan Tests



100% core flow

50% core flow

# Service Sampling

- RR have inspected over 350 individual engines
  - On-wing borescope / visual inspections
  - Off-wing component analysis
- Targeted sampling based on potential exposure to ash
  - Utilising novel EHM & Operational modelling techniques
- Nil findings
  - Off-wing sampling & analysis will continue throughout 2010

# Ash tolerant engine?

- R-R large engine fuel burn has improved ~20% in the last 20 yrs
- Emissions significantly reduced in the last 20yrs
- Improvement from:
  - Reduced core engine size
  - Higher pressure ratios
  - Increased Turbine Entry Temperatures
- Modifications to reduce susceptibility to volcanic ash would have a negative environmental impact.
  - Increased fuel burn
  - Increased emissions

# Conclusions

- Analysis based on ‘actual’ ash density
- Actual ash concentration for safe operation $2x10^{-3}g/m^3$
  - Engine OEM’s do not support flight in visible ash
- Probabilistic risk assessment supports this value
- Extensive service sampling has provided evidence that RR products were not exposed to predicted ash concentrations
- Removing the uncertainty from the Met Office model will provide a significant benefit for operations during future eruptions
- Designing an engine to be more tolerant to volcanic ash would increase fuel consumption and emissions