ODEHT

Orbital Detection & Exploration
for Helium-Three

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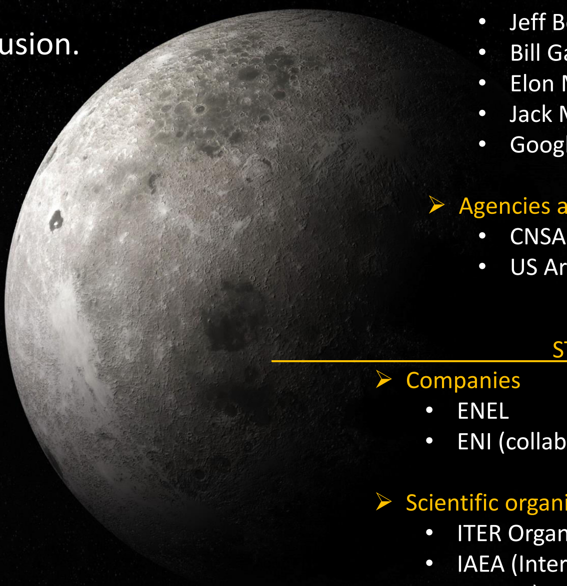
Why Helium-3 on the moon ?

- Future energy source for nuclear fusion.
- Clean energy: non radioactive
- Very rare and expensive on Earth.
  Abundance in lunar REGOLITH:
  ~ 23000 kg
- Great energy power: 4.93 MW/h
  using 3 grams of helium-3
- Huge profit: 20 M$/kg



CLIENTS

- Private
  - Jeff Bezos
  - Bill Gates
  - Elon Musk
  - Jack Ma
  - Google
- Agencies and Governments
  - CNSA / ISRO / ESA / CNES
  - US Army & Government

STAKEHOLDERS

- Companies
  - ENEL
  - ENI (collaboration with MIT)
- Scientific organizations
  - ITER Organization
  - IAEA (International Atomic Energy Agency)
  - JET (Joint European

PRE-EXISTING SPATIALS SOLUTIONS

Any possible terrestrial solution ?

Total amount in mantle 0.1-1million tonnes

Mantle not accessible

Anti economical production

Need to extract it from the Moon

Where is it ?

There is a safe place to extract it?

CHANG'E PROGRAM (2007)

- Image resolution about 10 m
- First complete mapping of Helium-3 density on Moon

CHANDRAYAAN-1 MISSION (2008)

- Image resolution between 5 and 10 m
- No precise map of Helium-3

WHY ARE NOT ENOUGH ?

It's necessary to find a specific safe place with high helium concentration where landing can be successful. Using available data, a rover crashed during Chang'e 3 mission.

WHAT'S OUR GOAL ?

Investigate only the richest area found out by previous missions, increasing the accuracy of the 3D images $\leq$ 5m in order to find optimal area to land and mine.

Mission Statement

To obtain Helium-3 concentration and 3D images of the lunar craters Grimaldi and Riccioli with a spatial resolution $\leq$ 5m.

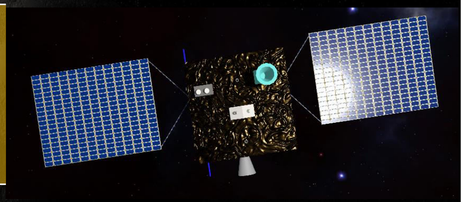
Mission Requirements

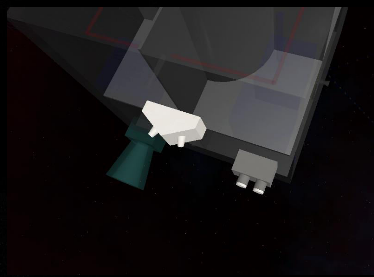
- Satellite must be put in a Low Moon Orbit in order to guarantee full coverage of the craters.
- Instrumentation has to be nadir pointing
- Instrumentation has to have the following accuracy:

INSTRUMENTATION	PRECISION
Altimeter	< 5 m
Polarimetric camera	Photo: 320 nm Polar: 430 – 650 nm
Spectrometer	<4% @661 keV
Camera	450 - 850 nm

Payload

Instrument	Description	Specifications
LTI (CCD sensor)	Perform high-resolution imaging of the lunar surface to locate convenient future landing sites and make a map	Mass =10kg GSD : 4m at 100km Swath: 8 km Power= 7W Cost=50000$
PolCam (Wide-Angle Polarimetric Camera)	Provides new information about the lunar surface working on 2 different modes: Photometric (320 nm) Polarimetric (430, 750 nm)	Mass= 3kg $\lambda = 320{,}430{,}750\ nm$ RES= 80m @h=100km Power=5W Cost=100.000$
GRS (Gamma Ray Spectrometer)	Map the surface distribution of major elements, included water.	Mass : 5kg Power= 18W Cost=50000$
Altimeter	To study global topography of the surface and support the LTI	Mass= 7,5kg Power= 20W Cost=50000$





Launch & Trajectory

ODETH

Launcher: Falcon 9

Launch site: SLC-40, Cape Canaveral (28.56°N 80.58°W)

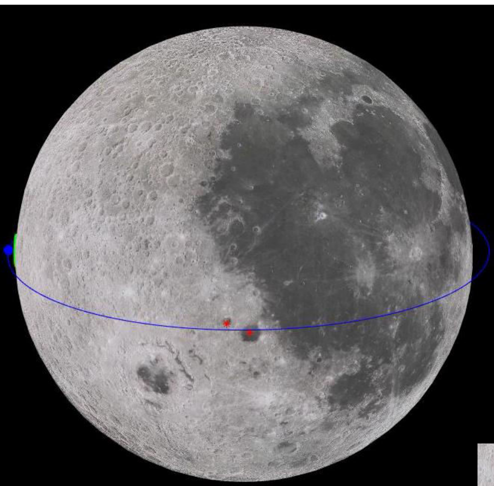
Launch date: 30/08/2024 10:30 UTC

Launcher	Cost	Reliability
Falcon 9	50 M$	97 %
Ariane 5	180 M$	95.3 %
Delta IV Heavy	164 M$	97.5 %

ΔV launcher	11.60 km/s
ΔV spacecraft	1.75 km/s
ΔV tot	13.35 km/s

Flight time: ~18 days

Orbit & Ground Track



- Frozen low altitude and low inclination orbit (60x125 Km orbit):
  - Min ΔV for station-keeping: 100m/s per year
- Trade-off based on:
  - Stability
  - Coverage
  - No collision
  - Revisit time
- 15 minutes per orbit in coverage with short revisit time
- Mission lifetime: 1 year: 17/09/2024 to 17/09/2025

Parameter	Value
a	1825 km
e	0.02
i	3.5°
Ω	11°
ω	180°

Ground segment & TT&C

NASA Deep Space Network

Frequency UPLINK	S-band
Frequency DOWNLINK	X-band
Data Rate	5 Mbit/s
Modulation	BPSK
BER	10^(-6)
EB/N0	11.29 dB
EB/N0 margin	2.2 dB
Power Tx	1.15 W
Gain	37 dB
Antenna diameter	1 m
Antenna efficiency	0,6

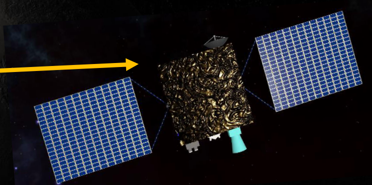
Thermal & Power

GOAL

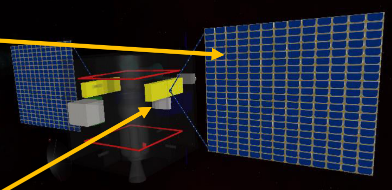
Internal Temperature $\simeq 20°$
Heat Dissipation 280 W

Solar Panel Power 2.2 kW

Thermal protection	*Power* (W)	*Mass* (kg)	*Dimensions*	Cost ($)
Multi Layer Insulation	0	17.52	1.3 cm thickness (15 layers)	3500
Radiator	0	12.98	3.91 m^2	7500
Heater	685	6		4000



Solar panel power	**2200 W**
Average Daylight Power	1200 W
Average Eclipse Power	1200 W
Solar array area	9.66 m^2
Solar panel mass	88 kg
Batteries (Ni-H_2)	2
Battery capacity	652 W hr
Battery mass	18.6 kg



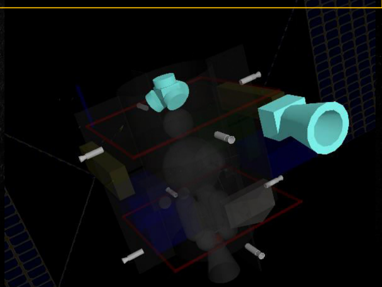
AOCS

GOAL

Control Accuracy $< \pm 1°$
Control Stability $\leq \mathbf{0.005\ \frac{deg}{sec}}$
3-axis stabilized spacecraft

Attitude determination

AOCS Sensor	*Mass for unit* (kg)	*Volume* (mm^3)	*Max Power* (W)	Cost ($)
Sun sensor ×2	0.3	95×107×35	2×(0.35 W)	9000
Star trackers ×3	3	195×175×288	3×(12 W)	270.000
Gyroscopes ×4	7.1 (package)	180×149×289	38 (package)	330.000



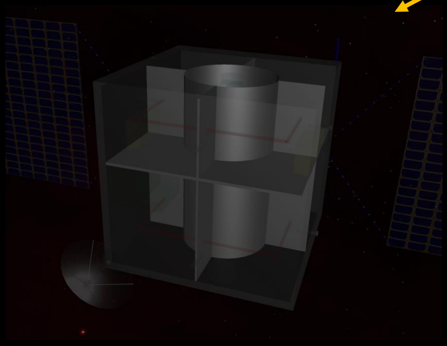
Control System

AOCS Control	*Diameter (mm)*	*Max Torque (N*m)*	*Capacity (N*m*s)*	*Max Velocity (rpm)*	*Mass (kg)*	*Max Power (Watt)*	Cost ($)
Reaction wheel ×4	102	0.02	0.65	9000	1.5	4×(22 W)	11000

AOCS Control	*Mass* (kg)	*Thrust* (N)	*Propellant* (kg)	*Type propellant*	Power	Cost ($)
Thruster ×8	5.2	8×(10 N)	200	Hydrazine (N_2H_4)	8x (3W)	8x20000

Structures & Propulsion

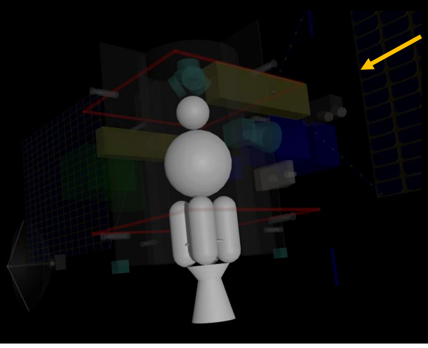
Lightness of the payload and central cylinder structure ensure a high safety margin of the mission.



External Panels	
Side	2 m
Mass	100 kg
Thickness	0.002 m

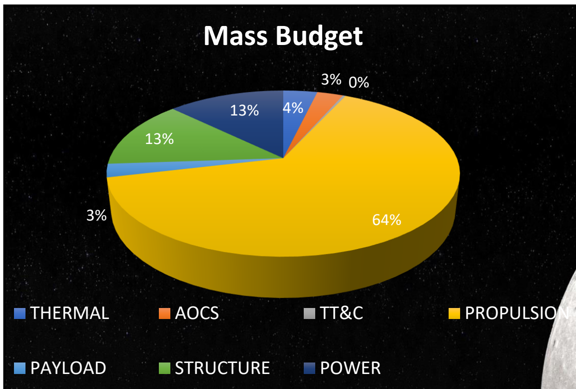
MATERIAL	AZ80A-F
E	45 Gpa
ρ	1800 kg/m^3
σ_y	250 MPa

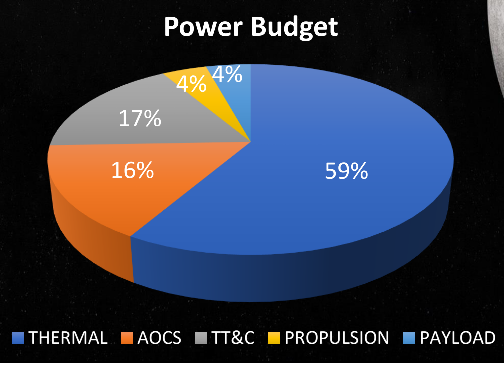
PROPELLANTS	Ox: NTO Fuel: MMH
F_{vac} - Nominal	400 N
F_{vac} - Range	340 - 450 N
$\dot{m}$- Nominal	125 g/s
$\dot{m}$ - Range	106 – 141 g/s
I_{sp}	326 s
Mass engine	4.5 kg
Single Burn Life	0.94 hours
m_{NTO}	266 kg
m_{MMH}	157 kg
Total Power	50 W



Propellant cost	150 k$
Engine cost	700 k$
Structure cost	150 k$

Alimentation	Pressure fed
Pressurizing gas	Helium
Gas mass	5.25 kg





Total cost of the mission, including Launch, Ground Operations and Mission Development :

154 M$