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# Accelerating Product Innovation Through Agile Development and Continuous Engineering

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# Introduction

Software is driving an expanding percentage of embedded system functionality and value, fueling growth in code base volume and complexity. Frequently, rising complexity is further compounded by an increasing desire for connectivity. Parallel to these mounting software creation challenges, engineering organizations are facing tighter time-to-market windows. Companies resolutely clinging to traditional software development practices are finding their antiquated and protracted processes insufficient. Many OEMs are now mandating that their engineers communicate and collaborate more throughout the software development process. Methods focused on ensuring greater cooperation, such as Agile, are spreading in embedded systems development as a strategy to maintain schedule adherence while meeting quality objectives and accelerated software content creation requirements. In VDC's 2014 Software and System Development Survey, 31.6% of embedded engineers indicated use of an Agile methodology for software development on their current project. However, as the advance of code complexity and device functionality expectations continues to outpace the expansion of development budgets, engineering firms must continue to investigate new ways of managing their overall system development and organizational efficiency. In order to combat the accelerating rate of change in system requirements, OEMs need to extend the basic tenets of the Agile methodology and embrace a continuous engineering approach. New device development and management paradigms will be required to ensure engineering organizations can adapt to the accelerating pace of business change.

## Background on VDC

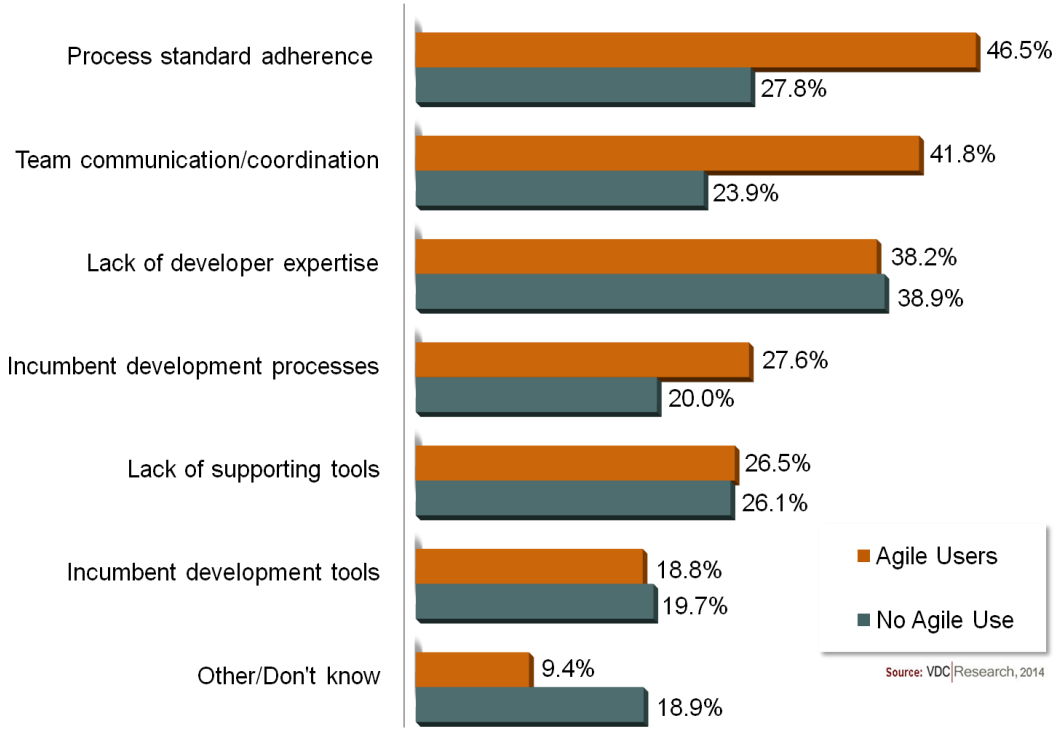
VDC has been covering the embedded systems market since 1994 and the use of lifecycle management solutions since 2000. Data supporting discussions in this paper is based on findings from VDC's most recent Software and System Development Survey. This survey collects input from more than 500 engineers across the globe and will also be used within a series of reports produced by VDC in 2014. The respondents are directly involved in software and systems development, across a range of industries including automotive, aerospace and defense, telecommunications, medical, industrial automation, and consumer electronics, among others.

## Converging software development needs, but unique challenges remain

Engineers in the embedded and enterprise or IT realms now face many challenges around software development complexity, volume, and impacts from vulnerabilities. As a result, they are pursing similar strategies in areas such as security and iterative design methodologies. Enterprise developers more rapidly embraced Agile software methods and can offer guidance on best practices on tooling. As embedded organizations look to the IT market, adopting a few methods and tools, some will also import Agile experts. However, critical differences remain between the embedded and IT spheres that present unique challenges and pain points for the systems development market.

Embedded systems more frequently operate in IT-deprived or safety-critical environments where system failure can have potentially dire consequences that, in some applications, can even result in death. Accordingly, embedded software design and tooling infrastructure must include a higher level of discipline or rigor added beyond what might suffice in the enterprise/IT realm. For example, software in embedded devices must often comply with strict process standards, such as DO-178B or C, many of which were originally developed with older serial development workflows in mind. Some recent updates provide more flexibility with regards to iterative methods, but standard adherence remains the most commonly cited challenge for engineers using Agile methods. Furthermore, the legacy of these older standards engendered development processes, staffing backgrounds, and tooling investments that stalled initial use of Agile software development.

### Exhibit 1: Perception of largest challenges of Agile/iterative design methodologies



## Collaboration, but with more rigor

Embedded software developers face the same mounting software creation burdens and tighter time-to-market windows that fueled broader use of more collaborative software development practices in the enterprise/IT realm. However, the combination of lengthy, complex development projects with numerous process-standard demands continues to necessitate a higher level of rigor and initial project planning than is typically required in the enterprise market. Agile, adapted for the systems market, must be a hybrid approach combining iterative development and increased discipline with which requirements and change are managed. Rather than replacing older practices, Agile methods are best used as a strategic addition, augmenting other approaches.

Early embedded OEM adoption of iterative development methods was challenged by the perception that Agile was an excuse to abandon planning or disciplined processes. Viewpoints have evolved as Agile methods have become more of a standard element of software development. OEMs are increasingly using iterative software design to accelerate quality code development, but within a more structured, predefined project plan as necessitated in the embedded environment.

The emphasis on feedback cycles and design iteration endorsed by the Agile methodology is promoting the use of formal requirements and change management tools by a broader pool of stakeholders across embedded organizations. Use of these tools by a wider audience favors easy-to-use solutions, allowing users with a range of technical skills to check progress and make updates.

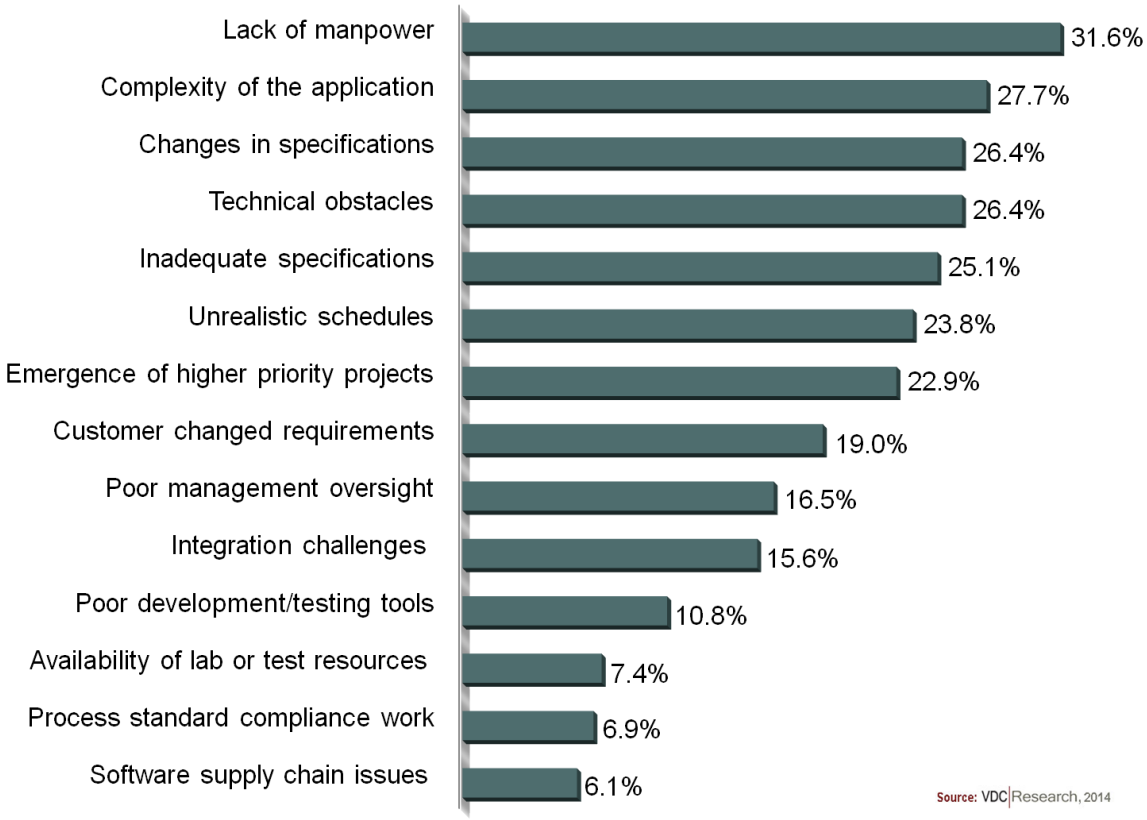
## Embedded firms are still falling behind

Embedded engineering organizations are in the midst of a difficult evolution. Across the embedded industries, solutions that were historically hardware-oriented are now relying on software for innovative new features. As system functionality depends more on software, there is a requisite increase in development costs dedicated to the domain. Expansion of software development costs is outpacing spending increases for the design of electrical and mechanical elements of embedded systems. Embedded engineers surveyed as part of VDC's 2014 Software and System Development Survey spent 51.1% of their current project's development budget and attributed 51.0% of end-product value to software components. As recently as 2012, software only consumed an average of 41.8% of development budgets and produced 35.8% of embedded system value. These rapid changes have a widespread impact across the embedded system design cycle.

Whether the OEMs realize it or not, many of them are becoming, in essence, software companies – consuming a majority of their development budget in the domain and deriving a majority of system value from software. But it is not enough. Despite the elevated spending, continued advances in embedding computing components, and increased use of automated software development tools, engineering organizations are still struggling to meet release deadlines. In our most recent survey,

41.6% of embedded engineers were behind schedule in their current project. Today's OEMs need to design products with increasingly complex software that can include millions of lines of code, the functionality of which is tightly integrated with other system components. They need to manage distributed development teams and develop complicated hardware architectures and highly integrated component functionality, all within narrow budget windows and tight schedule constraints. A transition to more collaborative approaches has already begun; 31.6% of embedded engineers use Agile methods to help address these challenges. Furthermore, 45.7% of engineers indicate their organization has started to investigate or implement integrations across their engineering domains (software/system development ALM, mechanical engineering/PLM, and/or electrical engineering/EDA). Embedded OEMs must continue to investigate and adopt more flexible and collaborative development practices to help accelerate development of their embedded systems. Further embracing a continuous engineering approach can help these organizations more rapidly respond to customer needs and shifting market expectations.

Exhibit 2: Reasons for delays in project schedule (percent of respondents)




Central tenets of the Agile methodology – valuing teamwork and sharing of information – are helping adherents improve their organizational efficiency and overcome many of the major contributing factors for software project delays. The combination of complex engineering interdependencies and

acceleration in the pace of change in customer requirements necessitate a more holistic process change than can be achieved through increased point development tool adoption alone. Specification changes and technical obstacles can be all but inevitable over the course of lengthy, complex projects. In this environment, it becomes more critical for engineers to have a greater awareness of the impact from the actions and needs of other engineers, teams, and even divisions.

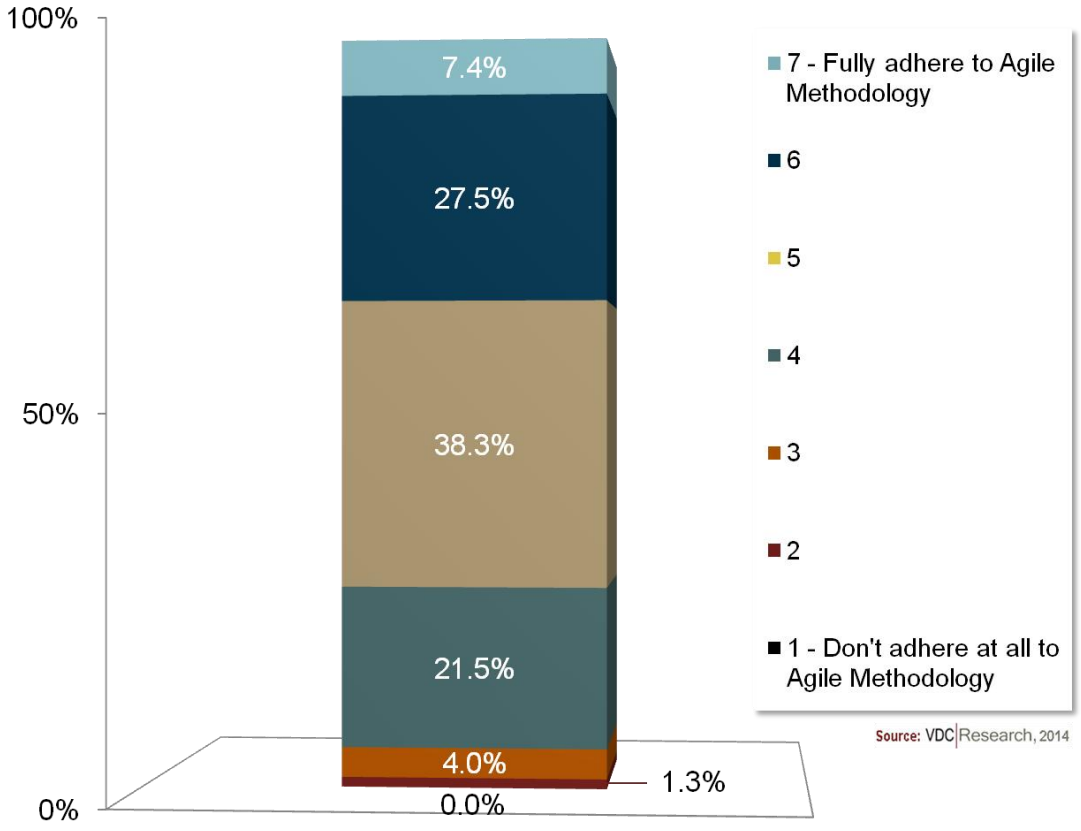
Exhibit 3: Largest advantages/benefits of Agile/iterative design methods


In addition, the number and variety of stakeholders involved in software creation management is expanding in line with the rising proportion of overall system value from software. A higher level of iteration and team collaboration than is routinely exercised in serial development project workflows is needed to deliver timely information to directors, project managers, QA staff, and senior executives so they can effectively manage and allocate limited budgets. Agile methods allow developers to work and receive feedback incrementally. This is an efficient strategy for segmenting complex requirements into more manageable tasks and for developers to offset delays caused by customers' changing requirements. Indeed, the ability to quickly adapt to changing requirements is Agile's most commonly identified benefit, selected by 64.5% of embedded engineers using the methodology. The capacity of Agile methods to address the most critical delay factors in software development affirms the importance of increasing use of the methodology in systems engineering.

## Embedded engineering today – collaborative strategies on the rise

Technical requirements and market conditions hinder universal Agile adoption in the embedded industries. As a result, few organizations fully adhere to the methodology upon implementation. However, improvements made to lines of communication within organizations that are implementing iterative process are spurring tangible benefits. Upon initial adoption of Agile, many companies rapidly expand their investigation into new, additional methods of improving overall efficiency through enhanced collaboration. OEM perceptions of the Agile methodology are evolving as the magnitude and depth of adoption in the embedded market increases. Initial opposition or apprehension is fading in light of the productivity improvements experienced by early adopters. Agile is increasingly viewed as a more standard element of the overall development process. To ensure continued progress, OEMs must apply Agile concepts more deeply into existing projects and scale use of the methodology to include more teams and projects.

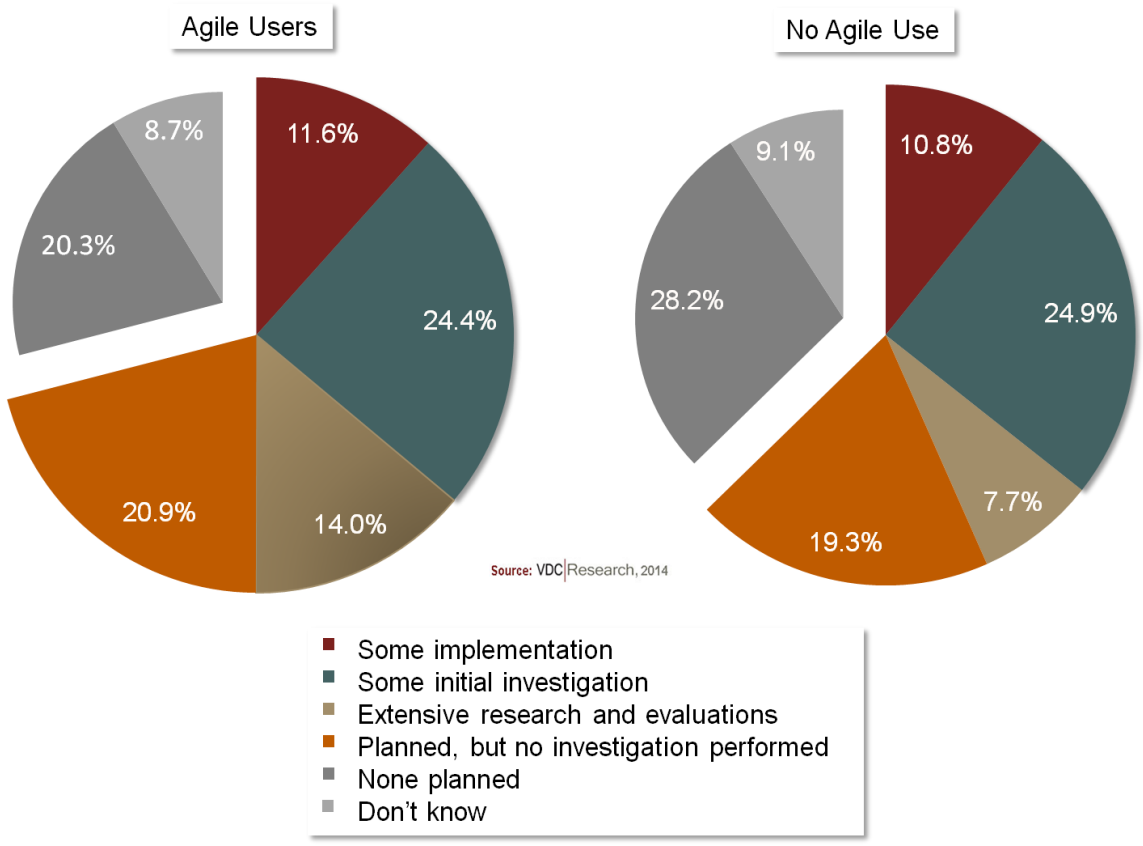
### Exhibit 4: Degree of adherence to the Agile methodology in software development



## Expanding collaboration - across domains and departments

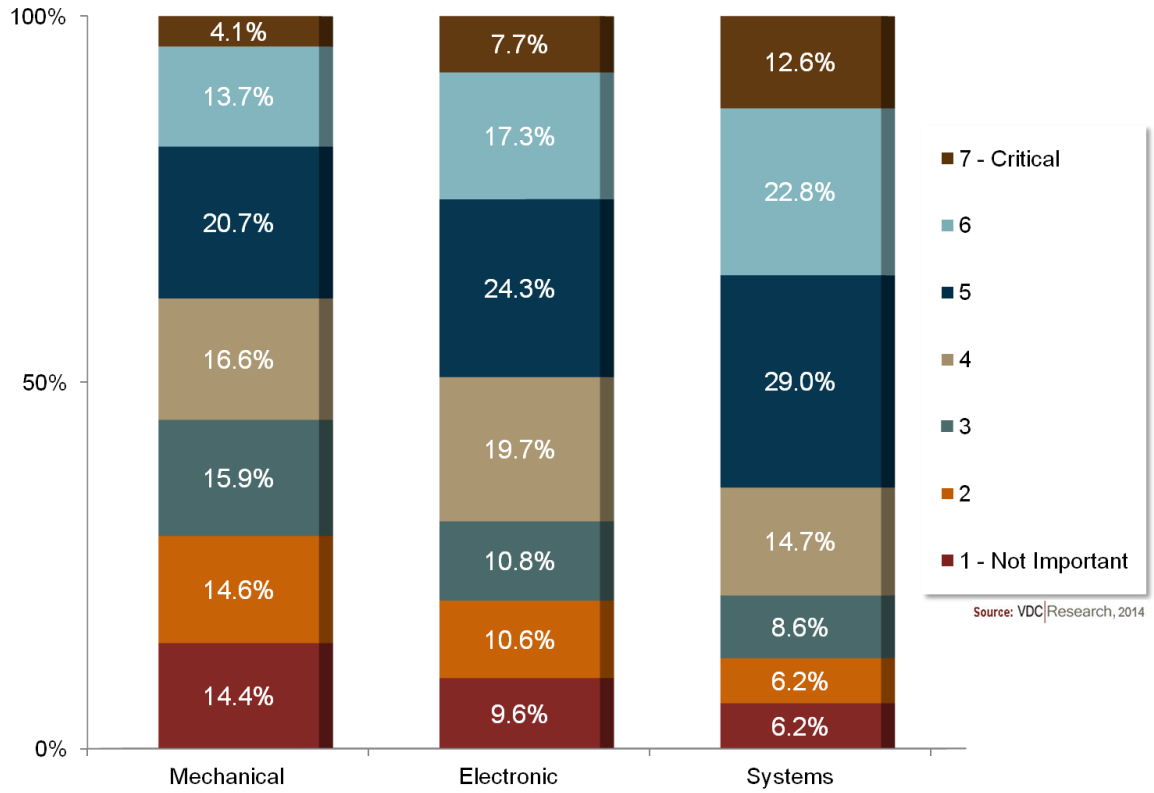
Embedded device functionality is ever more dependent upon a tight interaction between software, electrical, and hardware components. This interaction, and the ability for actions in one domain to influence others, necessitates greater awareness of potential impact from decisions made in each engineering discipline. The challenge of ensuring the needed degree of integration is compounded by the multiple distributed engineering teams and the typically wide range of separate companies that comprise the extensive supply chains of large-scale embedded projects. As a consequence, more embedded OEMs are pursuing strategies that integrate development teams from these traditionally separate engineering domains. This investigation is especially prevalent where Agile methods are already in place. A total of 70.9% of engineers surveyed in VDC's 2014 Software and Systems Development Survey indicate their company has begun or plans to begin an investigation of integrating across their development engineering teams.

### Exhibit 5: Level of cross-domain engineering integration



However, interest in this strategy is not limited to Agile users; 62.7% of the engineers surveyed who are not using Agile indicate their company is pursuing a cross-engineering domain integration. This suggests Agile methods, while effective in demonstrating the benefits of enhancing cooperation, are not a necessary gateway on the path to a continuous engineering approach. For example, OEMs in vertical markets such as aerospace and defense (A&D), which face process-standard requirements and long, complex development projects, have been slow to embrace Agile methods for software design. Only 34.3% of embedded engineers in this industry use Agile methods. But a majority of these organizations recognize the benefits of strategies to extending collaboration through the broader product lifecycle; 62.9% of A&D engineers report their organization is currently planning or investigating cross-engineering domain integration.

## Exhibit 6: Importance, by embedded developers, of aligning engineering domains to Agile practices



VDC's survey results demonstrate that embedded engineers using iterative software development methods are keenly aware of the importance of applying Agile software methods to more of their organization. There is strong interest in integrating Agile concepts into development practices of engineering domains other than software. Interest in expanding Agile methods to address the challenges of systems engineering is particularly strong.

## Cultural opposition slows change

Necessary cultural changes pose additional challenges for embedded OEMs as they advance to a more collaborative development environment. In the past, embedded engineering teams have often operated in separate hierarchies. Cultural opposition has been particularly acute in safety-critical industries, such as A&D and automotive, where the presence of process standards has injected a level of uncertainty and inhibition regarding the adoption of iterative software development methods. Maintaining process standard compliance is the most critical challenge for engineering organizations in these industries, which has led to a widespread culture of conservatism and deferral of change.

Beyond merely improving the cadence of inter-team communication, teams must reconsider organizational goals as their company advances toward cross-domain engineering integrations and DevOps. Rather than metrics focused on lines of code written or projects thrown over the wall to the next group, more holistic objectives centered on delivering value to the customer should be favored. An example of this could be measuring the cycle time between discovering or deciding a feature is needed and then successfully releasing that feature.

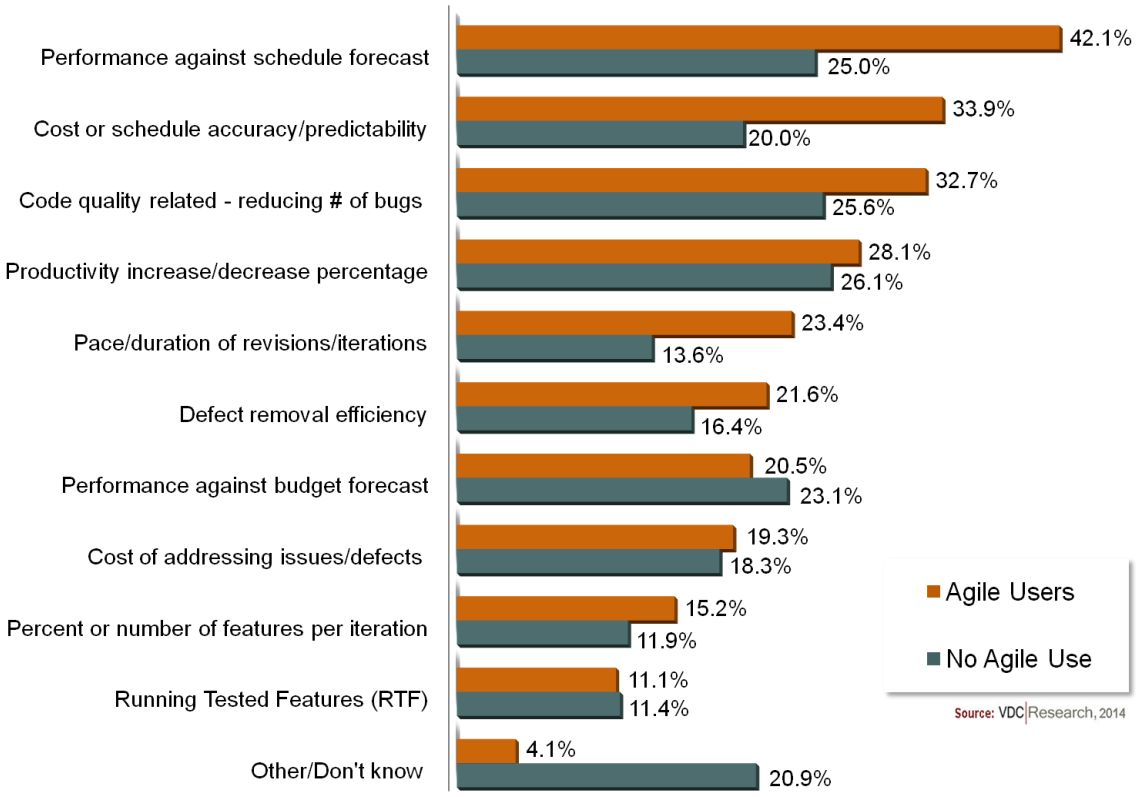
## Concepts like DevOps are the next step on the path

The improved communication and expanded collaboration of Agile software development is helping early adopters discover new engineering synergies and increase their planning predictability. There is wider recognition for the effectiveness of more flexible and iterative strategies such as Agile and cross-engineering domain integration in addressing systems development challenges and rapidly responding to shifting customer needs or market expectations. Better management of design interdependencies through cross-domain integration can often increase operational efficiencies, resulting in cost savings. Use of these methods helps organizations further advance toward a continuous engineering approach, accelerating the pace of software content creation.

The practice of more frequent feedback cycles in iterative software design allows engineering teams to develop more granular, and therefore more accurate, project forecasts. In fact, more Agile developers select "*performance against schedule expectation/forecast*" and "a*ccuracy/predictability of estimates*" as the most important metrics in the evaluation of Agile/iterative methods rather than selecting metrics focused on productivity or the pace of development. The establishment and tracking of metrics that enable proper allocation of resources can be as critical to project success as

new development efficiencies. Agile developers' emphasis on code quality as an evaluation metric reflects the importance of consistent quality in developing greater scheduling predictability in a continuous engineering environment.

## Exhibit 7: Most important metrics in evaluating Agile/iterative methods




Some embedded engineering firms are now seeking to build on Agile's central themes of expanding communication and cooperation to ever-larger portions on their organization. This approach, commonly referred to as DevOps, extends the concept of collaboration beyond development into QA and operations, covering the full design/test/deliver lifecycle. A DevOps approach can help raise efficiency and improve predictability through increased automation and better alignment of workflows. Insight into the actions and requirements of adjacent groups facilitates the accelerated progression of work from design through delivery of value to customers. As with cross-domain integration, we expect organizations that have been slow to adopt iterative software development will still be receptive to the potential benefits of increasing collaboration through the more holistic DevOps approach to the lifecycle management of their systems.

## Tooling changes

Embedded design teams make sizable investments in licensing and training for legacy tooling, and these tools often hold a significant portion of their intellectual capital. An organization progressing to more continuously collaborative lifecycle management practices must modify its tooling choices to support the key development practices associated with this shift. Our findings show the use of several tool classes increases sharply as organizations implement Agile practices. Continuous integration/release management, software test management, peer code review, data/database analytics, and static analysis tool classes show the most significant increase in tool usage. In an Agile development model, testing and integration start as part of the software design process rather than part of a later stage of a linear process. Accordingly, developers using Agile methods are more frequently involved in the purchasing decisions for automated test (static, dynamic, and model-based) and continuous integration tools.

The increased focus on collaboration and sharing of information elevates the criticality of providing integration with a wide range of lifecycle management solutions as a selection criterion. As more stakeholders in the organization need access to information in a tool, its ease of use and integration with the rest of the development infrastructure becomes increasingly vital. Tool selection decisions must reflect this changing environment. In the same way that performance metrics must evolve to a more holistic approach, so too must tool purchasing decisions mature. Consideration of tools should balance the needs of multiple teams rather than favor the preference of individual teams or engineering domains for a particular tool.

## A future of continuous engineering

The rapid expansion of code base volume and complexity in embedded devices provided initial motivation for the investigation and utilization of Agile methods for systems development. In much the same way, the burgeoning requirement for systems dependent on tight interaction between software, electrical, and hardware components fueled enthusiasm for integrating tooling infrastructure and workflows across the engineering domains. There is a growing understanding of the value in the flood of data generated and shared by increasingly powerful and connected development tools. This awareness, coupled with potential of the real-time data generated by the connected devices themselves, is serving as a catalyst for further change.

It is growing more critical for embedded engineering organizations to continue extending the principles of collaboration to increase the pace and predictability of their processes. Reducing uncertainty during development enables OEMs to focus more on establishing their unique value differentiators. A continuous engineering approach is vital to OEM success in extending customer relationships, delivering new post-deployment updates and services, and establishing effective

informational feedback loops. These bidirectional feedback loops will help support the full development lifecycle, manage supply chains, coordinate design interdependencies, facilitate predictive maintenance, and guide ongoing product evolution. OEMs should plan for increasing the use of integrated, commercial lifecycle management tools as a strategy for successfully managing the continuous evolution of deployed device software necessary to provide these services. Utilization of the new, more collaborative methods and proper development tooling will be necessary to support an accelerated cadence of product updates. Tight integration that includes not only the tools used across the full product lifecycle, but also the corresponding teams, is critical for unlocking the full potential of a continuous engineering approach.

Initial progress toward continuous engineering is now underway. Systems engineering organizations are increasingly adopting Agile software development methods to address growing software creation and tighter time-to-market challenges. Successful efficiency and quality improvements made by early Agile adopters are fostering a broader recognition of the benefits gained by improved integration and collaboration.

Yet due to the heterogeneity of the embedded industries, Agile in systems engineering needs to be measured by degrees of alignment to the method rather than complete adherence. Successful adoption will continue to hinge on customized, hybrid implementations. Pockets of cultural opposition and a legacy of separate tools and teams present ongoing challenges in the embedded market. Universal adoption of Agile across the heterogeneous embedded industries remains unlikely. However, the method's proven success in quickly adapting to changing requirements is encouraging a continued increase in the use of collaborative strategies. OEMs are now looking to extend these principles to more of their organization while on a path to a continuous engineering future. They are scaling the methodologies to address more software development projects, integrating teams across the engineering disciplines, and applying Agile methods to these other engineering domains. The same understanding of the benefits of increasing collaboration through the full development lifecycle, including domains besides software, is helping fuel interest in DevOps as part of a continuous engineering strategy – expanding cooperation beyond development into testing, delivery, and operations.

# About this Report

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