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ESMT Case Study

Team Wikispeed: Developing hardware the software way

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Introduction

It was near midnight on June 10, 2013, when Joe Justice ended his call with Rainer Brueckman. They had discussed various options to solve the problem of the axles for the fourth car model they were building. Finding a pair of axles with exactly the right measurements seemed impossible. Joe wanted to move fast and suggested they take a pair of axles they had in stock in their Wikispeed shop in Seattle, cut them, and weld them back together to make the right length. Rainer was more in favor of taking some time, involving the team to get the full set of specifications for the axles, forming a group to design them to the agreed specifications, building them in their workshop, and testing them on car number four. His point was that they would probably need more of these axles for future orders. In Joe's opinion they should get it done as quickly as possible to be able to test them and then find a new solution for the next car. In addition, he pointed out, they were relying on volunteers to do the job. His approach would give more freedom to the team, which would boost their motivation. After all, even as the founder of team Wikispeed he had no power and budget to form teams and set deadlines. They looked very serious as they quickly weighed the pros and cons and thought back on what they could use from their experience to help them decide.

This case study was prepared by Martin Kupp of ESCP Europe, Linus Dahlander of ESMT European School of Management and Technology, and Eric Morrow of University of Oklahoma. Sole responsibility for the content rests with the authors. It is intended to be used as the basis for class discussion rather than to illustrate either effective or ineffective handling of a management situation.

The beginning of team Wikispeed

It was in 2008 when Joe discovered the Progressive Insurance X Prize – a $10 million innovation contest aimed at inspiring work in the area of energy efficient cars. The contest had many rules (50+ pages), but it centered on the idea of getting a car to reach a 100 miles per gallon efficiency (equivalent to 2.35 liters per 100 kilometer) and meet established road-legal safety specification. The models that already existed, more closely resembled bobsleds than cars. No one could dispute their energy efficiency, but they were neither practical for daily use nor safe enough to drive on our streets.

Like many others, Joe became interested in the idea of producing ultra-efficient transportation and was encouraged by his wife to follow this dream, and use their meager recent college grad savings of $5,000 to pay the X Prize challenge registration fee. At first he worked alone but used different social media tools to document his advancements and to ask others for advice. His questions ranged from simple to technical and complex ones. As a result, others learned about what he was doing and came to check out the project at his garage, some even helped out. About three months later, Wikispeed had 44 members and had developed a functioning prototype which they entered in the X Prize competition (see **Exhibit 3** for membership growth).

Shortly before entering the competition, a technical inspector from the X Prize competition informed Joe that there were problems with the suspension as it did not meet the required specifications. With only 36 hours to go, most people would have given up, but Joe and his team removed the suspensions, modified them according to the specification, and put it all back into one piece. They managed to get it all together under severe time pressure, but just before the competition was about to start a critical set of systems wires were accidently cut, and the run for the prize was over. But it was still considered a success: they had built a car that came 10th in the mainstream division.

The success of team Wikispeed at the Progressive Insurance X Prize competition in 2010 received a lot of attention from the press. In 2012, team Wikispeed was invited to showcase their concept car at the Detroit auto show, the largest auto show in the world. Their car, the SGT01, was put on display in Cobo Hall right next to Ford and Chevrolet. That display car had updated aerodynamics and a bit more civility than their X Prize race car. It was brought to the show as a rolling chassis, with the engine module back at the shop, and the aero shell had the form of a racing car.

After receiving positive press feedback, Wikispeed was contacted by more than a hundred people interested in joining the team as well as in ordering the prototype. By 2013 more than 500 people had joined team Wikispeed, with about 170 of them actively involved, according to Joe. They had also sold nine prototypes.

In April 2013, Wikispeed delivered its first car to an external customer. In May they installed a car on public display at Boeing's Future of Flight Innovation Center where more than 230,000 people were expected to explore the car from the inside and outside over the one-year period of the exhibition. Shortly after, Wikispeed delivered a car kit and assembled it together with students

and faculty from Red River College in Winnipeg, Canada. The college used this car to teach Agile for Hardware and Extreme Manufacturing to faculty, staff, and students.

Since its foundation in 2008 Wikispeed had not actually grown in conventional terms; it had rather opened up to involve people from multiple geographic locations. Their model of working was inspired by Linux, Wikipedia, and groups like Open Source Ecology that had proven successful for information-based products. Shared knowledge and collaboration allowed for economies of scope rather than economies of scale, and quality was assured through common tests and a shared backlog of tasks to pursue. Wikispeed didn't invent new practices that they used to organize their innovation process, but rather adopted established practices used in software development to hardware.

The whole process was designed to be agile – to allow for many iterative changes to arrive at a good outcome. The Agile model stands in contrast to the sequential Waterfall model in software: A lot of effort is put into a project right at the beginning in order to come up with a perfect plan of what is to be achieved in the development cycle. The Waterfall model typically asserts that more upfront planning reduces costs downstream. The waterfall model works for many projects but is also believed to result in problems emerging from (1) change of requirements, (2) customer turnover, and (3) new innovations that make old designs partially obsolete.

Agile development can be seen as a reaction to this model as it uses iterative and incremental changes, though at a higher pace. **Exhibit 1** compares the two models. Joe set out to use an agile approach borrowed from software to the development of a new car, and he also used a range of practices to make this happen.

How team Wikispeed was organized

Team Wikispeed used Scrum, a low-overhead project management technique for collaboration. In Scrum, there were three main roles: product owner, team member, and Scrum master. Each new member was expected to own their role, but over time they could take on different roles depending on what he or she was most excited about doing. There was no central manager who would allocate people to respective roles; instead newcomers self-selected into areas of interest. That allowed volunteers to stay motivated and yet have an established structure to coordinate their efforts. The Scrum roles Wikispeed adopted were not new and are similar within all organizations using Scrum. The roles are summarized in **Exhibit 2**.

Product owner

The product owner represents the stakeholders and is the voice of the customer. It is the product owner who is responsible for delivering customer-visible value. The product owners write customer-centric items (called user stories), prioritize them, and add them to the product

backlog with a list of things to do. For example, one user story would be the properly-sized axles from the introduction.

This is a role and not a title. In Scrum, the person who assumes the product owner role could change frequently, which is what happened at Wikispeed. The minimum time would be one week, which was the time of a "sprint." With these short development cycles the team could always choose the appropriate product owner for the upcoming backlog items.

Team member

Team members are responsible for producing new incremental improvements specified before each sprint. Literally anybody could join team Wikispeed, regardless of their educational background, skills or location. The only requirement team Wikispeed asked for from new team members was to spend a minimum of two hours per week working on backlog items and filming clear, less than five minute demonstrations of what they had accomplished each week.

Scrum master

A Scrum master works as a buffer for the team members by removing problems that could slow down the process. Being a master implies overseeing that the main principles are being used. A master is not a manager with the authority to tell others what to do.

The working principles of team Wikispeed

When Joe started the Wikispeed project he borrowed heavily from his experiences in fast-paced software development teams. The team worked with him to adapt best practices that Joe had learned during his software development career, specifically Agile development, to hardware development, in this case the development of a car. A pre-requisite for Joe to enable self-organizing teams to work independently was to divide the car into certain modules that allow for rapid increments on each module, without ramifications for the overall architecture.

Dividing the work into modules

"This is the only way I know to think about a complex system, to break it into loosely coupled pieces. Object-oriented architecture, that is, splitting the car into separate modules that can be worked on independently, is a pre-requisite for reducing the costs of rapid iteration. It helps to have only a limited number of types of pieces though, less than ten seems about right for the team to iterate quickly."[a]

[a] This quotation and all following quotations are from Joe Justice, founder of Wikispeed.

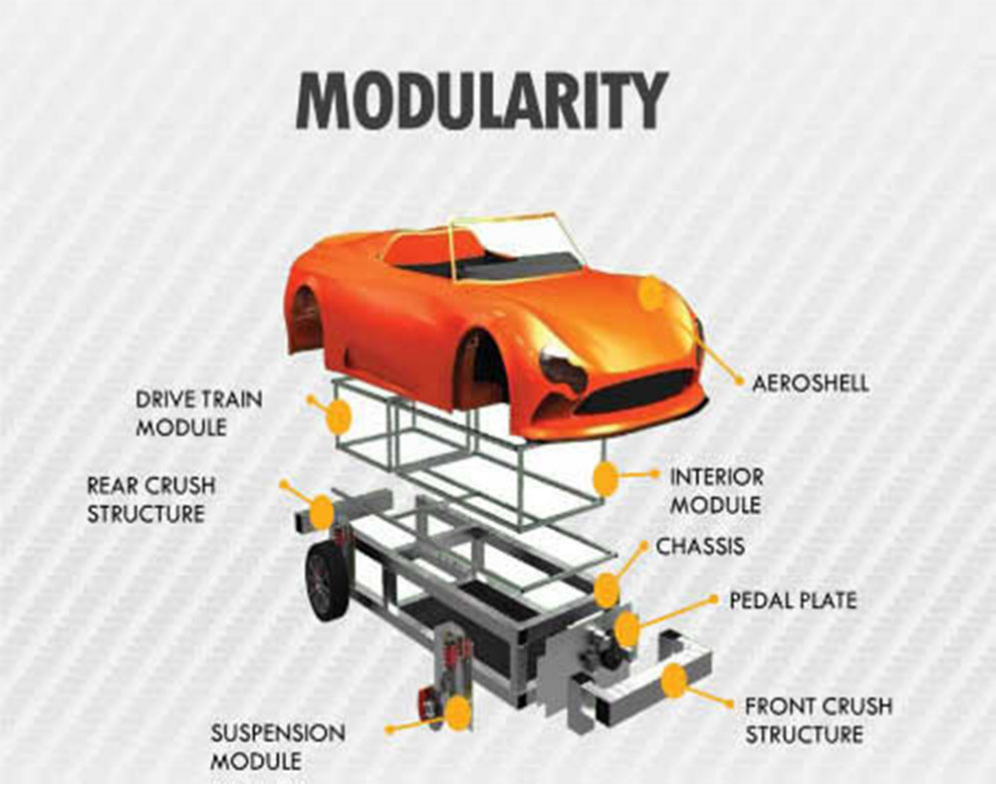
In Joe's mind, any module of his 100 mpg car should be able to be replaced while leaving the rest of the car intact. This is what software teams refer to as "loose coupling," allowing rapid changes of entire sections of a solution at a time, without requiring changes in the other areas of the solution. Each module is built to comply with an "interface" or a known and defined connection to the neighboring modules. So if one team found a way to make the doors lighter, they could try very different materials or designs and still know the door would fit into the car at the end. He thought of plastic building bricks. "Plastic building bricks come in all shapes, sizes and colors, but if you stay within the same building system you can swap them freely and build many different creations. Imagine how slow it would go if you had to make a mold and form a new type of brick each and every time you change your creation. It wouldn't be as fun, it would take longer, and it leads to defunct parts with inventory bloat or scrap."

Team Wikispeed started by developing a chassis, which would connect to the front, rear, and side crush structure. The team decided that the car would consist of nine main modules: suspension, side crush structure, front crush structure, rear crush structure, the frame, the interior, the drive train, the pedal plate, and the body. The suspension, for example, had eight bolts with certain positions that were fixed to the chassis. Anything else on the suspension could change as long as those bolts did not change their place.

This modularization allowed team Wikispeed to work independently on each of the modules. It allowed the team to design individual safety tests for all the car's parts before producing them. This is an established practice in software development that they adopted for the production of the car. The modularization allowed allowed for short development cycles, which were at the core of what he wanted to achieve given the short time frame he had to prepare for the competition.

The team still had to pass the road legal safety specifications and they were running out of time. Modularity allowed Wikispeed to choose the tests they had to pass and experiment on each part individually to pass them. After much iteration, Wikispeed had developed the lightest possible chassis to pass a five-star crash rating equivalency.

In the modular design, the team worked hard to reduce complexity and "use less stuff when we can." The main idea was that if changes were inexpensive it would allow the team to iterate more often and more quickly whenever a team member came up with a new idea or whenever a new technology became available.



Source: Team Wikispeed.

"Innovation is a form of variance! So by maximizing the ability to produce the same thing well in traditional companies, we minimize variance using standard manufacturing techniques, with the consequence of also minimizing innovation."

Modularity according to Joe decreased the cost of changes by adopting multiple short iterative cycles rather than one development process. It also enabled each individual team to work swiftly on their respective module, without having to wait for others to complete their tasks. It allowed the team to incorporate changes proposed by users and customers. Development processes in the car industry often took 2.5 years for a fast-track project, but Wikispeed had seven day "sprint" cycles.

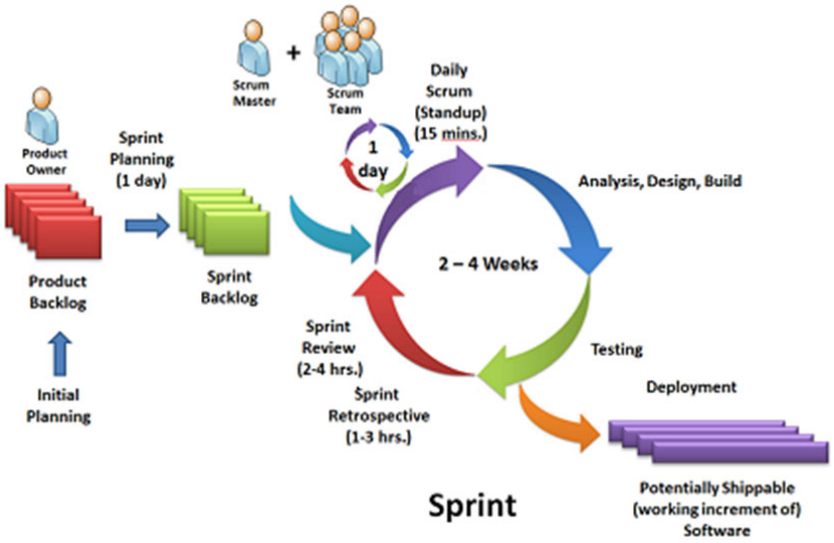
Applying Scrum to organize the team work

"Scrum teams go from the typical 'plan/do/check/act' to 'plan/**MEASURE**/do/check/act'. We work on a set rhythm, with built-in retrospective points to inspect and adapt, to learn from our work."

Joe started this endeavor as just one person and knew the only possible way to succeed would be to welcome anyone with the curiosity to join in and work as part of a distributed collaborative team. From his work in software development, he had the background to organize the teamwork according to Scrum principles. He hoped that the use of Scrum principles would increase team velocity and morale. Joe knew team morale was key to keeping up the pace and maintaining high quality.

He adopted the Scrum principles[b]:

1. Organize work in short cycles,
2. The management doesn't interrupt the team during a work cycle,
3. The team reports to the client, not the manager,
4. The team estimates how much time the work will take,
5. The team decides how much work it can do in an iteration,
6. The team decides how to do the work in the iteration,
7. The team measures its own performance,
8. Define work goals before each cycle starts,
9. Define work goals through user stories,
10. Systematically remove impediments.



Source: Based on Sutherland, J. (2010). *Scrum handbook: Everything you need to know to start a Scrum project in your organization*. Scrum Training Institute Press.

[b] Schwaber, K., and J. Sutherland (2011). *The definitive guide to Scrum: The rules of the game*. Scrum Inc.

Team Wikispeed adopted the Scrum principles to organize their work. Sprints worked in seven-day development cycles that allowed Wikispeed to develop quickly. The team prioritized and defined the best tasks to work on and then tried to finish that task in a period of seven days. Daily "stand-up" meetings enabled people to check their progress by responding to three questions: (1) what did you do yesterday; (2) what will you do today to complete the top priority task as a team; and (3) what is slowing down completing the top priority task as a team? This fostered coordination in the distributed team, and facilitated moving forward.

Team Wikispeed organized all work in teams of two or more. The idea was to avoid time spent on training that was not productive and allow on-the-job training as in an apprentice system. It allowed people to learn as they worked, decreasing the importance for documentation and increasing the enjoyment of making progress.

It was not necessary to adopt any expensive new tools to make this happen. Instead, the team relied on free available tools such as LinkedIn, FreeConferenceCall.com, Dropbox, GoogleDocs, YouTube, Skydrive, and Facebook. These tools were used for sharing documents, communicating, and marketing. They paid for tools only when no free competitor was adequate, such as Geomagic and Kerika.

Other important elements in the approach of team Wikispeed was the adoption of user stories of clients' needs as a means to stay focused on important tasks without increasing the burden of excessive documentation. With the help of user stories the teams stayed responsive to the clients for whom they produced prototypes. This idea is central in Scrum where user stories capture requirements in a very simple way (on a Post-it note). It is often faster than creating formalized requirement documents.

None of these practices were new. But team Wikispeed made sure all practices were conducted together. They ensured that all work was completed in a disciplined way by applying these traditionally software principles to hardware development.

Joe described his approach for a blogger as: "In Wikispeed we are aiming for mass customization, very rapid development and technologies and efficiencies that haven't yet existed, that are fully game changing and not just an incremental evolution of old and sometimes defunct technologies."

Applying these principles to manufacturing: "Extreme manufacturing"

The third element of the Wikispeed approach was to treat hardware development like software by applying Agile principles. Joe called this approach "extreme manufacturing" (XM) to pay tribute to "extreme programming" (XP) as developed by Kent Beck in the late 1990's.

To explain his idea, Joe liked to refer to the production of aeroshell parts of a car, like car doors: "Imagine that today you spent $10 million to make a huge machine that can print car doors incredibly quickly. Now imagine that tomorrow an engineer that works in your company comes to you and says he found a way to make that car door one percent more efficient. Could you find a way to get that better door design made? The answer is probably not – since you aren't making another $10 million machine until the first one makes enough doors to pay for itself. This is the dilemma with today's manufacturing. While being incredibly efficient at reproducing existing designs, it is slow and expensive to make any changes. That's why product development time is actually getting longer, not shorter, despite all of the advanced tools available for us today."

XM was different as in this type of manufacturing final design decisions were avoided for as long as possible. This could be achieved by either progressively locking down requirements or even keeping back-up approaches alive when making design decisions. To do this, modularity was an important factor. Overall, XM aimed at making more frequent specification decisions in a shorter time horizon. One way to achieve this was by running tests from the very start. The team started any sprint by defining the appropriate tests for any goal, such as road-legal safety, comfort or efficiency. In order to validate the iteration of a working product, the team had to pass the defined test and at the same time meet the product owner's vision. Some of the required tests like crash tests were very expensive, at $10,000 per crash plus the $14,500 material cost of the car, $2,500 to deliver the car to the crash testing facility, and then a recycling fee for the remainder of the car. In order to move quickly, Wikispeed replaced physical testing whenever possible with computer simulations. The accuracy of these simulations was compared to the results from the physical tests and was refined whenever they could afford the real test. Overall, XM followed a series of steps, as Joe pointed out:

1. Defining the product vision (role of the product owner),
2. Crafting user stories to make the vision tangible for everyone,
3. Defining the tests required to validate each user story for the product,
4. Defining the tasks that need to be done to iterate the product on each user story,
5. Prioritize the user stories and flag dependencies: some may need to come before others,
6. Planning the demo to showcase the new current state of the product,
7. Planning the work time (including tests) ahead of demo, and allowing team members to self-assign tasks.

As team Wikispeed was widely distributed over several countries and even continents, they decided to have a one-hour weekly stand-up call involving everybody working on backlog items. Whenever possible a short YouTube video was shown and uploaded on the Wikispeed YouTube platform that was accessible to all team members. The video would showcase the current state of the product. During the stand-up, team members assigned themselves new tasks. In addition each garage had its own (often physical) Kanban board to optimize its workflow. All boards were synchronized weekly with Scrumy or Kerika, online tools for backlog management. "We can

machine aero shell molds out of foam instead of aluminium. They only last one hundred stampings, but only cost a couple hundred dollars to make (instead of millions of stampings and millions of dollars to make). We can also wrap the foam in carbon fiber so they last for thousands of stampings."

Reactions to team Wikispeed

The success of team Wikispeed both at the Progressive Insurance X Prize competition in 2010 and the Detroit auto show in 2011 saw very different reactions from the press, the automotive industry, and also management scholars. While press reactions were mostly positive, enthusiastic even, the automotive industry reacted with skepticism and were occasionally even outright negative. In his blog on *Forbes*, Steve Denning wrote that existing companies might not be nimble enough to even try these techniques and might go out of business before restructuring, or fresh start ups could allow them to try Agile techniques like Scrum.[c]

The key arguments against applying some or even all of the elements coined by Joe Justice and his team Wikispeed as "extreme manufacturing" were that only extremely highly motivated and skilled teams could work like that, and that this kind of development and manufacturing would clash with the overall corporate culture in established large-sized companies. Further, this methodology might only apply to small teams and small projects, teams might need to be co-located to successfully apply these principles, and last but not least, this type of team work would not fit the existing project management processes already established and widely accepted in large companies. Management scholars largely ignored the developments made in the world of software and particularly by team Wikispeed and stated that, if anything, this was just another management fad.

Some of these challenges were answered by the industry as blue chip companies like John Deere and Lockheed Martin had visited team Wikispeed shops and had brought in Joe and other team members to share Wikispeed methods with their executives and management. Boeing, one of the world's largest manufacturers of commercial and cargo airplanes, had applied these techniques to their avionics and reported 2.4x improvements as a result, according to their own metrics. Tait Communications used XM to reduce new model development time. They reported that development time for a prototype was cut from over a year to presenting it to their customer representative in just five days. General Motors had launched these techniques across their OnStar division, hardware, and software. While this shows some success in multi-national companies with deep cultural inertia, there are still many questions to be answered about how far these methods can be applied. And the main question remains: how far can these practices be applied within organizations, and when does it make sense to do so?

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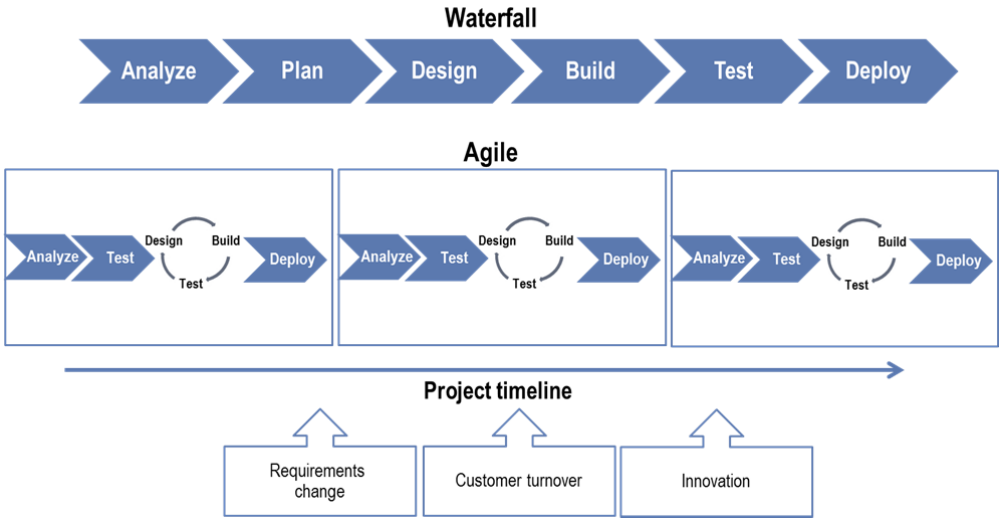
[c] Denning, S. (2012). How manufacturing can learn from software to become agile. Forbes, September 24. http://www.forbes.com/sites/stevedenning/2012/09/24/how-manufacturing-can-learn-from-software-to-become-agile/ (accessed August 14, 2013).

Conclusion

"The tooling costs and basic materials costs of producing an Aston Martin and a Toyota Camry are basically the same. Up to today the cost difference is in how many cars you produce. If we want to break this correlation we have to radically change the tooling, materials, and development and manufacturing process."

Up to that point, it had been an exciting journey. But Joe knew that he could considerably boost the value of his idea if XM could really be useful for many groups and established companies. He had only borrowed practices from software development and applied them to the development of the car, but he knew that he had stumbled over something big. It had the potential to add value and maybe even positively disrupt product development and possibly manufacturing itself, as it was being planned and executed around the world by small and large manufacturing companies. Evidently, companies were playing around with similar ideas with varying success, so interest clearly existed. But before he could get carried away with making plans for team Wikispeed's future and the whole automotive industry, Joe still had to resolve the axles problem.

Exhibit 1: Comparing two models of development: Waterfall and Agile



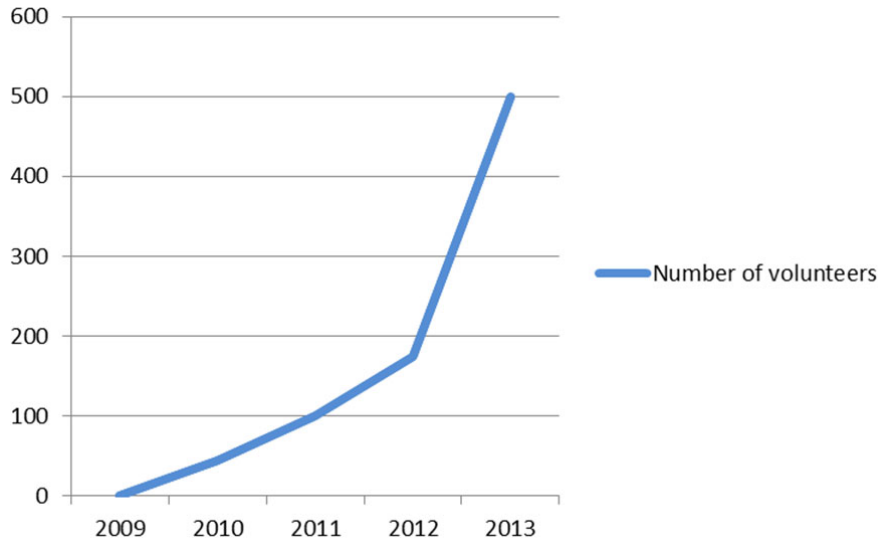
Source: Based on Core Scrum: Values and roles, Scrum Alliance, http://www.scrumalliance.org/why-scrum/core-scrum-values-roles (accessed October 2, 2013).

Exhibit 2: Three (flexible) Scrum roles

Product owner	Team member	Scrum master
Represent stakeholders and the voice of the customer	Responsible for delivering potentially shippable product increments at the end of each sprint, with quality	Accountable for removing impediments to the ability of the team to deliver the sprint goal/deliverables
Accountable for ensuring that the team delivered customer visible value	Spend a minimum of 2 hours per week working on and less than 5 minute demonstrations of what they accomplished each week	Not the team leader, but acted as a buffer between the team and any distracting influences
Customer-centric items (called user stories), prioritized them, and added them to the product backlog		Ensured that the Scrum process was used as intended
Roles change frequently to match up with "sprints"		

Source: Based on Core Scrum: Values and roles. Scrum Alliance. http://www.scrumalliance.org/why-scrum/core-scrum-values-roles (accessed October 2, 2013).

Exhibit 3: Membership growth



Source: Team Wikispeed.