The Development of the "Mole with Sampling Mechanism" Subsurface Sampler

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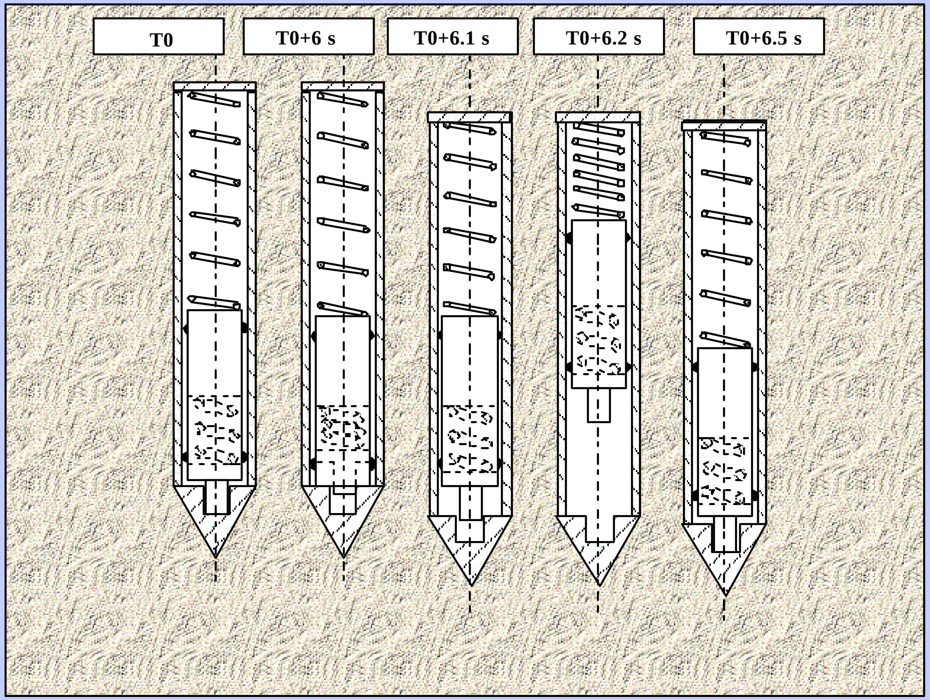
Subsurface access on planetary missions

- subsurface samples and / or access of in-situ sensors to the subsurface on planetary landing missions scientifically useful for
  - acquisition of material protected from current surface conditions
  - investigation of physical & compositional properties of soil as function of depth (stratigraphic relationships, layering)
  - geophysical studies (e.g. measurement of interior heat flow below the planet’s thermal skin depth)
- Mars: acquisition of subsurface soil samples particularly important (exobiology)
  - VIKING: no detection of organics in surface samples
  - subsurface material believed to have been protected from stipulated strong oxidants at immediate surface, and from solar UV
  - such samples expected to have preserved organic molecules imported through meteorites, and possibly from earlier biological activity

Mole development in ESA TRP

- from 1995-97: development of initial prototype of compact, percussive Mole (325 mm length, 20 mm diameter, 400 g mass) for self-penetration into soil-like materials
- 2000-2001: development of a “Mole with Sampling Mechanism” (MSM):
  - requirements relevant to subsurface sampler for BEAGLE 2, requiring length reduction of Mole
  - development of soil sampling capability (one sample of - 100 mg at a time)
  - development of retrieval mechanism for returning Mole to the surface (including Mole reverse hammering capability)
  - specified accessible depth: up to 2 metres
  - study of accommodation of in-situ sensor heads inside Mole for measurements in the subsurface
  - anticipated mass of complete system: - 1 kg

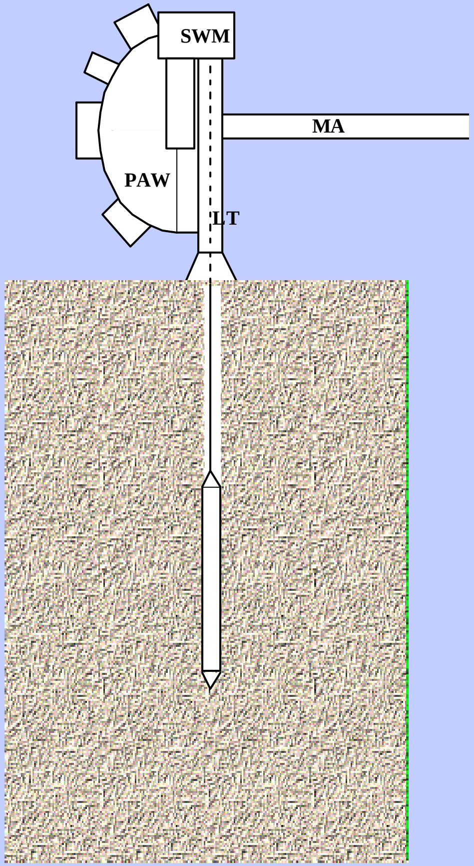
Original Mole

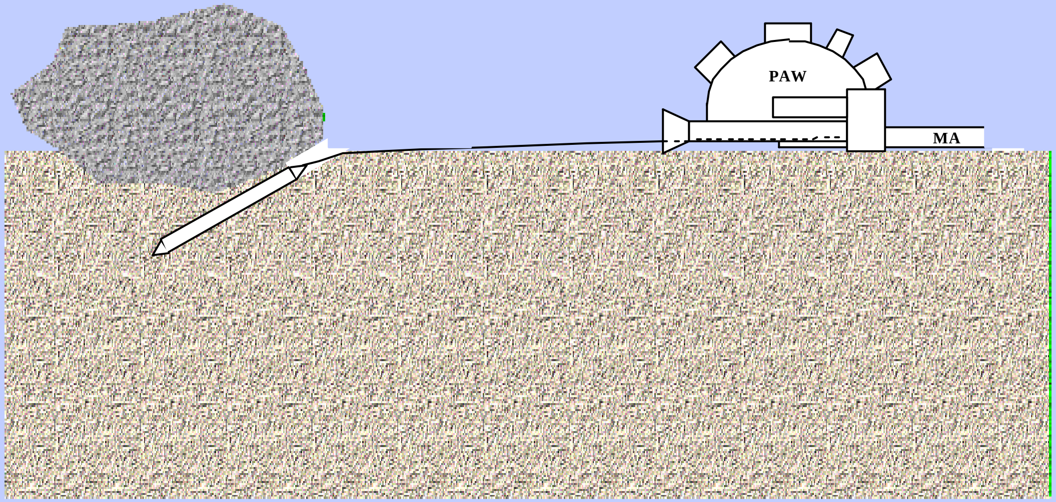


Mole principle

- sliding hammer mechanism in a closed casing
- single actuator compresses main spring
- light striking mass impacts against casing with large force causing elastic & plastic soil displacement
- heavy suppressor mass compresses weak brake spring with brake spring force being below friction of casing with surrounding soil
- second shock from internal hammer falling back to initial position: again causing elastic & plastic soil displacement
- energy delivered to soil as sum of both shocks: - 0.1 Nm
- one shock cycle every - 6 s
- plastic deformation of soil in longitudinal direction per shock cycle - i.e. the “set” - is typically a few mm
- penetration down to m-scale may take several h but time usually not critical

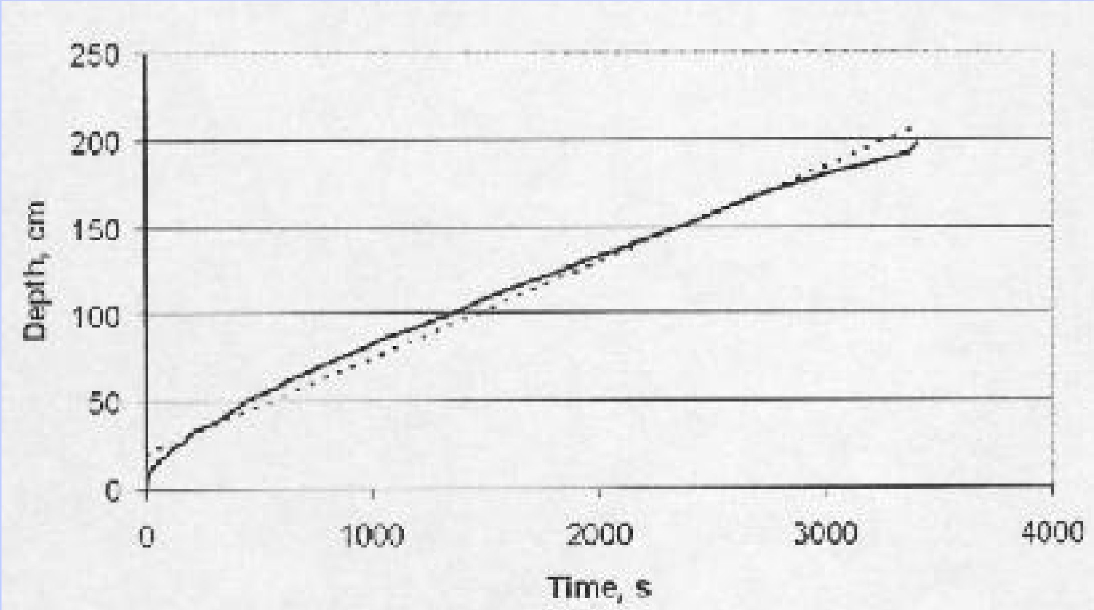
Application on BEAGLE 2





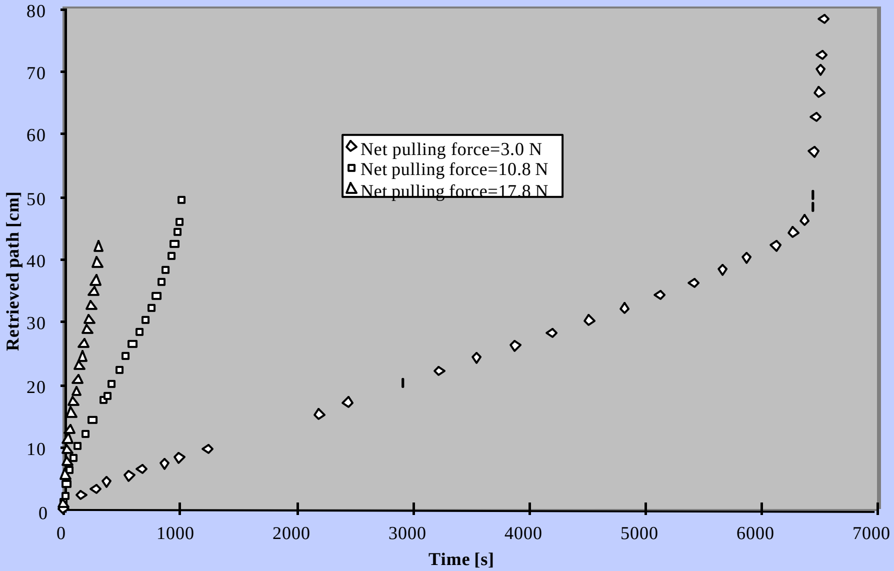
Mole soil penetration characteri-zation

- intrusion testing into Martian soil mechanical simulant
- resistive force against intrusion increases with depth & with gravity (for constant shock energy, limit depth for soil penetration)

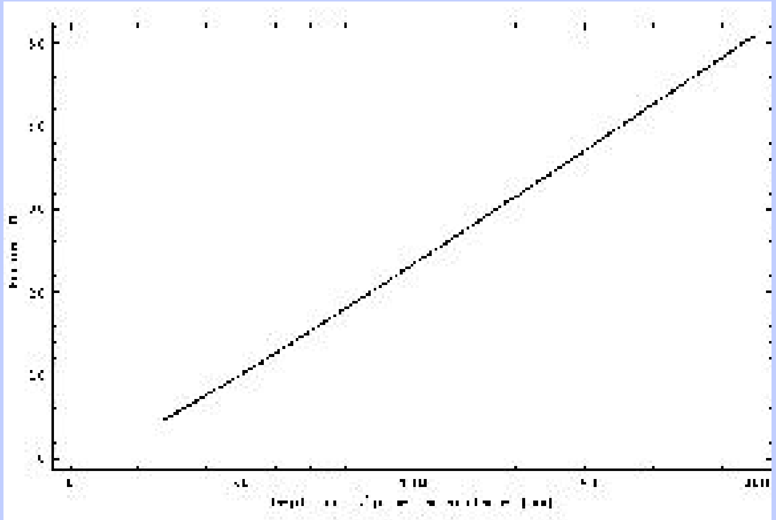


Mole retrieval

Retrieval from quartz sand barrel (collapsed hole) with reverse hammering



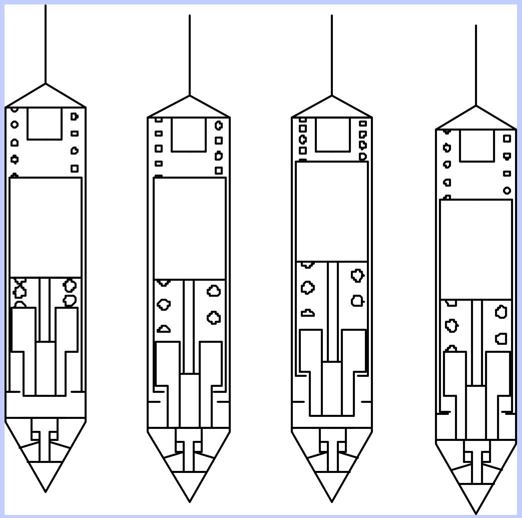
Predicted retrieval force without reverse hammering, in Martian soil, at Mars gravity



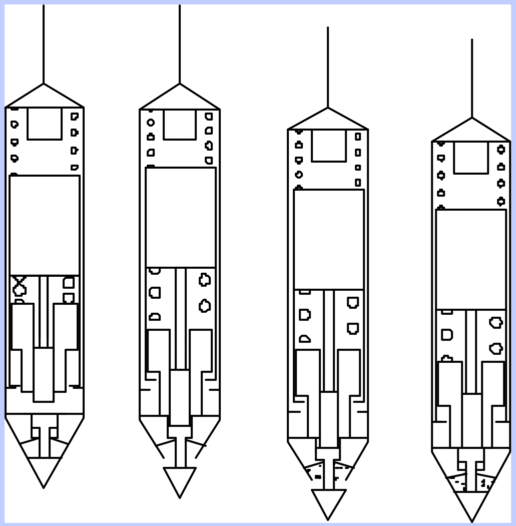
MSM Mole - design principle

- new shock mechanism design for:
  - forward hammering
  - opening of soil sample volume
  - reverse hammering to support retrieval

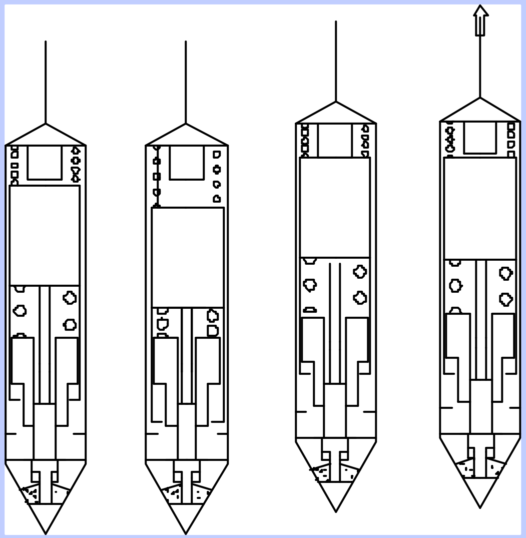
Forward hammering



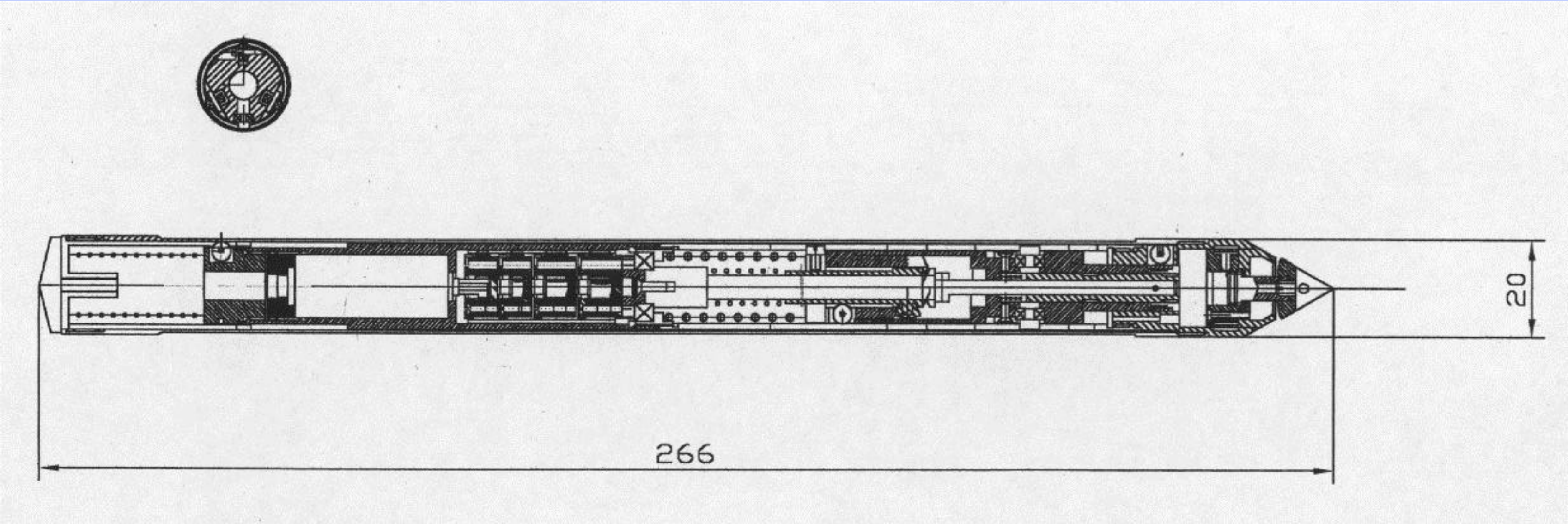
Sampling



Reverse hammering



MSM Mole - mechanical design



Development schedule

- functional testing of MSM Mole (penetration, sampling, retrieval) under ambient conditions: Nov.-Dec. 2000
- environmental testing of MSM Mole at level of Qualification Model: Feb. 2001
- until end of 2000: actuator adaptation programme for Mars environmental conditions

Conclusions & outlook

- self-penetrating, percussive Moles are lightweight & compact, and attractive for
  - subsurface soil sampling down to several metres of depth (exobiology missions)
  - in-situ measurements in the subsurface
- development of small Moles has been going on in the TRP programme since 1995
- first use of small Mole on a landing mission: BEAGLE 2, for subsurface soil sampling
- possible other applications:
  - carrier for in-situ sensor heads on BEPI COLOMBO mission
  - subsurface soil sampling on further Exobiology missions to Mars (“Subsurface Probe” in the ESA Life Sciences Programme)