HOW TO WIN THE GRAIN REVOLUTION

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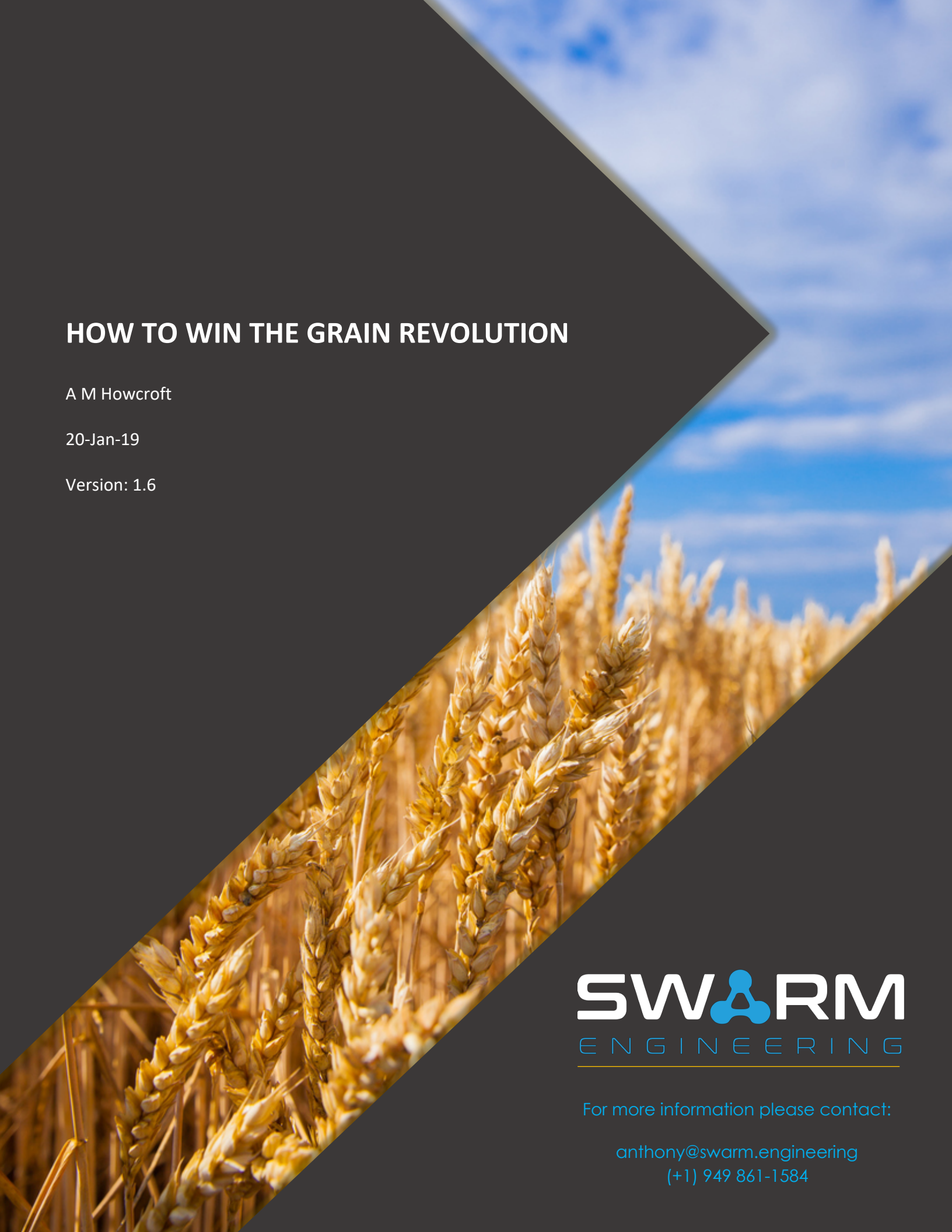

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EXEC SUMMARY

Grain has been with us since at least 10,000 years BC, and you might imagine we have mastered how it is grown, harvested, stored, and transported, yet this market is poised for innovation. In 2017/18 global production was more than a billion metric tons of corn, along with 757 million metric tons of wheat, with rising levels of consumption. The 2018/19 season is forecast for a rate of wheat consumption higher than production for the first time in nearly a decade. Yet there is a technology revolution ripping through agriculture, changing many aspects of the food supply chain, and today's dominant organizations will have to adapt or suffer the fate of other industry leaders that have ignored similar changes (Blockbuster anyone?). The dominant grain firms are already in a state of digital transformation, with industry giant Cargill stating in their annual report they are '…thinking like a technology startup'. Most firms are gathering data and exploring new approaches.

Finistere Ventures and Pitchbook have tracked more than $123 million in angel and seed investments in agtech, across 108 deals in 2017. Firms like Swedish startup BoMill, who can sort and identify each kernel in a batch of grain, or image analytic firms like Vibe that support disease identification in seeds. New ventures like Ripe.io have introduced blockchain for a better food chain. Not all investments are early stage, Indigo with their grain eMarket have received $650 million in funding – valuing them at $3.2billion, and major competitors Cargill and ADM have joined forces to launch a joint technology venture, Grainbridge – announced in October 2018, and still awaiting regulatory approval.

Underneath this wave of technology is data, and a rising tide of new requirements and criteria driven by environmental, grower, and customer demands. The math behind these changes shows a combinatorial explosion is materializing in key supply chain areas, such as blending and logistics. A 3-way blend of 100 grain silos with a few criteria which was once several million choices can suddenly have 10^{45} potential options. Operational decisions are still possible, but are a long way from being optimized, and it's highly probable that current practice is a significant factor off the best choice, and declining fast when compared to decisions that could be made by competitors. This optimization decline is especially dangerous as it's invisible, being a comparative change - like thinking your Sony Walkman is great, as the iPod hits the market.

Nature solves complex optimizations of this scale using multi-agent systems (MAS); like bees foraging for honey. Software equivalents are moving to the mainstream, as there are far more agent-capable smart devices (thanks to the Internet of Things), plus AI has advanced rapidly in the last few years (especially in the realm of machine learning) and the number of problems suitable for a MAS+AI is rapidly expanding because of the combinatorial explosion.

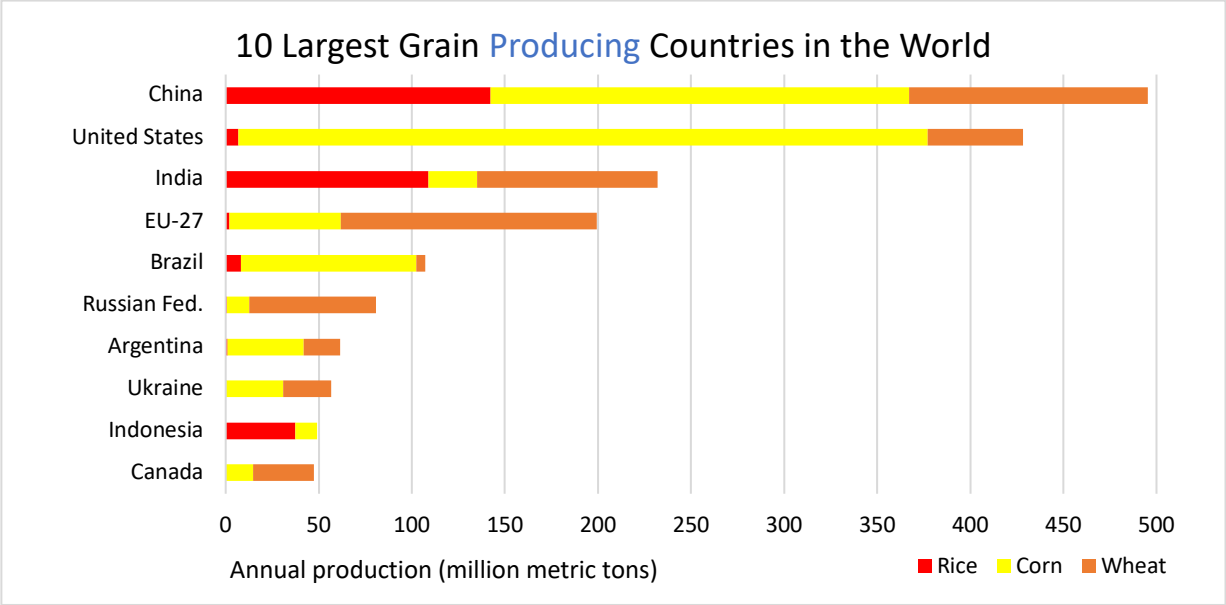
The next leaders in grain will need to be fast, flexible and forward-looking, with dynamic supply chains. SWARM enables this vision by combining a multi-agent system with reinforcement learning, allowing enterprises to achieve superhuman performance by automatically optimizing their critical processes.

STATE OF THE MARKET

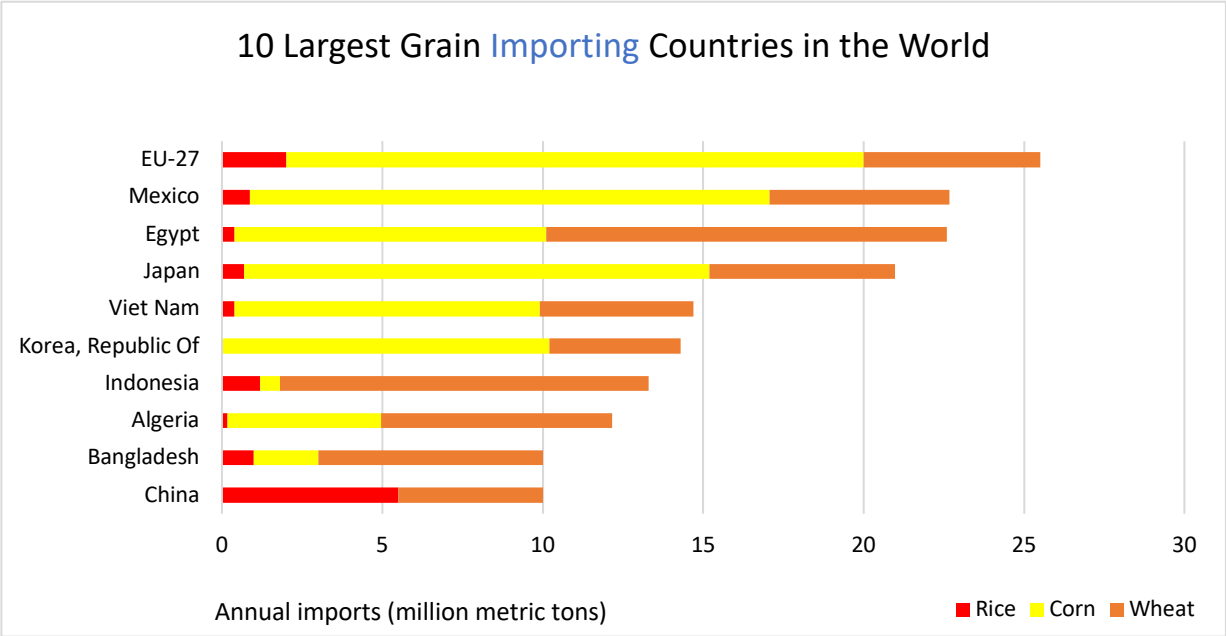
Worldwide grain production & consumption

As recently as the 1960s the "Green Revolution" resulted in wheat, rice and maize yields more than doubling thanks to high-yield crop varieties, new fertilizers, pesticides, herbicides, the application of irrigation technology, and the increasing use of mechanization. This trend has continued, with grain yields moving from 1.4 tons per hectare in the 1960s to an average of over 3.2 tons per hectare today. The Green Revolution is considered to have saved more than a billion people from starvation, but is not without its critics, who point to societal impacts on farmers, the dangers of an overpopulated planet, environmental damage caused by the chemicals used, and negative consequences of a reduction in biodiversity.

As of today, 11% of the planet's land surface is used to farm crops (that's approximately 33% of all land suitable for crops – you can't utilize a mountain or a desert), and on a global basis we produce and consume gigantic quantities of grain. The number one product is corn, with more than a billion metric tons produced in 2017/18, followed by wheat at 757 million metric tons, with rice coming in a distant third place at 488 million tons. Other cereals such as barley, oats, and rye, make up the rest of the world production, along with the legumes such as soybeans, lentils, peanuts, and finally the oilseeds such as canola and sunflower.



Source: USDA. In terms of global production, the USA sits behind China, although it leads in corn and has historically switched places with Russia in a battle for third/fourth place over wheat. The EU combined countries of the top 27 nations are a significant force in wheat production, along with India.

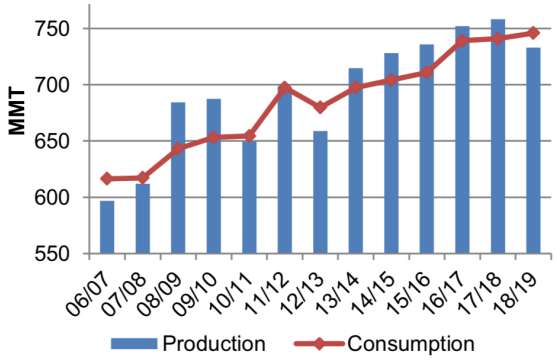


Source: USDA. Looking at importers, Indonesia and Egypt top the chart for wheat, but the EU is the major importer overall despite being third in the list of production.

We can see above a huge disparity in production volumes vs import (China producing nearly 500 MT while the EU imports just over 25 MT) which suggests there's either a huge amount of hoarding taking place on a global basis, or else the vast majority of grain produced is consumed within the home markets. While China is believed to have stores of 136 million metric tons, and America has the next largest grain stores at 25 million metric tons, most countries consume the majority of each year's production. The Wheat Council of America have some interesting statistics showing consumption of wheat in pounds per person per year, which shows the average Chinese person eating 180 pounds per year (mainly in the form of noodles), compared to 133 pounds per American, or 441 pounds for someone living in Algeria – now that must be an interesting diet! The worldwide consumption of grain continues to rise and is forecast to keep growing. In fact, for 2018/19 the rate of consumption of wheat is forecast to be higher than production for the first time since 2011/12.

Global wheat production and consumption

Source: USDA Office of Global Analysis



What are the biggest grain companies talking about?

Set against this background, we took a look at the Chairman's reports for ten of the largest grain companies in the world, and created a word cloud to see what was on their mind:

At first glance, the Chairman appear to be reflecting on a business year with strong growth, in a global, billion-dollar industry. In many cases, though, they are actually talking about growth opportunities for *next* year, as wheat is some way from its historical price peak of over $10 per bushel in 2010, and is closer to half that value today ($5.1 per bushel), and the same is true for corn ($3.8 per bushel compared to a high of $8), and rice ($9.7 down from $20). However, forecasts are for prices to rise, especially if consumption begins to outstrip production.

Hidden amongst the word cloud, you will see where the Chairman are focusing their organizations efforts: sustainability, nutrition, track and trace, new ventures, along with supply chain operations. We might argue that one key word is missing: *data*. From a technology perspective, we could also note the absence of *artificial intelligence*, *analytics*, and *blockchain*, although these terms are very common in the SI and Investment reports for the Agricultural sector. The Chairman reports are targeted at investors, though, and beneath the public themes, you will find teams hard at work implementing analytics, and investigating/piloting/ experimenting with big data, AI, and blockchain. We know this from direct conversations with several CIOs, along with public presentations at industry events.

There are some exceptions. While one or two firms we reviewed are lagging the trends, others such as Cargill, are making it clear in their collateral that they see technology as a core element of their business. The opening sentence of the Cargill 2018 Annual Report states **'Why does a food and agriculture company start thinking like a technology startup?".** In his letter to the shareholders, the Chairman comments that "...through investments in technology, we are better connecting our global operations, honing our competitive edge in trading and analytics, and bringing greater insight to customers."

This approach to applying technology and innovation from companies like Cargill is becoming more common, as companies look to evolve their own business models before they are disrupted by new entrants or more forward-looking organizations.

The Gartner 2018 CIO Agenda Industry Insights report surveyed 3160 CIOs from 98 countries, across 15 industries. The Board of Directors were challenging their CIOs – in 47% of all of the companies – to make progress in digital business. In the vast majority of industries, CIOs rated digital transformation as a top three priority.

Many CIOs are launching Digital Transformation initiatives, applying technology to alter the process by which they engage with their stakeholders, from farmers through to internal departmental functions and external third parties, on to consumers.

Where's the fire?

You may ask why many grain companies (and agricultural firms in general) are focused on digital transformation and innovation. The answer is that executives are under pressure from multiple directions. There are changes in consumer patterns, disruptive new market entrants, shifting grower behavior, along with nascent technology permeating every aspect of the process.

THE TECHNOLOGY LANDSCAPE

Emerging startups

We spoke to a handful of vendors that are transforming the agricultural landscape, across a broad swathe of technologies. Companies like **BoMill** in Sweden, who can sort and identify each kernel in a batch of grain, processing 3 metric tons per hour per system - their largest installation processes 30 metric tons per hour. Karin Wehlin, Managing Director, told us that "With our proprietary technology we are enabling our customers to capture the true value in a grain batch by sorting on internal quality, kernel-by-kernel, which transforms the way they can use different value streams in order to optimize and unlock the true value. With our technology you minimize the waste by only sorting out the really "bad" kernels instead of pricing according to the mean value".

Other vendors like **Vibe** have used image analytics to support the inspection of grains, and are able to identify the size, shape, and color of grains, picking up such issues as pink or white diseased seeds in wheat, or field fungi or sprouted grains in barley. They can improve the inspection process by a factor of 10x, as well as storing the data for subsequent analytics.

There are startups that are focused on local soil and weather conditions; firms like **Pivot Bio** that activate microbes in the soil to enable crops to be fertilized without using synthetic nitrogen fertilizers, or **Understory** that use specialized sensors to provide hyperlocal weather data for farms, with sensors that record more than 3,000 measurements per second, everything from rainfall and hail to wind speeds, temperature, and so on.

At the other end of the scale, firms like **Descartes Labs** has petabytes of satellite images, and recently added weather information, to their geospatial analytics platform that provides a real-time map of the planet, used by agro-firms such as Cargill to predict crop growth, health and analyze food security (and trading).

Ripe.io is looking to reimagine the food chain. Phil Harris, President and co-founder, and CEO Raja Ramachandran, both came to agriculture via the world of finance where blockchain had already shown its potential impact. They were looking at how blockchain technology could transform other industries, and in food, they saw issues of wastage, fraud, quality, and safety. Ripe.io was founded in 2017 with a goal to provide 'better food for all through a quality network that maps the food journey to answer what's in our food, where it comes from, and what has happened to it.' They secured $2.4M in funding in Sep 2018.

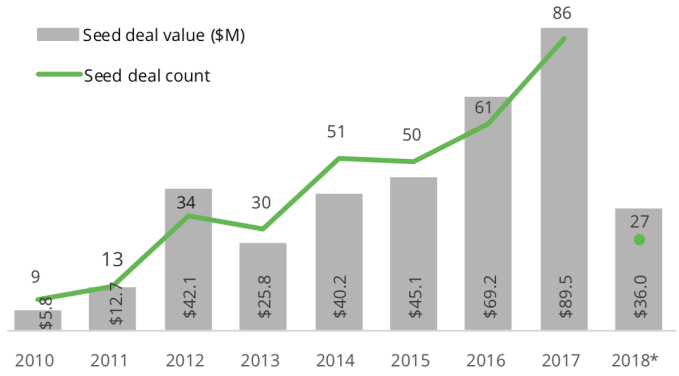
The eMarket space for agriculture is also getting more investment and attention. In September 2018, **Indigo** secured a $250M Series E investment on top of the $400M previously raised, pushing their valuation to $3.2Billion. While originally known for their microbial products, they have been growing an independent market for growers to connect with buyers directly. They state that they will have more than $500M in bookings this year and have more than $6 billion of grain listed on their platform by

farmers. Indigo manage the purchase, transport, and testing of the grain. Then there is **FarmLead**, who include Monsanto in their list of investors. Buyers and Sellers register for free and can trade grain without typical brokerage fees – essentially cutting out the large grain firms that act as 'middlemen', with the goal of empowering farmers. They don't test or transport grain, although they are adding additional tools to help buyers and sellers manage that process. Cargill and ADM announced in October 2018 a technology joint venture called **Grainbridge** 'to convert data, free of charge to the farmer, into information that will help farmers maximize their profits'.

These are not the first two companies to create eMarkets that allow farmers to trade directly with buyers. Eastern Australia's **GrainCorp** grew from the government's grain authority and have a model that allows growers to store their produce in GrainCorp's storage facilities, whoever they ultimately decide to sell their grain to, and have their own transport network to efficiently move the grain once a purchase has been made. Their model allows farmers to sell at any stage in the cycle – from planting through to post-harvest and late season. GrainCorp have added tools such as their FastWeigh, Croptimiser and CropConnect services to give growers as much flexibility and protection as possible, as well as continuing to invest in 'Project Regeneration' which provides annual capital improvements to the core infrastructure. Since grain storage and transportation still carries risks from pests, fire and water damage, not all farmers want to carry this risk by themselves, or to invest & lock-up the capital needed for the equipment – which is where a full-service adds value.

Investment in agtech

In their Early Stage Agtech Report, Finistere Ventures and Pitchbook documented $123.8M in financing across 108 angel and seed rounds in 2017, and they state that this may not be all of the activity, as datapoints at this stage in the cycle are notoriously hard to gather, especially given the global nature of the agtech industry (not all of the finance is tied to Silicon Valley, and there are hotspots in Israel, New Zealand, South America, and many other locations). The chart below shows the growth rate of seed deals in recent years, which shows strong growth in early-stage investment, whether measured by deal-flow or total investment.



Source: Finistere/Pitchbook, as of May 2018

There are some strong patterns within the data: investments are rising quickly in animal technology, for example. Significant investments continue in precision agriculture, and crop management, and there was a spike for indoor agriculture in 2017 (not too hard to guess why). Certain technologies, such as Supply Chain, have a strong role to play in the sector, but are not considered ag-specific.

Agtech is now a global ecosystem, with rapidly rising innovation and investment.

The technology arms race

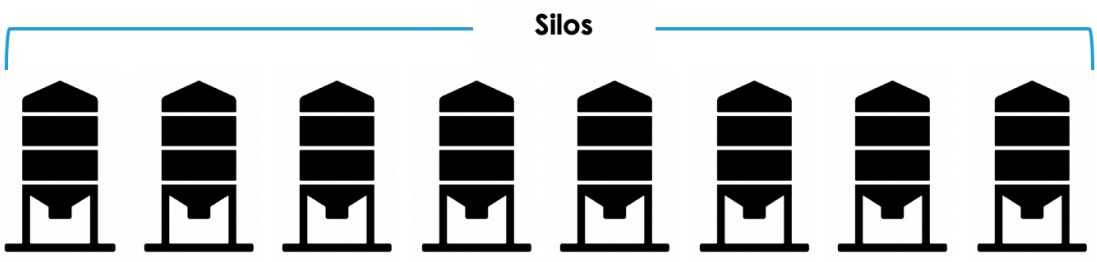
As we can see, technology is a primary factor driving change in the grain industry. If one company gains huge benefits with a new approach, the next had better start exploring this option too, since the potential advantages are too big to ignore. Right now, there is an arms race between the agricultural giants, and those that are not set with the right technological weapons and defenses will be vulnerable over the next decade.

Whichever technology paths the grain companies choose to follow, underneath all of the technology, we see more data. There is streaming information from a range of sensor devices, along with high definition images, weather feeds, point-of-sale and consumer data in fine-grain detail that has never been available before, and real-time tracking of supply chain elements like trucks, trains, ships, and individual storage units. This tsunami of data floods IT departments, and requires new hardware, software, and expertise to take best advantage. Firms that have spent the last few years hiring scarce data scientists with relevant skills and are now seeking AI and Machine-Learning engineers. Or else they are paying a large slice of their budget to the System Integrators that have managed to recruit and keep talented specialists.

Clearly, good use of curated data adds tremendous value. It is a core competence for every modern enterprise, and most CEOs can quote examples of actionable data insights that have delivered meaningful results for their firms. While there are obvious benefits in the niches where new technology has been successfully deployed, the end-end process is still sub-optimal, and dare we whisper it, sometimes this wave of new data washes out valuable information, making it ***even harder to make good decisions*.**

A combinatorial explosion

Consider a company that has a port with grain storage silos, from which they blend either 3, 6 or 9 silos for customer orders. The table below shows the possible number of combinations.



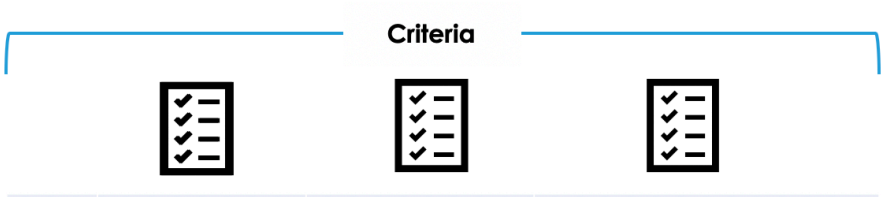
		100	200	300	400	500
Blends	3-way	161,700	1,313,400	4,455,100	10,586,800	20,708,500
	6-way	1,192,052,400	82,408,626,300	962,822,846,700	5,478,557,838,600	21,057,686,727,000
	9-way	1,902,231,808,400	1,175,445,251,780,800	48,052,241,692,154,700	659,797,329,990,168,000	5,006,325,637,513,060,000

You can see at a glance how the number of combinations becomes an exponential problem as the potential number of blends (and silos, to a lesser degree) is increased.

Now let's look at the customer order which is based on three criteria – let's say grade, protein, and moisture content. If each is a simple Y/N value (which is a gross simplification of the real scenario) then a 3-way blend combination would have 512 possible values:

= (number of choices ^ criteria) ^ silos in blend = (2^3) ^3 = 512 possible values

For 100 silos this results in 161,700 * 512 options, i.e. 82 million choices, which is something a cloud server could process in a reasonable amount of time. However, digital transformation is increasing the number of criteria we *can* include in the decision, and the number we are being *asked* to include. Let's take a look at the result:



Blends	3	5	10
3-way	512	32,768	1,073,741,824
6-way	262,144	1,073,741,824	1,152,921,504,606,850,000
9-way	134,217,728	35,184,372,088,832	1,237,940,039,285,380,000,000,000,000

Both the Silo and Criteria tables show a combinatorial explosion of choices, and when you put them together (multiply one by the other) the challenge is daunting. Taking 10 criteria into account when blending 9 silos out of 500 = 6.2×10^{45} options – which is approaching the number of atoms in the earth – all for what should be a relatively simple business decision.

Reality for many businesses is far more complex than the simple scenario outlined above. We are working with a global grain organization that has more than 8,000 storage units, and 30+ criteria for each decision, and these criteria are not binary options but floating-point numbers and text with numerous potential values. What used to be possible with spreadsheets a few years ago, and cloud-based analytic platforms more recently, suddenly becomes a sub-optimal decision that utilizes filtering to second-guess the best options and reduce the number of possible choices to a more manageable quantity. This makes operational decisions possible, but they are a long way from being optimized, and it is highly probable that current best practice is a significant factor off the best possible choice – aka the "global optima", and declining fast when compared to decisions that *could* be made by competitors who use the data.

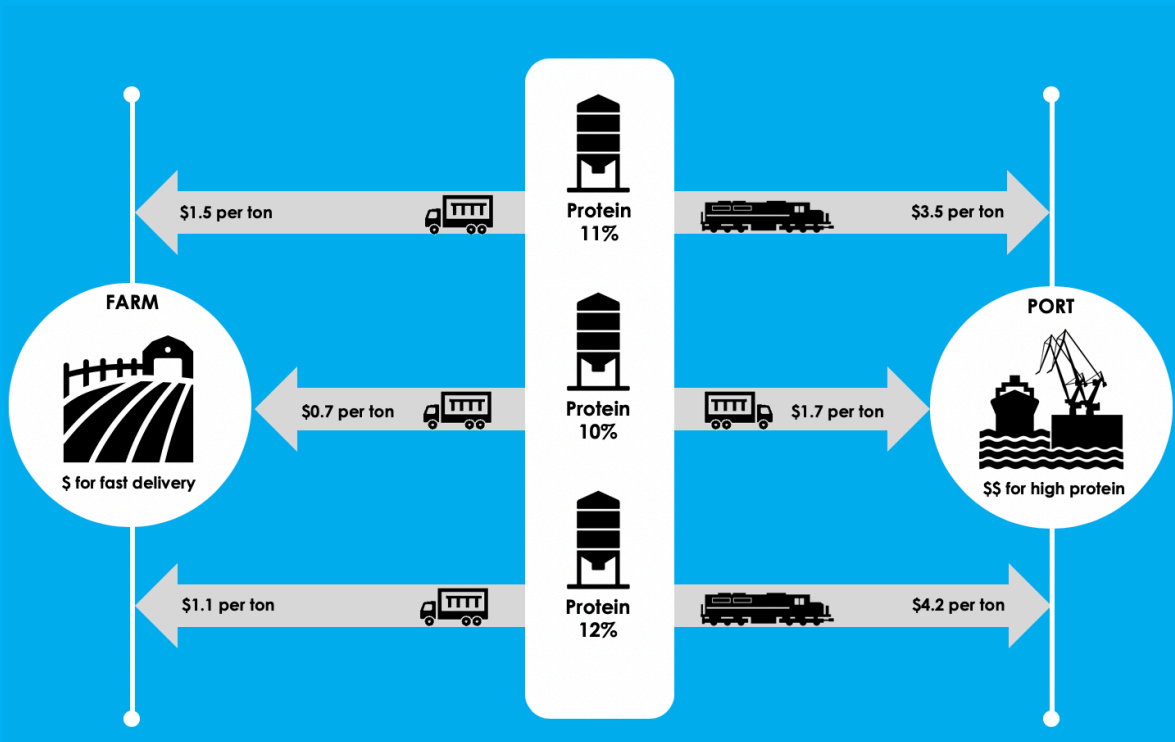
As data sources and requirements multiply, so will the exponential growth of potential possibilities. What was once a straightforward choice, becomes a decision that is an order of magnitude harder to make, at a time when competition is at its most intense.

It gets worse – let's add in supply chain logistics

One of the primary advantages of grain, perhaps the key reason why it has become so successful globally, is its ability to be stored and transported with relative ease, especially when compared to fruits and tubers. What's more, grain can be ground up and used (or transported) as flour, oil, or gas.

The physical movement of grain is a complex system (typically several 'travelling salesman' problems combine to form a supply chain). While transportation is handled by logistics experts, the demands and pressures on grain firms (see *Where's the fire?* on page 7) are forcing organizations to consider logistics as an integral part of the process, rather than a standalone function, e.g. a customer order needs to be blended based on quality criteria, but we must also take into account the logistics cost and time involved as a result of the blend choices

Integrating Logistics into Blending Decisions



If we have a customer order for wheat with protein of 10.9%, what mix should we move to port via train (several hundred miles), where it can fetch a good price per ton, and what should we transport by truck to a local farm where it is urgently needed for animal-feed?

Logistics has always been an integral part of supply chain optimization. As the complexity of product choices increase because of the combinatorial explosion, logistics adds 'fuel to the fire' making it even harder to arrive at optimal decisions in a realistic operational timeframe.

A WINNING STRATEGY

Nature does this all the time

Complex systems are not new. A nest of army ants on the rampage is a complex system, as is a murmuration of feeding swallows, a hive of bees foraging for honey, and even the human body. Nature handles these systems by allowing for the interaction of many entities via simple rules, out of which complex behavior emerges, e.g. individual neurons in a human brain fire and respond to other neurons, even though they have no independent 'intelligence' separate from the consciousness of the brain. Academics have studied multi-agent systems (MAS) for many years, with insights and highly performant results in specialized niches – the routing of data packets across a telecom network, for example. There are some key characteristics of these MAS:

- Highly adaptable
- Cope with dynamic/disruptive environments
- Decentralized
- Fault-tolerant (self-healing)

There are two reasons why MAS have not been deployed more broadly in industrial and/or enterprise environments.

1. **Too many dumb participants:** the agents need to have a base level of processing power and environmental awareness to join in a successful MAS
2. **Immature AI:** we can solve simple problems in controlled spaces, but large dynamic environments with multiple participants require a more sophisticated AI approach and associated algorithms

Critically, both of these obstacles are no longer true.

The Internet of Things (IoT) has massively increased the number and variety of sensors, making billions of items 'smart', so that (1) is no longer accurate. If you follow the mainstream press, you will have witnessed the seemingly daily advances of AI that have made (2) an obsolete position.

> **Multi-Agent Systems provide the tools to optimize complex systems, as our supply chains rush towards a combinatorial explosion that will render traditional approaches ineffective.**

Artificial Intelligence for grain

In previous sections we have looked at the explosion of data and choice, resulting in complex systems which are best suited for multi-agent systems (MAS) that can make use of the latest Artificial Intelligence (AI) algorithms, and in particular for machine-learning systems that can take the raw data and make sense of it *for themselves*.

As a horizontal layer of technology, AI is applicable to all industries. There are many categories of AI technology, in varying stages of maturity, from the latest theories in academic think-tanks to those algorithms widely deployed and used by millions of users (such as Siri or Alexa). The last few years have seen a burst in activity around the AI subset of machine learning, and most recently in deep reinforcement learning. Google caused a wave of publicity based on their results in this field (see below).

Google: AlphaGoZero

In 2016, Google's algorithm AlphaGo beat Lee Seedol (18-time world champion) in the ancient strategy game of Go, resulting in many news stories similar to when reigning Chess World Champion Gary Kasparov was first beaten in a tournament by a computer in 1996. Go has always been considered a much harder AI challenge, as it has far more potential moves - approximately 10^800 moves in Go compared to 10^120 for chess. In 2017, Google deployed a new algorithm called AlphaGoZero which played AlphaGo over a 100-game series, winning by a score of 100-0. What was incredible, was that AlphaGoZero taught itself to play Go with no training data, in 3 days, becoming the most effective Go player of all time. The results were published in the journal Nature:

"Our results comprehensively demonstrate that a pure reinforcement learning approach is fully feasible, even in the most challenging of domains: it is possible to train to superhuman level, without human examples or guidance…"

354 | NATURE | VOL 550 | 19 OCTOBER 2017 ARTICLE
Mastering the game of Go without human knowledge

Machine Learning typically requires a large source of data and can be either 'supervised' where the operator can guide the machine to correct or incorrect decisions (often by giving it a set of data where information is tagged with values), or 'unsupervised' where the algorithm is left to make choices, potentially discovering patterns in data for itself. The goal is for the machine learning algorithm to use statistical approaches to determine certain outputs based on the input, e.g. use this image and weight data to determine if this seed is barley or wheat. It is usually much faster to train an algorithm (and requires far fewer lines of code) than to write software that will perform the same task. A machine learning algorithm is also general purpose (it can be trained to recognize wheat from barley, a dog from a muffin, or a John Deere tractor from a Caterpillar machine).

Deep reinforcement learning is a subset of machine learning that combines two methods: a neural net, and reinforcement learning. It promises to deliver results, as Google stated '…to superhuman level without human examples or guidance…'. It is beyond the scope of this report to go into detail on the technical aspects of deep reinforcement learning, but put simply, the system takes actions millions or billions of times in a simulation, while automatically identifying patterns and recording the results. It learns which patterns and choices give the best results – which means it needs a goal and some metrics to measure itself against. This learning is done in a batch mode, and can then be deployed as a 'results' table which a live system can use in practice, e.g. if my grain silos are in this state, should I move the high-quality grain from A to B, or use it to fulfill this order?

For grain organizations, AI can be deployed in a myriad of different ways. **AI should not be thought of as a specific application or piece of infrastructure, like a data warehouse.** It may be easier to consider each function of the business and ask, how could AI help in this area? Most vendors are incorporating AI into their tools, so if you are looking at image analytics for land fertility, crop damage, or seed sprouting, it will most likely be built into the product.

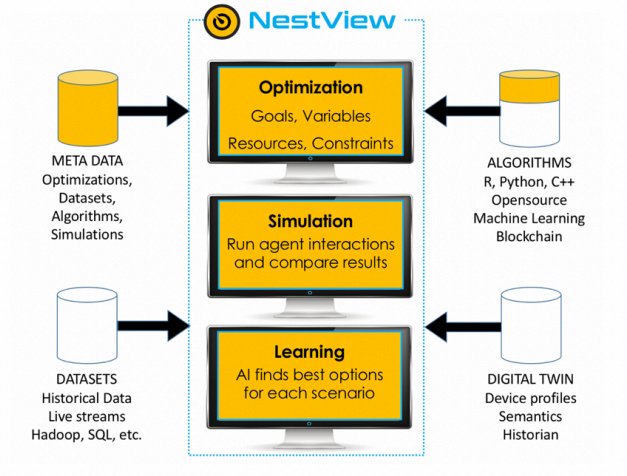
Rather than focusing on specific tasks and the value AI can bring, though, we have been examining the wider explosion of data and criteria, which added to logistics results in an exponential multiplied by an exponential for the number of choices we could make. Today's best decision may soon be suboptimal and our performance characteristics versus our competitors could suffer dramatically. There is an interesting new strategy, though, which is to take a multi-agent system and to add deep reinforcement learning.

Combining a Multi-Agent System with deep reinforcement learning we can achieve the twin goals of managing complexity, while achieving superhuman performance from what would have otherwise been an overwhelming volume of information.

Introducing SWARM Engineering

SWARM is at the forefront of the next generation of cognitive computing, combining a multi-agent system with reinforcement learning. We enable organizations to achieve superhuman performance by automatically optimizing their critical processes. We make it easier for human experts to focus on goals and desired outcomes, rather than data science, and let machines figure out how to achieve these aims via collaborative approaches.

SWARM is comprised of **NestView**, a cloud-based tool which allows for optimization modelling, simulation of the scenario, reinforcement learning, and deployment management, plus **AgentFlock** – the individual software agents that execute specific algorithms, and represent 'personalities' in the modelled system, such as a grain silo, a train, or a shipping container.



Command & control for experts to manage optimizations

Independent software agents that collaborate to solve optimizations

To clarify one very critical point; the SWARM system adapts to a goal based on your definitions of the scenario and your unique data - we do not share client information - each customer's learning and value is unique and remains the IP of the client.

We can manage single objective problems or multiple objectives - allowing the connection of multiple parties in a value chain, to minimize costs and maximize earnings for each participant, automatically balancing conflicting priorities while giving each organization the ability to model and manage their own slice of the process, while keeping their data and business rules private.

SWARM has been used to optimize grain blending to meet order specifications, and to manage supply chain logistics. Our reinforcement learning can optimize results for a season, rather than on an order-by-order basis – ensuring that daily decisions are informed by longer term goals.

While the initial results on grain blending and logistics have been impressive, SWARM is not a platform specifically built for grain. It is a general-purpose optimization platform, that could equally be used, for example, to improve feeding strategies for dairy farmers, providing customized menus for individual cows based on data from in-line milk sensors + herd and nutrition information, improving milk yields and income/ feed cost ratios. Let's not forget that more than half of the typical production costs at a dairy farm come from the feed; and more than half of the feed costs come from concentrates – much of which comes from grain.

The SWARM optimization approach can be used in any environment where decisions based on multiple variables are required in near real-time – in grain blending, feeding cattle, or managing logistics. In the next few years, it is highly likely that additional use of better quality/sampling techniques will become more commonplace, along with geospatial information about crop quality and weather – increasing the number of factors that can be taken into account when trading or blending grains. Following additional health scares, more stringent tests for certain pesticides are likely to become standard. SWARM excels at adapting as the criteria and conditions change, and as disruptions occur – this is the forte of a multi-agent system.

How to win the new grain-game

If your organization aspires to be the new leader in grain, or to maintain its leadership position in the next decade, you will undoubtedly require more data, and probably a blockchain implementation for traceability in a trustless world. You will want new ways to rapidly assimilate changing consumer demands, and the ability to meet growers' evolving requirements, plus the capacity to influence and be influenced by farmers and other stakeholders. There will be more sensors and better analytics required, new microbial approaches and bioscience, advanced sorting and filtering of grains, along with a corporate sensibility to political and societal factors on sustainability, the environment and climate.

Your supply chain must *automatically* cope with dynamic conditions and frequent disruptions. You will have to do this in a scenario where you have mor*e* data than your existing systems can handle. You will need to get comfortable with change, and if you haven't done already, you should talk to your favored System Integrator about how to manage the digital transformation.

In essence, you will need to be **flexible**, **fast**, and **forward-looking**.

Two major organizations are already using SWARM technology to optimize aspects of their global grain business. The initial results are very promising, and we continue to enhance the product based on their feedback and input from our world-class advisory team of academics and industry experts. Please contact us if you would like to learn more, or if your supply chain would like to learn by itself.

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