Lunar Penetrator Technology for Ice Detection

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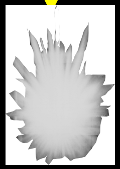
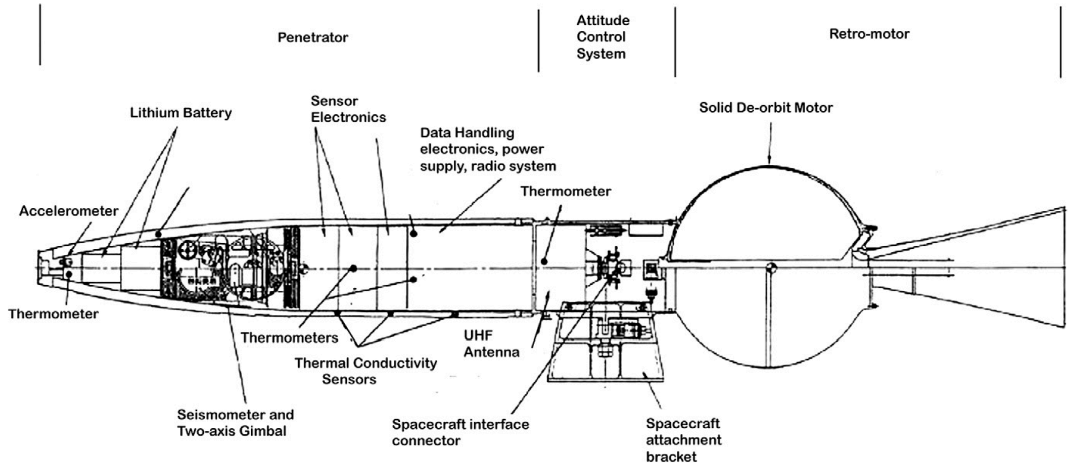
What are kinetic penetrators ?

- Instrumented projectiles
- Survive high speed impact ~ 300 m/s
- Penetrate surface ~ few metres
- A complementary alternative to soft landing
- Lower cost and low mass => multi-site deployment



Typical Penetrator Design

Lunar-A penetrator



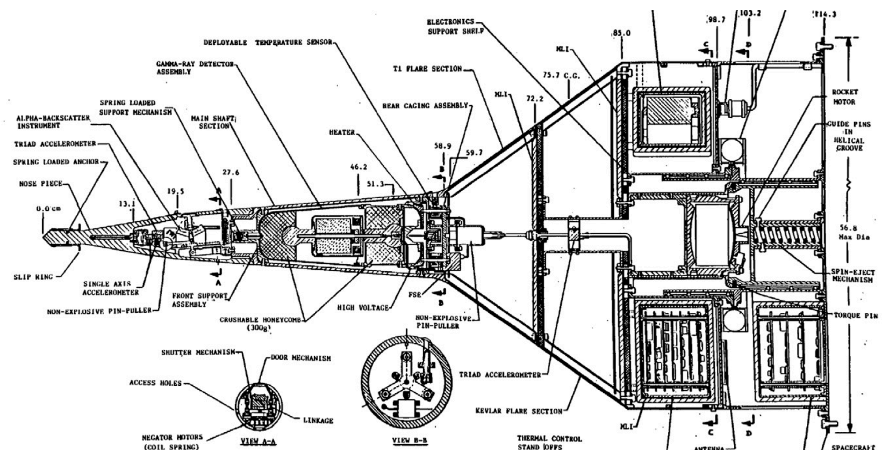
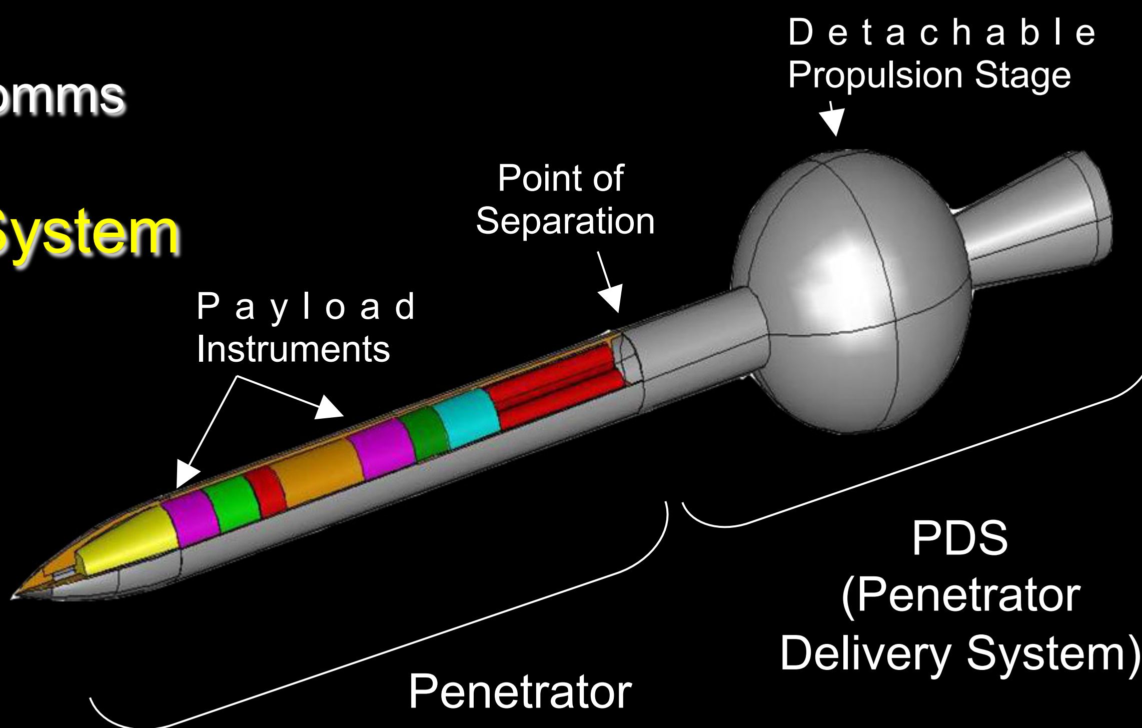


Figure 2-1a Baseline Penetrator Design

Fig. 12. Original, detailed design of the CRAF penetrator, from a 1986 Martin Marietta NASA study (Adams et al., 1986).

Architecture

- Spacecraft Support
  - attachment, power, comms
- Penetrator Delivery System
  - structure
  - thruster
  - ACS
  - Camera
- Penetrator
  - platform
    (structure, power, comms, data handling)
  - instruments



Justification

- A single penetrator with neutron detectors and mass spectrometer could measure the abundance (with depth), phase, and isotopic ratios of H-bearing species
- Multiple penetrator probes could do this for diverse (thermal) environments
- Without a sampling system and mass spec, could still get abundance and distribution of H-bearing species

History

- First detailed planetary penetrator discussion is probably a Mars Penetrator design in 1974 at Sandia National Labs based on military technology
- Targets for studied, proposed, or flown missions include: Mars, Moon, Mercury, Vesta, icy satellites, comets, and Earth

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09
Mars	S	D	D	D	S	S																													
CRAF												S	S	S	S	S	D																		
Lunar-A																S	S	S	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D		
DS-2																						S	D	D	D										
Mars-96																	S	D	D	D	D	D													
VESTA														S																					
Marsnet																			S																
Metnet																												S	S	S	S	S	D	D	D
MoonLITE																																	S	S	

(From Lorenz, 2011. "S" indicates a study or proposal, "D" indicates development or flight)

Payload Accommodation

- ~0.5-1.0 m in length, ~10 cm diameter?
- Neutron spectrometer
- Mass spectrometer + sampling system
- Sampling systems:
  - Passive port
  - Drill + inlet
- Seismometers
- Heat flow + soil conductivity
- Many other possibilities: magnetometer, x-ray spectrometer, alpha proton spectrometer, etc.

Navigation for Airless Bodies

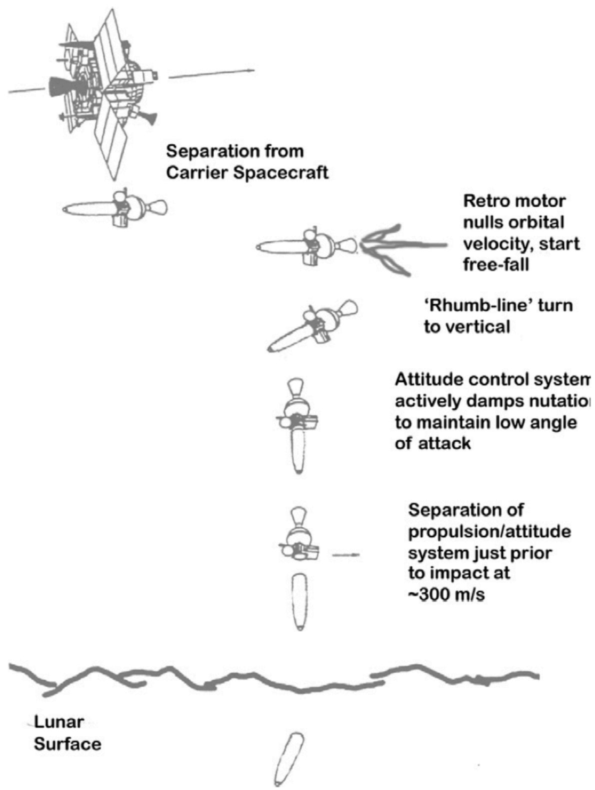
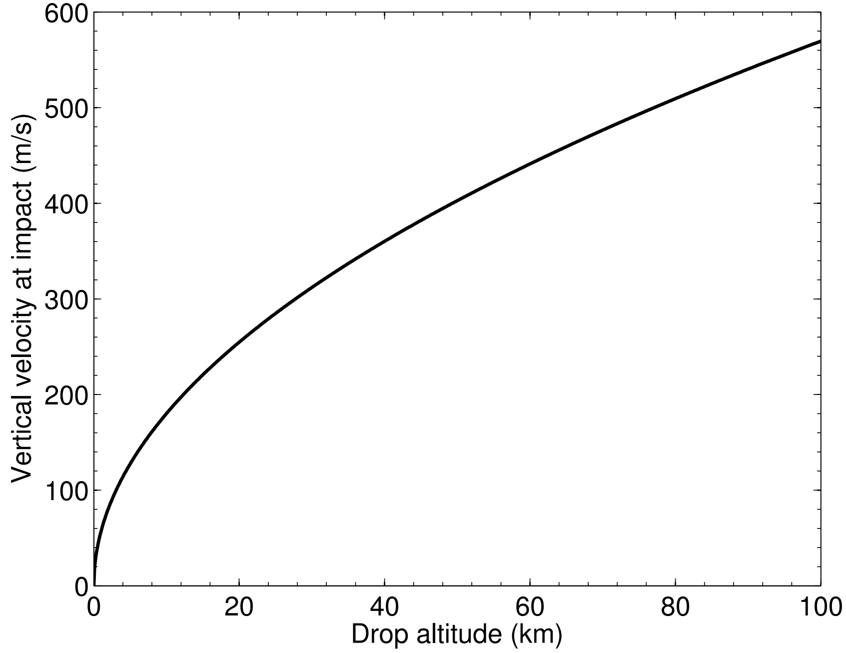
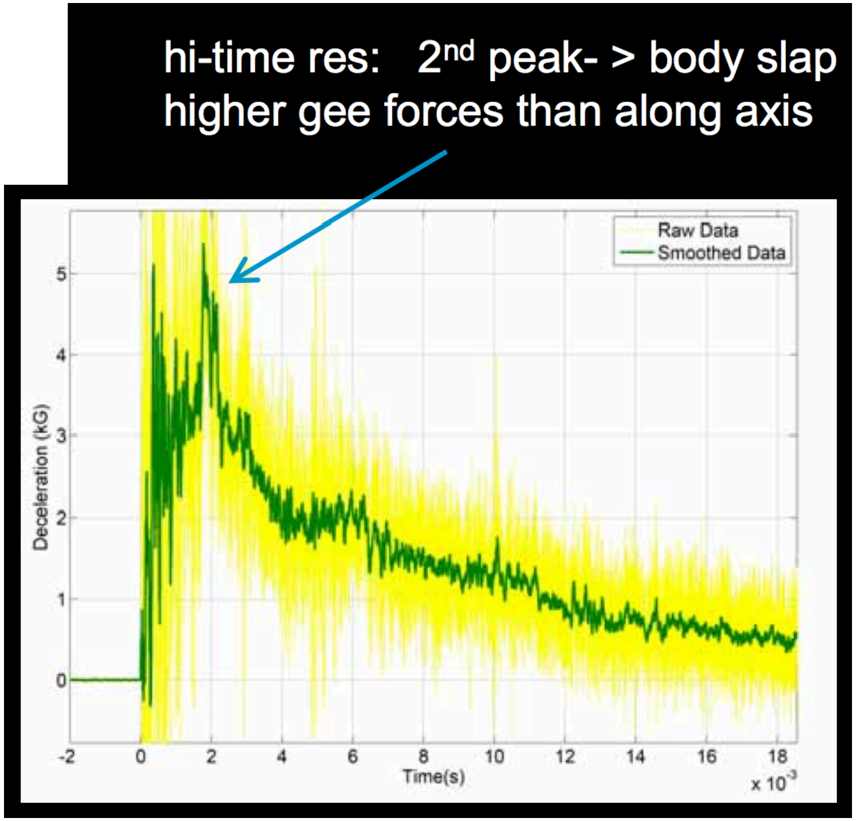


Fig. 21. The Lunar-A delivery concept. The free-fall phase after the motor burn lasts only a few tens of seconds, during which time the vehicle must be precessed around to the vertical. Note that the whole vehicle penetrates the surface (no aftbody), and communicates through the lunar regolith.

- Need spacecraft to get to low lunar orbit
- Decelerate to near zero velocity ("stop and drop")
- Spin rapidly to stabilize orientation

Impact Velocity and Mechanical Loads



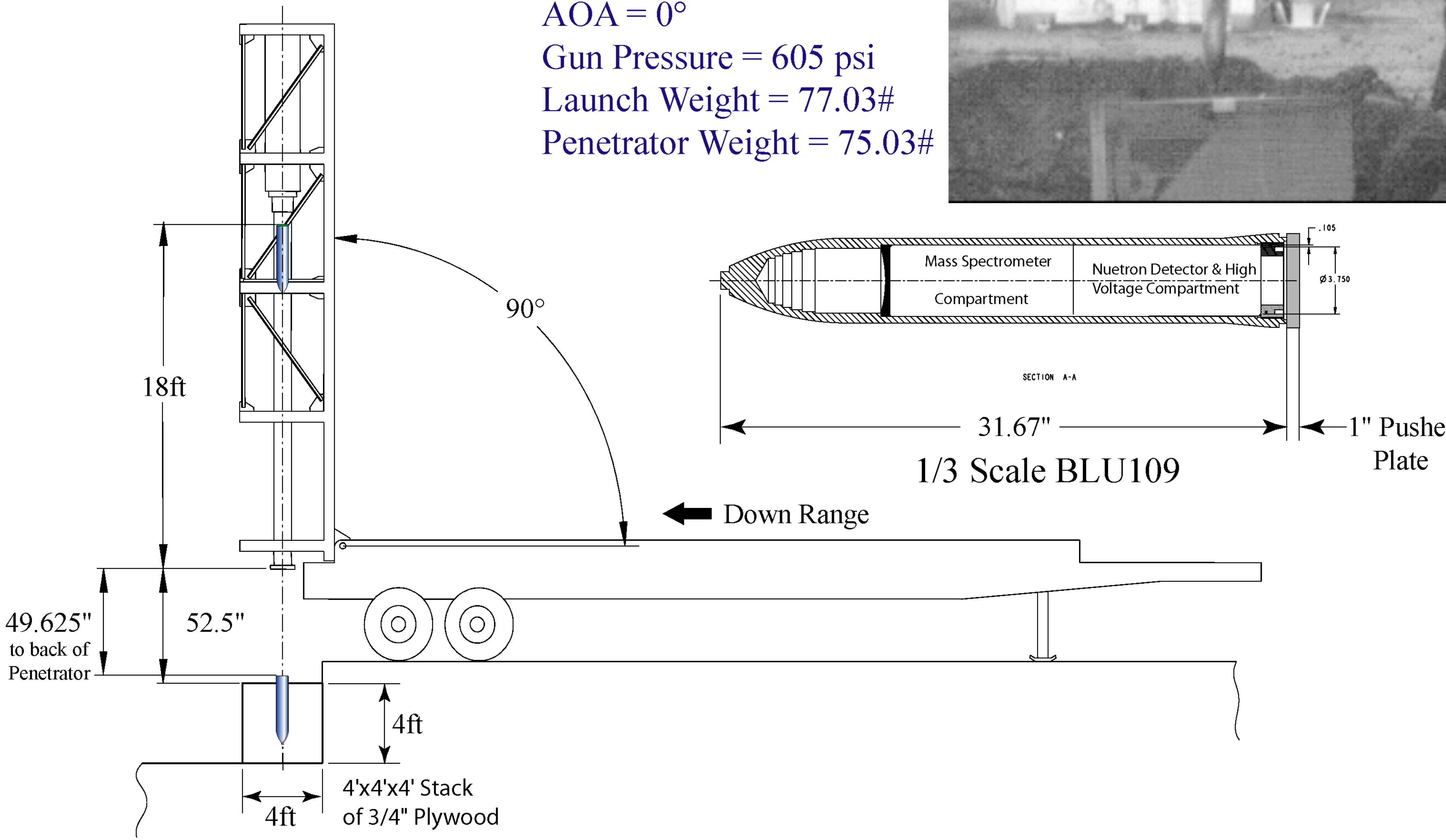


Military weapons technology has proven instrument survival with > 50,000 g and penetration depths of 30 m earth, or 6 m of concrete

PN 1 GAS GUN TEST

PN 1 Test Parameters

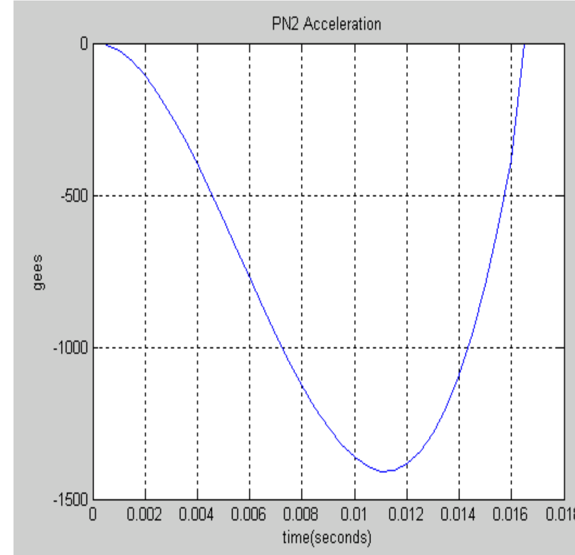
Test Date: 2/20/03
Velocity = 425 ft/sec
AOI = 90°
AOA = 0°
Gun Pressure = 605 psi
Launch Weight = 77.03#
Penetrator Weight = 75.03#

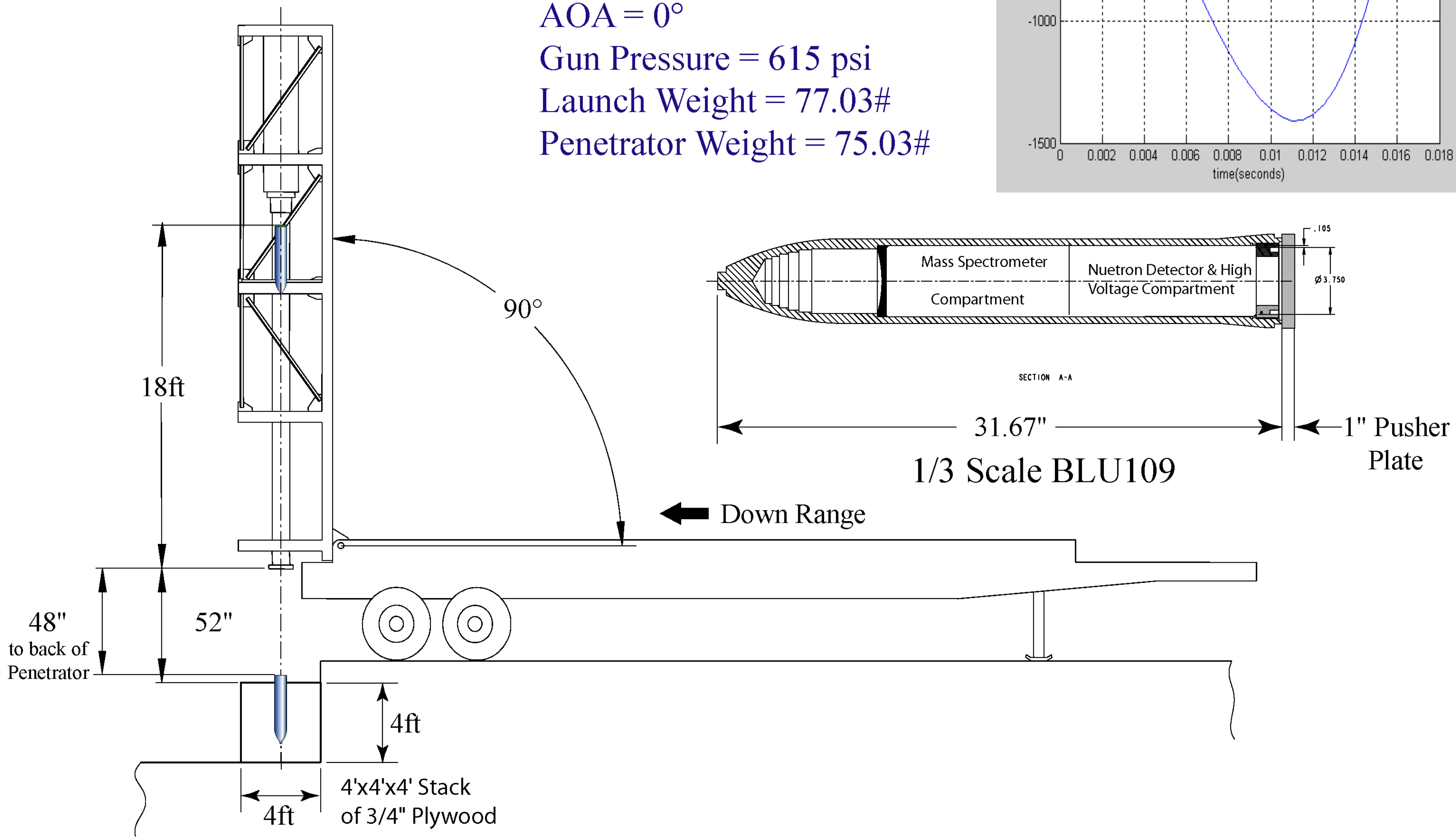


PN 2 GAS GUN TEST

PN 2 Test Parameters

Test Date: 2/20/03
Velocity = 425 ft/sec
AOI = 90°
AOA = 0°
Gun Pressure = 615 psi
Launch Weight = 77.03#
Penetrator Weight = 75.03#





Communications/Telemetry

- Many penetrators use two-body approach, where antenna is left behind at surface
- Mars penetrators used ~1 W power to transmit ~7 kbps to relay orbiter
- How much power is needed to transmit a minimal amount of data direct to Earth? To relay orbiter e.g. LRO?

Fig. 1 Two body penetrator (DS2) [25]

Power and Lifetime

- Typically batteries, sometimes charged by RTG
- 12-hr lifetime without RTG (Polar Night penetrators)
- Lifetime many days with RTG

Cost

- DS-2: ~\$30M (hitched a ride on Mars Polar Lander)
- Lunar-A: \$132M (not completed)
- Polar Night: ?

- What drives cost? Probably spacecraft system to slow down the penetrator. Inexpensive instruments (e.g. neutron detector) exist