NASA Exploration Systems Enterprise
Request for Information
Solicitation Number: RFI04212004

CHANGE OF PARADIGMS: DESIGNING HABITAT VS DESIGNING MACHINES

Importance of integration of Aerospace Architect in early design phases

A White Paper
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The aim is the successful product., K. Ehrlenspiel (1995), p.329

an architect should have that perfect knowledge of each art and science which is not even acquired by the professors of any one in particular, who have had every opportunity of improving themselves in it.

Pytheos, 4th century BC, (Vitruvius, 25/15BC)

The need to intergrated aerospace architects in the early design phase of space habitats.

Architects traditionally combined the "engineer", the “scientist” and the "artist" in one person. With the growth of knowledge and specialization, this has become more and more difficult. Nevertheless the architect is still considered to be the main professional entity to be responsible for the complete system of turning customers’ needs into a full working building. The architect is developing together with consultant engineers and specialists a concept for a building to live in. The education of the architect is next to its highly trained technical knowledge human centered. Structural and mechanical engineering are as much a part of it as sociology and psychology. Also creative skills are trained. Especially creative skills, human environment sciences and cultural historical context are often unfortunately lacking in an engineering education. The architect has a human centered design approach, understanding what people need and how the uses spaces. Through the design process, which is clearly understood as an optimization process, rather than a mechanistic checklist of requirements and trade-offs the technical reality of structures is developed. It has been shown, that the envolvment of trained architects in the very early design phase can greatly benefit the development of human habitats in space. Architects also benefit strongly from their training in sketching and model building, where concept are quickly and early in the design process tested in the 3rd dimension, this is reducing many flaws, which usually only become apparent in mock-ups in later stages

Terrestrial Architecture Education	Aerospace Architecture Extensions
General Education	
Verbal and Writing Skills	
Graphic Skills	
Research Skills	
Critical Thinking Skills	
Fundamental Design Skills	
Collaborative Skills	
History and Theory	
Formal Ordering Systems	Orbital Organizational Principles
Use of Precedents	Aerospace Precedents
Western Traditions	
Non-Western Traditions	
National and Regional Traditions	
	Relating Traditions to Space Architecture
Technology	
Structural Systems	Space Structures
Environmental Systems	Consumables and Life-support
Life-Safety Systems	Radiation Shielding, Fire Safety
Building Envelope Systems	Pressure Vessels and Thermal Control
Building Service Systems	Airlocks and EVA Facilities
Building Materials and Assemblies	Materials in Harsh Environments
Building Systems Integration	Systems Integration
	Vehicles, Propulsion, Kinematics
	Gravity, Microgravity, Artificial Gravity
	Atmosphere and Vacuum
	Orbital Mechanics
	Rotational Dynamics

Table 3: Aerospace architecture extensions to skill sets and learning criteria

Design

Comprehensive Design	Habitat Design
Site Conditions	Orbital and Planetary Conditions
Detailed Design Development	
Program Preparation	Space Architecture Programming
Building Code Compliance	Space Standards
Accessibility	Space Ergonomics and Hygene
Technical Documentation	
	Logistical Support

Environment and Behavior

Human Behavior	
Human Diversity	
Environmental Conservation	
	Countermeasures
	Confinement
	Acoustics
	Color, Lighting, and Interior Design

Practice

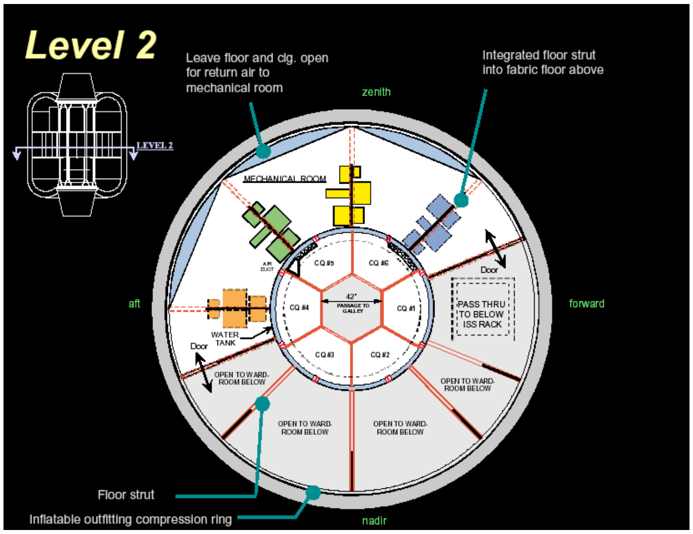
Legal Responsibilities	
Practice Organization and Management	
Contracts and Documentation	
Building Economics and Cost Control	Space Program Economics
Professional Internship	Internship in Aerospace Industry
Legal Context of Architecture Practice	
Architects Leadership Roles	Architect s Roles in Aerospace
The Context of Architecture	The Context of Aerospace Industry
Ethics and Professional Judgement	

Table 4: Aerospace architecture extensions (continued)

Positive examples of aerospace architect's integration

1. In the early 1980ies studies of space station alpha configurations and layouts have been conducted by architects (David Nixon and Marc Cohen at NASA Ames). A variety of modular configurations and interior rack based layouts have been tested in model form in a very early stage, which allowed a clear assessment of the inhabitable spaces, but also of maneuverability of racks and astronauts within the space.

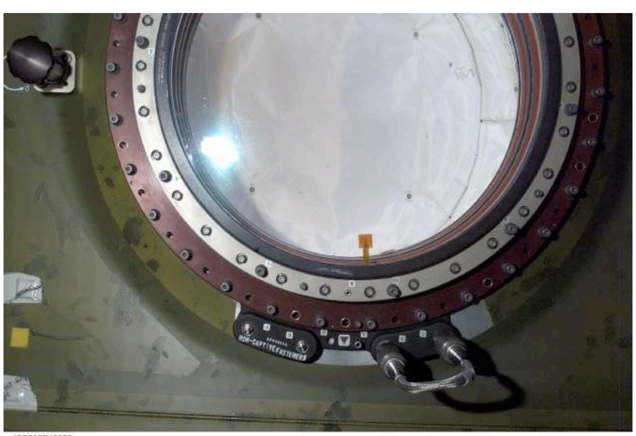
2. It was the outlook to go beyond Earth orbit and the more and more realistic mission plans for a manned Mars mission, which led to the development of the TransHab Module by NASA. TransHab was less driven by cost reduction, but by the outlook for long-duration spaceflight. Lessons learned in space human factors showed, that for long duration missions like the transition to Mars for a crew of six astronauts, more volume and space is needed. It is worth noting, that this demand is human factor driven and that two aerospace architects were in the 22 people team, which developed TransHab[[1]]. TransHab deploys to approximately 7,6m diameter in space and is organized around a central hard core, which contains the crew quarters, which are radiation shielded by water tanks. Three floors are built in after deployment. Unlike the Livermore concept TransHab extends well over the shuttle cargo bay diameter and still fits to the existing ISS modules. TransHab developed through the design process from a horizontal, radial layout to a vertical layout introducing 3 floors, which made the spaces much more legible and better to organize. Also privacy needs and social layout can be organized like this much clearer.



Figures above are showing TransHab Mid-Deck level and computer illustration

<u>Negative examples of aerospace architect's non-integration</u>

1. Early this year the cause for a leakage in the ISS was discovered after several weeks: The flexible hose, which is used to prevent condensation between the glass panes. (See images below). As an architect understanding the habitability and ergonomics of a microgravity environment the problem is immediately obvious: the hose was used by the astronauts as a restraint, for which it was clearly not designed. The architect is trained to understand the window as a place for people to look out first, and then the engineering and technical problems for its realization in space. The aerospace engineer is not trained to do that. It is reported that astronauts spend about 80% of their non-working time in front of the window earth-gazing. Also in space they stay, even if trained, normal human beings, who want to take pictures. Also it has been reported from long-duration flights on MIR, what a psychological important role the look on the the Earth play: it connects the astronauts to 'home'. So, the window is more than a facility to look out, it is also an psychological element of self-reflection and self-projection. This would be the design driver for the architect, which would clearly prevent problems like the leakage through misuse of elements designed without thinking of its human context. As can bee seen on the image below the astronauts restrains himself on the electric cable. It is likely that, when taking a picture holding the camera with both hand, the restraint will happen by pressing the head against the flexible hose.



ISS006E12765

2. From Bioplex it is reported, that at the time architects where involved a ceiling height on the highest point of only 190cm was found as the result of the engineering process before. This seems pretty grotesque for a structure, which is design as a surface 'habitat' in presumable low-gravity environments like Mars or Moon. Even more so, since NASA by its own standards STD-3000 defines the range of astronauts up to 1,95cm. This are problems, which cannot be corrected in a phase, when the structure is defined, but must be realized and discussed in early design phases, when there is still possibility to change and options to find other solutions in the same constraints.

Conclusion

Space agencies should implement more human centered and interdisciplinary design processes as they are applied in terrestrial architecture and not a sequential design process, where the architect is misunderstood as a 'decorator' at the end of the process and not as a design integrator over the whole process. These architects should have terrestrial job experience and need to be additionally trained for space. They will be needed in early design phases, to help prevent flaws in late phases. Architects are by education used to communicate and integrated different profession ranging from the rocket engineers to the psychologist and medical advisor, and know by design experience, that especially psychological factors and requirement cannot be intergrated on a 'solution' basis into a design, but only by considering the habitat as a complex ecology, where a multitude of elements have to be fine-tuned and tested in design.

References

Please refer to information and publication list on www.spacearchitect.org, which is the website of the AIAA DETC Aerospace Architecture Subcommittee

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"I have the greatest enthusiasm for the mission"
HAL 9001 after being deprived of the 'Auto-Intellection' panel.
Arthur Clarke, 2001 - A Space Odyssey

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[1][The Architects were Constance Adams and Kriss Kennedy. Constance Adams writes in a unpublished contribution to Macmillan: "TransHab was first conceived in 1997, by a team of engineers and architects at the Johnson Space Center. In June of that year, a small group put forward the idea of developing an inflatable space habitation module that was capable of supporting crew needs on a long transit journey. In October the Space Human Factors group was asked to perform a habitability evaluation of the vehicle and to recommend a dimension for the pressure-shell. This evaluation based its findings on lessons learned from earlier US and Russian missions regarding psychological, social, operational and anthropometric issues associated with human spaceflight."

Appendix: NASA Response

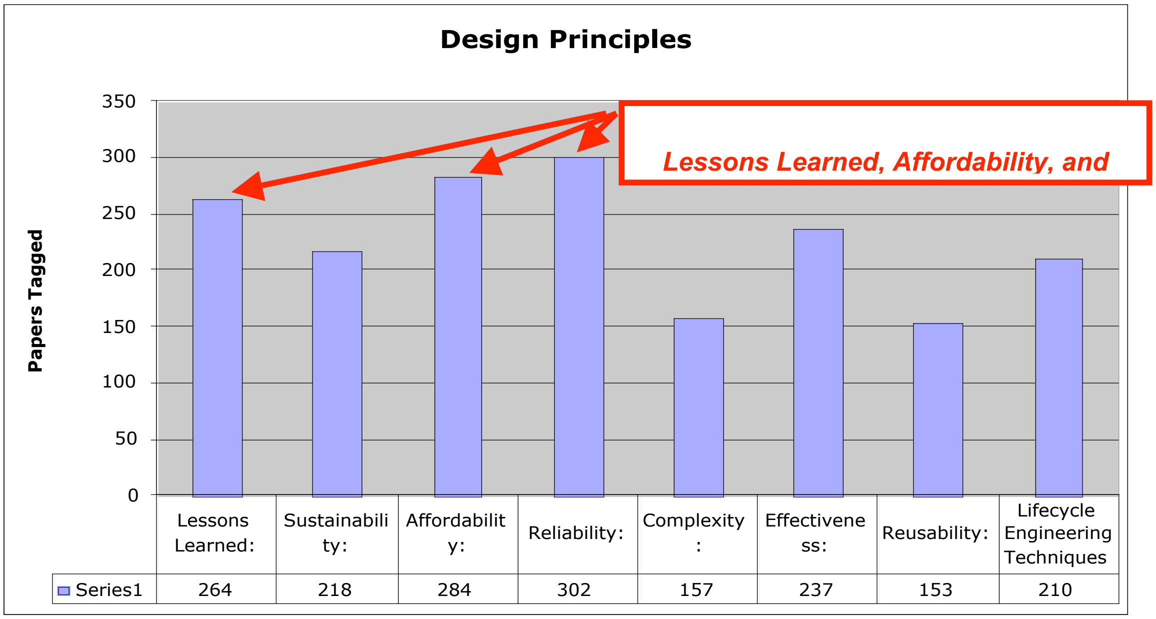
Dear RFI Respondent Andreas Vogler,

Ten weeks ago, you contributed to a crucial first step in NASA's implementation of the Nation's new Vision for Space Exploration. In a broadly-focused Request for Information, the Office of Exploration Systems sought white papers analyzing key technical and programmatic issues relevant to the execution of a sustained campaign of human and robotic exploration of the solar system.

The complement of 998 responses that we received have not only affirmed a high level of external interest in the Vision, but have stimulated and refined our formulation of requirements, technology portfolios, and acquisition strategies. Responses came to us from a diverse array of government research centers, private companies, university research laboratories, student organizations, non-traditional sources ranging from architects to computer game developers, and at least two Nobel Prize winners.

Upon our receipt of the responses, we commenced an evaluation process that judged submissions on their demonstrated effectiveness, innovation, and potential to improve performance in cost, schedule, or risk. In this process, our evaluators also tagged submissions for relevance to multiple RFI focus areas, Work Breakdown Structure (WBS) elements, and technology types. In combination with keyword searches, these evaluation metrics and metadata now support our utilization of RFI contributions for purposes of formulating requirements and program plans.

Generally, we were impressed by the high number of quality submissions provided in the "Program Management" RFI Focus Area, where responses focused on Requirements Formulation, System-of-Systems Development Strategies, and Modeling & Simulation. We noted that a high number of submissions emphasized the importance of lessons-learned, affordability, and reliability in the "Design Principles" Focus Area. Among "Cross-Cutting Design Drivers," respondents cited commonality, autonomy, and mission operations as critical elements of optimal exploration architecture. (See following charts.)


Design Principles
Lessons Learned, Affordability, and
Papers Tagged
350
300
250
200
150
100
50
0
Lessons Learned:
Sustainability:
Affordability:
Reliability:
Complexity:
Effectiveness:
Reusability:
Lifecycle Engineering Techniques
Series1
264
218
284
302
157
237
153
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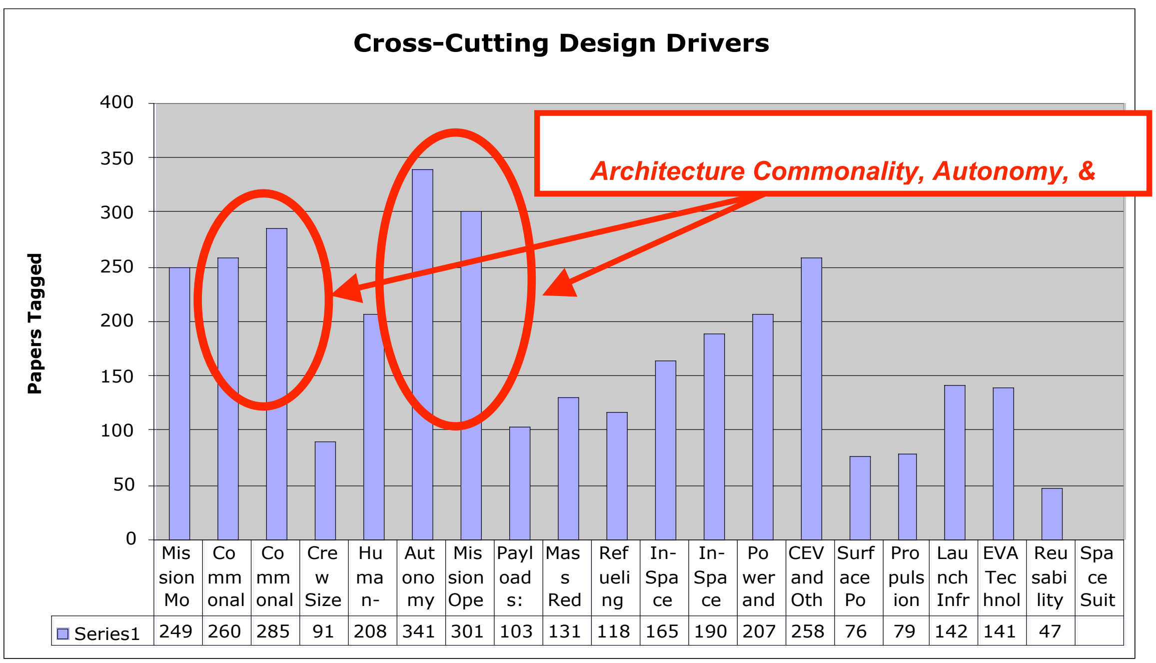
Cross-Cutting Design Drivers
Architecture Commonality, Autonomy, &
Papers Tagged
400
350
300
250
200
150
100
50
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Mission Mo
Commonal
Commonal
Crew Size
Human-
Autonomy
Mission Ope
Payloads:
Mass Red
Refueling
In-Space
In-Space
Power and
CEV and Oth
Surface Po
Propulsion
Launch Infr
EVA Technol
Reusability
Space Suit
Series1
249
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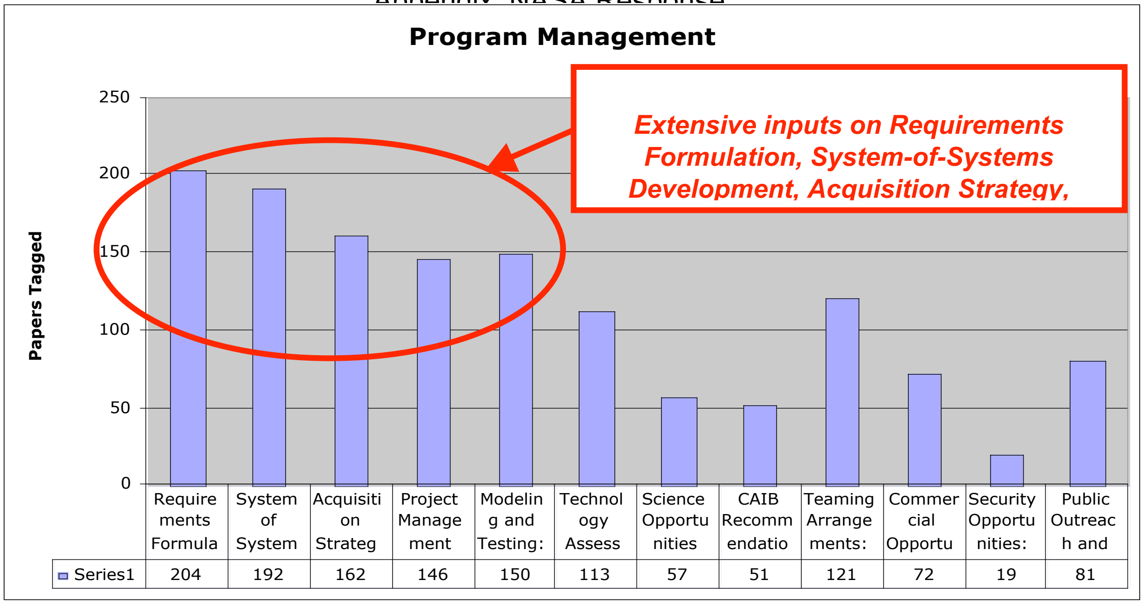

In the evaluation process that concluded in June 2004, your paper, which was submitted in the Crosscutting Design Drivers and Architecture Elements category, received the following scores:

Demonstrated Effectiveness / Technological Maturity: 5

Innovativeness / Variation from Historical Approach: 5

Potential Improvement in Cost, Schedule & Risk: 5

These scores were based on a one- to five-point scoring system, five being the highest possible rank. The scores were compiled based upon comprehensive evaluation guidelines, which can be viewed with other relevant updates on the RFI at the Acquisition Portal of the Exploration Systems website at http://exploration.nasa.gov. While these metrics are a useful piece of metadata that we use in searching our RFI database, they are only one element of the techniques we employ in mining high-value ideas and proposals.

In the coming months, we will be using your RFI response in concert with hundreds of others to inform government analyses and priorities as we bring on an increasingly large population of contractor teams through Broad Agency Announcements and Requests for Proposals. We hope that you will continue to contribute to our nation's implementation of the Vision for Space Exploration by submitting proposals through the mechanisms appropriate to your organization and domain of expertise.

Your input has already served an important role in kick-starting our efforts at NASA, and will continue to be a valuable resource as we proceed. Thank you, and please join us in the years ahead, as we design and build the next generation of systems that will humans and robots on exciting missions to the moon, Mars, and beyond!

Very respectfully,

Craig Steidle

Associate Administrator

Exploration Systems Mission Directorate

NASA Headquarters