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CORRELATIONS BETWEEN CEV AND PLANETARY SURFACE SYSTEMS ARCHITECTURE PLANNING

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ABSTRACT

This paper will present key issues and concepts that illustrate interrelationships between Crew Exploration Vehicle (CEV) and planetary surface systems design decisions associated with human exploration of the Moon and Mars. Such decisions will influence surface element sizing, configurations and deployment. Important implications include impacts and constraints upon habitat module efficiencies, safety and surface implementation

A correlation between planning for CEV and surface system requirements demands an integrated approach. Launch and orbital transfer means must be analyzed in parallel with comprehensive payload needs and element design options. Accordingly, studies should address a variety of option drivers and alternatives, including:

- Surface landing strategies applicable for the Moon and Mars that place payloads above, in plane with and below landers.
- Surface element geometrics and configurations that orient landing elements (including habitats) in vertical vs. horizontal orientations.
- Habitat model options that apply conventional ISS-type fixed pressure vessels and expandable (inflatable and telescoping) approaches.
- Influences of sizes and types upon design and operations of surface mobility systems.
- Surface transport requirements/options that involve use of pressurized and unpressurized vehicles.
- Surface element configurations requirements/options and their influences upon deployment, crew safety, evolutionary growth and other factors.

INTRODUCTION

A guiding priority of habitat planning and design is to deliver and deploy the greatest amount of useful real estate assets possible to the destination of use in the most practical and efficient manner, considering such factors as :

- Interior living and work volumes:
  - Maximizing the total amount of space available for transport of equipment and supplies to the destination site.
  - Optimizing the amount and layout of space available for living and work activities after the module is delivered and deployed.
  - Planning interior circulation within and between modules for efficiency and safety.
- Utilities and Equipment:
  - Accommodating manifesting and delivery of as much equipment as possible within transportation mass and volume constraints.
  - Enabling rapid relocation, integration and change-outs of utility-dependant systems during and following initial operational setup procedures.

LAUNCH VEHICLE INFLUENCES

Surface module options are driven by mass and payload shroud capacities of available launchers:

- If Heavy Lift Vehicles (HLVs) with capabilities to launch payloads approaching 100MT and 7 meter diameter, the module of choice is likely to be a large diameter cylinder with a landing system attached below. (Figure 1).
- Approaches that utilize Medium Lift Vehicles (MLVs) with capacities ranging from about 15MT to somewhat less than 100MT may use smaller diameter conventional or expandable module types which might be placed directly on the surface by overhead landers. (Figure 2).

Fig. 1. Typical Lander Concept

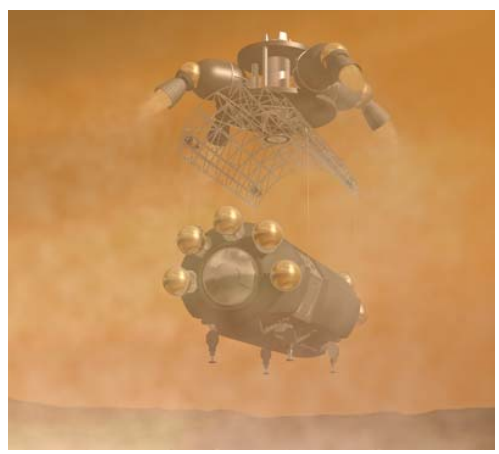


Fig. 2. SICSA Lander Concept

SURFACE MODULE CONFIGURATIONS

SICSA correlated selected module types with possible surface configurations to assess advantages and limitations of each. This study considered Heavy and Medium Lift Vehicle-class modules guided by assumptions which follow. (Figure 3):

Fig. 3. HLV vs. MLV Options

Surface module design options are driven by mass and payload shroud capacities of available launchers:

- If Heavy Lift Vehicles (HLVs) are available (100MT and 7 meter diameter launch capabilities), the module of choice is likely to be a "bologna-slice" cylinder with a landing system below:
  - This approach combines CG balancing and stability advantages for landing, good internal volume features, and abilities to pre-integrate utility and equipment systems.
- Approaches that utilize Medium Lift Vehicles (MLVs) (about 15MT to less than 100MT) are most likely to use a layout of horizontal conventional and vertical inflatable modules:
  - This pattern combines advantages of conventional modules with pre-integrated utility/equipment, and large volumes enabled by inflatables.

HLV-CLASS CONFIGURATIONS

The reference patterns shown provide separate module surface access/egress locations at center locations and berthing tunnel connections between modules at the habitation level:

- A triangular pattern scheme affords certain advantages and disadvantages (Figure 4):
  - Pros: A relatively compact configuration footprint at the entry airlock level can minimize the area for site surface preparation if required.

    Loop egress is achieved with three modules.
  - Con: May be more difficult to position/ assemble.
- A rectilinear scheme also offers advantages/ disadvantages:
  - Pros: Greater spacing between berthing locations affords more useful wall/ equipment space.
  - Cons: Larger footprint for good site selection and/ or surface preparation.

    Four modules are needed for loop egress.

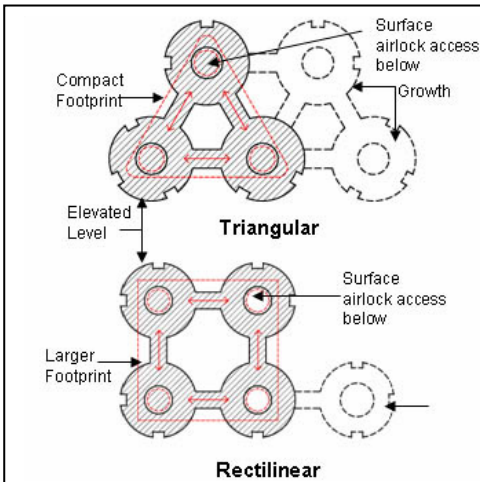


Fig. 4. HLV Module Configuration

MLV-CLASS PATTERN COMPARISONS

Given that HLV-class module configurations and all triangular module patterns present limitations, SICSA compared four different possibilities for MLV-class modules (Figures 10-16):

- Scheme A includes a combination of horizontal conventional and vertical inflatable modules to realize special advantages of each type:
  - EVA access/egress would be provided by suitlocks in each horizontal module.
  - The cruciform plan could later be expanded into a closed-loop racetrack.
- Scheme B utilizes only horizontal modules in a racetrack pattern:
  - Each module is assumed to contain an airlock which also serves as a berthing/ interface passageway.
- Scheme C utilizes a combination of horizontal conventional modules and corner berthing/ airlock nodes:
  - Suitlocks could be used, but are not presented to conserve space.
- Scheme D presents a raft pattern with 2 types of horizontal modules and separate berthing/airlock nodes:
  - The configuration assumes that 2 EVA access/egress airlocks will be provided.

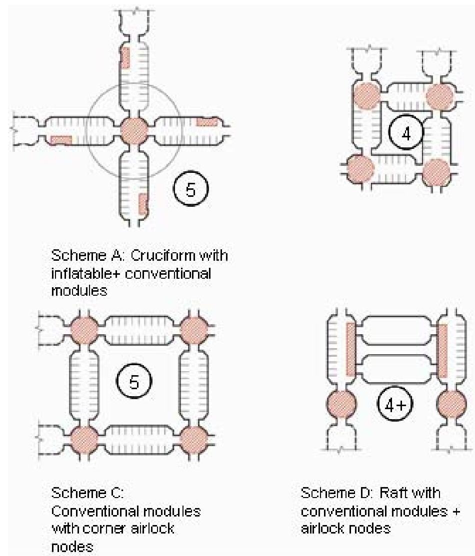
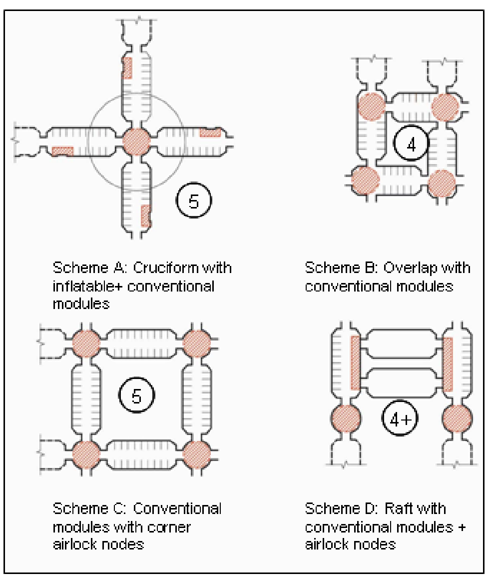


Fig.5. HLV Module Configuration.



Non-functional space

Number of launches required to achieve configuration

Scheme A:

- Suitlocks minimize non-functional space associated with conventional airlocks.
- Inflatable module greatly increases crew living/ work volume over all other schemes.

Scheme B:

- Internal airlocks in all modules produce a high non-functional/ useful volume ratio.

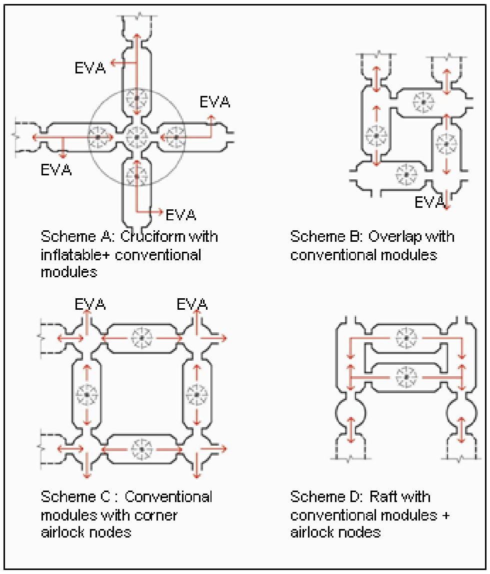
Scheme C:

- External airlocks enable full utilization of modules but impose additional launch requirements.

Scheme D:

- Special circulation modules plus external airlocks impose substantial launch requirements.

Fig.6. Space/Launch Efficiency



Emergency Evacuation

To Connecting Module

EVA To EVA

Scheme A:

- Direct connections, all modules.
- EVA-suitlocks in conventional modules.
- Worst case- central atrium emergency.

Scheme B:

- Connections/ EVA egress through internal airlocks.
- Worst case- airlock failure prior to complete racetrack, isolating modules.

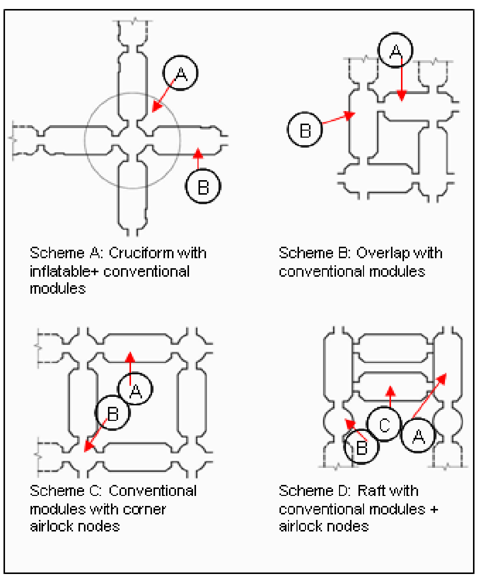
Scheme C:

- Connections/ EVA egress through external airlocks.
- Worst case-airlock failure prior to complete racetrack, isolating modules.

Scheme D:

- Connections through special modules.
- EVA egress through separate nodes.
- Worst case- airlock failure prior to complete racetrack, isolating modules.

Fig. 7. Emergency Egress.



Separate Module Types

Scheme A:

- Applies 2 module types, each with important functional support benefits (inflatable volume & conventional module pre-integration).

Scheme B:

- Uses a single standard module but with constricted volume capacity.
- For double connection interfaces the module must be modified for a 2nd berthing port.

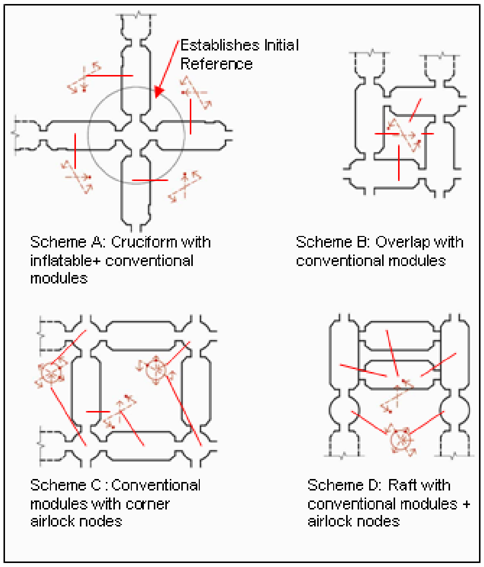
Scheme C:

- Uses a single standard module + separate airlock element.

Scheme D:

- Uses 2 types of modules + a separate airlock element.

Fig. 8. Module Commonality.

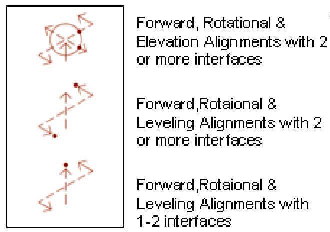


Scheme A:

- Central inflatable module establishes the site center & is not repositioned.
- Conventional modules with wheels are aligned to interface at a single point.

Scheme B:

- Conventional modules with wheels must be forward & rotationally aligned for mating at 2 berthing points.
- Placement positioning may be difficult by towing due to interference by obstructing modules.



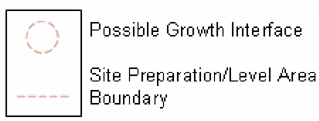
Scheme C:

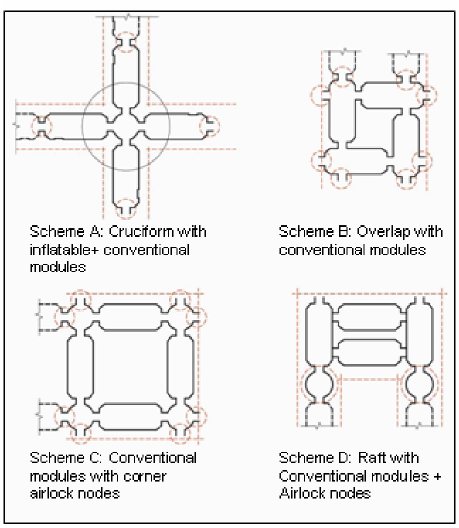
- Accurate positioning of conventional modules and nodal airlock elements may be difficult, particularly on rough, uneven sites.
- While conventional modules can have wheels, means for transferring/ aligning nodal airlocks are unknown.

Scheme D:

- Accurate positioning of all 4 conventional modules to accommodate berthing interfaces may be difficult, particularly for rotational alignments of end circulation modules.
- Transport & positioning problems for nodal airlock elements are similar to Scheme C.

Fig. 10. Surface Positioning.





Scheme A:

- Configuration can extend lineally & possibly replicate.
- Smallest boundary for level site requirement.
- Does not impose a requirement for more than 2 modules/ launches prior to operational configuration.

Scheme B:

- Configuration can grow along 2 axes & can replicate a 2nd racetrack group.
- More compact for site preparation than Scheme C.
- Requires 4 modules/ launches to achieve racetrack advantage.

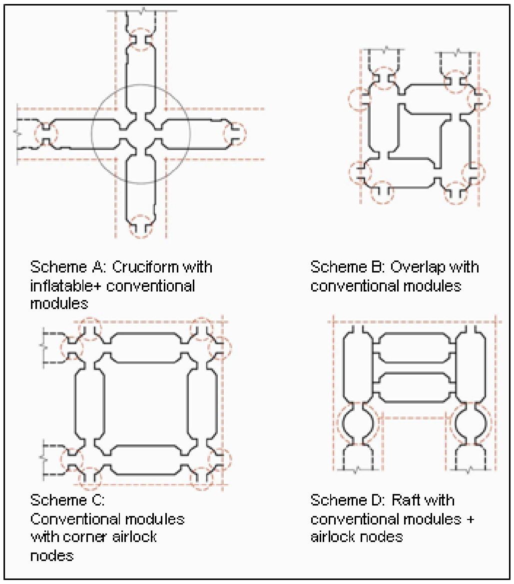
Scheme C:

- Configuration can grow along 2 axes & can replicate a 2nd racetrack group.
- Imposes the largest level site requirement of all schemes.
- Requires 4 modules/ 5 launches to achieve racetrack advantage.

Scheme D:

- Configuration can grow along one side (unless additional airlocks are added) requiring 4+ launches, and can replicate.
- More compact for site preparation than schemes B&C.
- Requires 4 modules + 2 airlocks to achieve racetrack advantage.

Fig. 9. Evolutionary Growth.



	SPACE/LAUNCH EFFICIENCY	EMERGENCY EGRESS	MODULE COMMONALITY	EVOLUTIONARY GROWTH	SURFACE POSITIONING	SUMMARY COMPARISON	RANK ORDER
SCHEME A	GOOD	FAIR	FAIR	GOOD	GOOD	GOOD	1
SCHEME B	POOR	FAIR	GOOD	FAIR	POOR	FAIR	3
SCHEME C	FAIR	FAIR	FAIR	FAIR	POOR	FAIR	2
SCHEME D	POOR	POOR	POOR	FAIR	POOR	POOR	4

Options Comparison

Fig. 11. Summary Observations.

SUMMARY CONCLUSIONS

Guided by the configuration option comparisons, SICSA selected a reference design that combines use of conventional and inflatable (hybrid) modules (Figure 12) for further investigation:

Fig. 12. Module Combination Approach Module

- This approach combines advantages of large interior volumes of inflatables with means to integrate utilities and equipment systems afforded by conventional modules. In addition:
  – It allows conventional modules to be used to transport cargo/ equipment that can't be carried in inflatables.
  – It enables conventional modules to be standardized for use as laboratories and for use as logistics carriers that can be used for lab/hab functions when emptied (excellent commonality functions).
  – It can evolve into a racetrack pattern, offering dual egress capabilities.
  – It can accommodate separate attachable airlocks, but potentially will not require them.
  – It presents a small footprint to minimize site preparation.