

# Progress of MoonLITE Penetrators

Rob Gowen  
on behalf of the UK  
Penetrator Consortium



# Contents

- Brief overview
- Status
- Phase-A elements
- Impact Trial
- Collaboration

# MoonLITE Mission

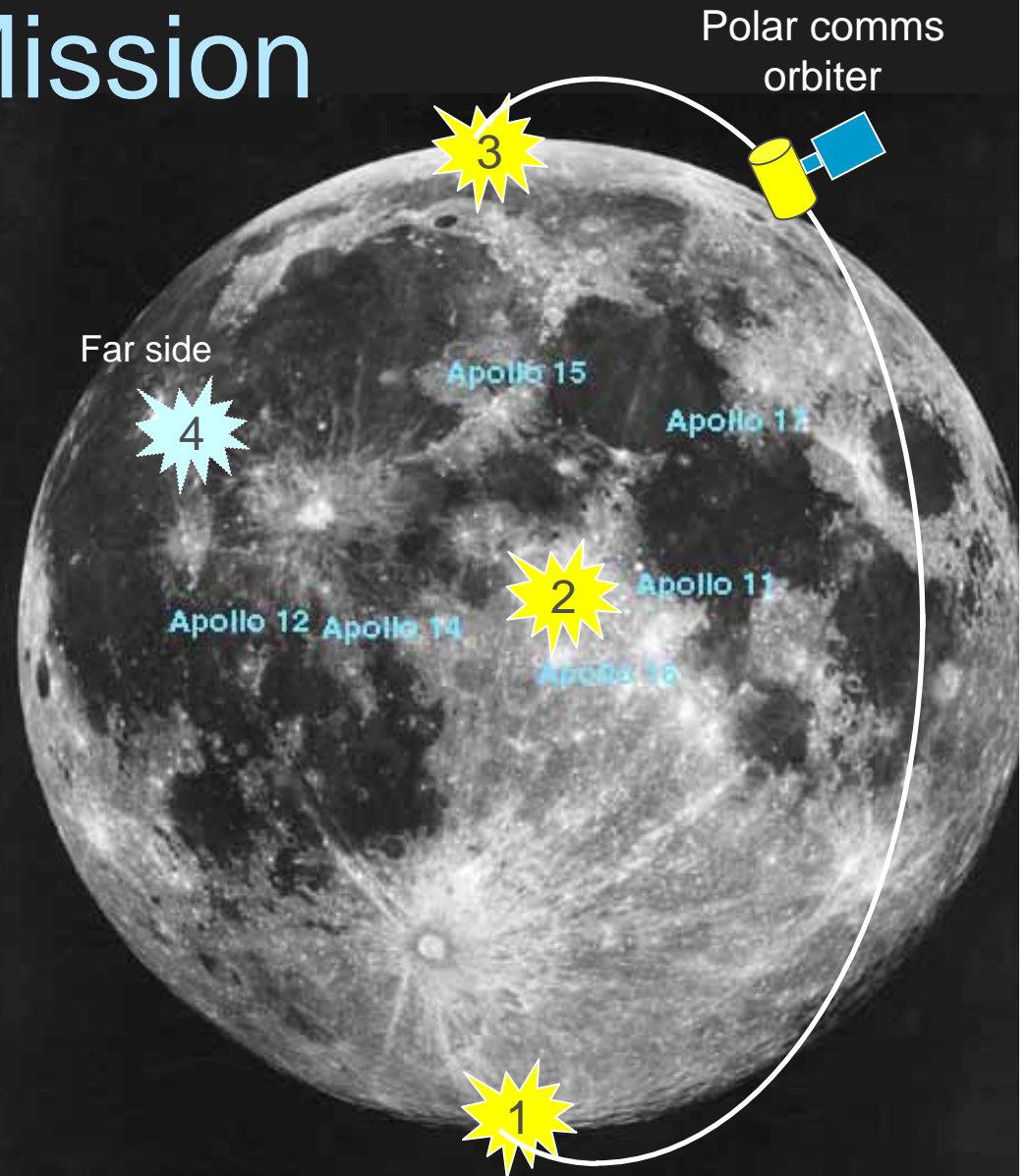
A UK led science mission including an orbital communications package and to emplace 4 penetrators on the Moon for :-

- **Science:** Lunar science (inc. geology, chemistry, interior structure)  
+ water ice/volatiles in permanently shadowed craters and astrobiological connections  
+ ground truth.
- **Exploration:** For manned missions -> water for ISRU  
+ sites of possibly dangerous seismic levels for lunar bases  
+ radiation shielding effectiveness of lunar regolith.
- **UK plc:** Showcase British Innovation
- **Public interest:** First UK led mission for 30+ years, already much media and personal interest.
- **Strategic Potential:** For future solar system bodies (e.g. Europa/Ganymede, Titan/Enceladus, NEOs...)

*Penetrators - a new tool in the toolbox for planetary exploration*

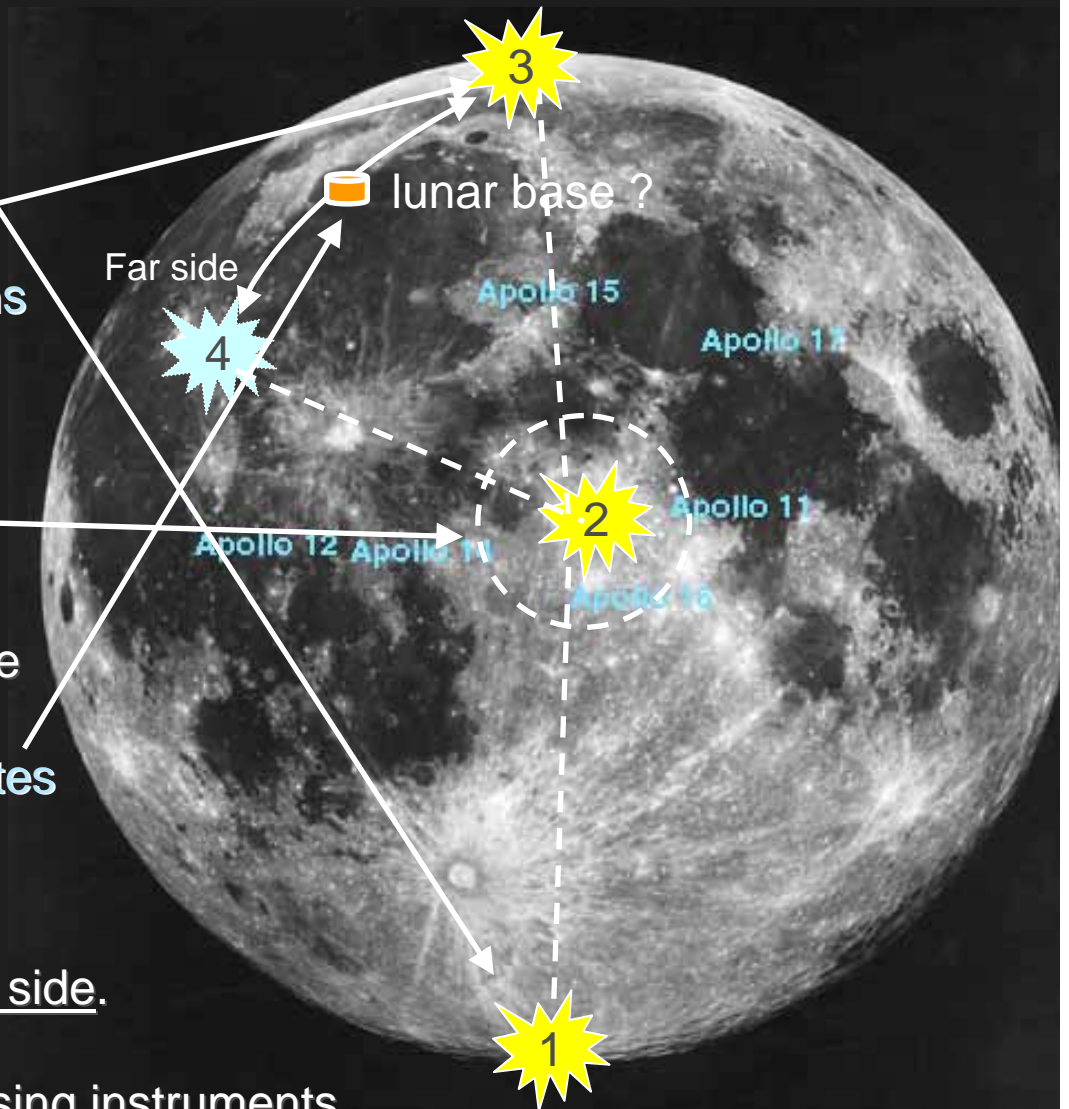
# MoonLITE Mission

- **Delivery and Comms Spacecraft (Polar Orbiter)**
- **Emplace 4 penetrators into lunar surface**  
each 13Kg @300m/s
- **Landing sites:**  
Globally spaced
  - far side
  - polar region(s)
  - one near an Apollo landing site for calibration
- **Duration:**  
**1 year operations**

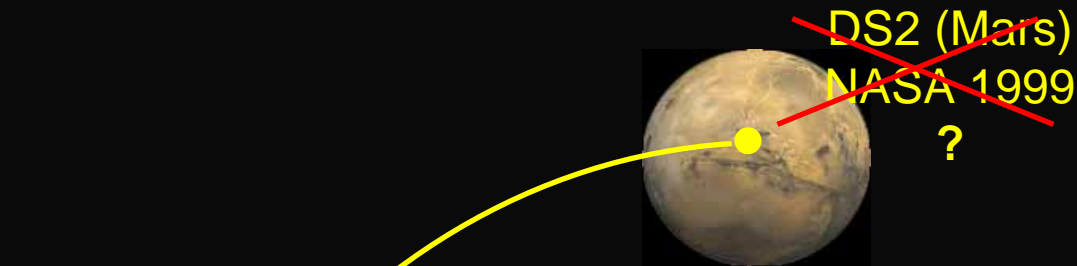


# Science & Exploration Objectives

- Characterize water, volatiles, and astrobiologically related material at lunar poles.  
=> **Water is key to manned missions**
- Constrain origin, differentiation, 3d internal structure & far side crustal thickness of moon via a seismic network.
- Investigate enigmatic strong surface seismic signals  
=> **identify potentially dangerous sites for lunar bases**
- Determine thermal & compositional differences at polar regions and far side.
- Obtain ground truth for remote sensing instruments



# Feasibility & Heritage



- Lunar-A and DS2 space qualified
- Military have been successfully firing instrumented projectiles for many years
- Most scientific instruments have space heritage

*When asked to describe the condition of a probe that had impacted 2m of concrete at 300 m/s a UK expert described the device as 'a bit scratched'!*

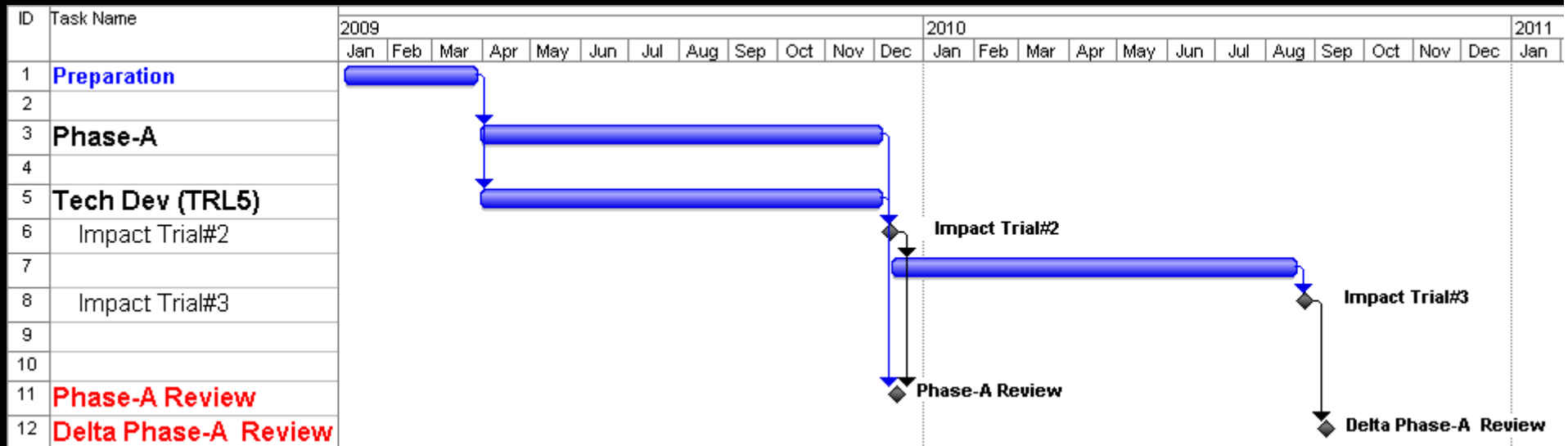
# Program and Status

- **Late 2006** : PPARC initiated lunar mission studies
- **Early 2007** : MoonLITE recommended for first mission
- **May 2008** : Full scale impact trial at Pendine Sands, Wales.
- **July 2008** : MoonLITE International Peer Review. Strongly endorsed and recommended proceed to Phase-A study.
- **08 Sep'08** : MoonLITE SOI considered by STFC Peer Review Process
  - **passed: now ⇒ 3 part Phase-A Mission, PDS, Penetrators**

*' MoonLITE mission...inspirational...' NASA*

# Proposed Development Program

**Objective:** within 2 years to be ready to proceed to mission construction

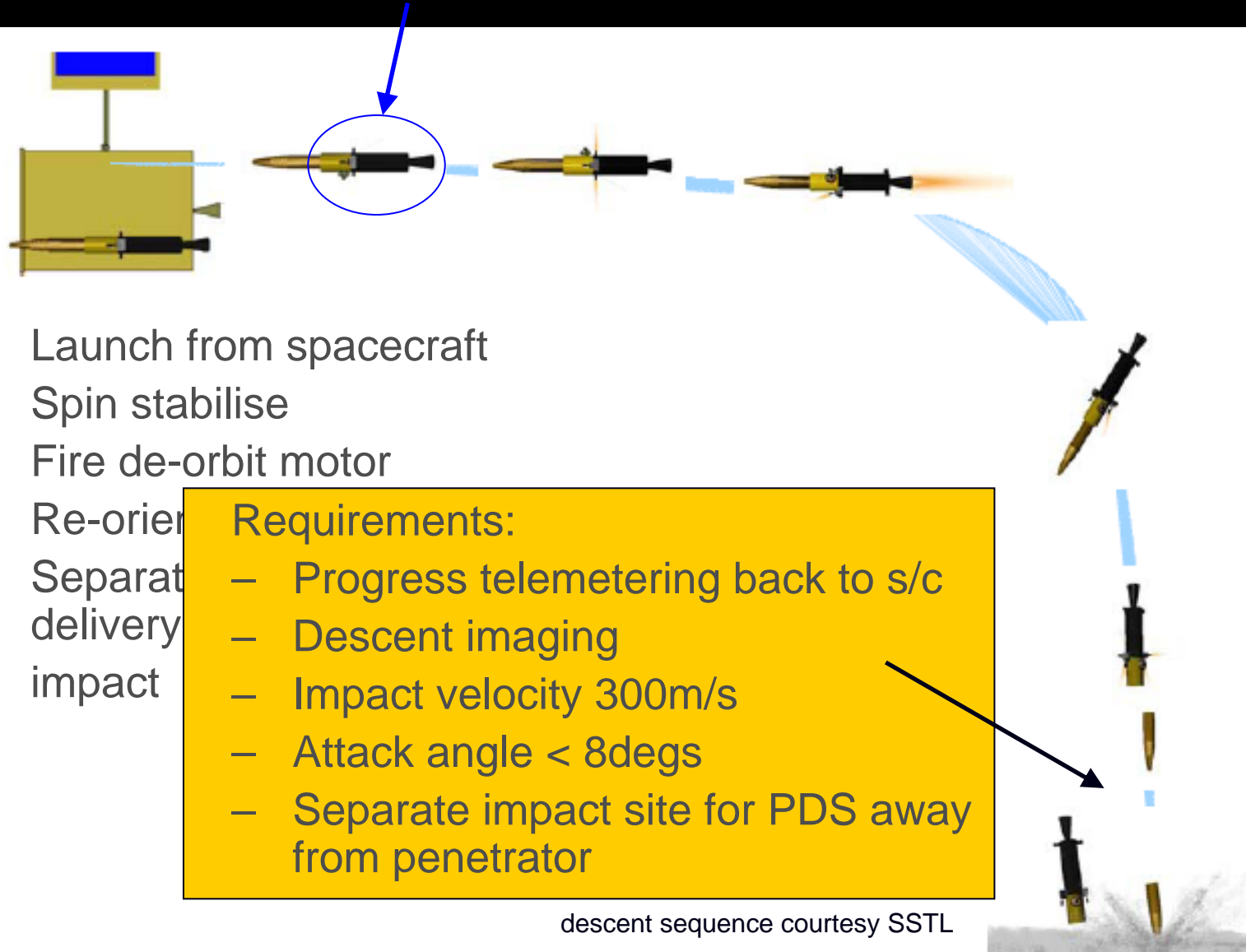


- Parallel Phase-A and Technical Development
- Review at end of Phase-A
- Final Review at end of technical development

# PHASE-A

- Penetrator Delivery System
- Penetrator
  - baseline
  - options

# Penetrator Delivery System



- Launch from spacecraft
- Spin stabilise
- Fire de-orbit motor
- Re-orient
- Separat
- delivery
- impact

## Requirements:

- Progress telemetering back to s/c
- Descent imaging
- Impact velocity 300m/s
- Attack angle < 8degs
- Separate impact site for PDS away from penetrator

descent sequence courtesy SSTL

# Penetrator – post impact

## Impact physics group

- regolith properties
- cratering
- skin depth modification

- Phase-A study:
- impact physics
  - aft flare
  - power options
  - internal bay options

for flight  
stability in  
regolith

batteries/RHU  
& heat switch  
(CofG forward)

- power options:
- fuel cells
  - micro-rtg

## Internal bays

- ease of AIT
- consider plastic
  - > good insulation
  - > save power
  - > improve lifetime

few metre below surface

# Penetrator – post impact

option: trailing aerial  
(de-risk comms through  
regolith & save power)

comms

crater

Phase-A study:  
– trailing aerial

# Penetrator – post impact

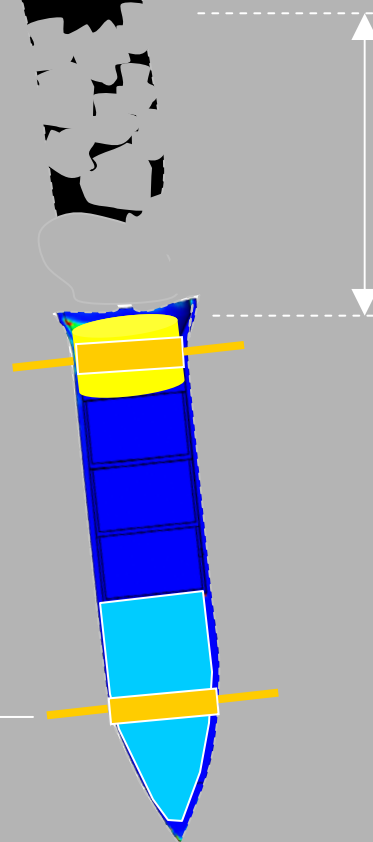
Phase-A study:  
– needle probes

- heat flow
- (magnetometer)
- accelerometers

Maximum vertical separation  
for gradient measurements

- Baseline: needle probes
- Backup: patch thermometers

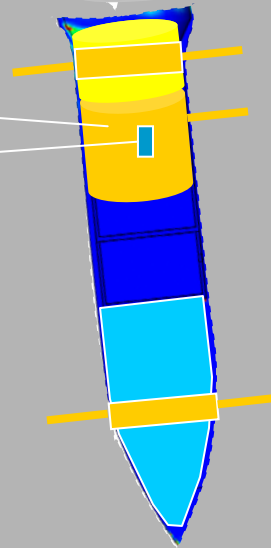
sub-surface  
 $\geq 0.8\text{m}$



# Penetrator – post impact

Phase-A study:  
– sample imager  
– stand off  
techniques

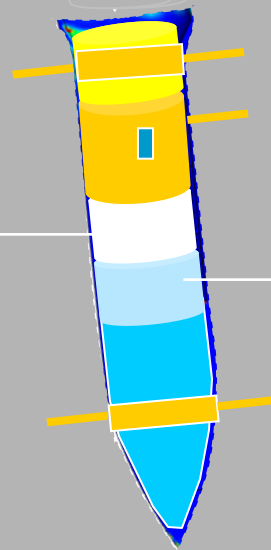
- water/volatiles
- geochemistry
- sample imager  
(geologic context,  
mineralogy)



drill  
(sample acquisition)

# Penetrator – post impact

micro seismometers

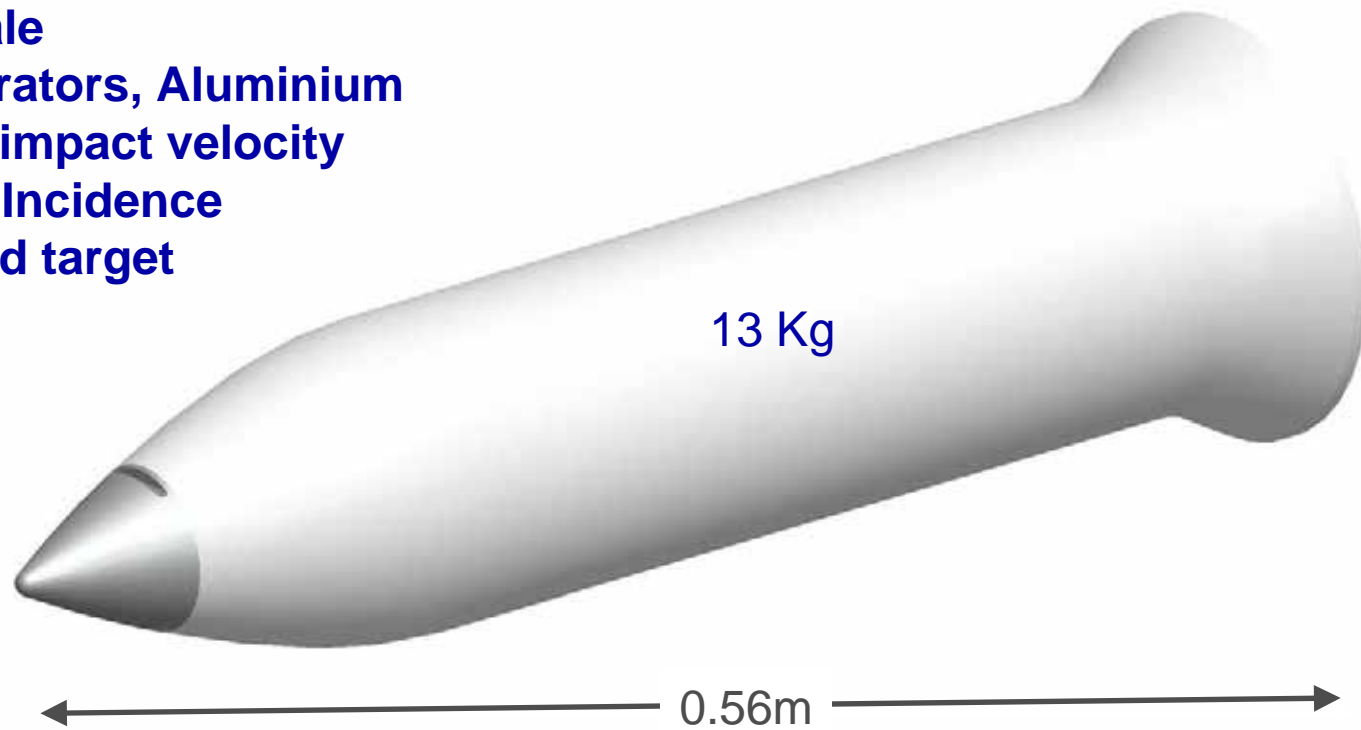


DHU  
PCU

# Full Scale Impact Trial May19-21 2008

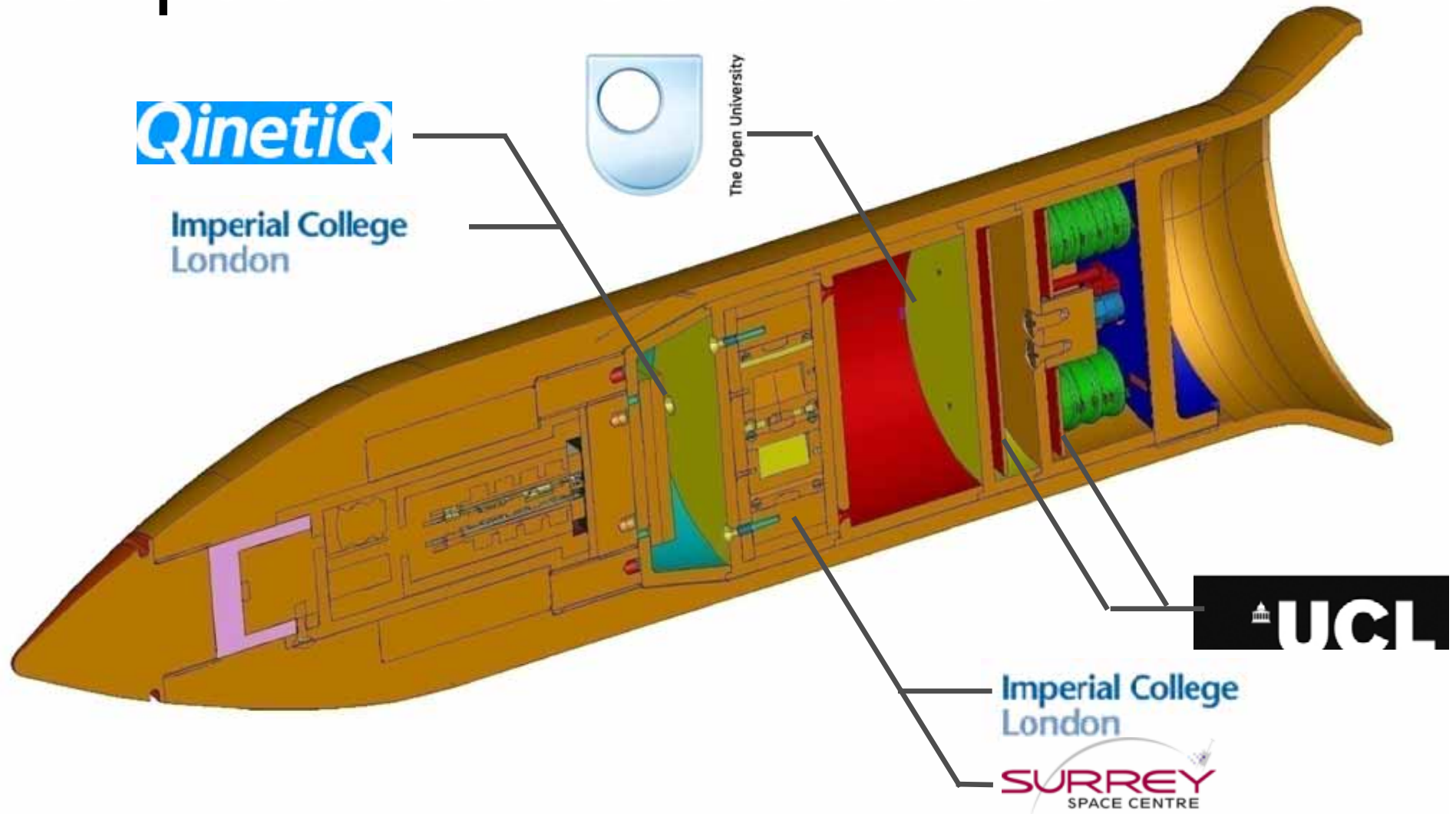
# Impact Trial: 19-21 May 2008

- Full-scale
- 3 Penetrators, Aluminium
- 300m/s impact velocity
- Normal Incidence
- Dry sand target

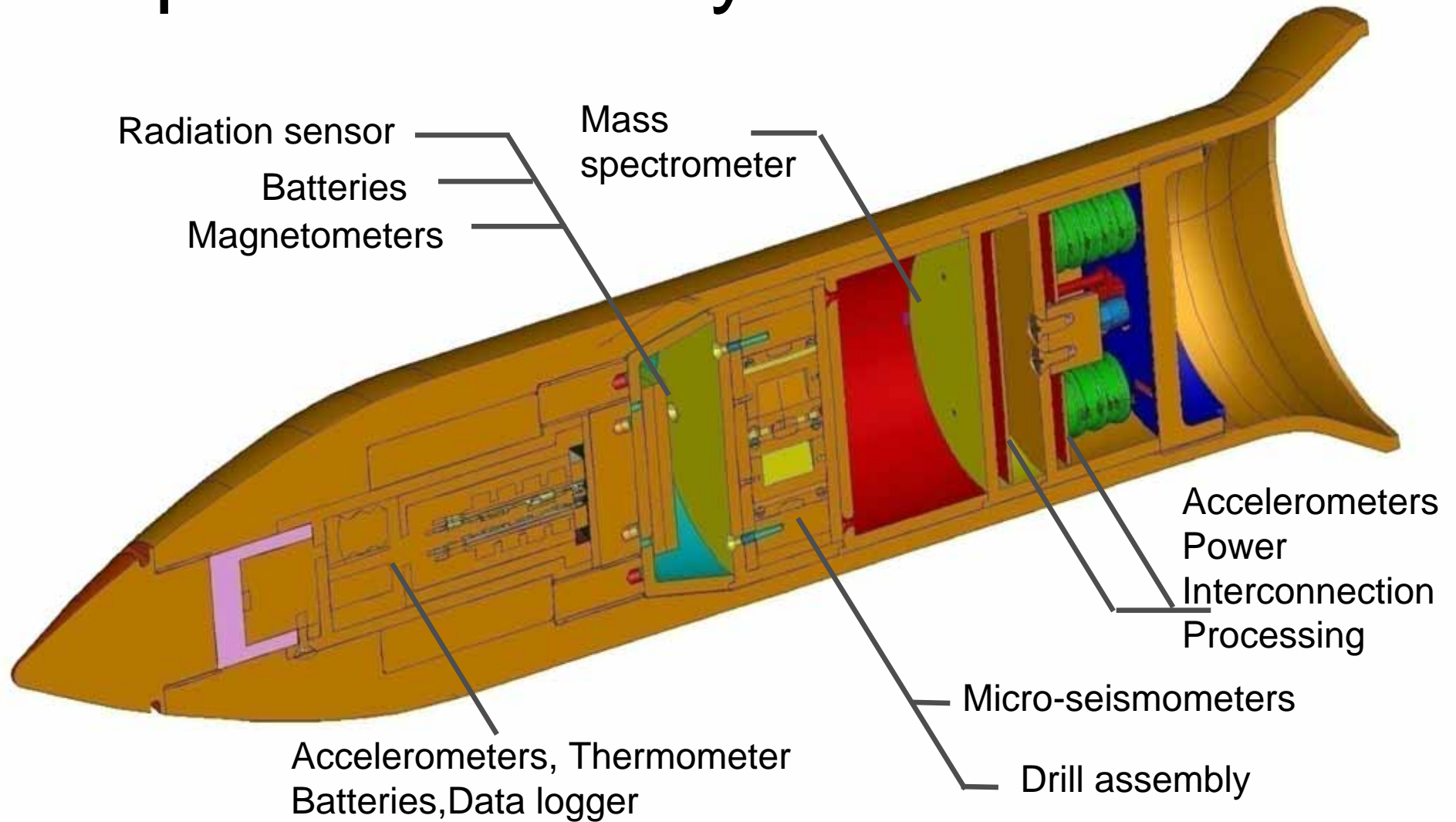


**... just 9 months from start to end. Starting from scratch in Sep'07**

# Impact trial - Contributors



# Impact trial – Payload



# Impact Trial - Objectives

- **Demonstrate survivability of penetrator shell, accelerometers and power system.**
- Assess impact on penetrator subsystems and instruments.
- Determine internal acceleration environment at different positions within penetrator.
- Extend predictive modelling to new impact materials and penetrator materials.
- Assess alternative packing methods.
- Assess interconnect philosophy.

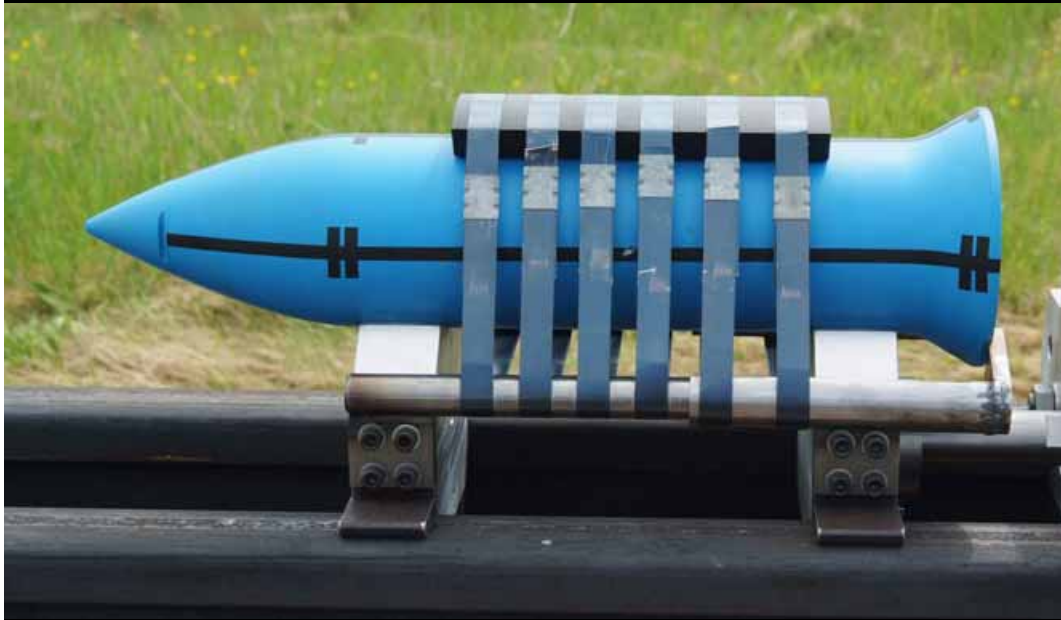
# Trial Hardware

Inners Stack



# Impact Trial - Configuration

- Rocket sled
- Penetrator



# Target



- Dry sand
- 2m x2m x6m
- Small front entrance aperture (polythene)

# Real-Time Impact Video





# 1'st Firing - Results

Firing parameters:

- Impact velocity: 310 m/s  
(c.f. 300m/s nominal)
- Nose-up ~8degs  
(c.f. 0 degs nominal)

=> worst case

- Penetrator found in top of target
- Glanced off a steel girder which radically changed its orientation.
- Penetration: ~3.9m
- Much ablation to nose and belly
- Rear flare quite distorted.
- Penetrator in one piece ✓





**Post Firing  
belly up !**



# First Firing – Opening up

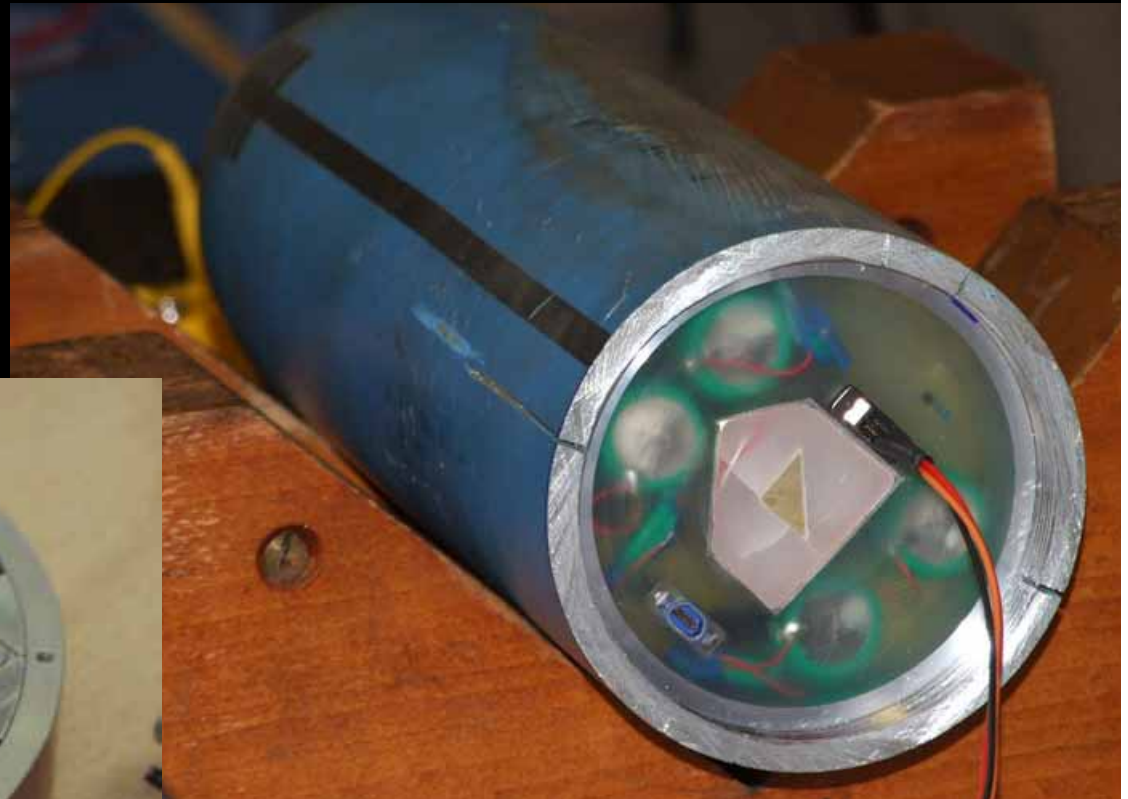
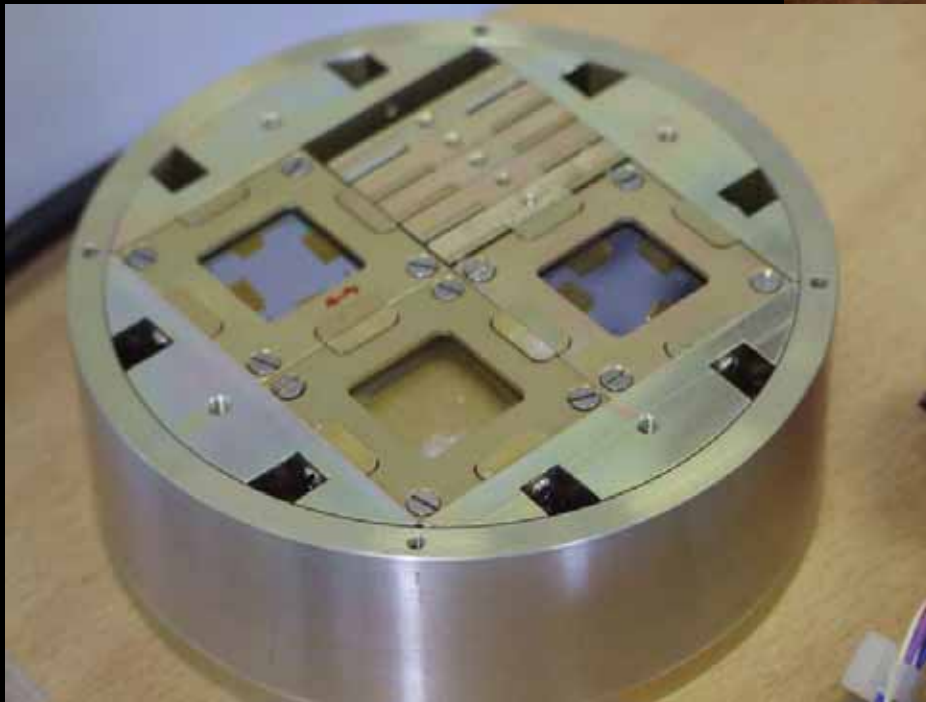


LEAG 2008 : Florida, Oct 30

MSSL/UCL UK

# 1<sup>st</sup> Firing – internal Results

Micro seismometer bay

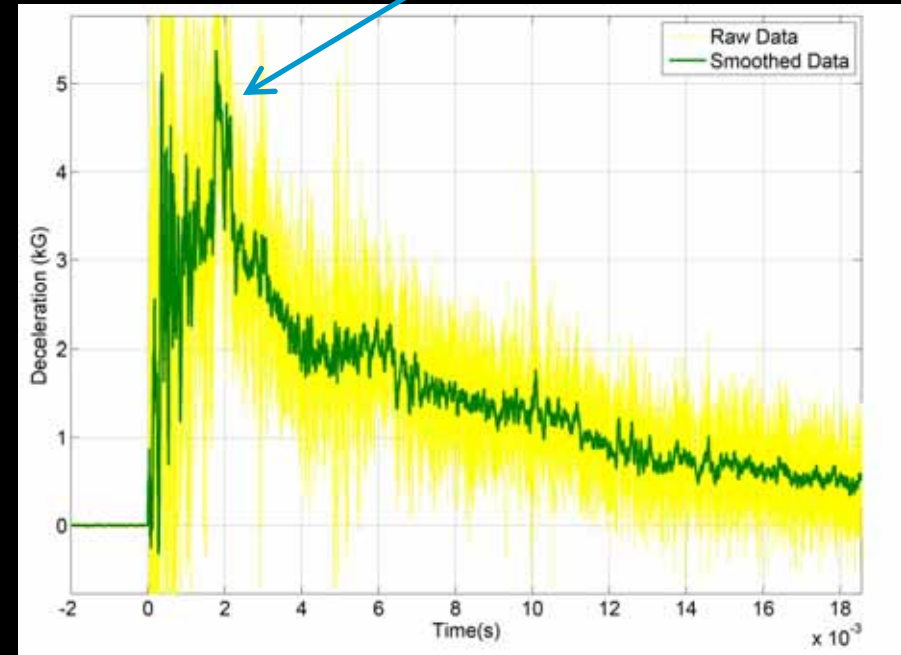
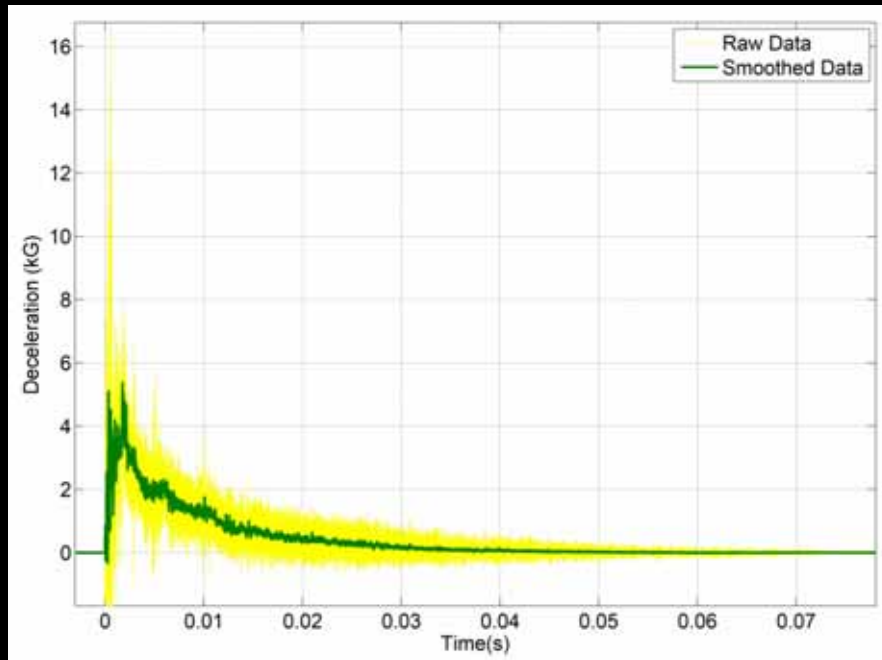


Connecting to MSSL accelerometer and data processing bay

# 1'st Firing – accelerometer data

## (a) Front end (QinetiQ)

hi-time res: 2<sup>nd</sup> peak- > body slap  
higher gee forces than along axis



~ 5 kgee smoothed,  
~16 kgee peak  
high frequency components ~5khz

# 1<sup>st</sup> Firing - accelerometer data

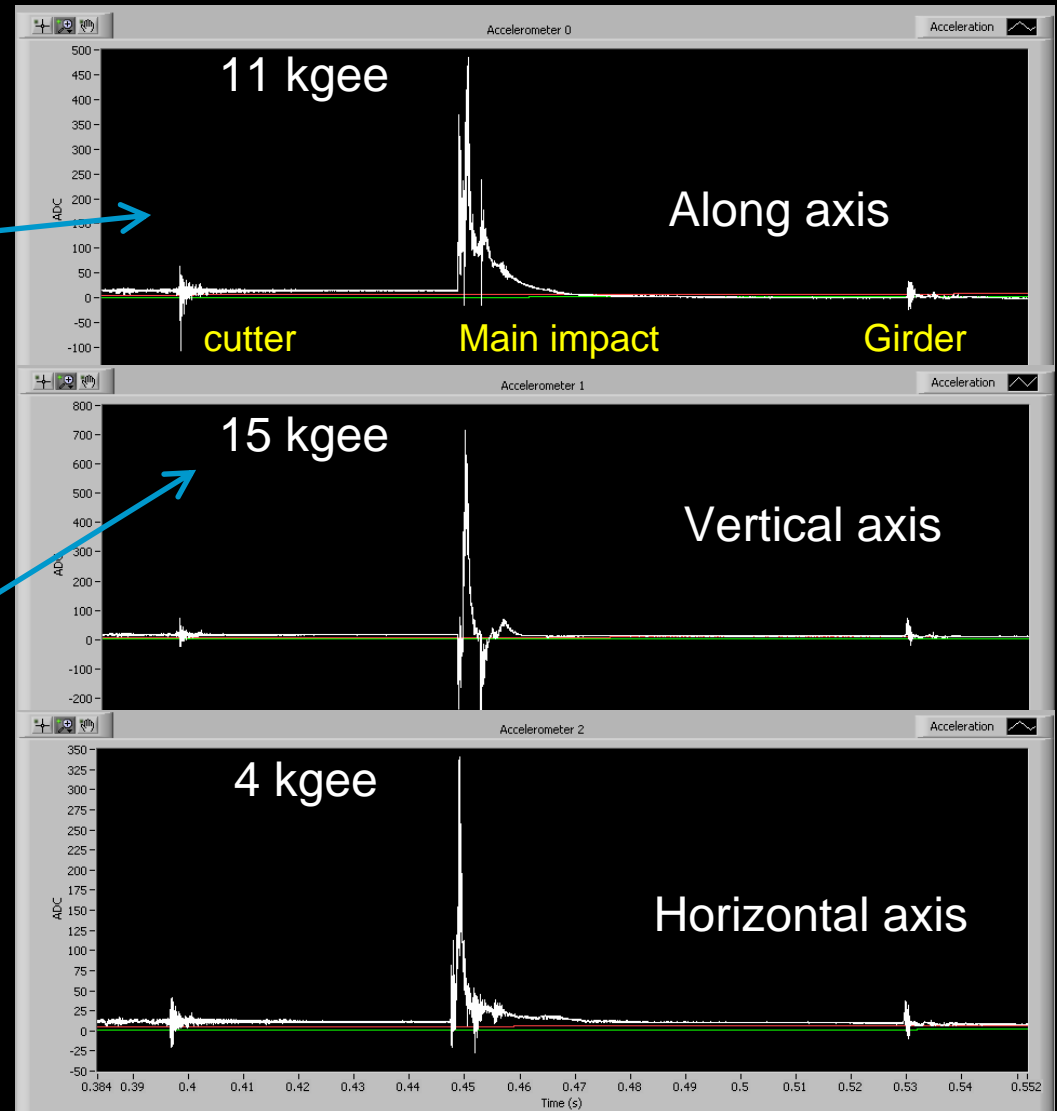
## (b) Rear end (MSSL)

Along axis:

- Cutter impact : 3kgee
- Main impact : 10kgee
- Girder impact : 1kgee

Lateral Axes:

- ~40% more gee forces than along axis.



# 2nd Firing



*“Jaws-3” ?*

..struck steel girder and  
moved it 6 inches

# Survival Table

No critical failures

Triple worst case: exceed 300m/s, >8deg attack angle

Item	Firing 1	Firing 2	Firing 3
Penetrator	✓	✓	✓
Q-accel sys	✓	✓	✓
Rad sensor	✓	not present	not present
Batteries	✓ (reduced capacity)	not present	not present
Drill assembly	✓	not present	not present
Magnetometer	✓	not present	not present
Micro seismometers	not present	✓ (protected suspensions ok)	✓ (protected suspensions ok)
Mass spectrometer + other package elements	not present	✓ x pressure sensor x 3" heating element	✓ x pressure sensor ✓6" heating element
MSSL accel sys	✓	✓	✓

# Impact Trial Objectives

- ✓ **Demonstrate survivability of penetrator body, accelerometers and power system.**
- ✓ Assess impact on penetrator subsystems and instruments.
- ✓ Determine internal acceleration environment at different positions within penetrator.
- ✓ Extend predictive modelling to new penetrator materials, and impact materials.
- ✓ Assess alternative packing methods
- ✓ Assess interconnect philosophy.

# Next Steps & Strategy ...

- Next full scale trial – aiming for 4<sup>th</sup> quarter '09.
- Small scale trials – de-risk full scale trials and allow more complicated scenarios (e.g. regolith layering.)
- Impact into closer representative lunar regolith
- Design for Moon

...and eventually...

- Full-up system (all operating)
- Transmit from target

**in parallel :-**

- MoonLITE Phase-A

# Collaboration Possibilities

- Communications
- Artificial Seismic event
- ILN
- Launch
- Other



- End -



Penetrator website:

[http://www.mssl.ucl.ac.uk/planetary/missions/Micro\\_Penetrators.php](http://www.mssl.ucl.ac.uk/planetary/missions/Micro_Penetrators.php)

email: [rag@mssl.ucl.ac.uk](mailto:rag@mssl.ucl.ac.uk)

