

# Agile Embedded Software Development

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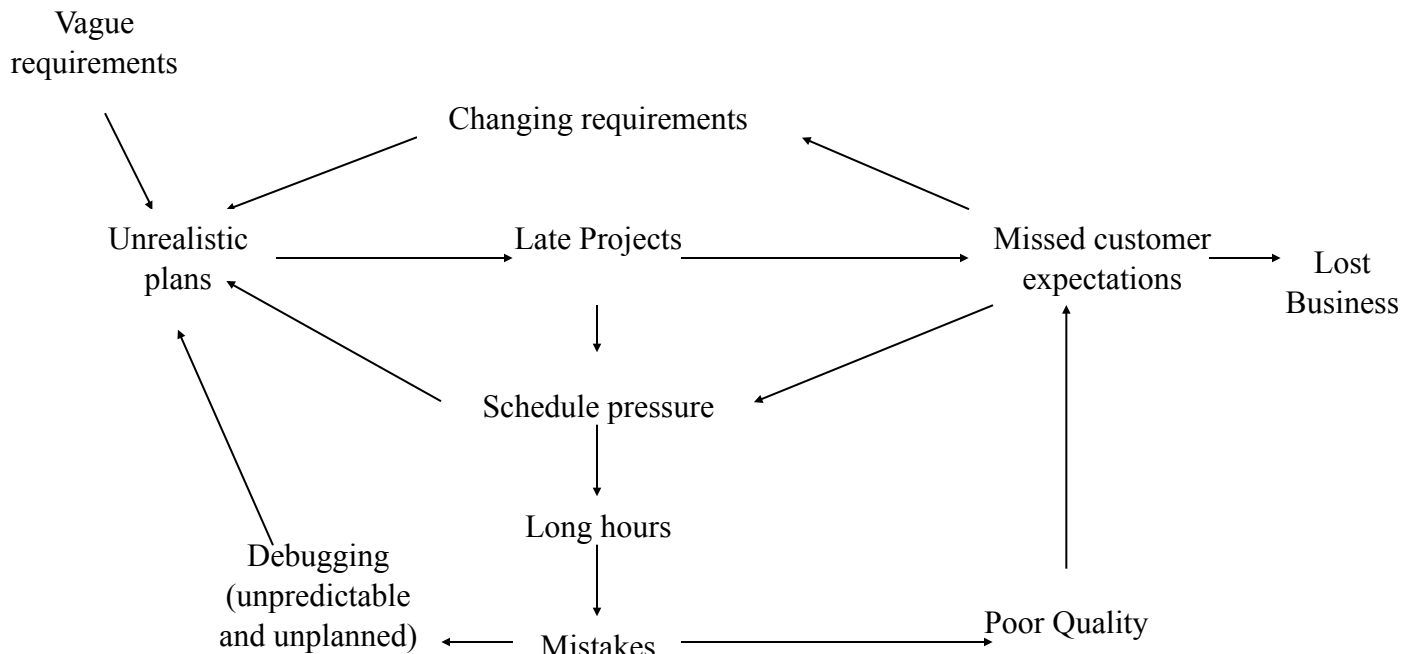
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Why should you consider adopting Agile software development practices? Not because it is the latest buzzword (actually a 10 year old buzzword). You should consider adopting it because you want to improve. The plan driven approach hides a lot of problems until it is too late. Ad hoc development does not provide the business with the needed visibility to confidently plan product releases and rollouts.

Software development projects often suffer from long development cycles, late delivery, unpredictable schedules, poor quality, missed customer expectations and developer burnout. These problems often interact to become a positive feedback loop. Unpredictable delivery leads to schedule pressure, and unrealistic plans. Schedule pressure leads to long hours and shortcuts. Long hours lead to burnout. Shortcuts lead to defects, defects lead to more long hours debugging. Bug removal is an inherently unpredictable activity leading to even more schedule pressure, shortcuts, defects, etc.. Figure 1 shows some of the interactions software development problems.

Figure 1 – Vicious Cycle



You can see a few positive feedback loops in this vicious cycle. There are scheduling, defects, and requirements vicious cycles. These are important problems to solve for which the iterative approach of Agile Development has been shown to be effective. The specify-design-test-build-test-deploy approach used by waterfall-based software development lifecycles sounds appealing but has proven time and again to give less than adequate results.

Iterative development, one of the core practices of Agile development has been around for decades. As far back as 1987 Fred Brooks' as chairman of the Defense Science Board Task Force on Military Software recommended that the waterfall process be replaced with iterative development due to waterfall's history of failure on large DoD contracts. Iterative development has been used successfully on some very high profile projects from the 1950's to present day including: the X-15 rocket plane, project mercury, trident missile submarine control systems, the space shuttle avionics, and the Canadian Automated Air Traffic Control System, to name a few.<sup>[LARMAN]</sup>

Over the last ten years, agile has been mostly associated with software development other than embedded. Even though embedded does have its unique and special challenges, we can and should benefit from Agile development approaches. Yes you are special, but there is nothing special about some of the problems we share with non-embedded development. We can learn, benefit and apply agile to embedded.

## What is Agile Development?

A good place to start in describing agile development is to see what a group of respected software developers (which I am lucky enough and honored to be associated with), that coined the term, had to say about it. The Agile Manifesto says:

We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan

That is, while there is value in the items on the right, we value the items on the left more.<sup>[AGILEMAN]</sup>

### ***Individuals and interactions over processes and tools***

The first point stresses the importance of human interaction and teamwork. Many development processes try to take the human element out of software development, but the agile manifesto's leading statement is about leveraging the people and their interactions. Tools are needed, but it is good people, working in teams who build successful software products. This point is often misconstrued to say that processes do not matter. Processes and discipline do matter, but people matter more.

This statement could be misconstrued to suggest that Agile developers get things done by sitting in a circle and singing Kumbaya. However, there is another interpretation. An increase in teamwork does not automatically lead to a decrease in discipline. Consider, for example, the teams at the Skunk works, or Burt Rutan's team who built SpaceShipOne to win the X-Prize. These teams capture the intent of the Agile Manifesto well. While they deeply value discipline and process, they value teamwork even more.

### ***Working software over comprehensive documentation***

The second point stresses the importance of having working software as a measure of progress. Documents may be valuable, but working software is a more meaningful gauge of software development progress. I have heard this misinterpreted as, "We're doing agile, so we aren't doing documentation". That's baloney! Documents are often invaluable. Those that are, must be produced. However, documentation is expensive to create and maintain so it is important to create only those documents you truly need. In document-centered development, I've heard more than once that the reason for the document is "our process requires it". This is wasteful. Agile developers articulate and validate the reasons for documents. They know who the customer of the document is. Then produce documents if, *and when*, they are needed and try to find an economical way to create them.

Remember also that most documents don't execute (some do, like test cases); so they cannot be used as effective measures of project completeness. Agile developers believe they are 50% complete when 50% of the features of the system have been demonstrated.

Even though embedded software is often only delivered once, along with the hardware, does not mean we cannot track our progress by demonstrating progress through working features. This can be challenging, but necessary to reduce risk and build a feature rich and robust system.

## ***Customer collaboration over contract negotiation***

This point addresses the need to work closely with the customer. By customer we meant the person or persons that are specifying the product and can make trade-off decisions on features and dates. Ideally the customer is the person using the product, but in mass marketed products the customer role is internal and indirect at best. Customer interaction is favored because software is very difficult to completely specify up front. Requirements and market needs change over time. The customer has to be part of the team to help make trade-offs and to see what they have asked for.

## ***Responding to change over following a plan***

The forth and final point deals with the reality of any complex endeavor. Plans are important, but situations change and that require constant adaptation. Plans cannot be viewed as static, even though specific delivery dates are. This point is often misunderstood to mean there are no dates or commitments in Agile development. On the contrary, dates and commitments are taken very seriously in Agile development. Agile developers create working software in very short cycles in order to *measure* compliance to the plan.

## ***Principles supporting the Manifesto***

The Agile Principles back up the manifesto.<sup>[AGILEP]</sup> The principles are:

- Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.
- Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.
- Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
- Business people and developers must work together daily throughout the project.
- Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.
- The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.
- Working software is the primary measure of progress.

- Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.
- Continuous attention to technical excellence and good design enhances agility.
- Simplicity--the art of maximizing the amount of work not done--is essential.
- The best architectures, requirements, and designs emerge from self-organizing teams.
- At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

## ***Iterations***

Agile development is based on iterative and incremental development (IID). IID provides regular feedback by breaking the project into iterations that are generally one or two weeks in length. The output of each iteration is working software. Each iteration is like a stand-alone project ending after fixed amount of time, and delivering some executable version of the product. In early iterations the software might only run in a test environment or prootype.

There are two main roles in agile development, the customer role, and the developer role. Two groups of people usually represents each role. In a few words, the customer defines and tests the product and the developer builds the product. I will cover these roles more completely later.

Embedded software engineers should understand feedback. The control systems we design always have feedback mechanisms to keep the systems under control. An agile project is based on iterations that provide feedback to the critical variables of the project: schedule, requirements, and design. Think of agile as a control system for software development.

The team estimates, plans and organizes work into iterations. The regular cadence of delivery allows a team to establish a velocity that can be measured. Velocity is used to calibrate the development plan and monitor progress giving valuable management data. Work is estimated in effort points. For example, if the team is completing about 20 points per iteration and there are 200 points in the backlog, it will take about ten iterations. If plan only allows eight more iterations, we have some managing to do.

Skillfully, we are not in the 11<sup>th</sup> hour and have options. Maybe its not too late to add a couple people, move the date out, or remove functionality.

Requirements are the broken into smaller demonstrable units called stories. They are the estimate-able, testable, and deliverable units. They are small enough so that many can be completed within a single iteration. When the developers complete a story the customers get feedback on the requirements by seeing and touching what has been developed. In the early iterations, prior to hardware availability some of these stories are demonstrated through tests and simulations; but the demos are based on real working code.

By building the software incrementally the developers get feedback on the design as it evolves. The stories cut across elements of the design provide early integration of simplified versions of the subsystems giving the developers valuable experience with the architecture. Something that looks great in UML does not always look so great once it is coded, and it is better to figure that out sooner than later.

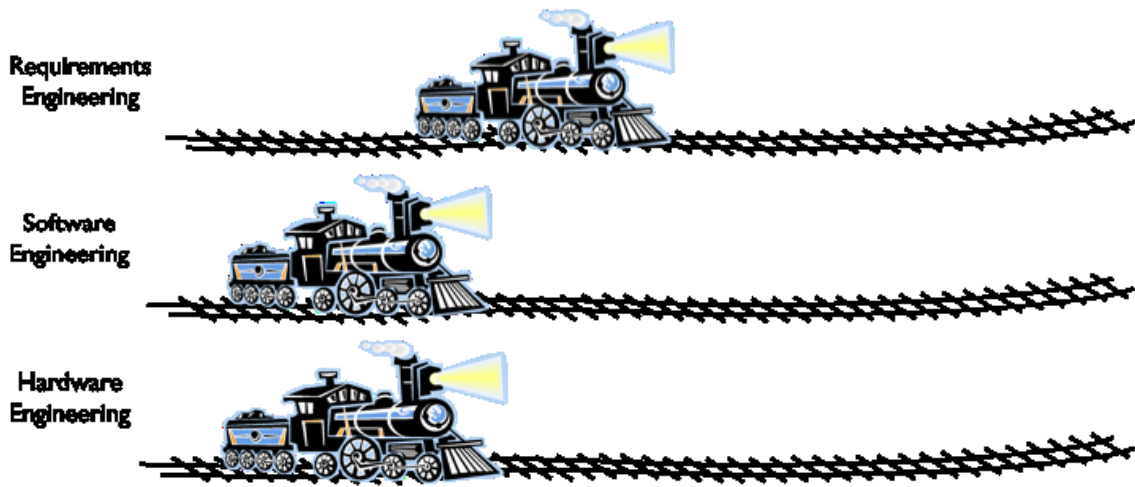
The incremental or evolutionary design approach is central to Agile development. Software requirements are constantly evolving. Priorities change. Software is expected to be used year and after year and evolve along with the market and changing hardware and technology. So it is essential that code has to be built to last, and that means being built to change. Designs and code will continue to be changed throughout the life of the product and consequently there is the ever-present risk of side-effect defects. I'll describe alter how agile developers use automated tests that help to lock in the existing behavior as new features are added.

Developing iteratively gives the business great power. The approach can be used to either manage to a specific delivery date, or to manage to specific feature content. The team's track record is input used to adjust the plan based on facts rather than wishful thinking

In the single-pass waterfall situation, considerable time is spent up front on items that may never make the final product. In Agile development effort is first expended on the highest priority features and capabilities, requirements are elaborated in parallel with development and consequently little time is wasted. Scope is managed at the detail level. When you have 10 must have features, they are broken into smaller stories, and the product content is managed at the detail level, deferring less important parts of the critical features.

## ***Concurrent engineering***

Imagine trains running on parallel tracks, one train represents requirements definition and the others hardware and software development.



The requirements train leaves the station a little before the development train. Requirements are discovered, refined and handed off while both trains are moving forward toward the final destination.

In phased development only one track is needed and the development trains would not leave the station until the requirements train arrived and wired back the requirements.



Maybe, just maybe, the development train will go faster knowing all the requirements, but it will never make up for all the time spent waiting for departure.

Concurrent engineering is a strategy designed to shorten development time-to-market by doing development activities in parallel that might have been done serially. Concurrent engineering is core to Agile, and Agile teams have to be skilled at working incrementally, without detailed knowledge of the whole picture, to be successful. This takes some getting used to after having waterfall based project management in the limelight for last twenty or so years.

Time to market critical is so we need to find ways to finish development sooner. A way to finish development sooner is to start building the product sooner. We need to begin development before all the requirements are known or we will unnecessarily delay the product. If you think about it, the requirements are never all known up front so what are

you giving up! Have you ever been on a project where there were no surprise requirement changes? The world of changing requirements is the world we have to live in, so lets master it.

I've seen too many teams paralyzed by not knowing all the requirements. There is a fear of making mistakes and a belief that we can figure it all out, and then design the perfect architecture with no false steps or rework. This sounds great but is not practical in the complex world of product development. So, at the beginning of a product development effort, we have to identify some of the core features, ones that are important and well enough understood, and begin development work immediately. Beginning development will lead us to confront our requirements misconceptions and design flaws. In addition, and maybe more importantly, the feedback will help us find our blind spots, the unknown risks and weaknesses we cannot anticipate. Getting development started buys time for the requirements team to work in parallel on the remaining requirements. Requirements details are delivered just in time. We can make sure we work on the most critical features first and get them rock solid.

Initial implementations explore the requirements and the design thus improving the team knowledge, clarifying the requirements and solidifying the software design alternatives. The early development of these high-value/high-risk features provides feedback to the customer as well as developers. The feedback helps to mitigate the risks of building the wrong product, or building the wrong architecture. We get executable feedback on requirements and architecture.

The uncertainty and risk the team is trying to manage is not limited to software, but also to hardware and the hardware/software boundary. One way to deal with hardware uncertainty is for the software developers to wait until the hardware design is complete and then start the software design. WAIT! Just kidding! I am not recommending waiting! So, please don't quote me out of context!

Embedded developers don't have to wait for hardware train to get to the end of the track either; the trains do not have to be coupled. Hardware abstractions are created in the software that decouples software from hardware. The abstractions define an interface for interacting with the hardware by defining the service the hardware will provide, without getting bogged down in volatile implementation details. Hardware abstractions enable concurrent hardware/software engineering by allowing software development and testing to start prior to hardware availability. This important practice can also provide input into the hardware requirements and help define and refine the hardware/software boundary.

The iterative approach to requirements gathering, risk reduction and development practices means that changes in customer needs, project goals and hardware architecture

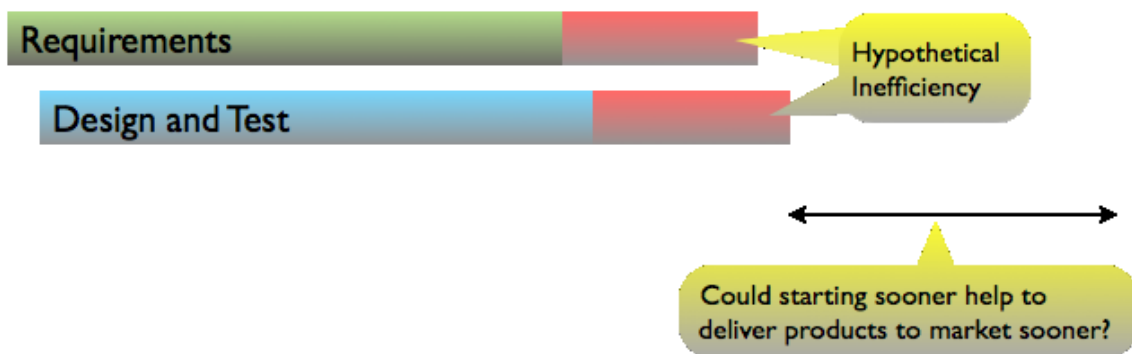


are more naturally accommodated. Time to market can be improved by eliminating wasteful serialization in the development process by engineering the requirements, software and hardware trains on three parallel tracks.

The sequential approach may appear to be less wasteful, allowing people to focus on their part and not starting development until we know everything about what we want to build. We strive to eliminate rework.



It is important to consider what we want to optimize. Is it the requirements phase, the design phase? Neither, we want to optimize product time to market. What if by working in parallel we could deliver the product sooner, even with some rework as shown in this next diagram.



I call the inefficiency hypothetical because most development efforts finish the requirements and the design the day the product ships. These phases never really end when we pretend they do.

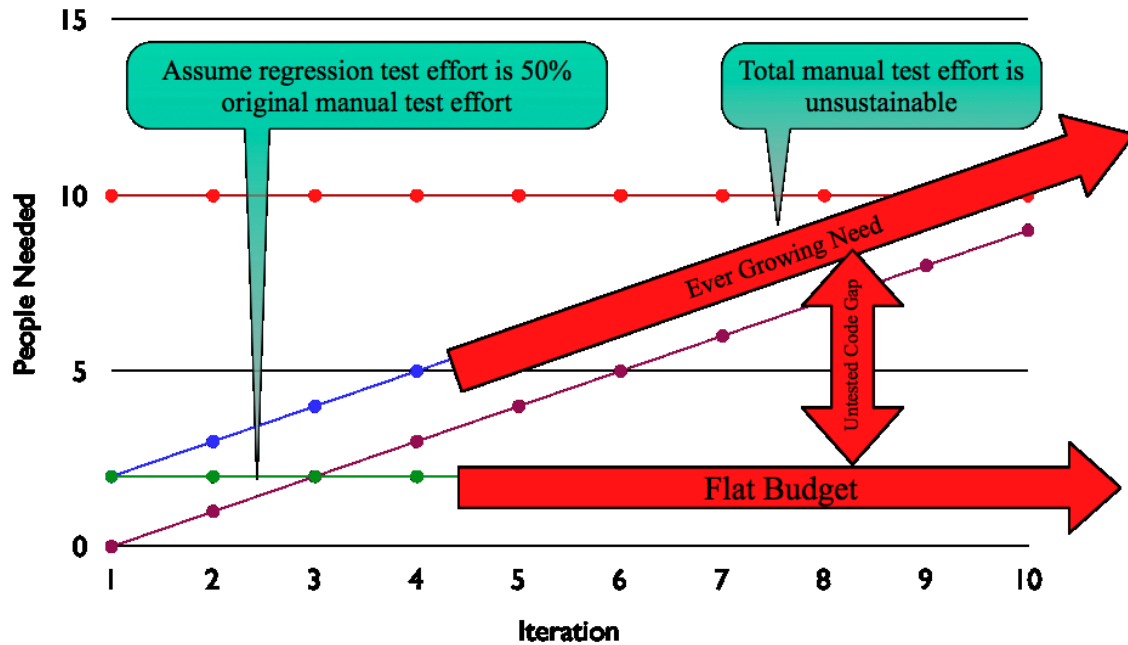
### **Automated Test**

The complexity and evolutionary nature of software development means there are many opportunities to break existing working software. A simple one-line change, carefully thought out, could bring the system crashing-down months in the future and leave no evidence of the crash. Side effect defects are common and often do not get discovered until long after the defect is injected.

Most product teams rely on manual testing in the real hardware to prove out their system. Manual tests have a few problems. First and foremost manual tests take a lot of clock time and are labor intensive. They might require special lab equipment. These realities

mean that the tests will not be run often enough. What we would really like is a way to verify each change that is made to the software. If you had a magic button that you could press that would tell you if your software was operating to specification, how often would you press that button? I would press it after every change, and I do.

When you manually test you have to select the test to run and that leaves you with a growing untested code gap as shown in this diagram.



Pick any coefficients you like for new-feature test effort and regression-test effort and you find that a manual test strategy is unsustainable. This means that unless you automate the bulk of your tests, you will have an ever growing untested code gap.

Agile teams automate unit and acceptance tests making rerunning tests very cheap. So cheap that we can run all the unit tests whenever any change is made to the source code. This is hard to do, especially when you are first learning, but the time saved will outweigh the time you normally would waste manually testing and debugging. Automated tests support the concept that new features should not break existing features. What a concept! I can just hear marketing now, “please add <new feature goes here> system, and its OK if you break any other random feature, no problem.” Marketing does not want that, but they might get the idea that software developers think it’s no problem.

If you think of the tests as a critical asset of the system, even though they are not shipped with the system, when you run the tests the system basically reports when it is broken.

Bob Martin (author of numerous good books on design and agile) tells us having tests is like double entry accounting, if the sum of the debits does not equal the sum of the credits, we have a problem. Accountants don't just sum the credits to save time, they make sure the books balance with their built in tests. They don't save time by only doing the credits, or the debits. They would prefer not to go to jail for messing up the books.

Where do these tests come from? Who writes them? When are they written? Automated unit tests are written incrementally by the software developers in a tight feedback loop with the production code using a technique called Test-Driven Development.<sup>[BECK]</sup> The unit tests tell developers if their code does what they intended. My book, Test-Driven Development for Embedded C, can help you apply TDD to the challenging world of embedded C or C++.<sup>[GREN-TDD]</sup> For a shorter introduction to TDD see my Embedded Systems Conference Paper.<sup>[GREN-ET]</sup>

Automated acceptance tests provide evidence that the system meets its requirements. The developers and test engineers working with the customer team write automated acceptance tests. The acceptance tests are written in advance of the iteration where the development is to be done. This practice changes the role of test engineers in a very profound way. Rather than drowning at the bottom of the waterfall, at the end of the project by a deluge of untested software pounding down on them, the test engineers adopt a proactive role by specifying the behavior of the system in the form of automated tests. These automated tests provide an unambiguous definition of done.

These tests are a very valuable investment. They make testing a repeatable process, that can be run with every change. The tests double as an executable specification. Unit tests provide examples of how a given module is used at a very detailed level, and provide feedback to the developer that the code behaves as expected. Acceptance tests demonstrate how larger groups of modules work together to deliver the product's requirements. Acceptance tests are written in a domain specific language so that non-engineers can read and possibly write tests. An open source tool called FitNesse is often employed for automating acceptance tests. You can find more about this in my Embedded Systems Conference Paper "Executable Use Cases".<sup>[GREN-XU]</sup>

As a side note, a very exciting thing about this approach to testing is that our design has built in hardware isolation from the start. Without the automated test influence, there would not have been an immediate need for isolating the core software from the hardware. Often good structuring like this is left out of embedded designs because of worries about performance. Please see my other conference paper on design for more discussion.<sup>[GREN-DES]</sup>

## **Working in iterations**

The team delivers working software every iteration. In non-embedded agile development software may be deployed each iteration every iteration. In embedded incremental development it may not be practical to release these small increments, especially when there is concurrent hardware development and high deployment costs. Because value cannot be delivered each iteration some say that agile cannot be used on embedded software development. My opinion is different. Instead of delivering value, we provide visible progress. I don't mean doing show and tell on what might be build, but rather a demonstration of real working running software. If real hardware is not available, the demos are done in the simulation, or evaluation environment.

Iterations are fixed-duration time boxes. A time box ends when the time is up, it is not extended when some selected stories are not complete, and it is not ended early when work gets done ahead of schedule (yes, this happens about as often as getting behind schedule in a well functioning agile team).

Iterations are short because people are not very good at estimating long activities. People are pretty good at a two week planning horizon. So, the long-term plans are made up of a series of smaller plans with more precision in the current and next couple iterations. There's more uncertainty and freedom in the further out iterations.

Because iterations are short, the work has to be broken into small pieces of functionality that can be completed within the iteration. We call them stories. The goal of the iteration is to complete all the planned stories and make the stores' automated acceptance tests pass. The stories and their estimates are used in tracking progress against the plan.

## **Stories**

We will have to look at stories in more depth because one of the big challenges of Agile development is breaking the system into the stories that allow incremental and visible progress on the product. Embedded agile development has even more challenges in defining stories because of the added complexity of hardware/software interactions.

Stories are usually referred to as User Stories. I prefer to call them Product Stories. Often the work we do in embedded development is not visible to the end user. the name Product Story seems to fit better.

A product story delivers value, shows progress or reduces some risk and can be completed within one iteration. Usually a story is considered a concise description of system behavior. In that sense stories are similar to a use case, or parts of a use case. In use case vocabulary there is the happy path and the variations. The happy path defines

what happens when all is well. The variations are also paths through the system that cover special cases, differing inputs or error cases. In embedded development we have stories like these but there is other work that does not fit this mold. That work is concerned with having the software communicate with and control the hardware. These hardware centric stories can be a challenge to fit into two-week time boxes especially when starting from scratch as many embedded developers do.

Lets say that we are integrating a USB port into a security system. In the top-level requirements, there is an item called “USB port”. This requirement is too high level to be actionable. High-level requirements have to be broken into stories that describe how the system uses the USB port. For example:

- Print the event log to the printer
- Backup configuration to USB memory stick
- Restore configuration from USB memory stick

These behavioral stories provide value to the end user of the system. I don’t see any of those stories being completed in an iteration unless the underlying infrastructure is in place. Using traditional practices we might have estimated 3 months to do the USB port and let a couple engineers go away for 3 months to get the job done. Sending a couple people away for a few months makes progress less visible and on top of that people are not very good at estimating big pieces of functionality. The lack of visibility and the inaccuracy of long-term plans can cause distrust between management and development and that should be avoided. So we have to make the progress more visible and to do that we must divide and conquer.

Divide and conquer is not new to engineering, although an agile team divides differently than most embedded developers are used to. Traditionally features would be broken down architecturally with integration after most of the work is done. This makes intermediate progress difficult to demonstrate because until all the pieces are complete there is no visible progress to the product stakeholders. With stories we make the process more visible.

Hardware integration and test stories are used to demonstrate progress toward the completion of the big story, or end-user story. When enough of the smaller stories are completed, the big story is no longer so big because the underlying support is in place. Here are some example stories that demonstrate progress toward the USB feature integration and lead to completing the story the end user cares about:

- Talk to USB registers
- Program the device – verify clocks with scope
- Detect when a device is plugged into the USB port
- Detect a printer

- Eject a page
- Print a line of text
- Print the event log
- Detect a memory device
- Open/close a file on the memory stick
- Read a file from the memory stick
- Write a file

Many of those stories are about getting the hardware to do what is needed, and delivering a series of demos that make the progress visible. In parallel to the hardware dependent work, the backup and restore functionality could be developed in a hardware independent manner. Once the memory stick is working in the system, and the hardware independent backup and restore stories are also working, the big stories finally become small enough to schedule and deliver. We try to imagine that stories are independent, and many times we can make them independent by inserting test stubs and making simplifying assumptions, at least temporarily. But with hardware dependent stories there often is a specific order.

You can find out more about stories in my ESC paper “Agile Requirements, Estimation and Planning – Iteration Zero”

## ***Test-Driven Development***

Test-Driven Development (TDD) is the practice of writing automated test code concurrently with the production code. The TDD workflow consists of the following steps <sup>[BECK1]</sup>:

1. Create a new test
2. Do a Build, Run all the tests and see the new one fail
3. Write the code to make the test pass
4. Do a Build, Run all the tests and see the new one pass
5. Refactor to remove duplication
6. Repeat

Tests are written just before the code that makes the test pass. This is a tight feedback loop on the order of a few minutes in durations. Writing of the test defines exactly what the code is supposed to do. Then the code is written to pass the test. Development becomes a series of small milestones, each with specific feedback on the outcome with the system incrementally growing in behavior. The automated tests are run every few minutes providing rewarding feedback on the developer progress. This predictable

development workflow replaces the less predictable code, test debug workflow. My other conference paper goes in depth into TDD.<sup>i</sup>

## ***Dual/multi-target development – Platform independence***

Making progress through TDD means that the embedded software must be designed to be hardware independent. Object Oriented design principles are used to create loosely coupled software modules whether an OO language is being used or not. The software is designed to interact with hardware, operating system and other subsystems through interfaces. Subsystems and modules must be kept independent so they can be tested before integration in the final hardware. Early in the project, the development system or evaluation hardware may be the only test vehicles. Testing on the development system or eval boards allows testing to be done earlier, so that when hardware is ready, less application problems are found.

## ***Design***

Agile design is evolutionary. There is no attempt to completely layout the high level and detailed designs prior to starting development. This is not to say there is no upfront design, there is and the amount of upfront design needed varies per project. A project consisting of a half a dozen developers probably will not need much up front design. A project made up of several teams of a half-dozen developers will need more up front design work so that teams work synergistically.

At the beginning of an agile project is an activity called exploration or Iteration Zero. During Iteration Zero the project goals are communicated, initial stories are written, initial hardware/software division of responsibilities is identified and an initial software architectural vision is created. The architectural vision identifies the system boundary, and major subsystems. The design shows example commands, queries, and events that allow one subsystem to collaborate with another.

The architectural vision is not an exhaustive/comprehensive design document. For smaller teams it may be recorded on a white board and only take a few hours or a couple days to establish. For larger teams more artifacts may be needed. The real value of the architectural design is to share the vision of the design so that the people work toward the same architecture.

The architectural vision is not realized subsystem by subsystem with a big-bang integration at the end. Stories are implemented that cut across the different parts of the design, initially with modules and subsystems with reduced capability. As more stories are added to the system the architecture evolves, becoming more and more complete.

Teams tend to be formed around feature areas, rather than architectural components. This leads to more flexible teams and members that have specialties across different parts of the architecture. This prevents knowledge silos that are both risky for an organization and for individuals (what if a key person leaves along with their knowledge silo; what if some specific technology becomes obsolete and its all the person knows).

An architectural vision is not cast in stone, it is not rigorously reviewed, approved and signed off. The agile development team expects that some of the vision will come true, but parts of it will change and evolve as the team learns more about the requirements and the design ideas that work well and the ones that have not worked so well.

Agile development does not prescribe the documentation needed by a development team. A team may decide that intra-group communications using the team's white boards are adequate for effective communications. Multiple team projects or distributed projects will need more documentation and formality. Software in regulated business such as medical devices, may have documentation requirements along with the functional requirements. You must adapt agile to your needs. Also, expect it to evolve as you learn.

When a document is needed because it is valuable to the team, or required by your customer, the team will try to find cost effective ways of getting the document. For example, if an architecture document is needed, the team may first get a working portion of the architecture coded and tested prior to producing the formal document. The team first works from a rough sketch of the architecture, and later after confirming the architecture the team documents it. This keeps the effort to produce and review the document down. Writing the document in anticipation leads to either an out of date document at the end of the project, or additional cost of revising the document as the architecture is revised and made to work. An implication of this approach is that the architects are also doing implementation. Some skilled designers are needed on every team.

## ***Release Planning***

The customer team works with the development team to produce a release plan, which is a series of iterations with critical dates identified. Each iteration in the release plan is made up of a set of stories. Stories are written on note cards to facilitate rearrangement during the planning meetings. The stories are estimated by the developers and are treated as independent. Stories are estimated in relative, but unit-less numbers. So the easiest story usually is assigned a single point and more difficult stories are estimated relative to that easiest story. So a five-point story is five times as difficult as a one-point story. The team estimates how many story points it can complete in an iteration, this estimate is known as the team's velocity. The stories grouped such that the sum of the estimates of

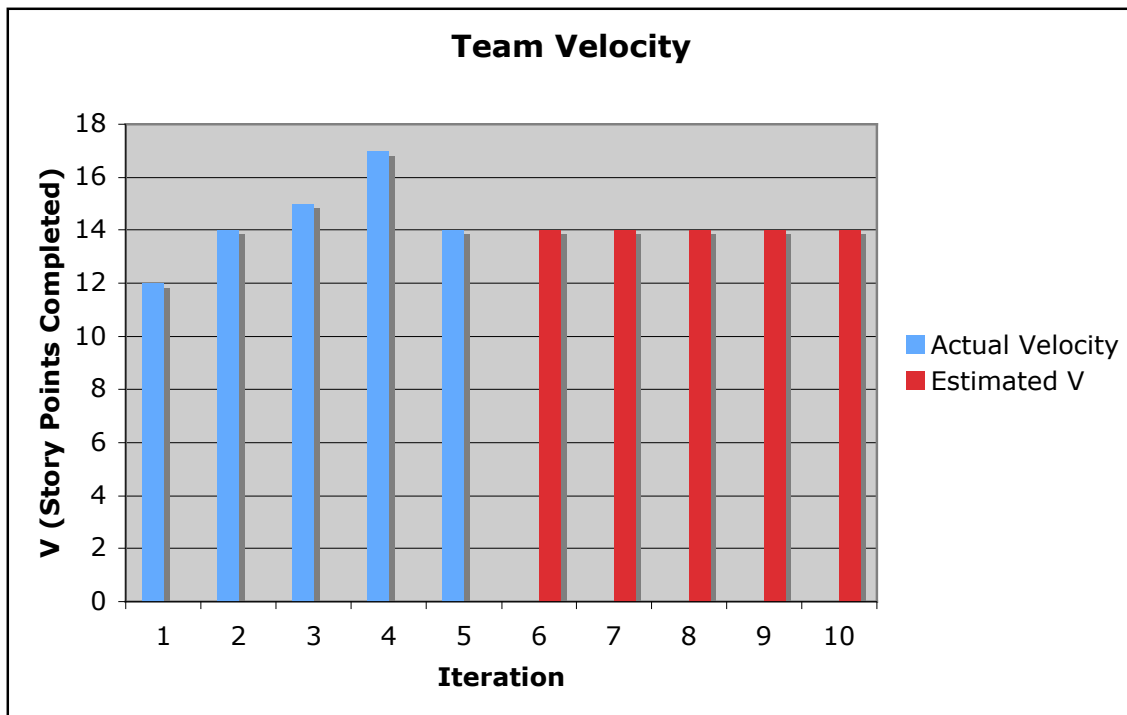


the stories in the iteration do not exceed the teams estimated velocity. Figure 3 represents a release plan. Each iteration is made up of a stack of stories.

**Figure 3 – Release Plan**

As mentioned earlier, after a few iterations the team will develop its velocity, which is the total of the points of stories actually completed by the team in an iteration. The teams' velocity is the critical metric that provides feedback on the team's measured progress. Figure 4 shows a team's velocity tracking chart.

**Figure 4 – Velocity Chart**



If the estimated velocity was optimistic, as it usually is, that optimism is checked by the actual track record of the team. Optimism is good but the business needs to know is the plan is realistic. Figure 5 shows and burn-down chart which is used to monitor project progress.

Figure 5 – Burn Down Chart



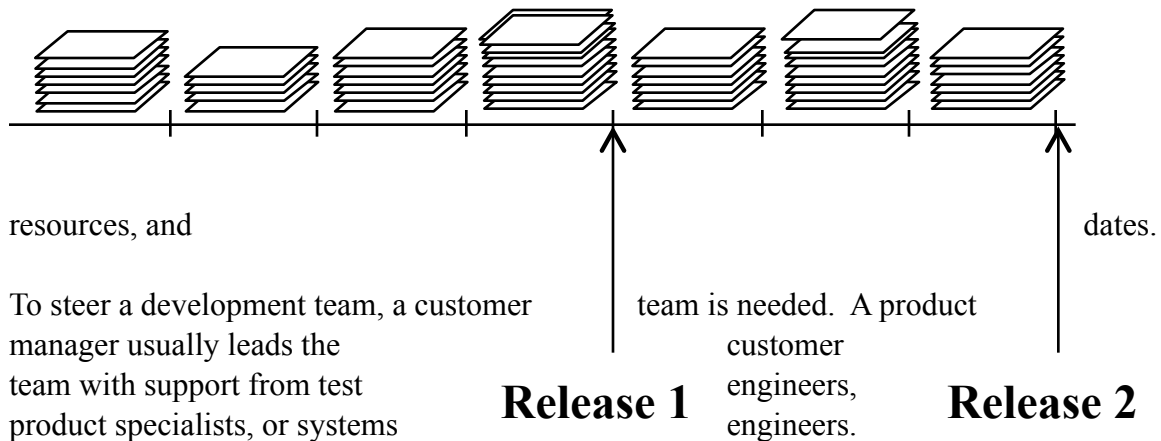
The velocity tracking and burn-down tracking can provide an early warning system for schedule problems, and this early warning gives the team management time to take corrective actions, such as reducing scope, adding people, extending the date, or possibly canceling the project. In this chart there is a new batch of requirements introduced in iteration 5. The velocity showed that the project was likely to be late, so in iteration 8 scope was reduced to 175 point and further to 150 points in iteration 9.

The most practical variable to control is project scope. With the behavior of the system having been broken down into stories, there are small bits of functionality that may be removed and rearranged in the plan. This is a highly visible planning process and this visibility can be used to remove higher-cost and lower-value stories. No one wants to cut scope, or delay the project, but knowing that the plan is in jeopardy is critical business information.

The nature of agile planning is that long term plans are less precise with more uncertainty than the short term plans. This sounds pretty natural. (What are you doing next weekend? What are you doing four months from this weekend?) The upcoming iterations in the release plan are more detailed and the iterations that are farther out have less precision. As time goes by the plan becomes more complete and the confidence in the plan improves.

## Impact on the organization

Agile development involves more than just technical issues. The iterative nature of Agile impacts the whole development organization. Companies that view Agile as just solving technical problems will probably fail at agile adoption. The most successful adoption of agile happens when management and development are both interested in solving the problems of late projects, inaccurate estimates, and low quality. Specifications, schedule dates, and plans cannot be thrown over the wall to development. Management and development must work together to steer the project to a successful delivery within the constraints articulated through requirements,



When there is hardware/software interaction, having hardware engineering represented on the team is also needed. The hardware engineers often help identify the hardware integration stories needed to realize the product.

## Communications

Agile teams embrace communications. They often use these practices and meetings to keep the team on the same page:

- Iteration Zero - at the beginning of a new release
- Periodic release planning – as needed
- Iteration review – every two weeks, usually immediately followed by iteration start.
- Iteration start – every two weeks
- Daily standup meeting – every day, fast

Questions at the daily standup

- What did you do yesterday?
- What do you plan to do today?”
- What is in your way?

During the standup meeting, people stick to the quick agenda and may offer to stay after to discuss issues further. Staying after is optional, respecting everyone's time.

## Continuous Improvement

During the iteration review meeting, the previous iterations stories and acceptance tests are reviewed, and velocity recorded. Teams also do a iteration retrospective. The team answers these questions:

- What went well?
- What problems did we have?
- What should we do differently?

Teams build continuous improvement into their regular development cycle.

## Final Words

We've done a quick overview of Agile Development. You probably recognize many of the practices of Agile Development. Agile is not new, some of these practices have been around for decades and have been very successful. Developers, business stakeholders, and end users should see improved schedule performance and product quality. Developers should feel the accomplishment of regular feedback of iterative development, TDD, and spend a lot less time chasing bugs. Business stakeholders should see improved predictability and visible fact-based management data.

There are some other very good references on agile development practices.

- Beck, Kent, Extreme Programming Explained
- Cohn, Mike, Agile Estimation and Planning
- Cohn, Mike User Stories Applied
- Martin, Robert, The Principles, Practices and Patterns of Agile Software Development
- Martin, Robert, Clean Code

Some of my work

- Test-Driven Development for Embedded C
- Papers: <http://renaissancesoftware.net/papers.html>
- Blog articles: <http://renaissancesoftware.net/blog>

Agile development can also be found by other names, such as:

- Extreme Programming
- Feature Driven Development (FDD)
- Scrum
- Crystal Clear

- DSDM
-

[LARMAN] Larman, Craig and Basili, Victor, Iterative and Incremental Development, a Brief History, IEEE Software, June 2003 Cover article

[AGILEMAN] <http://agilemanifesto.org>

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[GREN-TDD] Grenning, James. Test-Driven Development for Embedded C, Pragmatic Bookshelf, 2011  
([www.pragprog.com/titles/jgade](http://www.pragprog.com/titles/jgade))

[GREN-ET] Grenning, James, Test-Driven Development for Embedded C, Why Debug?, ESC-1004, Boston, 2012

[GREN-XU] Grenning, James, Testing Embedded Software with Executable Use Cases, ESC-4020, Boston 2012

[GREN-DES] Grenning, James, Object Oriented Design for Embedded Software Engineers, ESC-209, San Jose 2007

[BECK1] Beck, Kent, Test-Driven Development, Addison Wesley, 2002

These and other papers by James Grenning can be found here <http://renaissancesoftware.net/papers.html>