

Spring 2020 Intern Posters

Joseph Michael Daugherty Adam
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

Erick Aghaian
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

Damiana Catanoso
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

Anthony Emilio Cerezo
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

Erin Chin
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

Simen Ekstroem Soerensen
NASA INTERNATIONAL INTERNSHIP PROGRAM
Ames Research Center, Moffett Field CA

Noemy April Escobedo
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

Marina George Ghobrial
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

Yu Ting Huang
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

Chi Kei Loi
UNIVERSITIES SPACE RESEARCH ASSN
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Tyler David Neca
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

Jack Ryan Pope
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

Jason Ream
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

Aivaras Vilutis
NASA INTERNATIONAL INTERNSHIP PROGRAM
Ames Research Center, Moffett Field CA

Benjamin Health Alva
UNIVERSITIES SPACE RESEARCH ASSN
Ames Research Center, Moffett Field CA

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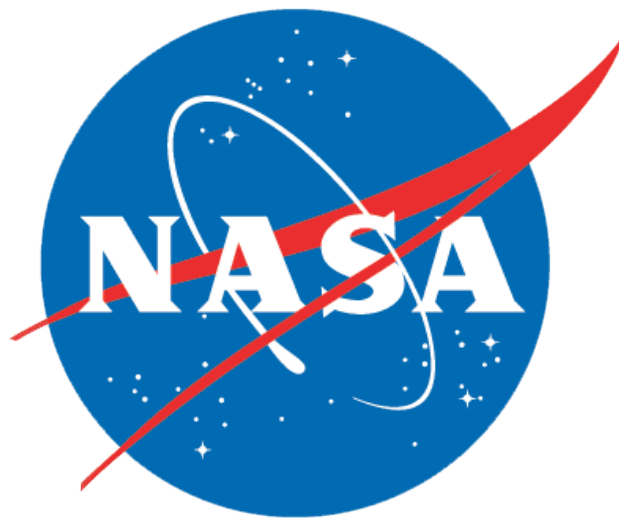
National Aeronautics and
Space Administration

*Ames Research Center
Moffett Field CA 94035*

April 2020

Acknowledgments

This report is available in electronic form at
<http://>



Health Manager Real Time Dashboard

Chi Kei Loi | San Jose State University | NIFS Intern

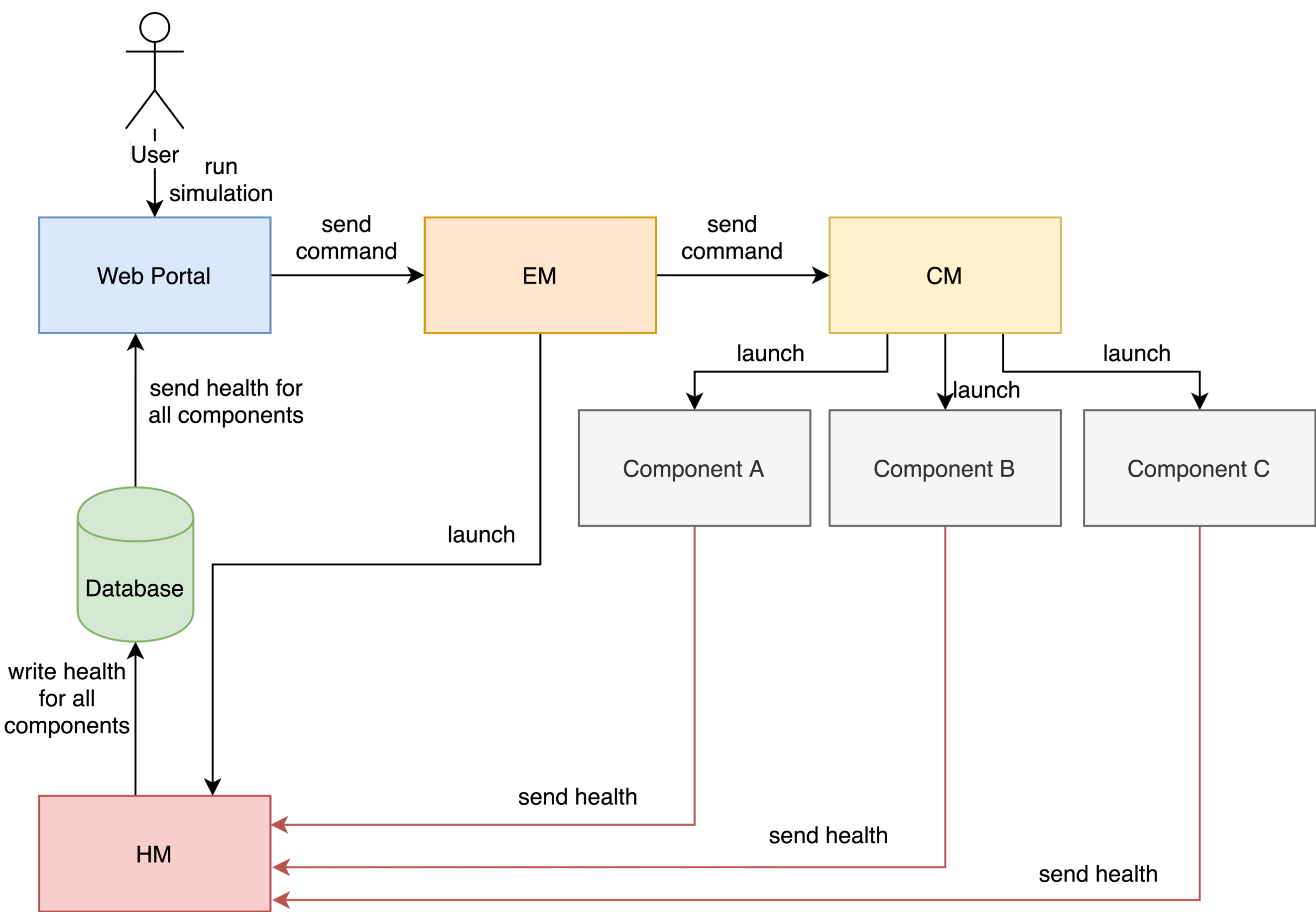
Abstract

Air traffic simulation is the main research area of SMART-NAS Test bed (SNTB). Being capable of identifying component failures while simulating current and proposed future air traffic concepts for the Next Generation Air Transportation System (NextGen) is an important feature currently missing from SNTB. We propose a new manager named "Health Manager" to bookkeep each simulation component's health and monitor related data by storing them into a persistent database. It will eliminate the need to use WebSocket to connect to the Testbed Messaging Layer via a back-end server. In addition to the new manager, we also implemented a real-time dashboard to display basic information such as the component ID, memory allocation and last revived time of each simulated component, so researchers can easily monitor the status of the simulation without prior technical background. If a component fails, researchers can restart the failed component or the entire simulation without having to waste time and money on invalid simulations.

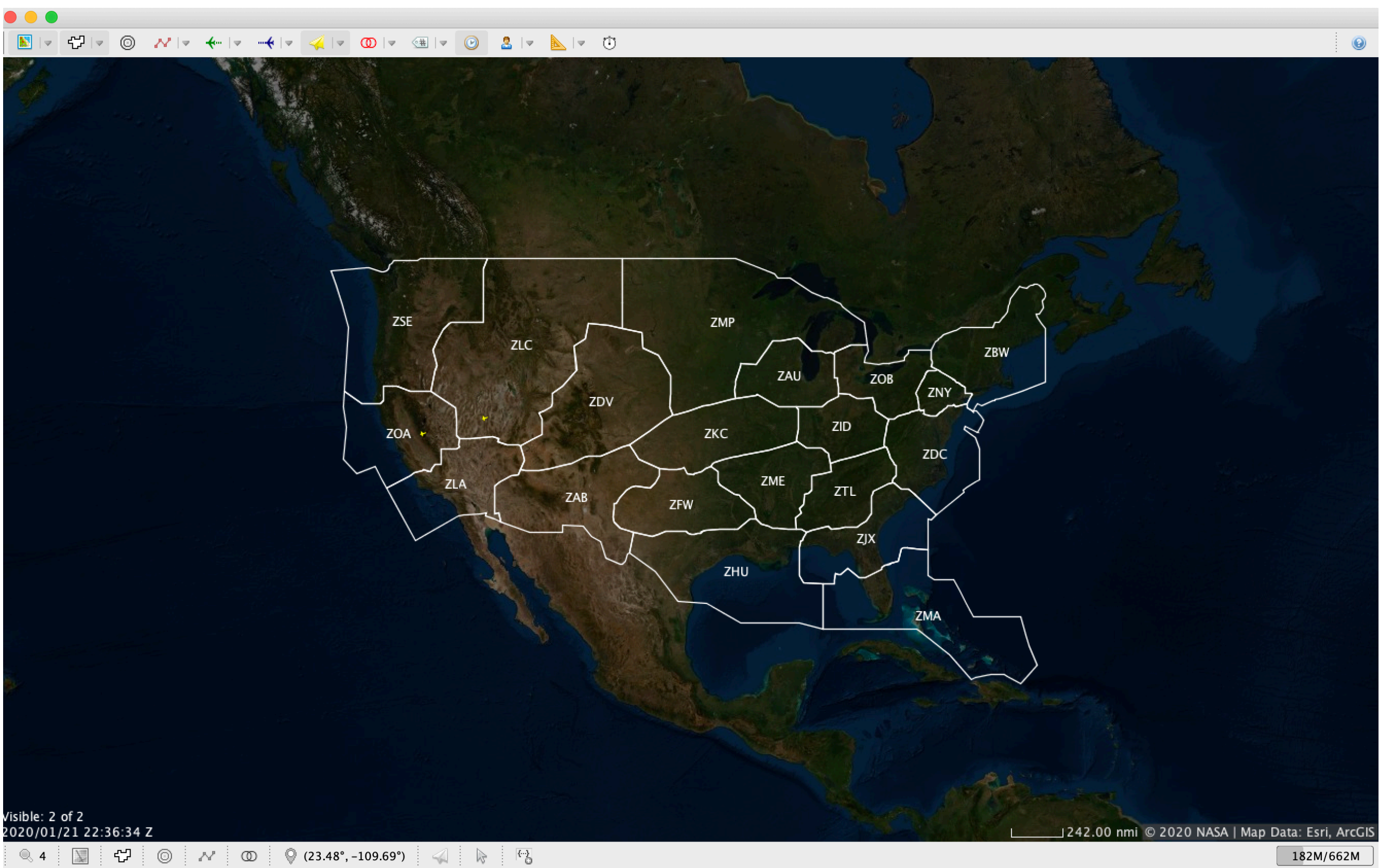
Objectives

- Gather all the components' health data into one database.
- Provide a real-time Dashboard to display health data of each component.
- Detect failure components that are not synchronized.

Software Architecture



- Execution Manager (EM) : Receives command from Web Portal and send commands to Component Manager and launch Health Managers.
- Component Manager (CM) : Receives commands from EM to download and run executable components.
- Health Manager (HM) : Gathers all the components health data and write them into database.
- Web Portal : Queries all health data in the database and display it in the health dashboard.



Result

SNTB Web Content

Simulation Information

	Status	ID	Host Key	Free Memory	Total Memory	Last Received Time
1		traffic-viewer.0.1	localhost	275 MB	698 MB	Mon, 30 Mar 2020 19:20:36 GMT
2		traffic-pub.0.1	localhost	198 MB	257 MB	Mon, 30 Mar 2020 19:21:05 GMT

The health dashboard will display the health data of subscribed components, including (ID, host key, available memory of the JVM, and last received time). The liveness of each component will depend on the last received time. If a component is not synchronized for 30 seconds, the status icon will turn red with cross mark, otherwise it will turn green with check mark.

The default order of the table is in ascending order of the last received time, so the failed component will always be displayed at the top of the table. However, the user can also choose other sorting items, such as ID, host key or memory.

Future work

1. Enable user to restart a component in health dashboard. It would be beneficial that user do not need to restart the entire simulation if one or more components failed.
2. Display graph of free memory and total memory for each component, so the user can evaluate the performance of a component.

Acknowledgements

A special thanks to my mentor Kee Palopo and Huu Huynh, as well as Chok Fung Lai, Alan Lee, Jimmy Nguyen and Phu Huynh for their support and guidance throughout this project.



SMART-NAS Testbed

SJSU SAN JOSÉ STATE UNIVERSITY

Development of a Small Unmanned Aerial System for Automated Facility Inspection

Joseph Adamson^{1,2}, David Murakami³

¹Universities Space Research Association, ²University of California, Santa Cruz, ³NASA Ames Research Center

Abstract

Critical NASA test facilities such as the National Full-Scale Aeronautics Center (NFAC) are large, aging, and difficult to inspect manually, requiring resources such as time, skilled personnel, scaffolding, and safety equipment. This IRAD-funded project explores the use of unmanned aerial systems for autonomously performing diagnostic imaging of the NFAC, while a separate portion uses machine learning to process images and catch defects such as loose/missing fasteners. Work completed during this project explores solutions for localizing in a dark GPS- and magnetometer-denied environment. Firstly, we have a software architecture using ROS, px4, and the ORB-SLAM2 algorithm to localize-and-map using visual techniques to provide positional feedback. Secondly, a hardware platform (drone and payload) has been developed, integrating cameras, lights, Pixhawk flight controller, and processing power into a lightweight system. Deliverables include demonstration of the system in NASA facilities and a sample dataset for processing. The project is also the basis for a Master's project emphasizing robotics and control; educational outcomes, therefore, include exploration and implementation of navigation, attitude estimation, localization, and control schemes in challenging environments.

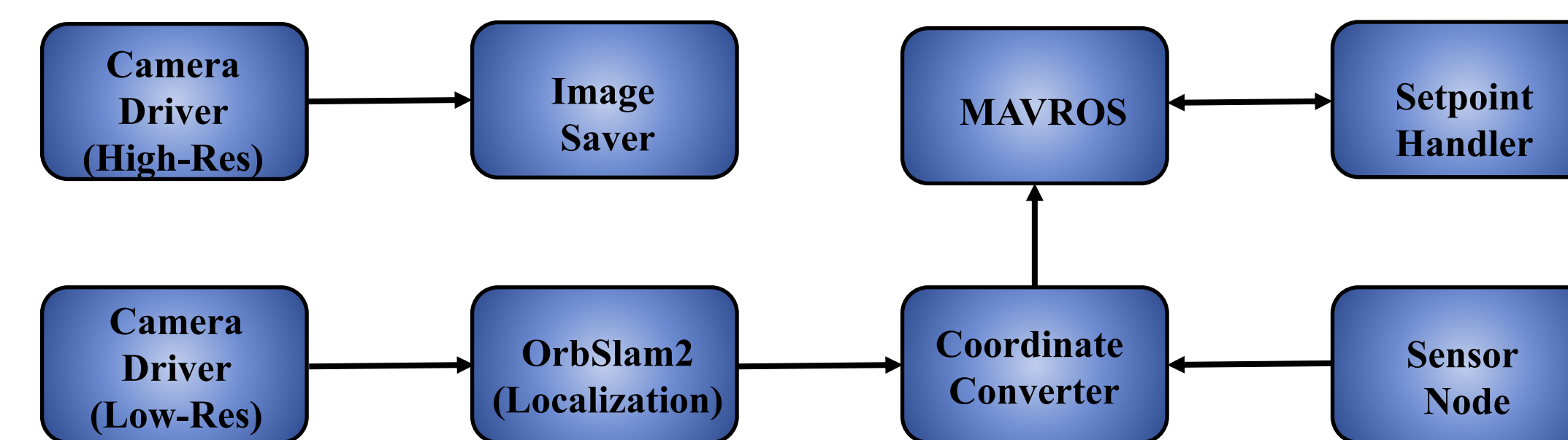
Objective & Solution

The NFAC (below) presents an enormous warehouse-like environment, with wall sections reaching roughly 10 stories tall. The ultimate goal is to fly a UAV (i.e., a drone) equipped with onboard lighting and high-resolution camera to capture diagnostic images at evenly spaced grid points along these walls at a distance of 1 meter. These images are post-processed via deep learning in a separate leg of the project, explored by Nick Califano. This type of indoor flying requires control systems to localize without the use of GPS or magnetometer; one such solution is Simultaneous Localization and Mapping (SLAM) which can be realized, among other methods, using computer-vision techniques and a small onboard computer. Combining SLAM with an off-the-shelf flight controller forms a powerful and viable solution for these objectives.



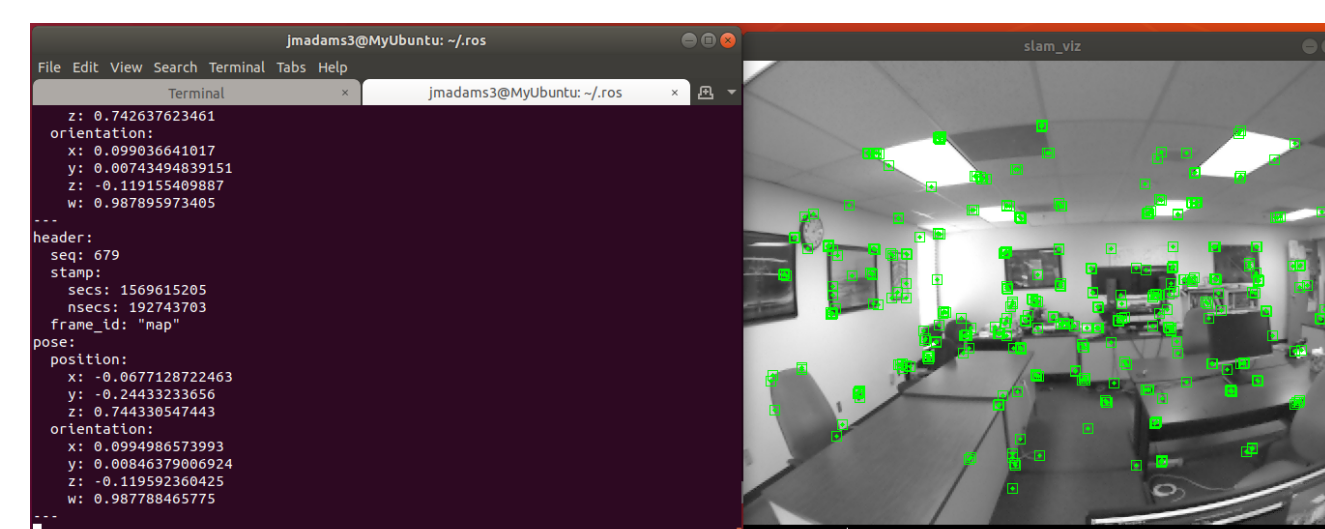
https://www.nasa.gov/centers/ames/images/content/109854main_AC84-0712-15.1.jpg

Software Architecture



Robot Operating System (ROS) is a message-based layer which allows interconnected drivers and other executable nodes to communicate in a highly modular fashion. ROS was used for the software running on the onboard PC (Intel NUC) with primary node information flow connected as above, and functioning as follows:

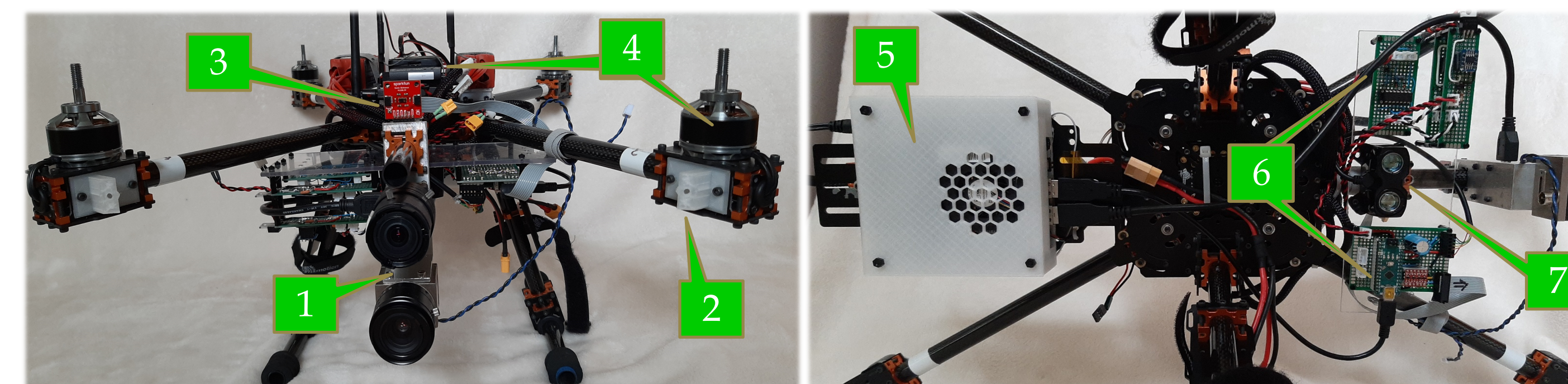
- **Camera drivers:** command cameras to take, save, and pass along images
- **Orb Slam 2:** performs monocular vision-based SLAM to provide position and attitude data, although scaled to arbitrary units and reference frame (example screenshot below)
- **Coordinate converter:** rotates and scales SLAM data into real-world axes using inertial and range sensor data, resulting in gravity-down readings given in meters
- **Setpoint Handler:** monitors position, snaps photos at gridpoints, and streams setpoints
- **MAVROS:** communicates with flight controller to exchange location data and setpoint commands with onboard computer



Left: Example OrbSlam 2 functionality localizing in office environment utilizing feature detection from the low-res camera stream, and outputting 6-dof pose data into the ROS ecosystem. [self-taken image]

The modular nature of ROS allows any localization option to be 'dropped in' without affecting any other node.

Hardware/Payload Architecture



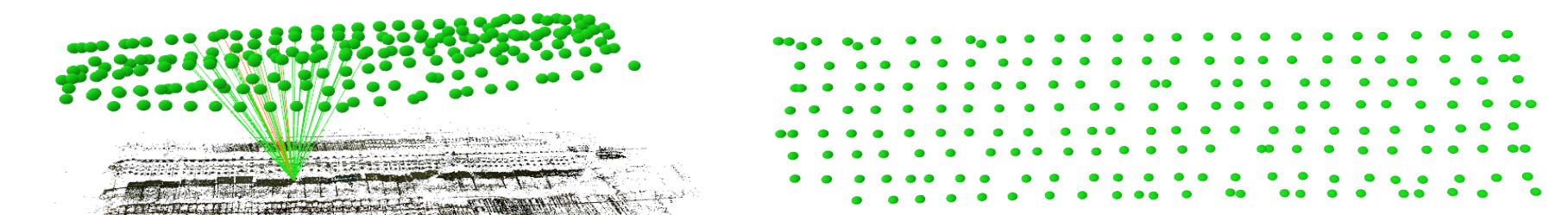
Front View [Self Taken]

Underbelly View [Self Taken]

- 1MP localization and 12MP data collection cameras
- Mount points for articulated LED array providing onboard lighting (LEDs not pictured)
- Forward-facing range sensor allows adjustments for constant distance to wall
- Flight controller, ESCs, BLDC motors, radio links, etc (standard drone platform hardware)
- Onboard computer in lightweight 3D-printed case (Intel NUC)
- Driver circuitry for LEDs and ranging sensors. LEDs triggered directly by camera GPIO
- Downward-facing range sensor used for measurement scaling and height data (optionally)

Results

- A payload prototype was developed, affectionately dubbed the "Drone on a Stick," which integrated the full hardware system into a handheld package. The prototype allowed testing and integration of the software system
- Cart-mounted testing successfully demonstrated the ability to localize in real-world coordinates using only the camera and ranging sensors. Work in the NFAC culminated in the collection of a new dataset for use with the deep learning portion
- The prototype was converted and optimized for integration onto a UAV platform as pictured under Hardware Architecture. Early flight testing is underway (protocol development, weight optimization, controller tuning, etc)



Data from lab wall, taken by cart-mount system and post-processed by Nick Califano via photogrammetry software. Demonstrates 3D camera poses and grid locations

Conclusion & Next Steps

This project served as a strong foundation and the culmination of my graduate career as a student of robotics and control. It explored a full range of topics relevant to the implementation of an autonomous system while helping to demonstrate the viability of UAVs for indoor inspection: ROS, OpenCV, controls, attitude estimation, and more. Furthermore, I learned a myriad of professional engineering skills including industry best practices, effective troubleshooting, navigating bureaucracy, and professional communication.

Future work for this project includes:

- Continuation of flight testing, including setpoint streaming and indoor missions following controller tuning
- Fine-tuning of the orb-slam conversion algorithms or exploring other localization solutions, as well as improving position filtering within px4
- Flight missions within the NFAC (long-term goal)

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With infinite thanks to:

David Murakami (Mentor, AOX); Gabriel Elkaim (Advisor, UCSC); Nicholas Califano (USF); Saba Hussain and Zeal Panchal (USRA); Nicholas Cramer and Christopher Seruge (TI); and everyone at the Fluid Mechanics Lab who made this experience utterly unforgettable!

Ultra High Temperature Reacting Plasma Measurement Techniques

Tyler D. Neca^{1,2}, Laura J. Simurda^{3,4}

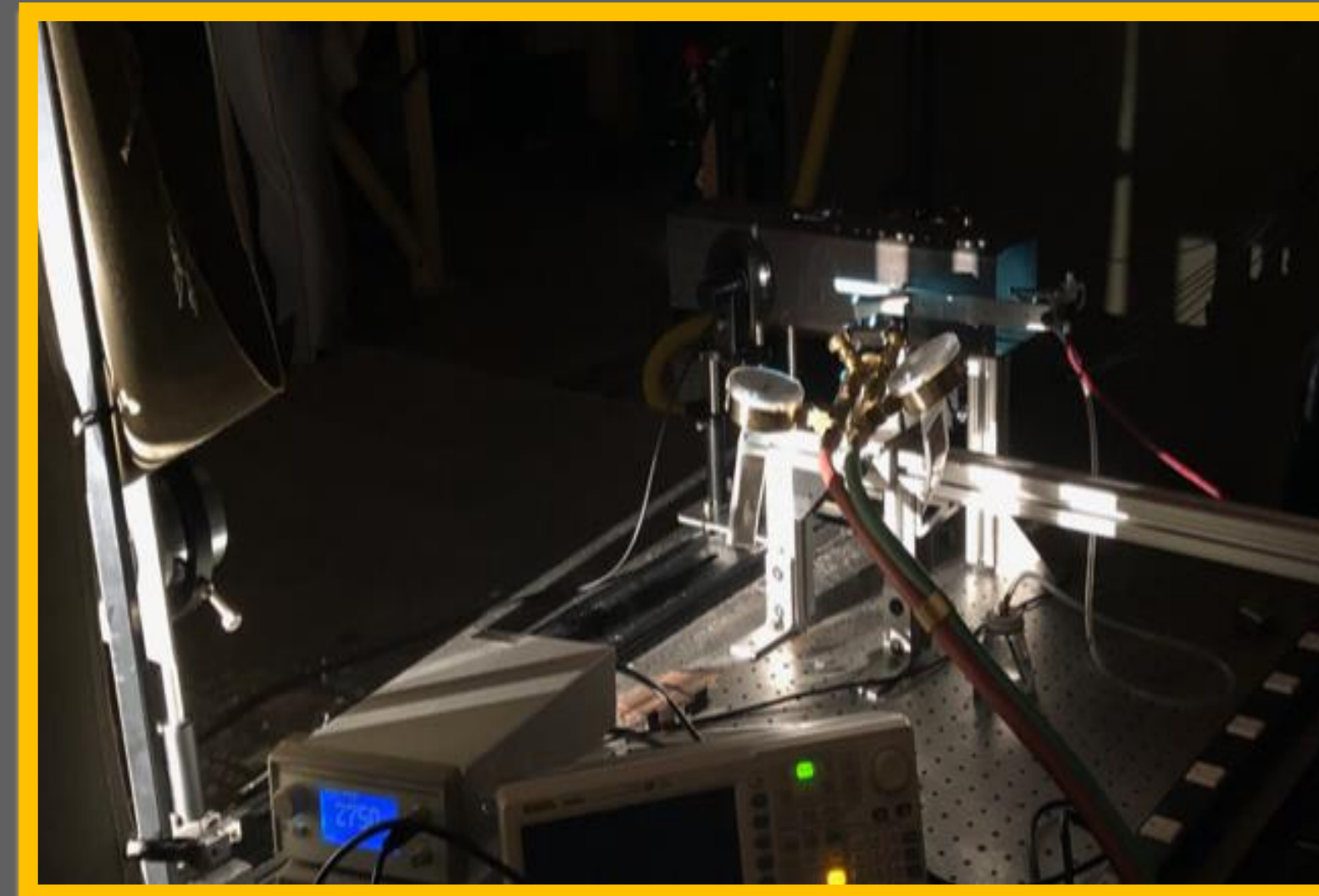
¹University Space Research Association, NASA Ames, ²San Jose State University, ³NASA Ames Research Center, ⁴Stanford University

Abstract

The next space race is upon us. Urgency and demand to land astronauts on the Moon and eventually Mars has NASA, SpaceX, and a multitude of other companies shifting into full gear to accomplish this. Advancement in rocket technology, specifically propulsion, is one of the many problems that modern day scientists/engineers face. Specifically, knowing the temperature of the plume at certain points from rocket engines is one way to measure its efficiency and allows for improvements in its combustion efficiency. However, measuring the temperature of plumes isn't easy and there are many problems that arise with doing so. That's where Laura Simurda's Stanford University PhD project: Ultra High Temperature Reacting Plasma Measurement Techniques project comes into effect; developing an accurate and effective method of measuring temperatures from rocket engine plumes. Two instruments have been developed, Sodium D Line Reversal Method and the Spinning Thermocouple, both collect the flame temperature from an oxyacetylene torch (in place of a rocket engine). If both of the measured temperatures match or are within a small error then the instruments are credible and effective. These instruments and techniques, if deemed credible, can be utilized within NASA, military, etc. to assist in the further development of propulsion by providing crucial temperature data which correlates to combustion efficiency within the rocket engines. The outcome expected revolves around the matching of the temperatures collected from each instrument and then replicated to prove consistency and credibility.

Sodium D-Line Reversal Method

The Sodium D Line Reversal Method is a technique used to calculate the temperature of a flame by measuring the absorption and emission of light at sodium's resonance lines at 589nm and 589.6nm. The emission of light is produced from a black body source (tungsten lamp) which is directed towards a lens, through an optical chopper, then through the flame that has been seeded with sodium particles, through another optical chopper and lens and eventually onto a slit of the spectrometer. The combination measuring the emission of the sodium particles in the flame alone measurement, measuring the absorption of the lamp light by sodium particles in the lamp plus flame measurements and using a background lamp of known brightness temperature allows for the determination of the flame temperature of the oxyacetylene torch. Because the oxyacetylene torch closely resembles a rocket engine plume, if the experiment proves to be credible, it can be transitioned to rocket engines for further testing.

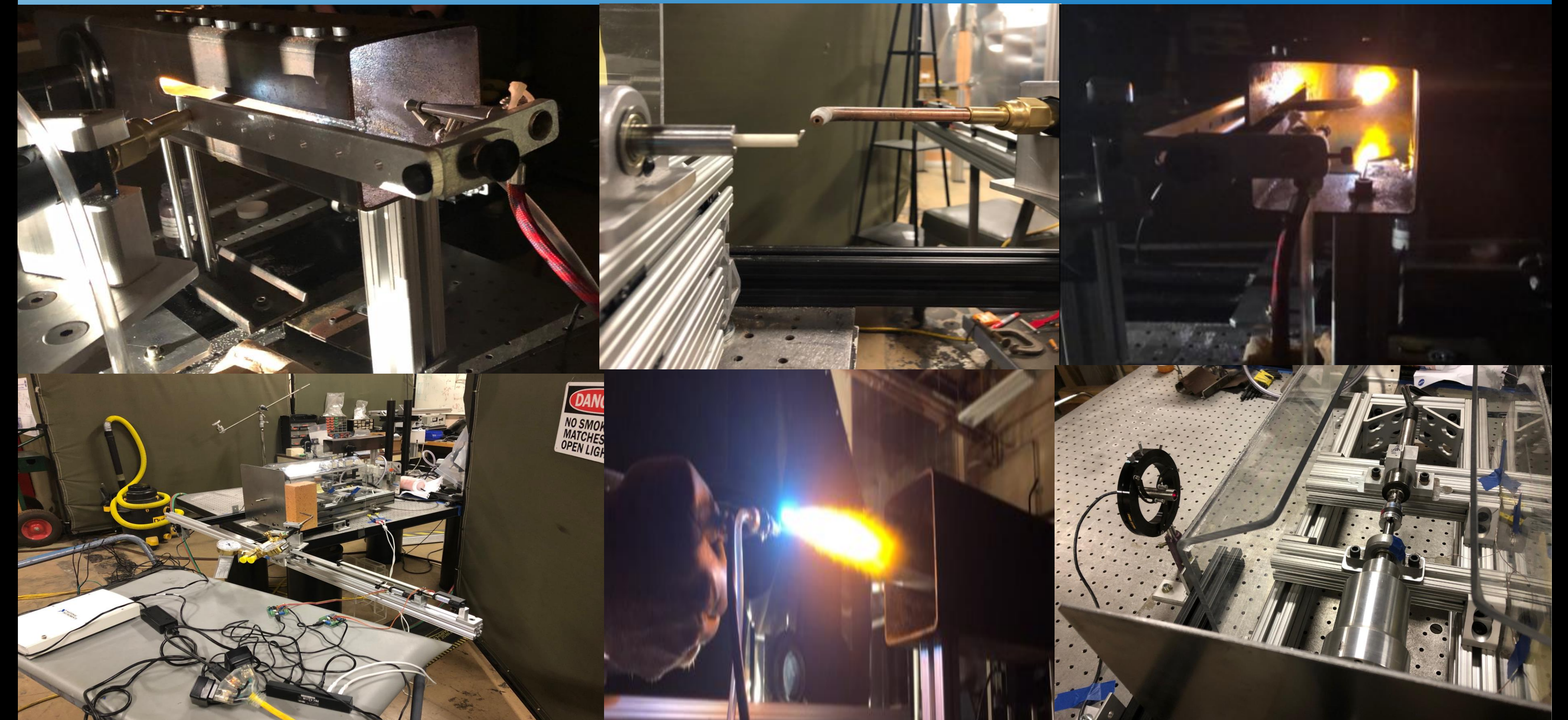


Spinning Thermocouple

The Spinning Thermocouple experiment is the second of two experiments created to effectively measure the temperature of the oxyacetylene torch flame. An air powered spinning motor was built to spin up to 22,000rpm as well as hold a data logger and a type B thermocouple. Spinning a thermocouple to 15,000+ rpm eliminates the complicated calculations needed to quantify the radiation and conduction effects by making them negligible compared to a larger, calculable convection term. Thus, convection is the only form of heat transfer that is relevant to the design and experiment process. Since the thermocouple melts from the heat of the flame, the thermocouple should spin about 10,000+rpm to prevent melting before the torch is actuated into place. The temperature of the flame is recorded by the data logger while the experiment is taking place. Multiple thermocouples were placed around the experiment to log the temperature at different points to ensure nothing overheats.

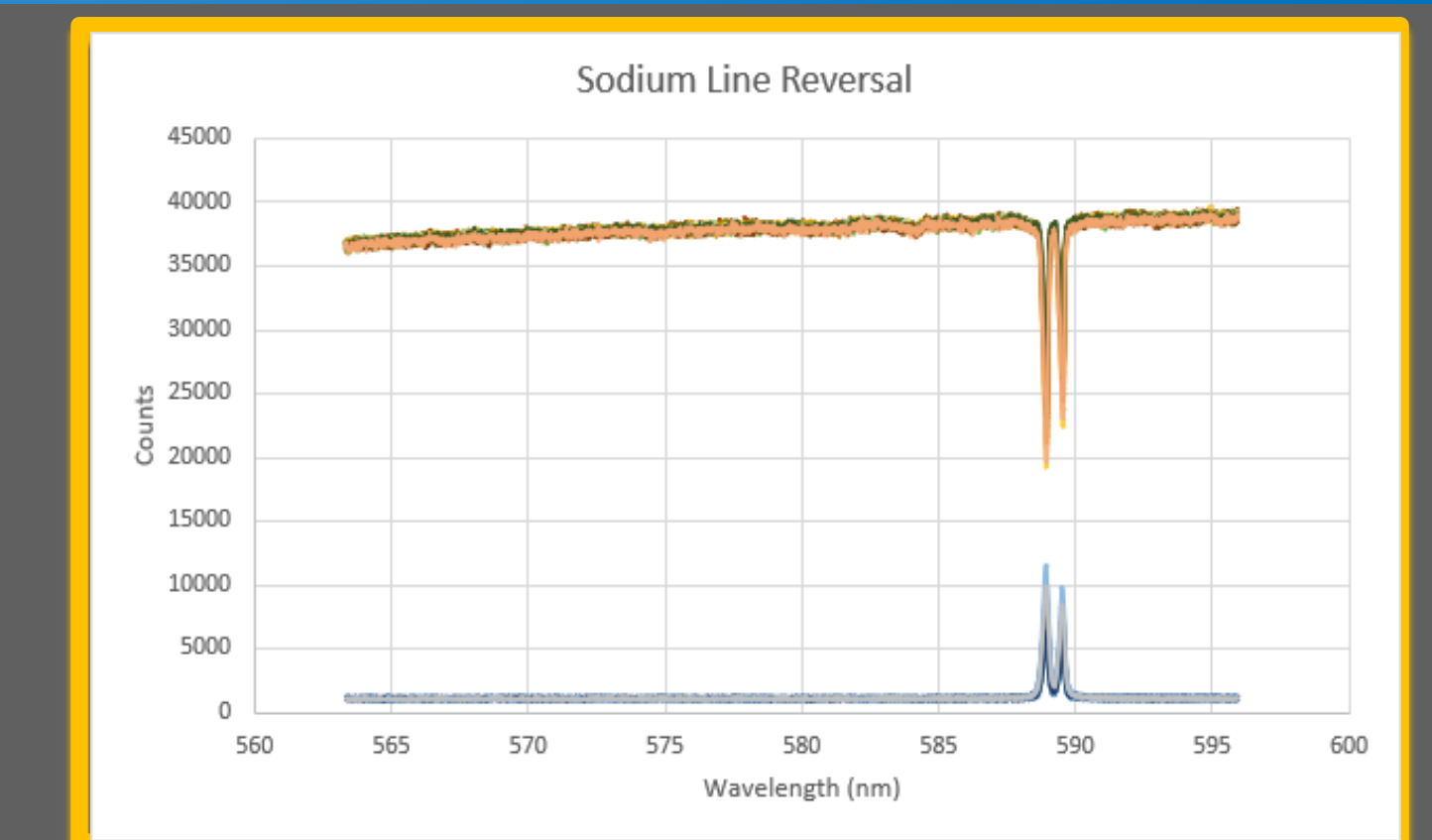


Testing



Results

During the Sodium D Line Reversal experiment, there are two optical choppers on each side of the mixing chamber which allow radiation from the tungsten lamp in at set moments. Since one optical chopper rotates twice as fast as the other one, this allows the spectrometer to measure flame only and flame + lamp emissions, each at every other time step. In the figure to the right the upper line is the lamp + flame measurement, which shows the absorption of the lamp photons by the sodium atoms at the absorption lines. The lower line is the flame only measurement and shows the emission of the sodium atoms at the emission lines. The absorption/emission of sodium atoms happen only at wavelengths of 589nm and 589.6nm, hence why there are only two readings for both measurements.



Conclusion

Overall, the techniques used in Laura Simurda's PhD project are promising at measuring the temperature of an oxyacetylene torch flame effectively. Due to unforeseen circumstances with the COVID-19 pandemic, further testing of the Spinning Thermocouple and the Sodium D Line Reversal technique have been halted. Although testing has been limited, both techniques have shown great potential and can be upscaled to rocket engines once adequate testing has been reached. In addition, both techniques can be altered and applied to other scientific purposes such as military advancements, space exploration, and propulsion.

Acknowledgements

I would like to thank my mentor Laura J. Simurda for her tremendous guidance and mentorship throughout my intern experience. In addition, I would like to thank everyone at the Fluid Mechanics Lab for their support and expertise. Lastly, I would like to thank NASA Ames Research Center for providing me with this unique opportunity to broaden my knowledge and further my experience in the aerospace engineering field.

Eric Chin^{1,2,3}, Yu Ting Huang^{1,4}, Jack Pope¹

National Aeronautics and Space Administration





Researching The Effect Of Various Factors in CO₂ Absorption

Marina Ghobrial | New Jersey Institute of Technology
Mentor: Darrell Jan
Life Sciences Research Laboratory

ABSTRACT

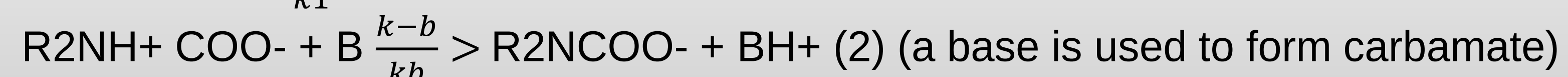
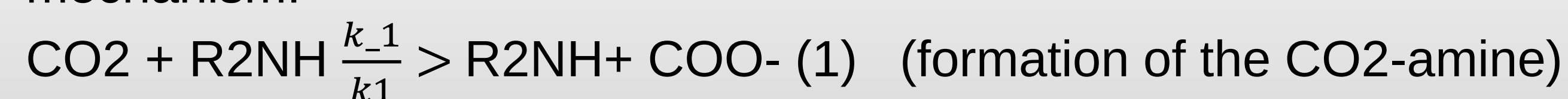
NASA astronauts travel for months to discover many new explorations. Part of the challenge they face is absorbing the substantial amount of Carbon Dioxide (CO₂) generated on the International Space Station (ISS). NASA seeks to obtain results on how to absorb the amount of CO₂ in cabin air. Large amounts of CO₂ is very harmful to the human body; it can cause fatigue, hyperventilation, and acidic blood. The Spacecraft Maximum Allowable Concentration (SMAC) is a 3.6 mm Hg on 1000-day missions. To combat this problem, we are experimenting with a liquid amine (Diglycolamine) chemisorbent CO₂ removal system. The CO₂ removal system has two main parts: contactor and a degasser. The contactor absorbs CO₂ in the liquid amine and the degasser heats the system so that the CO₂ can be released. We evaluated DGA compatibility in the degasser to decide on the best materials to use in our system. Sugar-water is a viscosity substitute sorbent for a flight experiment so we can understand liquid behavior in the system in microgravity. We worked on testing various concentrations, flow rate, and liquid flow with added bromothymol blue pH indicator to observe CO₂ absorption in the contactor. My main project is presenting research on the following: best pH indicator to use for CO₂ absorption in sugar water, calibrating the Raman Spectrometer to have a more accurate CO₂ concentration measurement in DGA, and how they both impact the chemisorbent project.

OBJECTIVE

- To research Raman Spectroscopy and its correlation to CO₂ absorption
- Understand how DGA reacts with CO₂
- Test bromothymol blue as a pH indicator

RESULTS

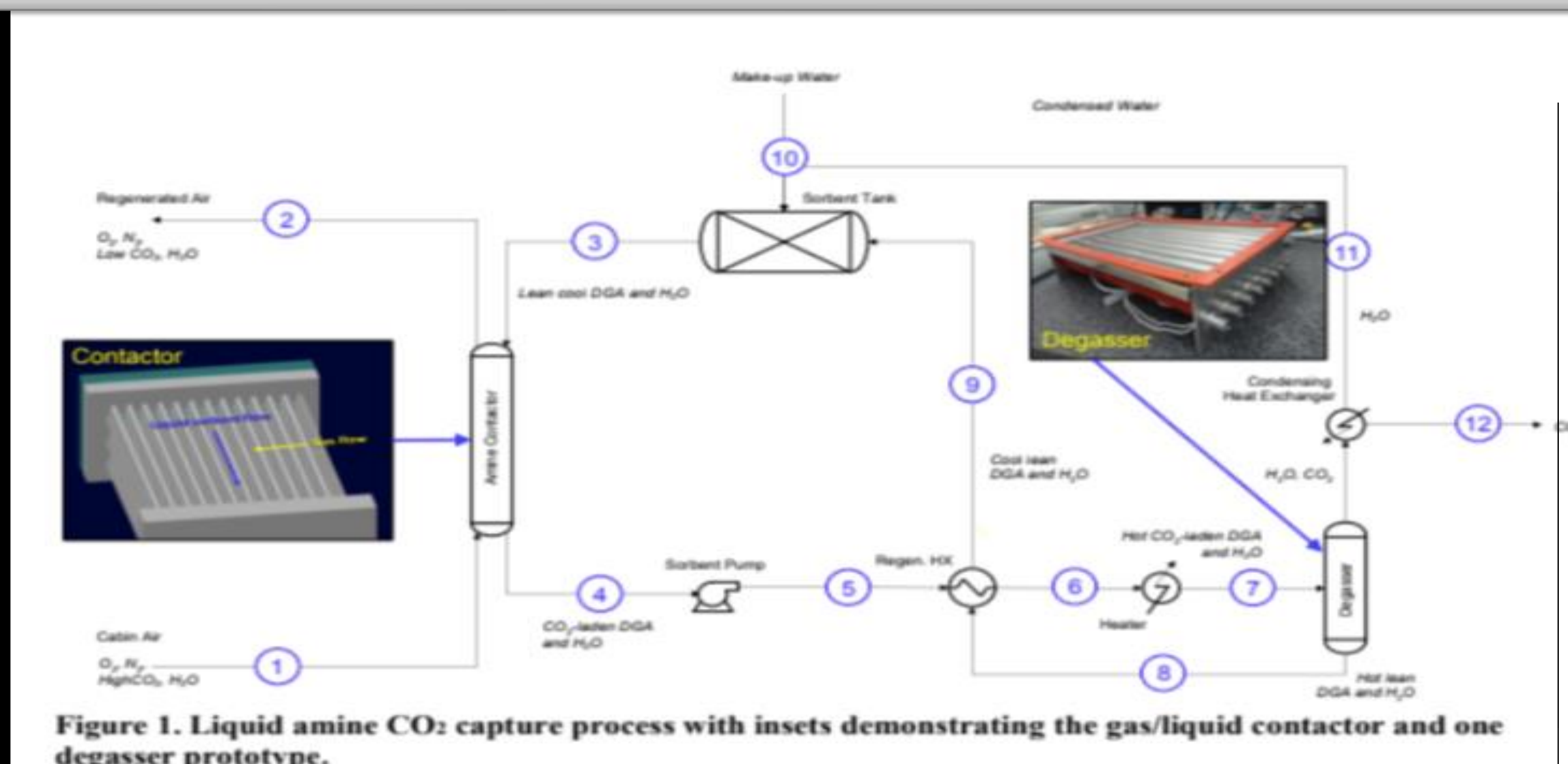
Raman Spectroscopy has a unique chemical fingerprint that is a result of the vibration of the molecules. The vibration is caused by the frequency of light which happens through the laser. The light is then scattered through an emitted photon which can be greater or less than the emitted photon. This Raman scattering gives the molecules it unique spectrum. It informs about the characteristics, phase, strain, concentration, and contamination in a molecule. In a compound, a Raman Spectrometer can give detail on all the mole and the concentration of all the molecules. DGA and CO₂ has a two-step mechanism known a zwitterion reaction mechanism:



In BTB experiment, we saw a color change from green to blue in the bromothymol blue experiment. We were expecting to see a change from green to yellow.



www.nasa.gov



BACKGROUND

CO₂ capture is a recurring process that takes multiple steps to complete. The two main focus processes in our project are the contactor and the degasser. In the contactor, gaseous stream of CO₂ and another stream of liquid sugar-water are pumped into the contactor. The result is a mixture of sugar-water and CO₂ solution. In the degasser, the sugar-water solution and CO₂ mixture is heat causing the two to separate. We observe the color change by a bromothymol blue pH indicator. We want to quantify CO₂ absorption so we use acid test to measure CO₂ absorption per mol of CO₂ to DGA. Raman Spectroscopy measure CO₂ percentages in solution. Using those two data we plot a graph to have a correlation curve to measure CO₂ without needing to take samples.

Bromothymol Blue (BTB) is a pH indicator that is low in acidity and has a pH range of 6.0-7.6. BTB is yellow when acidic, green when neutral, and blue when basic. Sugar-water is an acidic solution with a pH of 5, but addition of BTB causes the solution to increase pH to neutral (green). Water becomes more acidic as it absorbs CO₂, causing the indicator to turn from green to yellow.

CONCLUSION/FUTURE WORK

Raman Spectroscopy is one of the most helpful instrument to identify the molecules in a compound and their concentration a well as other helpful information. DGA and CO₂ react through a zwitterion reaction mechanism. Bromothymol blue experiment showed unexpected results. Work on identifying if there could have been a reaction between the indicator and sugar water solution, and research other possible indicators

REFERENCES & ACKNOWLEDGEMENTS

Alvarez, G. J., DeGraff, G. J., Swickrath, M. J., Belancik, G. J., & Sweterlitsch, J. J. (2019, July 7). Continued Development of a Liquid Amine Carbon Dioxide ... Retrieved from <https://ttu-ir.tdl.org/bitstream/handle/2346/84515/ICES-2019-320.pdf?sequence=1&isAllowed=y>

A special thank you to my mentor (Darrell Jan) and my co-workers (Grace Belancik & Allen Yau & Lisa Chu) for all their help and guidance throughout my internship. I have learned a lot because of their supervision and support. This internship is truly incredible and unforgettable.





Data Collection for the Statistical Classification of Biosignature Information

A. Vilutis (aivaras.vilutis@gmc.stud.vu.lt)¹, D. Gentry²

¹ Vilnius University, NASA International Internships Program ² NASA Ames Research Center

0 Could machine learning help us categorize earthly or extraterrestrial samples into 'life potential' or 'life non-potential'?

This question lead us to a novel idea: developing a classifier of biosignature information. Such a classifier must be trained on parameters to classify systems.

Systems are observable things, such as a rock, polymer, or tree, that can represented by a set of measurements. Parameters are these measurements, corresponding to features like chemical complexity or physical structure.

A good training data set needs diverse, well-studied system and parameters corresponding to mission instruments.

1 We asked ourselves which key questions we want to answer

- Which living and abiogenic systems have the most accessible and relevant data available?
- What tools are necessary to collect, standardize, and map these parameters and systems?
- Can any parameter combinations reliably differentiate unambiguous living/abiogenic systems?

2 What drove us to work on this early-stage study

Motivation

- There is no universal set of criteria for life yet. Missions like Mars 2020 include instruments that could detect various signs[2]. Numerous resources (i.e. the Ladder of Life Detection) highlight the need to identify measurable parameters for the evidence of life[1].
- Identifying available data for testing whether combinations of parameters can differentiate living and non-living systems will help future research and astrobiological ontology development.
- Unraveling the ultimate question – “Are we alone?” If the classifier can show a minimal suite of measurements that can distinguish life and non-life, it would help solve this life-long mystery.

What is the current stage of the project?

3 Results of data collection

3.1 SYSTEMS

Label	System	
alive	<i>Escherichia coli</i>	
	<i>Homo sapiens</i>	
	<i>Saccharomyces cerevisiae</i>	
	<i>Bacillus subtilis</i>	
	Plankton	
	<i>Arabidopsis thaliana</i>	
	Biofilms	
	Microbial mats	
	Diatoms	
	<i>Spirulina spp.</i>	
	abiogenic	Interplanetary dust
		Meteorites
		Lunar rocks
Lunar soil		
Magma		
Glass		
Salt		
Minerals		
Stardust		
Natural asphalt		

3.2 DATABASES

Encyclopedia of Life

BioNumbers

Planetary Data System

World Ocean Database

World Soil Information

OneGeology

Yeast Genome Database

AHED

Exoplanet Chemical Database

Mindat

RRUFF

The Paleobiology Database

Macrostrat

Dictionary of Natural Products

PhytCore

PheroBase

DiatomBase

VPL Biological Pigments database

The Powder Diffraction File Database

Chemical, environmental data

Frequent numbers in biology

Geological data

Ocean chemistry and other data

Soil profiles, chemistry and other data

Mineralogy and rock lithology data

Yeast and other fungi biodata

Mineralogy, biomineralogy, geochemistry

Exoplanet chemistry

Minerals, rocks, meteorites data

Spectral data from well characterized minerals

Fossil animals, plants, and microorganisms data

Geospatial data

Natural product chemical and other data

Various phytolith data

Pheromones and semiochemicals data

Environmental, fossil data

Spectral properties of biological pigments

Diffraction data

3.3 PARAMETERS

Main elemental abundance ^[3]	Trace/rare elemental abundance ^[3]
Mineral composition	Isotopic fractionation ^[2]
Elemental ratios	Enantiomeric excess ^[4]
Raman spectroscopy ^[5]	Visible and UV spectroscopy ^[6]
Differences of sugars ^[9]	Infrared spectroscopy ^[7]
Differences of aminoacids ^[8]	

- ### Challenges
- A good set of parameters has to represent selected features of life and non-life. It requires data that is representative, easily accessible and appropriate to meet our objectives. It should be either binary, discrete, interval or continuous. The systems for which we are collecting data also made us face some challenges - there aren't a lot of widely studied abiogenic systems.
 - There is a huge amount of general data available. We have to find databases that could be easily adapted to work as an input to a training set and the data has to remain characterized.
 - There are many machine-learning approaches and toolkits for classification, and we will need to compare multiple approaches to validate the idea.

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4 What are the future perspectives?

Parameter selection and system collection has to be expanded as much as possible, particularly for abiogenic systems – life on Earth has emerged billions of years ago and it has left its trace nearly everywhere.

Possible additional biogenic systems include sponges, other lichens, and species like *Mus musculus*, *Drosophila melanogaster*, *Danio rerio*a. These model organisms are valuable because the literature already provides nearly every parameter of interest.

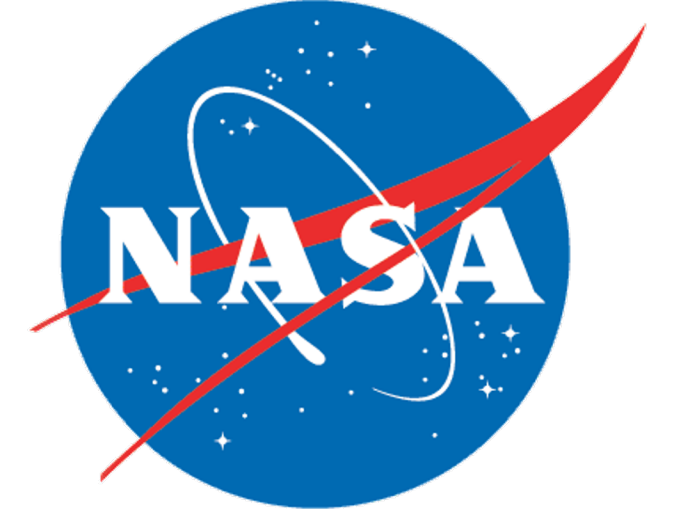
Possible additional abiogenic systems include ceramic clay, obsidian, different types of carbonaceous chondrites^[9], and other extraterrestrial materials like supernovae condensates and solar wind particles. There is a need to look for more data on already selected systems as well. Some systems may need additional lab work to generate values for parameters not usually measured in non-living systems, such as chemical complexity.

The next step after this would be to expand the training set to include non-extant biogenic systems. Stromatolites^[10], ichnofossils, phytoliths, and other bacterial encrustations would definitely fall into that category. Systems should still be unambiguously “indicative of life” or “not indicative of life” as validated by human subject matter experts.

Later on, different classification algorithms will also have to be tested using the training and validation data collected here.

5 What are the conclusions of this study

Even if some of the data was missing for specific systems, there were similar systems that have had these parameters characterized. These systems have to be included as well. That leads us to the conclusion that combining data is crucial if we want to distinguish alive systems from the abiogenic ones.



Modeling Icy Worlds Terrain-Lander Interaction Using Discrete Element Method

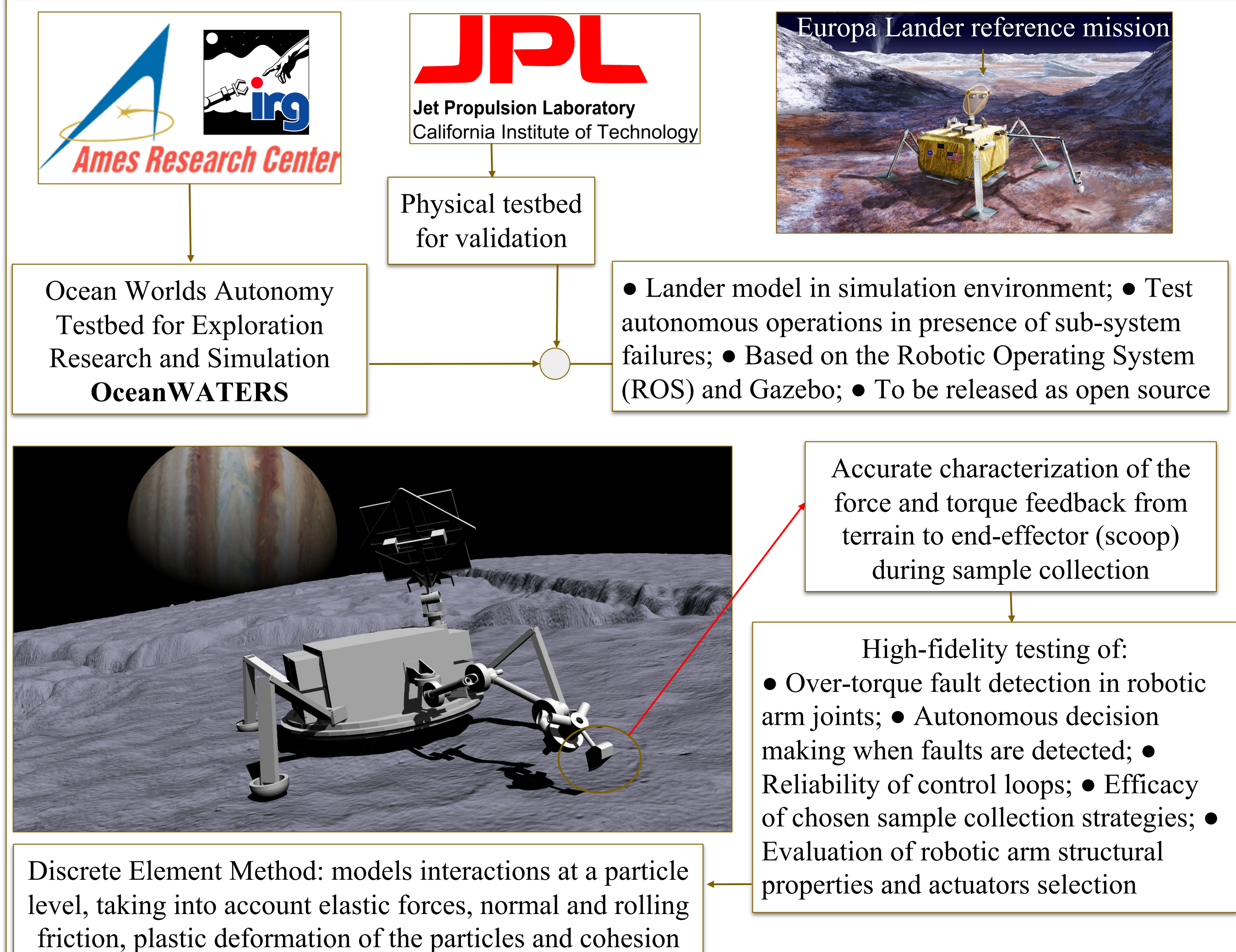
Damiana Catanoso¹, Arno Rogg², Thomas Stucky³, Jennifer Case⁴, and Laurence Edwards⁵

¹Universities Space Research Association, ²KBR, ³SETI Institute, ⁴NIST, ⁵NASA Ames Research Center

ABSTRACT

The analysis presented in this poster is conducted in the framework of the Ocean Worlds Autonomy Testbed for Exploration Research and Simulation (OceanWATERS) project, currently under development at NASA Ames Research Center. OceanWATERS aims at designing a simulation environment which allows for testing autonomy of scientific lander missions to the icy moons of our solar system. Mainly focused on reproducing the end effector interaction with the inherent terrain, this poster introduces a novel discrete element method (DEM)-based approach to determine forces and torques acting on the lander's scoop during the sample acquisition process. An accurate force feedback from the terrain is required by fault-detection and autonomous decision-making algorithms to identify when the requested torque on the robotic arm joints exceeds the maximum available torque. DEM models scoop-terrain interaction at particle level, taking into account elastic forces, friction, plastic deformation and cohesion. The DEM approach allows to compensate for analytical and experimental models' deficiencies and inaccuracies, i. e. provide force and torque vectors, defined in the moving reference (body) frame attached to the scoop, at each instant of the sample collection process. The specific OceanWATERS sampling strategy consists of collecting the planet's surface material through five consecutive passes with increasing depth, each pass following the same circular-linear-circular trajectory. Simulations are conducted considering a specific scoop design interacting with two types of bulk materials, which may characterize the surface of icy planetary bodies: snow and ice. Two studies are presented in this work, aimed at reducing DEM computation time, i. e. finding a compromise between complexity and size of the terrain particle and computational effort required. DEM simulation results are validated through an appositely designed, 3D printed and assembled physical testbed, that accurately reproduces the sample collection scenario.

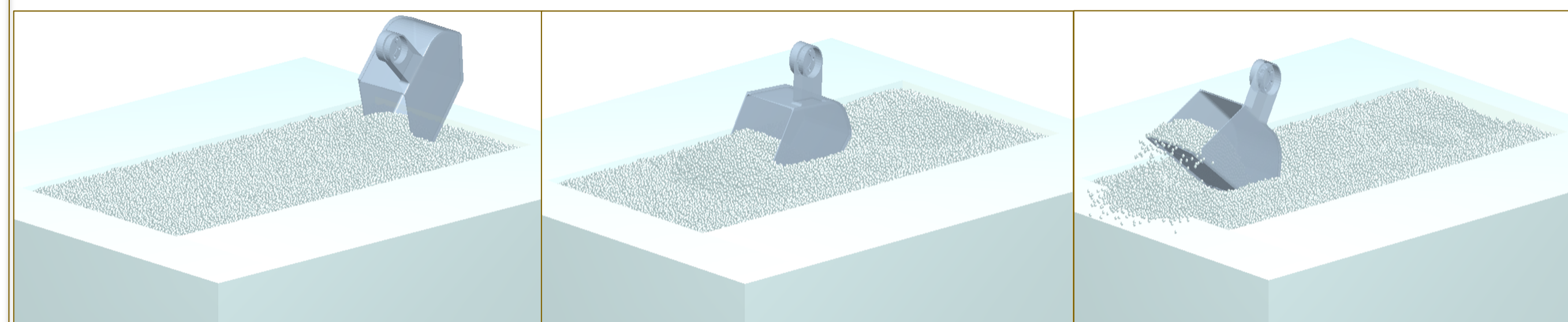
BACKGROUND & MOTIVATION



ANALYSIS & SIMULATION

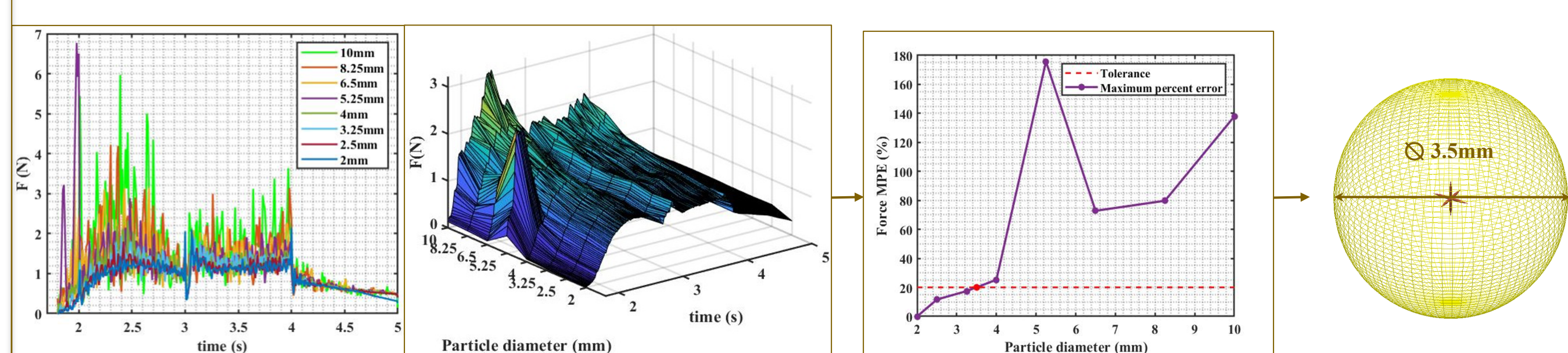
Sample collection strategy

- Circular-linear-circular;
- Multiple passes;
- Increasing depth between passes



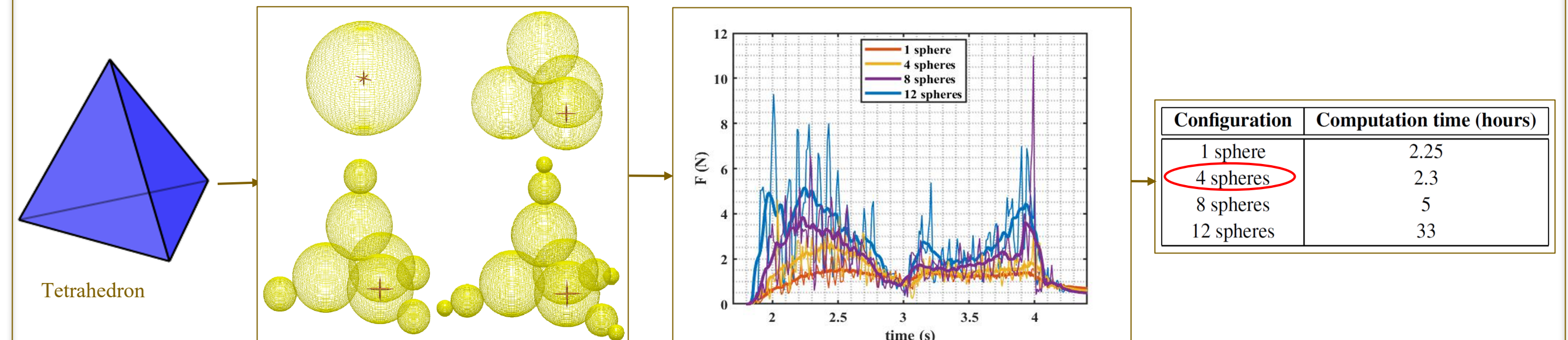
Snow sphere size determination

Aim: determine the largest sphere size that represents bulk behavior of smaller particles

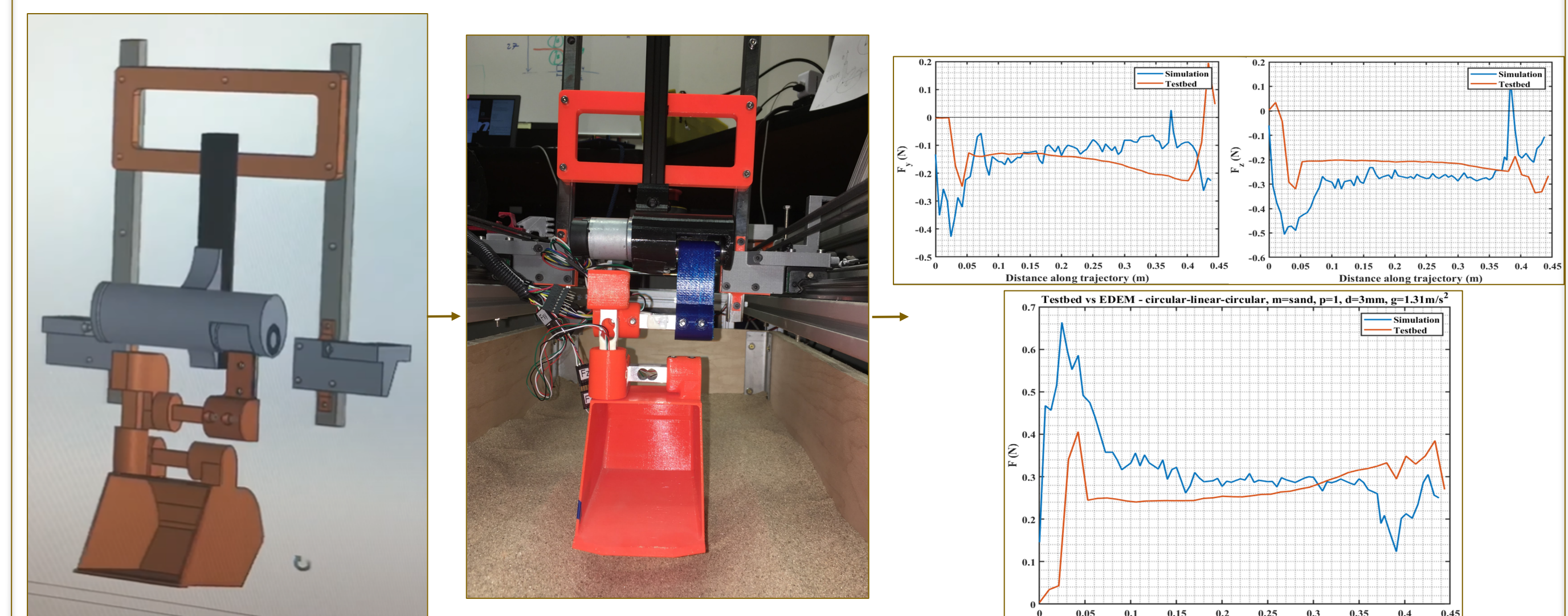


Ice particles configuration determination

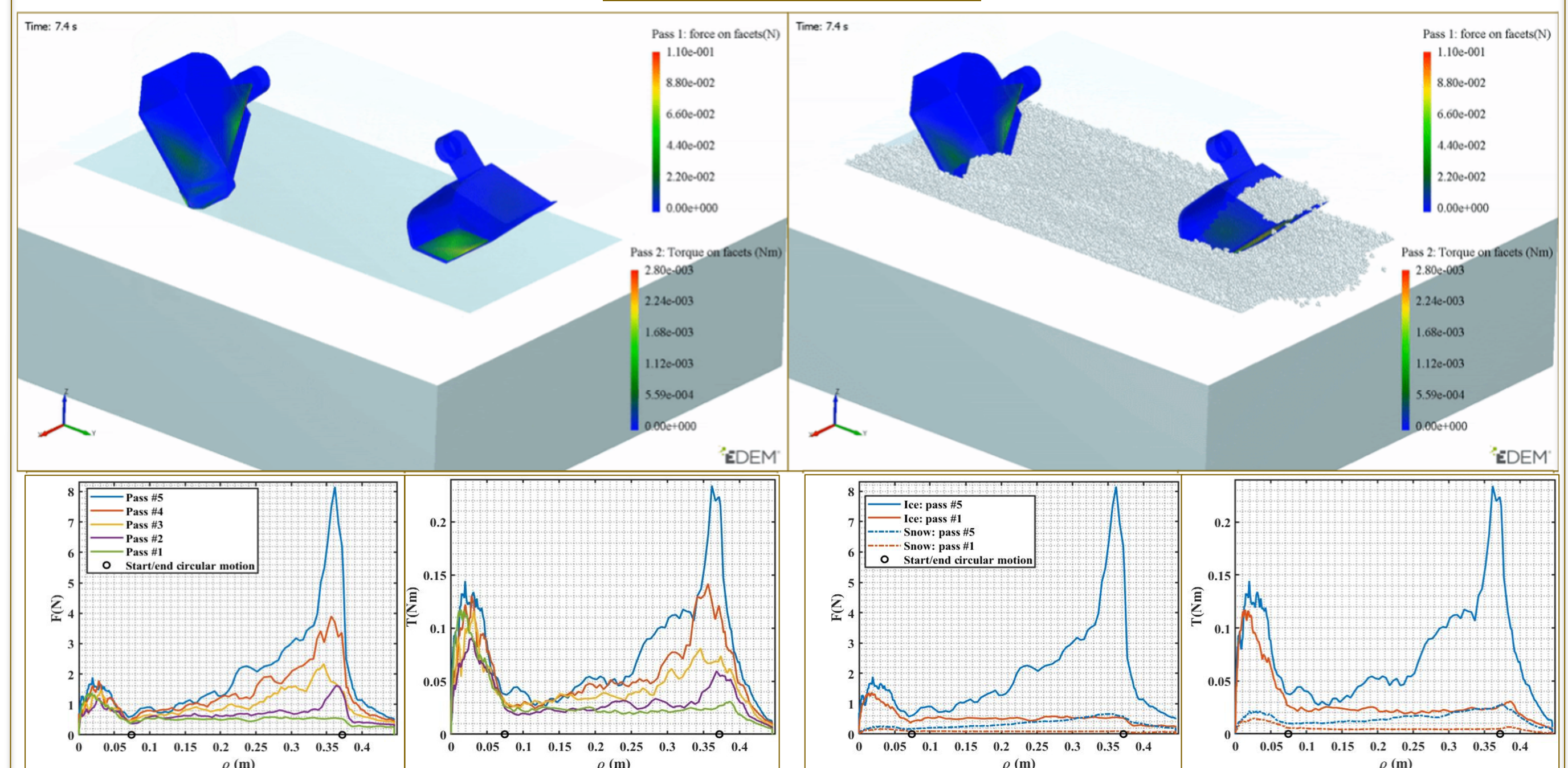
Aim: determine particle configuration as result of compromise between fidelity and computation time



Results validation through physical testbed



Lookup table simulations



FUTURE WORK

- Open source DEM software selection, validation, implementation in OceanWATERS.
- OceanWATERS software validation through JPL physical testbed.
- Investigation of more sample collection strategies.
- Inclusion of DEM force feedback information during ice drilling: bonded particles

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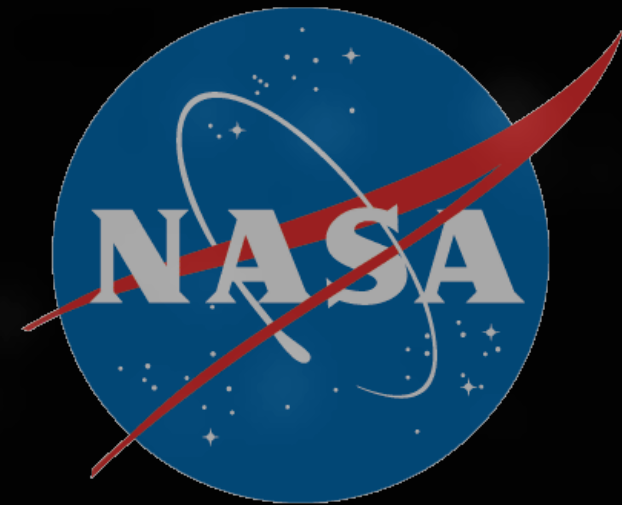
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*All photos and figures are credited to NASA





Processor-in-the-Loop (PIL) Simulation of the Distributed Spacecraft Autonomy Project

Jason Ream ^{1, 2} | Nicholas Cramer ³ | Jeremy Frank ³

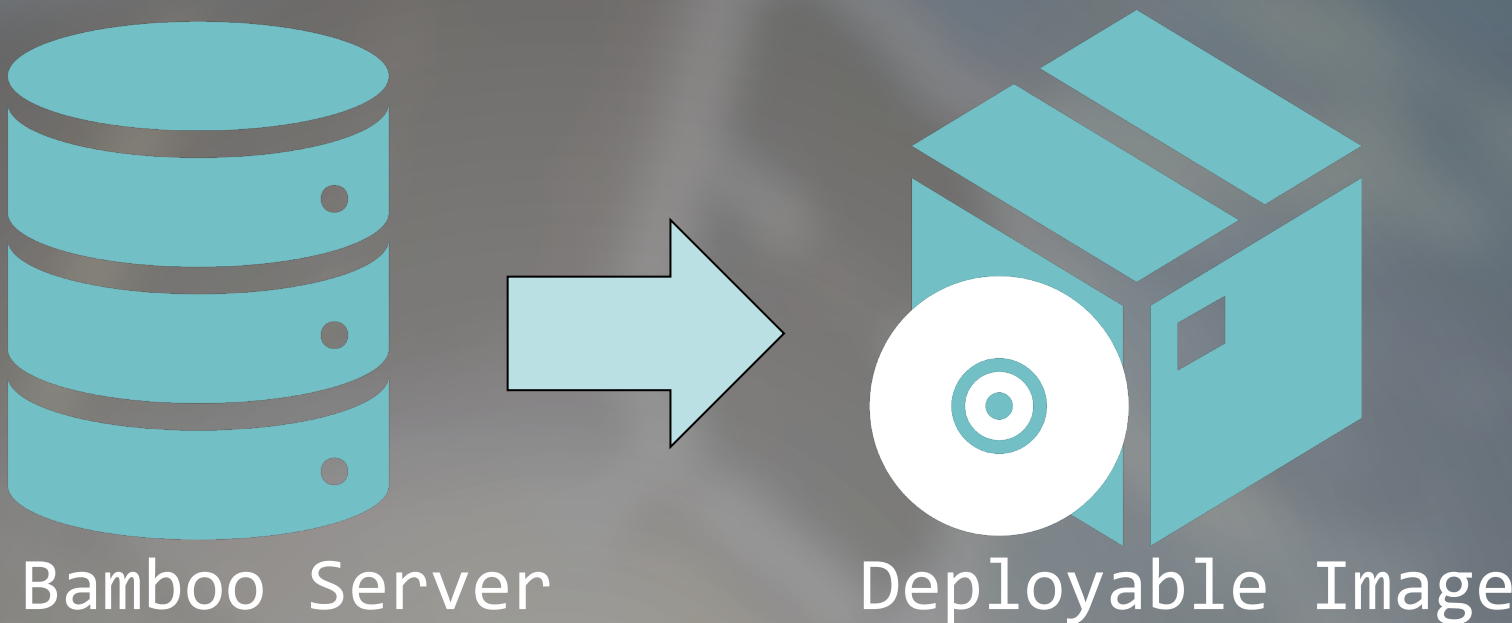
¹ University Space Research Association, NASA Ames | ² York Technical College | ³ NASA Ames Research Center

INTRODUCTION

The ability for multiple spacecraft to orchestrate their behavior as a cohesive unit will have a profound impact on the future of space travel. Multiple spacecraft expand the capability of missions providing a bridge for communications and multiple points of measurement or observations for scientific missions. The Distributed Spacecraft Autonomy (DSA) Project, is a software payload of the 2021, Starling mission. DSA will demonstrate how operating multiple spacecraft can address current limitations such as round-trip communications, data constraints due to bandwidth, and delays of mission-critical opportunities.[1]

BACKGROUND 1

- The DSA Project is currently developing several software algorithms for multiple spacecraft operations. These algorithms are implemented in the cFS software platform.
- Software-in-the-Loop (SIL) processes the executable applications using Atlassian's Bamboo platform, a Continuous Integration (CI) server that automates building and testing of software source-code.

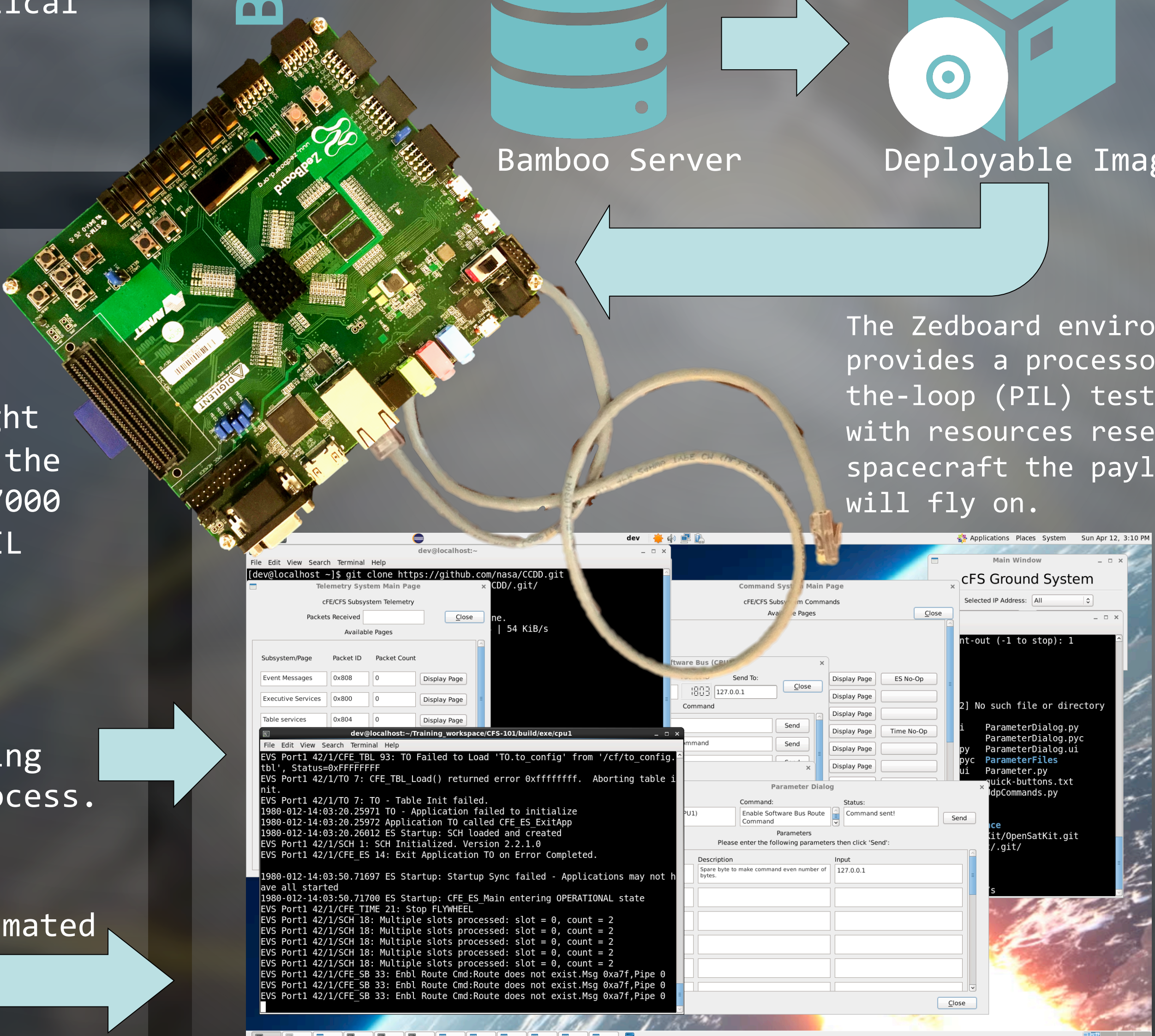


BACKGROUND 2

- The ZedBoard will allow the DSA Project to demonstrate functionality similar to the spacecraft the payload will fly on for its maiden voyage.
- The initial processor-in-the-loop (PIL) environment will allow for debugging the functionality of the algorithms and provide realistic performance assisting to isolate hardware or software related issues.
- PIL simulation will provide the groundwork for the next phase of testing where four ZedBoards will be networked together to demonstrate, test, verify and validate the autonomy aspect of the DSA Project.

OBJECTIVES

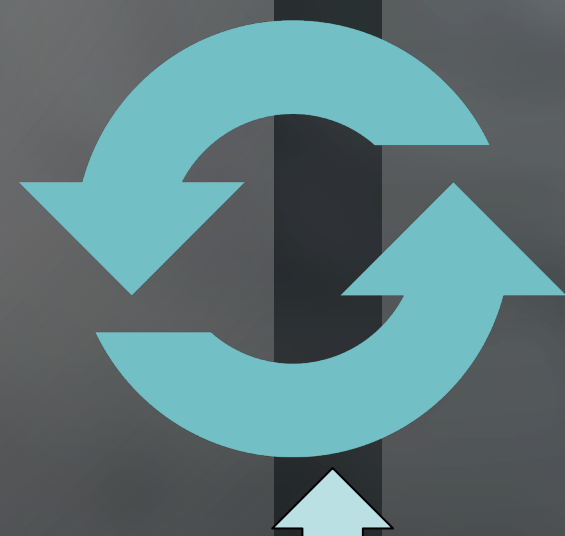
- Create** a stable instance of the Core Flight System (cFS) software environment onboard the AVNET ZedBoard utilizing the Xilinx Zynq-7000 All Programmable Software on a Chip for PIL testing. [2]
- Recreate** the cFS environment, utilizing COSMOS, and CCDD on the ZedBoard documenting any items that may expedite the set up process.
- Refine and assist** in developing an amalgamated Virtual Machine for use by the team's developers.



EQUIPMENT

The successful PIL demonstration will provide the preliminary build of the cFS, COSMOS, and CCDD. Baseline parameters will be documented for data logging, and run-time analysis to profile DSA code.

Proposed tests of the baseline environment with DSA applications implemented:



Continuous feedback loops of the DSA applications:

Pass - REPROCESS
FAIL

Regression testing for failed updates:
Reprocess build to find break point

Determining areas of resources strain, or resource failure

ANALYSIS

References

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I would like to share my appreciation for the patience and continued mentorship of Dr. Nick Cramer, and Dr. Jeremy Frank, following their guidance and experience has shown me a world of opportunities. I would also like to thank Chuck Fry, and Dr. Daniel Cellucci for sharing their support and expertise. Finally, without the assistance of the Notational Space Grant Foundation, and the South Carolina Space Grant Consortium this opportunity would not have been possible.

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Embedded Control System for Lightweight 3D-Microscope

Simen E. Sørensen¹ | Mentors: Michael Dille², Uland Wong²

¹ Department of Physics, University of Oslo, Norway, ² Intelligent Robotics Group, NASA Ames Research Center, California

Abstract

Detailed geometrical soil analysis is easier to perform with soil samples in hand than with pictures of remote samples. In planetary science, this is a luxury reserved for only a tiny selection of planetary bodies – so tiny, in fact, that many scientists will never get their hands on them. Being able to examine three-dimensional features and reflective behavior of the soil granules makes it possible to perform detailed segmentation and study of its constituents. So what if this information could be encoded in the digital data sent from a remote camera? The Intelligent Robotics Group at NASA Ames has recently developed a solid state 3D-microscope, using only a *single camera*, capable of presenting its user with high quality 3D models, selectable synthetic illumination, and demonstrated it with a variety of soil simulants. We have now engineered the necessary electronic circuitry to miniaturize this laptop-powered, benchtop-sized instrument and made it independent of external control. The result is a cheap, lightweight instrument smaller than 1U, making it ideal for planetary micro-rover missions and novel sensor network deployment applications. Ongoing work includes the preparation of mounting and packaging to demonstrate both applications.

Introduction

Future planetary surface missions such as micro-rovers demand unique compact sensor instruments. Our group has recently developed a single-camera, solid-state, 3D microscope in both a complete benchtop-sized version and prototyped a miniaturized optical stack. These designs have demonstrated the potential for an extremely compact instrument with a high quality data product, but they both rely on full size personal computers for controlling acquisition and experimental procedures. The next logical step was therefore to develop an embedded control system with power distribution circuitry allowing the instrument to be completely independent of external wiring.

Design Challenges

The 3D-Microscope has three key elements that need to be controlled in order to acquire a raw dataset:

1. LED control for illumination
2. LCD control for programmable aperture (see Figure 2)
3. Camera control for image acquisition

To acquire a single image, one will first need to illuminate the object, then select the size and cross-sectional location of the aperture, set shutter speed, ISO and other camera parameters before finally capturing and storing an image. To acquire a raw dataset, this process is repeated for a predetermined set of lighting conditions and aperture positions (perspectives).

Result

The new embedded control system, “µScope”, is designed to conveniently allow for future firmware development by being based around an open source development board running a 64-bit linux kernel on four processor cores. The development board also provides necessary basic utilities like RAM, permanent storage and Ethernet as well as convenient basic utilities such as USB, WiFi and Bluetooth. This means that only a minimum of code needs to be written in order to implement new functionality, without doing unnecessary work that would need to be discarded when customizing more specialized hardware in the future.

All specialized hardware is currently separated from the processor and basic utilities by being mounted on an easily removable expansion card (see Figure 1). The expansion card, or “shield”, includes the hardware and connectors to perform the three critical control tasks, as well as power distribution systems, circuit protection circuitry and battery management – making it entirely self sustained and independent from a host computer. The raw images can be transferred to a remote data processing unit via wireless communication.

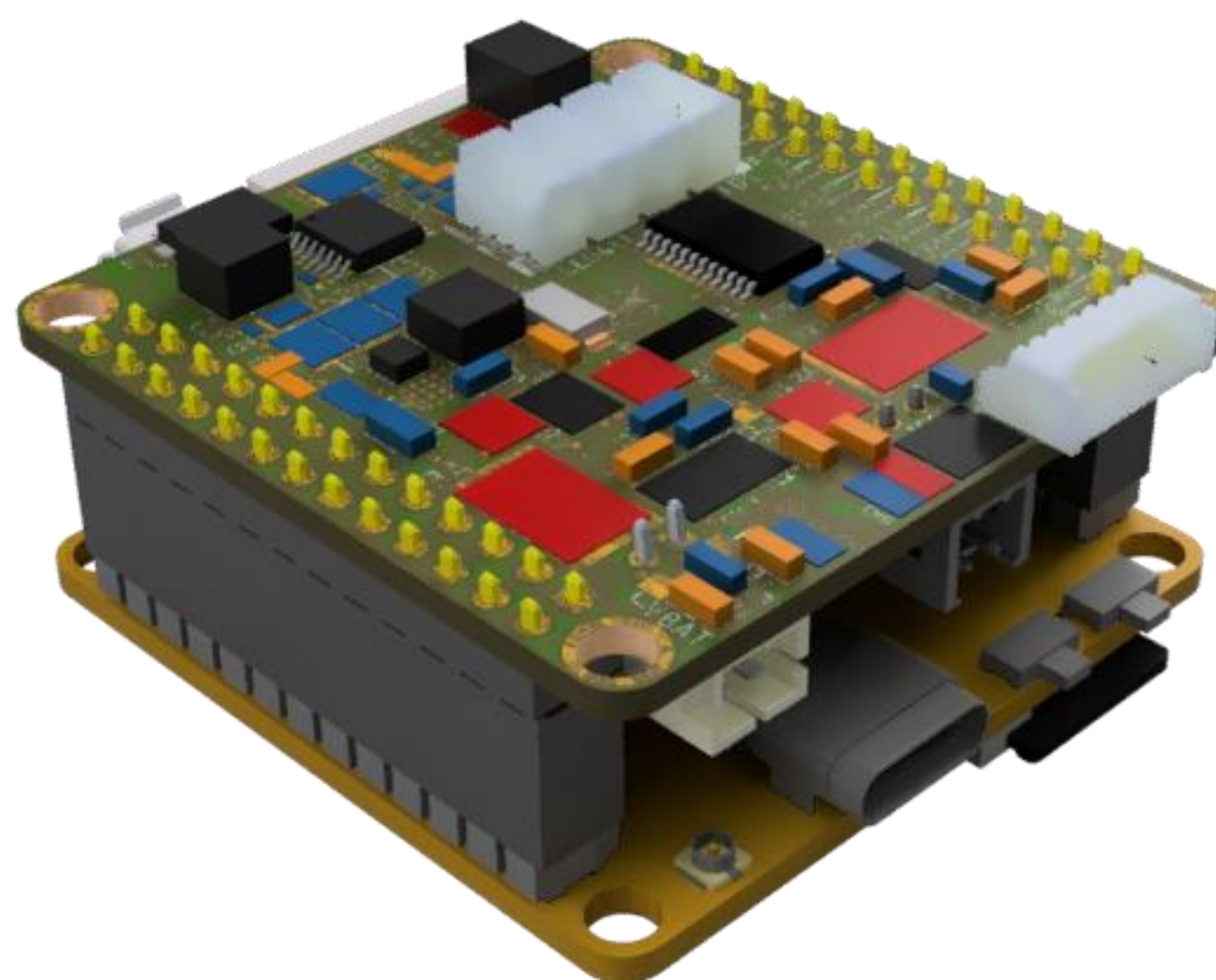


Figure 1: External hardware for control, power distribution, and battery management is separated from the processor and standard utilities on a “shield”.

Conclusion

The instrument, with all necessary control systems, has now been demonstrated to fit well within the 1 liter confinement of the 1U formfactor popularized by CubeSats (indirectly demonstrated in Figure 4). This means that the instrument is highly feasible for the proposed mission types: micro-rovers and sensor-networks. Since three of the processor cores are currently left unused it's also highly likely that on-board data processing can be implemented on the current platform. An exciting improvement expected to be made in the future is using a plastic LCD for the programmable aperture. This technology is immature at the moment but some manufacturers have started mass production, and even allow for custom “pixel” shapes – meaning that round apertures might be a possibility.

Multi-View Stereo

Multi-View Stereo (MVS) is a technique where a set of images captured from different perspectives are combined into a 3D model of an object. This is typically done by using several cameras in a known geometry, but one unique way to achieve a slight perspective shift is by utilizing a programmable aperture. In our microscope we use a transparent LCD-screen as the aperture, meaning that we need **no moving parts** to achieve the effect of changed perspective (see Figure 2).

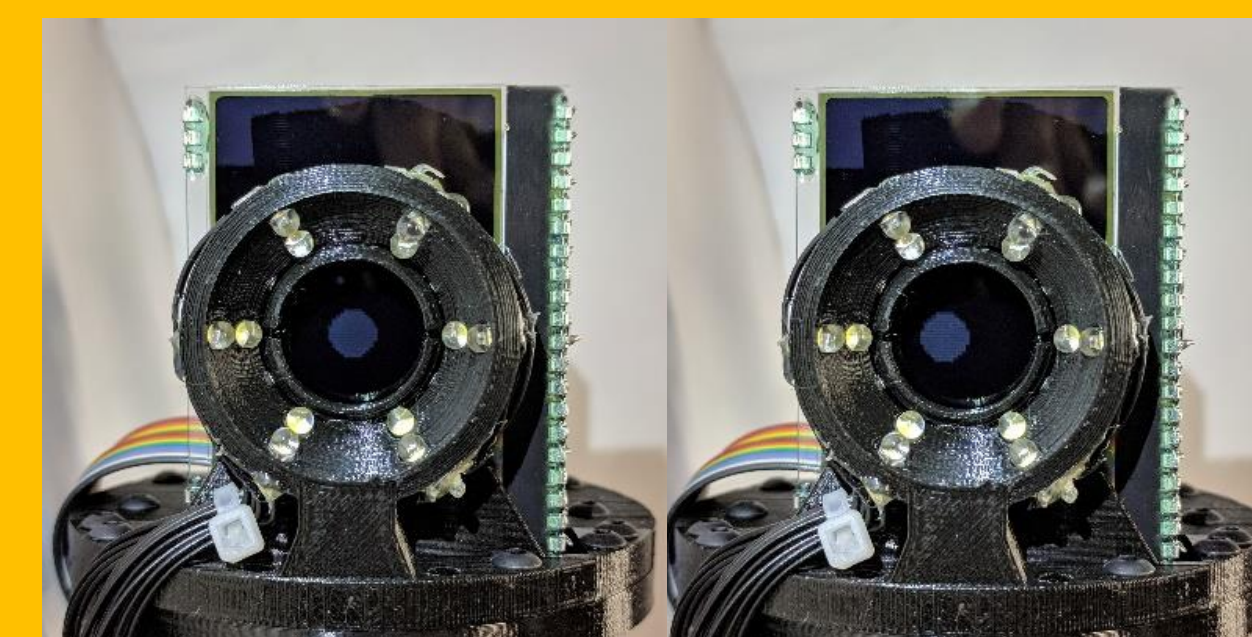


Figure 2: Using an LCD as programmable aperture allows solid state perspective shift using only a single camera.

Photometric Stereo

The controlled illumination allowed by the constellation of LEDs in the nose-cone (see Figure 2) means we can implement Photometric Stereo. Photometric Stereo is a complementary technique to MVS that calculates 3D features from reflections and shadows. This means that a 3D surface can be estimated from a single perspective. Additionally, the physically accurate reflection-data that is gathered allow for various enhancements to the processed dataset – such as synthetic re-illumination (allowing the user to “hold” a virtual flashlight) which is used for material segmentation and identification.



Figure 3: An example 3D reconstruction of JSC-1 MARS medium-particle soil simulant. Modeled using both Photometric and Multi-View Stereo.

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A special thanks to my mentors at NASA, Dr. Michael Dille and Dr. Uland Wong, for all their help and guidance. A special thanks to Porsche M. Parker as well, for the tremendous effort she has put down to allow the completion of this project during a chaotic set of circumstances as result of the COVID-19 pandemic. My work on this project was supported and made possible by the Norwegian Space Agency.

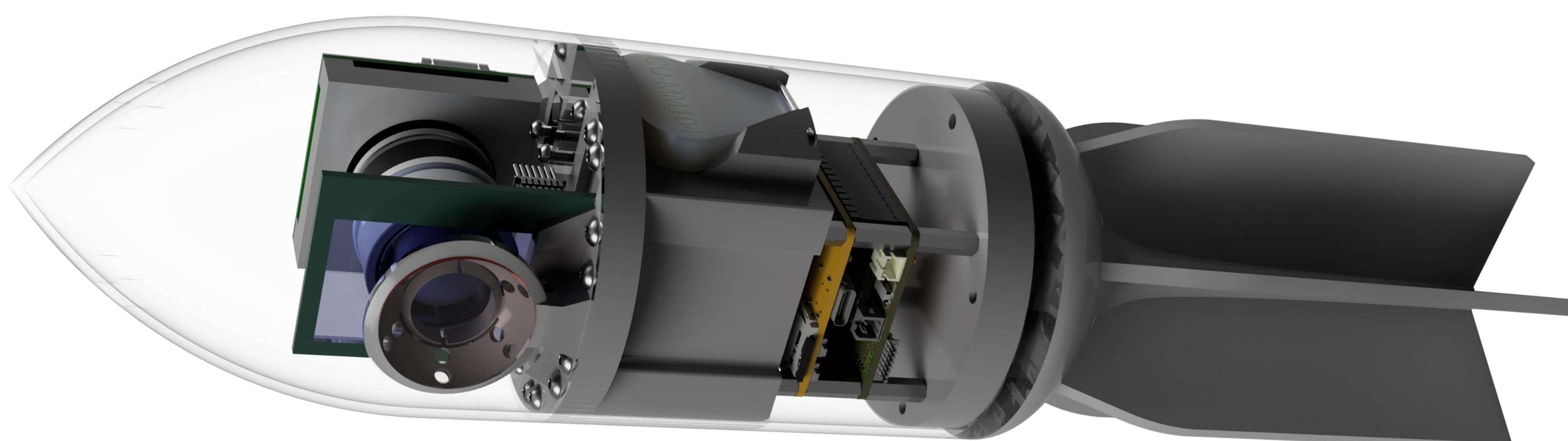


Figure 4: A CAD model showing what a fully assembled instrument may look like if used in a remotely placed sensor such as the PHALANX projectile sensor-network system developed by our group. The nose section (far left) contains the camera and optics as well as the programmable aperture and light field rig. The middle section contains all the necessary control hardware to perform tasks that were previously performed by a laptop. Even when including a relatively large, 3 cell, battery the volume of these two sections combined is far smaller than the liter of a standard 1U compartment.

References

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Additive Manufacturing of Ablative Materials for Low Earth Orbit (LEO) Return Vehicles

Anthony Cerezo^{1,2}, Tane Boghazian^{3,4}

¹San Jose State University, ²USRA Intern, ³NASA Ames Material Scientist/Engineer, ⁴Mentor

Introduction

Thermal Protection Systems (TPS) are needed to protect space vehicles from heat caused by atmospheric friction when entering a planet's atmosphere. Ablators are one form of TPS that dissipates aerodynamic friction by material ablation and pyrolysis. The extent and use of these materials rely on their properties to inhibit heat from transferring to the interior of a vehicle, to endure the stresses upon takeoff and entry, and allow vehicle payloads to be maximized. As space exploration continues to increase in both the private and commercial sectors, TPS for Low Earth Orbit (LEO) will need to be developed and address the needs of lower manufacturing costs and shorter lead times while retaining safety and reliability. Additive manufacturing, commonly referred to as 3D-printing, offers a unique processing ability to accommodate these factors through iterative part design and customization, close net-shape manufacturing, and lower production costs. By creating a printable ablative material, vehicle TPS parts could be manufactured to defined geometries and with repetition with the opportunity to optimized part properties by changing the printing material.

Objective

- ❖ Formulate and optimize low-density printing pastes using phenolic and silicone based resin systems for backshell TPS
- ❖ Evaluate and characterize ablative paste systems.
- ❖ Determine printing delivery system for additive manufacturing thermoset paste.

Printing Delivery System

Fused Deposition Modeling (FDM) is one of seven additive manufacturing technique that works by extruding or direct depositing material layer by layer until a shape is made via a bottom-up approach. The FDM printing has advantages of being more cost effective to implement, allowing large part scalability, and depositing a variety of material in paste form. Printing thermoset pastes presented a unique problem for delivering a continuous flow of material when plotting because of the unique materials and fillers chosen. To mitigate disruptive flow caused by filler clogging or dead zone flow, a moineau type extruder was developed.

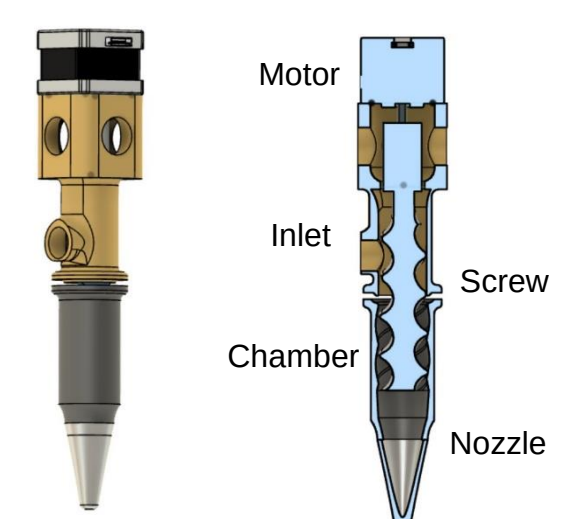


Fig 1: Developed paste extruder. 3D rendered and cross-sectioned.

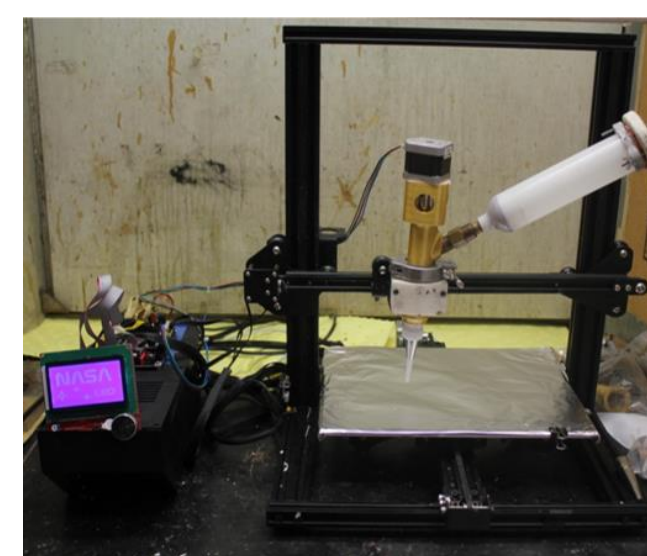


Fig 2: "Leo", a modified FDM printer to demonstrate 3D-printing of ablative paste.

Experimental Methods

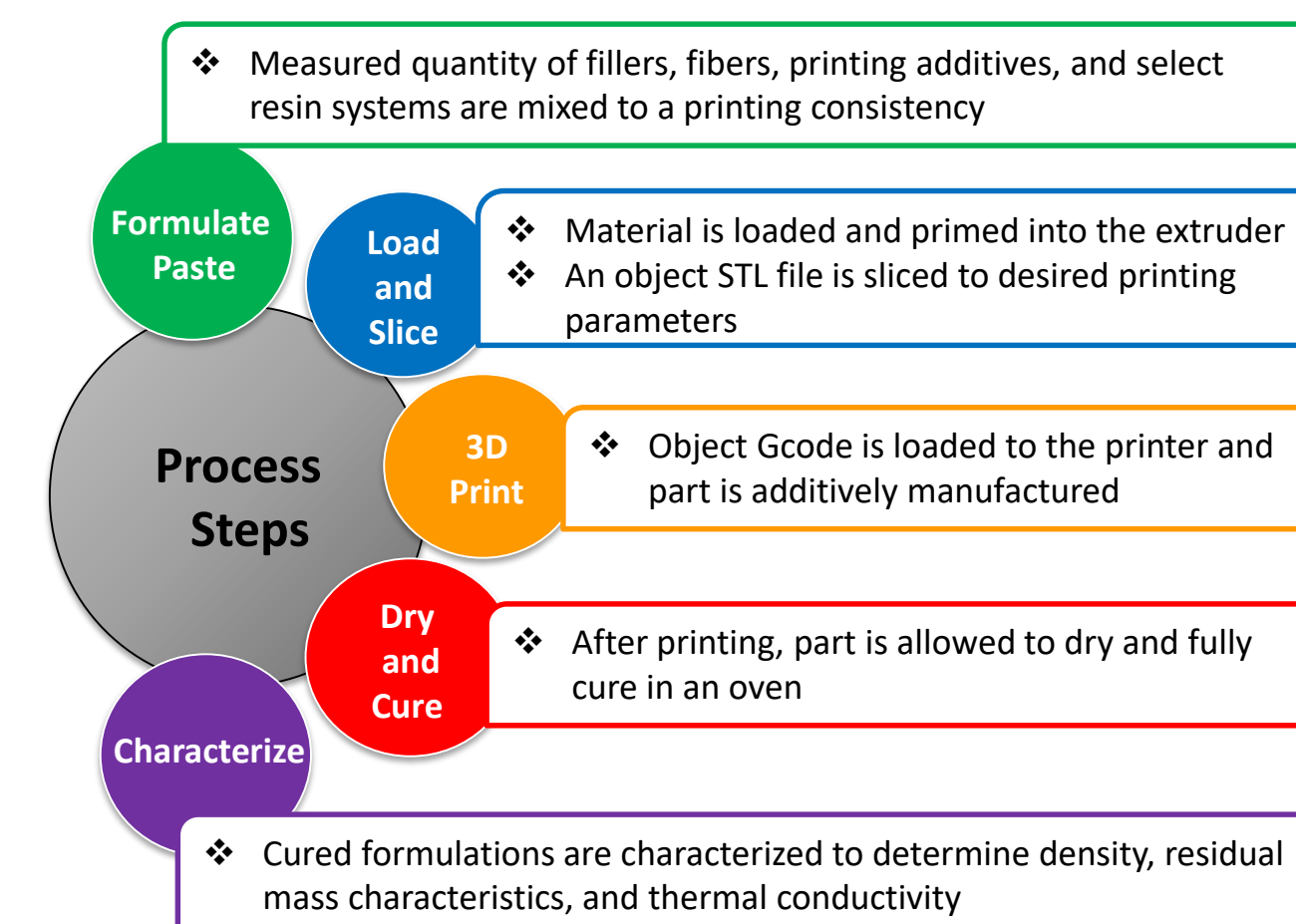


Fig 3: Process of printable ablative materials

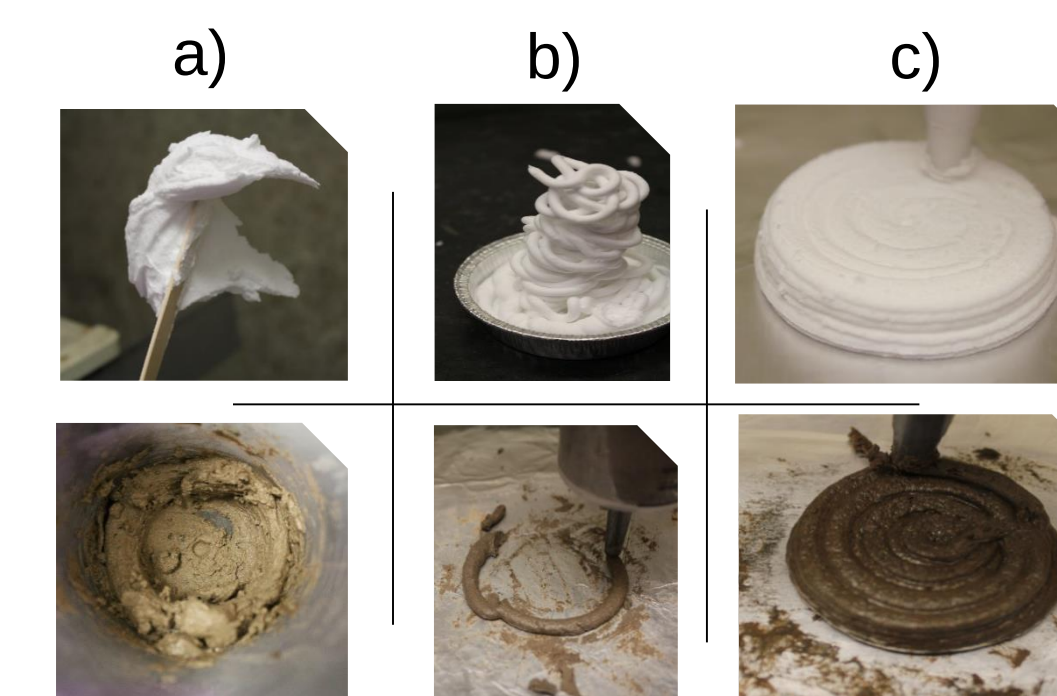


Fig 4: Phenolic (bottom) and Silicone (top) based paste formulations: a) after mixing, b) extruded, c) printing and layering

Layer Adhesion and Interface

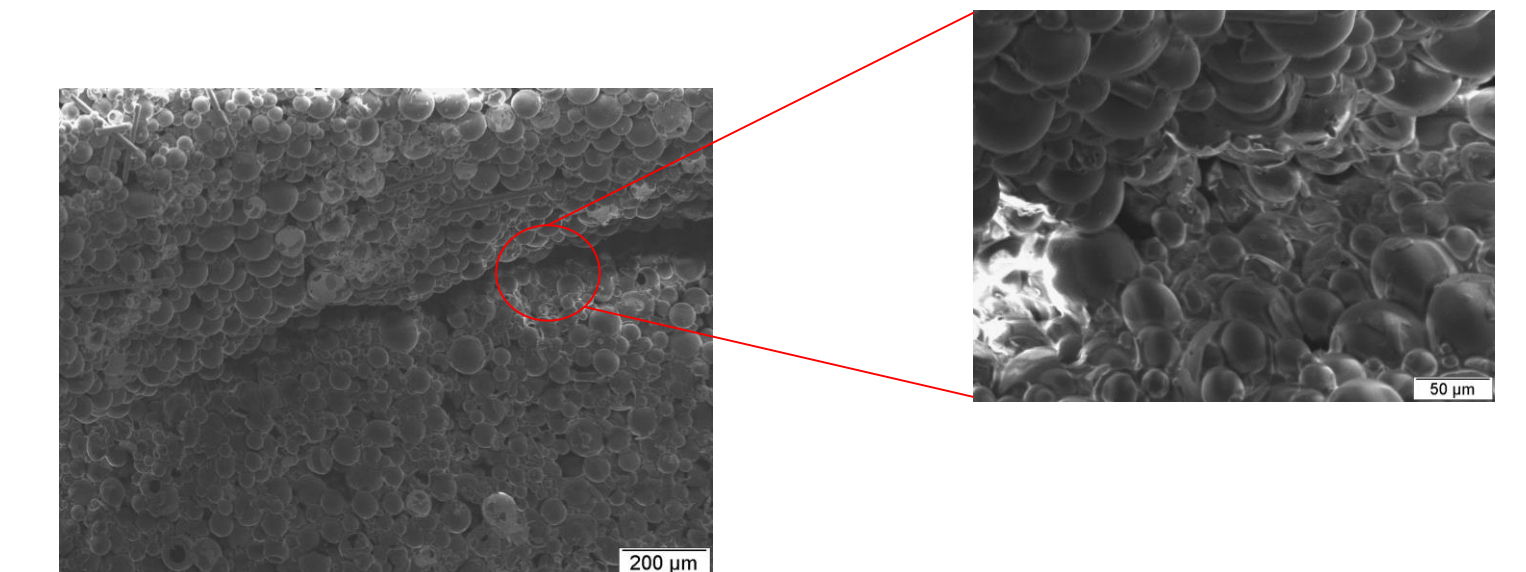


Fig 9: Silicone paste formulation after printing. As the layered beads adhere there is a natural interface that occurs as the part is developed layer by layer. However these interfaces will artificially induce pores and anisotropy.

Challenges Encountered

- ❖ Proper addition of materials for mixture homogeneity.
- ❖ Voids induced by interbead porosity and processing air pockets.
- ❖ Balancing act of printability, low-density, and material integrity.

Learning Opportunities

- ❖ Characterization techniques using thermogravimetric analysis (TGA), heat flow meter, scanning electron microscope (SEM), and more.
- ❖ Programming and computer aided design (CAD) modeling.
- ❖ Hands-on processing and fabrication of phenolic impregnated woven TPS.

Summary

Development of 3D-printable ablative paste offers a unique direction and option for future TPS materials. This research presents formulations of pastes that utilize silicone and phenolic based resin systems to determine feasibility for printing and demonstrating desired TPS properties. The current formulations of these phenolic based and silicone based pastes show slightly higher thermal conductivities compared to SLA but demonstrate low and comparable densities to LEO heritage material. Through various paste extruders it was determined that the delivery system for printing these unique porous pastes should FDM printed using a developed screw force extrusion systems that offers a solution to volumetrically dispense material pastes with compaction and while mitigating dead zone clogs. More research and characterization needs to be conducted for ablative paste optimization and down selection prior to a Hypersonic Materials Environmental Test.

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I would like to thank Tane Boghazian, Greg Gonzales, and the whole TSM branch for helping provide this facilitated learning and rewarding experience here at NASA Ames.

Results

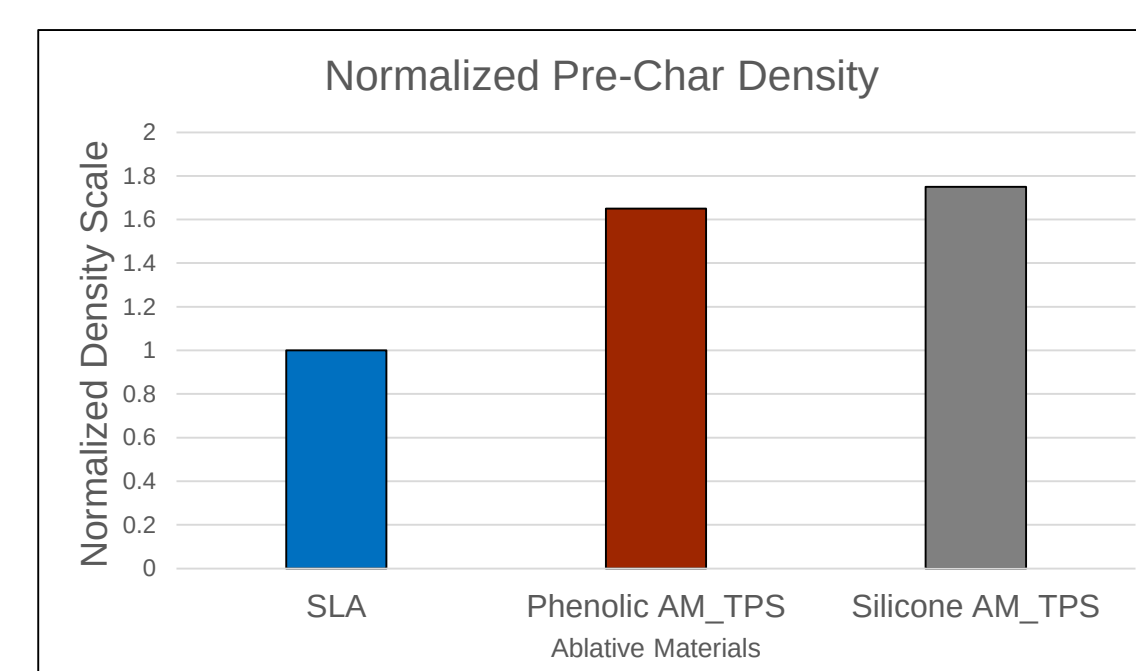


Fig 5: LEO ablative material pre-char density comparisons, normalized to SLA. This is a depiction, showing the relative density to one another's value. The 3D-printed pastes densities are heavier than SLA heritage material.

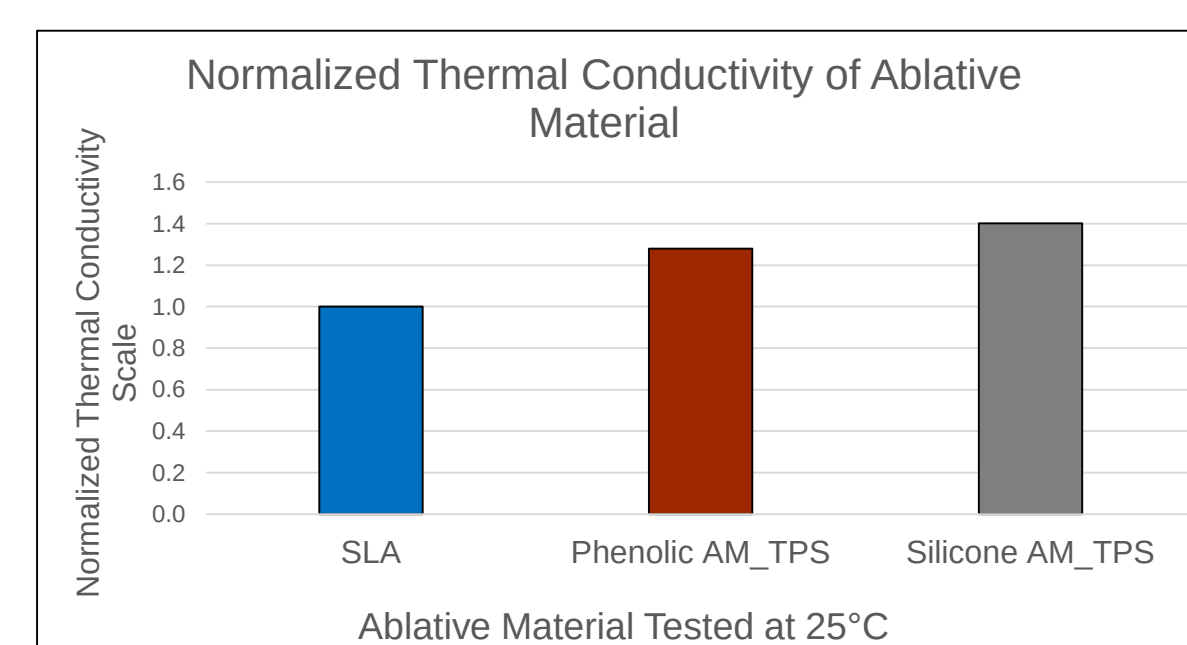


Fig 7: LEO ablative material thermal conductivity comparisons, normalized to SLA material. This is a depiction showing relative thermal conductivity to one another's value. 3D-printable pastes have slightly higher thermal conductivity.

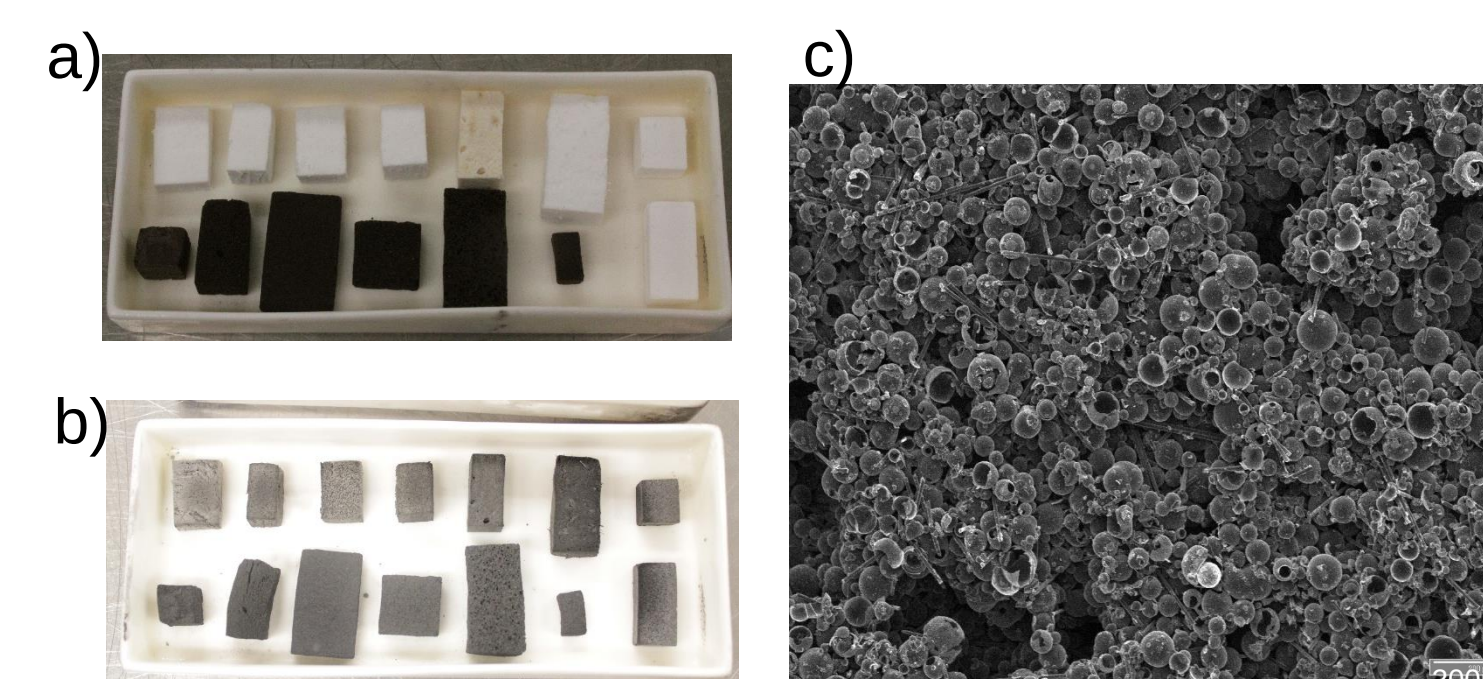


Fig 6: Molded 3D-printing paste sample formulations a) before char and b) after charring in a furnace. The SEM image c) is the morphology of an uncharred silicone paste formulation.

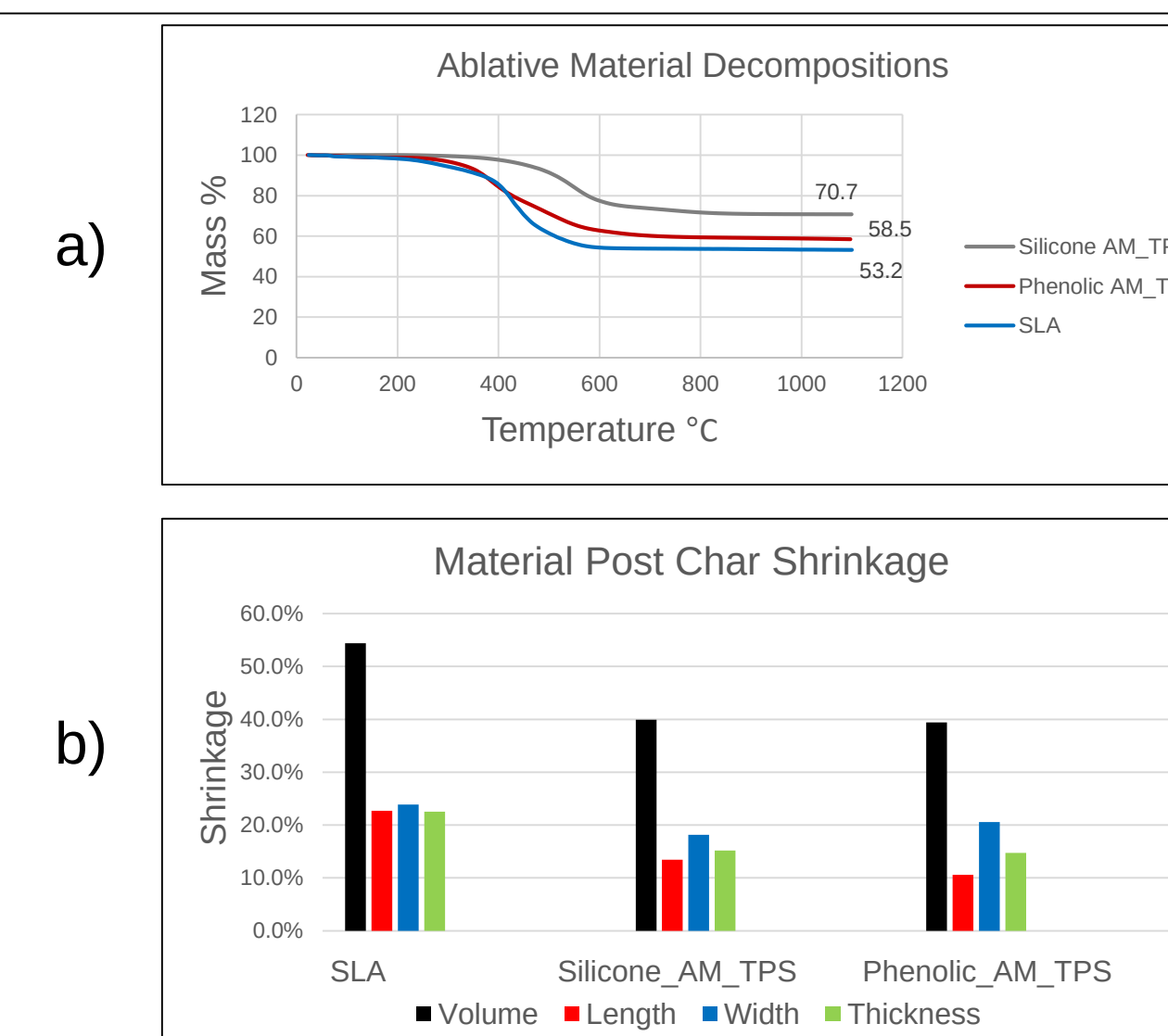


Fig 8: This graph shows ablative material depicting a) material shrinkage after charring during a heat treatment and b) the resulting char yield. The printed pastes show higher char yields, lower shrinkages, and anisotropic shrinking behavior compared to SLA.

Poster: Additive Manufacturing of Ablative Materials for Low Earth Orbit (LEO) Return Vehicles

Authors: Anthony Cerezo and Tane Boghoozian

Date: 4/10/2020

Image Sources

All lab photos were taken by me (Anthony Cerezo) using a Nikon digital camera. All instrumentation images using the SEM were also taken by me (Anthony Cerezo). Graphics and 3D renderings were also taken by (Anthony Cerezo). All images were completed in N223 and N242 laboratories.

Important:

- ❖ The graphs of thermal conductivity and material densities have been normalized to hide respective values.
- ❖ Values of crucial temperatures and times are not disclosed.

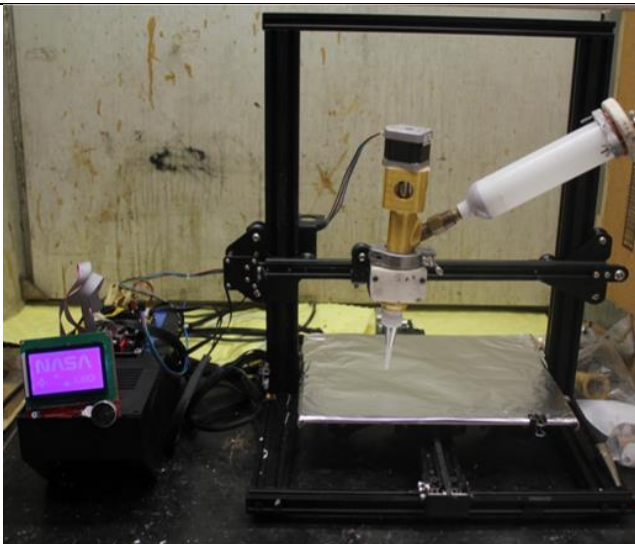


Fig. 2
Cerezo, Anthony, "FDM modified 3D printer". Imaged January 9, 2020 in N223

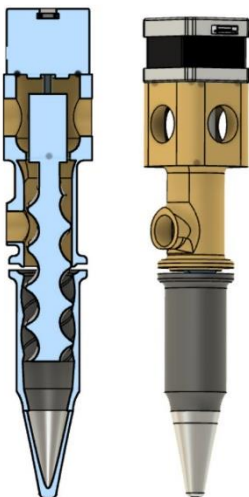


Fig.1
Cerezo, Anthony "3D rendered and cross-sectioned Moineau extruder"
Imaged April 1, 2020



Fig.3

Cerezo, Anthony "Compilation of paste process steps". Imaged and combined through the months of September-December 2019 in N223



Fig.4

Cerezo, Anthony, "Pre and Post Char". Imaged January 16, 2020 in N223

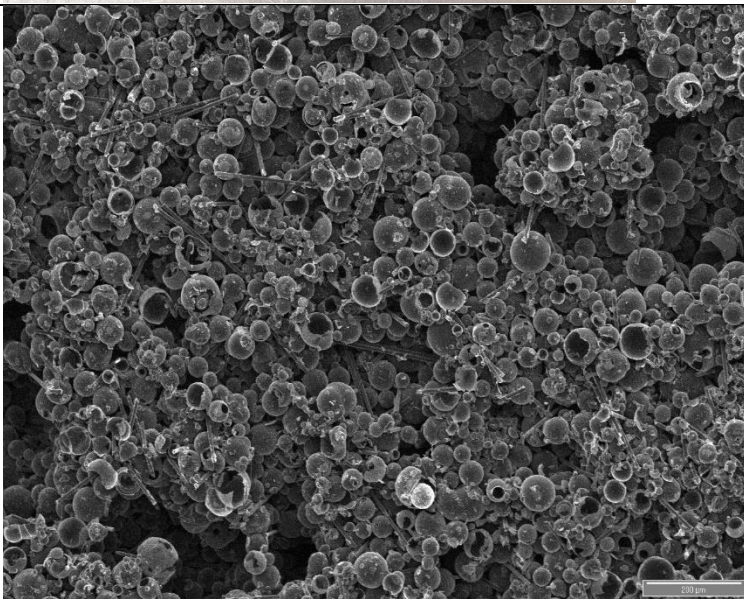
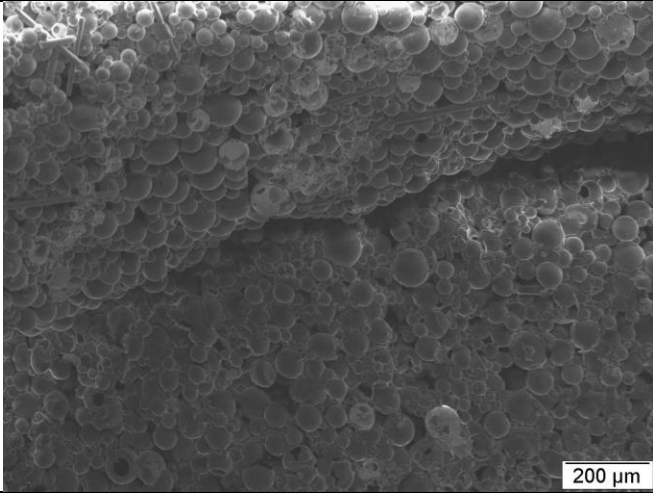
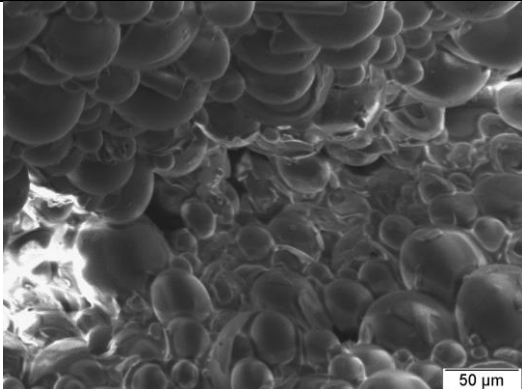


Fig.4C

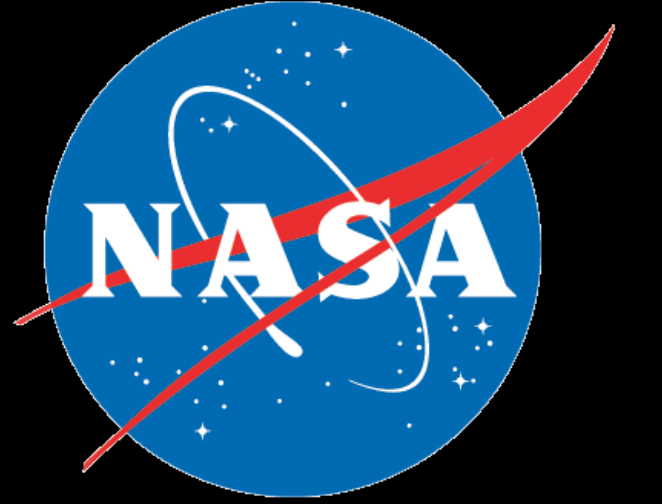
Cerezo, Anthony, "Silicone paste Morphology". Imaged September in N242

	Fig.8 Cerezo, Anthony “3D printing layer interface of silicone paste”. Imaged July 24, 2019 in N242
	Fig.8 Cerezo, Anthony “Indepth look at 3D printing layer interface of silicone paste”. Imaged July 24, 2019 in N242

Plasma Jet Printing of Metal Oxides for Sensors

National Aeronautics and Space Administration

Erick Aghaian, Rahul Ramamurti, Jin-Woo Han, M.Meyyappan, Ram Prasad Gandhiraman
NASA Ames Research Center, Moffett Field, CA, 94035



Abstract

As manned space exploration progresses, the need for manufacturing capabilities in space becomes more apparent. 3D printing has been a thoroughly utilized technology in the past decade and holds much promise. Printing in space requires customization to address microgravity related issues. Plasma printing is a new and emerging technology that can drive fluid through an electromagnetic field and plasma, which is not affected by the microgravity environment, enabling in-space manufacturing. Here we will discuss plasma printing capabilities and our efforts to optimize printing parameters. More specifically, we examined printing parameters for titanium (IV) oxide [TiO₂] and tin (IV) oxide [SnO₂] for gas sensor development as well as silicon (IV) oxide [SiO₂] as a dielectric for electronics. TiO₂ and SnO₂ were printed on a range of substrates including glass, silicon wafers, and PCB gas sensor chips. Electrical resistance measurements were made to determine gas sensing efficacy. The target resistance for gas sensing capabilities was established at <1 MΩ. TiO₂ and SnO₂ were successfully printed on tested substrates, but electrical resistance values varied considerably and were often >1MΩ. SiO₂ appeared to successfully deposit on silicon wafers using hexamethyldisiloxane as a precursor. Experimental parameters included varying carrier and plasma ignition gas flow rates, working distance, scanning speed, and electrode voltage. Further characterization using infrared spectroscopy (FTIR) is needed to confirm molecular composition of the silicon (IV) oxide test samples. These experiments have shown the potential for plasma printing technology to enable in-space manufacturing. Future experiments to further optimize printing parameters for various substances will greatly improve efficiency and expand humanity's manufacturing capabilities in space.

Introduction

In-space manufacturing capabilities will become vital for further exploration by NASA as well as the private sector. Plasma printing technology shows promise for electronics manufacturing in microgravity environments. Plasma printing utilizes gas flow through a high voltage electric field to generate plasma. The material of interest is suspended in an aqueous or ethanol solution, atomized, and transported via a carrier gas to the printing nozzle. The plasma can then ionize the material of interest (Ti and Sn nanoparticles, hexamethyldisiloxane) allowing it to adhere to the substrate surface. The system's reliance on pressurized gas flow and ionization for adherence allows it to overcome microgravity complications. Despite the promise, each nanoparticle or substance of interest requires optimization of printing parameters. Here we experimented with printing parameters for TiO₂, SnO₂, and SiO₂.

Methods

Our primary objective was to determine parameters that would yield consistently effective prints. Helium was used as the plasma ignition gas and carrier gas in TiO₂ and SiO₂ trials. Helium and argon were used to conduct separate SnO₂ trials. The experimental parameters investigated were:

- Carrier gas flow rate
- Plasma ignition gas flow rate
- Electrode voltage
- Scanning rate
- Working distance from the substrate

Electrical resistance values were used to determine the efficacy of TiO₂ and SnO₂ prints. The target resistance value was established at <1 MΩ.

Success in SiO₂ printing was gauged visually by the presence of a discolored pattern on silicon wafer substrates. Infrared spectroscopy (FTIR) will be used to verify chemical composition of printed coatings.

Results

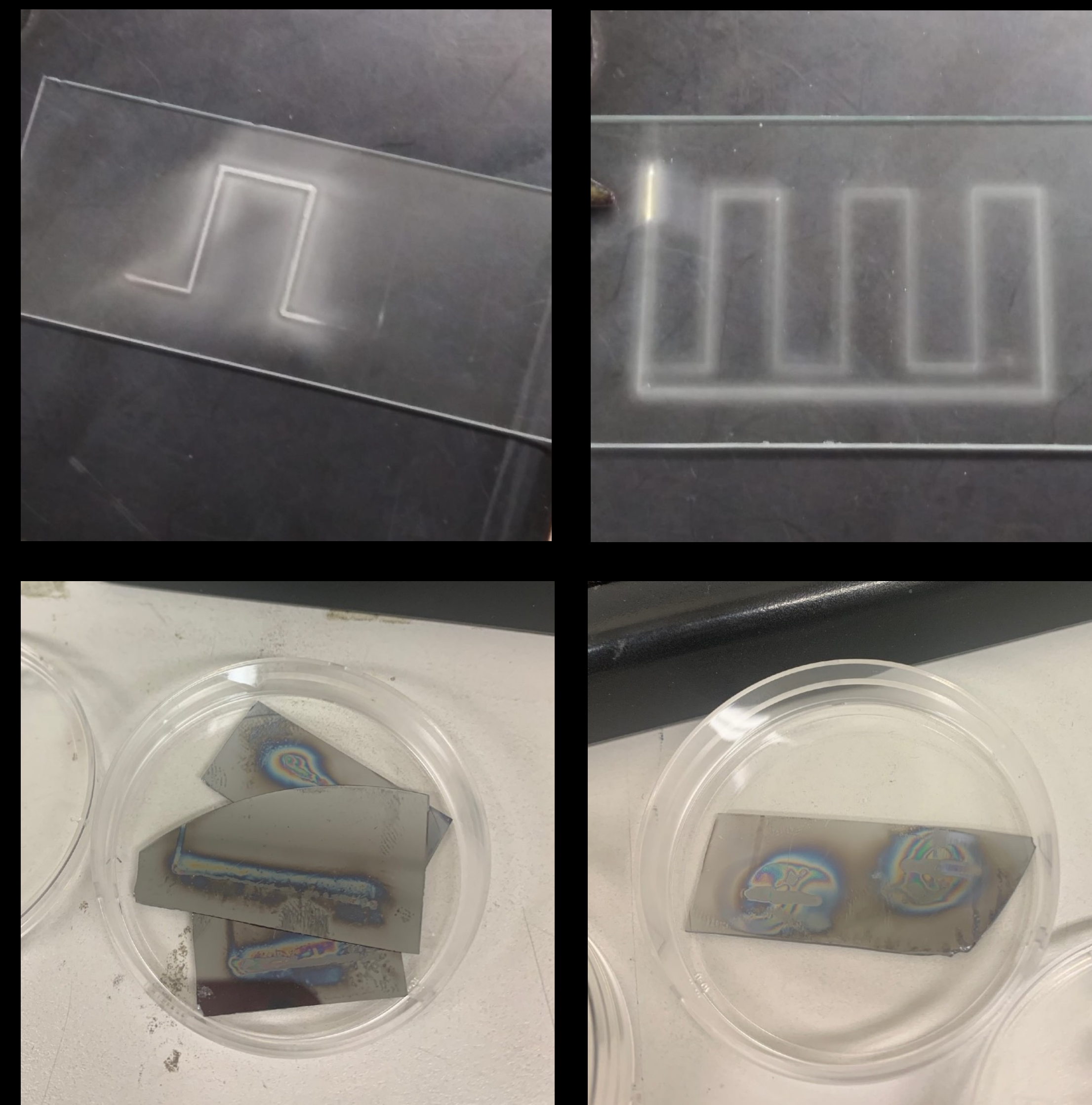


Figure 1: TiO₂ printed on glass microscope slides (top left and right) and SiO₂ printed on silicon wafers (bottom left and right).

Substrate	SnO ₂ Conc. (g/ml)	Atomization (%)	He flow (sccm)	Ar flow (sccm)	Scan rate (mm/sec)	Resistance (ohms)
SiO ₂ on Si	0.00431	35.62	510		0.1	Out of range
SiO ₂ on Si	0.00816	42.47	803		0.1	Out of range
SiO ₂ on Si	0.00816	35.62	815		0.1	Out of range
pcb	0.00835	43.84		803	0.1	10.62-16 MΩ
pcb	0.00835	43.84		803	0.1	out of range
pcb	0.00835	43.84		803	0.1	1 channel (kΩ), remaining (out of range)
pcb	0.00816	41.1		803	0.1	1-10 MΩ (across all 16 channels)
pcb	0.00816	41.1		803	0.1	13-40 MΩ on a few channels

Figure 2: Electrical resistance measurements for SnO₂ printed on SiO₂ coated silicon wafers and PCB gas sensor chips. All trials in the figure were conducted at 3mm working distance

Conclusions

The objective of these trials was to attempt to optimize printing parameters for TiO₂, SnO₂, and SiO₂. Although optimizing printing parameters for TiO₂ and SnO₂ will require further trials, SiO₂ printing yielded consistent thin film coatings. However, infrared spectroscopy is still required to confirm molecular composition of the deposited film. Future experimentation could also gauge the quality of the dielectric coating by measuring continuity in circuits coated in SiO₂ using plasma jet printing methods.

Acknowledgements

Special thanks to Dr. Dennis Nordlund, Dr. Yelena Gorlin, and Pranay Doshi for their invaluable guidance, insight, and expertise throughout this project.

References

- 1) Ram P. Gandhiraman, Vivek Jayan, Jin-Woo Han, Bin Chen, Jessica E. Koehne, and M. Meyyappan Plasma Jet Printing of Electronic Materials on Flexible and Nonconformal Objects *ACS Appl. Mater. Interfaces* **2014**, 6, 20860-20867
- 2) Ram P. Gandhiraman, Eric Singh, Diana C. Diaz-Cartagena, Dennis Nordlund, Jessica Koehne, and M. Meyyappan Plasma jet printing for flexible substrates *Applied Physics Letters* **2016** 108, 123103