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Space Architecture: Habitats, Habitability, and Bases (1)

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DERIVATION OF ARCHITECTURAL DESIGN PRINCIPLES FOR CITY-SCALE SETTLEMENTS ON THE MOON AND MARS

Abstract

Purpose: New Space companies such as Blue Origin and SpaceX are developing next-generation fleets of inexpensive, reusable spacecraft that could carry hundreds of passengers and thousands of tons of cargo to the Moon and Mars. However, the literature on habitat architectures and associated experimentation with Earth analogs has thus far evolved under pressure from older, mass-constrained space logistics architectures. The upcoming step change in transportation capacity gives rise to a need to better understand the challenges and opportunities inherent in the bootstrapping and growth trajectory of city-scale mission architectures for the human exploration and settlement of the Moon and Mars. **Methodology:** we reviewed the literature of mass-constrained human habitat architectures, including NASA's DRA 5.0, the now-defunct Mars One proposal, Foster+Partners vision for the Moon, and others. For each architecture, we decomposed the habitat into its functional architecture, identified all interfaces across its system boundary and tabulated its value-related metrics including estimated number of persons supported and maximum time until resupply is required. We then similarly assessed the historical functional architecture, interfaces and performance metrics of a number of today's megacities and ghost cities at a period in their history when they were still nascent small cities, a few years after their foundation. By comparing these results we identified weaknesses in the functional architecture of current human habitat architectures on the Moon and Mars. A review of these weaknesses led us to derive and propose a set of high level architectural design principles for city-scale settlements on the Moon and Mars. **Results:** the highest level principles we identified through this analog comparison with historical small cities on Earth were the importance of long-term access to persistent energy subsidies and to sources of water and a reliance on a diversity of tools and capabilities rather than overconstrained proscribed solutions. Secondary principles included: the integration of habitat construction and resource mining; designing for manufacturability and for additive manufacturing; a three-way division of labor between human, AI and machine; a nearly-closed-loop industrial ecology; three-dimensional urban planning; the mixed use of underground and overground habitats; and a bias towards multiple adjacent urban nuclei. **Conclusions:** by comparing current space habitat designs with the origins of megacities and ghost cities on Earth, we identified gaps and opportunities and derived numerous architectural principles that may usefully guide the design of self-sustaining cities on other worlds.