[Hydroponic] by courtesy of Gauthier Fekkar – 3D Goat

Powering Outer Space Farming!

At the 2022 Applied Power Electronics Conference (APEC) Plenary Session, John H. Scott, Principal Technologist, Power and Energy Storage, NASA Space Technology Mission Directorate presented a very interesting topic: ‘On the Moon to Stay’, covering the various aspect of the power electronics that would be required to make that statement feasible. Space exploration has not only been a dream and a source of imagination, but also an amazing research area in which to break ‘unbreakable’ limits, and provide benefits to many applications we are now using daily on planet Earth.

Taking humans to the moon, later to Mars and who knows where to next, is far from being an easy job as making life possible and sustainable in such hostile environments is much more than just ‘a challenge’. One example is how to feed the space explorers when they are so remote from Mother Earth? Considering Mars, at huge cost and risk it would take 210 days for a re-supply rocket to arrive, which is clearly not an optimum solution. Space farming has been part of that dream and we all remember the O’Neill Cylinder, designed by Princeton physicist Gerard K. O’Neill who published in 1974 an article in Physic Today: ‘The Colonization of Space’. O’Neill article and research fueled a number of sci-fi movies showing the huge rotating cylinder, hosting farms and lit by an artificial sun (Figure 01: next page). We are not there yet, but on that basis the first humans to inhabit Mars may be considered farmers rather than astronauts! So how will power electronics contribute to make the dream a reality?

From Earth indoor farming to Space

Feeding 10 billion people on Earth
Let’s start at the beginning and if we consider the latest estimation, Earth’s population is expected to reach

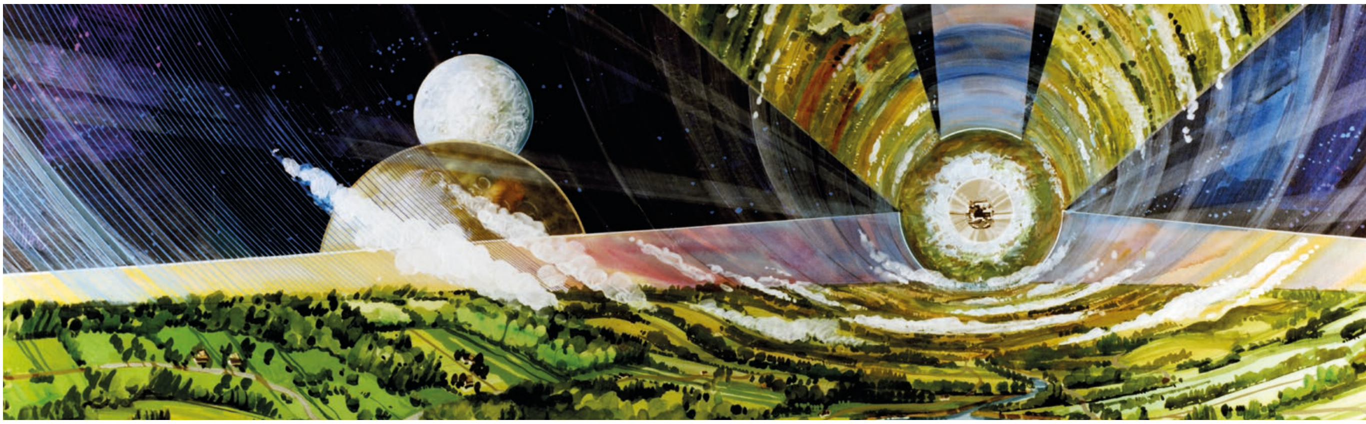

Figure 01 – O'Neill Cylinder interior - Painting by Rick Guidice (Source: PRBX/NASA)

10 billion by 2050. Simultaneously we are facing climate conditions changes that could affect the complete food ecosystem and require significant modification to the ways in which we produce and consume food.

Considering all the parameters and requirement to produce food with the highest respect for the environment, in 1999, Dr. Dickson Despommier with his students developed the idea of a modern indoor farming, revitalizing the terms coined in 1915 by the American geologist Gilbert Ellis Bailey: "Vertical farming." We have all heard about it, read a lot of articles about industrial building converted into vertical farms but from the early days using fluorescent or halogens lighting to Solid State Lighting (SSL), there is an amazing number of technology innovations contributing to optimize the energy delivered to the plants for optimal growth and benefits of indoor farming multiples. If we consider space utilization, 100 time more food could be produced by square meter compared to regular agriculture, reducing water utilization by 90% and hazardous chemical to none. Indoor farming is very attractive though to be really efficient such agriculture requires a very efficient lighting system (Figure 02).

Not all vegetables can grow with limited soil and nutrition by impregnation but for the ones applicable with this

Figure 02 – Solid State Lighting to grow vegetables in indoor farming (source PRBX / asharkyu-Shutterstock)

farming method, the results are impressive and getting even more impressive when using modern lighting technologies computer-controlled, which for power designers is a very interesting area to explore, combining advanced power electronics and modern agriculture, with software in mind.

as well as differing light balance and intensities between the seedling to harvesting stage. This often results in a requirement for the artificial light to have a number of different spectra channels that are individually adjustable for intensity. Some crop growing processes combine different sources of lighting, including the use of UV flashes to prevent the development of parasites, requiring

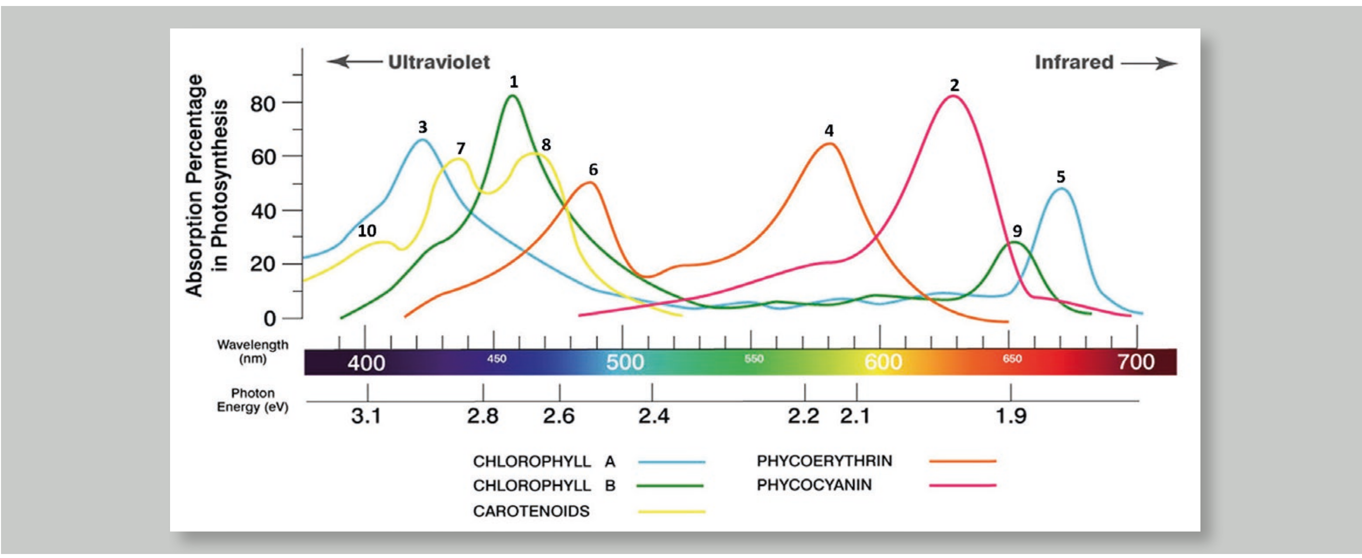

Figure 03 – The light spectrum to grow plants and vegetables typically starts at 450 nm (blue light) and goes through 730 nm (far red) (source PRBX)

Since its introduction, indoor farming engineers conducted research to validate spectrum and energy required by different plants to grow efficiently. From wide spectrum fluorescent or halogen lamps to narrower spectrum, the conventional lighting industry innovated a lot but those technology not flexible nor efficient enough to respond to the demand.

Following experimentations in Japan in 2005-2008, agronomical researchers investigated the different lighting methods to adjust spectrum and energy to specific plants. Researchers concluded that the specific light spectrum to grow plants and vegetables typically starts at 450 nm (blue light) and goes through 730 nm (far red) (Figure 03). The Photosynthetic Photon Flux Density (PPFD) required ranges from 50 micromoles (µmol) for mushrooms up to 2,000 micromoles for plants like tomatoes and some flowers that thrive in full summer light (Figure 04).

Agricultural experts tell us that for optimal results different plant types may require different light spectra

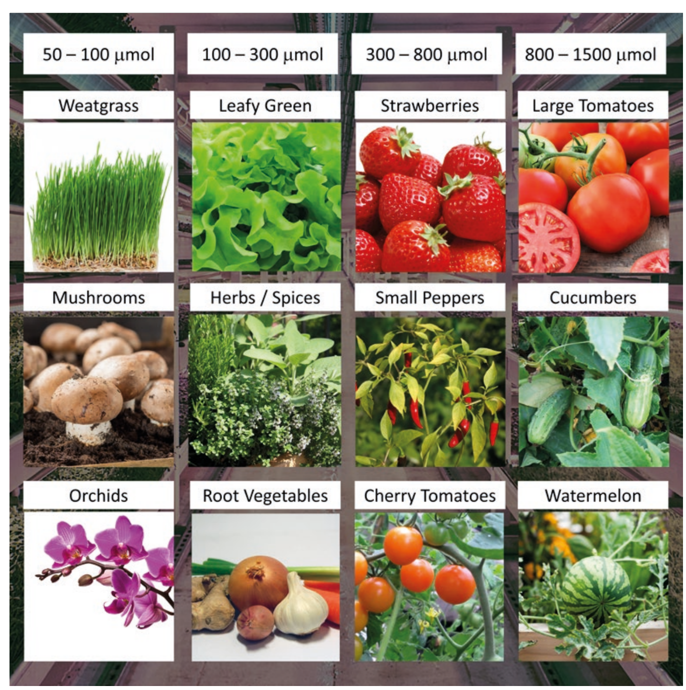

Figure 04 – Light energy required ranges from 50 micromoles (µmol) for mushrooms up to 2.000 micromoles for light intensive plants (source PRBX/ barmalini - Shutterstock)

Figure 05 – COSEL power supply with multi-modes for voltage or current constant from max to near zero (Source PRBX/COSEL)

a power supply able to switch from constant voltage to constant current within a range from almost zero to the maximum (Figure 05). This specification for a power supply is very much what will be required for Space Farming, with, for sure, a power electronics architecture able to combat the effects of space radiation.

Bringing Earth farming to Space

As NASA plans long-duration missions to the Moon and Mars, a key factor is figuring out how to feed crews during their weeks, months, and even years in space. Food for crews aboard the International Space Station (ISS) is primarily prepackaged on Earth, and requiring regular resupply deliveries. Now, while the ISS is able to be resupplied by cargo spacecraft, clearly it is much more complicated and expensive when based on Mars, which is at an average distance of 220 million km (140 million miles) and more than 200 days traveling.

In 2015, NASA in association with the Fairchild Botanical Gardens in Miami began a project called 'Growing Beyond Earth' to define what plants would be suitable from autonomous space-farming. After a series of experiments and taking into consideration the full development cycle, it was decided to grow a variety of plants including lettuces, mustard varieties, and radishes. Firstly, in a controlled lab on Earth, then in the ISS to study how plants are affected by the micro-gravity and other factors (Figure 06).
The 'Veggie' project included a large number of experimental factors e.g., "Pick-and-Eat Salad-Crop Productivity, Nutritional Value, and Acceptability to Supplement the ISS Food System (Veg-04A)" including research on the optimum lighting conditions to grow plants. On the ISS, two light treatments with different red-to-blue ratios were tested for each set of crops to define light colors, levels, and horticultural best practices to achieve high yields of safe, nutritious leafy greens and tomatoes to supplement a space diet of pre-packaged food, and later for Moon or Mars farming. A number of reports have been released e.g., 'Large-Scale crop production for Moon and Mars: Current gaps and future perspectives' published in February in 'Frontiers in Astronomy and Space Sciences' summarizing seven years of experimentation on Earth and in the ISS (Figure 07).

Figure 06 – NASA astronaut Peggy Whitson looks at the Advanced Astroculture Soybean plant growth experiment (Source: PRBX/NASA)

Considering the different varieties of plants to grow, the distance and cost, the power supplies for space-farming will have to accommodate different power profiles combining constant current or constant voltage, peak power, and to be energy efficient and small in size. That's in addition to specific constraints related to space in terms of immunity to radiation, operating temperature, shock and vibration.

The importance of optimizing the payload, the weight and size of everything is a big concern for space applications, and from low orbit satellites to out-of-space exploration, power supplies have been developed with very advanced technologies to make them smaller and energy efficient.

Figure 07 – Examples of Kennedy Space Center 8KSC) prior, current and future space crop production platforms selected and designed to lead to crop production units destined for the Moon or Mars (Source PRBX/NASA)

Wide Band gap semiconductors in space applications have formed a part of many research projects, and it's worth mentioning the report presented by NASA, in 2018, at the (RADECS) conference in Gothenburg: 'Radiation and its Effects on Components and Systems'. This identified the strengths and weaknesses of WBG when exposed to radiation, and the recent announcement about the newly funded national collaboration led by Penn State to better predict and mitigate radiation-induced damage of WBG semiconductors interesting. The U.S. Department of Defense awarded the team a five-year, $7.5 million Defense Multidisciplinary University Research Initiative Award. This clearly shows the high level of importance of WBG in space applications and their contribution to the next step.

In parallel, the semiconductor industry is moving forwards and one example is the new division and products for space applications launched by Efficient Power Conversion (EPC). For power designers, having access to COTS ruggedized GaN for space applications will reduce the development time and cost when developing power supplies for space applications (Figure 08).

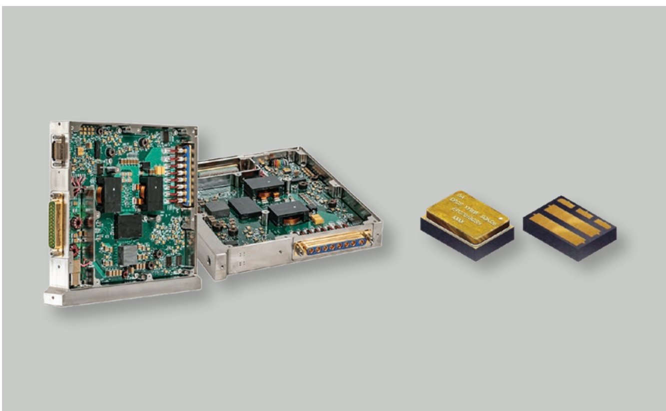

Figure 08 – Efficient Power Conversion (EPC) ruggedized GaN FET for space applications and DC/DC converter (Source: PRBX/EPC)

Conclusions:
Although one of the biggest challenges to in-spaceship farming is sourcing enough water and nutrients and then cycling them as efficiently as possible, there are many other obstacles we don't yet fully grapple with on Earth that will have to be considered too, such as cosmic radiation, lack of an atmosphere, and low levels of light. From the 2015 'Growing Beyond Earth' project to 2022, a lot of progress has been made, contributing to a better understanding of space farming, as well as in power electronics. We are in the early stages of a whole new era in which Wide Bandgap semiconductors in power electronics will play an important role.

Exciting time for power designers, isn't it?!

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About Powerbox

Founded in 1974, with headquarters in Sweden and operations in 15 countries across four continents, Powerbox serves customers all around the globe. The company focuses on four major markets - industrial, medical, transportation/railway and defense - for which it designs and markets premium quality power conversion systems for demanding applications. Powerbox's mission is to use its expertise to increase customers' competitiveness by meeting all of their power needs. Every aspect of the company's business is focused on that goal, from the design of advanced components that go into products, through to high levels of customer service. Powerbox is recognized for technical innovations that reduce energy consumption and its ability to manage full product lifecycles while minimizing environmental impact. Powerbox a Cosel Group Company.

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About the author

Chief Marketing and Communications Officer for Powerbox, Patrick Le Fèvre is an experienced, senior marketer and degree-qualified engineer with a 40-year track record of success in power electronics. He has pioneered the marketing of new technologies such as digital power and technical initiatives to reduce energy consumption. Le Fèvre has written and presented numerous white papers and articles at the world's leading international power electronics conferences. These have been published over 450 times in media throughout the world. He is also involved in several environmental forums, sharing his expertise and knowledge of clean energy.

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