Applied Industrial DevOps 2.0

A Hero's Journey

IT REVOLUTION

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Produced in the United States of America

Cover design and interior by Devon Smith

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LaunchDarkly

Preface

Since 2015, we've been assembling the DevOps Enterprise Forum in Portland, Oregon, for three days to identify and create written guidance for the top problems facing the community—it's always been one of my favorite professional activities that I get to participate in.

However, in the spring of 2020, the entire world changed. The COVID-19 pandemic had reached around the globe and changed the way we live, work, educate...everything.

For the sixth annual DevOps Enterprise Forum, we conducted the three days virtually—my heartiest thanks to everyone who helped with the planning, because it captured so much of the creative, serendipitous, generative, and high-learning magic that's been the hallmark of the event in prior years.

As always, industry leaders and experts came together to discuss the issues at the forefront of the DevOps Enterprise community and to put together guidance to help us overcome and move through those obstacles. It's no surprise that the global pandemic and social justice were both at the forefront of most of the groups' work.

A special thanks goes to Jeff Gallimore (Excella), who helped make sure all the trains kept running on time, to Ross Clanton (American Airlines), who also helped with planning, and Ann Perry, one of the people at IT Revolution who worked behind the scenes making sure that it all came together.

Additional thanks goes to this year's Forum sponsor, LaunchDarkly.

And most importantly a huge thank you to this year's Forum participants, who contributed their valuable time, expertise, and creative energy, and who always go above and beyond to put together these resources for the entire community to share and learn from.

Please read, share, and learn, and you will help guide yourself and your organization to success!

—Gene Kim
September 2020
Portland, Oregon

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Introduction

In this paper, we expand on the previous two papers introducing *Industrial DevOps* and *Applied Industrial DevOps.* We now consider the criticality of designing technical architecture, team organization, and intentional culture architecture with dynamic learning and feedback loops when deploying Industrial DevOps at scale. We will use the story of a fictitious leader, Nole, in a company called Alset to provide application context.

Outline

- The New Initiative
- Technical Architecture and Team Organization
- The Big Miss
- Intentional Culture Architecture Design

The New Initiative

The executive leadership team of Alset, a leading automotive company, understands that to remain competitive in the Digital Age and improve economic results, they must rapidly deliver increased value to customers. To realize part of their autonomous vehicle vision, they have funded and communicated the new *Improve Driver Safety* strategic theme, which will be implemented through the creation of a new value stream, *Active Safety*. The goals of Active Safety are to improve product quality and safety, reduce product lead time, and innovate faster.

Nole, a longtime Alset automotive engineer, has been appointed the lead of this new initiative. He is an electrical engineer turned systems engineer with experience across many different parts of Alset, including chassis, powertrain, and infotainment. His breadth of experience has positioned him for this new role. Nole and his teams need to drive significant innovation to achieve Alset's needs. He knows innovation is naturally coupled with uncertainty and risk, and he looks forward to helping Alset evolve from a risk-intolerant organization.

Nole witnessed the small and innovative Infotainment Software group's success in creating features that delighted customers. He knew that in order for Alset to scale these successes, the company would need to transform its traditional engineering practices into Lean, Agile, and DevOps practices. The challenge was the significant differences between the development activities of the Active Safety value stream compared to the development of the Infotainment Software group. While

software is a key component, Active Safety also requires numerous physical products like cameras, sensors, and custom processing units. The complexity of scale was daunting, as Active Safety is part of a larger system of systems supported by a team of teams.

Seeking success patterns from other organizations and industry thought leaders, Nole attended the DevOps Enterprise Summit (DOES). He found that many of the world's largest enterprises were also working to identify and define ways to scale DevOps practices from a single, two-pizza Scrum team to multiple teams of teams across large, sophisticated systems composed of hardware, firmware, and software. The intent was to enable complex interconnected environments to adjust and align with customer needs, learn faster than the competition, and release to market earlier. Enabling integration as continuously as possible and deploying frequently and utilizing DevOps pipelines for each system environment were key strategies Nole hoped to implement.

At the DOES Summit, the Industrial DevOps community helped Nole understand the technical and organizational challenges he would be facing at Alset and how to apply Lean, Agile, and DevOps practices and systems thinking within cyber-physical systems and products that include hardware. Nole learned about Industrial DevOps principles[1] that development organizations can use to bring the power of DevOps to those building large-scale, cyber-physical systems:

- Visualize and organize around the value stream.
- Use multiple horizons of planning.
- Base decisions on objective evidence of system state and performance.
- Architect for scale, modularity, and serviceability.
- Iterate and reduce batch size.
- Establish cadence and synchronization.
- Employ "continu-ish" integration.
- Be test-driven.

Nole needed support to implement Alset's Industrial DevOps transformation at scale. This was validated by the seemingly endless talks available at the DOES conference discussing the significant organizational change challenges with transformations and making them stick. In one of the talks, Nole learned how Alset could use a guiding coalition[2] to set the vision for change along with a Lean-Agile Center of Excellence (LACE) that would prioritize and help implement the changes needed for transformation. Armed with the Industrial DevOps principles and his newfound knowledge, Nole was ready to apply industrial DevOps (IDO) at Alset.

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[1] Suzette Johnson et al., *Industrial Devops: Applying DevOps and Continuous Delivery to Significant Cyber-Physical Systems* (Portland, OR: IT Revolution, 2018).

[2] J.P. Kotter, *Leading Change: An Action Plan from the World's Foremost Expert on Business Leadership* (Boston MA: Harvard Business School Press, 1996).

Applied Industrial DevOps Technical Architecture and Team Organization

Like the majority of the automotive industry, Alset naturally evolved around value streams of product lines that provide economies of scale and support multiple customers across a large and extended supplier network. This organization grew in a structure that supports the vehicle's architecture and in support of Conway's Law.[3]

Nole observed that Alset already supported IDO Principle #1: *Visualize and organize* around the value stream. He decided to apply it to the new Active Safety value stream.

The new Active Safety value stream, shown in Figure 1, is composed of independently releasable subsystems, or "streamlets," including a new camera and the algorithms and supporting software and hardware for collision avoidance and obstacle detection. Active Safety's subsystems must also interface with other value streams:

- Chassis to mount the camera and sensors
- Powertrain for acceleration and deceleration
- Braking to slow and stop
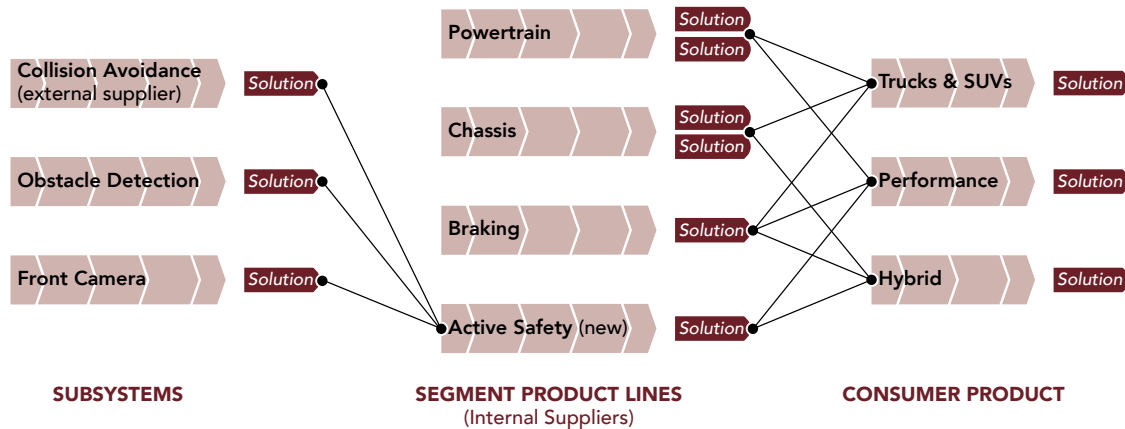- Lighting for control of turn indicator, brake, and headlights

Figure 1: New Active Safety Value Stream
A subset of the value streams in the automotive supply chain, including powertrain, chassis, and braking, which provide a product line of solutions to internal customers to build vehicles.

Each Active Safety value stream is a solution composed of hardware and/or software elements that can be built, integrated, tested, deployed, and released independently. This enables flexibility for the business. For example, Alset can release a capability to recognize traffic indicators in a new foreign country on a dif

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[3] "Conway's Law," Wikipedia (Accessed August 10, 2020). https://en.wikipedia.org/wiki/Conway's_law.

ferent schedule than new algorithms for collision avoidance. This ability requires support from the system's architecture and the continuous delivery infrastructure, which are discussed later in the section.

Define Solution and Value Stream Roadmaps

To apply Principle #2: *Apply multiple horizons of planning*, Nole defined a technical roadmap based on incremental solution development. He knew that Lean and Agile encourage fast learning, so the roadmap includes two types of work:

System of Systems: Large systems composed of other systems that can independently define, build, and deploy new functionality. Together, they achieve the intended solution behavior. All are aligned to a common purpose and share a common view of continuous exploration and analysis activities, and ensure compliance, traceability, and assurance.

Prototype: Model all or part of a system that mimics the desired functionality to provide feedback on decisions and reason about the solution for continuous learning and knowledge sharing.

Nole and the system architects plotted out the work the teams had committed to for the next quarter along with the work they forecasted for the remainder of the year. This technical architecture roadmap served as a visual informational radiator to help the teams lead with architecture and ensure cross-team alignment (Figure 2).

	2021 Q1	2021 Q2	2021 Q3	2021 Q4
SYS OF SYS	• Follow route to destination • Stay in lane • Detect forward object	• Avoid forward collision • Make turns • Obey speed limit indicators (US)	• Plan an unavoidable collision • Obey traffic lights (US)	• Navigate intersection • Avoid side obstacles • Self park
PROTOTYPE	• Determine camera mounting position	• Explore sensor mounting locations	• Collect German and Italian traffic indicators	

Today

Committed — *Forecasted*
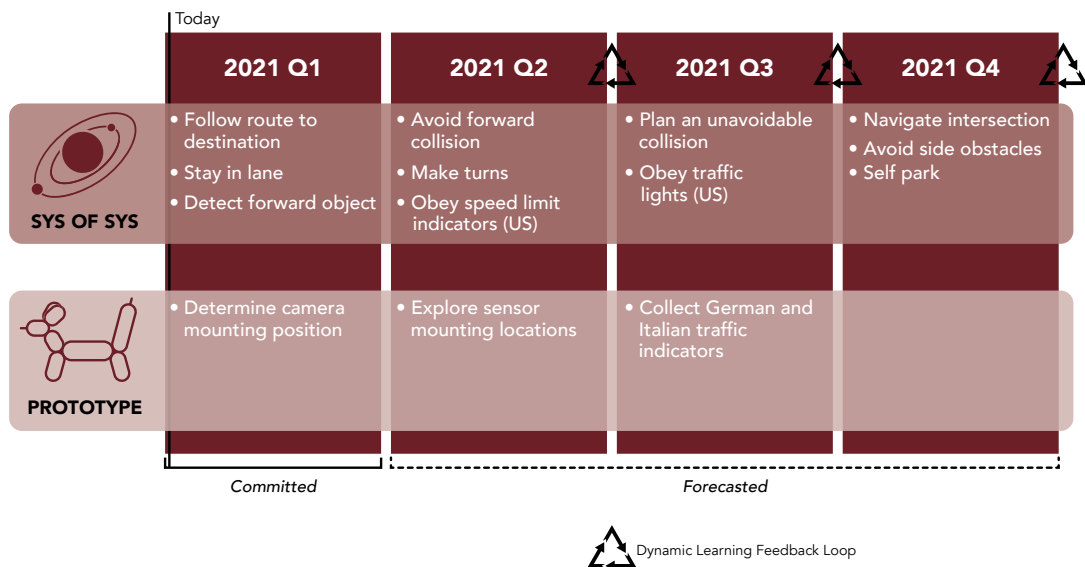
Dynamic Learning Feedback Loop

Figure 2: Technical Architecture Vehicle Roadmap

Hardware components also have roadmaps in support of the product roadmap. The development activities building the product work above must run on some platform. Figure 3 shows the hardware

roadmap and the defined milestones for physical hardware integration to support the development activities. The Camera value stream initially provided a mock signal generator that other value streams could use for development. That evolved into a prototype board and eventually the first hardware revision. Other milestones show integration points between Active Safety and other other value streams.
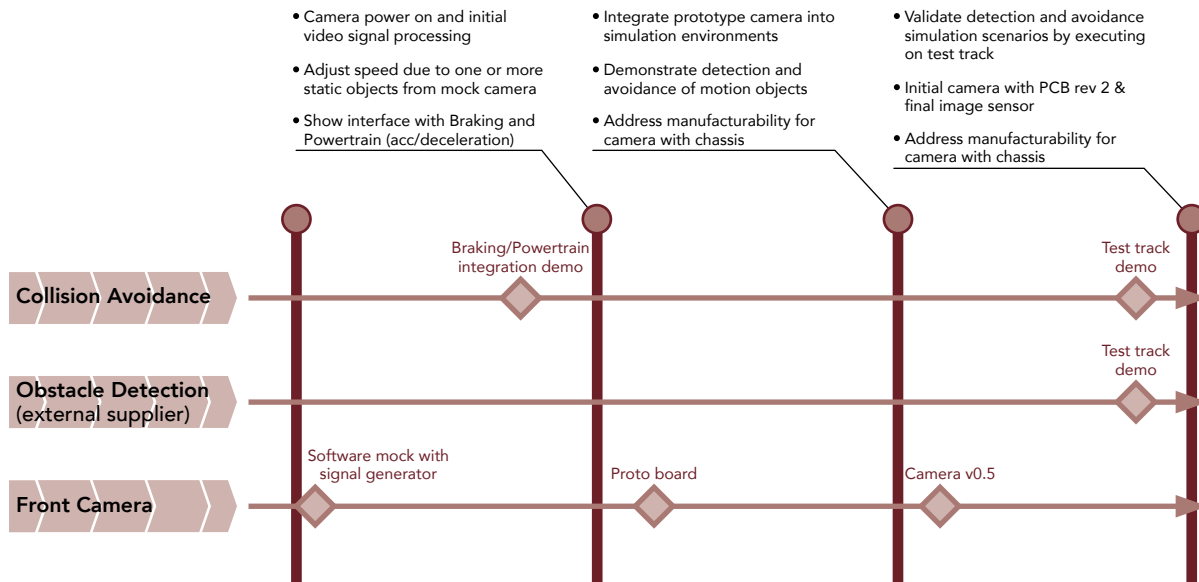

Figure 3: Active Safety Roadmap for Hardware Components

Employ Continu-ish Integration (Principle #7)

Nole ensured the Active Safety architecture could deploy as individual "streamlets." This allowed each streamlet to evolve at different rates across their own CI/CD pipeline. It also supported frequent, or in some cases continuous, delivery to the integrated test platforms, which included simulation, test benches, mule vehicles, or even production vehicles.

This decoupling supports set-based design (keep options open as long as possible) and allows components to independently iterate through successive design phases without impacting other parts of the system. The Camera component interacted with other parts of the system though a standard HDMI interface as shown in Figure 4. Dependent value streams could easily integrate new Camera revisions described in the hardware roadmap.

DevOps practices were pioneered at Alset in the Infotainment group. When Nole worked within that part of the organization, the group spent several years investing in automation to build, integrate, and test components through environments of increasing complexity and fidelity—development, system, staging, and even operational vehicles through over-the-air updates. They could continually deploy to test environments, "mule" vehicles, and even consumer vehicles in the operational environment. This allowed Alset engineers to test changes on different subsets (by region, by vehicle type, by security and regulatory requirements, etc.) for validation before releasing a change to all vehicles.
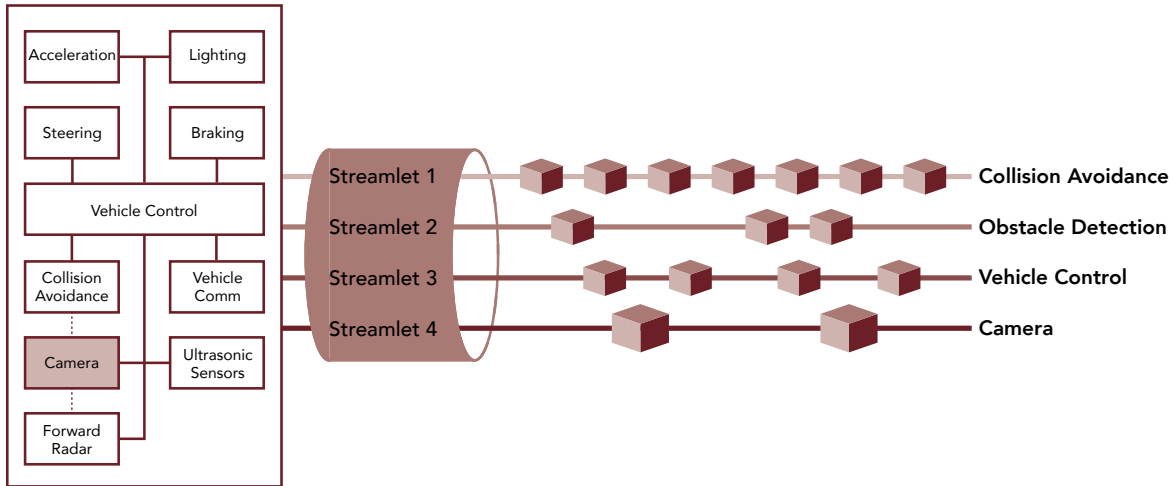
Figure 4: Active Safety Streamlets

Streamlets are separately deployable and releasable units.

Nole wanted the same benefits for Active Safety, but that included hardware components like the Camera. He knew this would require a different solution than what he had help create with the Infotainment group. Working with the Active Safety team, he shared his experiences and challenged them to find ways to create a continuous delivery pipeline for the Camera's hardware components.

They understood that hardware development began with modeling in electrical and mechanical CAD, so they started to uncover ways to apply Industrial DevOps Principle #8: *Be test-driven*, by building quality tests within the models. Mechanical created pass/fail equations based on design constraints.[4] Electrical added unit-level tests to the VHDL and Verilog code.
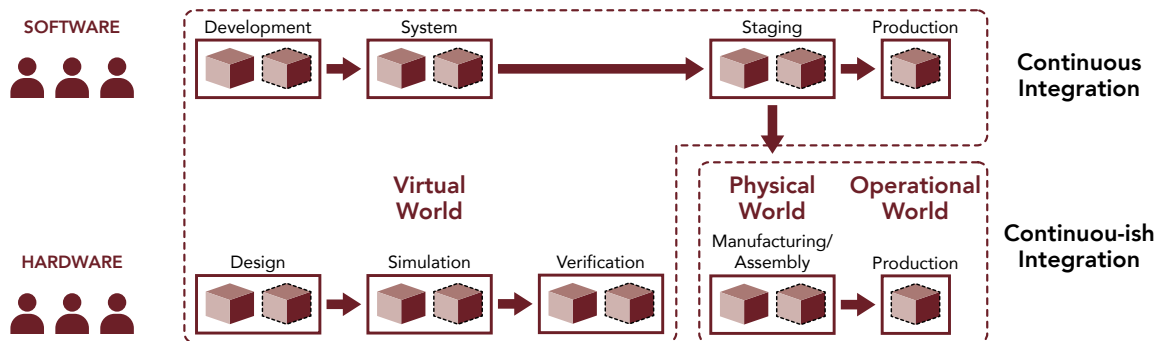

Figure 5: Continuous Delivery Pipelines

Continuous delivery pipelines differ for hardware and software.

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[4] Dagmara Szkurłat, "Test Driven Engineering: a different way of doing design," Medium.com (Last modified September 19, 2017), https://medium.com/@dagmaraszkurat/test-driven-engineering-a-new-way-to-do-mechanical-design-dd4d55ccf208.

Nole saw that these changes were starting to produce similar improvement results: they reduced errors, improved design quality, and increased teams' velocities. However, the team identified two steps in the hardware pipeline that they could not automate. These two steps block in continuous flow for hardware (see Figure 5):

- The manufacturing and assembling of parts
- Installation and configuration of those parts in the environment, which could include test, mule vehicles, or production vehicles

Nole worked with the teams on ways to reduce these blocks to continuous delivery for hardware:

- 3D print components for early validation and, when appropriate, for production parts.
- Assign system capabilities to programmable hardware (FPGA or system on chip) instead of custom ASIC parts.
- Lower quality standards for development parts to lower the manufacturing transaction costs and to allow for faster and more frequent hardware turns
- Acquire development parts from local manufacturers who can provide direct collaboration and faster turnaround times
- Use cost-effective methods for joins/interfaces (consider connectors vs. soldering, screws vs. welding)

The Big Miss

Nole was surprised when Alset's first increment in applying Industrial DevOps failed to realize some of the anticipated results. There were technical successes, including better alignment of work across components and teams, and earlier integration, learning, and adjusting. Initially, the teams were producing good results. However, several serious issues started to emerge over time:

- Teams were beginning to miss their iteration commitments and began producing more errors.
- The system-of-systems roadmap adjustments at the end of Q1 required the supplier to push some work back and pull other work forward. However, the supplier balked at changing the schedule and claimed it would create cost overruns.
- Near the end of Q1, Alset's quality organization (QA) informed Nole that every "release," no matter how small, had to run through their certification process, which had a two-month backlog. This would massively disrupt Nole's goal to push small releases to subsets of customer vehicles for innovation and learning.

- The Chassis value stream had no time to support the Camera team's need to explore design alternatives for mounting and manufacturing the camera.

These issues were very troubling. Thanks to his Lean background, Nole knew he needed to better understand the root cause of these problems. He facilitated a series of retrospectives and "five whys"[5] workshops with the parties affected by each issue. This helped Nole discover the following root causes:

- *Missed iteration commitments with an increasing number of errors*. These misses and errors stemmed from the team's emphasis on releasing new features, which left no time for refactoring and improving designs. With little time, the "tyranny of the urgent" for delivering kicked in, causing engineers to cut corners and not invest in the needed research and preparation for downstream work. Nole knew that exploration and set-based design would reduce fire-fighting downstream, and he understood that teams needed to make time to perform that work.
- *The supplier refused to change the schedule due to cost overruns*. Procurement selected the supplier due to their technical prowess, yet they were not a cultural fit. The supplier's engineering organization used classic waterfall methods and had not advanced in the adoption of Lean/Agile practices. They could not provide incremental solutions to validate early, which resulted in delayed or sometimes blocked solution-level Active Safety integration. In addition, the contract incentivized the supplier to find cost reductions instead of providing the best overall value to Alset's business solutions. Nole recognized the need to actively engage with the suppliers on improving engineering and quality processes and help them understand how early integration reduces schedule risk.
- *The quality organization required every "release" to run through their burdensome certification process*. While the engineering organization was making the transition to the Lean/Agile and systems thinking mindset of Industrial DevOps, other parts of the organization, like Quality, continued to use old practices. Some were still operating under the Industrial Age management mindset, focusing on command-and-control tactics, and were not actively engaged in the development process. Their quality inspections happened at the end of full systems integration, leading to steadily increasing cost and time delays. Nole began to realize that in order to be successful, the entire organization must understand the new way of working. The quality engineers would need to be embedded with the development teams to gain a full appreciation of and guide the integrated testing to increase confidence of safety and certification upon release.
- *The Chassis value stream had no time to support the Camera team in exploring design alternatives*. Nole discovered that Alset rewarded teams based on individual value streams rather than value

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[5] John Shook, *Managing to Learn: Using the A3 Management Process to Solve Problems, Gain Agreement, Mentor and Lead* (Cambridge, MA: Lean Enterprise Institute, 2008).

streams for the product as a whole. Consequently, the Chassis organization was disincentivized from supporting Nole's camera team. Nole saw that Alset needed to reward and recognize behavior that produced the best outcomes for Alset products, not solely focusing on individuals meeting their siloed goals.

Nole reviewed these root causes and realized there was still a long journey ahead. He saw two patterns: (1) tyranny of the urgent and (2) lack of psychological safety. Nole knew that he would need to work with the organization's LACE to resolve these issues and make industrial DevOps successful at Alset.

Intentional Culture Architecture Design

If the architecture of the system and the architecture of the organization are at odds,
the architecture of the organization wins.
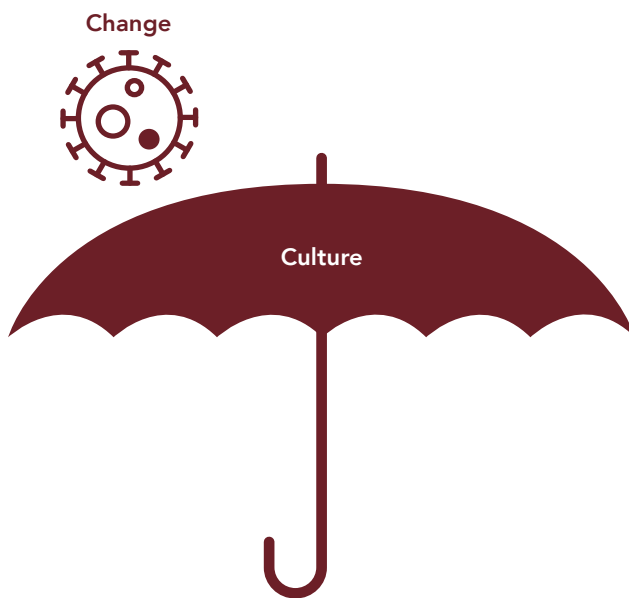
—*Ruth Malan*

Figure 6: Culture as a Barrier

As Nole was reflecting on these issues, he considered the people doing the work and Alset's culture. Since people are the component running and managing the systems, they are the most important component of the system. Individuals bring their own motivations and perspectives to work, and when an organizational transformation—like the one Nole was leading—is not aligned with those perspectives, pushback is to be expected due to cognitive dissonance (the mismatch between beliefs and behaviors). According to Leon Festinger's *Cognitive Dissonance Theory*,[6] everyone has an innate desire for inner harmony among their beliefs and actions, and people will go to great lengths to eliminate any dissonance. However, it takes time and practice to align new beliefs with a new set of behaviors.

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[6] Leon Festinger, *A Theory of Cognitive Dissonance* (Standford, CA: Stanford University Press, 1957).

[7] Edgar Schein, *Organizational Culture and Leadership. 2nd ed.* (San Francisco: Jossey-Bass, 1992).

[8] Michael Watkins, "What Is Organizational Culture? And Why Should We Care?" *Harvard Business Review* (Last modified May 15, 2013), https://hbr.org/2013/05/what-is-organizational-culture.

Further, people don't work in a vacuum; they work together within the organization's culture. According to Edgar Schein's Theory of Organizational Culture,[7] culture consists of both observable behaviors and processes (artifacts), as well as employees' tacit espoused values and basic assumptions. Like an immune system,[8] culture exists to protect an organization's norms against variants, which are systematically rejected by an incentive structure. Specific behaviors, language, and beliefs are rewarded by formal mechanisms such as job promotions and informal mechanisms like public praise. Likewise, variant behavior receives formal and informal punitive responses. As such, culture acts as a shield to resist change. Nole now began to understand why organizational change was so hard.

Cognitive dissonance and culture structures explained the four issues Nole had run into, such as quality requirements and subsequent delays. Because Quality had not been involved with the change, the employees' individual beliefs around Industrial Age management clashed with the values underlying the new processes, causing cognitive dissonance. Likewise, the strong culture in this area of the organization reinforced these values and shielded the organization from changing.

As a first step toward improvement, Nole pulled together the team to discuss the situation. In an effort to increase collaboration, he had them organize themselves into smaller teams to generate a list of cultural challenges they were encountering. After they reviewed the list, the team conducted a Pareto analysis to identify the top cultural impediments. They concluded that "tyranny of the urgent" and a "lack of psychological safety" were the top barriers that needed to be addressed.

- **Tyranny of the urgent:** Alset prized being competitive in the industry above all else, creating a culture in which priorities constantly shifted to attend to the most important opportunity of the day. This eroded bandwidth for efforts like technical debt reduction and innovation work, which together improve continuous value delivery. These efforts, which would have yielded delayed gratification, were considered less important than completing new functionality and earning immediate gratification. Schedule pressurization effectively eliminated all opportunity to innovate and explore alternatives, which led to insufficient analyses and false feasibility. To make matters worse, incentives were directly tied to schedule.
- **Lack of psychological safety:** Over the years, Alset had developed a culture in which leaders, managers, and frontline employees did not foster an environment in which it was safe to fail and learn fast. The environment was such that individuals could not discuss concerns freely without backlash from leaders. As a result, errors were fodder for blame and messengers were verbally shot down, considered insubordinate, or not seen as team players. There was a low tolerance for risk in the organization, which squelched creativity. At the same time, no one was comfortable bringing up risks or concerns, so avoidable mistakes abounded.

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[9] W. Edwards Deming, *Out of the Crisis* (Cambridge: MIT Press, 2000).

Nole, knowing that the system was broken, recalled his early reading of Edward Deming's *Out of the Crisis.*[9] He understood that management owns the system; thus, only management can change the system. He began to recognize his responsibility, along with that of the guiding coalition and management team, to improve the organizational system that management had created. They needed to model and mentor the Lean/Agile mindset and the behaviors they were expecting of others.

Nole and the Lean/Agile Center of Excellence worked with the teams to provide a short-term fix and a long-term solution. They first created two new categories of work, system health (for the elimination of technical debt) and innovation. They included these categories on the newly expanded Technical Architecture Vehicle Roadmap to go along with system-of-systems features and prototyping.

While the work would not be planned, as these were both emergent activities, the categories made visible a set capacity allocations that would be reserved in every iteration for the completion of these types of work. The teams and suppliers were empowered to adjust the allocations between the two types of work as needed. Everyone could see the balance between the work to build the current system and the work to improve quality and reduce risk for the future.
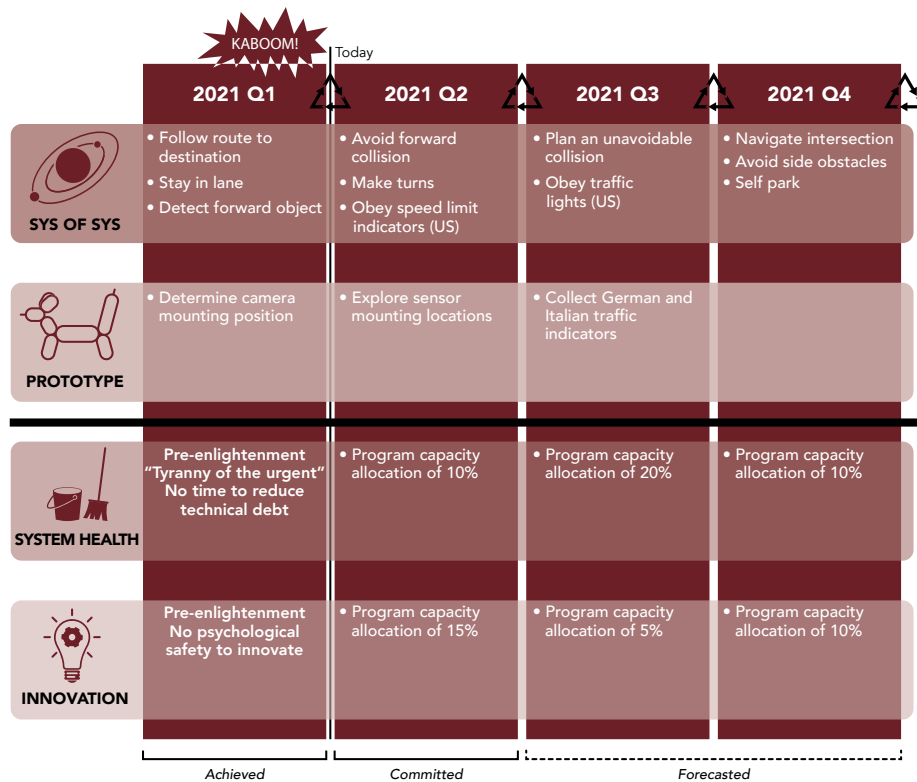
	2021 Q1	2021 Q2	2021 Q3	2021 Q4
SYS OF SYS	• Follow route to destination • Stay in lane • Detect forward object	• Avoid forward collision • Make turns • Obey speed limit indicators (US)	• Plan an unavoidable collision • Obey traffic lights (US)	• Navigate intersection • Avoid side obstacles • Self park
PROTOTYPE	• Determine camera mounting position	• Explore sensor mounting locations	• Collect German and Italian traffic indicators	
SYSTEM HEALTH	Pre-enlightenment "Tyranny of the urgent" No time to reduce technical debt	• Program capacity allocation of 10%	• Program capacity allocation of 20%	• Program capacity allocation of 10%
INNOVATION	Pre-enlightenment No psychological safety to innovate	• Program capacity allocation of 15%	• Program capacity allocation of 5%	• Program capacity allocation of 10%

KABOOM! — Today

Achieved — *Committed* — *Forecasted*

Figure 7: Expanded Technical Architecture Vehicle Roadmap
This roadmap indicates the capacity allocation for both system health and innovation work.

System Health: This work aimed to reduce technical debt by improving existing systems (hardware or software) without changing solution behavior. This work would allow for making future changes faster and less error prone.

Innovation: This work involved rapid hypothesising and early evaluation of a minimal solution value enhancement to serve user needs. Experimentation was encouraged at all levels to improve both the solution and the processes to define, build, test, deploy, and operate it.

Nole knew that without addressing people and culture, efforts to make time for innovation and technical debt reduction would fail. While the individuals doing the work understood that they should reduce technical debt and innovate, they were not empowered to take time away from what management referred to as "real work" to actually reduce debt and innovate. This individual cognitive understanding clashed with the culture of what was deemed valuable work, causing dissonance. To find harmony, people denied the importance of these tasks and completed the work they knew would be rewarded.

Addressing psychological safety and cultural barriers was going to be a much larger challenge and would take a longer time to see results than creating a roadmap. Nole was trained as an engineer, not an organizational psychologist, and had no understanding of what to do or where to begin. He did recognize that improvements in the culture of Alset would require the organization to acknowledge the cultural component of the strategy and would need the support of the guiding coalition. Nole worked with Alset's guiding coalition to help members recognize the need for a comprehensive approach to creating harmony and balance beliefs and behaviors that would stick. Four core tenets of organizational change were identified that would become part of their strategy:[10]

Mindset validation: If the value of change is understood and agreed with, people will be more willing to adjust their mindset and give it a try. Leaders communicate the vision of the change—with a compelling "why"—and the culture that is needed to support the change; managers provide specific next steps to their teams.

Active role modeling: People must see their leaders, peers, and those they respect actively modeling the change and the new cultural tenets. Leaders model through their language and, more importantly, their actions.

Technical competency: People must have the technical competency (skills) to complete the required action. Leaders ensure that employees have the resources and opportunity to gain this needed competency.

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[10] Emily Lawson and Colin Price, "The psychology of change management." *McKinsey Quarterly* (June 2003). https://www.mckinsey.com/business-functions/organization/our-insights/the-psychology-of-change-management.

Organize surrounding support structure: New behaviors must be enabled by all surrounding structures (such as permission to fail, or reward and recognition systems). Leaders address barriers or gaps, and work to make needed changes.

Each of these areas may be worked independently. Together, they enable organizational attitude and behavior change in the people doing the work. Nole plotted the improvement items on the intentional culture architecture roadmap (Figure 8). By treating the subsequent quarters as a forecast, Nole was able to assume variability in culture change and test how Principle #5: *Iterate and reduce batch size*, affected production.

Small batch size is fundamental in leading effective changes, according to John Kotter's *Leading Change*: "Complex efforts to change strategies or restructure businesses risk losing momentum if there are no short-term goals to meet and celebrate. Most people won't go on the long march unless they see compelling evidence within six to eighteen months that the journey is producing expected results."[11]
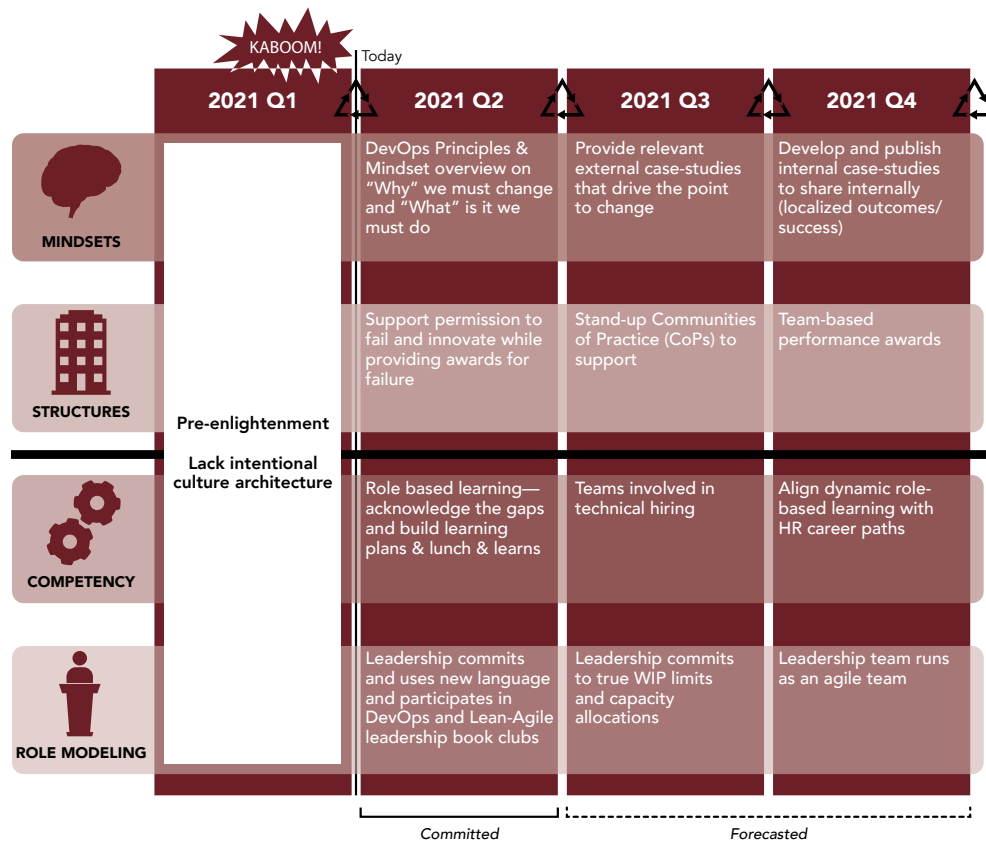

Figure 8: Intentional Culture Architecture Roadmap

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[11] J.P. Kotter, *Leading Change: An Action Plan from the World's Foremost Expert on Business Leadership* (Boston, MA: Harvard Business School Press, 1996), 11.

Nole, Alset's guiding coalition, and LACE embraced the IDO principles and implemented an intentional culture architecture design with dynamic learning and feedback loops to ensure the new principles were embraced throughout the organization. As the organization adopted a Lean/Agile mindset in both technical and cultural practice, Alset achieved scale and sustained Active Safety's goal to improve product quality, reduce product cycle time, and innovate faster. They became the market leader in the automotive industry through their adoption of Industrial DevOps and their commitment to continuous improvement.

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Our mission for the Forum is to bring together technology leaders across many industries and facilitate a dialogue that solves problems and overcomes obstacles in the DevOps movement. For three days at this private event, we gather fifty of the best thinkers and doers in the DevOps space to tackle the community's toughest challenges. We ask these thought leaders to collaborate and generate a piece of guidance with their best solutions to the challenges.

We would like to thank all of our attendees and our friends at LaunchDarkly for helping to make this year's Forum a huge success.