

A Review of:

Advanced Life Support Systems Integration, Modeling, and Analysis Reference Missions Document, JSC-39502, CTSD-ADV-383, 5 November 2001

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1. Introduction

The claim is made that the *Advanced Life Support Systems Integration, Modeling, and Analysis Reference Missions Document* (RMD) provides the *Advanced Life Support* (ALS) Project with several reference missions that are "likely scenarios for early human exploration and development of near-Earth space." It is claimed that it "expounds mission details to allow meaningful system-level analyses of proposed life support system (LSS) concepts."

2. "Dual-Landers" DRM

The following is a description of the "Dual-Landers" DRM taken from the report:

The Mars Dual Lander mission architecture employs three vehicles: a Mars Transit Vehicle, a Surface Habitat Lander, and a Mars Descent/Ascent Lander. This approach proposes employing a common descent stage for both the Surface Habitat Lander and the Mars Descent/Ascent Lander. Therefore, the Surface Habitat Lander and the Mars Descent/Ascent Lander are referred to as the Dual Landers. A single Mars Transit Vehicle is used for the outbound and return trips. The Surface Habitat Lander, which contains an inflatable structure to provide an expanded habitable volume once on the Martian surface, provides the crew's habitat quarters. The Surface Habitat Lander is piloted robotically during the trip from Earth to the Martian surface. A second lander, the Mars Descent/Ascent vehicle, transports the six crewmembers from Martian orbit to the surface at the beginning of the surface mission phase, and returns the crew to the orbiting Mars Transit Vehicle at the conclusion of the surface phase.

Since surface site selection is independent of any previous or following missions, multiple trips to Mars will allow explorers to visit any site, targeting exploration opportunities to satisfy demands for scientific information. This overall mission design also permits multiple visits to the same site where redundancy or common use of previous vehicles in whole or in part can reduce the overall cost of multiple missions.

The Mars Transit Vehicle launches initially into low Earth orbit. After outfitting, the Mars Transit Vehicle boosts to high Earth orbit [via SEP] to await transfer of the crew. Similarly, the Surface Habitat and Mars Descent/Ascent Landers initially launch into low Earth orbit before boosting [via SEP] to a high Earth orbit. In both cases, the Mars Transit Vehicle and the Dual Landers use energy efficient [solar] electrical propulsion and lengthy transfer orbits to reach high Earth orbit. All three vehicles are serviced for the voyage to Mars and the crew is delivered to the Mars Transit Vehicle by a taxi flight just before departure.

The voyage to Mars will nominally take 180 days for the crew. The Dual Landers, because they transfer to Mars under robotic control, follow a somewhat slower yet more energy efficient transfer orbit than the Mars Transfer Vehicle, so they depart from Earth ahead of the crew so as to arrive at Mars just before the crew. The Mars Transit Vehicle and the Dual Landers all enter

into a low Mars orbit through aerocapture and then rendezvous. Once they arrive in low Martian orbit, the crew transfers to the Mars Descent/Ascent Vehicle and descends to the Martian surface.

The Surface Habitat Lander will journey to Mars without a crew. After arriving in Martian orbit, the Surface Habitat Lander will perform de-orbit, entry, descent, and land on Mars at a pre-determined location autonomously. Once on Mars, the Surface Habitat Lander will deploy the deflated habitat, set up the power system, perform initial habitat outfitting, system checkout, and place the vehicle in stand-by mode. Thus, the Surface Habitat Lander will be operational when the crew arrives in the Mars Descent/Ascent Lander. The fully inflated and operational Surface Habitat Lander boasts a full LSS hardware suite and provides a crew habitat for the 600-day surface mission. During surface operations, the crew is expected to perform extensive EVA operations, totaling 700 half-day employing two crewmembers for each sortie.

At the time the crew arrives, the Surface Habitat Lander is already in place on the Martian surface. The Surface Habitat Lander deploys automatically, checks and verifies its functionality, and adopts a protected mode prior to crew arrival. Upon arrival, the crew has 30 days for acclimation and an in-depth habitat checkout. The crew need not commit to landing until the Surface Habitat Lander is operational. During the surface mission, nominally 600 days, the Mars Transit Vehicle awaits in stand-by mode untended in low Mars orbit, while the Mars Descent/Ascent Lander waits in stand-by mode on the Martian surface. After a second rendezvous in Mars orbit following the surface mission, the crew transfers to the Mars Transit Vehicle and returns to Earth. The return interplanetary voyage nominally requires 180 days.

The Mars Descent/Ascent Lander is a smaller vehicle designed to support a crew for a short time. It also journeys to Martian orbit without a crew. It launches from the Earth's surface into low Earth orbit. After outfitting, it boosts to high Earth orbit [via SEP] and transfers to Mars on near-minimum energy trajectory. At Mars, it aerocaptures into orbit. After the Mars Transit Vehicle reaches Martian orbit, the Mars Descent/Ascent Lander and the Mars Transit Vehicle rendezvous. The crew transfers from the Mars Transit Vehicle to the Mars Descent/Ascent Vehicle, de-orbits, and lands near the Surface Habitat Lander. To ensure crew safety while in orbit and initially on the Martian surface, the Mars Descent/Ascent Lander is designed to support the crew in all aspects for up to 30 days to permit sufficient time for surface acclimation and during any Surface Habitat Lander checkout activities. For the Mars Descent/Ascent Lander LSS, water for potable and hygiene use is produced as the byproduct of on-board fuel-cell operation. Since no water recovery is planned, and current demand for power generation is unlikely to produce adequate water to support the Mars Descent/Ascent Lander for 30 days, additional water is supplied from stored water stocks. Assuming wastewater dumping is not allowed, all wastewater will be stored within the descent stage tankage. Stored gases, either bottled or cryogenic, provide atmospheric gases. A solid amine vacuum desorbed (SAVD) carbon dioxide removal system and a TCCS remove atmospheric contaminants. Under nominal operations, the mission architecture requires one airlock (A/L) cycle on the surface of Mars for the Mars Descent/Ascent Lander. More specifically, assuming the crew depresses the entire cabin before transferring to the Surface Habitat Lander, the entire crew may leave at once. When the crew returns to the Mars Descent/Ascent Lander just prior to departure, sufficient stored gases allow pressurization of the crew cabin. Human accommodations employ moistened towelettes for bathing. The Food Subsystem also employs moistened wipes for cleaning operations. Due to its mass, a compactor does not appear justified for this short mission.

Conformal water tanks with internal bladders protect a portion of the crew cabin against radiation, effectively providing a “storm shelter.” Other life support systems are similar to configurations on other vehicles using ISS baseline technologies. Due to a relatively short duration for crew occupancy, no ALS Straw Man concept is proposed for this vehicle at this time.

3. Split Mission DRM (a.k.a DRM-1 and DRM-3)

The following is reproduced from the JSC report. Please note that inflatables were not in DRM-1 but were introduced in DRM-3 to reduce mass.

The Split Mission architecture is a well-documented approach for landing people on Mars and returning them safely to Earth. Three missions are assumed, all landing at the same location on Mars in order to build up an infrastructure that will provide a safer site than any other place in the Solar System except for Earth itself.

For each mission, two flights pre-position equipment around and on Mars before the crew transit. A cargo flight lands on Mars carrying a Mars Ascent Vehicle, an ISRU plant, and an inflatable habitat. A second flight prepositions an Earth Return Vehicle in a stable Martian orbit. At the next Mars transfer opportunity, a Surface Habitat Lander transports the crew from Earth to the surface of Mars, rendezvousing on the surface with the pre-positioned surface assets. During the same transfer opportunity, the two flights with the pre-positioned assets for the next crew also transit to Mars and arrive while the first crew conducts surface operations. Thus, the first crew could, if necessary, use the assets originally intended for the second crew for contingencies. As with the previous Mars exploration scenario, transit to or from Mars nominally takes 180 days, while the surface mission is nominally 600 days. Following the surface mission, the crew ascends to Martian orbit in the Mars Ascent Vehicle and rendezvous with the Earth Return Vehicle. The Earth Return Vehicle transports the crew to Earth. The second crew departs from Earth while the first crew is returning.

The second crew voyages to Mars and lands their Surface Habitat Lander at the site prepared by the first crew, integrating their vehicle into the existing infrastructure. Thus, each successive mission will expand the habitable volume. The cargo flights for the second and third crews each bring a pressurized rover in place of the inflatable habitat manifested for the first crew’s cargo flight.

As noted above, this mission architecture uses four vehicles. Three vehicles transit to Mars during the first Mars transportation opportunity. An inflatable Habitat Module and the Mars Ascent Vehicle land on Mars, while the Earth Return Vehicle is placed in a stable Martian orbit. At the second Mars transportation opportunity, the crew travels from Earth to the surface of Mars in the Surface Habitat Lander. This vehicle houses the crew for the descent to Mars and during their surface stay. The separate Mars Ascent Vehicle returns the crew to Martian orbit to rendezvous with the Earth Return Vehicle for the trip back to Earth.

Surface Habitat Lander

The Surface Habitat Lander transports the mission crew from Earth to the surface of Mars and provides the crew with a primary habitat during surface operations. As noted above, the Surface Habitat Lander volume, which is housed in an aluminum shell, is augmented on the surface by an inflatable habitat and/or additional vehicles from previous missions. As the Surface Habitat Lander is an independent vehicle, it carries a full suite of LSS hardware. Further, it carries food

for the outbound voyage and for surface operations, which totals 780 days of supplies. Development of the LSS architecture using ISS technologies for the Surface Habitat Lander is a continuing research topic.

Predeployed Surface Assets

Several important mission assets are predeployed on the Martian surface using robotic cargo missions on the Mars transportation opportunity before each crew transit. These assets include a Mars Ascent Vehicle, which arrives on Mars with dry fuel tanks. The Mars Ascent Vehicle is fueled on the surface with fuels from an ISRU plant operating on the Martian atmosphere with hydrogen feedstock to produce methane and oxygen. The first cargo flight also brings an inflatable module to expand the first crew's living volume. The second and third cargo flights each provide a pressurized rover. **Note that no discussion is provided in either DRM-1 or DRM-3 on requirements for H₂ storage in transit to Mars and on Mars, and NO MASS IS PROVIDED FOR STORAGE.**

Mars Ascent Vehicle

Under the Split Mission Architecture the crew only occupies it while they ride from the surface of Mars to the Earth Return Vehicle. The Mars Ascent Vehicle may also provide the crew with direct return to Earth's surface as a re-entry capsule. **No way! Not enough propellants for direct return. Furthermore, this small vehicle is unsuitable for 180 day trip.** Due to the limited operational lifetime, it is likely that the LSS for the Mars Ascent Vehicle will use consumable life support technologies similar to those employed for the Space Transportation System, or Shuttle. Thus, the Mars Ascent Vehicle is not considered further here.

Inflatable Habitat

While the inflatable habitat manifested for the first crew's cargo flight will provide crew living volume, it will probably derive most or all its life support functions from the initial Surface Habitat Lander. As such, the inflatable habitat is not considered here.

In-Situ Resource Utilization Facilities

Because ISRU is not one of the ISS technologies, ISRU is confined, under the present scenario, to providing only methane and oxygen for the Mars Ascent Vehicle using a stock of hydrogen from Earth. **Isn't this bass-ackwards? Because ISS does not utilize ISRU, they do not allow ISRU to provide consumables.**

Earth Return Vehicle

The Earth Return Vehicle is an independent vehicle with an aluminum habitat module that houses the crew on the 180-day return voyage. Thus, this vehicle carries a full suite of LSS hardware. Additionally, the Earth Return Vehicle provides a contingency habitat for the crew should they abort surface operations early and live in Martian orbit until the next transfer opportunity to Earth is available. As such, the Earth Return Vehicle must provide food and life support functions for a complete 600 day stay in the Martian system. **Wow! That is a lot of mass - unless you believe in 99% recycling.** The LSS architecture using ISS technologies for the Earth Return Vehicle is a continuing research topic. **Yes, but who is doing it, and what are they coming up with?**

Surface Habitat Lander

The Surface Habitat Lander carries the crew from Earth orbit to the surface of Mars and then provides a habitat for the entire surface mission. Therefore, the life support systems employed must function efficiently for extended periods of time both in microgravity and on the surface of Mars. This multi-segment mission is extremely demanding. While it is possible that local regolith at the site may provide some radiation protection, the mission segment in interplanetary space is the limiting environment and so defines the radiation protection requirement for the Surface Habitat Lander. However, use of regolith for radiation protection on the surface of Mars could allow material provided for radiation protection in interplanetary space, such as water, to be used elsewhere. Development of the ALS Straw Man architecture for the Surface Habitat Lander is a topic for continuing research. **I hope so!**

Earth Return Vehicle

The Earth Return Vehicle is a pure spacecraft. Thus, like the Mars Transit Vehicle, the LSS technologies employed must be insensitive to changes in local gravity, including microgravity. Further, radiation protection for the Earth Return Vehicle must rely solely on commodities initially included on the vehicle, such as water, or those generated from supplied commodities, such as waste products. Finally, because the Earth Return Vehicle will loiter inactive in Martian orbit for an extended period before the crew boards for the trip to Earth, the systems selected must be highly reliable both while crew-tended and while operating autonomously. Currently, the technologies proposed here do not have any known limitations that prevent them from operating for the duration of the prescribed mission. **This previous sentence is the great continental divide that separates me from JSC. In my view, any proposed system is guilty until proven innocent (i.e. it is insufficient until proven to be sufficient). The JSC viewpoint seems to be that the system is adequate until proven to be inadequate.** Development of the ALS Straw Man architecture for the Earth Return Vehicle is a topic of continuing research. **I hope so!**

4. Power Requirements

JSC's "DRM-1" design reference mission (DRM) for human missions to Mars included 160 kW nuclear reactor electric power plants on both the Cargo Lander and the Habitat Lander. The DRM-1 surface power system design was based on the reactor technologies developed within the SP-100 program, however with 3-80 kWe closed Brayton cycle engines operating at 1100 K. The first crew would have access to 320 kW of nuclear electric power, or alternatively 160 kW with full back-up. Each subsequent crew would add another 160 kW. No explanation was provided as to why 160 kW was needed or how it would be used, although a significant ISRU system was utilized. Additionally, each Habitat retained the solar arrays used during transit, and they could also be operated on the Martian surface. Each power system can produce approximately 30 percent of the power generated in space. For emergency situations, the pressurized rover's Dynamic Isotope Power System can supply 10 kW of continuous power.

DRM-1 was modified to generate "DRM-3." Updates to the original DRM-1 analysis, including operation at turbine inlet temperatures of 1300 K, enabled a reduction in overall power system mass from 14.0 to 10.7 metric tons. This assumed a temperature increase of approximately 150 K beyond current Brayton technology. In addition, a first order assessment of the mass impacts of utilizing the same reactor technology as for the nuclear thermal propulsion system was performed. If feasible and practical, only one development program would then be required for

both the nuclear thermal propulsion and surface power systems. A power system based upon a gas-cooled nuclear thermal propulsion engine was estimated to have a mass of 12.1 metric tons. DRM-3 carries the slightly heavier mass of the gas cooled reactor system.

As the 20th century wound down to a close, it became apparent that even with the mass reductions assumed in DRM-3, the masses involved in human missions to Mars were excessive, and furthermore, if (as seems likely) the nuclear thermal rocket would prove to be impractical or too costly or both, the required masses would increase significantly over those predicted by DRM-3. JSC's method for dealing with impractical missions seems to be to simply reduce the requirements. DRM-3 was replaced by the "Dual-Landers" DRM. In Dual Landers SEP is used for orbit-raising from LEO to HEO prior to Earth departure. The crew takes a fast taxi to reach the Mars Transit Vehicle in HEO. Inflatable habitats are used.

The power requirements of the Dual Landers DRM are given in the RMD as shown in Table 1. Power requirements are reduced to about 1/20 of those in DRM-3, and solar power is used throughout. Part of the justification for this is that ISRU is eliminated, although this introduces other problems and issues. It is not clear whether such power levels are adequate, and whether adequate attention has been given to energy storage requirements.

Table 1. Power requirements of the Dual Landers DRM

Mars Transit Vehicle Power	kWe
While the Crew is Awake ("Day")	15
While the Crew is Asleep ("Night")	12
Mars Descent/Ascent Lander Power	
Available Power during Landing	4.0
During Daylight	8.5
During Night	5.5
Surface Habitat Lander Power	
During Daylight with Clear Weather	18
During Daylight with a Dust Storm (contingency)	7.4
During Night	9

The report says:

"A major issue for any Mars mission is power generation. Nuclear propulsion and nuclear power generation on the surface may well be necessary for an affordable mission. Solar propulsion in the outer solar system requires very large arrays, perhaps too large to be practical. Solar power on Mars would also require very large arrays to provide adequate power during dust storms, and these would be costly and hard to keep clear of dust. Solar cases would be much worse for high latitudes compared with equatorial sites. Politically, however, power generation systems using solar energy have greater viability. Thus, scenarios employing solar generation should receive serious attention even though nuclear power may carry fewer costs and risks from an overall engineering perspective. In fact, the true costs for nuclear power are likely unknown as the strict protocols and procedures for its use are likely to add significant mass above what is deemed necessary for less controversial systems."

5. Contingencies

The report says:

"A wide variety of contingencies are important from a life support perspective. Adequate contingency planning must be performed and implemented for significant failure modes. Some significant concerns already identified, listed alphabetically, are:

- accidents
- environmental hazards
- equipment failure
- excessive consumption
- inadequate performance of life support and related systems
- leakage
- human error

Given sufficient time, accidents are inevitable. Accidents, which directly interfere with life support functions, include puncturing the pressure vessel, fires, and a release of toxins. LSS equipment must be designed to make accidents unlikely, and to limit the severity of accidents when they do occur. A technology that is inherently hazardous will require additional safety precautions, which will generally increase the technology's ESM compared to competing technologies.

Environmental hazards on Mars that could interfere with life support functions, aside from the surface being generally uninhabitable by human beings, would include dust, meteoroid strikes, radiation, and thermal cycling.

Another issue is that plant production systems may not perform as well in the new environments such as on Mars. To offset any shortages in the production of food or other life support commodities during early missions, the initial plant growth chambers design should support a greater capacity than just the anticipated nominal load. Additionally, stocks of consumable life support commodities could be used to offset any shortages in production from the plant growth chambers. As systems are operated in new and hostile environments, performance cannot be guaranteed.

To ensure life support, actual equipment must have the capability to increase its output and offset shortages. Leakage cannot be addressed by regenerative life support alone, because the lost gas must be replaced either by resupply or local production. Shipment from Earth is costly. Permanent gases in pressure vessels require an additional 36% to 64% mass penalty [for tankage].

ISRU costs and availability depend on the commodity and the source. The composition of and the ability to process the Martian atmosphere are fairly certain. Other potential sources of LSS commodities are not as certain. **Note: This bugaboo needs to be put to rest. The whole notion that ISRU is somehow inherently risky is baloney. ISRU would certainly be fully proven by robotic landers prior to human arrival, and furthermore in the Split Mission architecture, the ISRU plant operates for > a year prior to crew departure from Earth! See:**

<http://www.mars-lunar.net/Risk.in ISRU.html>

While large holes in the vehicle hull may not be immediately life threatening, they need to be closed off to prevent unacceptable losses of consumables. Further, as seen on Mir, such holes may be difficult to locate. While a punctured inflatable structure will eventually sag as gas is lost, it will not do so rapidly even when supporting a considerable load so long as the gas bladder material retards rapid crack propagation.

Crew errors are possible and even likely on long-duration missions. The probability of human error increases just due to the inevitable onset of stress associated with isolation. The resulting procedural errors may lead to equipment failures, to commodity loss, and possibly to acute hazards for the crew.

Actual life support designs will most likely use a mixture of approaches to ensure a high availability of life support functions during long duration missions. Contingency approaches will maximize chances of success and minimize the cost of doing so. Different technologies might provide robust redundancy for critical functions. Thus, a mix of supplied commodities, physicochemical technologies, bio-regeneration, and ISRU are likely to provide life support contingency capability as well as baseline capability.

International Space Station plans a 45-day contingency supply of all life support systems commodities. ISS carries three oxygen generators, two of which operate at all times. ISS contingency plans would not be economically feasible for long duration Mars missions. This is particularly true, as the criterion for the 45-day contingency duration is a missed re-supply. Such an event for a Mars mission would result in a delay of 26 terrestrial months. Total contingency mass for ISS is 5000 kg.

A key difference between missions to ISS orbit and missions to Mars is that the crew can always leave ISS on short notice using a crew return vehicle, loiter as necessary for orbit phasing, and return to Earth. Such an option is physically impossible from Mars, given the state of our transportation technology. Thus, ensuring high overall reliability and availability for the LSS is even more important. The approach to contingencies for the Mars Dual Lander Architecture and Mars Split Mission Architecture is as follows:

- The basic life support system provides equipment and consumable commodities to provide complete life support for the crew. The equipment will be designed for repair. Spares are provided for critical pieces of equipment so that there is high confidence that no failures will occur that cannot be repaired on-site with the resources and time available. This approach is expected to include scheduled and unscheduled maintenance, and significant work will be required during design and qualification to estimate sparing, tool, and crew time requirements. **This is not very convincing to me.**
- A contingency energy store to maintain critical life support systems for seven days without additional power generation will be provided.
- To ensure thermal control contingency, a design of multiple cooling loops sized to accommodate greater than nominal heat loads functions to service mission-critical systems, should any single cooling loop fail.
- A seven-day supply of critical life support commodities, such as air and water, is provided as an on-board cache. Such supplies should provide “open-loop” life support capability while the primary systems are repaired. Additionally, all long-duration vehicles are supplied with sufficient gases to re-pressurize the vehicle once following the complete loss of cabin

atmosphere. **There is something very, very, very strange about this statement. Unless the recycle recovery system is > 99% efficient, it would seem likely that there already are on-board caches that provide much more than a 7-day supply. These back-up caches that account for the less than 100% efficiency of recovery, are much greater than 7 days, and can be used open loop in an emergency. Whether 7 days is enough is another matter for discussion.**

- Provide the capability to produce all emergency water and air from ISRU **Note: only good on surface. No good for transits.** If the equipment is pre-positioned, it should produce and verify a cache of life support commodities before the crew is committed to the mission. **How about producing not only emergency water and air from ISRU, but all basic water and air? And, do it prior to crew arrival!**
- Clothing quantities are planned for the duration of the mission assuming use of a laundry. If the laundry fails, clothes could be laundered by hand if necessary.
- Prepackaged food, when supplied, is provided for the entire mission plus any feasible extension, perhaps 5%, and for any reasonable long-term consumption rate, such as the nominal rate plus 20%. Thus, food is provided for 125% of the nominal mission. Emergency rations for 100% of the nominal mission are provided in the form of completely shelf-stable, low-mass products and distributed as appropriate to each mission vehicle. In both mission Reference Mission scenarios, 600-days of contingency rations are provided on board of either the Mars Transit Vehicle or the Earth Return Vehicle in case the crew must abort to Martian orbit or they fail to rendezvous with the landing vehicle. This excess can be jettisoned prior to leaving Mars orbit. **For a crew of six, 600 days food is something like 5400 kg. But the real killer is water that requires a good deal more mass than that.**
- Support for two, two-person, eight-hour contingency EVA excursions during transit.

This approach provides up to three strings of life support on Mars, depending on the system, but only a single string of life support in transit.

For a mission design with multiple crews using the same facility, such as the Split Mission Architecture or Evolved Mars Base, only contingency and emergency supplies and equipment that are actually used really need to be replaced, assuming such commodities are shelf stable for the duration of the overall mission. However, in actual practice this issue is more complex because transit times between Earth and Mars are significant. For example, using the Split Mission Architecture the first crew does not leave Mars until after the second crew departs from Earth, making it impossible for the first crew to completely account for any contingency supplies it might use on the surface before the second crew leaves.

The plant growth chamber is a special case in that it is too large to duplicate completely. Most likely the plant growth capability will be compartmentalized and oversized so as to maintain 100% of the rated capacity even with one compartment not functioning. While changing the production rate in a plant growth system to add capacity is at best a slow process, other critical LSS equipment will have the ability to provide more than just the nominal commodity production.

Maintaining adequate food production is the critical issue following a failure in a bio-regenerative life support system because typical staple crops require two to three months to produce edible biomass. Further, other fairly economic options for air and water regeneration are

available. Re-supply and overproduction within the plant growth chamber could maintain and replace contingency stores of food, bearing in mind that transportation opportunities from Earth to Mars for re-supply occur only once every 26 months. A certain amount of buffering is possible by modulating the rate of oxidation of inedible biomass and other waste products. A bio-regenerative LSS is in balance when the oxidation rate for inedible biomass and the crew's metabolic rate provide sufficient carbon dioxide to support any plant growth. However, the oxidation of waste can be reduced to conserve oxygen while the carbon dioxide required by the plants can be provided from other sources, such as ISRU.

Contingency Issues

Several unanswered contingency issues include:

- What are the radiation levels experienced by crews in Martian orbit should they abort from their surface site to a waiting transit vehicle? The solar intensity at Mars averages 43% of the value at Earth, although Mars does not have a magnetosphere. Contingency food and other masses can provide some protection as radiation shielding. The waste resulting from consuming the food would provide a similar level of protection as the original food, but the risk of biohazards due to inadequate stabilization is a concern. In any case, the level of additional protection would be less than ideal for such a long stay.
- What are the gravitational effects on the crew of aborting to orbit? The 180-day transit is sufficient to raise concerns about physiological de-conditioning in weightlessness. An additional 600 days is certain to be of greater concern. However, the crew can spend several hours a day exercising, and the alternative of remaining on the surface with a major system failure would obviously be worse.
- How long can food technology extend the effective life of food systems including prepackaged foodstuffs before the food loses significant nutritional value?
- What additional capability arises from sending multiple missions to the same site? Which strategies for hazard management are most effective in such an environment?

The above list is vastly incomplete.