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The Tooling Abyss

A Technical Paper prepared for SCTE by

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1. Introduction

System support tools can be a vast ocean of internally-developed and externally-purchased groups of software solutions. This paper will focus on drivers and solutions to an organizational problem, the tooling abyss, that centers around the dual impacts of pace and sprawl of tools created and utilized to keep in stride with the innovation growth of the technology of our industry. This document will clarify the definition of what a tool is for our industry, identify the business impacts of our decisions, and recognize the perspectives of the user community.

"Just build a new one" is a typical response to developing tools to support new technology. This mantra has defined many aspects of the transformative technology growth in the industry. The "build a new" strategy, without a plan for the old, has led to an exponential growth of complex tools required to operate the business. This methodology increases user complexity and causes operational inefficiency. Technology innovation has unlocked an expansive sea of data and knowledge, but this simultaneously created a myriad of tools making it more complex for the user communities. Increasing complexity can result in inefficiency, such as when a single team member must reference multiple interfaces to troubleshoot a single problem. This complexity creates and exacerbates perceptions of information overload. The concept of "adding new to old" has also shaped new challenges, like a sense of searching through an abyss of information when trying to find critical troubleshooting data. The influx of added information and operating multiple interfaces causes challenges for teams responsible for managing the customer experience, maintaining the plant, and monitoring system events.

The persistent launch of new technologies in the industry has driven a constant change in the tools needed to operate them. This paper will focus on building a strategy around making instrumental tooling decisions, concentrating on when to develop new, when to integrate, and when to sunset tools. Tooling culture will be discussed to delve into the psychology of change, and the navigation of managing evolution, including the emotional attachment to tools team members, have historically known. This paper and presentation will review strategies on tool development that are based on operational efficiency while supporting new technology and driving overall business strategies.

The purpose of this paper is to understand how more effective development methods can lead to improved team performance across multiple technology tooling systems. Evaluating real-world organizational problems provides a pathway to investigate a specific business problem and seek opportunities that shape future business goals or strategies. The information will enhance the understanding of how business evolution, financial requirements, and consumer needs have led to the multitude of systems utilized in today's operations. The paper will focus on the history of how the tooling abyss has been created and the impacts on the user community. It will propose new opportunities in managing tooling systems to support the development of plausible and implementable solutions.

2. History Of Industry Technology

To help understand today's issues of the complexity of the tooling abyss, we can review the pace of innovation of the industry because every "chapter" brought with it a corresponding increase in tools. Cable television dawned in the 1940s when cable became the connection into the homes that could not be easily reached by standard over-the-air broadcast capability [2] (Cable History, 2014). Through the years, the technology evolved through amplifiers and the continuing focus to reach more people. The 1960s was an innovation milestone with the introduction of the Jerrold Channel Commander headend signal processor, the first pay-for-view (PPV) event offering, solid-state technology, and the enhancement of aluminum-shielded foam dialectic distribution cable. In 1969 the Society of Cable Television Engineers (SCTE) was established, focused on training and educating the industry's technology professionals. The innovations of the 1970s brought new concepts of two-way addressability and enhancements in drop

cable to improve in-home quality. Video evolution continued to grow through the years, and the expansion of the industry continued through compression technologies, industry channel expansions, and innovation in delivery systems.

The 1990s accelerated the pace of technology innovation with the introduction of the fiber to the node methodology or Hybrid Fiber Coax (HFC) [2] (Cable History, 2014). The innovation of the return spectrum opened the door for two-way communication that would support PPV revenues, telephony voice, and the ability to deliver the internet to homes. In 1995 copper-wire phone lines provided 14.4 kbps internet, while the then-new cable modems would provide 4000 kbps which, at the time, was groundbreaking. In 1997 CableLabs emerged as a governing presence to align broadband standards for manufacturers and operators to ensure consistency in the business. Since the beginning of DOCSIS 1.0 in 1997, these standards and the industry have grown exponentially. DOCSIS 1.0 became 2.0, 3.0, 3.1, and laid the future for 10G and beyond. Analog delivery systems have transformed into fully digital architectures, providing a stream of innovative technical data. All of this evolution transformed the experience for all internal users.

3. Tool Development Influence

The historic pace of innovation is a significant factor in recognizing how the tools needed to operate them have also transformed. The first 50 years of evolution centered primarily on video technology. The catalyst of the evolution of the cable modem created a pace of innovation in the next 25 years that has dramatically altered the amount of software development and tooling innovation required to keep pace with the accelerated growth. In early history, basic measurements of levels were the primary performance indicators compared to today's expansive data capabilities that provide insight into the customer premise equipment in the home. This history of acceleration is a primary contributor to the exponential growth of support tooling in the industry.

4. Industry Tooling

Some may ask: What is considered a cable tool? The focus of this paper is on the software developed "electronic toolbelt" [1] (Breymier, 2020) rather than the hands-on physical tools used by field teams. If starting from the catalytic point of the introduction of cable modems, that question can be answered by the desire to understand the state and levels of the cable modems when troubleshooting. Early troubleshooting would require logging into the CMTS (Cable Modem Termination System) and looking for a specific modem that required its MAC (Media Access Control) address. The use of the "show cable modem" feature and directly logging into the CMTS became quickly identified as a non-scalable way to gather and interpret information for troubleshooting.

As the technology and customer base have grown at an accelerated pace over the past 25 years, so has the technology of the tools that support it. Tools in the business can be those used for monitoring the systems, databases that store information, back-office systems, or tools used by front-line team members who work in the home or the plant. New user interfaces (UIs) are tool interfaces created using data pulled from the CMTS and developed into a more consumable view. As the technology evolved and new data became available, in many cases, new tools were created to support it. The answer to the question about what constitutes a necessary tool must acknowledge certain contributing factors. The next sections describe the vast amount of tools utilized in the course of supporting business needs to identify opportunities to optimize strategy for future development.

5. Organizational Importance

The purpose of this review of industry tooling strategy is to investigate the impact development decisions have on team performance, tooling development environment, and intra-organizational communication. The problem identified is that the methodology of creating tools in multiple departments to meet only specific needs, and potentially without a long-term strategy, can negatively impact team performance. When tools are created without a centralized, defined strategy, the organization is impacted by wasted investment tech debt due to software teams duplicating work effort. Team performance is negatively impacted when information does not directly aid internal users to efficiently complete their tasks. Cross-department team conflict leads to organizational impacts on performance and job satisfaction.

There are multiple inputs into what is needed for system tooling, such as new technology, process change, and internal operational-user requests. When internal departments do not have aligned priorities, this can lead to challenges with professionals and software-development engineers working with conflicting priorities resulting in resource inefficiencies. Understanding the drivers for tooling development within the organization and the various business departments are imperative when recognizing what influences the tooling strategy.

6. The Tooling Abyss

To support today's technology, the parallel rise in tooling can cause many internal users to feel like they are swimming in an unending deluge of information. There is an endless stream of new data driving constant change. New tools are developed to support new technology, while legacy tools are sometimes not decommissioned. Some methodologies add new data or widgets to existing tools, making them large and complex to operate. There are three notable areas where the growth of technology creates the pathway for this number to continue to grow:

- Centralized Tooling System Management
- Decentralized Tooling System Management
- Tool Ownership Conflict

Centralized Tooling Systems

Many organizations promote the centralization of tool development to control the development lifecycle. However, it is essential to recognize that the technology in and adjacent to our industry is advancing at an exponential rate. It is critical to understand that a centralized approach to tooling development may not result in one specific strategy. In essence, even centralized organizations may not always have a consistent strategy for tool development.

Commonly, organizations focus on launching new technologies and products to their internal users from a central viewpoint. However, not all have a centralized strategy for tooling, nor a software development plan for operating tool readiness. An increasingly common challenge that illustrates this is a new technology that becomes available to external users, but the tooling is not fully developed for the internal operators that support them. One practice commonly used is "just add new," where engineering organizations feel compelled to not only build the new capability but also create a tool to support it. New architectures and components may take years to completely roll out throughout a large system, which leaves the operators and technicians with no choice but to use multiple sets of tools. In this situation, one tool supports the new architecture, while one remains to operate the legacy. Further complicating this issue, by the time one "new' technology rollout is nearing completion, the following new technology is waiting to ramp up. Tooling never ends; the parallel strategic goal that is continuous integration/continuous development (CI/CD) assures it.

The negative impact to the teams responsible for operations and the technicians is this constant swiveling and cross-referencing of tooling information to complete everyday tasks. Advocates of the centralized model tend to focus on security standards as well as enhancing and growing existing operational toolsets. The risk and challenge with this methodology are that without discipline and long-term strategy, a system's code-stack can become obsolete. It can become so monolithic that continuing development becomes less agile and stability questionable. The thought in this method is that maintaining a centralized toolset reduces the swivel, but as technology data increases, the tool can become more complex to operate, and the amount of information contained in it can become overwhelming. Overall, technology and innovation are great things that drive growth, but there is an impact on the operations when the tools needed to support it are not available.

Decentralized Tooling Systems

Most of today's largest service providers are a product of acquisitions [2] (Cable History, 2014). That creates an increased number of tools integrated into the organization, some developed in-house and some contract acquired through business acquisition. The challenges consolidating organizations face include what to do with the newly acquired tool. Is its function duplicative? What is the cost to sunset the old one? Without a consistent strategy on organizational tooling systems, many choose to simply keep everything and operate in segments.

The broadband communications industry was started by and continues to attract an amazing talent pool that is capable of innovating new ideas, especially when it comes to supporting software-developed tools. Many talented teams have taken it upon themselves to create "gap solvers" where there may be centralized or common systems, but to operate them more effectively, they develop secondary enhancements. These individual solutions developed across the organization can create quick short-term solutions to a current business problem. They are also one of the highest contributors to the tooling sprawl. This methodology creates challenges in operational consistency, security, and system consistency, as well as hinders the ability to make future system changes.

Tool Ownership Conflict

Pride in ownership is a valued characteristic. People involved in the ideation and development of new tool ideas are no exception. Being competitive is a cornerstone of our business. Metrics commonly drive our teams to work hard and strive to be the best. In many business areas, this is a practice that has determined constant operational improvement through the years.

However, in the tooling and development space, this mindset can also be a contributor to conflict. It can perpetuate the keeping of obsoleting systems because of emotional attachments from those who created and used them. In organizational terms, dominant or competitive conflict culture is a winner versus loser strategy that can lead to negative, organizational influences [3] (Choi & Ha, 2018). The competitive conflict culture applied in the software development space leads to inefficiency and negative employee experience. In contrast, the collaborative conflict culture is a partnership-oriented culture focusing on coordinating the best outcomes for the business.

In both centralized and decentralized examples, leaders are responsible for the technology that overlaps with other teams. This overlap can result in continuous conflict, even when attempting to be effective and productive. This dynamic creates both a task and a relationship conflict for the teams that manage the tooling systems. When there is a lack of a clear strategy, negative team impacts can include job dissatisfaction and team inefficiency [3] (Choi & Ha, 2018). Negative individual behaviors are caused by a lack of direction as well as a competition where people are diligent in keeping what they own. It also means some tools may stay in operation because of a lack of willingness to let go of obsolete and antiquated electronic software systems.

Cost of Inconsistency

Job dissatisfaction is not the only business challenge created by competing or unclear tooling strategies. Another is duplication. Tooling duplication is a common result of the decentralization of operational support tools, where the same data is used in multiple ways. For example, different groups may download data on customer premise equipment, then use that data to create a plan of action, or evaluate a system's status. In doing this, developers create duplicate data stores for the information. This duplication creates a cost to the business in multiple ways.

- Multiple data stores mean replication on multiple platforms and systems, which take up much more storage space
- Multiple support teams are required to maintain the data and UI, or one support team is required to support multiple similar tooling systems
- Replicated system upgrades and security requirements
- A technical debt of overlapping and duplicated operational systems
- Inconsistent user experiences

Technical user inefficiency is an increasing cost to the business, especially when the abyss of tools and complexity requires team members to swivel to multiple interfaces to troubleshoot system issues. Team and individual metrics are impacted. As an example, time-per-task increases when the tooling lacks stability, speed of response, or contains more information than is needed for the task. When the utilization of the tool or tools to complete the work is inefficient, its users will avoid adoption. When complex information flows disrupt a tool user's ability to work swiftly and accurately, they will disregard it.

The pace of new consumer and system architecture technology has reached extraordinary heights. This timeline requires system tooling to innovate at the same pace to support the operational needs of the business. When there is system tooling duplication, lack of a focused strategy or extremely large monolithic systems, the ability to maintain pace is reduced. Reduced agility, when launching new features and technology, can result in products becoming available to consumers before they can be effectively supported, from an operations perspective.

7. Information Overload And The Human Factor

Understanding the user experience is an essential concept in any tool's development. The accessibility of data through the internet and system technology has created a rich opportunity to connect and collaborate in extraordinary ways. Recognizing the power of data, however, needs to be balanced with the human factor. Essentially, the cognitive value in the information relies on the design, structure, and quantity of the information shared with the user [6] (Voinea, Vică, Mihailov, & Savulescu, 2020). Cognitively people are likely to take mental shortcuts because, at any given time, the human brain can only process so much complex information. Information overload is a phenomenon that emerges when the amount of information and choices become so expansive that they impact the user's cognition. The psychology of how people process information is a critical understanding point in tool-development concepts. That is because simply adding new data, new widgets, and new information can ultimately have a significant impact on how the internal users adapt to the technology change.

The constant evolution of tooling and strive to drive more data to the internal users also create challenges in the best way to train new tooling technology. In an interview to inform this paper with Walter Breymier, a veteran technician at Comcast, he observed that the constant pace of change and volume of information impacts team members in different ways [1] (Breymier, 2020). The technician perspective must be a key factor in evaluating how a tool will be adopted:

- There is not always a clear understanding of who and what the software tool is for
- Technicians are not given time to truly absorb the best way to utilize the tools
- As a direct result, the tendency is to "stick to what you know" and avoid utilizing the new information.

It is worth noting that it can be the team members with the longest tenure who are the most resistant to change. They may also need more time to comprehensively understand the newest technology. Understanding the human factor is critical to ensure the information in the tooling is comprehended and utilized by all team members.

A study in information-avoidance behavior substantiates this view by modeling a stressor-strain-outcome framework. The intent is to qualify this avoidance as a consideration of network fatigue in comparison with social networking [4] (Guo, Lu, Kuang, & Wang, 2020). This concept evaluates the thresholds in which the time pressures, data irrelevance, information overload, and data fatigue indicate the predicted result of information avoidance. The study illustrates that stressors are created through information irrelevance, information overload, and social overload. These stressors become a strain when the individual reaches the point of network fatigue. When time pressures are factored in, the rate of information avoidance also increases; the calculation is noted in Figure 1 below.

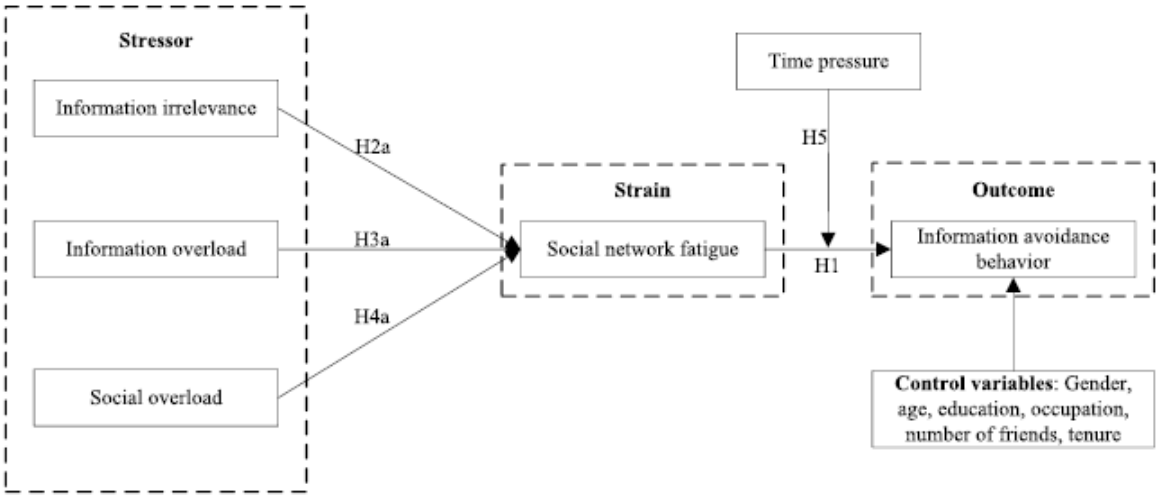

Figure 1 - Information Avoidance Calculation

This study is relevant to the concepts of exposing large quantities of information through system tooling with added time pressures. As an industry, the teams that utilize the system tools are typically held accountable to a very high level of time pressures, intrinsic with responding to system or customer issues. There is likely to be a broad and deep spectrum of data available to our team members that may not be the most relevant to the issue they are working on at that moment. The constant interaction with the networking data can conceptually be an aspect of network fatigue. All of these elements are factors in the introduction of tooling technology to ensure they are not creating even higher incidents of information avoidance.

8. The Solution

Creating a solution to the complex world of supporting tools for advanced technologies relies on multiple factors. The initial assessment comes from a survey of operational teams to identify how many system tools the team members are using and what information they value. Depending on the organization's

history and tooling strategy, it is entirely possible that a single department team could use up to 100 different electronic system tools to complete their work.

As a result, organizations must not only invest to advance network and consumer technology, but must also commit to the system tools needed to support it. Definition of the development culture, blended with leadership influence, creates the foundations of agility and success. Figure 2 shows a view of a tool development ecosystem. It begins with the need to ensure that regardless of what changes are being made, the tenet of operational reliability and stability are foundational to the business.

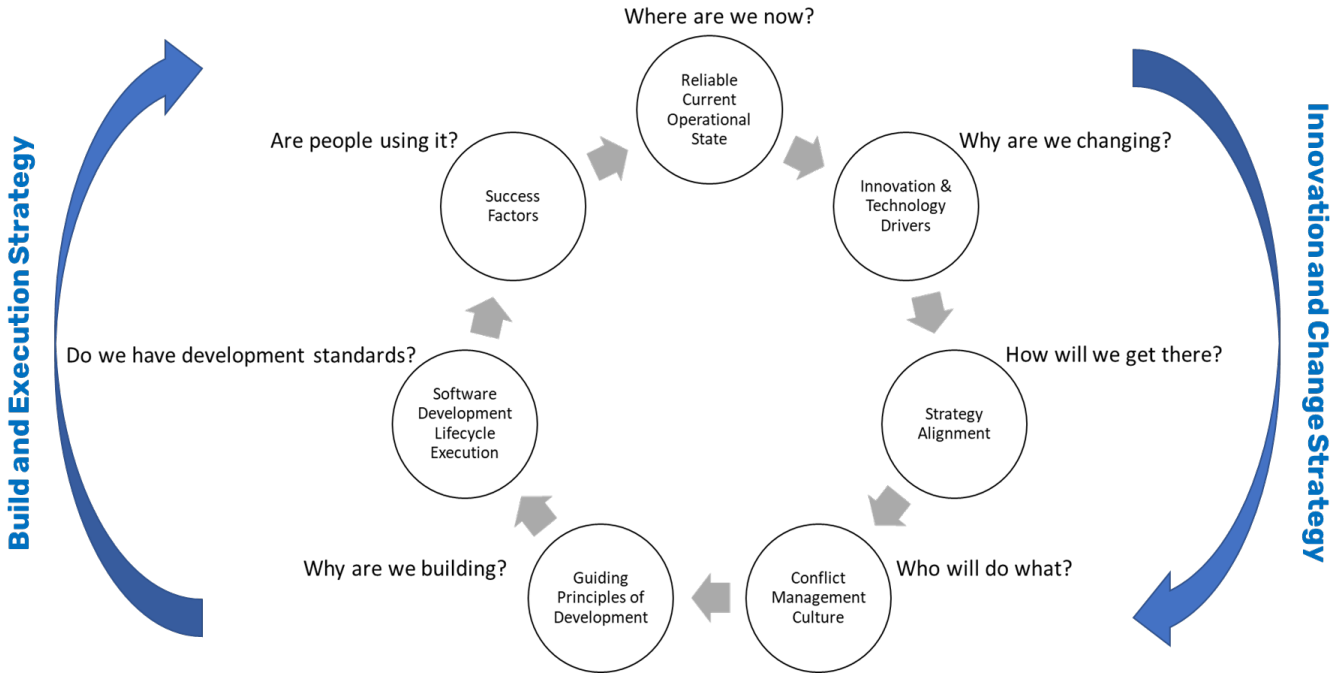

Figure 2 - Software Tooling Development Strategy

Change Drivers

The pace of innovation has primarily driven the need for tool evolution. The history of the technology evolution creates the basic drivers for much of the need to evolve the tooling systems. Comcast colleague and Engineering Fellow Larry Wolcott (2021) [8], a recognized industry expert on the topic of Proactive Network Maintenance (PNM), shared his insights about tooling for this paper. He noted that it is critical to recognize the drivers of the development changes and to be sure to integrate ideation and capability requirements when operationalizing a tooling system or update.

There are typically four primary drivers of change in tooling evolution: new industry technology, tool infrastructure technology, organizational process improvement, and enhancing the user experience.

Figure 3 - Drivers of Tooling Change

Strategy Alignment

The first step in optimizing tooling development for both the development teams and the teams that ultimately use the tools is to agree on a unified strategic planning process, specifically for software-developed systems and electronic tooling. Simply deciding if the organization will be centralized or decentralized will aid strategic alignment. As previously discussed, methodologies can and do differ from department to department, and there are various visions on what is valuable in the data that is presented to internal users.

Coordinating on any strategy, including tooling, starts with leadership alignment, both top-down, and ground-up. Department and area leaders need to be committed to a discipline that outlines the requirements for tooling development. Governance matters for the organizational accountability that integrates all of the change drivers into a cohesive strategic plan. The strategic plan should address standards for tooling technology, coding languages, reliability requirements, financial payback, and business value determination.

The strategy and structure for governance require a collective of experts representing the knowledge wheelhouses of engineering, software tooling development, finance, and operations. All must be equally represented to ensure that the expertise of each discipline is integrated, which creates a balanced business strategy. Engineering experts are responsible for the architectural vision of the technology that supports products. The software development experts are responsible for maintaining tooling technologies that support the monitoring and operations of the engineering systems. The operations experts utilize the software-developed systems and electronic tools needed to maintain and operate the engineering systems. The finance team is responsible for maintaining overall business financial objectives. Each of these groups is critical. Collaboratively, they create a comprehensive business strategy that directly influences the creation of operational support tools.

When the strategy is well balanced, the tools that are used to operate these systems are fully adopted, truly optimized, and streamlined. Each team has a critical role in creating a highly collaborative and focused strategy that optimizes overall business strategy and value. When they are not in balance and the strategy is not aligned, the abyss of tools grows, complexity increases and conflict can slow down the pace of innovation and development.

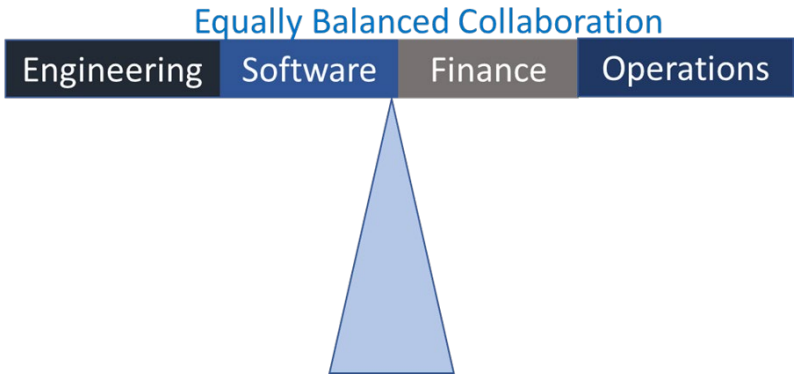

Figure 4 - Balanced Business Strategy

Conflict Management Culture

To maintain a balanced strategy, an organization needs to define expectations for resolving inevitable conflicts so that working teams have a clear path to work together positively. A collaborative conflict-management culture can have a positive impact on organizational effectiveness and improve job satisfaction [3] (Choi & Ha, 2018). Successful conflict navigation relies on cognitive flexibility, self-awareness, and commitment to collaboration. When the teams have more clarity on aligned goals and operate collaboratively, there is an opportunity to enhance innovation and create healthy tension. In this application, teams working in technology need healthy tension to innovate and strive for constant improvement. When there is trust and willingness to be more flexible, individuals feel that their contributions are valued. In turn, job satisfaction will be higher, and internal users will adapt to change and resolve conflict most effectively.

Executive leaders are tasked to define organizational responsibilities and create a process to entrench an inclusive and collaborative conflict-management culture into the entire organization. A collaborative conflict-management culture relies on individual cooperation to create a compromising versus competitive method for deriving agreements [3] (Choi & Ha, 2018). As a metric-driven industry, this concept for tooling development represents a notable shift from the competitive dynamic. An innovation strategy that is only focused on what is best for the technology, for purposes of a competitive result, can create conflict with financial standards, or challenges for operations. A compromise-oriented solution provides the potential to create a healthy tension in the organization that can lead to innovative breakthroughs and positive organizational influence.

When there is a non-competitive, collaborative environment, innovation is maximized, and integration is optimized. Larry Wolcott, mentioned previously, notes the engineering concept that "just because we can, doesn't mean we should" mindset. This concept means that even groundbreaking technology can be available, but if operational teams find it too complex or there are conflicts with operational efficiency, it may not reach its full potential. To ensure that balance is maintained between engineering and operations, there must be a focus on collaborative problem solving and conflict management.

Development Principles

The technical sprawl of tooling is expanded or contained by the software and electronic tool development strategy. Eric Wall (2021) [7], a leader of the support teams that develop several of Comcast's widely utilized operational tools, shared the perspective that the growth of tool development must have a clear, collaborative strategy. Without recognizing business benefits and how operators utilize them, the software developed may not have the intended impact. To aid in ensuring the strategic direction of development, below are a few guiding questions to drive the most efficiency in software tool development.

- Is this requirement strategically aligned and governed?
- What is driving the change or the problem that needs to be solved?
- Who and what development team is responsible for solving it?
- How will the user behavior be influenced, and what is the behavioral expectation?
- How does this fit in the business financial model?
- Should this be developed internally or purchased?

The answers to those questions will clarify new tooling initiatives and align with the expressed strategies of the business. As noted previously, the drivers for creating a large set of tools are driven by many factors: Building new without a plan for the old, "because my team can," and gap functionality all contribute to the steady growth in tools volume. To resolve this continuous sprawl, discipline and commitment adherence to guiding principles are paramount.

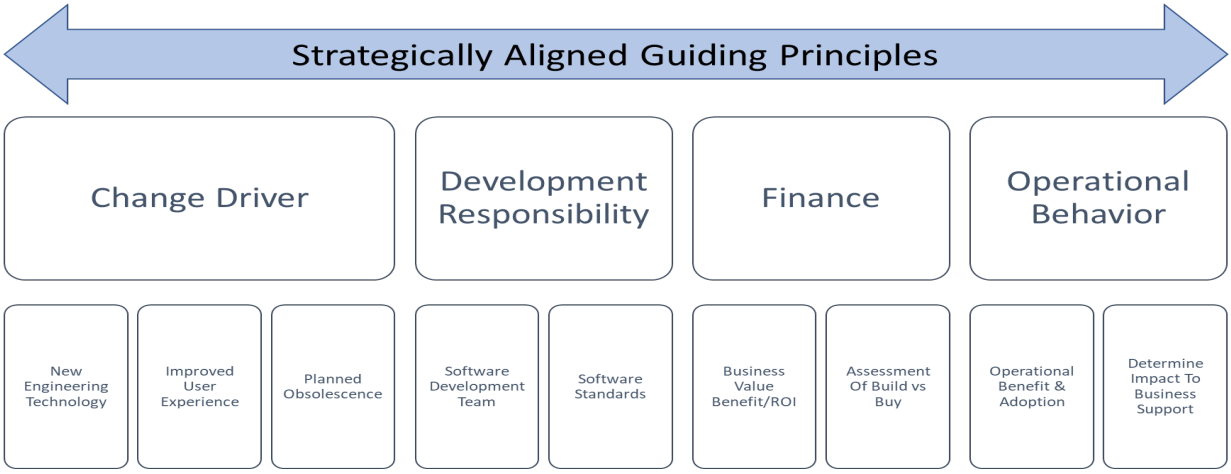

Figure 5 - Strategically Aligned Guiding Principles

Lifecycle Development Execution

Lifecycle execution for tools and tooling should be a structured approach based on the resources available and the overall business requests. The concepts of people, process, and technology are critical components to prioritizing work for development [7] (Wall, 2021). Development standards are set by software engineering experts to ensure a commitment to security and development standards. The challenge that developers face is that of a large number of requests to complete work versus a set amount of dollars to accomplish them.

"Cost modeling can lead strategy" is a common axiom in determining business value drivers for development [7] (Wall, 2021). Cost modeling is a strong influencer of development prioritization, along with engineering, tooling software, operations, and finance, all are essential parts of a comprehensive strategy. With this in mind, the recommendation is to create a foundational basis for development work prioritization by clarifying how each influences the lifecycle.

- Engineering Deployment Of New Technology
  - If tooling systems are not built or updated for the new technology, what experiences would fail?
- Software Development
  - If there was no investment into the systems to maintain reliability, modernize, and grow in capacity, would the system tools become unreliable or unusable?
- Operational Requirements

  - How will features and functionality improve the experience and drive business value?
  - Will there be improved efficiency or saved time per task?
- Financial Requirements
  - Is there a positive return on investment (ROI) analysis of the cost to create the tool or enhancement compared to the value benefit for the business?

Overall, even when the answers to some, or all, of these questions, are yes, the development work still needs to be prioritized to optimize developer time. All of these factors require equal consideration when planning the development work. Discipline in the business strategy and execution lifecycle is the best way to ensure the internal users of the tools are utilizing them most effectively.

Success factors

In the overall business strategy, success factors can rely on many considerations. The first leading indicator of successful development is whether or not the tool has been adopted and utilized by its internal users. Simply put: Are people using it beyond the break-in period? Positive feedback would indicate that the work completed has made their job simpler or better in some way. The success criteria of adoption and utilization is a leading indicator of success, because if people are not using it, then there was no value in building it.

"Success equals adoption. If they adopt it quickly, they value it, therefore, they're less likely to work around it."

-Larry Wolcott, Engineering Fellow, Comcast

The second leading success factor is recognizing how the development of the tool is benefiting the business. This factor requires evaluating that the desired impact was achieved and is positively influencing user behavior. Too much information at the wrong time, or the creation of swivels, can cause team members to take more time to accomplish a task. Therefore, success comes from the reduction of time per task by improving the efficiency of the person using the tool. This reduction in time also creates a component of the payback model by illustrating the cost of build versus the improvement in technician efficiency. A hypothetical example of the influence of calculating task time is in Table 1, below. If in pre-development a task takes 5 minutes to complete, and post-development it takes 3 minutes to complete, the savings are demonstrable.

Table 1 - Business Benefit Calculation (Average Cost Is Illustration Only, Not Actuals)

	Task Quantity	Time Per Task	Average Hourly Cost	Task Cost
Pre Development	100,000	5 min	$60	$500,000
Post Development	100,000	3 min	$60	$300,000
Total Business Benefit				**$200,000**

The third success factor is confirmation that the tool developed achieved the intended expected results and business behaviors without creating more tools for the technicians and other internal users to use in the course of completing their work. The strategy to innovate and create new must be balanced with the roadmap of the legacy technologies and not perpetuate information overload for the users. The success could be measured by a metric to create more technician efficiency, such as reducing the time per task and thus improving operational metrics.

"The gauge of success is when the tool accomplishes a meaningful task and the percentage of users is high".

-Walter Breymeir, Field Operations Comtech, Comcast

The perspective of the end-user is the final success factor. The tool must be easy to use and provide the best information at the right time, without overwhelming, and be quickly adopted. The tool must be viewable in a consolidated way, to 1) minimize swivel, 2) reduce confusion on when to use the tool in what situation and 3) be easy to learn for its users.

As well, and from a good sense perspective, the tool must be cost-effective to be available to the broadest number of users for the least amount of cost. Choosing the right balance of information and finding the most cost-effective way to reach the largest number of users provides an avenue to optimize adaptability and usability. The information provided is a vital factor in preparing the training for new technology and supporting tools. The tooling systems must be intuitive and easy to learn. Training must be provided to the end-users to not only teach them new technology but to provide the team members time to absorb and learn.

"A tool could be great, but without training and it being easy to learn, it will likely fail to be used by the majority."

-Robert Snare, Field Operations Comtech, Comcast

9. Conclusion

The tooling abyss is a real and reasonably universal consequence of industry consolidation and the after-effects of growth-by-acquisition. There are the tools traditionally used by the field, then there are the "new" tools that come in through the different (acquired) doors. The tooling abyss is similarly fed by the technological advancements in adjacent and over-arching technology sectors, thus creating a myriad of information that needs to be quantified and managed to operate the business.

It is a top-down and bottom-up challenge: Large companies that became larger because of industrial and geographic consolidation are particularly susceptible to performance challenges associated with duplicative tooling. And, strong emotional attachments to favored or long-used tools, at the individual and small-group level, as well as the earnestly-developed patches and workarounds developed over time, can make it difficult to "centralize" tooling and related support.

The outcome is "tool sprawl," which is evidenced by the amount of new swiveling teams need to do across multiple applications, which serves only to add time to task completion and raise frustration. While it is true that as service providers, we "sit on" mountains of actionable data, the definition of "actionable" requires continuous attention. Too much information at the wrong time can lead to information avoidance and overload, both of which hinder operational performance.

When cross-department technology teams are not aligned, tool development can overlap, which also drives inefficiency for the business. There is a business cost when there is competitive conflict, inadvertently causing developers to work against each other, usually to achieve a desired or published performance metric. Strategic alignment is crucial to ensuring a collaborative instead of conflicting culture exists for the teams.

Therefore, a clear and comprehensive business strategy needs to provide clarity to streamline both the overall technology development process and the tooling process. Collaboration within a cohesive strategy is what generates an environment of optimized innovation. When the development lifecycle is optimally

based on a balance of experiences and wisdom representing engineering, software, operations, and financial elements, the resulting tooling products will drive business benefit most effectively.

Success factors hinge on meeting the needs of the internal users and business operations. Development teams need to ensure that system reliability is a foundational cornerstone because unreliable systems will not be adopted and utilized by users. Listening to feedback provides insight into why or why not the tool is being used. Two-way communication provides a conduit for information sharing for both the developers and the users. This avenue allows developers to aid in training and learning while receiving critical feedback on improvement opportunities.

"The measurements of reliability, adoption, and feedback determine why or why not tools are utilized and successful in meeting the needs of the business."

-Eric Wall, Executive Director Software and Development Engineering, Comcast

The tooling abyss can be avoided through an overall alignment in business strategy that integrates the views of multiple teams. Engineering, tooling software developers, operations, and finance teams must work together to commit to a business strategy that is effective for all. When there is a strategic commitment, innovation is increased, conflict is positive, complexity is reduced, and the overall health of the business improves. The tooling abyss ultimately becomes a manageable pool of critical resources widely adopted and utilize to optimize business initiatives.

Abbreviations

CI/CD	Continuous Innovation/Continuous Development
CMTS	Cable Modem Termination System
DOCSIS	Data Over Cable Service Interface Specification
HFC	Hybrid Fiber-Coax
MAC	Media Access Control
PNM	Proactive Network Management
ROI	Return On Investment
UI	User Interface

Bibliography & References

[1] Breymier, W. (2021, July 15). Technician Perspective [Telephone interview].
[2] Cable History. (2014). The Cable History Timeline. Retrieved from https://www.cablecenter.org/images/files/pdf/CableHistory/CableTimelineFall2015.pdf
[3] Choi, Y., & Ha, J. (2018). Job satisfaction and work productivity: The role of conflict-management culture. *Social Behavior and Personality, 46*(7), 1101-1110. doi:http://dx.doi.org.libauth.purdueglobal.edu/10.2224/sbp.6940
[4] Guo, Y., Lu, Z., Kuang, H., & Wang, C. (2020). Information avoidance behavior on social network sites: Information irrelevance, overload, and the moderating role of time pressure. *International Journal of Information Management, 52*, 102067. doi:10.1016/j.ijinfomgt.2020.102067
[5] Snare, R. (2021, July 16). Technician Perspective [Telephone interview].

[6] Voinea, C., Vică, C., Mihailov, E., & Savulescu, J. (2020). The internet as cognitive enhancement. *Science & Engineering Ethics*, *26*(4), 2345–2362. https://doi.org/10.1007/s11948-020-00210-8
[7] Wall, E. (2021, July 9). Developer Perspective [Telephone interview].
[8] Wolcott, L. (2021, July 8). Industry Expert [Telephone interview].