Enabling ESM Reduction for Food Production at the Lunar Base

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Ames Research Center

Sustainability Requires On-Site Food Production

- Resupply to the Moon is expensive ($70K/lb in 2004 $)
- Shelf life of packaged food - a question and a challenge (spoilage, radiation)
- Certain anti-oxidants most effective from fresh fruits, vegetables
- Fresh foods will augment diet psychologically & nutritionally
- Eventual regeneration of O_2, H_2O, protein, carbohydrate, and fat from degraded wastes

A "salad machine" at the Lunar Base would…

- Augment crew diets with fresh salad foods:
  - containing anti-oxidants, vitamins, minerals
  - possessing psychologically important aromas, flavors, textures
- Provide recreation/stress relief by tending plants
- Provide a test bed for plant growth in the Lunar gravity/radiation/ISRU environments
- Require only 1-2 m^2 of area in one logistics module
- Use minimal power load
- Prepare for closed-loop life support at Lunar/Mars bases and beyond

ESM for Traditional Controlled-Environment Crop Production is high

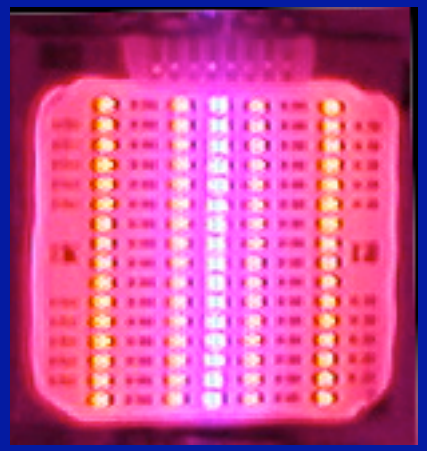
$$ESM = M + (V \bullet V_{eq}) + (P \bullet P_{eq}) + (C \bullet C_{eq}) + (CT \bullet D \bullet CT_{eq})$$

- Electrical power requirements for lighting / heat rejection a major component
- HID lamp ballasts heavy
- HID lamps very hot, require large separation from plants
- Refrigeration systems massive, power hungry

Solid-State LED Lighting Solves Several Energy-Related Problems

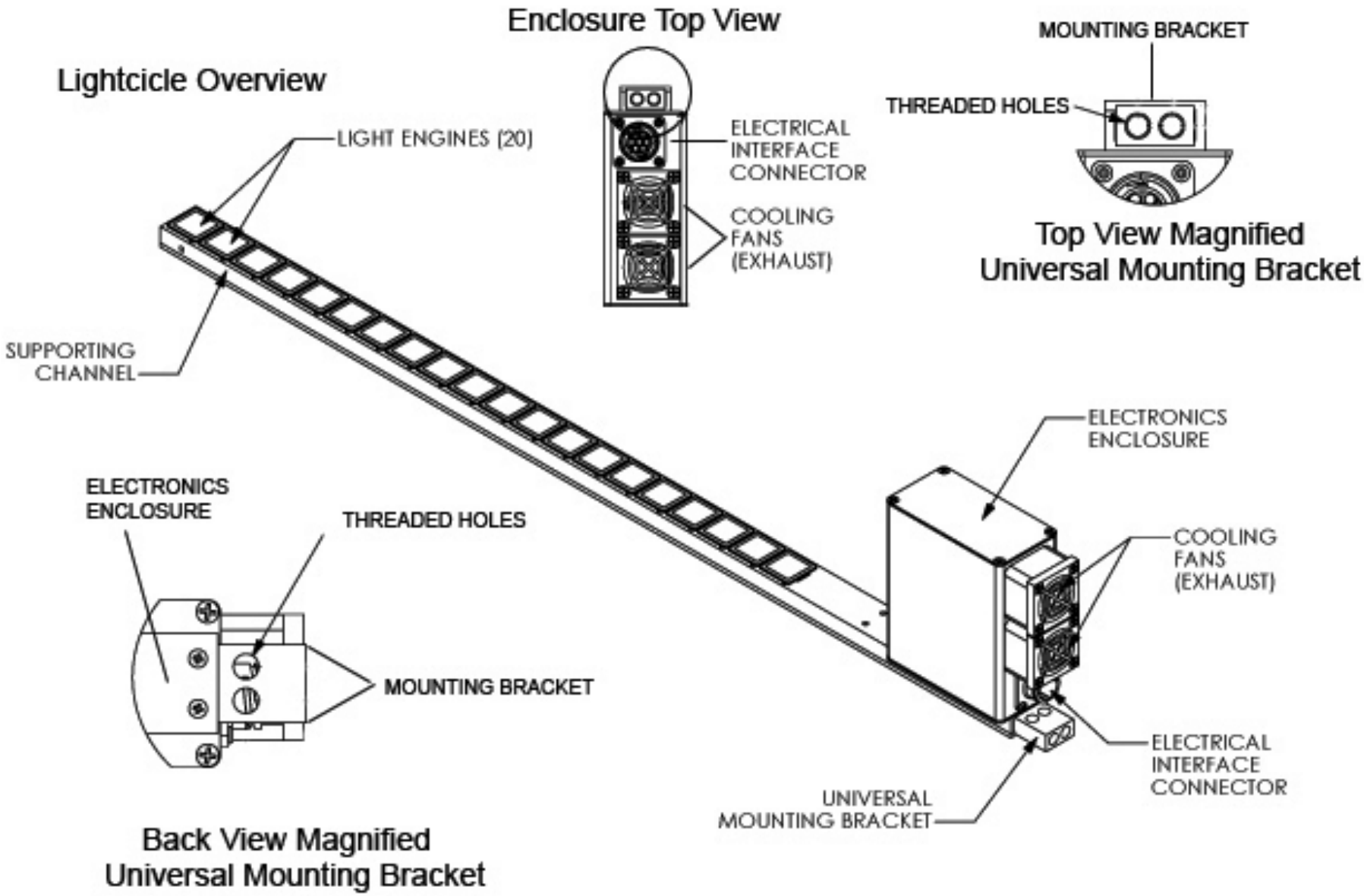
- Removal of waste heat separate from light emitters allows close LED placement to plants
- Close LED placement allows lower photon emissions to achieve same irradiance as HIDs
- Reduced photon emissions draws lower power
- Lower power generates less waste heat
- Less waste heat allows creative placement of LEDs

Printed-Circuit LED "Light Engines"



ORBITEC Light Engine

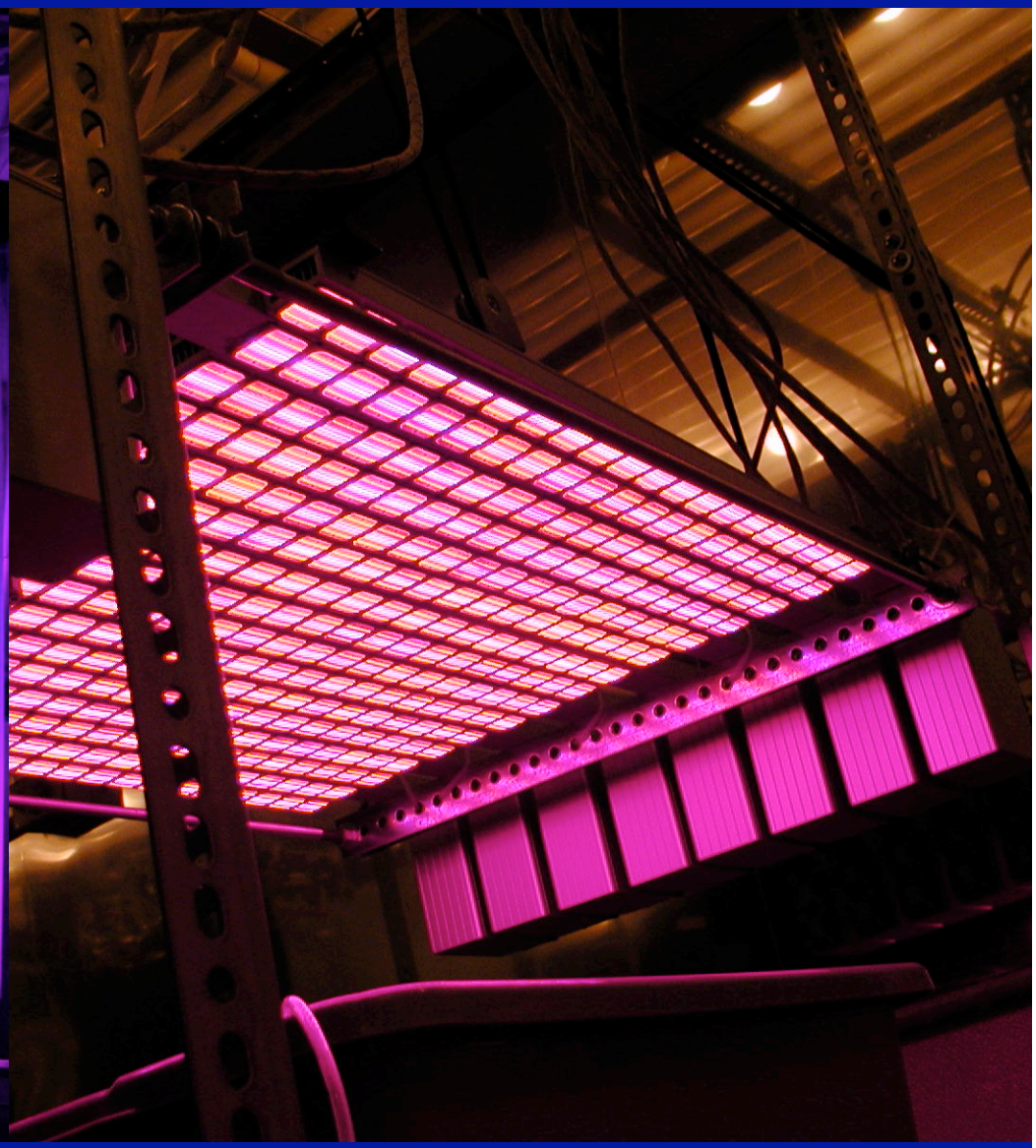
- 1 row of sixteen 440 nm blue
- 4 rows of sixteen 640 nm red
- 2 rows of ten 520 nm green
- 2 photodiodes


Lightcicle Overview
LIGHT ENGINES (20)
SUPPORTING CHANNEL
Enclosure Top View
ELECTRICAL INTERFACE CONNECTOR
COOLING FANS (EXHAUST)
MOUNTING BRACKET
THREADED HOLES
Top View Magnified Universal Mounting Bracket
ELECTRONICS ENCLOSURE
COOLING FANS (EXHAUST)
ELECTRICAL INTERFACE CONNECTOR
UNIVERSAL MOUNTING BRACKET
ELECTRONICS ENCLOSURE
THREADED HOLES
MOUNTING BRACKET
Back View Magnified Universal Mounting Bracket

Lightsicle Array

Intracanopy

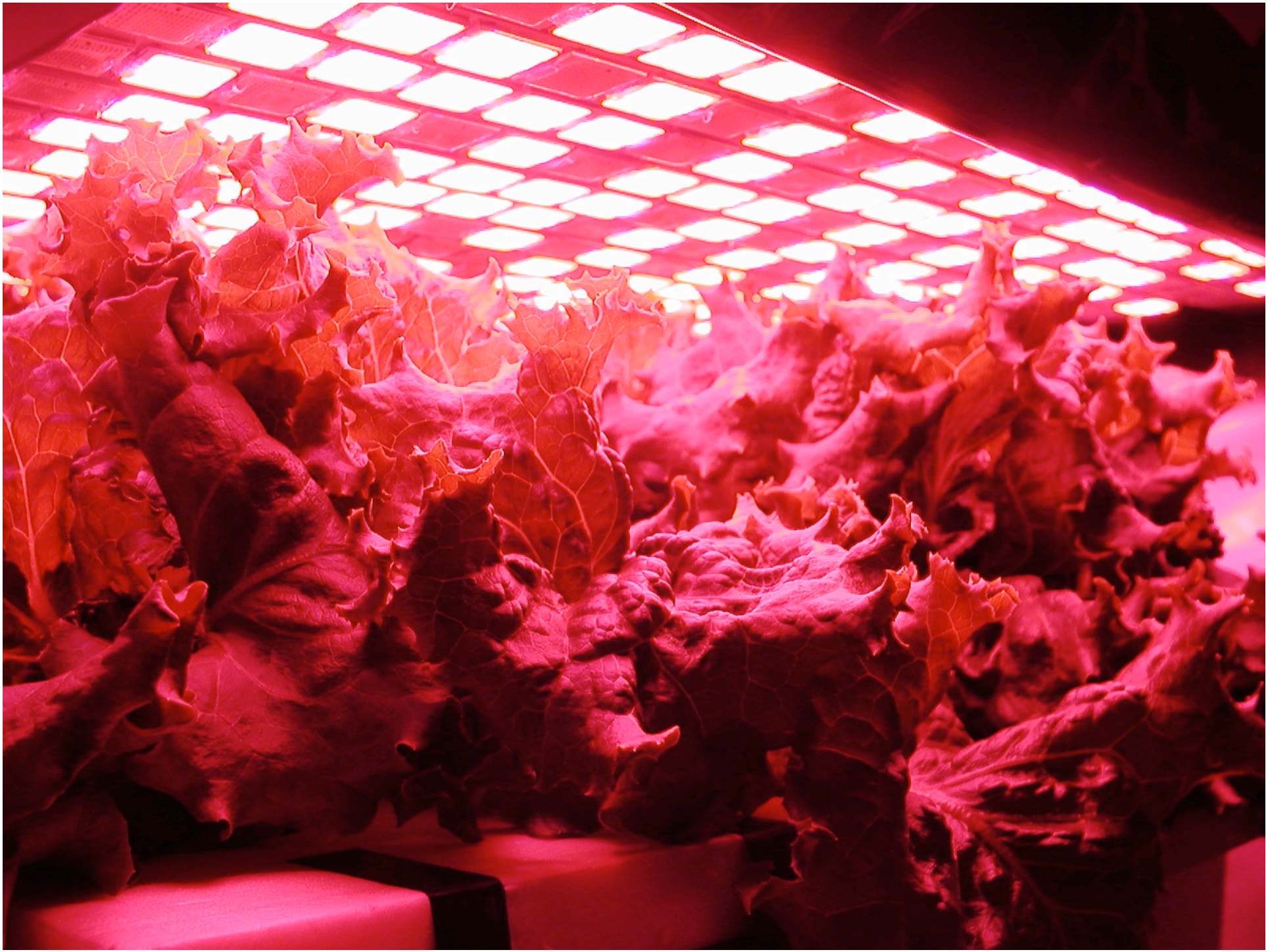
Overhead

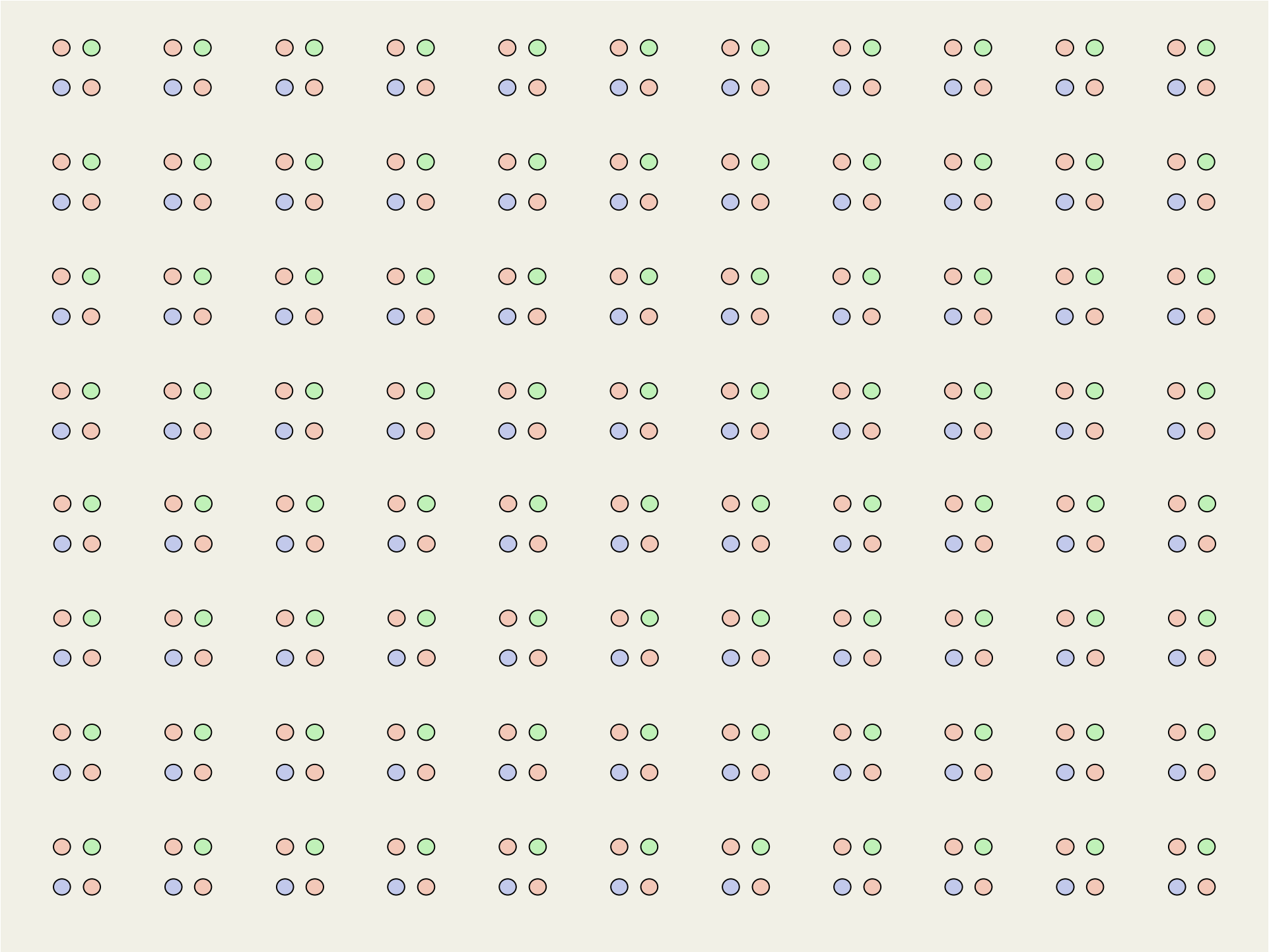


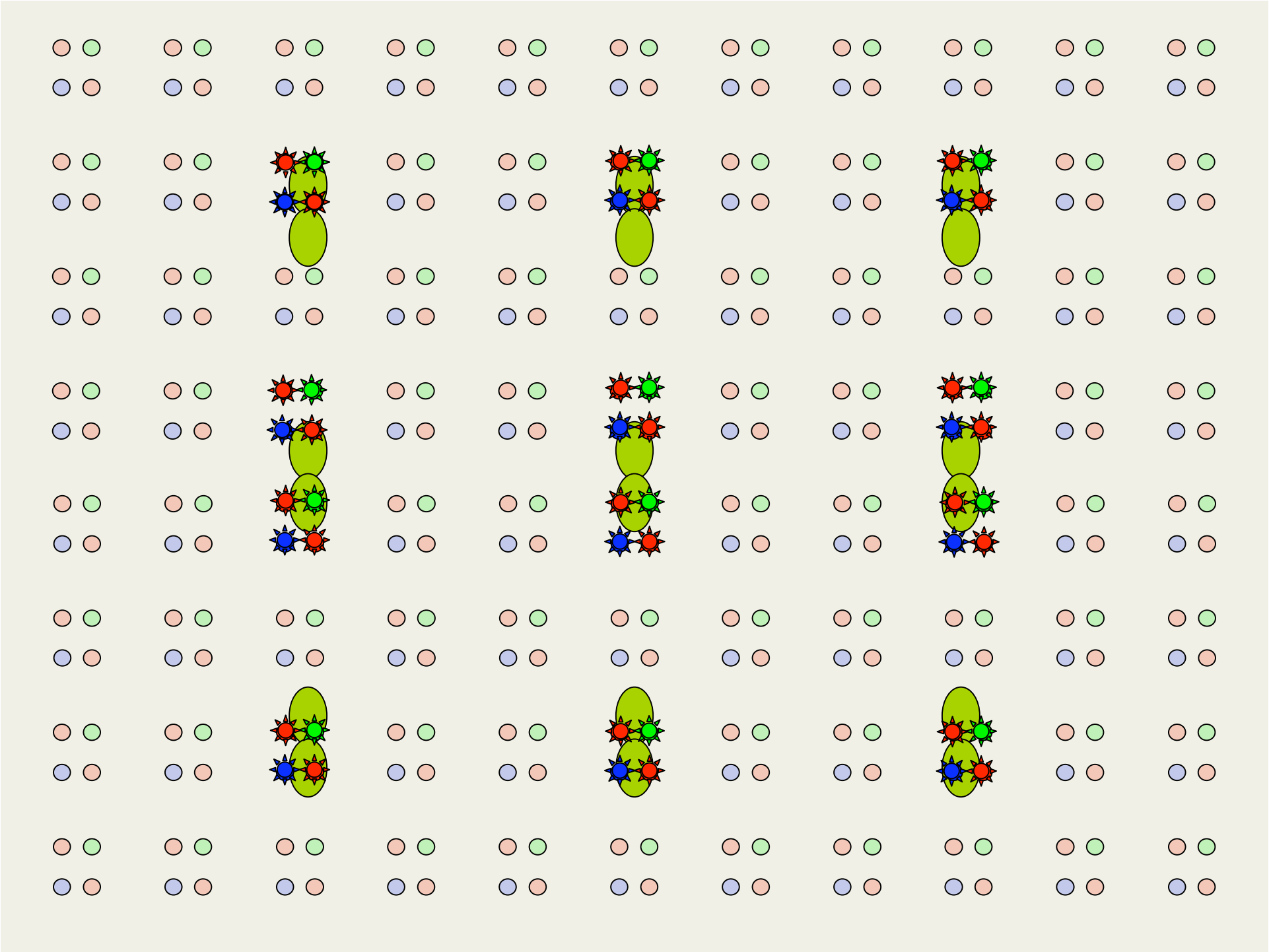
Intracanopy LEDs
Overhead LEDs

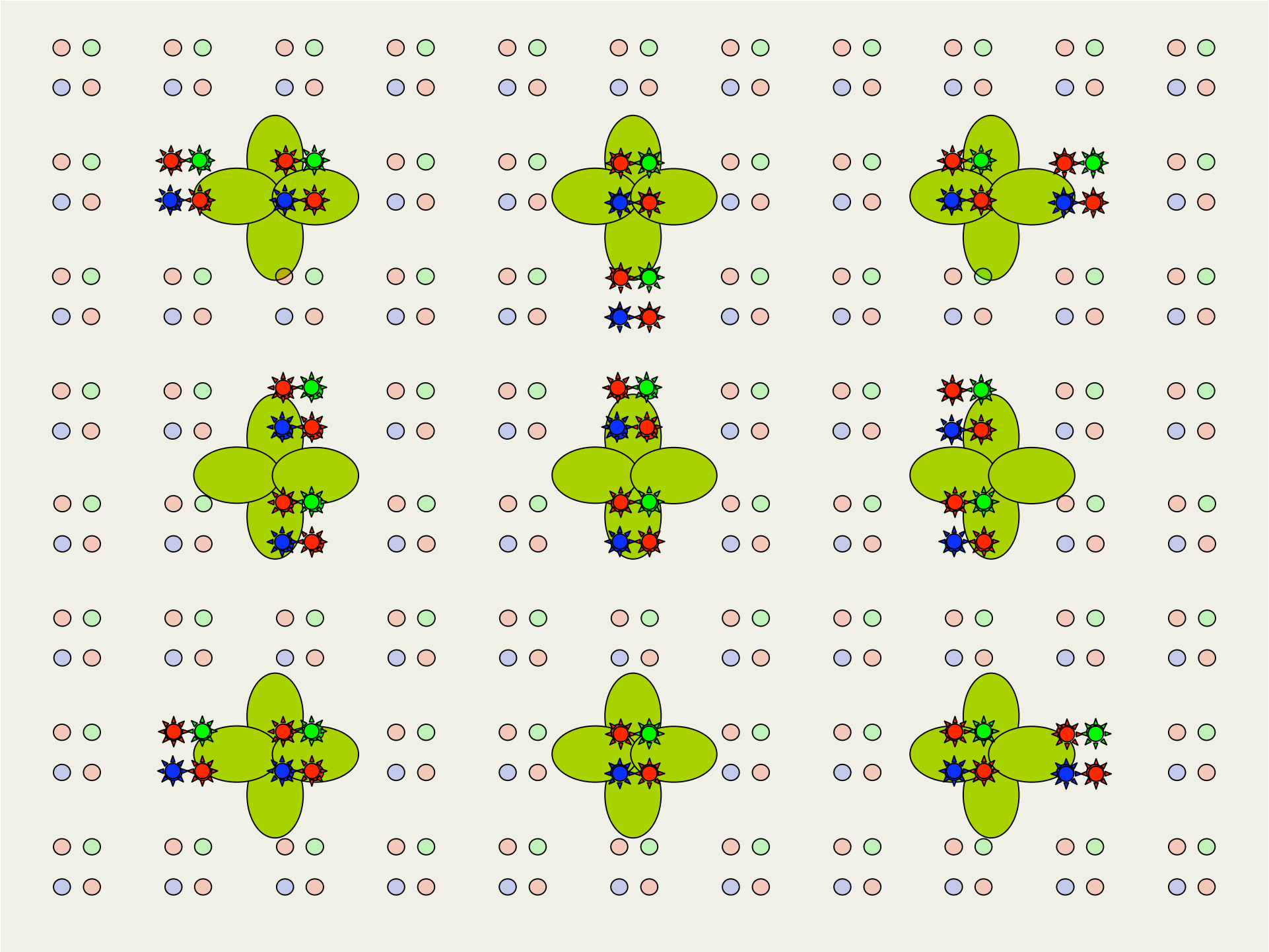
HELIAC

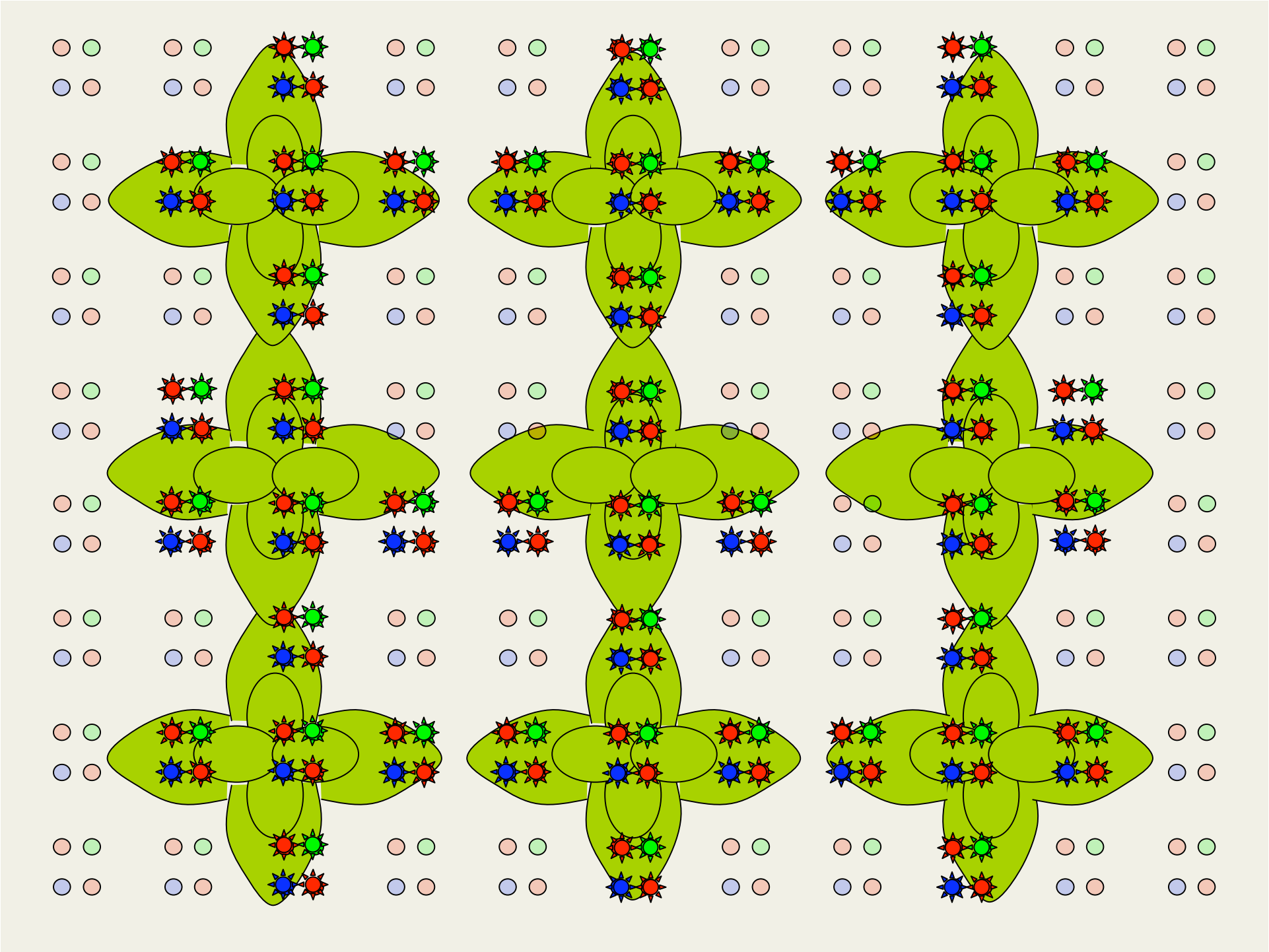
- High Efficiency Lighting with Integrated Adaptive Control
- Phase I and Phase II NASA SBIR to ORBITEC
- Testing with plants at Purdue
- Automated plant detection
- Green LED's flash → photodiodes sense reflection → red and blue LEDs activated

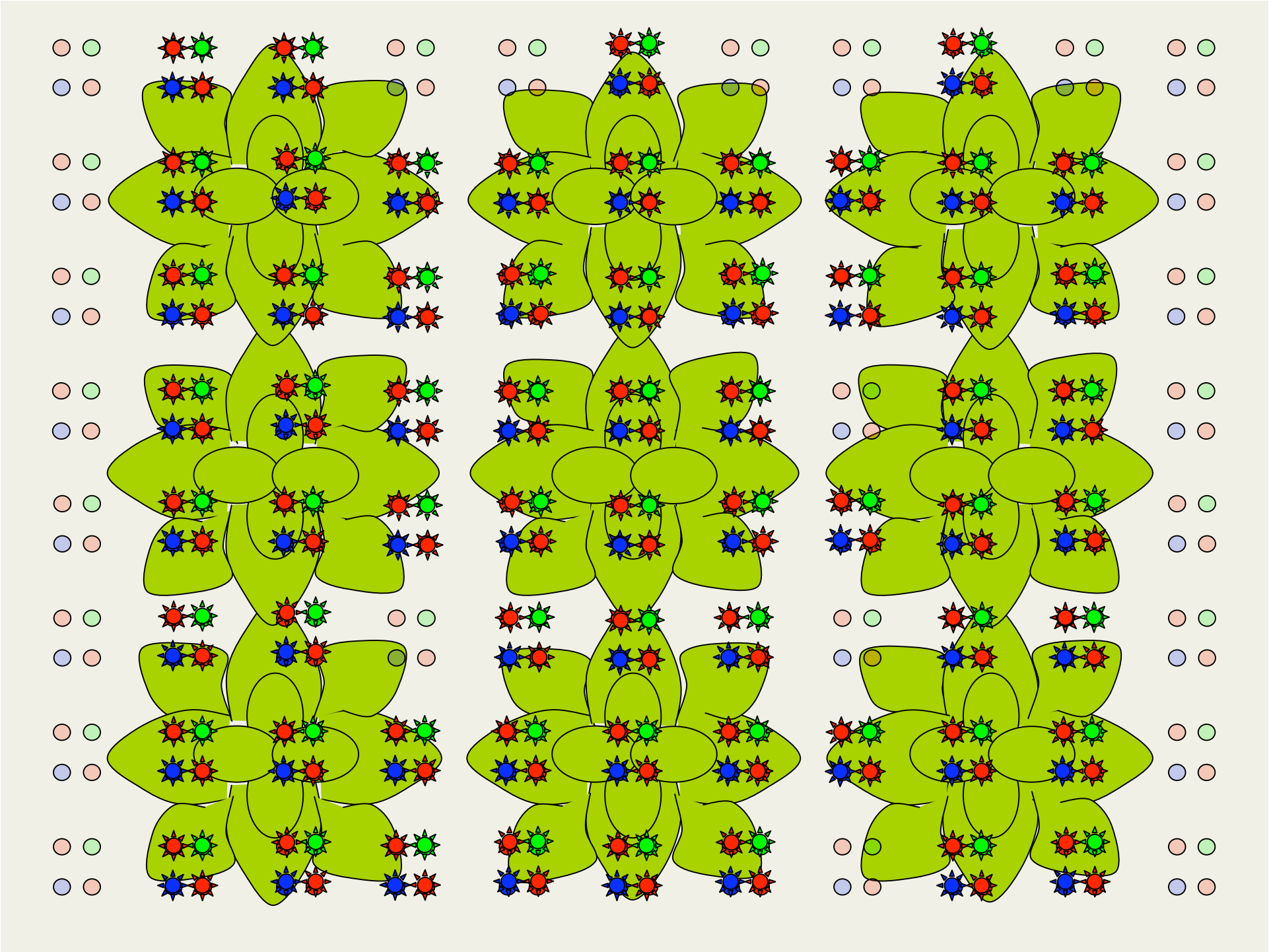


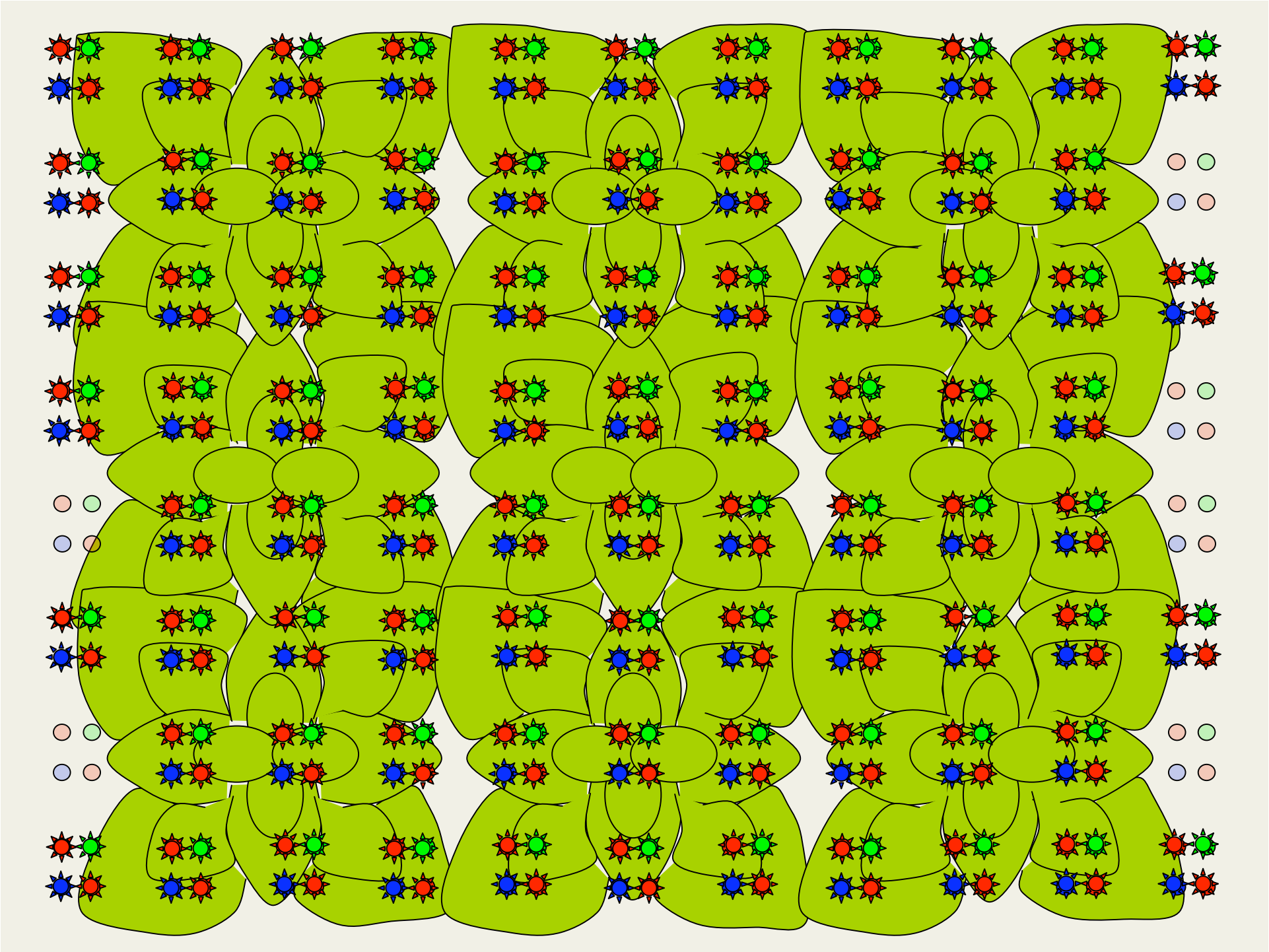






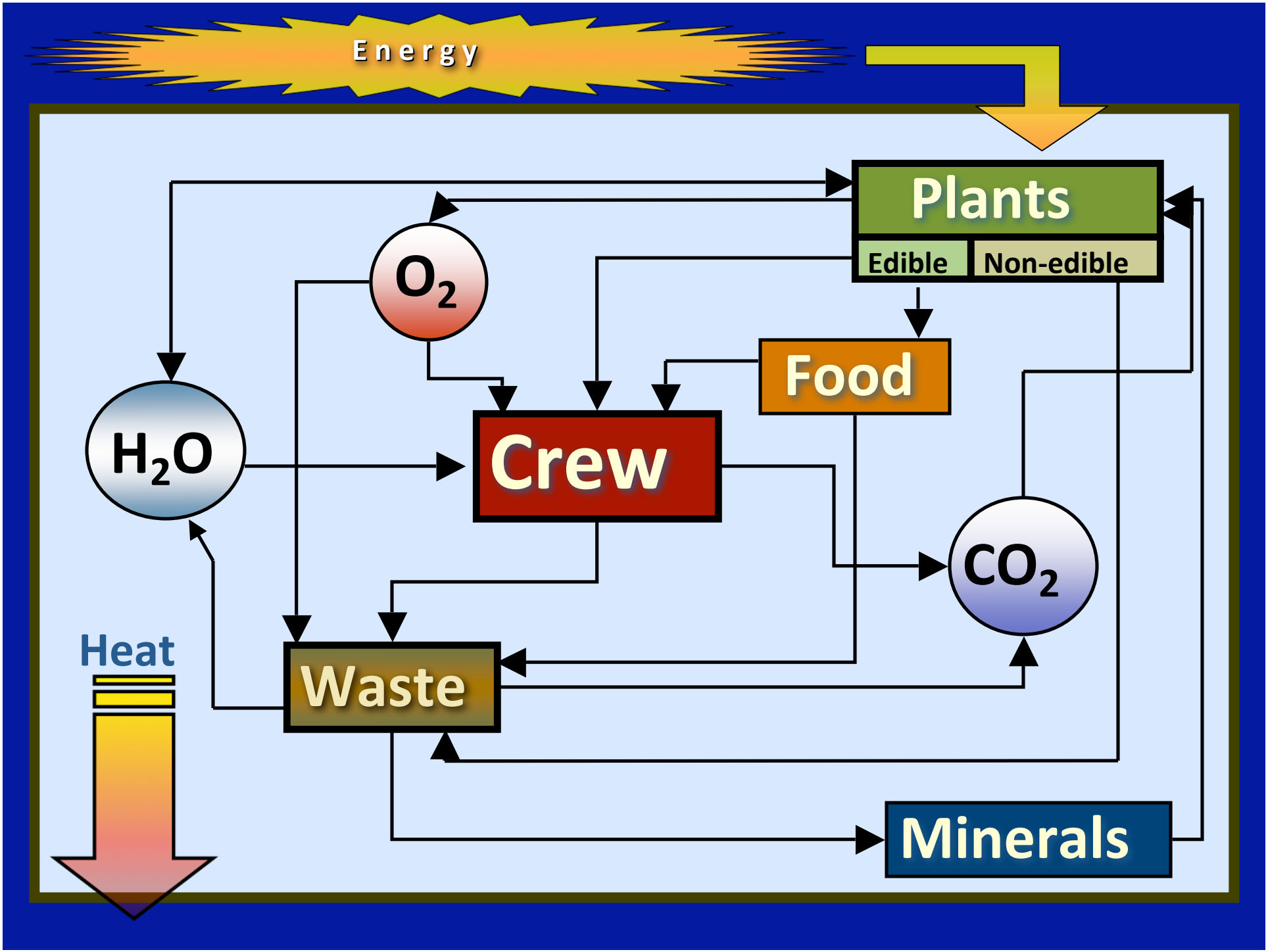






The reasons for HELIAC

- Energy efficiency for plant growth in a space life-support system or CEA on Earth
  - Intracanopy lighting for planophile crops
  - Overhead close-canopy lighting for rosette and erectophile crops
  - Lighting system automatically adjusts lighting only where leaves occur
- Future upgrades could include neural networks that adjust to plant needs, programmed settings for specific crop types at different stages, and new lighting architectures.


Energy
Plants
Edible
Non-edible
O_2
Food
H_2O
Crew
CO_2
Heat
Waste
Minerals

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