



### Autonomous Greenhouse Challenge (June 5, 2018):

In the two days for the preliminary round for the Autonomous Greenhouse challenge, our team (Huxley + Wegrow) made good friends with each of the team members ranging from Tencent, Intel, Microsoft, South China Agricultural University, National Autonomous University of Mexico (UNAM)\*, Chinese Academy of Agricultural Science, B-Mex, Wageningen, Let's Grow, Seoul National University, Humboldt University of Berlin, and others. While many corporate and academic partnerships were formed, many team members are still finishing bachelor/PHD's. It is unclear as to any official partnerships since Dec 12th, 2018, but as the dust settles, 2019 will be quite interesting, competitive, and fast moving.

- **Intel:** (1 Machine Learning programmer onsite, 30+ persons (Machine Learning/Computer Vision offsite) + UNAM: No 1 University in Mexico (non-agricultural)
- **Microsoft:** (2 onsite with 2 Wageningen team members, with 20+? offsite) The team is well paid, based in Amsterdam, willing to collaborate, and there's a large initiative within Microsoft for agtech. Also they pick the top Wageningen students.
- **B-Mex:** Fokke Buwalda (ex WUR) and his team specialize in modelling crop growth and diseases. (Fokke is such a nice guy, we all were going to team up at first, but split into 3 separate teams. He's great with sharing some information, but also quite competitive. **B-mex now integrated into Ledgnd.com who I got to know at Viscon. Not impressed**
- **Plant Vision/WeGrow:** worked very well together, lean and mean, 3 from our team, and 2 from WeGrow. Place 7/15, with a score above Microsoft, but the top 5 are more closely related to partnerships with Wageningen. We also got approved for the 2mil euro Dutch Top Sector grant that is still continuing with Syngenta, Hoogendoorn, and others... So we weren't too concerned with continuing the competition as it would have shared too many of our ideas with potential competitors.
- **SNU, HUB:** Not sure, most of the people were kind of boring actually, so we mainly interfaced with Intel, Microsoft, B-Mex, Wageningen. :D)

During the preliminary tests (online simulation via email to restrict speed of iterations to 2 minute intervals), we utilized supervised and unsupervised machine learning techniques to grow the most \$ cucumbers per sqm. After presenting our methods and running the simulation for 24hrs, **we realized basic but important key factors:**

- 1) The simulation software and the Let's Grow interface is buggy and unreliable. None of the teams were able to push set point data and utilize machine learning to advance. This motivated teams like Huxley and Intel to immediately team up with horticulture groups like WeGrow & UNAM. While the programmers spent days and nights trying to gain access to the simulation software, in parallel each of the successful teams either had horticulturalists onsite/offsite (Huxley had 2; Intel and other teams remotely 20-30 offsite)
- 2) Hard work was manually inputted via email to the simulation software by the horticultural teams, pushing set points for the air, light, and water combinations that returned values from \$30-130/Cucumbers per m<sup>2</sup>. The email system they had for the simulation software was buggy and didn't return consistent values. What teams realized quickly is that it would have to be manually inputted by the plant experts, because feeding the XML data wasn't working, and there wasn't any historical data to reference.
- 3) We performed on par with top 5 teams, achieving \$75/sqm vs. Microsoft's \$72/sqm. Quickly we saw bureaucracy at play, and fairly enough... Wageningen worked with top 5 who have capital and resources.
- 4) While there were 3-20 person teams on the ground, people like Intel, Tencent, China had 30+ technical machine learning experts in the background working on this. Over the 4 month period, \$100,000's to \$1,000,000's were most likely put into this competition to enter the emerging and necessary Controlled Environment Agriculture movement.
- 5) As experienced growers and companies know that these set points are not necessarily "self-updating", like "AI" is with the self-driving car (constantly updating road conditions etc.), (Air, Light, Water) x (Genetic) is learned by the masters over time. Efficiency can come from tweaking those inputs, but the recipe stays pretty constant.
- 6) Augmentation as our team proposed could give great percentages of yield increase, especially with new talent (\$2k now, but \$200 within a couple years). We believe that augmentation was pushed to the side to give fair advantage to the consistency of the master grower(s) at Wageningen, and that in the trials, augmentation wouldn't necessarily increase yield for the experienced grower; gains from augmentation would be more apparent in situations beyond the rules of the challenge which was primarily looking at autonomous (AI) vs. semi-autonomous (AI+AR). Also many methods were kept abstract from our side to not give away patent pending technology to the other teams/companies.
- 7) The Microsoft team supposedly were using different LED's, so did the AI beat the human grower? At least this is a very exciting benchmark to test more scenarios. :D

### **Autonomous Greenhouse Challenge (AGC)**

- [What were the strategies of the participants of the AGC, which skills and methods did they apply?](#) Being that there were many teams from many countries, each had a

different approach. While many groups already had a balance of tech & growers, companies like Intel, Microsoft, Huxley, quickly partnered with horticulture groups to understand all the complex variables and slow/buggy systems. Many in the plant world were excited by the prospects of machine learning for the simulation, but realized quickly that they were manually informing the set-point parameters rather than benefiting from any self-learning code. All teams had to manually input via email into the simulation software, the teams that placed highest had the Horticulture teams for the preliminary round. [The methods](#) of advanced teams like Microsoft looked at using cameras to optimize the Vapor Pressure Deficit, while others spoke about simple camera analysis methods (\$30 camera, or Smartphone Camera), and potentially guiding the Master Grower (not sure if this was implemented).

- [How would you rank them, looking at their performance, chances for the future and threat to the 'establishment', or opportunity for collaboration?](#)
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- 1) Microsoft team is very hip; they have a good combination of the best PHD students @ WUR and a strong understanding of camera technology/machine learning with sensor data. Also with many of Bill Gates initiatives lots of attention is going toward Agtech.
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- 2) Intel isn't as innovative as they used to be. Many from Intel moved to GPU Ventures @ Nvidia. Intel has smart machine learning programmers, but not that organized & timely. We were working out investments and deals 2 years ago and talking about AR, but large companies like this want to stay hip, and even their Ad Agency (Crispin Porter Bogusky) was at the meetings. So they like the aesthetics of vertical farming, but stay more on the tech side, and large emerging markets.
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- [How would Tencent benefit from this and how do you foresee their next steps?](#)  
Companies like Tencent are in danger of having their rapid growth slowed by the Chinese state's crackdown on licensing for [video games](#). They have to quickly adapt into other sectors. CXO David Wallerstein is from Berkeley, California... So he has a good Silicon Valley/Nature balance. When Elon Musk was first building Autopilot for Tesla cars, he looked for talent from video game companies. If you want to bring knowledge from gaming into the Horticulture sector, these would be the experts in not only advancing the efficiency inside the greenhouse, but reimagining the flow of plants. Look at this example of [Traffic flow optimization](#). Simulation software is super powerful, because you essentially are testing out your business model millions or billions of times, hundred of years in the future, without much capital or infrastructure. This is how game companies could have a significant advantage of owning the flow of goods/services in the future via Machine Learning/Computer Vision.

#### **New technology for protected crops:**

- Most innovative technologies for the next 10 years:

**30 MHz:** Excellent micro-climate control company, really awesome and friendly team. Collaborative to work together @ WUR, and are highly responsive. Amsterdam proximity a plus, and now Hoogendoorn thinks they are a competitor because of their new platform. They work well in the Dutch ecosystem, global, and potentially more with cannabis in North America, top growers like them.

**2 Grow:** Could be affordable? Looks mostly like vine sensors. **true, and some are relying on them for realtime sapflow/plant activity, and some say they're not reliable enough**

**Gremon:** Trutina, doesn't look like anything Priva doesn't do already? **True, it's weight sensors on the tomato hook. Also Paskal (Israel) have such a system. By now we know it gives great realtime information about evaporation/activity especially combined with rockwool slab weight sensor. Today, the noise (crop treatment, harvest etc) is filtered out by the software.**

**ScoutBot:** Good product, how fast can they scale? **This one we know now as Ecoation. Scoutbot partners separated not long after they won the Greentech innovation award 2019. Delphy, Metazet, a company in demise and the other one was Mycothon (Theo Verstraate, who I know well) is a reliable company, building autonomous sprayers and uv trolleys.**

**Hortikey:** Cool looking robot, expensive, hard to scale. **He was right.** This could all fit in augmented glasses in the next year or two, much more affordable/scalable. **No, hasn't happened, only for the UI/mixed reality but AR glasses cannot do accurate measurements can they?**

**Technolution:** ?

**Phenovation:** Affordable, looks a bit basic, could have buggy features. **Serves researchers**

**Manufacturers** (Pros/Cons from Plant Vision perspective, intended for clear collaborative strategies):

**Hortikey:**

**Pros:** Backed by Rabobank & created with Wageningen,

**Cons:**

They sell it for yield prediction, but would their technology be able to do more in the near future? **so far, no**

**Lemnatec:** (You and Tom brought them to us one year ago, they are too much focused on breeding and research if you ask me), their main competitor could be this one? **Same as Phenovation, only research purposes**

**Qubit:**

**Pros:** Hand-Held for Reflective Indices and Chlorophyll Fluorescence. Take Plant Phenotyping anywhere from field to lab to greenhouse. Measures Photosynthesis, Respiration and Nitrogen Fixation. Not sure of costs, but it looks to be widely used by many top companies. Could be helping the booming Canadian cannabis market.

**Cons:** Based in Kingston, Ontario, Canada (2.5hrs to Toronto/Montreal); probably focused more on staple crops for the North American market. Could be a good collaborator for the costs, but also could be difficult coordinating across the Atlantic/time zones.

**Iris Scoutbot:** is the scoutbot mentioned earlier

**Pros:** Innovation award at Greentech, closed a collaboration with Delphy.

**Cons:** No news or details ever since. Still too experimental? (Stealth mode).

**Phenospex:**

**Pros:** Gregoire Hummel runs a great team in Heerlen. Backed by LIOF, he can attract quick investments, and build teams in the large building they have access to. Their hardware is superior for capturing multi-spectral & 3D data. At \$20k for the camera the price is pretty solid for digital phenotyping, and he and his team are quite flexible for collaboration.

**Cons:** The phenotyping industry is difficult to scale as it's utilized by few companies. Many of these companies take 12 months+ to establish contracts. Not sure how 3D multi-spectral point clouds are worth the hardware costs, since it's going to be expensive to develop analytic tools around the large datasets. The iterations on development are slow. Heerlen has a lot of local talent from Germany/Netherlands and the area, but it far away for public transportation, and is busy with car traffic. Hard to attract international talent to the area, despite the efforts of LIOF, Brightlands, Chemelot, etc.

**Saga Robotics:**

**Pros:** Recommended by Driscoll's and the UK's Berry Gardens, it has solid traction and is backed by Norwegian funds, which are quite limitless. Hyperspectral? Used as a fancy term, only need specific camera for specific functions.

**Cons:** China loves to copy hardware and scale it quickly. 1 Billion person country backed by a unified government-driven agenda; hardware is more difficult to scale anywhere else.

**Optimal** labs: They are backed by Peter Thiel, who also invests in Tilray, SpaceX, Tesla, Palantir, etc.

**Pros:** <https://www.amazon.com/Zero-One-Notes-Startups-Future/dp/0804139296>

They are driven by Peter Thiel's mantra that you are either 0 or 1, that you are a monopoly or not... Did they just get all the information for free from Wageningen? **YES**. Will they be a

monopoly in the future? Most likely because of the experience of team members, and power of their investors.

Luckily for Priva, Silicon Valley mostly deals with software rather than hardware, and wasn't that aware of the Dutch Horticulture industry until recent months (Intel, Oracle, Microsoft, IBM, Tencent, Nvidia). Priva/Hoogendoorn/Hortimax have the key/gates/bottleneck to the greenhouse sector, and powerful Dutch alliance, but as they see flaws in services like Let's Grow/Hoogendoorn, or challenges with gaining access to API's: they will partner quickly with these companies (or push their own sensor IOT platforms), IBM Watson is moving fast in the Canadian cannabis sector. It will be important for the Dutch Horticulture industry to partner wisely with companies like Microsoft/Nvidia as who ever has the most powerful AI, will always have the lead. If you look at the self driving car market, whoever is partnered with Nvidia is succeeding (Tesla, [Mercedes](#)). Because their programmers are the top in the world, (\$200-500k), and they will have the access to the highest computational power for the next couple decades.

*From founder Dave Hunter's LinkedIn:*

**"Dave Hunter** is founder/CEO of Optimal Labs. Now, at Optimal Labs, we have the ambitious goal of building the world's best theoretical and applied AI team within greenhouse horticulture. We have made good progress and have team members who originated from AI labs at Google DeepMind, Oxford University (including me!),

Cambridge University, MIT and others. We are backed by world-leading deep technology VC firms, including Founders Fund, who have backed companies such as SpaceX, Palantir and Square.

(Note, we are in 'stealth' mode and so there isn't much about us online). I have been training as a tomato grower for 0.5 days/week over the last few months so I think I am one of the only people around with theoretical machine learning knowledge and beginner-level green fingers!"

**For more information see:**

<https://www.linkedin.com/in/davephunter/>



**3 weeks ago at a presentation in the Netherlands.**

**Hoogendoorn**: (20% Market Share)

**Pros:** Runs some of the largest greenhouses; more affordable than companies like Priva; Universities like Wageningen have strong connections because of the affordable qualities. [Let's Grow](#) is a very promising gateway to global greenhouse API data. We see this year at the [Autonomous Greenhouse Challenge](#) that they are pioneering API data (Air, Light, Water), for Machine Learning. This put attention from companies like Tencent, Microsoft, IBM, Intel, Oracle, Optimal, and Plant Vision as well as groups in China and Mexico that now understand how to interface with their platform. While not fancy, it provides a great start to bring AI into the horticulture industry. Knows that it has strength regarding relationships. Unified and with a good team of programmers, they will have good market potential for projects @ scale, where costs matter most.

**Cons:** Thinks of other companies as competitors, and is most likely taking the Henry Ford approach to trying to hold strength along the growth chain. Took over a year to get API data, Let's Grow platform is buggy and not reliable. Promised to do a 1mil deal with Nvidia 5 months ago, shook hands to build "trust", but went silent for 5 months, and took my years worth of work @ Wageningen, and tried to sell in parallel. **Mind the bitterness in Ryan because of his clashes with the Dutch companies...esp Wageningen** Monopoly and potential collusion with Wageningen, make it a sour environment for entrepreneurship and collaboration.

Advanced software is best created in ideal collaborative zones such as: Zurich, San Francisco, Seattle, Brooklyn/New York, Los Angeles, Amsterdam. Where cross pollination amongst

companies like IBM, Tesla, Microsoft, Google, Facebook, create the next level front end experience, with backend exported to countries that have scale. The “Netherlands as a Service”, or “Helping the World Grow Dutch” via AI, will take new and exciting business models, and realizing the real value is data, pipelines, and equity in the vegetative output.



[October 16th](#), 2 months after I showed them our augmented technology in August, 2018 with Prime Minister of China.

[Hortimax](#): (20% Market Share)

**Pros:** Affordable and reliable in the industry.

**Cons:** Smaller team, therefore longer time to deploy?

[Autogrow](#): (5% Market Share)

**Pros:** Very kind and informative team, decent visual interface.

**Cons:** Has said for 2 years that they would API their platform, but leaving developers waiting/disappointed. Hard to set up.

[Sensei](#): (Larry Ellison, Oracle, [now also Tesla](#))

**Pros:** [Oracle](#) is the legacy database provider for the world, started for facial recognition, runs many of the largest datasets. This data structure could lend itself to large enough information pools and infrastructure for AI to keep track of genetic, growth, and phenotypic information.

**Cons:** It looks as if they are promoting soil based yoga retreats, but know they are interested in vertical farm/greenhouses for food. Medicine also?

**[Agrowtek:](#)**

**Pros:** Used as backups for systems like Priva, for clients like [Glasshouse](#); Gurnee, Illinois.

**Cons:** Based in Illinois, decent tech experts within region, but best for backup systems.

**[Argus:](#)** (Surrey, British Columbia)

**Pros:** Says 2 years ago that they have an API and work well with others. Located in an ideal zone for Cannabis and proximity to transportation

**Cons:** Hard to attract tech talent to those regions.

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**People/Companies** to focus on in 2019:

**Damian Solomon :** Expert Advisor, well trusted, and knowledgeable about the whole industry. Kind and focused on future applications and bringing everyone forward.

**Matthew King:** Well connected investment advisor with Damian Solomon. Understands the technical and plant aspects quite fully.

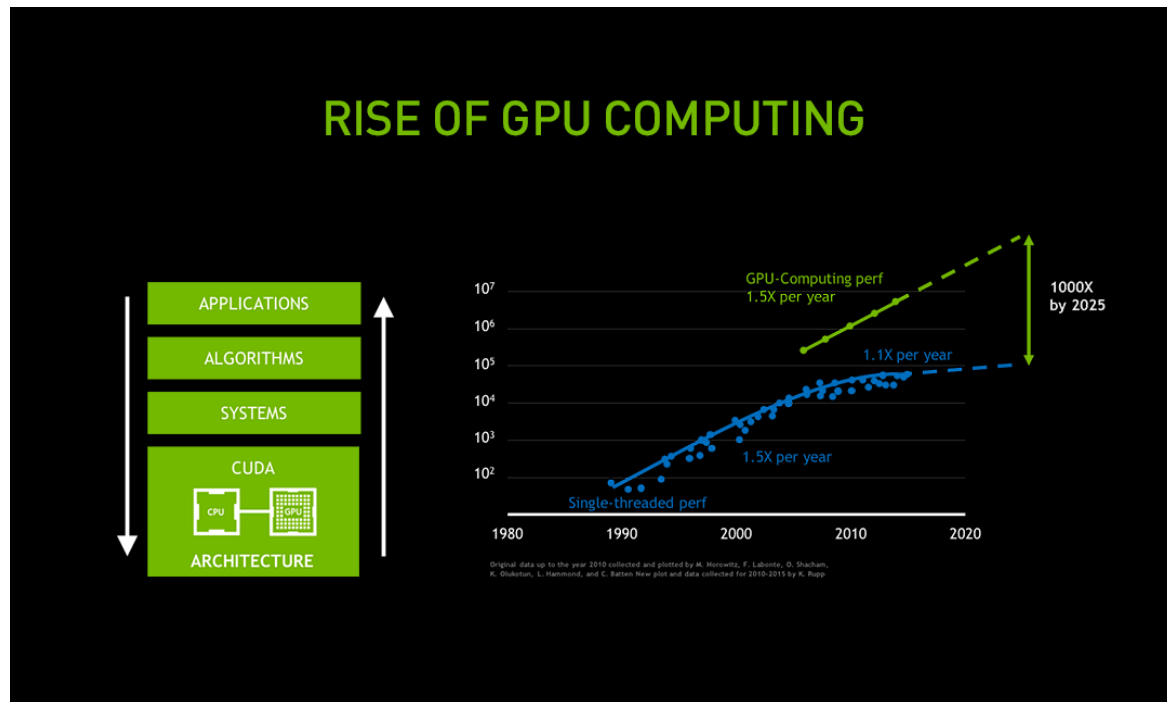
**Glasshouse Farms:** Graham is really great to communicate with, as he not only understands everything about horticulture, but also runs the one of the most advanced operations. He helped create Sonos speakers, so his technical approach is very wise and well-regarded.

**Legion of Bloom:** Willing to collaborate, parent investors are that of Glasshouse farms.

**Cronos Group: (Altria):** Very knowledgeable about the industry at large, sees huge opportunity in augmented, and new technologies.

**Plant Vision:** One foot in Amsterdam, one in Silicon Valley, taking an objective approach to technology in the horticulture/phenotyping/space sectors. (Many have said we are 2-3 years ahead of the curve). **This was the commercial break ;-)**

## Augmented & Digital Phenotyping Roadmap for 2019: Priva



As you can see in the chart above, CPU's (Numbers Based) or Transistors per mm<sup>2</sup> has been doubling every 18 months for over 100 years. Around 2010 is when Intel and other CPU manufacturers couldn't fit any more per mm<sup>2</sup>.

This is when GPUs (Visual Based, why a Tesla car can drive on Autopilot @ 100km/h from many high res sensors) from Nvidia started to accelerate, moving 5x faster than Moore's law, or doubling every 3 months. What took 100 years in computational development, now will happen in the next 10 years, or 1000x. By comparison, an iPhone X with a mobile GPU can process images near real-time for intensive processes like pose detection, (1 frame per second on iPhone 6 vs 16 frames per second, nearly 16x in 2 years.)

What this means for Digital Phenotyping companies that rely on expensive hardware (economies of scale are difficult as there are few seed companies and use cases), is that the industry needs more modern tools: to utilize increased computational power, that scale across

mobile platforms, and can easily interface/API into environmental data like Priva, Hoogendoorn, Hortimax, Argus, etc.

Silicon Valley talks about [Exponential Thinking vs. Linear Thinking](#). This basic principle allows Machine Learning/Computer Vision/AI to [utilize cheaper sensors](#) like 2 infrared cameras, gather stereoscopic data, and infer 4-10x the results with 2 small cameras, or by creating a hive of small sensors to get high quality results. Even with [1 camera](#) we can now pull [depth information](#), negating the need for costly hardware.

The data necessary to train Machine Learning models, and come up with high-accuracy (e.g. [0.994 \(best algorithm\) vs 0.884 \(best pathologist\)](#)), with 400-100,000+ carefully [annotated](#), [segmented](#), and [contoured](#) images. Feeding these datasets is very analogous to the [Visual Effects](#) industry I spent [12 years](#) in from New York to Los Angeles, instead this time with multi-spectral and environmental information. The more details you feed the AI, the better the results.

### **Gathering insights from other industries:**

There are currently over 300+ self driving car companies competing/collaborating to make high accuracy autonomous driving solutions for every environmental, lighting, and road condition.

“According to RAND Corporation, to drive even 20 percent better than a human requires 11 billion miles of validation. That translates to more than 500 years of nonstop driving in the real world with a fleet of 100 cars — an impossible task.” – [Nvidia](#)

What the self-driving car industry learned after years of competition, that without collaboration or creating [open-source](#) simulation [software](#), any mistake from a self-driving car would push back the industry years of perception. By collaborating, using real-life data, simulation data, and open-protocols, the industry was able to quickly patch holes together, and commercialize from there.

Looking at the Horticulture/Agriculture industry, there are over 391,000 species of plants, multiple lighting scenarios, and crop cycles from 30-270 days, from stems, leaves, to flowers & fruits, this presents itself with the “problem of infinities”. Also each size of plant and type require different spectra at different resolutions and time scales.

Many aspects of phenotyping rely on the counting of stamen in a flower to shape, size, length, width, much of which can be analyzed in real-time with a simple RGB smartphone, affordable camera, or more hyperspectral/3D like Phenospex (\$20k per camera). Infrared for crop stress/disease, and UV for pollination. Then detailed [analysis](#) can occur.

There’s a joke about Bitcoin, how it was the incentive model to spread [GPU’s all around the world](#), so that we could have affordable AI. When an industry creates value around the data

(Environmental, Genetic, Visual), it gamifies an industry to buy more hardware, pushing economies of scale much faster, creating affordable sensors, so that services like AI as a Service can exist. Instead of €€€ for the product, commission based (~10%) can occur for the optimal settings/optimization of crops, so that more yield and more profit happens. This also allows for operators to not leave behind important grows like tomatoes for cannabis, just for a temporary turn around. The value of the optimized crop is shared with the contributing parties.

### **Photosynthesis at Scale:**

There's a quick rule of thumb that with no more than 30% efficiency, solar panels essentially block out  $\frac{2}{3}$  of the photosynthesis potential. [Why Vertical Farming won't Save the Planet](#), (indeed it won't) pushes the viewers towards greenhouses (yes!), less transportation, and less beef solutions. Climate adaptation is thrusting breeders to find solutions that will speed up the exploration process of hybridization, from 7-10 years for crops like tomatoes, to shaving off years with tools like Machine Learning. Dry climates need more drought resistant crops, while wet zones need protection against diseases and to adapt to higher moisture levels.

You can see that [Optimal's](#) slogan is "Autonomous Indoor Farms Outside Every City on Earth", but the question is... How many acres of greenhouses from food to medicine does a city need per million people, for the thermal resistance (R-value), and the amount of light (PAR), for each region. Reimagining the global food/medicine supply chain will be more dramatic than any of the previous industrial revolutions combined, but will pave the way for a sustainable future.

(Jeff Bezos (Amazon), Elon Musk (Tesla), Peter Thiel ([Founders Fund](#)), Larry Ellison (Oracle, [Sensei](#), now [Tesla](#)) all have the power to do so).

*"[Jeff Bezos, Amazon founder](#) and technology entrepreneur, has said he hopes to see the solar system populated by one trillion people.*

*Mr Bezos, who recently accepted \$500m from the US military to help develop his Blue Origin space flight project, said he would not be there when the cosmos was so crowded, but added that people were "starting to bump up against the absolute true fact that Earth is finite".*

*The **military** could purchase up to 100,000 of the devices. The **US Army** has awarded **Microsoft** a [\\$480 million contract to supply the military](#) branch with as many as 100,000 HoloLens augmented reality headsets for training and combat purposes, according to [Bloomberg](#).*

It's looking like the US will dominate the world via AI and Augmentation, leaving Europe behind, as predicted by the [geopolitical game theorist George Friedman](#), but with The Netherlands and Switzerland as the stronghold, while many forward thinking people in the US are preparing to move to [New Zealand](#) or Canada for sustainable business. SpaceX and other [companies](#) are looking to launch and land via New Zealand due to sea rise volatility and noise accessibility for

[reusable rockets](#), which are 100-1000x cheaper for space and [terrestrial travel](#) (New York to Tokyo in 30 min).

1/11 investments in Silicon Valley are going towards the space industry, which is half of the US investments. Companies that have satellite (pun intended) operations in Los Angeles (SpaceX), and New Zealand (Space Community/Investors), Seattle (Amazon), and basically anywhere along Elon Musk and the US's supply chain, will benefit from rapid and sustainable growth, going well into the future. Launch sites in Florida and Los Angeles, are either sinking, or becoming politically unstable. The future is controlled environment systems around the globe, and with the visionaries that will need these technologies and fund sustained growth in the horticulture sector.

Also as we look at runaway climate change, just the grasses in the oceans absorb 30% of the CO2 in the atmosphere. Due to ocean acidification, within decades we will have much more methane and CO2 in the air. Rapid breeding/hybridization/CRISPR are all solutions to creating adaptive plants much faster, like sea grasses that can handle higher acidification and also absorb more CO2. This will bring digital/augmented phenotyping into many sectors as the demand will increase for efficiency and uniqueness.

The process simply starts with a matrix of "[Food Computers](#)" that can iterate on a multitude of environmental scenarios (air, light, water), stressing and testing genetic adaptation, and also crossing the gladiator mom and dads. Once genetics are rapidly tested for their adaptive properties, they can start to scale out into semi-controlled greenhouses, like [Glasshouse Farms](#).

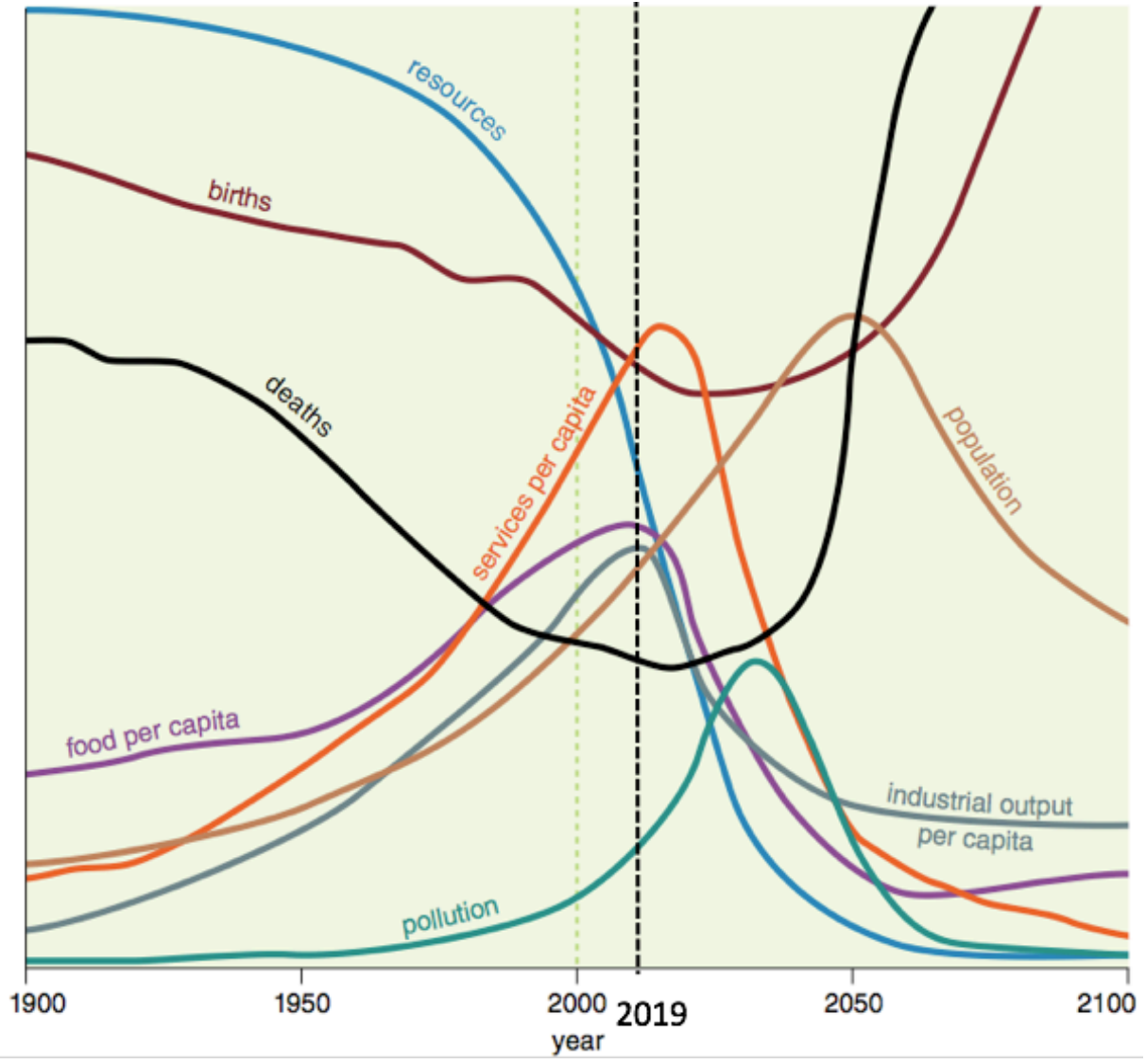
The microclimates in semi-controlled greenhouses will give nuanced expressions (phenotypes), from the cloned or seeded genetic. Then each year the 10% that survive, will have undergone rigorous scenarios, lending itself to the speeding up of new phenotypes. Augmented phenotyping is the blend between AI and production, finding phenomic gems while creating consistency across the crops.

Best,

Ryan Hooks

CEO

[Plant Vision](#)



[https://en.wikipedia.org/wiki/The\\_Limits\\_to\\_Growth](https://en.wikipedia.org/wiki/The_Limits_to_Growth)