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Oasis and Boxes
Green Friends / Amis Verts

Milestones
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The Why of Diamonds
Researching Jewellery, Matter, Time

Loud Tomah
100 Days

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1. Small greenhouses and large gardens

‘Plants are commonplace in homes, the workplace, and public indoor spaces like lobbies, atriums, waiting rooms, and shopping malls, but plants have commonly been kept in their own isolated and confined boxes during spaceflight.’[1] When comparing space greenhouses as featured in science-fiction movies to the devices that have been implemented in actual space habitats—such as the Salyut space stations, the Shuttle, Mir or the ISS—one cannot help but being struck by the differences in scale between the two types of greenhouses. The imagined ones are usually very large, while the real ones are not.

Since the beginning of space botany in manned long-duration flights, with the 18-day Soyuz 9 flight and the 1971 Salyut 1 experiment (involving the growth of flax, leek, onion and Chinese cabbage in eight cultivation slots located in the Oasis 1

1. Raymond Odeh and Charles L., Guy, ‘Gardening for Therapeutic People-Plant Interactions during Long-Duration Space Missions’, *Open Agriculture* 2 (2017): 7.

Photos of a Zinnia flower grown inside the Veggie facility onboard the International Space Station. This flowering crop experiment began on Nov. 16, 2015, when NASA astronaut Kjell Lindgren activated the Veggie system and its rooting “pillows” containing zinnia seeds. The challenging process of growing the zinnias provided an exceptional opportunity for scientists back on Earth to better understand how plants grow in microgravity, and for astronauts to practice doing what they’ll be tasked with on a deep space mission: autonomous gardening. The first flowers grown from seed in space happened before Mir, on Salyut-6 in 1982. Russian and American scientists have been doing plant research in space since the late 1970’s.

plant growth system)[2], the size of space greenhouses has not grown exponentially (nor have the sizes of extraterrestrial habitats themselves).[3] Despite the many achievements of space botany, hardware has remained limited in both its capacities and deployment. On board the ISS, for example, one finds the VEGGIE system, launched in 2004 and dedicated to food production. Each unit is deployable and provides only '0.17 m^2 grow area with a variable height of 5 to 45 cm'[4], which is far from being a surface that could feed a single soul.

The realm of fiction, on the contrary, feeds us with structures that are usually very large and penetrable, reaching the size of domestic gardens, or even bigger. This is the case in the milestone space movie *Silent Running* (1972) by Douglas Trumbull. It is set in the *Valley Forge*, a spaceship cruising around Saturn that is equipped with three gigantic greenhouses installed under geodesic domes, and whose aim is to help preserve specimens of plants threatened by extinction on a ravaged Earth. The greenhouses were modelled by Trumbull after the Climatron, the Missouri botanical garden in St. Louis and the world's first fully air-conditioned greenhouse that opened to the public in 1960, and after Kiyonari Kikutake's Landmark Tower, completed for Osaka in 1970.[5] In both cases, the referent is characterized by its architectural scale and natural lighting. It simply could not be contained in the limited volumes of our current spaceships and stations.

In the 1970s, as the first orbital stations were launched (and the first serious space colonization projects emerged), long-duration flights became a reality, and the necessity of artificial biospheres and greenhouses that would be part of bioregenerative life-support systems appeared to be more and more crucial for space research. The question

2. P. Zabel, M. Bamsey, D. Schubert and M.Tajmar, 'Review and Analysis of over 40 Years of Space Plant Growth Systems', *Life Sciences in Space Research* 10 (August 2016): 2.
3. ISS: 400 m^3, Skylab: 360 m^3 of inhabitable pressurized volume. Only Salyut stations and Mir were smaller, with less than 100 m^3 of habitable volume.
4. Zabel, Bamsey, Schubert and Tajmar, 'Review and Analysis', 7.
5. Interview of Douglas Trumbull by the author, July 2020, unpublished.

emerged in the arts, too. More greenhouses were featured on screen (although the dystopian touch of many space movies still tends to erase the presence of vegetation from most of the depicted habitats, leaving us with cold and grey mechanical interiors). In *Sunshine* (Danny Boyle, 2009) the ship *Icarus II* is equipped with a large 'oxygen garden' bathed in artificial light.[6] In *Highlife* (Claire Denis, 2017)[7], different sequences throughout the film show the transformation of the ship's greenhouse. Progressively abandoned, it returns to a wild state. Two other interesting examples are *Elysium* (Neill Blomkamp, 2013) and *Interstellar* (Christopher Nolan, 2014). Both films include space station models that can host a large population, named Elysium and Cooper Station respectively. Both accommodate extended areas dedicated to (space) farming. These examples show that the size of greenhouses mostly has to do with the ambition to reach scientific accuracy or at least plausibility. In the Netflix series *Away* (2020), the greenhouse is installed in a penetrable space and is, in this sense, not based on any actual structure. Still, this greenhouse is depicted in a more

Leonid Kadenyuk, the first astronaut from an independent Ukraine, is seen working with Brassica rapa sprouts aboard the middeck of the space shuttle Columbia during STS-87 in 1997.

A zucchini plant, floating freely in the International Space Station's Destiny laboratory, is featured in this image photographed by an Expedition 30 crew member.

6. Production designer Mark Tidesley, art direction Denis Schnegg, https://www.denisschnegg.com/sunshine.
7. Production designers François-Renaud Labarthe and Bertram Strauss.

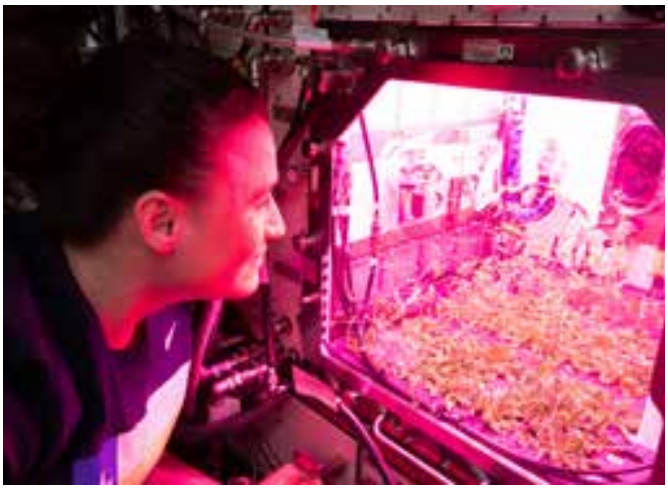
Wesley Meuris, *Aubergines and Turnips*, 2021

realistic manner: in a lab setting rather than on a garden-like set. The same could be said of the greenhouses in *Mission to Mars* (Brian De Palma, 2000) and *The Martian* (Ridley Scott, 2015). Unsurprisingly, all production processes involved NASA science consultants and aimed at scientific accuracy, in the Kubrickian sense of the word: detail-oriented and with 'a desire for scientific verisimilitude and a need for plausibility'.[8]

In *Elysium* and *Interstellar*, Elysium and Cooper Station were both based on Gerard O'Neill's archetypal colonies from the 1970s. Elysium was based on a torus, revisited by the concept artist Syd Mead, whereas Cooper Station was based on a Bernal sphere. O'Neill was a physician and Princeton professor. In 1975 NASA and Stanford University co-organized a ten-week summer workshop based on O'Neill's research on space colonies. Two illustrators, Rick Guidice and Don Davis, were separately commissioned to produce visualizations of the inner spaces of the colonies.[9] But the details were left to their imagination: Davis chose to focus on the landscapes, depicting them after a model based on North California's pastoralism, while Guidice reflected on the forms of putative habitats and constructed areas. O'Neill's theories themselves were attentively scrutinized by people from different backgrounds, including the counterculture activist Stewart Brand, SF writer Carl Sagan, and biologist Lynn Margulis[10], and also had major repercussions for pop culture. Pulp covers, SF magazines and novels, and scientific popularization books soon featured obsessively the visual materials drawn from Guidice and Davis. Here, scientific realism merged with a sense of wonder, presenting us with an ideal of the-station-as-a-space-oasis.

But if 'the idea of creating an oasis for man in the harshness of space'[11] has been present since the dawn of space botany (after all, the first plant cultivation

8. David A. Kirby, *Lab Coats in Hollywood Science, Scientists, and Cinema* (Camrbidge, MA: MIT Press, 2011), 4.
9. https://space.nss.org/settlement/nasa/70sArt/art.html, accessed 25 November 2020.
10. See Stewart Brand, ed., *Space Colonies* (New York: Penguin, 1977).



© NASA

system ever used in space was called Oasis 1), it remains a pure fiction for scientists and engineers to this day. The scale of and functional continuum between houseplants, kitchen gardens, greenhouses, fields and artificial biospheres still needs to be explored.

2. The greenhouse as window

The decorative use of greenhouses was acknowledged early in Russia. In 1977 the Malachite device was installed aboard *Salyut 6*. Equipped with 'four planting boxes containing anion exchange resin, a water supply system, and an illumination source', this system 'was designed for the sole purpose of ornamental plant culture to provide psychological comfort to the cosmonauts in the interior of the space station'.[12] (Orchids in blossom were taken to the station but the blossoms fell off before flowering.) In this case, the device was only meant as a substitute for the good old houseplant.

In space habitats, greenhouses function as little green windows, as things meant to be looked at and to improve psychological comfort, not only as scientific devices. Many photographs taken during space missions show astronauts and cosmonauts simply *looking* at plants. In these pictures, vegetals create little green living spots in interiors otherwise

11. D. M. Porterfield, D. M., G. S. Neichitailo, A. L. Mashinski & M. E. Musgrave, 'Spaceflight Hardware for Conducting Plant Growth Experiments in Space: The Early Years 1960–2000', *Advances in Space Research* 31, no. 1 (2003): 183–93.
12. G. S. Neichitailo and A. L. Mashinski, *Space Biology: Studies at Orbital Stations* (Moscow: Mir Publishers, 1993), 17.

Flight Engineer Serena Auñón-Chancellor checks on plants being grown for botany research aboard the International Space Station. NASA is exploring ways to keep astronauts self-sufficient as humans learn to live longer and farther out into space and beyond low-Earth orbit.

characterized by their technicality and lack of domesticity. In the words of Sandra Haüplik-Meusburger, Regina Peldszus and Verena Holzgethan, who studied the question of the design integration of greenhouses in space habitats, 'besides the technical benefits for space exploration, greenhouses support habitability [is] an integral design element in the spacecraft environment'.[13] The authors go as far as to imagine how greenhouse and plant facilities could in the future create a 'spatial enhancement of the habitable volume' by their location in critical zones, or how they could be treated in interior design to generate 'surrogate views', along with natural, virtual scenes, actual windows or the use of specific materials. The first sequences of *Aliens* (James Cameron, 1986), set in the *Gateway* orbital space station, show such a combination of an artificial and a natural scene. Ripley, the protagonist, sits on a bench and gazes at woods that turn out to be an image displayed on a large screen.

Astronaut Shannon Lucid is photographed looking at the wheat growing in the Svet greenhouse in the Kristall module of the Mir space station.

Haüplik-Meusburger, Peldszus and Holzgethan also imagine how greenhouses could add 'another viewing layer to the spacecraft environment', referring to the Japanese technique of the *shakkei* garden, which consists of stretching the view in limited spaces through the use of space sequencing. With all these tricks and techniques, they claim, greenhouses and plants could help transform the visual information landscape of space habitat interiors. But one should not forget that they also create a 'sensory enrichment'[14] comprising more than just the view. A

13. S. Häuplik-Meusburger, R. Peldszus and V. Holzgethan, 'Greenhouse Design Integration Benefits for Extended Spaceflight', *Acta Astronautica* 68 (2011): 85.
14. Häuplik-Meusburger, Peldszus and Holzgethan, 'Greenhouse Design', 87.

Wesley Meuris, *Jerusalem Artichoke in grow light*, 2021

living plant offers a complete sensory experience. In the words of Russian cosmonaut Valentin Lebedev, the living elements on board are also to be smelled, touched and, of course, tasted when eaten. 'Before going to sleep', he writes, 'I watered the pea and oat plants. The pea tendrils have grown, but the leaves have begun to wither. This is a little space garden. When I smell it, it seems I can smell the Earth. I feel great. I just can't believe that we're in space'.[15]

3. Green friends

'These are our pets.'
Viktor Patsayev (Salyut 1)[16]

'We keep a permanent watch on these plants and it is a pleasure to follow their germination, so we return several times daily to our greenery.'
Gueorgui Dobrovolski (Salyut 1)[17]

'The "green friends" of man grown by the cosmonauts are not only the subject of study but also—and I stress this—a not unimportant psychological factor exerting a positive effect on … emotions …'
Valery Ryumin (Salyut 6)[18]

'I spent some of my relaxation time working with the biological experiments … Back on Earth I had never loved tinkering in a garden. But onboard the space station it was as if I woke up all of a sudden to the Oasis apparatus. A tiny leaf opened up and it seemed to fling open a bright window out into the world.'
Valentin Lebedev (Salyut 7)[19]

15. Valentin Lebedev, *Diary of a Cosmonaut: 211 Days in Space* (New York: Bantam Books, 1990), 69.
16. Quoted in R. Zimmerman, *Leaving Earth: Space Stations, Rival Superpowers and the Quest for Interplanetary Travel* (Washington: Joseph Henry Press, 2003), 42.
17. Neichitailo and Mashinski, *Space Biology*, 22.
18. Quoted in B. J. Bluth and M. Helppie, *Soviet Space Stations as Analogs* (Washington: NASA Headquarters, 1986), I-43.
19. Bluth and M. Helppie, *Soviet Space Stations*, I-43.

‘The stems are in bud with leaves like small blue bells, still weak, but fresh and green. They make me happy; they were born in space.’

Valentin Lebedev (Salyut 7)[20]

‘It was not only that the fresh fruit tasted delicious, but it was seen as a gift, as “the aroma of the good earth”.’

Jerry Linenger (MIR NASA 3)[21]

‘(…) and rape seeds, which I planted three days ago, after a lot of checkout in the Greenhouse, are showing some little sprouts with leaves. Very encouraging.’

Mike Foale (MIR)[22]

‘Last week I got to photograph the soybeans. […] They were surprisingly tall, about 12”, filling the chamber and then bending over at the top, but not yet flowering. It was surprising to me how great 6 soybean plants looked. I assumed it was because I like plants, but Valery and Sergey had the same reaction and even wanted their photos taken with the plants. I guess seeing something green (that stuff we re-hydrate that they say is broccoli doesn’t count) for the first time in a month and a half, had a real effect. Sergey, of course, thought we should eat them as a salad. I managed to save the science and get them into the rack before he was able to eat them! From a psychological perspective, I think it’s interesting that the reaction was as dramatic as it was … guess if we go to Mars, we need a garden!’

Peggy Whitson (ISS, Expedition Five)[23]

‘I think we’ve learned a lot about doing this kind of experiment. We’re being

20. Bluth and M. Helppie, *Soviet Space Stations*, I-43.
21. J. Linenger, *Off The Planet: Surviving Five Perilous Months Aboard the Space Station MIR* (New York: McGraw-Hill,) 2000, 97.
22. Colin Foale, *Waystation to the Stars: The Story of Mir, Michael and Me* (London: Headline, 1999), 82.
23. Expedition Five, Letter home #5. Expedition Five NASA ISS Science Officer Peggy Whitson sent letters home during her stay onboard the International Space Station, https://spaceflight.nasa.gov/station/crew/exp5/lettershome5.html, accessed 25 November 2020.

farmers in space [...] I was extra motivated to bring the plants back to life. I'm going to harvest them on Valentine's Day.'

Scott Kelly (ISS, One Year Mission) [24]

4. Interlude: names

SYSTEMS

Oasis Series, Vazon, Malachite, Lyutik, Biogravistat, Magnetobiostat, Svetoblok, Phyton series, SVET, SVET-GEMS, Astroculture (ASC), Plant Growth Unit (PGU), Plant Growth Facility (PGF), Plant Generic Bioprocessing Apparatus (PGBA), Advanced Astroculture (ADASC), Biomass Production System (BPS), Lada, European Modular Cultivation System (EMCS), Plant Experiment Unit (PEU), Advanced Biological Research System (ABRS), VEGGIE, Vitacycle, The Salad Machine, Plant Research Unit (PRU), Portable Astroculture Chamber (PASC), AstroGarden, CPBF (Commercial Plant Biotechnology Facility), NASA Advanced Plant Habitat (APH), Science in Microgravity Box (SIM-BOX), Mars-Lunar Greehouse (MLGH), the Mobile Plant Cultivation Subsystem, MagISStra, Botany Facility (BF).

PIONEER SPECIES

Tradescantia, Triticum aestivum, Pisum sativum, Zea mays, Allium cepa, Nigella damascena, Brassica capitata, Linum usitatissimum, Allium porrum, Capsicum annuum, Arabidopsis thaliana, Brassica rapa.

5. Greenhouses as sculptures, sculptures as systems

In extreme environments, technological systems working as substitutes for natural conditions allow plants to grow. The morphological features

24. 'Flowering Zinnias on Space Station set Stage for Deep-Space Food Crop Research', https://www.nasa.gov/feature/flowering-zinnias-on-space-station-set-stage-for-deep-space-food-crop-research, accessed 25 November 2020

Wesley Meuris, *Growth Chamber Red Soil*, 2021

of those systems are variable. They may be open or closed, providing complete to no environmental control (lighting, water, nutrients, temperature, humidity, gravity and atmospheric gas composition being conditions subjected to control and variation), but they also possibly allow the astronauts to look inside them. The boxes may host—or not—a cinematic film system to record the progress of the plant growth. They may be compact or unfoldable. They may be standardized to fit in predesigned containers such as the International Standard Payload Rack, or they may be freely designed. They may be powered or unplugged, automated or handled manually. Modular, or not. They may also be un-technological, i.e. artisanal, such as the wheat-growth facility improvised by Maksim Surayev in *Mir* with seeds left from a previous experiment he found on board.[25] In short, 'plant growth chambers aboard spacecrafts have ranged from dark cans the size of petri dishes with no environmental controls to sophisticated machines capable of providing and monitoring light, nutrients and water'.[26]

A view of the Russian BIO-5 Rasteniya-2/Lada-2 (Plants-2) plant growth experiment located in the Zvezda Service Module on the International Space Station (ISS).

In spite of the formal and technical variations that characterize them, they all provide us with hybrid visions where natural (content) and artificial elements (container) mix up in multiple shades of green and grey, visions that art has fed us since at least the 1960s. In his micro-environments from the series *Pollution – Cultivation – New Ecology*, for instance, Tetsumi Kudo combines industrial living materials with everyday objects to create a relationship between

25. Margarita A. Levinskikh, Vladimir N. Sychev, Igor G. Podolskiy, 'Growing plants without gravity', Room n. 11, spring 2017, Asguardia, p. 50
26. R. Ferl, R. Wheeler, H.G. Levine & A.-L. Paul, 'Plants in space', Current Opinion in Plant Biology (5), 2002, p. 258–263

a polluted nature and a proliferating world of machines and electronics. The fluorescent paints he uses symbolize a new synthetic materiality that provides the foundations to reinvent our ways of inhabiting the world and finds a visual echo in the pink-fluorescent light that bathes current space greenhouses such as VEGGIE. The same could be said of Paul Thek's *Technological Reliquaries* series (a little hint of fluo here too). Even though the series is not actually made of living materials, it shows a similar combination of organic and non-organic matter. Or Derek Jarman's concept of 'modern nature' developed in his 1989 diary.[27] Jarman coined the term after vivid wild plants and rubbish mixed up in his garden at Prospect Cottage, a strange landscape on the Kent seashore in the vicinity of a nuclear power plant.

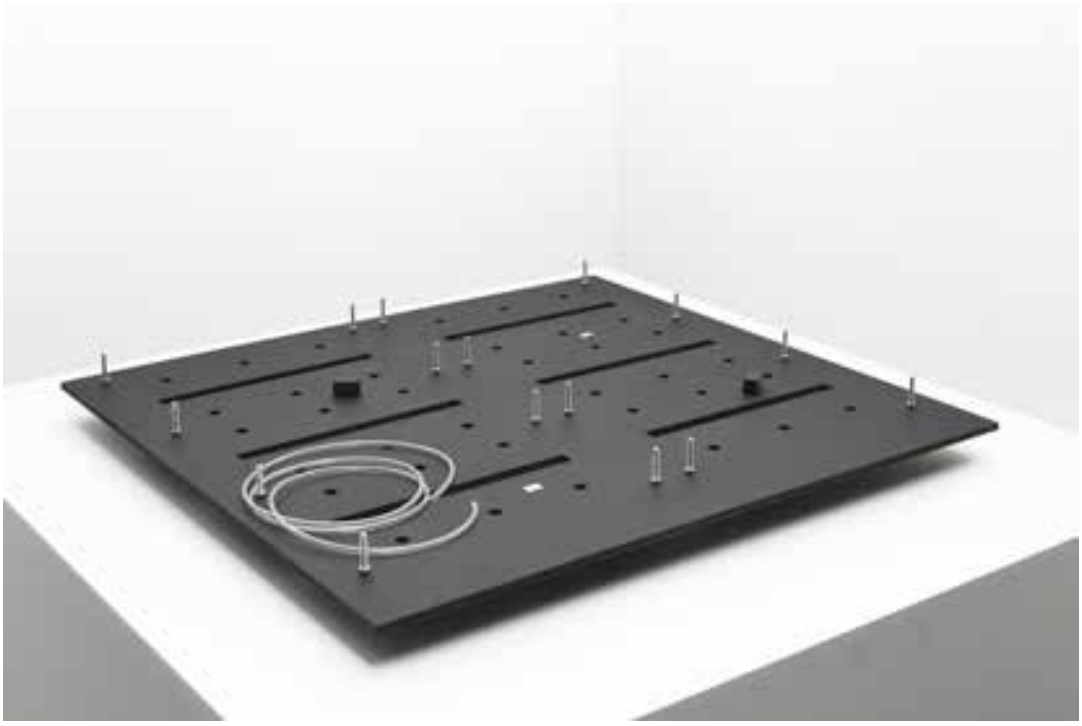
These plant-growth facilities would be better described as complex systems rather than simply called 'hybrids'. By all means, they also provide a model for a new form of art described in 1968 by art historian, critic and writer Jack Burnham: 'Increasingly, "products"—either in art or life—become irrelevant and a different set of needs arise: these revolve around concerns, such as maintaining the biological livability of the Earth, producing more accurate models of social interaction, understanding the growing symbiosis in man-machine relationships, establishing priorities for the usage and conservation of natural resources, and defining alternate patterns of education, productivity, and leisure.' He concludes as follows: 'In the past our technologically-conceived artifacts structured living patterns. We are now in transition from an *object-oriented* to a *systems-oriented culture*.' From this perspective, space greenhouses provide a model for art beyond the poetics of panels, platforms and hardedge boxes, one-way glasses and large mirrors reminding us of modernist sculptures; a model for art based on 'stable, on-going relationships between organic and non-organic systems'.[28]

27. Derek Jarman, 'February, Wednesday 1', 'February, Thursday 2', *Modern Nature* (London: Penguin, 2018), 7–8.
28. Jack Burnham, 'Systems Esthetics', *Artforum* (September 1968).

One should mention here the many experiments led by the Vienna collective Haus-Rucker-Co in the early 1970s and their research on the idea of 'second nature', hybrid systems taking the form of large inflatable and penetrable sculptures and of mini-landscapes enclosed in bottles: 'Where there is only rock mass and snow, or sand or sea', wrote two members of the collective, Laurids and Manfred Ortner, in the 2019 survey of their group activities, 'special facilities are needed in order to survive. A complete technical system that provides the required physical conditions, like a second nature, is necessary for us to infiltrate landscapes of this kind. [...] Replacing the values of purity, authenticity and naturalness with hybrid, replaceable and artificial; imagining with great effort one's way into a reality that already exists—this is what the near future will bring', they add, 'and with it, new meaning for everything that exists'.[29]

Let us not forget here a series of works Pierre Huyghe has been working on since 2009, such as *The Host and The Cloud* (2009–10), *Untilled* (2011–12), *Living Cancer Variator* (2016), and *After A Life Ahead* (2017). Referring to Burnham, art historian Flora Katz defines them as 'complex system[s]', stating that these works 'move away from a principle based on representation, using picture and sculpture, and tend to follow a logic of presentation. One penetrates them, and things are here, sometimes animated'. She adds that 'they are moving and transient. Via a causal principle, elements are in a state of constant co-evolution and develop without the visitor's help. Scales are multiple, and everything that happens is not necessarily visible to the human eye, nor predictable. They generate themselves as a biological/technological organism would'. Her analysis led her to state that the 'complex system' differs both from 'the installation where an ensemble of components are set fixed in space and from the performance that, though transient, needs an audience, sometimes interacting', and concludes

29. Haus-Rucker-Co, *Drawings and Objects 1969-1989*, vol. 2, (Cologne: Walther König, 2019), 9–11.



Wesley Meuris, *Growth Panel* & *Growth Box*, 2021

that it is 'more than an image of our word, […] a little speculative microcosm'.[30] Such hybrid, replaceable, artificial and speculative microcosms as the space greenhouses are the perfect metaphors for a form of art that deals with the crucial question of inhabiting the Earth as well as extraterrestrial spaces and back-up planets. As gardens used to do, they can 'scale down the cosmos to the level of human experience'.[31] But more importantly, they can help us develop a non-human perspective on life, within the multiple volumes of their enclosed biospheres.

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6. Back on Earth (or back on the surface of any planet)

In 1969 Gerard O'Neill asked a group of his students to answer the following question: 'Is the surface of a planet really the right place for an expanding technological civilization?' From this direct interrogation, the whole concept of space colonies emerged. The answer that his students articulated was, indeed, as we know now: 'No'. Because the right place would be an artificial habitat orbiting around Earth. Or to put it differently: we don't need a planetary surface to flourish as a species. All the same, plants do not need soil to thrive, as the massive development of hydroponics has shown. In such systems, plants, flowers and crops are planted in an inert substratum and fed with nutrient- and oxygen-rich solutions. In this regard, we already have an extraterrestrial agriculture here on Earth, i.e. an agriculture that needs

30. Flora Katz, 'Penser l'extinction avec Pierre Huyghe', *Critique* 860–861 (January–February 2019): 156.
31. Lisa Messeri, *Placing Outer Space: An Earthly Ethnography of Other Worlds* (Durham, NC: Duke University Press, 2016), 2.

NASA astronauts (left to right) Christina Koch and Jessica Meir harvested Mizuna mustard greens on Thanksgiving day inside the ESA (European Space Agency) laboratory module's VEGGIE facility.

neither soil, nor even a proper ground, one that is conceived after emergency situations so as to secure global food security. This is an agriculture detached from Earth.

Conversely, planetary surfaces such as those of Mars or the Moon are covered with a material made up of layers of unconsolidated debris: regolith. It would probably take a little more than the ingenuity of Mark Watney[32] to have anything grow on it, let alone be edible (Martian regolith contains high levels of toxic chemicals, such as perchlorates). 'We cannot develop attachments to people or places that we view as hostile; they must be grounded in a disposition of kinship or resonance. Moreover, thinking of our surroundings as hostile intensifies feelings of isolation—one of the major obstacles in long-duration Space travel. But if instead, the way we view and interact with our environment focuses on its positive attributes, then feelings of alienation are likely to be diminished.'[33] These words by Elizabeth Song Lockard show even more importantly that *if* one settles on such a planetary surface (or in such a colony), one will have to integrate these extraterrestrial grounds as defining coordinates for a renewed sensibility.[34] We will have to negotiate not only physically, but also psychologically with regolith and other artificial soils. We will have to start loving them. If technologies can help in this process, so can poetry and the visual arts. So, let us write and build odes to regolith.

32. The main character of *The Martian* (Ridley Scott, 2015), played by Matt Damon.
33. Elizabeth Song Lockard, 'From Hostile to Hospitable: Changing Perceptions of the Space Environment', *45th International Conference on Environmental Systems*, 12- 16 July 2015, Bellevue, Washington, http://links-series.com/wp-content/uploads/2019/11/From-Hostile-to-Hospitable.pdf, accessed 13 December 2020.
34. On the role played by ground surfaces in the definition of our perceptive systems, see James J. Gibson, *The Ecological Approach to Visual Perception* (New York: Taylor and Francis, 1986).

Wesley Meuris, *Regolith*, 2021