



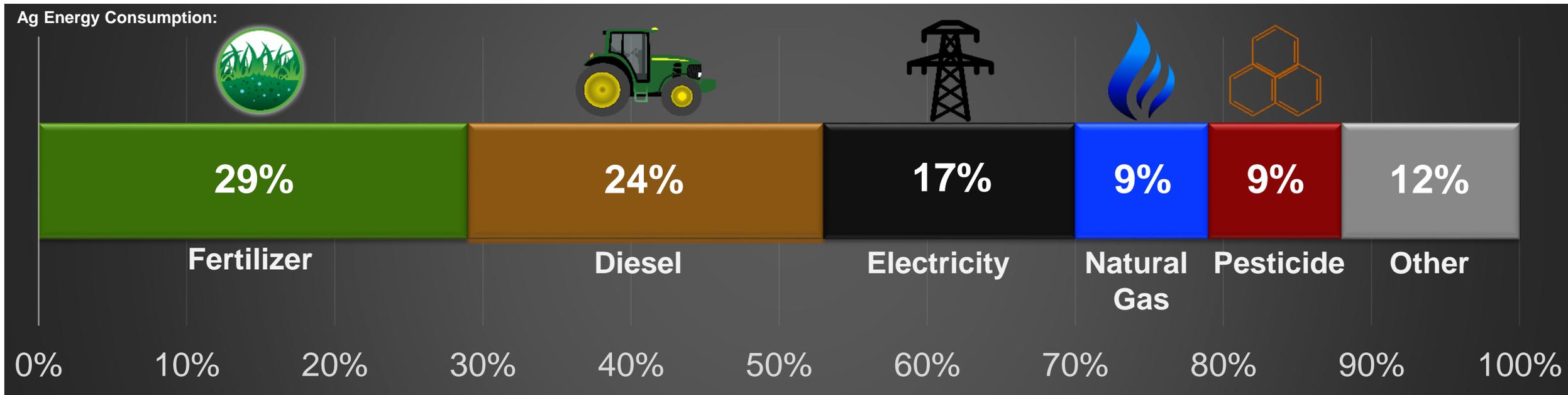
Bioenergy Moneyball

Rooted in Biology, Powered by Engineering, Enabled by Analytics

Joe Cornelius
Program Director
Advanced Research Projects Agency - Energy

Agricultural is BOTH a Consumer and Producer of U.S. Energy

In 2014 the Agricultural Sector Consumed 1.7 Quadrillion BTU of Energy...



... and Generated 4.9 Quadrillion BTU of Primary Energy from Biomass

With Unintended Consequences: 9% U.S. GHG Emissions and 80% U.S. Fresh Water Use

Q: What do Farming and Baseball have in Common?

“Managers tend to pick a strategy that is the least likely to fail, rather than to pick a strategy that is most efficient.” Michael Lewis



“Baseball is a game of inches”

Branch Rickey

^ and Farming



Analyze



Play



Win/Lose



With sabermetrics, baseball is now a game of nanometers.

Program Hypothesis: Future Productivity Relies on Data!

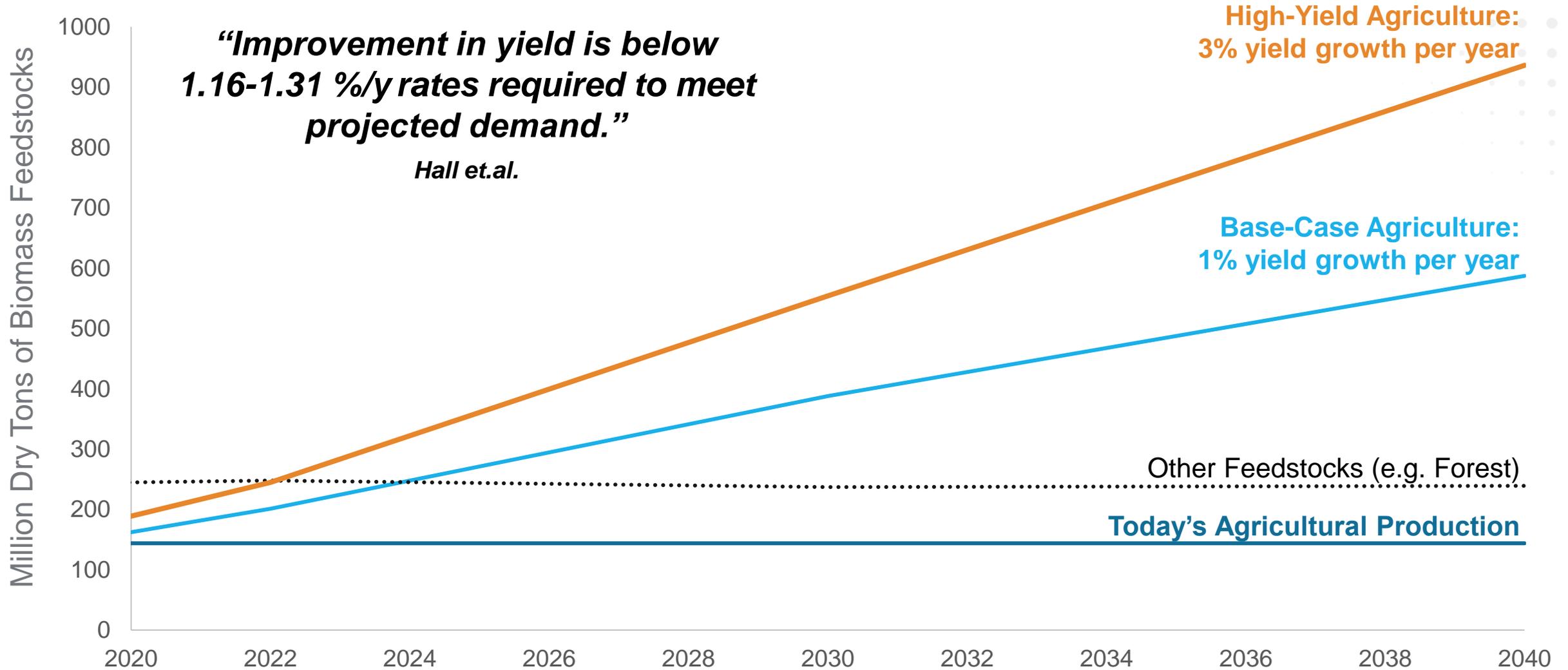


Imagine... a Bioenergy Sector that, in thirty years:

- ✓ Doubles Productivity
- ✓ Cuts Emissions in Half
- ✓ Conserves Resources by 1/3
- ✓ Triples Renewable Biofuels

Biomass has the Potential to Supply 20% of U.S. Energy Demand

But We Are Off Pace to Feed and Fuel the World



Genetic Gains are Limited by Environmental Conditions

Poor Management Decisions Further Reduce Potential Yields

Opening
Day

Defining Factors
(Genetics)



Series
Winners

Defining Factors

+

Limiting Factors
(Environment)



There's Always
Next Year

Defining Factors

+

Limiting Factors

+

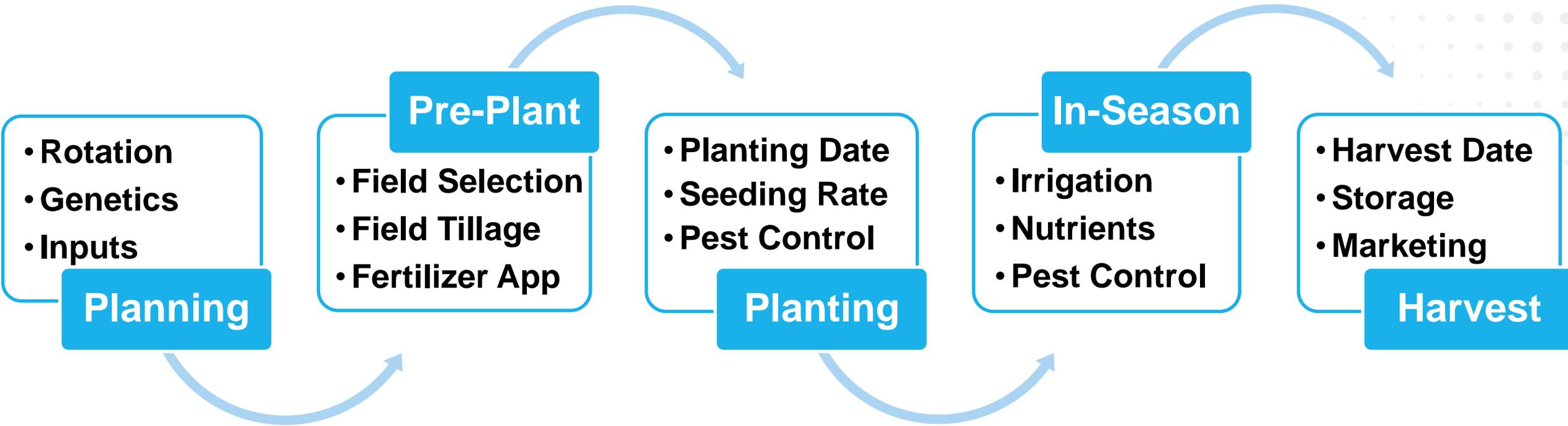
Reducing Factors
(Management)



Yield = Genetics x Environment x Management

A “Game of Inches”

Each Season, Famers Make a Multitude of Yield-Impacting Decisions



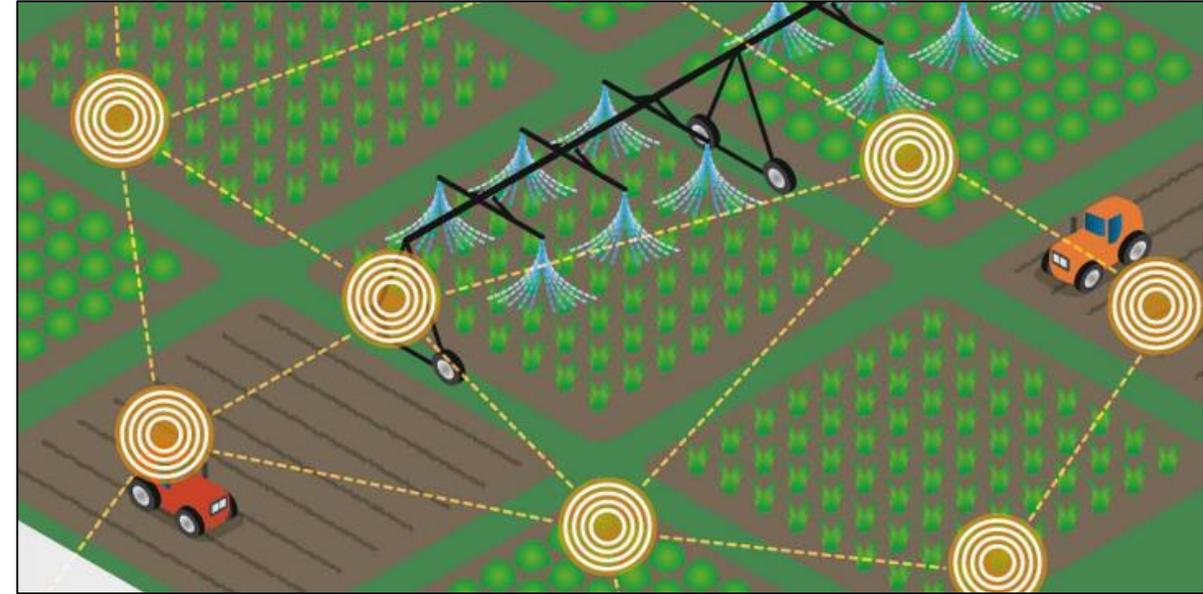
Without the Right Information, Management Practices can Reduce Yields by 60% or more.

High-Efficiency Production Requires High-Resolution Data

Problem: In-Field Environment Variability



Solution: In-Field Real Time Sensing



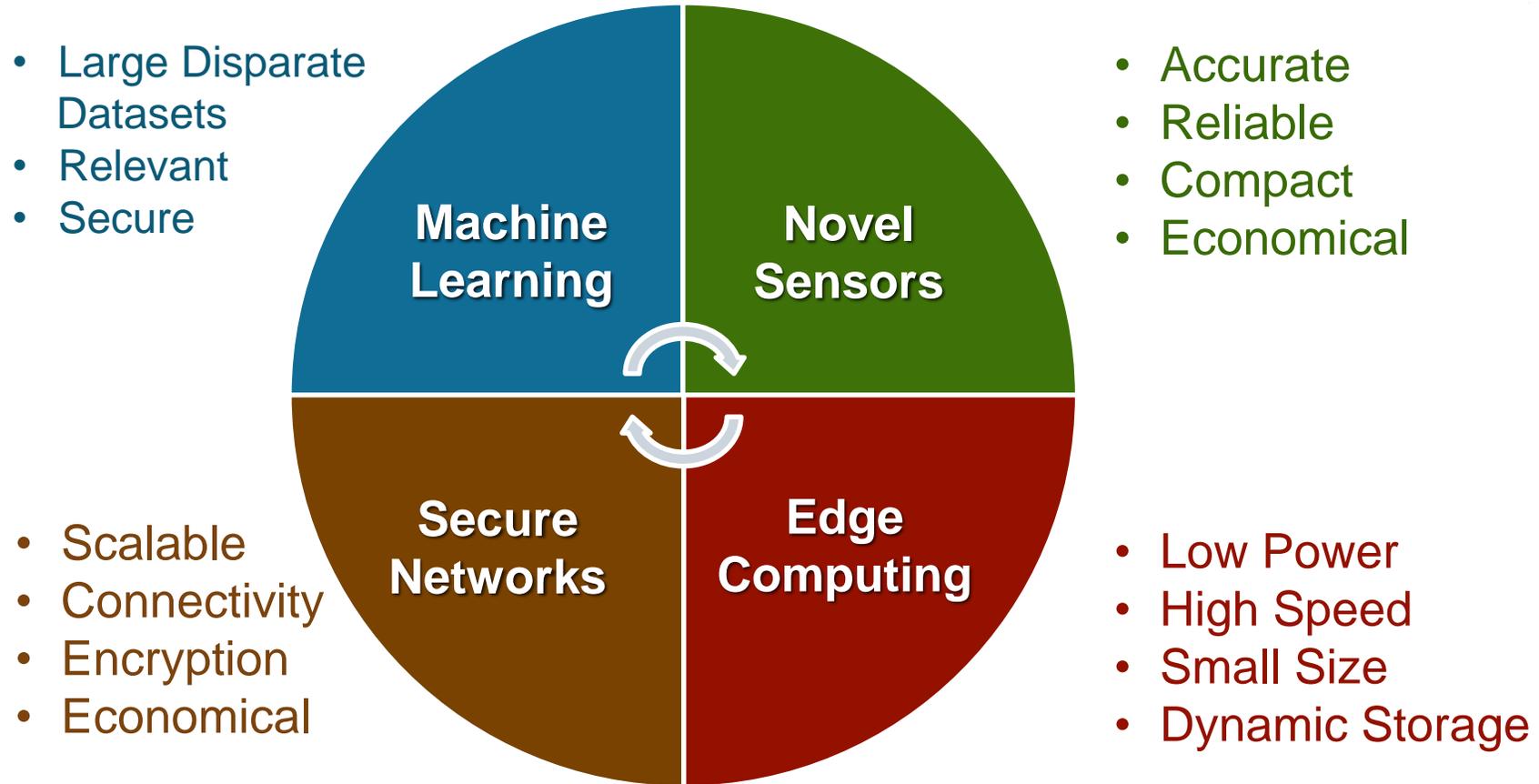
Examples:

- Micro-climate
- Soil Condition
- Nutrient Status
- Water Stress
- Canopy Temperature
- Growth Rate
- Disease Development
- Insect Pressure
- Pollination
- Lodging Stalk Strength
- Grain Maturation
- Rainfall and Heat Units

Distributed Intelligence is a REAL Challenge

in Highly Variable, Resource Constrained Environments

Integrated Platform Components



Examples of Cutting Edge Breakthrough Technologies

Capturing, Storing, Communicating, Processing, and Predicting

Innovation Frontiers:

Sensing:

microclimate, metabolic, chemical, nutrient, biologic, acoustic

Power:

zero power, energy harvesting, non-toxic, bio-electrons

Analytics:

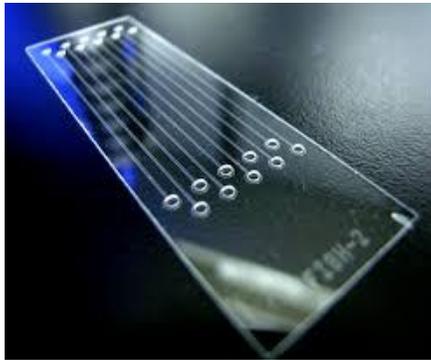
no central hub, ML without full datasets, crop in silico models

Communications:

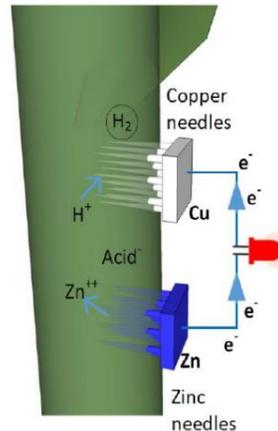
no line of site, swarm coordination, just in time

Examples:

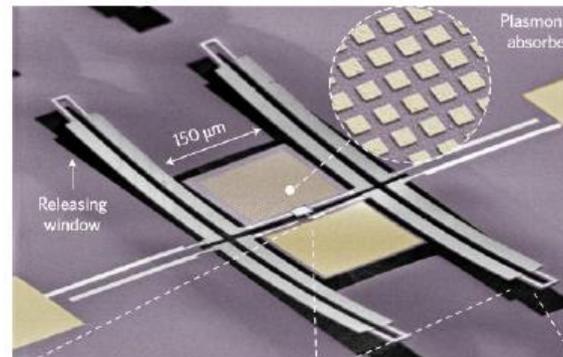
Lab on a Chip



In Planta Batteries



Ultra-Low Power Platforms



Ultra-Compact Computers



Program Goal: Digital Tools for the Energy Smart – Smart Farm

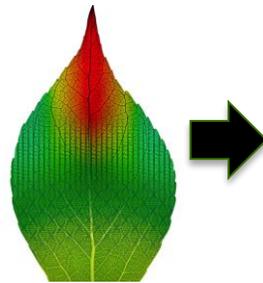
Make the Right Decision, at the Right Time, Every Time.

**“In-Field”
Network Connectivity**



+

**“Ground to Satellite”
Sensor Integration**



+

**“User-Friendly”
Data Analytics**



A wide-angle photograph of a lush green wheat field stretching to the horizon. The sky is a clear, pale blue. In the distance, a line of trees is visible on the left side of the horizon.

**One absolutely cannot tell, by watching,
the difference between a .300 hitter and a .275 hitter.**

The difference is one hit every two weeks.

- Michael Lewis, Moneyball: The Art of Winning an Unfair Game