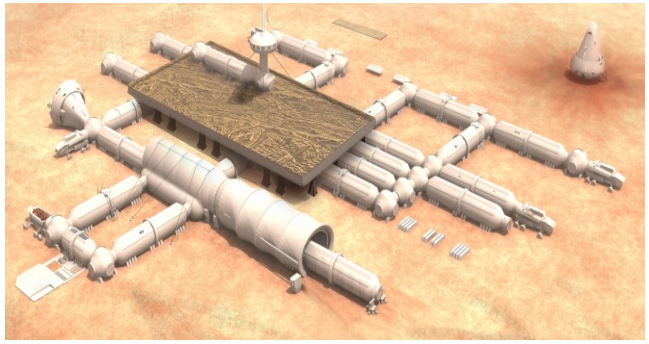
Mars, Gateway to the Solar System



Bruce Mackenzie, Mars Foundation, Mars Society, NSS
BMackenzie @ alum.mit.edu

Assume **widespread civilization** around solar system.
Uneven distribution of natural **resources**, energy, labor -
… thus Solar-system wide **Trade** will be inevitable.

How might Mars Industry help settlement of Asteroids, Luna ?

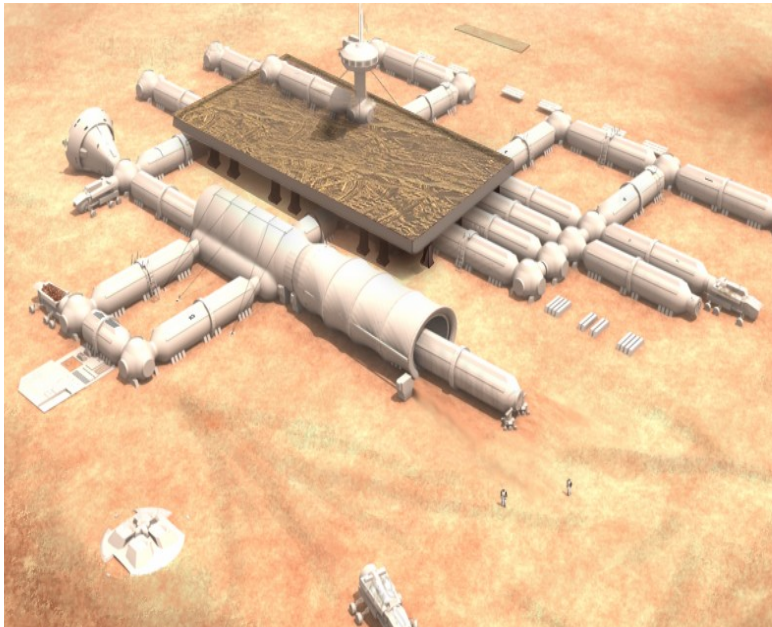
Exports from Mars to pay for imports?
Exports from Mars Orbital Stations, Phobos, and Deimos?

How might goods be **launched** out of the Mars gravity well?
? Will Mars have **advantages** in solar-system wide trade ?

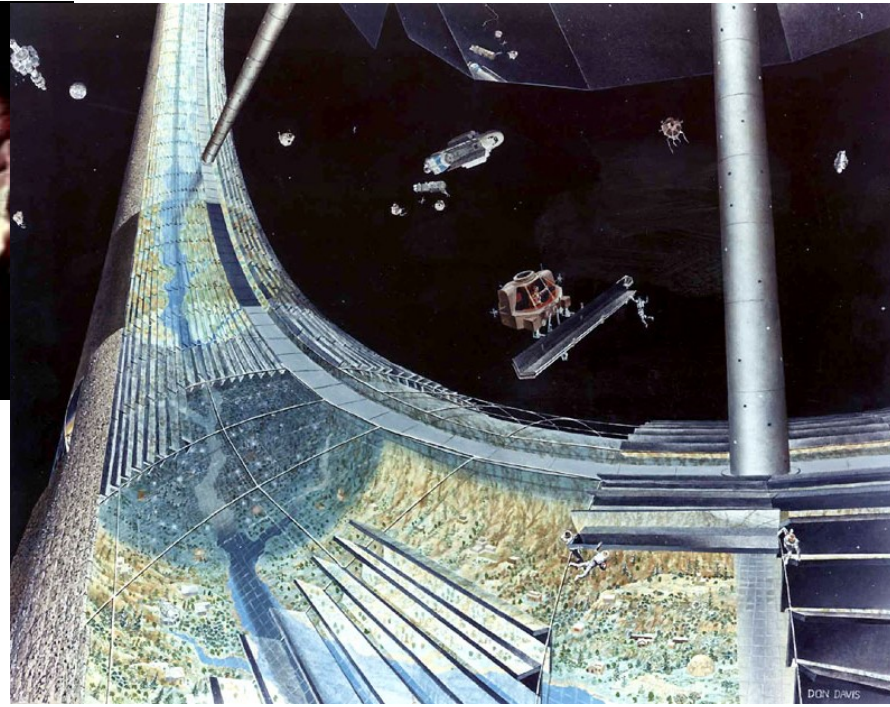
Why:

We should expand beyond the Earth, for/to:

- benefit of future generations,
- broaden the horizons of our youth,
- resources,
- cultural diversity,
- learning to manage ecosystems,
- apply the lessons to save the Earth's ecosystem
- isolate ecosystems,
- save civilization from <u>any</u> global catastrophe



Asteroids

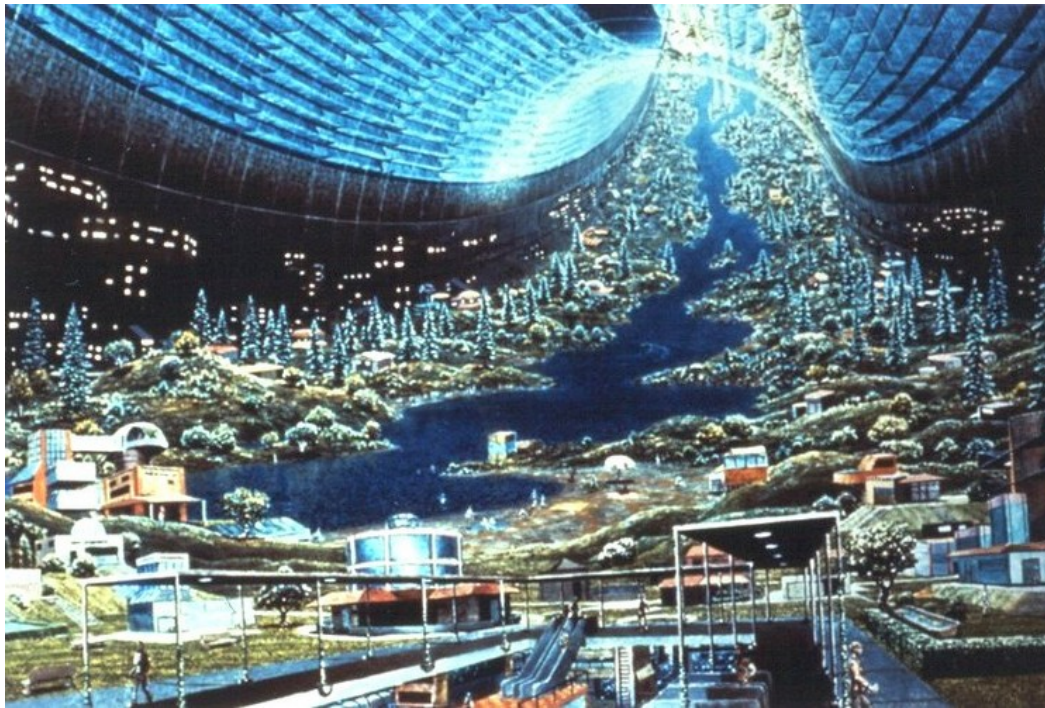


can support

Trillions of people …

…someday, but …

It is hard to build the first Asteroid settlement, due to distance, travel time, vacuum, distribution of resources, public opinion, funding…



Start with Mars …

Mars settlement will open up the solar system to humanity and life

<u>Start</u> with Mars, why:

Water for <u>Food</u>

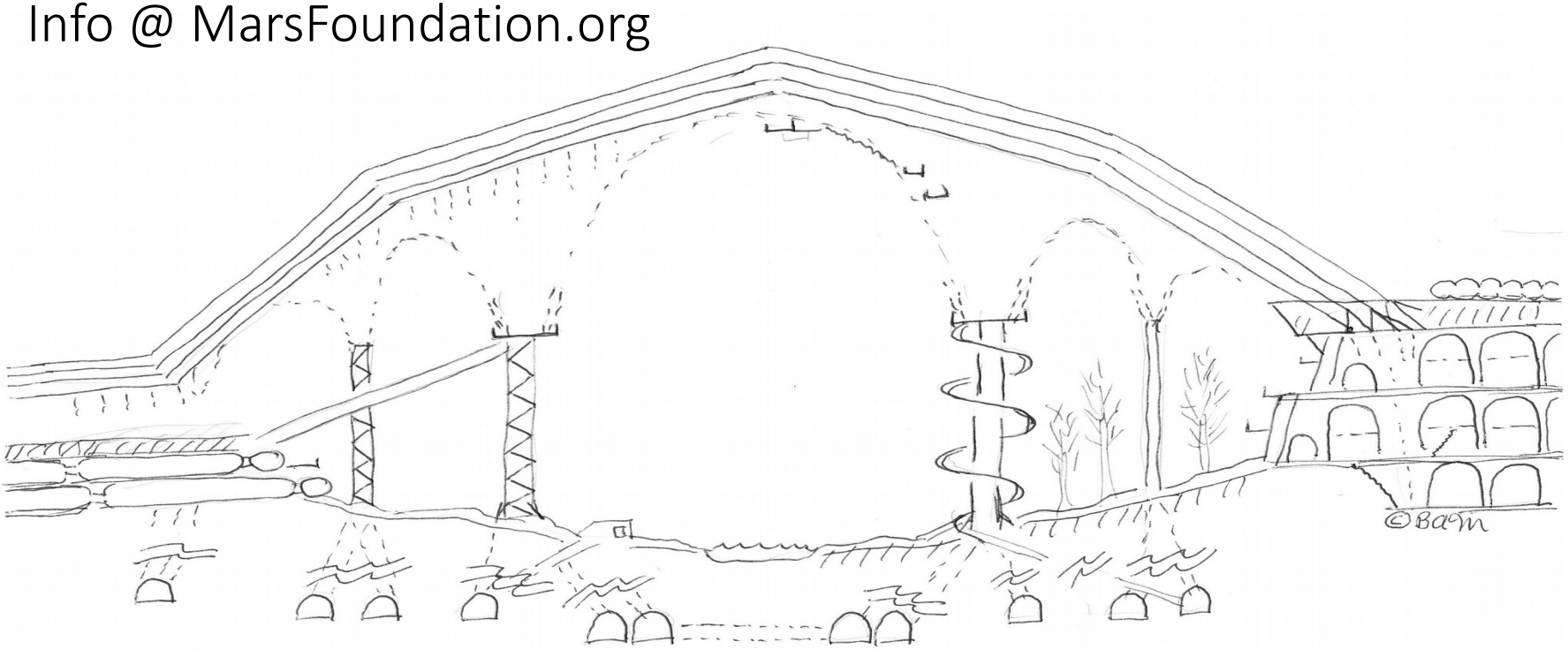
Carbon for <u>Food</u>

N2, nutrients for <u>Food</u>

4.a. Carbon – for Polymers
4.b. Water for industrial processing
4.c. Atmosphere, replenish air leaks, cooling
4.d. Dirt, raw materials, Si, Fe, Al, SiO, O2,
4.c. 24.6 hour day
4.d. ….

Mars Teaches Us: Interplanetary travel, Life support, Bootstrap Manufacturing, Manage biospheres (save Earth)

Side note: Help design a practical Mars Town,
Info @ MarsFoundation.org



Imports require Exports

To become economically feasible and self-supporting, while still importing certain critical items:

a Mars settlement **must export** goods that are needed elsewhere in the solar system.

Exports to Earth (not)

Few physical items valuable enough to export from Mars (or Luna, Asteroids) to Earth due to lower labor costs on Earth.

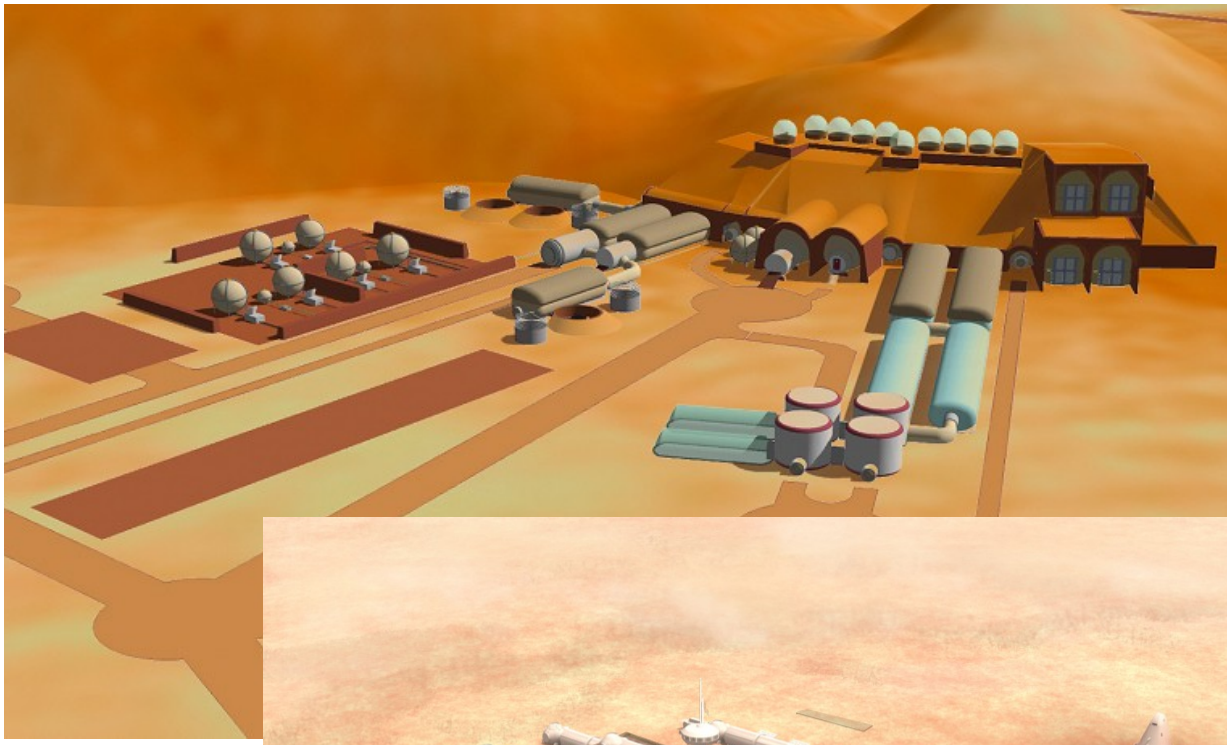
Exceptions would include:
- Scientific Information
-IP, patents, better ways of manufacturing

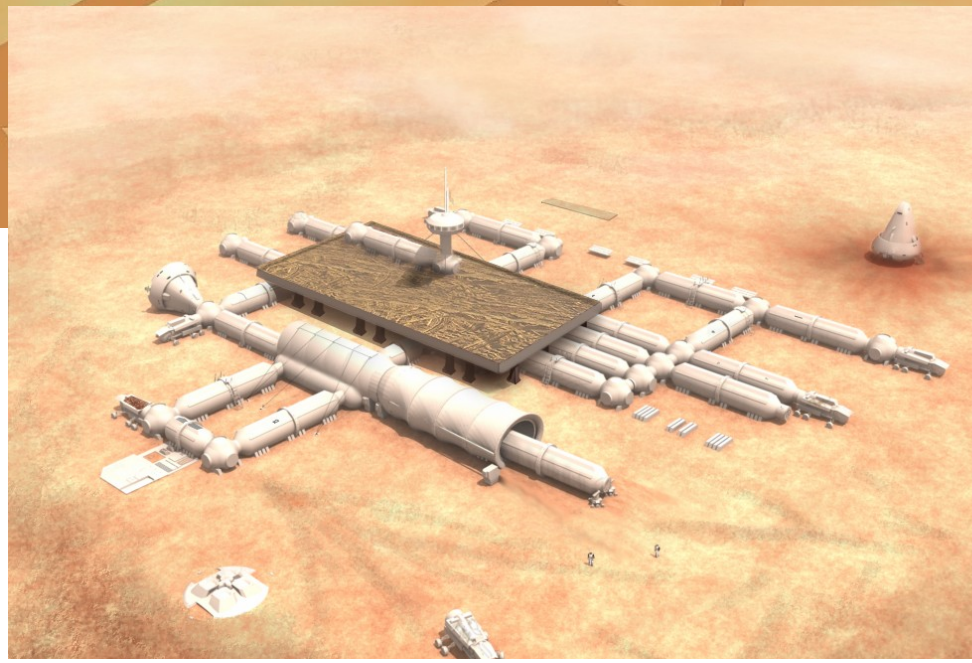
-Sale of Mars land & habitats, to immigrants from Earth.
-Sale of Living Quarters (Condos) in Space Settlements,
-Sale of Space habitats, craft, supplies to Earth companies

-Martian / Lunar souvenirs, i.e., certified Mars rocks, dust,
Mars-manufactured souvenirs & novelties.
Movies, Signed paintings. Artwork ie,

Infrastructure on Mars, Future

At main Settlement:
Greenhouses
Manufacturing
Materials Processing
    polymers, ceramics,
    fiberglass, metal
Residential areas:
    lower cost of living,
    center of tele-ops
Ice Road, Desert Trek
Farm communities, Truck Stops,
Polymer production near ice
Fuel production: CH4, CO+LOX





Mood Picture:

Less expensive for
Food an living on
Mars,
Simpler constrution

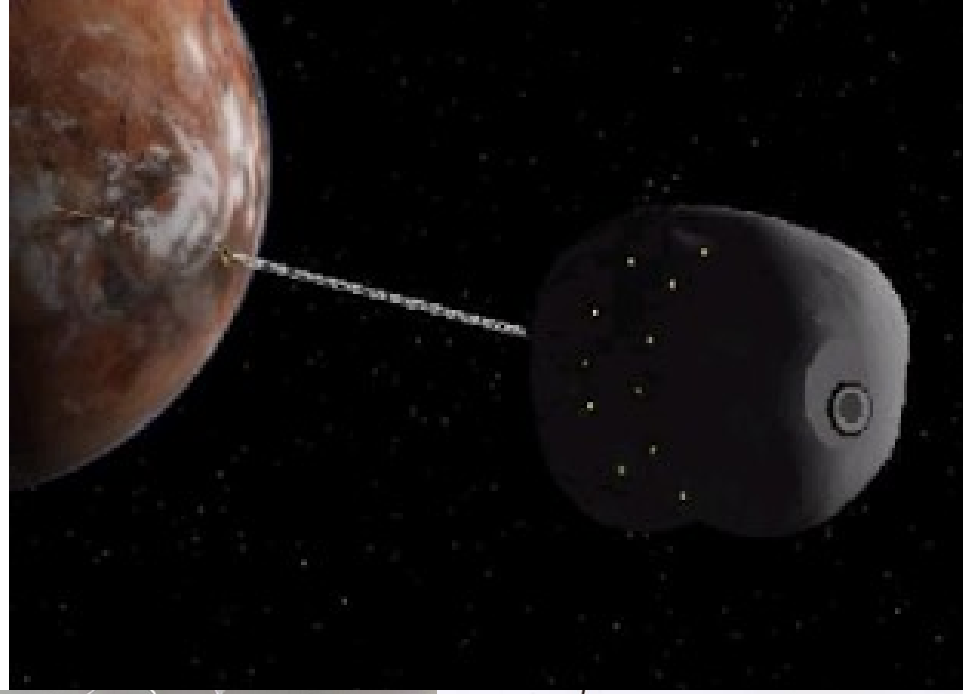
<- inflatable Greenhouse,
Shown before inflation ;)

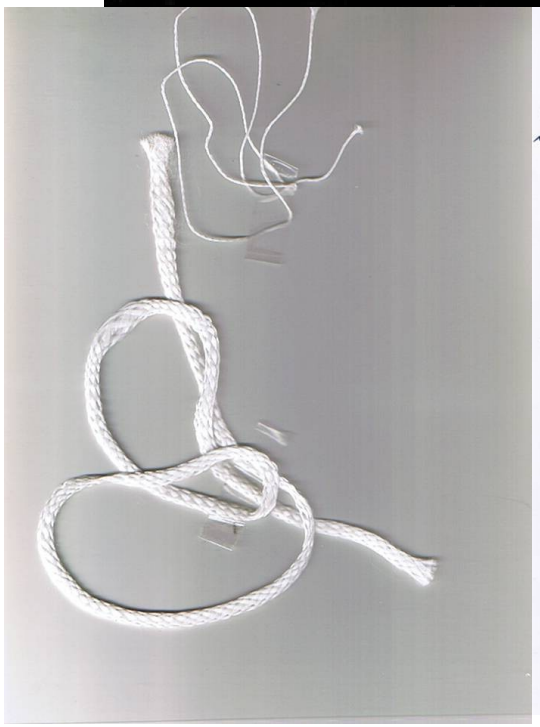
Infrastructure near Mars

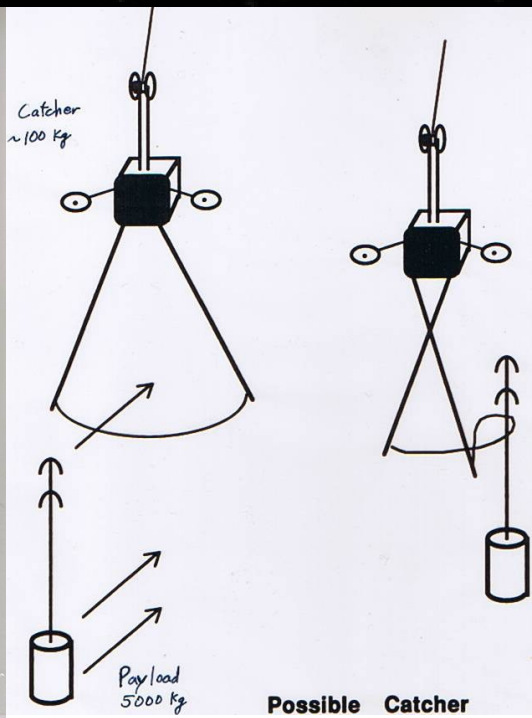
Phobos **Space Elevator** toward Mars
    catch sub-orbital cargo
Phobos Upper elevator,
    throw to asteroids or Earth,
    orbit plane change

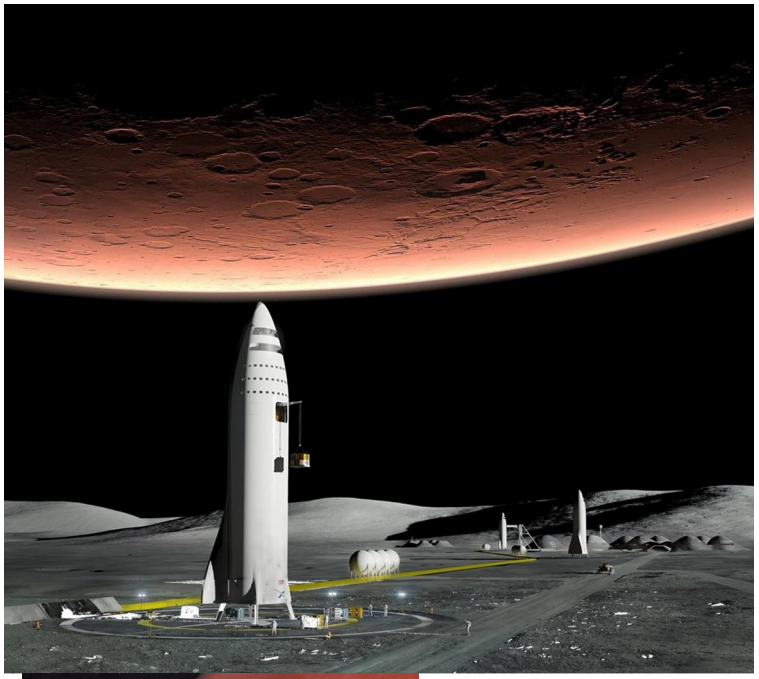
Launch from Pavonis on equator
    (any) Gun launch, tether sling,
    electro magnetic, mass driver,
    "rail gun", regolith rocket …
Fueled at Launch Site: **CO** + LOX?

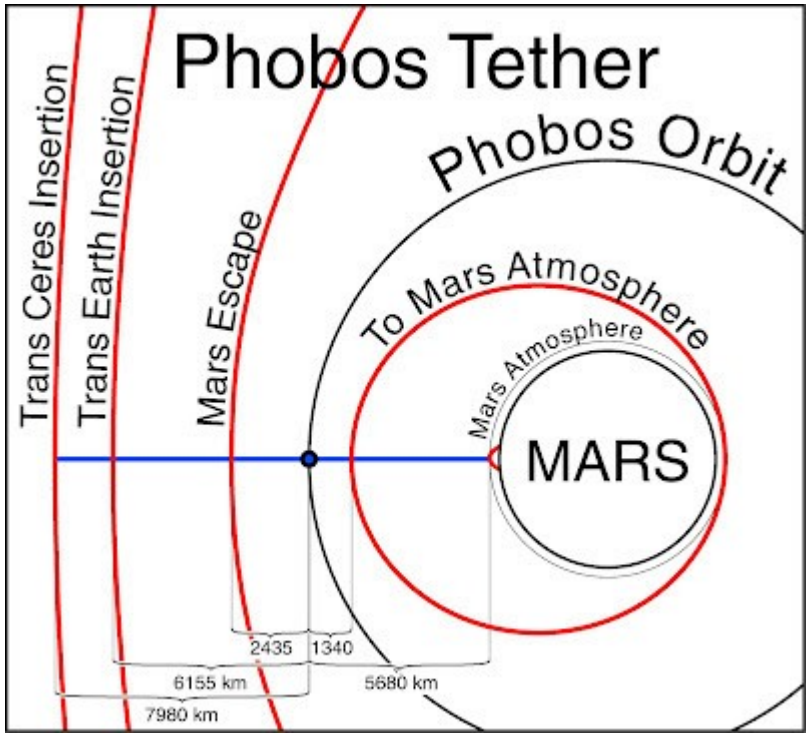
Orbital & near Mars:
Supply **depot**: fuel & consumables
Orbital greenhouses, export food
Space Dock: assemble & repair craft
Atmosphere **Scoops**
Cycling Craft
Asteroid Mines for Cyclers





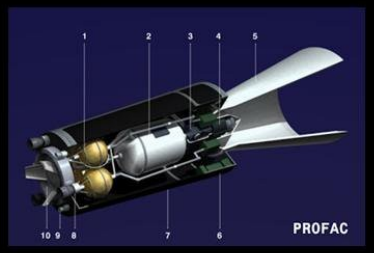


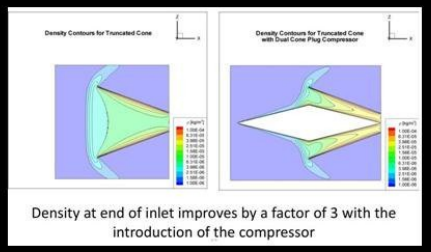



Phobos Tether
Phobos Orbit
To Mars Atmosphere
Mars Atmosphere
MARS
Trans Ceres Insertion
Trans Earth Insertion
Mars Escape
2435
1340
6155 km
5680 km
7980 km


CLOSE TO HOME by John McPherson
THIS NEXT ONE IS FOR THE JOHNSONS AT 137 MAPLE. SET IT FOR COORDINATES 84927906.
BALLIST PIZZA
PIZZA
FOOOSH!
BALLISTIC PIZZA
3-24
© 1995 John McPherson/Dist. by Universal Press Syndicate
McPHERSON
The latest technology in the quest for faster pizza delivery.

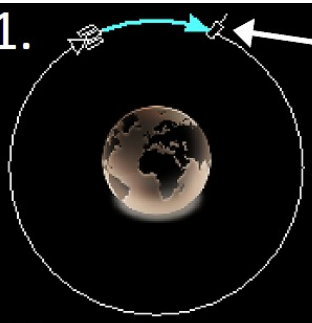
Non-Rocket Atmosphere-Orbit System»





Density at end of inlet improves by a factor of 3 with the introduction of the compressor

1.



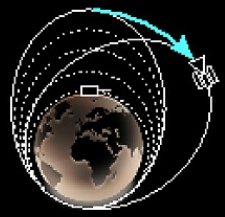
Rendezvous

1MT satellite @950 km. alt.

EP thruster

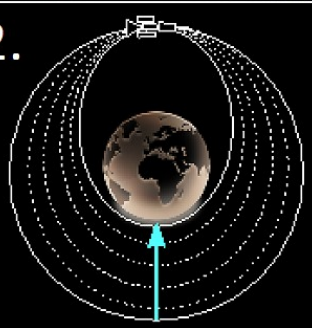
compressor

3.



Refuel & Reorient

2.



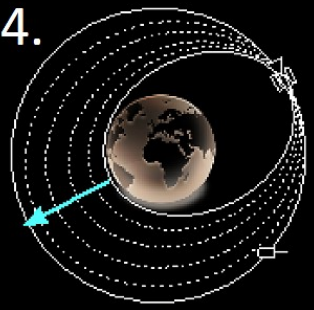
Walk-in

Solar Panels (5 kW)

storage tank

tapered "honeycomb" scoop (R = 1.8m)

4.



Walk-out

Bulk Exports:

Volatiles Gas & Liquids

Hydrogen (H2), oxygen (O2), nitrogen (N2), argon (Ar),carbon (C) as Water (H2O), Methane (CH4), Ammonia (NH3), CO, Dry Ice (CO2)
Frozen or compressed to liquid, in **graphite tanks**,
Carbon (C), as graphite structures, hydrocarbon polymers, CNT

Fuel (CH4, CO, LOX) for spacecraft returning to Earth, to asteroids, or cycling.

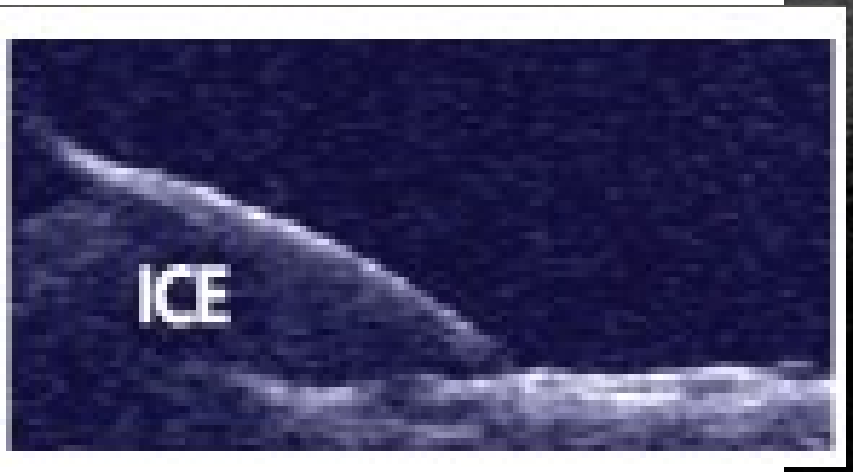
Needs: All humans and other life need water and certain gases.
The inner solar system (except for Earth) has shortages of water (H2O), nitrogen (N2), nitrates, and carbon (CO2).
Uses: food, fertilizer, protein, carbohydrates, other food, breathing.

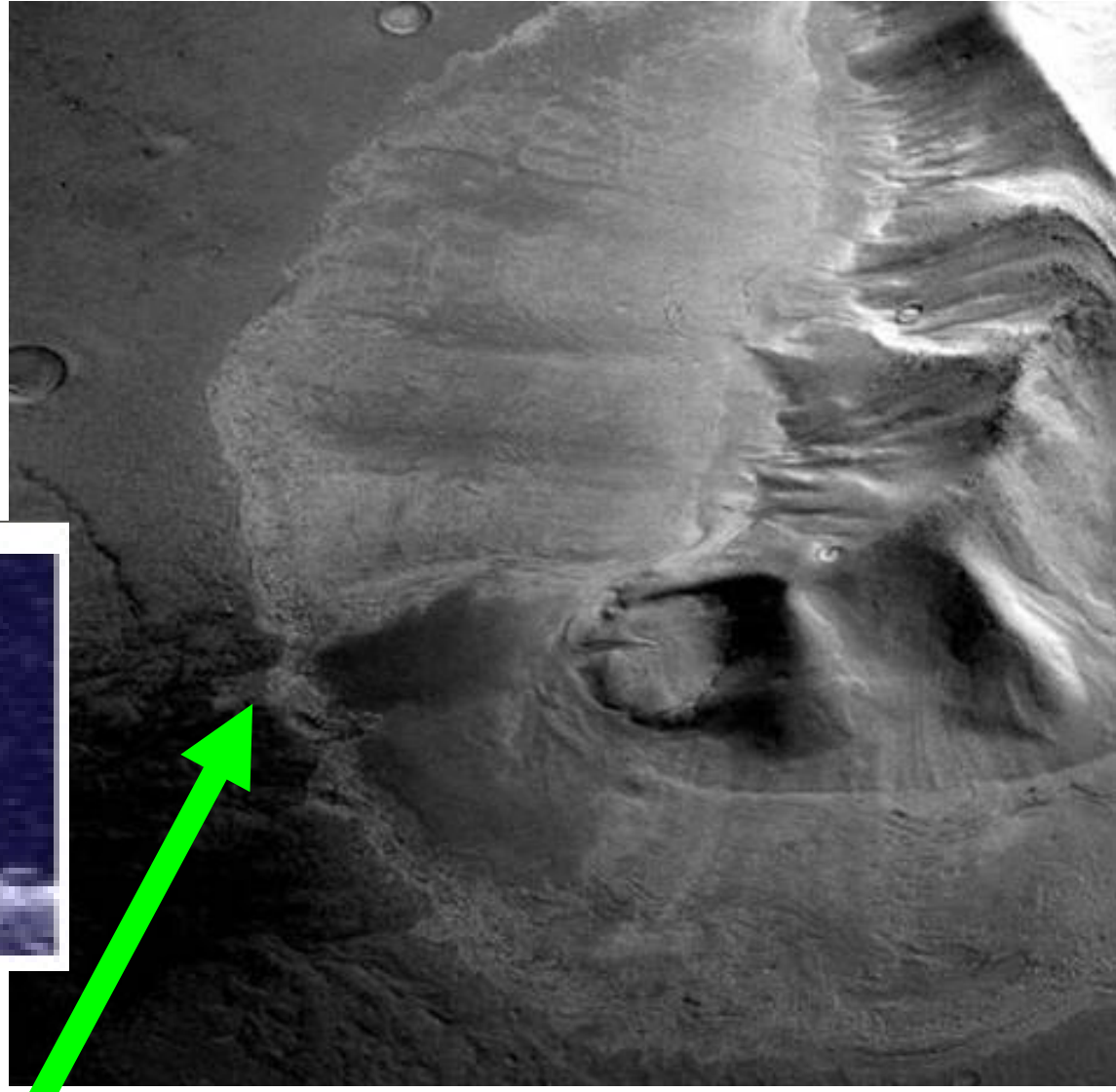
Surprisingly, **methane** (CH4) & **ammonia** (NH3) are especially useful.
Used on Luna (Earth's Moon), asteroid mining camps, cycling craft & any human settlements.
NH3 to make fertilizer to grow food, breathable.
CH4 oxidized with Lunar or asteroid oxygen -> CO2 + H2O for plants. CH4 isfeed stock for plastic / polymers.

Site Selection:

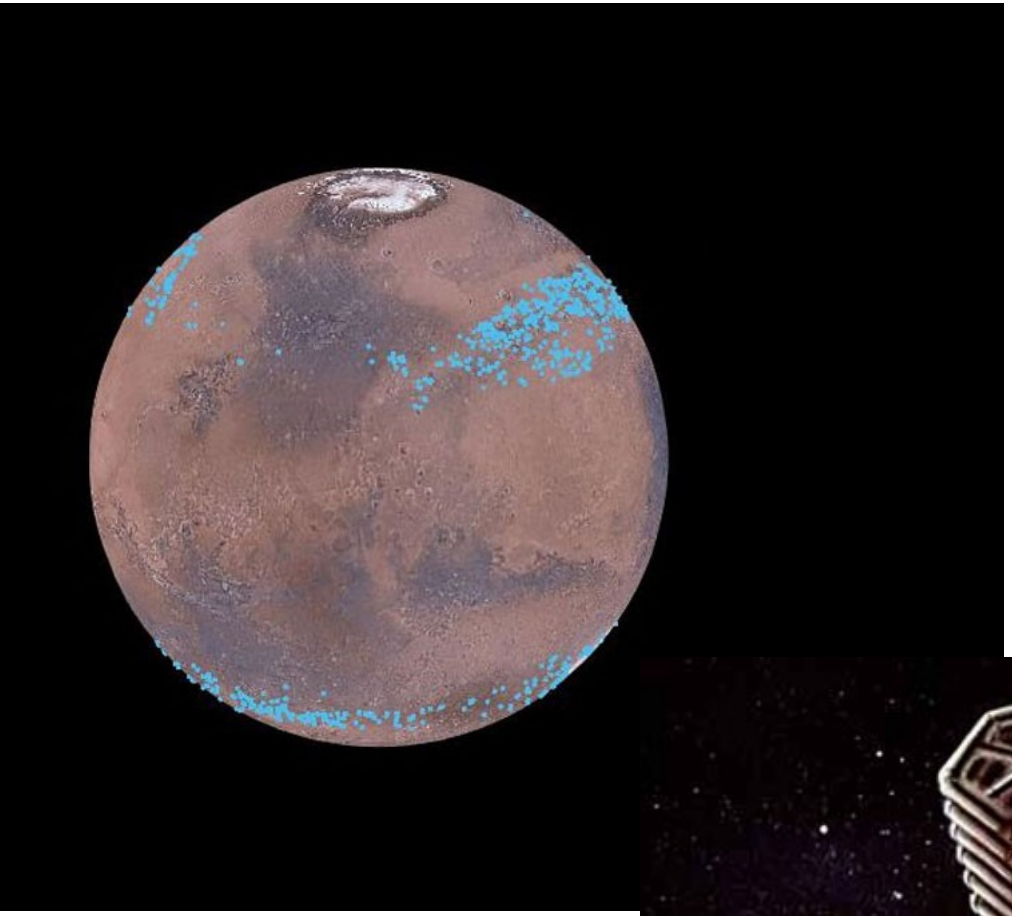
Adjacent to Ice

- Sunlight
- River sediment
- Denser Air (?)
- Geologic dust record in ice (?)



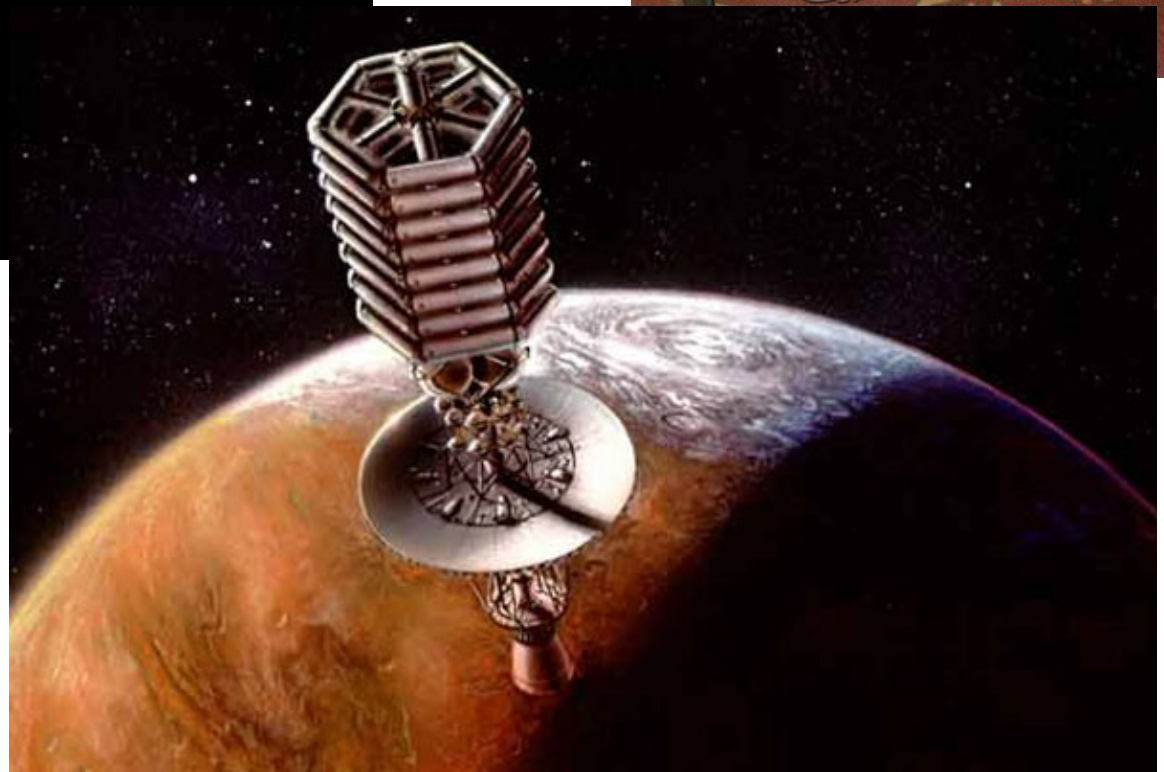


Mountain in the eastern Hellas region of Mars believed to be surrounded by water ice glaciers



Ice Deposits

Methane generator, test stand



Bulk Exports: Fuel

Fuel
CH4, CO, LOX, H2 (launched as H2O, ion drive fuels
for spacecraft returning to Earth, to asteroids, or cycling.
Also launched in graphite tanks.

<u>For Landers:</u>
Refueling Mars Landers in Orbit:
Martian fuel is especially valuable to refuel newly arrived Mars landers in Mars orbit.
Parachutes are not effective enough for heavy craft.
Note, not a source of net revenue, but reduces cost of imports.

Bulk Exports: Volatiles Gas & Liquids

Hydrogen (H2), oxygen (O2), nitrogen (N2), argon (Ar), and carbon (C)
as Water (H2O), Methane (CH4), Ammonia (NH3), CO, Dry Ice (CO2)
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CH4 oxidized with Lunar or asteroid oxygen -> CO2 + H2O for plants.
CH4 is feed stock for plastic / polymers.

“Bespin” Venus Cloud-City

Venus atmosphere, plenty of
Carbon (96.5% CO2 by volume),
Nitrogen (3.5% N2),
Little water (0.0020% H2O vapor)

Breathable air (N2 + O2) is a **lifting gas** in the CO2 Venus atmosphere.
It is technically possible to have giant aerostats (balloons),
perhaps kilometers in scale, with people, plants, and houses inside.
At 50 km altitude, conditions are Earth-like: 1 atm pressure, 0 to 50 C.

Automated craft suspended
from **Hydrogen balloons**.
(H2 is not flammable in Venus CO2)

Imports: Hydrogen (H) and nitrogen (N),
as liquid water or ice (H2O),
compressed ammonia (NH3) & Methane (CH4),
expendable plastic items burnt for H2O

(“Bespin”, from Star Wars planet & floating city,
(is technically viable, ref. Geoff Landis).

Structures Exported:

Reusable **Graphite Tanks**: exported with various fluids (CH4, CO, LOX, NH3, H2O)

Graphite: spacecraft frames, trusses, antennas, and rocket motor expansion nozzles.

Aluminum tanks and spacecraft frames

Steel (possibly, Mars is red with iron oxides)

Note: very little carbon is in Lunar soil, metallic asteroids, & free space. Surplus graphite tanks at a destination can be recycled, or burned with asteroid oxygen or lunar oxygen, to produce water (H2O) and CO2 to grow fresh vegetables for the local people.

“Bread-Basket” of the Solar System (but briefly)

“The first successful Lunar Casino serves food from Mars.”

Even fresh vegetables grown on Luna, are grown from fertilizer and carbon from Mars.

For a period of time, Mars will be the
“bread-basket” of the solar system.
With H2O, N2, CO2, usable sunlight,
24+hour day,
Mars is the best place to grow food.
Mars exports crops that do not grow well on Luna given its minimal sunlight for 14 days every month.
Human spacecraft & small bases everywhere beyond LEO benefit from less expensive imports of Martian food, compared to food from Earth.

Exported bulk goods (food and fuel) cost less to ship compared to food from the deeper 'gravity well of Earth

Short Lived Agriculture Dominance:
The dominance of Mars agriculture may be short lived. Orbital greenhouses are expected to become more practical with experience growing plants in simulated low gravity, increasing automation, and the availability of manufactured pressure shells in orbit. Therefore, the Mars farmers are shifting their efforts away from growing bulk food, toward specialty foods that are harder to grow in confined spaces on orbit.

Manufacture Orbital Greenhouses:
Due to expected competition from food grown in space, Mars companies are positioned to dominate that market by manufacturing, operating, and exporting "Turn-Key Orbital Greenhouses."

Operating Greenhouses in Mars orbit
Operating orbital greenhouses in high Mars orbit is now a growth industry due to the planet's proximity to the markets: asteroid mining camps and interplanetary spacecraft. These greenhouses use fertilizer, water, and carbon from Mars. They are controlled from the surface settlement on Mars, where it is easier to support people.

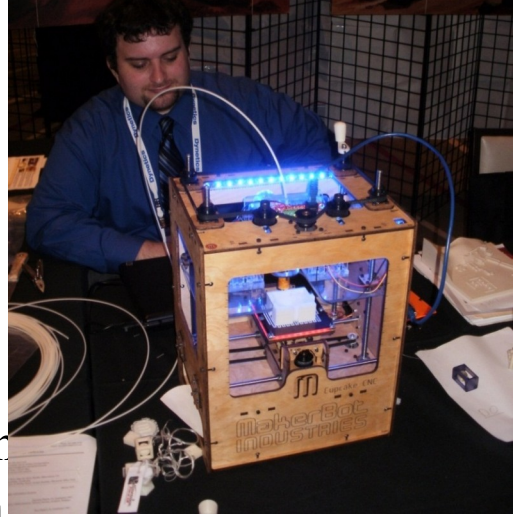
Orbital Greenhouse Manufacture:

Greenhouse **components** manufactured at Leominster,
the main manufacturing center on Martian surface.
Small / durable components: truck to Pavonis **catapult**,
launch to Phobos space **elevator**, lift to Phobos
(very little rocket propellant needed.)

Pressure **Shells**: of graphite or fiberglass or aluminum,
are too large & heavy for catapult & elevator.
launched "wet" from manufacture site,
ie, fitted with reusable **strap-on** (CO + LOX) boosters,
filled with (CH4 and LOX) fuel for 2nd stage rockets.
Can refuel in low orbit with fuel brought up elevator

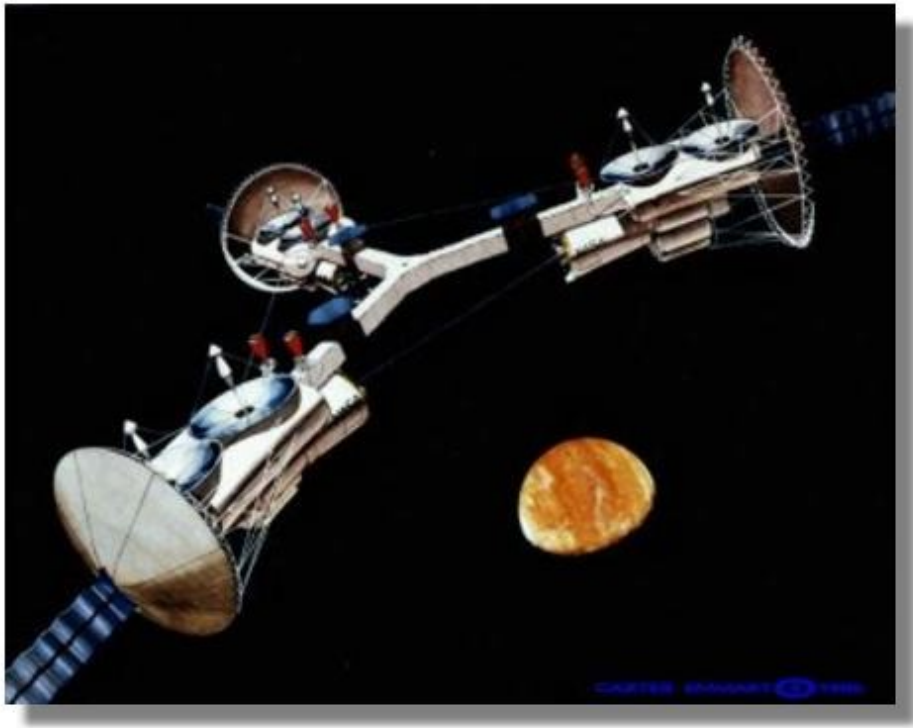
Internal components, water, and nutrients
installed in orbit near Phobos Station.

Furnishing Orbital Settlements:



Mars may have manufacturing head start
& lower cost of living:

Exported goods manufactured with automated equipment, such as: habitat pressure shells, paper, cotton clothes, polymer cloth, Molded plastic items of polyethylene, polyester, other plastics Pumps, valves, and electric motors, anything from 3D-printed or laser-cut plastic and metal.



Bulk plastics, various forms:
film, sheet, filament, trusts, panels, sheets for laser cutters,filament for 3D printers.

Already mentioned: tanks, graphite spacecraft frames, trusses, antennas, rocket motor expansion nozzles.

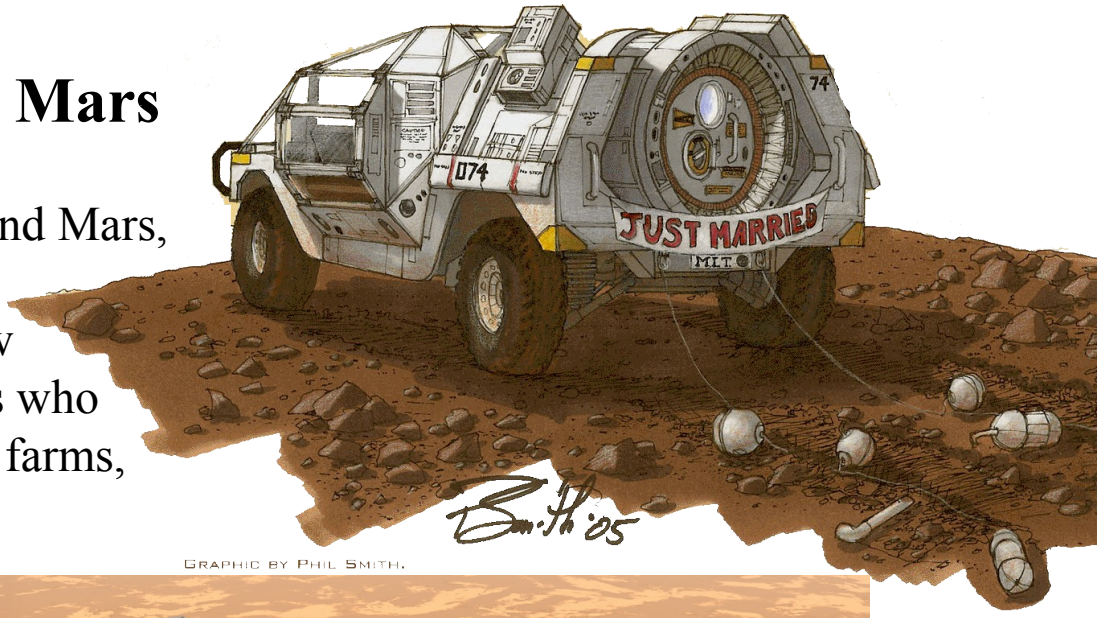
Other Exports

Bulk Manufactured Items
Asteroid Mining Equipment
Spacecraft
Launchers
Orbital Tugs
Solar panels
Cycling spacecraft & greenhouses
Tethers

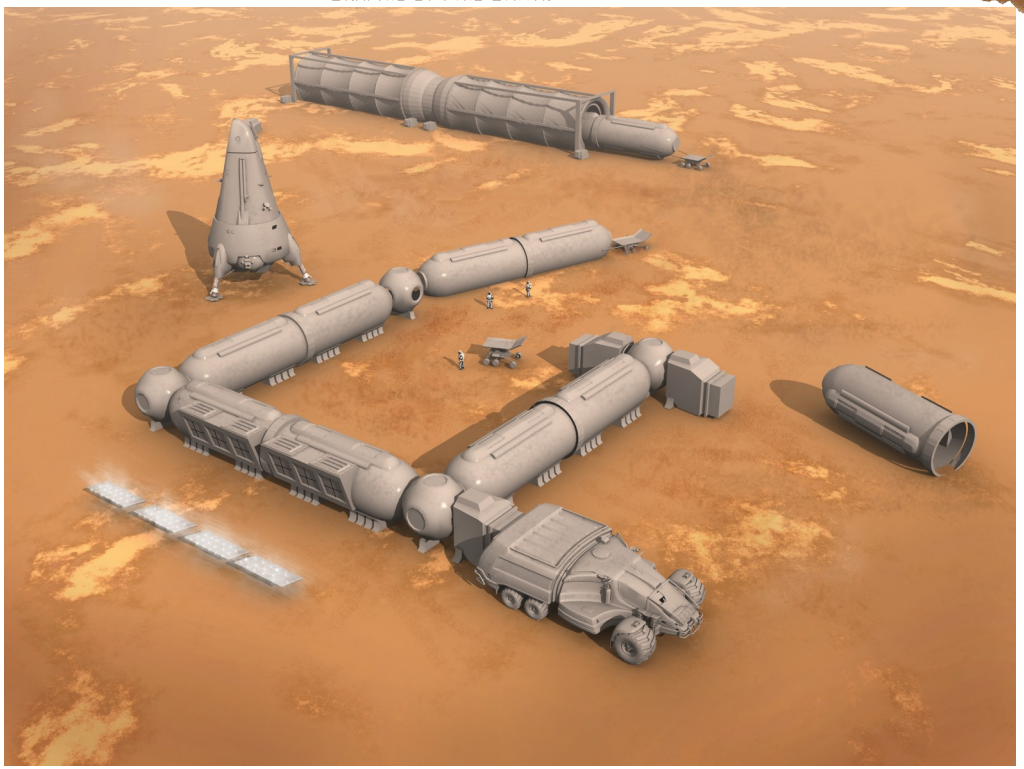
Local Use / Expansion on Mars

Don't forget items **not** exported beyond Mars,

but are paid for under contract by new arrivals, companies, and governments who wish to **expand on Mars**, set up new farms, towns, manufacturing.



GRAPHIC BY PHIL SMITH.



Summary: Mars, Gateway to the Solar System

Uneven distribution of natural **resources**, energy, labor
- leads to **Trade**

Advantages: for Mars settlers: H2, N2, C, dirt, day-night, easier to grow food (initially), lower cost of living (?), Phobos elevator, …

Exports, leverage the Advantages:
Food
Bulk volatiles: water H2O, Carbon C, Fuel, Ammonia NH3, Methane CH4, Oxygen LOX
Simple goods manufactured from those, ie, graphite, tanks, plastics
Space craft, greeenhouses, space habitats - assembled in Mars orbit

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Go Back, Backup Slides

TBD
New title Mars, Gateway to the Solar System
Event: SRI Development of Mars, the Asteroids, and Beyond
pre-conference program for the SRI 3rd International Congress.
add
SpaceX city,
Joel Serel Sercel ? Asteroid mining,

Luke Skywalker hanging from cloud city
https://www.deviantart.com/alxelder/art/Star-Wars-Hang-in-There-313996535

Asteroid and cycler
Peanuts at Hotel Luna

note that gamblers at Hotel Luna will eat peanuts grown on Mars at first, then food grown in cis-Luna space greenhouses which were assembled and get fertilizer from Phobos

Leominster big park,
Versteeg – asteroid mining
Leapfrog
Ort cloud
St. Louis , outfitting for homesteading, buy Conestoga wagon

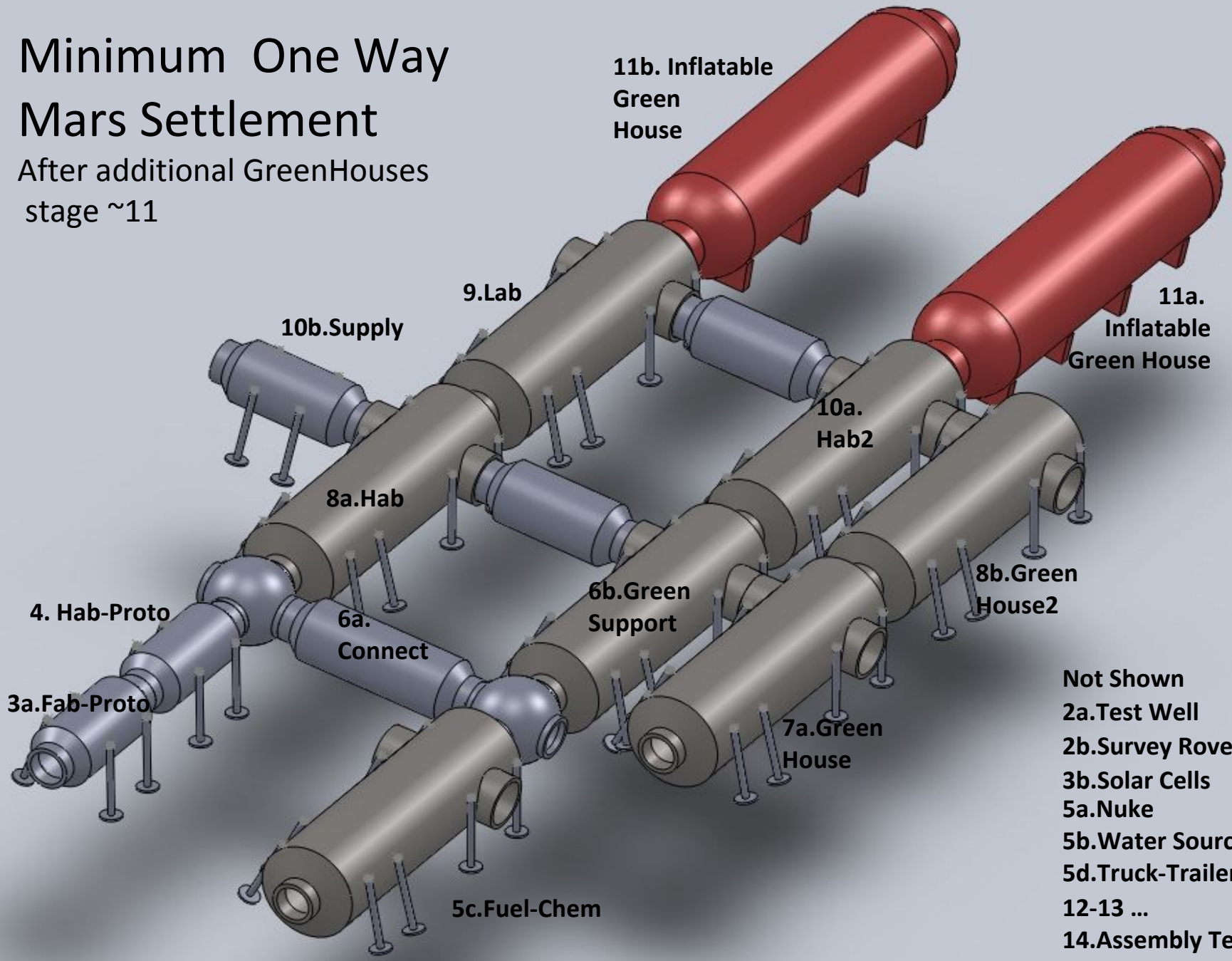
DRAFT Outline

Ovierview
To Earth (not)
Map of raw materials
Phobos Space Elevator,
Gun Launch, Pavonis, (alternatives…)
Upper elevator, sling to asteroids or Earth, Ice Road
Bulk Volatiles Exports
Hydrogen (H2), oxygen O2, nitrogen (N2),
argon (Ar), and carbon (C)
as Water, Methane, Ammonia, & solid carbon.
Fuel: where to…
Refueling Landers in Orbit, before landing
Fuel for interplanetary, asteroid missions, cyclers,
"Bespin," the planned prototype Venus floating cloud-city
Tanks and Structures
Food
Orbital Greenhouses
Operating orbital greenhouses
Orbital Settlement Furnishings

Other Exports Include:
Bulk Manufactured Items
Asteroid Mining Equipment
Spacecraft
Launchers
Orbital Tugs
Cycling Greenhouses
Tethers
Atmosphere scoop, see Profac and NIAC

Minimum One Way Mars Settlement

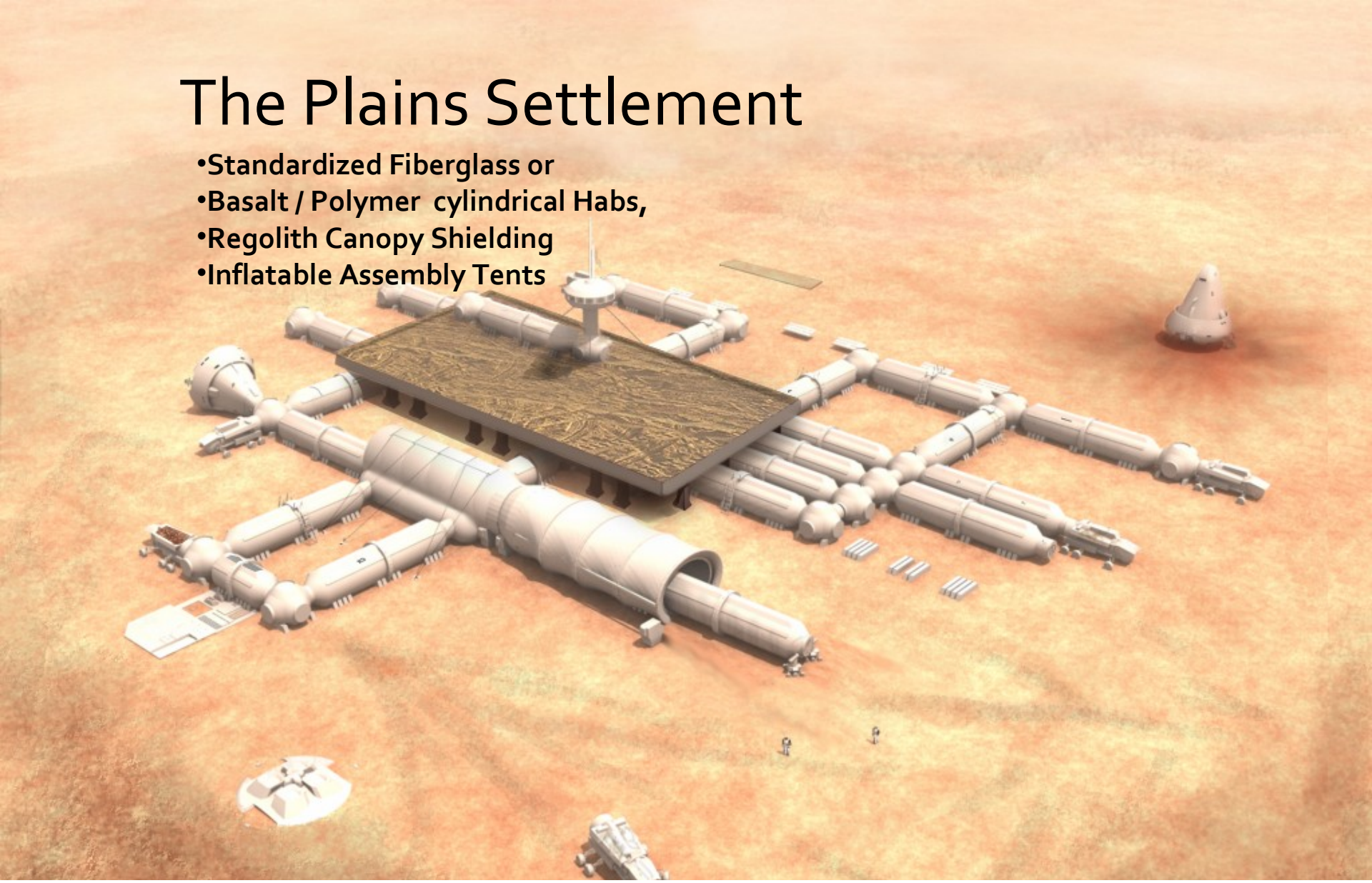
After additional GreenHouses
stage ~11



Not Shown
2a.Test Well
2b.Survey Rover
3b.Solar Cells
5a.Nuke
5b.Water Source
5d.Truck-Trailer
12-13 …
14.Assembly Tent

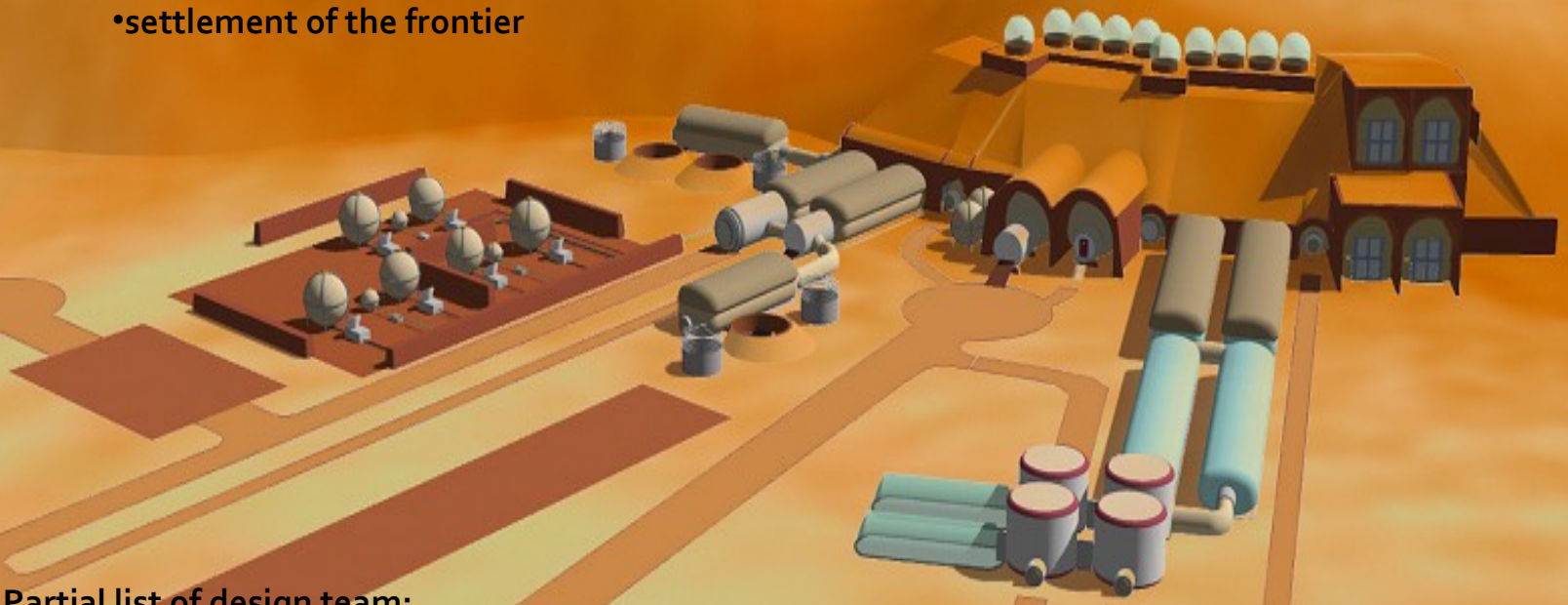
The Plains Settlement

- **Standardized Fiberglass or**
- **Basalt / Polymer cylindrical Habs,**
- **Regolith Canopy Shielding**
- **Inflatable Assembly Tents**



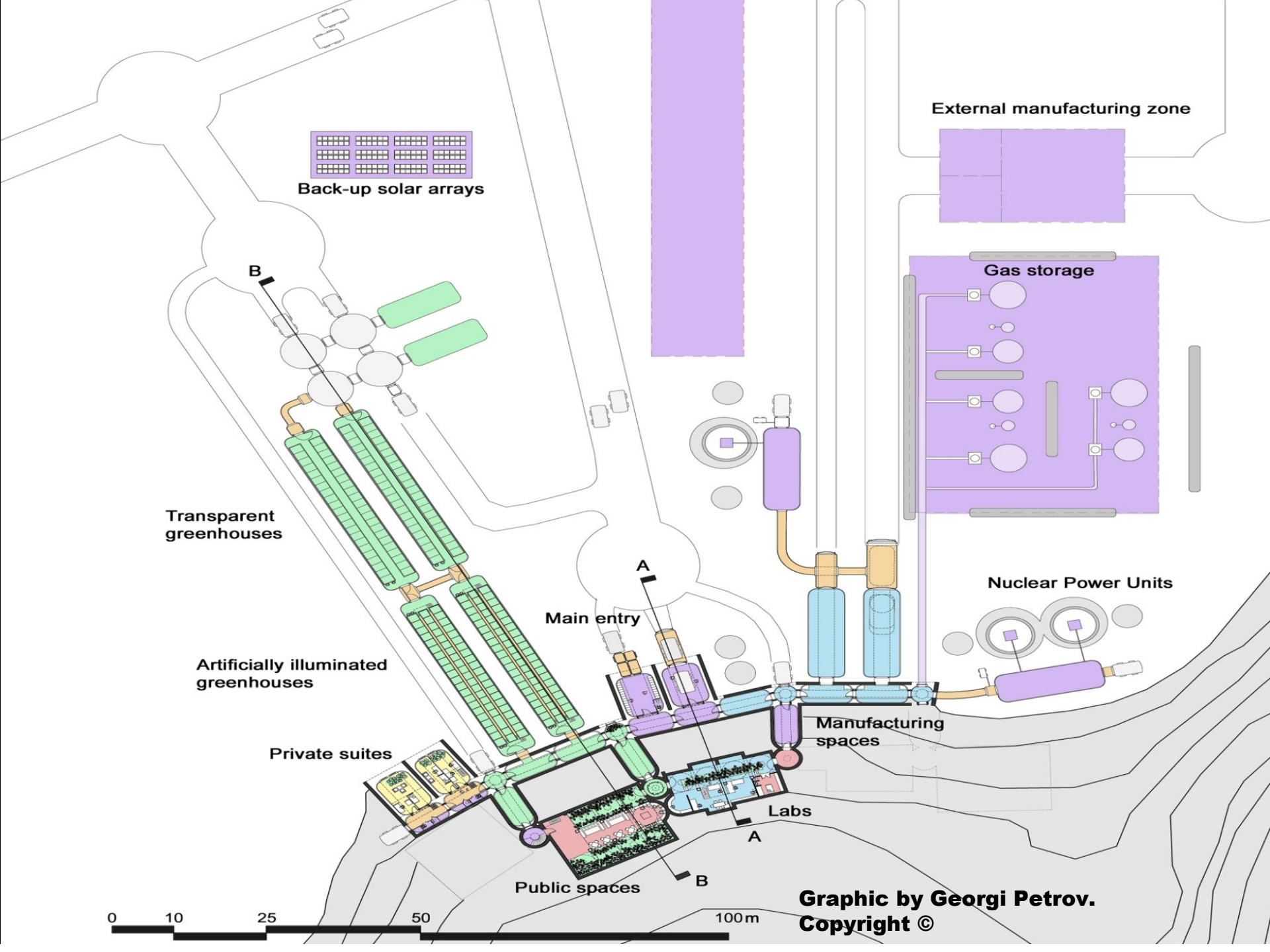
Hillside Settlement

- Built largely from local materials
- ~90% self-sufficiency by mass
- Industrial capabilities enable
- settlement of the frontier



Partial list of design team:
April Andreas – Mars Cookbook
James Burk – Webmaster
Frank Crossman – Polymers & Glass
Robert Dyck – Refining, Space Suits
Damon Ellender – Metals, Gas
Gary Fisher – Waste Treatment
Inka Hublitz – Agriculture

William Johns, MD – Psychology
Mark Homnick – Mgr
Bruce Mackenzie - Design
K. Manjunatha – IT / IC / Comm
Joe Palaia – Electrical, Nuclear
Georgi Petrov - Architecture
Richard Sylvan, MD. - Medical


External manufacturing zone
Back-up solar arrays
B
Gas storage
Transparent greenhouses
A
Main entry
Nuclear Power Units
Artificially illuminated greenhouses
Manufacturing spaces
Private suites
Labs
A
B
Public spaces
0
10
25
50
100 m
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do NOT
show.

To become economically feasible and self-supporting, the Mars settlement must export goods that are needed elsewhere in the solar system. In keeping with Mars' still-minimal industrial base, they are relatively easy to manufacture or refine on the planet. Also, materials that can be produced by simple automated equipment, such as raw chemicals, tanks, trusses, can be exported economically.

To Earth: There would be few physical items valuable enough to export from Mars to Earth due to the lower labor costs on Earth. Exceptions would include Martian souvenirs, i.e., certified Mars rocks, dust, and Mars-manufactured souvenirs. Some artwork is exported to Earth, especially signed paintings on plastic film.

Fuel: Fuel consisting of methane (CH4) and liquid oxygen (O2 as LOX) extracted from the Martian atmosphere is exported. This fuel is used by spacecraft returning to Earth, going on to asteroids, or cycling between the planets.

Refueling Landers in Orbit: Martian rocket fuel is also especially valuable to refuel Mars landers in Mars orbit. After they arrive from Earth, all heavy landers need fuel for their descent rockets before landing. Parachutes are not effective enough for heavy craft. Unfortunately, while this landing fuel is not a source of net revenue for the Mars industries, it greatly reduces the cost of imports.

A. Bulk Volatiles Exports

Bulk Volatiles Exports: Hydrogen (H2), oxygen O2, nitrogen (N2), argon (Ar), and carbon (C) as Water, Methane, Ammonia, and just solid carbon.

All humans need critical gases and water to thrive. The inner solar system (except for Earth) has particular shortages of life-sustaining chemicals, including water (H2O), nitrogen (N2), nitrates, and carbon. These are needed to grow food, and produce fertilizer, protein, carbohydrates, other food components, and breathing gas.

Surprisingly, methane (CH4), and ammonia (NH3) are in especially strong demand. These are used on Luna (Earth's Moon), asteroid mining camps, cycling craft and other human settlements. The NH3 is used to make fertilizer to grow food, and to produce free nitrogen as a mixing gas for breathable air. The CH4 is oxidized with Lunar or asteroid oxygen to derive CO2 and H2O, also used for growing food.

Also, “Bespin,” the planned prototype Venus floating cloud-city has signed a long-term contract to import hydrogen and nitrogen, in the form of water ice and compressed liquid ammonia. However, the contract is conditional on their IPO funding. (Note, although named for a fictional planet and floating city, Bespin is a technically viable proposal, see references by Geoff Landis).

End