Harvard Business Review
ANALYTIC SERVICES

BRIEFING PAPER

Building Teams for Software-Defined Products

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Michael Corcoran

**President,
DXC Engineering**

Bill Murray

**Senior Researcher and Advisor,
DXC Leading Edge**

The Platform-Driven Business for a Software-Defined World

We see the emergence of blended assets—cyber-physical products—gaining prominence. Examples of these complex systems abound: cars, robots, automated warehouses, biometric border control, and checkout-free stores. Organizations face a conundrum in trying to accelerate their digital transformation while modernizing their foundational systems yet pioneering initiatives to pursue a new software-defined future. This is more than a stepwise evolution of hardware once composed only of mechanical and electrical parts. Cyber-physical systems fuse hardware, sensors, processors, software, and connectivity features into programmable and easily updated interfaces, offering new business value to seemingly similar devices. Yet personalized digital cockpits reinvent the driver experience, and they come to us via software-defined vehicles. Virtual power plants optimize green generation and local storage. Virtual hospitals provide remote patient care, and robotic surgeons are becoming more common in operating rooms.

These cyber-physical assets connect and integrate an enterprise in a more significant way with its customers and suppliers. And deeper connections enable meaningful and continuous cross-industry collaboration.

Digital life cycle management (DLCM) presents an orchestration path for the end-to-end life cycles of these cyber-physical assets. DLCM is early in its evolution, but we are beginning to see some of its most critical elements: human-centric design, modern platform environments, and software engineering factories. These harness data flywheels that deliver intelligence, hardware, and software harmonization with data-driven design and development.

Companies embarking on DLCM can take their cues from the automotive industry where, for example, one German innovator is engineering a software platform for advanced features, hardware and software harmonization to provide a “system on a chip,” and a new tech hub in the United States. Instead of ordering cars (or planes or plant machinery) with pre-selected upgrades, drivers will simply turn on features at the point of need.

This will allow a truly bespoke driver experience for the customer but also substantial development, build, and upgrade efficiency for the carmaker, as future functionality gets delivered “over the air.”

We believe every industry sector will use cyber-physical assets, many at scale in fleets. The next wave of adopters will take the path of the automotive, aerospace, and electronics industries, following the direction of the hyperscalers and other digitally intense businesses, which have de facto digital operating models. These enterprises will move toward becoming platform-driven businesses.

We’ve sponsored this Harvard Business Review Analytic Services report to examine how executives can embrace digital life cycle management to create new business value in our software-defined world. Engineering and talent will be essential considerations, as will the way humans—be they customers, employees, partners, or suppliers—engage with and advance digital products and services. Read on to learn more about this and how forging the right supplier partnerships will be crucial for success.

Building Teams for Software-Defined Products

Industries have fully embraced the practice of embedding software in their products and services, and the world is only likely to see more software-defined or cyber-physical assets, with more companies deploying them for more use cases. Consider how software-defined cars, phones, call centers, smart factories, virtual customer service agents, aircraft, and drones increasingly rely on embedded software that defines each system's capabilities every bit as much as its hardware does.

Organizations connect software-defined assets to their operations and larger ecosystems to return benefits to themselves and their customers. For example, residential solar panels tie into the grid to improve network resiliency and allow residences to sell electricity to utilities. Connected cars exchange data via cellular and Wi-Fi connections with auto dealers, manufacturers, and even insurance companies to improve performance and reduce premiums. And smart pill bottles remind patients to take medications, track dosages, and keep caregivers in the loop.

Connected vehicles present a compelling example as the automotive industry undergoes a sea change driven by electrification. Accordingly, Gartner Inc. predicts one in two of the top ten automakers will provide fee-based software upgrades by the end of 2023, delivering a steady cadence of improvements after the original purchase.[1] And McKinsey & Co. predicts that nearly all new vehicles (95%) will be connected to the internet as part of normal functioning by 2030.[2]

Cyber-physical assets need continuous development, upgrade paths, and processes for eventual retirement. In short, they need advanced digital life cycle management (DLCM) practices. Advanced DLCM can provide a pipeline

HIGHLIGHTS

Industries have **fully embraced the practice of embedding software in their products and services**, and the world is only likely to see more software-defined or cyber-physical assets, with more companies deploying them for more use cases.

Cyber-physical assets need **continuous development, upgrade paths, and processes** for eventual retirement.

Getting that result requires **dedicated software platforms, teams, and pipelines** delivering faster times to market than may be practical for legacy IT departments.

> "Prior to software-defined products, you sometimes would have a year of lead time to design a marketing campaign around a particular product. Now, if things have cloud-native software behind them, you might have an hour's notice before a new function is released," says Marcia Walker, vice president of research at International Data Corporation.

of "over-the-air" updates for everything from cars and smart hubs in homes to assembly robots and autonomous carts in factories.

"If you want to innovate faster, you need the blend of reusable competencies, building blocks, frameworks, and services for both software and hardware," explains Paul Clarke, an independent technology advisor to companies and governments. "And just like a Lego set, the power comes not only from taking time, cost, and risk out of the development process but also the increased interoperability and standardization."

Getting that result requires dedicated software platforms, teams, and pipelines delivering faster times to market than may be practical for legacy IT departments. The fact is, the need for agility has seeped into all parts of the organization. Accordingly, companies must stand up semi-independent, multi-skilled teams with the product-centric mindset needed to move quickly at a scale capable of supporting a diverse product portfolio.

This paper examines the growing imperative for companies to adopt DLCM practices that support cyber-physical products and services. It explores how internal "software shops" aligned with DLCM practices are built, function, produce, adapt, and interact with the rest of the organization. It outlines how DLCM is helping organizations bring enhanced value and increased responsiveness to market changes customers have come to expect. Finally, it presents best practices and lessons learned from early movers to help organizations reconcile their need to develop software-defined products with their current limitations in achieving the required scale and faster development cycles.

"It's changing the nervous system of the organization," says Marcia Walker, vice president of research at Needham, Mass.-based International Data Corporation, of the DLCM challenge. "Prior to software-defined products, you sometimes would have a year of lead time to design a marketing campaign around a particular product. Now, if things have cloud-native software behind them, you might have an hour's notice before a new function is released."

Rewriting the Organizational Code

Organizations must undergo a cultural shift to adopt new DLCM frameworks, according to Walker. That means cultivating the necessary change management skills. "Culture change is a skill unto itself and requires specialists to come in and advise or budget for people on the team whose job it is to build those bridges and to keep them strong," she says. In other words, managers must help new DLCM-centered groups communicate and work well with existing teams.

The task is especially challenging because DLCM-focused development benefits from different cadences and priorities than traditional hardware and software development groups. Most notably, conventional groups with long lead times typically develop products more slowly and with more clearly defined versions than faster-paced DLCM teams engaged in continuous development and operations. Organizations must enable DLCM groups to move at a faster pace while maintaining an effective interface with legacy teams since both ultimately work toward the same end—providing value to customers.

To that end, Walker advises creating teams that work in parallel and report to the same upper managers rather than having one team subservient to the other. "If you want the hardware and software groups to work well together, they should probably be in the same reporting structure, and they should probably be measured on the same things," Walker says.

Despite the challenges of accomplishing the shift, the rewards seem clear. The Boston Consulting Group (BCG) estimates that automakers, for example, can realize up to an additional $7,500 in profit per car through over-the-air updates to consumers (i.e., software-defined products and services). The firm attributes the higher margins to both upsell opportunities and lower production costs—and that's not including an additional potential $2.5 billion to be gained across each automaker's value chain. BCG also identifies software-defined products as a boon to automakers, with usage data collected by vehicles—for example, about battery performance, brake usage, and other parameters—helping teams improve hardware development.[3]

Putting DLCM to the Test

DLCM groups and their organizational structures differ widely between companies, let alone across industries. But Walker identifies one significant differentiator: companies in heavily regulated versus less-intensively regulated industries. And although less-regulated companies may benefit from greater latitude in how they run their development shops, Walker recommends that even they adopt the strictest standards. "Even if you're not highly regulated now, you might be later, and it's much harder to reverse engineer it," she explains. She cites as an example prescription digital therapeutics, a relatively new category of medical technology delivered through mobile devices that has come under increased regulatory scrutiny since its emergence.

Clarke says a compartmentalized, but not completely walled off, approach to innovation works best for software and hardware engineering teams. "Those compartments, they are not watertight," he explains. "They are what I would call semi-porous because you want ideas, capabilities, ways of working, and people to flow across them." At the same time, compartmentalization ensures that prototypes don't migrate into production before they're sufficiently tested and engineered for large-scale release—jobs for traditional IT and engineering groups. "It creates a stage gate that says if prototyping demonstrates that your idea has legs, then you're going to force yourself to re-engineer it in the next compartment," Clarke explains.

Besides good working relationships with internal groups, Herman Claesen, managing director of Future Combat Air Systems at London-based BAE Systems, sees close relationships with suppliers as critical to successful DLCM teams. For example, in developing the U.K.'s next-generation fighter jet, his company is working more closely with the vendor for its life cycle management (LCM) software than on previous, more conventional design, development, and manufacturing projects. "In the past, we would buy these kinds of tools off the shelf," he says. "Or we would modify them." Now, the vendor is part of the BAE team developing a new LCM toolset.

The benefits of DLCM processes extend through every phase of a product's life cycle, including initial development, manufacturing, maintenance, and ongoing upgrades.

For example, Claesen says BAE uses digital modeling to accelerate the new jet's development. "We do a lot of wind tunnel testing," he says. "But we can also build an aerodynamic model digitally in a virtual world." The team plans to validate the model and its digital environment with real-world flight testing. "This significantly reduces the number of flight tests," Claesen says. "You pick a number of [data] points, and you compare these points to the model. And if they correlate, that's the end of the flight testing." He says digital testing has the potential to validate thousands of variables instead

INDUSTRY INSIGHT

Turning Sectors into Ecosystems

As software-defined, cyber-physical assets grow more sophisticated, numerous, and interconnected, ecosystem boundaries become increasingly fuzzy. Until recently, for example, the mobility ecosystem existed in industry islands, independently establishing products and go-to-market approaches. Now, shared data, features, and interactions have exponential benefits for all participants, thanks to digital life cycle management (DLCM), which provides a framework for orchestrating services and add-on integrations, working with other industry sectors and beyond the traditional tiered ecosystem.

When an automotive company offers a digital cockpit or autonomous driving experience, these personalized services are software-defined, connected, and regularly upgraded "over the air." Similarly, an app that remotely reviews automotive functions and schedules maintenance appointments shifts from general estimated "regular check-ups" in older models to actual condition-based scheduling in the cyber-physical model. When DLCM connects new systems of the automotive cyber-physical asset with the core enterprise systems, it delivers benefits back to the automaker, closing service revenue leakage, providing fleet performance data, and opening avenues to delight customers.

In addition, DLCM connects other industries to the ecosystem. It goes beyond the design-build-manage-operate-upgrade-retire cycles of one asset. Examples include the following:

- Energy companies can now provide grid-to-vehicle and vehicle-to-grid cyber-physical exchanges
- Media companies can now extend in-car entertainment possibilities
- Insurance companies could potentially provide on-demand, pay-as-you-go, micro-insurance to drivers
- Finance companies could potentially provide financing of on-demand service offers from vehicle makers and partners

In the automotive case, DLCM redefines the car as a mobility platform, loosening constraints on customer interactions and offering upgrades, customer feedback loops, and premium customer service.

INDUSTRY INSIGHT

Modern Platform Environments: Critical to DLCM

The real-world transformations required to realize software-defined connected assets like wind turbines, aircraft, or checkout-free stores are extremely complex. Multi-phase transformation requires concurrent, model-based engineering, then delicate decoupling and intelligent recoupling of simultaneous hardware and software development. Doing this at sprint pace to realize a "big loop" of fast systems learning requires multiple specialized teams working on simultaneous, synchronous component updates. Each is dependent on mastering cyber-physical engineering, with each incorporating platform-driven permutations—enabling key platforms for asset integration, software factory, shop floors, data-driven development, operations resilience, plus back-end and continuous integration/continuous development and deployment toolchains. Through careful DLCM, these tech flywheels are designed to engage with, learn from, and synch with each other while the whole cyber-physical entity evolves.

Modern platform environments build and run DLCM and IT life cycle management simultaneously to act as:

Intelligent Building Blocks

- Connecting fleets of assets across ecosystems and enterprise groups, such as aircraft components, city intersections, humans, medical devices, and embedded finance
- Generating data and learnings that organizations absorb and convert into actionable distributed intelligence

New Digital Operating Models

- Continuously automating and industrializing business processes with intelligence, mobilizing multi-disciplinary teams, and integrating and standardizing new technologies
- Enabling decisions and operations to flow at speeds that improve outcomes

Change Agents

- Transforming traditional structures and practices to focus on value creation at the cadence of customers while mitigating risk
- Enabling more localized decision authority and greater work satisfaction

Platform engineering used to be the craft of building technology platforms. Now it's the baseline of how we build digital businesses.

of only the dozen or so possible in a conventional flight test. The result: a safer and more capable aircraft entering service more quickly. In general, digital modeling may take into account such variables as geography, weather conditions, and human biometrics.

In a broader sense, software development, once considered an item to outsource, has matured into specialties critical to the evolution of cyber-physical assets, specifically embedded software development and data science. Data science does the heavy lifting of analyzing variables in potentially thousands of combinations to identify engineering needs and risks, compressing development time in ways that real-world testing cannot.

Avoiding Pitfalls

While it may be tempting to treat new software-defined product groups as a kind of internal Skunk Works—mainly working independently of the rest of the organization—doing so can lead to trouble, according to Walker. "You're not truly a startup if your funding and your performance metrics are tied into the larger, older organization." For example, a larger, publicly traded company with shareholders to answer to every quarter may need to proceed with technology investments at a slower pace than a smaller, privately funded company with more flexibility. Walker cautions against attempting to ditch the old organizational structure in favor of the new one too quickly. Instead, she recommends gradually adapting the old organization to new processes. "It's often better to invest in transitioning your people," she says.

One challenge is to keep organizational knowledge relevant and available while improving muscle memory. Blending existing and emerging talent can help organizations achieve this goal by accelerating skills diffusion and developing new ways of working.

In that vein, Clarke advises keeping things fresh by moving people through different roles to learn new skills and to spread competencies, culture, and ways of working. And he agrees

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The concept of "shrink to grow" isn't a new one and has been found more recently in competing visions of cloud vs. data center services.

with Walker. "You can't just glue an incubator on the side and hope that's going to transform an organization that is not innovative into the next Google. Unless innovation is deeply rooted within the culture of the organization, the incubator will be like a skin graft that does not take."

Beware of misaligned digital modeling, BAE's Claesen advises. If teams are not diligent in updating digital twins, those models won't reflect anticipated real-world results. Such mismatches risk disaster—especially in the case of vehicles and aircraft that can literally crash.

And on the business side of the equation, Claesen advises thinking carefully about new revenue streams to replace those you could render obsolete by making digital components a bigger part of your product offering. For a manufacturer like BAE Systems, that might mean weighing the potential revenue from new product streams and updates—for example, software subscriptions—against existing revenue that depends on regular, labor-intensive maintenance in a repair shop. "It's essential because if you don't, your traditional business shrinks as a manufacturing-dominated organization," Claesen says. "Your business models have to evolve."

First Steps

The priorities for DLCM must be clear at the outset. "It has to start with the end in mind," Walker advises on standing up a software-defined product team. "If the end in mind is 'We want to have primarily software-defined products with a shell of hardware products,' what's always going to change is the software." That setup is quite different from a focus on changing the hardware frequently, say once a quarter, while adapting software to match; one approach focuses first on software, the other on hardware, and each direction comes with its own challenges.

INDUSTRY INSIGHT

The Renaissance of Systems Integration

Cyber-physical systems (CPS) involve computation, networking, and physical process integrations. Today's realization of CPS builds on the older discipline of embedded systems, computers, and software built into devices. Early embedded systems melded computer hardware and software for a defined purpose, often within larger, programmable systems. These precursors of today's cyber-physical systems can be found in areas as diverse as aerospace, automotive, chemical processes, civil infrastructure, energy, health care, manufacturing, transportation, entertainment, and consumer appliances.

Today, we integrate new cyber-physical systems assembled from across ecosystems into websites, digital markets, products, services, and core process platforms. Yet they pose numerous challenges.

- Sophisticated modernization within complex, often rigid IT life cycles is difficult to achieve because apps run mission-critical processes all day.
- Designing, building, delivering, and caring for dynamic solutions in more fluid DLCM is so challenging in a difficult, ever-evolving space that some niche players specialize in this alone.
- Doing both modernization and digitization while simultaneously synching real-world, live operations requires experience and a dose of fortitude to make the old and the new work seamlessly together without breaking something or interfering with live operations.
- These challenges require mastery of complexity in the software-defined world of cyber-physical assets.

Now we have three variants of systems integration running in parallel and dealing with complexity: IT systems integration, digital systems, and cyber-physical systems integration. Cyber-physical assets are thus creating new forms of integration to deliver on new and emerging systemic complexities.

Companies that don't adopt these practices risk losing market share to competitors that do, partly thanks to revenue streams shifting away from hands-on, one-at-a-time upgrades to digital updates that scale more quickly.

Bringing in specialized expertise to lead the new effort can shorten the learning curve, Claesen says. For example, he hired an executive from the software industry to help guide the development of the digital production environment for BAE's new aircraft. "From a mindset point of view," he says, "I need somebody with digital experience who is embedded in the team to actually drive that mindset from the top."

To gain further inspiration for starting and running DLCM groups, Walker recommends studying such groups at other organizations, and not necessarily those in the same business. "Ask them what they learned and what they wish they had done differently. Ask everybody, not just the executives." She also suggests doing this exercise internally—for example, by having hardware engineers work in the software department for a few months. The goal: to help the two groups forge stronger working relationships through a deeper understanding of each other's day-to-day challenges.

The Future of DLCM

As DLCM practices advance and more cyber-physical products emerge, Claesen anticipates even tighter collaboration between manufacturers and suppliers of both hardware and software. "The easiest way of describing it is, in effect, an Apple kind of system, where you've got an iOS, the operating system," he says. "And then the operator can go to some kind of app store, configure the capability of its products by choosing a set number of applications, and then [install them] on the solution." In this scenario, the manufacturer maintains the app store and operating system and builds a business model on fees for upgrades—for everything from washing machines to aircraft.

Of course, such business models may undercut existing businesses in which manufacturers make money from overhauling products to provide new capabilities. But again, the trade-off involved may be more than worthwhile, given the cost differential, speed to market, ability to scale, and potential licensing revenue.

Yet the concept of "shrink to grow" isn't a new one and has been found more recently in competing visions of cloud vs. data center services.

In BAE's case, upgrading systems currently involves multiple weeks in an aircraft hangar to add weapons or other systems. The effort typically includes replacing computer hardware as well as updating software. Instead, Claesen says, "With an open architecture, you would place an app on the software that is attached to the management and control of that particular weapon or sensor. That could be an overnight thing that you software squirt onto the aircraft."

Conclusion

As organizations continue to develop and refine software-defined products, they must adopt DLCM management practices and roadmaps to help drive a new target operating model that enables continuous development and operations. When they engineer for the necessary culture change, they can examine new approaches to enable rapid innovation, even as they upend long-established business and operational processes.

Companies that don't adopt these practices risk losing market share to competitors that do, partly thanks to revenue streams shifting away from hands-on, one-at-a-time upgrades to digital updates that scale more quickly. Nevertheless, Walker, Clarke, and Claesen foresee a bright future for cyber-physical product development and DLCM. Advantages should accrue to manufacturers, customers, operators, and suppliers alike.

To be sure, companies may have to live in both worlds for some time, with some divisions following DLCM and others traditional development practices. This situation places pressure on companies to develop creative ways to handle potential conflicts, enabling teams to work alongside each other and evolve toward greater understanding.

In the end, organizations need to shift further into this new model as they disrupt their old revenue channels to create new and more fluid revenue streams and ecosystems. Customers and operators should see products gain capabilities more quickly. And suppliers with closer relationships with product companies should play a bigger role in shaping product design, giving them more opportunities as well. The new model ultimately should benefit entire economies as well as individuals and companies. As Claesen points out, "It opens up a whole new world for us."

Endnotes

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MCCRE37700423