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Thinking like Elon Musk: what helps to achieve success in rocketry and not only

The term “price tag shock” is not in the usual vocabulary of most Silicon Valley entrepreneurs. But this is exactly what Elon Musk experienced when he bought rockets for a spacecraft to Mars. Currently, billionaire Elon Musk is perhaps the most popular, inspiring and at the same time controversial hero from the list of the richest people on the planet. After launching and selling two successful internet businesses, why would he need to build rockets? How does he run Space X? Is there some connection between the way he thinks and the way innovators in rocketry and space exploration reason? Former NASA engineer Ozan Varol tried to answer these and other questions in his book “Think like Elon Musk and other simple strategies for a giant leap in life and work”. We are publishing several excerpts from the Russian translation of this book published by the BOMBORA publishing house.

The term “price tag shock” is not in the usual vocabulary of most Silicon Valley entrepreneurs. But this is exactly what Elon Musk experienced when he bought rockets for a spacecraft to Mars. On the American market, the price for two missiles was a whopping $ 130 million.

And this is only for the launch vehicle, without the spacecraft itself with its instrument compartment. Therefore, Musk decided to try his luck in Russia. He went there several times to buy decommissioned ICBMs (without nuclear warheads). His meetings full of vodka with Russian officials every two minutes were interrupted by toasts (To space! To America! To America in space!). But for Musk, the cheers turned to ridicule when the Russians told him that each missile would cost $ 20 million. Despite the fact that Musk was rich, the price made it too expensive to set up his space company. He realized that he needed to come up with something else.

This native of South Africa has entered a period of change since childhood, subjugating one industry after another to his will. At twelve, he wrote and sold his first video game. At seventeen he emigrated to Canada, and from there to the United States, where he studied physics and business at the University of Pennsylvania. He then dropped out of graduate school at Stanford to found Zip2, one of the first providers of city online travel guides, with his brother Kimball. With no money to live on his own, Musk slept on a mattress in his office and showered at the local Youth Christian Association.

In 1999, when he was twenty-eight years old, he sold the Zip2 to Compaq, instantly becoming a multimillionaire. He used his profits from Zip2 to create X.com, an online bank that was later renamed PayPal. By selling PayPal to eBay, Musk received $ 165 million.

A few months before the closing of the deal, Musk was already on the beach in Rio de Janeiro. But he wasn't about to retire or flip through Dan Brown's latest novel. No, Musk was reading a book on the basics of rocket propulsion on the beach. The PayPal guy wanted to be a rocket lover.

During its heyday, the space industry was at the forefront of innovation. But when Musk thought about getting into the business, aerospace companies were hopelessly stuck in the past. Space is a rare technology industry that violates Moore's Law, a principle named after Intel co-founder Gordon

Moore. According to this principle, computing power develops exponentially and doubles every two years. A computer that could have filled an entire room in the 1970s now fits in your pocket and has a lot more processing power. But rocketry goes against this rule. “We sleep well knowing that next year the software will be better than this,” Musk explains, “but the cost of the rockets is only increasing every year.”

Musk was not the first to notice this trend. But he was one of the first to do something about it. He launched SpaceX - short for Space Exploration Technologies - with the provocative goal of colonizing Mars and transforming humanity into an interplanetary species. But Musk's finances were not enough to buy the missiles on the American or Russian markets. He attracted venture capitalists, but it was difficult to convince them to fund this project. “Space is too uncomfortable for earth venture capitalists,” Musk explained. He refused to let his friends invest because he believed the company only had a 10 percent chance of success.

Musk was about to give up when he realized that his approach was deeply flawed. Instead of leaving, he decided to return to the fundamentals ...

The same qualities that make knowledge a virtue can turn it into a vice. Knowledge forms. Knowledge informs. It creates frames, labels, categories and prisms through which we look at the world. It acts like a fog

, the Instagram filter and the poetic structure under which we live our lives. As you know, these structures are difficult to mirror, and for a good reason: they are useful. They provide us with cognitive shortcuts for understanding the world. They make us more efficient and productive.

The standard carries tremendous strength, even in advanced industries such as rocketry. This is called path addiction: what we have done in the past affects what we do in the future.

Here's an example. The width of the engines that propel the spacecraft - one of the most complex machines ever created by mankind - was determined over two thousand years ago by an ancient Roman road engineer3. Yes, you read that correctly. The engines were 4 feet 8.5 inches (or 1,435 millimeters) wide, because that was the track gauge from Utah to Florida. In turn, the width of this railroad track was based on the width of the English tram lines. And the width of the tram lines was based on the width of the roads built by the Romans: 4 feet 8.5 inches.

The keyboard layout most of us use is deliberately designed to be ineffective. Before her, typewriters would jam if you type too fast. The qwerty layout (named after the first six letters on the keyboard) was created specifically to slow down the typing speed to prevent mechanical key locking. In addition, the letters that make up the word typewriter have been deliberately placed on the top line so that the salesperson can demonstrate how the machine works by quickly typing in the brand name (try it!).

Research shows that as we age, we become more dependent on rules. Life goes into rhythm. The days begin to repeat themselves. We mechanically repeat the same worn out clichés, do the same work, talk to the same people, watch the same shows, and buy the same product lines. This is an adventure book where you choose the course of events, but it always has the same ending.

The deeper the footprints in the snow, the more difficult it is to avoid them. The set execution method can hide the output. "When the road is built," wrote Robert Louis Stevenson, "amazingly, it absorbs the flow of people, as every year more and more people pass along it, and new ones come to fix it, perpetuate and keep it alive."

We treat our processes and procedures as roads that absorb the flow of people. A 2011 survey of over 100 US and European companies found that “over the past 15 years, the number of procedures,

vertical layers, interface structures, coordinating bodies and decision-making permits required in each of these firms has increased from about 50% up to 350% ”.

You cannot borrow someone else's path to success. You can't quit Reed College, take calligraphy courses, indulge in LSD, get into Zen Buddhism, open a store in your parents' garage, and think you're the founder of a new Apple. As Warren Buffet put it, “The five most dangerous words in business are 'but everyone does it.' The “monkey sees, the monkey does” approach creates a race in a crowded center - with far fewer competitors on the outskirts. “When you try to improve existing methods,” says Astro Teller, head X, Google’s ambitious project factory, “you are competing in intelligence with everyone before you. And this is not the best competition in which to participate ”.

Musk first entered this competition when he started buying rockets. His thinking was infected with what others had done in the past. Therefore, he decided to return to his studies in physics and reasoning from the first principles.

And a few more words about Musk before I continue. I have found that his name engenders unusually polarizing judgments. Some consider him a real Iron Man, the most interesting person in the world, a sincere entrepreneur who, more than anyone else, tries to move humanity forward. Others describe him as a Silicon Valley dilettante whose campaigns to save the world all too often threaten to turn into disaster, and a showman smugly making up stories about the future on his Twitter (while getting himself into trouble with breaking the law).

I do not belong to any of these camps. I think we are doing Mask a disservice by judging or praising him. But we will be doing ourselves a disservice if we fail to learn from the way he used first-principles thinking to turn many industries around, making his dreams of stars a reality.

For Musk, using fundamentals meant starting with the laws of physics and asking yourself what it takes to launch a rocket into space. He decomposed the rocket into its smallest subcomponents - its fundamental raw materials. He asked himself: “What is the rocket made of? Aerospace grade aluminum alloys plus some titanium, copper and carbon fiber. And then I found out what the cost of these ma

materials on the market. It turned out that the cost of materials is about 2% of the price of a finished rocket - this is an insane ratio. "

The price range is driven, at least in part, by the culture of outsourcing in the space industry. Aerospace companies outsource their services to subcontractors who outsource them to subcontractors. "You have to go down four or five levels," Musk explained, "to find someone who really does something useful: cuts metal and forms atoms."

So Musk decided to cut the metal with his own hands and build the next generation of rockets from scratch. Walk through the halls of the SpaceX factories and you will notice that they do everything: from welding titanium to creating on-board computers. Roughly 80% of all SpaceX rocket components are manufactured in-house. This gives her more control over cost, quality and pace of work. With a minimum of external suppliers, SpaceX can move from idea to implementation at record speed.

Here's an example of the benefits of in-house manufacturing. Tom Mueller, SpaceX's engine technology director, once asked a supplier to build an engine valve. “I was told it would cost a quarter of a million dollars and it would take a year,” Mueller recalls. He replied: "No, we need it by the summer for much less money." “I wish you luck,” said the seller and left. As a result, Mueller's team built the valve themselves and at a low cost. When the salesperson called Müller in the summer to ask if he still needed the valve, Müller replied, "We designed it, assembled it, prepared it and are going to launch it." Mike Khorkachuk, who oversees NASA's ties with SpaceX, was surprised to see

how Mueller's approach permeated the entire company: “It was unique because I almost never heard NASA engineers talk about part cost when making deals and decisions.”

Also, SpaceX has shown a creative approach to sourcing raw materials. One employee bought a theodolite, missile tracking and alignment equipment for $ 25,000 on eBay, finding the new modification too expensive. Another employee mined a giant piece of metal from an industrial dump to make a nose cone protecting the rocket. Cheap used components can perform just as well as new expensive ones if properly tested and prepared. In addition, SpaceX has borrowed components from other industries. Instead of using expensive hardware to make the hatch handles, the company used latch parts for the toilet stalls. Instead of developing expensive seat belts for astronauts, the company used race car belts, which are more comfortable and cheaper. Instead of specialized on-board computers costing up to a million dollars, SpaceX's first rocket installed the same system that was used in the $ 5,000 ATM. Compared to the total cost of the spacecraft, these costs may not seem as significant, but “when you add them all together, absolutely everything changes,” says Musk.

Many of these cheaper components are good because they are more reliable. Take, for example, the fuel injectors used in SpaceX rockets. Most rocket motors use a showerhead design in which multiple nozzles spray fuel into the rocket's combustion chamber. SpaceX uses what is called a pin motor, with only one injector that looks like a garden hose nozzle. Also, an inexpensive pin is less likely to lead to unstable combustion, which can cause what rocket scientists call a quick, unplanned dismantling, and laymen - an explosion.

Thinking from the ground up has prompted SpaceX to question yet another assumption deeply rooted in rocket science. Most of the rockets that launched spacecraft into space have not been reused for decades. They could sink in the ocean or burn up in the atmosphere, delivering cargo into orbit, and a new rocket had to be built. It was the space analogue of setting fire to an airplane at the end of each flight. The cost of a modern rocket is roughly comparable to a Boeing 737, but flying the 737 is much cheaper because planes, unlike rockets, fly over and over again. The solution is obvious: you need to do the same with missiles ...

At SpaceX, idealism and pragmatism are represented by two leaders. Musk, with his constant tweets of breakthroughs, is the idealist frontman and lead vocalist for the group. However, behind the scenes, someone is undertaking an extremely difficult task: taking Musk's crazy ideas and turning them into business. Her name is Gwynn Shotwell. She is the sober president and chief operating officer of SpaceX. Shotwell decided to become an engineer when she attended a Society of Women Engineers event as a teenager. During one of her performances, she was stunned by a mechanical engineer who owned a company that developed environmentally friendly building materials. As a result, sleep

Ker finally conquered Shotwell and inspired her to engage in engineering.

Now, more than three decades later, Shotwell stands at the pinnacle of the engineering world, in charge of SpaceX's day-to-day operations. Among other things, it serves as a “bridge between Elon and the employees,” says SpaceX's Hans Königsmann. Elon says, "Let's go to Mars," and she says, "Okay, but what do we need to actually get to Mars?" To fund the company's extraordinary dream of colonizing Mars, Shotwell travels the globe in search of conventional opportunities to deliver commercial cargo into orbit. When SpaceX was still in its infancy, it managed to win billions of dollars in contracts with satellite operators. These contracts continue to cover costs while SpaceX works on its breakthrough trip to Mars ...

In the movie Apollo 13, there is a scene in which a group of rocket scientists learn that on the way to the moon, the spacecraft was damaged by an explosion of an oxygen cylinder. The power of the ship is not enough, and the days of the astronauts are numbered. Scientists at the Mission Control Center

must find a way to bring them back to Earth before they run out of fuel. “We haven't lost Americans in space yet. And we won't, I promise, ”growls Flight Director Gene Krantz, before adding the punchline:“ Failure is not acceptable. ” Krantz later wrote an autobiography of the same name, the slogan of which he described as “the rule by which we lived” at the Mission Control Center8. NASA gift shops took advantage of this phrase and began selling T-shirts that read: "Failure is unacceptable."

This mantra makes sense when human lives are at stake. But it cannot describe all rocketry. There is no such thing as a rocket taking off without any risk. You will still have to face physics. You may be aware of potential glitches, but the space banana peel will always be nearby. When you create a controlled explosion in a machine as complex as a rocket, accidents are inevitable.

If we were not mistaken, we would never have taken the first steps in outer space. Doing something innovative takes risks, and risk means failure - at least in some cases. “At NASA, they foolishly believe that you can't be wrong,” says Elon Musk. “But you can make mistakes here [at SpaceX]. If you have no mistakes, then you are not creative enough ”. Only when we reach the unknown and conquer new heights - and at the same time we break everything - do we move forward.

The same applies to scientists working in the laboratory. Without the ability to be wrong, they will never prove they are right. Some of their experiments were successful, while others were not. If things don't go as planned, the hypothesis is wrong, after which they can change it, try a different approach, or abandon it altogether. British inventor James Dyson calls the life of an inventor “one of the failures”. It took Dyson 15 years and 5126 prototypes to make his revolutionary bagless vacuum cleaner work.

Several attempts by Einstein to prove the formula E = mc2 failed. In some areas, such as pharmaceutical development, the average error rate is over 90%. If these scientists lived by the “no failure” rule, they would be crippled by shame, embarrassment, and self-loathing. A moratorium on failure is a moratorium on progress.

Third time lucky. This is exactly what SpaceX employees said to themselves in August 2008, while awaiting the third launch of their first Falcon 1 rocket. At that time, observers were already busy putting together an obituary of Musk's "vain" project. Musk invested $ 100 million from his own funds when he founded SpaceX - enough for three launches. But the first two failed. Falcon 1's maiden flight in 2006 lasted only thirty seconds.

The fuel leak caused an unexpected fire in the engine, shutting it down and sending the rocket into the Pacific Ocean. “The first launch was unfortunate,” recalls SpaceX vice president Hans Koenigsman. “We have learned many things that we did wrong before, and learning sometimes hurts.” The leak was caused by corrosion around the aluminum union nut that secured the fuel line. To remedy this problem, the company replaced the aluminum fasteners with cheaper, more reliable stainless steel hardware.

A year later, in 2007, the Falcon 1 rocket returned to the launch pad for a second attempt. This flight lasted 7.5 minutes longer, but the rocket never reached orbit due to the fact that the engine stopped receiving fuel. The failure “was no longer as painful as the first time,” says Königsman. - The device flew quite far and although it did not go into orbit, but at least disappeared from view. Despite the failure, most of the mission's objectives were met: Falcon 1 took off and reached space. The malfunctions that caused the accompanying problems were quickly diagnosed and corrected.

The third attempt was made

that a year later. Although 2008 was a bad year for many people, Musk says it was the worst year of his life. His electric car company Tesla was on the verge of bankruptcy, the world was plunged into

financial crisis, and Musk himself had just gotten divorced. He borrowed money from his friends to pay the rent. He invested most of his fortune in SpaceX, and two Falcon 1 failures drained his investment. All that was left was at the launch site, awaiting a dangerous flight.

On the third try, the Falcon 1 came to life with a crash and took off, taking with it three satellites and the ashes of James Duane, who played Scotty in the original Star Trek series (remember his phrase: “I'm squeezing all the juice out of her, Captain!”). He soared into the sky, making a perfect flight of his first stage (recall that rockets are made up of stages standing on top of each other). After the first stage launched the craft into space, it was time to separate the stages - the most important stage in flight, when the first stage is disconnected, having used up all the fuel. It is then that the second stage comes into play, which allows the spacecraft to be put into orbit. The steps were divided as planned, but the first phase was not completed. After the separation, the first stage "caught up" with the second and hit it. “We've driven ourselves to a dead end,” recalls SpaceX President Gwynne Shotwell. "It looked like a Monty Python sketch."

The problem was overlooked during testing, since SpaceX did not follow the principle of "test as if you are already flying." The engine pressure that led to the unexpected increase in thrust was lower than the ambient pressure at SpaceX's ground test facility, so it was difficult to spot. But in the vacuum of space, the same pressure led to collision and disaster.

For SpaceX, this setback was the third blow. Hundreds of shocked SpaceX employees, who worked seventy to eighty hours a week for six years, awaited word from their boss at SpaceX's Hawthorne, California plant. “Everyone in the building was desperate,” recalls former SpaceX employee Dolly Singh. Musk walked out of the control center, from where he directed the flight along with the senior engineers. He walked past the press to address his troops, who had just lost their third major battle in a row.

Musk said everyone knew the project was going to be difficult. He recalled that in the end they are engaged in rocketry. Their rockets have reached space, doing what not all major countries have succeeded in doing. Suddenly, surprise: Musk announced that he had secured an investment that would allow SpaceX to make two more launches. This was not the end. As Shane Snow describes it, Musk told his troops that they “need to figure out what didn't work and build a new missile with those mistakes in mind. And then, using the experience gained, another one. And continue this way until there is a rocket on which you can fly to Mars. "

It was time to get back to work. “Within a few moments,” Singh recalls, “everyone went from despair and defeatism to a decisive attitude, people began to focus on moving forward rather than looking back.” The likely culprit for the failure was identified within hours. “After watching the video, I thought, 'We can pinpoint the problem,'” explains Shotwell. The solution was simple: increase the delay before stage separation to prevent collision. “Between the third and fourth flights, we only changed that, and nothing else,” says Königsman.

Less than two months later, SpaceX returned to the launch pad. “Everything depended on this launch,” recalls Musk's fellow student Adeo Ressi. “Elon lost all his money, but not only his fortune, but also his reputation was at stake.” If the fourth launch had failed, “it would have been over. This would be a case study for Harvard Business School: a rich guy goes into the rocket business and loses everything. ”

But the launch did not fail. On September 28, 2008, the Falcon 1 rocket left the atmosphere and made history as the world's first private spacecraft to reach Earth's orbit. SpaceX's record of zero out of three launches with Falcon 1 came close to killing the company, but those early failures were a sobering test of reality. They didn't let the company get complacent. When these setbacks finally gave way to success, SpaceX fell victim to its own arrogance. In June 2015, a Falcon 9 rocket

exploded en route to the International Space Station. Musk put all the blame for this on the company's successful track record. “For the first time in seven years, we failed,” he said, “and during that time the company has become a little overconfident.”

How to use close discrepancies to control what is happening

In aviation jargon, a close divergence is an incident that could have turned into a disaster. A close divergence means you are close, but not close enough to collide. This means you're in luck.

We generally ignore close discrepancies at both the control room and

meeting of the board of directors. Research shows that nearly all close differences are disguised as successes because they did not affect the bottom line47. The plane doesn't crash, business doesn't crash, and the economy remains stable. “All is well that ends well” or “No body - no work,” we say to ourselves and continue to live our life ...

The next time you want to bathe in the glory of your success while admiring the scoreboard, stop for a moment. Ask yourself what is wrong with this success? What role did luck, opportunity, and privilege play? What can be learned from this? If we do not ask these questions, luck will eventually take its toll and dangerous encounters will overtake us.

As you may have noticed, these questions are no different from those suggested in the previous chapter on failure. Asking the same questions and following the same process no matter what happens is one way to take your mind off the result and pay attention to what matters most: the decisions you make ...

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