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ON THE USE OF PATTERN LANGUAGES IN THE DEVELOPMENT OF CREWED MARTIAN SPACECRAFT AND HABITATS

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ABSTRACT

The purpose of this paper is to discuss how design pattern analysis and pattern languages can be used in the development of early Martian habitations, and to a lesser extent, to crewed spacecraft for a future Mars mission. Pattern analysis is a way of capturing design information and communicating it in a manner that makes it easy to use in development activities. It is also useful as an educational tool that can help students understand the multifaceted and interacting human requirements that factor into the development of human spacecraft. As well, pattern analysis can help form the basis of an open-source approach to spacecraft specification, and provide a means of systematically organizing many of the observations obtained from the Mars Desert Research Station and other Mars habitation simulation facilities.

A prototype space residence pattern language derived from the history of space station designs - parts of which are suitable for use in the specification of human-carrying Martian spacecraft - and a pattern language dialect derived primarily from the MDRS mission archives suitable for the specification of an early Martian surface residence, will be presented along with a sample pattern and a discussion on how to use the languages. These design pattern languages are continually developing and this paper only represents a summary and snapshot of where they stand today. Please refer to the space residence pattern language website [1] for further details and updated information.

INTRODUCTION

The original work in the pattern language field is Christopher Alexander's *A Pattern Language* [2] in which he and his colleagues introduced the concept of the architectural design pattern, pattern analysis, and the pattern language. They proposed these ideas as a way of rigorously codifying the things that make certain aspects of a building's, or region's, organization good in certain situations and bad in others. The basic idea behind pattern analysis when applied to buildings, or other artifacts with which people interact, is easy to understand: from a fairly long history of actual design examples recurring architectural solutions to specific life problems, called patterns, can be identified. These are not just any old repeated solutions, but specific ones that promote human activity in some positive way. The authors emphasize that it is not the specific technological implementation of a solution that is important in a pattern, but the organization and the relationship that people have within the social and environmental situation it helps create. More formally, pattern discovery is a means of finding, and eventually communicating, apparently implementation invariant, organizational design principles from a legacy of specific design solutions to problems that have also proven to enhance people's activities.

The patterns that Alexander discusses do not merely deal with matters of style or aesthetics, but with arrangements of architectural elements, objects, and people's behaviour, and their ability to solve organizational problems inherent in the activities of people. When excavated from the legacy of architectural history and written down in a consistent and explicit manner, these patterns link together to form a language from which new building designs can be generated. Rigorous application of the language makes it possible for people other than design specialists to be able to design buildings that incorporate timeless solutions into their own building projects. It turns out that a pattern language approach to design is both a way to organize the design activities of a project and a way to generate solutions to a specific problem.

The same sort of questions can be asked - and similar techniques applied - about the legacy of space station designs: what recurring organizational principles can be abstracted from the architecture of the Salyuts, Skylab, Space Shuttle, Mir, and the International Space Station for reuse in the design of new spacecraft ? In very basic terms, are any there any general organizational principles that have emerged that make life in space good, or conversely, make it bad ? Clearly, this could provide useful information in developing a spacecraft for taking people to Mars. And, along the same lines of thought, you can also ask the same questions about the various Martian habitation simulators like the Mars Society's Mars Desert Research Station (MDRS), the Flashline Mars Analog Research Station (FMARS), the EuroMars simulator, and any other Martian habitation simulators, in order to gain insight into the requirements for actual Martian surface habitations.

I wondered about these questions and worked on applying the ideas of Alexandrian pattern analysis to try and answer them. The results are discussed at length at my space architecture patterns website [1]. In this paper I'll try and summarize the approach used to address these questions, present some of the findings, discuss some drawbacks, suggest some ideas on how design work might proceed, and speculate on where further research might go. Also, I should point out that this pattern study is human-centered and may be thought of as focusing on a class of human-factors concerns as opposed to taking a mission design view of spacecraft architecture.

WHAT IS A PATTERN ?

Roughly speaking, a pattern is a organization of objects or elements that consistently recur over-and-over in various real-life crewed spacecraft. However, Alexander and his colleagues [2, p. x] define a pattern in a somewhat different way than we might expect to find in a dictionary:

> "Each pattern describes a problem which occurs over and over again in our environment and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice."

They later go on to elaborate that a pattern is composed of three basic parts:

1. a context,

2. a system of forces arising within the context which constitutes the problem to be solved, and
3. a configuration or solution to the problem.

The context is the setting; that is, the circumstances within which the problem is to be solved. A pattern's system of forces is broadly defined and can comprise both physical pushes and pulls, as well as more abstract sources of impetus like social, psychological, and political ones. The configuration is a design solution whereby all of the active forces, acting within the context, come to resolution. It is fairly independent of the technology used in the implementation and its most salient aspects can be implemented using a variety of technological approaches.

BASIC PATTERN STYLE

There is no official or enforced way of documenting a pattern. You are free to create your own form as long as it captures the context, forces, and solution. The form originally proposed by Alexander [2, p. x] which is, naturally enough, referred to as the Alexandrian form, and might also be thought of as the canonical form, is made up of the following components:

1. a short name, or title for the pattern;
2. a picture showing an archetypal example of the solution;
3. a short statement about the context of the problem, and its connection to higher level patterns;
4. a short statement about the problem to be solved;
5. the body of the problem giving such things as the background, evidence for validity, and a range of ways the pattern can manifest itself;
6. a short statement about the solution to the problem given in the form of an instruction;
7. a simple diagram of the solution;
8. a short statement about how this pattern is connected to those below it; and
9. a statement about the solution's invariance properties.

PATTERN LANGUAGES

Patterns do not exist in isolation. A complex artifact like a building, space station, or Martian surface habitat, consists of a large number of mutually interlocking patterns. Any particular pattern usually helps to bring about the full implementation of the solution of one or more other patterns, and, at the same time, that same pattern might also form part of the context for one or more entirely different patterns. It was postulated that this form of interconnection implied that a hierarchical relationship existed amongst patterns whereby any given pattern helps to solve higher level patterns and also helps set the context to lower level patterns. The basic message is: patterns and their interconnections form a pattern language.

Alexander [2] went so far as to state that the creation of the language - both the discovery of the patterns and their linkages - was the real work of designing any artifact. The artifact itself was merely an instantiation of particular instances of the patterns dependent upon unique conditions at the time of design.

It is possible for a pattern analysis of a class of artifacts to yield many pattern languages. What one arrives at can depend upon the criteria used for identifying and selecting the constituent patterns. In *A Pattern Language* [2] Alexander concentrates on presenting positive patterns active in architectural history with the criteria for selection as an invariance in the ability to have a good influence on human activity as well as solving a particular organizational problem. A language need not be purely positive or negative, but in general, a language might be built up of a mixture of positive and negative patterns.

Can a pattern language ever be called complete? In other words, is there a measure of completeness to give us an idea when a language is fully developed? In some respects the number of neutral and negative patterns in a language is a measure of completeness. Negative patterns are misfits, and in a developing language they should eventually be replaced by patterns that solve the problems they describe and, therefore, should be viewed as place holders. Neutral patterns point to areas that require further research, and should also eventually be eliminated; except possibly at the highest levels in the language where they help define the language's overall context. In general, negative and neutral patterns prevent full expression of a language's potential as they tend to form nodes of disconnection in a language's structure. However, don't be mislead by the absence of negatives and neutrals, since this does not always imply completeness. One also needs to look at the number of invariant positive patterns, as well as the shear number and types of patterns in the language. Too few invariant patterns may indicate that the domain itself is too immature for a language to be constructed, or that too little work has been done in pattern development. Also, one needs to review the vintage of the patterns. If they are old - the definition of old depends on the level of dynamism in the domain - they may be out of date with respect to current ideas and thereby reduce the completeness of the language. Another measure of completeness is the ability of the language to be used to generate complete and varied design solutions. If design instantiations are missing elements, or are not varied, then gaps may be present in the language and further pattern development may be required. A healthy language is never truly ‘complete’, but is always in a state of change.

STRUCTURE OF THE SPACE RESIDENCE PATTERN LANGUAGE

When I first began with patterns I studied the history of space station designs since there was a history of actual artifacts to examine and the results might be useful in developing future spacecraft that would provide some form of transport or residential functionality such as future Mars bound spacecraft, Earth-orbiting space hotels, or LEO-based private industrial parks. A study of the literature of the history and engineering of human spacecraft, as well as publications of first hand accounts of life in space, has provided the basis for the proposed language's structure and the identification of its basic patterns. If you are interested in working your way through the literature - which I highly encourage since it will be the most important way you can verify the patterns and begin to identify new ones - I would recommend starting with Stuster [3], White [4], and Harrison [5] as they provide good summaries of the effects of space flight on humans. The writings of Burroughs [6], Cooper [7], Harland [8], Lebedev [9], Linenger [10], and Lucid [11] form an introductory course of accounts about day-to-day life in various space stations. As well, NASA's Man-Systems Integration Standards [12] provides good insight into engineering-codified human factors design principles for spacecraft development.

I refer to the pattern language derived from the space station legacy as the 'space residence pattern language' since it deals with the architecture of residing in space. As an initial proposition, Figure 1 shows the overall hierarchy of patterns for a possible human-centered space residence pattern language.

At the very top of the hierarchy are the patterns dealing with the environment. These patterns deal directly with the most significant conditions in the space environment near the Earth: mainly with the natural physical lack of life support in its most extreme form. These physical patterns, like those on Earth, are not really independent entities as presented herein, but form integrated and interdependent networks. The pattern presentation merely allows for particular aspects to be emphasized to make clear certain important considerations.

Immediately below the Environment category are patterns of human activity. These divide into two contrasting groups: those dealing with being, and those with doing. The Being category includes patterns that discuss such physically based things as the requirements and limitations of a man-made life-support environment, and the good and bad effects of being free of gravity along with the patterns employed in helping to cope with the condition. As well, the Being category encompasses what might be called softer patterns that deal with the subtle mix of behaviours surrounding the experience of living in outer space within relatively small confines. Basically, the Being category contains the patterns of immediate physical and mental survival.

The contrasting Doing category deals with the patterns of work and other formal, or programmatic activities that the residents may undertake. It contains patterns that deal with the physical apparatus needed to perform work in weightlessness, and on the physical, personal, workflow, and social organization of such activities unique to a space station. In many ways these patterns are a direct consequence of the context within which space residences have been operating. Ostensibly, the reason for going into space to date has been to perform certain scientific, military, and limited amounts of commercial and industrial research and development tasks, so these patterns currently reflect those uses. Along with these research-type jobs there is also a certain amount of maintenance and repair required as in any Earthbound residence. To effectively get these chores done patterns have arisen that support doing work in general and transcend many narrowly defined task objectives. These form the high level core of patterns in the Doing category. As well, a certain amount of work also happens outside the residence from time-to-time. This involves donning a space suit and leaving the amenable conditions of the residence. This working environment is not dealt with in these patterns at this time; however, this category could accept them.

Below the Being and Doing categories are the patterns of satisfying short and long term needs: the Supporting and Remaining categories respectively. The Supporting category presents patterns that are necessary for people to get by for a few days to a couple of weeks, and Remaining deals with patterns necessary for much longer stays on the order of many weeks and months. The Supporting and Remaining level is where the patterns in the language begin to deal with the requirements of living arrangements. Above this level, the patterns deal more with what might be called the personal physical and psychological attributes of space travel. Patterns at the Being and Doing level help to define the context which shape the form of the solutions in the

Supporting and Remaining categories. The Supporting category contains patterns for such things as the need for a private bathroom, sleeping space, and the structure of common areas. In the Supporting category the period of residence is somewhat like an extended camping trip, so the amenities are generally subordinate to the programmatic objectives.

The Remaining category contains patterns that typically characterize situations necessary to enable people to get by for a long time, which so far means for a few months up to and including about a year. These patterns expand and elaborate upon Supporting patterns, but do not necessarily supplant them. A space residence capable of providing long term occupancy requires patterns from both the Supporting and Remaining categories, but a short term occupancy residence need not contain patterns from the Remaining category.

Finally, at the level below the Supporting and Remaining categories the patterns begin to deal with more specific technological implementation choices for patterns at the higher levels. These are the patterns of Shaping and Organizing. Shaping deals with how to form the actual living spaces, and Organizing deals with the patterns of arranging the living spaces. For example, the Shaping category contains patterns that deal with such things as rigid pressurized containers, protective coverings, inflatable structures, and windows. It is important to note that they are driven by architectural concerns from above and from below by technology. As technology changes then so will the available repertoire of shapes.

The Organizing category, which contains patterns about how to arrange spaces to generate complete residences, is comprised of patterns dealing with such things as the gravitational needs of the residents, visual orchestration of the spaces while moving, modularity, and decommissioning.

Shaping and Organizing contain both patterns and the beginnings of the highest level requirements for detailed specification of actual hardware that would occur below this level. Patterns end at this level, and specific technology based engineering specification begins in earnest from here on.

Figure 2 lists the titles of the currently identified patterns appearing in each of the categories.

One important aspect that Figure 2 does not show are the linkages between the patterns - that is, how one pattern flows from other patterns above it in the hierarchy and in turn helps derive patterns below. For more information on this aspect, please refer to the space architecture patterns website [1].

STRUCTURE OF THE MARTIAN PATTERN LANGUAGE DIALECT

There is less information available for doing a pattern analysis of human-carrying Martian spacecraft and surface residences - the problem is that there are no actual artifacts. For these dialects I drew heavily from the work of Zubrin [13] [14] [15], Clancey [16], [17], [18], and the data from the MDRS simulation studies archived at the Mars Society website. Although these simulations are indeed just simulations they are typically conducted in a manner so as to stay close to day-to-day life on Mars; hence, they provide a valuable source of information for research into the requirements of these vehicles. However, since these dialects are not based on actual artifacts, the invariance of the patterns is not yet completely clear.

The Martian pattern language dialect has been divided into two distinct branches: the first deals with patterns associated with spacecraft whose job it is to transport people to and from Mars, which is called the Martian Spacecraft (MSC or msc) language, and the second deals with patterns associated with residences that early visitors will use on the surface of Mars, which is called the Martian Surface Residence (MSR or msr) language. I must stress that the MSR dialect focuses on the earliest of residences that will be used in the first trips to the Martian surface and how they might evolve. I do not try and speculate beyond that since it is not currently possible to say with any confidence what those later, and more truly Martian, residences might be like. Figure 3 presents the titles of the patterns in the still immature MSC dialect. At present this dialect only reflects that a landing craft of some sort will be all or part of the Martian transit vehicle.

One point to consider is that I do not think that the MSC and MSR dialects are completely independent of one another. Early trips to Mars will bring with them surface landing craft and these most likely will be used as residences once on the surface. Mars Direct [14] utilizes the lander as the in-transit vehicle and dissolves true independence between MSC and MSR.

The structure of MSR is very similar to that used in the space residence pattern language. There are four basic levels: Shelter, Life, Requirements, and Formal Properties. Shelter consists of neutral environmental patterns and is called msr-Environment. The Life level consists of patterns in the msr-Being and msr-Doing categories which deal respectively with patterns of human existence in Martian conditions and those dealing with working on Mars. The next level is the so-called Requirements level and in the space residence pattern language this consisted of the Supporting and Remaining categories which dealt with patterns necessary for short-term and long-term stays respectively. These categories are not as applicable to early Martian surface residences since periods of residence are most likely to be on the order of 500 days. Now, once residencies stretch out to several years and eventually become permanent our patterns to support 500 days will truly be called short-term patterns. So for now, it is difficult to make short-term and long-term distinctions so there will only be one category at this level called msr-Dwelling. The bottom level is the Formal Properties level and has two categories called msr-Shaping and msr-Organizing. And, as for the space residence pattern language, patterns at this level are strongly derived from technology from below, as well as from human needs requirements from above. Since this language primarily looks at human needs, the technological enablers and detailed mission design considerations are left to other sources. Figure 4 lists the current titles in the MSR design pattern dialect.

Two new pattern concepts are introduced by these dialects: the variant pattern and the collection pattern. Many of the patterns in the Martian dialects are not unique, but are similar to those in the space residence pattern language, and even to some in the classical Alexandrian pattern language [2]. We find that several are essentially the same except for some important difference that is attributable to the Martian condition. These patterns are called 'variant patterns'. They are indicated by a suffix of either '- msc' or '-msr' in the pattern's title depending on whether the pattern is in the MSC or MSR dialect. Strictly speaking collection patterns are not really patterns at all. In their basic form they are just lists of objects of a particular type, or for a particular use, that are necessary for some aspect of Martian life. Since the dialects are so immature at this point in history, there are not yet defined architectural artifacts and ways of use that organize these collections into distinct patterns. But, these collection patterns nevertheless need to be in the dialects because they form statements about things that must be accommodated in the design of a residence or spacecraft. Think of it as building requirements explicitly into the dialects as a means of further developing the language instead of introducing them later. The sub-patterns *Shocked lithic microbiology* and *Paleoenvironmental assessment* are examples of collection patterns.

The immaturity of the dialects raises other questions as well. At present we do not fully appreciate or understand how a Martian residence might be lived in, that is, how actual residents would use it to further their objectives. An arbitrary design, that is one whose design considers its residents mainly in the abstract, might be actually used in ways never intended or envisioned by its designers, and these ways might arise because the basic design never properly accounted for how the residents needed to use it do what they needed to do, William Clancey's ethnographic studies [16] [17] [18] of scientific research practices in the Mars Society's FMARS simulation in the Canadian arctic and the MDRS in the Utah desert shed light on how various sorts of specialized research activities might be conducted on Mars and from these studies patterns of behaviour might be discerned. These 'ethnographic patterns' themselves might be incorporated into the msr-Doing category in the same way collection patterns were as a means to explicitly force actual resident behaviours to drive research into architectural patterns that can be built into actual designs for residences. Crabtree [19] also provides examples of ethnographic patterns in a Earthbound domestic setting.

PATTERN STYLE

The patterns used in the space residence pattern language and the Martian design dialects are presented in a somewhat simplified form based on the canonical Alexandrian style previously presented and is defined as follows:

1. a title;
2. a representative photograph;
3. a statement about the problem and the linkages to other patterns;
4. a discussion;
5. a statement about the suspected invariance of the pattern;
6. an instruction; and
7. a simple diagram of an archetypal image.

In the next section we will have a look at an example pattern in the MSR pattern dialect. A detailed look at all the patterns mentioned in Figures 2, 3, and 4 can be found at the space residence pattern language website [1].

AN EXAMPLE PATTERN: PRIVATE PLACES-MSR

This MSR pattern, *Private places - msr*, is quite fundamental to a Martian residence and, as might be assumed, is also present in both the space residence pattern language and the Alexandrian language [2] with a high degree of invariance. Figure 5 shows a representative photograph.

Private places - msr is a variant of *Private places* in the Remaining category, and is also partially derived from *Regular hours* in the msr-Being category and *Commander & executive officer* in the msr-Doing category. It is also related to the Alexandrian patterns *A room of one's own* [2, p. 668] and *Bed alcove* [2, p. 868]. *Private places - msr* is a positive pattern.

Small, private rooms, dominated by a single bunk, are provided for the residents of the MDRS and the EuroMars simulators on the upper most levels of those simulators as is shown in the floor plans presented in the *Multiple stories* pattern. A small amount of storage space is also provided and some are also equipped with a rudimentary desk. In some rooms the bunk is high off the floor and in others it is at a more normal level in order to pack as many bunks as possible into a minimum of floor space. In the MDRS, as of 2002, the *Commander & executive officer* pattern comes into play in determining who will receive a prime room with a low bunk and desk space: the commander. In many ways these private rooms are not that much different in size and kind to those on Mir and ISS - discussed in *Private places* - except that significant gravity is operating in the Martian environment, and in the other pattern the residents are essentially weightless which allowed residents to sleep 'vertically' along a wall instead of horizontally.

In the MDRS the private rooms are located directly off the main *Salle commune* / *Easily reconfigurable space,* and in the EuroMars simulator they essentially have their own dedicated floor along with *A necessary toilet - msr* and *Storage room*. In the MDRS the only toilet is on the lower level.

Figure 6 is interesting from several points of view. It is an onsite modification to one of the bunks in the MDRS with tools and materials found in the simulator - a good illustration of why it is important to study and document creative user responses to their living conditions. It is one thing for residents to tell you their needs later, if they happen to remember and don't second guess themselves, and another to provide the means to let them do as they need to on the spot and document what happens - it is the most effective means to figure out actual design requirements. Yes, the actual implementation maybe a little crude, but the intention is sophisticated. From the results we might say that a guard, possibly a retractable one, may be required for bunks that are elevated far from the floor. Maybe the use of elevated bunks themselves needs to be questioned. Spontaneous responses to the environment invariably lead to interesting questions.

Invariance
Unknown. Speculated invariance: moderate based on the variance of the *Private places* pattern.

Instruction
Provide a private room for each resident that at a minimum has a bed, horizontal work surface, chair, and some personal storage.

Archetypal Image
There is not yet a true archetypal image. One of the goals of the EuroMars simulator is to determine what this might be by providing several different arrangements and running tests to judge which is best. Figure 7 has many of the basic elements and tries to pack them into a minimum area.

The archetypal plan should raise many questions such as: is a small closet needed; could the entrance door be a pocket door or some other kind of door; is a window needed; and so on.

DEFINING REQUIREMENTS FOR A MARTIAN RESIDENCE

Patterns and pattern languages can be used to develop our understanding of what various kinds of Mars bound human-carrying spacecraft should be like. The following discussion will focus primarily on early surface landing craft that double as Martian residences, but the argument extends to other kinds of residences and spacecraft as well.

The Mars Society's MDRS, and its other expedition simulation facilities such as the EuroMars and FMARS, provides a unique opportunity to learn how a residence should be configured for optimal utility, as well as serving their main purpose of providing an environment for developing methods for exploration and scientific work on the Martian surface. At present they are rudimentary in their modeling of the everyday conditions of a future residence on Mars, but even that can provide insight as long as the residents rigorously attempt to live as their future Martian counterparts would. Also, these basic simulators could be further developed to increase their fidelity as we develop our understanding of how they should be configured. As Persaud [20, p.116-120] points out, a variety of studies need to be performed where the impact of the residence on the residents' expedition effectiveness is assessed as a precursor activity to the actual development of a Martian residence.

The MDRS, or similar facilities, can be arranged to model some internal configuration of elements based upon previous candidate patterns, proposals for new patterns, and traditional analyses of requirements. The behaviours and activities of the residents can then be observed to assess whether these prototype arrangements are effective, and see what surprises and insights actual users introduce. The work that Clancey [16] [17] [18] has performed with respect to studying the behaviour of field scientists at work in the Mars simulators is an example in one particularly important line of inquiry. Also, these type of observations can be supplemented with direct questioning of the residents either verbally, or with the use of a printed questionnaire. Since relatively large numbers of people do a term in the MDRS during a field season, it's possible to get a good sampling of responses. From these data we will get an assessment of proposed organizations and clues about new patterns.

This process can be made more interactive - and I would argue more valuable - if the simulation facility provided the ability for the residents to temporarily modify or shape their environment during the course of a simulation thereby allowing them to tryout new proto-patterns in response to situations as they arise. This may call for the development of a facility in a less remote location in order to provide a setting or laboratory that has a wide variety of materials for the residents to use, as well as nonresident helpers to assist with setting things up on the fly and providing design feedback or advice. One could then test any persistent patterns in a more remote simulation facility in order to get a full assessment.

It is possible to leverage the involvement of past and future residents, designers, engineers, operational experts, field scientists, and other interested communities even further by making the patterns available online for examination and modification as well as allowing entry of new patterns. Although the space residence patterns website site [1] presents a preliminary set of patterns in a book-like form, a form based on the online encyclopedia Wikipedia (http://en.wikipedia.org/wiki/Main_Page) or the Portland Pattern Repository's WikiWikiWeb (http://c2.com/cgi/wiki) would be more appropriate since it allows the community to actively modify and critique its entries. Obviously, this form could certainly be subjected to editorial scrutiny as necessary.

I cannot stress enough the importance of studying and critiquing the patterns, and their proposed linkages, by the broader community as they are being developed. It helps to sanitize them, determine if their scope is too big, see if linkages are missing or over-specified, or make proposals for possible missing patterns, etc. For example, take a look at the linkages for the *Private places - msr* pattern, which is a pattern that helps derive the *Combination lander and interplanetary spacecraft pattern* (This chart uses a notation proposed in Appendix A of the space residence pattern language website [1], but elaborated upon to account for some of the new concepts developed in the Martian pattern language dialect: > means 'is derived from'; ø means 'contrasts'; v means 'is a variant of'; a means ' is related to the Alexandrian pattern'.):

- Private places - msr
  - v Private places
    - > Crash pad
      - > Buckling down & strapping in
        - > No gravity
        - ø A sense of power over personal space
        - ø Cluttered niches
      - > Single room
        - > Shirt sleeve environment
        - > Visual vertical
        - > Buckling down & strapping in
        - ø Private places
    - > Human-scale rooms
      - > Visual vertical
        - > Body is a 1G machine
          - > No gravity
        - ø A sense of power over personal space
        - ø Multi-dimensional living space
        - ø A big room
      - > Buckling down & strapping in
        - > No gravity
        - ø A sense of power over personal space
        - ø Cluttered niches

> Eliminate edges
> No gravity
> A sense of power over personal space
> No gravity
ø Visual vertical
ø Buckling down & strapping in
ø A big room
ø A sense of power over personal space
ø Single room
ø A necessary toilet
ø Salle commune
> Commander & executive officer
> Regular hours
a A room of one's own
> a Intimacy gradient
> a The family
> a House for a small family
> a House for a couple
> a Common areas at the heart
a Bed alcove
> a Bed clusters
> a Communal sleeping
> a Marriage bed
> a A room of one's own

Since this pattern is primarily a variant of the *Private places* pattern in the space residence pattern language, and is also something of a variant of two Alexandrian patterns, you need to assess some of the assumptions behind those patterns. For example, will operation in weightless conditions play any role in the operational life of the residence / lander? If so, how much attention do we need to pay to the patterns in the chain that are strongly derived from effective zero-gravity conditions? In the Alexandrian components, you need to ask what sort of social arrangements are actually influencing the pattern selection and how that interacts with the social arrangements being proposed for Martian operation (in the example, only the first level of linkages have been shown in the Alexandrian patterns)? And in the *Private places - msr* pattern itself you might ask if it has been closely observed enough to capture it in detail. Have enough uses been observed, both 'official' and impromptu? Do we need to be very specific about its size? Do we need to introduce collection patterns to help detail it? Does it absolutely have to have a window? Going even deeper still, you may want to assess the metaphors that help derive all these component patterns and think about if there are other ones that are more suitable. Thoughtful input from a variety of members of the community would be important for properly specifying this pattern.

As well as developing the Martian design pattern dialects some work should also be done to refine and further develop the space residence pattern language since it really is only a sketch of a deeper set of patterns. The Alexandrian pattern language should not be taken for granted either, since other contexts, and the passage of time, would certainly yield other patterns.

Basically what is being proposed is a highly interactive framework where the development of the requirements for a Martian residence is being 'open sourced'. This has the advantage of allowing deep involvement from a variety of user communities - if they want to be involved - beyond their more normal rather superficial role in design development [21], and also overcomes criticisms of pattern languages being too biased to the views of their creators for use in the real-world [22]. However, open-sourcing is not a panacea and also requires its own management structure to be effective. I recommend referring to Edwards [23] and Stalder & Hirsh [24] for some guidance.

Some software tools might be useful in supporting any pattern development effort, although they are not strictly required beyond an interactive website that all can access. Digital still and video cameras for capturing images, and digital pens and graphical input devices for directly entering archetypal sketches by hand while the real things are being created could also be useful. However, the most powerful software devices might come from combining the pattern language database with software for computing applicable metrics - say, with the methodologies proposed in Larsen and Pranke [25] and Messerschmid and Bertrand [26] for example. As was discussed in the Metrics section of the Language page of the space residence pattern language [1], mass, volume, and power are important metrics for these types of artifacts, so being able to compute them instantly as new patterns and phrases in the language are being developed, or candidate designs are being proposed, could be quite valuable. Some sort of handheld or tablet hardware platform with a wireless internet connection might be helpful. These type of software devices would certainly put further demands on what needs to be captured in a pattern in order to make metric computation viable.

CONCLUSIONS

At present the spacecraft design pattern languages are nowhere near complete and still require significant detailing to make them fully useful - one might say they are ‘stringy’ and only hint at the complete language. But, no matter how much detail a pattern language might have at any given time it is never really complete, because places for people to live in space and on other planets will continue to develop and mature as time goes on. Contexts will change and people will change. Much will be discovered by the future residents of the International Space Station and the Mars Society simulators. A great deal may be learned about cultural and organizational influences on the design language since both will house residents from a diverse mix of countries for extended periods of time. The patterns could be pushed, pulled, stretched, twisted, torn, or entirely distorted out of their initial outlines and organization, but that will be a normal consequence of the natural growth of understanding. What the pattern language concept can allow is a way of organizing what we find out, and what we might discover, about creating habitable residences. As well, the patterns, and their organization, may suggest other patterns that are not in current application, so an experimental branch of space architecture may develop - as well as related design methodologies - as a way of investigating new spatial organizations. This would certainly give added meaning to the concept of space exploration.

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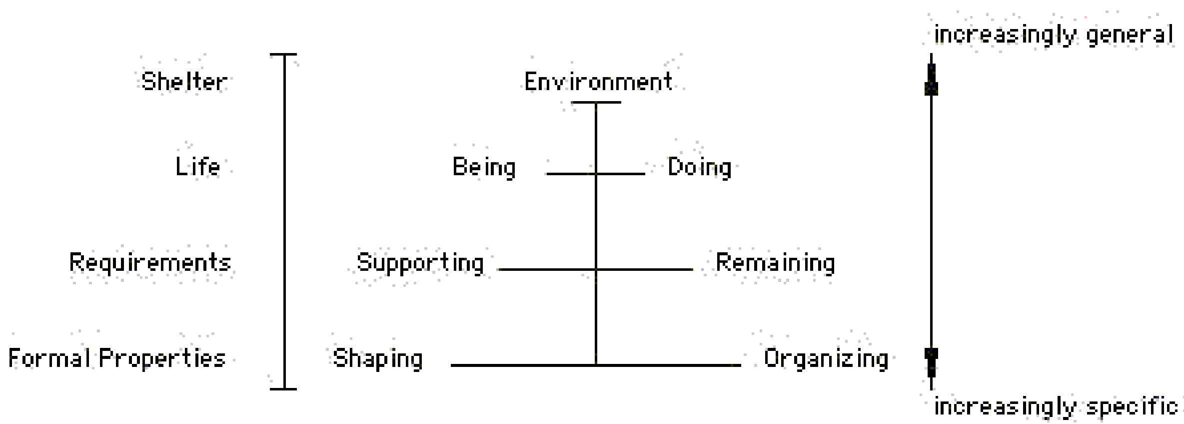

Figure 1: Categories in the space residence pattern language

Environment
(the conditions of space)
No air
Too much radiation
No gravity
Light and dark
Space junk
Near and far

Being
(physical & mental survival)
- Shirt sleeve environment
- Body is a 1-g machine
- A sense of power over personal space
- Visual vertical
- Deepening

Doing
(formal activities & work)
- Incarceration melancholia
- Autonomous work life
- Thoughtful & active participation
  - Overlapping skill sets
  - Buckling down & strapping in
  - Cluttered niches

Supporting
(to get by for a couple of days or weeks)
- Keep a horse headed for home
- Single room
- Room with a view
- Eliminate edges
- A necessary toilet
- Structured storage
- Crash pad
- A variety of exercises

Remaining
(to get by for a long time)
- Human scale rooms
  - Private places
  - Multi-dimensional living space
- Shower
- A big room
  - Entertainments & communications
  - Mobilia
  - Salle commune
  - Remote manipulation
  - Remote viewing
  - Garden
  - Lookout tower

Shaping
(to form the individual living spaces)
- Pressurized can
- Protective coverings
- Radiation shielding
- Two ways out
- Integrated ducts
- Grapple fixtures
- X marks the spot
- Clear windows
- Shades and shutters
- Inflatable volumes
- Airlock
- Minimize outside maintenance
- Noises off

Organizing
(to arrange the living spaces)
- Ambient gravity
  - Self-contained core
  - Building over time
  - Visual transitions
- This end up
- Five minute float
- Workshop gradient
- Spaceship Earth
  - Enhanced gravity
  - Impermanence

Figure 2: Pattern titles in the space residence pattern language

msc-Environment
Too much radiation - msc

msc-Organizing
Battlestar Galactica
Lander
Kon-Tiki
Combination lander and interplanetary spacecraft

Figure 3: Current pattern titles in the MSC pattern dialect

msr-Environment

Unbreathable trace atmosphere
More radiation than we are used to
Nearly 40% the gravity of Earth
Twenty-four and one-half hours per day
Dust
Cold

msr-Being

An army travels on its stomach
Bread machine
Regular hours
Art spirit
Water is scarce

msr-Doing

Autonomous worklife - msr
Commander & executive officer
Labouratory equipment
Shocked lithic microbiology
Paleoenvironmental assessment
Wheeled vehicles
Spacesuit
Writing on the wall

msr-Dwelling

Pervasive dust
Vertical orientation
Easily reconfigurable space
Horizontal work surfaces
Movable chairs
A necessary toilet - msr
Entertainments & communications - msr
Private places - msr
Chores and maintenance
Trash disposal

msr-Shaping

Five pounds per square inch
Vertical cylinder
Dust room
Spacesuit storage
Preparation to go outside
Garage
Greenhouse
Storage room
Legs

msr-Organizing

Multiple stories
Stairs not a ladder
Dumb waiter
Widow's door
Isolated labouratory
Pie plan
Half-slice plan
Space within space
Connected airlocks
Cottage country

Figure 4: Pattern titles in the evolving MSR pattern dialect

Figure 5: Representative photograph of the Private places - msr pattern. Composed of: Commander's room in MDRS [MDRS-1] / Doors to private rooms - MDRS [MDRS-2] / Writing on the bunk - MDRS [MDRS-3] / Sleeping on the bunk - MDRS [MDRS-4]

Figure 6: Adding a makeshift guard rail to an upper bunk [MDRS-5]

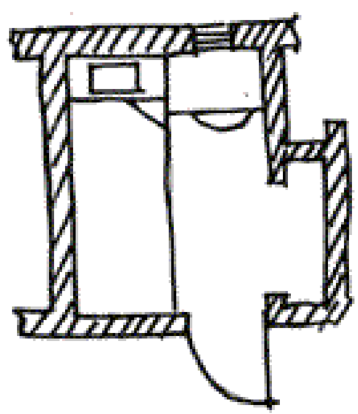

Figure 7: Archetypal image of the Private places - msr pattern.