Kinetic Micro-Penetrators For Exploration Of Solar System Bodies.

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What Characterizes kinetic micro-penetrators ?

- Very low mass projectiles ~2-5Kg (c.f. Lunar A 13.5Kg; DS-2 3.6Kg)
- High impact speed ~ 200-500 m/s
- Very tough ~10-50kgee
- Penetrate surface ~ few metres
- Perform initial important science on planetary surface

Planetary Penetrators - History

No survivable high velocity impacting probe has been successfully landed on any extraterrestrial body

~~DS2 (Mars) NASA 1999 ?~~

~~Mars96 (Russia) failed to leave Earth orbit~~

Japanese Lunar-A cancelled
(maybe now to fly on Russian Lunar Glob ?)

Many paper studies and ground trials

TRL 6

Feasibility

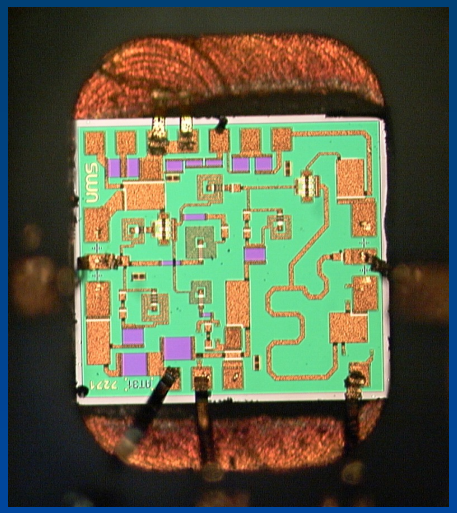
- **There is no 'history' of failures of high speed planetary penetrators.** Has only ever been one planetary deployment - Mars Polar Orbiter DS2 which failed alongside the soft lander.

- Military have been successfully firing instrumented projectiles for many years to at least comparable levels of gee forces expected. Target materials mostly concrete and steel.
  - **40,000gee qualified electronics exist (re-used !)**
  - **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' !**

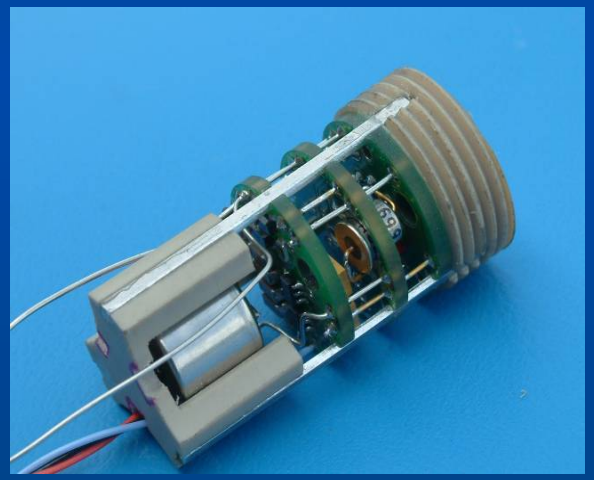
Examples of hi-gee electronic systems

Designed and tested :

- Communication systems
  - 36 GHz antenna, receiver and electronic fuze tested to 45 kgee
- Dataloggers
  - 8 channel, 1 MHz sampling rate tested to 60 kgee
- MEMS devices (accelerometers, gyros)
  - Tested to 50 kgee
- MMIC devices
  - Tested to 20 kgee
- TRL 6



MMIC chip tested to 20 kgee



Communication system and electronic fuze tested to 45 kgee

Technical Roadmap

1. Generic Penetrator Development → confidence building.
   - Ground demonstration
2. Technical Demonstrator Mission → confidence building.
   - MoonLite UK initiative
   - LunarEX (Cosmic Visions Proposal)
3. Scientific Missions → delta development, delta costs.
   - Europa (Cosmic Visions Proposal)
   - Tandem (Titan-Enceladus) (Cosmic Visions Proposal)
   - Other possibilities (Mars (seismic network), NEO's/asteroids (accelerometers0

- UK Penetrator consortium **has funding awarded** to provide ground impact demonstration tests in next 2 years.
- Because of lead times we are working on above largely simultaneously
- Consortium is being gradually internationalised.

Suitable Bodies for Investigation ?

- Moon (MoonLite- UK Intiative/LunarEX – Cosmic Vision)
  - is closeby – ideal technical demonstrator + excellent science (polar water, core structure, astrobiology …)
  - Airless -> like Europa, Enceladus
  - Very cold (polar traps) -> like Europa,Enceladus,Titan
- Europa,Titan/Enceladus (Cosmic Vision)
  - Astrobiology, interior ocean(s).
  - Europa – very high radiation environment
  - Titan has an atmosphere – different approach !!!
- NEO/Asteroids
  - Accelerometer particularly interesting for investigating internal structure
- Etc, etc, (Mars, Venus, Mercury, Neptune, Pluto, Uranus)…

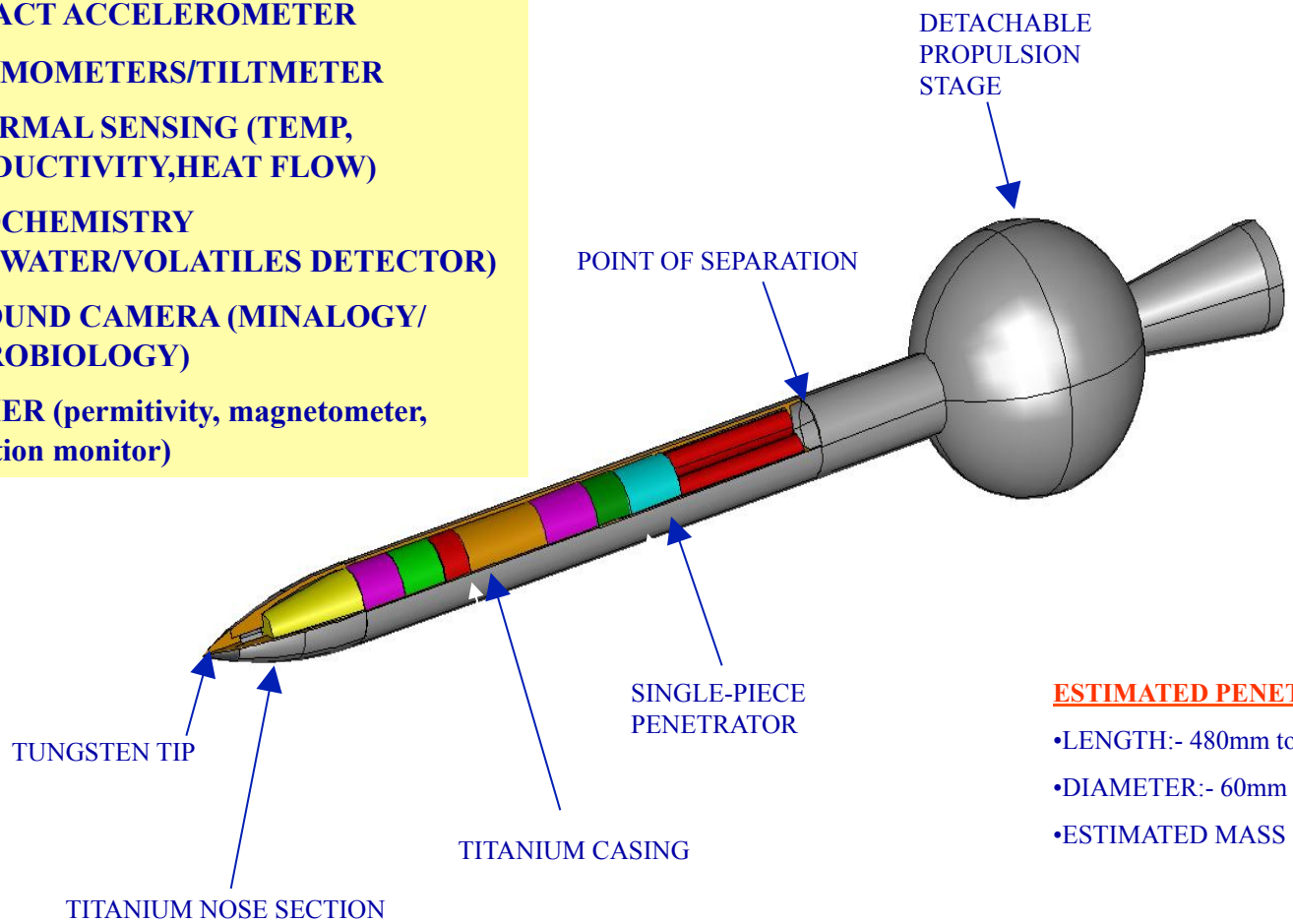
Penetrator Design Concept

Payload

- DESCENT CAMERA
- IMPACT ACCELEROMETER
- SEISMOMETERS/TILTMETER
- THERMAL SENSING (TEMP, CONDUCTIVITY,HEAT FLOW)
- GEOCHEMISTRY (E.G. WATER/VOLATILES DETECTOR)
- GROUND CAMERA (MINALOGY/ ASTROBIOLOGY)
- OTHER (permitivity, magnetometer, radiation monitor)

Platform

- S/C SUPPORT
- AOCS
- STRUCTURE
- POWER/THERMAL
- COMMS
- CONTROL & DATA HANDLING



ESTIMATED PENETRATOR SIZE

- LENGTH:- 480mm to 600mm (8:1 to 10:1 RATIO)
- DIAMETER:- 60mm
- ESTIMATED MASS 6-8kg

PROS and CONS ?

PROS

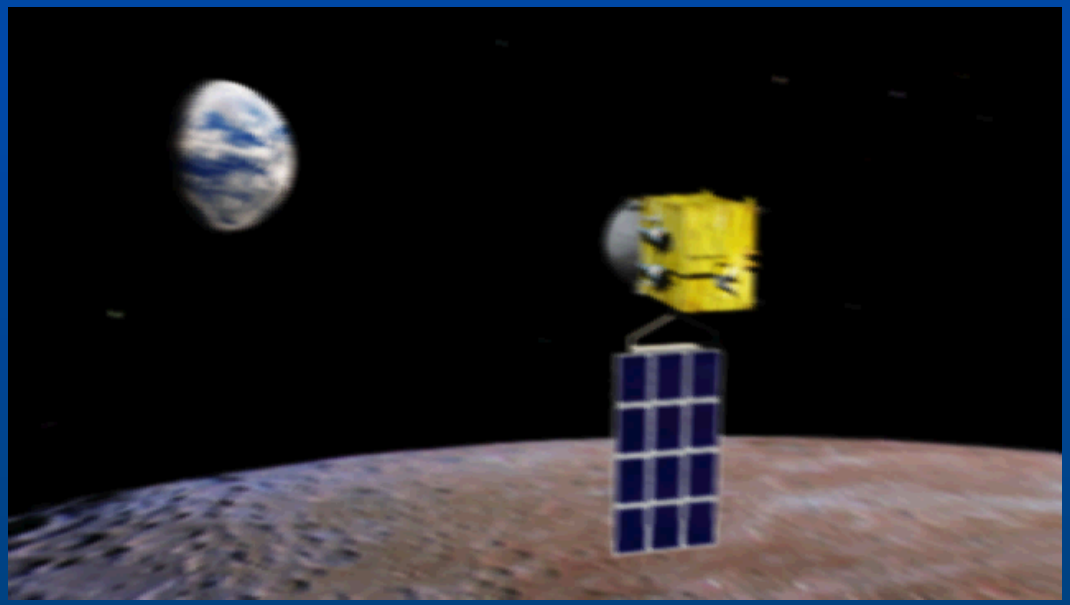
- It is difficult to envisage any other method which allows widely spaced surface exploration of airless planetary bodies that is not prohibitively expensive. (because they are low mass, and largely generic)
- Thruster descent technology through an atmospheric body can allow more specific targetting of surface locations for investigation than for parachute or balloon investigations.
- Can target areas (e.g. more rugged) which are not accessible to soft landers.
- Mostly autonomous so very little ground operational support requirements.
- Provide ground truth, with feedback to interpreting orbiting instruments.

CONS

- Can achieve key science, but low payload mass and high-gee constraints will limit capability c.f. soft landers.
- Communications through surface material can be a challenge. (may require a trailing aerial)
- Surviving for long periods for e.g. seismic network will be a challenge with limited mass. (Insulation and RHU's with primary batteries)

…good for pre-cursor investigations, seismic networks, and cost effective targetting of specific terrain features.

Last day today (Cinderella time) to sign up support for LunarEx Cosmic Visions Bid email: as@mssl.ucl.ac.uk

See **http://www.mssl.ucl.ac.uk/planetary/missions/**

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