



# Rolls-Royce

## Eyjafjallajökull

# The impact of volcanic ash on aircraft engines



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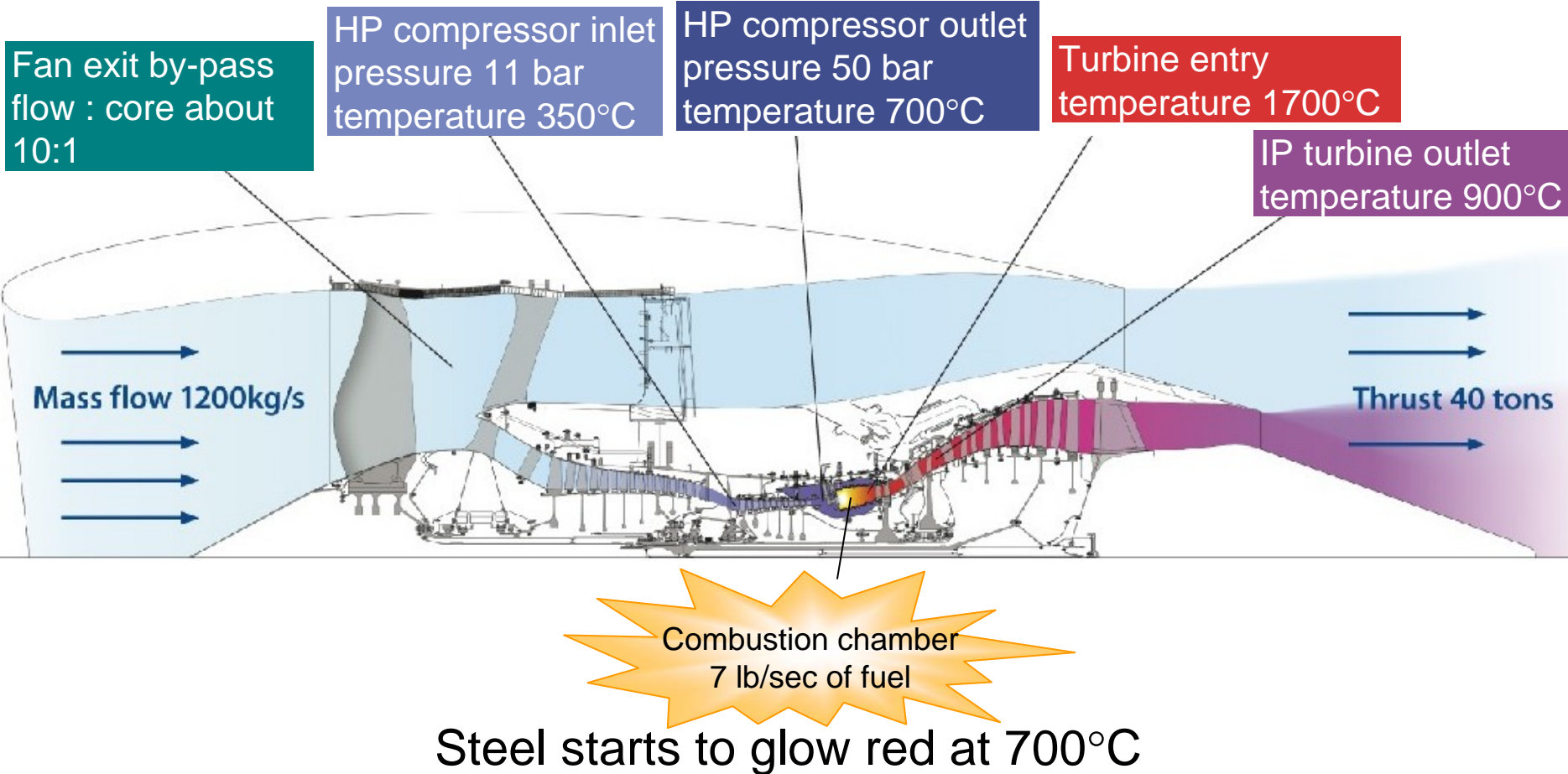
# The impact of volcanic ash on aircraft engines

- 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

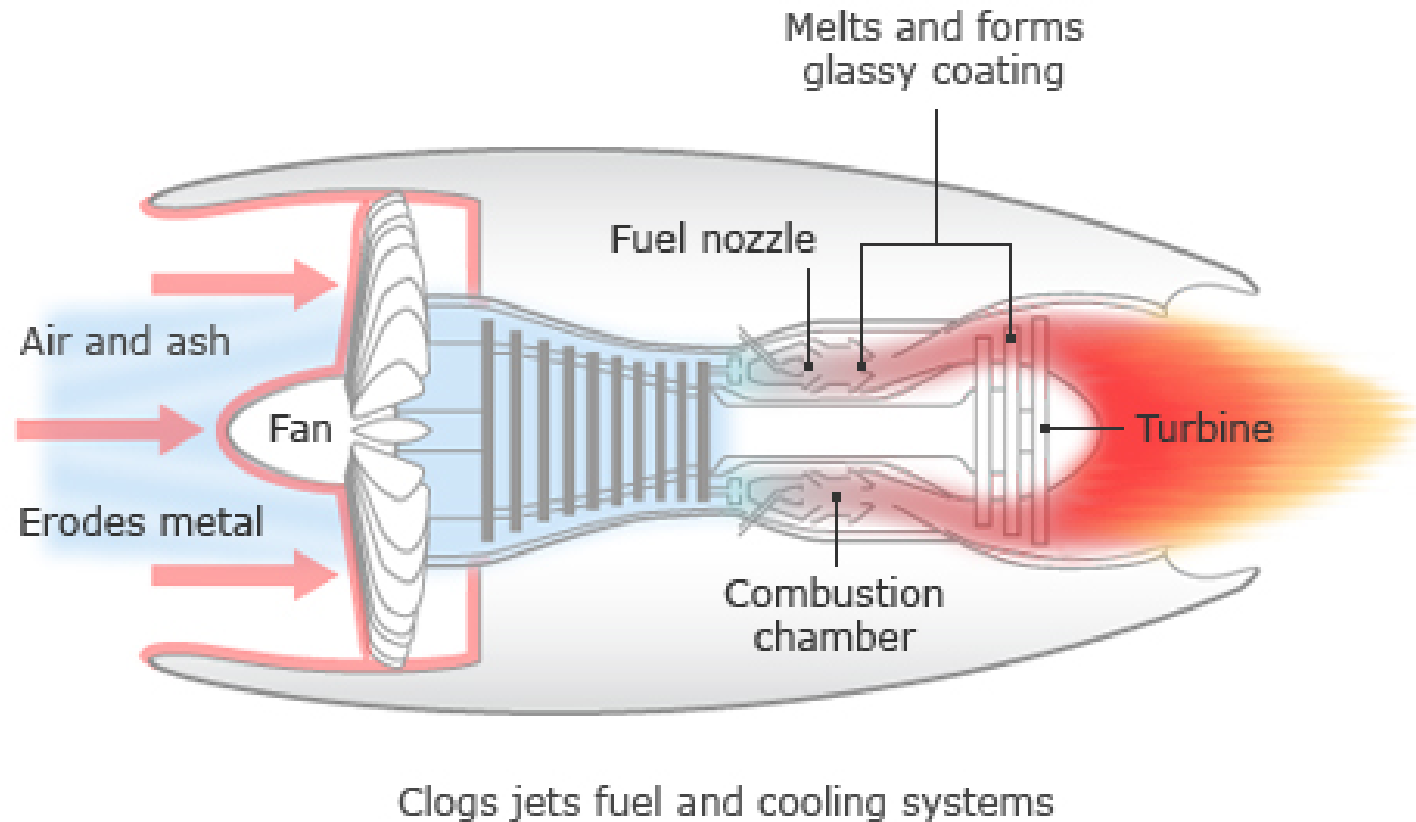
Operating principle of a modern jet engine and some key figures

Overall Pressure ratio: ~50



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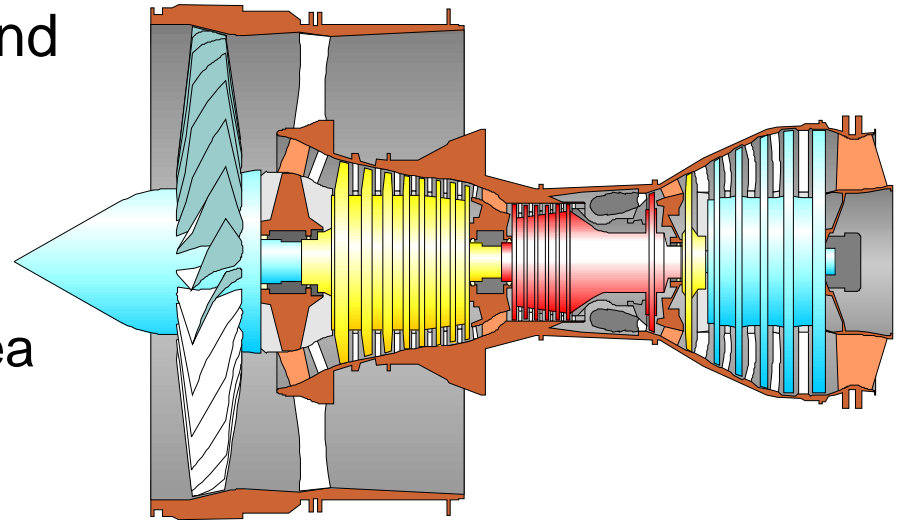
# What does the ash do in the engine ?



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# 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

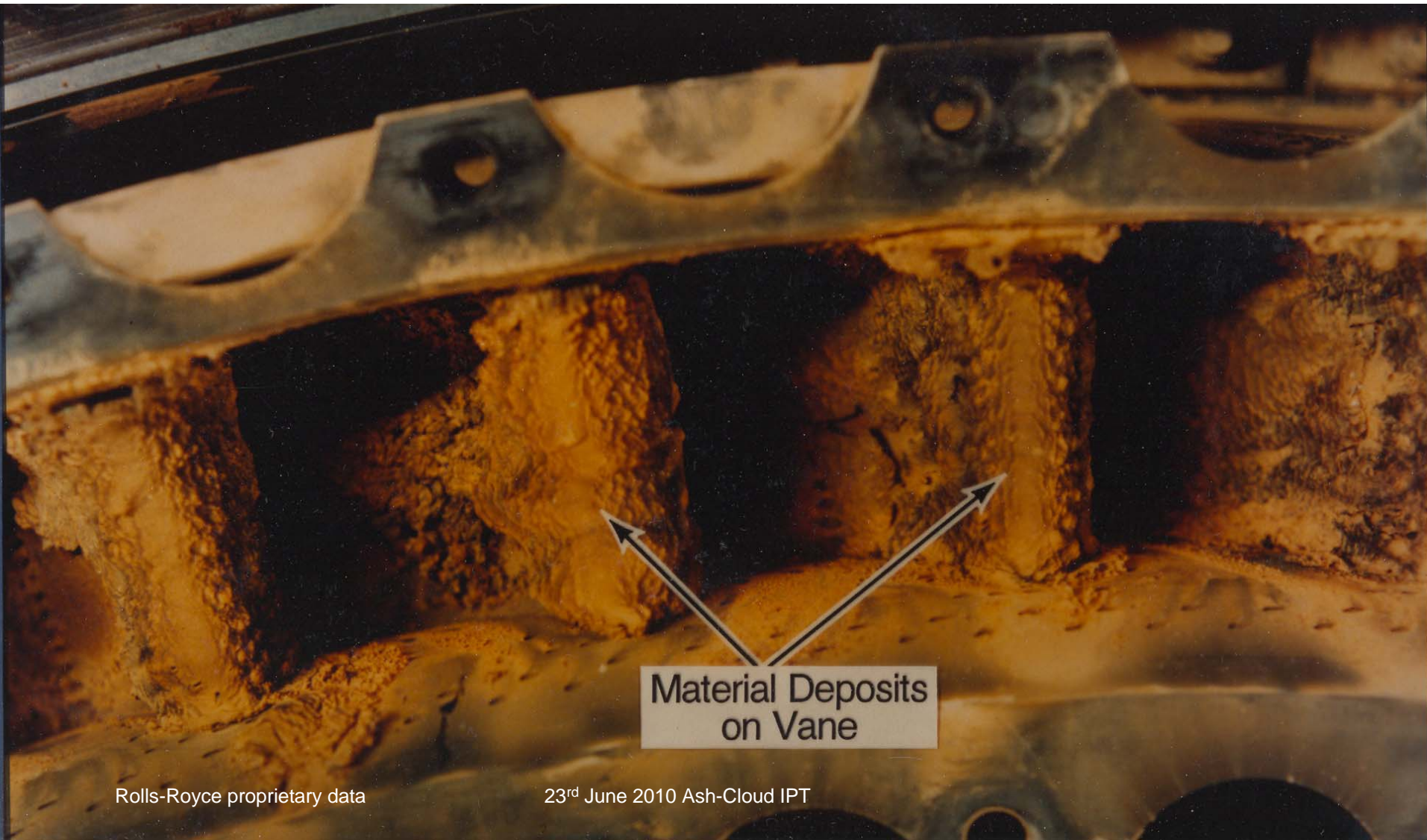


Heavy HP NGV contamination  
(BA747, Jarkarta 1982)



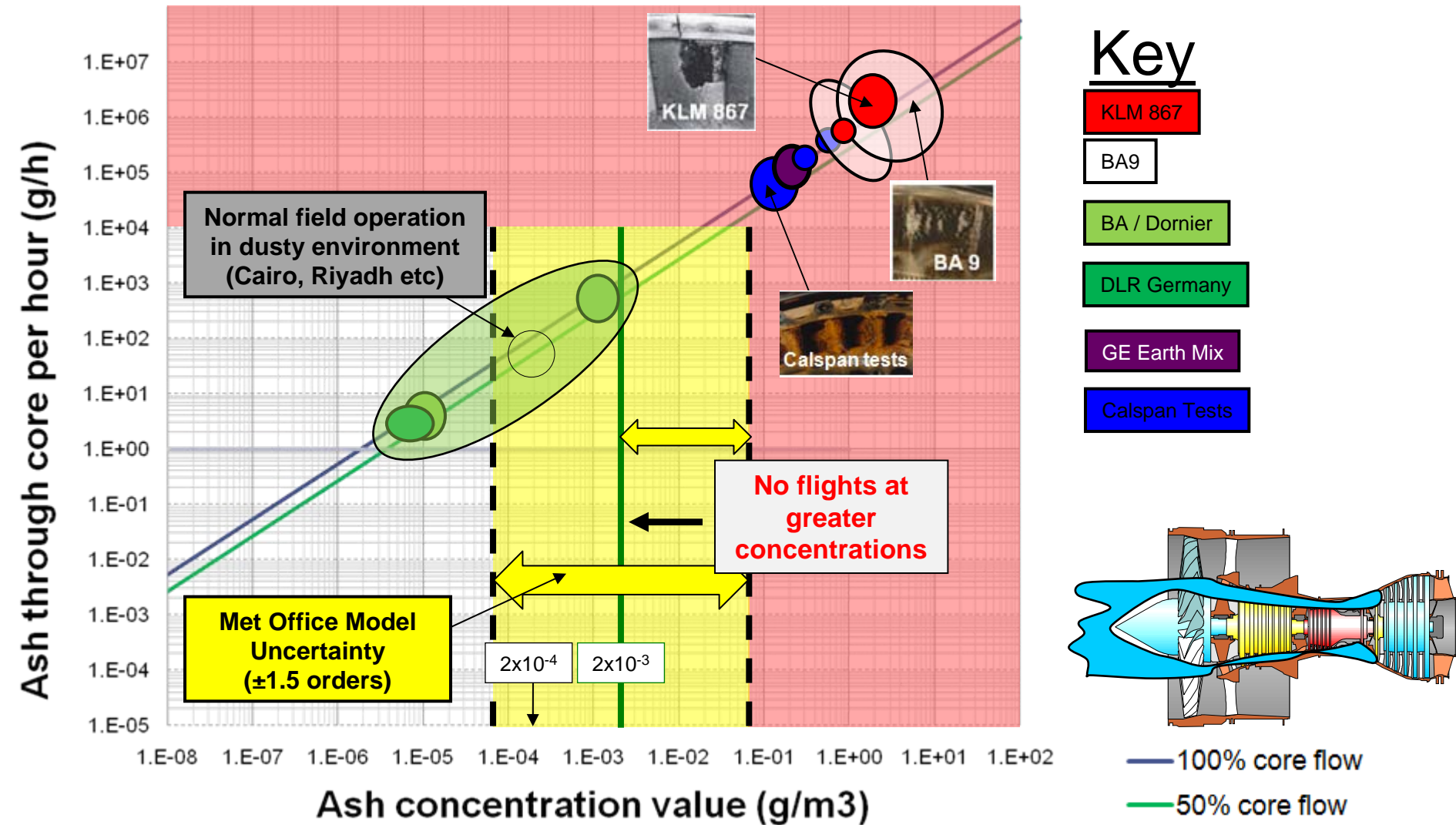
# HPT Vane; After Dust Exposure

(concentration about  $>2 \times 10^{-1}$  g/m<sup>3</sup>)  
(exposure around 1 hour)



Material Deposits  
on Vane

# The Safe to Fly – Chart: 17<sup>th</sup> May 2010



# 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  $2 \times 10^{-3} \text{g/m}^3$ 
  - 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