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CITY AS A SPACESHIP (CAAS)

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While past visions of future cities were often inspired by space and exploration of the unknown, and thus based in science fiction, we propose future visions of the city based in science fact; that which is known and learned from our accumulated space exploration experience.

Technological spin-offs from space design could integrate into our daily lives, but the confined conditions of extraterrestrial shuttles seldom serve as Earthly inspiration. If Earth were a spaceship and we were the Astronauts, how would we live differently? What if living conditions in outer space informed and exchanged the cramped social environments down below, such as the worker-housing and informal settlements in our mega-cities? How can space systems inform the structure and workings of extreme urban environments? We are exploring the City as a Spaceship and the reciprocities it offers by mapping extraterrestrial experiences onto earthly settings.

Half the world's 7.25 billion inhabitants (Population Clock at 11.41 GMT on 15/08/2014) live in urban settings. Sao Paolo, Tokyo, Mexico City, Mumbai, Moscow, New York City, Hong Kong, London are the big cities, the Megatropolises, which all have rapidly growing populations within their densely packed urban centres with equally densely packed peripheries. Living conditions on Earth must change, irrespective of economic or social status, so that we can equalize opportunity and achieve a better standard of living for all.

We propose that the (mega)City and the Spaceship be viewed as parallel and reciprocal case studies to think about contemporary forms of working and personal engagement; compact spaces, multifunctional spaces, public-private spaces, resource management, alternative energy harvesting, waste management, health management and inclusion of nature into our built-up environment.

City As A Spaceship (CAAS) inspires technological humane innovation by positing the spaceship as an analogy of the modern, densely built urban space, with its complex structures and technologically advanced infrastructure, where the designed intention is to configure all systems to eco-efficiency to optimize the use of available resources. We believe the time is now to meet our primary needs through CAAS architecture and design, using technologies for space that can immediately impact the humane retrofitting of these cities. The CAAS City can be an inspiration, an alternate view, for a future city and a way to project and achieve our dreams and visions of an equitable and environment-friendly urban life.

1. INTRODUCTION

We view Space habitats and space transport vehicles as analogous to future cities. With over 50 years of accumulated human spaceflight experience, technological spin-offs from space design could integrate into our daily tendencies, but the remoteness of the accumulated space exploration needs to be interpreted, translated, brokered and curated to serve as Earthly inspiration. As designers and inhabitants of this planet, this paper shares the Authors contribution to design the thinking, the topic, and the theme, leading to designs that address the question: *If Earth were a spaceship and we were the Astronauts, how would we live differently?*

This paper sets out future visions of the city as a spaceship in four parts: At Scale, Paradigms for Living Together, Spaceship Ecologies, and

Mapping. The authors start '**At Scale'** by presenting a stark statement of the population paradox facing cities over the next 35 years, and a case in point of an Asian urban slum. **Paradigms for Living Together** follows and sets the stage by viewing cities as socio-ecological systems and citing other complex systems that benefit our understanding of: what is needed for survival; what is a suitable environment; and, how do we share spaces for creating the knowledge needed to thrive in the future? Enter **Spaceship ecologie**s; the characters or players. The Greek word '*oikos*' (the root of Economy and Ecology) is used to profile the International Space Station (ISS) as **System οἶκος Spaceship** with its five ecologies for exploring the interrelationships and rules governing living systems of organisms and their environment. Lastly, in **Mapping**, the authors explore interpretations of the "city" as a "spaceship" metaphor using graphical representations of information. As this is the debut of City As A Spaceship (CAAS) on the international research scene, we conclude with reflections on its' generative capacity to conceive and synthesize future living systems; living, thriving, survival-challenging uber-cities as collections of self-contained, super redundant microcosms to prove themselves reliable and hardy over time.

1. AT SCALE: THE "GEOMETRY AND ANGUISH" OF CITIES

Lorca[1] refers to the two elements of the big city as "geometry and anguish." With over 7.25 billion inhabitants, and increasing by over 50 million per year, the world's urban centres face significant challenges. In the years up to 2050, it is expected that nearly 70% of the world's population will live in cities. The Rio+20 United Nations Conference on Sustainable Development (2012) reconfirmed that in the next years we will face even more challenging topics to our lifestyle to reduce CO2 levels, to generate more energy through alternative non-fossil sources, and to stop the diminishing levels of biodiversity. According to Urban Theorist Mike Davis, our current state seems to be a paradox. He refers to as the city "as its own solution" whereby the exact cities that contributed to the decreasing health of our environment today probably hold the solutions for the survival of humankind in the 21st century (Davis, 2010).

Living both in space and in dense cities brings into sharp focus considerations such as: sustainability, material recycling, and regenerative life-support (Sherwood et al., 2009). Yet, the big cities of the world are cities within cities with equally densely packed shantytowns or slums. The largest within Asia, is Dharavi, a former fishing village that is now a hyper-dense slum in the heart of Mumbai, the financial capital of India. Dharavi is located between two main suburban rail lines so its attraction as an affordable option for commuting outweighs its reality of population of one million, with 600,000 housed in over 100,000 makeshift homes; a density of over 12,000 persons per acre. It lacks sewage, yet 10 to 15 people live in the same house, cooking, sleeping, and sharing the same toilet (Figure 1).

Fig. 1: Bringing the Orbiting International Space Station and Dharavi closer, metaphorically speaking ("Low Tech, High Tech", International Artmap Workshop, Paris, 2012).

Living and working in Dharavi is very similar to living and working in outer space. The extreme shortage of real estate, breathable air, water, and waste disposal in such informal settlements, presents living problems not dissimilar to those

[1] "The two elements the traveler first captures in the big city are extra human architecture and furious rhythm. Geometry and anguish." **Federico Garcia Lorca**

encountered in extra terrestrial synthetic environments. Likewise, the problems of odor, noise, crowding, privacy, hygiene, upkeep and storage are quite comparable. The challenge, both in Dharavi and in outer space, is to not just survive the extreme environment, but to live real, productive lives, constantly improvise, invent techniques to live off-the-grid, manage with scarce resources and out of necessity, locally harvest power and water, to the extent possible (Mohanty, 2012).

CAAS means:

The city that you live in; imagine that one day it just unplugs and takes off and goes and lands someplace else. If it is a friendly city it leaves no trace of having been there. No trash, no trace. It has lived there lightly.

In CAAS, the word ''City" is not literal. Rather it is a metaphor for life on the spaceship(s) we inhabit – the "City" could well be a megacity or a 'megatropolis', a slum, a village, a neighborhood, a home, an office, a laboratory or for that matter any other (product) system or sub-system. The word "Spaceship" conveys the nature of the habitat in size, basic amenities and socio-psychological stressors, whether in orbit or that of a micro compact home or workspace in super dense cities like Mumbai, Tokyo, New York or Sao Paolo. In viewing the "City" as a "Spaceship" we are encouraging the blurring of boundaries between the language and contexts of Outer (Space) and Terrestrial environments, to facilitate the creation and free-flow of knowledge between disciplines and cultures, yielding holistic approaches to design future systems for both living on Earth and one day on other Planets.

CAAS is a metaphorical movement in urban planning, a new way of thinking about human lifestyles, habits and tendencies, which history tells us do not change easily. To change the character of thought one needs to remodel the forms of habitation, or in the words of Buckminster Fuller words: 'reshape their environment; don't try to reshape man' (Fuller et al., 1999). Designing cities to be comprised of small, spaceship-like closed-loop eco-systems, where the waste they spit out gets recycled back in, can lead to the design of future cities that could exemplify what Fuller meant with "Spaceship Earth." While CAAS opportunities lie in technology, at the foundation is the well of human creativity, and our desire and essential need to share space intelligently and responsibly.

2. CAAS: PARADIGMS FOR LIVING TOGETHER

"*Resilience is more about thinking about systems that can absorb shocks and that could constantly fall into healthy balance.*[2]" Angelo Vermeulen

"Operating Manual for Spaceship Earth" (Fuller, 1968) conveys Fuller's vision of earth as a floating body within space – self-contained and self-sufficient, as is a spaceshuttle – where what exists onboard is the extent of available resources. Fullers' projected analysis of Earth predicted the population boom and extreme extraction and use of its finite resources. His design work offered solutions to real problems; new ways to view familiar ways of inhabiting. As a kind of extension and inversion of this Spaceship Earth analogy, CAAS looks at the city – as a spaceship – as offering reciprocity for the exchange of ideas, technology and experience.

In his 2010 lecture at the Glasgow Centre for Population Studies, Professor Max Boisot offered a perspective on forms of knowledge that could benefit complex organizations like cities (Boisot, 2010), based on lessons learned from the collaborative ATLAS experiment at CERN[3]. The ATLAS detector is one of the largest and most complex experimental machines ever constructed. Likewise, the International Space Station rivals it for technological complexity and for requiring cooperative and symbiotic working relationships, and both offer lessons on ways to share and diffuse different forms of information.

The exchange of knowledge at scale is a complex undertaking. Saskia Sassen approaches the issue from a global context, with cities at the centre of our environmental future, and draws attention to the 'urban knowledge capital' they hold (Sassen,

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2 Quote by Angelo Vermeulen, cited in Transcripts from the 'Growing as Building" Symposium titled "Biological growth into technology: between fiction and fact" held March 25, 2014 at the University of Applied Arts, Vienna, Austria. www.growingasbuilding.org

3 ATLAS (A Toroidal LHC Apparatus) is one of seven detector experiments at CERN (the European Organisation for Nuclear Research).

2009). Cities and their inhabitants have been described as complex adaptive systems, with their networks of interactions, their dynamic relationships between environment, structure and body, and their adaptability through behaviors; individual and collective (Boisot, 2010). But the question remains: How can we exchange relevant information and ideas, and generate reciprocities between these mutually complex systems; Cities and Spaceships?

Sassen proposes building stronger connections between cities and the biosphere as a means to produce positive outcomes; 'outcomes that allow cities to contribute to environmental sustainability?' (Sassen, 2012) The authors confer that the potential for positive connections are broad, and CAAS serves as an accessible starting point for envisioning connections. In doing so, they look to the past, present and future for lessons and technologies that confer reciprocities. They reference knowledge of mixing species to ensure balance, of closing loops to challenge resource efficiencies, and of looking to both scientific and creative fields to understand what the biosphere can do.

While past visions of future cities were inspired by space and exploration of the unknown, CAAS proposes ideas based in science and social science fact; that which is known and learned from accumulated space exploration, and in observation and understanding of the complex relationships between space, material, technologies and the various modes of habitation and use. With scientific occupation of space – both human, animal, and machine we believe in a 'symbiosis' – looking at both 'here and there' – at the multitude of scale (in between) – looking at technologies and the principals of survival to envision parameters for future living. When we speak of surviving and thriving we are talking about the human body and its environment; the needs of the body and the factors that surround the body. Go into and out of the body. The Home || The City || Air || Food || Waste || Water || Atmosphere || Gas = requirements of the body and a suitable environment.

3. SPACESHIP ECOLOGIES

The study and translation of ancient Greek texts reveals that the whole Greek world and philosophy was reflected in their language and in the meaning of the words which sometimes had more holistic meanings than one would associate with them today. To define the spaceship ecologies the authors would like to introduce "oikos", the Greek word for house. "Oikos" in the Ancient Greek interpretation describes not only the house, the shelter itself, but the whole household and everything that belonged to the house. Economy and ecology have the same root, namely 'oikos'. Thus 'oikos' can be described as a system (of the house). A spaceship is not merely a house, it also resembles a whole system, a very complex system that provides shelter, energy, and nutrition, and houses inhabitants using specific technology, needing water and air, living with animals and producing waste. For CAAS, the International Space Station (ISS) can serve as a role model.

The ISS orbits the earth 350 km in the z-axis, a distance that might be closer to the reader's location than some of their nearest cities, yet the Space Station shelters against temperature differences of 300 degrees and a vacuum, environmental conditions unfamiliar to most. There is only limited habitable space available, including limited resources of water and air, which are set into a nearly closed loop. The ultimate goal is to implement closed loop life support systems. These will include the inhabitants, animals, food production for all organisms aboard and their waste management. The only renewable energy source is the sun. A complex technology connects all systems, yet this technical system co-functions with the human system: human interaction of multi-cultural crews with a variety of professional backgrounds.

The ecologies of the **System οἶκος Spaceship** are the interrelationships of the aspects of shelter, energy, technology, nutrition, inhabitants, animals, air, water and waste management, with each ecology understood as the relationship between the organisms and their environment.

The authors present the **System οἶκος Spaceship** with its' ecologies as a metaphor for thinking the future city and urban developments. Cities are complex systems in their geographies of consumption and of waste- production and this complexity also makes them crucial to the production of solutions. The network of global cities is a global space for the management of investments but also potentially for the re-engineering of environmentally destructive global capital investments into more responsible investments. In this sense, the authors view the system OIKOS as not only closed; it is also open as a city – connected **and** closed, it is the "and" according to Ulrich Beck's description of the "OFFENE STADT". According to Ulrich Beck this is about urbanity and ecology in a new "as well as" or "and". Beck refers to cities in a world where nothing can be isolated anymore. He continues: On one hand we can identify architecture as a school of aesthetics, on the other hand there is the architecture's sensitivity to develop for a social ecology of a place. The reflexive architecture of the "and" discovers and expands the history of the place into the public space. The architecture proclaims: if I can not change the society, at least I would like to influence the way people move through spaces, perceive the connections of spaces including the built-in contradictions.[4]

CAAS proposes the following five ecologies as foundation:

1. Shelter as Transformable: can be viewed as an envelope that defines interior and exterior: inhabitants need appropriate shelter to protect them from weather and create distinctions between public and private spaces. On Space Station only very limited space is available to each crewmember for living functions and social spaces. Storage volume is scarce, even laboratory space is finite. In highly populated cities we experience the same issues. Concepts for multi-functional spaces which are inscribed for more than one single function; transformability of spaces, furniture and systems including mobility, have already become a main topic of space design and will become equally important for future city related design and planning in all scales.

2. Energy as Renewable: In the city, the consumption will rise with the integration of more technologized infrastructure and equipment. Fossil fuel resources are limited so low energy consumption lighting, heating, ways of transporting, communication machines, computers etc. will be necessary to reduce the overall increasing energy need. Energy sources will need to come from clean and renewable sources to mitigate the side effects of current energy productions. A spaceship's energy ecology meets this requirement, as it generates the energy needed from clean and renewable sources as exemplified on the International Space Station where all energy is harvested the sun.

3. Technology, Automation, and Infrastructure: a spaceship is a technology-rich envelope incorporating certain intelligence. Space Station, for example was assembled completely robotically using the 'Canadarm' (Figure 2); astronauts only controlled and supervised the process. All on-board life support systems are automatic but allow for a certain degree of manual control, as necessary. Other supporting technologies have been developed, such as a diagnostic tool that allows detailed on-orbit monitoring and logging of all avionics bus messages; the nerve system of the Space Station. Through CAAS, all these systems and more, can be imagined in future smart cities where construction, communication, health, traffic and infrastructure support and maintenance is controlled by intelligent systems.

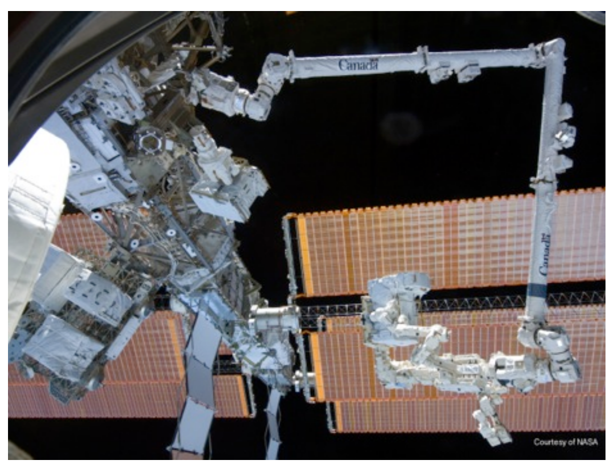

Fig. 2: Solar panels of the ISS robotic arm/CANADARM used to build the ISS. (Image credit NASA).

[4] Ulrich Beck, Die offene Stadt, DeutschesArchitektenBlatt, 3/96, 1996, Bonn p.362-364http://www.kulturregion-stuttgart.de/offeneraeume/texte/beck_offene

4. Inhabitants: on ISS there are a few fish, or from time to time other small animals, which need to be incorporated into the closed-loop living system. Crewmembers have inhabited the ISS since 2009 and in doing so they reflect international cooperation between the US, Canada, Russia, European countries, and Japan. According to the inhabitants, this presents challenges in social interaction, requiring appropriate training, because cultural understanding just does not come without an effort. The same applies to cities, which are and will be faced with a completely mixed population, a huge variety of professions and more importantly with different cultural backgrounds (Figure 3).

Fig. 3: ISS-Earth reciprocities: A multi-national crew collage. (ISS image credit: NASA).

5. Life Support Systems: In closed environments only limited resources of air and water are available, thus both essentials for life need to be treated carefully, responsibly, and sustainably through recycling processes (Fig. 4). On Space Station astronauts drink purified water recycled from their urine. A major challenge whether on earth or in space is the production of nutrition and management of wastes. Intensification of harvest in limited space: changing strategies, densification (growing vertically), using specific substrates for cultivation and growth of plants, selecting the 'right' plants with high levels of minerals (algae), proteins (beans), vitamins (algae), and carbohydrates (sweet potatoes), etc. as an approach to reduce and recover waste into useful material, which will become essential factors to address. Greenhouses, as enclosed structures for cultivating and protecting plants, must be integrated not only on space station (Fig. 5) but also in the city, to reduce transportation and create food and even provide valuable psychological for the inhabitants, an approach that has already been integrated in some cities of the world.

Fig. 4: ISS-Earth reciprocities: A water collage. (Image credit: Sarah Jane Pell (water performance), NASA (ISS cupola)).

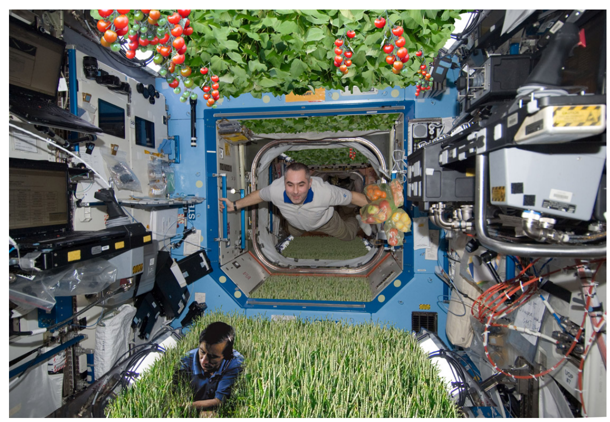

Fig. 5: ISS-Earth reciprocities: A nutrition collage. (ISS image credit: NASA).

The five main ecologies can guide the designs for future cities, derived from the CAAS approach, applied at micro and macro scale. CAAS cannot only be seen as the city being the spaceship but also as the house being a spaceship. A workshop held at ESA's Astronaut Centre in Cologne in 2012 took the first step in identifying European spaceflight technologies that could be applied to terrestrial housing. IP-STAR, a Dutch company has made this a reality in having derived a water purification system from the ESA Melissa Life Support Systems programme and applied it to larger hotel complexes. CAAS can serve as direct approach to spin-off technologies from space and the ISS and as conceptual guideline in developing designs that meet the many constraints; limited space, resources and closed-loop-cycles with regard to air, water and waste. Offering a paradigm for future urban developments and staging CASS as spaceflight parameters, provides a way to look at life in Space from a different perspective and find commonality with Earth living systems and contemporary tendencies.

4. MAPPING CAAS

We further explored the "city" as a "spaceship" metaphor using graphical representations of information (data). We attempted to map terrestrial tendencies, human density, consumption and waste. This section presents three sets of visual data sets for comparing and contrasting the world's densest cities such as Mumbai, Tokyo, New York, Sao Paulo, Cairo, Mexico City, Amsterdam, Paris, Lagos, Johannesburg and compares them to smaller counterparts such as Vienna, San Francisco, and Toronto (Figures 6-8).

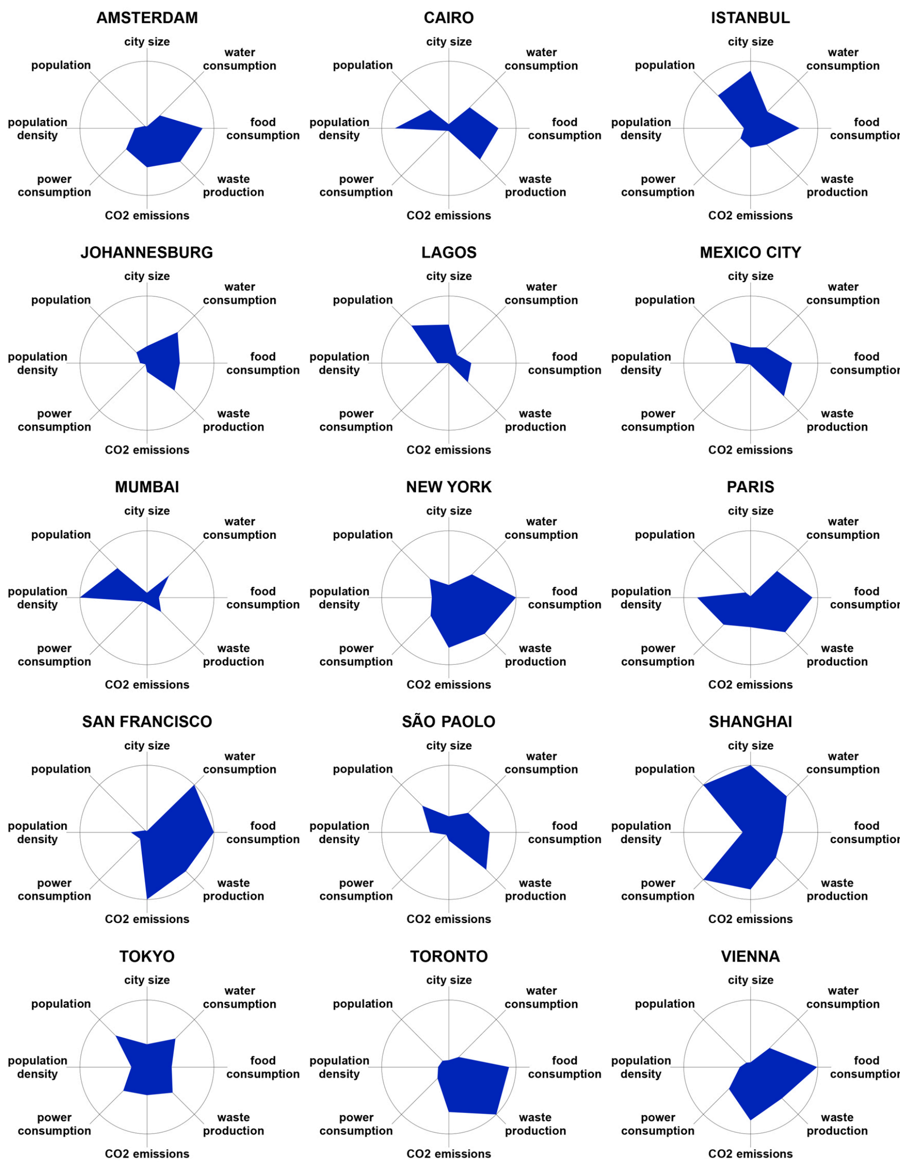

Figure 6. Cities of the world – TENDENCIES – a visual vector portrayal of comparative data points.

The first set – titled – TENDENCIES (Fig. 6) – presents a visual vector portrayal of comparative data points such city size, population, population density, waste production, CO2 emissions, power-water-food consumption. As an infographic, it evidences the consumption patterns of cities from industrially advanced nations (e.g. Amsterdam, New York, Paris) outstrips that of the less industrialized ones (e.g. Mexico City, Mumbai, Lagos). But there is more to it than meets the eye. Even among the industrial nations, the (water, food, power) consumption patterns vary. Further analyses and thinking is necessary to get an in-depth understanding of what these maps convey.

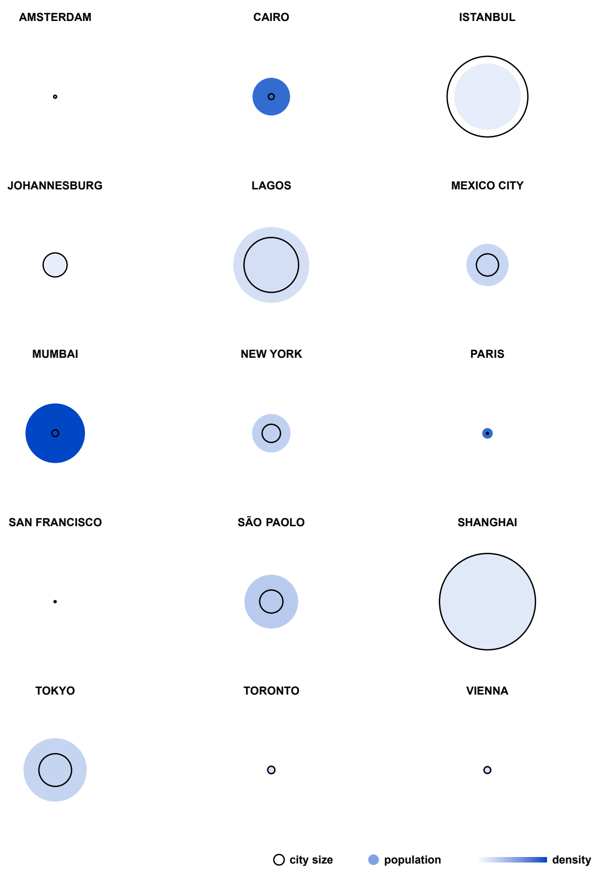

Fig. 7: Cities of the world – CITY STRUCTURE AND HUMAN DENSITY – depicts population vis a vis geographic footprints.

The second set – titled – CITY STRUCTURE AND DENSITY (Figure 7) – attempts to depict the population of each of these cities *vis a vis* their geographical footprint. The black ring indicates the physical size, while the blue ring is an indicator of the population. The intensity of the blue indicates the human density i.e. number of people per square kilometre. Mumbai, Cairo and Paris stand out as the densest cities in this cluster.

The third set – titled – CITY CONSUMPTION AND EMISSIONS (Figure 8) - presents a simple input-output graph, where the input takes into consideration – power, water, food consumption and the output lists the waste and CO2 emissions. As with the first set, in the third set one finds the industrialized economies consuming a lot more and thus, spitting out a lot more in terms of waste.

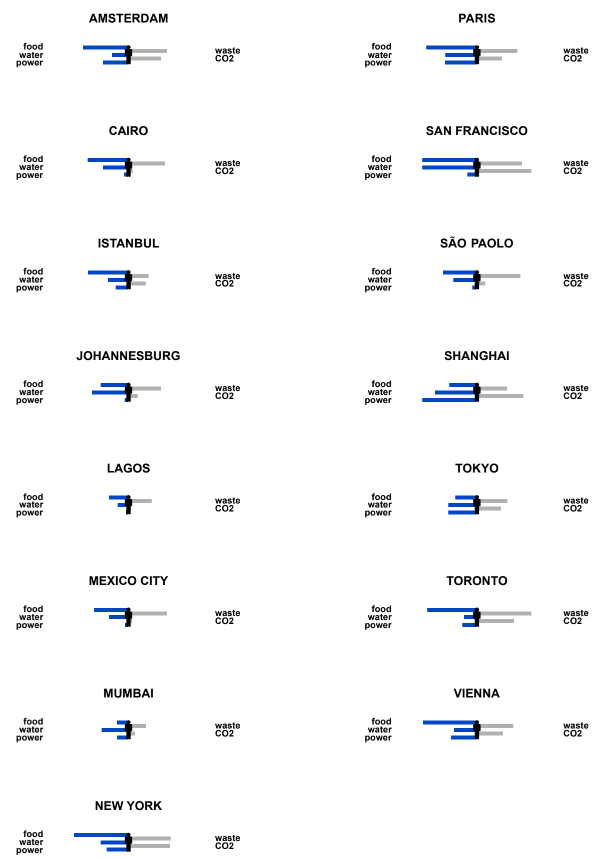

Fig. 8: Cities of the world – CITY CONSUMPTION AND EMISSIONS – presents input-output for a range of resources.

The emerging economies will likely catch up with this pattern in the coming decades and the situation might get out of hand putting the future of the planet in peril. Several questions come to mind when one surveys these graphic representations of data (information) especially relationships within the datasets. The answers are not immediately obvious, but need further investigations. For example, is the standard of living in a city directly proportional to the levels of consumption? Is there a relationship between power consumption and CO2 emissions? Why do some cities consume a lot more power than they consume food or water? Can a mega city have consumption patterns similar to a micro city?

The graphs also bring forth comparative questions between cities, such as: Are the consumption and emission patterns of New York and Vienna similar? Why is Tokyo's consumption footprint more balanced than the other cities featured in this infographic? Is San Francisco's consumption and waste production *vis a vis* its population out of control?

We hope to take this CAAS mapping exercise forward and map it to extra-terrestrial (ET) situations, both current (e.g. the orbiting International Space Station – ISS) and future (e.g. space colonies). We believe that these maps can help designers and planners identify, understand, and if need be, alter tendencies for consumption, growth, waste-production, CO2 emissions in ways that are planet-friendly. They can help identify patterns that are often lost in hard data and enable intelligent and well-informed resource and waste management decisions, both on and off the planet.

5. CONCLUSIONS

By grounding space innovations and uplifting Earth innovations, CAAS can challenge and shape ideas and serve as curator and broker to the planning, designing, developing and inhabiting of near future cities.

#1. We are, by no means, propagating that the way we live in outer space is more eco-efficient than how we live on our Earth, or the other way round. There are parallels, there are differences and there are reciprocities. CAAS believes that our earthly experiences can inform and influence our extra-terrestrial explorations and vice versa.

#2. The initial CAAS mapping explorations reveal that humans tend to consume more to achieve a higher material standard of living. As the emerging economies move towards higher material comforts and consumption (as did the industrial economies before them), the planet might not be able to sustain the increased levels of cumulative consumption and waste production. This makes the CAAS philosophy ever more relevant, especially in the present day context when global climate change is staring us in the face and the western industrialized nations are re-thinking the results of several decades of thoughtless depredation of the earth. Two of the most populous nations on the face of the planet - India and China - are urbanizing at a monstrous pace, and doing it in much the same way as the industrialized world did in the preceding decades. These parts of the world need new answers if we are stand a chance to keep the world habitable, and sustainable.

Figure 9. Future CAAS City as envisioned for Vienna Science Festival 2013 (Image credit: Damjan Minovski for LIQUIFER Systems Group, 2013).

#3. The premise of CAAS is that the city of the future will connect Earth and (outer) space in seamless ways. This future vision, such as the one depicted in Figure 9, can be achieved through applications and ideas derived from innovative technologies such as the space elevator, space-based solar power plants, closed-loop waste and water recycling as well as technologies from other fields such as nuclear fusion, tissue engineering, and medical nanorobots. An extension of this utopia is - Architects, designers, technologists, economists, policy makers and planners can work together towards an "urban future" in which every person - can achieve a high standard of living - regardless of economic or social status, without depleting the resources of his or her home planet.

#4. The “Earth as a Spaceship” is not merely a metaphor; it is a tangible, viable way for the future survival of humankind. CAAS is a vision and a programmatic step towards new designs for living together - living together on a space station needs some practice – as in cities, and current global challenges make this vision pressing.

REFERENCES

Beck, U. (1996) Die offene Stadt, DeutschesArchitektenBlatt, 3/96, Bonn p.362-364 http://www.kulturregion-stuttgart.de/offeneraeume/texte/beck_offene (accessed 15/08/2014).

Boisot, M. (2010) “The City as a Complex Adaptive System: Lessons from the ATLAS Experiment at the LHC” presented at Glasgow Centre for Population Health Seminar Series 7, Seminar 1, Summary Paper.

Davis, M. (2010) “Who will build the Ark” in ARCH+ No. 196/197: Post-Oil City, The History of the Cities Future, edited by *Elke aus dem Moore; Iris Lenz; Nikolaus Kuhnert; Anh-Linh Ngo, ARCH+ Verlag GmbH, Stuttgart / Aachen 2011.*

Fuller R.B. *Operating Manual for Spaceship Earth*, Southern Illinois University Press. 1969, 144 pp.

Krausse, J. and Lichtenstein, C., Editors. *Your Private Sky. R. Buckminster Fuller*, Zurich: Lars Mueller Publishers,1999, p528.

Mohanty, S., “What has Outer Space got to do with Dharavi?” Invited lecture “Low Tech, High Tech”, International Artmap Workshop, Paris, 2012.

Sassen, S. (2009) “Cities are at the center of our environmental future”, *S.A.P.I.EN.S* [Online], 2.3 | 2009. http://sapiens.revues.org/948 (accessed 30/08/2014).

Sassen, S. Cities and the Biosphere, in The Berkshire Encyclopedia of Sustainability: The Future of Sustainability, Berkshire Publishing 2012, p36.

Sherwood, et al., (2009) Report of International Academy of Astronautics (IAA) Commission-6 Space Architecture Study Group (SASG) 6.9: ‘The Architecture of Space: Tools for Space Development in the 21st Century’, Paris, 2009.

http://www.worldometers.info/world-population/ (accessed 15/08/2014).

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