Center for Research and Production in Controlled Environment (CIPAC-AIP)

Advances in CEA and Vertical Farming

Prof. Joel Cuello, Ph.D.
The University of Arizona

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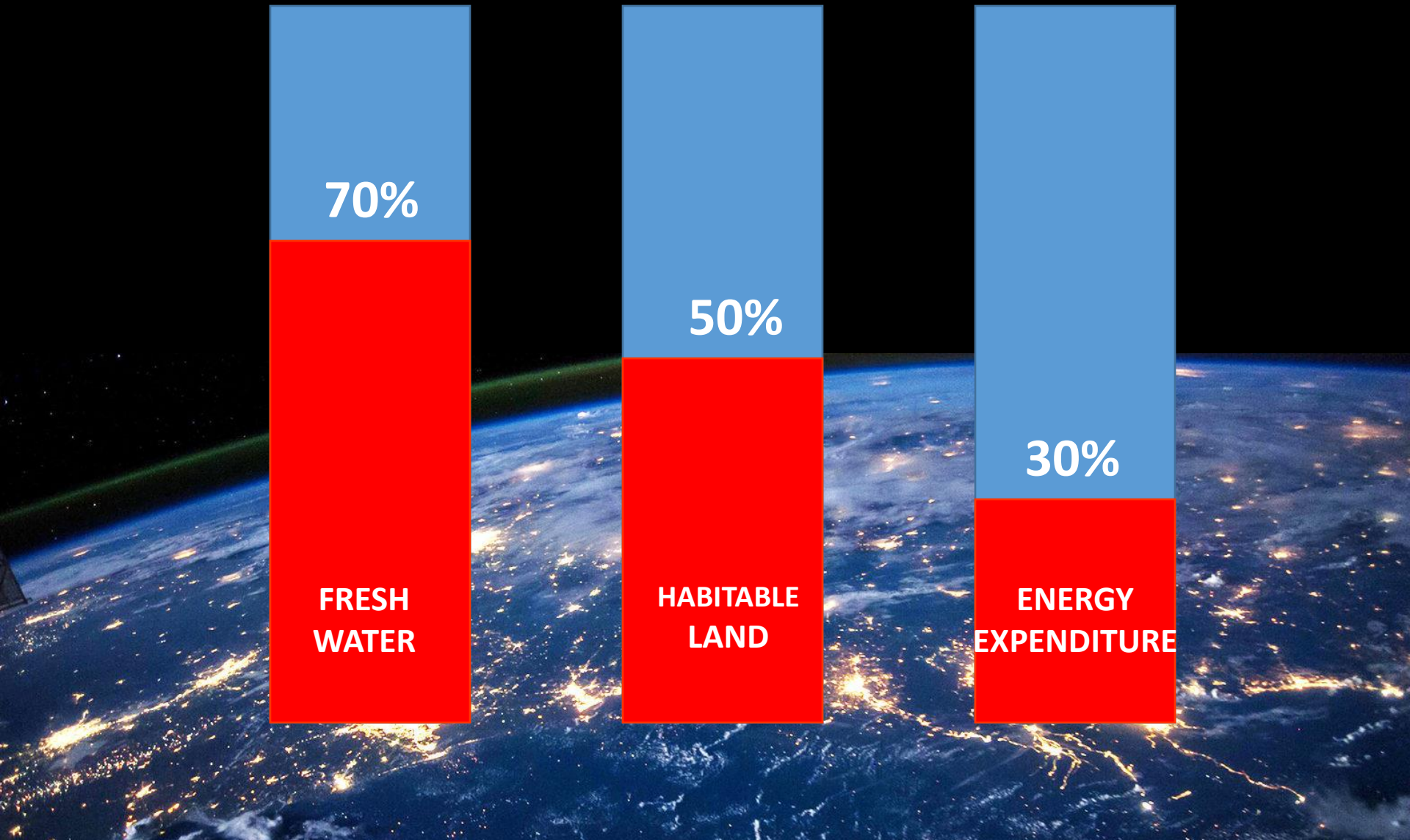
Tuesday, 03 May2022
Panama City
Panama

An Urgent Planetary Grand Challenge:
Food

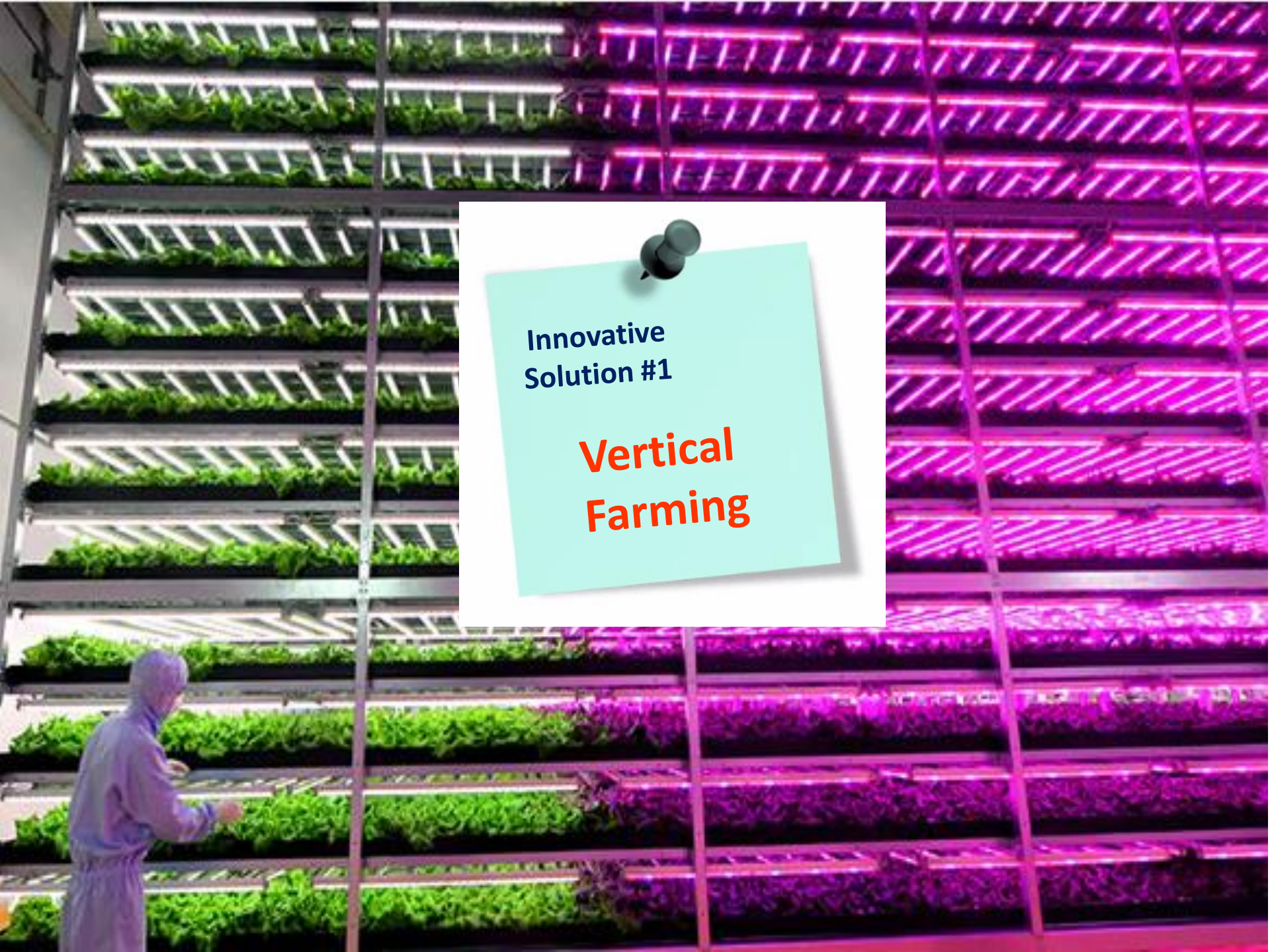

Dreamstime

Current Usage of Resources for Food on Earth



Pandemic

Changing Climate


Innovative
Solution #1
Vertical
Farming

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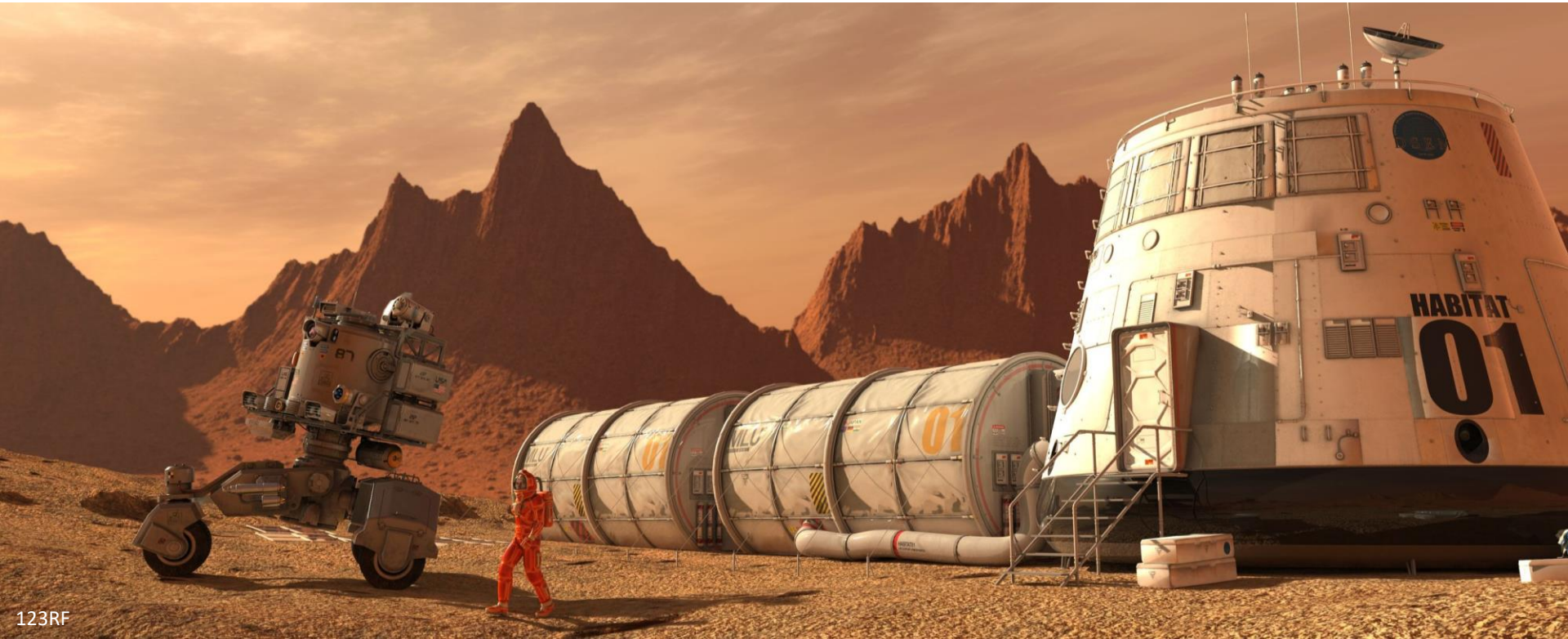
CEA and Vertical Farming

- Technosphere – hardware and software
- Hortisphere – crops and environment
- Resourcesphere – input and output resources
- Businessphere – markets and economics



123RF

CEA and Vertical Farming

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Hortisphere
crops and environment

Technosphere
hardware and software

Resourcesphere
input and output resources

Businessphere
markets and economics

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VF Trends & Challenges ✓

My Focus & Priorities

Main Challenge for Latin America

CIPAC's Central Role

Arizona Cooperation With CIPAC

Trends and Challenges

✓ • Technosphere

WAREHOUSE VS. MODULAR

Trends and Challenges

- Technosphere

FIXED VS. MOBILE

Trends and Challenges

✓ • Hortisphere

NEW CROPS/VARIETIES

Omakase Berries from the Japanese Alps (Oishii Farms, NJ, NY, CA)
2-3x sweeter than U.S. strawberries


BAYER
TEMASEK
HOLDINGS
UNFOLD


Unique Environment
of Vertical Farms
Size and Morphology
Growth and Productivity
Nutrients Profile
Flavor Profile
BAYER
UNFOLD

Trends and Challenges

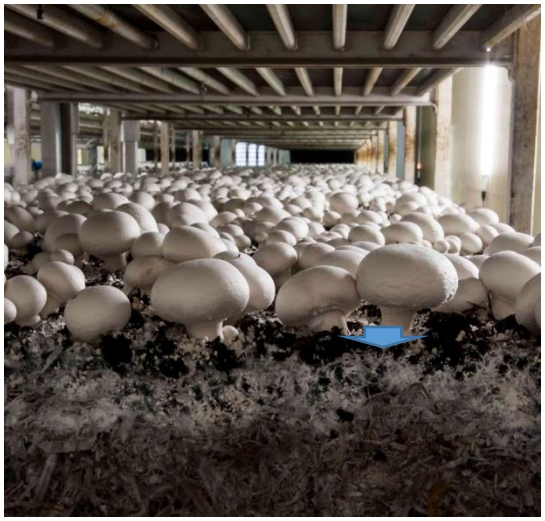
✓ • Resourcesphere

ORGANIC FERTILIZER

Trends and Challenges

- Resourcesphere

CIRCULAR DESIGN



Trends and Challenges

- Resourcesphere

RENEWABLE ENERGY

Trends and Challenges

✓ • Businessphere

STRATEGIC PARTNERSHIP

Plenty™

Trends and Challenges

- **Businessphere – markets and economics**

STRATEGIC PARTNERSHIP

Nate Storey, Ph.D.
Chief Science Officer and Co-Founder
Plenty Unlimited, Inc.
San Francisco, California, U.S.A.

Joel Cuello, Ph.D.
Professor of Biosystems Engineering
The University of Arizona
Tucson, Arizona, U.S.A.

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VF Trends & Challenges

My Focus & Priorities ✓

Main Challenge for Latin America

CIPAC's Central Role

Arizona Cooperation With CIPAC

Biosystems Engineering Lab

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My Focus and Priorities


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ARIZONA Green Box
Same Planet, Better Crops


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- **Technosphere**

The V-Hive Green Box

Cuello
BioImagineering Lab

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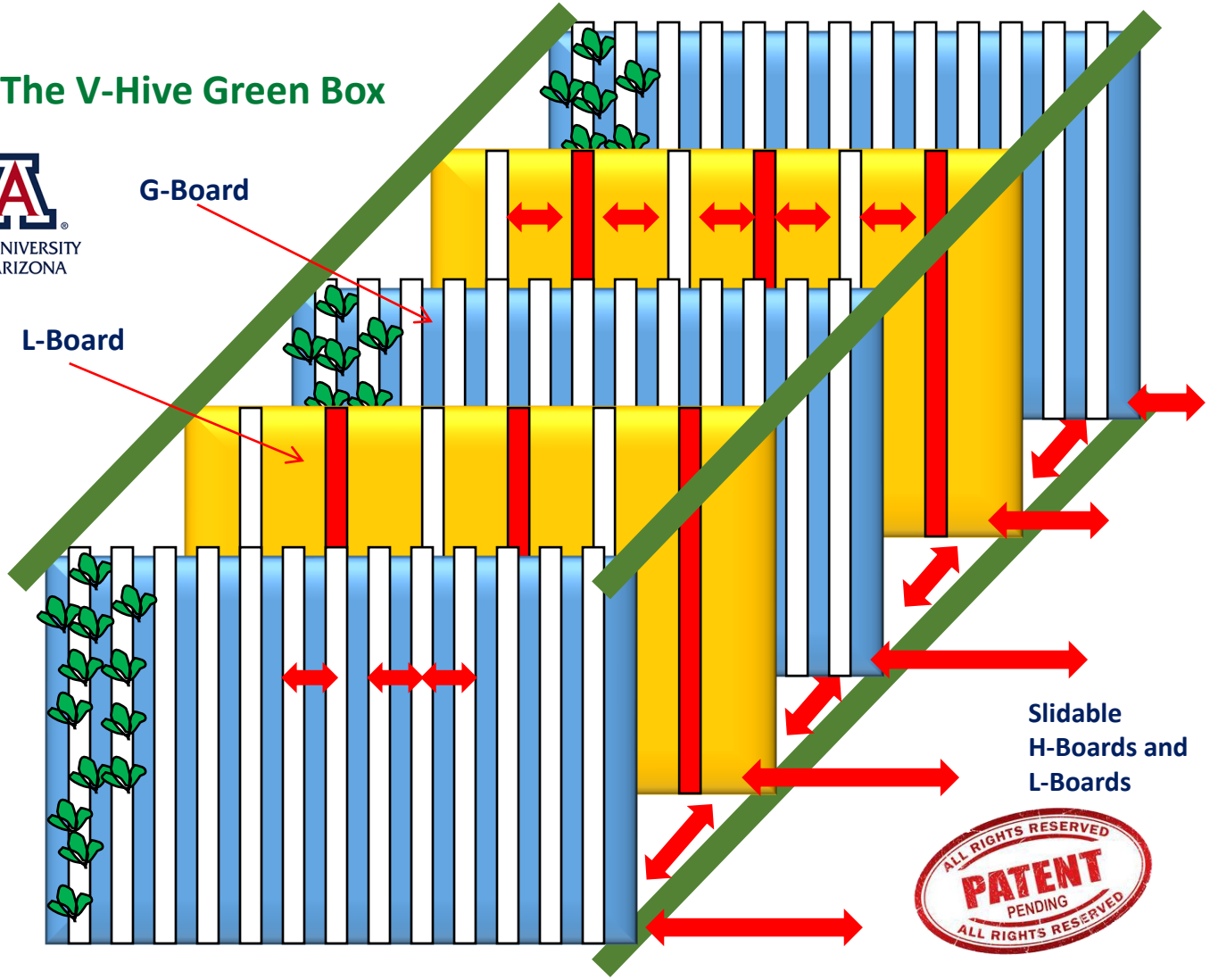
The V-Hive Green Box

THE UNIVERSITY OF ARIZONA




AGRICULTURAL & BIOSYS
BE SHOP


V-Hive Green Box
Same Planet, Better Crops
Lighting Board
Growing Board
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V-Hive Green Box

Same Planet, Better Crops

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V-Hive Green Box

Same Planet, Better Crops

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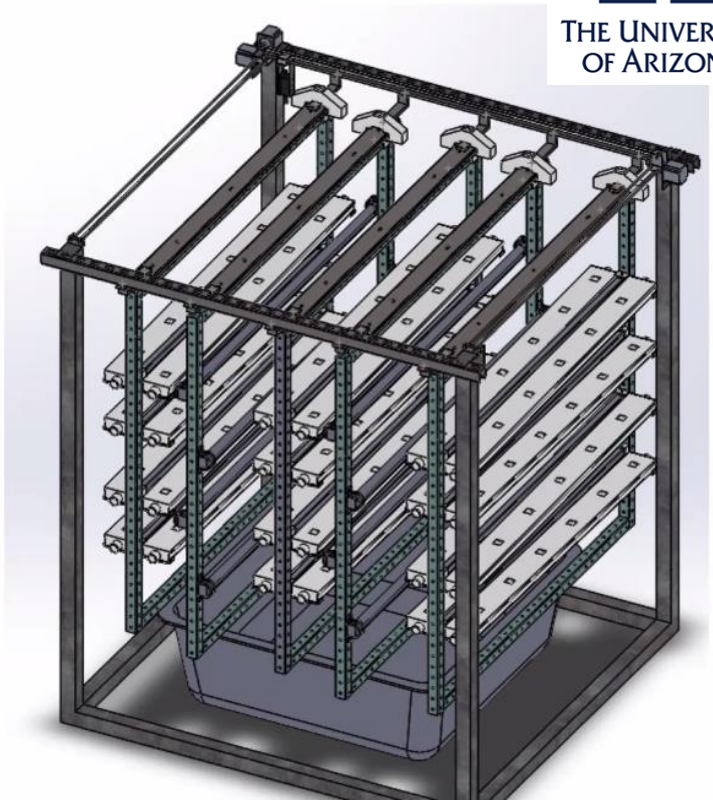
Torin Hodge

Alexis Canez



Emma Menden

Kate Stalkfleet

Zachary Shellouff

Peter Joyce

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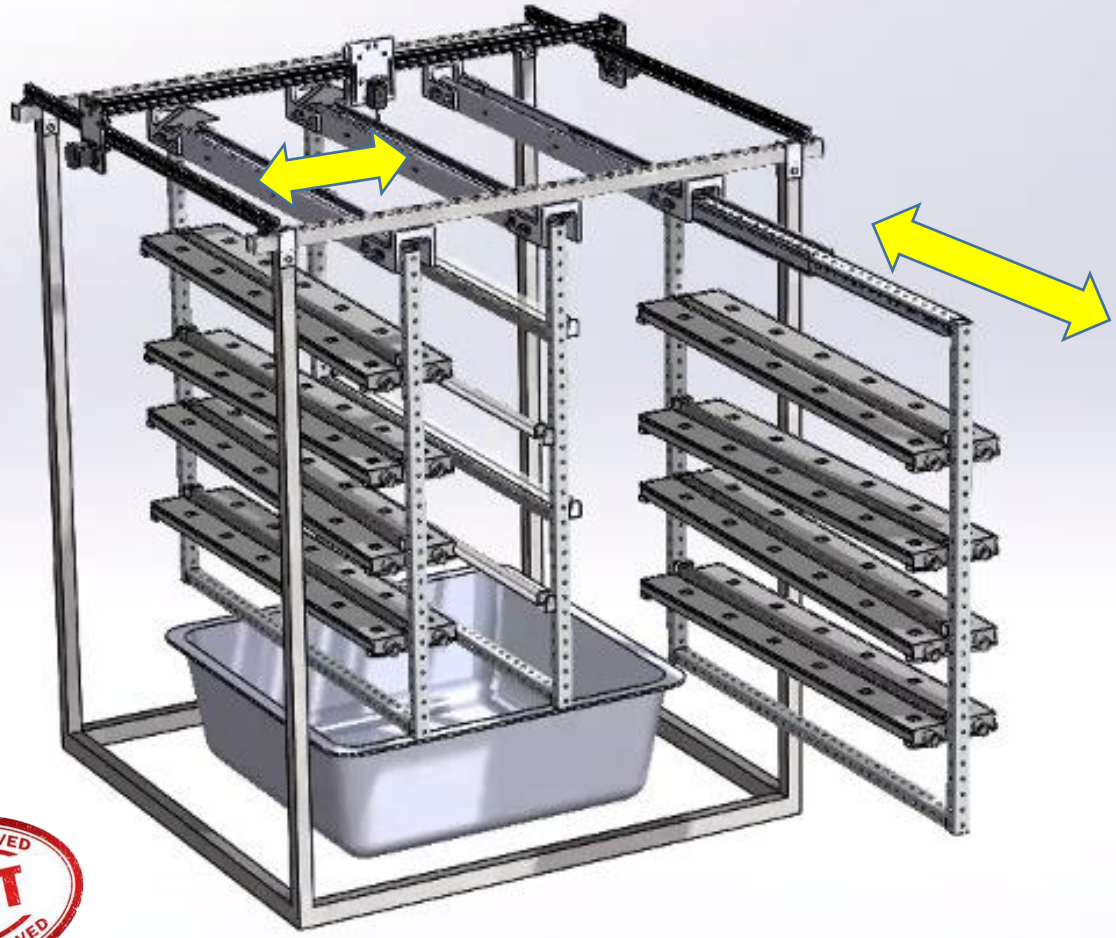
The V-HIVE Green Box



Prof. Joel Cuello

V-Hive Green Box

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LED's by

SANANBIO®

- **Technosphere**

MOBILE VERTICAL FARM
LifeGrow Bots

Cuello
BioImagineering Lab

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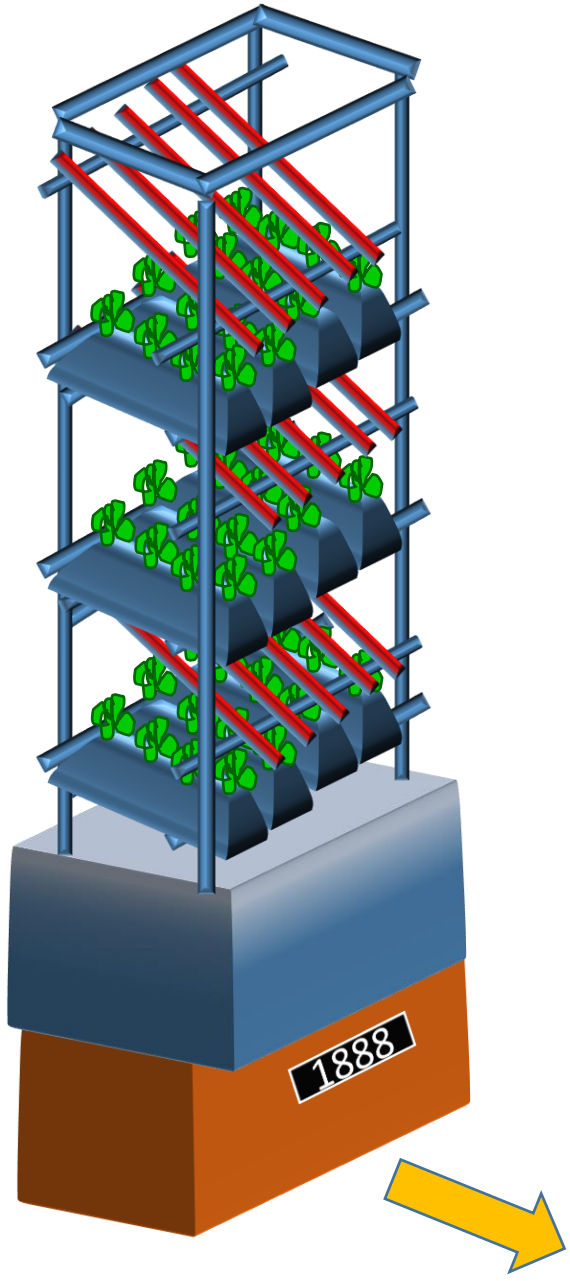

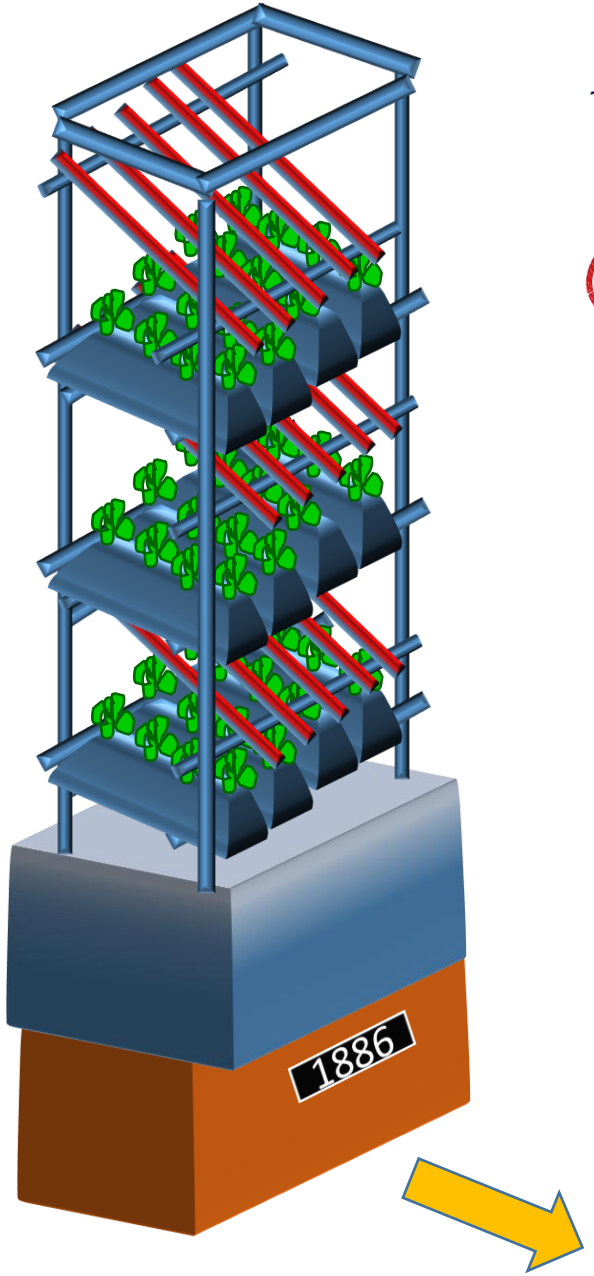

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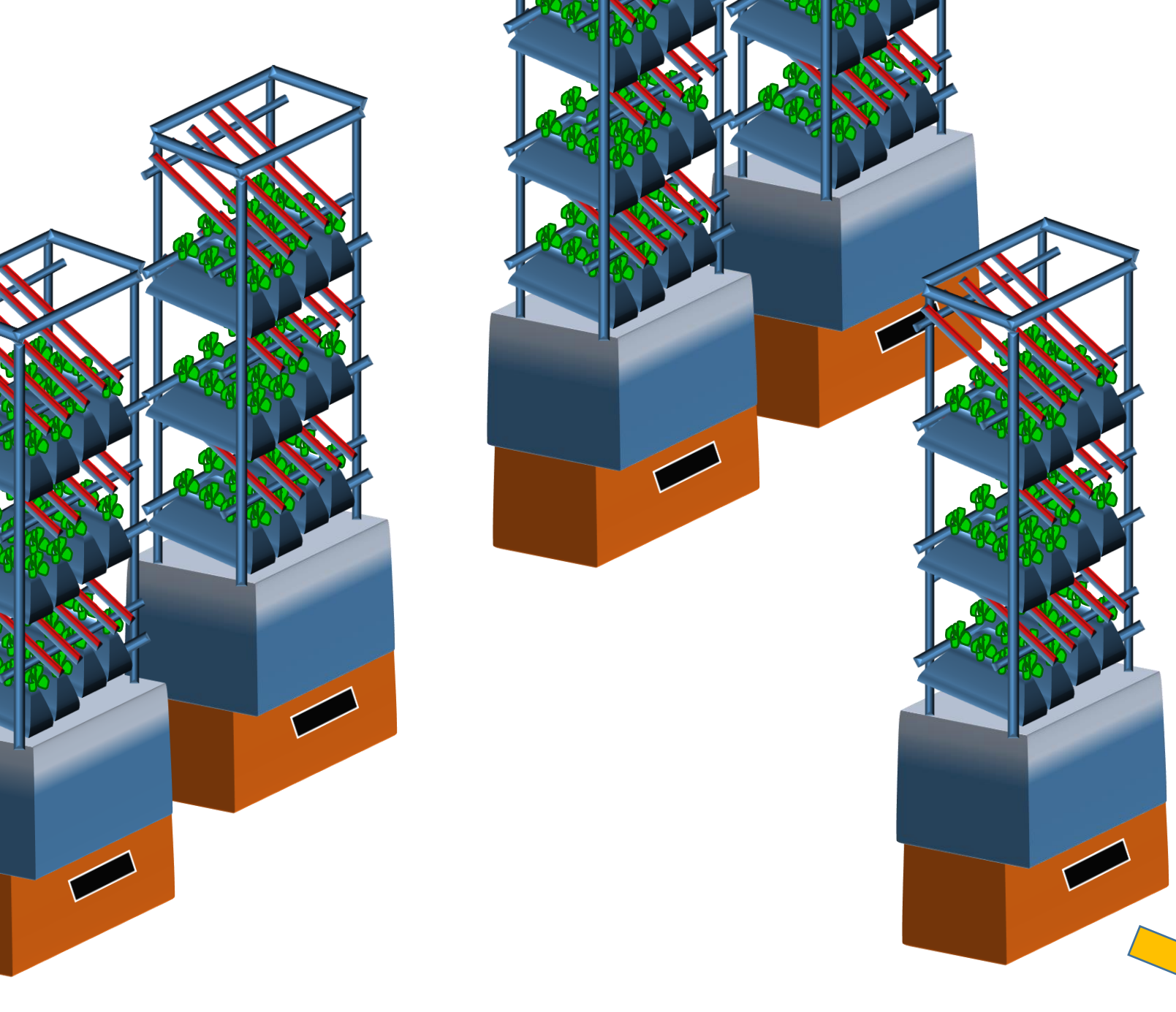

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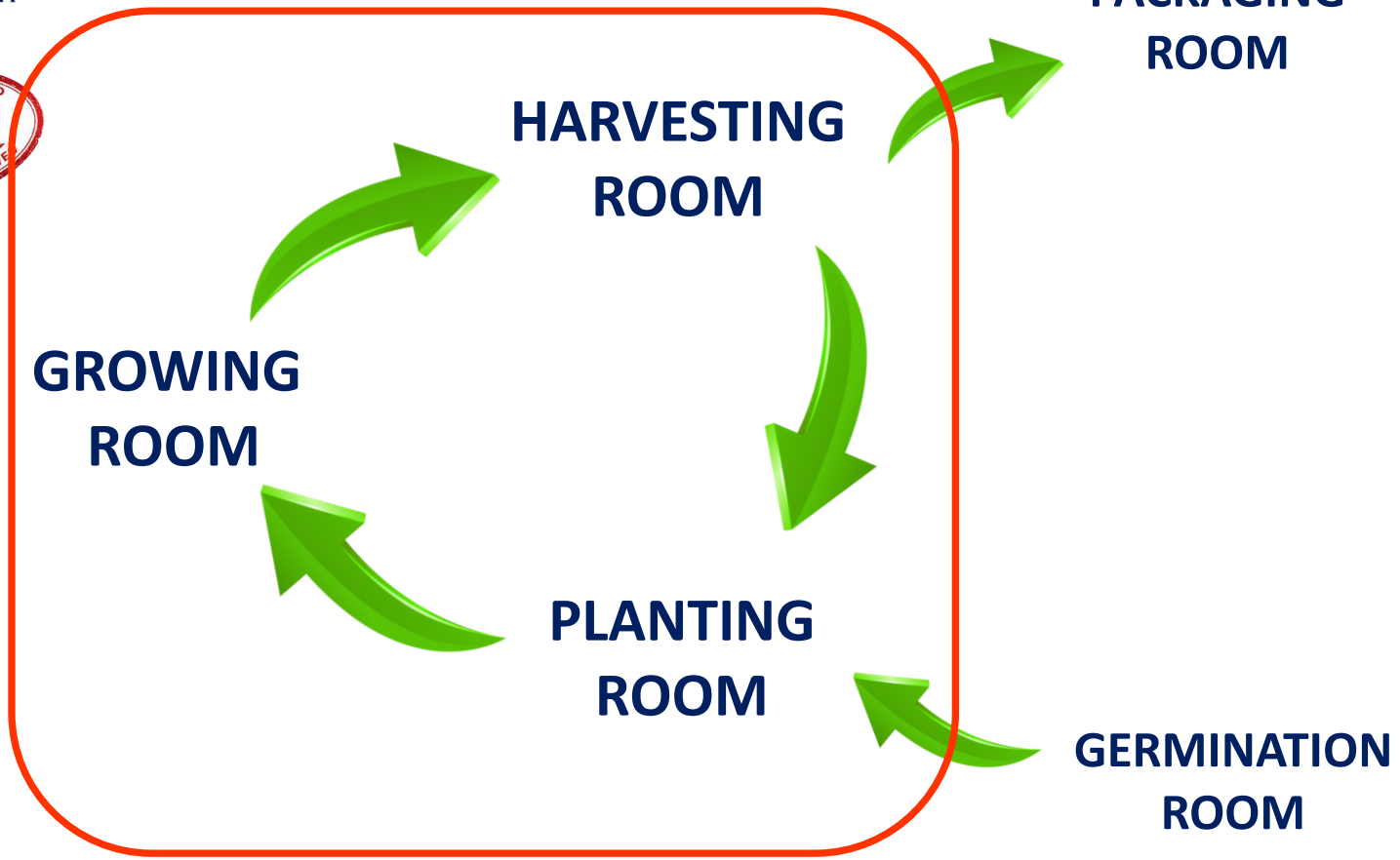
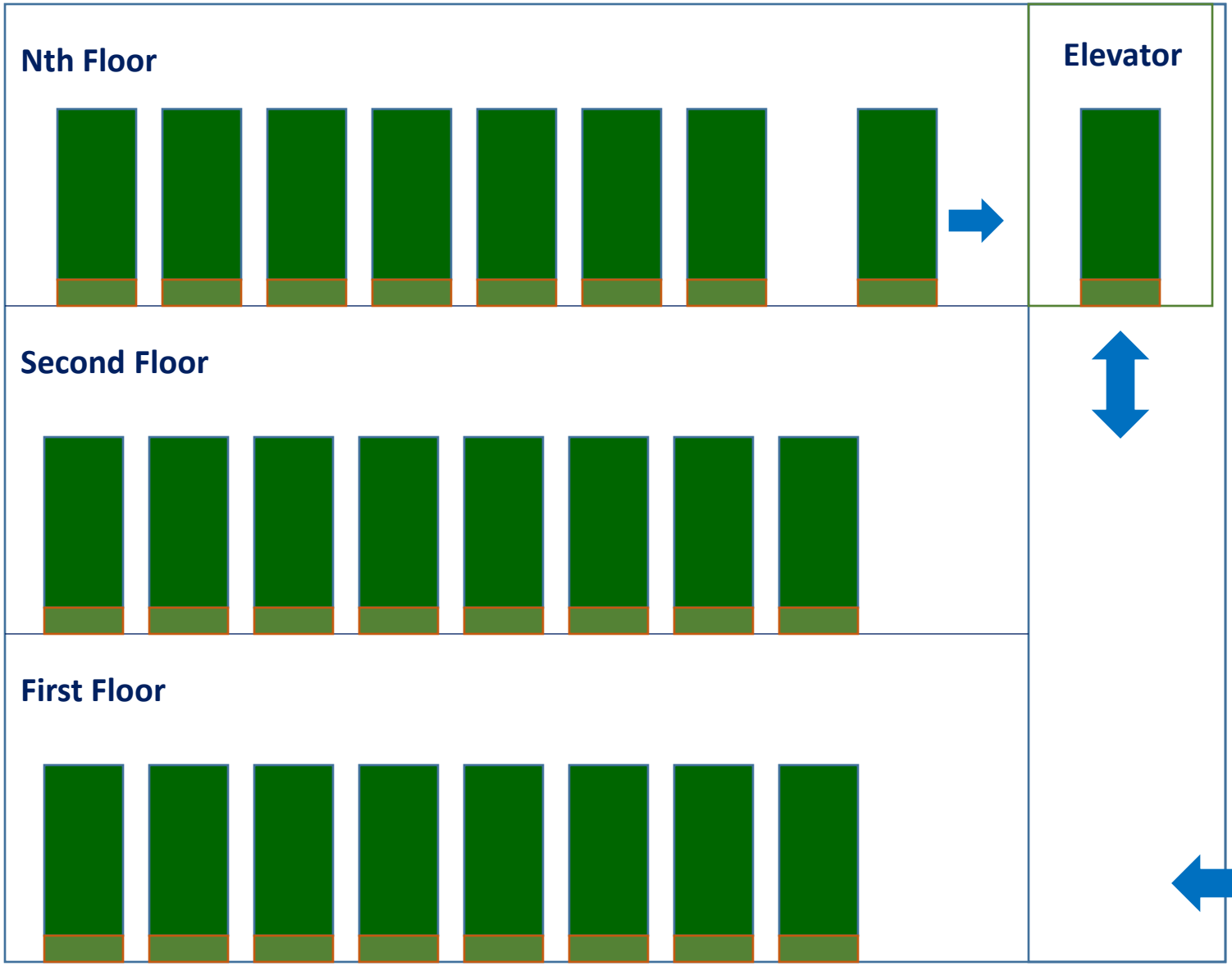


Automated Circular Operational Protocol (ACOP)

SIDE VIEW OF GROWING ROOM



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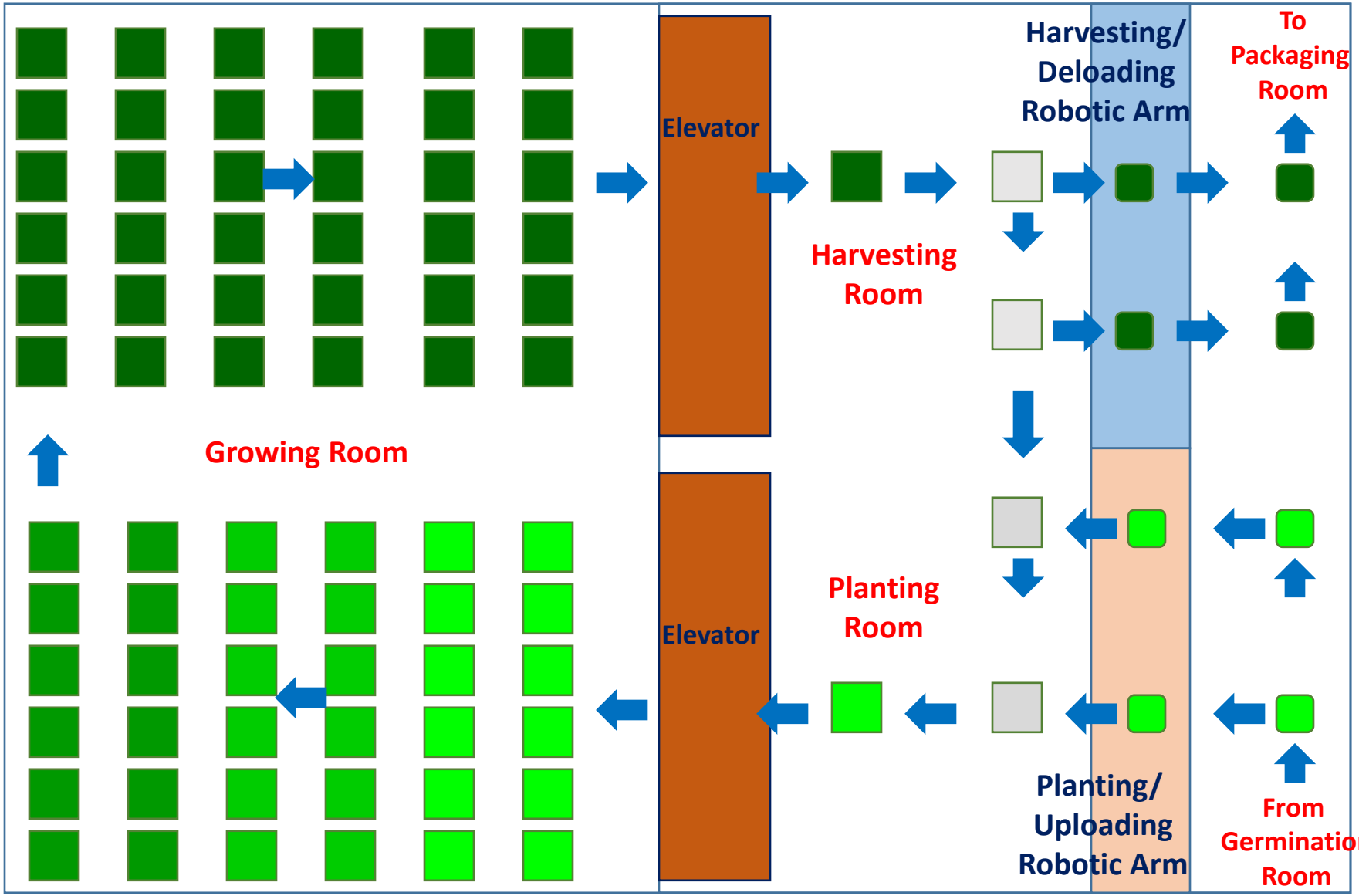
TOP VIEW



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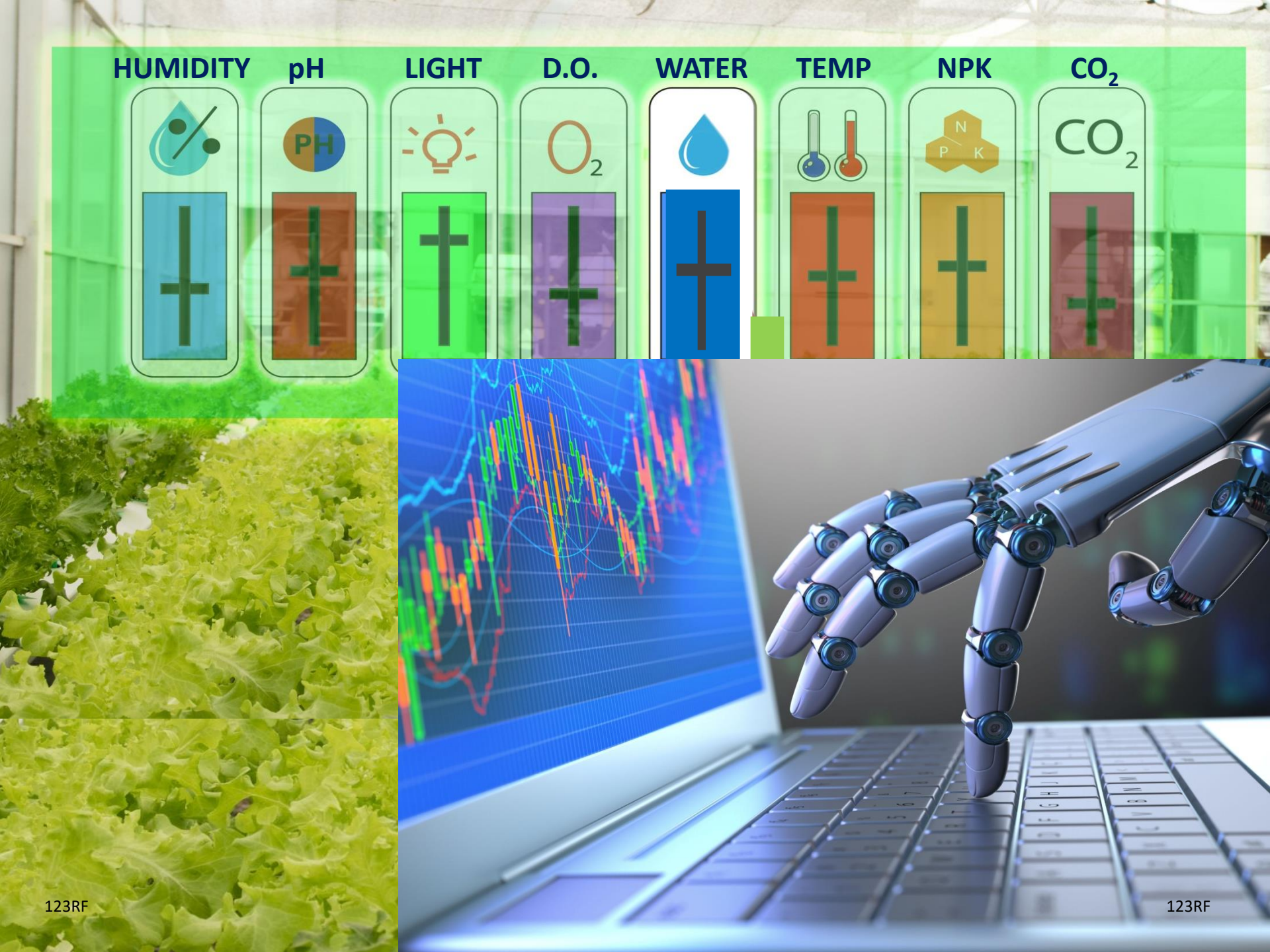
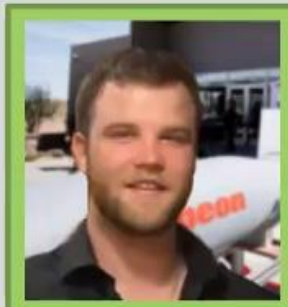
Cuello Biosystems Engineering Lab


HUMIDITY
pH
LIGHT
D.O.
WATER
TEMP
NPK
CO_2
PH
O_2
N
P
K
CO_2
123RF
123RF

The Go-VERTICAL FARM

- Mobility and Automation
- Access
- Efficiency
- Safety
- Clean operation
- Growth and Nutrition Optimization
- Machine Learning & Data Analytics

The LifeGrow Bot Team



Joseph Green
Mechanical Lead
Mechanical Engineering

Tristan Martin
Procurement Lead
Biosystems Engineering

Christopher Kaufmann
Team Lead
Biosystems Engineering

Diego Moscoso
Technical Lead
Computer Engineering

Daniel Fernandez
Electrical Engineering

Tom Maillard
Mechanical Engineering

Byron Snead
Software Development

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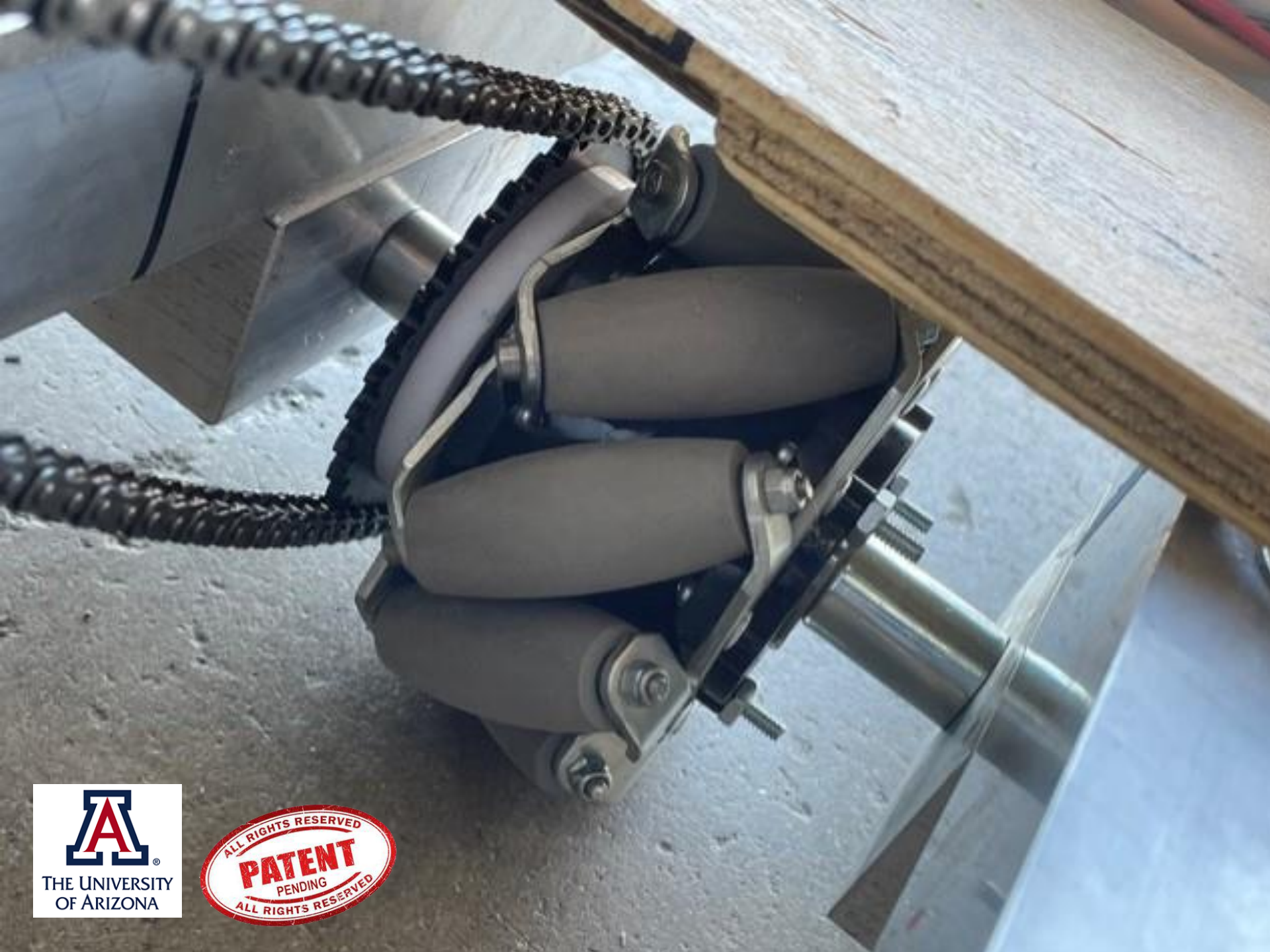
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LG Bot Prototype

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LEDs by SANANBIO®

- **Technosphere**

Intelligent Aeroponic Microgravity & Earth Nutrient Delivery (I-AMEND) System for Bioregenerative Space Life Support and Earth Applications

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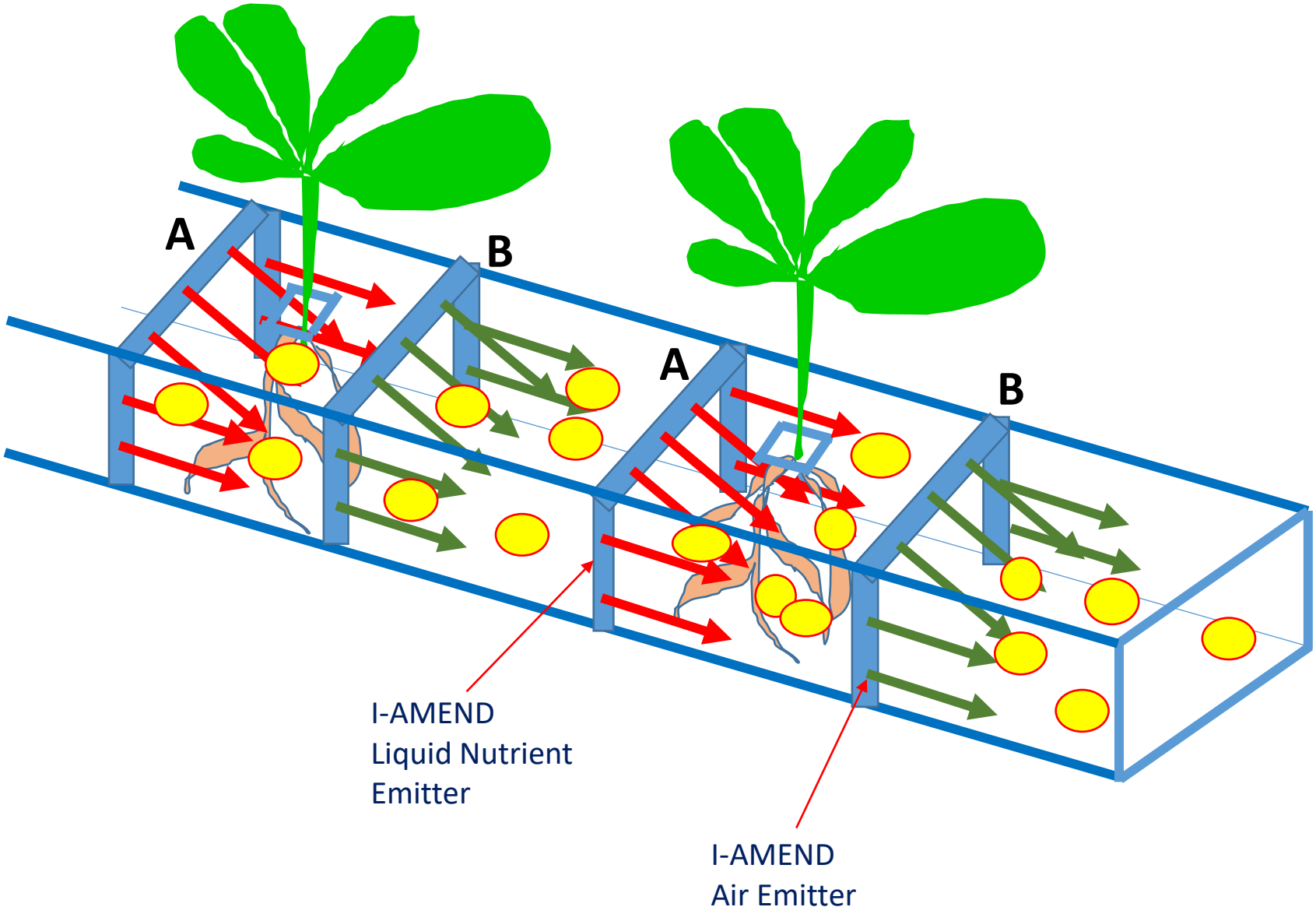
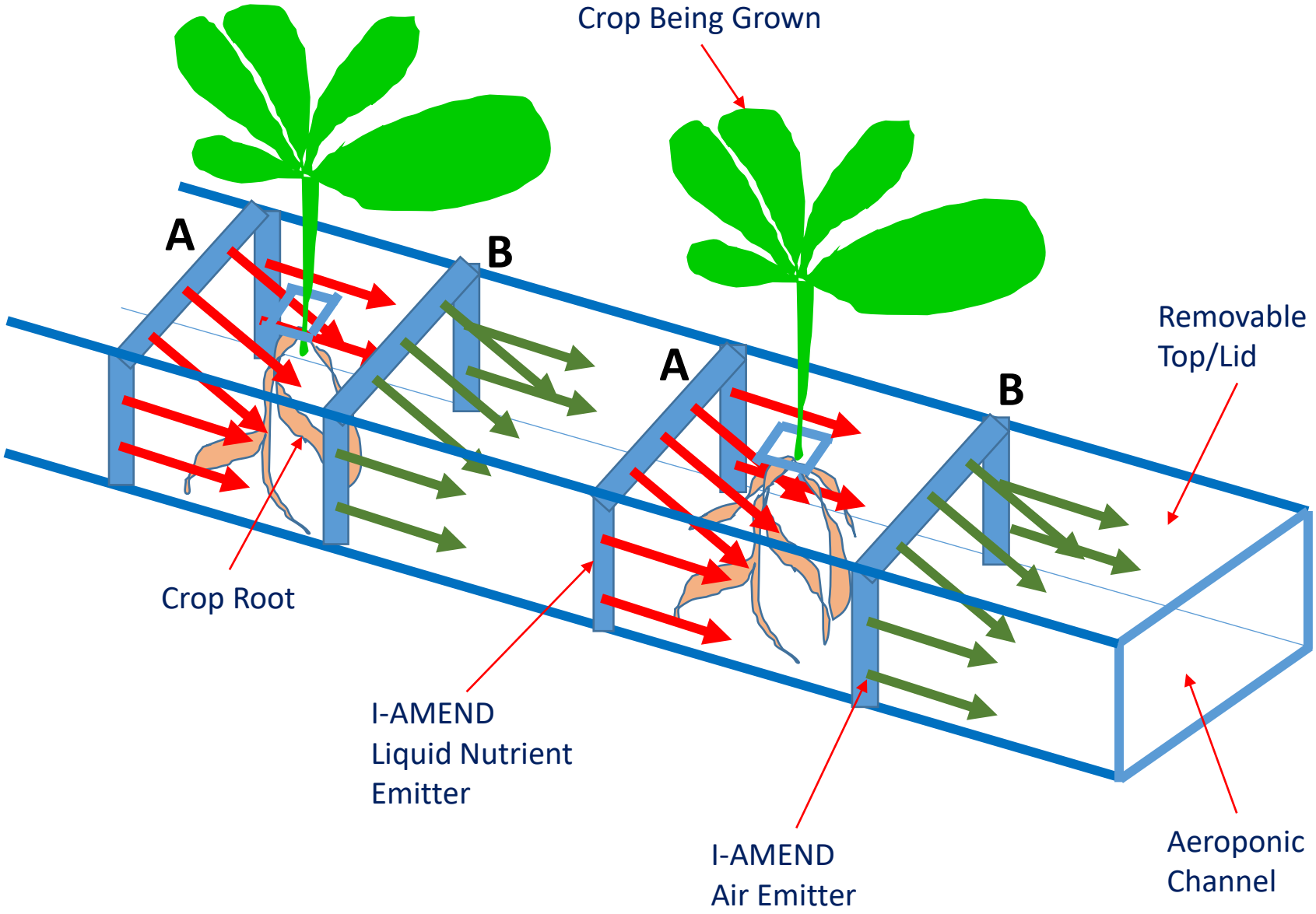
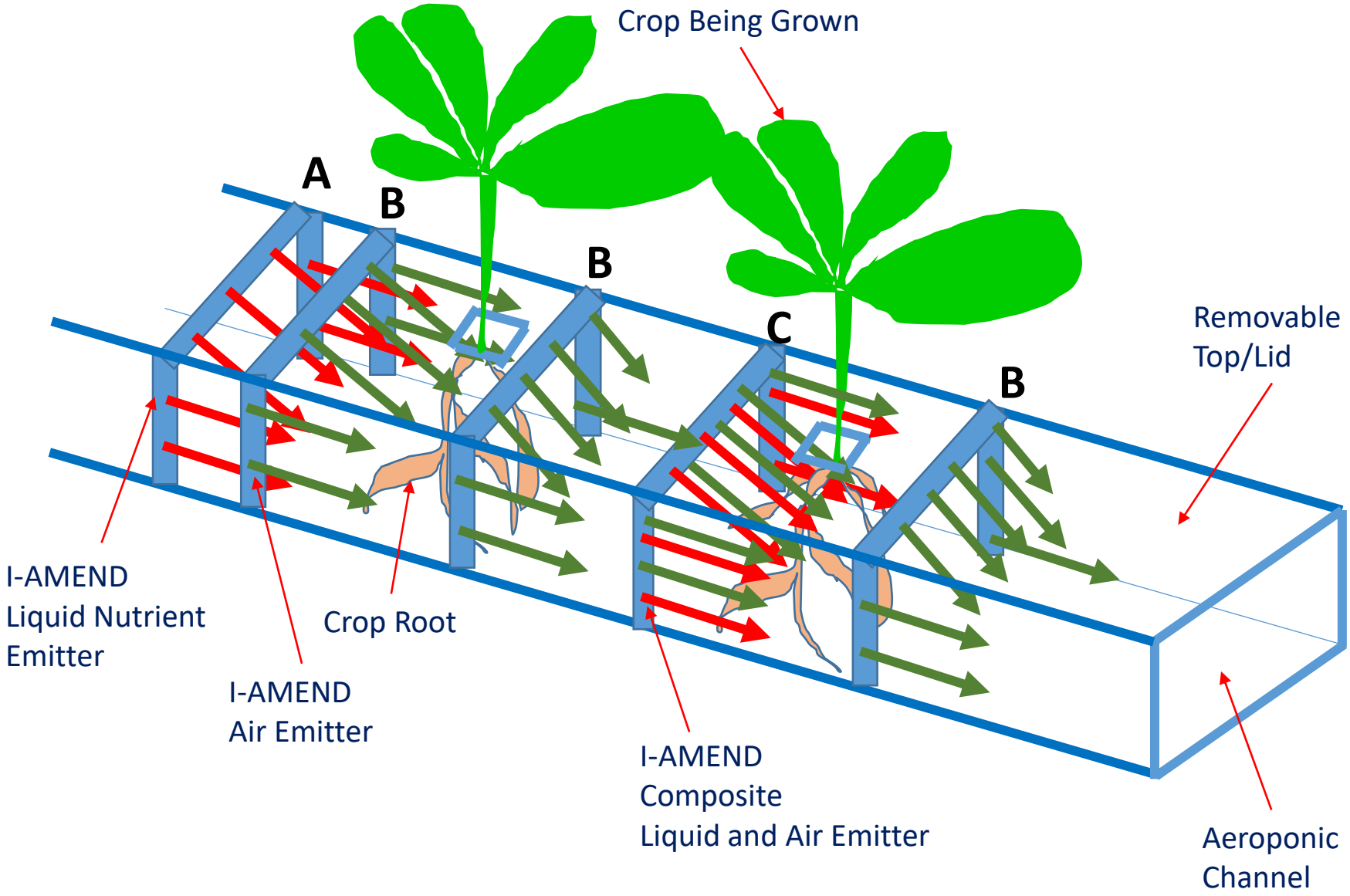
Vegetable Production System (Veggie)

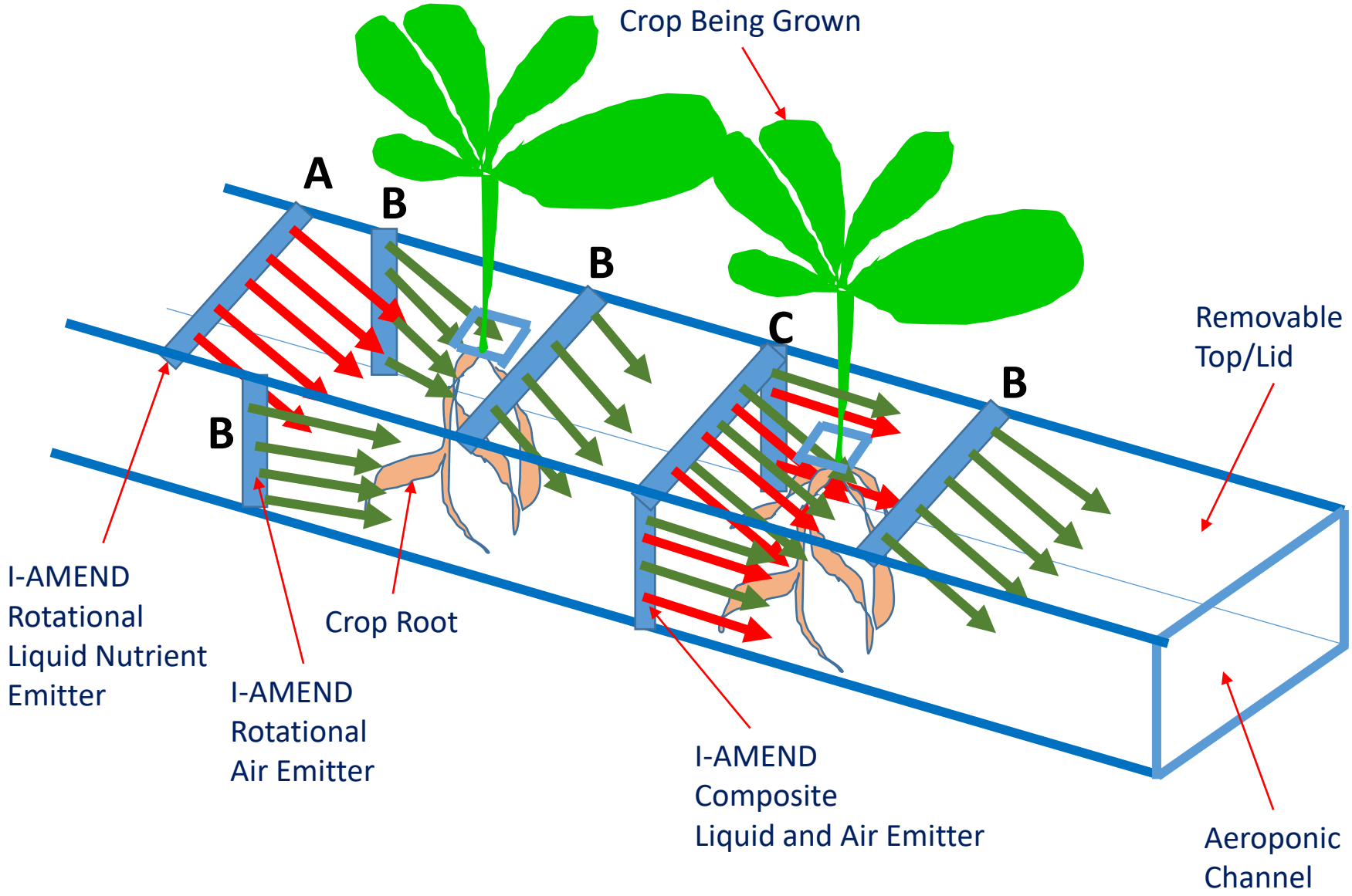
ORBITEC
Madison, WI

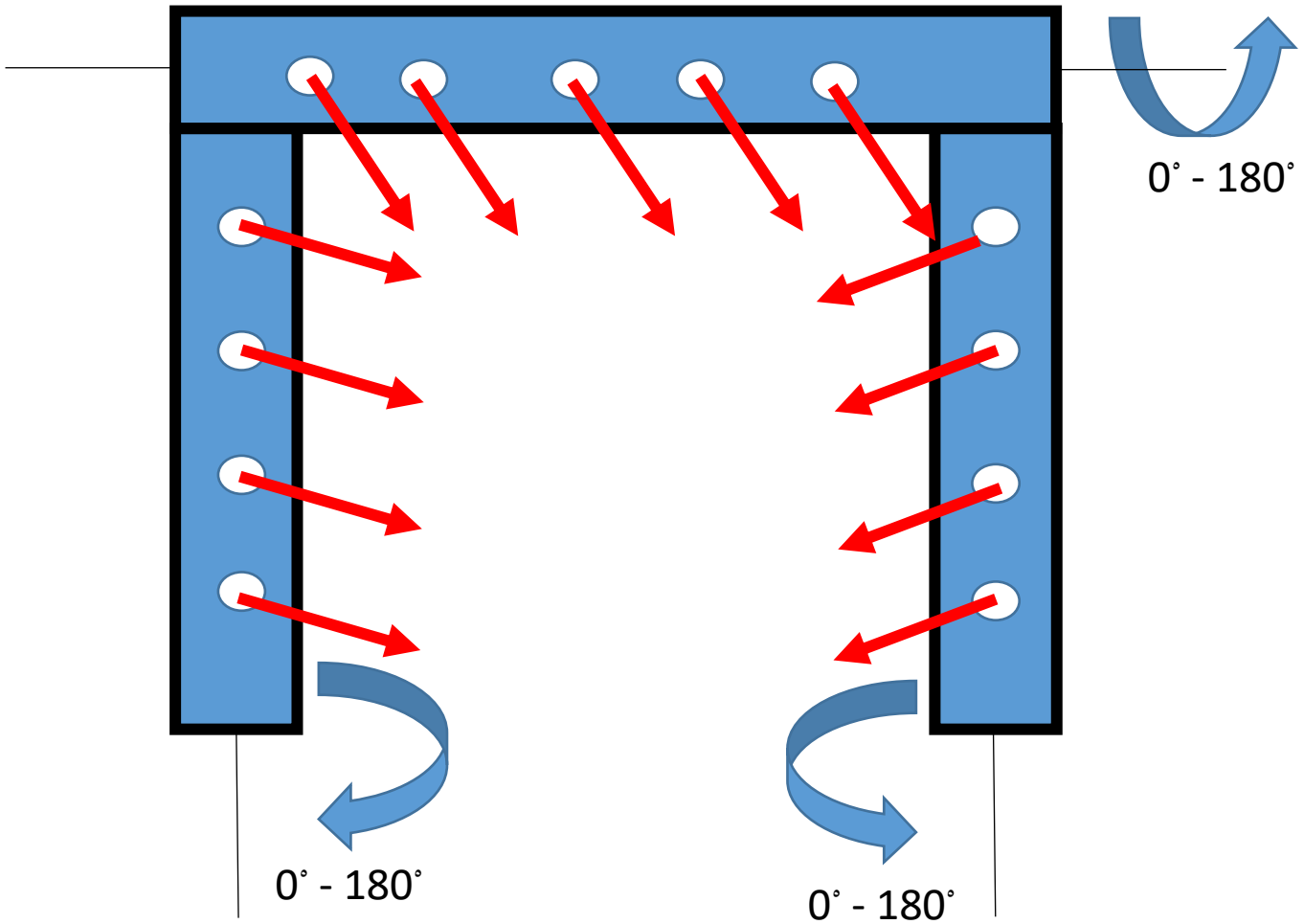
NASA


A
B
A
B
I-AMEND
Liquid Nutrient
Emitter
I-AMEND
Air Emitter


Crop Being Grown
A
B
A
B
Removable
Top/Lid
Crop Root
I-AMEND
Liquid Nutrient
Emitter
I-AMEND
Air Emitter
Aeroponic
Channel


Crop Being Grown
A
B
B
C
B
Removable
Top/Lid
I-AMEND
Liquid Nutrient
Emitter
I-AMEND
Air Emitter
Crop Root
I-AMEND
Composite
Liquid and Air Emitter
Aeroponic
Channel


Crop Being Grown
A
B
B
B
C
B
Removable
Top/Lid
I-AMEND
Rotational
Liquid Nutrient
Emitter
I-AMEND
Rotational
Air Emitter
Crop Root
I-AMEND
Composite
Liquid and Air Emitter
Aeroponic
Channel



I-AMEND Rotational Concatenated Liquid Nutrient (and/or Air) Emitters

TEAM MEMBERS

- Sydney Harrison: Biosystems Engineering
- Karen Perkins: Biosystems Engineering
- Madison Baity: Mechanical Engineering
- Julia English: Mechanical Engineering
- Justus Tiffany: Systems Engineering

I-AMEND DESIGN PROTOTYPE

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I-AMEND DESIGN PROTOTYPE

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- **Hortisphere and Technosphere**

The Auto-Optimizing Plant

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BioImagineering Lab

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The Auto-Optimizing Plant

Cuello

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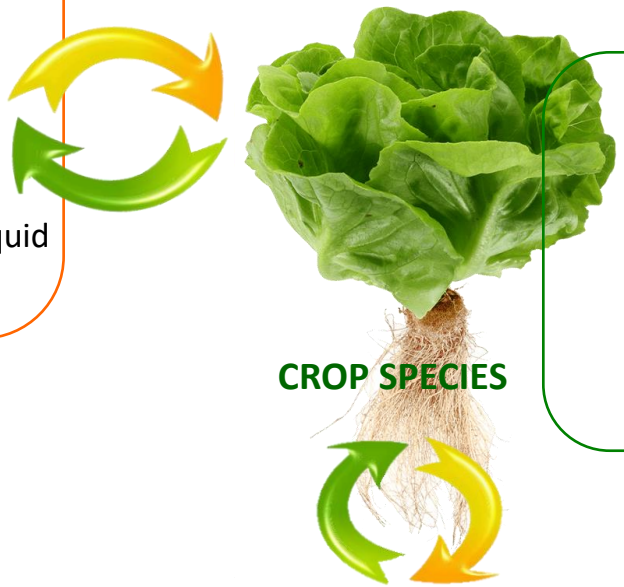
Plant-Feed-Back-Loop-Optimized Crop-Environment Growing System for Earth and Space

ENVIRONMENTAL FACTORS
Light Intensity
Light Wavelengths
Light Photoperiod
Air Temperature
Air RH
Soil/Liquid Temperature
Nutrients Mix
Aeration/Oxygen in Soil/Liquid
Soil Packing Density



CROP SPECIES

CROP VARIABLES

GROWTH
Biomass
Productivity

NUTRIENT PROFILES
NUTRIENT DENSITY

GROWING SYSTEMS
V-Hive Green Box – Hydroponics
I-AMEND – Aeroponics
LifeGrow Bots – Automated Hydroponics/Aeroponics

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- **Technosphere**

The EcoVertiBox

Cuello
BioImagineering Lab

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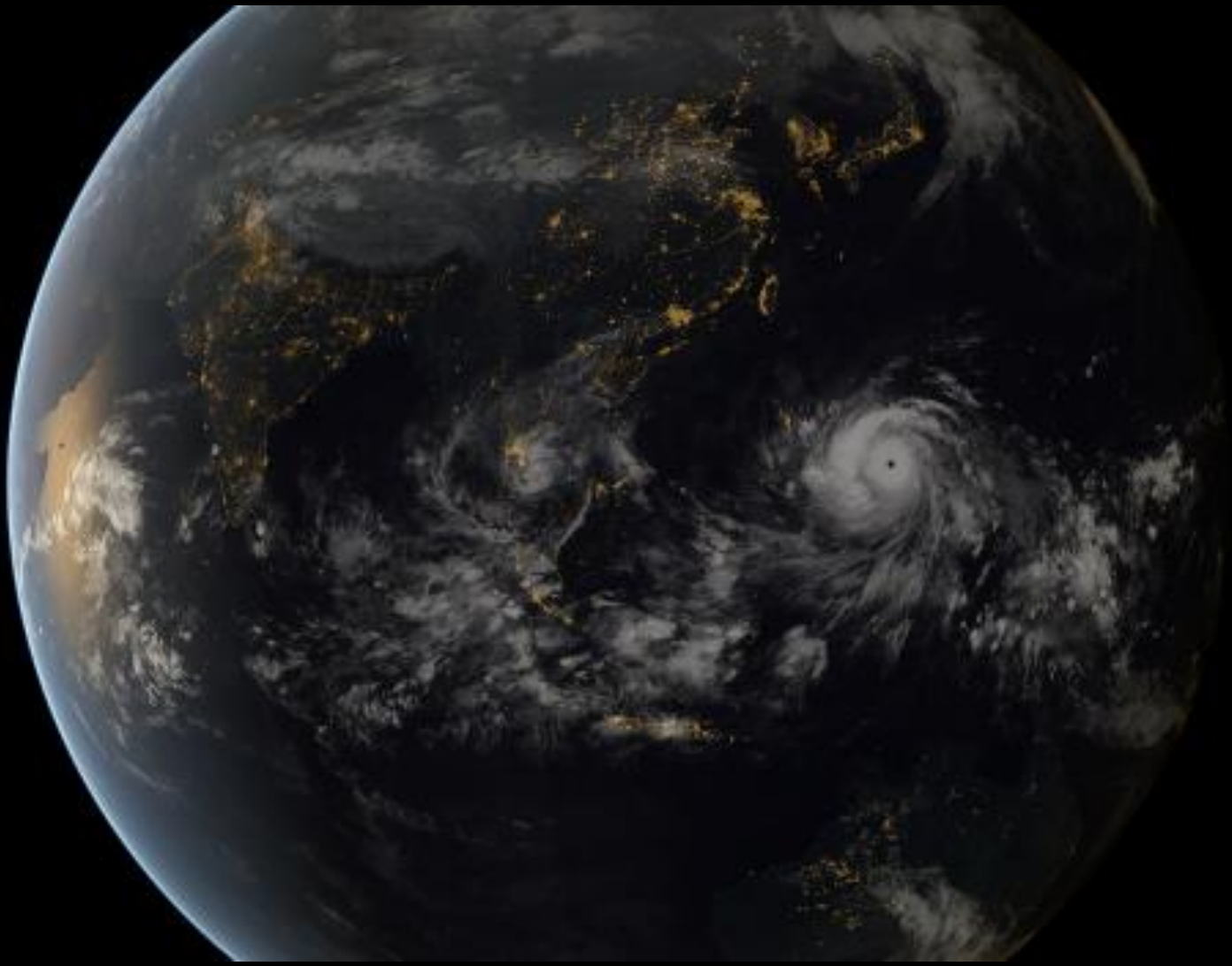
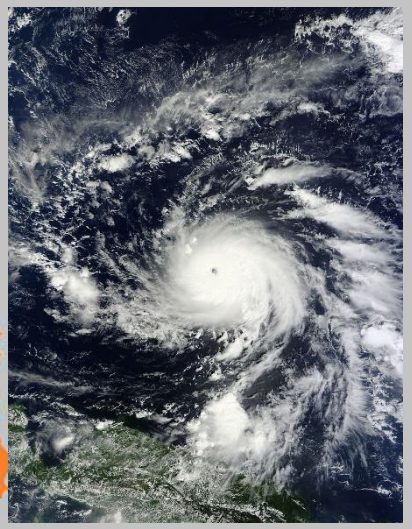
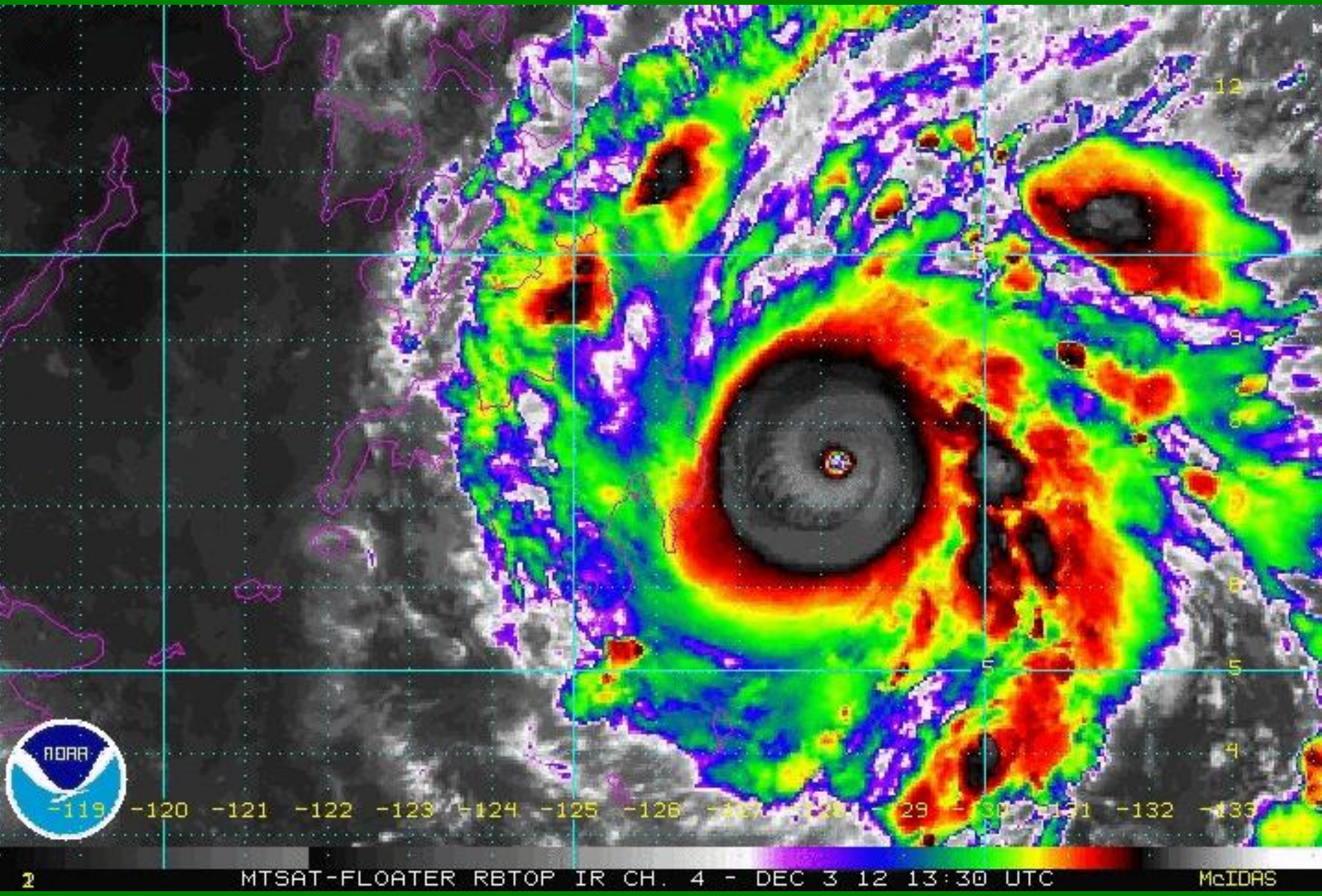
Locally Available Materials
Low-Cost Ventilation and Cooling
Renewable Energy



PHILIPPINES



Super Typhoon Pablo
Signal #5
Nov-Dec 2012


NOAA
-119 -120 -121 -122 -123 -124 -125 -126
29 31 -131 -132 -133
12
11
9
8
6
5
4
MTSAT-FLOATER RBTOP IR CH. 4 - DEC 3 12 13:30 UTC
McIDAS

Barangay Dahilayan
Manolo Fortich, Bukidnon

Excessive Heat
Excessive Rain

Fernanado Vellarino, Farm Manager


Villa Conzoilo Farmers' Association
gerryruiz


La Granja Farmers' Association

Locally Available Materials
Low-Cost Ventilation and Cooling
Renewable Energy

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VF Trends & Challenges

My Focus & Priorities

Main Challenge for Latin America

CIPAC's Central Role

Arizona Cooperation With CIPAC

Main Challenge for Latin America

Growing and orchestrating region-wide Indoor Farming Technosphere, Hortisphere, Resourcesphere and Businessphere to produce thriving Indoor Farming Enterprises

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CIPAC's Central Role

Address main challenge above and leverage Panama's global connectivity to establish a CIPAC Special Economic Free Zone for Indoor Farming with incentivized global access

Arizona Cooperation With CIPAC

Technosphere, Hortisphere, Resourcesphere, Businessphere and Competitivene Stretegies for CIPAC Special Economic Free Zone for Indoor Farming

THE PANAMA CANAL IS CONNECTIVITY

Connects 144 routes and 1,700 ports in 160 countries, providing reliable and efficient service to the maritime industry

Center for Research and Production in Controlled Environment (CIPAC-AIP)

Cuello

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BioImagineering

Innovations for people and the planet

UA Biosystems Engineering Lab

Joel L. Cuello, Ph.D.
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