NATO AVT – 250

INTEGRATION OF KNOWLEDGE & TECHNOLOGY

ENVIRONMENTAL PARTICULATES – FOREIGN OBJECT DAMAGE (EP-FOD)

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BLUF

- **Future operations will demand presence and maneuverability in all types of harsh environments**
  - ***We won't have the luxury of just avoiding these areas***
- **Integrating/transforming EP knowledge from new insights**
  - **Outputs of recent programs**
  - **Integration of effects of volcanic ash, sand/dust, etc.**
  - **Collaboration synergy has started – *All-in***
  - **International team - operators, academia, & industry**
- **Opportunity exists to look forward and link our knowledge**
  - **Planning for AVT-250 output to be computationally useful**

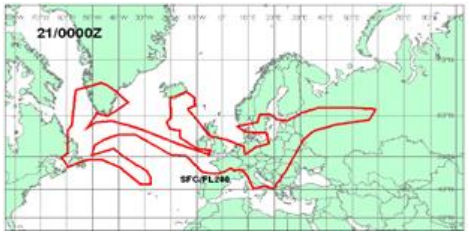
Overview

- Environmental particulate impacts to operations
- AFRL and NATO responses to Ops needs
  - VIPR III
  - EP-FOD
- Making output of AVT-250 computationally useful
- Vision and Way Forward
- Conclusions

Particulate Impacts to Aviation

FREQUENT CLEANING

EFFECTS ON HUMANS



REROUTING AND AIRCRAFT EVACUATION

ENGINE COKING AND GLASS

LOSS OF ENGINE/AIRCRAFT

REDUCED VISIBILITY

ELECTRICAL CHARGE BUILDUP

ABRASION

INCREASING SEVERITY

ENVIRONMENTAL PARTICULATES – FOREIGN OBJECT DAMAGE (EP-FOD) IMPACTS

- **Unintegrated EP-FOD S&T investments**
- **Unintegrated message between aerospace, geology, weather**
- **Immediate and latent degradation**
  - Weapon system power and propulsion
  - Propulsion system power and propulsion performance
  - What Engine Health Management (EHM) technologies are needed?
  - Life and cost of ownership
- **NATO operations in 2010 impacted by lack technically aligned information**

OPERATORS NEED CONFIDENCE

Capability To Operate In Harsh Environments

TODAYS INVESTMENTS FOCUS CROSS ROADS

People, Products, Place, Participation

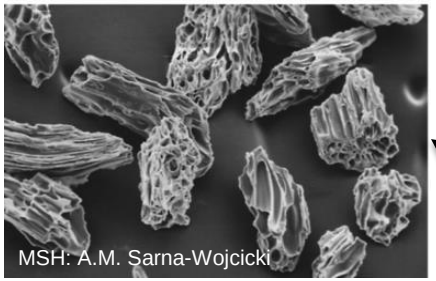
AVT -250 INTEGRATION OF KNOWLEDGE & TECHNOLOGY

NATO maintainers, operators, mission planners, & decision makers

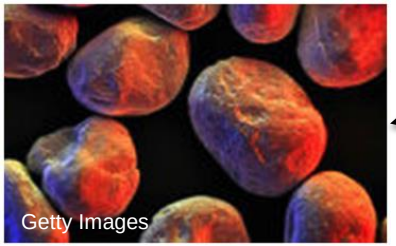
Lays A Foundation For Integrated Guidance & Harsh Environment Protocols

EP-FOD Types

- **Similar damage**
  - Volcanic ash



  - Sand & dust



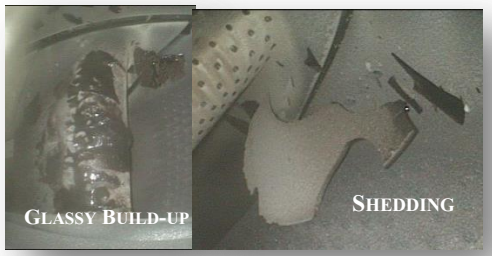
  - Volcanic and pollution aerosols
  - Detonation dusts
  - Fire ash

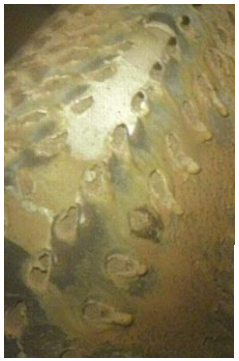
- **Other**
  - Ice
  - Maritime salt
  - Weapon dust
  - UAS Swarm ingestion

Cause similar types of engine damage

Vehicle Integrated Propulsion Research
(VIPR-III) Ash Ingestion Test (2015)

- **Controlled concentrations of volcanic ash were injected into a running C-17 engine**
- **Borescope inspections conducted after the tests failed to reveal the extent of damage**
- **Current procedures would have indicated that all-is-well ⟶ <u>WRONG DECISIONS</u>**
- **Incomplete reporting failed to accurately characterize battlespace conditions**





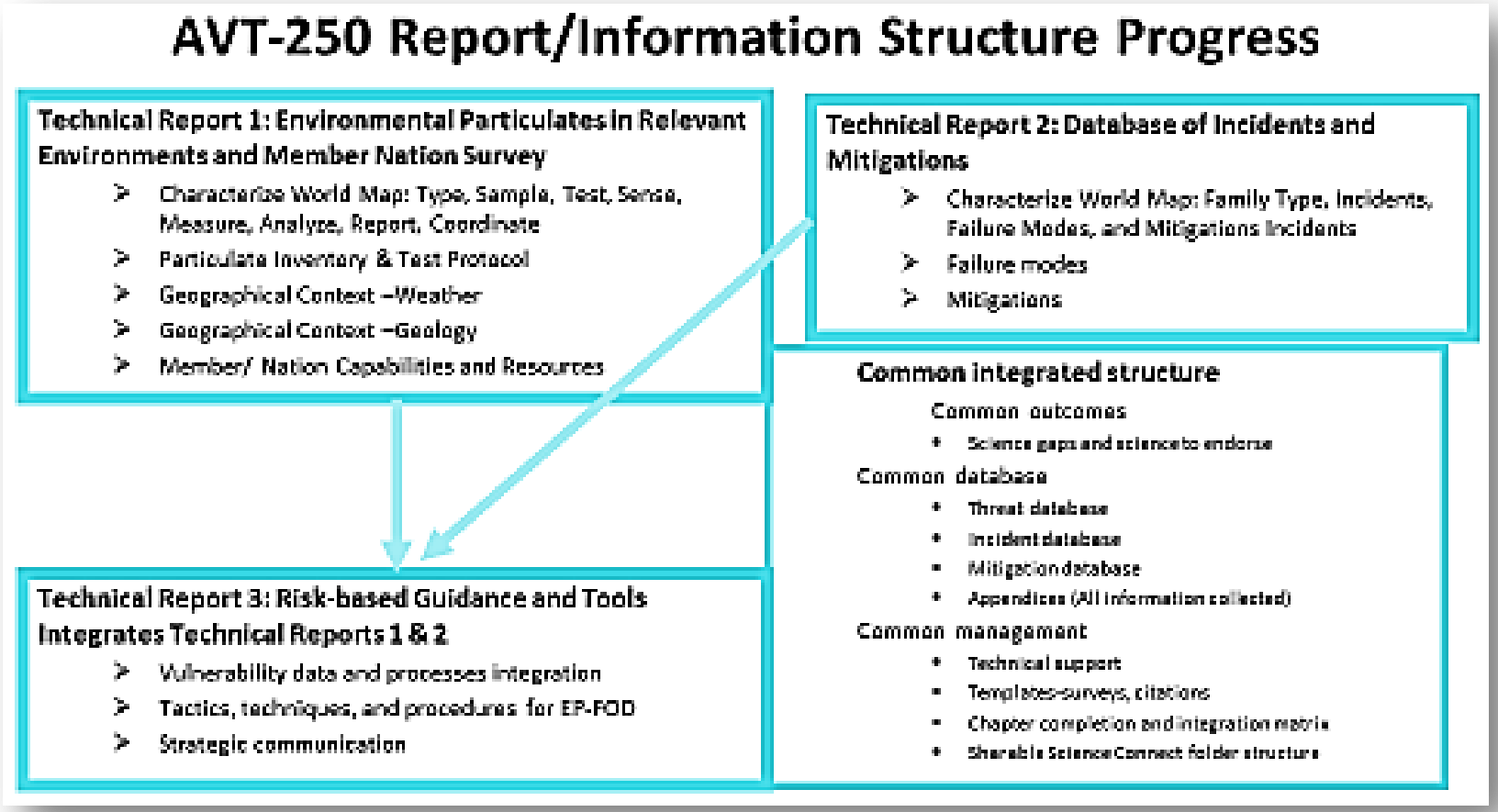
Data Analysis & Engine
Analytical Condition
Inspection are now complete!

Teardown Inspection revealed
<u>significantly</u>
<u>greater</u> amounts of deposits

ROLLS ROYCE

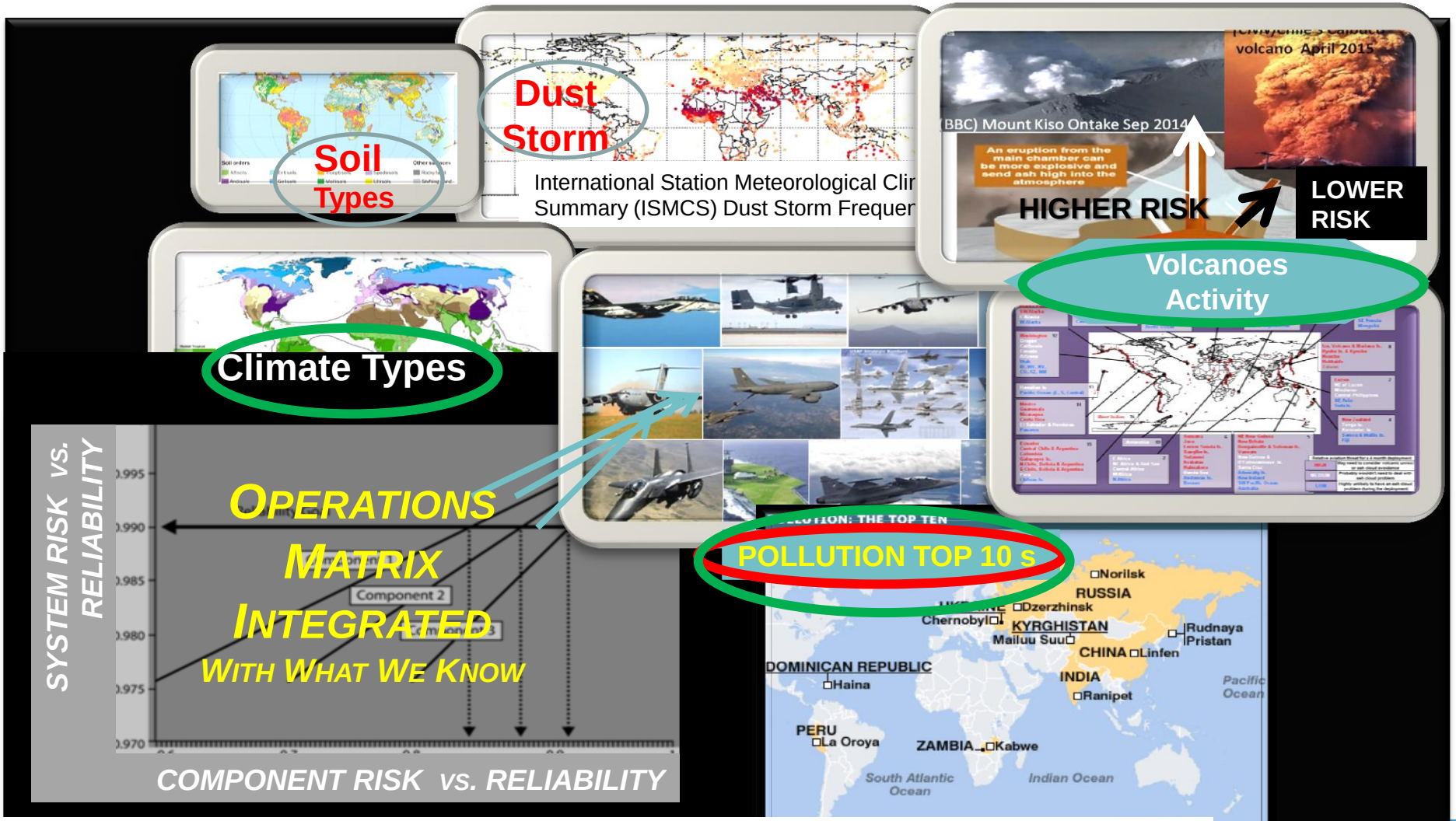
Courtesy of
Rory Clarkson

NATO Task Group AVT-250
EP-FOD Impacts to Military Operations



Integrating Research, Data, & Models

Key to Future Operations in EP-FOD Environments



ACCELERATING OPERATOR'S DECISION-MAKING

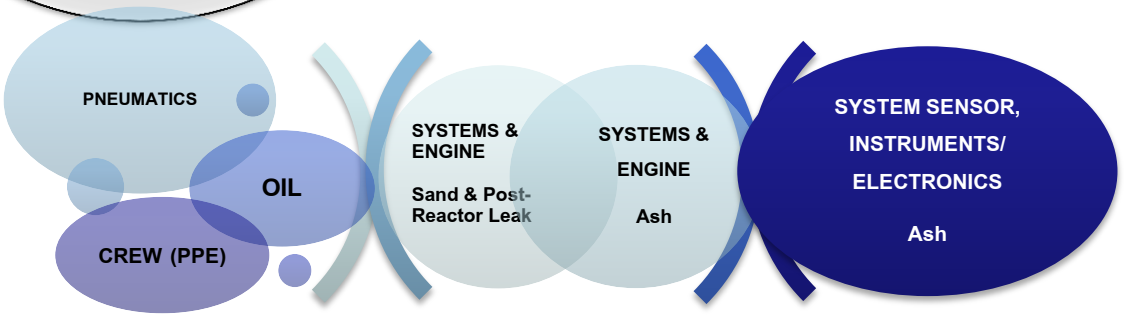
EP THREAT - Degraded Visual Environment Impact

Contested battlespace: ATTRITABLE/DISPOSABLE

Elevated Ops: DEGRADATION RISK – RELIABILITY, PERFORMANCE

Normal Ops: AIRWORTHINESS

What we think we know for some EP impacts



NATO AVT-250
Feeding Digital Thread Use-Case

- **Operators, OEMs, Geology, & Weather – One Team**
- **Today's and Future Operations Opportunities**

Delivering Three Technical Reports – Aligned to appropriate user

TR-1 " Threat Environment- EP and their transport and detection"

TR-2 "Vehicle Incidences Experience and Characterization"

TR-3 "Products and Application for the Warfighter Impacts, Tools(integrating TR-1 & 2) , and Procedures for Operations in EP Environments"

- **Next Gen UAS considerations**
- **EP-FOD**

Advice/data to accelerate operator's decision making!

Planning for Future Operating Concepts

- **Special opportunities to deliver operational multi-domain agility**
- **Acquire limited high-cost/high-capability & many lower-cost/lower-capability platforms**
- **Considerations for operations in EP-FOD conditions**
- **Development of appropriate mitigation options and guidelines EP-FOD**
  - Bring an orchestrated effort to advance understanding, generate mitigations
  - Payoffs: Long endurance missions, autonomous operations
- **Sensors, electrical systems and subsystems are susceptible to EP-FOD**
  - Performance degradation
  - Latent failures…high cost, unreliability, and impacts to availability
  - Catastrophic events
- **Yesterday's UAS is not tomorrows UAS**

… We need to understand EP-FOD impacts to design health management

Way Forward

- **Define and set standards for global EP-FOD battlespace awareness**
- **Assemble documented experiences and lessons learned.**
- **Identify partner nation EP-FOD related capabilities and resources**
- **Obtain foreign disclosure authorization to share framework**
- **Leverage our digital thread and twin technologies**
- **Develop use-case making output of AVT-250 computationally useful**
- **Establish common procedures for technical/business cases**
- **Mature semantic technologies for standardizing data collection**
- **Bridge tech gaps by leveraging international efforts /collaborations**

Conclusions

…We Are At A Crossroads

- **Understanding, advancing & mitigating EP-FOD impacts**
- **Many databases and information stores exist**
  (e.g., particulate types, environmental demographics, effects on aircraft system)
- **VIPR III provided critically important data points, but we need more…**

NATO AVT-250 goal

- **Proactive international partnership of academia, industry, & gov**
  - Integrate knowledge base
  - Fill in technology gaps in current efforts
  - Deliver guidance and useful tools to planners, operators, and maintainers
  - Deliver the future roadmap digital thread use case and advanced predictive health

Please Join Us in this Revolutionary Journey

Sources

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- Source: Rory Clarkson, Rolls-Royce; approval to use via e-mail (as long as we credit him and put RR logo on the slide).