Phobos 2026 - 2070

The rise of the hub of the solar system

What could make Phobos valuable

- It could be a "base camp" for the Mars surface missions (several NASA/ESA studies)
 - Enables purely propulsive (DV = 5.5 km/s) landings-returns on Mars surface, eliminating the need for risky aerobraking
- It may be a binary comet = more ice content (20%-80%)
 - Water is fuel, atmosphere and ... water ... for propulsion around the solar system (just a DV = 1 km/s from Mars escape)
- No atmosphere + very low gravity = a large resource rich space station with built in radiation shielding
- If people are banned from Mars surface, then it a good real time robotic/rover teleoperation base
- Close orbit to Mars (closest moon in the solar system), tidally locked, Mars fills 30% of sky
 - Facing side is warmer, thermally stable, has ~70% less CGR and micro-meteorite risk than interplanetary space, and less than Mars surface ... add spin gravity facilities inside Opik crater and you have a nice environment for work
- This assumes that SpaceX Starship does not quickly become a reliable surface lander and easy to refuel return ship, and that Blue Origin LH2 re-condenser tech works well





Phobos Image from Mars Express

High potential earth events

- International treaties limit the crewed occupation on Mars to a small area with a limited number of people (essentially mirroring what has happened at the South Pole), but robotics on Mars is unlimited.
- Chinese success on the Moon (vs Artemis) rebuilds a western resolve to make a statement with a robust Mars program
- Launching of significant radioactive material though the Earth's atmosphere is banned, creating a need to mine on the Moon and Mars and then transport it the Moon, Phobos and MEO (where NEP cores are attached to spacecraft).

What makes Phobos unique

- As there is no atmosphere and tiny low gravity it is more like a gigantic space station
- Close orbit to Mars, tidally locked
 - Facing side is warmer, has less CGR, micrometeorite risks
- It may be a binary comet = more ice content (20%-80%)
- The DV needed to transit Phobos to LLO is less that LEO to LLO
- Can enable purely propulsive landings and returns on Mars surface, eliminating the need for risky aerobraking and landing ops.



Best case Phobos Eras

- 2030s: Era of unmanned exploration, mapping, testing machinery
- 2040s: Era of the first base, support for Mars teleops, robotics landings
- 2050s: Era of spin gravity, water exporting, MW space nukes, small Mars Crew base (if allowed)
- 2060s: Era of base expansion to 1,000+ people, tourism option testing, 100 person Mars base
- 2070s: Era of 1,000 people per synod commercial crew hosting / tourism
- 2080s: Era of initial Phobos ice caverns and colonization for 10,000+ people, 10,000 visitors per year (\$3M 2-year adventures)
- 2090s: Era of ice cavern towns connected by tunnels





70% Based on Blue Moon Mk2 tech: BE-7, Carbon Composite Tanks, Recondensors

Red Moon LEO <-> Phobos/MLO/LLO Reusable Spacecraft



Radiation Minimizing .7 -.6 Annual limit Dose equivalent, Sv/yr .5 Aluminum shield .4 .3 Water shield .2 Liquid hydrogen shield .1 Top design 40 10 20 30 50 0 Shield thickness, g/cm²



Steps #0 (2026 – 2036)

- Detailed recon of Phobos
- Phobos lander and surface characterizer
 - Japan's MMX will launch in 2026
 - As MMX descends to Phobos for landing, it will deploy a small <u>German and</u> <u>French-built rover</u> based on the <u>MASCOT</u>, which <u>Hayabusa2</u> dropped to tumble around asteroid Ryugu. The rover will travel around Phobos for at least 100 days analyzing the surface.
- Marslink (2028) SX has announced a 2026 mission to Mars
 - Better Mars to Mars and Mars to Orbit comms
 - Better Phobos to Earth (laser) comms

Marslink: Complete Comms





MarsBridge Laser Comms in LEO (3 sats - StarLink integrated)



MarsBridge Laser Comms in LMO (3 sats - MarsLink Comms integrated)



MarsLink based on Starlink

#2. Power & HydroLOX production (2038)

- 3 Phobos Express Cargo (PEC) each with a 20T package
- 20T Water production (1 Phobos Express Cargo)
 - 5T Ice Anchors
 - 5T Ice Melter
- 20T Solar power plant (1 Phobos Express Cargo)
 - 10 T Solar array film -> 2,000 sq meters -> 118 kW peak
- 20T HyrdroLOX production (1 Phobos Express Cargo)
- PEC can return to Earth for reuse



Water is key, more key than Methane

- Water -> breathing, drinking, HydroLOX high ISP engine fuel
- Water (as a liquid) can be moved around the solar system without the boil off losses you get with HydroLOX or MethLOX. It can be converted to HydroLOX when and where it is needed.
- Every hour 1T of HydroLOX is created using 5200 kWh of power, which would require about 1 football field sized thin film (30%) solar array

Phobos to Earth = 109 T HydroLOX < 5 Days of Production





Phobos to Mars = 50T HydroLOX (refuel on Mars)







Robotics and EVAs plug parts together On Phobos





Broadband Marslink enables real time, high definition telerobotics on Mars (and Phobos) from Phobos (2040?)



Phobos OTV (2042 to Mars)

- 10T Dry Mass HydroLOX Spacecraft refueling and operating out of at Phobos.
- A Starship OTV can send 45T to MTO and then return to Starship for reuse (~\$20M/mission).
- Phobos OTV can "catch" 45T passing near, so just fuel costs to send these packages.
- Can also rescue incoming spacecraft if they can't thrust to Phobos.





OTV

10T OTV + 250T fuel (~ 10 days of production) + 4 km/s To Rendezvous -> 10T OTV + 105T fuel

OTV + Payload

10T OTV + 45T Payload + 105T fuel 4 km/s To Enter Phobos Orbit ->10T OTV + 45 T Payload





#4 Building up Phobos Base (2044) Add 1/3 g spin gravity centrifuge with 2 habs (6 40T packages) Phobos OTV catching 40 T packages



Mars Taxi (2048)

- Mostly propulsive
- Optimized for a crew of up to 10
 + 5 tons of total payload
- Designed to land at a Mars base
- Mars water to HydroLOX refuels ship
- Reworks Blue Moon Mk 2 tech



First Crewed Mars Base 2050 (4-6 crew)



2050s



1 Phobos OTV catching 6 40 T packages every Synod



Phobos Water for NRHO (2050s) ...

- Use Nuclear Electric Propulsion (NEP), slower transfers but more DV efficient than Holman, Use Uranium from the moon? (South Pole Aitken Basin)
- DV < 3 km/s to NRHO (starting full) and < 3 km/s back (near empty). DV from Earth surface is about 14 km/s by comparison (~25x fuel use)
- Heat from NEP keeps water liquid
- Minimal pressure allows a thin composite water tank
- Spin gravity keeps water pipe pressurized
- First break apart the H20 into H2 and O2 for the ion engine (increases ISP)
- At an ISP of 2000s >900 T of water can be delivered to NRHO with 2 T remaining to support the return to Phobos
 - Much higher ISPs may be possible
- Run cost of \$20M amortizing the cost of the Phobos Water Tanker (PWT) over 20 runs + cost of water production in Phobos

NEP ref: https://www.sciencedirect.com/science/article/pii/S2352484722014123

10T Dry Phobos Water Tanker:

trips of Blue Moon Mk2







Trade Routes

- Assume Mars and Phobos are rich in water
- From Mars to Phobos: Nitrogen, Argon, Uranium
- From Phobos to Mars: ?
- From Phobos to Moon: Water, Mars sourced Uranium
- From Moon to Phobos: ?
- From Earth to LMEO: Spacecraft, supplies



Phobos Cruiser (2060)

Reuse radiation shield water for fuel Up to 100 crew possible 20-25 cm of water Water taken from front first Dry mass of ship, people and cargo is ~ 2000 T (mostly carbon composite structure) rotation 200 m Optional Ice Miner (For Asteroid Belt) 40 m diameter hab sphere, 25 cm of water = 2500 T of water 5000 kW reactor = 30 days to make enough HydroLOX to break Ť Assume 2KT dry mass + cargo _0.4g

To Phobos: 3 water tankers from Phobos fill ship in LEO Water layer, LOX and LH2 tanks start full (~5000 T), then all burned to get to MTO

LOX & LH2 empty during most of flight to Phobos Some water is then converted to HydroLOX near Phobos Orbit over 30 days for the burn into Phobos

~1100 T of water (and wastewater) is dumped before Phobos burn. Water is refilled at Phobos with Phobos water

To Earth: water tank is full, LOX and LH2 tanks are partly full (just 2500 T of fuel needed for ETO). The burn to ERO empties the LOX and LH2 tanks 40 days before LEO the reactor makes the rest of the water layer to LOX and LH2 for the burn into LEO

5000 kW reactor

Aluminum shield

40

Annual limit

Water shield

Liquid hydrogen

30

Shield thickness, g/cm²

ISP = 500 sec

25 cm water layer cuts radiation by 50+%

This design



LEO <-> MTO =3.8 km/s (sizes LOX/LH2 tanks)

MTO <-> Phobos = 2.4 km/s (sizes Water needs)



https://ntrs.nasa.gov/api/citations/19900008219/downloads/19900008219.pdf

10

20

Dose equivalent, Sv/yr

Phobos Solar Cruiser (2050) frame this could be built at ~90 T in MEO

50 Crew +

supplies = 20 T

0.3 g

Using 0.1mm metal coated mylar over a carbon composite



Partial pressure ATM w/ backup

Tension Wires (Deema)

50 Crew + supplies

Leaves for outfitting:

20

20

20

58

60

80

100

Focus challenge: ~5 km/s Earth -> Mars Fast Transfer is needed, so it will be leaving the mirror at about 1.9 km/s average over ~5000 seconds. Thus, the system must be able to focus on target (maybe 5 m radius spot) for 1000 -> 12,000 km in distance.

| Payload (Tons) | System | lsp (s) | Water Needed (Tons) | Dry Mass (Tons) | Total Wet Mass (Tons) | Thrust (N) | Acceleration (m/s²) | Burn Time | Total Mission Time |
|-------------------|---|------------|---------------------------|-----------------------|--------------------------------|---------------|------------------------|--------------|--------------------------|
| 100 | LHWP (Laser- Heated Water, 30 MW) | 1,500 | 54 | 15 | 169 | 300,000 | 3.0 | ~1 hour | ~3-4 months |

Hybrid Solar Thermal Propulsion (45 Days from LEO to Phobos) using LH2

Payload Mass for the LEO to Phobos Transfer Mission

We previously designed the mission with the following mass breakdown:

| Component | Mass (Tons) | large solar | |
|---------------------------------|-------------|--|--|
| Total Wet Mass | 334.5T | collectors | |
| LH ₂ Propellant Used | 127T | $(1200m^2 \text{ total})$ | |
| Dry Mass | 20T | | |
| Engines & Tanks | 80T | Payload Breakdown | |
| Power & Radiators | 50T | Scientific Instruments & Cargo: 30T | |
| Payload | 57.5T | Crew Module & Life Support (if manne Communications & Navigation: 7.5T | |

| Phase | Duration | Objective | Δv Contribution | LH₂ Used |
|---------|----------------------------------|-------------------------------|-----------------|----------|
| Phase 1 | LEO Spiral Escape (~4.5 days) | Escape Earth's gravity well | ~3.2 km/s | 55T |
| Phase 2 | Interplanetary Cruise (~33 days) | Adjust trajectory toward Mars | ~2.4 km/s | 50T |
| Phase 3 | Mars Arrival (~5 days) | Reduce velocity for capture | ~0.4 km/s | 10T |
| Phase 4 | Phobos Rendezvous (~2.5 days) | Final orbital insertion | ~0.2 km/s | 6.5T |

Total Mission Timeline:

| Phase | Time (Days) | |
|--|---------------------------|---------------|
| Outbound Trip (LEO \rightarrow Phobos) | ~45 days | |
| Phobos Stay (Waiting for Return Window) | ~390 days (avg.) | |
| Return Trip (Phobos → LEO) | 100% refuel | ~120–150 days |
| Total Mission Duration | ~1.5 years (555–585 days) | |



Here is the velocity vs. distance to Mars plot for the LEO to Phobos transfer using a Solar Thermal



Detailed Analysis: https://chatgpt.com/share/67af6b64-59f4-8002-bc50-15528bde7f40



Also use for water mining of Phobos Also use for lunar illumination

- Can use LH2 (45-day trip) or Water (4-month trip)
- Eliminates the need for Nuclear Engines, but results in as good or better results

Low Altitude Mars Sightseeing (2060)

• For a small DV from and back from Phobos, a group of sightseers could spend a day flying very low (100 km) over most of the features on Mars.



Habitation of sealed ice caverns after being mined for ice (2070?)

- After 30 years of ice mining these caverns may be available for habitation.
- Temps would need to be raised to 20 F, and O2 replenished as it leaks out to allow for helmets-off living.
- Spin gravity habitats would compliment to open space, providing 1/3 g apartment like living.

