Introduction

While there is often disagreement as to what aspects contribute to a digital ecosystem, the consensus as to what one is quite robust. The following description, an amalgam from a plethora of reliable sources, captures the essence well –

The term digital ecosystem exists worldwide without consensus regarding a formal definition, casting a wide net towards many terms. We offer the following as a robust foundation, at least for his body of work -

'A digital ecosystem is an open, distributable organizational system that evolves through adherence to Socio-technical theory, i.e., it can only be improved on through design and performance considerations from both social and technical perspectives. Digital ecosystems are adaptive, scalable, and highly sustainable, with every element treated as an interdependent part of a complex system. Finally, the ability to mirror the capabilities of natural ecosystems to solve complex challenges through self-organization is a highly desirable, increasingly exploited aspect of contemporary digital ecosystems.'

It is often better understood as a concept through relatable examples; for instance, below is a short list of tools that can make up a part of a digital ecosystem –

- Communication and collaboration systems like video conferencing, email, and file sharing
- Knowledge management solutions like wikis
- Research and development tools that offer previously hidden insight
- Public platforms like social media, websites, and mobile apps
- Engagement solutions like customer relationship management software.
- Program and project management tools

Throughout this paper, we will explore the multitude of extant and near-term applications for Digital Ecosystems, but first, it is worth establishing their value.

Take the blue pill

Most of the world's leading companies have established digital ecosystems, which should spark interest. They often expound on the virtues, including control and cost reduction, revenue growth, and customer engagement. Still, these are

high-level business objectives, so we shall dig deeper and determine why we should care and what's in it for us. There are also legitimate concerns about privacy, intrusive surveillance, and systems making human effort less valuable or, in some cases, surplus to requirement.

Despite the legitimate concerns, there are several palatable reasons to embrace the new frontier; to take the blue pill.

Digital ecosystems are the ideal conduit for **stakeholder engagement.** They provide increased, easy accessibility options to various services, products, and intellectual property. Much of this can be personalized and attuned to specific needs and preferences, an integral part of a relevant, engaging experience. Collaboration and communication are heightened, and the provisions for the collation, distribution, and coherent, transparent analysis of information are critical aspects of cooperation. Given that the same data, the same insights are available to all stakeholders, there are significant improvements when it comes to the equitability of team power dynamics

Given the multitude of data, there are also great opportunities to account for competing and converging stakeholder priorities by applying complex Multi-decision analysis mechanisms.

Establishing a digital ecosystem can provide several **opportunities for efficiency,** especially regarding cost. It is common for digital tools to streamline and automate a wide variety of activities and, as such, reduce the need for human effort and other resources. In the same vein, productivity gains are possible due to the insight p[rovided by real-time, on-demand data analysis.
Digital ecosystems can also play an integral part in supply chain improvement through enhanced, augmented visibility leading to inventory optimization and reductions in transportation and lead times, something of great value to consumers.

Coherent insight depends on three major factors, and each is improved by applying a digital ecosystem. These are –

Real data, really fast – The ability to collate and share knowledge instantly enables stakeholders to become informed quickly (often on demand) and respond expeditiously. Having more insight at one's figurative fingertips faster is often a key differentiator.
Communication tailored to the context and audience – Didigtal ecosystems but their very nature open up the vehicles for communication, such that it can be tailored to the recipient. Videos, Images, infographics, etc., can convey a message better.

Messages for the Masses – Digital platforms, including social media, community forums, and subject-oriented websites, broaden worldwide access, which means that thoughts can be shared and solutions can be sourced with a crowd mentality. This process fosters community and solidarity, as common interests and problems are shared and sometimes acted on.
Being able to see the wood amongst the trees – Digital ecosystems can often for the collation, analysis, and communication of data in a more coherent manner

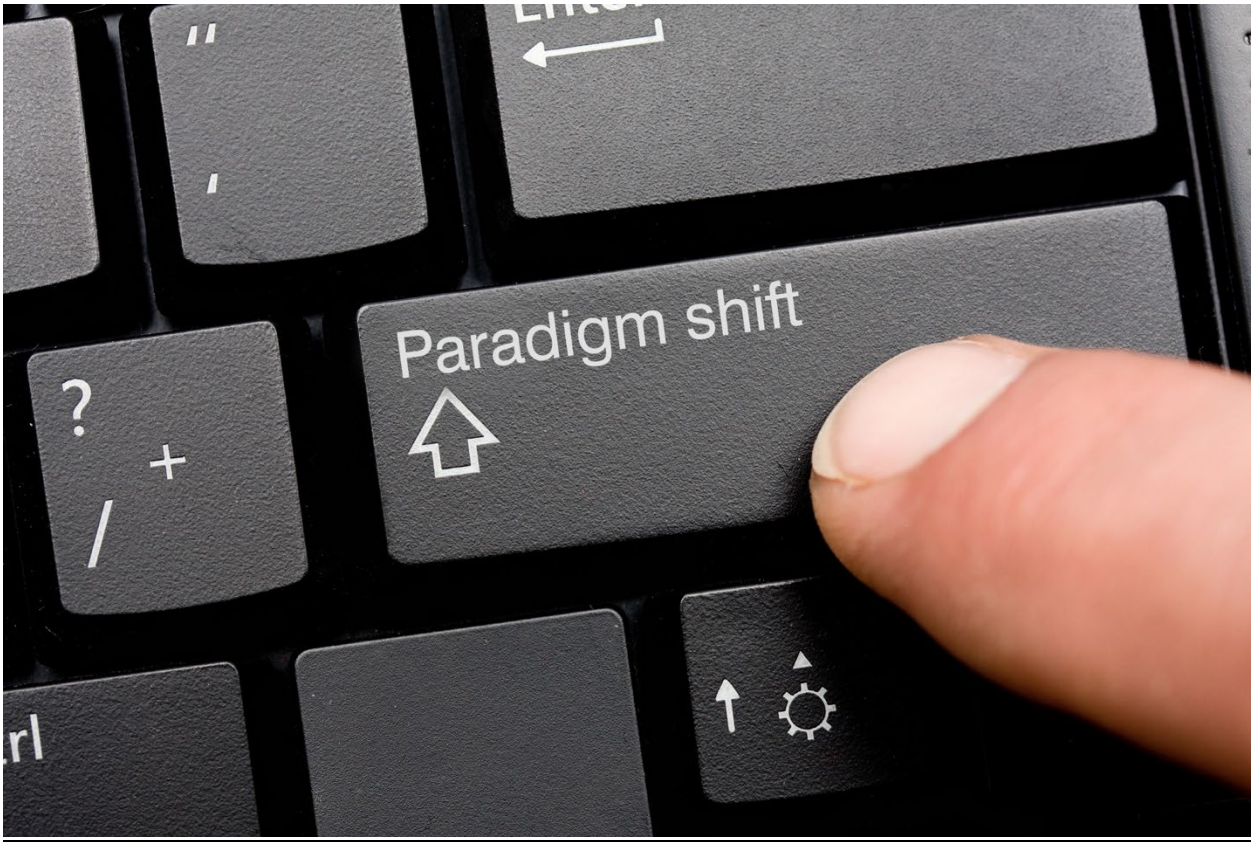
Risk analysis and management benefit significantly since real-time monitoring of an immense variety of operations can facilitate the identification of the most influential and early response. Rapid reaction is an integral aspect of effective mitigation. Still, the predictive analytics cadre of capabilities associated with digital ecosystems predicates the opportunity to avoid or minimize both the likelihood and/or impact of a risk. There are also considerable benefits from having a centralized mechanism for control that offers many risk management functions and regulatory compliance.

The often-overlooked opposite / counterpart to risk management is opportunity analysis and exploitation, the cornerstone of any **competitive gain.**
Being first to new ideas, approaches, and processes supports innovation, new market capture, increased margins, and creation in line with embryonic needs.

Digital systems working in concert can generate massive amounts of data, which, when collated and analyzed, can be leveraged to offer insight instrumental in robust, **data-driven decisions.**

An often-cited example would be how retail outlets make an effect, ie, use of customer profile data collected from many sources to anticipate the need and understand changes in purchasing appetite and preference.

Practical Exemplars



The following use cases exemplify the previously detailed value, impinging on our daily work and home environs.

Market forces analysis - Nobel prize winner (economics) Paul Samuelson, who specialized in consumer theory, once wrote the universally subscribed to the law of supply and demand that,

"The equilibrium price, i.e., the only price that can last…must be at this intersection point of supply and demand curves."

That reveals part of the story because the value one places on something drives the price one is willing g to pay. Digital Ecosystems offer a higher level of insight into how the perception of value can impact demand and how features influence the perception of value.

Logistics and the Supply Chain – Digital ecosystems represent and incorporate the critical aspects of modern infrastructure, including Logistics visibility, coherent, integrated planning and execution, cutting-edge warehousing, and supply chain analytics. All of this enhances the stakeholder experience, mandates cost reductions, and fosters innovation.

Internet of Things – The internet of things [IOT] describes a wide range of physical devices with embedded sensors, software, and communication mechanisms that facilitate the collection and exchange of real-time information. This enables the automation of optimal processes across a broad spectrum of functions and industries, including transportation, Healthcare, and manufacturing. Downtimes are expected rather than unplanned, and maintenance is preventative. The effort, resources, energy consumption, and costs are controlled, and waste is effectivity irradicated.

Virtual Reality [VR] and Augmented Reality [AR] - offer purpose beyond gameplay, including education, health care, and engineering analysis. It is now possible to visualize that which does not exist in the physical world, testing ideas, alternatives, and often the intangible. An immersive experience can be the conduit toward innovation.

The near-term future for Digital ecosystems

The future for digital ecosystems seems to be dependent on whom you talk to, promising, world-changing, or terrifying, but what is clear is that the pace of change is rapid, the applications vast, and the benefits broad.

Artificial Intelligence and machine learning will continue to form an integral part of the digital engineering landscape. Internet of things applications will be critical in developing smart cities, smart homes, and smart factories.

Cloud computing will continue to provide the infrastructure required for the many digital applications, services, and 'big data' sources. Aligned with this is the increased need for cybersecurity that mirrors the rapid pace and innovation of emergent threats.

The advent of 5G networks will likely be impactful due to the rapid transmission rates and low latency needed for most digital technologies.

Closer to home, the contemporary landscape for those that belong to the Aerospace and Defense world will be markedly different. The primary advances are likely to be as follows -

Design for Life cycle cost - Life cycle cost reduction is a ubiquitous requirement for every manufacturing company, as it increases market share, profit, and customer value.

The collaboration needed to ensure that the cost reflects the design and the design is cognoscente of the need to reduce costs has been stymied due to the analog nature of things before the advent of digital ecosystems.

Design to Cost is a systematic organizational methodology for integrating cost management with decision-making at the design stage, when it matters the most, and when designs can be changed.

Considerations include reliability, redundancy, and commonality when it comes to design, as they can have a tangible impact on availability.

Time-to-market reduction due to the limitations of churn target costs can form a part of the design specification.

Blockchain for the supply chain - Blockchain is a digital database or ledger solution that can authorize, validate and store transitions on a computer network and, as such, avoid the frailties and nefarious conduct that come from human intervention.

Blockchain platforms create transparency around assets, including geographical origin, sustainability footprint, and compliance standards. It can bring new insights into the life cycle of items such as manufactured items, software codes, and luxury goods. A Blockchain platform stores an authenticated digital record, a digital twin of an asset in a blockchain that contains details on how it came to be, where it came from, and who made it. As the asset moves through the life cycle, all details are recorded, and because of provenance and immutability, all stakeholders can have greater confidence in the details of an asset.

The solution helps us understand, for example, where (and by whom), a manufactured item was made to what standards and using what materials. It offers real-time insight into where a physical object is, whether it is counterfeit, stolen or made using banned materials. It cuts out the need and hence the cost of human governance, providing better value to the end consumer and more significant margins to the producer.

Holistic Systems Engineering - A high-performing systems engineer has historically completed the ability for a program to toggle the cost model with internal systems. The individual was responsible for maintaining a watchful eye for design changes and communicating with the impacted department. The future will be a highly sophisticated system of systems that will provide live updates to program leadership. The system will also be toggled to Key Performance Parameters (KPP), which will indicate the impacts on the program of record sales.

For example, the system will state the impact on the Program of Record (POR) sales due to a payload reduction, decreased fuel range, increased operational cost, and aircraft features. The United States Government has tried to shift from recurring cost centric to a total program of record cost estimates. The life cycle cost is a ubiquitous requirement for every manufacturing company, as it increases market share, profit, and customer value. The effort can only be calculated with the help of supercomputer clusters that connect so many input variables.

The human systems engineer will have a role in future programs but shift towards a system maintainer. The engineer will implement changes based on emerging needs or stakeholder feedback on a system of systems improvements.

Machine Learning - The ability to have a software system that tracks how Computer Numerical Control (CNC) machine responds to a design. The learning is based on monitoring the motor resistance, spring back, chipping, vibrations, speed, cooling fluid, etc., for machined parts is the next generational objective. The ability to notify an engineer that the design is at high risk for the material void, delamination, and resin-rich prone areas based on demonstrated performance mitigates the chance for a redesign. Machine learning will apply to all commodities used in the aerospace sector.

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The tribal lessons that walk out the door when a Subject Matter Expert (SME) retires will be a thing of the past. Artificial Intelligence (Ai) will guide the designers to the best solution, which we will discuss in the following section.

The ability to fine-tune the cost estimating software to your capital equipment can be advantageous to estimate internal make hours per part. The computer cluster can track 12 months of quality defects and then suggest a series of changes that collectively justify a design iteration.

Machine learning opens the cost impact awareness to all company swimlanes and drives the desire to generate engineering solutions that respect the allocated budget constraint.

Design for manufacturing - Artificial Intelligence will aid the supply chain by analyzing drawings and mapping the requirements directly to the cost-estimating software. The software will develop a cost estimate and publish a "Should Cost" analysis. The procurement specialist could then create cost estimates and compare them with supplier quotes during negotiations. The ability of the procurement/supply chain to have a robust solution highlights the future state.

In addition, Ai plays a critical role because the learning loop keeps the software fresh and incorporates feedback. The ability to have software that can automatically highlight design improvement based on quality department dashboards. Also, auto-populates post-process operations based on material selection and Work Breakdown Structure (WBS) designation.

The Ai technology can track a configuration as a function of time (Program maturation), thus allowing the cost analyst to track parts that merged, separated, and eliminated. The role is essential when leadership asks for traceability of the cost changes.

The Ai will toggle the qualification process's recurring cost, tooling cost, and NRE. The capability is a game-changer as designers will have situational awareness of the financial impacts of the baseline design.

The configuration grows in complexity due to design maturity; periodically, there are opportunities to merge parts. The Ai will scan the structure for opportunities to incorporate neighboring elements for cost reduction. For example, several months later, a machined spar and a sheet metal clip are added to support a wiring harness. Unless the systems engineer is fully deployed to the program, that opportunity might result in a missed opportunity. The Ai would scan the configuration for trades that merit a revisit by the program.

The Ai will also highlight part clashing and assembly tool confined spaces and suggest the incorporation/removal of a kit to the final assembly line due to recurring costs. The Ai would track customer configuration trends and make recommendations accordingly.

"The Ai will toggle the recurring cost, tooling cost, and NRE for the qualification process."

Conclusions

Incorporating digital systems into an ecosystem has benefits that, at least for now, outweigh any concerns. For economical and societal reasons, it is imperative that, as a community, we embrace this tidal wave of innovation and swallow the blue pill. We will benefit from improved connectivity, higher levels of effectvticuy, greater insight, innovation, and flexibility.