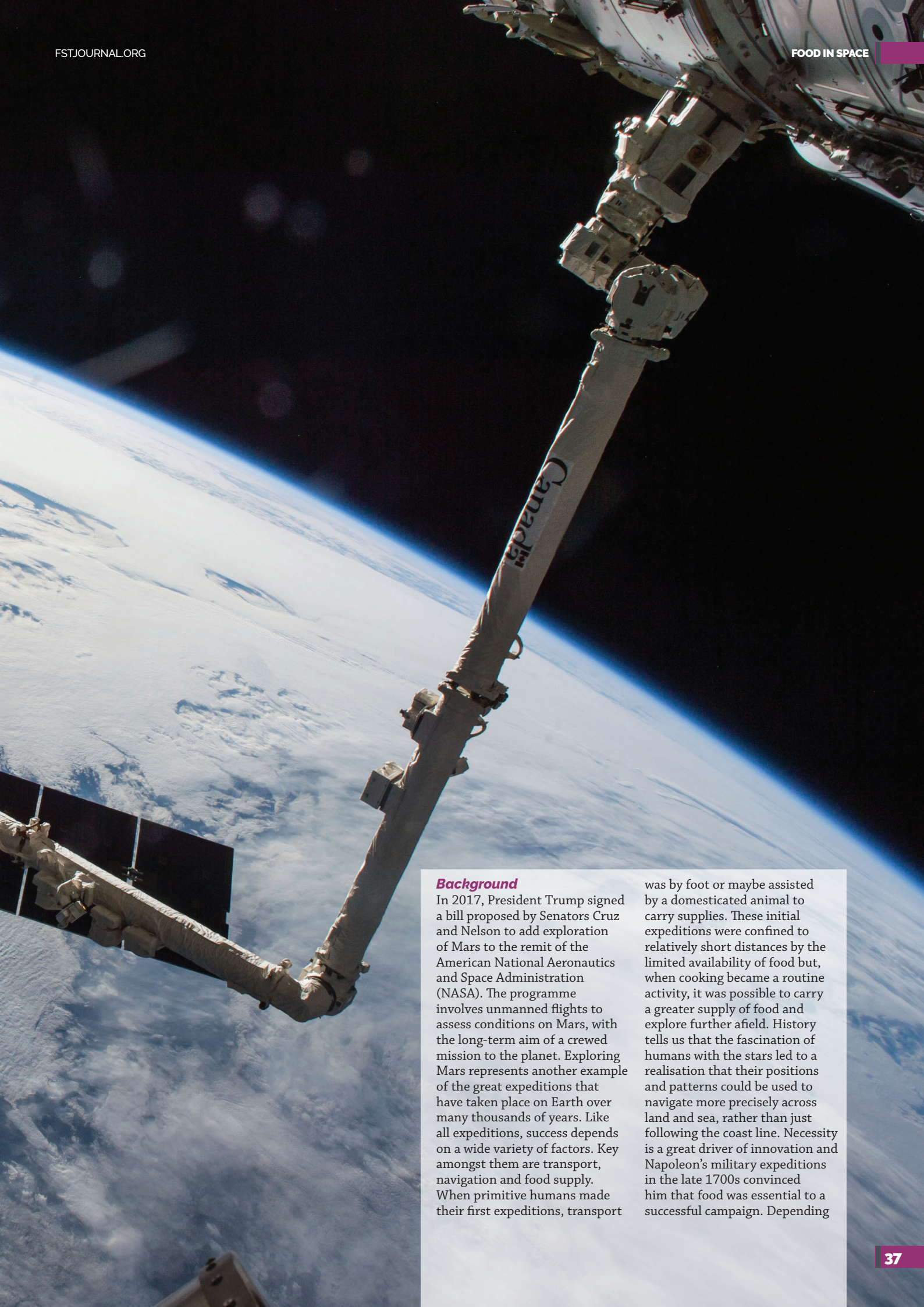


# A taste for space

*Andrew Taylor, Jonathan Beauchamp, Loic Briand, Victor Demaria Pesce, Martina Heer, Thomas Hummel, Scott McGrane, Christian Margot, Serge Pieters, Paola Pittia and Charles Spence consider the role of food flavour in combatting under-consumption of nutrients by astronauts on the Mars expedition.*

*View of earth from the ISS showing the flexible arm that can move equipment around the exterior of the ISS*



### **Background**

In 2017, President Trump signed a bill proposed by Senators Cruz and Nelson to add exploration of Mars to the remit of the American National Aeronautics and Space Administration (NASA). The programme involves unmanned flights to assess conditions on Mars, with the long-term aim of a crewed mission to the planet. Exploring Mars represents another example of the great expeditions that have taken place on Earth over many thousands of years. Like all expeditions, success depends on a wide variety of factors. Key amongst them are transport, navigation and food supply. When primitive humans made their first expeditions, transport

was by foot or maybe assisted by a domesticated animal to carry supplies. These initial expeditions were confined to relatively short distances by the limited availability of food but, when cooking became a routine activity, it was possible to carry a greater supply of food and explore further afield. History tells us that the fascination of humans with the stars led to a realisation that their positions and patterns could be used to navigate more precisely across land and sea, rather than just following the coast line. Necessity is a great driver of innovation and Napoleon's military expeditions in the late 1700s convinced him that food was essential to a successful campaign. Depending

on recently-conquered towns and villages to supply food was not a reliable way to keep the soldiers healthy and ready to fight, so the French Government set up a prize which led Nicolas Appert to invent the first thermal processing of food in containers, the forerunner of the present canning industry. Naval expeditions in the 1700s also had a food problem; most voyages were severely compromised by the frequent occurrence of scurvy in crew members with mortality rates of 50 to 80% being a common occurrence. Realising the importance of healthy crews, the British Navy appointed a physician (Dr Lind) to investigate. Working on the hypothesis that scurvy was caused by poor diet, his work significantly decreased the incidence of scurvy and was a key factor in allowing Captain Cook to voyage from the UK through the Pacific Ocean and on to Australia. Lind's work also established nutrition as an essential scientific discipline. In contrast, a failure in food supply led to the disaster of the Franklin expedition to the Arctic in 1845 when the whole party of 129 people perished in distressing circumstances.

Now we are considering extra-terrestrial expeditions, the same fundamental issues remain but are more complex due to the vast distances and times needed to travel to Mars as well as the many unknown factors relating to the conditions far away from Earth. For example, some of the Polar expeditions established food dumps along the route in advance of the actual expedition to reduce the weight carried on the sledges. Setting up food dumps on the way to Mars over a distance in excess of  $4.5 \times 10^8$  kilometres is in itself a mammoth task and raises questions of food shelf-life, the costs of sending the supplies to the desired location and the consequences of missing or losing a food dump.

Our main source of knowledge about space flight comes from the International Space Station (ISS). This huge structure (about 100m x 30m and weighing 408 tonnes) has been orbiting the Earth 15.5 times per day for over 20 years at 27,580 km/h and at



a height of 400km. In that time, it has hosted several hundred astronauts who have not only built and maintained the ISS but have also carried out research on space-relevant topics. The ISS is a collaboration between the USA, Russia, Europe, Japan and Canada. Each partner supports the ISS financially as well as supplying equipment and consumables. Despite the political tensions on Earth, the ISS project has survived and, at any one time, there will be a mixture of American astronauts and Russian cosmonauts on board the ISS with visitors from the other participating countries. Tim Peake was the UK participant when he launched into space on December 2015 for a six-month visit to the ISS.

#### **ESA study on under-consumption of food in space**

The European Space Agency (ESA) is supporting NASA in the Mars project and one issue they have highlighted is the decreased consumption of food during space flight. Nutritional studies of astronauts have shown that in the vast majority of missions, only around 80% of their recommended daily calorie intake is consumed<sup>[1]</sup>. Over the six- to 12-month period that astronauts remain in space, this does not seem to affect their performance, but the Mars voyage will take around three years and there is concern that this under-consumption could affect physical and mental performance, both of which are vital for a successful

*The food rehydration station adds hot water to the dehydrated food packages; food is eaten directly out the packets to save the weight of plates and bowls*

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mission. ESA has set up two Topical Teams (TT) that are looking at the fundamental science behind this under-consumption. One TT is focused on nutrition and is evaluating the effect of under-consumption of the macronutrients (protein, carbohydrates and fats) on micronutrient (vitamins and minerals) intake, as well as considering the potential long-term effects of three years under-nourishment. The other TT is focusing on whether the flavour of space food is a potential reason for decreased food intake because flavour quality and food intake are related, as described in the following paragraphs. The objective of the team is to consider what factors might affect flavour and food intake during space flight and propose experiments that could provide evidence to support these hypotheses.

The flavour team members were selected to ensure the TT had the necessary skills to evaluate the role of flavour in space food. The TT contains academic and commercial members with expertise in areas such as physiology, nutrition, taste and smell receptors, flavour chemistry, product development, shelf life, sensory analysis and the psychology of multimodal perception. Since the remit of the project is to evaluate the information available and propose a future research plan, the team funding is for two face-to-face meetings during the two-year project duration with all team members working



**Microgravity** plays havoc with hair styles! Tortillas replace ordinary bread on the ISS as they don't create crumbs that end up in the air recycling system.

| RECEPTOR | SCREENING FOR...                 |
|----------|----------------------------------|
| Salt     | Micronutrient content – minerals |
| Sour     | Spoilt food detector             |
| Bitter   | Potential toxic compounds        |
| Sweet    | Carbohydrate                     |
| Umami    | Protein                          |
| Fat      | Fat                              |

**Table 1** Translating taste function into the food screening functions proposed in the text

unpaid and in their own time. However, the fascination of the subject is the 'glue' that holds the team together, not the financial reward.

### The importance of flavour in under-consumption

During the first year of the project, the team has studied what is known about the flavour of space food and how flavour affects food consumption. The science behind food intake and the body's control mechanisms that affect satiety and appetite have been well-documented<sup>[2]</sup>. We know that the human body

A recent study, proposed that there is another food intake mechanism that allows humans to overeat if the taste receptors indicate that the food is nutritionally beneficial.

strives to maintain food intake so it meets the body's needs for energy, repair, growth etc. It is now apparent that taste and smell receptors are part of this regulatory process, not just when we eat food and interpret the receptors' signals as 'flavour' in our brains but the receptors are also involved in controlling the uptake of nutrients in the gut. Because of the multiple roles of these receptors, they are often referred to as chemosensory receptors. If food does not taste good it is rejected, presumably to avoid toxic compounds or spoiled foods that may contain food poisoning organisms, but the current thinking is that the chemosensory receptors that identify the taste of our food also screen the incoming food for its nutrient value. An attempt to translate between the taste function and the screening function of the chemosensory receptors is shown in Table 1.

The role of chemosensory receptors in the mechanisms governing food intake (what is allowed to pass through the mouth) and food uptake (what is absorbed in the gut) is a fairly recent discovery and has led to much research on the 'mouth-gut-brain axis' i.e. how the receptors, the hormones and the brain control our food intake<sup>[3]</sup>. The food intake control is undoubtedly complex and not fully understood but the key factor is that chemosensory receptors (and probably odour receptors too) are an important part of that control mechanism<sup>[4]</sup>. A recent study<sup>[5]</sup> proposed that there is another food intake mechanism, that allows humans to overeat if the taste receptors indicate that the food is nutritionally beneficial. This is thought to be part of our ancient survival mechanism, which means we can overeat one day so we can store energy as fat in order to survive if there is no food available for the next few days. Now that many parts of the world enjoy regular and nutritious food supplies, it has been postulated that this 'overriding' mechanism may be the factor that causes some people to over-eat and become obese. If we turn this hypothesis around, then it is possible to

postulate that poor-tasting food may decrease food intake and this may be a factor in the decreased food intake during space flight.

If we take this as our first learning, then the scientific questions that arise are along the lines of 'What factors can interfere with the chemosensory receptors and could be responsible for decreased food intake during space flight?'. The team has spent some time looking at the various possibilities and has rejected some ideas while homing in on other specific areas. One area that was considered and rejected was the information about flavour perception in commercial aircraft flights, where poor flavour of airline meals is a recurring theme. However, the ISS living space is pressurised to 1 bar, the same as on Earth, unlike commercial aircraft that are pressurised to around 0.75 bar. Therefore, the conditions are similar but not the same and it is not valid to translate the flavour perception results from commercial flights to the ISS situation.

### Conditions on board

Our focus areas have been chosen after consideration of the conditions on board the ISS. The first is the quality of the recycled air which contains not only the usual volatile organic compounds (VOCs)<sup>[6]</sup> but also, a high level of carbon dioxide (2-4%), which is way above earth levels (0.04%)<sup>[7]</sup>. It is known that carbon dioxide in fizzy drinks is converted to carbonic acid by the enzyme carbonic anhydrase and that this compound activates the sour taste receptor and may activate some of the trigeminal receptors as well. The first question from this observation is 'What effect might constant stimulation of the sour/trigeminal receptor have on overall flavour perception? Is it like a background signal that interferes with the other flavour sensations and diminishes the overall taste quality of food or do the receptors/brain react to filter out the signal?'. The second question is 'How could we test these hypotheses in Earth-based studies to determine if this is a significant effect, worthy of further investigation?'.

Another relevant area is the quality of the recycled water on the ISS<sup>[8]</sup>. Currently, urine, washing water and water vapour (e.g. sweat) from the air within the ISS are collected and cleaned by passing them through two massive (500 kg) filters<sup>[9]</sup>. Studies by NASA have identified potential toxic contaminants in the recycled water and limits, referred to as Spacecraft Water Exposure Guidelines or SWEGs, have been set to ensure the safety of astronauts. Closer inspection of the NASA data reveals that some compounds are marked RWC, which stands for Reduced Water Consumption i.e. these compounds are flavour-active at the levels found in recycled water and decrease the amount of water an astronaut will drink. Anecdotal evidence from interviews with astronauts is that very few, if any, drink water on its own; they add fruit cordial or squash, presumably to mask the taste of the recycled water. Some of the compounds found in recycled water are reported to have bitter flavours and are present at 10 to 100 times the taste threshold for these compounds. This means that recycled water is safe to drink but not very palatable. However, much of the food on the ISS is dehydrated to save weight and therefore recycled water could affect the perceived flavour of much of the food supply, not just drinks.

### **Bitter compounds**

The information that water may impart a bitter note to food on the ISS, then led to the question 'What evidence is there that bitter compounds actually affect food intake?' After all, we like bitter tastes, such as quinine in tonic water or hops in beer. A scan of the scientific literature showed that some publications report a negative effect of bitter taste on food consumption, others report no effect. A deeper dive into the literature shows that there are 25 different bitter receptors in humans, which are activated by different bitter compounds, but it is not known if all the bitter receptors are involved in the food intake mechanism or just a subset. If the latter is the case, then it could

**An astronaut observes Earth from the window in the ISS**



**The 'dining' table on the ISS, note the clips and Velcro tethers on the food packages and the lanyards on the scissor to stop items floating away due to the microgravity conditions**





**Astronaut preparing food on the ISS**

explain why some compounds affect food intake while others do not. As ever in scientific research, one question typically results in another set of questions to which there are no answers! To resolve this question, further experimentation is needed. As a way to break through the unknowns, one idea is to run sensory experiments to determine if the ISS contaminants affect the flavour of some selected foods. However, the astute reader will realise that the compounds in question are toxic and it will be difficult to design a sensory study that delivers clear results and meets ethical guidelines.

### Noise

A slightly simpler factor to investigate is the effect of noise on food intake. Although there is no sound in space (due to the lack of air to transport sound), inside the ISS there is a constant drone of life-support equipment. Sampling the ISS noise is easy as it only requires a recording from the ISS to a ground station and the decibel level is already well known. Published work<sup>[10]</sup> has shown that background noise can affect eating habits and it is easy to envisage an experimental set up where subjects eat food with different background sounds while both flavour perception and food intake are measured to determine the effect of the background noise.

Another noise effect is related to the nature of the foods available on the ISS. Weight and space are crucial

With reduced texture in the foods, are the astronauts missing the 'sonic sound' we get when crunching crusty bread or savouring the texture of *al dente* vegetables?

on board, so dehydrated foods with little texture are common because they pack flat in the ISS larder. With reduced texture in the foods, are the astronauts missing the 'sonic sound' we get when crunching crusty bread or savouring the texture of *al dente* vegetables? There is evidence that people generally have trouble accepting foods with which they are not familiar. Reports from the American military on the acceptability of field rations<sup>[11]</sup> are that soldiers frequently complain about the flavour and tend to eat less or, in some instances, refuse to eat the rations altogether, even though they are hungry. Another experiment, where a good-tasting meal was 'doctored' by adding an unpleasant flavour, showed

that the decrease in food intake was directly proportional to the amount of added unpleasant flavour. Translating these results into a more general scenario, it could be suggested that, if a food is missing its key sensory properties, it becomes less acceptable, as the expectations of the consumer are not being met and this could be a factor in the under-consumption of food on the ISS.

### Early observations

So far, it is clear that providing palatable food to maintain a Mars crew for a three-year mission is a formidable task. Other issues are that NASA originally estimated that the journey to Mars would require 12 tonnes of food supplies. When the cost of launching one kilogram of freight to the ISS is around \$15,000 then the food-launch cost would be in the region of several hundred million dollars. For this reason, NASA is looking at alternatives. Growing food during the mission is one idea but growing enough for a crew of six and avoiding a disaster if the plants die or get contaminated, are the current issues under consideration. Like all ambitious expeditions to explore the unknown, there are significant risks involved but the Mars mission is moving way outside our current comfort zone and it will take a lot more work to get systems in place before a crewed launch can be considered. NASA plans to use the Moon as a training camp to test some of the new systems and is also considering using the Moon

as the launch site for the Mars mission. With reduced gravity on the Moon, a launch to Mars would require less rocket power. Sending more robots to scout the Martian surface is also planned.

Whoever crews the Mars mission, will need exceptional skills, backed up by all the knowledge available. Our tiny team is proud to be involved in that endeavour. ■

References and article available online at [fstjournal.org/features/33-4/food-in-space](http://fstjournal.org/features/33-4/food-in-space)

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Andy Taylor's career involved flavour research at the University of Nottingham and then at Mars Petcare. The academic research led to the formation of a spin out company, Flavometrix, to apply the fundamental ideas of flavour release to commercial products and still provides consultancy services to small and large companies. Andy also is the Chief Assessor for the annual GIRACT awards ([www.giract.com](http://www.giract.com)) which are sponsored by food and flavour companies to encourage students to consider flavour research as their PhD choice.

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