

Volcanic Ash and Aircraft Engines

BATA Volcanic Ash Workshop – 15 October 2013

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Engine Environmental Protection

Rolls-Royce

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Introduction

- The exam question:

Progress across the industry since 2010 – has it been enough?

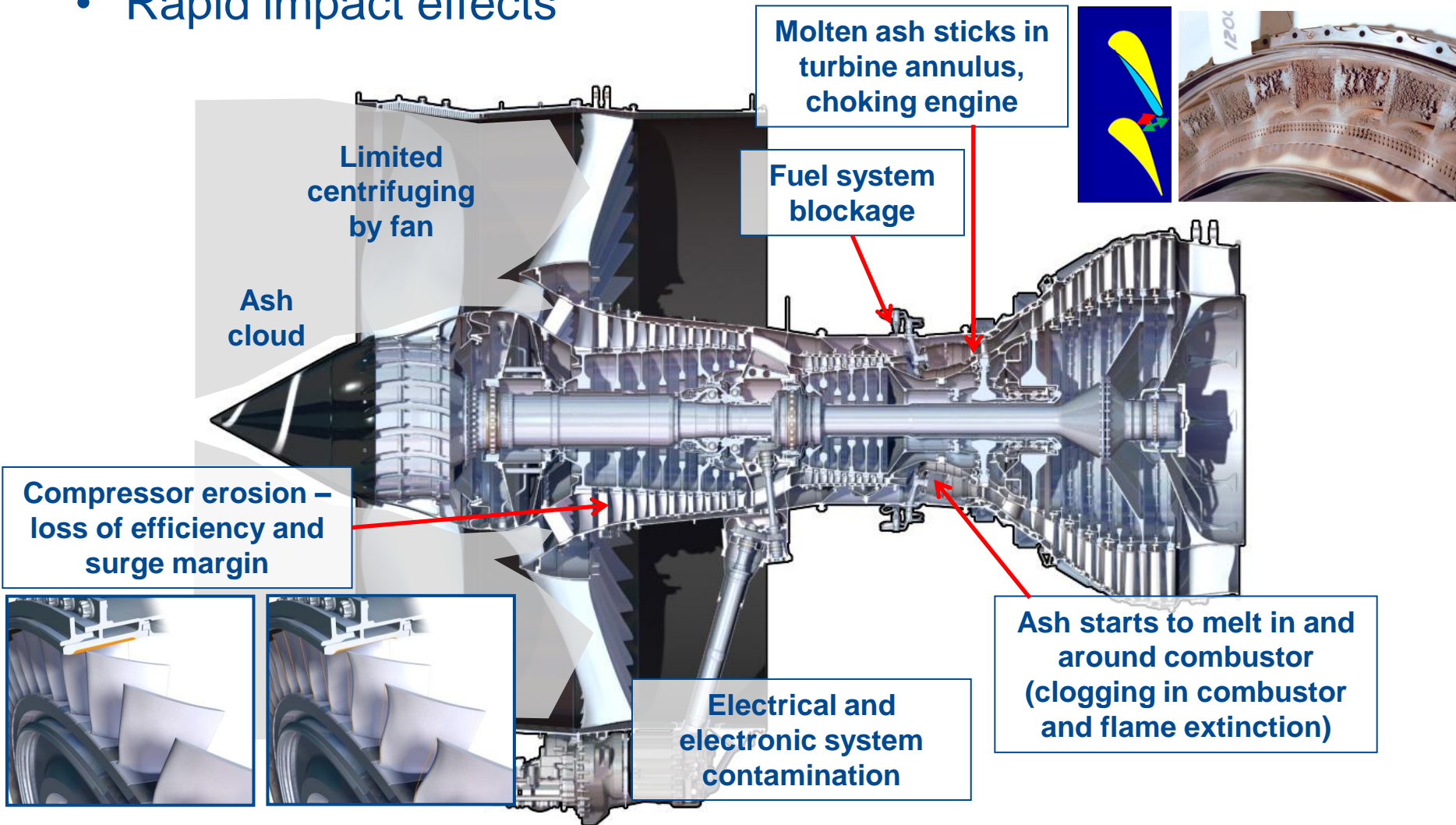
- What was known in 2010:
 - Damage mechanisms
 - Quantitative understanding
- Rolls-Royce activities 2010-2013
- Current position



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What We Know – Engine Damage Mechanisms ³

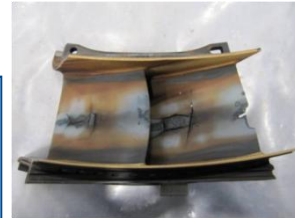
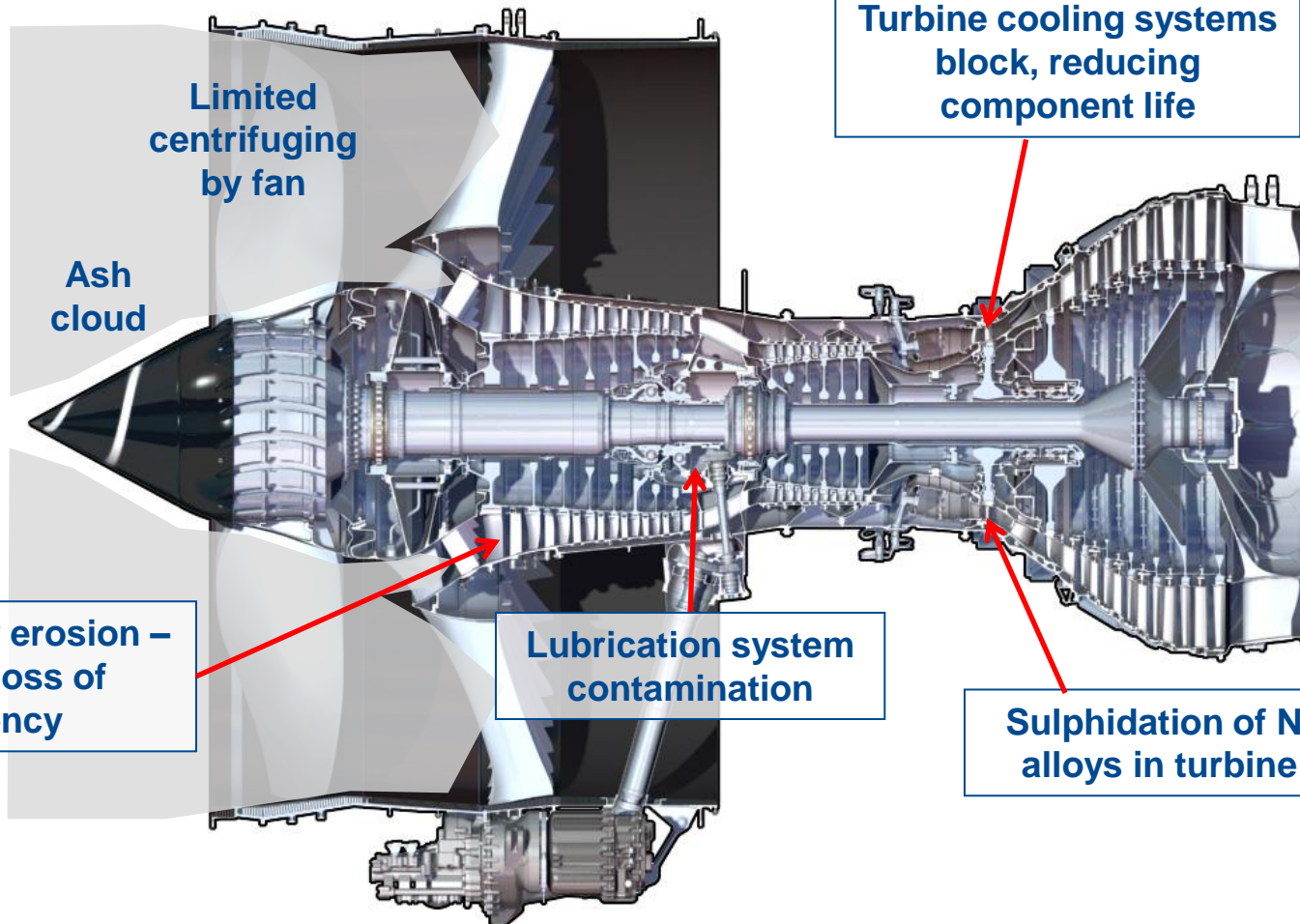
- Rapid impact effects



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What We Know – Engine Damage Mechanisms ⁴

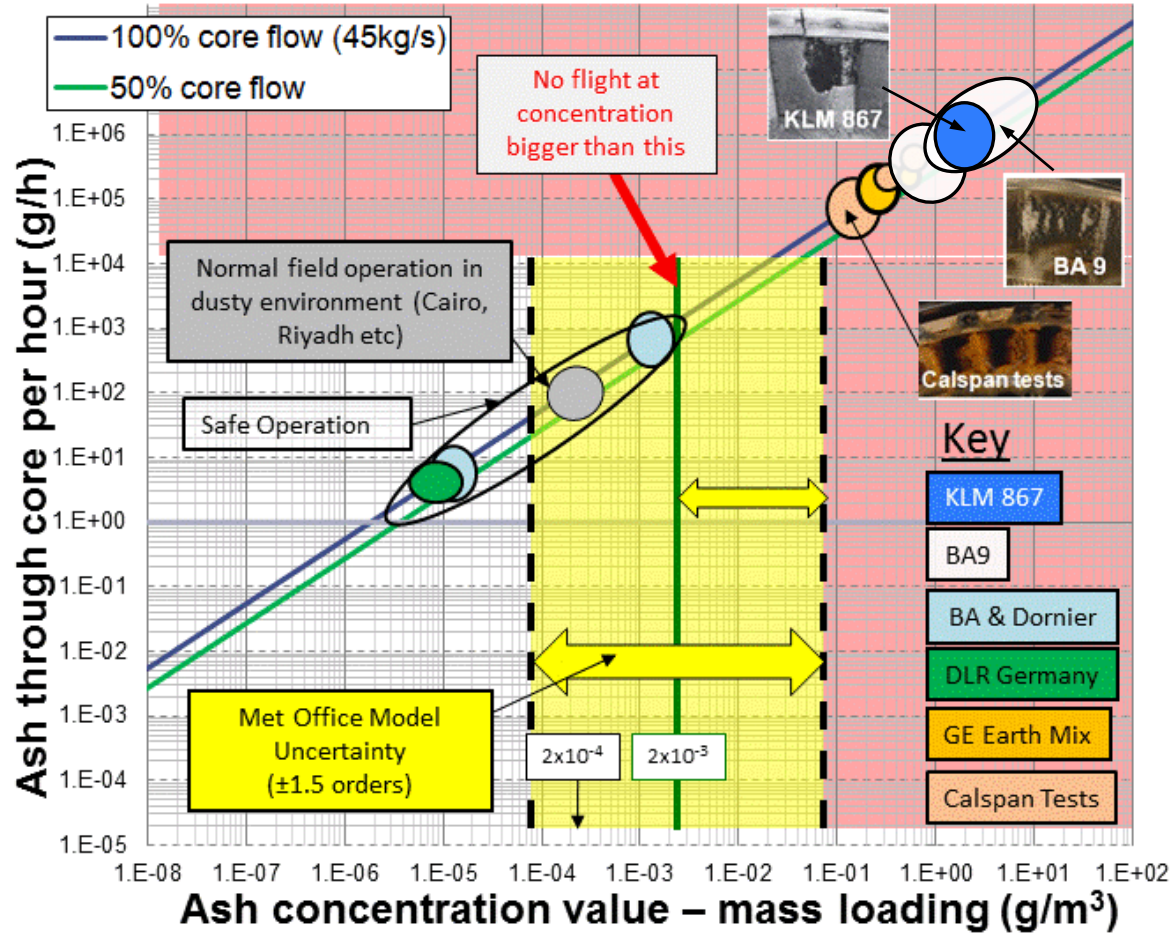
- Longer term ‘cost of ownership’ damage



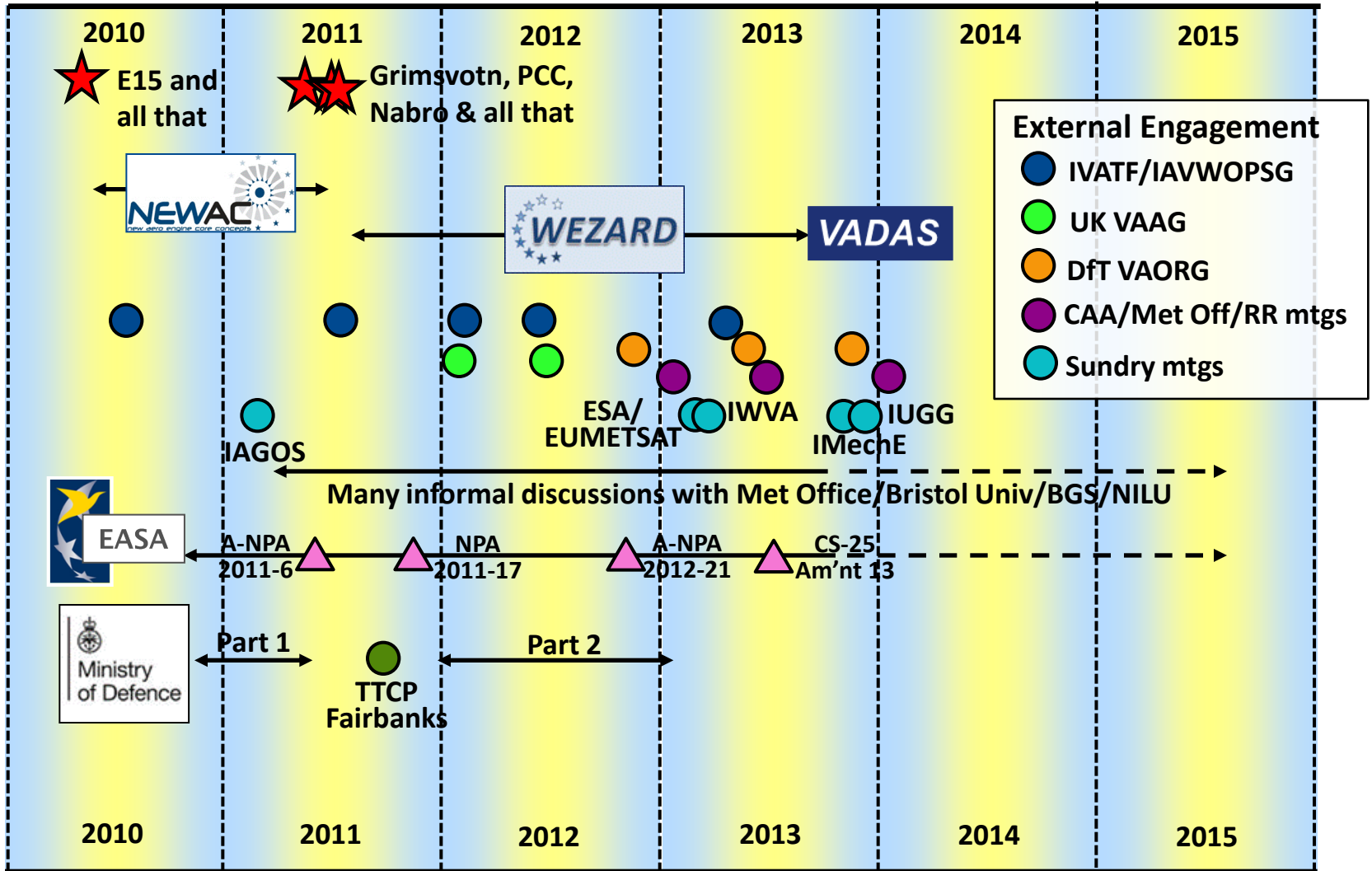
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Engine Susceptibility

- 2010 quantitative understanding – RR engine ‘Safe-to-Fly’ chart

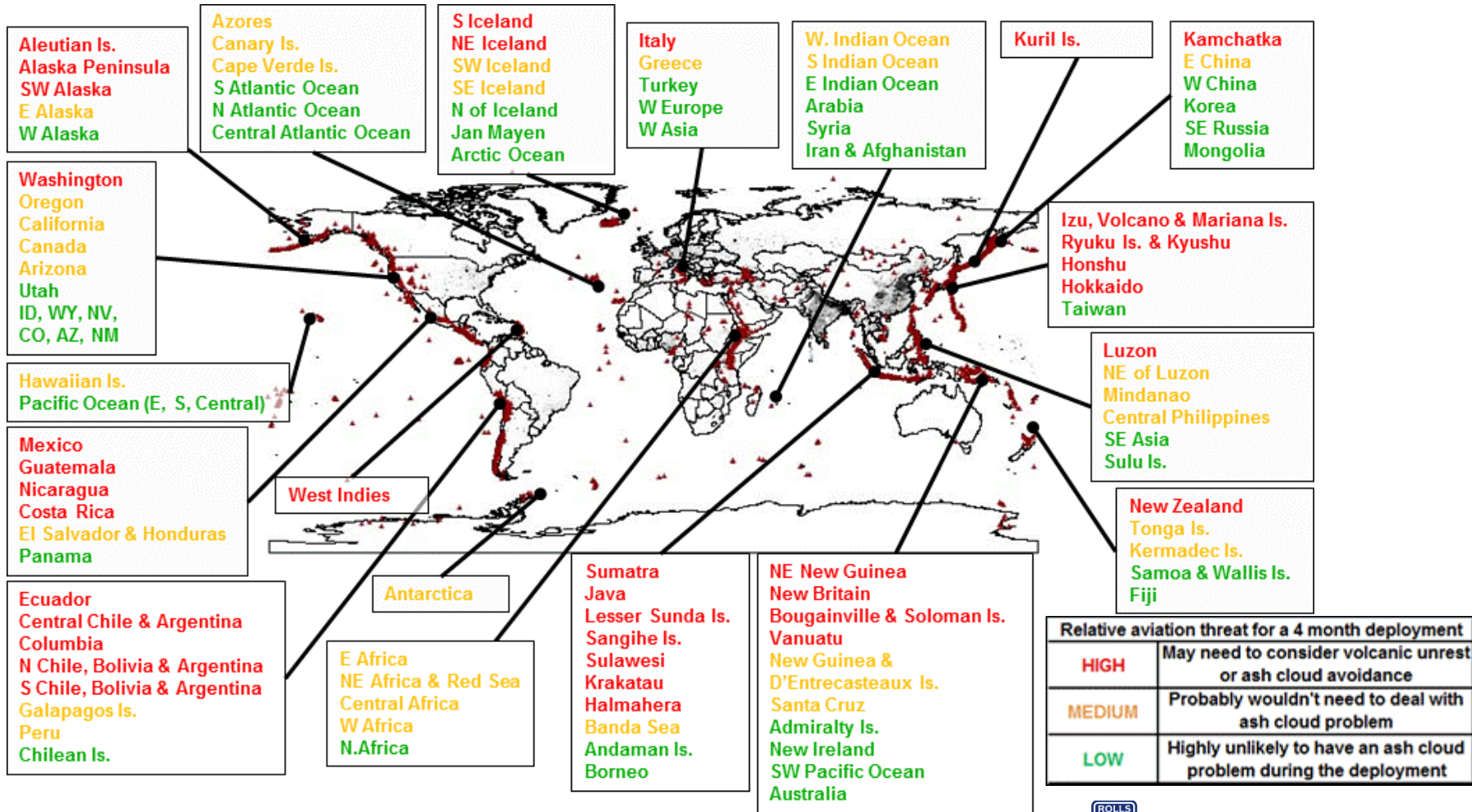


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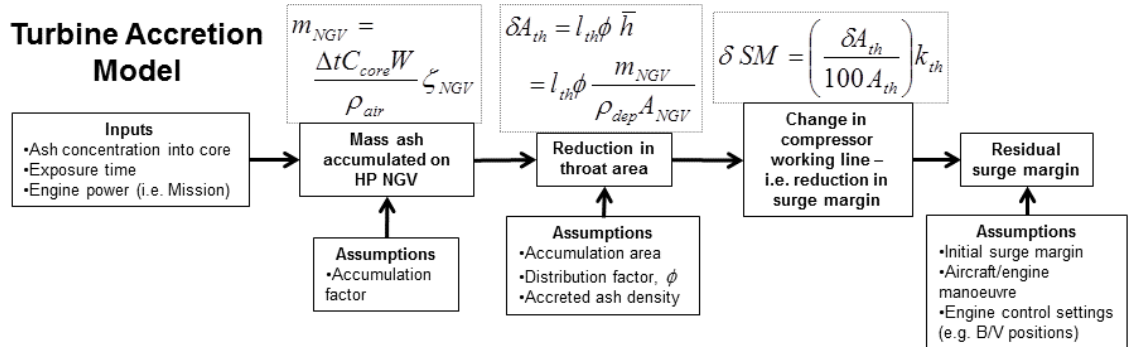
- MoD support 2012 – Global VA Risk Assessment



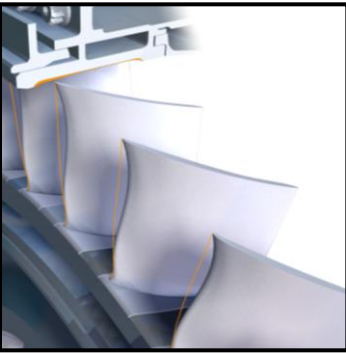
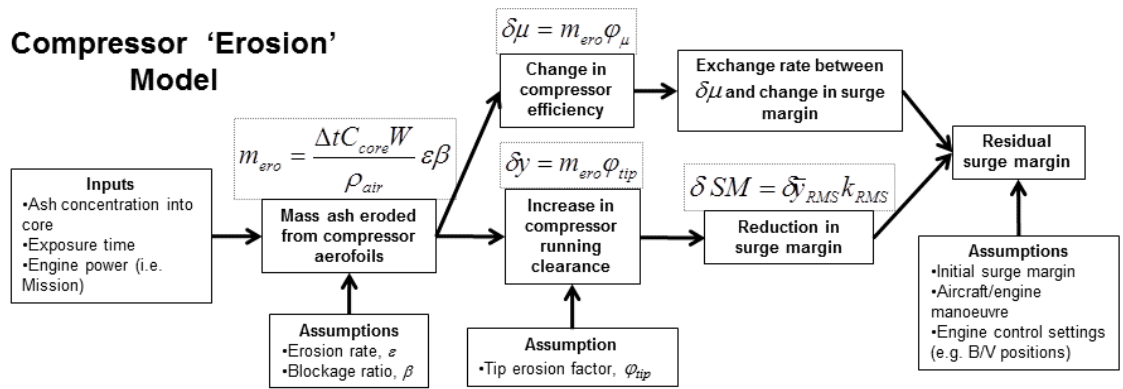
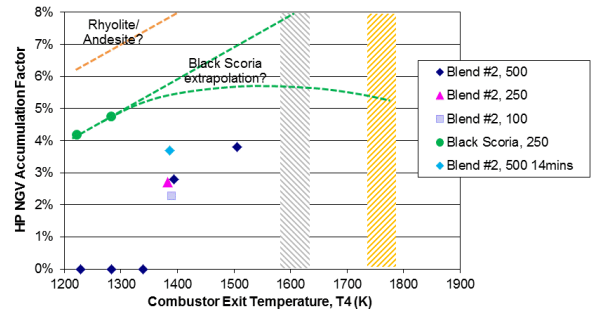
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- MoD support 2012 – Operability Model Uncertainty



T4 vs NGV Accumulation Factor After 7 mins Exposure to Blend#2 or Black Scoria (concentrations in the legend are in mg/m³)



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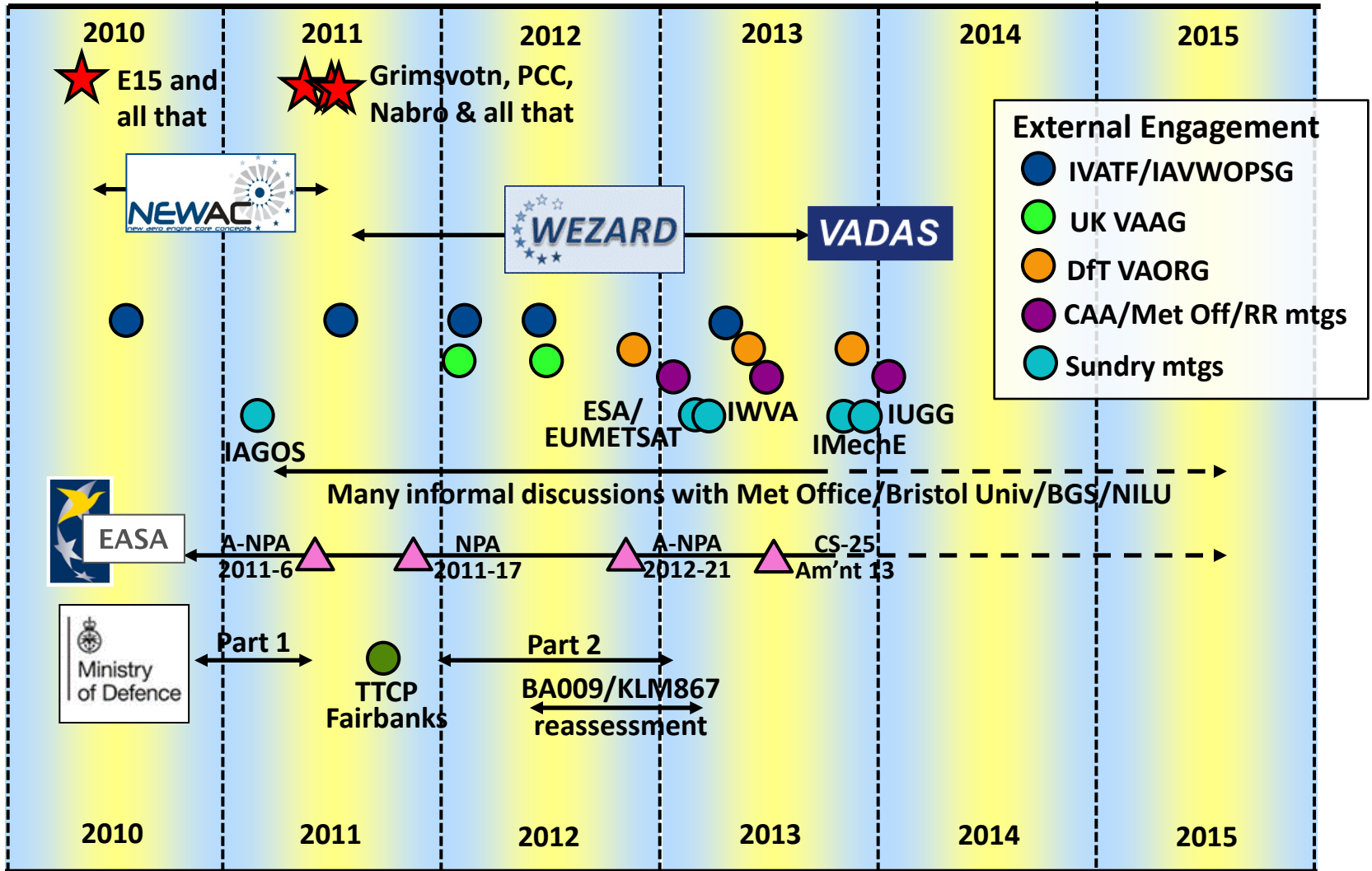
- MoD support 2012 – Proposed Research Programme

	Fan	Compressors	Combustors	Turbines
Phenomena	Particle centrifuging	Impingement, Erosion, Abrasion	Particle aggregation, Accretion	Ash accretion, Deposit shedding
Damage		Erosion, Rotor path lining abrasion	Fuel nozzle blockage	NGV throat blockage
CFD model	~£50k	~£100k	Combustor & NGVs ~£170k	
Sub-element test rig		Erosion ~£300k Abrasion ~£1M	Hot NGV accretion £500k-£1.5M	
Sub-assembly test rig		Compressor rig ~£4M	Combustor with NGV rig ~£2M	
Engine test		>£3M		

- Partial reduction in modelling uncertainty - £1.5M - £2M
- Substantial reduction in modelling uncertainty - >£15M

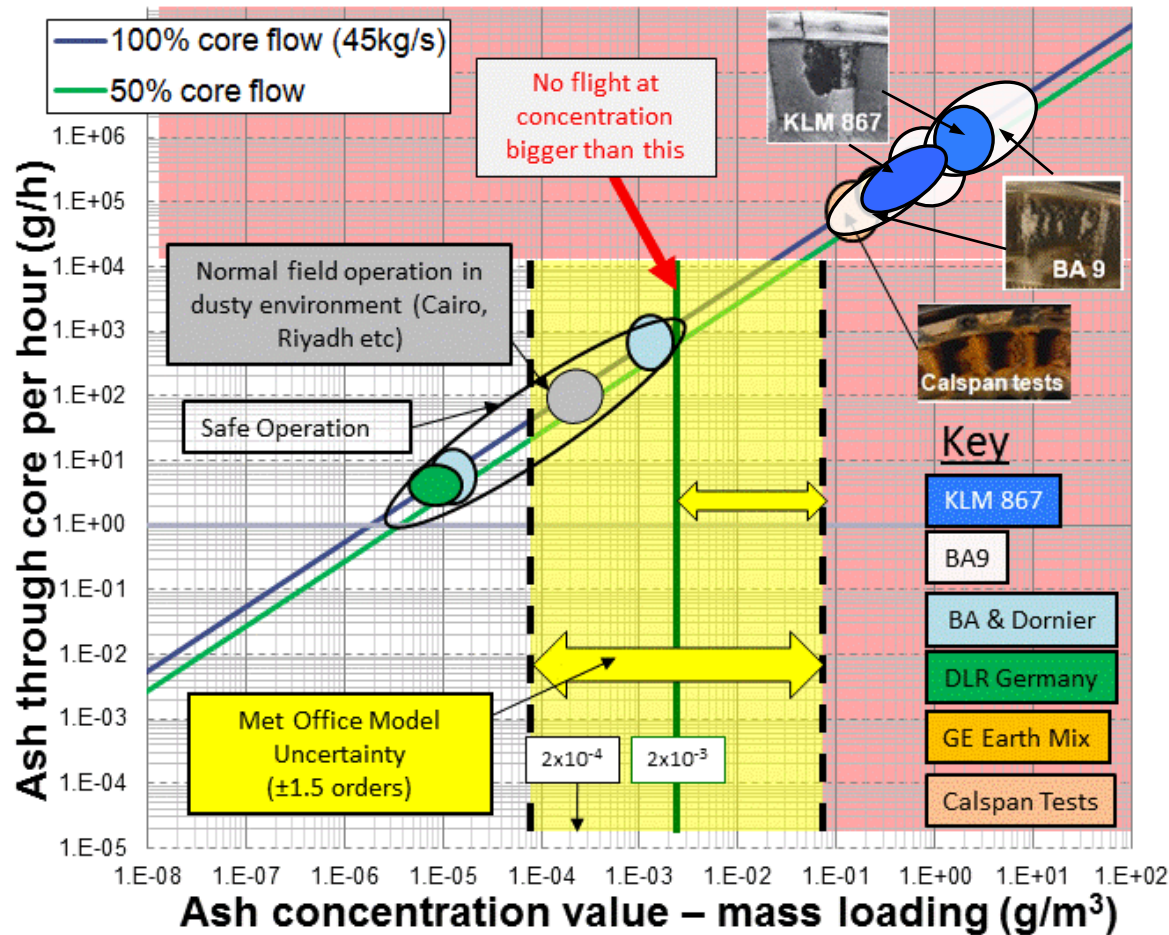


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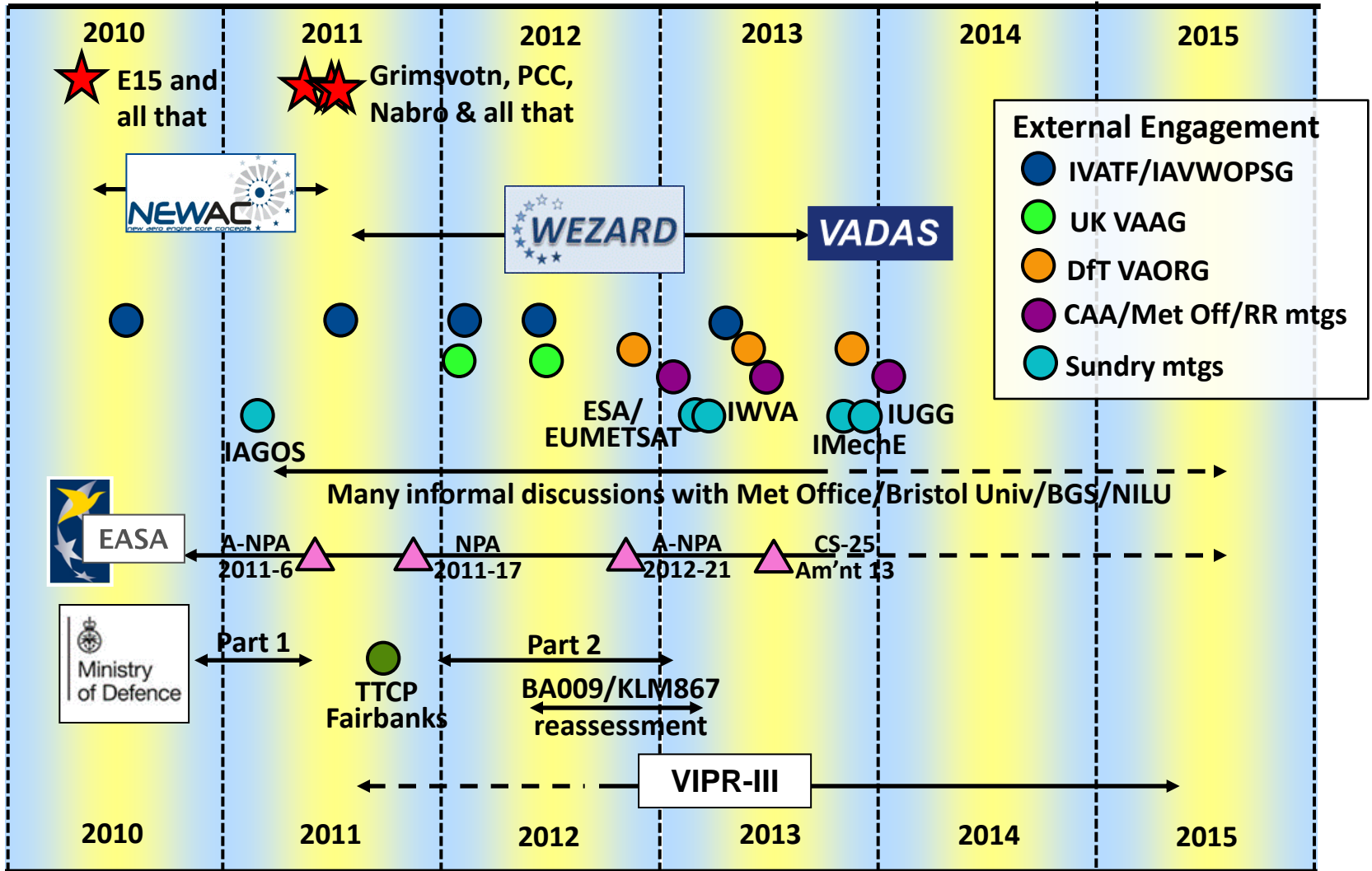


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- Engine 'Safe-to-Fly' Chart - 2012 Revision

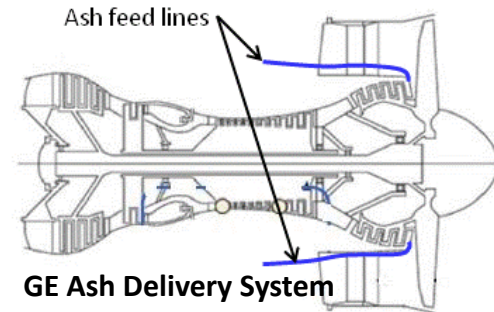
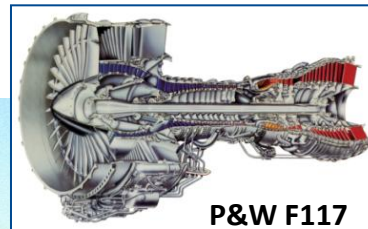


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Rolls-Royce Activities 2010-2013

- Vehicle Integrated Propulsion Research – VIPR
 - NASA/USAF Engine Health Monitoring (EHM) technology development
 - Volcanic ash (VIPR-III) is a good way to deteriorate an engine



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VIPR-III Participants



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VIPR-III Key Questions:

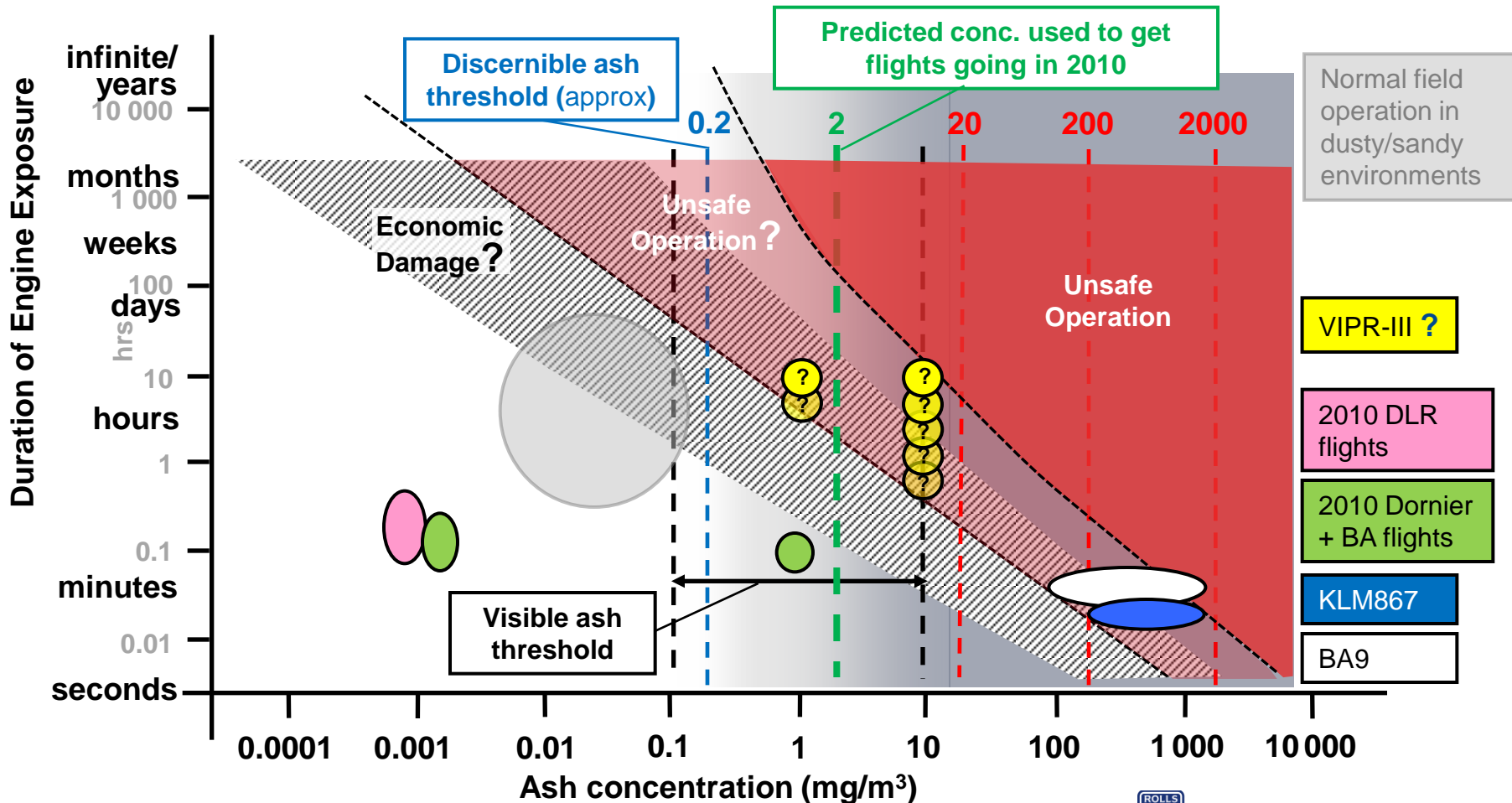
- FAA – Exposure to low concentration visible ash; safety or economic damage concern?
- What type of ash to use; fresh ash or 7,000 year old ash?
- What ash concentrations to run test to?



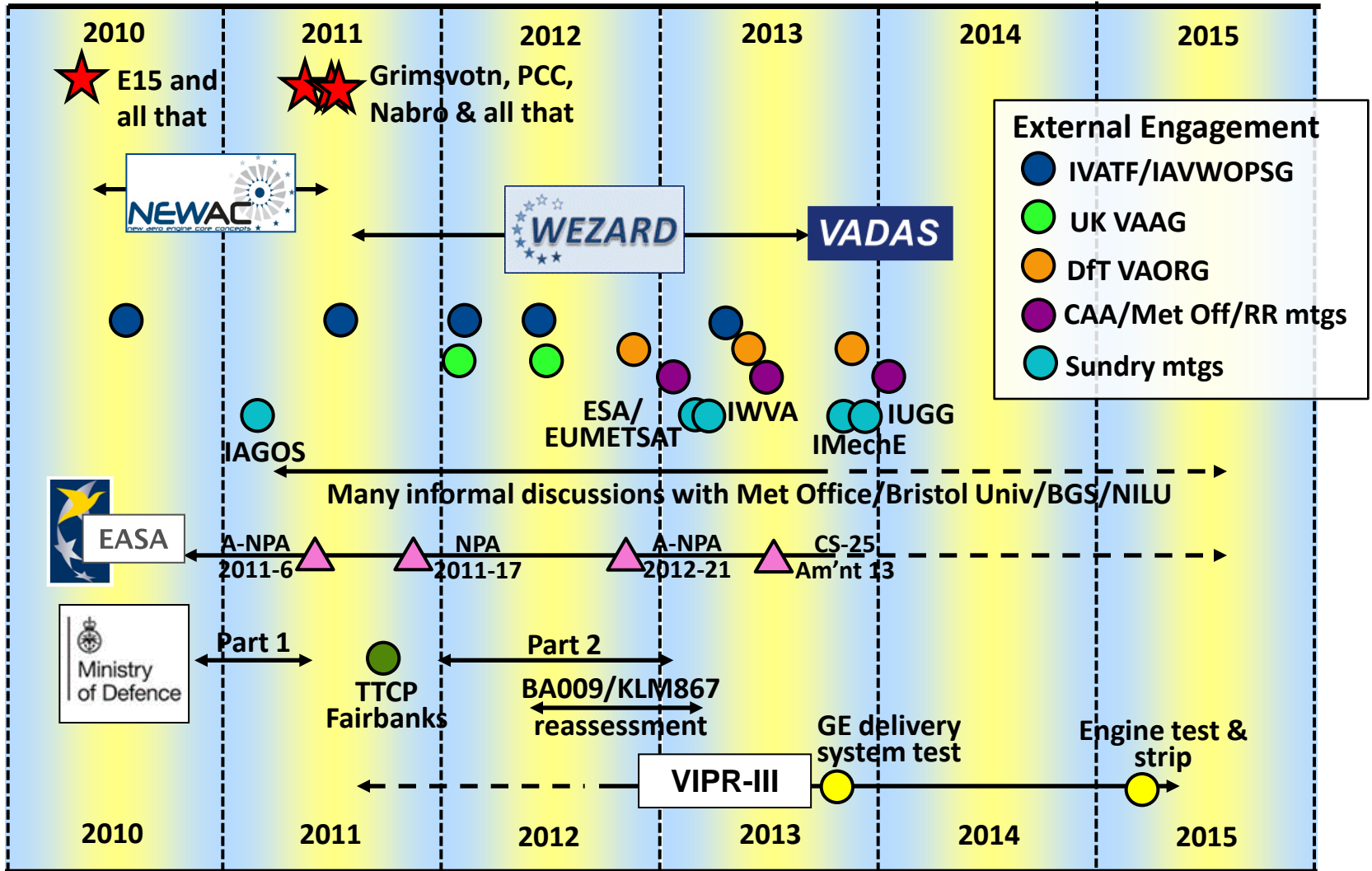
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- VIPR-III Test points?

MoD Requested & Funded
Duration of Exposure v Ash Concentration
Chart – A Cartoon



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Current Position & Conclusions

- Since 2010 work has continued on improving the engine manufacturers' understanding of the volcanic ash problem:
 - Better understanding of what we know and don't know
 - Better understanding of what it would take to improve our knowledge – should it be required
- There are various international initiatives running to address some of the gaps in our knowledge
 - Modelling and measurement of ash clouds – e.g. VADAS, ESA/EUMETSAT, ...
 - Engine effects – e.g. VIPR-III
- EASA regulations have evolved slightly
and finally...
- We are in a better place than we were in April 2010



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