Accenture / Fjord Dublin (via teleconference) 29 September 2020

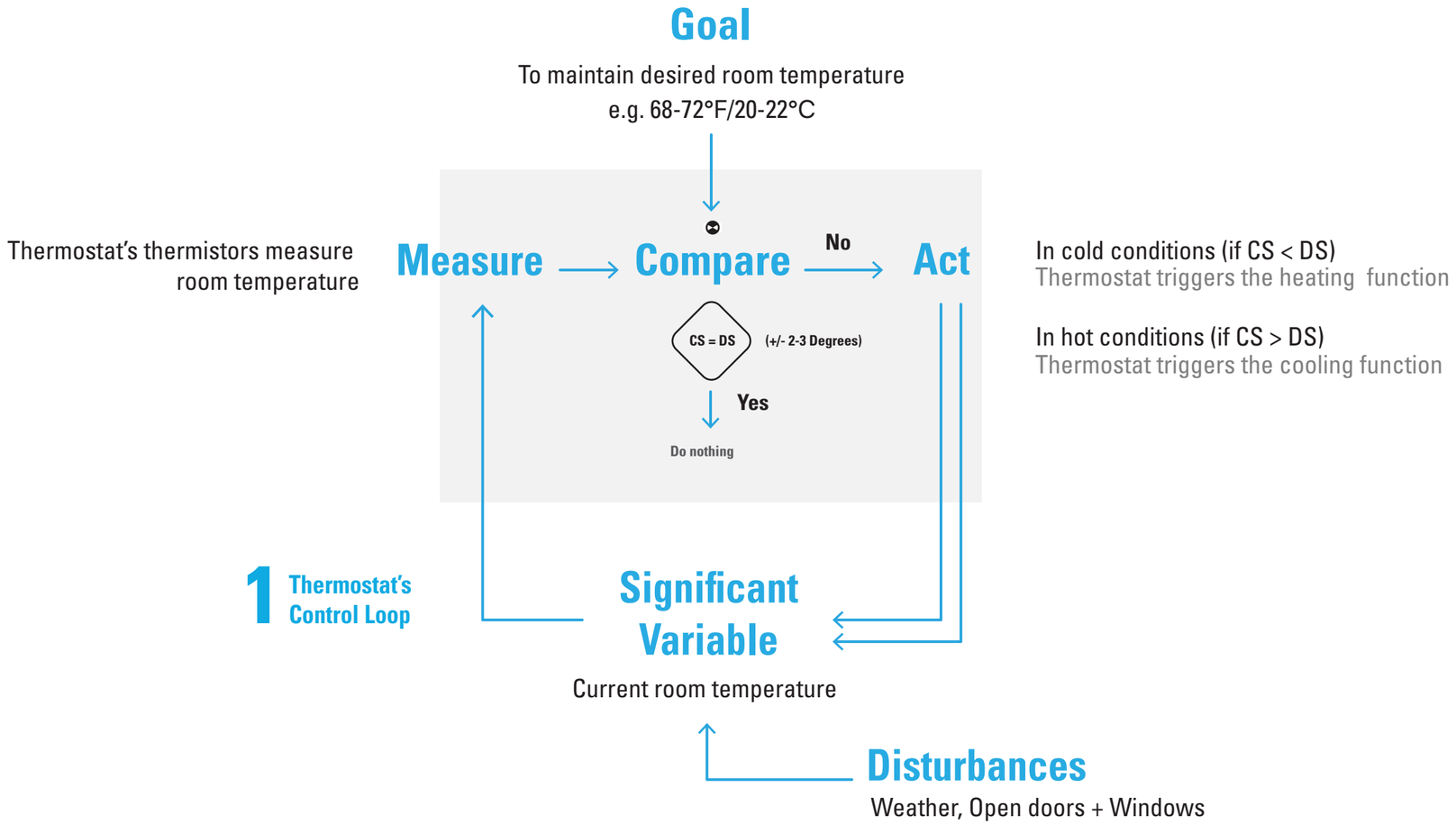
Systems Theory in Design

Third-order Systems + Bootstrapping

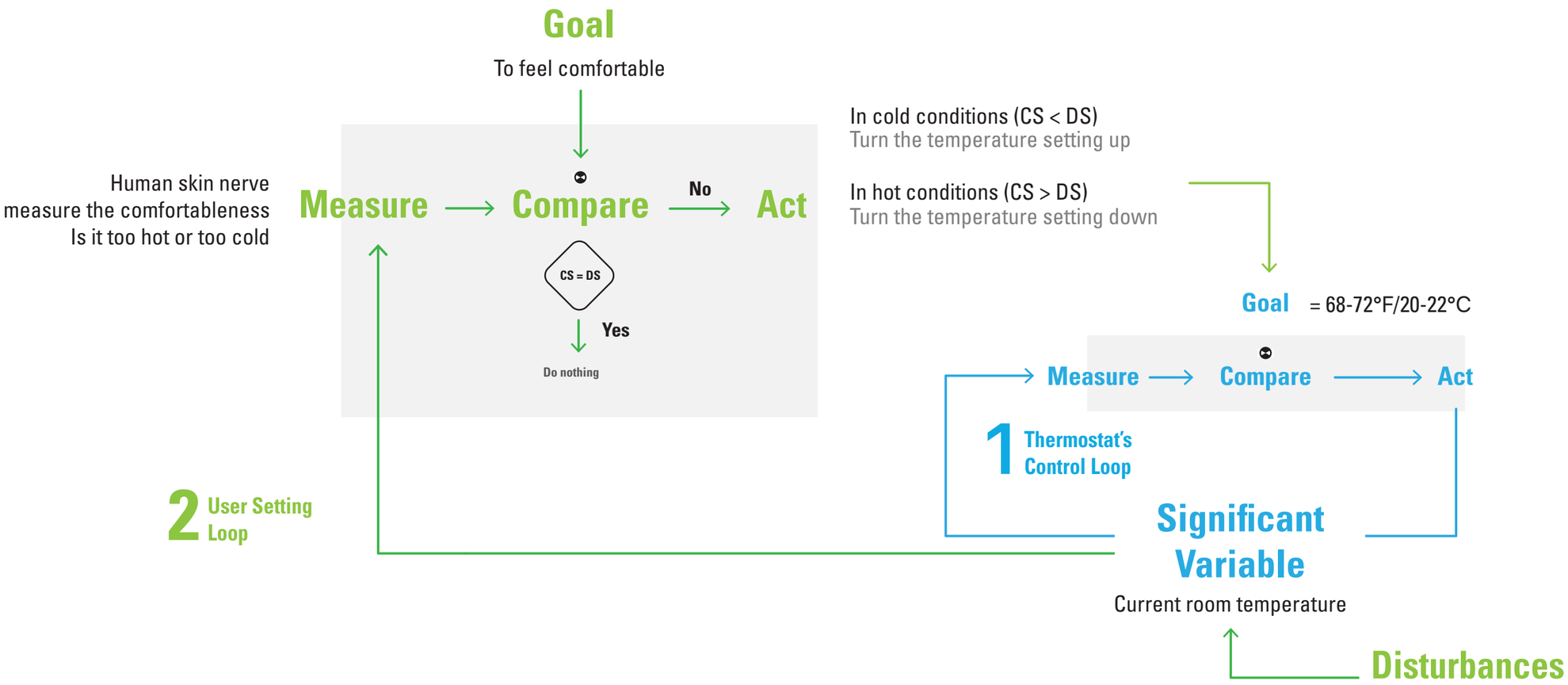
Hugh Dubberly
Dubberly Design Office

More about second-order systems

Revisiting the thermostat example — two first-order loops, one for heating + another for cooling (air conditioning).



A human changes the set-points of the two first-order loops, regulating them according to a higher-order goal of ‘comfort’.

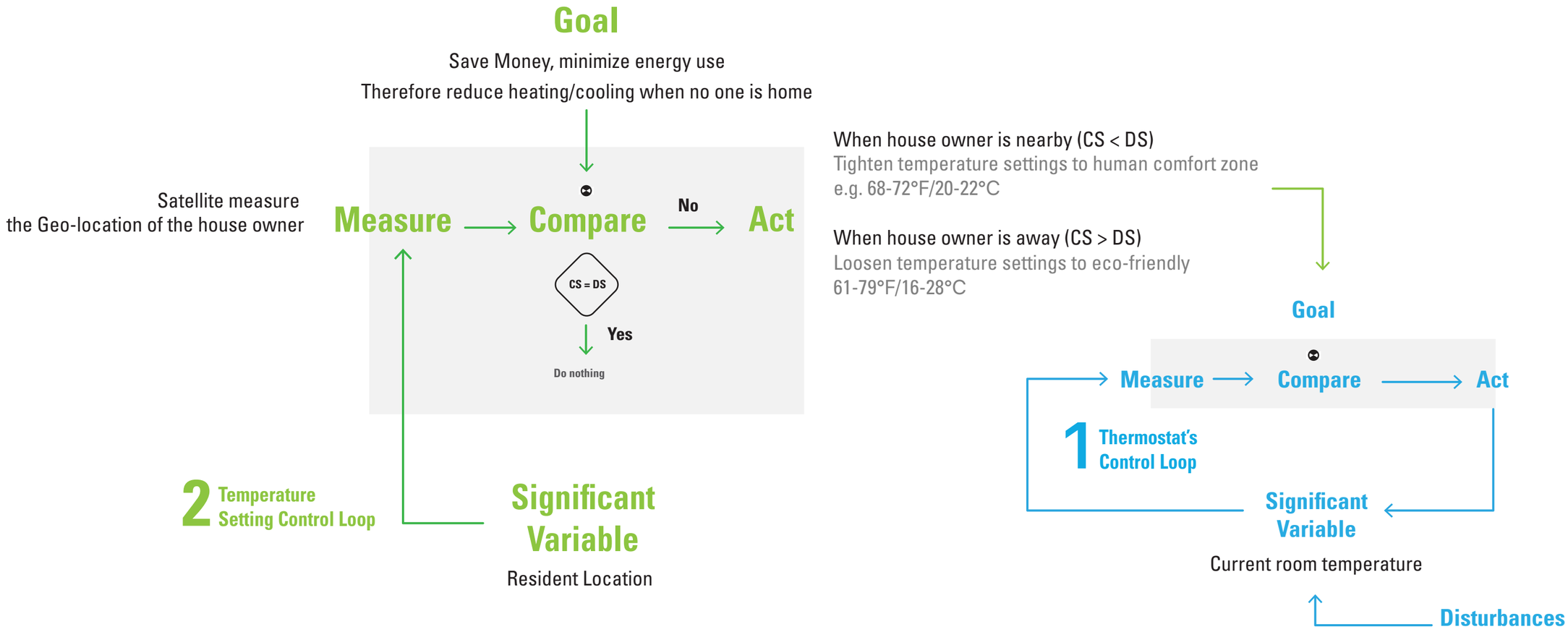


Exercise

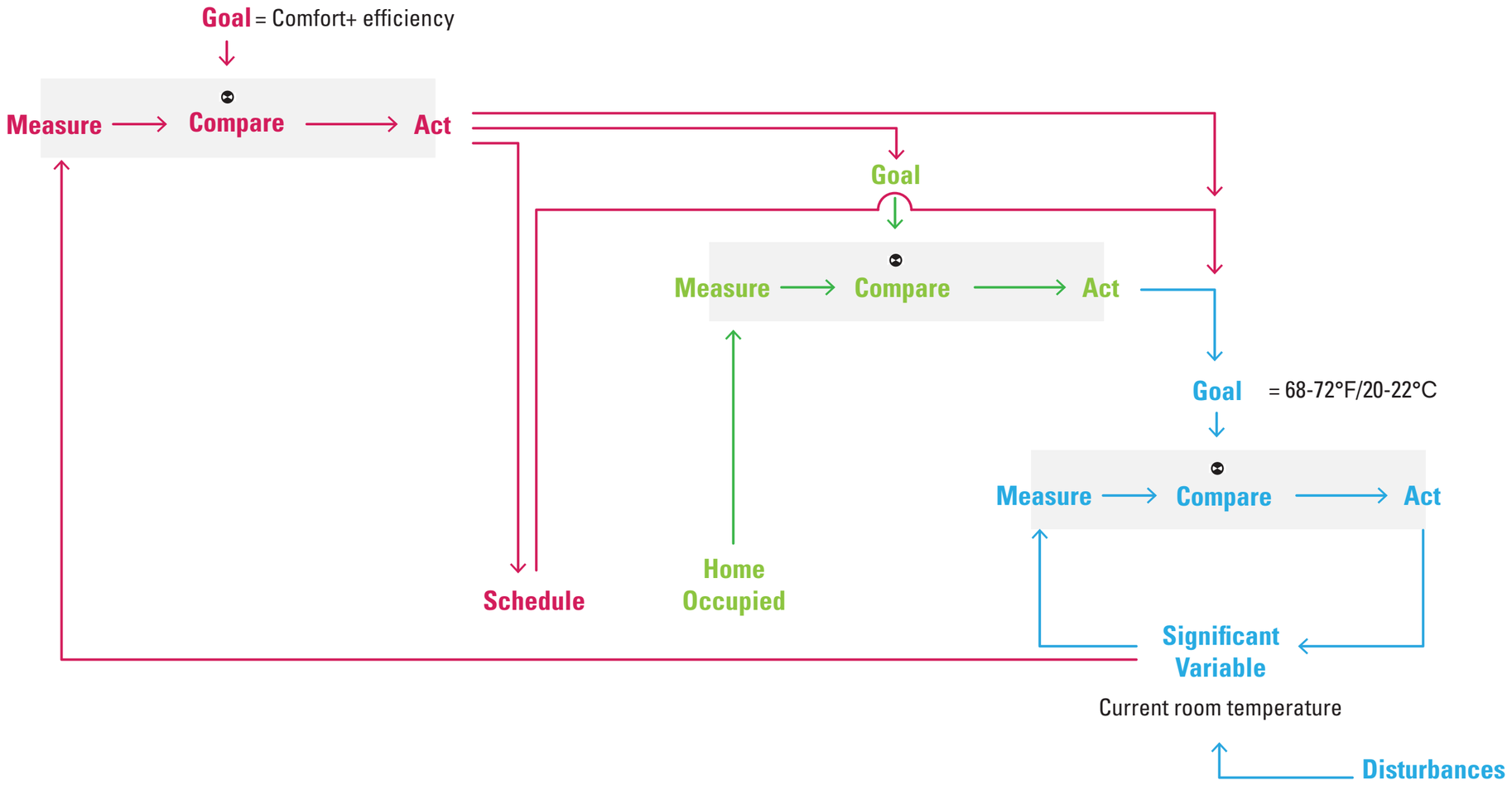
Is that a complete systems model of a ‘smart thermostat’?

What features might it include?
How might you arrange them in a model?

An automatic system might also change the thermostat's set points, based on whether or not the home is occupied.



The human operator might have multiple goals — comfort + efficiency, linked in a complex control system network.



Self-driving:

- cruise control (maintaining speed)
- auto-steering
- auto-piloting (following a route)

Exercise

Make a first-order feedback model for each aspect of self-driving: maintaining speed, maintaining heading, and following a route.

Then add a higher-level function to connect and manage the first-order loops.

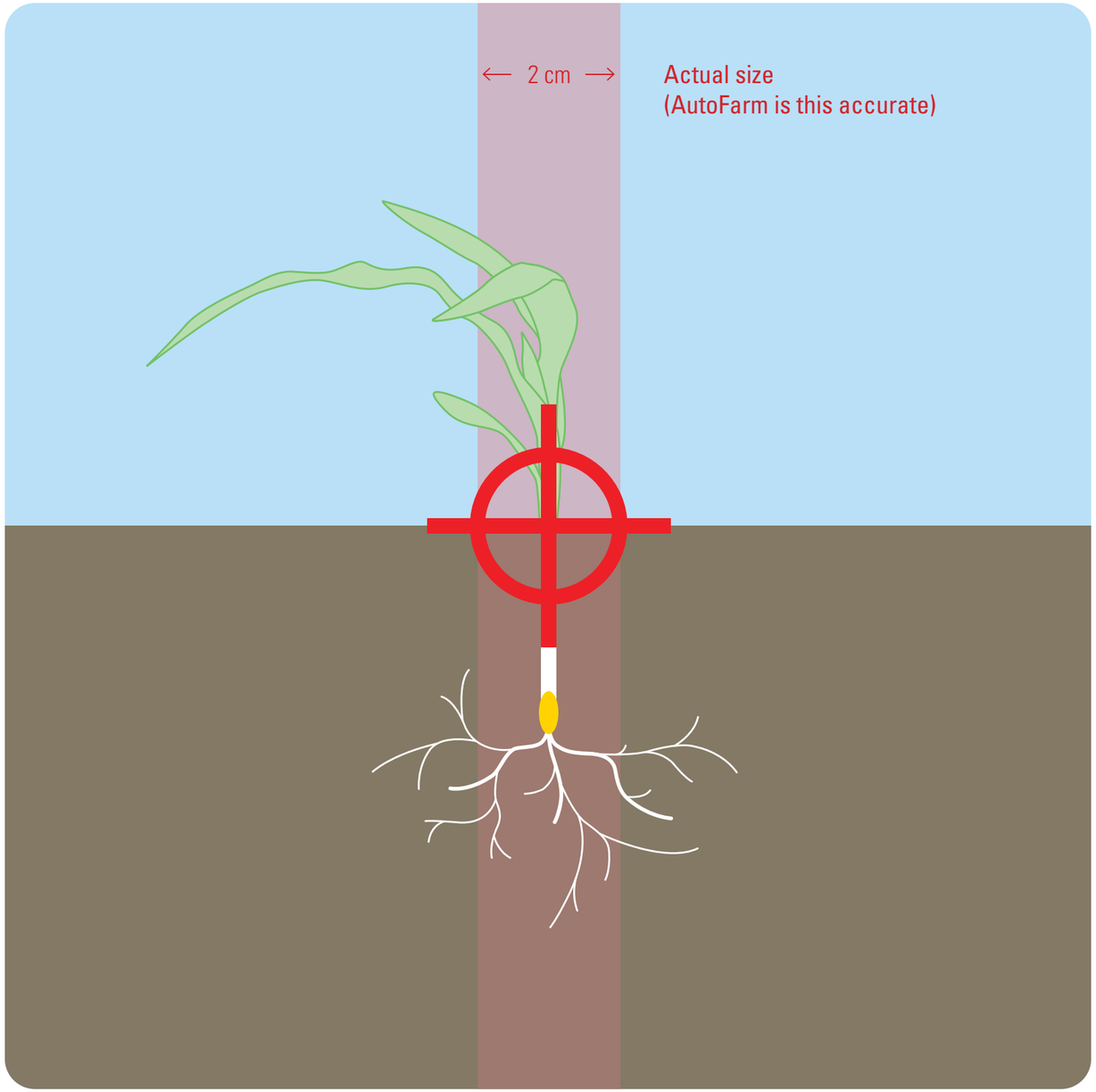
How would this system differ in regulating vacuum cleaners versus cars?

Case study: Precision farming

Steering path | Center line

what we promise above all else:

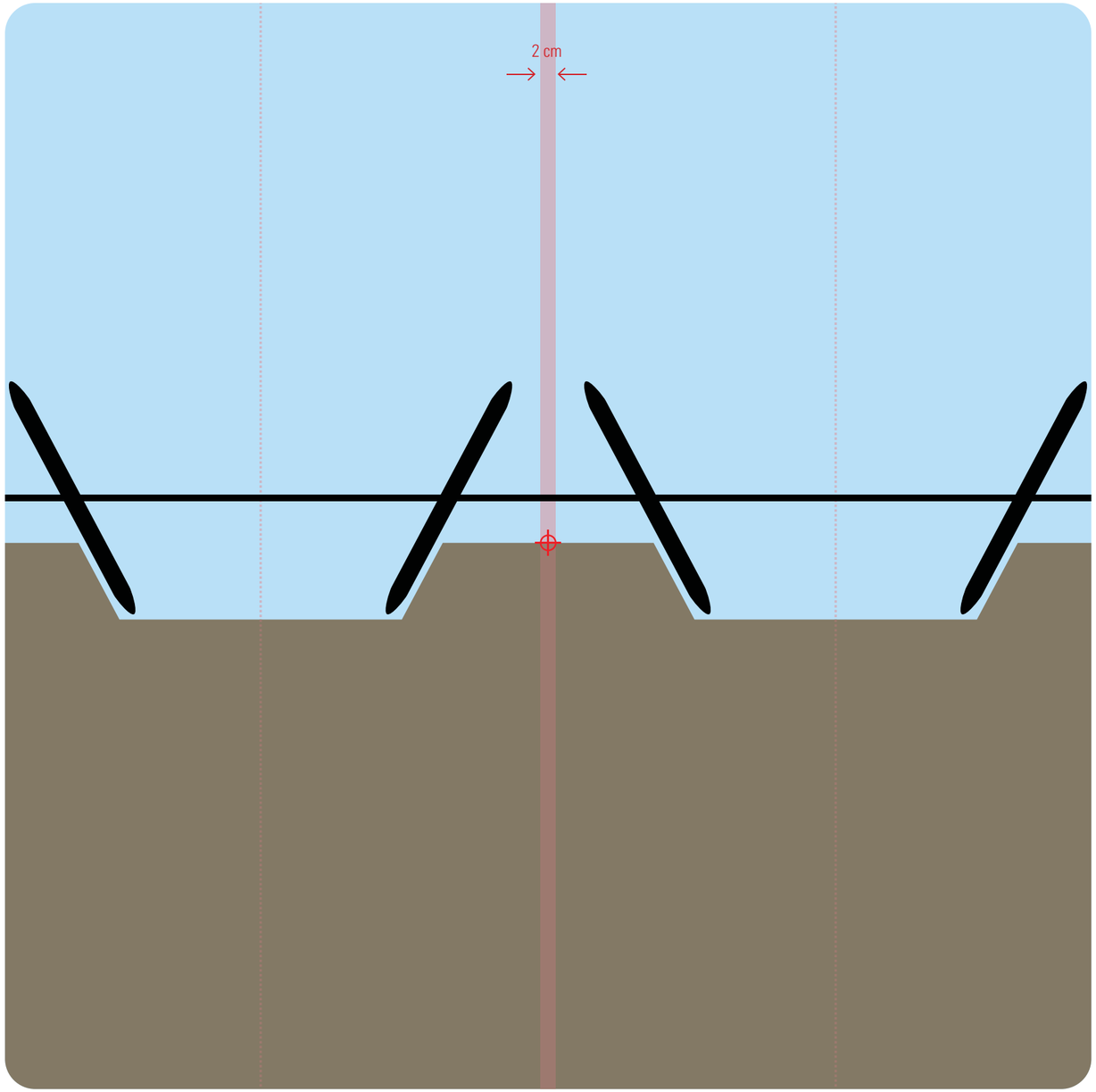
AutoFarm is the leader in precision steering—delivering sub-inch accuracy and repeatability, season after season, in any conditions.



Steering path | Center line

the big idea:

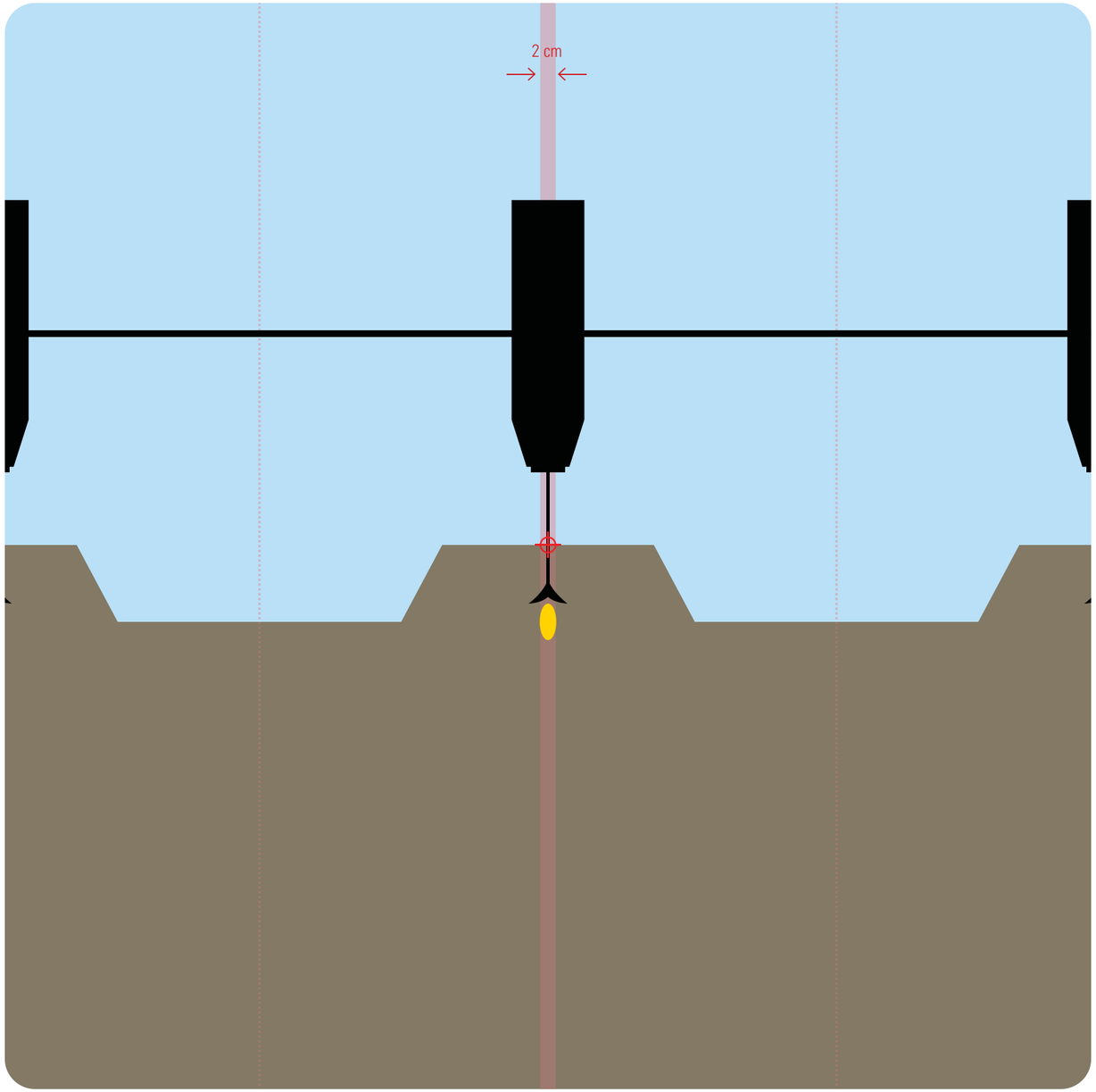
Sub-inch accuracy means being able to put your vehicle exactly where you want it.



Steering path | Center line

why it matters:

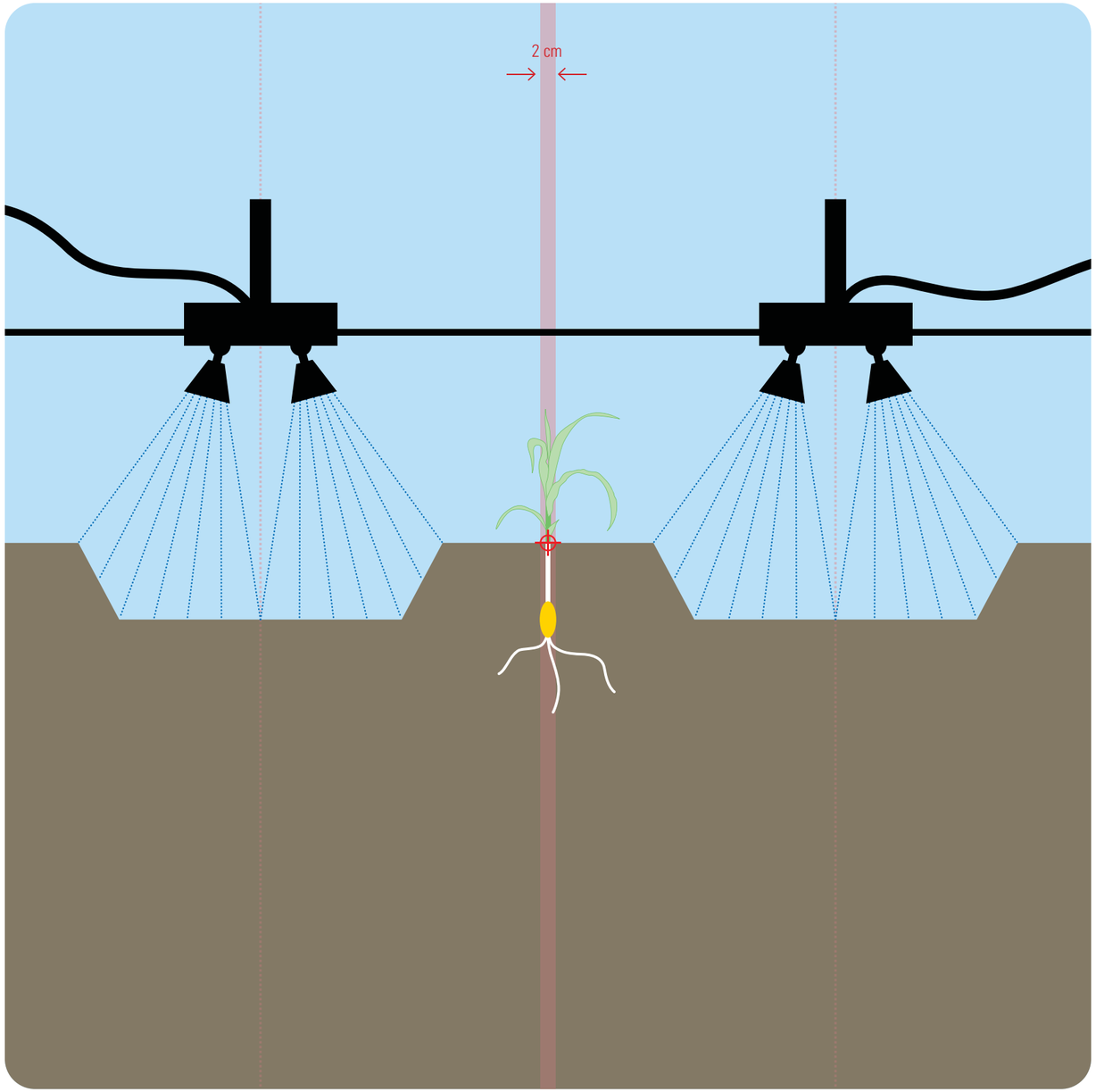
Repeatability means steering the same line for **prepping.**



Steering path | Center line

why it matters:

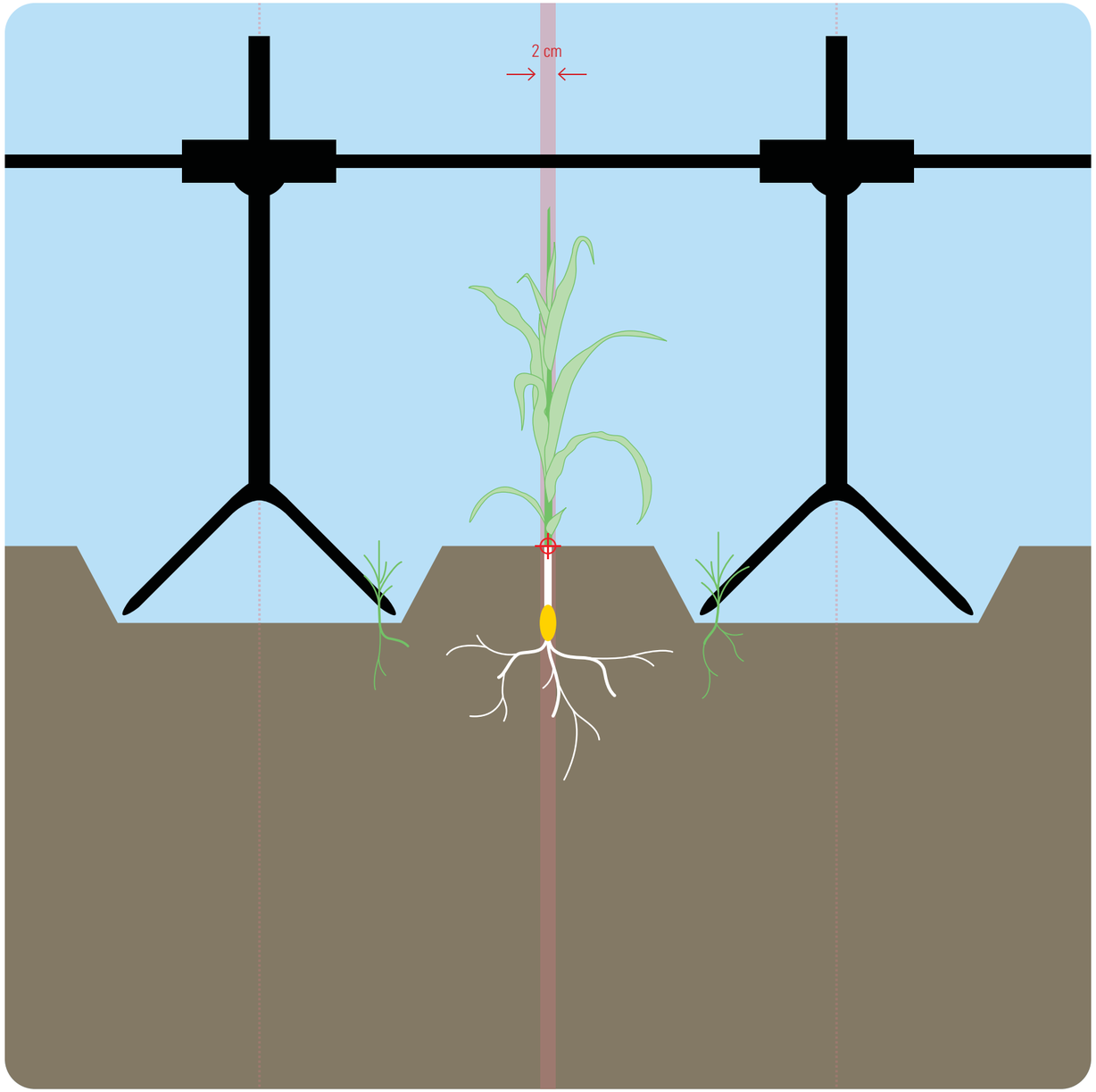
Repeatability means steering the same line for **planting.**



Steering path | Center line

why it matters:

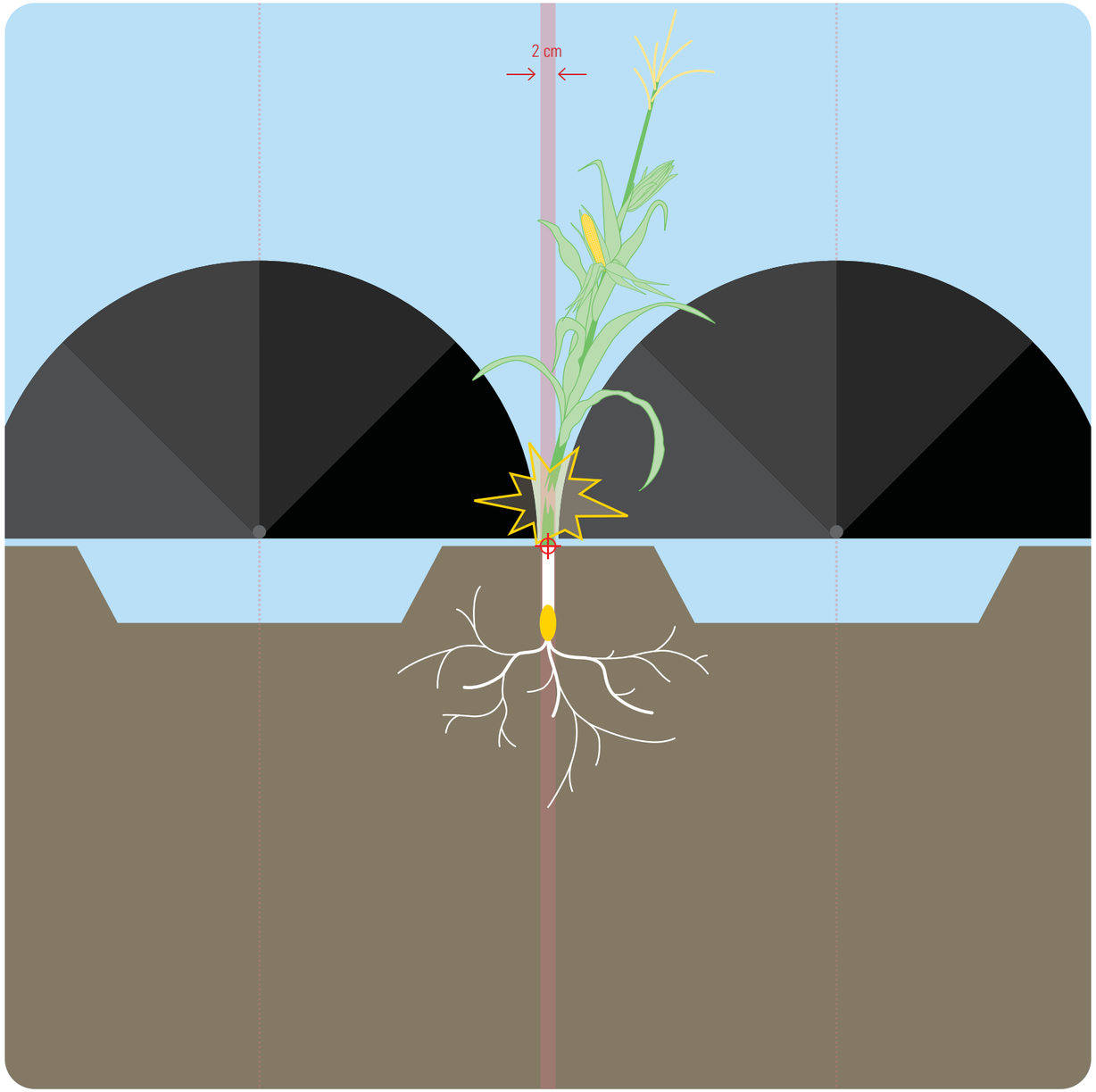
Repeatability means steering the same line for **spraying.**



Steering path | Center line

why it matters:

Repeatability means steering the same line for **cultivating.**



Steering path | Center line

why it matters:

Repeatability means steering the same line for **harvesting.**

Growers face a variety of challenges in the field.

Poor visibility
AutoFarm allows the grower to operate even when trash obscures the path.

Fog or dust
AutoFarm allows for operation during foggy and windy conditions.

Operating longer hours during peak seasons
AutoFarm minimizes fatigue and enables night time operation.

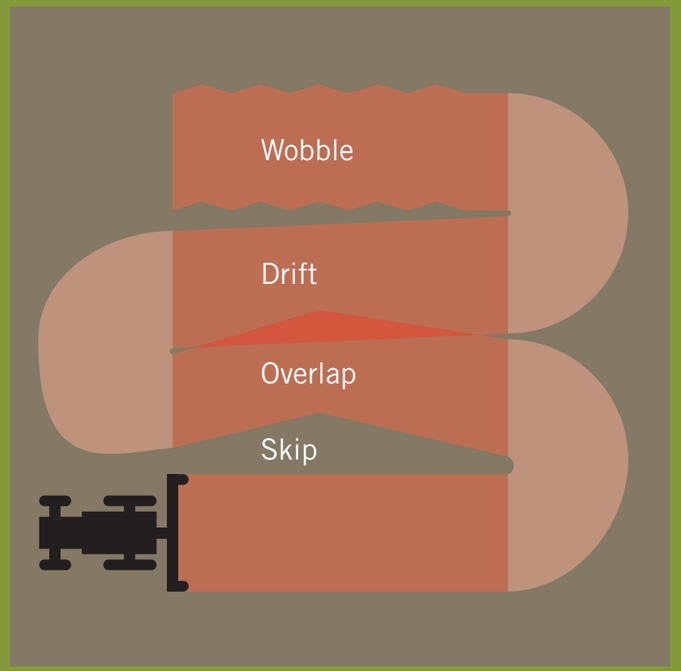
Mechanical blight
AutoFarm virtually eliminates accidental damage to crops.

Taking advantage of new cultural practices
AutoFarm makes strip tillage easy.

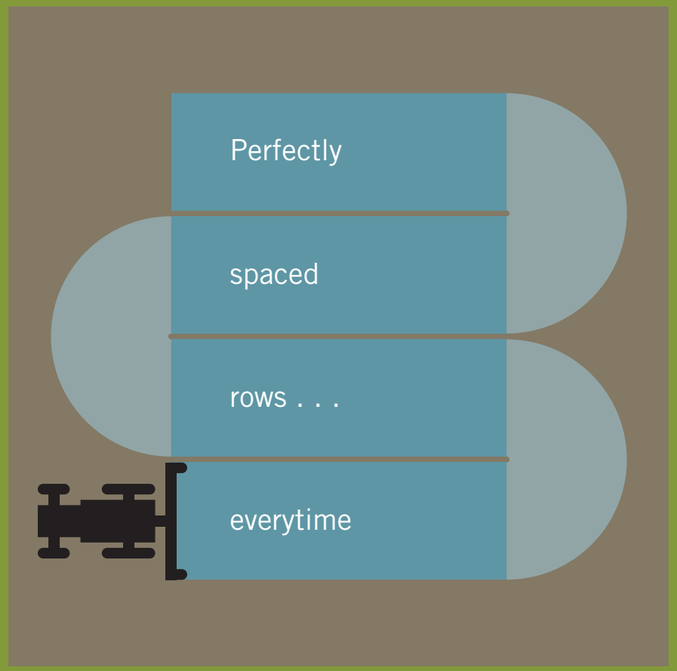
Planting on hillsides
AutoFarm controls for crabbing so growers can achieve repeatability on hillsides as easily as on flat fields.

Field work—the RTK difference

without RTK



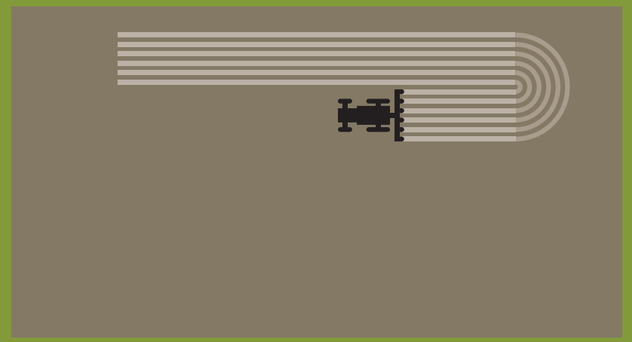
with RTK

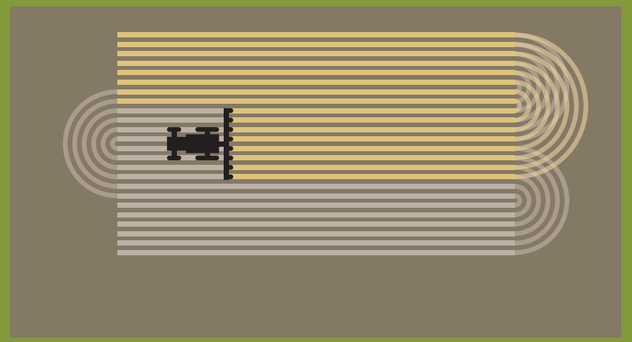


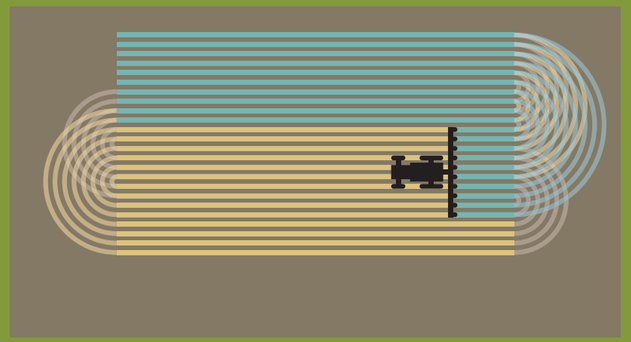
Greater accuracy and consistency in passes result in more efficient use of field space—and in improved yields.

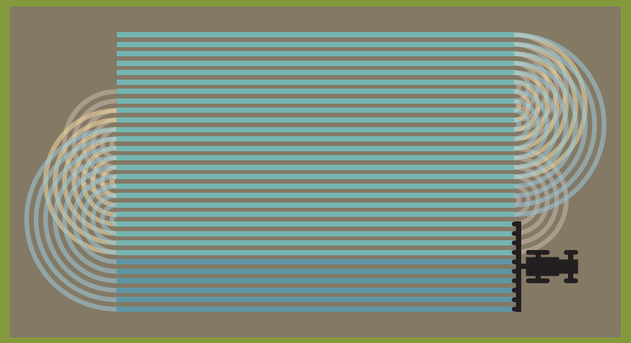
Repeatability means being able to use implements of different widths in the same field.

Growers can use their existing equipment to perform a variety of functions—season after season—and save thousands of dollars.









6-row planter (first cycle)

With RTK, growers can create a perfect guess row between passes, with no wobbles or drifts.

8-row cultivator (second cycle)

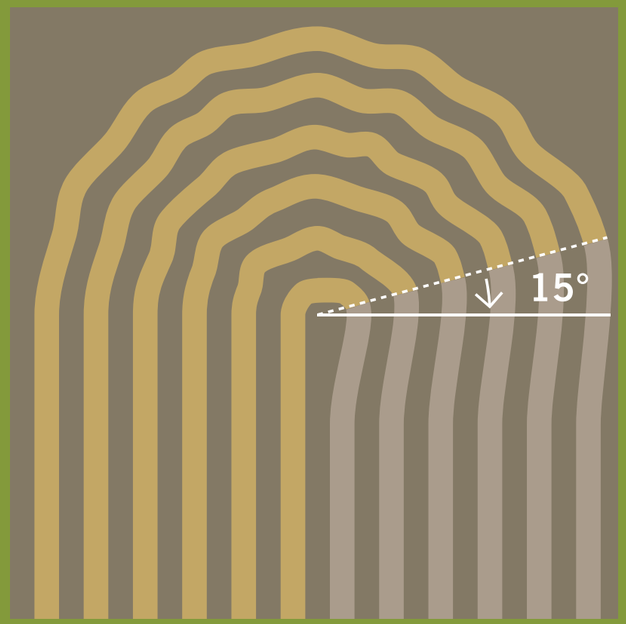
Since the guess row and subsequent rows are perfectly spaced, the grower can use a different implement and row set during the second cycle—and match the rows perfectly again.

10-row sprayer (third cycle)

Since the guess row and subsequent rows are perfectly spaced, the grower can use a different implement and row set during the third cycle—and match the rows perfectly again.

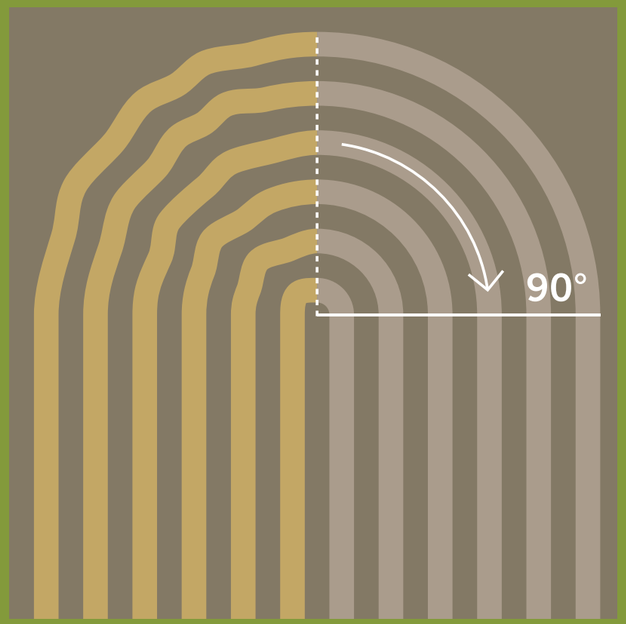
Acquire the steering path center line more quickly

The competition



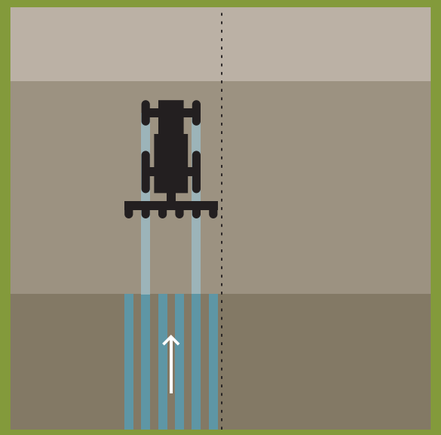
Requires manual steering to within 15º of the line
With competitive systems, the driver must steer much closer to the line; that leaves the system little time to correct for driver error and may result in misaligned areas as the system requires up to a tractor length to recover and find the line.

AutoFarm

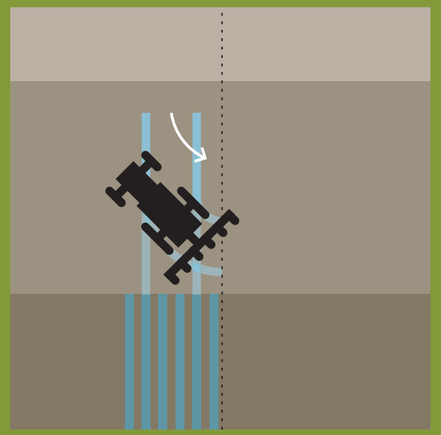


Requires manual steering to within 90º of the line
With AutoFarm, the driver can rely on AutoSteer much sooner; that leaves the system enough time to correct for driver error and avoids misaligned areas.

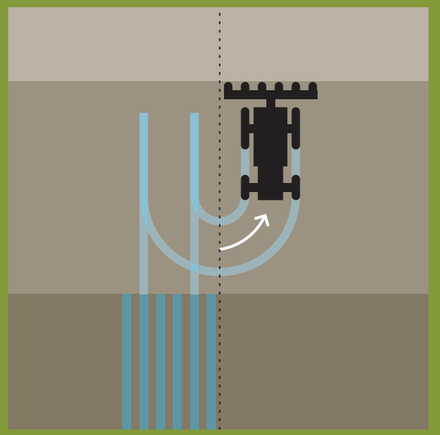
Only AutoFarm can acquire the steering path center line while in reverse



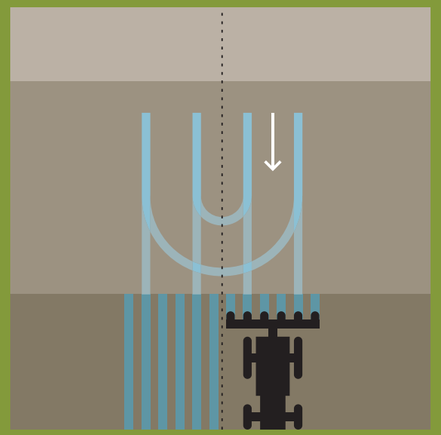
1) Drive to boundary



2) Lift implement



3) Acquire line in reverse and at slow speed

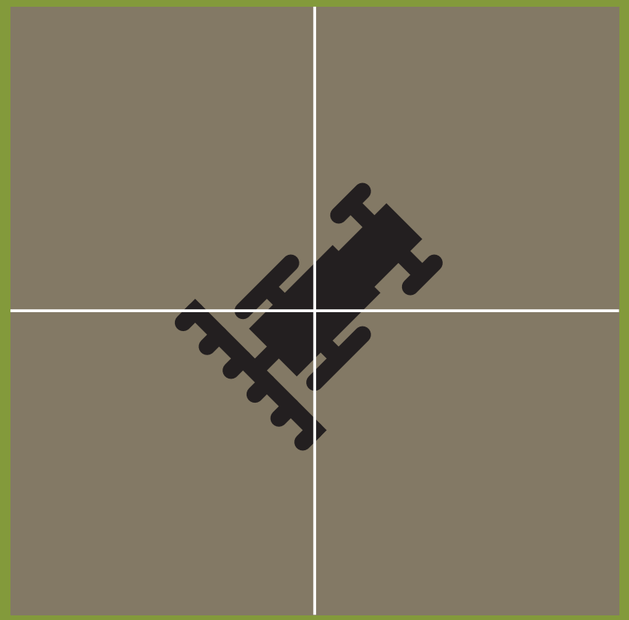


4) Lower implement and continue

When working close to a boundary—such as a wall, road or stream—AutoFarm helps the growers maximize field use because it enables them to acquire the steering path center line in reverse.

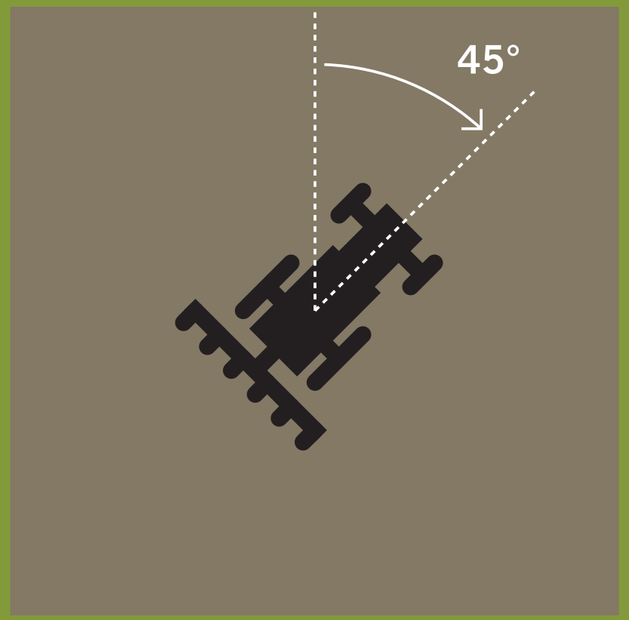
AutoFarm tracks position, orientation, and heading

Position



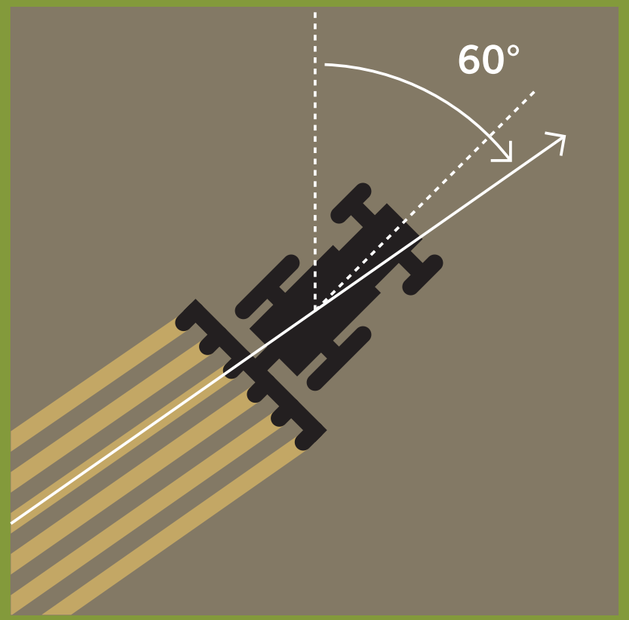
AutoFarm tracks exactly where your vehicle is with an accuracy of 2 cm.

Orientation



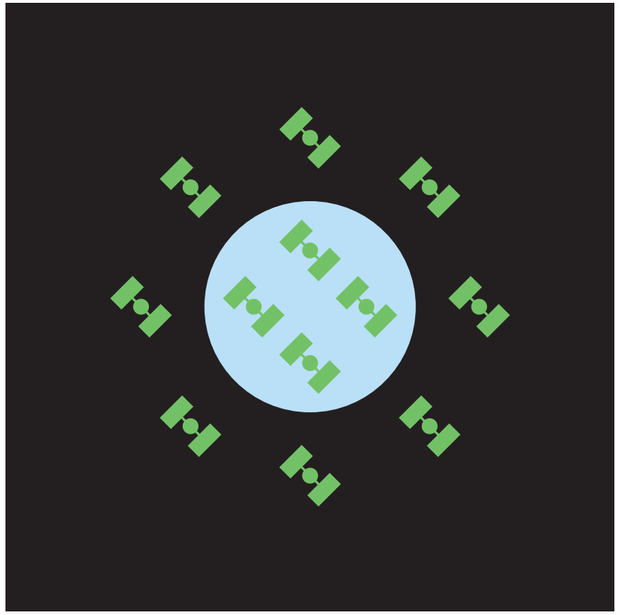
AutoFarm also tracks your vehicle's orientation, the direction in which it's pointed.

Heading

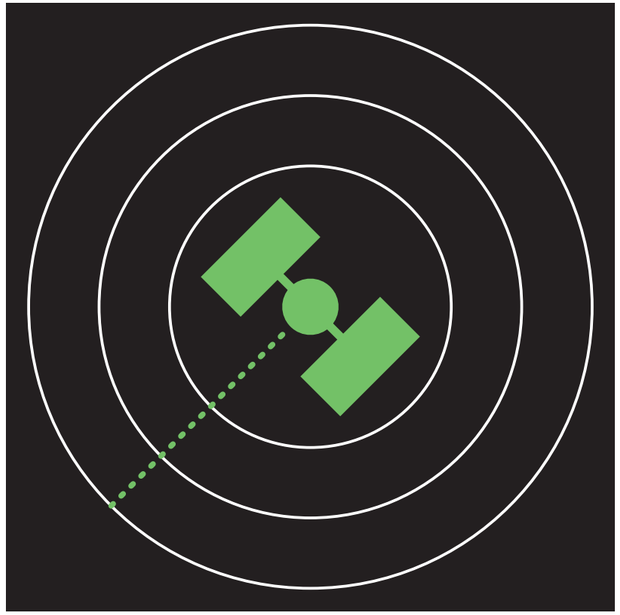


Separately, AutoFarm tracks your vehicle's heading, the direction in which it's travelling. If the heading is not the same as orientation, crabbing is occurring (sliding sideways), and AutoFarm can compensate.

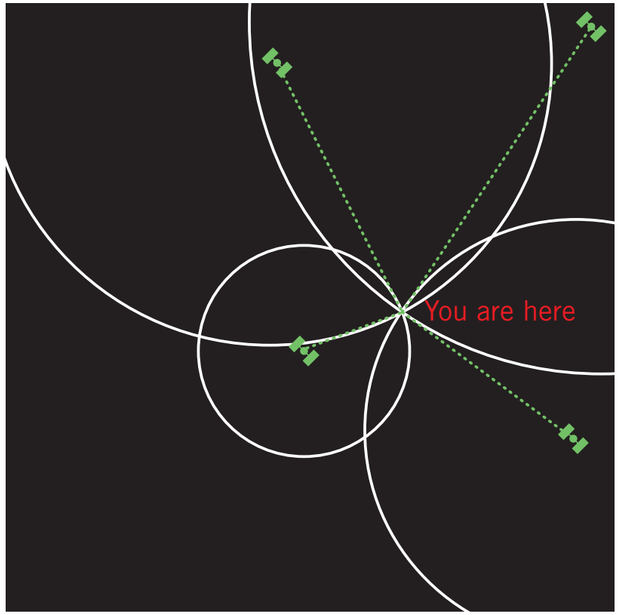
How GPS works



The US government maintains a system of 24 GPS satellites circling the earth. Each satellite has an incredibly precise clock on board.

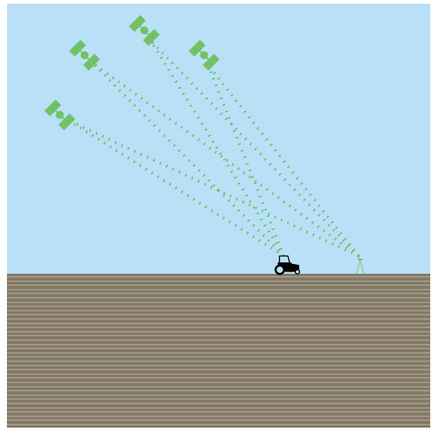


The satellite uses its clock to generate a radio signal. The signals travel out from the satellite in an expanding sphere. You can calculate how far you are from the satellite by measuring how long the signal took to arrive.



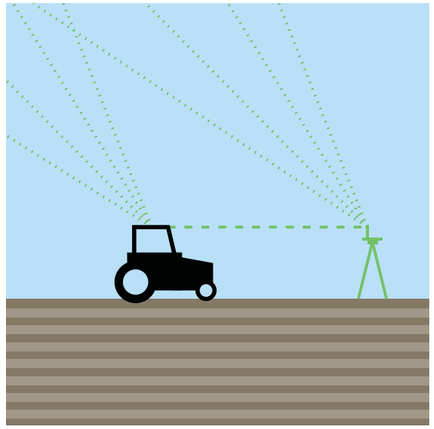
You can determine your location by calculating the intersection of the signals from the four satellites—the intersection of four spheres.

How RTK makes GPS sub-inch accurate



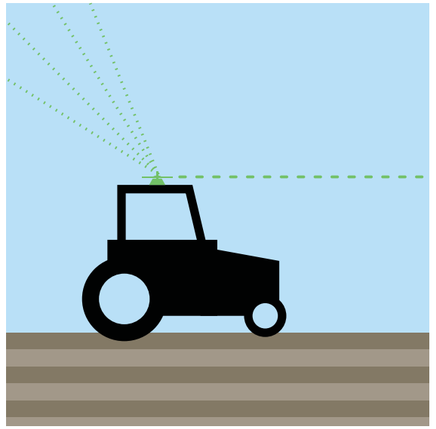
RTK begins with GPS satellite signals

GPS satellites send signals to the antenna on the vehicle and to the base station. (See the previous page for more details on GPS.) Changes in the density of the atmosphere can slow the satellite signals and introduce an error in basic GPS.



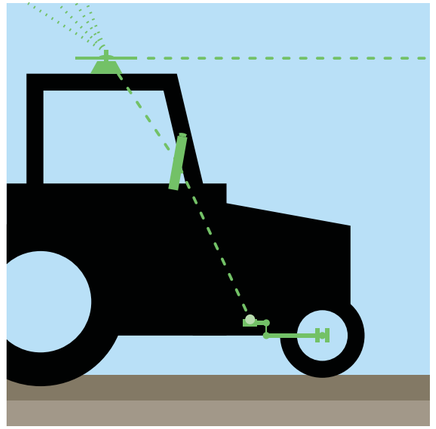
The base station provides correcting signals

RTK corrects for errors in basic GPS by introducing a known reference point—the base station. The base station calculates the shifting error in the satellite signal and sends a second signal to the vehicle to constantly correct for the satellite signal error.



Multiple antennas measure position and orientation

AutoFarm AutoSteer includes multiple roof antennas to measure both position and orientation.



The wheel angle controller and sensor insure precise steering

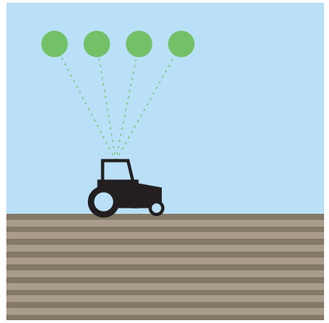
The system sends signals telling the wheel angle controller how much to turn the wheels to stay on course. AutoSteer includes a special wheel angle sensor to insure the wheels turn as directed.

Inside the cab, the operator can use the touch screen to monitor the system and to make any necessary minute changes.

Quick comparison:

GPS

Using GPS satellites only.
(10 meter accuracy)

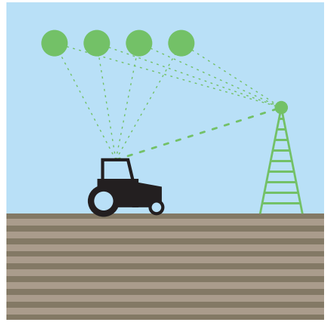


DGPS

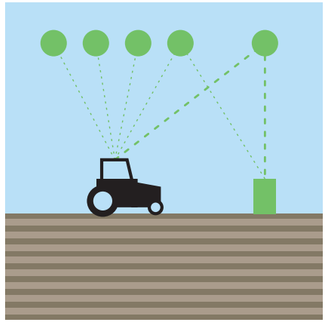
GPS satellites plus local area reference stations,
e.g., Coast Guard (coverage limited).
(25 centimeter accuracy, pass-to-pass)

or

GPS satellites plus wide area reference satellite correction,
e.g., OmniSTAR, StarFire, WAAS (fees average about $1000 per year & coverage is not available everywhere).
(8 centimeter accuracy, pass-to-pass)



or



Ground based reference station

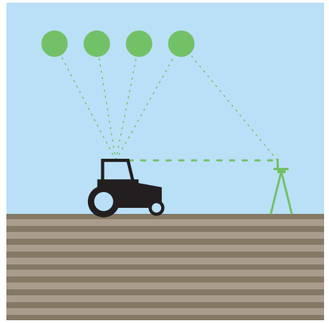
May be 200 miles away or more.
These satellites don't provide complete worldwide coverage.

RTK GPS

GPS satellites plus base station.
(2 centimeter accuracy, both pass-to-pass and with true repeatability)

or

In many places, distributors are setting up networks of RTK base station.



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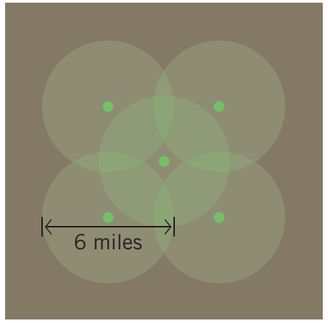
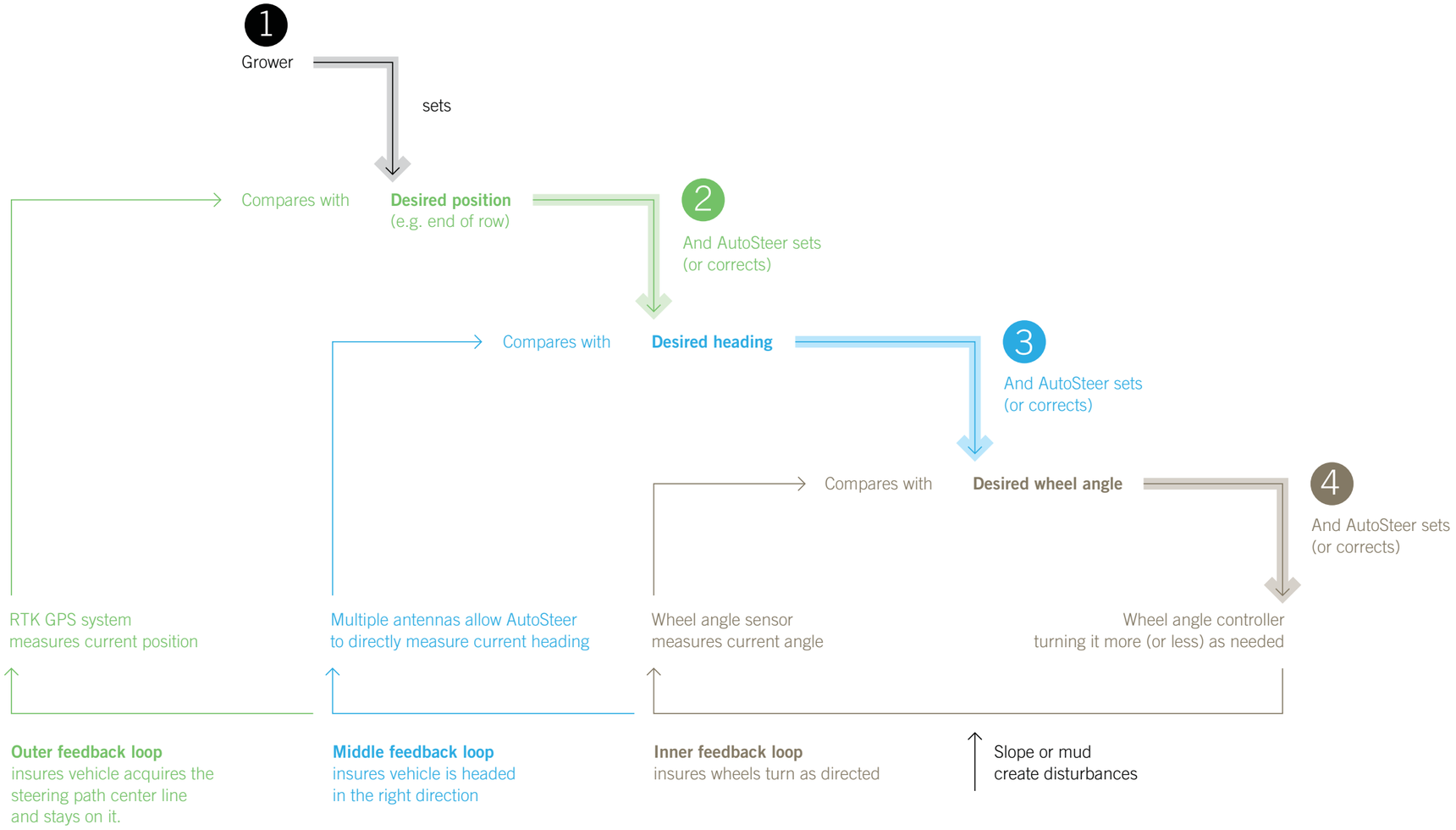
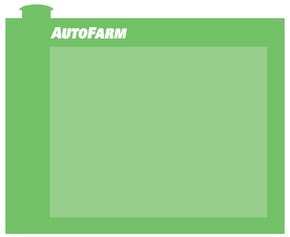
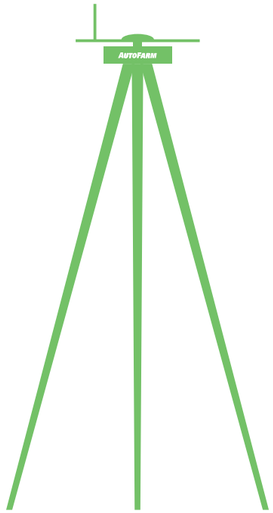


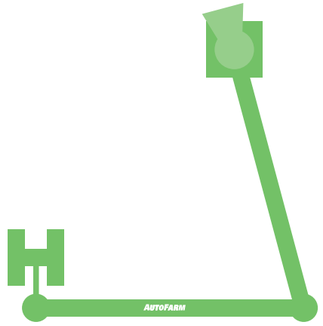
How precision steering correct mistakes almost before they happen



Components of AutoSteer







Roof module (multi-antenna)

AutoFarm's patented roof module is unique to the AutoSteer system, and features multiple GPS antennas that deliver virtual information to the control system to correct for roll, pitch and yaw. The roof module releases quickly and is easily transferred between vehicles without the use of tools.

Touchscreen terminal

The large 10.4" color touchscreen terminal is designed for all-weather use and has a high-contrast screen that is easily readable in direct sunlight and easy on the eyes. It's as easy to use an ATM.

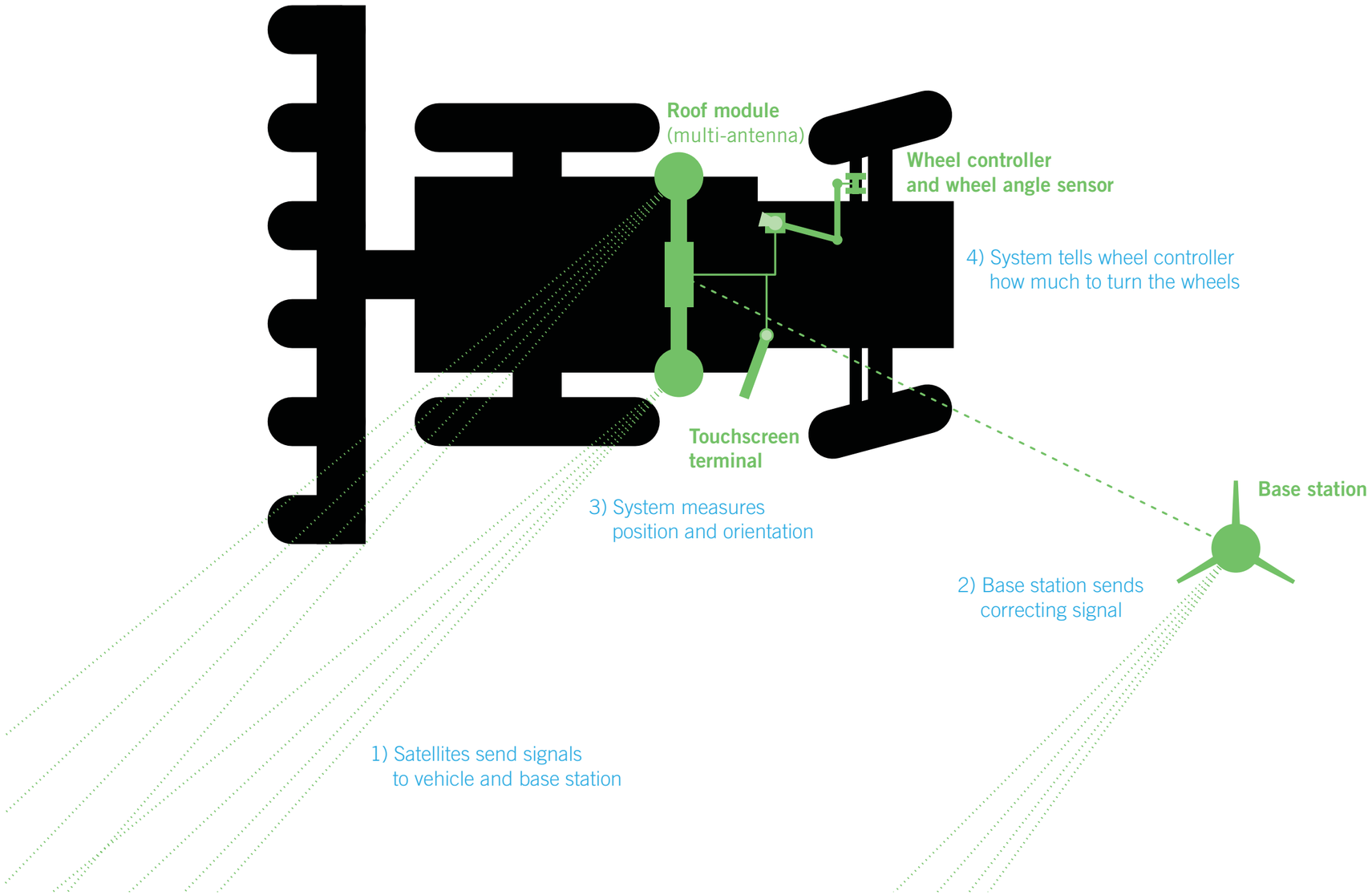
Base station

The foundation of RTK accuracy across all brands and types of equipment, a single base station can control multiple vehicles simultaneously. Available in two convenient configurations: portable for fast, easy set-up or tower-mounted for extended range.

Wheel controller and wheel angle sensor

AutoSteer includes a wheel angle controller to turn the wheels and steer the vehicle. Unlike competitors, Autosteer also includes a wheel angle sensor to measure how far the wheels have actually turned—since different terrain, such as mud, may require more or less pressure to turn the wheel the right amount.

How the components work together



Boot strapping

“The better we get at getting better

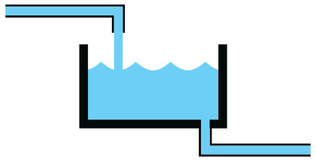
the faster we will get better.”

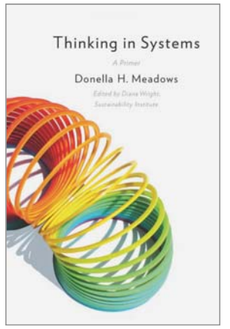
— Douglas Engelbart

Doug Engelbart coined the term ‘bootstrapping’ to describe how whoever is working on developing and/or deploying new/improved tools and practices for boosting Collective IQ could use what they build to boost their own effectiveness.

Three systems ideas you can use tomorrow morning—
in your life, on the job, and in your community.

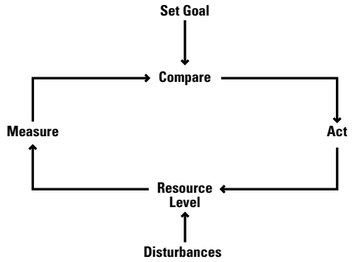
Dynamic equilibrium





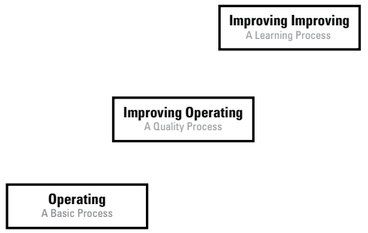
Thinking in Systems
Donella Meadows

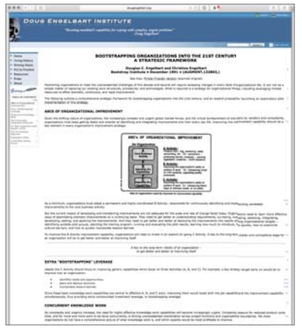
Self regulation



An Introduction to Cybernetics
Ross Ashby

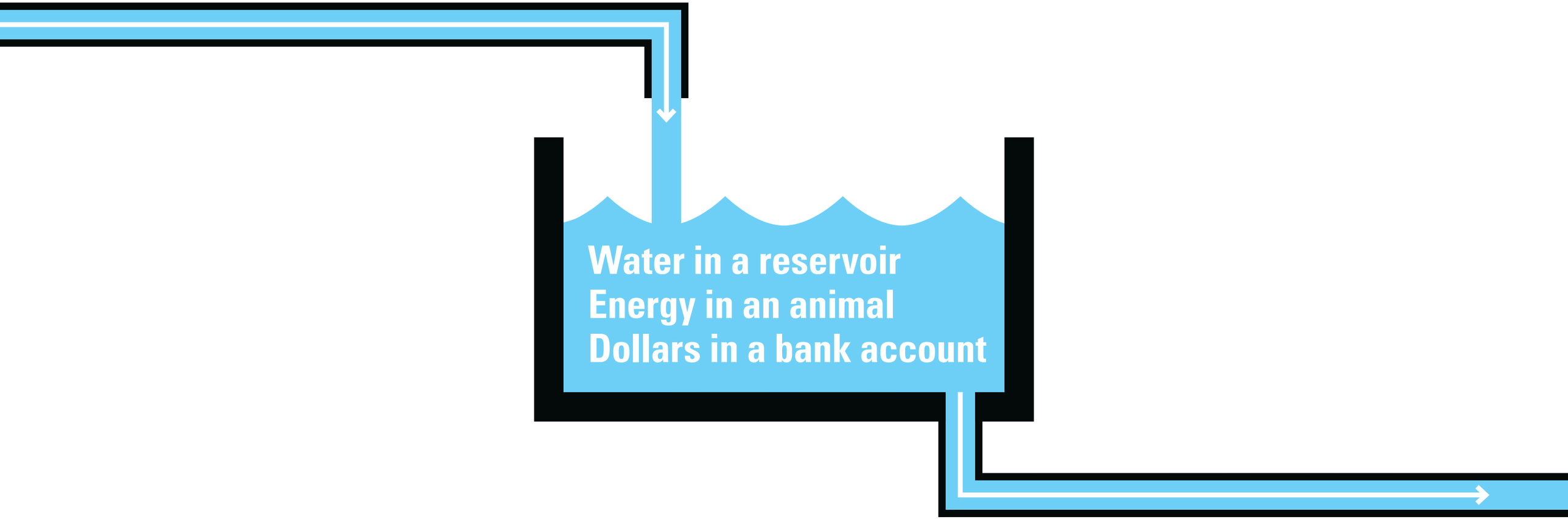
Boot-strapping



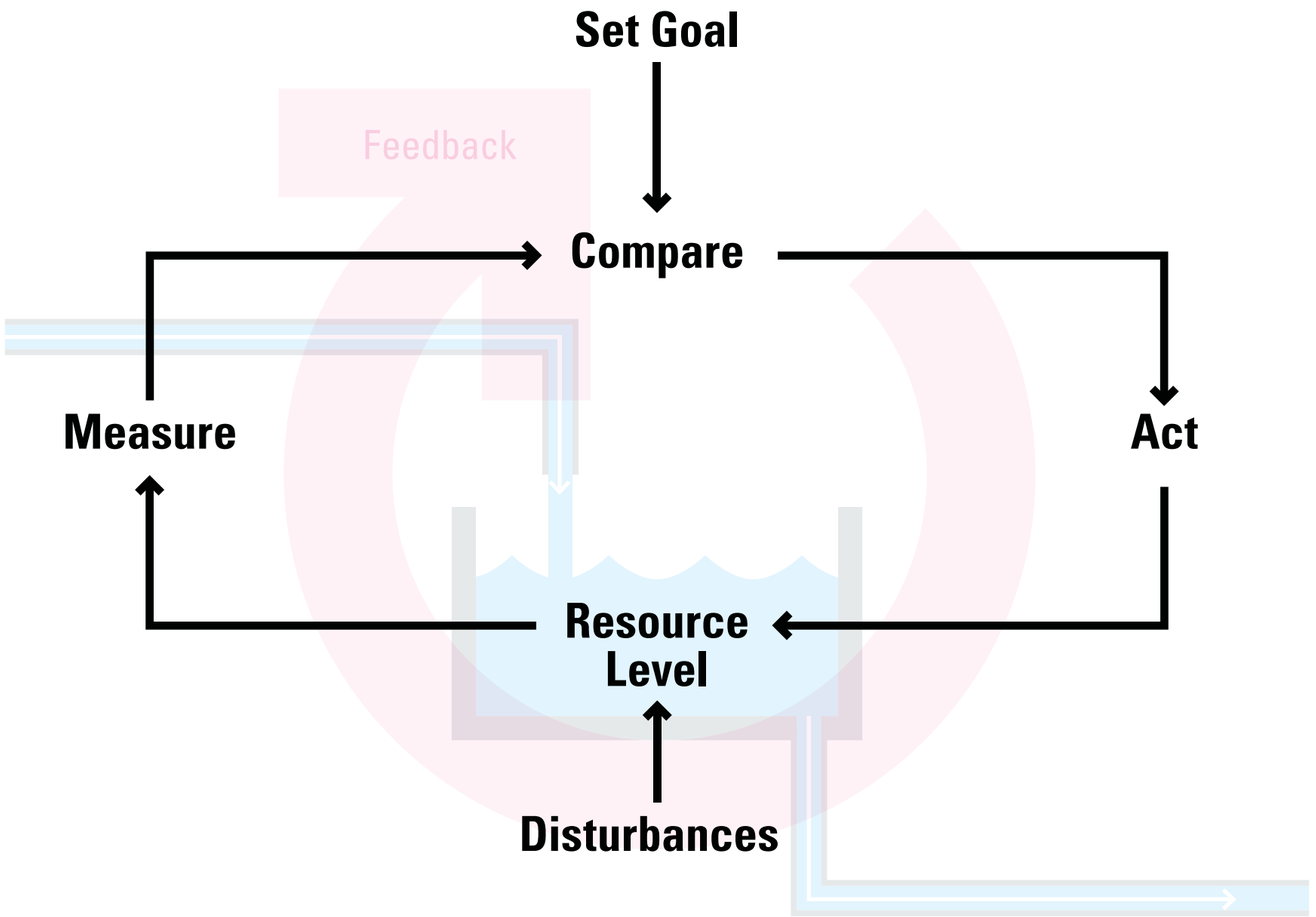


Bootstrapping Organizations into the 21st Century
Douglas Engelbart

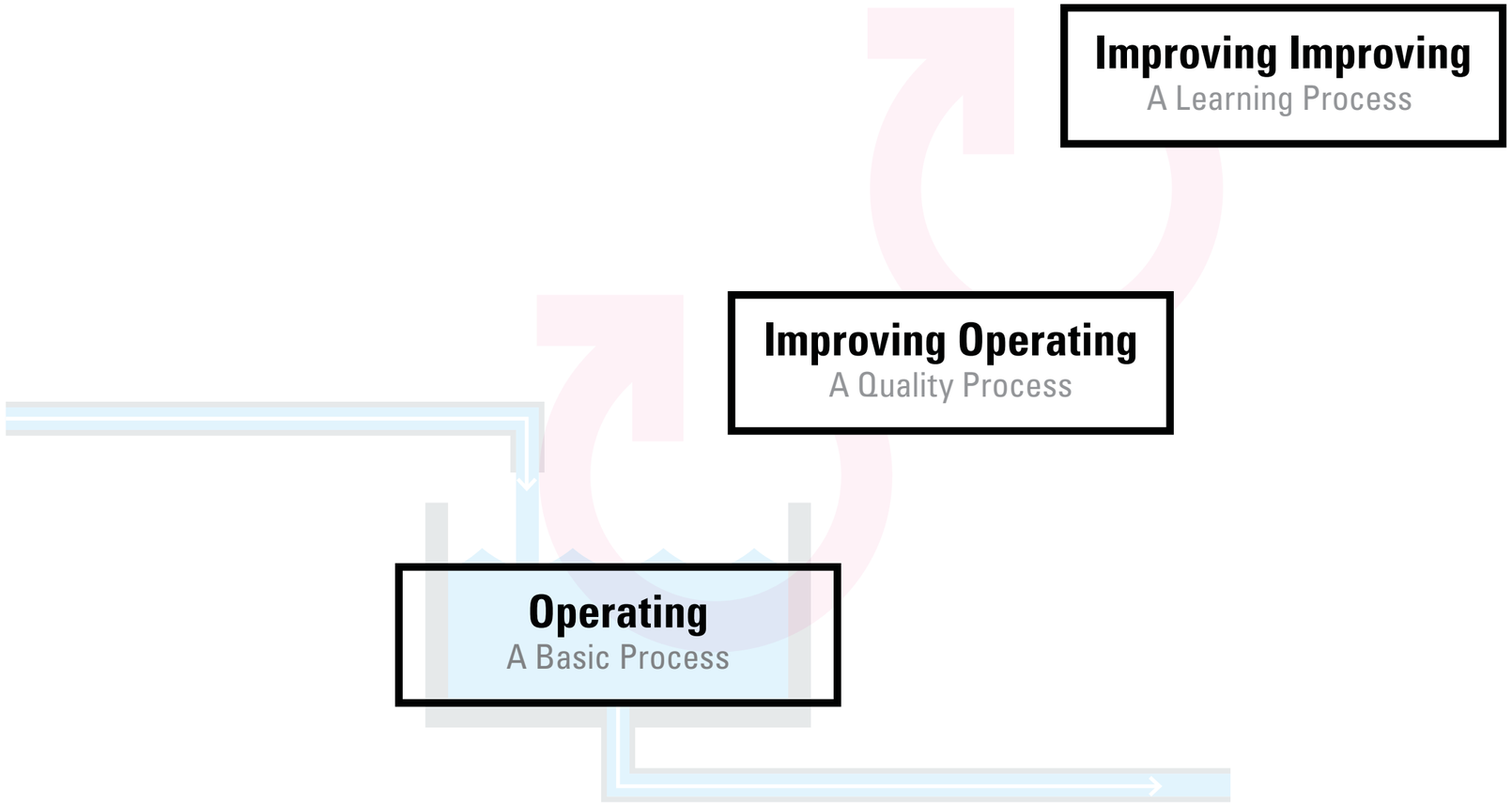
Dynamic equilibrium is a state of balance—
a resource that stays at the same level
even as it flows through a system.



Self regulation is a process of maintaining balance—
using feedback to control the resource level,
e.g., governing how much flows in or out.

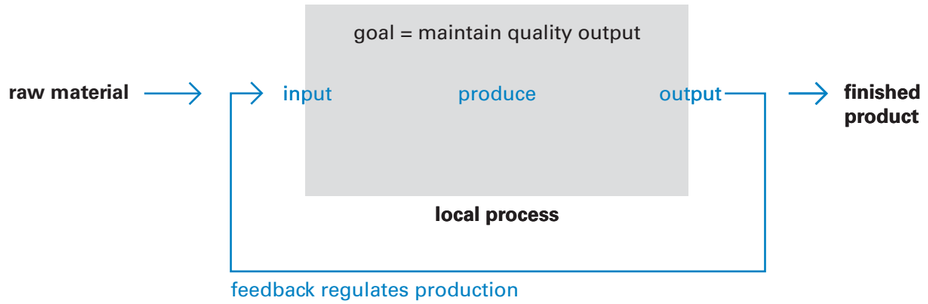


Boot-strapping is a process of self-improvement—
studying a basic process to improve it
and in turn studying the improvement process to improve it.

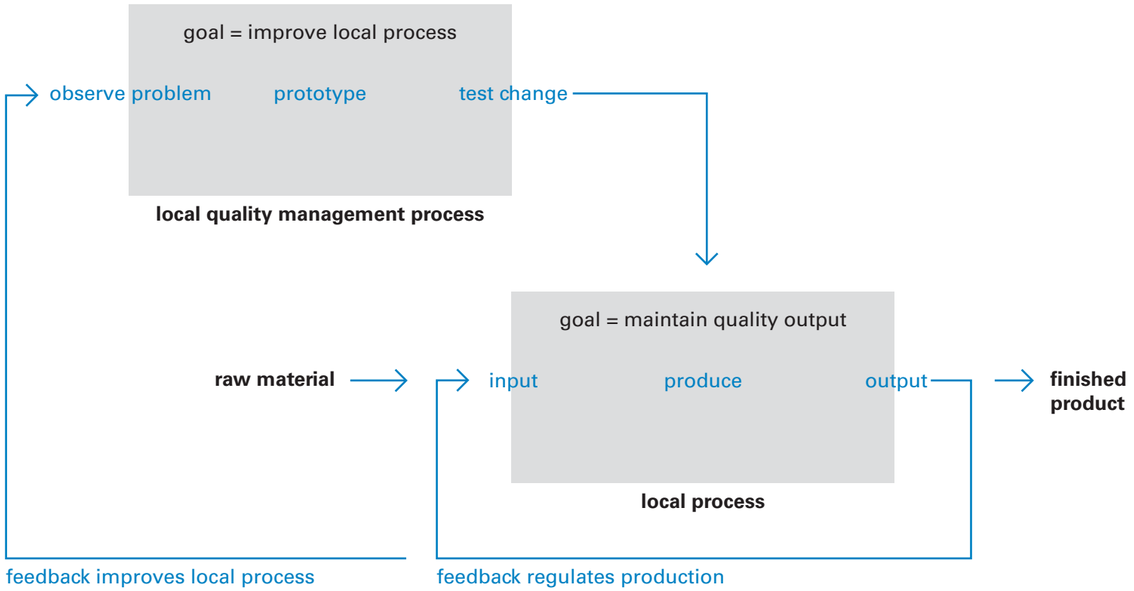


Let's look at bootstrapping more formally, beginning with a simple process.

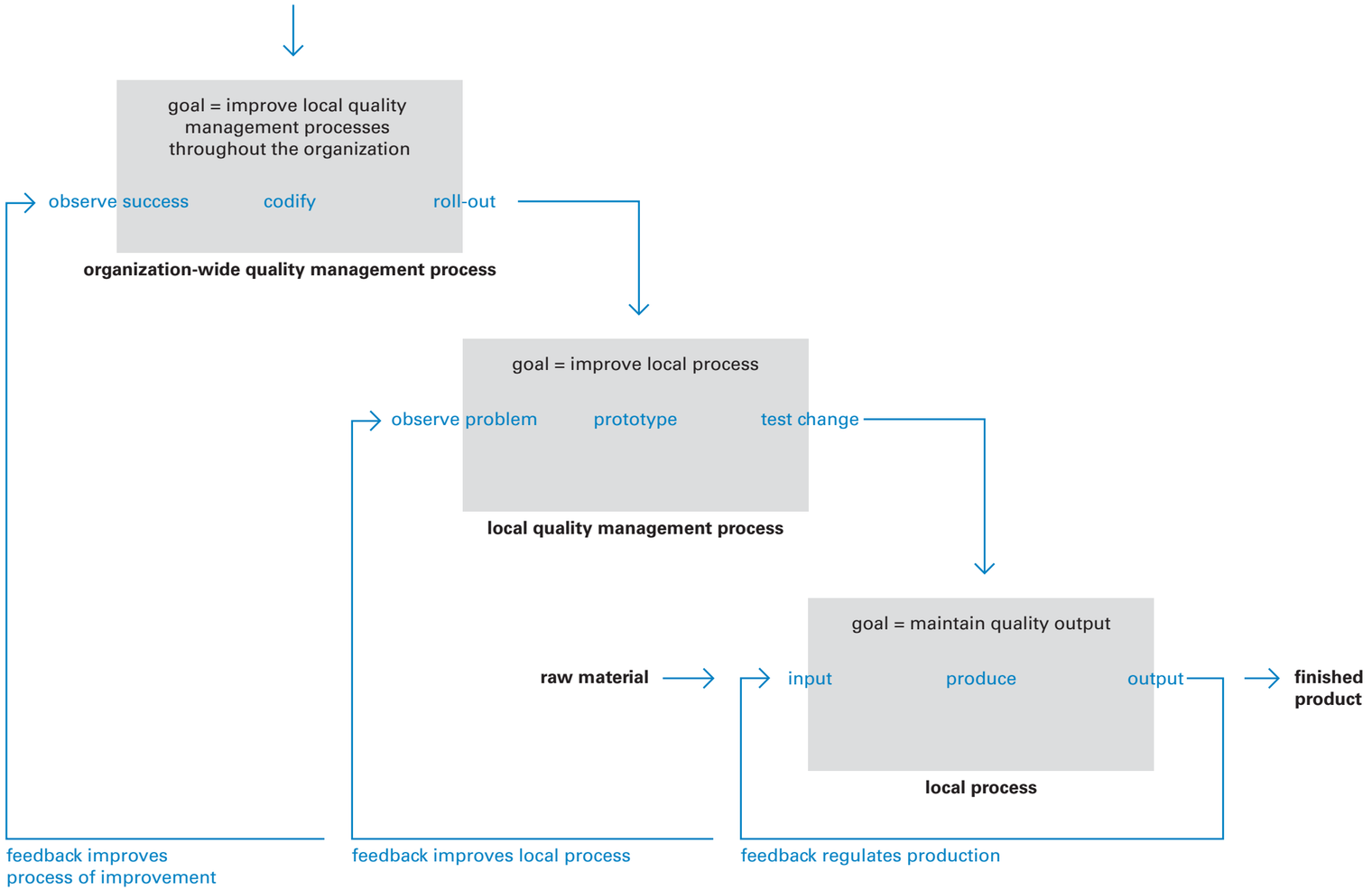
The ‘local process’ benefits from regulation — quality control, if you will.



Smart managers will implement a quality management system, e.g. TQM or Six Sigma to find ways to improve quality.



A third level may be advisable, a system for improving — sharing quality practices across the company.



Exercise

Please consider a ‘design system’ in terms of bootstrapping.
What levels of rules, regulations, and governance might be required?
Or at least recommended?

Special thanks to
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