# Autonomous Multi-cycle Farming in Space

Team Members:

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**Client Meetings:**

| Date | Reason |
|------|--------|
| January 17, 2020 | Initial Meeting |
| Starting Jan 31th, 2020 | Meeting every two weeks |

**Project Plan Version Control:**

| Document ID: PP-000001 | | | | |
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| **Revised Version** | **Date** | **Collaborators** | **Version** | **Reason** |
| N/A | 1/15/2020 | All | v1.0 | Initial creation |
| 1.0 | 1/22/20 | Chris | v1.5 | Milestones and diagram changes |

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**Document Reference:**

Log of all document references where version number is needed. To maintain version control.

| Document | Date Refenced | Version Referenced |
|----------|---------------|--------------------|
|          |               |                    |

**Project Definitions:**

| Word/Phrase | Re-worded/*Notes*: | Definition |
|-------------|--------------------|-----------|
| Autonomous Multi-cycle Farming Device | The AMCFD | The subject of this project and the product being created |
| Control(s) | *Not re-worded & definition may not always apply to* | The process by which software dictates the |

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[1] When updating this document's version update the version found on the title page, name, referenced documents, baseline and footer ↘

| | software | behaviour and movement of certain devices or software triggers. |
|---|---|---|
| Software Abstraction | *Not re-worded* | A high-level description of implementation instead of giving detailed code. The software abstraction column is given to show where computer science engages with project features |
| Embedded, microcontroller, single board computer | *May be used interchangeably & not re-worded* | The computer chosen to be the brains of the AMCFD. It will manage the various components of the AMCFD |

## Motivation and Goals

In preparing long lasting missions in space, one of the most important factors for the well being of an astronaut is ensuring they are healthy and well fed. Given the cost of launching materials and the busy schedules of crew members, the optimal way of producing food to meet nutritional needs is through an automated farming system.

This system must complete multiple autonomous cycles from seed to harvest, then cleanup. To ensure astronauts' longevity and health, it must be highly reliable and use few resources. Given this will be initially designed to be aboard the International Space Station, it must fit within one of the standard experimental lockers aboard the ISS; the ultimate goal is to provide a renewable food source for astronauts. The goals for this project can be broken up into ultimate and current, where the ultimate goals are future oriented with how/what we project the device to meet the needs of its users. The current goals define a scope for this senior design project and a few project iterations after. Current goals for this project include high crop yield in accordance with what NASA produces, scheduling stability where the tasks of the device are completed correctly; on time, in expected order, & efficiently. Also improved crew morale and UX/UI study compared to current software at NASA.

The computer science goals on this project will be to provide the requirements and software needed to automate various parts of the AMCFD. These software needs can be

categorized into sensor reading, actuator controls, timers, scheduling, interfaces, operating system components, and various resource management i.e. mitigating power drawn and pushed/pulled data.

As an extension we will build out a software system where the users can access prewritten configurations for the device in a configuration library. The application will provide configuration tools, several reports for the users so that efficiency and correctness can be monitored, and manual control of the device.

To understand the goals of this project we need to define the needs listed above.

- **Sensor reading:** Data from sensors that will be attached to the AMCFD to be used by the the AMCFD to make decisions at each phase of the cycle.
- **Actuator controls:** The software mechanism to move and command various motors "actuators" to complete certain tasks.
- **Timers:** Timing is extremely important in farming and especially important in space farming; all the sensors and actuators must read and perform at the right time in order for the automation process to cycle properly. Timers will run over dynamic tasks which will be periodic actions based on a delay between the termination of one task, the commencement of the next, and/or other triggers, along with giving timing offsets from dynamic tasks to the driver.
- **Scheduling:** Highly productive people need schedules to initiate and complete their task lists, it is the same with a computer. In order to make sure everything cycles correctly and completely the AMCFD must follow a schedule which will be determined by software. The driver will keep a list of times at which cycled tasks are to take place. Scheduling will also be a component of the operating system on the chosen microcontroller.
- **Interfaces:** The AMCFD will be fixed in an experiment locker on the ISS that will require ISS and AMCFD programs to talk to one another.
- **Operating system components:** Timers and scheduling will also take part in the operating system of the chosen embedded board.
- **Resource Management:** Resources in space are limited and extremely valuable. The AMCFD will be fed power from within the experiment locker along with push and pull requests[2] from the interfaces that need to be metered and controlled.
- **UX/UI:** User interface and user experience.

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[2] Push and pull requests are basic elements of two-way communication between machines. If machine A has data to send it will push it to machine B and if machine B needs data it can pull it from machine A.

# Approach - Phases

To ensure the wellbeing of the astronauts the system will use single board computers and/or microcontrollers. Sensors will be powered on at appropriate intervals to conserve power. Once the sensors detect the farm is ready to move on to the next stage, various physical systems will be engaged to transition. These stages are described below and each action of the AMCFD has a corresponding software abstraction.

**Seed:**

| Action | Software Abstraction |
|---|---|
| Planting seeds | Scheduling and timing actuators to plant the seeds while reading in data from the AMCFD's internal environment |
| Detecting germination | Reading in sensor data to detect that the plants germinate properly |

**Grow:**

| Action | Software Abstraction |
|---|---|
| Providing a nourishing environment by sensing environmental factors | Using sensors to detect environmental compositions like Nitrogen and $CO_2$ and to trigger appropriate system responses via controls using reactive autonomy |
| Tracking plant growth phases over time | Using sensors to detect changes in plant growth over time and cataloging those changes in a database to make any adjustments to the actuators if needed using proactive autonomy |
| Water needs | Tracking/sensing water levels, and controlling water pumps to provide water to plants as needed |

| Lighting needs for photosynthesis | Turning light(s) on and off |
|---|---|
| Detecting diseased or under-grown plants | Using artificial intelligence[3] to monitor for potential diseased plants based on visual data |

**Harvest:**

| Action | Software Abstraction |
|---|---|
| Remove the grown plants for consumption | None, this will be done by the astronauts |

**Clean up:**
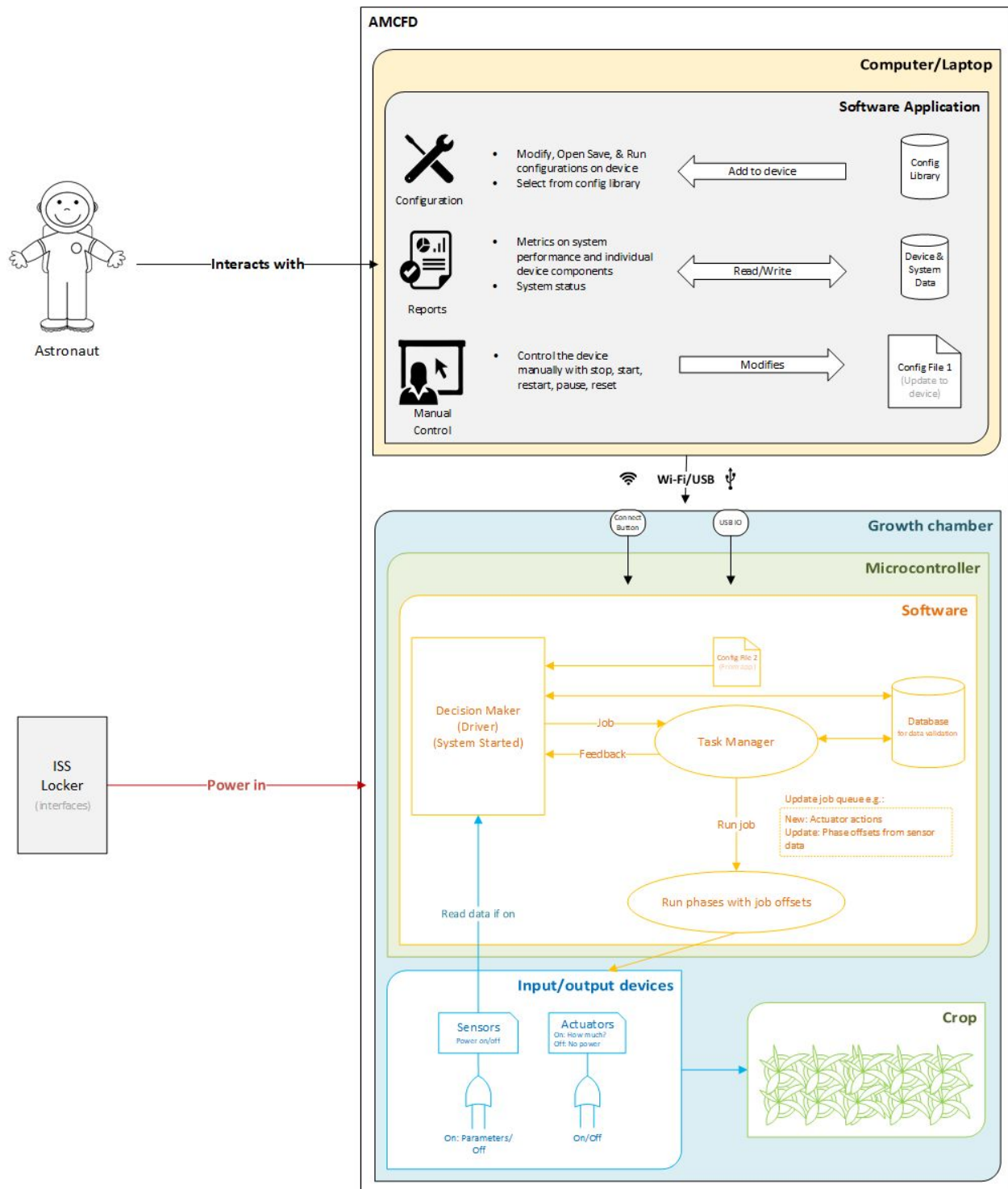
| Action | Software Abstraction |
|---|---|
| Remove dirt and other particulates | Control actuators to move unused particulates to a safe disposable location for recycling |
| Harvest & prepare for the next cycle | Reorder all actuators and queues for the next cycle |

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[3] Using AI to analyze visual data is an enormous project on its own and it may not be completed with the first POC.
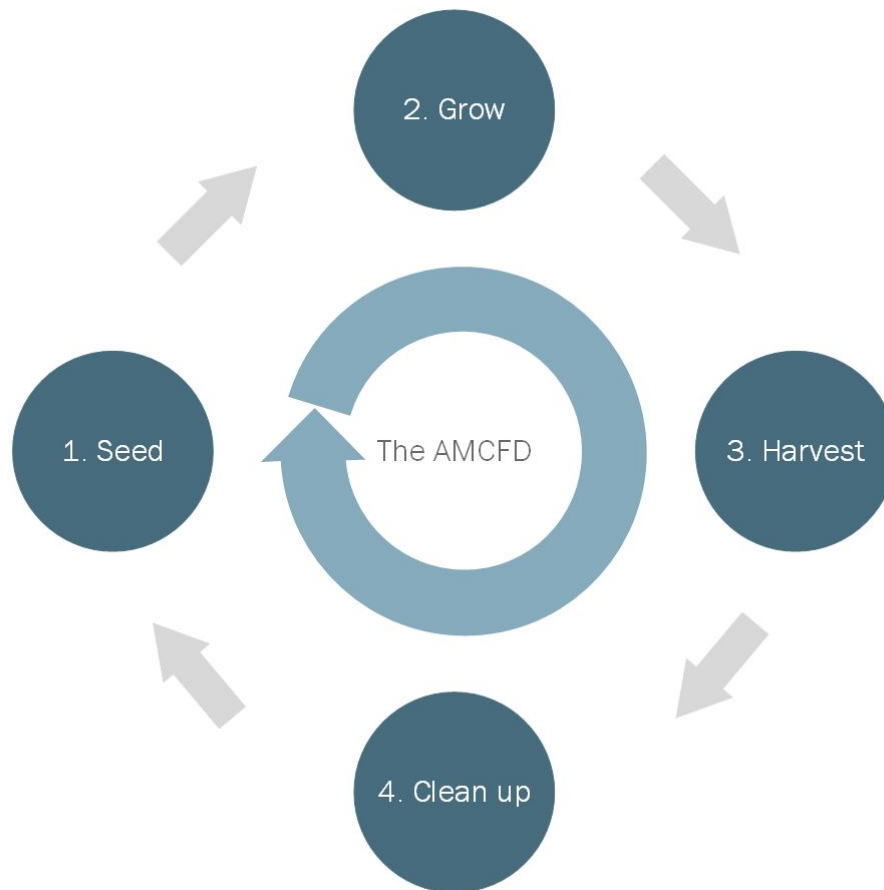
## Approach - Application

The application will be a one-stop-shop for managing and configuring the device(s). Communication to the device will be done over Wi-Fi, but for our system it will be done over USB for now. The application will give the user reports for devices globally and individually. A feature will need to be created to facilitate adding configuration files for specific devices and specific crop types. Potentially the seed configuration files can be made available by ground control through the ethernet connection so that configurations available match the seeds onsite.

**AMCFD**

**Computer/Laptop**

**Software Application**

Astronaut — Interacts with →

Configuration
- Modify, Open Save, & Run configurations on device
- Select from config library

← Add to device

Config Library

Reports
- Metrics on system performance and individual device components
- System status

← Read/Write →

Device & System Data

Manual Control
- Control the device manually with stop, start, restart, pause, reset

Modifies →

Config File 1 (Update to device)

Wi-Fi/USB

Connect Button     USB IO

**Growth chamber**

**Microcontroller**

**Software**

Config File 2 (From app)

Decision Maker (Driver) (System Started)

Job →
← Feedback

Task Manager

← Database for data validation →

ISS Locker (interfaces) — Power in →

Update job queue e.g.:
New: Actuator actions
Update: Phase offsets from sensor data

Run job

Run phases with job offsets

Read data if on

**Input/output devices**

Sensors
Power on/off

Actuators
On: How much?
Off: No power

On: Parameters/Off

On/Off

**Crop**

## Novel Features

1. Low-power autonomous multiple-cycle growth and harvesting of food for astronauts driven by software.
2. Utilizing the latest in sensor, actuator, and software technology to protect and optimize throughput of said food.
3. Detecting diseased or under-grown plants using vision-based data.
4. Web application that can run on Mac, Linux, and Windows to control autonomous devices.
5. Library to store and access configurations for autonomous devices.

## Technical Challenges

- Programming microcontrollers, possibly in conjunction with and/or parallel to other single board computers.
- Scheduling of sensors and mechanical components to reduce energy consumption and maximise throughput.
- Communicating between sensors and mechanical components.
- Processing and abstracting sensor data.
- New algorithms no one on the team has used before.
- Enterprise web application.
- Designing effective reports.
- USB and Wi-Fi communication.

## Fourth Milestone - Due February 17th

- Design for application used to manage device
  - Configuration
    - Design for configuration library service where users can select new configurations for device, i.e. apples, lettuce, etc.
  - Reports
    - System performance and status globally down to each individual subsystem of a single device
    - Appropriate metrics and report hierarchy based on user selected feature
  - Manual control
    - Stop, start, restart, pause, and reset

- ○ UX/UI survey for CS Forum
  - ■ Appropriate hierarchy based on what user selected
- One production actuator working on control board
  - ○ Not working in system
- Testing progress

## Task Matrix for Milestone 4 - Due February 17th

| Task | Giampiero | Christopher |
|------|-----------|-------------|
| Design for application used to manage device:<br>Configuration<br>    Design for configuration library service where users can select new configurations for device, i.e. apples, lettuce, etc.<br>Reports<br>    System performance and status globally down to each individual subsystem of a single device<br>    Appropriate metrics and report hierarchy based on user selected feature<br>Manual control<br>    Stop, start, restart, pause, and reset | 50% | 50% |

| | | |
|---|---|---|
| UX/UI survey for CS Forum with appropriate hierarchy based on what user selected | | |
| One actuator working on production control board | 50% | 50% |
| Testing progress | 50% | 50% |

# Fifth Milestone - Due March 23rd

- Functional setup of actual actuators and sensors working with system
  - Seeding head on track
  - Light and fan
  - Linear actuator
  - Nema motors
  - Moisture sensor
- Working POC of application to configure and manage device
- Working config download service - low priority should be easy
- Metrics for reports
- Testing rules in SonarQube
- Testing scripts

# Sixth Milestone - Due April 20th

- Finalized build of device with system
- Finished application
- Finished download service
- Final user manual
- Finished reports
- Testing
- User manual complete draft
- Evaluation on:
  - Crop yield
  - Multicycle experiments and tests
  - Failure and success criteria

## Signature of CSE Students:

Signature: _____ Date: _____

Signature: _____ Date: _____

## Approval from Faculty Sponsor:

*"I have discussed with the team and approved this project plan. I will evaluate the progress and assign a grade for each of the three milestones."*

Signature: _____ Date: _____