MARS PLAN

A Reference Master Plan for Space Development

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Abstract

Most plans for Martian development are based on the transportation system to reach the red planet. But once Mars is reached with a manned mission, set up an outpost and explores the surroundings, what's next?

In this paper we want to establish a reference Master Plan for Martian for profit development. We believe that any Mars proposal must be considered not as a single goal of a manned mission but as part of an integrated Master Plan for the development of the entire planet. The reasons and motivations are many. Several groups and companies are trying to reach the red planet with different approaches and goals. In this paper we want to define a Roadmap for considering any Mars mission as part of a business plan that can bring profits for its partners and represent a profitable venture that could help in solving terrestrial problems as well as opening up a new territory.

Enabling technologies and systems to be considered in the Master Plan range from:

- Entirely reusable and affordable two-way Earth-Mars transportation system.
- Martian Habitat Systems from outpost to settlement using ISRU.
- Martian Urban cell (MUC) as a basic planning unit for Mars development.
- Underground Terraforming for an immediate shirtsleeve terrestrial ecosystem environment.
- Supporting and business activities.
- Local equipment, robotic help and transportation system.
- Martian technology development to establish a self sufficient Martian economy.
- Planned MUC expansion and distribution in the planet.
- Strategies for Martian development.
- These and other themes will be considered in this paper with proposals for each one open for discussion.

Keywords: *Mars Development, Business Activities, Master Plan.*

Introduction

There is a long list of proposals for Mars manned missions. A manned mission to the red planet is still considered a technological must and many organizations have proposed specific plans. Most of these plans are based on the transportation system to reach the red planet. But once Mars is reached with a manned mission, the crew set up an outpost and explores the surroundings, what's next?

Scientific research is not enough to justify the huge costs of manned missions to Mars, and any plan must compete for budgeting with other programs more or less urgent that needs the limited funds at disposal. For that reason Mars development, as well as space, cannot depend on governmental agencies or public funds. Space development in general and Mars in particular must depend on private venture capital, sound business and profit plans if they want to be an essential part of our future economy.

In this proposal we want to establish a reference Master Plan for space for profit development where planet Mars plays a key role. We believe that any Mars proposal must be considered not as the single goal of a manned mission but as part of an integrated Master Plan for the development of the entire planet as part of a more general space development Master Plan, entirely missing as of today. Such plan must be considered as an advanced business plan, if we really want it to be implemented and not subject to political reasons.

The reasons and motivations are many. Several organizations and companies are trying to reach the red planet with different approaches and goals. Here we want to define a Roadmap for considering any Mars mission as part of a business plan that can bring profits for its partners and represent a profitable venture that could help in solving terrestrial problems as well as opening up a new territory. Such plan is based in the Mars Fast Track concept where the transportation and infrastructure creation activities goes hand in hand in a coordinated way and the end result of the first manned mission will not be a single breakthrough but the establishment of a permanent operational transportation and infrastructural system in the red planet as well as on the Moon and in NEOs as part of a more ambitious vision and the need to obtain faster ROIs for the investors.

Once the transportation system and basic infrastructures will be operational an entirely new approach to Mars can be considered, and the planet will become one more frontier for technological and economic development at exponential growth rate. To achieve such goals a global effort have to be implemented, to finance and support such development, to consider new and advanced space and local technologies, to create a manufacturing capability on the planet, to multiply human settlements and create a local network, to expand human presence through Underground Terraforming facilities and finally to start Terraforming operations as part of an economical expansion plan.

Such steps will be briefly analyzed in this paper.

1-The goals

Several important goals must be considered and reached and are at the core of this plan, we can list the general ones for the red planet:

- Consider Mars development as part of a more general space development plan and related integrated effort.
- Develop standard components for a space transportation and infrastructural systems
- Mars development to increase our economic territory.
- Create new wealth opportunities.
- Develop advanced technologies for solar system and planet exploitation.
- Create new hi tech local economy with full employment at skilled level, integrating human and robotic manpower.
- Develop related technologies and benefits to face and solve terrestrial problems.
- Develop new local technologies for supporting activities.
- Develop conditions for Terraforming, to create an entire new world and expand the terrestrial ecosystem.
- Start Terraforming activities as part of a profitable business plan.

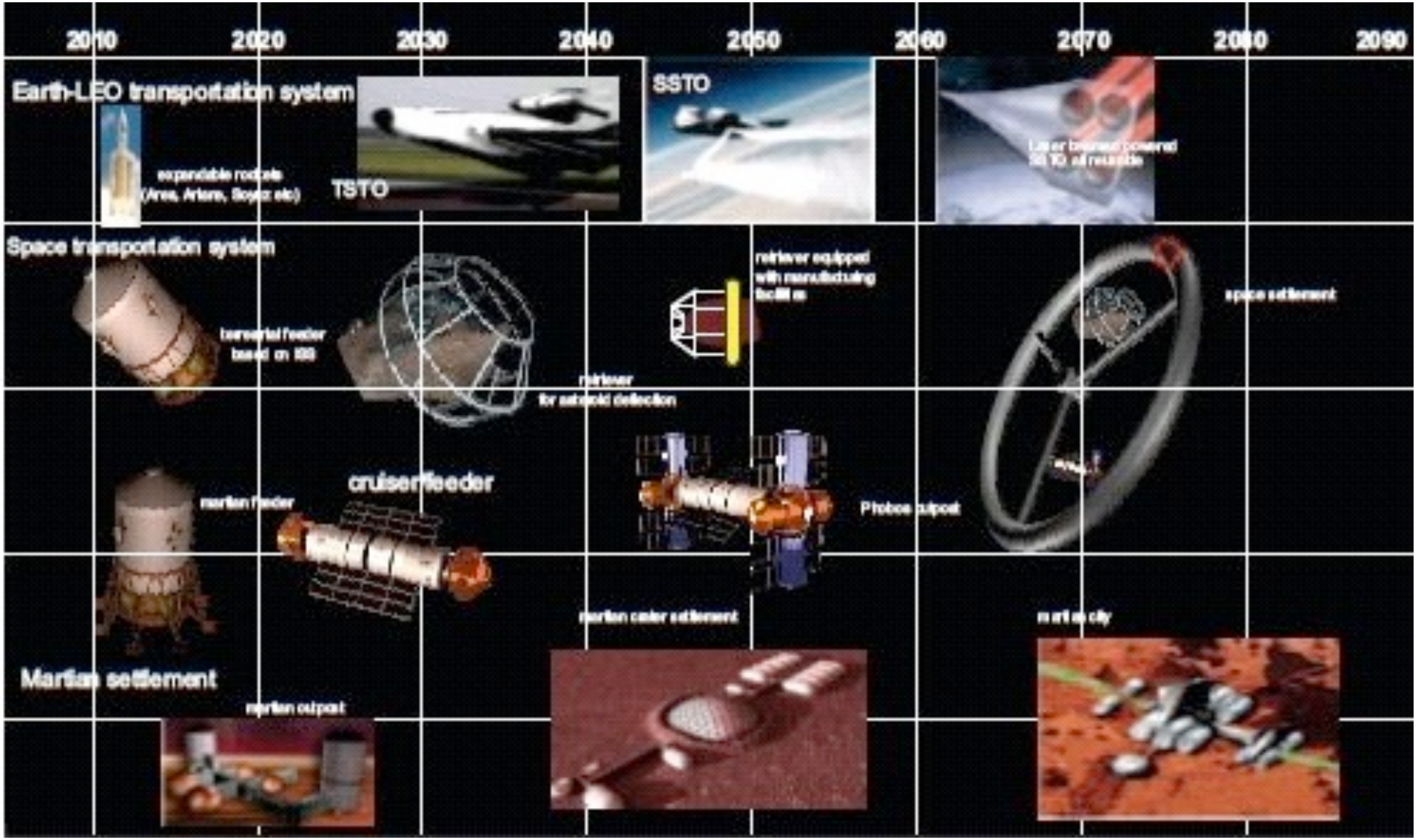
The reference Master Plan

To start a long journey to an unknown city or territory the first needed instrument is a roadmap. To reach Martian development capabilities the first needed tool will be the Master Plan that will define the schedule of activities, their sequence, the critical paths and the milestones. For each scenario, while the needed technologies will basically be the same, a different Master Plan and Roadmap will be required.

We can divide the general space development Master Plan for the next hundred years in different sectors such as:

- Access to space.
- Space transportation system.
- Space infrastructures.
- Lunar development.
- Mars development.
- NEOs development.
- Solar system development.

Each one of them may seem as an individual theme, in reality they are totally and holistically integrated with a single major scope. While the above refers to the general space development plan activities on Mars we may follow a well defined phase schedule but utilizing same enabling technologies that must be developed to allow smooth and profitable operations.



2010
2020
2030
2040
2050
2060
2070
2080
2090
Earth-LEO transportation system
(Ares, Ariane, Soyuz etc)
TSTO
SSTO
Space transportation system
retriever equipped
with manufacturing
space settlement
cruiser/feeder
Phobos outpost
martian feeder
Martian settlement
martian outpost

In order to define a logical sequential activity flow, we must specify several different phases in Mars development. They don't have to be totally completed before the next one can get started, since they can be interrelated but, even in a limited Martian territory, they must follow a step by step sequence. We can list the activity phases for the Martian plan as follows:

- Phase 1- Exploration.
- Phase 2- Mars Fast track missions to set up transportation and infrastructural system.
- Phase 3- Underground Terraforming development with MUCs network.
- Phase 4- Martian Technology development.
- Phase 5- Martian economy creation.
- Phase 6- Start Terraforming activities.

Enabling technologies

We will analyze in the following pages the enabling technologies for a successful development of the red planet that range from:

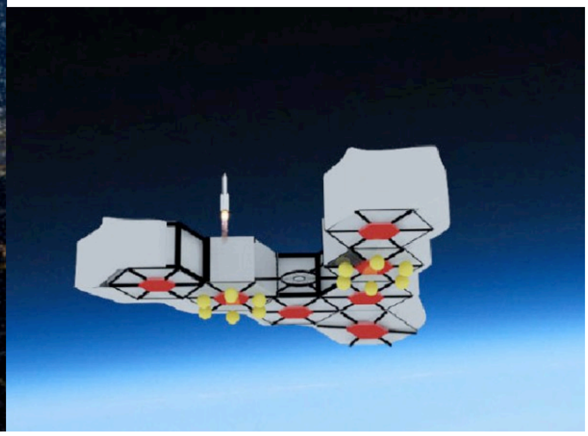
- Affordable access to space.
- Entirely reusable and affordable two-way Earth-Mars transportation system.
  Standard Habitat Systems from outpost to settlement using ISRU.
- Underground Terraforming for an immediate shirtsleeve terrestrial ecosystem environment.
- Martian Urban cell (MUC) as a basic planning unit for Mars development.
  Supporting local technology and logistics for business activities.
- Local equipment, robotic help and transportation system.
- Martian technology development to establish a self sufficient Martian economy.

Affordable access to space

The first leg of any transportation system, at least as long as we will be earth based, will be the Earth to LEO or GEO part. While several state of the art possibilities are available with the conventional disposable system, we will mention other proposals that can meet our goals that are:

- Fully reusable.
- Commercial aviation type of maintenance, take- off and landing.
- Single vehicle with transformable capabilities at different speeds and altitudes.
- Advanced technologies such as pulsed laser propulsion, Skylon, high altitude bases and others.





Planetary Transportation system

In order to allow maximum affordability and to promote space activities in general and Mars development in our case, an advanced interplanetary transportation system must be developed. That is the basic condition for a profitable land settlement development including the utilization of space based materials and resources. To reach such goal we propose a re-usable cruiser-feeder system. The goal of this system is to utilize wholly reusable space-based vehicles that will ultimately operate as a commercial venture providing passenger and cargo transportation on the Earth-Mars route as well as in other important routes since its development will generate heavy traffic in a permanent way.

The cruiser will travel as a cycler between origin and destination bodies, (Earth, Moon, Mars etc) in a permanent back and forth trajectory while the feeder, at the planet's vicinity, will rendez-vous with the cruiser and transfer incoming and outgoing passengers and cargo in modular containers.

The key condition for its affordability, besides total reusability, is standardization. Components of the transportation system, must be few and highly standardized, to be produced in several numbers allowing scale economies while reducing equipment and manufacturing costs.

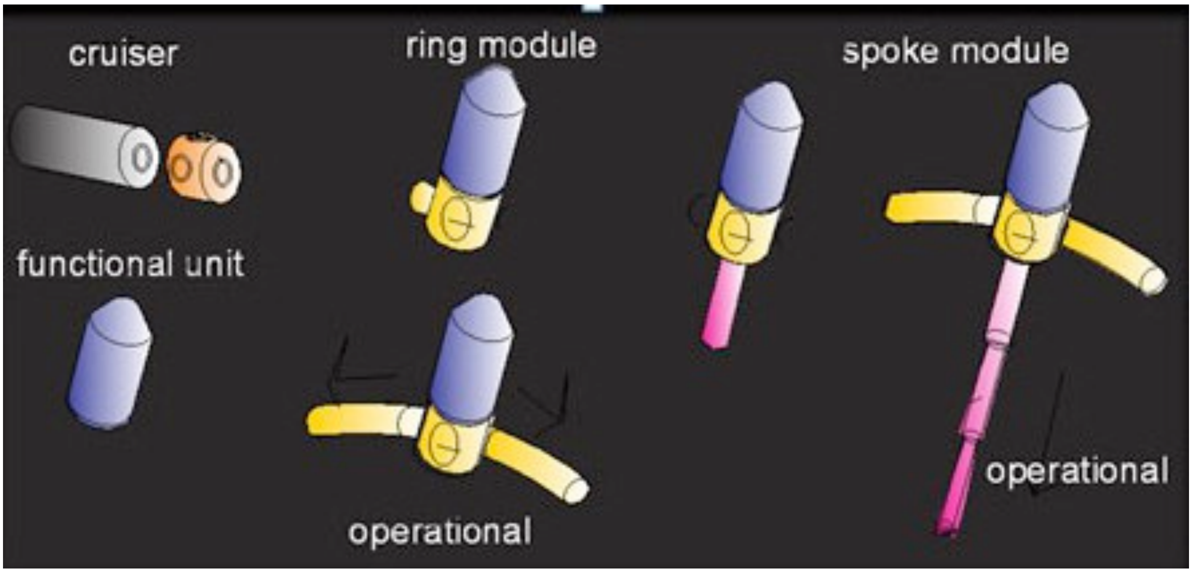
The design goals of such system must be:

- Standardized and entirely reusable components.
- Based in space for launching, storing and servicing.
- Refuel in space with ISRU materials(LOX manufactured in Mars, Phobos, asteroids)
- Flexibility and expansion capabilities.
- Ease of transferring passengers and cargo through standardize container system.
- Maximum self-sufficiency during missions.
- Provide terrestrial gravity.
- Become an independent and immediate source of profitable business activities.

The goal of the system is to utilize wholly reusable space-based vehicles that will ultimately operate as a commercial venture providing passenger and cargo transportation on main space routes (Earth-Moon, Earth-Mars, Earth-NEOs etc).

System components

The system will be composed of few basic modular components, that can be added to the first one and allow any type of expansion.



Systems Components

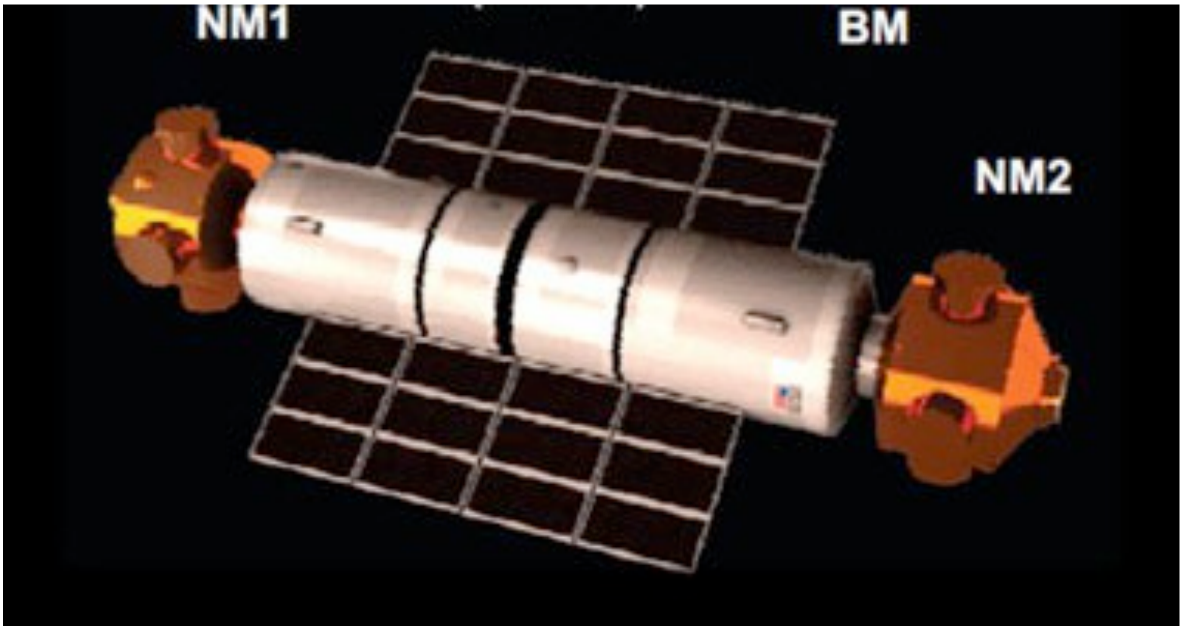
1-A cruiser, or basic propulsion module

Will operate on cyclical trajectory with several destinations (Moon, Mars, NEOs, etc) as needed. The basic module, a 5 m diameter, 10mt long cylinder to fit most existing launchers, will be equipped with the following systems:

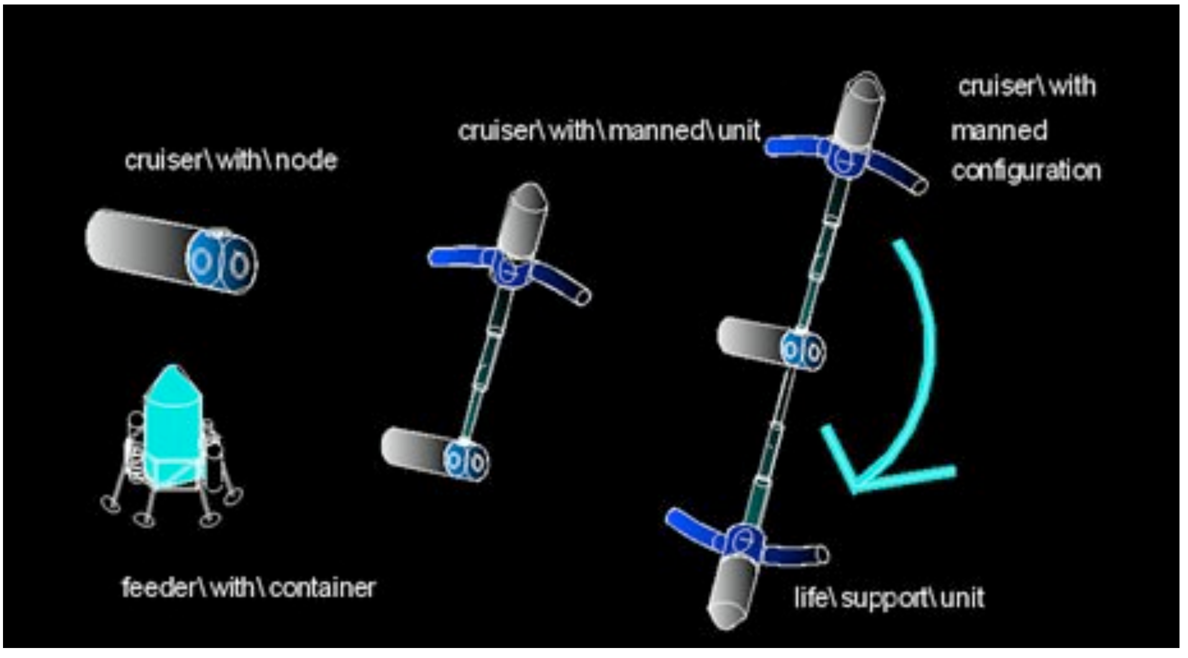
- Communications.
- Navigation.
- Power generation.
- Fuel tanks.

- Engines.

After the initial mission, the cruiser will acquire man-rated additional modules such as a habitation Hab, fully equipped and a life support systems module for air, water and fuel production as well as waste treatment and recycling equipment plus a food production facility.

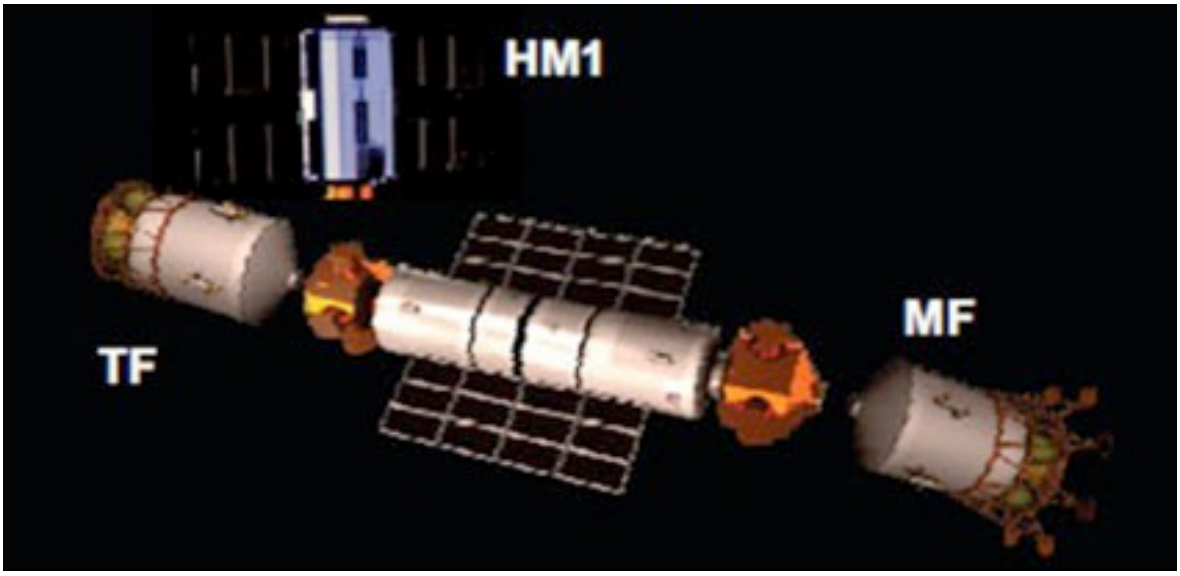


Cruiser-basic module with nodes.

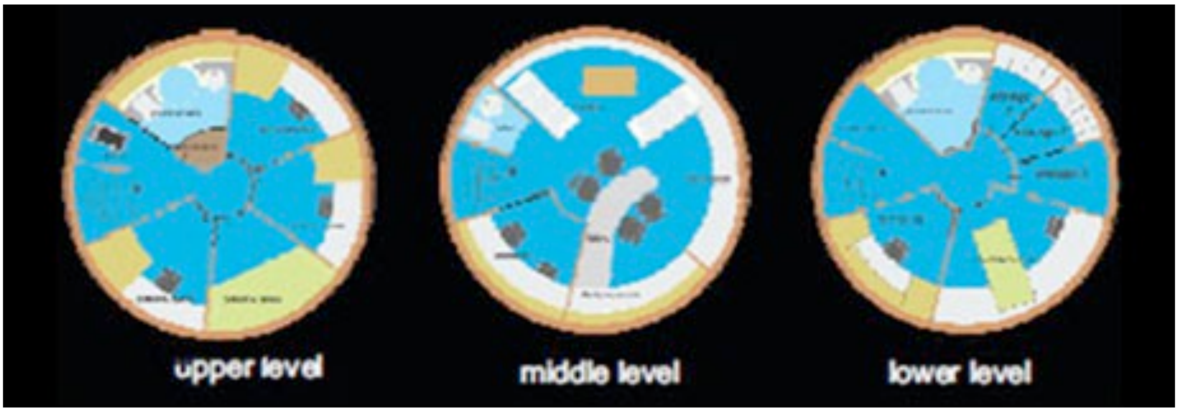


Cruiser-manned configuration.

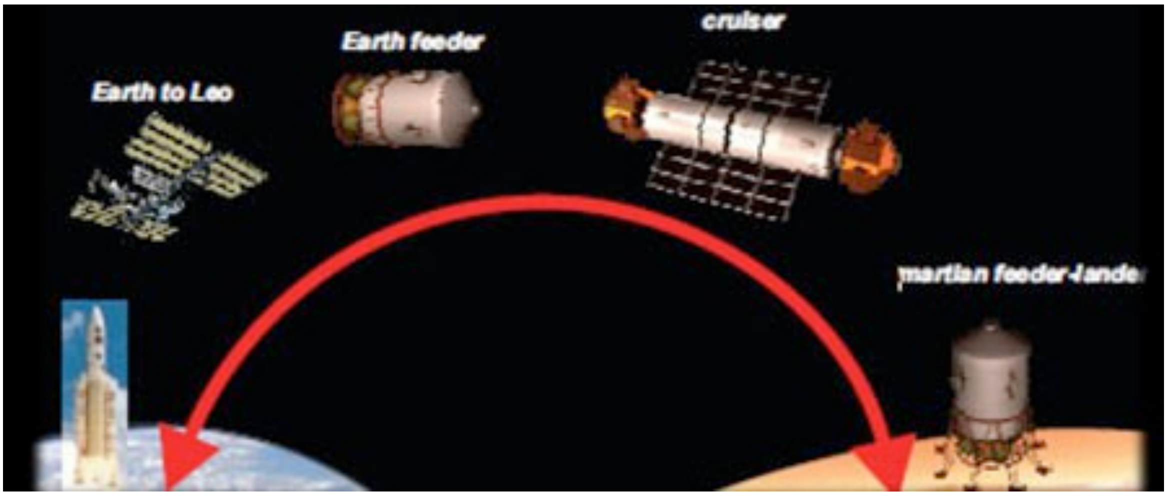
Several modules of the cruiser for manned capabilities, such as the Hab and the life support system will be connected by the time of the first manned mission in order to be operational in due time.



Cruiser with feeders.



Habitat module.

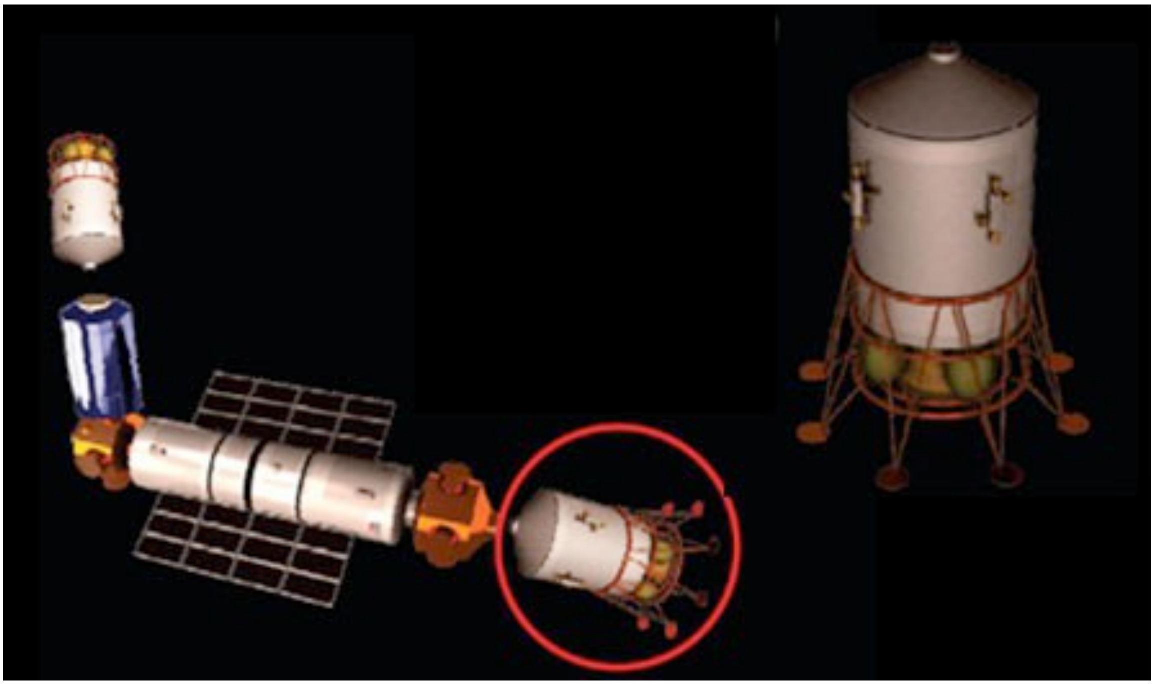


Basic Mission.

2-A modular feeder or feeder-lander

Such vehicle will connect the cruiser with different ground or space bases by transferring modular containers. A hexagonal shaped deployable exo-structure equipped with engines, fuel tanks, landing pads and navigation systems, to carry space containers to be transferred to and from Earth and other destinations. Such space tug or feeder will represent the standard container carrying vehicle for most space–based transportation requirements.

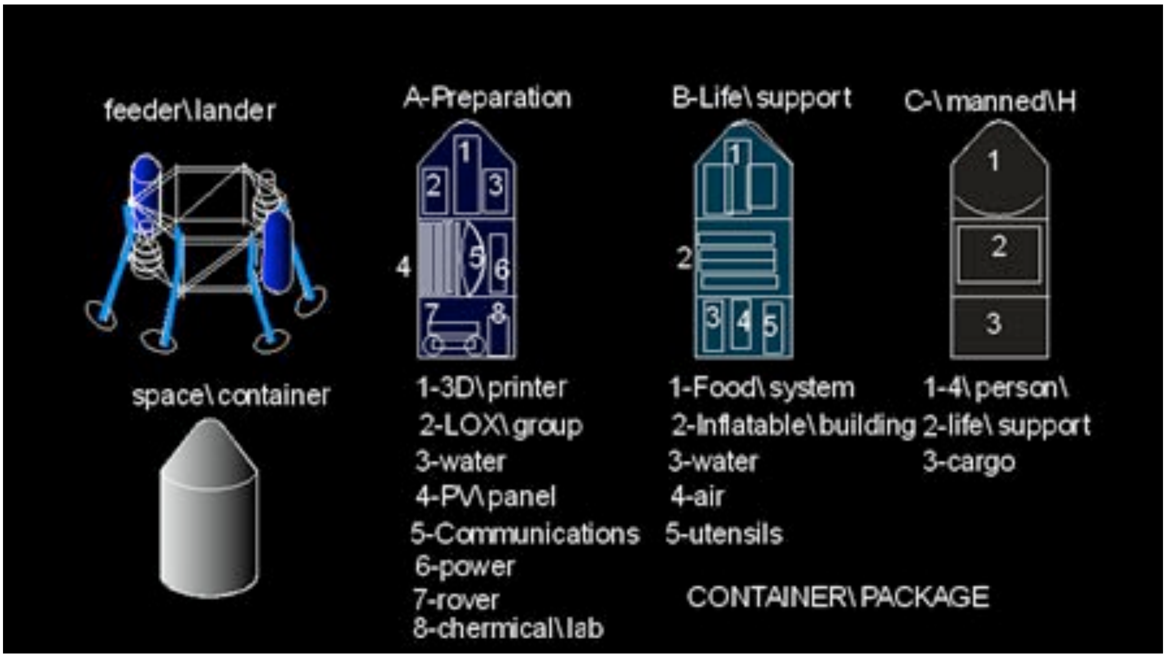
Terrestrial Feeder.



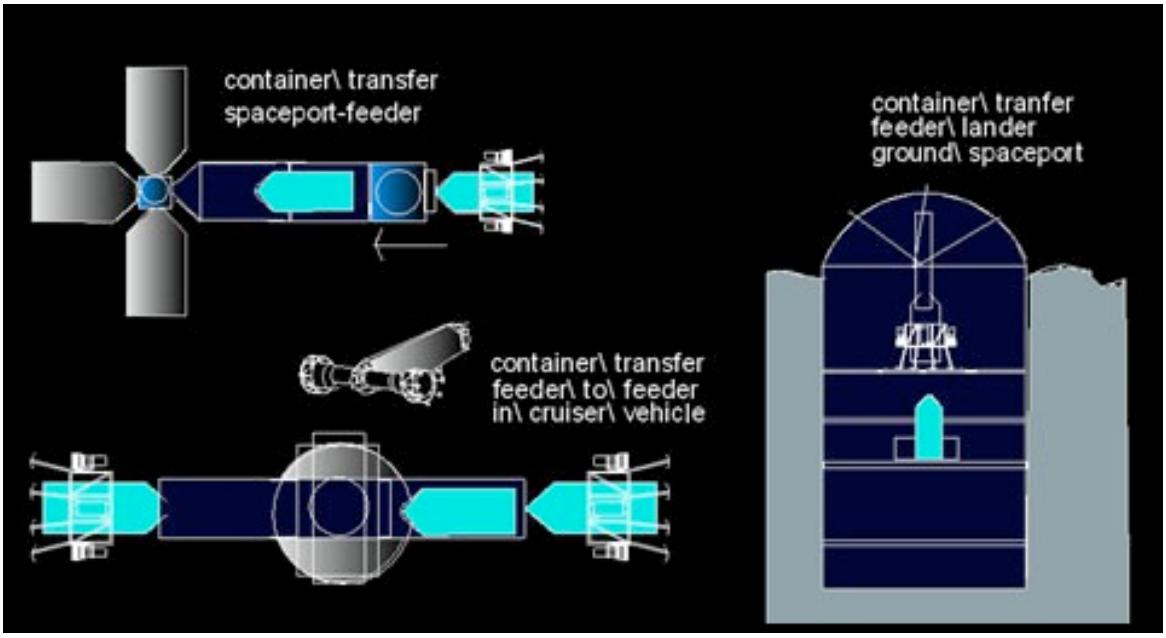
Martian Feeder-Lander

3-A standardized space container system

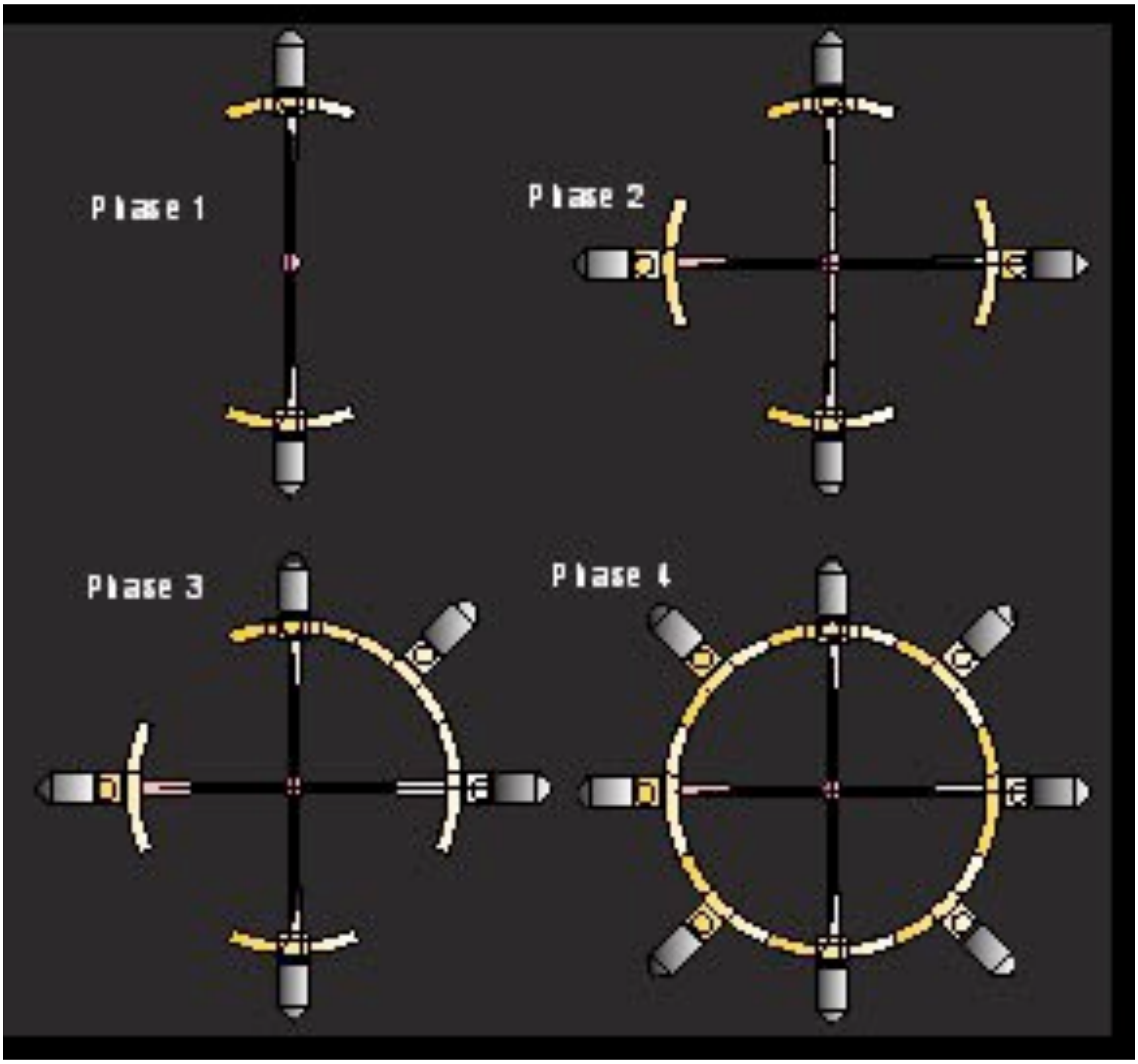
In order to transfer cargo and passengers between vehicles and infrastructures the recommended way is to utilize a container system. In this way there will be important savings in time with minimum risks. The space container consists in a two-level capsule, the lower one for cargo and the upper one for the crew and human passengers with manned life support capabilities. Such a container, of cylindrical and conical shape, will contain all pax and cargo payloads for each mission. It must be carried by both feeders and have the capability to be transferred from one feeder to the other, during flight, as well as passengers to the cruiser through specific node connections.



Container types.



Container Transfer System.



Assembly sequence.

To reach operational manned capabilities a few missions are required. Scope of these missions will be to deliver manned a Hab and a life support module with telescopic units that will dock with the cruiser nodes and allow central rotation and obtain artificial 1G conditions at the perimeter of the system (the Hab and life support systems). In this way the system will be operational for manned missions and will allow further expansions in accordance with its design capabilities.

Further functional modules will be connected to the system to allow it to perform different functions, and to become an Orbital Operational Platform (OOP) as its final configuration.

The Martian transportation development plan, as part of a larger system, can be divided in three phases.

- Phase 1-Mars fast track missions to set up manned feeder-cruiser transportation system.
  The first goal of this phase is to establish a reusable and affordable cyclical transportation system between the two planets, by installing and equipping in its final orbit the cruiser vehicle. Such result will be accomplished with three missions

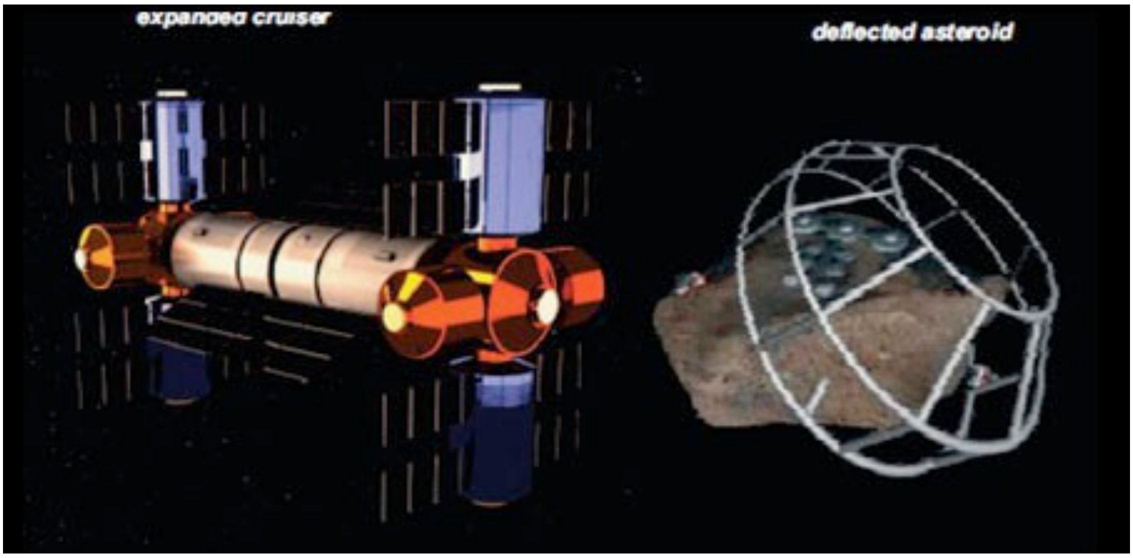
and four launches from Earth as part of a systematic approach to space transportation in accordance with the Mars Fast Track plan. The final operational configuration of the cruiser, after the first three missions, will be composed of:

- A basic propulsion module.
- Two connection nodes.
- The Hab and life support module including food production module and facilities including telescopic connectors to ensure 1G gravity by rotation.
- The feeders attached at the proper node connection.

Particular provisions are made to health issues. The Hab module of the cruiser will contain a heavy shielded area, entirely self sufficient, that can be occupied by the manned crew during solar flares or other high radiation events that need special protection, furthermore in the Hab module a medical care facility is included and will be fully equipped for radiation effects or other emergencies. Two node modules, one for the terrestrial feeder and the container transfer system another for the Martian one, will be part of the first mission. Once operational the system can provide immediate ROIs by supporting all future Mars missions.

- Phase 2- System expansion with asteroid capture and its utilization.
  The main available in-situ resources in outer space are asteroids and comets.
  By reaching and deflecting a small water rich NEO asteroid (30m-40m diameter, approx. 150.000 tons to 180.000 tons), the cruiser can expand, utilizing asteroid local resources, allowing more room for its pax and cargo and expand its transportation business.

- Phase 3- Self sufficient space settlement as transportation system.
  Such main business will guarantee a continuous and exponentially growing economical development to allow expansion throughout the solar system. A business plan must show profit possibilities from such developments with activities originated in the settlement.



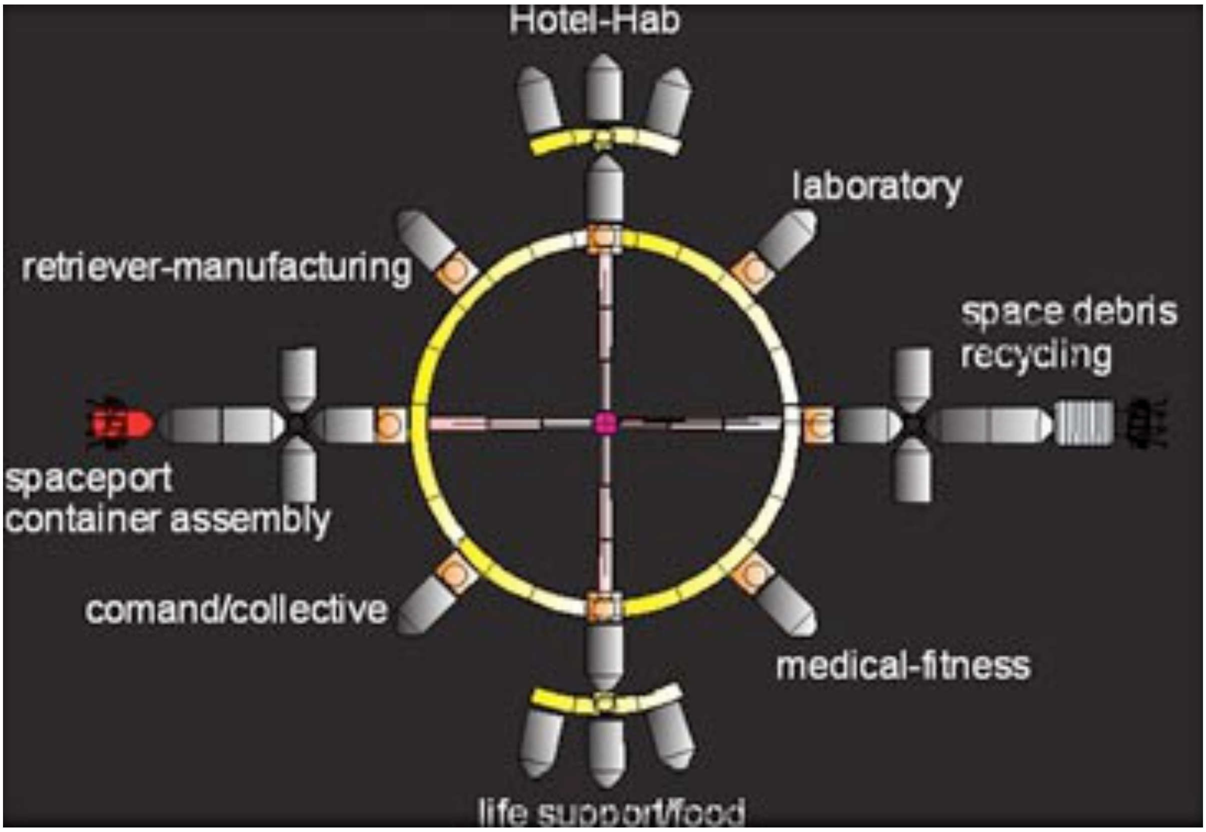
Expansion with asteroid retrieval.

The space infrastructure

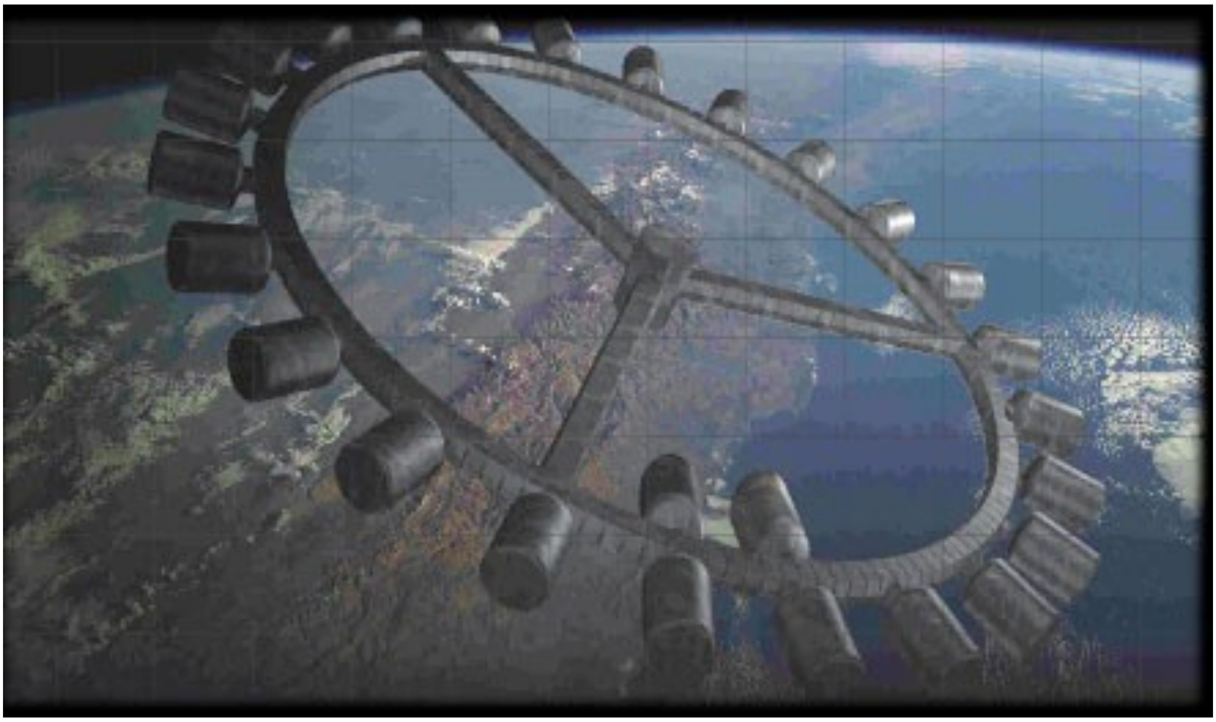
To complement and support the transportation system space and land based infrastructure must be provided. They are analyzed in the following pages.

OOP as a cycling alternative

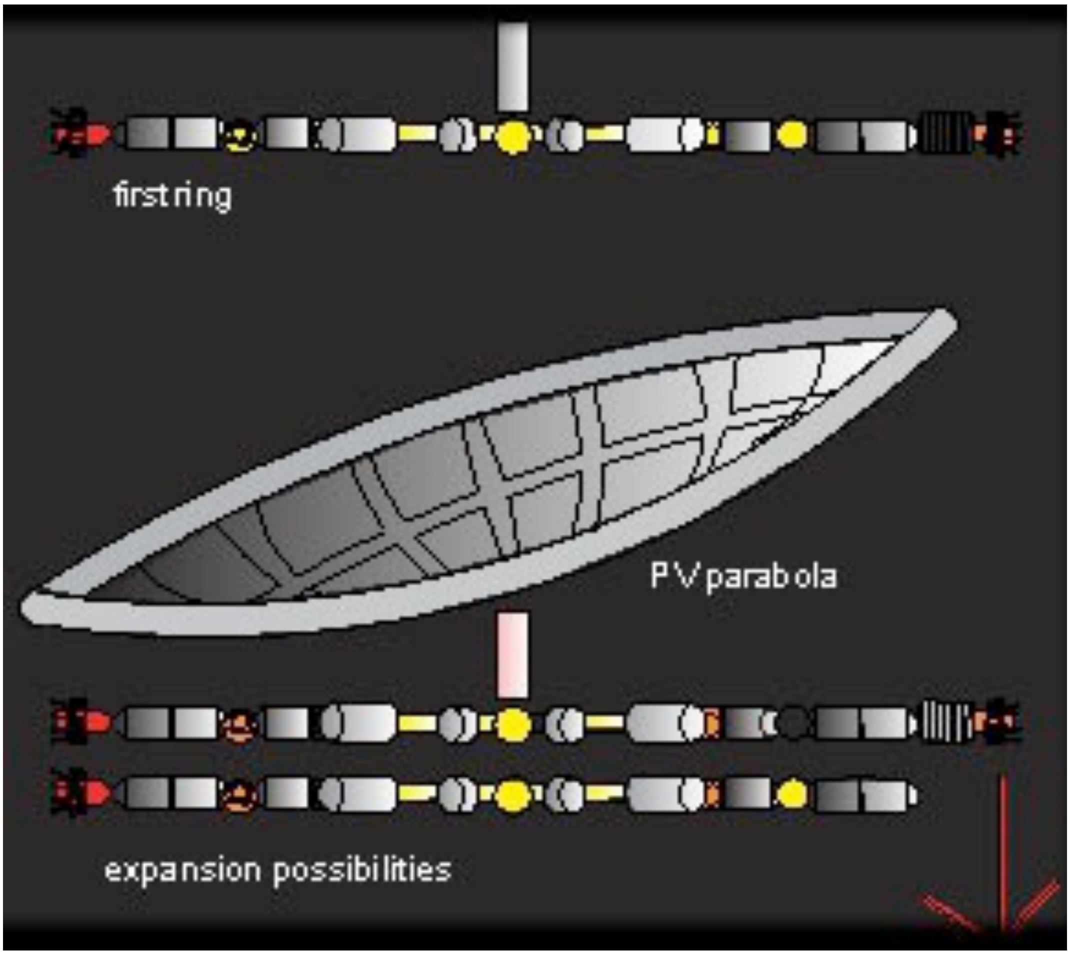
An orbiting terrestrial station is one of the basic components of the transportation system. Such space infrastructure must support arrival and departure operations of the feeders outgoing and incoming. A specialized and dedicated spaceport module, properly equipped for the container handling and the feeder storage, refueling and maintenance, with expansion capabilities, must be available to manage the heavy traffic expected. In our case, as a more profitable alternative, the OOP (orbital operational platform) will not be in a permanent Earth orbit but in the Earth-Moon cycler trajectory. At Earth proximity it wills rendez-vous with send and receive terrestrial payloads, while at convenient Moon vicinity, it will perform the same activity for Moon and trans-Moon missions. In this way the feeder support will be another additional for profit activity in an already profitable lunar transportation system.



Single ring system



Alternative possibility



Expansion alternatives

The land based infrastructures

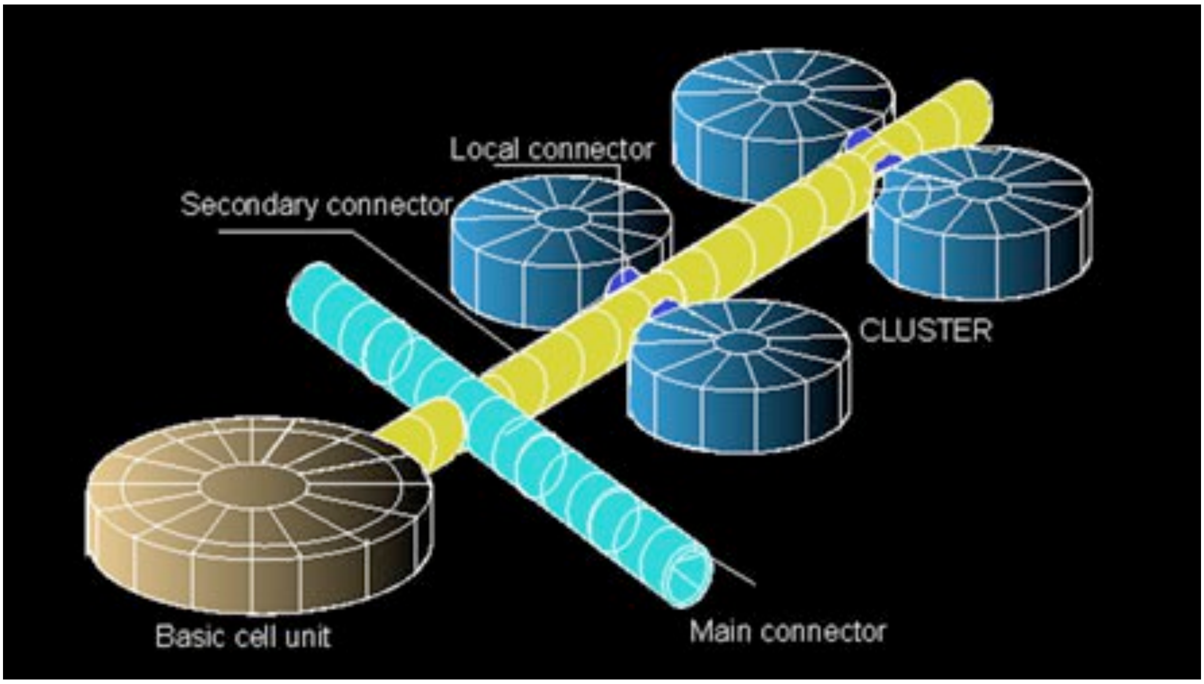
The system components

The specific requirements of extraterrestrial planning are unique and quite different from the terrestrial ones. We are entering mostly uncharted territory since extraterrestrial town planning is not yet a discipline. We can describe extraterrestrial town planning by describing the main components:

- **The basic cell**: a self sufficient enclosed volume of different dimensions, (small initially for technological limitations) and different destinations.
  The cell is the basic planning unit

- **The connector**: to render the cells functional, they must be connected to other components. The connector will guarantee physical access and utilities to support the cell. While common to both, we must consider the possibilities and different requirements of above and underground settlements, which will be evaluated later on. Utilizing the basic cell in different dimensions and combinations we may obtain the first group to define the UC (Urban Cell).

- **The cluster:** We will define as cluster, a group of cells, interconnected between them, as part of a functional ecosystem (agricultural areas, manufacturing facilities, residential system etc). Before starting the architectural layout let's define some basic planning concepts for an extraterrestrial base.



Station basic components

Step 1-Unmanned Outpost

The facilities prepared for the first manned mission will be an unmanned outpost including the following:

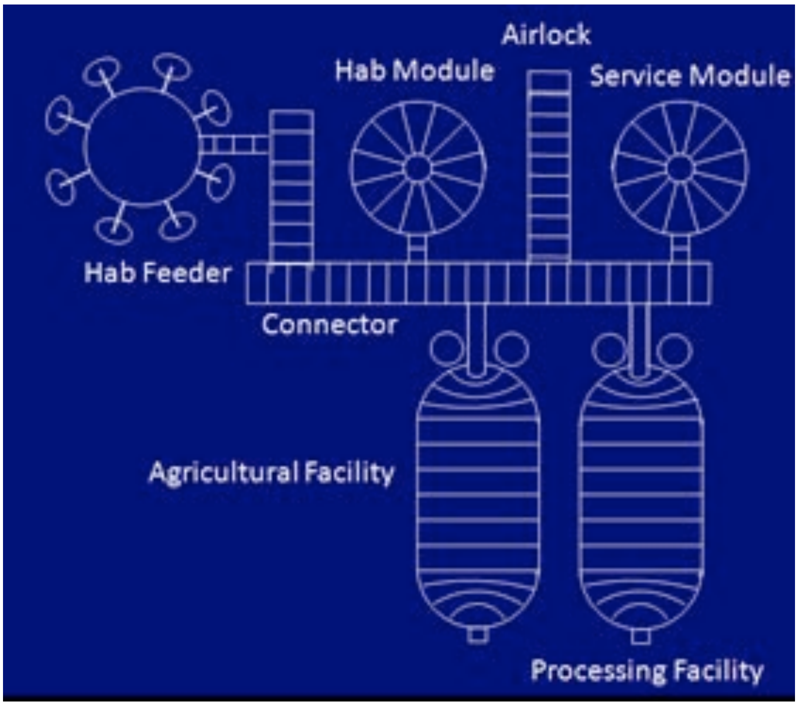
- Habitat module.
- Food production dome.
- Life support units.
- One rover vehicle.
- Power generating unit.
- 3D printing equipment.

With these facilities installed the first manned crew would arrive, complete and render operational the first outpost.

Step 2-Manned Outpost

This phase will consist of the building of the supporting base by the following manned crews in accordance to a flexible Master Plan.

- **Mission1**- during this mission, with proper excavating equipment, to be attached to a multifunctional rover vehicle, excavations will continue to prepare the vertical Hab facility. Once excavations are completed construction will proceed as shown in the sequence attached.
- **Mission 2**-During this mission the vertical Hab will be finished and occupied and main connectors will be erected, including initial food production and manufacturing facilities
- **Mission3**- All facilities built, prepared for following mission, and most construction technology tested and implemented. The supporting base will be fully operational and will allow starting massive excavation activities for the construction of the Martian settlement.



Outpost layout

The MUC (Martian Urban Cell)

City planning of extraterrestrial bodies is not a common science, therefore in this paper we want to establish the foundations of this incoming discipline of extraterrestrial planning requirements in a hostile body to allow the best conditions for its human population as well as schemes for expansion. The Martian Urban Cells (MUC), being the basic urban cell, consist in a combined above ground and underground habitat that will contain all needed equipment and facilities for self sufficiency as well as all expansion capabilities. The MUC will be our development goal for the initial base to support the settlement construction activities. The MUC must become the basic component of habitat planning that can be isolated or in clusters and must be: totally self sufficient, connected with a ground terminal and to a spaceport facility, and multifunctional or specialized. The planned population for an urban cell ranges from 18 to 90 people. City planning considerations and alternatives will be examined following these goals:

- Minimum required space.
- Shirtsleeve environment.
- Maximum protection from radiation and hostile environment. Maximum in situ resources utilization (ISRU).
- Totally self sufficient.
- Connected with a ground terminal to other facilities and MUCs.
- Multifunctional or specialized.
- Connected to a spaceport directly or through a transportation system.

The MUC, ranging in population from 20 to several hundred will be our development goal for the initial base to support the settlement construction activities.

Several expansions schemes will be analyzed and a networks of MUCs with their individual functions with needs and requirements, including Martian transportation system to supply the units. Once established the expansion pattern the MUCs will be analyzed and their underground and above ground components fully described. They range from spaceport, partially underground, above ground facilities with minimum human presence, agricultural centers, manufacturing facilities, surface access units, transportation systems and terminals, vertical hubs, totally underground will connect the surface with the underground facilities and contain habitats and needed common and supporting areas. Their expansion and specialization will also be considered in a general master plan of Mars development

Settlement system decision

Before proceeding to architectural design we still need to define the type of settlement that we may find most suitable to guarantee all needed conditions to the settlers, such as maximum protection and comfortable environment.
Our main choice must be between an enlarged above ground settlement versus a more compact underground one. The parameters involved in rating the alternative are:

- **Safety**: Need to protect crew members from the hostile external environment and deadly radiations.
- **Built-up area:** Areas and volumes to be constructed in order to house all needed functions.
- **ISRU percentage:** Percentage of local materials utilized in order to be less dependent from terrestrial supplies and equipment.
- **Ease of construction:** Simplicity of construction, including assembly and erection time and complexity, as well as requirement of special large scale construction equipment.
- **Expansion:** Possibility to expand in all directions with lesser activities and construction.
- **Flexibility:** Possibility to use areas and volumes for more alternate functions.

The evaluation chart shows a better performance of the underground facility for manned activities and above ground for those not requiring full time manned presence.

RATING SCORES: 1-poor 2-low 3-average 4-good 5-optimal

SYSTEM	EVALUATION PARAMETERS							RATING SCORES	
	SAFETY	BUILT-UP AREA	ISRU Percentage	EASE OF CONSTRUCTION	EXPANSION	FLEXIBILITY	TOTAL	NOTES	RECOMMENDATIONS
ABOVEGROUND	2	2	3	2	3	2	13	Big dimensions Poor safety	not recommendable
UNDERGROUND	5	4	4	1	3	2	18	Optimal safety small dimensions	recommendable

System evaluation matrix

Underground Terraforming

The decision to proceed with an underground facility allows us to consider the concept of underground Terraforming as a valid option for future space development plans.

The word Terraforming was coined by science fiction writers to describe the process by which an extraterrestrial planet, with hostile conditions for humans, can be modified to suit terrestrial ecosystems. In the solar system, only Mars can tentatively be adapted with a process that may take centuries, needing advanced technology not yet existing, with cost estimated in quadrillions of dollars. Following such heavy requirements and natural limitations like different gravity that could never match the terrestrial one, the most convenient system for human presence in space seemed to be space settlements where you could match temperature climate environment and gravity. Actually while we can't overcome the gravity requirements we can certainly make human friendly and habitable most space bodies by creating an artificial terrestrial ecosystem, well protected, that can simulate all terrestrial conditions except gravity. We name underground terraforming such condition and possibility.

1-Underground Terraforming concept

We define Underground Terraforming, the capability to build entire, self sufficient terrestrial ecosystem based communities, for human utilization in other bodies.

Design goals for underground human settlements in extraterrestrial bodies must guarantee the following:

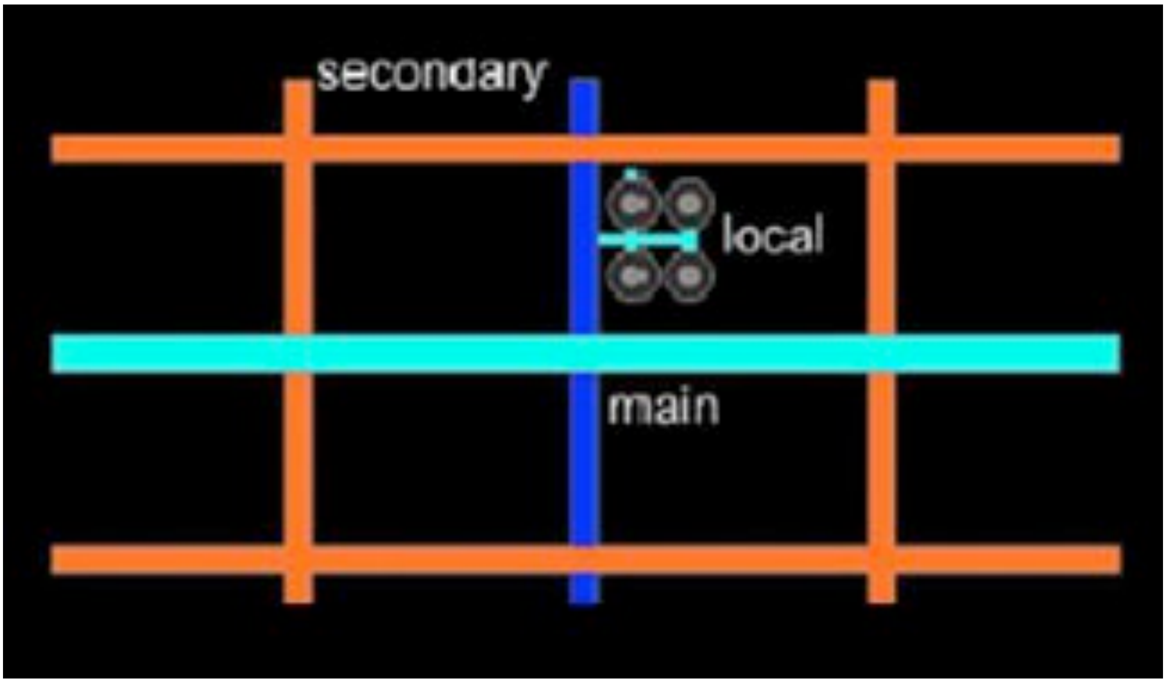
- Comfortable environment for the human population "shirtsleeve conditions".
- Possibility to prepare adequate outpost before the arrival of the first manned missions.
- Standardized systems, subsystems and habitable units.
- Maximum flexibility for installation upgrades.
- Expansion capability in any or all directions.
- Create self-sufficient communities for technological and economical development of the host celestial body.
- Have short travelling distances between the interconnected habitable nodes.
- Small volume Habs in single successive steps.
- Affordable costs.
- Radiation and environmental protection.
- Maximum ISRU utilization.
- Intervention possibility in most bodies.
- Immediate operational capability.

A natural barrier is supplied by the above soil, guaranteeing protection from radiation and extreme conditions. This settlements can be built immediately, allowing livable conditions, without the need of much complex, expensive and time consuming atmospheric Terraforming (in the very few bodies possible), in most solid bodies.

4-Planning concepts

Starting from a basic self sufficient unit, called Urban Cell, representing the City planning component, we must define its growth and expansion possibilities in accordance to a plan that allows the optimal utilization of local resources and conditions, both above and underground. Extraterrestrial settlement growth is primarily conditioned by the need to enclose all paces to protect them from the hostile external environment. In addition, design constraints must account for the lack of infrastructures, the very high transportation costs, the size limitations of transported components and the difficulty in building large spaces. For these reason several expansion alternatives must be analyzed and rated so that a recommendation can be made with the following goals:

- Possibility of expansion in all directions.
- Maximum dimensional flexibility.
- Specialized areas.
- Central identity core.
- Minimize connector distances.
- Compactness of the overall areas due to the need to close all spaces and connectors.
- Shirtsleeve environment duly protected from exterior hazards.



Connector hierarchy

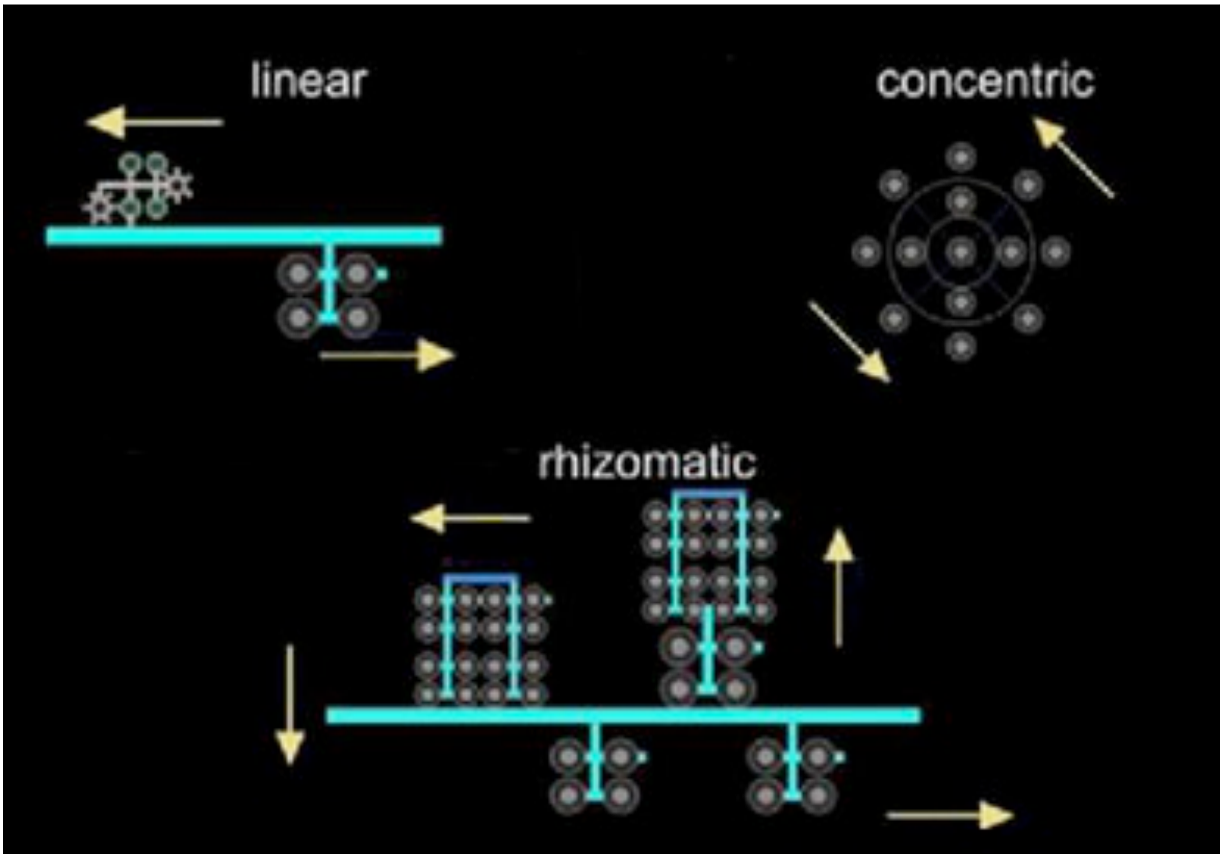
Expansion schemes

In order to analyze expansion schemes we must first define the basic urban unit of a settlement. Alternative schemes with expansion possibilities are shown in the chart. We can analyze different types of expansion:

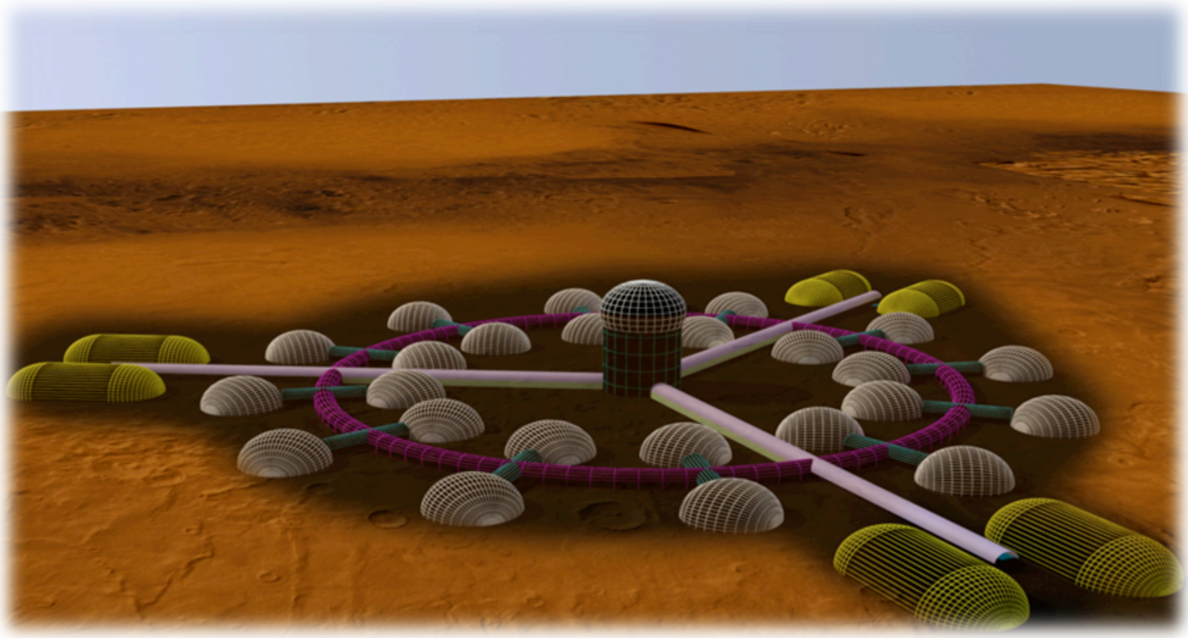
- **1-Linear:** The linear expansion system, while the easiest to build have several disadvantages:
  - -Low flexibility due to single direction.
  - -Large volume needed because of big distances to reach functional units.

- **2-Concentric:** This growth pattern, while utilizing less volume due to shorter distances and allowing expansion in all directions, limits accessibility to the inner circles by ground vehicles.

- **3-Rhizomatic:** “A part of the whole that can reproduce the whole”. This system allows maximum expansion in all directions, by individual units or cluster of any size. To better define and decide which system is most convenient we added an evaluation chart with selected parameters, fig. Analyzing expansion possibilities of MUCs, the linear, the concentric and the rhizomatic, the latter appear to be the recommended one with the option of growth in all directions for the above ground settlement while the concentric system is most recommended for the underground one as per the enclosed system evaluation chart.



Expansion alternative



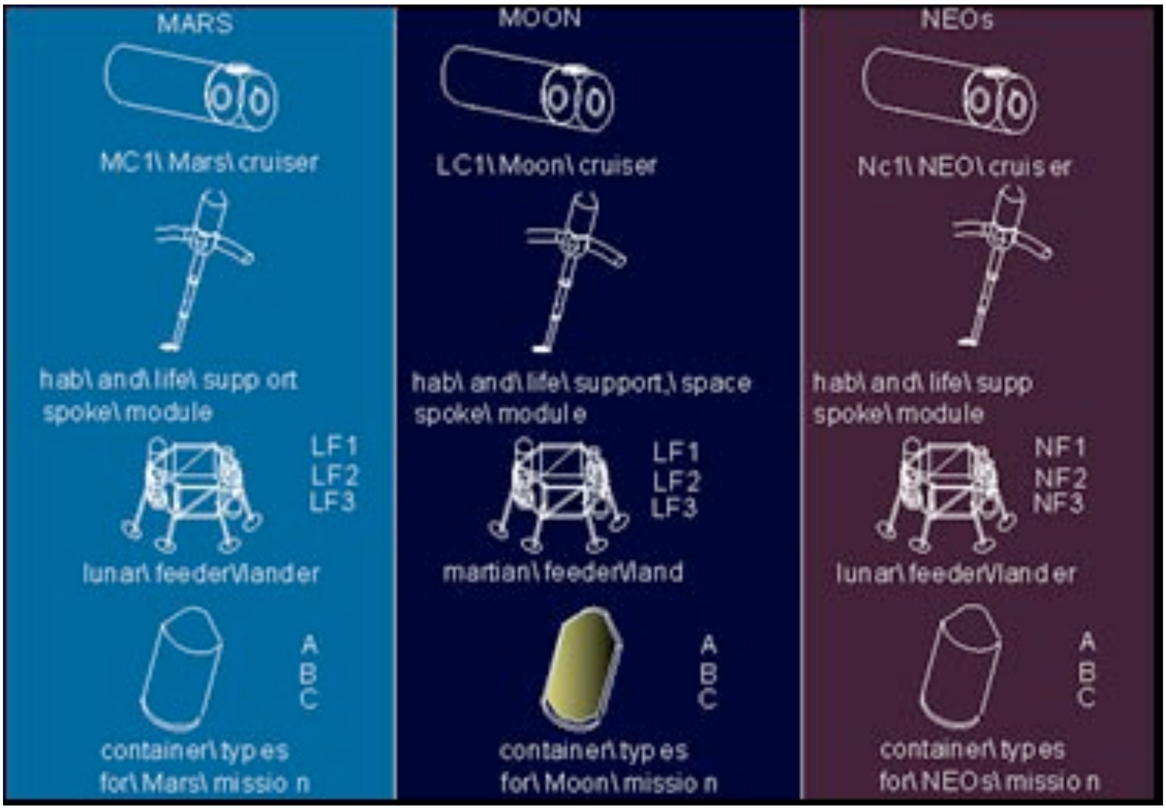
Underground basic scheme

Mars fast Track: Mission Architecture

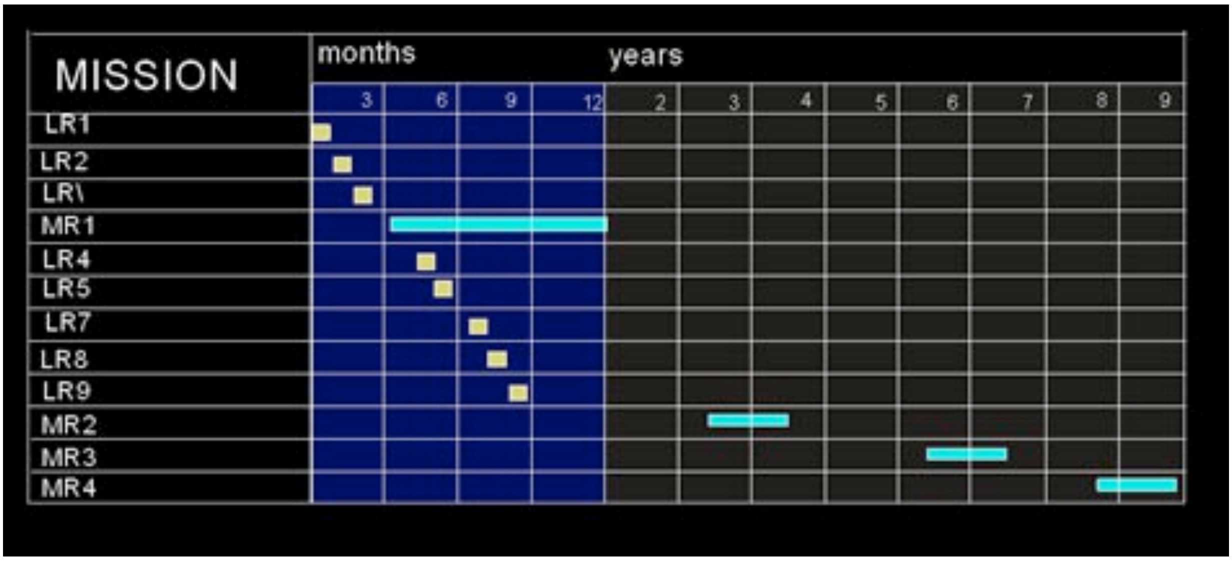
Having defined the enabling technologies and the proposed system we can utilize its components in the best combination to perform the first mission to Mars as an integrated activity of a larger development plan.
This concept will allow establishing an operational space transportation and infrastructural system, as well as becoming the first manned mission to the red planet. The standard components involved in the fast track mission are:

- **Cruiser module:** MC1 (Mars cruiser 1) for the earth-mars system and LC1 (Lunar cruiser (for the Earth- Moon trajectory) for the Lunar system and NC1 (NEO cruiser) for the NEOs system.
- **Feeder module:** LF1, LF2, LF3 for the lunar operations, MF1, Mf2 and Mf3for the Martian operations NF1 for NEOs.
- The **container packages** are very similar for all missions.

- **Type A:** Site preparation package, including: communication equipment, power generation system, solar PV cells and /or nuclear, equipped multifunctional rover, LOX production equipment, 3d printer.
- **Type B:** Life support package including: Life support equipment (water, air, regolith processing). Mining equipment, mineral processing.
- **Type C:** Manned Hab package A residential, service command Hab including medical facilities, airlock, and all life support systems.
- **Functional types:** Functional package, specific for each needed function (Lab, command, food production, health care, laboratory etc).



Main components



Mission schedule

For the first manned Mars landing the planned sequence is as follows, considering standard components and lunar development with the same goal:

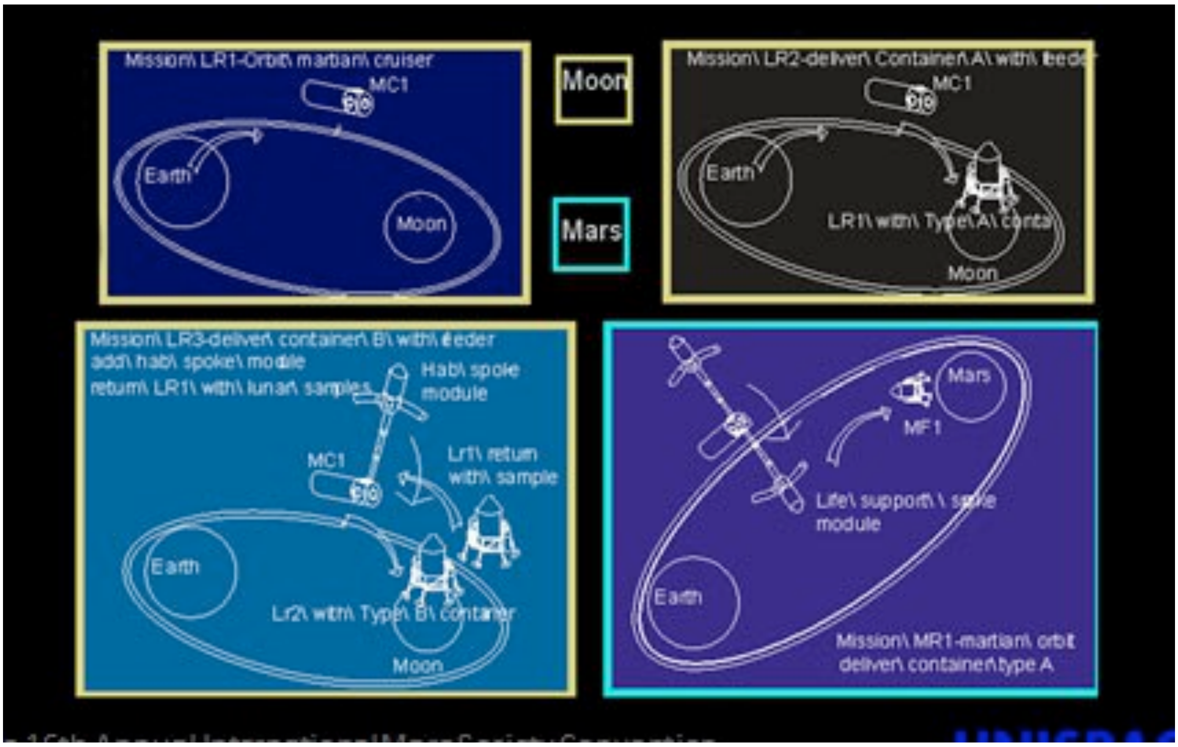
- **Mission L 1 - Cruiser capability:**

  This first mission consists in orbiting the Earth to Mars cruiser module (MC1) in a lunar cycling trajectory.

- **Mission L2- Add lunar feeder lander**:

  The reason is to allow after one week and not after a much longer Martian two-way trip to connect the feeder –lander vehicle (LF1) In this case such vehicle, with the container package type A, will land on the Moon surface and start immediately operations.

- **Mission L3-Add package B:**
  In this mission the cruiser will deliver to the moon a package type B to prepare for manned missions, return package A with soil samples and install a Hab telescopic module to the cruiser.



Mars fast Track 1

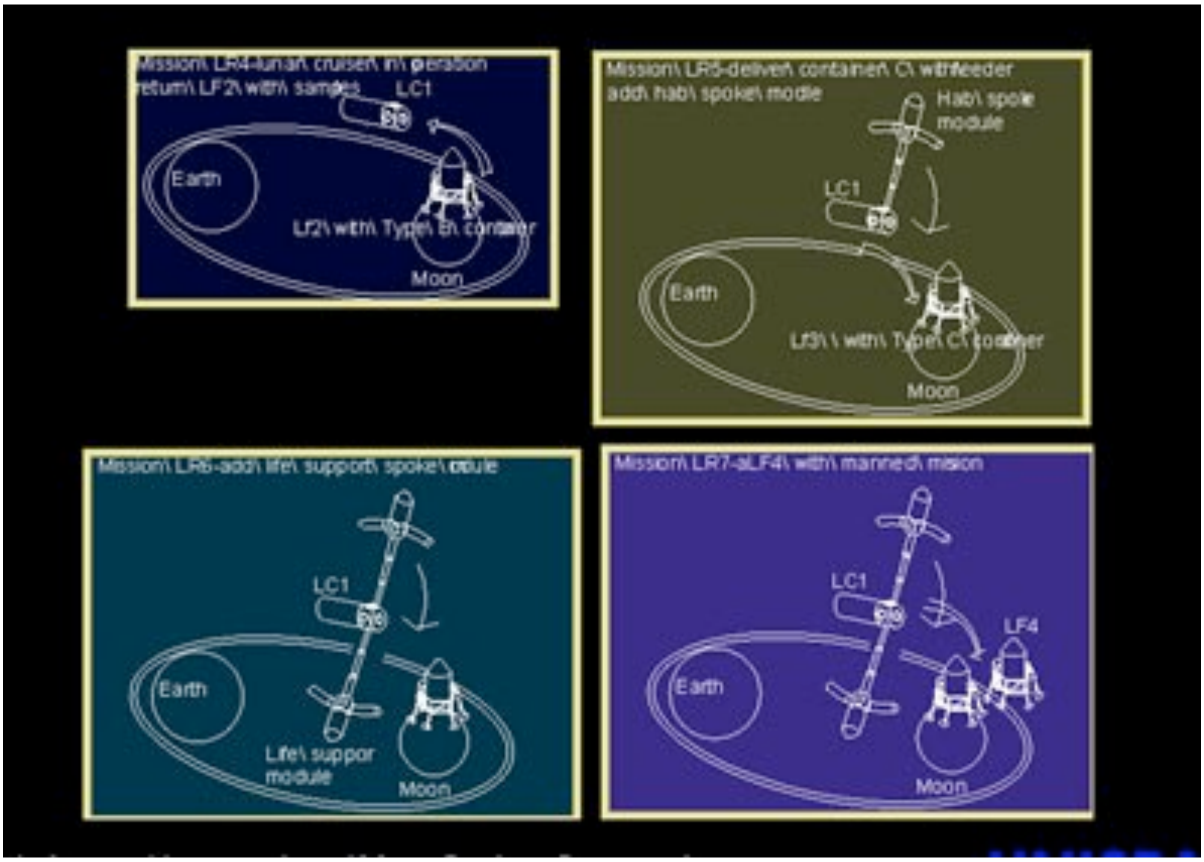
- **Mission M1-Cruiser to Mars:**
  This mission consists in returning the cruiser to earth proximity where it is connected by a Martian feeder-lander (MF1) with a container type A. After docking the vehicles will change trajectory and follow an earth- mars cycling orbit. During this mission, at mars vicinity the feeder –lander MF1 with package type A will land on the planet to prepare the arrival of the following mission.

- **Mission L4- Earth-Moon cycler:**
  A new Earth-Moon cycler propulsion module (LC1) to be inserted in the orbit to replace the former one on its way to Mars. At Moon vicinity such cruiser LC1 will rendez-vous with the previously landed lunar feeder (LF2) that will transport precious lunar samples (regolith and other interesting rocks and minerals, supplied by the rover and its robotic arm for tests in our planet.

- **Mission L5- Add type C , lunar hab package to lunar facilities:**
  New lunar feeder-lander (LF2) delivering type C package, will be connected to the cruiser (LC1) on earth vicinity while the returning lander LF1will leave the cruiser LC1 and be based on the orbital facility with its samples to be analyzed in earth's laboratories. LF2 To land on Moon site and perform its tasks for manned mission preparation. During this mission will be delivered and connected to the cruiser a Hab spoke module.

- **Mission L6- Add life support module:**
  Cruiser LC1 to be docked by new lunar feeder lander LF3 with Hab package and telescopic connector. From Moon feeder LF2 back to Earth with samples and drilled terrain.

- **Mission L7- Manned capabilities package:**
  Feeder lander LF5 with manned capabilities for emergencies, to dock with LC1 and land on moon site for emergencies during future manned missions.



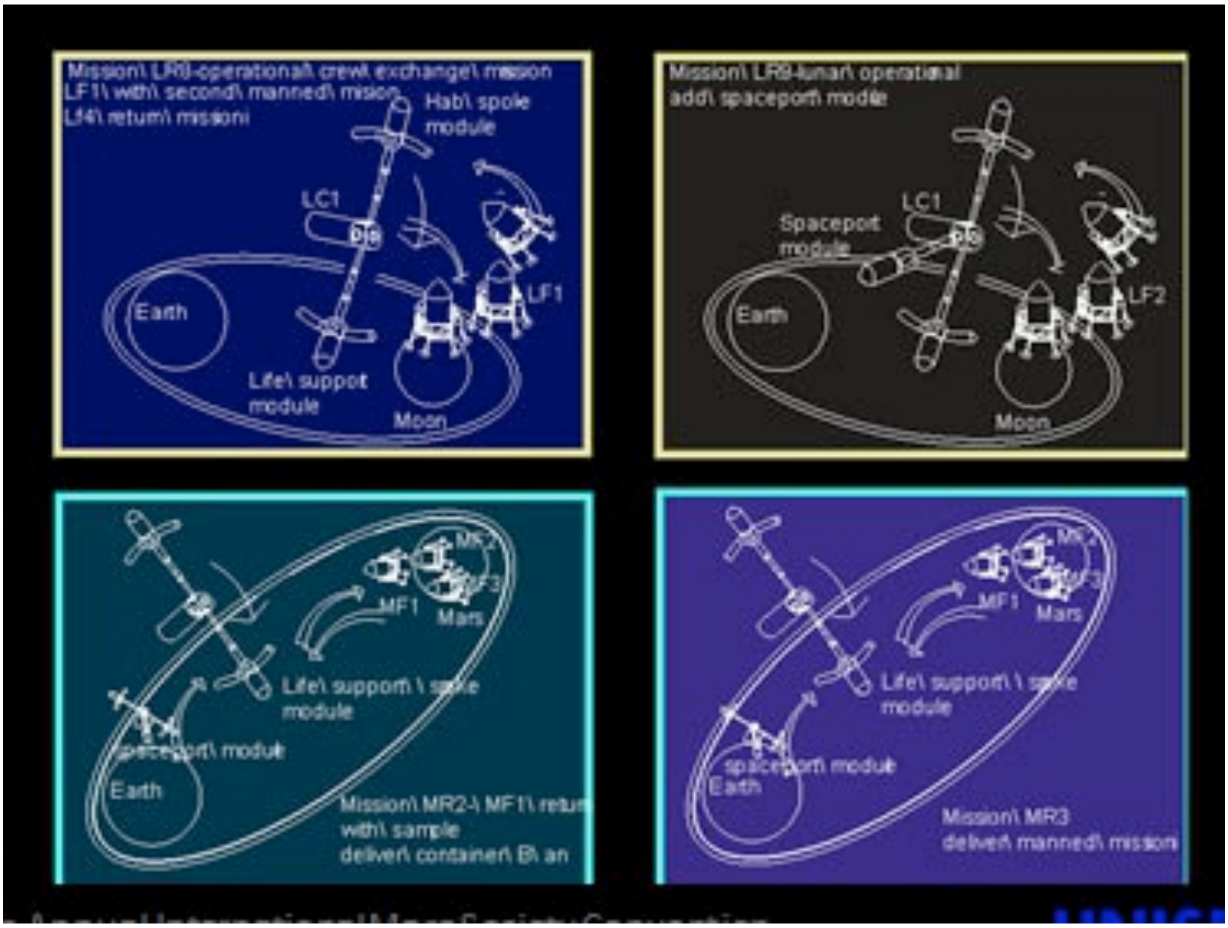
Mars fast track 2

- **Mission L8-Manned mission:**
  Feeder lander to deliver manned mission with new standardized system. Crew to activate outpost, 3d printed housing system and inflatable buildings.

- **Mission L9-Second manned mission:**

The second crew will reach the lunar outpost and replace the first crew that will return to earth. This crew will start operations on the lunar surface utilizing the completed outpost.

- **Mission L10-Spaceport module added to lunar cruiser:**
  The spaceport module will be added to the lunar cruiser to support future non lunar missions. At the end of this mission the lunar cruiser-station will be perfectly equipped to support further Martian missions.



Mars fast track 3

- **M2-Second Martian mission:**
  From the new spaceport attached to the cruiser-station will starts this most complicated mission. It will deliver three modules to the Martian cruiser, the life support telescoping system, to complete manned capabilities and two feeder landers with packages B and C (to be used for emergency purposes as well as for manned capabilities). At Mars vicinity it will receive the first Martian container with soil samples.

- **M3-Mars manned mission:**
  The manned type C package with a crew of four will be delivering to Mars to perform the first manned landing on the planet and to complete the outpost.
  Following the first mission others will render operational the Earth-Mars cruiser and Martian outpost allowing the colonization of the red planet.

Mars Urban Cell Architectural program

Having decided on the underground settlement type let’s analyze an architectural program for the Urban cell, that will represent the Martian base unit. The urban cells are composed of different main systems that can be summarized as follow:

- Above ground facilities and connectors
- Underground facilities, connectors and vertical Hab

AREAS	Missions Mission 1	Mission 2	Mission 3	Mission 4	Mission 5	total
surface access units	-	209	-	209	-	418
labs and workshops	76	Incl	220	270	-	566
core habitat	76	-	440	-	-	516
agricultural zone	146	-	-	146	146	438
manufacturing zone	146	-		146	146	438
connectors	32	32	110	292	8	474
maintenance	-	Incl	Incl	Incl	Incl	Incl
life support	76	Incl	Incl	Incl	Incl	76+Incl
total	552	241	770	1063	300	2926

Station Areas chart

Station initial population chart

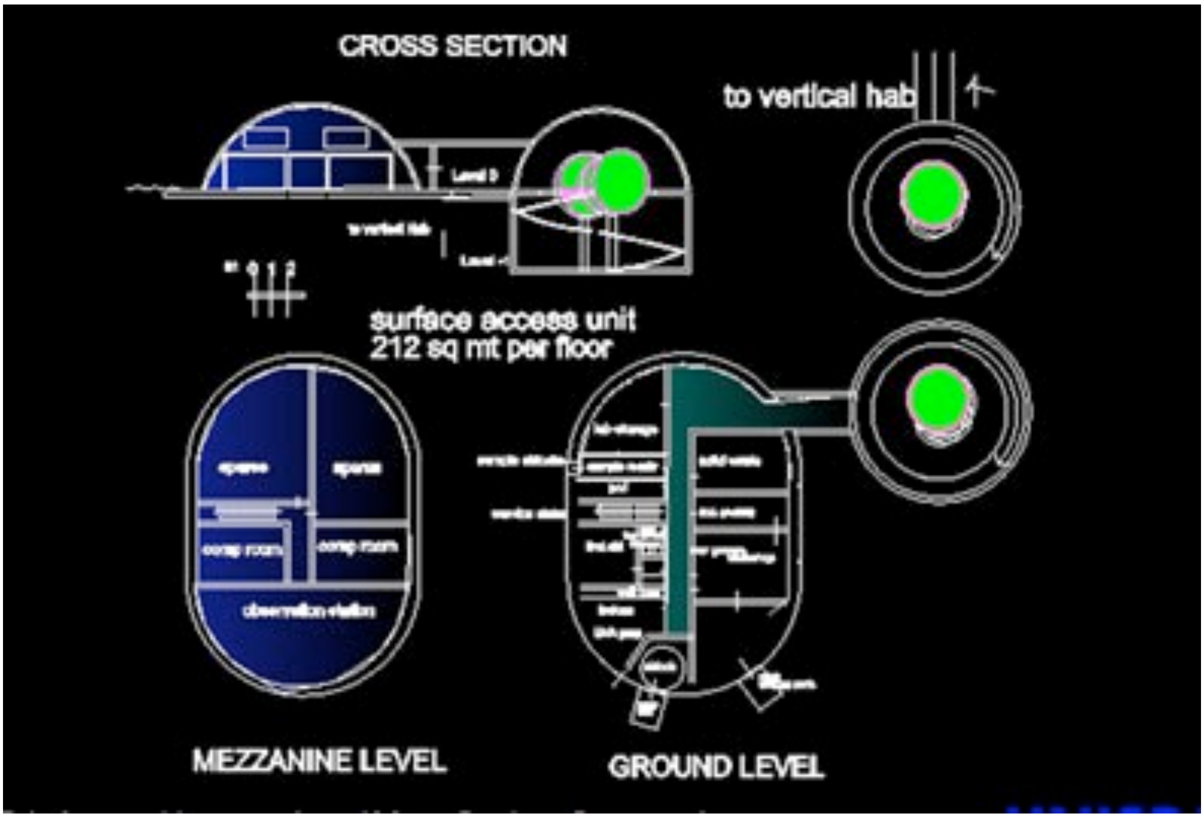
ABOVE GROUND

Surface Access Unit (SAU)
This enclosed facility divided in two levels, will be provided mainly to guarantee safe EVAs for the crew and vehicles as well as all supporting activities, such as:

- Rover support, storage and maintenance.
- Material storage.
- First aid.
- Airlock systems.
- Connections with Phase 1 section and Phase 2 vertical Hab.
- Future monorail terminal.
- Workshop and lab area (WL).

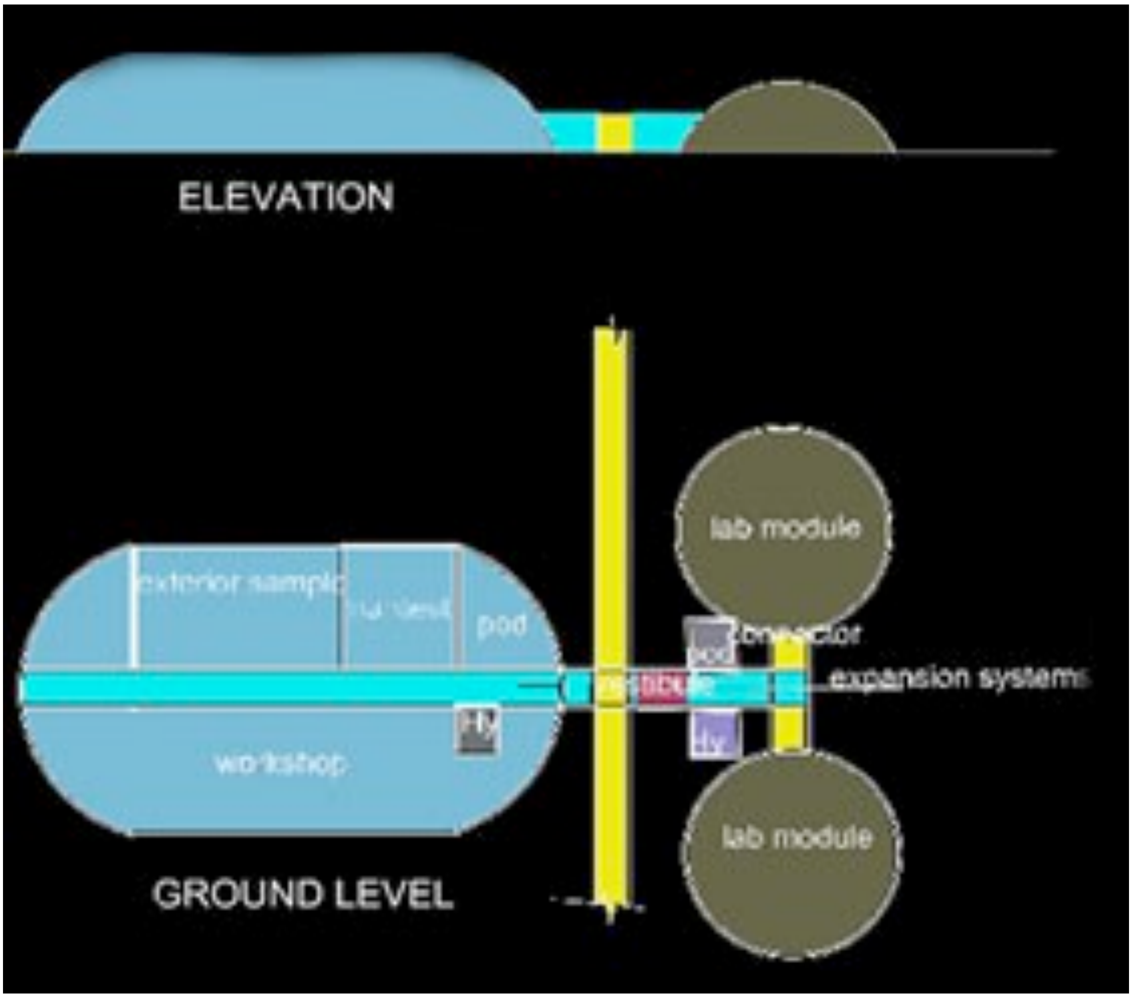
This facility will contain research labs for incoming materials, to be studied and tested by the geologist for local utilization, as well as for terrestrial companies that will contract such services to the asteroid organization.

Being close to the manufacturing plants it can also be utilized for small pilot plant tests for processing materials and manufacturing products.



Surface Access Unit

Workshop and lab area:
This facility will contain research labs for incoming materials, to be studied and tested by the geologist for local utilization, as well as for terrestrial companies that will contract such services to the Martian organization. Being close to the manufacturing plants it can also be utilized for small pilot plant tests for processing materials and manufacturing products.



Workshop and lab areas

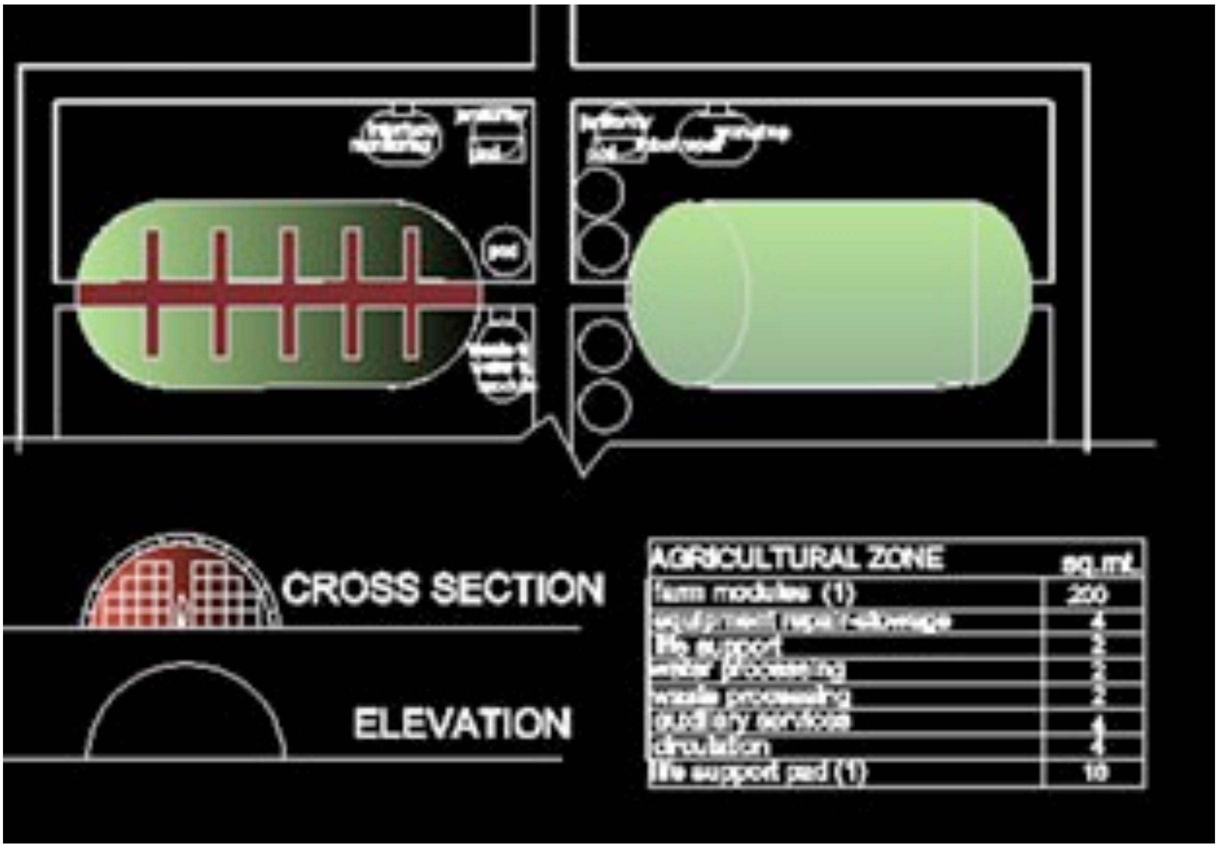
-Agricultural Zone (AZ)

To provide food for the settlers we plan on building an aeroponics greenhouse to provide foods. Aeroponic growing systems provide clean, efficient, and rapid food production. Crops can be planted and harvested in the system year round without interruption, and without contamination from soil, pesticides, and residue. Since the growing environment is clean and sterile, it greatly reduces the chances of spreading plant disease and infection commonly found in soil and other growing media.

The suspended system also has other advantages. Seedlings don't stretch or wilt while their roots are forming. Once the roots are developed, the plants can be easily moved into any type of growing media without the risk of transplant shock, which often sets back normal growth.

Aeroponics systems can reduce water usage by 98 percent, fertilizer usage by 60 percent, and pesticide usage by 100 percent, all while maximizing crop yields. Plants grown in the aeroponic systems have also been shown to uptake more minerals and vitamins, making the plants healthier and potentially more nutritious. A convenient greenhouse system is planned, which could be initially built with inflatable, later on inside the settlement agricultural cylinder. In the interior of the buildings, aeroponic growth could be implemented in several levels, maximizing the interior volume. Animal breeding is also included in the cluster named agricultural zone, mostly fish and seafood, at least initially.

All supporting facilities are included in the agricultural cluster which, being modular, can expand as needed in any direction.



Agricultural facilities

Manufacturing Zone (MZ)

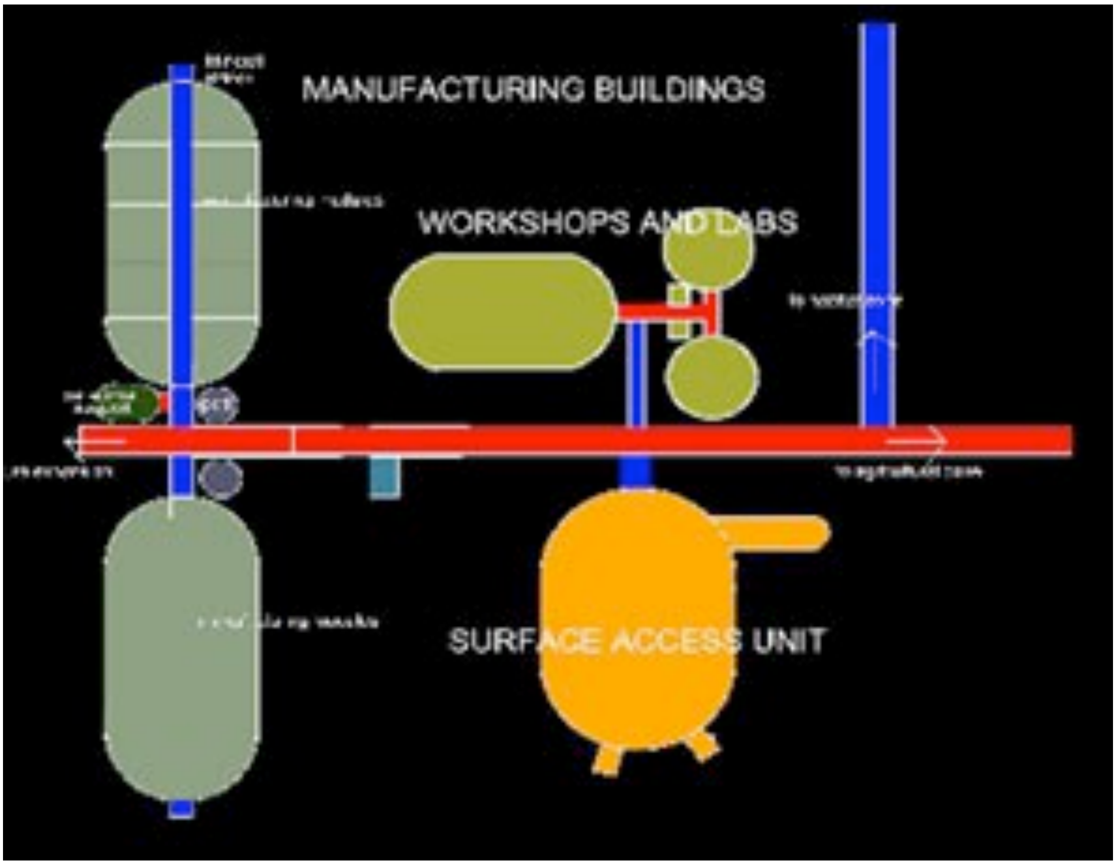
In order to implement the development of the Martian settlement, another important requirement is to manufacture locally most of the needed products to become self-sufficient initially and to allow massive construction plans needed for the settlement. A local technology must be developed, starting with the production of all life support systems, including LOX to fuel space vehicle .A manufacturing area. served by a systems of specialized buildings, with expansion possibilities, must be assembled above ground, since most of the heavy production and processing activities will be handled by robots, while laboratory, testing and small products manufacturing can be implemented in the underground facility.

The planned areas include:

- Ore storage.
- Mining support facility.
- Pilot plants.
- Mineral processing facilities.
- Construction components manufacturing plants.

While the manufacturing cluster will require, in addition to the main manufacturing buildings:

- Specialized SAU for vehicles and materials.
- Monorail terminal.
- Storage area for excavated ores.
- Spaceport (SP) proximity.



Manufacturing facilities

The Spaceport

For Phase 3 developments including main supporting facilities to future settlement construction, the spaceport will be a highly needed facility also considering the microgravity conditions of the asteroid.

Located in the vicinity of the base and connected with it, this underground facility will allow all overhauling and maintenance activities as well as passenger arrival and departure support. The protected facility will load and unload the shuttle lander, store items to be processed, be a terminal for incoming and outgoing crew. Main associated activities will include:

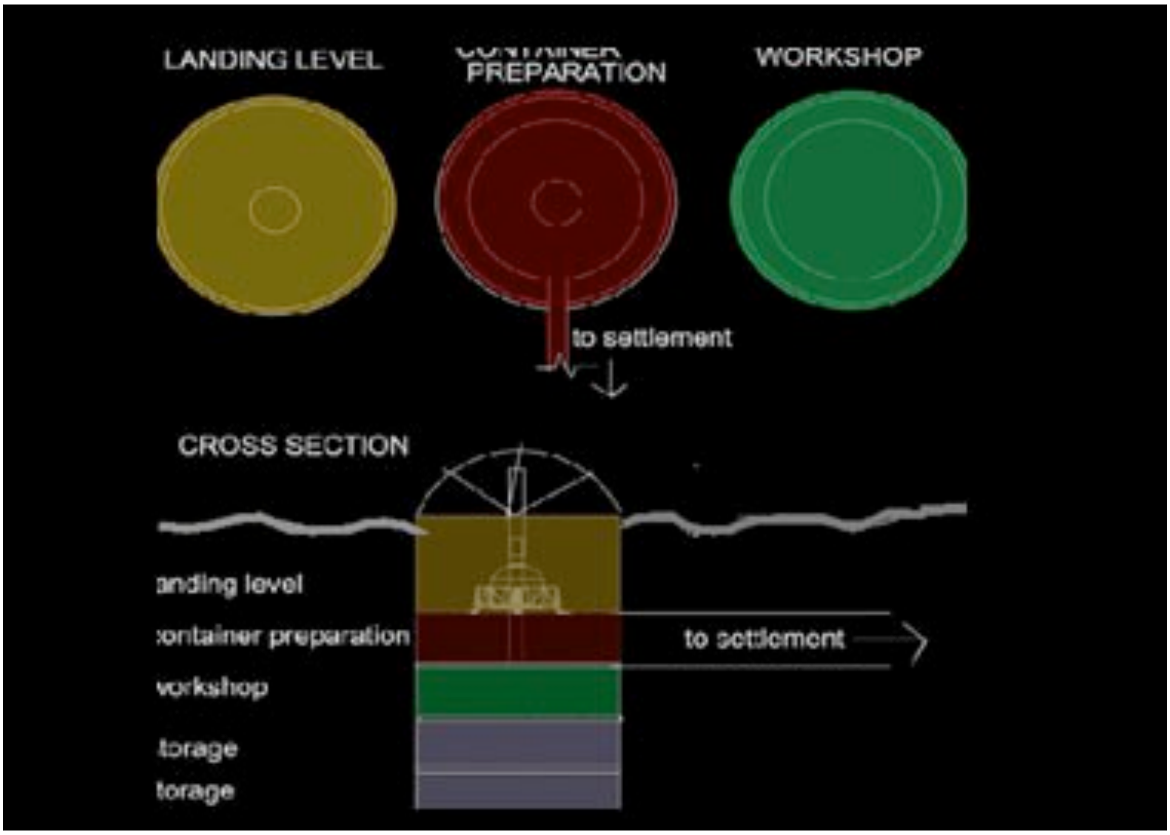
- Lox manufacturing facilities and storage.
- Feeder-lander support and maintenance.
- Incoming and outgoing cargo processing.

The facility will be provided with:

- Emergency systems.
- Monorail terminal.

The opening system will consist in an inflatable closure, a system already in use in our planet.

The enclosed chart defines the areas required.



Spaceport system

The utility pod

Common utility system is designed to provide life support (including water), power, communications and data connectivity as a common utility system to all pressurized volumes and functions as required. We may consider life support as a decentralize function throughout the underground habitat and surface elements. We are packaging all life support functions into self contained, pre integrated units, called pods, to allow ease of maintenance, standardization and transportation.

The life support pods will provide:

- CO_2 removal and recovery.
- Air revitalization- O_2 replenishment, with emergency storage of O_2.
- Buffer gas management for N_2.
- Temperature and humidity management and control.
- Heating, ventilating, air conditioning (HVAC).
- Particulate contaminant, including local dust, removal and filtration.
- Trace contaminant detection, removal and control.
- H_2O polishing and reserve water tank.
- Odor control and removal.
- Grey water primary reprocessing.
- Solid waste primary processing.

Underground Facilities

Vertical Hab

The initial excavation will prepare a small crater for immediate utilization, through a detailed construction sequence, avoiding too time consuming mining and construction activities. In the crater several functions, at three levels, will be designed such as:

Upper level.:

- Research laboratories, administrative offices, medical facilities.

At Middle level

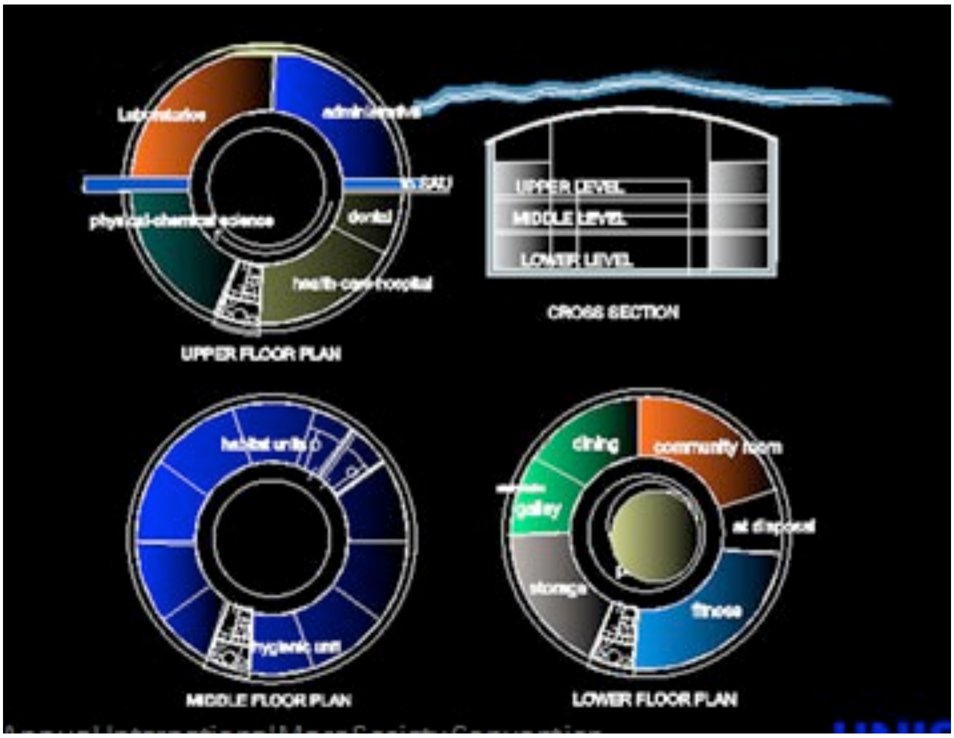
- Residentail and habitat facilities.

Lower level

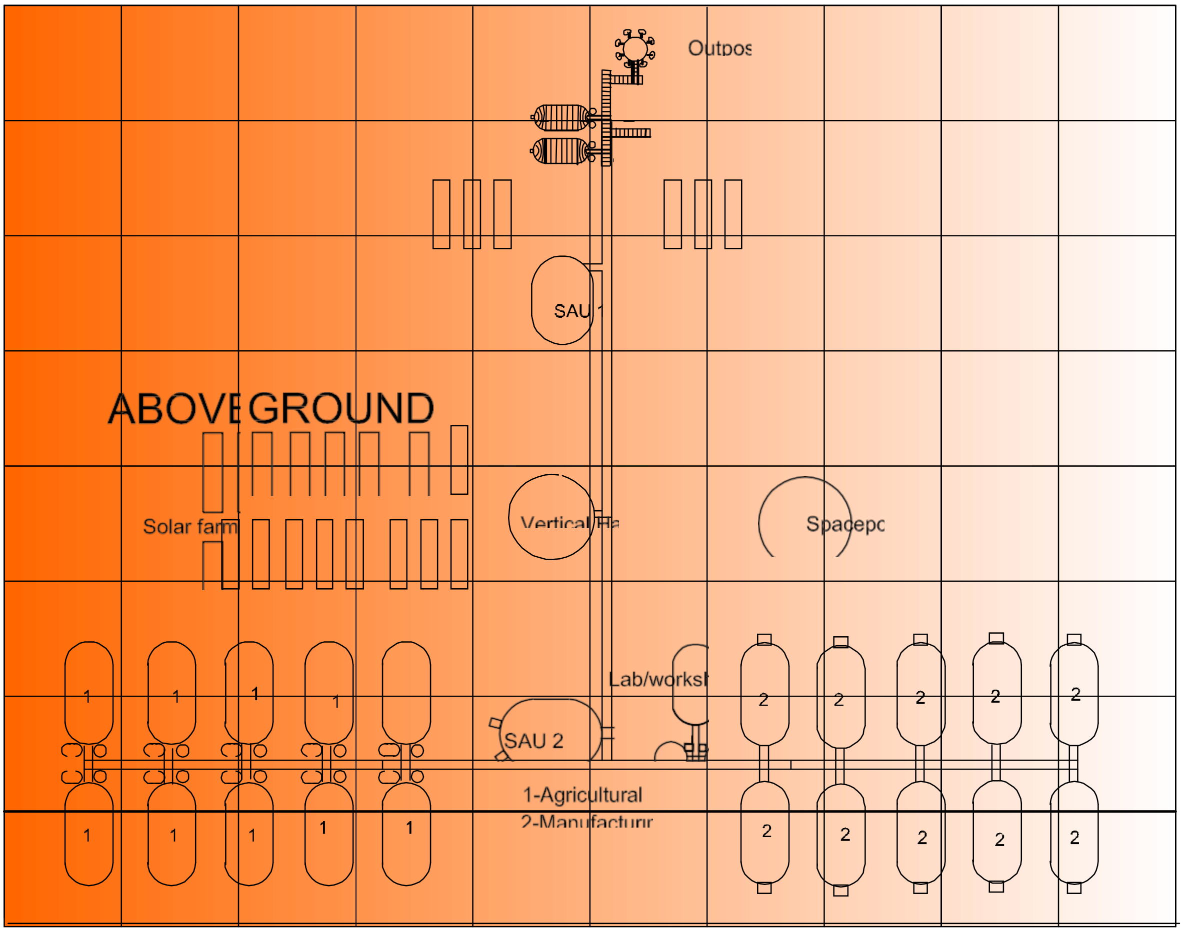
- Community activities, landscaped plaza, entertainment, restaurant, fitness.

At the upper level will be located all connections with the connector network, to the underground and above ground facilities. A central piazza, in the lower level, will create a community feeling for the population, being the center for most public activities, including dining, fitness and entertaining.

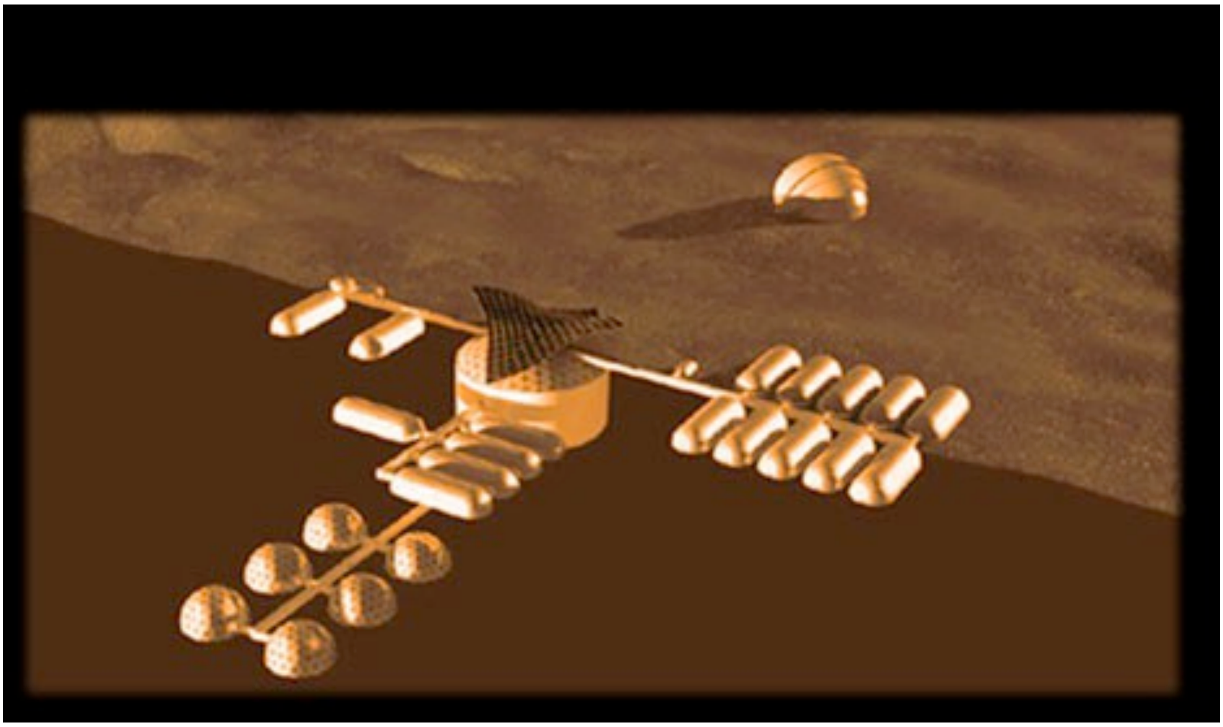
For future expansions, connections with other MUCs and specialized functions (LOX manufacturing, spaceport, construction components industry etc) a network of underground connectors and modular units can be built totally connected with the core MUC.



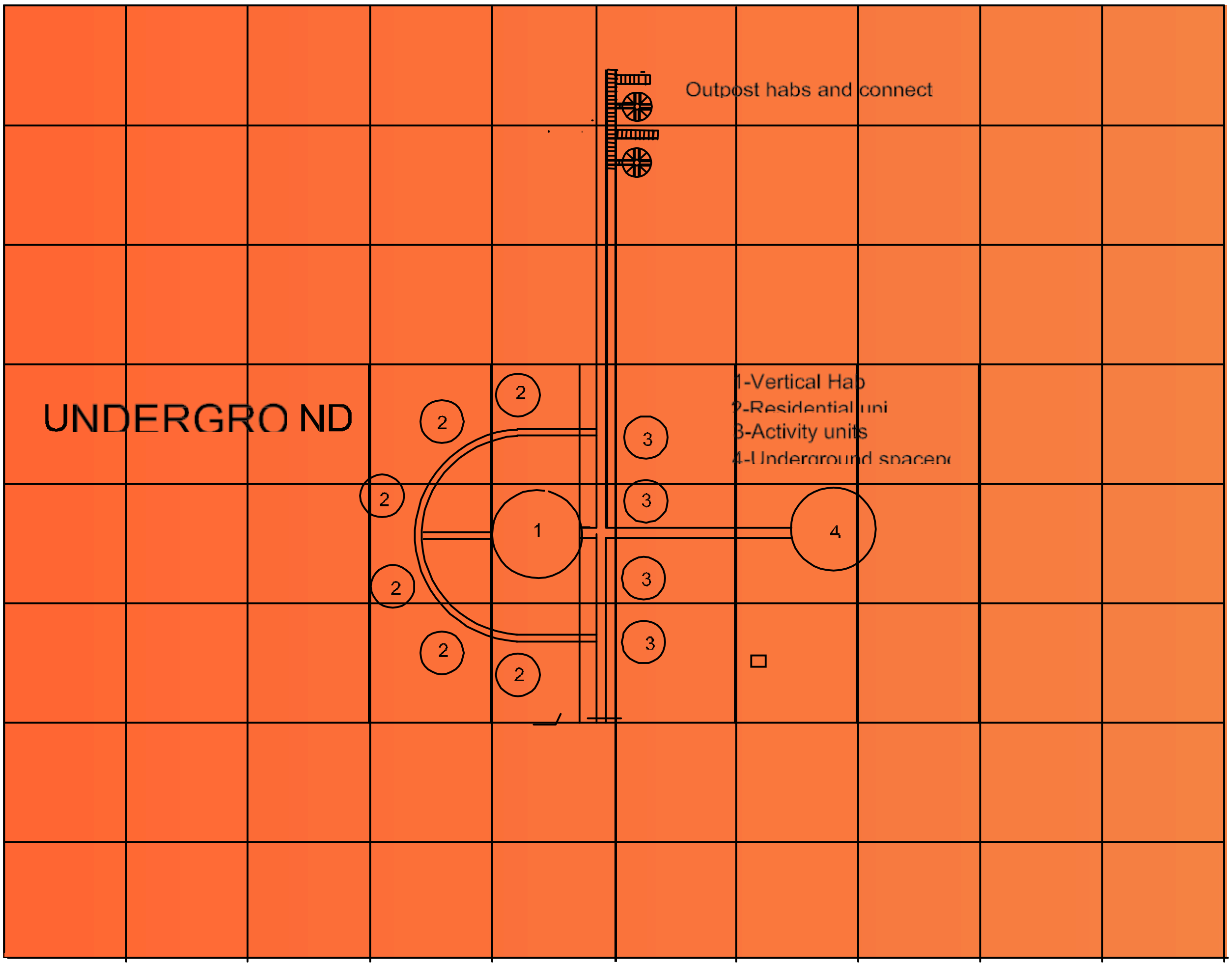
Vertical Hab



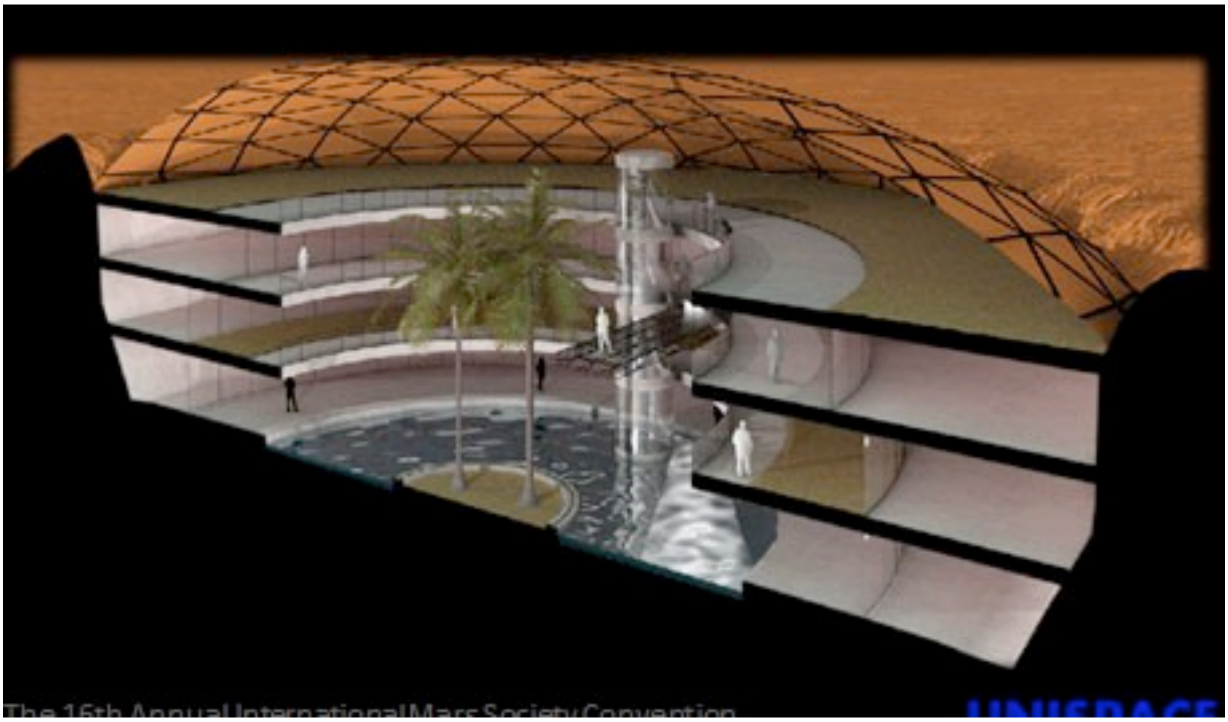
Base general above ground layout



General view



General underground layout



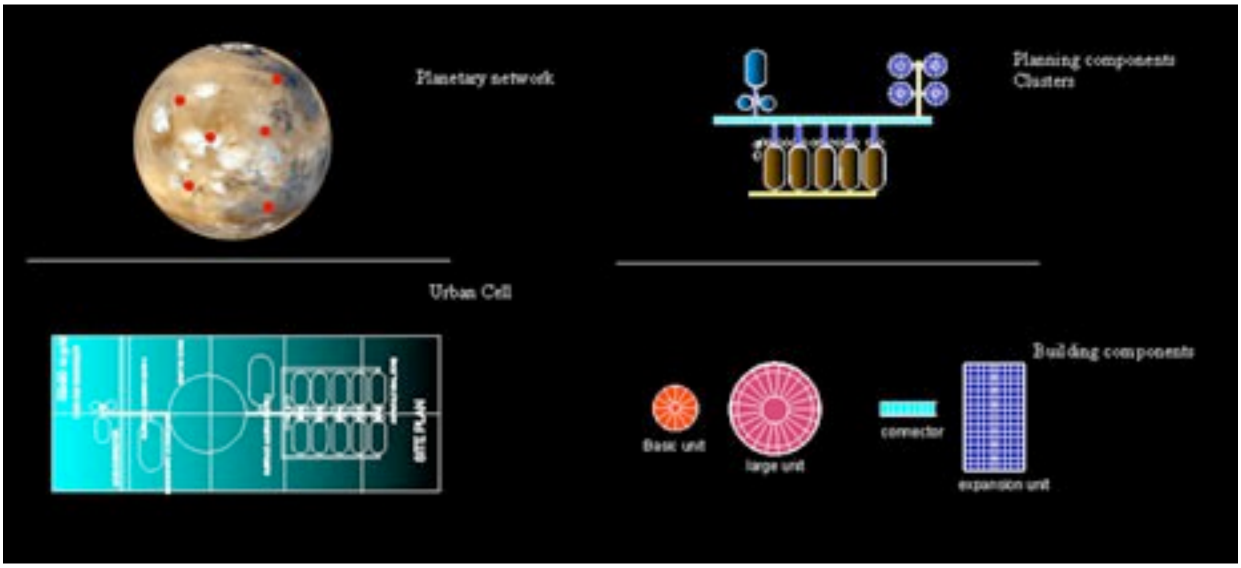
Vertical Hab cross section

The complex has a main connector, partially underground and above ground, as a major axis with the Hab in the center.

Secondary connectors serve the single areas.
This system allows shirtsleeve capability in all areas with the need for EVAs only for exterior missions. This configuration allows all components, with the exception of the Hab, to expand in all directions and dimensions, with both cells and clusters. In case of a potential expansion of the Hab, a design that leaves excavated volume free of facilities can be considered, but is not included in this design.

Major expansions
They are possible in different phases, minimizing the dimensional requirements by adding an entire complex on one side to double capacity and in the opposite one for further needs. The Martian Urban Cell (MUC) can be considered a prototype for planetary development. Being totally self sufficient and part of a settlement network, they can be standardized in their construction and specialized in their functionality.

The planet will be dotted by the MUCs as the main requirement for its development. The possibility to utilize advanced technologies like 3D printing will help to reduce costs and allow the construction with maximum ISRU utilization.



Martian Urban Cell system

Business Activities
Several business activities can be develop immediately on Mars. We are listing the main ones Business activities and profitable enterprises will be at the basis of Mars development. Following the integrated Mars plan, Transportation and basic infrastructures set up), several core business can be developed. Let's list some of them:

- **Earth-Mars transportation**
  By the time of the first manned mission, the entire system would be operational. Being reusable it can be immediately utilized to support other missions as well as specific mars directed payloads, for a price. Such capability can be expanded to transport, robotic and manned crews as well as any type of third party equipment. Having an affordable transportation system will represent the first and one of the most important business capabilities that will generate profit. Capability will include logistic support for manned crew such as all Hab at disposal as w ell as life support and food producing facilities. A pilot can be, if needed, part of the crew.

- **Mars logistic support**
  Having a functional outpost operational it will be possible to supply logistic support (habitat, transportation, maintenance, life support systems, food production, services) to established or incoming groups for exploration, prospecting and base set-up. Food, lodging, medical and health care services can be supplied to incoming manned missions as well as all needed support to unmanned ones such as power, maintenance, operations.

- **Mars mission support**
  Once the transportation and mars infrastructural system is operational, at the end of the first manned mission, may business and profitable activities can get started. Needed equipment and instruments can be sent inexpensively to the base by third parties while with 3d printing capabilities, much work can be done at the Martian

facilities. Only files will be needed to be sent from our planet. Once all equipment and instruments will be operational the mission can be supported with power, communications, transportation and other local requirements available in the base itself. This and several other similar services, including equipment maintenance and repair, can be provided and become business opportunities.

- **Scientific support**
  A scientific lab will be an important component of the initial outpost building system. Such facility can be supportive of several scientific missions, directed from Earth, but operated on the red planet. Scientific experiments may range from geochemical analysis, photo surveys, underground drilling for soil composition tests and other experiments, prospecting, mineral processing, manufacturing, develop Martian technology and others. Biological tests will also be important and required, from plant and agricultural to food production, as well as bacteria bioengineered to support Martian environment and many others. A parallel earth-Mars scientific lab system can be supported from the red planet and be a permanent source of activities. With the local help of 3d printers, to build heavy equipment to the support of robotic vehicles for transportation an entire research ecosystem can prosper and bring important results.

- **Exploration**
  This activity will represent, in the first years of Martian development, one of the main drivers. We must know in detail all topographical features of the planet create needed maps, know all land and underground resources since they will be critical for further settlement locations and planet exploitation. Several vehicles will be needed such as Cruiser-feeder type of airships that can permanently visualize the planet from low orbit (10Km) or less where necessary with landing possibility by feeders, to deliver equipment, robots even manned crews in specific locations. Other vehicles will include unpressurized rovers and more sophisticated SUVs fully equipped with mobile Hab and labs will be part of this activity. They can be directed form earth by interested organizations (academia, private enterprises, research labs etc) and performed on Mars with proper and adequate equipment.

- **Prospecting**
  Together with exploration prospecting will represent another important driver in Mars development. Most decisions on business opportunities and settlement locations will depend on the knowledge of the planet's resources and availability. Water presence will be one, especially for manned facilities location but not only. Unmanned facilities can be built around interesting mineral resources availability. Once a detailed resources map will be available, for land and underground resources many mining, mineral processing and manufacturing operations can get started. Prospecting activities will utilize the instruments described in exploration

but with more sophisticated instruments like drilling and mining, as se well as chemical and test labs, possibly mobile. Again this activity can be directed from our planet while the Martian base will supply all needed support without costly displacement of personnel with interplanetary trips.

- **Supply space vehicle maintenance and refueling**
  The Martian feeder lander will be the most utilized space vehicle on Mars. Such vehicle must be maintained, refueled and overhauled in the Martian base. A specific facility for this purpose is being provided in the spaceport area. A workshop will also be part of the system. Needed parts can be locally produced by the 3D printer, or if not possible, sent from earth in the first available mission, while a reserve of needed spares must be present since the very first missions. Together with the feeder, any other space vehicle present in the planet must be supported and overhauled in the specific facility. Another important source of income will be represented by refueling of all space vehicles. Local LOX manufacturing plants will refuel all vehicles including those needing refuel in space for further missions. Lox (liquid oxygen) manufacturing from local atmosphere and life support systems will be another important full time activity. Lox manufactured on Mars will be sent by the Mars feeder to the cruiser and fuel all vehicles (cruiser and Earth feeder).

- **Trans mars mission support in orbit or Phobos base**
  A stopover in Mars vicinity or in Phobos, in case of the development of a way station in mars satellite can be very helpful for trans-Mars missions that can be supported in their flight reducing dependence from earth and its higher payload costs. Proper shuttles stationed on Phobos can rendez-vous and refuel trans-Mars vehicles as well as supply other equipment that could be manufactured on Mars. A Phobos base can also be utilized from the Earth-mars transportation system by reducing the risks involved with the short available time for rendezvous with the incoming cruiser vehicle. A base on Phobos can send and receive all feeders to the cruiser while being in constant connection with Mars.

- **Technology development**
  This will be one of the most important activities since a Martian technology will be needed to develop the planet properly with the utilization of local resources. Such technology may be entirely different from Earth’s. It is a critical and one of the first goals to be totally self sufficient on Mars in order not o depend on earth and the long distance availability of good, services and technology. Starting with life support systems manufacturing (water, air, fuel, food) to all mining and mineral processing activities, construction and building components, local technology will guarantee self sufficiency to the local community and create a prototype of parallel technologies that can be used as models for other future extraterrestrial bodies’ development.

- **Food production**
  Since the first unmanned missions food production will represent another critical activity for human support. Hydroponic based on inflatable facilities will be operational to be followed by larger agricultural dedicated buildings while experience will allow the growth of more plants with local technology. Food and lodging for manned missions will be another of the business activities of the local base. After agriculture also animal breeding will be experimented, with such animals to produce eggs, milk, honey or food itself like small fishes, rabbits, seafood. Dedicated food producing facilities will multiply on the planet following expansion of manned activities. Together with food production a catering system must be developed to supply, where needed, meals and services.

- **Waste treatment**
  Waste in general, on Mars in particular, must be considered a precious resource. Waste components must be treated, recycled and reutilized since they contain rare materials especially in a non terrestrial ecosystem. Waste treatment and recycling plants, with the possibility to procure needed materials will represent another asset, and business possibility for a Martian base.

- **Mining**
  At the basis of any Martian development is the utilization of local resources, from the atmosphere, the surface and the underground locations. Mining will guarantee the procurement of most needed minerals to be transformed in needed materials after due processing. Mining activities, once the proper equipment will be available will represent an important source of income for the base. Such activities can be performed for third parties, to be followed by mineral processing and product manufacturing. Rockheaders, mostly built by local 3d printer technology with specific components to be delivered from earth and other dedicated equipment to be connected to multi functional rover for drilling; excavating and boring soil will contribute to the mining operations. Monorail type of surface transportation system will also be developed to transport the mined ores to the storage and processing facilities. Concrete, bricks, metal beams glass, ceramics will be the most looked for construction materials.

- **Mineral processing**
  Connected to the mining activities proper mineral processing facilities will be available with improved systems adapted and studied to perform through Martian technology availability. Compact machines will be developed that will perform the job with permanent assistance of robotic machines with high AI level. All basic materials or construction, equipment and structural beams manufacture and other utilizations will be produced. Third parties, wishing to develop a local industry and business can build their facilities prior to their physical arrival with dedicated personnel by utilizing local technology and capability managed by the base organization. Such presence and services may

multiply the business opportunities by reducing their overall costs and allowing immediate implementation.

- **Manufacturing**
  Following availability of local resources from the land and the atmosphere manufacturing needed products will create a local industry based on Martian technology, Lox for the feeder lander vehicle will be one of the first products to ne manufactured, even before the human presence. All life support components like water and air will also be considered. With the presence of 3d printer more complicated products can be manufactured with local materials. Heavy and large components of rovers, excavating and mining equipment, buildings, material handling and smaller products like furniture and house-wares can be manufactured in such way. Plant development will also allow the production of textiles for clothing and other specific products. All this capability as well as products will become available creating new market and business opportunities in the red planet settlement.

- **Construction industry**
  This is another critical activity. After completion and operational utilization of the basic outpost, construction will expand the settlement to become a basic cell with larger population capacity. Such expansion is based on the development of local construction technology that will complement the 3d printer. On Mars, habitat construction will be one of the main activities. For such purpose a local technology must be developed. Special interlocking bricks, to be manufactured from local materials through a 3D printing process, could be utilized for most construction.

  Bini shells systems, utilizing inflatable forms, can be used to erect domes and closed buildings, as well as inside craters, in order to minimize radiation effects in full time manned facilities.

  Concrete Martian bricks, Martian concrete, metal trusses, beams, reinforced steel, laminated metals etc must become available together with other materials for construction such as glass, ceramics, copper for wiring, piping and ducts from earth only specialized equipment must be delivered leaving all heavy and larger components to be manufactured locally. Entirely new construction technologies will be developed, with intervention of 3d printers, robotic assistance, mobility and compactability with possible utilization, with several benefits in our home planet.

CONCLUSION

With the above listed activities the Mars development plan will become a successful global enterprise and can starts immediately, not depending on political decisions but private entrepreneurship.

Several technologies will be affected by Mars development and will need important advances.

Reusable transportation systems, initially based in cruiser modules, later on asteroids deflected in cyclical orbits, with all deflection technology in place, will spur space development, including the Martian one. Robotics, mining, mineral processing, excavation, underground construction, 3d printing just to name a few will be critical for the underground terraforming development.

The possibility to render immediately habitable and human friendly most celestial bodies by the Martian experience, will certainly spur further development and promote space based economy by multiplying its territory.

Such possibility can precede manned missions and human arrival creating the base for settlement capability in several bodies considered hostile to human presence. Mars would be the first one.

Profitability will be the main driver to the creation of a multi-planetary economy.

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