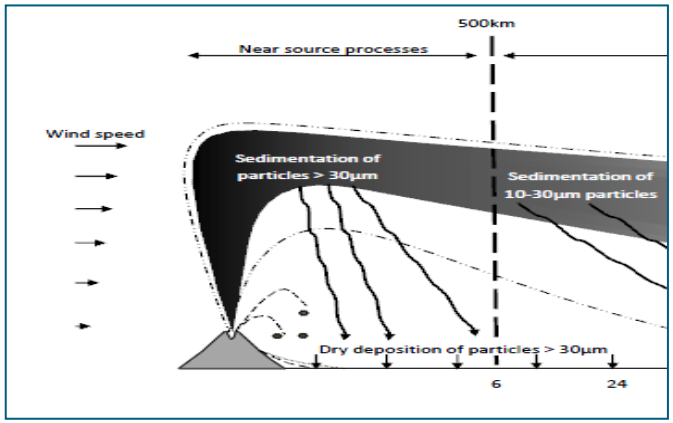
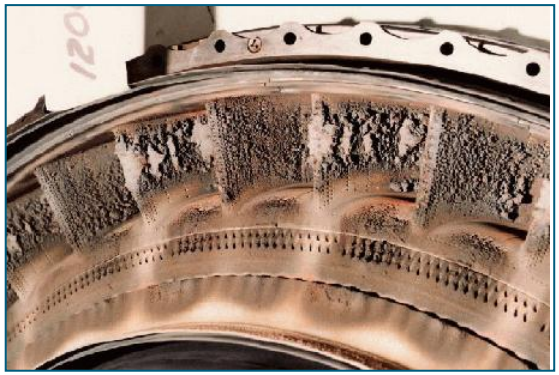
UK MoD Volcanic Ash (VA) Research



Dacre et al. (2013)



HPT IGVs after 1982 British Airways encounter (scijinks.nasa.gov)

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7th of April 2014

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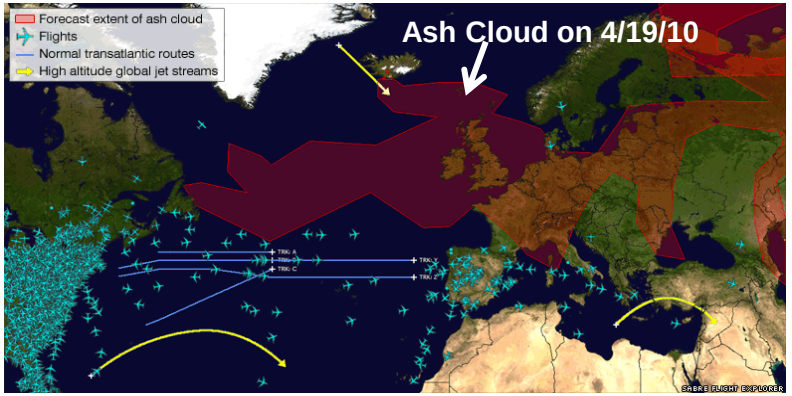
Background and Scope

Following the eruption of Eyjafjallajökull (E15) volcano in Iceland the International Civil Aviation Organisation developed guidance emphasising extant guidelines that operators should not fly in 'visible' Volcanic Ash Cloud (VAC). Military operators are advised by MAA that 'flight in areas affected by VAC is at the discretion of the operational duty holder (ODH) and should be supported by appropriate risk assessment'.



Eyjafjallajökull: Impact on International Air Traffic (http://news.bbc.co.uk/2/hi/uk_news/8625813.stm)

There is an urgent need to provide robust evidence to underpin ODH decisions on military flight in VAC. The key issues are:

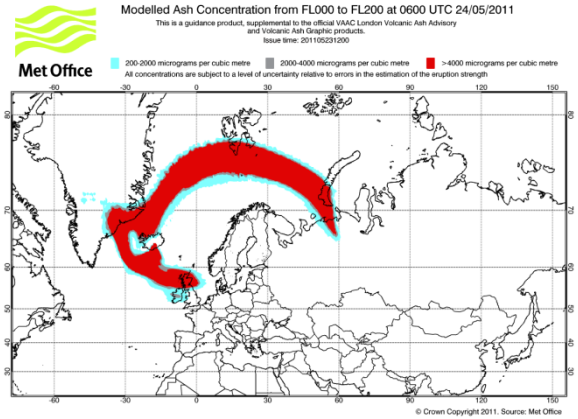
- What is the risk of the military being impacted by volcanic eruptions?
- What are the Airworthiness and Safety risks related to engines and other critical systems?
- What are the safe concentration limits for flight in a generic ash composition and aircraft/engine type?
- How long can we fly in a particular concentration (single sustained flight, cumulatively)?
- What sampling/inspection is necessary to monitor platform effects and to highlight performance/technical issues?
- What are the long-term (financial and technical) costs of ownership issues?
- What are the military-specific departures from the Civil Aviation guidelines?

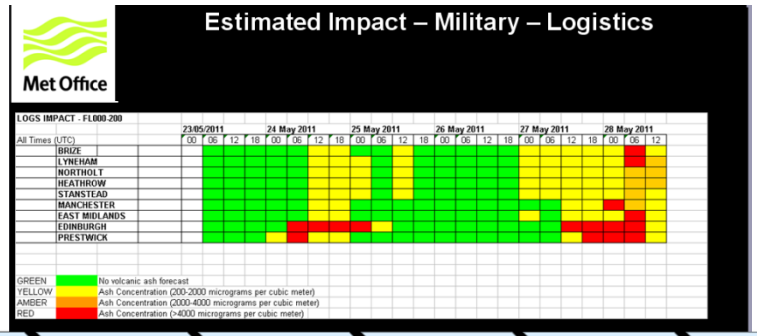
MOD Priorities

Short term	• Global risk assessment of an ash encounter • Refining current understanding of the propulsion system impacts • Refining current understanding of the Air Vehicle (non-propulsion) impacts
Medium term	• Validate the engine models for predicting exposure limits to VA • Review propulsion system vulnerability to sulphidation • Review the vulnerability of specific propulsion system features
Long term	• Define standards for VA, testing equipment/methods and specimen • Novel ways to protect against VA inflicted damage. • Understand the long-term (financial and technical) cost of ownership issues

UK MOD Current Policy

- Routine flight in GREY or RED zones i.e. > 2mg/m³ ash concentration is to be avoided.
- Flight in the Cyan zone (0.2 to 2 mg/m³) is allowed subject to additional engine inspections and operational caveats determined by individual Operational Duty Holders based on 'Risk'.
- Flight in the Clear zone i.e. < 0.2mg/m³ is un-restricted





Mitigating the VA Risk

Sense | Protect | Coordinate

VAC encounter analysis → Previous eruptions, current model data, ash type, regional analysis → Quantifying the probability of ash encounter

VAC/SO2 plume prediction modelling → PUFF/NAME data, real world validation… → Trusting the forecasts

Met data dissemination processes → NOTAM/SIGINT/METINT, Civ/mil interfaces.. → Disseminating robust data

Real-time detection and warning → ATM advisories, on-board data and warning → Reducing the operational impact

Engine modelling and validation
Rig and engine testing
Materials effects assessment
→ Accretion, shedding and erosion rates
→ Hot erosion, sulfidation, cooling blockage
→ Understanding the systems/performanc e effects

Non-engine effects assessment → Airframe, windscreen, P/S, avionics, cooling…

Sampling/inspection/repair strategies → OEM data and advice, engine comparisons… → Reducing the Inspection/Repair burden

Am I going to be affected?
Will I have the right information ?
Can I complete the mission?
Safely?
Repeatedly and within resource ?

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UK VA Research

Sense

- Volcanic Ash Sensor
- Volcanic Ash Sampling Methodology
- Global Threat Assessment

Protect

- Propulsion System Impacts
- Air Vehicle Impacts
- Engine Performance Model

Coordinate

- UK Met Office
  VA Coordination Programme
- Standardisation

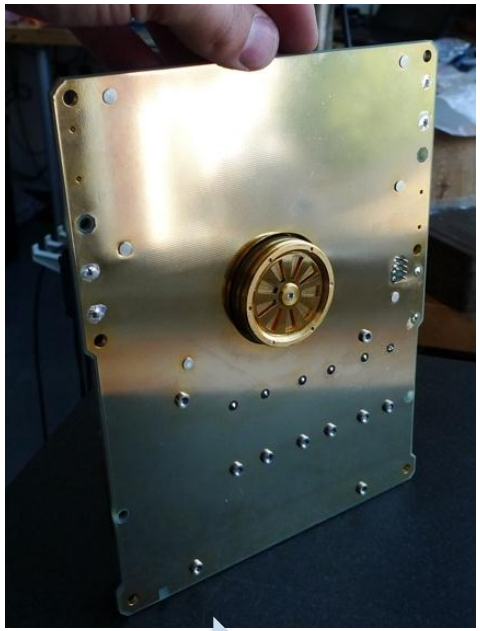
Sense: VA Sensor

Ongoing work with UK Met Office:

- On prototype ‘passive‘ onboard VA sensor which produces a ash/no ash signal using electric field.
- To show that the signal measured due to flying through volcanic ash in the 2010 eruption is separable from signals from any other factor.
- Compliment the current MoD sampling methodology to reduce testing burden during an event.

Future plans:

- Studentship with Lancaster university to provide an end to end product.



Prototype lab bench tests (6 months)

Prototype flight tests (6-12 months)

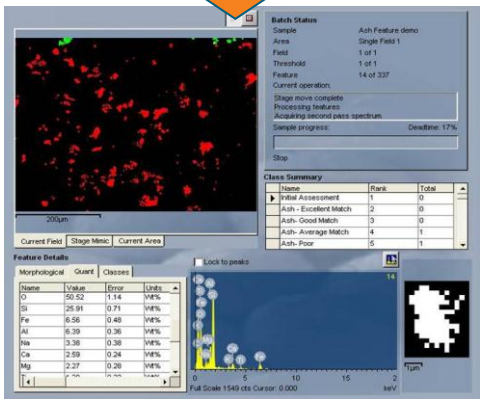
Incorporation with MoD sampling methodology (1-2 years)

Sense: 1710 NAS Sampling Methodology

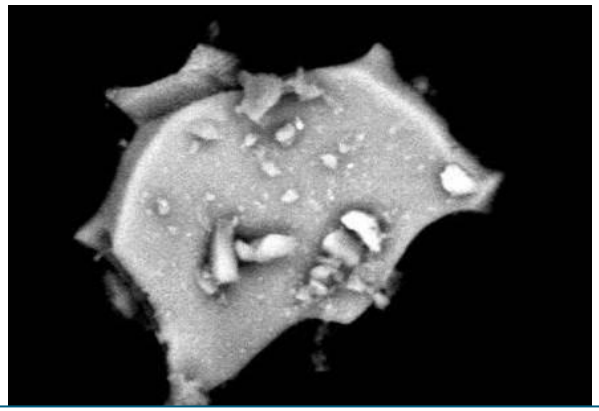
Engine turbine blade sampled post flight using volcanic ash kit.

Sample Stub

Analysed via SEM-EDX using automated technique



Particles compared against known volcanic ash composition for eruption and classified based on match strength.



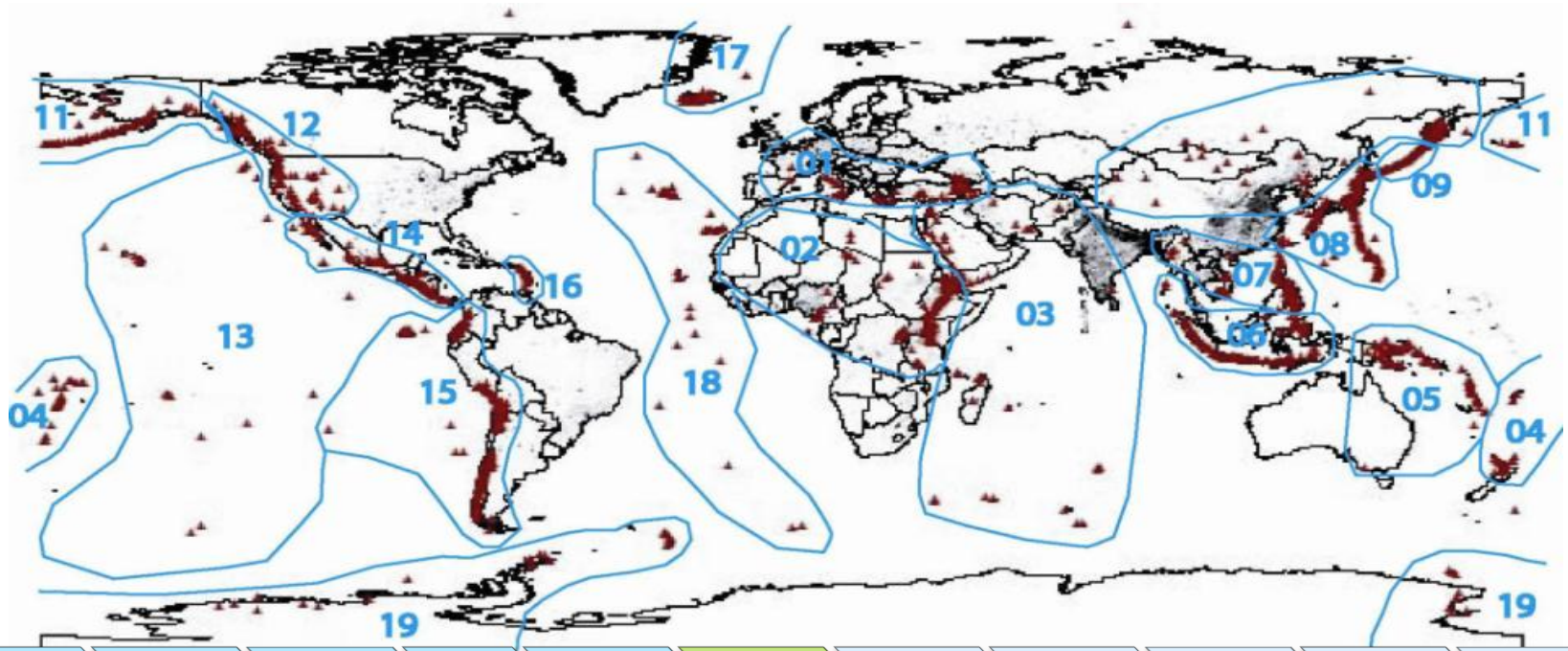
Strong matches re-examined post run to examine morphology and confirm analysis

NAS: Naval Air Squadron, SEM: Scanning Electron Microscopy, EDX: Energy Dispersive X-Ray

Sense: Global VA risk map

VA global threat to aviation taking into account:

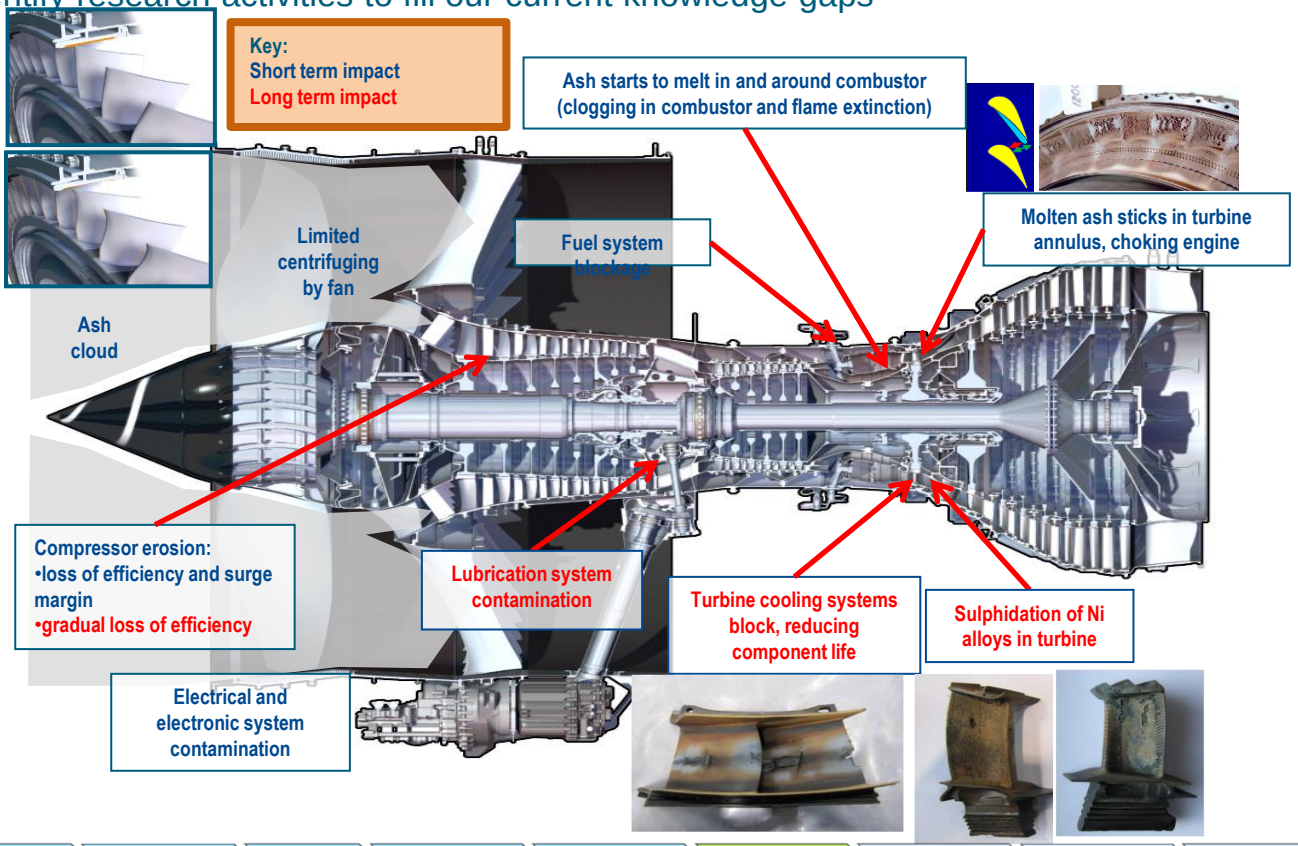
- Location
- Type of Volcano
- Frequency of eruption
- Volcanic Explosivity Index



Protect: Propulsion System Impacts

Develop VA engine performance model:

- Identify key parameters regarding engine damage mechanism
- Identify research activities to fill our current knowledge gaps



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Protect: Air Vehicle Impacts

Failure Modes and Effects Analysis (FMEA) at aircraft systems level for:

- Fast jet
- Military transport
- Large rotorcraft.

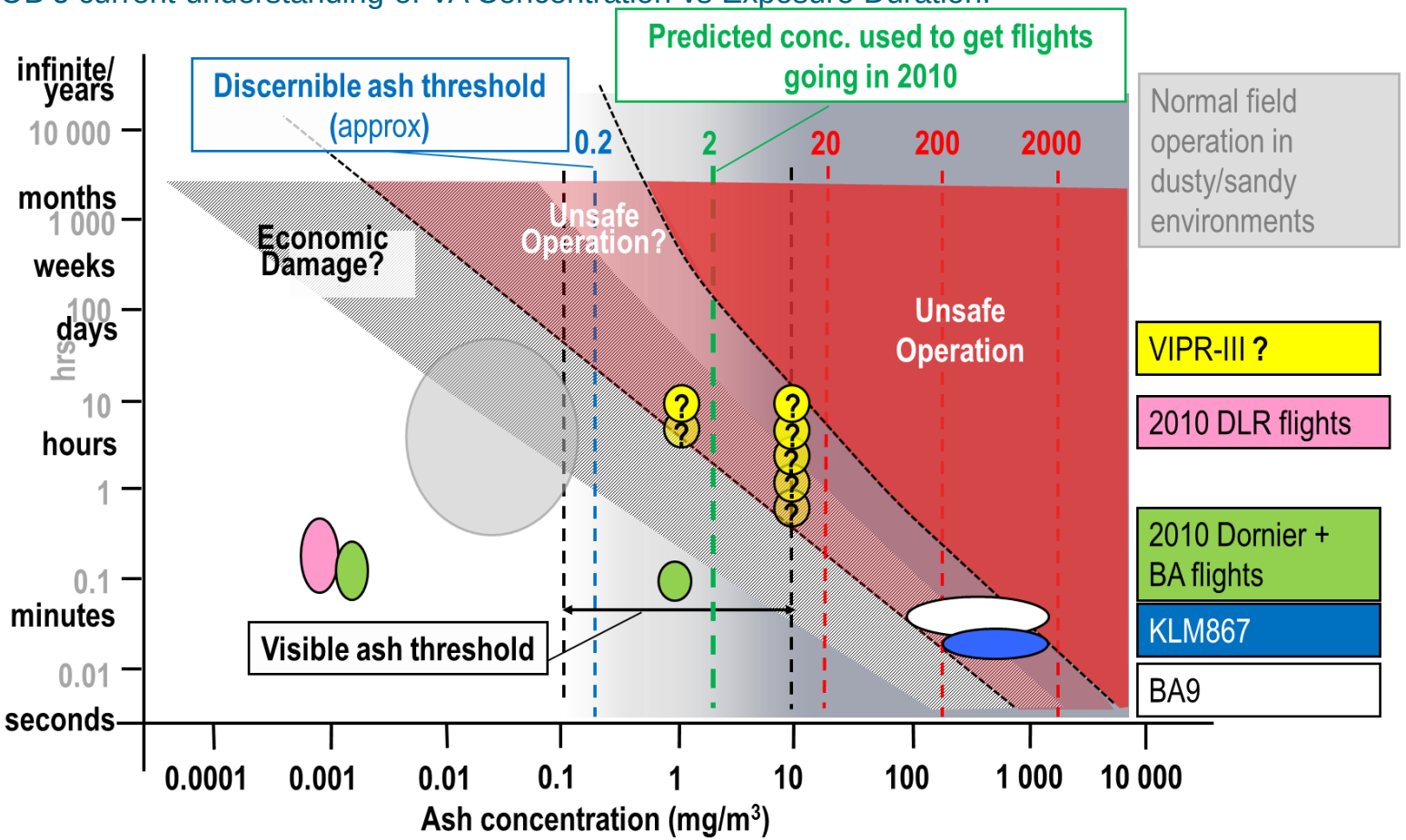
Fuel Tanks		
Clogging of fuel filters	Corrosion of tank internals	Sticking of clack valves

Air Conditioning/Pressurisation System and Air Data Systems			
Erosion of wheels in Air Cycle Machine (ACM)	Damage of ACM bearings	Corrosion of internal components	Clogging of pitot-static probes

Antennae		
Large Particle Impact	Erosion of Surface	Refraction of RF Signal on VAC

Protect: Engine Performance Model

MOD's current understanding of VA Concentration vs Exposure Duration.



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Coordinate: UK Met Office VA Coordination Programme

Following the Icelandic volcanic eruption of April 2010 the Volcanic Ash Coordination Programme (VACP) was formed. Main Objective - "To continually improve the effective and efficient delivery of VA related activities."

Current

- MOCCA (Met Office Civil Contingency Aircraft) – airborne plume - sensing
- LCBR (Laser Cloud Base Recorder) LIDAR (Light Detection And Ranging) - ground based sensing network
- Satellite data – improved visualisation and interpretation
- NAME (Numerical Atmospheric Modelling Environment) - inverse modelling work leading to further improvements in the derivation of the eruptive source term
- WEZARD (Weather Hazards for Aeronautics Project) - comprehensive R&D roadmap for meteorological aspects of the volcanic ash hazard

Future

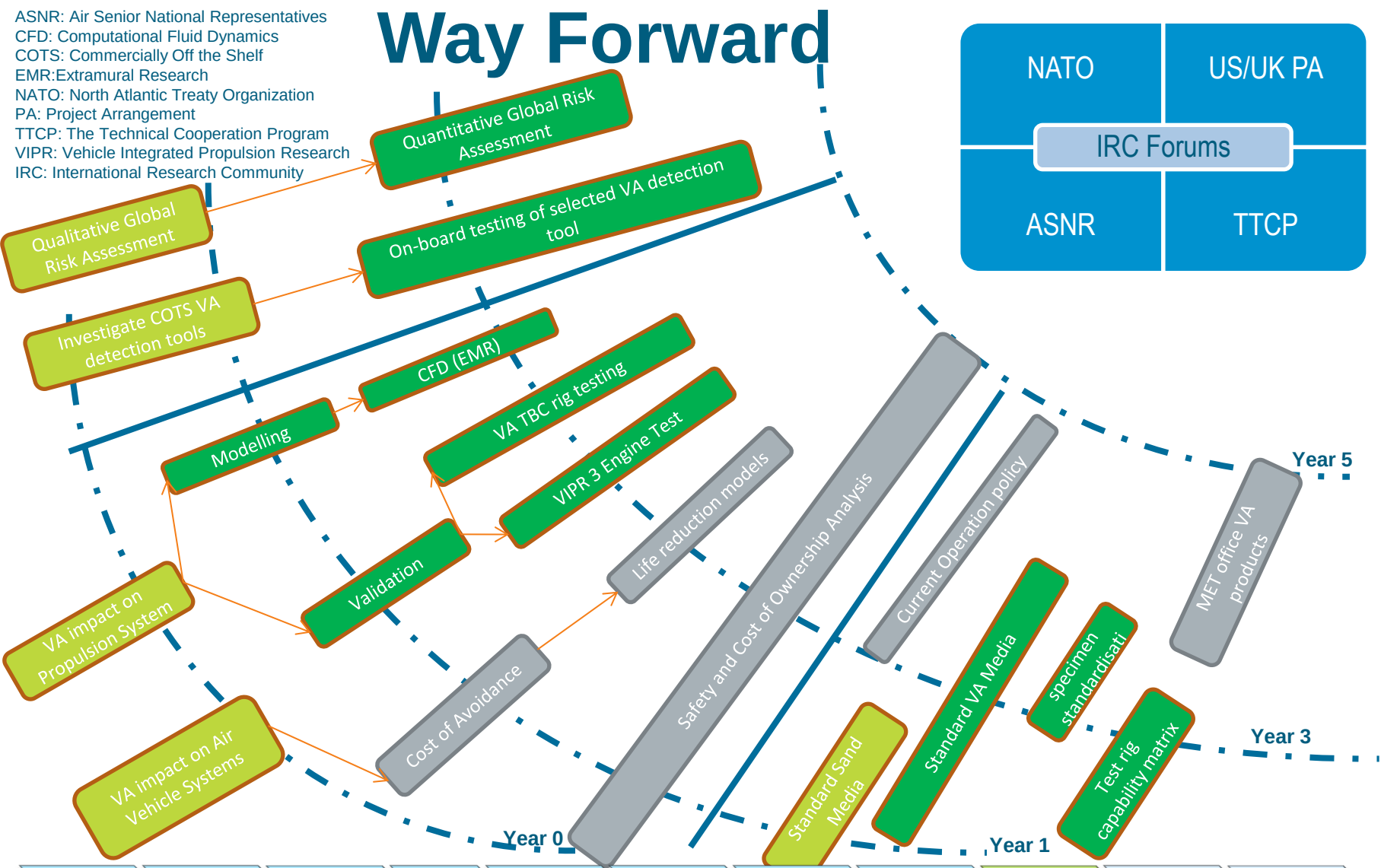
- New "high power" LIDAR / Sunphotometer network – observing to 10km+ by 2014
- Met Office London Volcanic Ash Advisory Centre (VAAC) - website consolidation by 2014
- The IMO/BGS/NCAS/UKMO - improving pre-eruption and eruption monitoring
- Euvonet (EUropean Volcanic ash Observing NETwork) – part of Horizon 2020
- Continued National and International lead and co-operation to establish best practice.

Standardisation

- Test Rigs
- Engine tests
- Testing methodologies
- Volcanic ash
- Test Specimens

ASNR: Air Senior National Representatives
CFD: Computational Fluid Dynamics
COTS: Commercially Off the Shelf
EMR:Extramural Research
NATO: North Atlantic Treaty Organization
PA: Project Arrangement
TTCP: The Technical Cooperation Program
VIPR: Vehicle Integrated Propulsion Research
IRC: International Research Community

Way Forward



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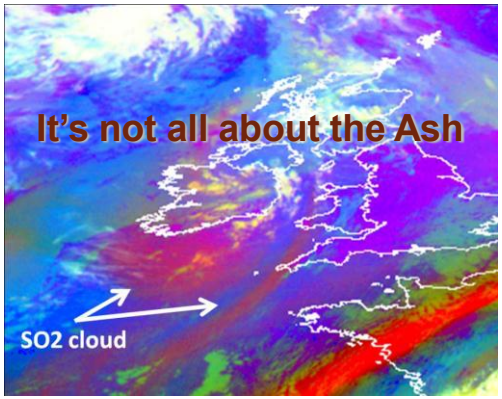
Challenges

- Resource
- Co-ordinating gas turbine engine testing
- Look beyond the immediate gas turbine engine issue
- Consistency in OEM advice
- Keep abreast of commercial aviation responses to VAC
- Discernible Ash



Back up Slides

High Level Goals		

Sense
• Understanding the atmospheric environment.
• Enhance VA detection technologies.
	Protect
	• Benchmark 'state of the art' tolerance level.
	  • Erosion/ Abrasion models
	  • CFD models
	  • Test Rigs
	  • Engine tests
	• Investigate mitigation options (coatings, Controls, maintenance, operation methods)
	• Understand the safety implications of flying through VA.
		Coordinate
		• Test specimen
		• Test methodologies
		• Test rig capability
		• Volcanic Ash composition