Automated Food Tracking & Surveying Interface (AFTSI) for the HI-SEAS Analog Habitat

A Design Report

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Masters of Engineering

by

Jeffrey Lac Ly

August 3, 2017

Advisor: Professor Jean B. Hunter

Contents

Abstract

The Hawai'i Space Exploration Analog and Simulation (HI-SEAS) is an analog habitat for study of human space missions on Mars. As the National Aeronautics and Space Administration (NASA) is currently developing future manned missions to Mars in the 2030s, work has begun now to identify key factors to ensure space flight crew is happy and healthy during a prolonged space flight mission. The research conducted on these missions includes studies of food, crew behavior, roles and performance that directly impact space flight and primary mission success. This paper describes the conception, design, prototyping, initial testing and potential experimental designs of the Automated Food Tracking & Surveying Interfaces (AFTSI). Details are given on efforts to streamline the process which food intake can be measured and monitored, in addition to allowing easy tracking of how much a food is liked or disliked. The synergy of this information can help mission planners develop diets that not only ensure that crew is properly nourished, but also kept in good spirits throughout the duration of the mission.

Food tracking is an integral part of mission studies that NASA is conducting in preparation for a Mars mission. Food choices and nutrition have effects on crew morale and productivity. AFTSI is designed to be a non-invasive all in one solution that keeps track of caloric intake while providing insight the best food choices for the crew over a prolonged mission on an Earth-based space analog habitat or on another planetary surface.

Nomenclature

AIAA	=	American Institute of Aeronautics and Astronautics
ARM	=	Asteroid Redirect Mission
CAD	=	Computer-Aided Design
COTS	=	Commercial off-the-shelf
EAMD	=	Exploration Analogs and Mission Development
EVA	=	Extravehicular Activity
EYES	=	Encouraging Young Engineers and Scientists
ISS	=	International Space Station
JSC	=	Johnson Space Center
LEO	=	Low-Earth Orbit
MDRS	=	Mars Desert Research Station
NASA	=	National Aeronautics and Space Administration
NBL	=	Neutral Buoyancy Laboratory
NEEMO	=	NASA Extreme Environment Mission Operations
HI-SEAS	=	Hawai'i Space Exploration Analog and Simulation
SLS	=	Space Launch System
STEM	=	Science, Technology, Engineering and Mathematics

Introduction

NASA's recently-released "Journey to Mars" roadmap outlines the intermediate steps necessary to advance the United States' human spaceflight program beyond low earth orbit (LEO) in pursuit of the eventual goal of a human journey to Mars. While the commercial space industry works hard to maintain and resupply the International Space Station (ISS) via the Commercial Crew and Cargo programs, the agency is looking to expand human capabilities in prolonged space flight missions as well as long duration exposure on non-terrestrial bodies like the Moon and Mars.

Despite NASA's existing studies of the effects of prolonged space travel, most notably Astronaut Scott Kelly's one year mission at the ISS in 2015 along with the considerable number of NEEMO missions, until the Mars 500 analog mission (520 days) and the first HI-SEAS mission (120 days), no modern study subjected crews to prolonged isolation from core support groups like family and friends. On an ISS mission, the proximity of LEO (Low Earth Orbit) allows for near instantaneous electronic communication between the crew and Mission Control as well as providing the psychological support and comfort to the crew via real time video messaging. In addition, the ability to abort mission and enable a safe return to the Earth's surface provides a shell of comfort that makes such missions, while still daunting, mentally comforting. However, on future manned missions to Mars where the round-trip time for a radio signal ranges from 8 to 40 minutes, a crew is on its own if something goes wrong. The furthest that a human crewed mission has traveled from Earth is the far side of the moon.

While instantaneous communication may not be possible on a Mars mission, several mission elements that can be designed to bolster crew morale[1]. After emotional support from loved ones, the next most impactful element is food[2]. It is important to note that as effective food can be to improving crew morale – it can also have the potential of an equally negative impact on the crew. Food that is favored by the crew means they are more likely to consume the necessary calories to maintain bone and cardiovascular health and have the physical and mental strength to perform mission critical tasks. Lack of food, or lack of food favored by crew is a hazard to mission success. Overtime crew morale can decline, affecting their overall effectiveness[2]. In order to prepare a menu that provides necessary nutrition as well as maintain positive morale, food tracking is an integral part of mission studies that NASA is conducting in preparation for a Mars mission.

Purpose and Problem

Past and current studies have shown that crew morale greatly impacts the productivity and overall success of a mission[4]. Among the factors that significantly contribute to crew morale in the long term are connection with home and food. While connection with home from Mars is difficult under the condition of communication delay, food acceptability comes into focus as the "new and refreshing change" that helps break the monotony of a trip. Not only does good food increase overall mental wellbeing of the crew, it also increases a crew member's caloric intake (following the adage that people are more likely to eat food they like) so he/she has increased energy to conduct primary mission tasks.

The first HI-SEAS analog mission tracked food acceptability using pen and paper surveys. The crew member who was designated cook for the day prepared a list of food for breakfast, lunch and dinner. After each meal, the crew completed a pen and paper survey; the dishes consumed were manually in written in and rated for visual appeal, interest in eating and acceptability. While this process was reasonably convenient for crew, it took tremendous amounts of valuable mission time to keep track of and even more post mission time to analyze. Video was recorded manually as food was weighed and was painstakingly viewed during post-mission analysis to extract scale readings to transcribe and obtain food weight data in a suitable form for study. This process created difficulties in data matching during post-mission analysis, especially when the same food was referred to by a different name by individual crew members. This provided strong incentive to develop an all-in-one system that can quickly and reliably track food intake of the crew and collect data on food acceptability as well. This project establishes the design goals for the Automated Food Tracking & Surveying Interfaces (AFTSI), selected suitable hardware and developed software and prototype systems which was successfully demonstrates in May 2017.

Design Goals

AFTSI was built with 3 core design goals in mind – to consolidate and streamline data collection for food consumption and food acceptability tracking, reduce workload for crew members and save time for post-mission analyst. Two sub-systems work together to enable AFTSI: the Food Survey Data Port System (FSDP) and the Food Intake Tracking (FIT) system.

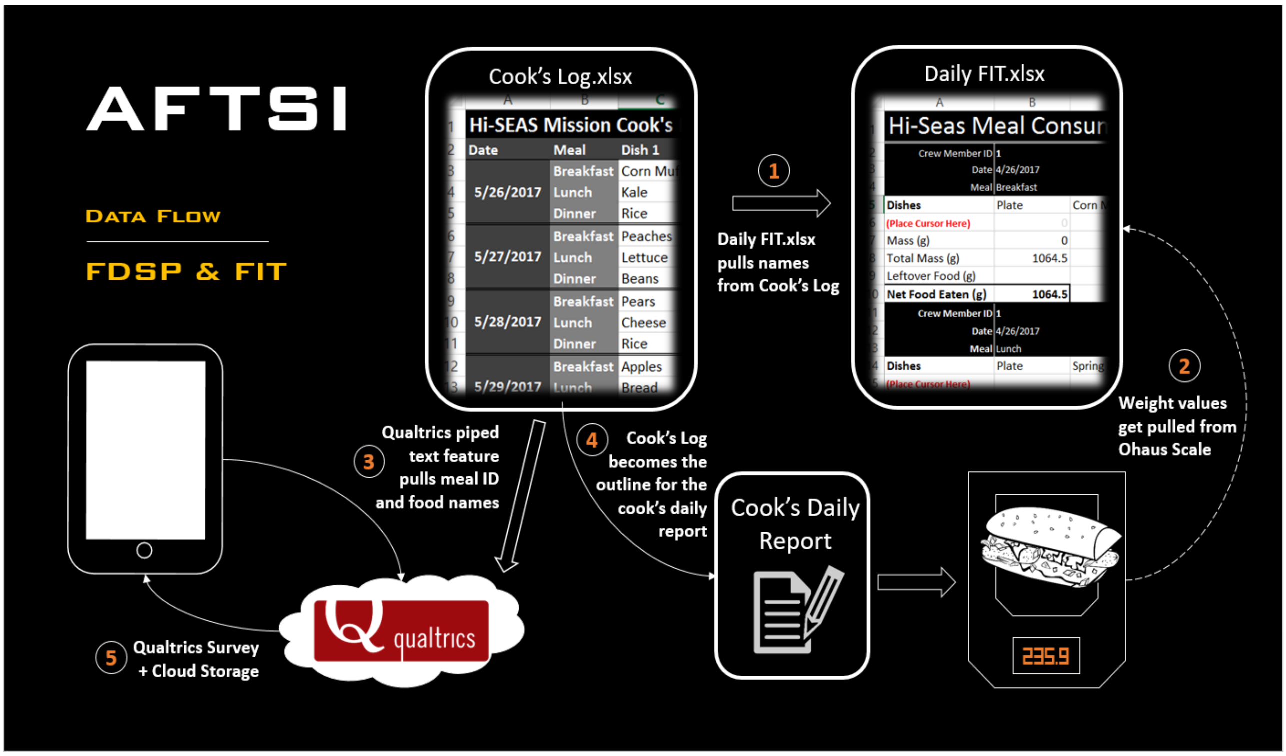


Figure 1. AFTSI schematic demonstrating data flow through the FSDP and FIT Systems

FSDP Design

Starting with the FSDP, this system's design criteria focused on streamlining the process to determine how much crew members like or dislike certain dishes. FSDP needed to be able to track dishes for the day, sort them by meal and dynamically update food names to the meal time survey given to the crew. The process that made most sense was to provide a separate survey for the designated cook for the day and have the results of that survey feed the choices provided in the meal-time survey. The surveying system used is power by Qualtrics – an experience management company, with co-headquarters in Provo, Utah and Seattle, Washington that has developed a suite of online survey building and data handling tools that the HI-SEAS mission uses for a wide variety of surveys. The Qualtrics survey engine has a function called piped text which allows survey questions to dynamically change, providing a solution to reflect updates in the crews daily menu. Unfortunately, while piping internal results in a survey was possible in Qualtrics, pulling data from an external survey was not feasible, either as a built-in functionality or via the Qualtrics Javascript API. Even if such functionality was available, it was essential to keep a running list of dishes from up to 2 days prior to account for use of leftover foods as well – this was not possible simply from piping text from a single survey. However, it helped to establish the baseline for the first iteration of FSDP – repurposing existing functionality in Qualtrics. The first working iteration leveraged the Web Services function of the piped text service. Designed to access an RSS feed, the title of a blog post on a specified web server acts as the source of text that can used in the survey questions. To make this system work, a web service that could accept posts by email while supporting RSS Feed was required. While several options were available (Wordpress, Wix etc.), Squarespace, a website and blog service, was one of the few services that offered both services at an affordable price. To dynamically update food choices for each day, Squarespace's email-to-post functionality was used to bypass manual entry of menu data from within Squarespace's built-in UI. To further streamline the process, the mass email service in Microsoft Office was used to send multiple emails listing the meals for the day, resulting in multiple posts to the Squarespace server. To ensure that the subject lines of individual emails in mass emails were customized to reflect different dishes, an Excel macro was devised in a formatted .CSV to automatically account for different dishes in a list. The designated cook would update this list with the new dishes for each day and send the mass email to the Squarespace server, which in turn updated Qualtrics surveys for each crew member.

While the first iteration (FSDP v.1.0) was fully functional and answered all the design criteria for FSDP, it still required more steps than ideal (updating the Excel document and manually sending a mass email each day) and was thus error prone. During a test, the email used to mass send the updated list was mistyped. There was no way to verify whether the update was successful without checking the actual survey or accessing the full Squarespace server. Both tasks would be problematic to troubleshoot under the 20-minute communication delay enforced on the HI-SEAS mission server. In addition, since the mass email depended on Microsoft Outlook's mass email service, emails were sometimes queued for extended intervals in the outbox, sometimes even failing to send at all. These issues, and Squarespace's decision to discontinue their post by email service in December 2016 effectively ended the functionality of FSDP v.1.0.

Development of the second iteration from FSDP (FSDP v.2.0) again built off a clever repurposing of existing Qualtrics functionality – while keeping the number of dependent parts at a minimum. While Qualtrics surveys cannot pipe text from an external Excel documents, they can pull text from an internal database populated from a contact list, a feature that was originally intended to personalize surveys. The internal contact list is readily updated from a specially formatted Excel document and contained fields for first name, last name, address, email and other identifiers. Leveraging this existing functionality, while the title of the fields had to remain the same, by entering dishes, meal indicators and dates, in the corresponding columns, the Qualtrics API was able to treat the dishes simply as text and the Cook's Menu became the source of "contacts" for the internal database in Qualtrics. The designated cook for the day updates this list in Excel and uploads the updated pseudo-contact list to Qualtrics. With the data flow reconfigured within the Qualtric surveys, the new dishes on the menu into survey questions were populated from the repurposed contact list. FDSP v.2.0 solution has now been fully tested through many simulated use cases and has proven sufficiently robust to be deployed on future HI-SEAS missions.

Hi-SEAS Mission Cook's Log (5/26 - 6/1)

Date	Meal	Dish 1	Dish 2	Dish 3	Dish 4	Dish 5	Dish 6	Dish 7
5/26/2017	Breakfast	Corn Muffin	Cheetos	Oranges	Ginger Snaps	Sardines	Oreos	
	Lunch	Kale	Tomatoe	Ham	Bacon	Lentils	Beets	
	Dinner	Rice	Beans	Potatoes	Beef	Soup	Corn	
5/27/2017	Breakfast	Peaches	Cereal	Yogurt	Bagel	Coffee	Cream	
	Lunch	Lettuce	Cheese	Ham	Bacon	Lentils	Beets	
	Dinner	Beans	Rice	Corn	Beef	Cheese	Beans	
5/28/2017	Breakfast	Pears	Cereal	Yogurt	Bagel	Coffee	Cream	
	Lunch	Cheese	Ham	Bacon	Lentils	Beets	Spinach	
	Dinner	Rice	Potatoes	Steak	Soup	Corn	Beans	
5/29/2017	Breakfast	Apples	Cereal	Granola	Bagel	Berries	Cream	
	Lunch	Bread	Tomatoe	Bacon	Lentils	Beets	Spinach	
	Dinner	Rice	Potatoes	Pork	Beans	Lettuce	Spinach	
5/30/2017	Breakfast	Plums	Cereal	Granola	Bagel	Coffee	Cream	
	Lunch	Spinach	Tomatoe	Cheese	Ham	Bacon	Lentils	
	Dinner	Rice	Potatoes	Chicken	Soup	Corn	Beans	
5/31/2017	Breakfast	Grapes	Cereal	Granola	Bagel	Tea	Cream	
	Lunch	Spinach	Tomatoe	Ham	Bacon	Lentils	Beets	
	Dinner	Rice	Potatoes	Corn	Beef	Cheese	Beans	
6/1/2017	Breakfast	Apricots	Cereal	Cream	Bagel	Granola	Tea	
	Lunch	Lettuce	Carrot	Ham	Bacon	Lentils	Beets	
	Dinner	Rice	Potatoes	Chicken	Soup	Cheese	Beans	
6/2/2017	Breakfast	Pineapple	Cereal	Bagel	Berries	Coffee	Cream	
	Lunch	Spring Leaf	Lettuce	Ham	Bacon	Lentils	Beets	
	Dinner	Apple	Rice & Bea	Cookies	Hummus	Crackers	Carrots	

Cook's Log | 042617

Figure 2. Cook's Log – central location where the menu is entered and the data is ported to Meal time Surveys and the Cook's daily log.

FIT Design

The purpose of the Food Intake Tracking (FIT) system is to streamline the mealtime food weighing process and consolidate data in a format that post mission analysts can use readily. The system used on the first mission relied on a video system to record crew members adding food to plates on a scale. To ensure proper data collection, each crew member had to manually reset the system, ensure that the scale was properly tared and place an information card within camera view to confirm their identity, the date and the meal being recorded. While simple for crew, this system was error prone and time consuming during data analysis. Weights and identity of dishes had to be verified from cooks' reports and manual paper and pen surveys. If the lighting was poor or the digital display on the scale was covered inadvertently, food weight data was lost and had to be estimated by the analyst. The lack of a standardized food naming convention also made it difficult to confirm what food was being weighed, especially when foods looked very similar under poor lighting. These issues formed the background for FIT's design criteria. FIT needed to streamline the data collection while improving post-mission analysis with direct logging of food weight and a single-source standardized food naming convention.

Development of FIT began by determining whether existing video clips could be analyzed via image recognition software and Matlab codes to effectively read text via OCR (Optical Character Recognition) and input the data into structured Excel document. Unfortunately, the image quality from the video footage was too poor (low lighting or out of focus) for reliable read-off of the data. So, while this method would have been ideal, the available raw data limited its utility.

Moving forward, the next iteration of the FIT development sought to utilize an automatic data capture feature of the Ohaus Navigator Scale line. The Ohaus Navigator product line features a RS232 to USB converter to aid in porting values of weight from the scale to any computer with USB functionality. Unfortunately, Ohaus provided poor support for software configuration needed to interface the scale and data input into an Excel document. Even switching on the USB functionality to stream data through USB was already a challenge on the Navigator 2101. Efforts shifted to another model, the OHaus Scout H-5849, which has USB functionality always on. Limited software compatibility once again shifted efforts back to the Navigator 2101. The breakthrough came in the form of a free third party software interface: 232Key[4] by Smartlux. Its built-in functionality to transform RS232 data through USB into text proved perfect for inputting data quickly to Excel .CSV files. However, since the functionality was built by a third party, a detailed review of documentation on the OHaus and Smartlux websites helped fill in the understanding needed to properly configure both the scale and 232Key software.

The final iteration of the FIT system pulls data from scale on command by a crew member, ensuring the weights taken are accurate. The supporting Excel documents helps to track weight of the dishes chosen. A crew member begins by first stepping up to the scale and placing their plate or bowl on the scale. When the crew member is satisfied, the scale has stabilized and is ready to start adding food, he/she simply waves a finger above the scale's right IR sensor. The value is entered under the column labeled "Plate" and the cursor automatically moves to the next column, ready to capture the weight of the first food the crew member wishes to add. In the event that the next food selection does not match the column title, each column has a built-in drop down menu containing all food choices for the day from the Cook's Menu. This allows users to easily change column title to reflect whatever food they add. In addition, FIT can also quickly account for additional foods not on the menu. In add-on columns located after the set daily menu, the crew members can manually input the name of the new dish and ensure its weight is also accounted in the meal. In the event that leftovers remain, the system can also account for weight of food returned following a meal. All the crew member has to do is tare the scale to zero, return the plate to the scale, place the cursor under "Leftovers" column and wave a

Figure 3. Right IR Sensor that triggers the scale is shown in the red circle.

finger of the Right IR sensor again. FIT automatically removes the weight of the leftover food away from the original weight providing the net food consumption and flagging the event for later attention by the data analyst. With these features, FIT provides a robust solution to quickly track food consumption while decreasing workload for analysts post mission. While the post mission analysts will still have to estimate the weight of each type of food in the leftover (the leftover weight is a single weight not individualized by dish) it may be possible to automate this feature in the future. Meanwhile, weighable leftovers occurred in more than 10% of the plates in the first HI-SEAS missions so the results should not be significantly skewed.

	A	B	C	D	E	F	G	H
1	**Hi-Seas Meal Consumption Tracking (Demo)**							
2	Crew Member ID	1						
3	Date	4/26/2017						
4	Meal	Breakfast						
5	**Dishes**	Plate	Corn Muffin	Cheetos	anges	Ginger Snap:	Sardines	Oreos
6	(Place Cursor Here)	0	420.8	636.4	892.3	1064.5		
7	Mass (g)	0	420.8	215.6	255.9	172.2		
8	Total Mass (g)	1064.5						
9	Leftover Food (g)							
10	**Net Food Eaten (g)**	**1064.5**						
11	**Crew Member ID**	1						
12	**Date**	4/26/2017						
13	**Meal**	Lunch						
14	**Dishes**	Plate	Spring Leaf	Lettuce	Ham	Bacon	Lentils	
15	(Place Cursor Here)							
16	Mass (g)	99.4	6.3	11.8	14.7	7.4	7.6	
17	Total Mass (g)	47.8						
18	Leftover Food (g)	10						
19	**Net Food Eaten (g)**	**37.8**						
20	**Crew Member ID**	1						
21	**Date**	4/26/2017						
22	**Meal**	Dinner						
23	**Dishes**	Plate	Apple	Rice & Beans	Cookies	Hummus	Crackers	
24	(Place Cursor Here)							
25	Mass (g)	186.7	117.3	71.6	22.1	7.1	21.1	
26	Total Mass (g)	239.2						
27	Leftover Food (g)	81.4		268.8				
28	**Net Food Eaten (g)**	**157.8**						

Figure 4. Screenshot of sample data demonstrating food weighing interface with the Ohaus Navigator 2101 scale. Data enters this sheet from the scale through the RS232 to USB adapter.

How it Works

In Figure 1 below, the AFTSI system schematic provides insight on how AFTSI works from stem to stern. It is broken into 3 phases: Cook Phase (CP), Eating Phase (EP) & Survey Phase (SP). Cook Phase + Eating Phase = FSDP; Survey Phase = FIT.

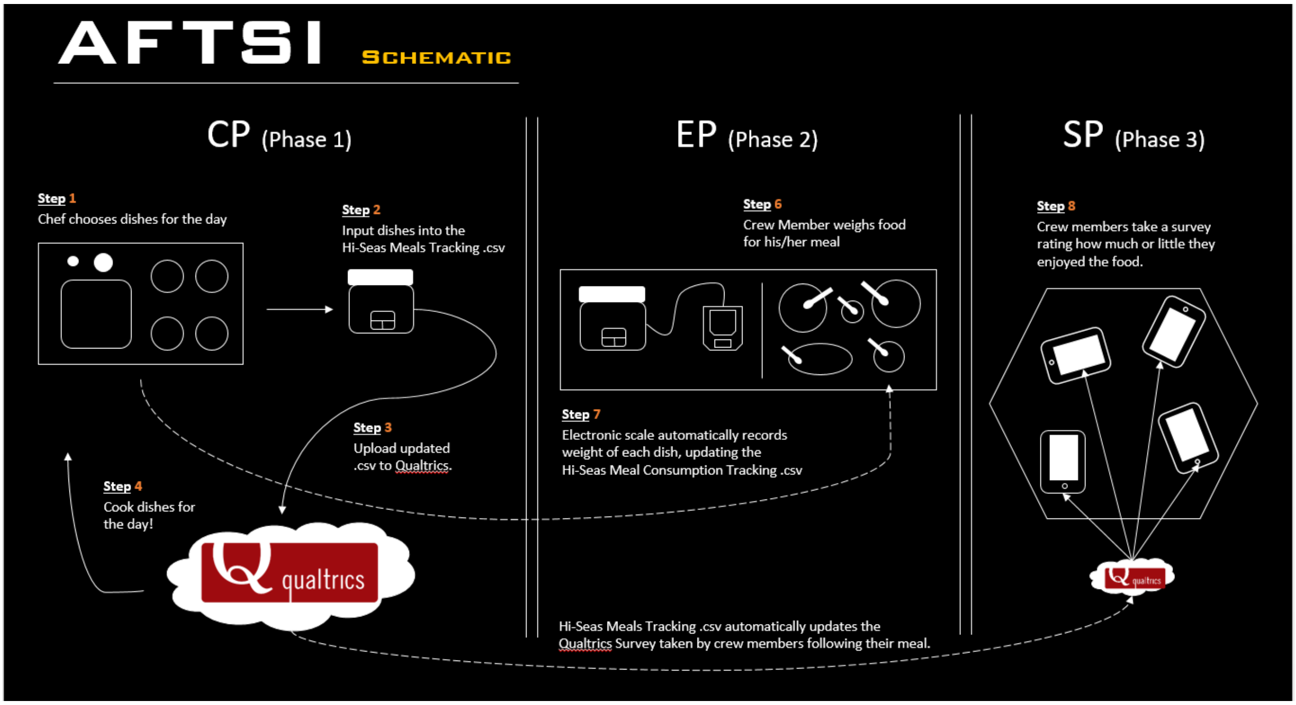


Figure 5. Schematic overview of AFTSI 3 main stats – CP (Cook Phase), EP (Eat Phase) & SP (Survey Phase).

Cooking Phase (CP)

This is the initial phase of AFTSI. The designated cook for the day begins by inputting the names of dishes, drinks or snacks that will be served into the "Cook's Menu" of the HI-SEAS Meals Tracking sheet. Those values immediately port to the HI-SEAS Intake Tracking document used by the crew to weigh the amounts of each dish for the meal. Once the dishes have been entered in the Cook's menu, the cook saves and uploads this newly updated document to the cloud

Figure 6. Key components of AFTSI.

on the Qualtrics server. The menu is saved in the form of a contact list in the Qualtrics cloud and allows the meal time surveys to pull updated dishes to the survey the crew member will later take using the Qualtrics piped text feature. Thus the AFTSI system consolidates food name entry into a single task for a single crew member – the head cook. When crew members take their mealtime survey, they no longer have to rewrite the dishes manually. They can simply pull down from the drop-down menu of dishes uploaded earlier by the cook to Qualtrics. During post-mission analysis, the normalized naming convention removes any uncertainty in determining the exact foods consumed by crew members,

Eating Phase (EP)

The middle stage of AFTSI provides a streamlined system for crew members to track the food they consume at each meal. It is developed to be as minimally invasive as possible by maintaining a natural process of obtaining food for a meal. At meal time, each crew member simply pulls up their Intake Tracking sheet before beginning to load his or her food choice for the meal. Next, the crew member tares the weight of the plate or bowl and begin loading food onto it as they normally would. AFTSI pulls weight values for each food selection directly from Ohaus Navigator Series NV 2101 scale itself on command from the crew member via infrared motion sensors. The Intake Tracking sheet has already been updated from the “Cook’s Menu” so the crew member does not need to input the name of each of food they have added to the plate manually. Following the meal, AFTSI can also account for the aggregate weight of leftover foods that are uneaten by the crew member so the final weight of food consumption can be confirmed. By re-weighing the plate or bowl with the leftover food, the remaining weight can be subtracted from the weight of the original meal to provide the net weight of food intake. In the event that a food added to the plate does not match the order of food listed in the Meals Tracking sheet, the user can access a drop down menu of all available foods for the day to change the dish they’ve added. In the event that the food they choose is not in the list of foods for the day, there is also a manual input for the dish name. The EP should also be recorded in video files to provide post-mission analyzers with a backup source of data in the case the weights or selection of foods must be verified. The system is activated at the beginning of the meal before the crew member weighs in and saved at the end of the meal with a time stamp.

Survey Phase (SP)

The Survey Phase marks the final phase of the AFTSI system. It collects full metrics on how much the user liked or disliked the meal in addition to their current state of hunger. This data is append to the data collected throughout CP and EP to help mission planners determine the most favorable meals for future missions. At each meal, the food names entered earlier in the Cook's Menu and stored in the form of a contact list are piped directly into a Qualtrics survey that crew members can complete on their Android tablet, mobile device or laptop. The survey first asks for the meal the survey will represent and then allows crew members to identify the dishes consumed from a drop down list prioritizing the food choices for that meal. This step filters the dishes down to only those consumed by the crew member, helping to avoid potential info

Figure 7. From the top view of the scale used in AFTSI testing. Note how the plate is clear and positioned so that the camera has clear view of the weight being measured.

overload and error by asking them to evaluate only the dishes they have personally selected. Crew members are also able to manually add names of dishes that were not part of the original menu. The finished surveys are accumulated on Qualtrics cloud servers and can be accessed at any time thereafter.

Benefits of AFTSI

AFTSI is a rapid solution of tracking and surveying food consumption of the crew, minimizing the invasiveness that the former system had during meal times. It reduces the labor of data cleaning and analysis for both food intake tracking and food acceptability, and reduces error and discrepancy in data collection and analysis. In addition, AFTSI also reduces the time needed for data cleanup during food identification and food weight data transcription. The core benefits of AFTSI can be summarized into 3 main categories: Speed, Error Prevention, Robust Redundancy.

Speed

AFTSI significantly reduces the time needed to collect food weight data at meal time from crew members so that monitoring intake is much more streamlined than before. Crew members no longer need to enter food names multiple times during the EP or SP phases. That data is entered once, by one person – the cook – and piped to all the mealtime use points – when crew are weighing food before a meal and when they are completing the survey after the meal. This process reduces the unnecessary time spent by all crew members to write the food eaten into a single step only one crew member, the designated cook, saving extensive amounts of time for the crew later own. AFTSI also streamlines the analytic process post-mission. In the past, data had to be transcribed from paper and pen surveys into a spreadsheet and thoroughly checked for errors. This included the data from the weighing of food as well as the survey of food likeability, requiring many hours to glean data post-mission. AFTSI completely revolutionizes this process, saving countless hours and delivering clean data from the mission to analysts directly in a .CSV or spreadsheet format that can immediately be analyzed.

Error Prevention

The AFTSI system enables standardization of food names, eliminating uncertainty on what dish was consumed and minimizing an important data cleanup step during post mission analysis. While paper and pen surveys used on past mission are flexible, allowing for on-the-spot changes to be made if the meals were altered, deviations from the menu are tricky for data analyst to identify, key in and keep track of. In addition, the flexibility of the paper and pen survey led to differences in naming of a food or dish among different crew members. During the first HI-SEAS mission, the lack of official naming convention led to numerous discrepancies identified only in post-mission analysis. For example, if whole wheat and white bread were both offered at a meal, but the crew members simply write "bread" – there is no way of tracking down the actual bread consumed without viewing video files of the food weighing. While this may seem like a simple issue, when dishes become more complex, the lack of naming convention requires post-mission analysts to rely on a great deal of guesswork, which cannot help introduce error into the data. The official naming convention established by AFTSI also helps track leftovers since each dish has an official name that travels with it throughout the usage cycle. AFTSI reduces crew workload during meal-time weighing and post meal-time surveying into electronic form, reducing paper handling on the part of the crew and decreasing risk of error during post mission analysis.

Robust Redundancy

In the former system, food weights were read off video of the scale by the analyst. This process was error prone and time consuming especially when video quality was compromised by poor lighting or focus. The new AFTSI system enables keyless weighing of foods direct to a .CSV file accurately and quickly. The process will be videotaped as a back-up record. This redundant system incorporating cook logs, video back-up and electronic scale records creates a robust system that ensures data can be reconstructed even if one of the modalities fails.

Future Work

While the system works to streamline food weight data collection it is not without flaws. Below we describe several functional features that currently limiting the usability of the AFTSI as well as several features that we recommend for inclusions in the near future. The biggest features to be added is a full-fledged smart video backup system.

Smart Video Back-Up

Currently, the entire system depends on trusting crew members to accurately set-up the system and take measurement of weights. While every effort is made to ensure that the process is as seamless and intuitive as possible, human error cannot be eliminated. One example is when a weight taken, it could accidentally be attributed to the wrong food; what's worse is that there is no safeguard that prevents this error from going unchecked. While there is a back-up camera footage, it must be activated and stopped manually, an additional step that takes time for crew members to track and one that can result in much confusion if the previous crew member forgets to either start or stop their record. In addition, manually naming these files can lead to extraneous errors for which meal and which crew member is being documented, and automatic naming of clips by time stamp fails to identify the crew member though day and meal can be inferred from the timestamp. These files also happen to range in the 1 to 3 minutes in length, quickly accumulating to hours of footage that post mission analyst must go through.

A future system would utilize either facial biometrics, I.D. cards or hand signs to activate and deactivate video footage automatically and establish layovers and attributes to the video footage, linking food weight data to the correct crew member, meal and day. This system upgrade would allow this back-up footage to be taken automatically and seamlessly without a single input from the crew, while providing a wealth of easily accessible information following the mission. This back-up system will also feature audio feedback to speak the name of the foods being served and ask after a certain time delay of no movement whether the crew member has completed weighing his or her food and automatically shut off the video recording. This system will also ask for the user's spoken ID to activate video recording while the plate is being tared, again saving keystrokes for the crew and reducing error in the data.

Reference

1. Vodovotz Y, Smith SM, Lane HW. Food and nutrition in space: application to human health. Nutrition 2000; 16:534.

2. Stuster J. (2010). Behavioral issues associated with long-duration space expeditions: Review and analysis of astronaut journals experiment 01-E104 (journals): Final report (NASA TM-2010-216130). Houston, TX: NASA Johnson Space Center.

3. Stuster, J. Bold Endeavors: Lessons From Polar and Space Exploration. US Naval Institute Press: Annapolis, MD, 1996. Ch 10 "Food Preparation"

4. Gretebeck RJ, Greenleaf JE. Utility of ground-based simulations of weightlessness. In: Lane HW, Schoeller DA, eds. Nutrition in spaceflight and weightlessness models. Boca Raton: CRC Press, 2000; 69.

5. Smith SM, Zwart SR. Nutritional biochemistry of spaceflight. Adv Clin Chem. 2008; 46:87-130.

6. 232Key Documentation Copyright © 2017 Smartlux SARL https://www.232key.com/documentation/index.html

7. OHaus Navigator Balances Instruction Manual http://dmx.ohaus.com/WorkArea/showcontent.aspx?id=24546.

Acknowledgements

I would like to take this opportunity to thank some very special people who have worked so very hard to support me throughout this M.Eng project and helped me carry myself. This project and report would not be possible without them.

To Professor Ana Diaz-Artiles and the support staff at A123 Systems and Qualtrics, thank you for your insight and for lending your technical prowess to support my journey.

A very special thanks to Brenda Marchewka who has helped accommodate to my crazy and always changing schedule with understanding and warmth – I am so fortunate to have you be the one to support me.

And last, but not least, my advisor, mentor and forever close friend, Professor Jean Hunter. This project literally would not have existed if it were not for you bringing me aboard. I owe so much of my success to you and your unrelenting support through my ups and downs from my very first day on BEE when I stepped into your office for the first time, to now, 5 very eventful years later. Thank you for always believing in me, for challenging me and for never giving up on me.

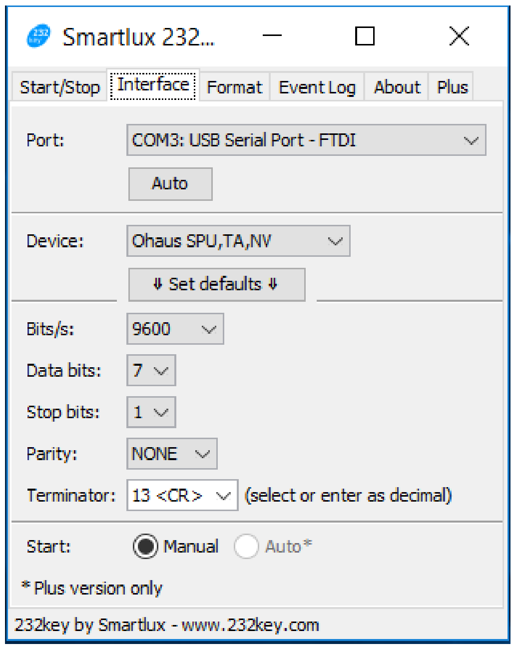
Appendix A

Ohaus Scale & 232Key Integration

A Step-by-Step How to Manual

The purpose of this document is to aid in setting up an OHaus Navigator 2101 scale and 232Key software so one can pull data readings of weight from the scale.

1. First, install 232Key (https://www.232key.com/), open 232Key up to get the settings set-up with the correct preferences. Follow the screenshot below to set-up accordingly:



(It is important to ensure your port is set-up correctly, it won't necessarily be "COM3", but it should be a USB Serial – FTDI Port. In addition, the Device should be set on "Ohaus SPU, TA, NV". The settings: 9600 Bit/s and 7 Data bits + NONE Parity are important because they must match the default settings on the Ohaus Scale)

2. Once the 232Key is set-up properly close the preferences pane and then the program.
3. Plug the Ohaus Navigator 2101 Scale into power and USB ports respectively.
4. Ensure that the computer recognizes the scale through the correct port (COM 3)
5. The next step is to set-up the Ohaus Navigator NVa2101 scale.

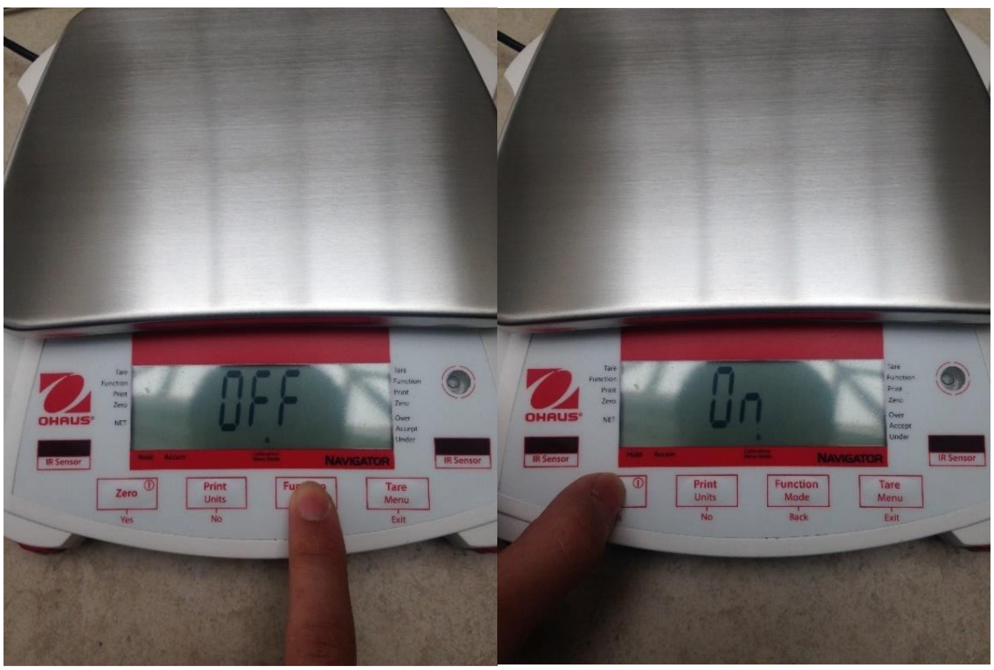
USB Settings:

The fine points of the Ohaus Navigator NVa2101 functionality are controlled via a menu in which selections are made by pressing buttons on the scale. The complete command list can be found on EN-6 at this link: http://dmx.ohaus.com/WorkArea/showcontent.aspx?id=24546.

1. Press and hold the "Tare/Menu/Exit" button for 3-5 seconds to activate the menu.

2. Push the "Function/Mode/Back" button twice to scroll past "END" and reach the "USB" menu.
    a. Press the "Zero/Yes" button to access the "USB" settings
    b. Pressing "Zero/Yes" again displays the "ON-OFF" readout

3. To change the setting from "OFF" to "ON", press "Zero/Yes" again.



   a. Use the "Function/Mode/Back" button to toggle between "ON" and "OFF.
   b. Press "Zero/Yes" to exit and save the "ON-OFF" settings with the "ON" setting displayed.

4. The Scale will now automatically display the next setting, "bAUd" (https://www.setra.com/blog/what-is-baud-rate-and-what-cable-length-is-required-1) which coincides with the Bits/s setting in the 232Key software and sets the rate of data transmission.

5. To change the data transmission rate setting to the correct 9600 Bits/s to match that set in the software, push “Zero/Yes” again; this action displays the rate in bits/s.

   a. Use the “Function/Mode/Back” button to toggle among 19200, 9600, 4800, 2400, 1200 and 600.
   b. Once you’ve reached the 9600, Press “Zero/Yes” to exit and save the “bAUd” setting.
6. You should now be in the next setting now, “PAritY” (https://www.computerhope.com/jargon/p/paritybi.htm) which coincides with the Data bits and Parity settings in the 232Key software.
7. To change the setting to the correct “7-NONE" to match that set in the software, push “Zero/Yes” again.

a. Use the “Function/Mode/Back” button to toggle between 7-nonE, 7-Odd, 7-EvEn, and 8-nonE

b. Once you’ve reached the 7-nonE setting, Press “Zero/Yes” to exit and save the “PArity” setting.

8. Press the “Zero/Yes” button again to scroll past the “HAndShJ” setting set at “nonE” (which defaults to the correct setting) and reach the “End” of the menu.

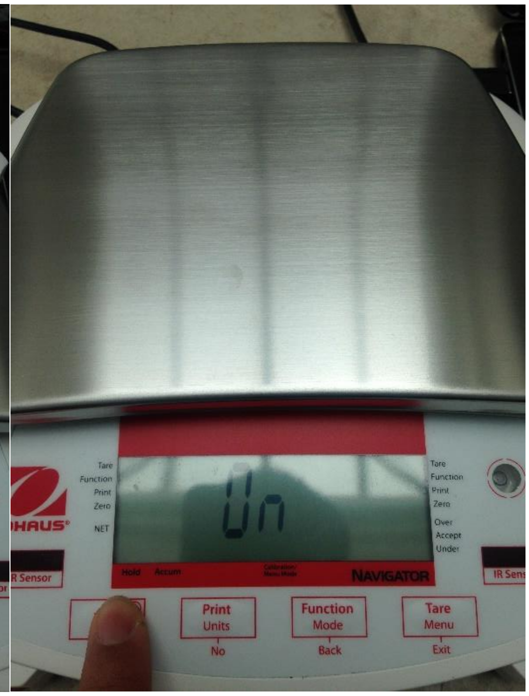
a. Push “Tare/Menu/Exit” to return to regular weighing mode at which point the scale will display “End” and then automatically cycle to 0.0 grams.

Print Setting

1. Press and hold the "Tare/Menu/Exit" to re-enter the scale control menu.

2. Push the "Function/Mode/Back" button three times to scroll past "END" and reach the "PRINT" menu.
3. Press the "Zero/Yes" button to access the "Print" settings

4. Pressing “Zero/Yes”, will display the “StAble” readout.



a. Use the “Function/Mode/Back” button to toggle between “On/Off” settings.

b. Once the “ON” setting is displayed, Press “Zero/Yes” to exit and save the “StAble” setting.

5. Once exiting the “StAble” setting, the scale should cycle the next setting, “A.Print”.

a. To change the setting to the correct "On.Stbl" setting, press the "Function/Mode/Back" button to toggle between "Off and On.Stabl".

b. Once you've reached the right setting, Press "Zero/Yes" to exit and save the "A.Print" setting.

6. You should now be at the "End" of the Print menu.

7. Push "Tare/Menu/Exit" to return to regular weighing mode.

Operation

1. To start sending readings to the computer, open the 232Key software and press "Start" on the 232Key software, then place the mouse cursor into the Excel document to take a test reading
2. Place a test weight on the scale.
3. Once it stabilizes, wave a finger above the right IR sensor to trigger the scale to send the data to the Excel file; the number should coincide with the reading taken in the scale. Speed
4. As more weight is added, the scale will continue to record readings and await a crew member's command (wave a of finger above the right IR sensor) to push the value into the cell adjacent to the first reading. If IR sensors doesn't work, update the firmware on the scale.

Known Limitations:

- In order for the scale to stabilize a new reading, the new weight must be at least 0.5-0.6 grams different from the old weight. Smaller than that, and the scale is error is too great to maintain accuracy. While there are many errors in nutrient intake tracking and the low energy value in 0.5-0.6 grams of food (no more than 5-6 calories or 0.3% out of a more than 2,000 calorie/day diet), this limitation means that condiments such as salt, soy sauce and ketchup or vitamin supplements should not be weighed in, but rather estimated on the meal time surveys.

Future Work

- Build an Excel GUI that's easy for HI-SEAS crew members to use easily in conjunction to weigh their food quickly and easily during meals.
- Error detection and a built-in audio/visual feedback system to ensure the data collection is as accurate as possible.

Appendix B

Definition of Files	
"Cook's Log"	A daily list of food/drink that the cook plans on serving for the day.
"Cook's Menu"	Menu of the dish names that are prepared and piped to Qualtric surveys.
"HI-SEAS Meal Intake Tracking"	Excel tracker that pulls dishes from the "Cook's Menu" and displays it readily for tracking food weight for each individual crew member.

-