
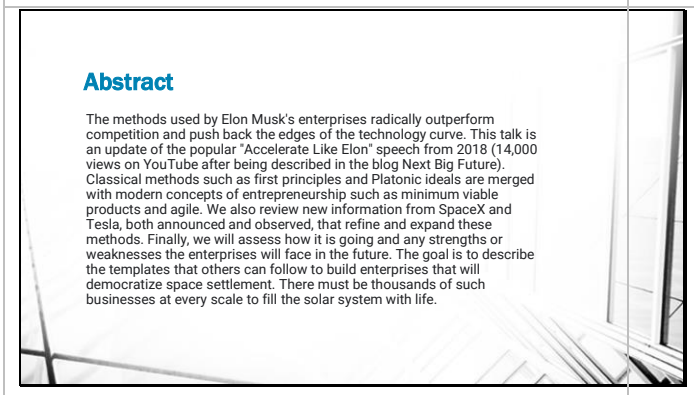



Let's start with a little context on technology revolutions before getting too deep.

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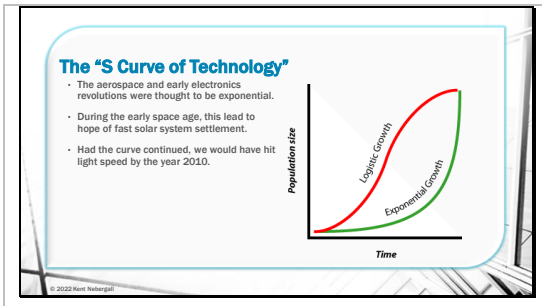
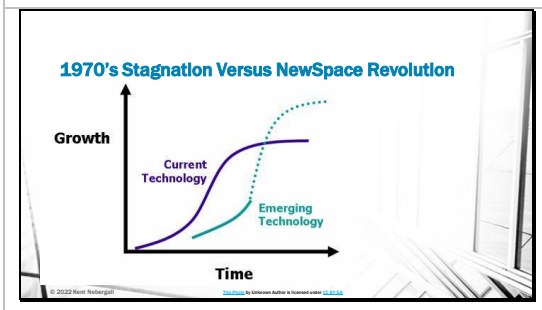
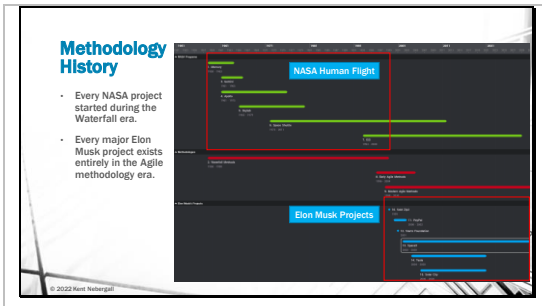
|  | Whenever a tech revolution comes, the growth rate appears exponential. There is a wave of writers and experts who assume this will go on forever. However, eventually hits a saturation point and slows dramatically, becoming the new baseload economy. This logistic curve is called the "S curve of innovation".<br>With aerospace, only 66 years separate Kitty Hawk from Apollo 11. However, it's been almost as long since then with nothing remotely comparable in crewed spaceflight. |
|  | What typically happens then is that a new company comes along with new methods that disrupt the industry. This happened on an evolutionary basis when US launch leadership passed to the Europeans, then Russians, and then Chinese. Each started with a lower cost model and made incremental advances. But then SpaceX made reusable boosters and the game changed entirely. Lets get into the details on how this happened. |




First, there are two major project management methods: Waterfall and Agile.

Waterfall and was the main system from 1958 to 1998. Things are fully designed before building, fully built before testing, and fully tested before seeing the light of day. This can be a huge waste if the product is obsolete before delivery.

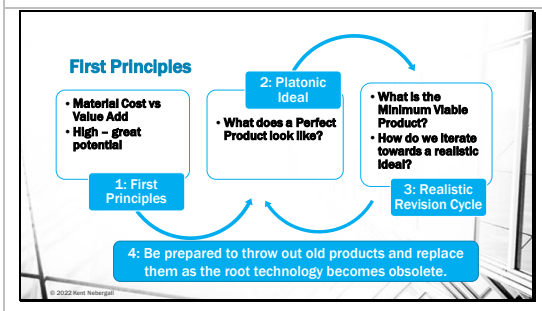
Agile was built in response to the explosion of software development needed to keep up with advances in computer hardware. It's been the lead method for high tech companies since roughly the year 2000.

All major NASA Projects from Mercury to the space station were built in the waterfall era.

Every project in Elon Musk's career all the way back to his first business, was in the Agile era. So his companies work more like Internet startups than traditional factories. The benefit is that they move as fast as technology allows. The negative is that the joke about "Elon Time" always being late is a draw-back of the methodology itself.


**Energy, invention, and Information** are the **material components of technology revolutions**. Technology revolutions are bursts of adaptation and efficiency that change the civilization from the inside out.
But broader acceptance depends on **affordability and excitement**. Getting many people doing many experiments at once generates dramatic **growth and convergence**.


Let's start with Elon's own statements and expand from there.




Elon's businesses are based on reasoning from first principles. In this case, it's the cost of the materials in a rocket or electric car in raw form versus the finished goods. If the value add is at least tenfold, it makes sense to design a new, more efficient competitor in that market. Even if your company is only a third that profitable, you can still make a lot of money in the industry.
Second, find the platonic ideal of that invention. What does the perfect car or rocket look like? How do you convert the

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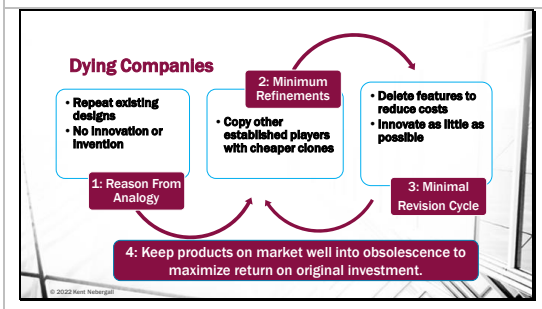
| | raw materials into something like that? By aiming high, you maximize the lead you gain once the company is big enough to pursue it.<br>Third, what is the minimum viable path to get something to market? In this case, it was the Tesla Coupe and the Falcon 1. These minimized the amount of money burned to get a product to market. In both cases, they nearly bankrupted the companies. Once you have the minimum product, though, you can iterate toward the ideal.<br>Finally, be prepared to throw out old ideas and inventions if they hinder progress. |
|  | All these methods are the exact opposite of what flatlined companies do. The developers copy old systems, which is called reasoning from analogy. Often their new product is simply a cheaper copy of an established product, known as a substitute good. They design incremental products that are only slightly better or different than earlier, and occasionally remove useful features to cut production costs. Then they keep those products on the market well after they become obsolete because they are maximizing the return on investment. . A good sign that a company is stagnating technologically is when they try to milk every dime out of an obsolete product. They also buy up small start-ups, either |

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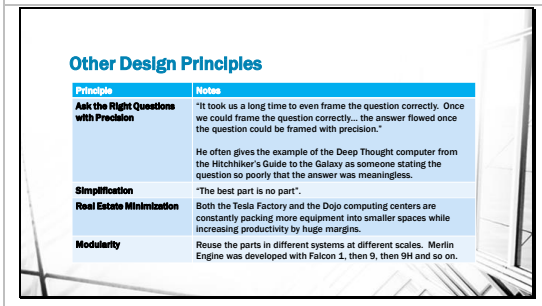
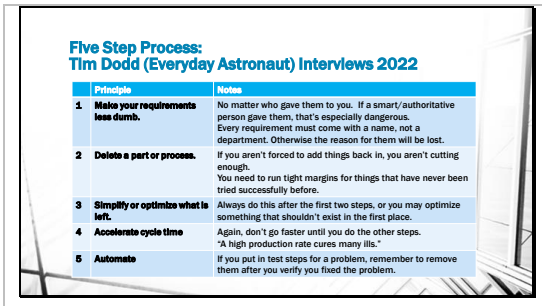
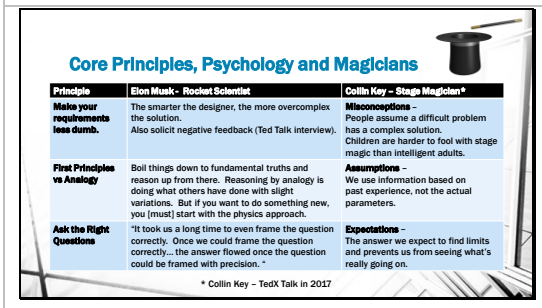
| | to ride them to success or to keep them from growing into competitors.<br>When the engineers that create the companies are replaced by MBAs and lawyers, it's time to create competition for them. |
|  | Another first principle is that of asking the right questions with precision. He said the Starship design was remade as a result of asking the right questions.<br>We see trends in simplification – the best part is no part. No part is free and can't break. Sometimes he asks engineers what they designed out of a product rather than what they added to it.<br>We also see a recent obsession with reducing the physical size of factory and computer space. This is probably to both speed operations and fit as much manufacturing capacity as possible in a given building.<br>Another key technique is modularity – they took the main engine from the Falcon One and still use a radically updated iteration of it on the Falcon rockets today. |



**Five Step Process:**
**Tim Dodd (Everyday Astronaut) Interviews 2022**

| | Principle | Notes |
|---|---|---|
| 1 | **Make your requirements less dumb.** | No matter who gave them to you. If a smart/authoritative person gave them, that's especially dangerous. Every requirement must come with a name, not a department. Otherwise the reason for them will be lost. |
| 2 | **Delete a part or process.** | If you aren't forced to add things back in, you aren't cutting enough. You need to run tight margins for things that have never been tried successfully before. |
| 3 | **Simplify or optimize what is left.** | Always do this after the first two steps, or you may optimize something that shouldn't exist in the first place. |
| 4 | **Accelerate cycle time** | Again, don't go faster until you do the other steps. "A high production rate cures many ills." |
| 5 | **Automate** | If you put in test steps for a problem, remember to remove them after you verify you fixed the problem. |

He expanded on the concepts of simplification and iteration with an interview with Tim Dodd. He gave a five step process that can be summarized as simplifying the design and assembly processes until you have to add things back in. In a separate interview, he said a high production rate cures many ills. They learn and build better frequently instead of rarely.
Then optimize what's left and automate it where possible.
I particularly like how he recognized up front that the smartest people, himself included, can have blind spots when designing anything. He has made it a point to seek negative criticism.



**Core Principles, Psychology and Magicians**

| Principle | Elon Musk - Rocket Scientist | Collin Key – Stage Magician* |
|---|---|---|
| **Make your requirements less dumb.** | The smarter the designer, the more overcomplex the solution. Also solicit negative feedback (Ted Talk interview). | **Misconceptions** – People assume a difficult problem has a complex solution. Children are harder to fool with stage magic than intelligent adults. |
| **First Principles vs Analogy** | Boil things down to fundamental truths and reason up from there. Reasoning by analogy is doing what others have done with slight variations. But if you want to do something new, you [must] start with the physics approach. | **Assumptions** – We use information based on past experience, not the actual parameters. |
| **Ask the Right Questions** | "It took us a long time to even frame the question correctly. Once we could frame the question correctly… the answer flowed once the question could be framed with precision. " | **Expectations** – The answer we expect to find limits and prevents us from seeing what's really going on. |

* Collin Key – TedX Talk in 2017

Let me pause for a minute to point out something.
A magician was giving a Ted Talk on how to figure out magic tricks. The point of knowing these methods was to better problem solve in business and science. He ended up coming to some of the same conclusions as Musk in terms of asking the right questions from first principles and with humility and simplicity.
The goal is to get engineers to see the illusions before them and come up with better, clearer solutions than their competition. Magic tricks appear magical because they take advantage of the audience reasoning from analogy when they see something. The hardest to fool

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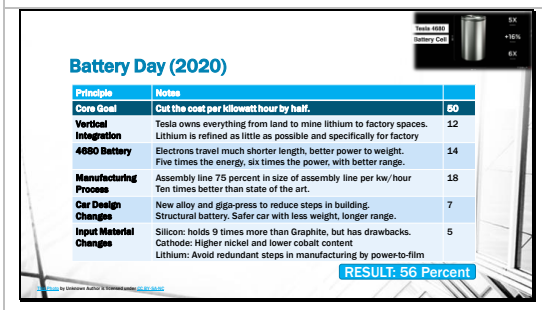
| | with magic tricks are children who don't have the reason from analogy scripts written in their heads yet. The intellectuals are so over-scripted that they are the easiest to fool. As the magician pointed out, the answer we expect to find prevents us from seeing what's really going on.<br><br>Carl Dunker – candlestick test<br>Functional fixedness – people see objects only in the way originally intended.<br>https://youtu.be/tEPEHpgK09Q |
|  | On Battery Day a couple years back, we got an insight into simplification of processes for the new Tesla batteries. They had a goal to optimize one parameter of the batteries by cutting the cost per kilowatt by half. In the end, they not only exceeded that goal but met many others in terms of weight, range, cost, and assembly line capacity.<br>Note that each major revision did not singly account for the majority of the shift, but when the benefits of each change were stacked together, they exceeded the target. Starship is similarly being optimized with Raptor engine development.<br>Note also we see more vertical integration, or a company that makes all its own subcomponents. SpaceX owns its own test sites so it doesn't have to wait in line for government rocket test stands. It makes its own avionics and most sub- |

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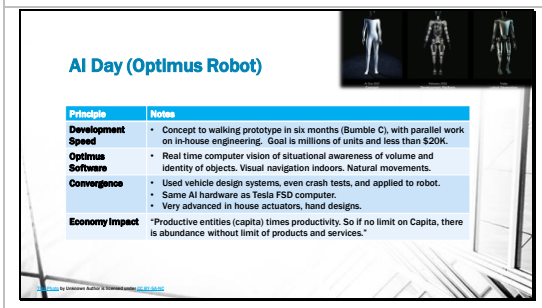
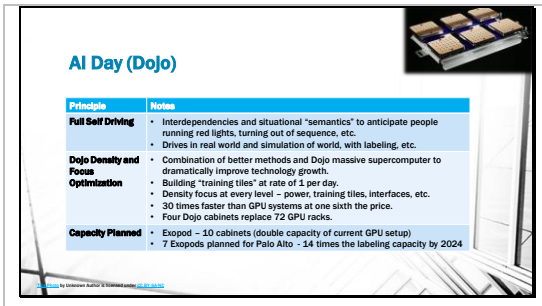
| | assemblies. Everything is made exactly as they need it and is perfectly suited to task. |
|  | Now on to the Optimus robot plans. The software for full self driving does a lot with situational awareness and goal seeking that is also useful in making a humanoid robot that can walk around a home or factory. They even used the automotive crash test software to make a robot that could fall down and get back up again without damage. The goal is to make millions of robots for under $20 thousand each with deliveries starting in three years. This has massive implications for the manual labor market. Note also they started with a platonic ideal concept and pushed each test version as close as they practically could. |



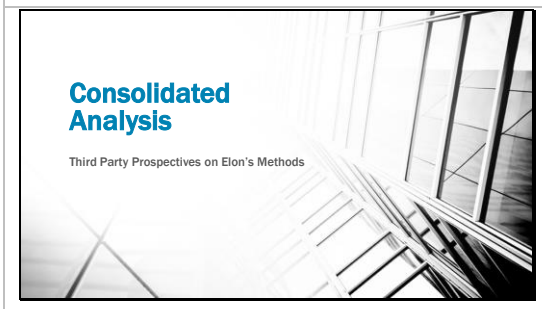

Speaking of AI day, the Dojo or central computer that pulls the video from every Tesla on the road and adds it to a huge artificial intelligence database is growing dramatically each year. It's working out all those little things we take for granted like people crossing intersections out of turn - what they are calling the "Semantics" of driving.

We do this heuristic reasoning but we don't even realize it. The semantics would have been wired into their years of experience and expectations.

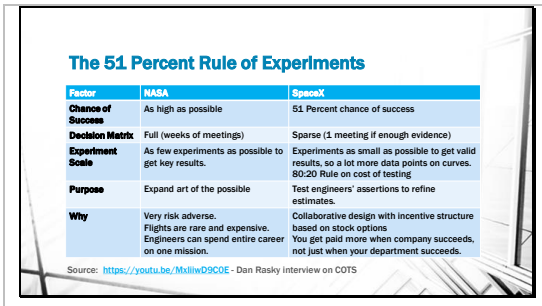
That said, even Tesla is having a massive problem with the semantics of full self driving. I suspect the level of computing that Tesla is having to use will start scaring off competition rather than pathfinding for them.

The advanced Dojo under construction has 14 times the capacity of the current system and will be built out in the next few years. This overlaps with the development and release of the Optimus robot. How much of that AI will be indoor semantics of household chores and factory work versus full self driving is an open question.


Here are some quotes from the recent Jay Leno interview.
Patents are useless if you are leading so fast no one can catch up with your innovations.
Something unsaid here is that you can give away enough intellectual property to make your products part of a broader market, which extends your sales rather than hindering them. Someone gets a major automotive brand electric car, but then aspires to get a Tesla later. It also increases the number of charging stations beyond what one company could sustain.
He also discusses the convergence between automotive and aerospace engineering to benefit both.

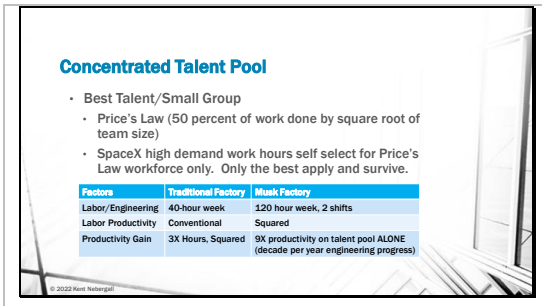



Let's move on to some Third Party analysis of Elon's methods.




This particular analysis is extracted from talks by Dan Rasky – a NASA engineer who was embedded with SpaceX as part of the Dragon Cargo program. He was amazed at how fast SpaceX innovated in part because they did the minimum amount of planning for experiments but did WAY more of them than NASA. As a result, they got a lot more data points for heat shields much faster. SpaceX then built a thermal protection system factory in 9 months that exceeded the best in the world. And that was for Cargo Dragon. Crew Dragon and Starship tiles are even more advanced.

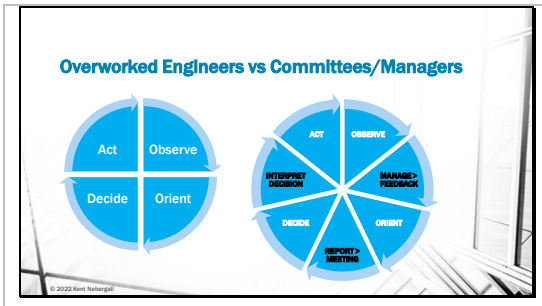

So just taking the two principles from the analysis and graphing them together, we see that for every hour or year that NASA and SpaceX do the same thing, the gap grows dramatically in both cumulative hours and cost disadvantages to NASA. This is already far too great for NASA to catch up, and NASA is the best funded space program in the world.




As for labor and engineering talent, Elon Musk has intentionally set very high bars in terms of hours worked and the quality required. This may have been partially an adaptation to both companies nearly going bankrupt and having to push things so hard during that crisis at both SpaceX and Tesla. But he kept the pace up after the crisis. And now, only the most ambitious and hard working talent works for Musk.

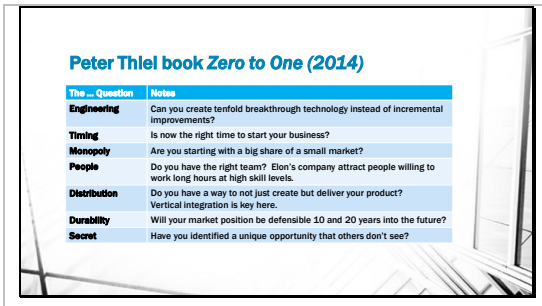
There is a concept called Prices law that states that in any activity half the productivity is done by the square root of the team size. For a massive operation like a factory, that can result in huge headcount for minimal results.

By setting the bar and reputation so high, only the square of the total talent pool in engineering end up working for Musk. Less devoted or talented people know they will eventually get fired at SpaceX, so they don't even apply. It's a very clever strategy in a sense, though it may have been discovered by accident.

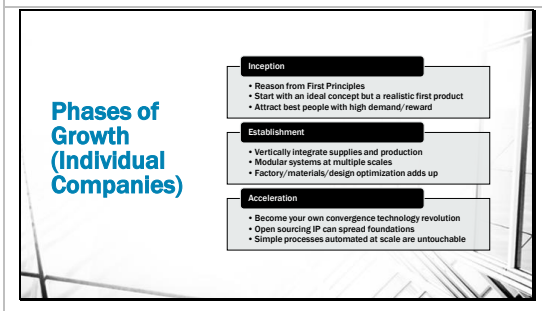



OODA, or Observe, Orient, Decide, Act, is a method designed for fighter pilots. The advantage of engineers working another 20 hours a week is that they are basically operating with the productivity of two people. They are not stuck in meetings or managing and interpreting feedback across larger teams. Since the observation and reaction loops in each engineering mind are tightened, the value of each engineer explodes in another dimension besides Price's Law. Each SpaceX or Tesla engineer works more like a fighter pilot and less like a bus driver.

When Bell Labs was the world leader in technology in the mid Twentieth Century, they had a similar attitude. They told employees that their pay was based on 40 hours a week, but their promotions and bonuses were based on what they did in the other 80 hours. Consequently, employees who were ambitious also worked longer hours, making hard work a primary factor in promotion. That may sound obvious, but we see many ambitious lazy people in large organizations.




Peter Thiel is friends with Elon Musk all the way back to PayPal. He writes glowingly of Elon in the book entrepreneurial guidebook Zero to One from 2014. he has this analysis of Tesla in particular where he calls each aspect a series of questions. The Engineering question is can your new technology be a tenfold breakthrough?
There are questions of timing, people, distribution networks, and so on. His point is that if you can answer yes to all these questions, your business concept has a much better chance of success.




So finally, a consolidation of the rules. I'm breaking these into three phases you'll also see at tomorrow's talk on space independence. We have rules for starting a company, establishing it, and accelerating its progress. Each set of rules is clean, scientific, and optimized for speed and simplicity.

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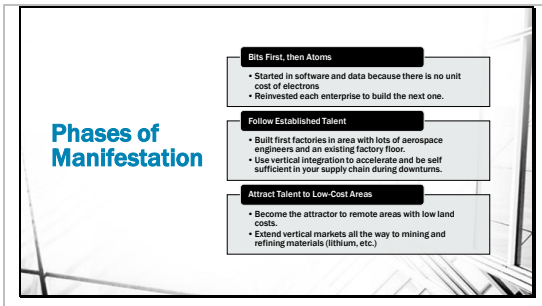
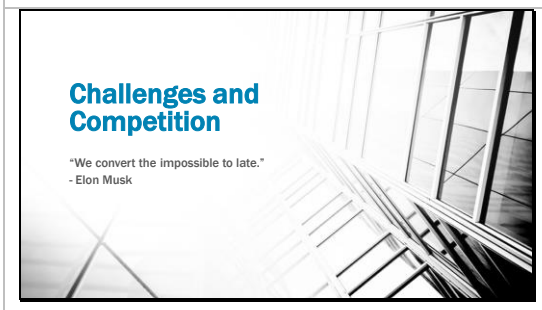
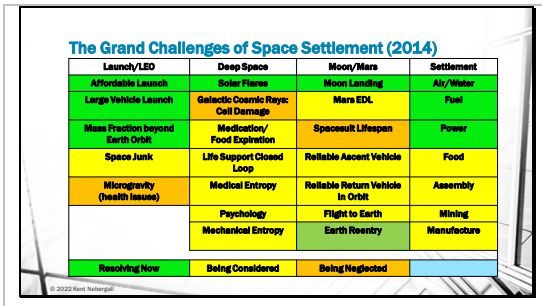
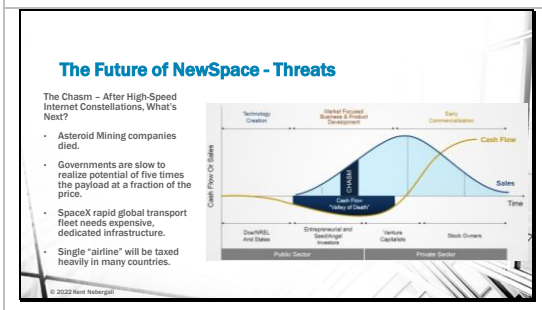
|  | Let's extend this to Elon's whole life in a nutshell. We have a life where he started with developing data systems before moving onto building with physical materials. His early companies were Internet systems that made enough money that he could later reinvest in manufacturing. Also, he originally built systems in areas with lots of local talent but high land prices. He then relocated when he was big enough to attract talent to remote areas with low land costs, both for factories and employee housing. |
|  | Finally, lets look at some challenges ahead. |



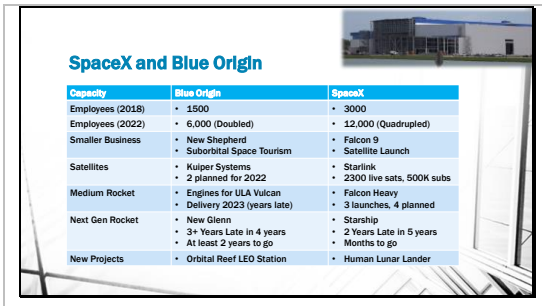

This is my grand challenges of space settlement chart. SpaceX has pioneered the challenges shown in green. However, there are still lots of barriers to space settlement they aren't addressing. Having a good surface spacesuit or keeping medications from expiring must also be resolved.

This is the first weakness of SpaceX – not having fully vertical integration of all necessary elements.

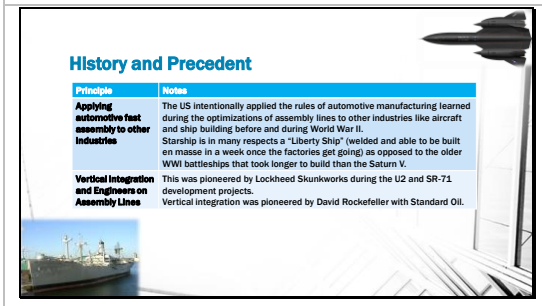
For example, what good is a moon landing if the spacesuits are still years away from delivery?



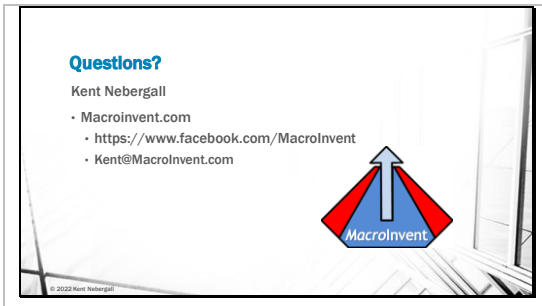

There is also the matter of trying to dramatically expand the market for launch services. I suspect fast point-to-point travel isn't going to be as popular a concept as it was before Covid. Asteroid mining companies died out. So that leaves Starlink which should be good enough. It's projected to make $14 billion, which is more than all of NASA's space budget.




Here is a comparison with Blue Origin. Blue Origin has doubled in staff but SpaceX has quadrupled over the same four years. Starlink is live with a million terminals and half a million subscribers. Everything Blue Origin is doing other than New Shepherd is still pending.




One last point – history does repeat. The application of automotive technology to other industries to accelerate them was done for US manufacturing in the World War II ramp up. And the principles of embedding the engineers in the assembly line and vertical integration date back to Lockheed Martin's Skunk Works, where the SR-71 was designed and built. So very good company.
If you want one last illustration, think of the Saturn V as a World War I battleship and SpaceX Starship as a World War II Liberty Ship. I'll probably give a talk on that one of these years, but it's a very on-target metaphor.




Thanks! Any questions?