



HELLENIC AIR FORCE ACADEMY

DEPARTMENT OF AERODYNAMICS AND FLIGHT MECHANICS

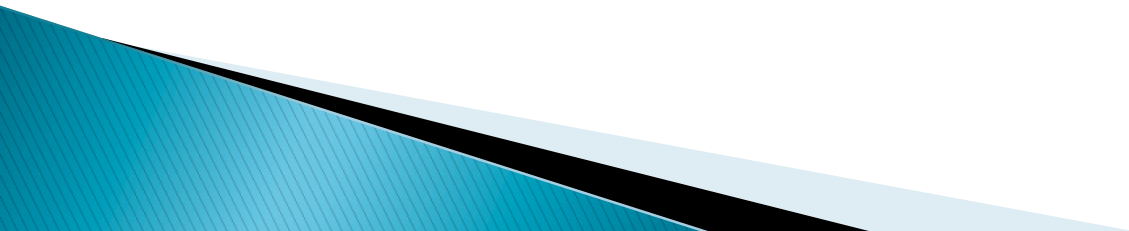
DUST IMPACT ON AVIATION

TH. I. LEKAS, G. KALLOS, J. KUSHTA, S. SOLOMOS, E. MAVROMATIDIS

6th International Workshop on Sand/ Dust Storms and Associated Dust fall,
September 7-9, 2011, Athens, Greece

OBJECTIVES

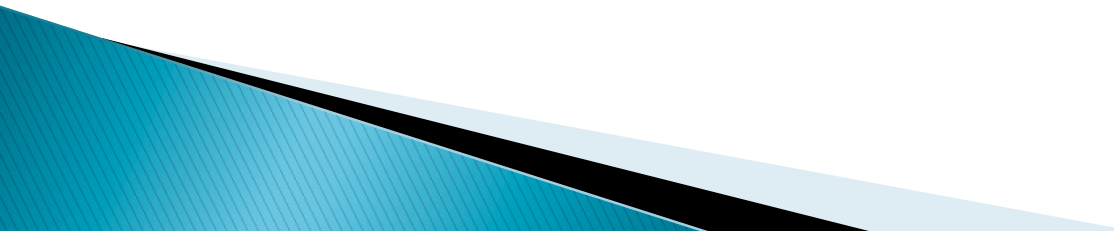
The major objective is to draw attention on a series of potential problems that might be associated with the flight of aircrafts in dust loaded areas as well as to propose some means to minimize these problems



PREREQUISITES

- The operational procedures must take into account quantitative predictions of dust air masses along the routes and especially in low altitude flight as well as the engines tolerance in dust mass ingestion
- The quantitative prediction of dust mass in the atmosphere started to become available despite the large uncertainties associated to them
- By utilizing such predictions the area, timing and the amount of ingested dust can be calculated along the flight path

CONCERNED GEOGRAPHICAL AREAS

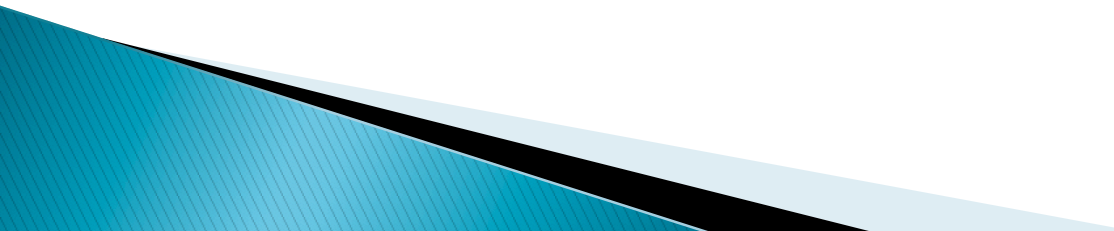
- Desert areas are the main source of sand and dust in the atmosphere because they cover a considerable amount of land and their dust is a major source of airborne particles
 - Areas affected by volcanic eruptions or venting
 - Due to atmospheric circulation the problems associated with desert dust or volcanic ashes can affect extended airspace
- 

THE PROBLEM

Desert dust or volcanic ashes can cause significant problems in aviation such as

- Rerouting due to poor visibility
- Disturbances in airport operations
- Massive canceling of scheduled flights
- Mechanical problems such as erosion, corrosion, pitot-static tube blockage or engine flame out in flight

In this presentation only some mechanical problems will be discussed



EROSION

Desert dust and volcanic ash particles impact and bounce on cold areas of the engine (fan or propeller blades) causing surface damages and gap size augmentation leading to gas flow deterioration and gradual loss of performance of the engine.

Damages are also caused at the external surface of the aircraft.

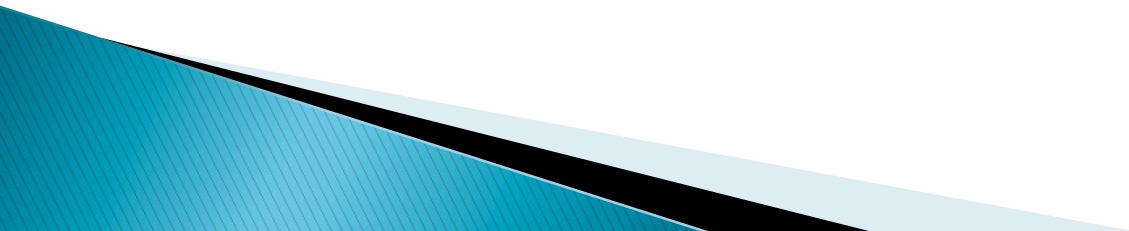
The problem is more severe in the case of volcanic ashes due to their irregular shape with sharp edges.



CORROSION

If dust particles or volcanic ashes impact on hot surfaces (combustor walls, turbine blades...) they will form a glass deposit with rough surface which may lead to a rapid loss of performance (potential risk during take off or landing operations) by disturbing the flow field.

This deposit may also lead to thermal corrosion of a component of the engine or of electronic devices by blocking cooling holes



PITOT – STATIC TUBE DAMAGES

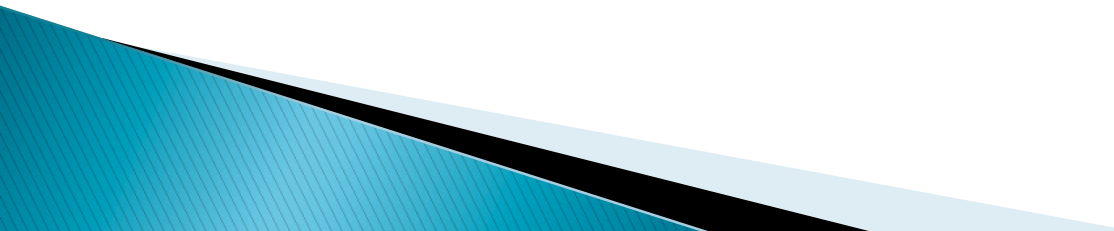
Desert dust particles as well as volcanic ashes can lead to false flight speed reading by blocking pitot-static tubes. This may be extremely hazardous especially in low level flight as during take off or landing procedures.

\

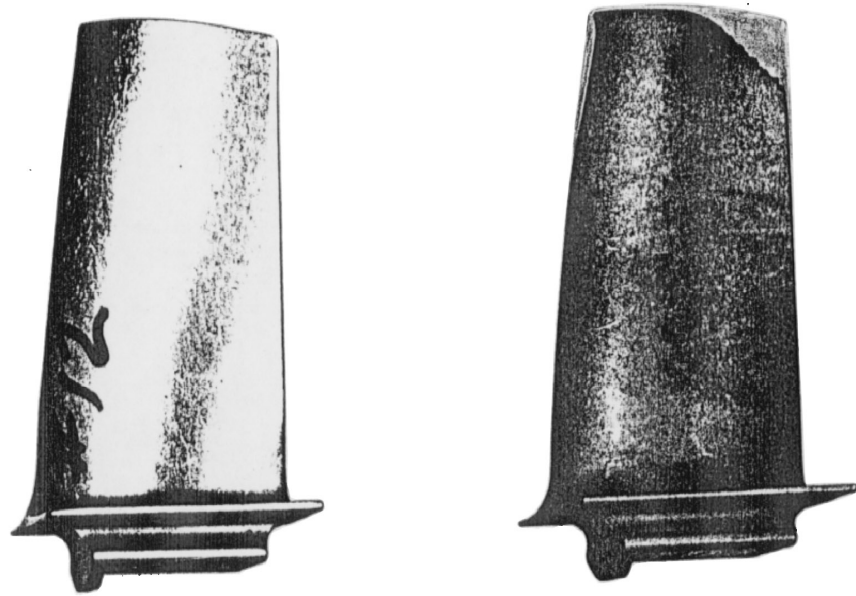
IN-FLIGHT FLAME OUT

THE GLASS DEPOSIT ON HOT PARTS OF THE ENGINE CAN SIGNIFICANTLY DISTURB THE AIRFLOW, EVEN LEADING TO TURBINE BLADES STALL AND IN FLIGHT ENGINE FLAME OUT

SITUATION MUCH MORE CRITICAL THAN EXTERNAL PAINT SCRATCH

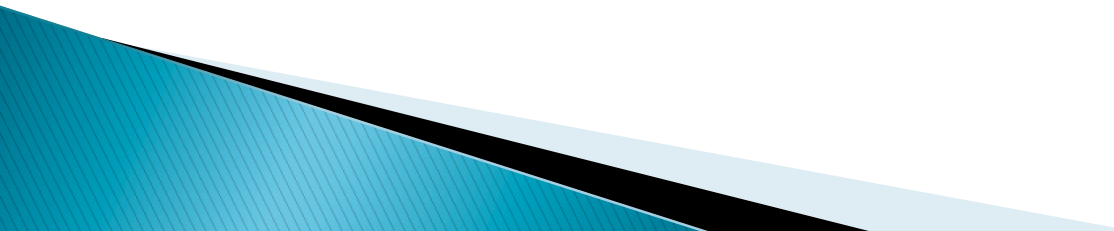


ENGINE DAMAGES BY DUST INGESTION

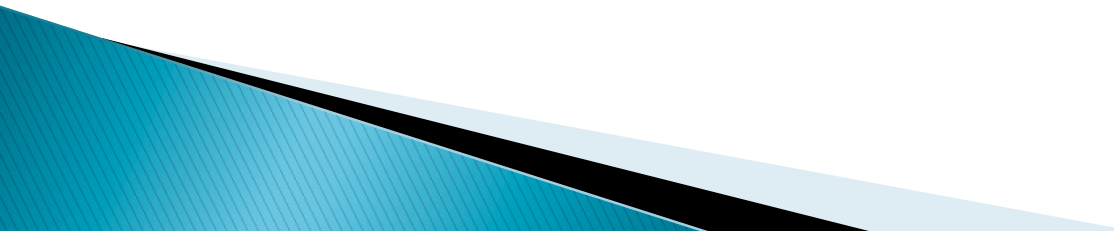


WHAT IS NEEDED?

Understanding of the physics of dust erosion and corrosion in order to adequately modify :

- The engine design
 - Maintenance procedures
 - Routing and approaching procedures
- 

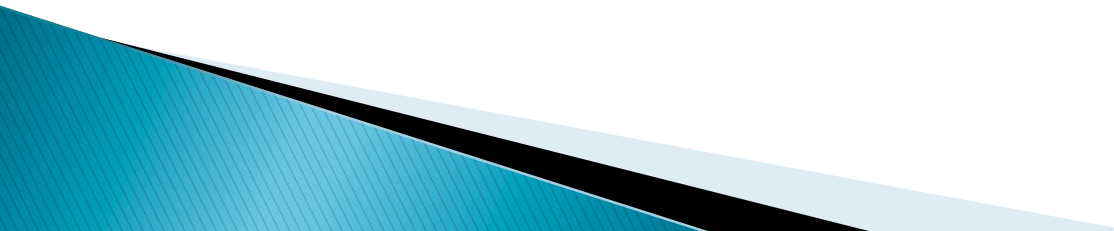
SPECIFIC TARGETS

- ▶ New engines design with higher particle mass ingestion tolerance
 - ▶ Knowledge of particle mass ingestion tolerance of existing engines for better air traffic management in contaminated air space and better maintenance rescheduling
 - ▶ Possibility of particle detection, especially volcanic ash, ahead of the aircraft in order to rerouting
- 

PROCEDURE

Once the particle concentration at the flight area is known the contaminated parts of the engine, the shape of the deposit which may be formed, the critical particle mass ingested as well as parameters leading to an engine loss of performance in a short or long term can be found for given flight parameters (flight altitude, aircraft angle of attack, flight speed and throttle settings).

A parametric procedure based on both experimental and theoretical approach will permit to determine the critical ingested particle mass for a given engine.



EXPERIMENTAL APPROACH

ADVANTAGES

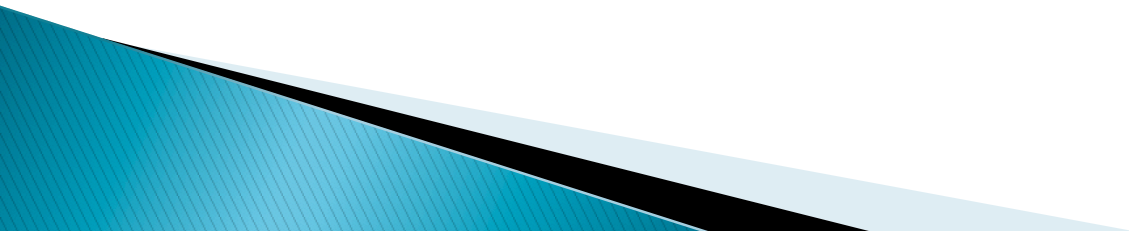
Possibility of realistic simulation of the physical phenomena

DISADVANTAGES

Need for complex and rather expensive equipment

CURRENT STATUS

There are specialized research centers able to simulate dust storms of various intensities and with various particle sizes



THEORETICAL APPROACH

ADVANTAGES

Physical approach as good as the efficiency of the mathematical model in use

No need for important infrastructure

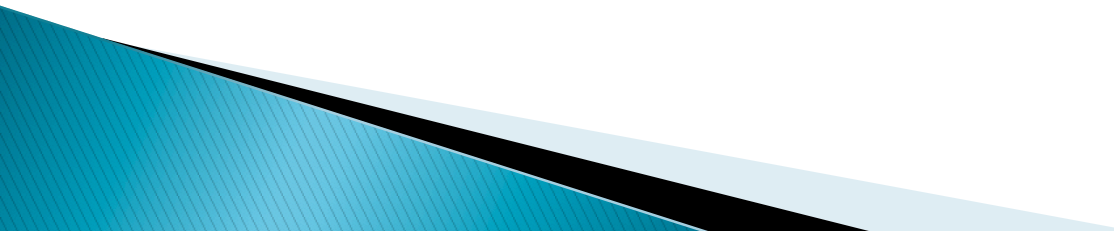
DISADVANTAGES

Significant numerical problems may occur

Computational time may be prohibitive

CURRENT STATUS

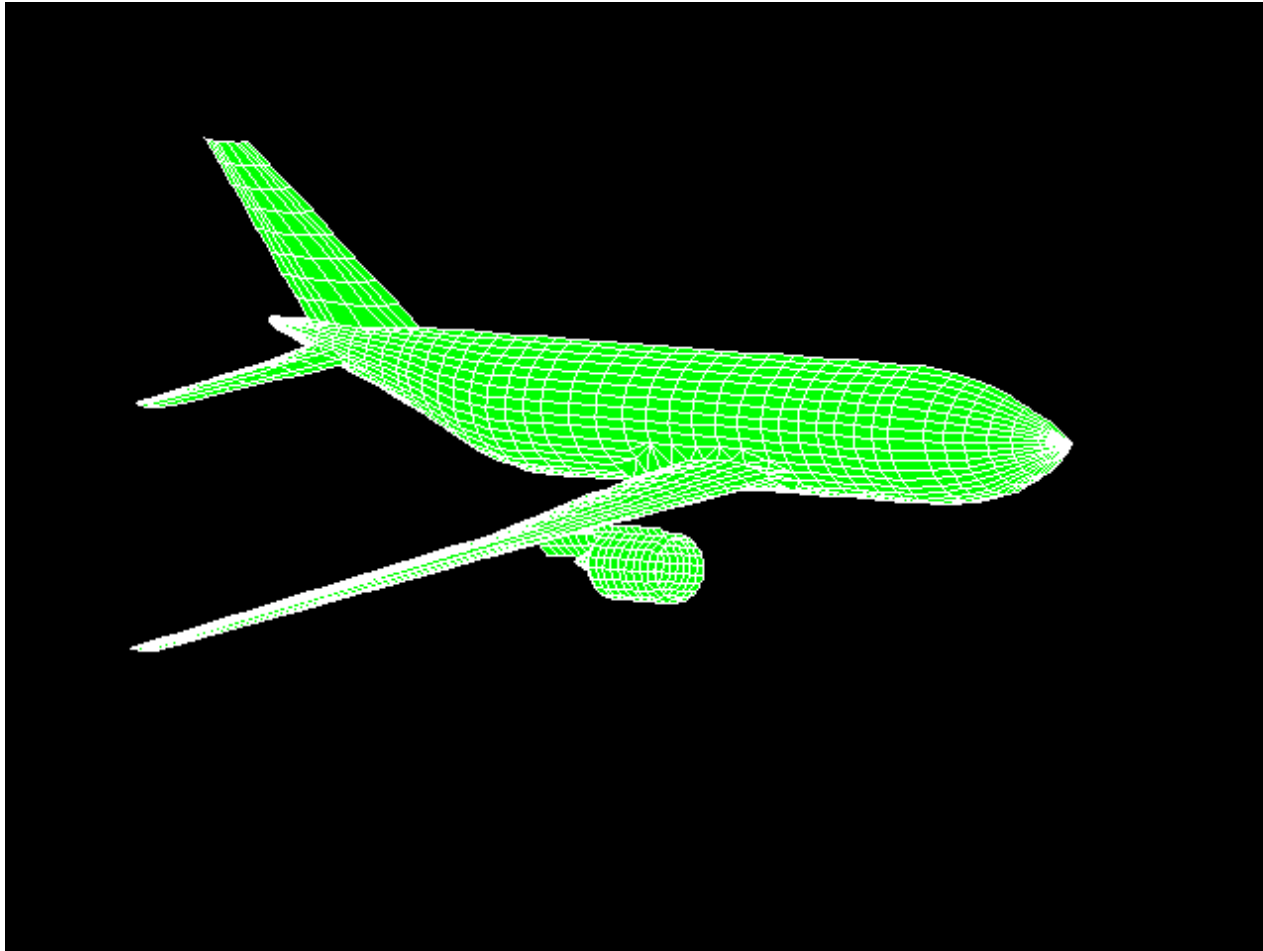
The continuous increase of computational power allows for very accurate computation of the flow field and dust particle trajectories around an obstacle with complex geometry



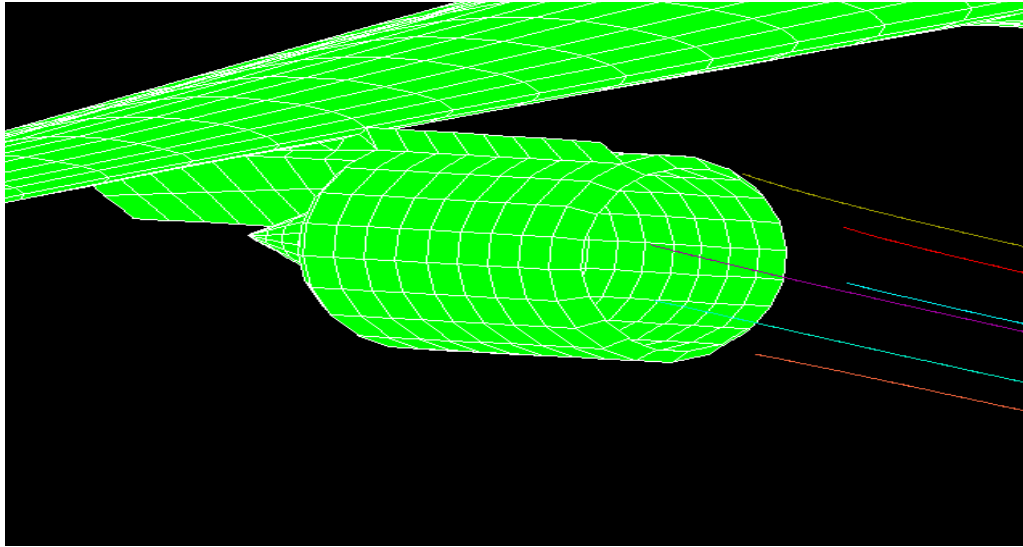
STEPS OF THE THEORETICAL APPROACH

- Description of the geometry of a given obstacle (aircraft)
 - Computation of the flow field around the obstacle
 - Computation of particle trajectories due to the flow field around the obstacle
 - Determination of impact points
 - Knowledge about the contaminated area and the shape of the deposit on the obstacle
 - Knowledge about the particle mass ingested
- 

GEOMETRY



TRAJECTORIES

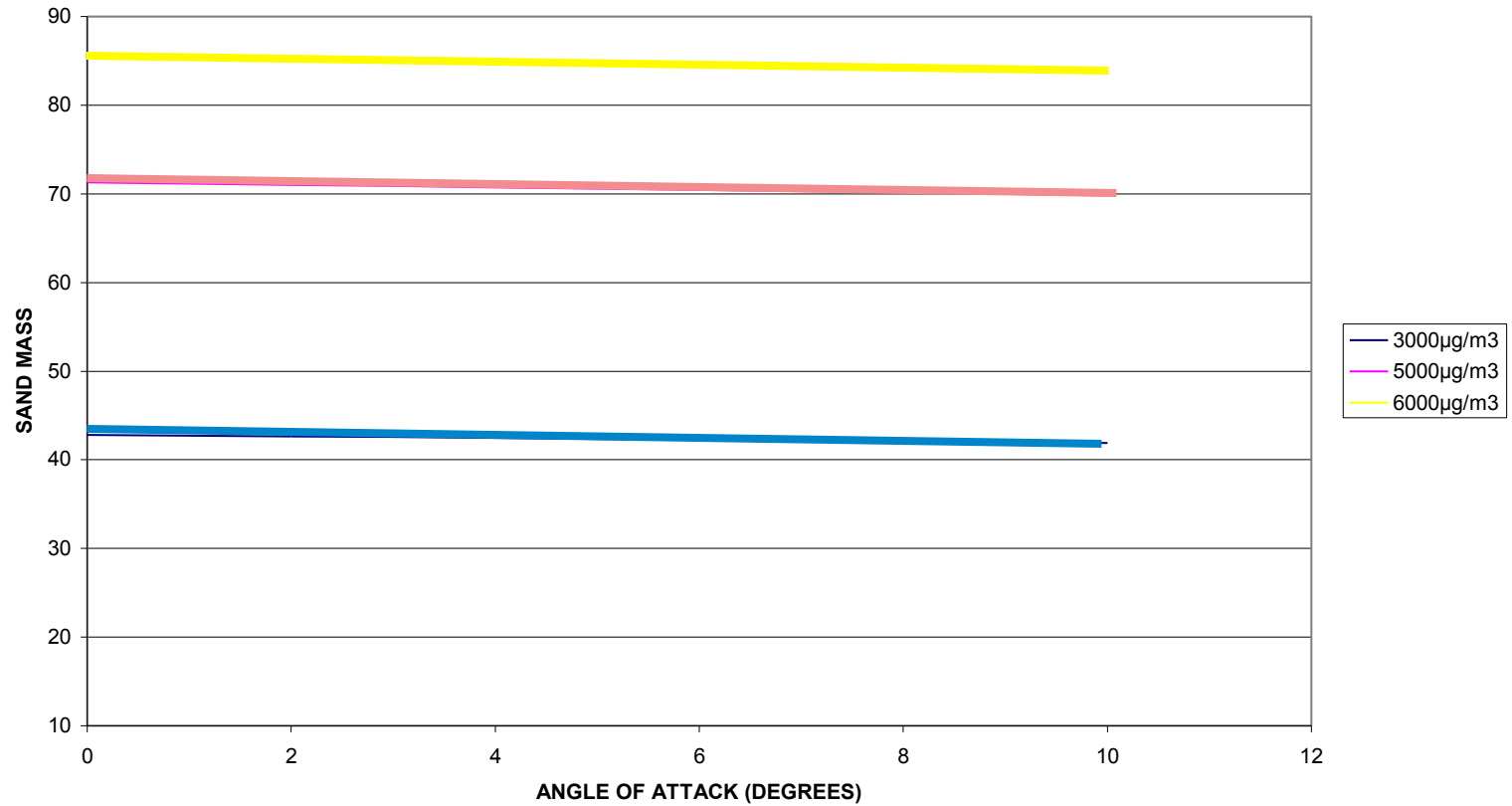


As a first look the ingested amounts of dust (volcanic or desert) must be small taking in the consideration the engine diameter.

But this is not true because the throttle setting, the angle of attack, the flight speed and the particle concentration are multiplying parameters.

SAND MASS INGESTED

TOTAL SAND MASS OVER 1 HOUR OF FLIGHT



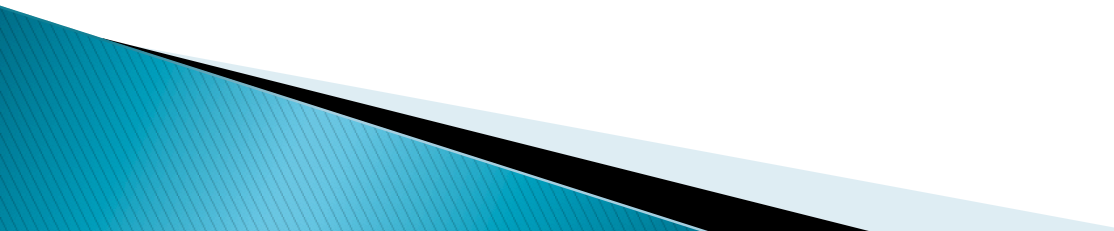
VOLCANIC ASH DETECTION AHEAD

Special attention should be allowed on volcanic ash particles because of their physical characteristics.

Due to their irregular shape, volcanic ash particles have a very different “optical fingerprint” from any other airborne particle.

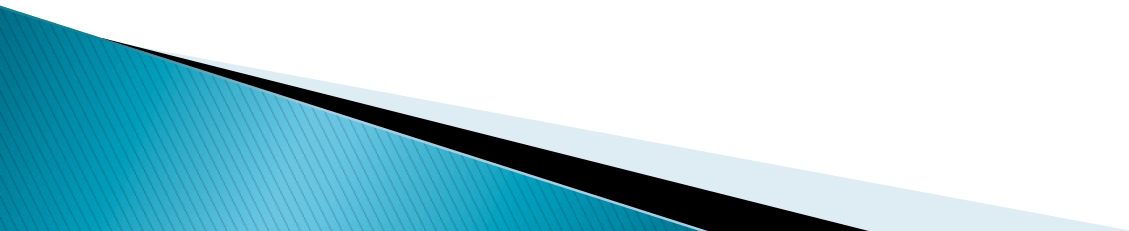
Detection devices (e.g. laser beams) should be used but the associated technical and operational problems are considerable.

Alternatively satellite platforms should be used.



SEA SALT PARTICLES

Similar problems should be encountered in airports adjacent to coastal areas due to the ingestion of sea salt particles from evaporation of water droplets produced by wave breaking



CONCLUSIONS

- ✓ Desert and volcanic dust as well as sea salt particles have safety and maintenance implications on aircraft operations
 - ✓ The ingestion of these particles have impacts on the aircraft performance that are not fully explored yet for the aerospace industry
 - ✓ Sand and dust storms occur much more often than volcanic eruptions and affect aviation operations in many places on the Earth with significant safety and financial implications
 - ✓ For this reason maintenance and operation plans should be revised
 - ✓ More specifically, flight paths and flight management in dusty environments must be re-assessed
- 