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Pioneering Objectives and Activities on the Surface of Mars

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Agenda

- **How do we pioneer an extended human presence on Mars that is Earth independent?**
- **The Mars Surface Field Station, Regions of Interest, and Exploration Zone concepts**
- **Options for emplacing the Mars Surface Field Station**

One of several questions guiding the Evolvable Mars Campaign

- ***How do we pioneer an extended human presence on Mars that is Earth independent?***

- **Need to agree on a common understanding of the three phrases in this question to provide guidance for Mars surface systems and ConOps planning**

  - **What is meant by "pioneer"?**

  - **How long is "an extended human presence"?**

  - **What is meant by "Earth independent"?**

What is meant by “pioneer” ?   By “independent”?

- **Pioneer**
  - **“a person or group that originates or helps open up a new line of thought or activity or a new method or technical development”**
  - Downplay another common usage: “one of the first to settle in a territory”
- **Independent**
  - **“not requiring or relying on others (as for care or livelihood)”**
  - **Useful synonyms: self–sufficient, self-reliant, self-supporting, self-sustaining**

Note: definitions from http://www.merriam-webster.com/dictionary

How Long is "an extended human presence"?

- **There are at least two ways to interpret "human presence" both of which are relevant:**
  - The amount of time spent by a single individual on the surface
  - The collective time spent by all crews visiting the surface

- **A two-step definition of "extended human presence" was proposed in terms of objectives to be satisfied**
  - A threshold goal for both interpretations would be to remain on the surface for a minimum of 12 - 18 continuous months
    - This stay time range being determined by the arrival and departure dates of "long stay" trajectories and the capability of in-space transportation
  - An ultimate goal for both interpretations would be to remain on the surface indefinitely
    - With any individual or crew leaving the surface as a matter of choice not necessity

Restating the Original Question

How do we develop new ideas, methods, technologies, systems, and operations that enable humans to initially remain on the surface of Mars for a minimum of 12 - 18 continuous months (as determined by the arrival and departure dates of "long stay" trajectories and in-space propulsion) and ultimately remain on the surface indefinitely (leaving only as a matter of choice not necessity) without requiring or relying on support from Earth for routine operations; a self–sufficient, self-reliant, self-supporting, self-sustaining infrastructure.

**There are known unknowns, and very likely unknown unknowns,
that can <u>only</u> be addressed and understood by
human crews living and working on Mars
before an Earth independent, indefinite stay time can be achieved**

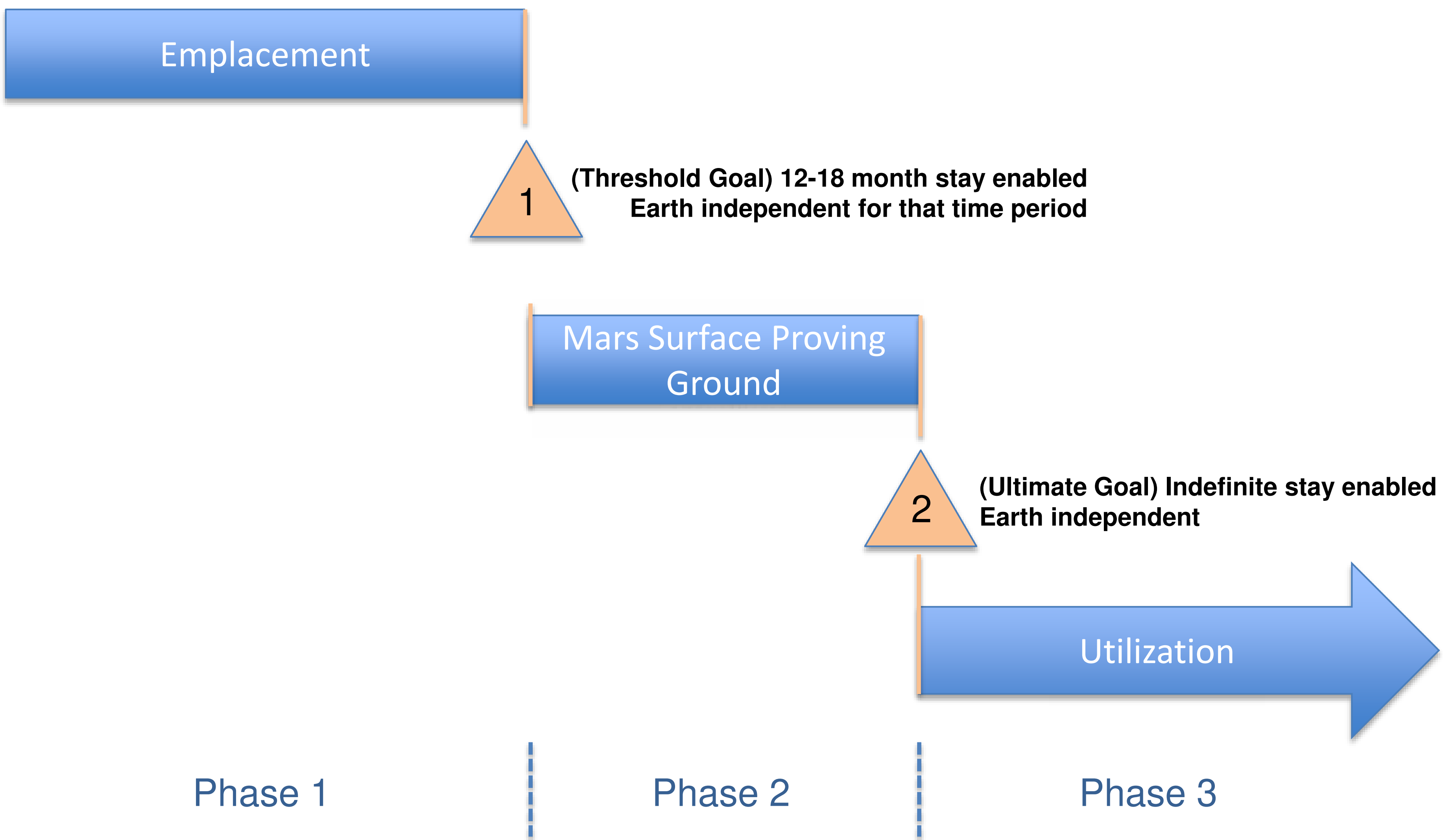
<u>Known unknowns</u> (to achieve Earth independence) – examples include:

- Human physiology in the Mars environment (e.g., gravity, radiation, dust, etc.)
- Plant/animal physiology in the Mars environment (e.g., gravity, radiation, lighting, etc.)
- Source of usable water (where is it and how can it be collected and processed)
- Martian civil engineering "best practices" (e.g., surface preparation/stabilization)

<u>Unknown unknowns</u>

- By definition unknown, but not unanticipated
- Surface infrastructure should be implemented in such a way that it is adaptable and has built-in margin to accommodate different (than originally planned) activities without requiring a complete redesign and redeployment

Architecture Approach within the EMC – Mars Surface



Capabilities Needed to Achieve Primary Objectives and Defining Characteristics

- **Utilization**
  - Indefinite stay time on the surface will be enabled by:
    - Reliable source of power
    - Reliable source of breathable air and potable water
    - Ability to produce food, consistent with a basic but balanced diet and sufficient to support a crew of four (TBR)
    - Protection from / mitigation of (harmful) environmental effects
    - Ability to maintain and repair emplaced infrastructure using local resources and supplies (i.e., existing infrastructure can be maintained but not necessarily expanded)
- **Emplacement**
  - Interplanetary transportation system for crew and cargo
  - EDL at a scale sufficient to support human mission payload needs and landing accuracy
  - Basic habitation
  - Support infrastructure (i.e., power, communications, etc.)
- **Mars Surface Proving Ground**
  - Capabilities and knowledge / experience sufficient to ***bridge the gap*** between Emplacement and Utilization
    - This includes addressing the known unknowns and any unknown unknowns revealed to be an impediment to achieving Utilization objectives

Bridging the Gap: A Mars Surface Field Station

- **Once the primary Emplacement objective – enabling crews to remain on the surface of Mars for 12 – 18 months – is achieved, this infrastructure and experience base will be used as the foundation for building capabilities needed for the Mars Surface Proving Ground phase**
- **These capabilities should give priority to investigating the known unknowns with flexibility to investigate unknown unknowns as they emerge.**
- **One well-established concept that is used to handle "unknowns" is the *field station* or *experiment station***
  - Field Stations bring the basic tools of research—from electricity to communication to community—to the places where research needs to be done
    - They provide access to the environment.
    - They provide logistical support for a wide range of activities including individual research projects; networking of research on larger scales; science, technology, engineering, and mathematics (STEM) training; and public outreach.
    - Through time they become environmental and operational models in which the steady accumulation of knowledge becomes a platform for future research.
  - *Field Stations* create a bridge between natural environments and [Earth-based] research laboratories. *Research laboratories* offer considerable power to conduct analyses in a predictable environment and to infer cause and effect from manipulative experiments, but they may miss factors that turn out to be critical in a natural environment. Field studies can encompass the full range of relevant interactions and scales, but they are not as tightly controlled. By offering access to both laboratories and field environments, Field Stations combine the best of both worlds.

Note: Adapted from Billick, I., et.al. 2013. Field Stations and Marine Laboratories of the Future: A Strategic Vision. National Association of Marine Laboratories and Organization of Biological Field Stations.

Architectural Field Station Analog – McMurdo Station Antarctica

Emplacement

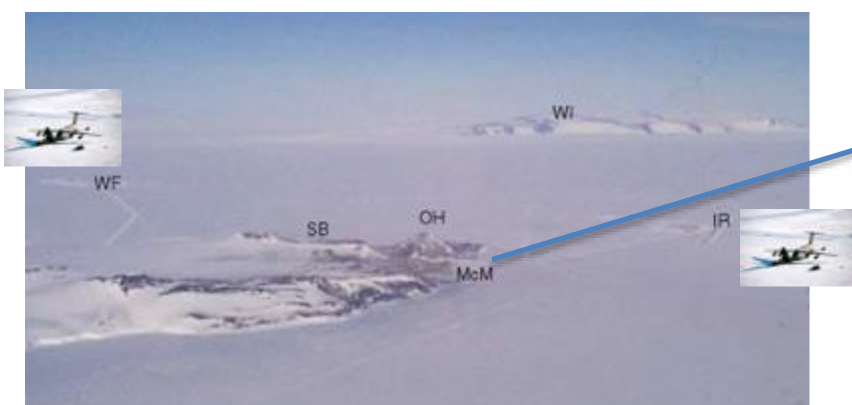
British National Antarctic Expedition 1902
R.F. Scott's "winter quarters hut." Used for both local scientific research and as a logistical base for traverses inland.

Permanent occupation - 1955
Naval Air Facility McMurdo part of "Operation Deep Freeze" to support the International Geophysical Year. A collection of semi-permanent structures (e.g., tents, Jamesway huts)

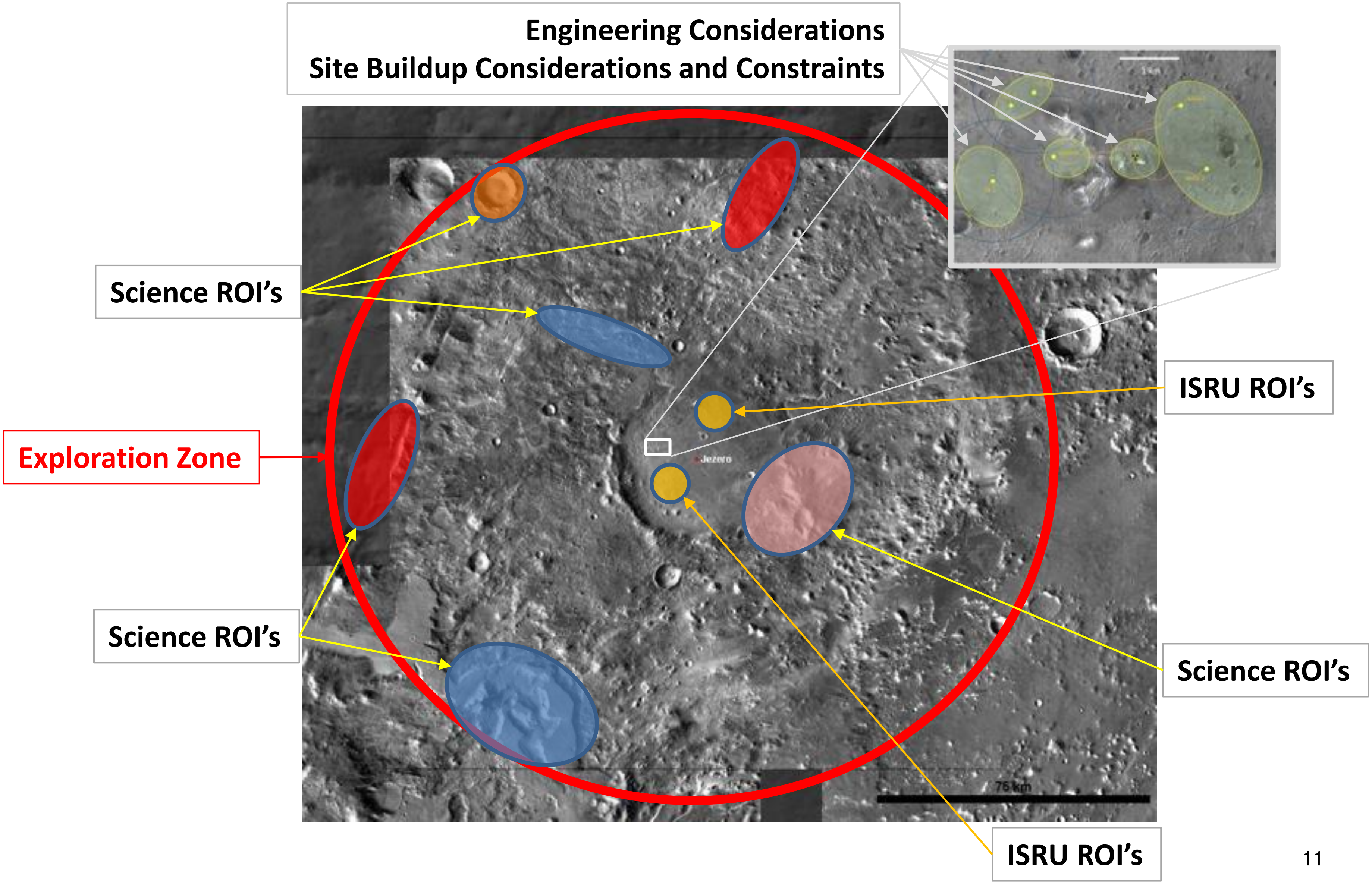
Mars Surface Proving Ground

McMurdo Station Today
Antarctica's largest community and a functional, modern-day science station, including a harbour, three airfields (two seasonal), a heliport, and more than 100 permanent buildings

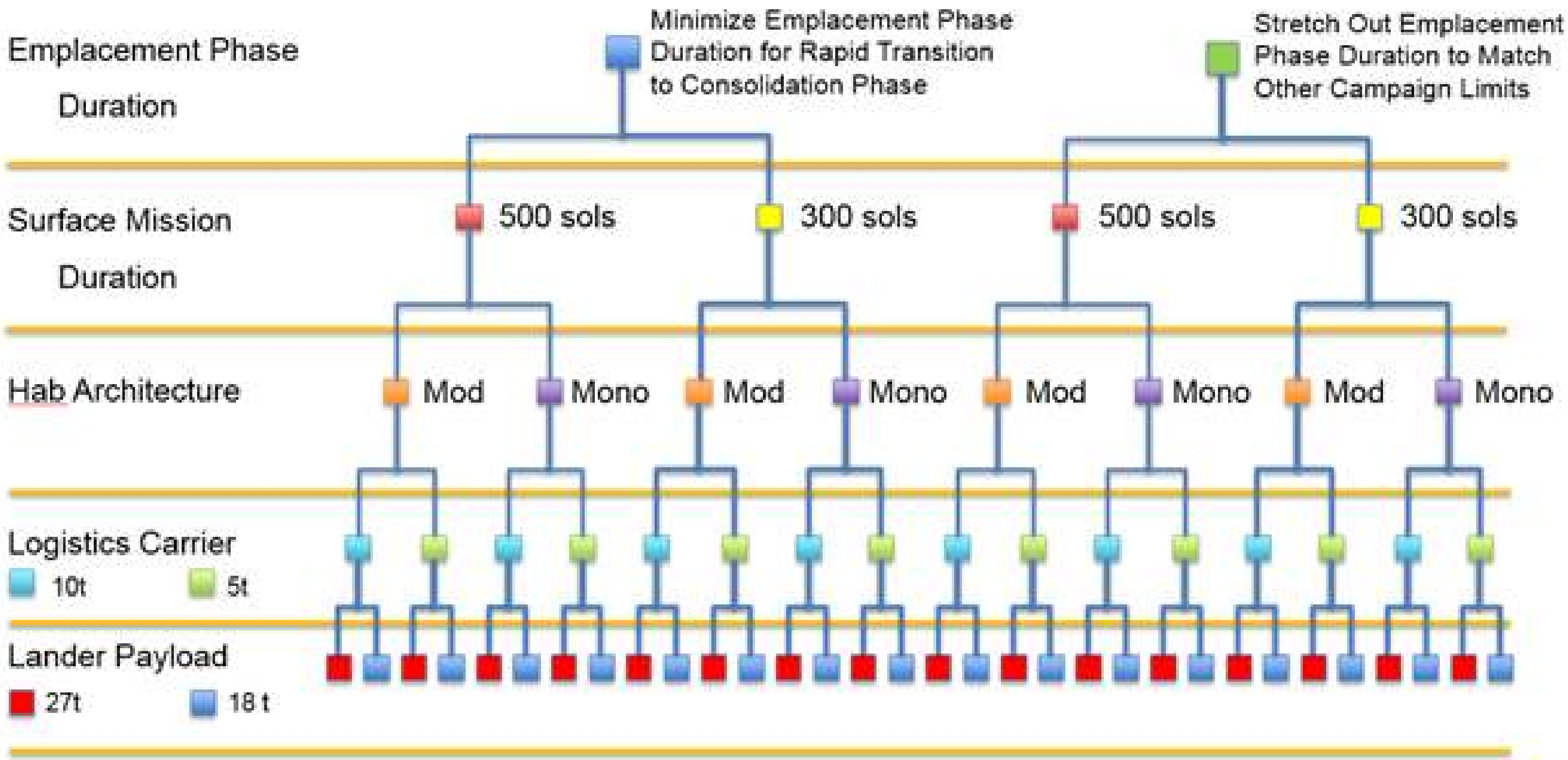
Utilization



Example Mars Surface Field Station and Surrounding Regions of Interest (ROI's)

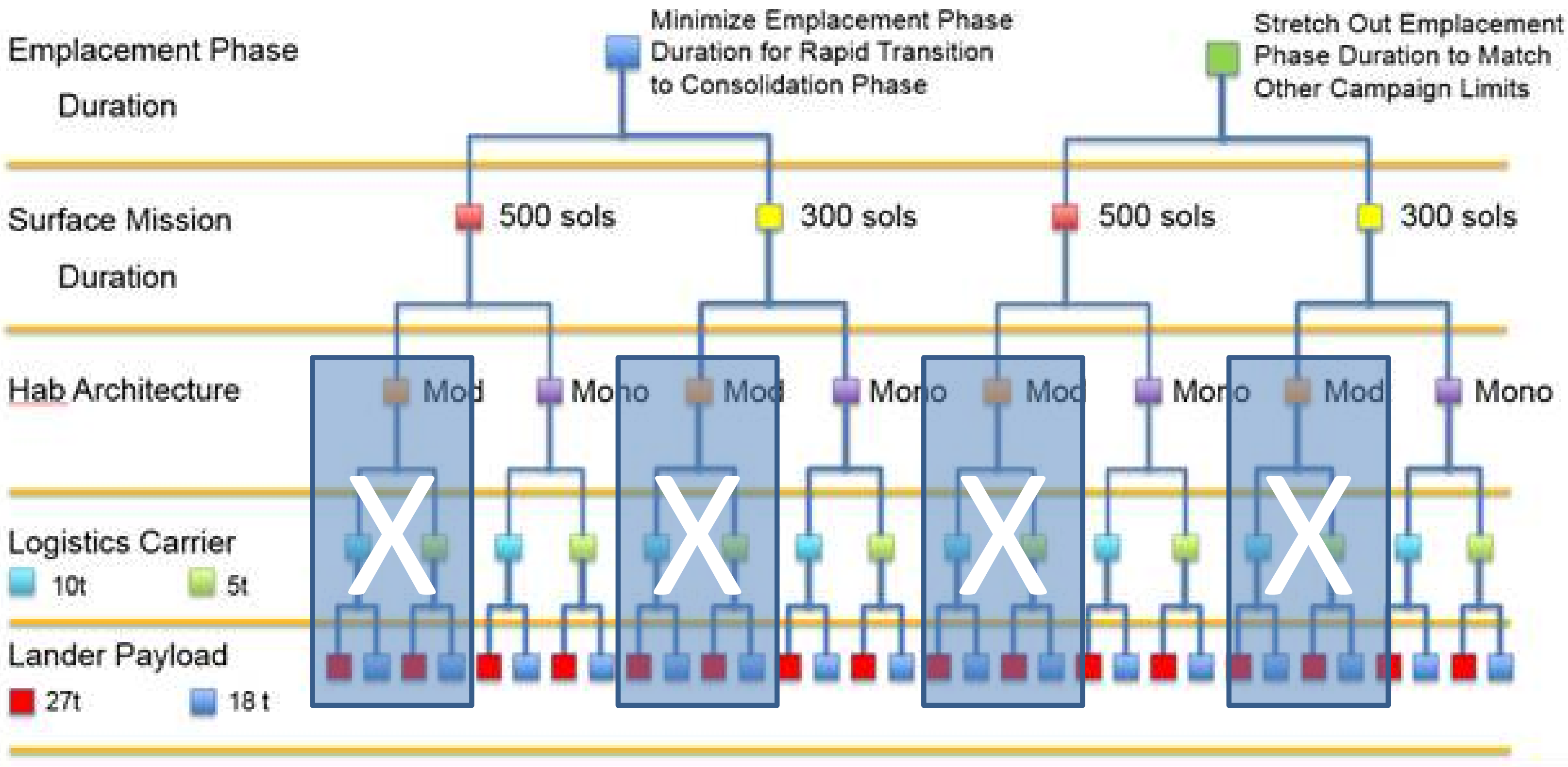


Option Tree


Emplacement Phase Duration
Minimize Emplacement Phase Duration for Rapid Transition to Consolidation Phase
Stretch Out Emplacement Phase Duration to Match Other Campaign Limits
Surface Mission Duration
500 sols
300 sols
500 sols
300 sols
Hab Architecture
Mod
Mono
Mod
Mono
Mod
Mono
Mod
Mono
Logistics Carrier
10t
5t
Lander Payload
27t
18 t

Option Tree

X Not assessed in this paper



“Rules” for Constructing Manifests

- ***Power*** **units and an off-loading / mobility system are always delivered first (to relocate the kilopower units).**
- ***Mars Ascent Vehicle (MAV)*** **is always delivered second or delivered with the power systems.**
- **Two *power cables* are delivered on the first lander**
  - One cable is used to connect the first lander to the power systems if power is moved away from the lander
  - The other cable is connected to the power “grid” and prepositioned such that it can be quickly connected to the next lander
  - Each successive lander carries just one power cable that will be prepositioned for the next lander in the sequence.
- **The *crew* is delivered on the final lander in the sequence**
  - The first crew arrives in the surface habitat; each subsequent crew arrives in a descent module and eventually transitions to the surface habitat
- ***Crew consumables*** **(i.e., food)**
  - Delivered in the habitat if there is sufficient payload mass to allow this
  - Any consumables not arriving with the crew are delivered on the cargo lander that arrives just prior to the crew
  - At a minimum, approximately 300 kg of food is delivered with each crew to allow for several weeks of acclimation time prior to retrieving any previously delivered consumables.

Key Tables and Figures in the Paper

Emplacement Phase Duration	Minimize Emplacement Phase Duration for Rapid Transition to Consolidation Phase							
Surface Mission Duration	500 sols				300 sols			
Hab Architecture	Monolithic				Monolithic			
Logistics Carrier	10-ton		5-ton		10-ton		5-ton	
Lander Payload	18-ton	27-ton	18-ton	27-ton	18-ton	27-ton	18-ton	27-ton
Lander # of 1st Crew	6	4	6	4	5	3	5	4
Unallocated Mass Through 1st Crew Launch (kg)	15,218	21,618	9,818	17,638	4,949	2,349	1,512	27,289
Lander # of 2nd Crew	9	6	9	6	7	5	8	6
Unallocated Mass Through 2nd Crew Launch (kg)	30,406	36,876	21,026	28,916	6,005	21,405	19,078	44,925
Lander # of 3rd Crew	12	8	12	8	9	7	11	8
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Lander # of 3rd Crew	11	7	11	7	10	7	11	7
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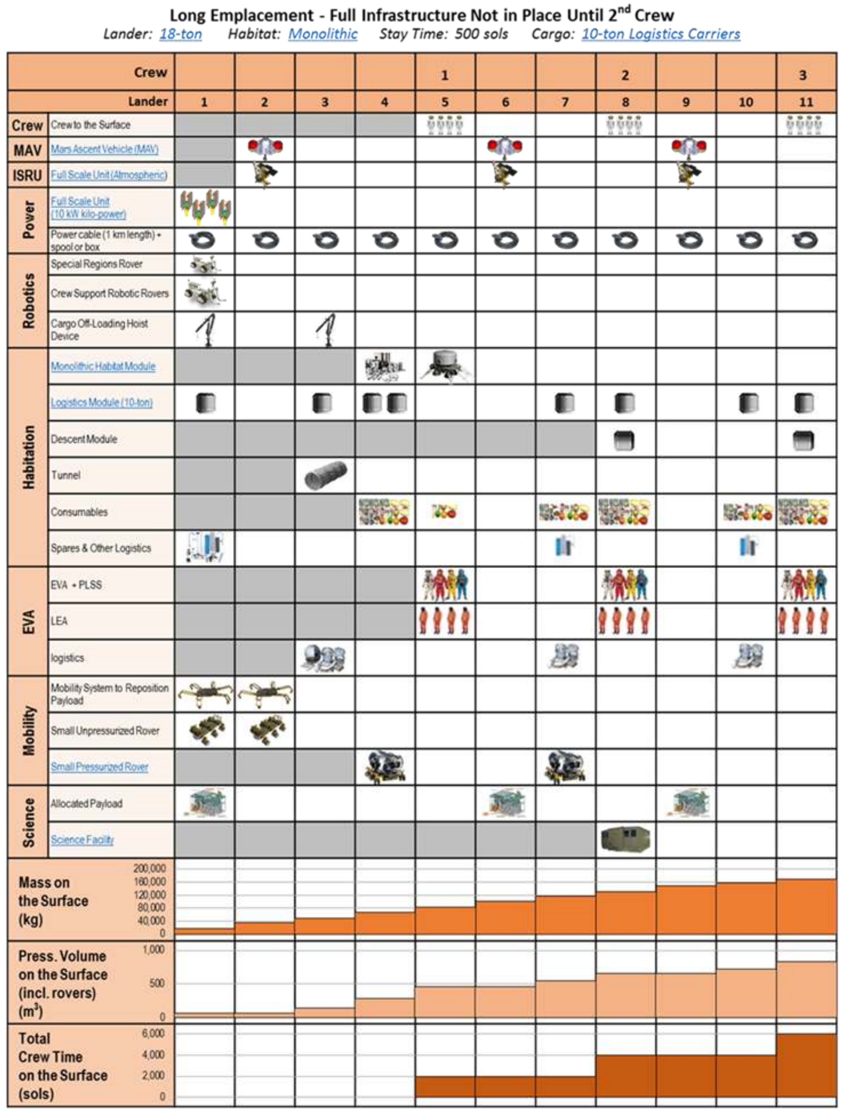


Observations

- **First tier: *how fast is the infrastructure emplaced?***
  - The only elements that were candidates for deferring were one of the SPRs and the science facility; deferring the second SPR would make MAV entry difficult for crew departure
  - Deferring one or both SPRs would severely constrain crew traverse operations during the first mission
    - for example, limited to traverses no more that 10-15 km from the habitat (i.e., EVA walk-back distance)
  - Minimizing the Emplacement phase "costs" either 5 or 6 18-ton landers and either 3 or 4 27-ton landers.
  - Stretching out the Emplacement phase "costs" 5 18-ton landers or 3 27-ton landers for the first crew.
  - So the swing is at most one lander
    - Note: making the first crew's surface stay only 300 sols for either in-space transportation option accomplishes the same reduction in landers for the first crew

Observations (continued)

- **Second tier: *maximum number of Sols on the surface***
  - This impacts the mass of crew consumables and other logistics (and the associated logistics carriers) delivered with each crew.
  - Staying on the surface for no more than 300 Sols compared to 500 Sols can save one lander for the first crew and can reduce the number of 18-ton landers in the post-Emplacement phase by one (from 3 to 2 landers for each "sustaining" crew); the 27-ton landers are typically unaffected in terms of number of landers required by this change in surface duration ("sustaining" crews require the minimum number – 2 landers – for each crew; the difference for these 27-ton landers appears in the magnitude of the unallocated payload mass on each lander).

Observations (continued)

- **No Third Tier at this time – modular habitats are still being evaluated**
- **Fourth tier: *logistics carrier size***
  - These elements have a fixed empty mass but cannot always be filled to capacity due to the overall payload mass limits of any one lander.
  - The so-called “10-ton” carriers can be more efficient in this respect – that is, more logistics mass can be carried in one 10-ton carrier than could be carried in two 5-ton carriers on a single lander, depending on what other payloads are being carried.
  - This situation affects both lander types, but negatively affects the 18-ton lander more often when looking across all options examined.

Observations (concluded)

- **Fifth tier: *lander payload capacity***
  - The 18-ton lander cannot deliver the monolithic habitat in its fully outfitted condition requiring some amount of internal accommodations to be delivered separately (and assumed to be delivered in a logistics carrier).
  - Both landers have an unallocated payload mass on each flight (by design) but there is no clear trend when tracking the unallocated mass for any individual crew or tracking accumulated mass across several crews.

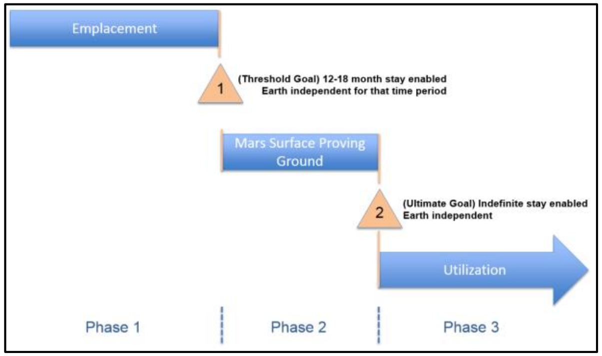
Some Bigger Picture Observations

- **5-ton versus 10-ton logistics carriers**
  - The 5-ton carrier is probably better suited for the off-loading capability options if the monolithic habitat is used. That is, the 10-ton carrier becomes the driving case for the off-loading system when paired with a monolithic habitat architecture; a 5-ton carrier is similar in size to other payload elements and would allow for a smaller payload off-loading and surface maneuvering system
  - Over time, many of these carriers will build up on the surface (each “sustaining” crew uses two 10-ton or four 5-ton carriers). This provides an opportunity for element repurposing and habitable space expansion. This could favor the larger volume 10-ton carrier
- **Minimum number of landers for the first crew on the surface**
  - Reducing the 27-ton lander case from three landers to just two would require pushing both SPRs and a tunnel to later crews and reducing the first crew’s surface time to just a few weeks
  - Reducing the 18-ton lander case from five landers to four could be accomplished by pushing both SPRs and the tunnel to later crews but still staying for 300 Sols **OR** keeping one SPR and the tunnel but staying on the surface for roughly 160-170 Sols
  - Reducing the 18-ton lander case from four landers to three could be accomplished by pushing both SPRs and the tunnel to later crews AND reducing the first crew’s surface stay time to just a few weeks

Conclusion

- **How do we pioneer an extended human presence on Mars that is Earth independent?**

By means of a three-phase architecture, gradually building up experience and infrastructure



- **The Mars Surface Field Station, Regions of Interest, and Exploration Zone concepts**

Extended stay times and traverse distances gave rise to the Exploration Zone containing multiple ROIs. Many useful analogous Field Station examples point to a surface ConOps

- **Options for emplacing the Mars Surface Field Station**

Many options exist, trading factors such as stay time, capabilities, etc. with no clear discriminator at this time. Assessments continue.

Back up

What “Unknowns” need to be addressed?

Known unknowns (to achieve Earth independence) – examples include:

- Human physiology in the Mars environment
  - Gravity
  - Radiation
  - Dust (e.g., perchlorates)
- Plant/animal physiology in the Mars environment
  - Gravity
  - Radiation
  - Light
- Source of usable water
  - If in the form of H_2O then where is it and how can it be collected
  - If in the form of hydrated minerals then where is it, how is the raw material collected, and what is the “best” process (given local environmental conditions and available infrastructure) to extract the water
- Martian civil engineering “best practices”
  - Surface preparation/stabilization
- Martian chemical engineering “best practices”
- TBD others

Unknown unknowns

- By definition unknown, but not unanticipated
- Surface infrastructure should be implemented in such a way that it is adaptable and has built-in margin to accommodate different (than originally planned) activities without requiring a complete redesign and redeployment

A difference between DRA 5.0 and Mars Surface Field Station

- In DRA 5.0, exploration of the Martian surface was accomplished by setting up identical surface stations at a minimum of three different locations. Understanding Mars was accomplished by visiting these diverse sites.
- The Mars Surface Field Station concept invests in a single site that is upgraded and expanded as the knowledge and understanding of the Martian surface expands and improves.
- But part of the expansion of understanding assumes the ability to visit and study a diversity of surface sites. This implies that (a) a surface transportation capability is developed and (b) the Field Station is located within range of a diversity of surface sites.
- The Mars Surface Field Station begins as a proving ground for basic capabilities and evolves into a logistical support hub for exploration of remote and diverse surface sites.

Surface System Elements Needed for the Emplacement Phase

- **Mars Ascent Vehicle (MAV)**
- **Crew Descent Module**
- **Atmospheric ISRU**
- **Power (10 kW units)**
- **Robotic Rovers**
  - Special regions
  - Crew support
- **Cargo Off-loading**
- **Habitation**
- **Tunnel**
- **Science payloads**
- **Logistics modules**
- **Logistics**
  - Crew consumables
  - Fixed system spares
  - Mobile system spares
  - EVA spares
- **Mobility platform to reposition payloads**
- **Small unpressurized rover (crew)**
- **Small pressurized rover (crew)**

Results

Emplacement Phase Duration	Minimize Emplacement Phase Duration for Rapid Transition to Consolidation Phase							
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Example: Mission Manifests

Long Emplacement - Full Infrastructure Not in Place Until 2nd Crew

Lander: *18-ton* *Habitat:* *Monolithic* *Stay Time:* *500 sols* *Cargo:* *10-ton Logistics Carriers*