In short: verify an astronaut’s fidelity to standard operating procedure.
A combination of three approaches:

1. Computer Vision
2. Sensor-embedded tools; IoT
3. Formalization of procedure writing
Computer Vision

- Real-time neural network-based object detection and localization
- Analyze the spatial relationships between objects to deduce semantics
- Static image analysis for deducing quality of astronaut-taken photographs
Problem Specification

Sensor-Embedded Tools

- Active NFC glove, coupled with passive NFC tools, to reliably identify current tool in use
- IMU in glove to detect macroscopic hand motion, e.g. swinging a hammer
- Bluetooth beacons for user localization
Procedure Formalization

- Context-free grammar specifically for expressing procedures in a way easily mapped to sense data
- Internally represent procedures with precedence graphs, rather than lists, to only capture strictly necessary ordinal relationships

```plaintext
<Mission> ::= <Task>+
<Task> ::= <Record Set> | <Image Set> | <Translate>

<Record Set> ::= <Record>+
<Record> ::= <Quantify> | <Qualify> | <Sample>
<Quantify> ::= <Verbalize> | <Write>
<Qualify> ::= <Verbalize> | <Write>
.Sample> ::= <Search> <Identify and Mark> <Collect Candidates>
<Collect Candidates> ::= [<Sterilization>] <Collect>+
<Collect> ::= <Isolate Sample> <Image Set> <Bag Sample> <Record Set>

<Image Set> ::= <Image>+
<Image> ::= <Picture> | <Video>
<Picture> ::= [<Place Guide>] <Take Picture>
<Video> ::= [<Place Guide>] <Take Video>

<Translate> ::= (<Move> [<Record Set>] [<Image Set>])+
```
Product Development Team

- **Ryan Lorica**: Lead, Computer Vision
- **Jingzhen Chen**: UI, IoT Algorithm Design
- **Anzhe Ye**: UI, IoT Algorithm Design
- **Jiacheng Liu**: PCB, Sensor Testing and Interfacing
- **Leo Mei**: PCB, Sensor Testing and Interfacing

*All members will cooperate for sensor fusion*
Processor

Nvidia Jetson TX2

- ARMv8 (64-bit) Multiprocessor CPU Complex
- 256 core Nvidia Pascal GPU
- Clock speed
  - CPU - Up to 2 GHz
  - GPU - Up to 1.3 GHz
- Power Requirement: 5.5V - 19.6V
- Peripheral Interfaces: I2C, UART, HDMI, USB
- Connectivity: Bluetooth Version 4.1
Problem Specification

**Sensors**

Adafruit PN532 NFC
- Detect current using tool
- Embed NFC chip in glove, tags in tools
- Range of transmission: 10 cm
- Interface: UART

GeeekPi 5 inch LCD Touch Screen
- Display tasks and remind errors
- Resolution: 800 x 480 pixels
- Power requirement: 5V via Micro-USB
- Interface: HDMI
Sensors

Bluetooth Unit

- On-board Bluetooth Version 4.1
- Receive signal from a bluetooth beacon
  - Approach a site
- Lose signal from the bluetooth beacon
  - Leave the site

Bluetooth Beacon

- Localization
- Embed in marker
- One-way transmission
- Range of transmission: 1 m (expected)
Sensors

- Adafruit 9-dot BNO055 IMU Breakout
  - Communicates via I2C
  - Memory-mapped addressing to specify sensor, which allows for reading specific data

- Sensors used:
  - Accelerometer
    - ±2/±4/±6/±8/±16 g ranges.
    - Accuracy: ±60mg
    - Data rate: 100Hz
  - Gyroscope
    - ±245/±500/±2000 degree per second ranges.
    - Accuracy: ±10/±15/±75
    - Data rate: 100Hz

- Successfully tested on TX2
## Bill of Materials

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Software Development

Software Architecture - Overview

Problem Specification

Software Development
Problem Specification

Overall structure flow ...

Task Controller

Two main part:

- **Task Manager:**
  Controlling the overall tasking flowing.

- **Procedure Manager:**
  Controlling the little procedures in each task.

When Task Manager switch to a new task, Procedure Manager activated;

Then Procedure Manager will send information to the **signal processing part**;

(next slide)

When all procedures in Procedure Manager finished, user can go to the next task.
In Signal and Data Processing part, two modules used to process signal:

- **Signal Request**
  Receiving information from Procedure Manager, (which signals needed to check ...)
  Then sending the signal request to the parts (IMU, Bluetooth, NFC, Camera)

- **Signal Receive**
  Receiving the processed signal response from **Data and Signal Processor** (next slide)
  Then sending a completion signal to Procedure Manager, indicating the procedure completed
Software Development

Software Architecture - Overview
Software Development

Overall structure flow (continued) ...

Core Module in Data and Signal Processing part:

- Including all the algorithms used to process the signal and data coming from PARTS: (such as Video Processing)

- When the processor received data feedback from the PARTS, it would analyze this data and decide whether they satisfied the procedure’s request or not.

- If satisfied, it would send the signal response to Signal Receive Module;

- If not, it would send a signal request to Signal Request Module and do this procedure again; at the same time, it will alert users on LCD Screen.
UI Overview

- Synopsis of current task.
- Status of current task, using different color to indicate each kind of state.
- Three buttons at bottom to help user switch tasks.
- Hint of details.

![Current Task](image)

- **Green** -- “Done”
- **Gray** -- “Waiting”
- **Yellow** -- “In-progress”
- **Red** -- “Warning”
UI Detail Windows

Current Task Detail:

1. Use the bluetooth and body camera to search the samples;
2. Use the body camera to identify those target samples;
3. Use the hammer to collect some samples.

- Click left part of main interface to show the task detail.
- Click right part of main interface when working status is “Warning” to show the detail for...
UI overview

- Press “Back” to the last task.
- Press “Review” to task list window.
- Press “Check” to end the whole procedure.
Acknowledgements

Thank you to:

Dr. Yogananda Isukapalli

Carrie Segal

Brandon Pon

Dr. Jessica Marquez (NASA)

Dr. Richard Joyce (NASA)

Laritech

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