Has Engineering changed since the 1620's?

The Lessons Today's Project Managers Can Learn from a 17th Century Fiasco

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Bold, aggressive, state-of-the-art, commissioned by King Gustave Adolf II of Sweden, the *Vasa* was designed to be one of the premier warships of the 17th century. Unfortunately, the ship sank 2 hours after its initial launch in an eight-knot wind. "How could such a thing happen?" you might ask. In hindsight, with the help of modern mathematics, physics, and nautical engineering, it's easy to understand where the design went wrong. Yet the key issue was not the technology, it was – the leaders of the project failed to shoulder their personal responsibility to the project because they allowed poor decisions to be made and did nothing to fix it.

Has engineering and the process of building something really changed since the 17th century? Are we capable of making these mistakes as well? This article argues that many of the mistakes learned from this waterlogged disaster are still true today. While the science of individual engineering fields has progressed a great deal, the dynamics in running projects and motivating a team to drive difficult projects have not changed. Human error and inadequacies can certainly doom a project as easily today as it did in the 1620s.

My interest in all of this came because my flight home from Stockholm was three hours away and I needed something to fill the time. My host pointed to a huge green building saying "In there is a seventeenth century sunken ship that has been restored and it is worth seeing." I wandered over to see the Vasa and was treated to the story of an engineering failure dating back to the 1620's. It certainly made me feel like the problems we are seeing in today's large projects are no different than the problems seen in 1620 when they were guessing about how to build ships.

To get a more detailed explanation of why the Vasa tipped over so quickly I bought a book[1] in the museum shop dedicated to that topic. As I sat on the plane reading the book, the description of the people, the decisions, and the dynamics of the project all confirmed what I saw at the museum: the Vasa sank in 1628 due to management failure, not technical failure. While the science of individual engineering fields has progressed a great deal, it seems that actually running projects, and the dynamics involved in getting mere mortals to drive difficult projects has not changed as much as I would have thought. It seems, indeed, that the frailty of human beings can sink a project as easily today as it did in the 1620's.

We engineers - - be it software, hardware, mechanical – are fond of expounding upon the uniqueness of our craft. We love to discuss the fact that "never before" has anyone built things of such great complexity with so little comprehension and documentation of the underlying science that could make building software, for example, a more controllable event. This is particularly true of software, where the underlying theories of building large systems have not been developed yet. In the 1620's, engineers and craftsman struggled with building ships in much the same way we struggle with building software today. And, when they failed, they

[1] Why Vasa Capsized?, By Curt Borgenstam and Andres Sandstrom, Vasa Museum Press, Stockholm

failed for reasons that software fails today (look at the space shuttle Challenger, the Denver airport luggage system, Boston's Big Dig, or the FAA air traffic control system for modern-day examples).

So in many ways, engineering and the management of projects have not really changed very much. We may learn the underlying field, but have we developed any real science in running these projects. The Vasa was a large project, there was no science to provide proper guidelines, things changed along the way, the people involved were too weak to make good decisions or stand up for what they saw, and everyone assumed someone else would handle things. Nobody really took responsibility for the outcome. Sound familiar? To capture it properly and show the flow of this project, I would like to follow the project's course and flow, as recorded by the king's scribes and historians.

It all began in roughly 1625 when the King, Gustav II Adolf of Sweden contracted for a ship (later to be called the Vasa) to be built by Master Shipwright Henrik Hybertson. The king was in need of more ships, as he was at war with Poland and had just lost a few too many. The king contracted for several ships to be built simultaneously and wanted them quickly, so they could swiftly be put into service ("quickly" in those days meant 2-4 years). So, even in 1625 it seems that engineering projects start off behind schedule. Master Shipwright Henrik had built other ships before, so contracting him to build these ships seemed like a good decision on the part of the king. He had a seasoned veteran leading the project.

Like software in our own era, shipbuilding in the 1620's was a learned craft, not a science. To learn the craft, one worked with others who knew the rules of thumb that resulted in ships that worked. Today we know that in shipbuilding there is a relationship between the width of the ship, its height, and its ballast. We know that when in the right balance a stable ship can be built. If the balance is wrong, the ship will tip over too soon. Today, we would use terms like center of gravity, center of displacement, center of buoyancy, and meta-center to calculate the exact requirements for building a ship that will be stable in the needed conditions. The people building the Vasa had no such science. In 1620 craftsmen just sort of knew what it took to build a good ship, had done it before, but really did not know all of the items that we today take for granted. In 1620 one relied on people who really seemed to understand, more than on a methodology that would guarantee an outcome. It was experienced chief engineers who were the key to the project. Sound eerily familiar?

Wooden ships in 1620 were built with hand labor from trees that were specifically chosen for the various needs of a particular ship. For example, bends in the tree often were chosen to match bends in the needed boards so that the corner brackets were stronger. The lumber was usually ordered a year or more in advance of the work starting. One might say that once the architecture was laid down, there were real limits to what could be changed. The basic design of the boat was thus often locked down very early at the time the lumber was ordered.

Then, as today, ships are built from the bottom up, so the basic framework - or architecture - is even more strongly established when the first planks are laid down. The length and width of a ship are the first decisions and are then reflected in how the very first boards are arranged. Initially, the Vasa was a 108 foot long ship with a width of 22 feet. The initial dimensions seem to be reasonable for the practice of the day. At first, the project progressed uneventfully and there was no way to know if the original design was a good design or a bad design, as there seem to have been no time to write down specifications.

But, as so often happens, the requirements changed long after the project got started. You might say "feature creep" came into the project and nobody seemed to be able to stem the tide. It started with the king's desire to increase the size of the ship sometime in 1627; years after the building had begun. In a letter to Master

Shipwright Henrik the king indicated that he preferred a ship that was 135 feet long and that could carry many more cannons then the earlier design allowed. He had lost yet more ships and felt that this extra size might help in the coming wars. He was also a student of shipbuilding and felt he knew the proper dimensions for a ship. Henrik did not think he could accommodate the changes. It is easy to imagine the impact on poor Henrik, trying to satisfy a king and still build a ship that could sail. Some of the letters that were sent on the subject have been preserved, so we have a feel for the dynamics of this desired change in plans.

Henrik indicated that he did not think he could build the ship the King desired, as the foundation had been built and the project was already well under development. The King insisted that he needed the longer ship. After a few months of this dialogue Henrik caved in (I mean, saw the light) and indicated that he now thought he could come close to what the King wanted. The King gave him a concession that said he should do the best he can. As you can imagine, things went downhill from there because nobody really adjusted to the changes as they should have. Before we indict Henrik for buckling under the pressure, we must remember that a King has life and death power over people like Henrik. If he wants, the King can have your head taken off, your children sent into poverty, and all sorts of other unpleasantness. Those of us leading projects today do the same buckling at the insistence of people who have far less physical power over us.

So lesson number one seems to be the main lesson here, don't let fear cause you to do the wrong thing. If you are going to make changes, make them real changes and not, as we will see later, cosmetic changes designed to make the boss shut-up and go away. Speaking of the fear of being be-headed, as it turned out, even though the ultimate result was that the ship sank and an inquest was held immediately following the sinking of the ship, nobody was convicted of any wrongdoing or was sent to jail. So the initial fear of these kinds of displeasure may have been greater in the minds of the engineering team than the ultimate reality, something we could all do well to remember.

The real engineering problem was not making the ship longer, which they promptly undertook; the real problem was adding all the extra guns. Yes, it seems that the number of guns desired on the ship doubled as well. The increase in the number of guns caused a great deal of pain and many configurations were tried. Master Shipbuilder Henrik finally concluded, a whole new gun deck should be added to the ship to accommodate the extra guns. No ship at that time actually had two full gun decks, so Henrik was breaking new ground. Adding a deck makes the ship taller and heavier. It raised the center of gravity of the ship to an unacceptable height. Usually, when a ship is made taller it is made wider and/or ballast is added to the bottom. Ballast is the weight at the bottom of a ship that helps right the ship when it heels over. Unfortunately, for reasons we will never know, neither of the required design changes occurred and the shipbuilding proceeded full speed. So we have a major feature change with no basic architectural adjustment. *This leads us to lesson number two, if you are going to change direction, take the time to do what you think works and change the schedule.*

Henrik had built other ships and so a reasonable guess is that he was aware of some of the problems that needed attention. He did not act on those problems for reasons we will never know for sure. We cannot know for certain that he understood what needed to be done, but can only speculate that Henrick had a basic understanding because of his initial resistance and his ability to build other ships that worked well. If software projects are a modern-day indicator of what caused this lack of action, I would guess it was a direct consequence of lesson number one - fear of giving bad news got in the way. Henrik did not want to displease the king further by telling him the ship was going to be late. After all, the king had said "…the Vasa ... shall

be ready by … July 25th, and if not those responsible would be subject to His Majesty's disgrace." *Lesson number three has to be, don't let the schedule pressure cause you to lie to yourself and try to build what can't be built.* Clearly, the king (the customer, the manager, the CEO…) can want something to happen by a specific date but that does not mean it can be done. If the king really has no clothing, we should say so.

But this project had even more in common with today when it came to feature creep because many people felt they could add to the project. The King's tutor, for example, wanted the ship to reflect on the grandeur and power of the King and pushed for the ship to be made in that image. Among other things, the battery deck (the top decks on the stern of the ship) was enclosed and wooden carvings were added high up on the ship, adding to the weight of the top portion of the ship. Given that the ship was already too high, this was a somewhat smaller factor but none-the-less contributed to the overall instability of the ship and the chaos of the project. The project seemed to grow in many such areas as different parts of it grew in complexity and in weight. The project got even more out of control when Master Shipwright Henrik became ill and was bed ridden.

Henrik continued to guide the project from his sick bed, but he could not actually inspect the design or the building of the ship itself. So his guidance on the project was more second hand; he made decisions based on what others told him was occurring on the project. This can't have helped the project at all. *Lesson number 4 says that you can't build what you can't see.* Remember that the specification process was almost non-existent, so that Henrik could only get very loosely stated conclusions about what was going on. Given that he was the key decision maker, this meant his decisions were based on limited information. The guy in charge stopped looking at what was being built.

This got even worse when Henrik died and the building proceeded with Henrik's assistant Hein Jacobsson taking on new duties as Project Manager…I mean Master Shipwright. Jacobsson's experience is not known, so the exact nature of the new leadership team might well be in question. But, it does seem clear that whatever leadership existed before, it most certainly changed so that many of the players felt they did not need to communicate with other members of the team. As later events demonstrated, Jacobsson was not a strong leader nor was the team ready to follow him. With Master Shipwright Henrik no longer a factor in the project it seems that the team developed several leaders each with their own ideas. *Lesson number 5 might well be, clear lines of authority are required for any coordinated action to be successful.* This lesson becomes all the clearer as we follow the coming events of this disaster.

Everyone continued to build "with haste" to try and make the schedule. It is not clear if these folks read books on the "dreaded death march to the end of the project[2]" but one can assume that they kept the kind of hours we often see in projects that are late: long hours with a neglect of basic process. The guns that were dredged up, for example, clearly showed a lack of attention to detail and completion. The project was now maturing and moving quickly and quality was out the window.

Clearly some people were getting nervous. The Admiral in charge decided some testing was worthwhile. A few months before launch Admiral Flemming decided to test the stability of the ship - you might say he did an alpha test. After launching the ship secretly, he had thirty men run from one side of the ship to the other to see how stable the ship was. He stopped after three such runs because each time they ran across the ship it heeled over more and more, to the point where he was afraid the Vasa would actually tip over. Strangely, Master Shipwright Jacobsson was neither invited to the test nor informed of the result.

[2] A common saying in software projects today.

Each leader on the project had a different idea of how to make the ship more stable. For example, the Captain of the ship decided that less ballast was needed while the Boatswain decided that more ballast was needed. Admiral Flemming assured them, however, that "the Shipwright had built ships before and we should not be worried." At the inquiry after the disaster, new Master Shipwright Jacobsson had said he would have added more ballast had he known of the test and been ordered to do so. In the end, they all ignored the test results. Why? Who did they think was going to make it right? Were they just lying to themselves? Who was going to tell the architect (new Master Shipwright Jacobsson) to change the design? The Admiral seemed to think the Shipwright was in charge; did the Shipwright think the Admiral was in charge? Who should have told the Shipwright about the test results?

Clearly strong leadership was not in place. They not only did not act on the information they had, they did not even share it. *Lesson number 6 is: communicate the facts of the project widely and act on that data.* The data that this ship was wrong was everywhere, but nobody acted upon it. The people in charge did not act on the data they had, they just went along with a faulty plan. Sound familiar? I am not sure what people hope for in these situations, but it has been going on since at least 1627, and it is still going on today. Someone else will take the personal risk and force the changes to occur. Remember the disaster we had with the Space Shuttle a few years ago?

So they launch the ship, it turns around in the harbor; an 8-knot wind comes by and knocks it over. The captain is arrested, an inquiry is started and an attempt to figure out the truth is underway. In the end they could not decide who was guilty, so everyone was let off. The inquest notes are revealing for it seems many people knew this ship was not right. Some said they knew it was too narrow, others said they knew it was too high, others said they knew it did not have enough ballast, and so on. Many claimed to have taken action themselves to overcome the deficiencies they saw. There were plenty of brilliant designers and critics, after the disaster(!), who were more than happy to come forward and let everyone know that, while they had no power to stop anything, if they had only been consulted they could have told people this was not going to work. It seems equally true today that after things have gone wrong, everyone seems to suddenly have "known it all along. " For me, *lesson number 7 can best be summed up by a quote from Jack Blaeser, CEO at Concord "After a disaster you can only say 'I told you so' if you were jumping up and down on my desk making sure I knew you thought so* ***before*** *the disaster strikes."* This may not save the project (see lesson #1) but it will surely makes the aftermath easier to live with.

Given that building a ship is much more of a science today, some modern naval engineers set about figuring out why the ship heeled over and sank so easily. The changes in the design of the ship caused it to be too high and too heavy up high. Doubling the ballast would have allowed the configuration to be reasonably safe. Unfortunately, doubling the ballast would have knocked out one of the gun decks, which if you recall, was one of the major reasons for the change in the first place. So you might argue that the architecture could not have been adjusted to accommodate the desired changes to the projects' features. In short, today with the benefit of math and science we can see that the changes doomed the project. The team should have just said "no". *Lesson number 8 is: "Just say no"*

Has engineering in a field that has no real science to it changed a great deal in the last 374 years? I think not. Building software requires the same basic discipline that any other type of activity requires: a dedication to getting to the facts and to act upon them with clear lines of authority; to make decisions and take responsibility. Our failings to build software well are less the result of the lack of software science than they are the lack of internal discipline and the commitment needed for the basic integrity of the task at hand. What

is required of us is that we be willing to overcome our own fears and to dedicate ourselves to the best possible outcome.

What is required is that we take responsibility for the things in which we are involved by creating environments that make it hard to lie to ourselves. Fear of stepping in front of moving projects is not at all unreasonable; we have many examples of people being punished for stepping forward. Those driving projects, or companies, or countries, are often not very kind to those that try to stop a moving project, however well-meaning those people may be. People who try to stop projects are called names, sued, fired, jailed, and ostracized because they are often perceived as hurting the common good. We have yet to figure out how to build a management system that consistently empowers people to raise issues and have them reviewed. We are much better at creating environments that stifle openness and criticism. *Rule number 9 is: "Create mechanisms that truly listen to and encourage the voices of dissent, so that these views can be reviewed and utilized for the good of the project."*

Perhaps a part of the Vasa's legacy should be:

> ***Schedule- oriented rules:*** *Don't let fear cause you to do the wrong thing. If you are going to change direction, take the time to do what you think works and change the schedule. Don't let the schedule pressure cause you to lie to yourself and try to build what can't be built.*
>
> ***Coordination-oriented rules:*** *You can't build what you can't see. Clear lines of authority are required for any coordinated action to be successful. Communicate the facts of the project widely and act on that data. "After a disaster you can only say 'I told you so' if you were jumping up and down on my desk making sure I knew you thought so* ***before*** *the disaster strikes." Just say no.*
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> ***Management rules:*** *Rule number 9 is "Create mechanisms that truly listen to and encourage the voices of dissent so that these views can be reviewed and utilized for the good of the project."*

In conclusion, there is no substitute for strong people who care so deeply about the projects they manage that they are willing to overcome their own fears in order to follow these rules. The state of the art of management systems is such that we are clearly dependent on good people in the right jobs. Hiring really strong people and giving them the freedom to create the systems needed is the critical factor, in my experience. These rules are hard to follow because you have to overcome fear on a regular basis and you have to cause other people discomfort as they, in turn, are forced to overcome their fears. Dealing with reality usually means dealing with bad news and that causes fear in many people. People who are possessed to deliver good product and who have reasonable inter-personal skills are the key to success because they care more about the outcome than about their momentary fear.

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