

MSS21B Thesis Project Student Opportunities

1. Introduction

ISU is searching for qualified applicants for MSS21 Thesis Projects to start in January 2021. Qualified applicants **must** have either:

- Previously completed ISU's MSS Year A with an overall grade of B- or better
- Be a current MSS20A student with grades of B- or better in both M2-ISS and M4-IPR **and** be in a position to complete MSS20A by (December)

Thesis project tuition is EUR 7500. Financial aid is available through ISU's Admissions Office. Depending on the particular thesis project topic, the thesis project may have to be performed at ISU or may be performed remotely.

2. Application procedure

Interested applicants shall provide a curriculum vitae/resume and a letter of interest (both in English) indicating how their background and experience fit the requirements of the thesis project(s) that they are interested in. Applications shall be submitted no later than midnight CET Sunday 6 December 2020 and shall be sent to: admissions@isunet.edu

3. MSS21B Thesis Projects Opportunities

The overall list of thesis project opportunities is given below with descriptions following:

1. ISU SPL ISS Interactive Payload Design
2. ISU SPL SMiLE Payload Development
3. ISU SPL SHEE Restoration
4. Biomedical findings from NASA's Project Apollo
5. Medication production made feasible for space missions
6. Search for nearby comoving stellar streams
7. Refurbishment of the ISU Haystack antenna and radio astronomy
7. Interaction between life and magnetic field
8. Human factors for analog astronauts before, during, and after a 4-week Mars analog mission in the Negev Desert, Israel
9. Evaluation of the market of dedicated European smallsat launchers to launch at Southern Hemisphere
10. Bloom event prediction by satellite image analysis
11. ETHNO-ISS: An ethnography of an extra-terrestrial society

3.1 ISU SPL ISS Interactive Payload Design

Building on the successful design, construction and testing of the Hydra-3 interactive payload [1] the ISU Space Payloads Lab (SPL) now wishes to continue research into interactive payloads on the International Space Station (ISS).

The International Space Station is now in 20th year and will shortly be receiving two private astronaut missions (PAMs) each year. Space Hero plans to deliver a private astronaut - the winner of a global casting show - to the ISS in 2022, for a 10-day stay. While the private astronaut is on board the public will be able to interact with them. This is quite a narrow time-window, however, and it would be beneficial to increase public interaction with the ISS after the private astronaut has returned to Earth via a payload that would be delivered on the flight.

Building on the SPL experience of interactive ISS payloads and relevant missions to date [2][3], the aim of this thesis project is to carry out the preliminary conception and design of an interactive payload/system for the mission with the aim of bridging the gap between space exploration and research and the public's perception of it. Background questions (not an exclusive list) to be addressed might include: Would interactivity through technology help? If so how? What role might smartphones play in enhancing the relationship of the public with the space sector?

The objectives of the project are

1. Identify potential roles for an interactive payload and the relevant.
2. Downselect to a preferred list of functions/payload.
3. Perform conceptual payload design.
4. Propose the payload for flight to the ISS.

[1] ISU SPL: <https://www.isunet.edu/space-payloads-laboratory/>

[2] Airbus: "Hello, I am CIMON*!": <https://www.airbus.com/newsroom/press-releases/en/2018/02/hello--i-amcimon-.html>

[3] Scoles, Sarah: "The Floating Robot With an IBM Brain Is Headed to Space": <https://www.wired.com/story/the-floatingrobot-with-an-ibm-brain-is-headed-to-space/>

3.2 ISU SPL SMiLE Payload Development

SMiLE (Spun Microgravity Liquid Experiment) is an ISU Space Payloads Laboratory project for the ISS. The purpose of SMiLE is to investigate the development of droplets produced when a liquid issues from a circular nozzle at a constant flow rate in a microgravity environment. SMiLE consists of a liquid injection assembly and a viewing chamber assembly which includes image recording capability. The experiment provides precise control of the flow velocity (Reynolds and Weber numbers) via a syringe pump driven by a stepper motor and records the surface profiles of the produced drops via a high-resolution stereoscopic camera setup. Fluid temperature and system state properties are monitored and logged. The experiment itself requires a large number of droplets to be produced at each condition ($N > 1,000$) to provide statistically relevant results on drop formation dynamics. An engineering model of SMiLE has already been designed, constructed and flown on a parabolic flight.

The aim of this thesis project is, with ISU SPL staff, to extend the SMiLE project further and start the final preparation of a flight model and related design reviews. The expected objectives supporting this aim are to:

1. Review the current status of SMiLE and identify and further design changes required.
2. Conduct a design review and implement any recommendations that arise.
3. Develop and test flight hardware in accordance with flight provider requirements.
4. Support preparation for payload flight.

Required student skills/attributes: Interest in public space education, outreach and public communication combined with suitable analytical and technical skills.

3.3 ISU SPL SHEE Restoration

The Self-Deployable Habitat for Extreme Environments was a European-commission funded project to develop a self-deployable autonomous architecture and technology test-bed prototype for simulation of operations in extreme environments for analog research. The project was executed by a seven-member consortium, managed by ISU and was completed in 2017. SHEE is currently located in the ISU High-Bay. In late 2019 the ISU Space Payloads Laboratory (SPL) tasked with responsibility for SHEE. At three years old, however, SHEE has started to develop some issues which need to be addressed if it is to continue to be of value as research and outreach tool.

In the three years between since the end of the project SHEE's structure has deformed leading to significant issues with its deployment and closure. The extent of this deformation and the appropriate remedies for it need to be identified and, if possible, implemented to restore SHEE to original operational state.

The aim of this thesis project is, with ISU SPL staff and members of the SHEE consortium, to initiate the renewal of SHEE and, where possible, execute it.

The expected objectives supporting this aim are to:

1. Assess the current status of SHEE.
2. Identify the key issues that need to be addressed to restore SHEE.
3. Define and cost potential solutions to these issues both in the short-term and the longer-term.
4. Develop a plan for the implementation of these solutions.
5. Where possible, implement the solutions identified.
6. Restore the SHEE project archive.

3.4 Biomedical Findings from NASA's Project Apollo

This is part of a continuing (unfunded) collaboration with a retired flight surgeon William Carpentier and retired chief scientists from earlier days of NASA. Dr. Carpentier has a wealth of biomedical data he collected but never published. One paper using his data from Project Mercury has recently been published. It included a new analysis across all the Mercury flights and simulations and the findings are relevant for new missions being planned by space agencies and commercial spaceflight providers. The intention is to do the same with Carpentier's data from the Apollo missions.

The aims of this thesis project are to:

1. Examine unpublished Apollo-era biomedical data with the needs of new lunar, exploration, deep space, and commercial spaceflights in mind.
2. Publish results in the biomedical literature so that others may benefit from the findings.
3. Publish the data so that others in the future may benefit from access to the data.

The tasks to be carried out during the thesis project include:

1. Reading through old paper documents (provided by W. Carpentier) to extract biomedical data.
2. Compiling the data for analysis.
3. Performing basic statistics and graph making.
4. Collecting details of the Apollo missions from additional sources.
5. Developing and testing new hypotheses using the data set.
6. Examining current and planned mission designs, equipment (government and commercial) to ensure re-analyses has relevance for future missions.
7. Writing manuscript(s) for publication in peer-reviewed biomedical literature

3.5 Medication Production Made Feasible for Space Missions

There are two major issues for supplying medications for spaceflight. Medications can be sent along with astronauts, but the upmass is costly, and it can be operationally difficult to match supply with demand. One currently unsolved problem for long-duration spaceflight missions is medication expiration. Medications degrade over time and most medications expire after two years, one year short of planned Mars mission durations. Inflight production of medications could address both issues.

It is now technically feasible to genetically-engineer plants and algae to produce active pharmaceutical ingredients. Growing plants and algae is desirable during a space mission since they remove carbon dioxide from the spacecraft environment, reducing a potential hazard to human occupants. Other projects (funded by NASA & ESA) are investigating the growth of plants and algae for astronaut food; this project will determine the feasibility of using plants and algae to produce medications needed on space missions.

Aims:

1. Choose a yeast, plant or algae feasible for growth during a spaceflight mission
2. Choose a pharmaceutical need on space missions whose active pharmaceutical ingredient (API) is also feasible for genetic transfer, and also feasible for purification from the host plant or algae.
3. Perform proof-of-concept demonstration. Engineer a plant or algae to produce a pharmaceutical active ingredient.
4. Develop & test a mission-feasible protocol for purification of the active pharmaceutical ingredient (API)

3.6 Search for nearby comoving stellar streams

The study of stellar streams has become a hot subject in astrophysics, because the study of such nearby populations of single-age, single-composition stars can shed light on a variety of topics, from stellar and brown dwarf evolution, target list to search for exoplanets (around young stars), stellar cluster evolution and gravitational perturbers such as black holes and giant molecular clouds.

The technological advance leading to the ESA Gaia mission and massive spectroscopic surveys has allowed us for a couple of years to efficiently look for such structures, that are defined by a common 3D space motion. With these data, we can look among 10s or 100s of millions of stars using their angular motion (projected on the sky), distance (or parallax really), photometry (colours and luminosities) to identify groups of 10s or 100s of stars that likely originate from the same birthplace.

The goal of this project is to test sophisticated methods to efficiently swipe through a large dataset (10⁸ entries in multi-dimensional space) and obtain a meaningful sample of stellar group candidates. The student will learn and work on statistical methods, as well as some background in stellar physics and dynamics of the Milky way.

The starting point of the project will be to adapt a code written to detect stellar streams of the Galactic halo, STREAMFINDER (Malhan et al., 2018), developed at the Observatory of Strasbourg, that has efficiently detected dozens of new streams in the Gaia DR2 data. With the help of the code developers, the intern would adapt and run the code on the Gaia DR2 data to search for nearby streams, within 500 pc (1500 ly) of the Sun, in contrast to the streams detected so far, at hundred times the distance. The student will analyze the stream candidates, select the most interesting ones, and study their properties.

The student will:

- understand the methodology beyond the code, and key parameters to be adjusted to perform the search
- define and prepare the dataset out of the Gaia Data release 2 catalogue: identify the well-measured stars and the parameters of interest;
- run the analysis pipeline to select stream candidates;
- try and adjust the selection parameters;
- identify the most promising stream candidates
- perform the analysis of their properties
- write a paper explaining the different steps of the selection, the final sample, and an analysis of their properties.

3.7 Refurbishment of the ISU Haystack antenna and radio astronomy

About 10 years ago a 2.3-m radio telescope (SRT) capable of continuum and spectral line observations in the L-band (1.42 GHz) was installed at ISU. Designed and named after the MIT Haystack observatory, the telescope has been successfully used to detect neutral hydrogen gas at the 21cm emission line, allowing to map the hydrogen content of the Galactic Plane and deriving its radial velocity distribution and the rotation curve of the Milky Way.

As of about a year ago, the antenna got stuck. The antenna was dismantled in October and we began investigating the problem. Unfortunately, mid-February 2020, Storm Ciara damaged the instrument. In addition, 10 years of operation and weathering have taken their toll and some parts and cables have aged.

The goal of this thesis project would then be to refurbish the antenna mechanical support, cables and electronics. The current problems should be studied, worn parts identified, and a solution should be proposed, and put into place. Outside boxes should be made waterproofed again. In addition, the control and analysis software should be upgraded and ported to a 64-bit computer.

Finally, an observing program, which could be conducted by future MSS students and Unistra students, should be established and tested.

The main goal of the project is to refurbish the antenna so that it can again operate satisfactorily, obtain measurements, and be prepared to cope with the weather for another 10 years.

Once this is done, an educational program can be designed, described in a manual, and performed. Outreach options for this instrument could also be proposed.

3.8 Interaction between life and magnetic field

It is well established that the geomagnetic field (GMF) protects life on Earth by deflecting harmful solar and cosmic radiations thus preventing DNA damage. However, multiple observations are pointing towards a more intimate relationship between the GMF and life from animal navigation, plant growth, circadian rhythm synchronizer or basic survival. This means that a PMF would be absolutely necessary for life maintenance on exoplanets.

Several scientific articles are mentioning that weak magnetic fields are also important for animal survival and tissue regeneration. One of the best animal models for regeneration is planaria, a well-studied flatworm in the field of tissue regeneration. In fact these animals when cut into small pieces can regenerate a whole individual. Besides many molecular biology tools have been developed and the genes involved in such process are now known

The general aim is therefore to study the effects of different magnetic field conditions (shielded, GMF, strong field) on planarian and tissue regeneration

Sub Aims:

1. Learn how to maintain different planarian species in the lab.
2. Build set-up in order to apply different magnetic field conditions (material available in INCR CNRS lab)
3. Implement tools to assess animal and tissue regeneration
4. Draw conclusions on magnetic field and life

3.9 Human factors for analog astronauts before, during, and after a 4-week Mars analog mission in the Negev Desert, Israel

Between the 15 October and 15 November 2021, the Austrian Space Forum (OeWF) – in cooperation with the Israel Space Agency as the host agency and D-MARS – will conduct an integrated Mars analog field mission in the Negev Desert in Israel. The expedition will be carried out in a Martian terrestrial by a small field crew of 6 highly trained analog astronauts using Mars suit prototypes thus taking part in preparing for future human and robotic Mars exploration.

Two Human Factors Experiments have been selected for the AMADEE-20 mission in the Negev Desert in Israel. Both experiments will be finalized, deployed, run, analysed completed and published as part of this thesis project. The thesis project outline will be the same in each case:

- Literature review
- Finalize experimental procedures
- Optimize experimental cascade
- Participate in and Represent Principal Investigator at meetings and dress rehearsals (virtually)
- Prepare and ship experimental tools to Mission Support Center in Innsbruck, Austria
- Implement experiments with the Mission Support Center in Austria
- Collect and analyze data
- Draft final report
- Prepare results for scientific publications and conferences
- Engage with media
- Complete and submit thesis

Experiment A: PsychScale: Scientific Description

Research Rationale: Mars analog astronauts undergo a rigorous selection and training process to ensure crew cohesion and mission success. However, even the healthiest, strongest individuals may face psychological challenges due to various stressors in extreme or abnormal environments. Examples of these stressors include isolation, confinement, close living quarters, monotony of food, delayed communication with ground control, time pressure, scientific or engineering failures, sleep difficulties, fatigue, etc. In our effort to further human space exploration in a safe and effective way, we must thoroughly understand and protect the psychological well-being of crew, before, during, and after the space analog mission. This project has the potential to inform prevention strategies including resilience training for the mental health and overall well-being of analog crew members at the individual and group level.

Research Aims: This project aims to study crew member anxiety and depression levels before, during and after space analog mission in order to better understand psychological well-being in response to known and unknown environmental stressors. This project further aims to study the correlation between crew anxiety and depression levels and the possibility of a “third quarter phenomena” (TQP) whereby the first quarter of the mission may be characterized by crew excitement or anxiety, the second quarter by boredom and depression, and the third quarter by increased emotional outbursts.

Experimental Tool: This experiment uses the Hospital Anxiety and Depression Scale (HADS) - an

internationally recognized, validated questionnaire on anxiety and depression with a fourteen-item standardized scale that generates ordinal data for later analysis and interpretation (attached). We have included two open-ended qualitative questions that allow the participant to inform the scientific team of any issues related to individual or crew mental-health. This experiment is currently running in the DMARS mission, and can be further optimized for use during the AMADEE-20 mission to create a unique longitudinal data set for robust analysis. In addition to the standardised questionnaire, we have added two additional open-ended questions to allow crew members the opportunity to inform the scientific team of any issues that may have impacted their mental health. The protocol is very simple and only requires the use of a working pen, preferably in black ink, paper copies of the two-page questionnaire, and sealable envelopes for each crew member. The envelopes will be numbered to coincide with the time-points the questionnaire was completed. Completed questionnaires will be collected at the end of the mission, scanned by the AMADEE-20 team to ensure electronic back-up of data, and paper copies will be sent to the project PI. Data analysis will be conducted at the end of the experiment by the PI and project team using a secure network, university commissioned laptop, and statistical software.

Duration: Participating crew members will respond to the questionnaire before, during and after the analogue mission. To ensure operational efficiency, exact dates for completion of the questionnaire will be confirmed with the AMADEE-20 team.

Number of participants & participant expertise: The minimum number of participants is one (1). Participants require no expertise in the fields of psychology, medicine or human factors. However, the questionnaire will be administered in the English language and participants will therefore be required to read and respond in English.

Ethics and Risk Assessment: The experiment is safe, and the questionnaire will be self-administered in paper format for which no expertise in the fields of psychology, medicine, or human performance is required. Once completed, crew members will insert their completed questionnaire into numbered, sealed envelopes. The questionnaire responses are anonymous. Crew names or other identifying information will not be made available to the research team. All crew members shall retain the right to stop their participation in this experiment at any time. Ethics approval will be sought from the home institute of the PI. Final acceptance of this experiment is dependent on ethics approval from the PIs home institution.

Dissemination plan. The study protocol and research results will be submitted for conferences and peer reviewed publication, and used for teaching purposes including:

- submitted for presentation at the International Astronautical Congress and the European Mars Conference
- submitted for publication in the peer-reviewed journal Acta Astronautica
- used for teaching purposes at the International Space University, and other institutes upon request

Experiment B: MOVE: Scientific Description

Research Rationale: Normal bowel movements differ between individuals, and within the same individual over time. Factors such as diet, dehydration, increased stress, reduced physical

exercise and exposure to extreme or abnormal environments, can have a negative impact on the frequency, consistency, color and overall control that an individual has over his or her bowel movements. Short-term difficulties may be alleviated by addressing some of these factors, for example, increased fiber or fluid intake, but longer-term issues or acute difficulties in the shorter-term may be symptomatic of something more serious. For example, diarrhea or blood in the stools may indicate an infection. Abnormal bowel movements could negatively impact biological, psychological and social domains of the individual, and potentially the entire crew. By tracking the bowel movements of analog crew we have the opportunity to intervene with medical care if necessary. Results from this study have the potential to inform prevention strategies for future planetary analog missions.

Research Aims: This project aims to study the frequency and consistency of bowel movements among crew during the isolation period of the space analog mission. We aim to better understand the effects of environmental stressors on bowel function. The data will be monitored weekly to inform the medical team, and prevention strategies will be established to ensure optimum health and well-being of crew members on future analog missions.

Experimental Tool: This experiment uses a laminated paper size A4 with four different images in each quarter of the paper. The quarters will be labelled A-B-C-D. Each quarter will display a unique image representing four possible types of excrement ranging from healthy to unhealthy. The four images will be selected in collaboration with the AMADEE-20 Medical team. The laminated A4 with accompanying images will be affixed to the inside of the door, at eye level to a crew member sitting on the toilet. Immediately after a bowel movement, the crew member will log the entry using a pen and paper summary sheet that will be posted on the outside of the door. A photograph of the log chart will be taken weekly and sent to the support team. The data will then be monitored by the Medical team to inform intervention if necessary. Prevention strategies will be developed to ensure optimum health and well-being of crew members.

Note: Because of the timing of the field mission, this project would start in the March-June 2021 timeframe.

3.10 Evaluation of the market of dedicated European smallsat launchers to launch at Southern Hemisphere

The Southern Hemisphere offers a number of advantages to put satellites in SSO and polar orbits (estimated in the future of over 50% of all smallsat orbits), in particular offering the advantages of

- Low population areas
- Low air-traffic interference
- Low shipping/fishing activities and interference

This is resulting in a number of launch proposals from that area (in particular Australia and New Zealand) to provide such launch platform, by using launchers from Western countries.

These launch providers are in particular interested in non-US launchers to avoid ITAR issues.

Aims and Objectives

- Evaluate the feasibility of launching European launchers in Australia
- Provide an inventory of potential candidates including readiness

Tasks will include

- Examine the development of such micro-launchers in Europe
- Evaluate the TRL of each of them with the published estimated readiness
- Study the new export control regulations of Australia
- Evaluate the export control regulations of the different European states producing these launchers, in particular with emphasis on launchers and components
- Evaluate other barriers, such as transport cost penalty

3.11 Bloom Event Prediction by Satellite Image Analysis

WATERSHED MONITORING EUROPE and SCALIAN propose to conduct a joint feasibility study on the BEPS-IA (Bloom Event Prediction by Satellite Image Analysis) project. The latter will be based on the development of a solution capable of estimating the probability of occurrence of a cyanobacterial proliferation event in the medium term (a few days after the satellite image is taken). The solution will consist of an application integrating an artificial intelligence model that has learned to extract the detailed information contained in spatial infrared orthophotographs that have undergone digital post-processing. We will propose to integrate into the study a variable study area, ranging from local to regional scales. Indeed, the current state of the art indicates that the dynamics of cyanobacteria populations are largely impacted by fluctuations in their local environment, but also by events taking place several kilometres away from the water body under study.

o Proliferation of cyanobacteria :

It is unanimously agreed that cyanobacterial blooms in the world's freshwater reserves already represent a pronounced health, economic, and ecological risk, and that their frequency will increase in the context of global warming.

In this context, attempts to model the behavior of cyanobacterial communities in lakes on a global scale have been emerging for many years, identifying water temperature and nutrient resources as key factors in the dynamics of these populations. However, thermal or chemical surveys are for the vast majority of cases carried out in situ which are costly. In addition, traditional spot sampling efforts do not offer sufficient spatial coverage and therefore do not lead to an efficient predictive tool. The need for predictive tools is currently clearly expressed, particularly in the USA [13].

o Spatial imaging

Spatial imagery made available to a larger number of economic actors, tends to demonstrate its usefulness in a wide field of application. In the present case, we note that this technology manages to remove obstacles in the monitoring of water quality, in particular the difficulty of evaluating the values of certain key variables at the scale of a lake or its catchment area.

This project builds in part on the findings of work published in 2005 demonstrating that thermal infrared data from ASTER, Landsat and MODIS instruments can be used to map updrafts and flows associated with heat, solute and particle transport in lakes. These same events are identified as impacting the dynamics of cyanobacteria bloom development (see previous paragraph). Temperature is not a simple predictive variable, but rather an indicator rich in information on the dynamics of a lake.

o Artificial intelligence:

Very early in the history of neural data science, convolutional networks demonstrated interesting properties for processing complex signals, but it is only with the arrival of GPUs that the full potential of these methods emerged, especially in image processing. While the initial disadvantage of this technology is its huge need for data in order to achieve satisfactory learning, Transfer Learning methods make it possible to overcome this constraint by adapting pre-trained networks for similar tasks.

Today, there are a large and innumerable number of networks pre-trained for identification and classification tasks, and made available to Data Science communities. Among the editors of the most popular models are Google and its Inception models, or Facebook and its ResNeXt-50 . The diversity of network architecture accessible today makes it possible to address the use case by its temporal component (prediction thanks to several successive images over time), or for a single snapshot (identification of a profile recognised as being conducive to the development of a water flower).

A5. Project Aims and Objectives

The prediction of cyanobacterial proliferation events is a major challenge for any population dependent on a freshwater reservoir (artificial, semi-artificial or natural). The service provided by the BEPS-IA project aims to provide water agencies, the public, government agencies and the water supply managers with an accessible means of predicting, through spatial imagery, a bloom event that may affect human and animal health but also local activity due to its potential toxicity.

SCALIAN, as a bonus, wishes to consolidate its expertise in the development of artificial intelligence on a subject of environmental importance and in relation to its scientific development strategy for the urban health market.

WATERSHED MONITORING EUROPE, as an expert in water quality monitoring, wishes to take advantage of the efficient exploitation of knowledge intrinsically supported by spatial images.

Objectives :

The main objective of the BEPS-IA project is the implementation of a tool (distributed environment) for the prediction of cyanobacterial blooms on lentic water bodies by comparing spatial orthophotographs and a deep learning algorithm (Convolutional Neural Network). The main purpose of this tool is the preservation of health, economic activities and ecology that depend on water bodies.

The second objective of this tool is the optimization of water quality monitoring programs by using data that have so far been little or not at all used, thus reducing the load dedicated to data sampling. This is where the year-B student would concentrate his/her efforts.

- Specific objectives :
- Conduct a literature review on the use of spatial imagery to improve water quality monitoring of lakes & estuaries ;
- Establish use-cases on how spatial imagery could improve traditional water quality monitoring;
- Conduct a stakeholder survey to verify interest in these type of monitoring solutions and predictive tools;
- Note: Other specific objectives will be established based on the capacities, knowledge & objectives of the student.

3.12 ETHNO-ISS: An Ethnography of an Extra-terrestrial Society

ETHNO-ISS a project based in the School of Anthropology at University College London (UCL). UCL and ISU are engaging in co-operative activities in the space domain and an ISU thesis project in the area of Ethno-ISS is under consideration as part of this co-operation.

The International Space Station (ISS) is arguably the oldest extra-terrestrial society in low earth orbit. To date this radical new form of human habitation and society has not been the object of systematic and comparative ethnographic inquiry. This project aims to correct this and proposes a comparative and multi-sited ethnography of the ISS among the contributors to its modular architecture: The Russian Federation, The United States of America, The European Union and Japan. The ISS offers invaluable insights into fundamental questions at the heart of the social sciences. The most obvious is the effect of micro gravity on our understandings of material culture and sociality. To date material culture has only been theorised in terms of Earth's gravity.

This project affords the opportunity to critically re-examine our terrestrially based theories. Related to this are the distinctive political aesthetics in this setting and its innovative dimensions of 'worlding' (Heidegger) and the materialities entailed therein. These relate to wider notions: the nature of transcendence in both anthropological, material and metaphysical terms as well as broader issues concerning territoriality and the expansion of the human and habitability and general understandings of materiality. Methodologically the project focuses on the quotidian and material dimensions of the ISS and its bodily and material techniques, re-examining traditional empirical assumptions within the innovative conditions of the new polymedia environments in which the ISS is situated. More importantly the project situates the respective Mission Controls and their wider communities as co-terminous with the ISS site, examining it as a complex nexus of inhabitation encompassing both terrestrial and extraterrestrial realms in a novel configuration and thereby provide the first ever integrative and comparative study of this unprecedented form of human society and the material conditions of its emergent 'wording'.

What happens to our fundamental categories of analysis in the social sciences when we study them extraterrestrially? To date most of our understandings of the fundamental concepts which underpin the social sciences, such as transcendence, kinship, materiality, architecture, sovereignty and the body, have been conceived solely in terms of Earth's gravity. How these basic categories of analysis might be understood under conditions of microgravity affords us the opportunity to move beyond the 'meta-assumption of gravity' that informs our theorising. For over 18 years, humans have lived in a 'home' that has left Earth and orbits it every 90 minutes in low Earth orbit (LEO). Yet, this unique extra-terrestrial society has been largely unexamined within mainstream anthropology and material culture studies. ETHNO-ISS will question and investigate how extra-terrestrial living informs our longest held terrestrial assumptions within the social sciences in a ground breaking and innovative, comparative and multi-sited ethnography of the International Space Station (ISS).

ETHNO-ISS will concentrate on the key governments and space programmes that constitute the ISS: Russia, USA, European Union, and Japan. The ETHNO-ISS Team will consist of six researchers: the PI, four post-docs and one PhD/post-doc. Building on earlier ethnographic study of the ISS (Palinkas 2007, 2001; Stuster 1990, 2011, 2016), each researcher will conduct fieldwork in six interweaving themes: altered bodily states; materiality and microgravity; the body and built

form; body/robotic hybrids; visibility and sovereignty; and transcendence and kinship. Research will be conducted at five terrestrial sites where ISS mission controls are located in Houston, Munich, Moscow, Tsukuba plus London. These themes and field sites are unified under the general theme of 'worlding' (Heidegger 1993) through the one common object: the ISS in its combined terrestrial and extraterrestrial nexus. To date such a comprehensive and comparative study that takes in both the terrestrial (Mission Controls and their communities) and the extra-terrestrial (the ISS and its communities) has not been attempted.

The ISS is arguably the oldest extra-terrestrial society in human history and likely to be decommissioned in 10 years. ETHNO-ISS is therefore proposed at an historically important juncture before this unique extra-terrestrial society disappears along with the opportunity to study and interrogate our fundamental, terrestrially based assumptions of materiality in the social sciences. This research will be conducted at an unprecedented scale and level of synthesis through a methodologically innovative, systematic and comparative ethnographic study of this radical new form of human habitation and society.

ETHNO-ISS SIX THEMES: Over five years, ETHNO-ISS will develop along six themes which explore the project's overarching theme of 'worlding'. An iterative, collaborative structure of exchange between the researchers will occur across the project's terrestrial sites. These mirror the ISS's daily and regular communications with the different mission controls. Each of the ETHNO-ISS post-doctoral researchers is a mature scholar in their own right whose specific skills, expertise and established background in space based research and the wider theoretical themes of the study will shape their individually focused research projects in relation to the themes discussed below. The programme also supports a closely supervised PhD.

UNIFYING THEME) 'Worlding': The ETHNO-ISS' six themes are unified by and contribute to the scholarship of 'worlding'. Heidegger's neologism describes the dynamic, mutually constitutive and continuously unfolding processes whereby that which is intimate (on a bodily level) and that which is far-reaching (in terms of relationships with the cosmos) is dynamically and mutually configured in relation to one another in terms of empirically describable constantly expanding worlds (Heidegger 1993 and following Battaglia et al. 2012). The ISS is discussed as an extra-terrestrial home by those who inhabit it terrestrially and extra-terrestrially. Yet it is a home that is both 'homely' and 'unhomely' as it negotiates this expanding nexus between these two convergent realms in the process of 'worlding'. The observer is fascinated by the seemingly banal activities of extra-terrestrial domestic daily life which under the vexing conditions of microgravity produce an extraordinary grip on the scientific and lay imagination. If seemingly mundane activities encapsulate the deepest structuring principles of a given society (Bourdieu 1977), then these activities on Earth and in space acculturate one into the other expanding both and enabling 'worlding' at the most intimate level. The quotidian serves as the immediate and readily assimilated means by which one participates in and relates with the 'other,' enabling a fusion of horizons and provides the empirical evidence for the processes of 'worlding' the ETHNO-ISS Team will examine across each of the research sites.

THEME 1) ALTERED BODILY STATES: The ISS presents a unique challenge to the way we think of the body and body techniques in anthropology. Under conditions of micro-gravity, the body adapts and changes as it leaves the origins of its evolution – muscles atrophy, bone density diminishes, calcium is lost, and balance is compromised by the lack of a vertical orientation. The

lower body appears superfluous, and radical new 'extreme' bodies (to use Olson 2010 and Battaglia et al.'s (2012) phrasing) are reconfigured in novel and unfamiliar ways. Here, a new emergent political economy is literally experienced bodily and atmospherically as it is aligned and dissipated in new conditions in relation to the expanding nexus of terrestrial and extra-terrestrial worlds (in this case, the ISS in LEO, see Valentine 2017). The ISS crew's notion of self is permeable, multiplicitous, extended, and influenced by their engagements with the social and material in ways that are unprecedented. The Munich based and former NASA funded researcher will examine these questions in depth in relation to the ESA's physiological experiments on the ISS.

THEME 2) MATERIALITY IN MICROGRAVITY: Just as the study of the body has always been understood under the conditions of Earth's gravity, so has the study of material culture and its social effects. ETHNO-ISS offers a unique context for the study of material culture. The PI will conduct ethnographic research at two US sites. First in California at 'Made in Space' at Nasa Ames Research Centre who designed and manufactured the first 3-D printed artefacts on the ISS and examine their emergence in both their terrestrial and extra-terrestrial nexus. This work will examine the intimate 'attunements' (Stewart 2011) within this expanding nexus that characterise this 'expandable space aesthetic' (Jakubowski 2016) that characterises the expansion of new spheres of neoliberal democratic participation (Turner 2013) and the wider processes of 'worlding'. Second, this work will be supplemented by extensive archival work at NASA's Johnson Space Center in Houston which houses an exhaustive, publicly accessible video and audio data library with footage 24/7 of the ISS. These data allow the study of the quotidian effects of microgravity in one sustained setting in extraordinary empirical detail to contextualise the work on 3-D printing and the other project themes. ETHNO-ISS will examine the way these materialities and their aesthetics generate novel relations, as terrestrial and extraterrestrial worlds are brought into emergent and unexpected forms of intimacy, each mirroring and reconfiguring one another (Messerli 2011, 2016, 2017b).

THEME 3) THE BODY AND BUILT FORM: This theme investigates the traditional imbrication of body and built form, which conceptually is analytically difficult to disentangle in ethnographic research (Carsten and Hugh-Jones 1995). Yet in LEO it is experienced with an alacrity exceeding terrestrial contexts due to the ISS itself, the materiality of which contains and makes safe the deadly and hostile conditions of extraterrestrial environments. However, the ISS nexus which supports, extends and distributes the functioning of the body under such historically novel conditions is intimately tied to terrestrial settings. These are the organizational structures, both physical and bureaucratic, of NASA and other Mission Controls on Earth. A space agency's organizational structure, national politics and cultural history play an enormous role in producing and maintaining such bodies in a wider multi-sited expanded architectural nexus. In particular, conventional distinctions are blurred between humans, body, and the built environment, harkening back to those problematic distinctions within the Euro-American tradition (Mauss 2006) and to later work by Marilyn Strathern (1999) in terms of concepts of personhood and gender. Despite dominant Euro-American notions of skin-enclosed human subjectivities, these are challenged by the novel configurations of the ISS crew's bodies under conditions of microgravity (Aiken 2015) and their engagements with the built environment both terrestrially and extra-terrestrially and draws many comparisons with non-EuroAmerican settings known ethnographically. The Houston based researcher and NASA civil servant, will study this using the evidence of the ISS video archive and its wider institutional context. Her work will expand our understanding of the human body and the material and architectonic conditions that support it,

both terrestrially and extra-terrestrially as an empirical object in its own right.

THEME 4) ROBOTIC/HUMAN HYBRIDS: Robotic/human interfaces are a vital component in space habitation such as NASA's robot 'Robonaut'. However, 'annihilation anxiety' (Richardson 2015) challenging the nature of human subjectivity shoots through all these approaches as Aiken (2015a,b; 2013) has demonstrated in her work at NASA. Japan lies between competing political authorities in space, yet provides the largest international module, the KIBO module, along with its robotic arms. Anglophone scholarship to date has not attempted to examine the political aesthetics at play in the processes of 'worlding' at the Japanese Space Agency (JAXA) and their robotics programme based in Tsukuba. This will be the challenge and opportunity for the member of the Japan ETHNO-ISS team, as she examines the role of the Remote Manipulator System (JEMRMS). JEMRMS which mimics the human arm, is sited externally and designed to move maintenance equipment and to carry out experiments in space while controlled from a console inside the ISS. It is intended that this strand of the research be carried out as part of a specific and dedicated PhD programme and a researcher has already been recruited for this role. Building on her earlier MA research on Japanese robotic 'smartsuits', she will examine how existing Japanese concepts related to robotics are enacted at the ISS. This provides a comparative frame with which to understand similar robotic practices (consider Vertesi 2015), namely those surrounding NASA's 'Robonaut' which will complement the work on bodily hybrids and built form at the ISS alongside the other educational and experimental aspects of the ISS JAXA KIBO module both terrestrially and extra-terrestrially in its attendant communities.

THEME 5) VISUALITY AND SOVEREIGNTY: The ISS offers a sustained and empirically rich research site to examine how the seemingly unified and totalising notions of the extra-terrestrial belie divergent political motivations at the national level. Transcending the Earth allowed the Soviet state and avant-garde to imagine a seamless technologically utopian and liberated Earth, free of capitalism within a communist realm that would literally escape earth's gravity. However, new forms of inequality emerged, then, as they do now. Hart and Negri (2000) argue that new cosmopolitan sovereignties place all people under the view of a hegemon who controls the view from space creating new disciplinary orders that subjectify human life as power moves beyond territory so that there is, in their words, "No More Outside" (2000: 186).

ETHNO-ISS will empirically examine the profound socio-economic implications for the workings of sovereignty in terrestrial and extra-terrestrial communities as they are produced through the production and consumption of visual images at the heart of the 'over-view effect' (White 2014). The ISS simultaneously reproduces terrestrially based forms of sovereignty and troubles them through the modular architecture of the ISS itself and its management from multiple mission controls. The cognitive shift at the heart of the 'over-view effect' obviates some tensions and generates others through the political aesthetics of its forms and visual tropes such as 'spaceship Earth'. These serve to erase differences and produce a borderless, unified Earth. 'Earth-gazing' demonstrates the ecological results of our interconnected relations at the expense of new forms of inequality generated by these political aesthetics, thereby privileging particular forms of moral action over others. The London (Terra) based researcher, with extensive experience in the anthropology of territorial claims, will examine how emergent cosmopolitan sovereignty interacts with and affects such claims on Earth (Battaglia et al. 2015, Gorman 2007) through the production of this unique and unprecedented body of visual culture and how this in turn is experienced extra-terrestrially and terrestrially within the wider themes of ETHNO-ISS.

THEME 6) TRANSCENDENCE AND KINSHIP: In addition to the new understandings of humanity's relation to itself which emerge through the ideas and vistas of the 'overview- effect' and 'earth-gazing', the ISS and the Mir, Skylab and Salyut space stations before it pushed the boundaries of what traditionally might be imagined as a celestial scape. This extends our ideas of the transcendent and presents novel implications for our understandings of kinship and the aesthetic forms it generates (Aubrun 1999). How one should relate to and be for the 'other' (Sahlins 2011), is not just the basic question underlying the study of kinship anthropologically but informs how selfhood and the Earth are transcended and related to one another within the ISS nexus and the new social relations that ensue.

The tradition of 19th century Russian mysticism established by Feodorov aimed to resurrect all our dead ancestors and achieve immortality through space exploration and colonization. This has resonances with modern day American adherents of the 'singularity', whereby a unified immortal disembodied consciousness emerges in relation to space exploration as a form of neounilinear evolutionism (Farman 2012). Conversely, there are the politics of religiosity at sites such as those within the Russian space program where Russian Orthodox Priests bless Soyuz rockets and icons are housed in the Russian modules of the ISS. These Feodorovan impulses are shot through the entire history of the Soviet and Russian space programmes (Siddiqi 2010, Miller 1991). They are also discernible in the American tradition of 'singulartarians' and in rituals at the ISS, extra-terrestrially and terrestrially, surrounding the dead of the 9/11 terrorist attacks and their kin (Catchpole 2008). These activities provide evidence of distinctly new terms by which the transcendent impulse of kinship, and its aesthetics to overcome the self and 'mutuality of being' (Aubrun 1999, Sahlins 2011) are produced. These novel understandings of kinship and transcendence will be the central inquiry of the Moscow based ETHNO-ISS Team researcher and expert on Orthodox Christianity.

THE ETHNOGRAPHY OF THE ISS: The ISS is a complex object in a novel nexus of habitation between the ISS itself and various international mission controls and communities which will be the ethnographic scope of ETHNO-ISS. Methodologically, however, ETHNO-ISS challenges the traditional notion of physical co-presence and speaks to similar conditions of another era when research was conducted at a distance. Though physical co-presence for the ethnographer here is not (yet) possible within the orbiting ISS itself – we are emphatically co-present through the various media networks which sustain the ISS from both its respective Mission Controls and to various publics via sophisticated polymedia (Madianou and Miller 2012, Jakubowski 2016, Walton 2017). In addition, the extensive video and audio collections held at the Johnson Space Center in Houston provide unparalleled data for an ethnography of this unique society. This database forms the core extra-terrestrial data for the comparative study of ETHNO-ISS across its terrestrial sites. This is not traditional 'armchair anthropology'. Rather, it is emphatically copresent ethnographically with the ISS within its own innovative registers of co-presence. This project both experiments with and develops tools for ethnography beyond those techniques that have been informed by conventional registers of physical co-presence that shaped ethnography in a very different technological era.

ETHNO-ISS will conduct ethnography within a setting of copresence, openness and intimacy that could never be imagined in a traditional ethnographic setting on Earth. Anthropological research to date has been ground breaking in establishing the wider social and cultural parameters in

which extraterrestrial activities take place (see Battaglia et al. 2015, Battaglia 2017, Valentine et al. 2012, Valentine 2016, Messeri 2011; 2016, Olson 2010: 2018, Gorman 2009 and Gorman and J. Walsh's recent blog site: issarchaeology.org). ETHNO-ISS, however, will be more intensive and empirical with its focus on quotidian life, material culture, and techniques of the body that are manifest within the day to day activities and lives at the ISS and its wider distributed terrestrial nexus of mission controls and their attendant communities.

The overall theme of 'worlding' is further informed by Stewart's (2011) recent work on 'attunement' with its focus on the novel and mutually constitutive intimacies that are produced in such seemingly prosaic contexts. The project follows a line of inquiry that has noted the importance of a particular transcendent political aesthetic regarding the 'thin blue-line' and 'blue marble' tropes that have emerged since the first man in space, Yuri Gagarin saw no God there. Yet, Gagarin's heirs fly in Soyuz rockets blessed by Russian Orthodox priests with holy water. These themes of transcendence and religiosity at the ISS, and their relation to 'worlding' will relate to all the investigators but by the Moscow based researcher in particular. Taking the theme of 'worlding', and the way intimate bodily configurations are related to wider cosmological ones, the project proposes that the extension of human habitation extra-terrestrially reconfigures the conditions of terrestrial life and, in particular quotidian life, in new and unexpected ways (following Battaglia et al. 2015, Messeri 2011; 2016). The project, in its focus on the material conditions of daily life at the ISS and its related terrestrial communities will empirically trace how new human subjectivities unfold through the lived reality of post-Earth living. ETHNO-ISS will examine quotidian life on the ISS and the teeming nexus of the constant processes of calibration, coordination, and 'attunement' (Stewart 2011) that bring diverse realms of experience into novel relations of entanglement (Holder 2012). It is this focus on the quotidian which forms the most intimate points of interest amongst lay observers and participants of the ISS project terrestrially, and which seeks to engage, mimic and then reconfigure the most intimate and seemingly banal understandings of the body, its habitus and the wider material nexus which it inhabits (Bourdieu 1977). It is here, within this novel bodily and political aesthetic, that new emergent conditions of human life and habitability are generated and expanded in unprecedented and yet to be understood ways. Each ETHNO-ISS researcher will examine this expanding nexus gathered about the ISS and its attendant communities at the five terrestrial sites. This will result in a study that is systematic, cross-cultural, multi-sited, diachronic and empirically focused on the material culture of the ISS that is without precedent.

THE ANTHROPOLOGY OF THE EXTRA-TERRESTRIAL. ETHNO-ISS follows a long standing theoretical concern within anthropology that historically has always dealt with the daily communing with ancestors, transcendent divinities and the extra-terrestrial. Traditional dwellings often serve as terrestrial analogues for such celestial extraterrestrial spheres (Rivière 1995, Blier 1987, Milbrath 2009). As Mary Douglas has observed, the dwelling is the nexus whereby these terrestrial, transcendent and extra-terrestrial cycles are regulated and experienced in embodied form in our everyday material culture and architecture (Douglas 1991). The terrestrial becomes a mirror for the extra-terrestrial and vice versa, and both are inhabited simultaneously. While this form of analogic thinking might seem to be imitative of given cosmological forms and thought, such "Simulation does not imitate; it generates" (Messeri 2011:250, 2016,2017b) as Messeri has noted in her ethnographies of NASA extra-terrestrial analogues on Earth. This is part of the wider processes of 'worlding' (Heidegger 1993) that Messeri and others have observed (Battaglia et al. 2015). ETHNO-ISS will examine and further understanding of these novel ways in which we

sensuously embody and inhabit our ever-expanding worlds. The body, under the conditions of microgravity, is a concern of particular urgency in the hostile environments outside of Earth's atmosphere. Olson (2010,2018) has described how the astronaut's body is inversed, augmented, layered and turned inside out in various experiments. These manipulations create an entirely different and speculative relationship between the body and its environment and even what a body might be. Architectural experiments for space habitats serve to create better habitats both terrestrially and extra-terrestrially (Olson 2010,2018), yet the lived experience of these new configurations is yet to be fully assessed. The ISS offers detailed and extensive data over its years of existence to understand these new relationships. ETHNO-ISS will trace the effects of existing and emergent understandings of the body under the particular and yet universalising conditions of life aboard the ISS. ETHNO-ISS will focus critically on the ways in which humanity is produced under a new universal totalising paradigm where Earth and space are not dichotomised. As Olson's informant notes: "There's only one paradigm, its all the same" (Olson 2010 :225). ETHNO-ISS will examine the implications of this totalising movement for our wider terrestrially based understandings of territoriality and sovereignty.

In recent years, a group of anthropologists has pioneered the field of space anthropology (Battaglia et al. 2015, 2012; Battaglia 2017; Valentine et al. 2012; Valentine 2016; Messeri 2011, 2016; Olson 2010, 2018). They address a broad range of concerns that challenge our terrestrially based assumptions about human and material life. The refiguring of terrestrial/ extraterrestrial boundaries and the cosmologies of new political economies provide a lens through which to look at emerging relations between power, sovereignty and territory. The focus developed on extreme environments and the commercialization of space enterprise (Valentine 2012) contributes to our understandings of what 'globalisation' ultimately is, and how this manifests in notions of the global future of Humanity as 'post-Earth'. Further, our concomitant understandings of 'home' (Battaglia et al. 2012) are challenged along with a focus on the 'extreme', where the extra-terrestrial under these conditions becomes a form of 'worlding', and more importantly a realm that is novel, tentative, emergent, unstable and unknown – a site of radically redemptive alterity in the 'subjunctive' mode (Battaglia et al. 2012: 1020). As such, the ISS and emerging off-world environments represent a new field for anthropologists to study. They provide a crucial base for the novel and expanding terms of 'worlding' that ETHNO-ISS will scrutinise in a sustained and unprecedented, comparative framework, examining the evidence emerging from the ISS 'home' and its wider nexus. These processes have been taking place for some time on the ISS and yet they remain largely unexamined. This is to the detriment of our critical understanding of terrestrially based concepts in the social sciences. ETHNO-ISS will recover and examine these processes in this ground breaking comparative project before the ISS itself is broken up and disappears.