FROM **POTS** AND **VATS** TO **PROGRAMS** AND **APPS**

How Software Learned to Package Itself

Second edition

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This book uses Palatino Linotype and Gill Sans MT typefaces (and Red Hat Display for the cover).

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About the authors

Gordon Haff (right) is technology advocate for Red Hat, the leading provider of commercial open source software. He is a frequent speaker at customer and industry events. He writes for a variety of publications including The Enterprisers Project, opensource.com, and Connections. His Innovate@Open podcast includes interviews with a wide range of industry experts. He's the author of *How Open Source Ate Software (second edition)*, published by Apress. He also works on strategy for Red Hat's hybrid cloud portfolio and other emerging technology areas such as Edge/IoT, Quantum, AI, and DevSecOps.

Prior to Red Hat, as an IT industry analyst, Gordon wrote hundreds of research notes, was frequently quoted in publications such as *The New York Times* on a wide range of IT topics, and advised clients on product and marketing strategies. Earlier in his career, he was responsible for bringing a wide range of computer systems, from minicomputers to large Unix servers, to market while at Data General.

He lives west of Boston, Massachusetts in apple orchard country and is an avid hiker, skier, sea kayaker, and photographer. He can be found on Twitter as @ghaff and by email at gordon@alum.mit.edu. His website and blog are at http://www.bitmasons.com.

Gordon has engineering degrees from MIT and Dartmouth and an MBA from Cornell's Johnson School.

William Henry (left) has been heavily involved in container initiatives at Red Hat. He contributed all the manual pages for the original Docker project and has developed portfolio architectures and validated patterns. Most recently he has been advising on DevSecOps (security in DevOps) and software risk management. William joined Red Hat in the office of the CTO, in 2008, focusing on emerging technologies.

William has over 25 years experience developing distributed applications and systems and service oriented architectures for both government and private industry. William's roles have included engineering, professional services, partner alliances, several management and director roles, and he owned a startup that was acquired by a publicly traded company.

He travels extensively, speaking with customers in various industries about how the latest technology shifts will affect how they do business. He has been a guest speaker and/or expert panelist at Red Hat Summit, LinuxCon, ContainerCon, OMG, JavaOne, TheServerSide, SDI, DevOps Summit, and many other industry events. He holds both a B.Sc. and M.Sc. in Computer Science from Dublin City University, Ireland and currently lives in Monument, Colorado, USA with his family.

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Photographs are credited throughout this book.

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Introduction

Packaging was the theme for the MonkiGras conference James Governor organized for early 2017 in London. James encouraged ex-analyst colleague Gordon to go "meta" on the topic. (Analysts love meta and metaphors and historical context.) The result was a presentation titled "A Short History of Packaging: From the Functional to the Experiential."

Light bulb moment.

The overall packaging theme of MonkiGras and the research Gordon did for his talk turned out to be a great hook for the two of us to jointly write this book. We work together at Red Hat and have collaborated on a wide variety of DevSecOps and container-related activity.

It immediately became clear that protecting contents, conveying information about contents, communicating legitimacy and trust, and enabling transactions were all attributes common to both how packaging in the physical world has evolved and the hot topics in software packaging today. And there was clear overlap with the container and DevSecOps strategy work that William was focused on for his day job. This second edition extensively updates the container-related content to reflect the many changes that have taken place since the first edition published in 2017.

The meta view of packaging highlights critical tradeoffs. Unpackaged and unbundled components offer ultimate flexibility, control, and customization. Packaging and bundling can simplify and improve usability—but potentially at the cost of constraining choice and future options.

Bundling can also create products that are interesting, useful, and economically viable in a way that fully disaggregated individual components may not be. Think newspapers, financial instruments, and numerous telecommunications services examples.

Open source software, composed of malleable bits that an end user can change and even redistribute, offers near-infinite choice. Yet, many software users and consumers desire a more opinionated, bundled, and yes, packaged experience—trading off choice for convenience.[1]

This last point is a critical tension around open source software and, for lack of a better umbrella term, "the cloud" in the current era. Which makes understanding the role that packaging plays not just important, but a necessity. Ultimately, packaging helps open source create the convenience and the ease of use that users want without giving up on innovation, community-driven development, and user control.

Perhaps most importantly though, this second edition doubles down on considering the role that different forms of packaging can play in operationalizing and simplifying the consumption of open source software as an alternative to cloud-native services specific to a single provider.

[1] As James' partner at RedMonk, Stephen O'Grady, observed in "The Power of Convenience."
http://redmonk.com/videos/monki-gras-2017-stephen-ogrady-the-power-of-convenience/

In the Beginning

If we go back far enough, humans didn't package anything. Today, a chimpanzee might use a leaf to collect some water. Various animals gather food to prepare for a cold winter. But none really package food or drink in any meaningful way. That's a pretty good indication of the state of affairs in the earliest human hunter-gatherer societies as well.

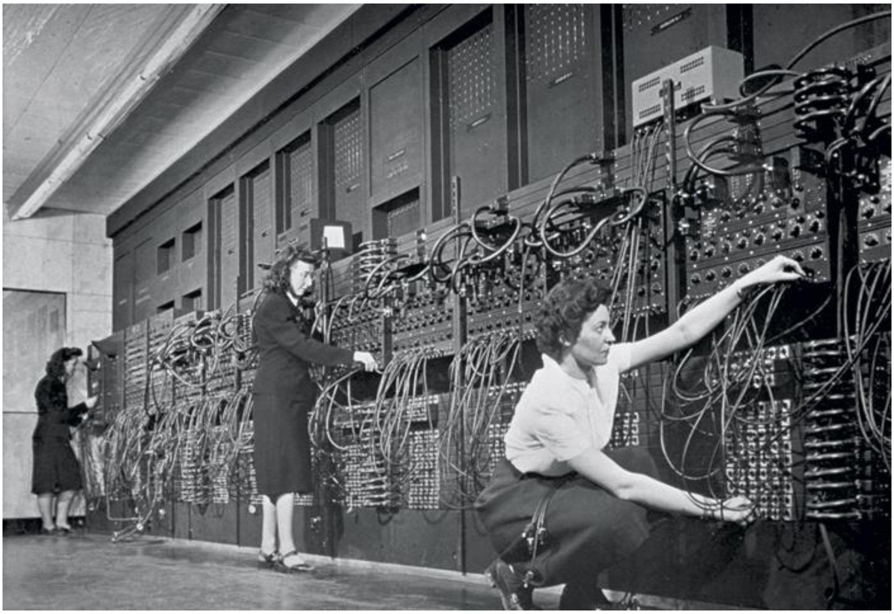
As a result, most anything the earliest humans might have collected had to be consumed both quickly and near to where it was scooped up or gathered. Without some form of packaging, there was no way to carry water or grain to a new location against a future need.

Our earliest computer programs weren't any more packaged and portable.

ENIAC (Electronic Numerical Integrator And Computer) was the first general-purpose digital computer. Built at the University of Pennsylvania during World War II, ENIAC was programmed by a combination of plugboard wiring and three function tables each of which had 1200 ten-way switches which were used for entering tables of numbers.[2]

As Franz Alt would write in 1972: "It was similar to the plugboards of small punched-card machines, but here we had about 40 plugboards, each several feet in size. A number of wires had to be plugged for each single instruction of a problem, thousands of them each time a problem was to begin a run; and this took several days to do and many more days to check out."

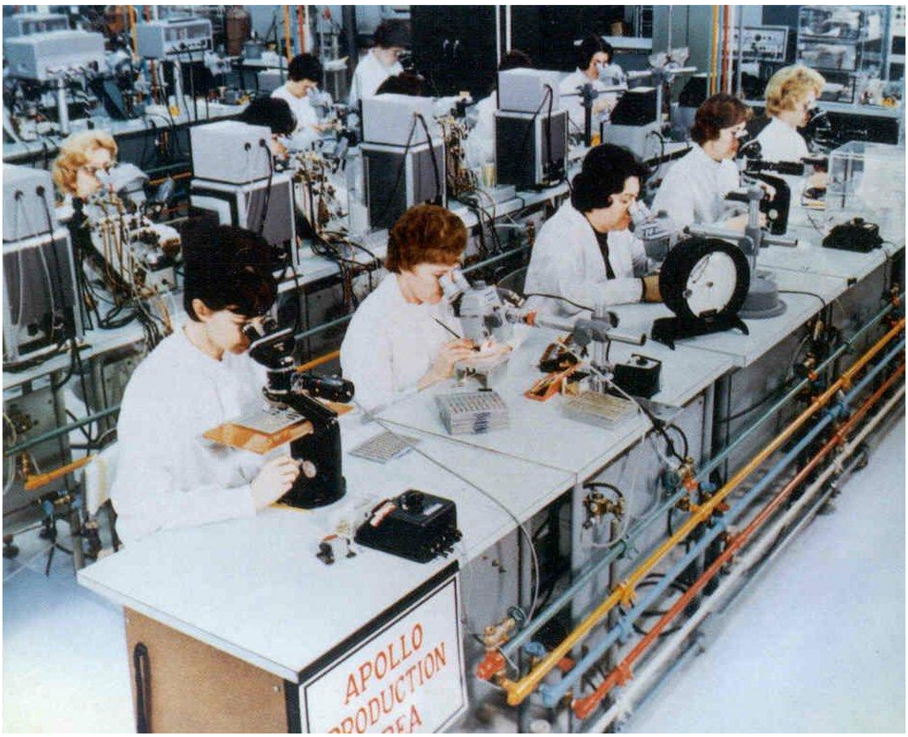
[2] http://www.columbia.edu/cu/computinghistory/eniac.html



ENIAC, the world's first digital computer at the University of Pennsylvania, had six primary programmers: Kay McNulty, Betty Jennings, Betty Snyder, Marlyn Wescoff, Fran Bilas and Ruth Lichterman. They were initially called "operators." Source: Los Alamos National Laboratory

Unpackaged code would remain around in various forms for a perhaps surprisingly long time. Richard Battin, who led the design of the guidance, navigation, and control systems for the Apollo flights while at the MIT Instrumentation Lab (now named after its founder Charles Stark "Doc" Draper), once recalled a story about the core rope memory used in the Apollo Guidance Computer.

Core rope is a form of read-only memory for computers; the ferrite cores which stored the electrical signals were "woven" to compose programs by a team of ex-textile workers and watchmakers working for Raytheon. It was sometimes nicknamed "Little Old Lady" memory as a result.[3]



"Sewing" rope core memory for Apollo. Source: Raytheon, from the files of Jack Poundstone.

One day, the astronauts toured the facility. As Battin told it, one of the goals was to impress upon the production workers that it was

[3] http://news.bbc.co.uk/2/hi/technology/8148730.stm

really important not to make a mistake in their “sewing” lest these “nice young boys” die.

Programs such as these were one-off affairs, rooted in a single system with no existence outside of that instance of hardware.

Containing

It's hard to say when the first primitive packaging put in an appearance. It probably consisted of leaves, woven grasses (primitive baskets), and other readily available materials such as animal skins. Little evidence has been preserved of these soft and perishable containers.

The oldest examples of pottery yet discovered are remains found in the Xianrendong Cave in the Jiangxi Province in China; they go back about 20,000 years, predating agriculture and what we generally consider to be civilization.[4] Pottery spread widely in subsequent millennia and fragments are ubiquitous at archeological sites around the world. Such pottery vessels would have been used for storing, cooking, and serving food—as well as carrying water.

Indeed, potsherds—fragments of pottery—are widely used by archaeologists to date and otherwise better understand when a particular site was occupied and by whom. Characteristics such as temper, form, and glaze help determine the time period and the technologies that were in use at a given site.

The first wine was probably fermented in a pottery container, possibly dating to early Middle Eastern civilizations about 7,000 years ago.[5] Hold that thought for now though; we'll return to packaging for preservation in due course.

In the case of computers, containing instructions and data originally took its cue from earlier forms of storing repeated patterns.

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[4] http://science.sciencemag.org/content/336/6089/1696
[5] http://archive.archaeology.org/9609/newsbriefs/wine.html

The precursors to software storage

Perhaps the very oldest such storage can be found in the barrel organ which "owes its name to the cylinder on which the tunes are pricked out with pins and staples of various lengths, set at definite intervals according to the scheme required by the music."[6] The concept dates to the Netherlands in the 15th century but detailed diagrams of a large stationary barrel-organ worked by hydraulic power were first published in 1615 by Jehan van Steenken, a Belgian organ-maker.

You may be familiar with a barrel organ in the guise of a street instrument played by an organ grinder, or perhaps a trained monkey, turning a crank.

The most widely cited precursor to today's data storage came by way of the silk industry in Lyon France in 1725. It was there that Basile Bouchon, a textile worker and son of an organ maker, had the idea to extend the concept of the rotating pegged cylinders used in automated organs to "program" textile weaving. His innovation came from realizing that, before fabricating the expensive metal cylinders used by devices such as barrel organs, the information content had to first be laid out in paper form.[7] For textile weaving, instructions could just be encoded on paper without subsequently creating a costly metal version.

Neither Bouchon's device, nor follow-on refinements by Jean-Baptiste Falcon and Jacques Vaucanson, were very successful or effective. But the Jacquard loom, invented by Joseph Marie Jacquard in 1804, was. Not actually a loom in its own right but a controlling device for looms, Jacquard's invention is widely

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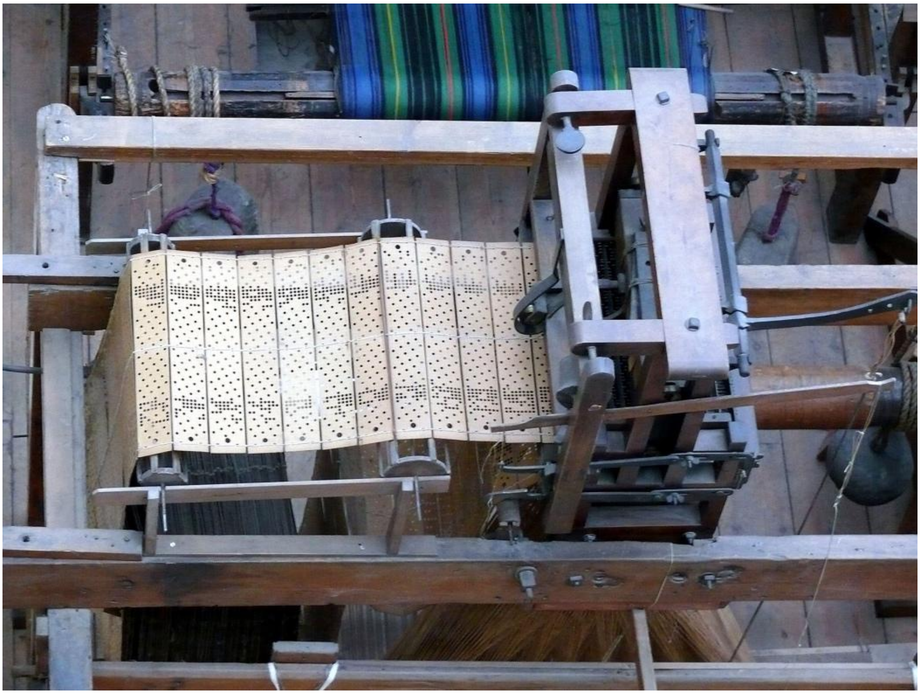
6 https://en.wikisource.org/wiki/1911_Encyclop%C3%A6dia_Britannica/Barrel-organ

7 http://history-computer.com/Dreamers/Bouchon.html

considered to be one of the most important inventions in the history of textiles.



Jacquard loom in the National Museum of Scotland, Edinburgh. Source: Ad Meskens / Wikimedia Commons.

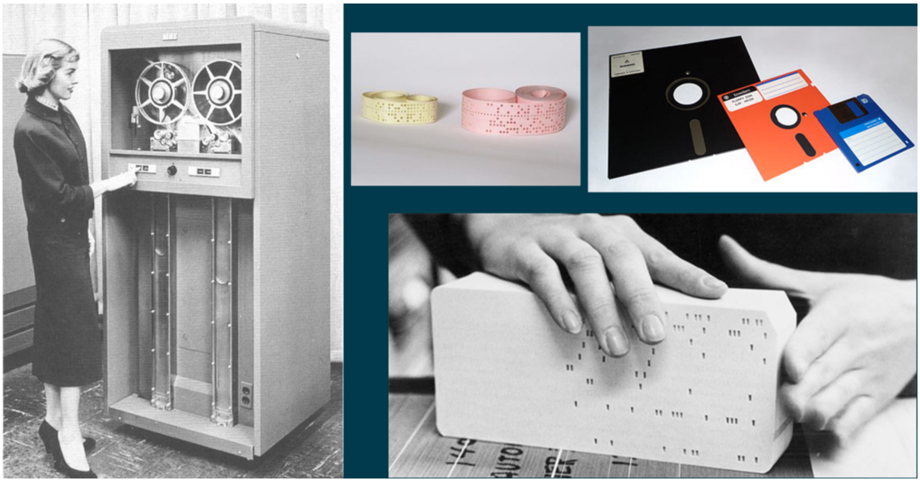
Variegated packaging of data

The punched cards used in automated weaving are a direct ancestor of the punched cards used throughout a large chunk of the history of computers. Charles Babbage planned to use them in his never-completed Analytical Engine in the mid-1800s. But they were first actually used in something like computing machinery when Herman Hollerith created a punched card tabulating machine to input data for the 1890 U.S. Census. Hollerith's company would combine with three other firms to become IBM, whose 80-column punched cards were the ubiquitous way to store data until the 1950s (when magnetic data storage started to become common) and remained commonplace for data entry for a couple decades after that.

Paper tape spools being used for newspaper typesetting, circa 1976. Source: Gordon Haff.

Punched tape had its own parallel history, most associated with teletypewriters and various types of specialized computers such as newspaper typesetting equipment and computer-controlled manufacturing systems. The mechanisms required to write and read a spool of up to one-inch wide paper tape were smaller and simpler than card keypunch machines and card readers—and thus a better fit for equipment that was typically much lower cost and much smaller than that associated with mainframe computing.

The first magnetic media dates to the UNISERVO reel-to-reel tape drive, which was the primary input/output device on the UNIVAC I, the first commercially-sold computer. It recorded on a thin metal strip of half-inch wide nickel-plated phosphor bronze. Shortly thereafter, IBM introduced ferrous-oxide coated tape similar to that used in audio recording. This general type of reel-to-reel drive and media was standard on large computer systems until about the 1990s.



Clockwise from left: Magnetic tape, paper tape, diskettes, and punch cards. Sources: Punched tape and diskettes, Wikimedia. Punched card and tape drive, IBM.

Smaller, cheaper, and more numerous computers sparked a demand for smaller removable magnetic storage. (Reel-to-reel drives were large, complex, and expensive.) In 1972, 3M introduced Quarter-inch cartridge tape (abbreviated QIC, commonly pronounced "quick"), variants of which are still (rarely) in use today. The media is an enclosed package of aluminum and plastic which holds two tape reels driven by a single belt in direct contact with the tape.

Over time, other cartridge tape formats included IBM's 3480 and 7380 families, Digital Linear Tape (DLT) from Digital Equipment Corporation, Linear Tape-Open (LTO), and DDS/DAT. Cartridge tape remains fairly common for large-scale data backup; it's often used in conjunction with large robotic tape library systems. However, they've been replaced for many backup applications by hard disk drives that are optimized for capacity rather than performance; they're also often powered-off when not in use to reduce operational costs.

Floppy disk drives are most associated with the PC era but the original 8-inch floppy was developed in 1967 at IBM's San Jose, California storage development center. It was designed as a reliable and inexpensive system for loading microcode (essentially the initialization system) into System/370 mainframes.

Shugart Associates subsequently developed the 5-¼-inch format diskette for a desktop word processing system that Wang Laboratories was developing in the late 1970s. This form-factor was widely-used in many of the early PCs including the Apple II and the original IBM PC and its clones. One or two floppy drives often served as the only persistent storage in these machines although, once hard disk drives dropped in price, "floppies" were increasingly relegated to loading software and backing up data.

The floppies used in the IBM PC initially had a capacity of around 360,000 bytes—essentially characters. Later ones had about four times that capacity. But even that higher capacity would not store a typical compressed MP3 music file of today, nor a JPEG photo file from a smartphone.

In 1982, the Microfloppy Industry Committee, a consortium of 23 companies, finally agreed upon a 3½-inch media specification after years of competing formats saw spotty use. (It was not actually "floppy" because it had a hard shell.)

Some variant of a floppy image serves as a "save" icon in countless programs and elsewhere. Many people clicking on those icons have probably never used an actual floppy disc drive.

The floppy wasn't widely replaced until the adoption of the compact disc (CD) which had about 600 times the capacity. This digital optical disc data storage format, released in 1982 and co-developed by Philips and Sony, was originally developed for audio where it replaced most vinyl and cassette tape for music sales.[8] But over about the next ten years, it became the dominant distribution and sometimes backup medium for PCs. Eventually, a combination of cheap hard drives, high-bandwidth networks, and multi-gigabyte flash memory sticks made it largely redundant.[9]

The higher-capacity DVDs created to distribute movies to consumers were followed by an even higher capacity optical format, Blu-Ray; both enjoyed a period of popularity for distributing movies for home viewing. However, because of an early-on format battle with HD-DVD and initially expensive writable media, by the time Blu-Ray might have been broadly interesting as a computer data storage format, it was no longer needed as external hard disks and online backups became more practical options.

What's common to all these formats that have dotted the computing landscape over the years is that they were a way to contain information in a digital form. As with retail shelving and physical packaging, there were attempts to introduce some degree of

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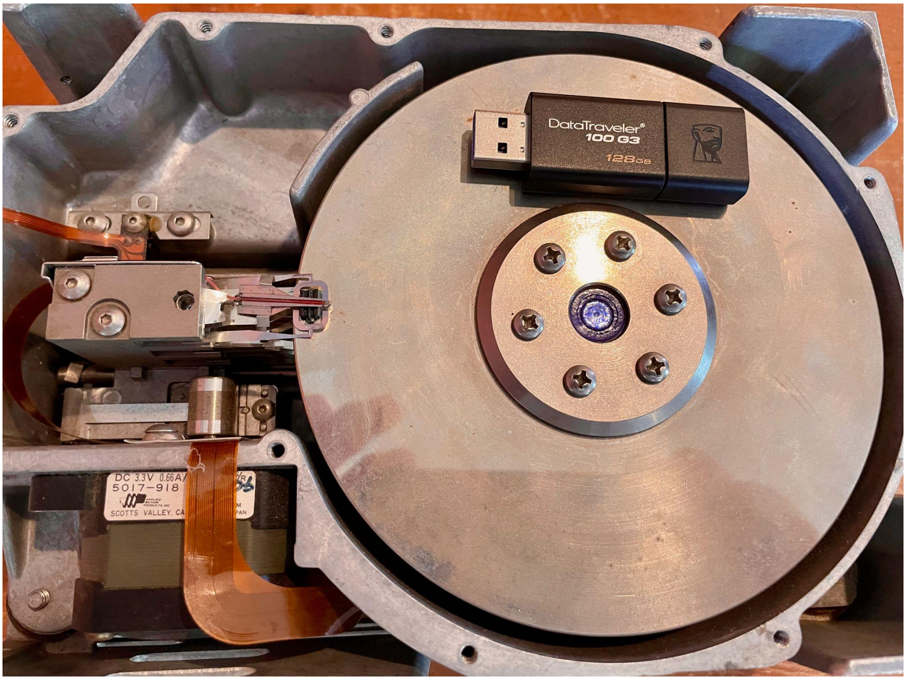
[8] Vinyl has staged something of a retro comeback and actually exceeded CD sales in 2021.

[9] CDs were originally a read-only pre-pressed format. However, subsequent writable versions made them more generally useful in the PC space. For a time, not the least of those uses was making copies of purchased audio CDs or creating mixes of music downloaded from the Internet.

standardization. But standards are always somewhat at war with the desire to differentiate or to optimize for a particular use.



A modern flash drive sits on an exposed platter of a hard drive similar to what you could have purchased as part of an IBM PC XT in the early 1980s. The flash drive has over 6,000 times the capacity at about 1/100th the price. The size difference of a modern 3.5-inch hard disk is less stark but the capacity difference can be over 1,000,000:1. Source: Gordon Haff.

Over time, various innovations to use data storage more efficiently were also developed. For example, especially for uses where storage performance was less important (and/or where some information in the original can be discarded), compression allows more data to be stored on a given size of media.

However, as with other forms of packaging, data storage didn't originally exist primarily to make buying or selling software easier—other than incidentally.

Transact

As goods increasingly flowed over long distances and trade became a central part of many economies, traders naturally wanted to streamline both transporting goods and selling them. New designs of pottery containers lent themselves to efficient shipment. One such container was a twin-handled amphora with a characteristic pointed base and elongated shape, which facilitated the transport of oil or wine by ship. The amphorae were packed upright or on their sides in as many as five staggered layers.

Standardization

Amphorae originally differed considerably in shape and size. However, during the Roman empire, the weights and measures used in commerce became more formalized. For example, the temple of Jupiter in Rome housed a standard model of an amphora called amphora Capitolina. The capacity of this vessel corresponded to the principal Roman measure of capacity for fluids, amphora quadrantal—or just amphora. The measurement derives from the capacity occupied by 80 pounds of wine, about 10 gallons or 39 liters. By law, the quadrantal was connected to the measures of length as its volume was a cubic foot.[10]

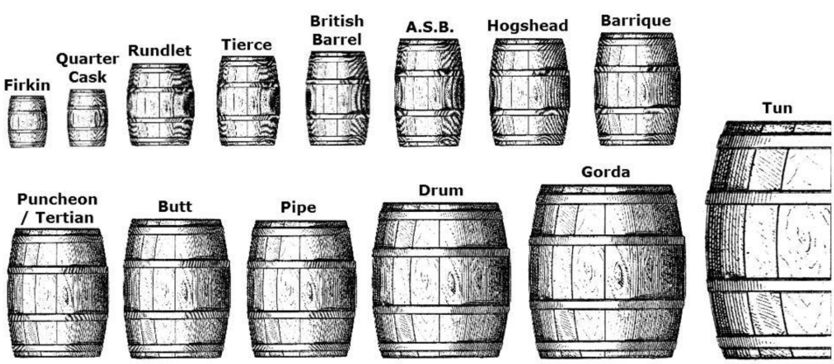
Standardization enables more formalized transactions. An amphora quadrantal might not have signaled anything about the quality of the wine or olive oil it contained. But it at least communicated a predictable quantity.

The Romans also used barrels. But barrels in the form we think of today, made of wooden staves bound by wooden or metal hoops, were more typical further north in Europe—especially in the territories of the Gauls and Celts. Until the twentieth century and

[10] William Smith, A Dictionary of Greek and Roman Antiquities, 1875

the introduction of pallet-based packaging systems, barrels were often the most convenient packaging for shipping all sorts of bulk goods, from nails to whiskey. Bags and crates were also common because they were cheaper, but they were not as sturdy, didn't protect their contents as well, and could be more difficult to handle.

Barrels of various sizes became standard measures of volume across a broad swath of industries. Firkin, hogshead, gorda, tun, butt, and barrique measures all derive from cask sizes. The practice carried over when steel drums, including the standard 55-gallon steel drum, replaced barrels for many applications. The 42-gallon standard oil barrel volume measurement is still used today throughout the petroleum industry, even though actual physical barrels are no longer used to transport oil.



Some of the historical sizes of barrels (casks).

The gallon (galun or galon in Norman) probably dates to about the time of William the Conqueror, who invaded England in 1066, although the details get fuzzy prior to the year 1300 or so. The liquid version of the gallon was the basis of a system for wine and beer measurements in England. A variety of gallon variants were used in Britain and its colonies at different times and for different purposes. In the early 19th century, the US standardized on the wine gallon, the volume of which was first legally defined during the reign of Queen Anne in 1706. However, in 1824, Britain standardized its gallon by adopting a close approximation to a different gallon variant, the ale gallon or imperial gallon, which is about 20 percent bigger than the US version (4.5 vs. 3.8 liters). Because pints are one-eighth of a gallon in both systems, this is the historical oddity that gives you four extra ounces of beer when you order a pint in a London pub compared to a Boston one.

Another application of barrel-like containers such as kegs.

The shrink-wrapped software era

We see analogs to amphoras and barrels in the way that software packaging can bring together bits so that they can be sold to and consumed by a customer in a standardized way. The shrink-wrapped software era was made possible by the fact that programs could be written onto standard media from which they could be then loaded onto a customer's computer. There are earlier examples of software being delivered on magnetic tape to business users, but selling software in volume to individual consumers brought an even greater need to simplify the delivery of software from the manufacturer to the retailer and from the retailer to the end-user.

It's difficult to identify the first company to sell software that wasn't also hawking hardware (which is to say, the first Independent Software Vendor (ISV)). However, Cincom Systems—founded in 1968—is a good candidate. It sold what appears to be the first commercial database management system not to be developed by a system maker like IBM. Fun fact: Not only is Cincom still extant as a private company in 2022 but one of its founders, Thomas Nies, is the CEO.

Over time, pure-play or mostly pure-play software companies packaging up bits and selling them became the dominant way by which customers acquired most of their software. ISVs like Microsoft selling closed-source proprietary software even became major suppliers of the operating systems and other "platform" software that historically were supplied by vendors as part of a bundle with their hardware.

Linux distributions

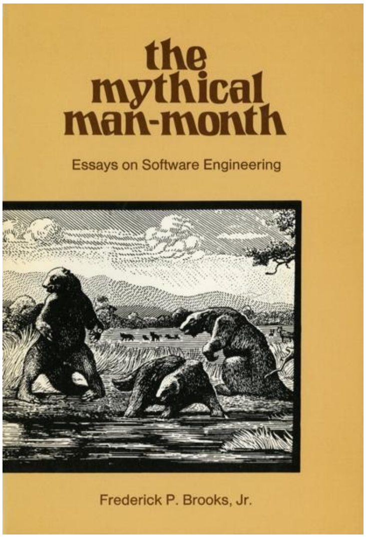
In the world of open source software, distributions brought together the core operating system components, including the kernel, and combined them with the other pieces, such as the utilities, programming tools, and web servers needed to create a working environment suitable for running applications. Although it wasn't the first Linux distribution, Slackware, released by Patrick Volkerding in 1993, was the first that can reasonably be considered well-known. Over the next decade, the number of distributions exploded although only a handful were ever sold commercially. In a 2003 analyst report, Gordon wrote that in addition to the major commercial distributions from Red Hat and SUSE:

> There are a lot of Linux distros out there, ranging from the whimsical to the serious, from the general-purpose to those that are specialists in some function such as real-time computing or for some geographic region such as Asia-Pacific. There's Debian, Slackware, Conectiva, Lindows, Mandrake, SCO/Caldera, Red Flag Linux, and Turbolinux, to say nothing of the literally hundreds of other special-purpose Linux distributions including Bootable Business Card (designed to be booted from a business-card type CD), ChainSaw Linux (for video editing), Xbox Linux (to turn a Microsoft Xbox game console into a Linux computer), UltraPenguin (for SPARC and UltraSPARC), YellowDog Linux (for PowerPC), spyLinux (fits on a single floppy), and the initially alarming and recursively acronymic JAILBAIT.

Distributions were a recognition that an operating system kernel and even the kernel plus a core set of utilities (such as those that are part of GNU in the case of Linux) aren't that useful by themselves.

Commercial open source subscriptions, such as Red Hat Enterprise Linux, further extend the idea of distributions by incorporating support, security fixes, hardware and software certifications, legal protections, and other things that customers value. This is the next step to creating a more complete experience for buyers through packaging. It's also part of an overall trend to streamline the path from developer to the user. What analyst Stephen O'Grady calls the "power of convenience." Making it easy for users to meet some business need through software is a central aspect of how packaging and software intersect.

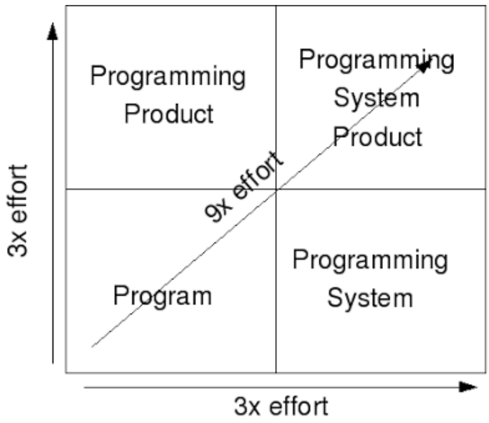
The Product



Fred Brooks is best known for writing *The Mythical Man Month*, a series of essays reflecting on the development of the operating system for IBM's System/360 mainframe which began in the late-1960s. What everyone remembers from that book is the adage that adding more people to a late project makes it even later for reasons of ramp up time, communication overhead, and the inability to divide up many tasks. Hence, the book's title.

Programming Systems Products

However, *The Mythical Man Month* kicks off with a different discussion: namely the distinction between a Program and a Programming Systems Product. From Brooks' perspective, evolving the Program into a "truly useful object" required evolving it along two dimensions, as shown in this figure from his book.



In the first dimension the program becomes a programming product, a program that can be run. This involves tasks like testing, documentation, maintenance, and generalization to a range of inputs. In the second dimension, the program becomes a programming system: "a collection of interacting programs, coordinated in function and disciplined in format, so that the assemblage constitutes an entire facility for large tasks."

Brooks estimated that costs increased by about 3 times along each of these dimensions, resulting in a useful product costing about 9 times the money and effort that went into the original program.

It's probably worth noting that this discussion is very much flavored by the large system, waterfall development model in which it was rooted. Nonetheless, we see echoes today in humorous aphorisms such as the ninety-ninety rule: "The first 90 percent of the code accounts for the first 90 percent of the development time. The remaining 10 percent of the code accounts for the other 90 percent of the development time." (Attributed to Tom Cargill of Bell Labs.)

Products are a form of packaging.

Products aggregate. This is similar in concept to Brooks' programming system. In many cases, people prefer to purchase products that include all the parts and dependencies that they need to use a product. There's a reason that the old Christmas morning "batteries not included" trope was not intended as positive commentary (and has become largely a thing of the past).

Furthermore, finished products often aggregate a *prescriptive* bundle of parts. There are certainly cases where buyers want to exercise maximum control over individual components. But, more commonly, they're looking for someone else to have done the work of researching and sourcing parts that are to be used together.

Source: The Internet (unknown).

Beyond aggregation

Products generally also go beyond aggregating parts to integrating them. An automobile is not a box of parts. It's a fully integrated assembly that's sold as a complete product. Customers may be offered some options. (The automotive industry is notorious for using option packages to bundle things that many customers want with things that they might not otherwise buy.) However, whatever the specifics, almost no packaged product just throws a bunch of parts in a box. Rather, it constructs and presents a new thing out of an often complicated web of component supply chains.

Brooks' programming product dimension applies even when the nature of the final good means there's "some assembly required." Testing, instructions, support, and (for some types of products) updates are all part of delivering a packaged product to a customer.

Ikea very much sells complete packaged products even if the buyer needs to assemble them. In fact, its packaging is central to both its identity and its business model. For example, the European Logistics Association noted that: "In order to lower logistics costs and increase efficiency in its transportation and warehousing operations, IKEA started an internal competition to reduce unnecessary air in their product packaging. This 'Air hunting competition' focused on removing as much air as possible from packaging and thereby increasing true product volume during transportation and storage."

We see aspects of creating both programming systems and programming products in the open source software world.

Turning open source into products

Entire new categories of software are open source by default, in part because of the success of the development model. Open source underpins the infrastructure of some of the most sophisticated web-scale companies, like Facebook and Google. Open source stimulates many of the most significant advances in the worlds of cloud, big data, and artificial intelligence. Furthermore, as new computing architectures and approaches rapidly evolve for cloud computing, for big data, and for edge computing and the Internet of Things (IoT), it's also becoming evident that the open source development model is extremely powerful because of how it allows innovations from multiple sources to be recombined and remixed in powerful ways.

But the huge amount of technological innovation happening around open source can be something of a double-edged sword. On the one hand, it creates enormous possibilities for new types of applications running on dynamic and flexible platforms. At the same time, channeling and packaging the rapid change happening across a plethora of open source projects isn't easy—and can end up being a distraction from the business goals of a company that's just using open source software to achieve some objective.

In some respects, you can think of many open source projects as programs in Brooks' parlance. They embody a set of capabilities but they're not always fully fleshed out in the ways that let customers depend on them for critical needs.

Commercial open source subscriptions are about creating programming system products. In other words, they make community open source technologies more usable and supportable by enterprise IT. This usually involves working "upstream" to engage with open source communities and influence technology choices in ways that are important to the users of that software. This takes advantage of the strengths of open source development while maintaining technology expertise to provide fast and knowledgeable product support.

Part of this process is also selecting which upstream projects are in a state that's appropriate for a given customer use. For some uses, this means prioritizing stability and maturity. Other uses are a better match for a rapid development and release cycle that provides the latest technology on current hardware platforms.

Al Gillen, at industry analyst firm IDC, noted in an interview that: "As we go up the [software] stack, customers still see value associated with commercialization, so a company that will take your project and make it something that is consumable will provide the support. The reason why that's so valuable is that [customers do] not have to have the expertise on staff."

Surveys show this value as well. Red Hat's 2022 The State of Enterprise Open Source[11] report showed enterprise open source software usage predicted to climb from being 29% of their software at the time of the survey to 34% in two years. Community open source was forecast to climb too but by a more modest 3 points from 21% to 24%. During the same period, proprietary software was expected to drop from 45% to 37%. The respondents also highlighted a variety of enterprise open source benefits but, tellingly, higher quality software, better security, and the ability to safely leverage open source technologies—all attributes we associate with solid software products generally—were all in the top six.

Not just support

It's worth mentioning at this point that commercial open source often gets pigeonholed as being about "support," which in turn conjures up an image of support staff at call centers waiting for a telephone call or email. That's a part of it of course.

But subscriptions also provide access to knowledge about using products more generally that goes beyond support in the event of a problem. It can include automated access to knowledge repositories, product documentation, and other resources. This sort of self-service access is often faster and easier than opening a support case.

Commercial open source products also typically include updates and upgrades through a defined product life cycle. This is particularly important when security vulnerabilities happen. During the Shellshock and Heartbleed security incidents, for

[11] https://www.redhat.com/en/enterprise-open-source-report/2022

example, Red Hat customers received the knowledge, patches, and applications needed to verify their exposure and successfully remediate potential issues within hours of the bugs being made public. Subscription products can also carry legal protections and certification agreements with other vendors.

It can even include access to the experts who work with upstream communities on a daily basis in order to solve a problem or prioritize a feature on the roadmap.

As Fred Brooks wrote back in 1975, this packaging makes the difference between a program and a system product that's generally useful for business.

Delivery

We've now arrived at a packaged good, perhaps a complex packaged good, which can be sold and used in a supportable way. But we need to deliver it efficiently.

The container ship metaphor

There's a powerful metaphor for this in the physical world—indeed so powerful and useful (if somewhat flawed as metaphors are wont to be), that many tech folks are a bit tired of hearing about it by now.

Container ship MSC Oscar, first visit in Rotterdam. Source: kees torn (MSC OSCAR & SVITZER NARI) CC BY-SA 2.0, via Wikimedia Commons

The shipping container, as described by Marc Levinson in *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger*, radically changed the economics of shipping the goods we purchase and use every day. Without the shipping container, the globalization of goods would never have happened—at least not at the scale it has.

Containers have been around in various forms since at least the 1800s, beginning with the railroads. In the United States, the container shipping industry's genesis is usually dated to Malcom McLean in 1956. However, for about the next twenty years, many shipping companies used incompatible sizes for both containers and the corner fittings used to lift them. This in turn required multiple variations of equipment to load and unload containers and otherwise made it hard for a complete logistics system to develop.

But around 1970, standard sizes and fittings and reinforcement norms were developed (with all the political jostling between the incumbents that you'd expect). This points to the important role that standards can play. Without the standardization of the shipping container, it would have effectively been just another type of box rather than the component at the heart of an international intermodal[12] delivery system.

Existing infrastructure also influences the design of this system.

Individual forty-foot long containers are about the maximum size that can be transported by truck.

The size of container ships is largely constrained by the width and depth of the Panama and Suez Canals, as well as length. A "Panamax" (or, now, New Panamax or Neopanamax) container ship is the maximum size that can go through the Panama Canal; an Ultra Large Container Vessel (ULCV) is the largest that can go through the Suez Canal.[13]

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[12] Intermodal means that two or more different modes of transportation are involved. For example, a (typically) 40-foot long container can ride on a container ship, flatcar railroad rolling stock, or semi-tractor-trailer truck, all without unloading the contents of the container.

[13] The "Suezmax" term is sometimes used but mostly to refer to oil tankers.

In a totally different context, there's a good argument that the Segway, a much ballyhooed self-balancing "personal transportation vehicle," failed, not so much because of price or poor design, but because it wasn't a good fit with either existing sidewalks or roads (which also inhibits widespread bicycle use in many American cities). Packaging systems are most effective when they fit within existing constraints and infrastructure—or at least can play off them.

As important as standards in the adoption of containers were changes to the labor agreements at major ports. When containers were first introduced, existing labor contracts negated much of their economic benefit by requiring excess dockworkers or otherwise requiring processes that involved more handling than was strictly necessary. Because of both new labor agreements and infrastructure, containerization allowed the Port Newark-Elizabeth Marine Terminal to largely eclipse the New York and Brooklyn commercial port. Making the best use of packaging systems can require making changes to processes and workflows.

The container embodies a lot of interesting lessons for how technologies evolve more broadly—and how everything old is new again. How does this apply to software packaging?

The rise of software containers

Some of the core technologies underpinning (software) containers are nothing particularly new.

The idea behind what we now call container technology first appeared in 2000 as a way of partitioning a FreeBSD Unix system into multiple subsystems, aka "jails." Jails were developed as safe environments that a system administrator could share with multiple users inside or outside of an organization. The intent was that, within a jail, software ran in a modified environment. It had access to most of the usual system services but was walled in so that it couldn't escape and compromise other users and tasks. Jails weren't widely used and methods for escaping the jailed environment were eventually discovered.

In 2001, an implementation of an isolated environment made its way into Linux, by way of Jacques Gélinas' VServer project. As Gélinas put it, this was an effort to run "several general purpose Linux servers on a single box with a high degree of independence and security." Once this foundation was set for multiple controlled userspaces in Linux, pieces began to fall into place to form what is today's Linux container.[14]

Like other types of software partitions (including hardware virtualization), a container presents the appearance of being a separate and independent operating system—a full system, really—to anything that's inside. But, like the workload groups that containers extend, there's only one actual copy of an operating system kernel running on a physical server.

The operating system causes the applications running in each container to believe that they have full, unshared access to their very own copy of that operating system when, in fact, they're sharing the services of a single host operating system. (By contrast, hardware virtualization, normally just referred to as virtualization, requires that each partition include an individual copy of a guest operating system.) This also points to why the Linux operating system is so integral to Linux containers; container performance, isolation, and security all depend on inherent operating system capabilities.

[14] Other container implementations included Virtuozzo from SWsoft/Parallels and Sun Microsystems' Solaris. The Solaris 10 implementation is probably what most popularized the "containers" term, which was Sun's marketing name for isolating workloads within an operating system. Solaris containers first appeared in a beta release in February 2004. (Sun's technical docs used the "zones" moniker for the same thing.) IBM also introduced containers in AIX which were unique in that they allowed for moving running containers between systems.

Containers were initially viewed as a more lightweight isolation alternative to hardware virtualization. But it's their ability to package applications and their dependencies that has triggered much of the current interest. Source: Illuminata.

From a technical perspective, containers build off the concept of a process, an instance of a computer program that is being executed by one or many threads. It contains the program code and its associated activity. Although a process is not truly an independent environment, it does provide basic isolation and consistent interfaces. For example, each process has its own identity and security attributes, address space, copies of registers, and independent references to common system resources.

The original BSD Unix jails took advantage of chroot, a Unix/Linux operation that changes the root directory for the current running process. One can see how this benefits Linux containers. While depending on the underlying kernel, a completely different root file system, including the Linux distribution libraries and binaries, can be located at the changed root.

Over time, more technologies combined to make this isolation approach a reality. Control groups (cgroups) is a kernel feature that controls and limits resource usage for a process or group of processes. Cgroups use systemd, an initialization system that sets up the userspace and manages its processes, to provide greater control over these isolated processes. These technologies, while adding overall control for Linux generally, were also the framework for how environments could be separated successfully within a single copy of an operating system.

Advancements in user namespaces were the next step. Namespaces isolate and virtualize system resources in a group of processes. They essentially allow changes within one container to be made without affecting other containers on the system.

User namespaces allow per-namespace mappings of user and group IDs. In the context of containers, this means that users and groups can have privileges for certain operations inside a container without the need to give them those same privileges outside the container. For example, an administrator can give someone uid 0 (root[15]) in the container without giving them uid 0 on the underlying system. This is similar to the concept of a jail, but with the added security of further isolation of processes, rather than jails' concept of a modified environment.

In the Transact chapter, we discussed operating system distributions. For the purposes of a container discussion, the operating system can be broken down into two areas.

[15] i.e. Essentially complete control.

First, there's the operating system kernel which schedules and manages running programs, or processes, and the resources associated with those processes.

However, an operating system distribution, whether Fedora, Ubuntu, Red Hat Enterprise Linux, or something else, also provides added libraries and applications. For example, almost all Linux distributions include the GNU packages, a widely-used set of utilities and other programs.

For containers to run on a host they only require the host's kernel, often with the addition of modules such as SELinux for additional security, and other tools. An application running in the container may also have dependencies on specific packages from a specific distribution. Those packages must then be made part of the container image. Glibc, the GNU C language library needed to build the kernel and other software from source code, is an example of a common package dependency in many containers.

Containers: From isolating to packaging

So far we've considered containers as an isolation mechanism. However, containers were largely ignored when they were viewed solely through the lens of partitioning workloads, losing out to virtualization for a variety of reasons. This changed when containers became about packaging as well.[16]

By providing an image that also contains an application's dependencies, a container can be made into a packaging construct that is portable and consistent as it moves from development, to testing, and finally to production.

[16] KubeVirt is a project that allows virtual machines to be managed as if they were effectively containers.

Imagine you're developing an application. You do your work on a laptop and your environment has a specific configuration. Other developers may have slightly different configurations. The application you're developing relies on that configuration and assumes specific files are present. Meanwhile, your business has test and production environments which are standardized and have their own configurations and their own sets of supporting files.

You want to emulate those environments locally as closely as possible, but without the work of recreating the server environments manually. So, how do you make your app work across these environments, pass quality assurance, and get your app deployed without massive headaches, rewriting, and break-fixing?

The answer: Containers. The container that holds your application also holds the necessary configurations (and files) so that you can move it from development, to test, to production—without nasty side effects.

That's a simplified example, but Linux containers can be applied in many different ways to problems where portability, configurability, and isolation are needed. This is true whether running on-prem, in a public cloud, or a hybrid of the two.

How did the industry move from containers as an approach for isolation to an approach for packaging?

Docker Inc. came onto the scene (by way of dotCloud) with their eponymous container technology, initially released as open source in 2013, which combined existing Linux LXC container tooling with further-improved tools for developers, increasing the user-friendliness of containers.

Its most important innovation was in the area of packaging container images. The docker project's image layering technique helped standardize the way Linux container images are built and shipped. Docker subsequently moved control over the standardization effort for container image formats and the container runtime to the Open Container Initiative (OCI).

The OCI, which is under the Linux Foundation, launched in 2015 "for the express purpose of creating open industry standards around container formats and runtime." This project is focused on determining and setting specifications. The first two such specs were Runtime and Image.[17]

The Runtime Specification sets open standards around a filesystem bundle, the structure of supporting files and artifacts in a container, and how that bundle is unpacked by a compliant runtime. Basically, the spec exists to make sure containers work as intended and that all supporting assets are available and in the correct places. The reference implementation of the runtime specification is runC.[18]

A container runtime automates deploying the application (or combined sets of processes that make up an app) inside this container environment. That is, the container runtime starts and stops the container process with the stipulated storage and network resources it requires.

OCI's Image Specification defines how container images are created. This creation outputs "an image manifest, a filesystem serialization, and an image configuration."

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[17] The history of Docker Inc., the docker project, and relationships among various industry players is both fairly involved and not very relevant for our purposes. I'll use the OCI containers moniker here but you can read that as equivalent to what many call docker containers.

[18] https://github.com/opencontainers/runc

Container tools use an image-based deployment model. This makes it easy to share an application, or set of services, together with dependencies across multiple environments.

These specifications work together to define the contents of a container image and those dependencies, environments, arguments, and so forth necessary for the image to be run properly. As a result of these standardization efforts, the OCI has opened the door for many other tooling efforts that can now depend on stable runtime and Image specs. For example, Red Hat has been involved heavily in container registry and container building projects such as Podman, Skopeo, and Buildah. (Of which, more later.)

One of the interesting dynamics with container standardization today is that it reflects an industry that's more willing to adopt standards in areas where gratuitous differences don't actually differentiate but do hurt adoption.

Chris Aniszczyk is the CTO of the Cloud Native Computing Foundation and he put it this way in a 2017 interview:

> People have learned their lessons, and I think they want to standardize on the thing that will allow the market to grow. Everyone wants containers to be super-successful, run everywhere, build out the business, and then compete on the actual higher levels, sell services and products around that. And not try to fragment the market in a way where people won't adopt containers, because they're scared that it's not ready.[19]

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19 http://bitmason.blogspot.com/2017/02/podcast-open-container-initiative-with.html

A detour into applications

We've been talking infrastructure. The plumbing. But it doesn't really make sense to talk about containerized infrastructure unless we also at least touch on the application architectures that are going to use those containers.

For a time, it was popular to talk about legacy applications and cloud-native applications using the "pets vs. cattle" metaphor.

This metaphor is usually attributed to Bill Baker, then of Microsoft. The idea is that traditional workloads are pets. If a pet gets sick, you take it to the vet and try to nurse it back to health. New-style, cloud-native workloads, on the other hand, are cattle. If the cow gets sick, well, you get a new cow.

Pets and cattle roughly corresponded to the Systems of Record and Systems of Engagement taxonomy proposed by consultant Geoffrey Moore (of *Crossing the Chasm* fame).[20] The former were stateful, big, long-lived, scale-up, and managed/maintained at the individual machine level. The latter were assumed to be stateless, small, transitory, scale-out, and managed at the level of the entire application (with individual instances destroyed and recreated in the event of a problem).

As an initial pass at distinguishing between traditional transactional apps and those designed along more cloud-native lines, the metaphor isn't a bad one. "Ants" may be a better fit than "cattle" in that it captures the idea that individual service instances are not only disposable but they work together cooperatively to perform tasks. In any case, the distinction between long-running mutable instances and short-lived disposable ones is broadly relevant.

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[20] https://en.wikipedia.org/wiki/Crossing_the_Chasm

That said, both the metaphor and the binary distinction break down if you stare too hard at them. For example, many stateless web-tier applications require persistent data storage in their back-end. Nonetheless, the idea that apps are generally shifting to a more services-oriented modular approach is spot-on.

Purists will argue that microservices inherently embody concepts like single-function services built and operated by small ("two pizza")[21] teams, independence from the implementation of other functions, and communication only through public interfaces. But, whether or not "microservices" apply in the most narrow sense (or are even the best approach) in a given situation, they point to a general architecture of modularity, reuse, and optimization at the level of the individual function.

This is a great match for container infrastructure. In fact, microservices plus containers represent a general shift to delivering applications through modular services that can be reused and rewired to perform new tasks.

One of the key ideas behind microservices is that, instead of large monolithic applications, application design will increasingly use architectures composed of small, single-function, independent services that communicate through network interfaces. This approach is better aligned with agile development practices and reduces the unintended effects associated with making changes in one part of a large monolithic program.

Writing apps for containers

Traditional Linux containers use an initialization system that can manage multiple processes. This means entire applications can run as one—effectively just as if they were in a virtual machine or on a

[21] Two pizzas can feed the whole team.

“bare metal” physical server. However, modern OCI-compliant Linux container technology encourages breaking down applications into their separate processes and provides the tools to do so.

Each container image file is made up of a series of layers. These layers are combined into a single image. A layer is created when the image changes. Each layer is a set of filesystem changes. Layers do not have configuration metadata such as environment variables or default arguments; those are properties of the image as a whole rather than any particular layer.

Each layer can be isolated into an archive and each of these archives combined into a single archive along with metadata on the layering. Later these layers can be unarchived onto a layered filesystem like overlayfs or similar.

Two primary tools, Buildah and Podman, are used to work with OCI images. A third, Skopeo, performs various operations on container images and image repositories.

Buildah specializes in building OCI images. Buildah's commands replicate all of the commands that are found in a Dockerfile. This allows building images with and without Dockerfiles while not requiring any root privileges. The flexibility of building images without Dockerfiles allows for the integration of other scripting languages into the build process.

Podman specializes in all of the commands and functions that help you to maintain and modify OCI images, such as pulling and tagging. It also allows you to create, run, and maintain those containers created from those images. Podman functions as a command line replacement for the docker daemon without itself requiring a manager daemon to remain running.

The image layers are reused when building a new container image. This makes the build process fast and has tremendous advantages for organizations applying DevOps practices like continuous integration and deployment (CI/CD). Intermediate changes are shared between images, further improving speed, size, and efficiency. Inherent to layering is version control. Every time there's a new change, you essentially get a built-in change-log.

Orchestration

A single shipping container is just a box. It's the whole transportation logistics system built around that box that makes it interesting. A software container by itself can be useful for an individual developer. Just an OCI-compliant container runtime and its associated tools is still very good at managing single containers. But for production applications, you need something more.

When you start using more and more containers and containerized apps, broken down into hundreds of pieces, management and orchestration can get tricky. Eventually, you need to take a step back and group containers to deliver services—such as networking, security, and telemetry—across your containers.

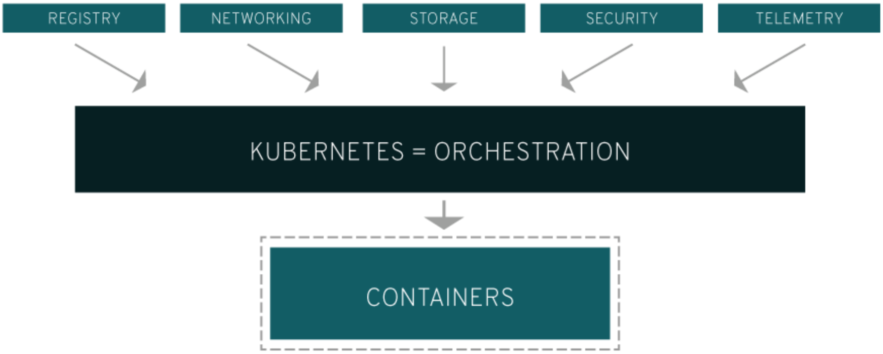
Furthermore, because containers are portable, it's important that the management stack that's associated with them be portable as well.

That's where orchestration technologies come in. One open source project in particular, Kubernetes, has come to dominate in this space.

Kubernetes is an open source platform that automates Linux container operations. It eliminates many of the manual processes involved in deploying and scaling containerized applications. In other words, you can cluster together groups of hosts running Linux containers, and Kubernetes helps you easily and efficiently manage those clusters. These clusters can span hosts across public, on-prem, and hybrid clouds.

Kubernetes was originally developed and designed by Joe Beda, Brendan Burns, and Craig McLuckie at Google. Google had been using a similar platform, Borg, to manage containers internally. The lessons learned from using it became the primary influence behind the Kubernetes technology. The seven spokes in the Kubernetes logo refer to the project's original name, "Project Seven of Nine." Google donated the Kubernetes project to the newly formed Cloud Native Computing Foundation (under the Linux Foundation) in 2015.

Orchestration allows you to interact with groups of containers at the same time, scheduling and implementing container registry, networking, storage, security, and telemetry services. Once you scale to a production environment and multiple applications, it's clear that you need multiple, co-located containers working together to deliver the individual services. This significantly multiplies the number of containers in your environment and as those containers accumulate, the complexity also grows.



Kubernetes provides an orchestration layer on top of containers.. Source: Red Hat.

Kubernetes fixes a lot of common problems with container proliferation by structuring containers together into a ”pod.” Pods add a layer of abstraction to grouped containers, which helps you schedule workloads and provide necessary services—like networking and storage—to those containers. Other parts of Kubernetes help you load balance across these pods and ensure you have the correct number of containers running to support your workloads.

Kubernetes provides a platform to schedule and run containers on clusters of physical or virtual machines. More broadly, it helps you fully implement and rely on a container-based infrastructure in production environments. And to do so in a way that automates many operational tasks.

Because of the standardization of containers through OCI, technologies like Kubernetes can manage containers better and automate critical tasks. At a high level, these include orchestrating, scaling, and maintaining the health of apps and containers running across distributed environments. Kubernetes can also mount and add storage to run apps that require persistent access to a specific set of data. Kubernetes is also attuned to modern service deployment practices—for example, the use of blue-green deployments to introduce and test new features without affecting users.[22]

For most enterprise deployments, even Kubernetes by itself probably isn’t enough. There are plenty of open source projects out there looking to work with Kubernetes. In fact, surveying all the projects that complement Kubernetes can make you feel a bit like a

[22] The blue-green deployment approach does this by ensuring you have two production environments, which are as identical as possible. At any time one of them, let's say blue for example, is live. As you prepare a new release of your software you do your final stage of testing in the green environment. https://martinfowler.com/bliki/BlueGreenDeployment.html

kid in a candy store. There's monitoring, security scanning, service meshes, CI/CD tools, registries, and more. It can be tempting to jump right in, download some software, and start building a container platform. Sure, it all looks a bit complex but how hard can it be?

Pretty hard it turns out. Which is at least a major contributor to Kubernetes' reputation for being complicated. Many who went the do it yourself (DIY) route also came to the realization that their organization is not in the business of building custom container platforms.

Red Hat OpenShift is an example of a complete container application platform. It runs on-prem or managed in a public cloud. It integrates OCI-compliant containers and Kubernetes and combines them with a variety of other components needed for an enterprise product, such as monitoring, dashboards, continuous integration/continuous delivery tooling, logging, distributed tracing, developer tools, and more.

An enterprise Kubernetes distribution is a good way to maintain some choice—for example, by choosing where you physically run your Kubernetes cluster or clusters—while having someone whose job it is to build a container platform make prescriptive choices, perform integration testing, and choose sensible defaults. You still have the option to customize as needed, but an integrated, supported, and documented product takes a lot of the friction out of getting started developing and deploying cloud-native applications.

Kubernetes runs on top of an operating system (Red Hat Enterprise Linux CoreOS, for example) and interacts with pods of containers running within the operating system on the nodes (physical systems or virtual machines). The Kubernetes control plane takes the commands from an administrator (or DevSecOps team) and relays those instructions to the compute nodes. This handoff works with a multitude of services to automatically decide which node is best suited for the task. It then allocates resources and assigns the pods in that node to fulfill the requested work.

From an infrastructure perspective, Kubernetes doesn't change the fundamental mechanisms of container management. But control over containers now happens at a higher level, providing better control without the need to micromanage each individual container or node. And all this enables not just containerizing applications and services but deploying and managing the entire assembly at scale.

Manufacturing the Delivery Process

Ultimately, the goal is to efficiently and repeatedly deliver standardized and tested capabilities in a repeatable way, a process that transformed manufacturing in the physical world over a period of about 200 years beginning in the late 18^{th} century.

It started with standardization. French General Jean-Baptiste Vaquette de Gribeauval promoted standardized weapons in what became known as the Système Gribeauval after it was issued as a royal order in 1765. Standardized boring allowed cannons to be shorter without sacrificing accuracy and range because of the tighter fit of the shells. It also enabled standardization of the shells.

Gribeauval provided patronage to Honoré Blanc, who attempted to implement the Système Gribeauval at the musket level. By about 1778, Honoré Blanc began producing some of the first firearms with interchangeable flint locks, although these were still carefully made by craftsmen. Blanc demonstrated in front of a committee of scientists that his muskets could be fitted with flint locks picked at random from a pile of parts.

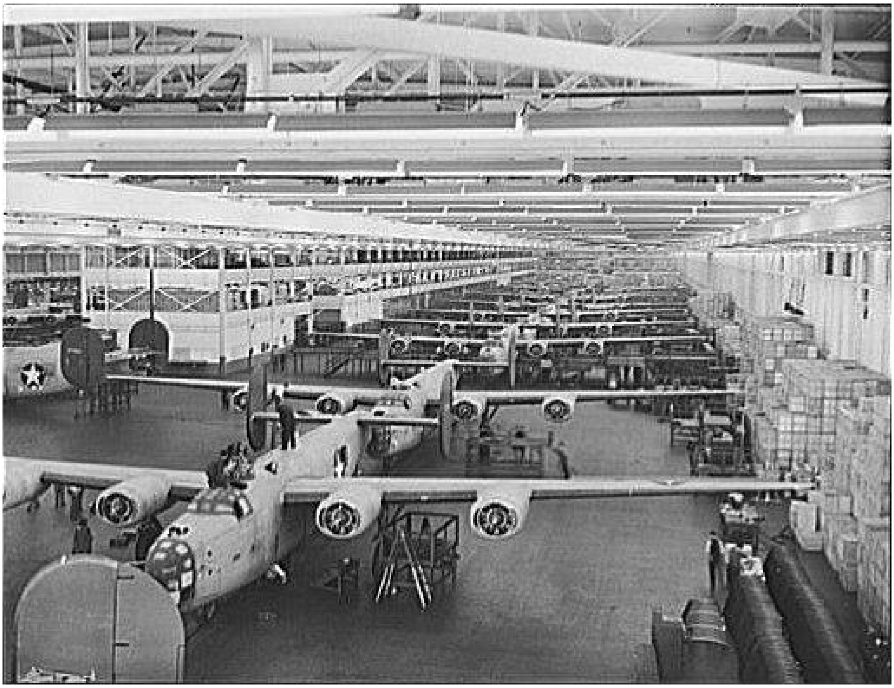
Example of a sailing block. Source: GK Bloemsma, Wikimedia, CC BY-SA.

Brunel and Maudsley's sailing blocks brought process to standardization. Marc Brunel, a pioneering engineer, and Maudslay, the founding father of machine tool technology, collaborated on plans to manufacture block-making machinery; the proposal was submitted to the British Admiralty who agreed to commission their services. By 1805, a dockyard had been fully updated with the revolutionary, purpose-built machinery at a time when products were still built individually with different components. A total of 45 machines were required to perform 22 processes on the blocks, which could be made into one of three possible sizes. The machines were almost entirely made of metal thus improving their accuracy and durability. The machines would make markings and indentations on the blocks to ensure alignment throughout the process.

One of the many advantages of this new method was the increase in labor productivity due to the reduced number of workers needed to manage the machinery. Richard Beamish, assistant to Brunel's engineer son, Isambard Kingdom Brunel, wrote: “...So that ten men, by the aid of this machinery, can accomplish with uniformity, celerity and ease, what formerly required the uncertain labour of one hundred and ten.”

However, it was World War II that truly brought fully standardized and optimized infrastructure to manufacturing. In *Freedom’s Forge*, author Arthur Herman tells the story of how Charles Sorensen of Ford led the construction of the Willow Run manufacturing complex in the early years of World War II. The plant was optimized for the mass production of aircraft, especially the B-24 Liberator heavy bomber. It was the largest manufacturing plant in America because that’s what Sorensen’s assembly line demanded. He didn't try to squeeze the process into the hangar in San Diego where bomber construction had previously taken place and he introduced processes that resulted in much greater component consistency. At Willow Run, Ford built half of the total B-24s, which holds the distinction of being the most produced heavy bomber in history.[23]

[23] At least that’s the cleaned-up story. In reality, Willow Run had many startup and labor problems and Sorensen was replaced by Mead Bricker in 1943. Consolidated Aircraft also continued to manufacture in San Diego throughout World War II, employing as many as 45,000 workers. Nonetheless, once it got running properly, Willow Run was producing up to 650 B-24s per month and made 9,000 total.



B-24 bombers on the Willow Run assembly line.

The delivery of modern applications using agile development processes, is very much tied to the modern manufacturing thinking that was originally most associated with the Toyota Production System (TPS). Key concepts underpinning this modern approach to manufacturing came from W. Edwards Deming, an American who is generally credited with championing the field of statistical process control, building on earlier work by Walter Shewhart. Ironically, Deming was mostly ignored by American manufacturers and ended up being most credited with being an inspiration for what became known as the Japanese post-war economic miracle of 1950 to 1960. Toyota built on Deming's ideas and incorporated concepts such as lean manufacturing, kaizen (continuous improvement), just-in-time inventory,[24] build-to-order, and systems thinking ("The Toyota Way"). The goal was to make a process as flexible as necessary without stress or "muri" (overburden) since this generates "muda" (waste). It's a long-term philosophy that emphasizes understanding of underlying concepts. However, it also incorporates the idea that tactical improvements can be valuable as well. There's a significant element that's about organization, incentives, and even culture.

We see echoes of all this throughout the DevOps and DevSecOps approaches used to deliver cloud-native applications using such platforms. Core DevOps principles such as maintaining a single source repository, automating all the things, making builds self-testing, and providing transparency into the code and the process would all be familiar to anyone designing or running a manufacturing system.

At the same time, many of these changes can also be thought of as cultural shifts: craftwork to factories, ad hoc observation to statistical quality control, reduced cycle times, and the empowerment of assembly workers. In essentially all cases, they represent a decisive and deliberate shift from business as usual. We largely agree with JP Morgenthal when he argues that "There is no single agreed-upon standard of what culture looks like when DevOps adoption is complete."[25] However, cultural *inputs* like transparency, tolerance of failure, collaboration, leadership, and appropriate incentives are all clearly important.

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[24] It's worth noting that one significant motivation for a system like TPS was inventory reduction—which doesn't really apply to software. Nonetheless, many aspects of the overall philosophy remain highly relevant.

[25] https://opensource.com/business/15/2/devops-culture-needs-be-created

Preservation

A package can also play a direct role in protecting and preserving its contents. Some of this is essentially inherent to its function. Just the act of containing can help to shield contents from the elements and containing liquids is the essential first step towards making preservation processes such as fermentation possible.

As Gary Cross and Robert Proctor write in *Packaged Pleasures*:

> Nature is ephemeral—at least that part that grows and dies. When plucked, a plant will spoil or simply disappear… Containerization liberated us from nature, at least a little. This is most obvious with food. Neolithic peoples beginning ten millennia or so ago learned to preserve and pack their nourishment, saving it from decay and also creating thereby entirely new kinds of foods—and sensory delights—in the process. Fermented drink is one notable outcome.

Containerization allowed foods (and drink) to become portable while also being saved to use another day in the future.

Napoleon is often quoted (whether or not he actually did) to have said "An army marches on its stomach.” In 1795, the French military offered an award of 12,000 francs (about $50,000 today) to anyone who could devise a practical method for food preservation for armies on the march. A confectioner and chef in Paris, Nicholas Appert, began experimenting with ways to preserve foodstuffs, including soups, vegetables, juices, dairy products, jellies, jams, and syrups. He placed the food in glass jars, sealed them with cork and sealing wax, and placed them in boiling water—a process which, the method of sealing the container aside, would seem familiar to anyone making jam at home today.[26] Appert won the prize, patented his invention, and established a business to preserve a variety of food in sealed bottles.

The history of cans is a bit more convoluted.

Another Frenchman, Philippe de Girard, reputedly demonstrated canned foods at the Royal Society in London in 1810 a few years after Appert's invention. The story is a bit murky[27] but it seems that Englishman Peter Durand took out a patent for this preservation process which could use tinplate cans, among other containers. Solder was used for sealing the can seams.[28]

In 1812, Durand sold his patent to two Englishmen, Bryan Donkin and John Hall, who refined the process and product, and set up the world's first commercial canning factory on Southwark Park Road, London. By 1813 they were producing their first tin canned goods for the Royal Navy.

However, although Girard is often credited with inventing the tin can, some form of tinned iron cylinders appears to have been used by the Dutch navy as early as the mid-1700s. Records show that from 1772 to 1777, while quelling a revolt in what was then Dutch Guiana in South America, the navy was supplied with roast beef packaged in this way. Before the end of the eighteenth century, the Netherlands had a small industry that preserved salmon by canning.[29]

The first can openers weren't patented until 1855 in England and 1858 in the United States. This must have made for an interesting 40 years or so given the instructions like the "Cut round the top near

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[26] Lance Day, Ian McNeil, ed. (1996). Biographical Dictionary of the History of Technology.
[27] http://www.bbc.com/news/magazine-21689069
[28] http://www.canmaker.com/online/frequently-asked-questions/
[29] Food Packaging: Principles and Practice, Third Edition, Gordon L. Robertson

the outer edge with a chisel and hammer" to open a can that have been passed down to us.

The reality is that early cans were specialized; the can itself could weigh more than the enclosed food. It wasn't until near the beginning of the twentieth century that food in cans became a common consumer item. The American Can Company was founded in 1901 and was soon producing 90 of the tin cans[30] used in the United States.

Reducing the weight, bulk, cost, and (most recently) environmental impact of protective packaging has long been an ongoing theme. There's also been a widespread recognition that packaging intended primarily to solve some problem for a manufacturer or retailer, such as reducing theft, shouldn't get in the way of the consumer's experience. Blister packs made of thermoformed plastic are one particularly notorious example.

Online retailer Amazon has even offered "frustration free packaging" as an alternative for a wide range of products. It's a good bet that if someone markets an alternative to your product as frustration free, you're probably doing something wrong.

Preservation and the supply chain

Preservation can also intersect with the supply chain through which a product is delivered and the manner in which a product is consumed. Frozen food is a case in point.

Clarence Birdseye is generally considered to be the founder of the modern frozen food industry. In 1925, after a couple of false starts, he moved his General Seafood Corporation to Gloucester,

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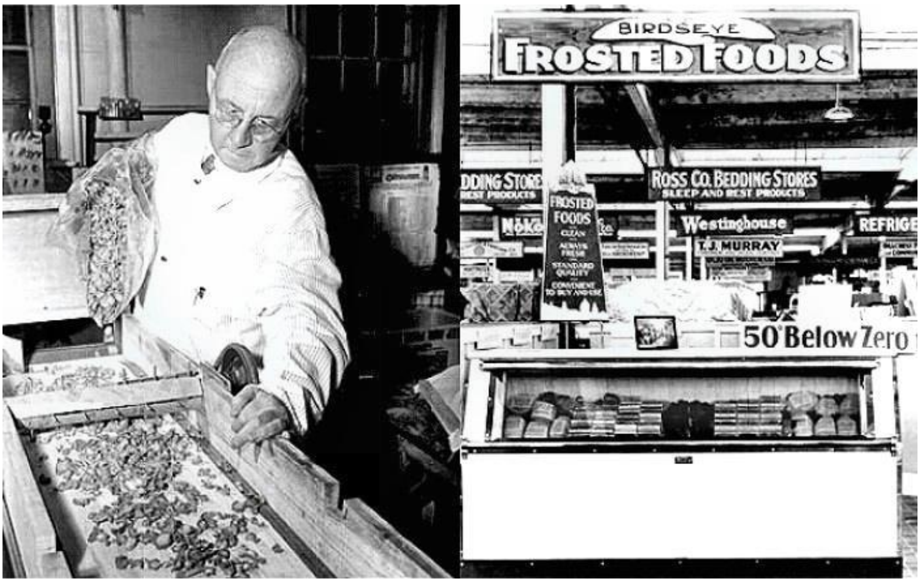
[30] The "tin can" term reflects the nearly exclusive use of tinplate steel for cans until the second half of the twentieth century. It combined the physical strength and relatively low price of steel with the corrosion resistance of tin.

Massachusetts. It was there that he used his newest invention, the double belt freezer, to freeze fish quickly using a pair of brine-cooled stainless steel belts. This and other Birdseye innovations centered on the idea that flash freezing meant that only small ice crystals could form and, therefore, cell membranes were not damaged.



Clarence Birdseye is considered to be the founder of the modern frozen food industry.

A couple of points are worth highlighting. The first is that frozen food depends on a reliable supply chain between the original source of the food and the consumer that can maintain the right temperature for the package. The second is that, in the course of preserving it, food can also be processed in ways that make consuming it more convenient. (For better or worse. Frozen vegetables are easier to be positive about than TV dinners.)

Nor is the task of food preservation complete when a truck leaves the factory loading dock. Packaging and supply chains need to reliably protect, secure, and preserve the overall integrity of contents until they're in a consumer's hands and even beyond.

Food supply chains are a topic of active industry discussion and are one of the target uses of enterprise distributed ledger technology (a.k.a. blockchain) projects, such as the IBM Food Trust.[31]

Securing the software supply chain

With the increased use of open source software generally, open source code is finding its way into more and more applications—proprietary as well as open source. For example in its "2020 Open Source and Risk Analysis Report," Synopsys audited 1,253 applications and found that 99% of them included open source components and that, overall, 70% of the total code was open source.

That's good, right? Open source really is eating software.

However, there's a flip side to that reality. Synopsys also found that 82% of codebases had components more than four years out of date and 88% of the codebases had components with no development activity during the last two years.

The issue isn't that companies (and individuals) are making use of open source components. It's that, in many cases, they're not managing that use. We see similar patterns for container images downloaded from public repositories and for applications that are simply no longer maintained.

Open source code can be a source of security vulnerabilities if you use unsigned software or deploy open source code in an insecure manner.

[31] https://www.ibm.com/blockchain/solutions/food-trust

These attacks take many forms, including hijacking software updates and injecting malicious code into legitimate software and have been on the rise.

The lesson though shouldn't be to not use open source software. The same problem exists with proprietary libraries that haven't been updated.

Rather, one lesson should be to know the answer to questions such as whether a software component is being maintained, who is maintaining it at what level of activity, and who is vetting it for trustworthiness? Another is to obtain software directly from trustworthy sources. And still another is to actively scan your software throughout its life cycle with automated tools that can detect unpatched known vulnerabilities, insecure configurations, or other factors that an attacker could take advantage of.

Enter DevSecOps

In the software world, the packaging of applications and services can protect and secure their contents throughout their life cycle.

The DevOps term was supposed to connote breaking down the wall between developers and operations teams. But quite a few people started arguing that historically very siloed security should be explicitly part of the term as well, even if others felt it was already part of it implicitly. Hence, DevSecOps put in an appearance.

DevSecOps is a way for organizations to extend some of the practices and processes from DevOps to continue rapid development and release cycles while simultaneously addressing security concerns. And doing so without the overhead and delays for which security has often been blamed.

Specifically, the goal of DevSecOps is to take DevOps and secure every aspect of the application development pipeline, delivery, and operations. This includes integrating and automating appropriate security tools, methods, and culture throughout the entire application life cycle. It also requires combining DevOps expertise with security expertise with a common goal of providing the optimal balance of security, speed to market, and stable, reliable applications in production.

One ongoing challenge of DevSecOps with respect to both applications in general and cloud-native applications in particular is that security is a multi-faceted problem. There's scanning for known vulnerabilities in source code. There's confirming that current versions of application dependencies like libraries are used to build the application. There's checking that applications running in production remain up-to-date. There's searching for vulnerabilities in containers that encapsulate applications together with other components they need. There's making sure that the application platform, toolchain, and developer clients are themselves secure. There's checking for misconfigurations. The list goes on.

Real-time monitoring and enforcement of policies can not only address performance and reliability issues before the problems become serious, but they can also detect and mitigate potential compliance issues. Automation reduces the amount of sysadmin work that is required. However, it's also a way to document processes and reduce error-prone manual procedures. Human error is consistently cited as a major cause of security breaches and outages.

Operational monitoring and remediation needs to continue throughout the life cycle of a system. It starts with provisioning. As with other aspects of ongoing system management, maintaining complete reporting, auditing, and change history is a must.

A common theme of DevSecOps is "shift left," which is to say implement security practices and scans earlier, when it's cheaper to catch problems, rather than later.

With traditional long-lived application instances, maintaining a secure infrastructure also meant analyzing and automatically correcting configuration drift to enforce the desired host end-state. This can still be an important requirement. However, with the increased role that large numbers of short-lived "immutable"[32] instances play in cloud-native environments, it's equally important to build in security in the first place. For example, you may establish and enforce rule-based policies around the services in the layers of a containerized software stack.

But the need for security policies and plans doesn't end even when an application is retired. Data associated with the application may need to be retained for a period or personally identifiable information (PII) may need to be scrubbed depending upon applicable regulations and policies.

The very simplicity of containers can turn into a headache if IT doesn't ensure that all software running in a container comes from trusted sources and meets required standards of security and supportability.

It's much like a large and busy port with thousands of containers arriving each day. How does a port authority manage the risk of allowing a malicious or illegal container into the port? By looking at which ship it arrived in and its manifest, by using sniffer dogs and other detection equipment, and even by physically opening and scanning the contents.

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[32] With lightweight services, the general model is to shutdown and restart instances that have a problem or need to be updated rather than changing the running instance as was historically the usual approach.

The verification of shipping container contents is a public policy concern because many inspection processes are largely manual and don't scale well. Fortunately, verifying the contents of software containers and packages is more amenable to automation and other software-based approaches.

Most of the vulnerable images in public repositories aren't malicious; nobody (probably) put the vulnerable software there on purpose. Someone just created the image in the past but after it was added to the registry, new security vulnerabilities were found. However, unless someone is paying attention and can update those images, the only possible outcome is a registry that contains a large number of vulnerable images. If you just pull a container from one of these registries and place it into production, you may unwittingly be introducing insecure software into your environment.

Many software vendors help secure the supply chain by digitally signing all released packages and containers and distributing them through secure channels. Ongoing scans provide additional protection. For example, StackRox, now Red Hat Advanced Cluster Security for Kubernetes, integrates with CI/CD pipelines and image registries to provide continuous image scanning and assurance. By shifting security left, vulnerable and misconfigured images can be remediated within the developer environment with real-time feedback and alerts.

The early 2020s have seen a heightened interest in software supply chain security due to well-publicized vulnerabilities such as the severe one in log4j, a ubiquitous piece of software used to log activities in a wide range of systems, discovered in late 2021. Software supply chain security was also one of the topics covered in a US federal government cybersecurity directive earlier that year.

What's next in operationalizing?

This chapter has delved into some specific tools for keeping software for going "bad" over time. But what about some approaches to keeping software humming along in general, perhaps even if you don't want to shoulder *all* the burden yourself?

Operationalizing

The last chapter began to touch on an ongoing relationship between buyer and seller in terms of both user experience and ongoing commercial relationships. This one will focus on what needs to happen to get that relationship started and keep it going over time because that's at the heart of a central tension in the IT industry today.

What happens when you get it home?

Earlier in this book we riffed on frustrating packaging and missing batteries on Christmas morning. These are relatively trivial examples of how a manufacturer can make it harder to actually use a product.

But just about anything that stands in the way of gaining utility or pleasure from whatever is in the box is a candidate. Are the assembly instructions hard to follow? Is the (perhaps only available via download) manual inscrutable? Do you have to puzzle through setting up a device rather than it holding your hand through the onboarding process?

Any of these scenarios stand in the way of a happy user. Indeed, make it too hard and that user may just give up and return your product in disgust.

The unboxing experience isn't just experiential. It's about transforming an inert object into an object that satisfies some desire or need of the user.

Furthermore, it's not just about getting a consumer or a user started on Day 1.

Consumers can have a number of different types of ongoing relationships with brands and products. For example, Susan Fornier has extensively researched brand relationships through the lens of personal relationships starting in the 1990s. Brand relationships are clearly central to some companies' business. Take Apple for example. But *many* companies have brand relationships with their customers to greater or lesser degrees.

For our purposes here we're going to focus on more pragmatic aspects that follow the sale.

Many day-to-day purchases are pretty transactional. If I buy a recharging cable for my phone, the Day 2 experience and beyond is pretty much about the cable doing what I bought it to do for whatever I consider a reasonable lifetime.

However, a complex long-lived product like an automobile is *mostly* about the experience after the sale. Is the vehicle reliable? Does any necessary service at the dealer go smoothly?

This is even more so the case with software. The unboxing experience, which is to say its installation and configuration, can be complicated enough. But as software changes via updates through its life cycle and as it handles new tasks or interacts with other programs, there are many opportunities for things to go wrong. And open source software has historically often made tradeoffs that make it do even less well than software overall. Which brings us to the central tension.

The central tension

On the one hand, there's the innovation taking place in open source in all its sometimes unruly and rough-around-the-edges glory. On the other hand, there are the generally more packaged, curated, and polished offerings from what we'll call generically "the cloud" whether as complete Software-as-a-Service applications or as more discrete cloud services such as storage.

This isn't a new tension. Just a little over a year after Amazon, still the leader in public cloud services today, announced their first iteration of Amazon Web Services (AWS) in 2006, Gordon wrote a research note titled "The Cloud vs. Open Source."

> Some of the concepts within AWS had existed previously. S3 resembled the storage service providers of the dot-com era. EC2 bore more than a passing resemblance to Sun Microsystem's much-hyped Sun Grid Compute Utility—although that was based on physical servers rather than AWS' virtual infrastructure. But Amazon succeeded where those others had not through a combination of scale, low pricing, embracing new lightweight Web protocols, and an aggressive focus on continually rolling out new services and new capabilities.

It probably didn't hurt either that AWS rolled out around the dawn of the second great Internet boom. This one distinguished itself from the first one in part by far less investor appetite for huge outlays of up-front capital spending on rooms full of computers, disks, and networking gear. In such a startup climate, the availability of cheap pay-per-use compute capacity was extremely attractive.

Some of that writing seems a bit off today. It didn't really foresee the degree to which cloud service models would inspire whole new categories of computer software. (Including containers which, at that time, were mostly just a little-used alternative to hardware virtualization.)

The tension between the freedom and flexibility of open source and the convenience of the cloud. Source: Illuminata.

But it did get a few things right that remain relevant.

First (and probably controversially at the time) was that it downplayed the importance of a flavor of open source licensing that requires modifications to be contributed back to the commons under some circumstances. Gordon wrote:

> Such a worldview implicitly assumes that copyleft[33] is the only reason that Open Source users contribute back their enhancements. Copyleft may or may not have played a major role in the rise of Open Source. Certainly, the GPL has long

[33] A copyleft license requires that if changes are made to a program's code, and the changed program is distributed outside an organization, the source code containing the changes must likewise be distributed. Permissive licenses don't.

> been the most common Open Source license, used by Linux, GNU, and many others. However, the BSD license—which does not require that code changes be made available—is also widely used. It's an interesting historical debate whether the ultimate impact of Linux was far greater than the BSD operating system because of license differences, or because of other reasons—of which there were many. In any case, Open Source does not begin and end with the GPL and copyleft.

And, indeed we've seen a general trend toward permissive licenses such as BSD, MIT, and the Apache Software License[34] and very limited take-up of licenses that close some cloud software delivery "loopholes" such as the Affero GPL. This shift reflects less concern about preventing free-riders and more concern about growing communities.[35]

The Eclipse Foundation's Ian Skerrett puts it this way: "I claim all these projects use a permissive license to get as many users and adopters, to encourage potential contributions. They aren't worried about trying to force anyone. You can't force anyone to contribute to your project; you can only limit your community through a restrictive license."

Which brings us to Gordon's next point which remains germane:

> Indeed, focusing too narrowly on Open Source in a Cloud Computing world is counterproductive. Source code may matter, or it may not, depending upon the circumstances. But

[34] Matthew Aslett of market researcher 451 Group wrote in 2011 that: "2010 was the first year in which there were more companies formed around projects with non-copyleft licenses than with strong copyleft licenses."

[35] The past few years have seen a contentious thread around software licenses that are mostly about preventing cloud providers from offering services based on open source projects or otherwise trying to prevent them from competing with open source project sponsors. This is mostly peripheral to the topic at hand and, in any case, out of scope for this book. The topic is covered at length in Gordon's *How Open Source Ate Software second edition* (Apress, 2021).

> it's the many other aspects of Open Source development (community, extensibility) or Open Source principles (portability of data, open formats) that matter far more.

Open source code allows organizations to collaborate with each other. It's not sufficient. It's an enabler but collaboration happens because openness exists across many dimensions within an environment where people can work together.

Without a viable, independent community, it's hard to realize the collaborative potential of open source. Delivering the most innovation means having the right structures and organization in place to fully take advantage of the open source development model.

There's no single approach to fostering communities. The best approach in any given case to engaging with and governing a community will depend on the nature of the project. Who is contributing? What are the project's goals? What business or licensing constraints are there? These and many other factors will affect governance structure, as well as copyright, trademark, and licensing decisions.

Open standards, or protocols and formats that are moving toward standardization, can also be important. Earlier we saw the example of the OCI. Chris Aniszczyk told Gordon that "I think the industry has changed over the years. Open source is more prevalent. People have learned a lot of lessons around lock-in, and they don't want to repeat the mistakes. The visualization fiasco with the format [is] a painful memory in a lot of people. People are worried about paying the 'VMware tax.' Lots of lessons have been learned."

Portability is closely tied to, and in many ways a product of, aspects of openness such as this. Without being able to deploy on a choice of infrastructure, you don't have portability. Portability requires thinking about how applications and data can be moved from one place to another and assessing the impact of such a move. Multiple technologies can come into play, although, ultimately, it's about making business decisions regarding the degree to which you're tied or not tied to a specific vendor or provider in some manner.

At the same time, there's a general recognition that you need to choose when and where the time and place are right for standardization and when it makes sense to let approaches compete or details to sort themselves out. This is the messy bazaar aspect of open source (to use Eric Raymond's Bazaar vs. Cathedral metaphor).

Clouds are the ultimate cathedrals. They contain. They prescribe. They package. They're the ultimate bundle.

Open source, by contrast, is the ultimate force for unbundling. Mix and match. Modify. Tinker. Move.

Preserving the freedom to tinker.

But the current era also values packaging and experience more than in the past. And that's the challenge that open source adherents must collectively address in a world where public clouds don't always offer portability and interoperability—but do offer more convenience instead.

Getting prescriptive

Enterprise open source products based on open source projects do a great deal to simplify the use of a product such as documentation and support. They also aim to reduce risk through timely security updates and certifications. But one of the most valuable things that a product can bring to the table is curation.

Red Hat OpenShift Container Platform provides a good study point. As we've seen, complementary to containers and a necessity at scale is Kubernetes, which provides the orchestration needed for production deployments. OpenShift is often described as an enterprise Kubernetes distribution.

As we've also seen, Kubernetes also effectively serves as the nexus for a vast number of cloud-native projects that have grown up around it in areas such as registries, security and compliance, networking, storage, service meshes, and CI/CD. Thus the new foundation for IT is container-optimized Linux, Kubernetes, and an integrated suite of other tools targeting developers, operators, and other individuals interacting with the platform.

But which ones? There are so many of them. And the upstream projects don't always play nice with each other.

That's where curation and integration work comes in. Most companies just want to use a container platform rather than assemble one from community projects just like most companies before them didn't want to be Linux kernel engineers. They just want platforms that work.

Now, curation does imply exclusion. Just as a specialty retailer will decide that only certain products meet its standards and the needs of its customer base, so too will an enterprise open source software vendor decide only certain projects are sufficiently mature, have a large enough community developing them, and are a match with the requirements of its customers.

The degree of curation is a balancing act. Some users value someone else making informed decisions on how a product should work, which can make it much easier to use and easier to adopt, but you do lose some flexibility. Others prefer flexibility because they have edge cases that they want to address. In general, all products will be curated to a certain degree, but on-prem software tends to lean towards flexibility while hosted services are usually a more opinionated offering.

Getting started

Before getting to how we can more efficiently and effectively operate our own software systems over time, we first need to consider the initial installation experience.

Especially at the level of the individual developer, containers by themselves can help a great deal in this regard. As we've seen, containers package programs with their dependencies, such as libraries, and isolate that bundle from other bundles running on the same system. Therefore, even if one program needs version X of some library and another program needs version Y, there's still no conflict.

However, as the complexity of an environment increases, so does the number of containers and the knowledge needed to configure everything correctly.

Kubernetes can manage and scale stateless applications, such as web apps, mobile backends, and API services, without requiring any additional knowledge about how these applications operate. The built-in features of Kubernetes are designed to easily handle these tasks.

However, stateful applications, like databases and monitoring systems, often require additional domain-specific knowledge that Kubernetes doesn't have. It needs this knowledge in order to scale, upgrade, and reconfigure these applications.

Kubernetes operators encode this specific domain knowledge into Kubernetes extensions so that it can manage and automate an application’s life cycle. Such a Kubernetes operator is a method of packaging, deploying, and managing a Kubernetes application. It helps deploy a Kubernetes application on Kubernetes and manages it using the Kubernetes API (application programming interface) and kubectl tooling.

A Kubernetes operator is effectively an application-specific controller that extends the functionality of the Kubernetes API to create, configure, and manage instances of complex applications on behalf of a Kubernetes user. It builds upon the basic Kubernetes resource and controller concepts, but includes domain or application-specific knowledge to automate the entire life cycle of the software it manages.

In Kubernetes, controllers of the control plane implement control loops that repeatedly compare the desired state of the cluster to its actual state. If the cluster's actual state doesn’t match the desired state, then the controller takes action to fix the problem.

An operator is a custom Kubernetes controller that uses custom resources (CR) to manage applications and their components. High-level configuration and settings are provided by the user within a CR. The Kubernetes operator translates the high-level directives into the low level actions, based on best practices embedded within the operator’s logic.

After Day 1

The ongoing management aspect is important. Running software isn’t a Day 1 and done experience. It has to continue to run throughout its life cycle, perhaps in environments that place greater demands on it than in a typical test environment. Furthermore, software products don’t run in isolation and real world architectures can get complicated. However, we often do see repeatable patterns. Documenting these is another form of flexible curation.

Finally, it doesn't need to be a choice between a cloud-native service that's specific to a single large cloud provider or an open source on-prem deployment. Open source-based managed services that are portable across multiple clouds are a third option.

Operate First

That we still talk about the open source *development* model is telling. That language emphasizes developers and other participants in that virtuous cycle, such as users and businesses. Thus, fundamentally, the focus is on the code. But there's also a dawning recognition that just writing code in a vacuum isn't sustainable for most significant projects.

The attention to code is understandable. Even when proprietary software was nearly the only game in town, vendors were focused on delivering packaged bits to users with maybe some consulting on the side to get it running. Open source software freed users from a vendor's proprietary IP and let them harness the innovation in a community extending beyond a single company. But it didn't really change the software delivery model. Users were still mostly obliged to operate the software by themselves.

What to do?

As Marcel Hild, who researches AIOps—essentially augmenting IT operations with AI tools, starting with data exploration—in Red Hat's Office of the CTO puts it:

> There's a principle in development called Shift Left, which means that we should involve testing really early in the development cycle—in other words, moving left in the process.

> This is already done with unit and integration tests. No line of code gets merged if it does not pass the tests. But what about operations?
>
> At Red Hat we coined the term Operate First for this. The idea is similar to Upstream First, where we strive to get every line of code into an upstream project before we ship it in a product. In Operate First, we want to run the software in an operational context by the group that develops the software. And since we develop mainly in open source communities, this extends our open cloud to another group of people, the engineering community.
>
> The very authors of the code can be asked in an incident ticket about a misbehaving piece of the cloud. This not only increases the probability of getting the incident closed quickly, but it also exposes the software developer to the operational context of their brainchild. Maybe they come back later and just watch how their software is being used to make future design decisions based on the operations. The next level would be to try out new features in bleeding-edge alpha versions of a particular service and get a real workload instead of fake test data.

Operations is becoming as important, and sometimes more important, than code. Software-as-a-Service and public cloud providers have increasingly offloaded the operational burden of software from users. This is a challenge for open source software. While the open source development model is powerful, the value of software lies in operationalizing it so that a user can be productive with it.

You can think of Operate First[36] as a concept, philosophy, and vision to improve open source software through open sourcing operations.

[36] https://www.operate-first.cloud/

Concretely, Operate First is a project to define, build, and improve the open source hybrid cloud through learning and developing code and practices in an open production community cloud. By incorporating operational experience into open source software development, Operate First extends development to include operating, testing, and proving code in a production environment—and simplifying the deployment of that code. It builds on and complements a variety of nascent and ongoing projects in the cloud space.

Operate First started as a segment of the Mass Open Cloud (MOC; massopen.cloud) called the *zero cluster*, a production cloud set up to host projects and developers seeking to operate first. Announced in 2014, the MOC is a production public cloud based on the model of an Open Cloud Exchange (OCX). In this model, many stakeholders, rather than just a single provider, participate in implementing and operating the cloud.

In addition to the MOC, Operate First is closely associated with various overlapping initiatives, including OpenInfra Labs (under the Open Infrastructure Foundation; openinfralabs.org) and the Red Hat Collaboratory at Boston University.

OpenInfra Labs hosts the Telemetry Working Group (openinfralabs.org/telemetry), one of the working groups included under the Operate First umbrella. Observability of infrastructure has become an increasingly hot topic given the challenge of reliably operating distributed systems such as those in Kubernetes environments. The term can cover a lot of ground, but a typical definition of observability spans metrics, tracing, and logging. Monitoring is often considered something distinct, but it's also at least closely related. A key part of observability is the automatic collection and transmission of data about the system. In other words, telemetry. Telemetry is an integral component of Operate First.

The development of a community around Operate First is still in its early stages as of this writing. A primary goal of that development is recognizing that there are many constituencies with disparate concerns and motivations. The Operate First founders want to engage with them in a manner and through a path that those constituencies prefer.

To start this process, community leaders conducted a series of interviews with a variety of different stakeholders: developers, quality engineering (QE), site reliability engineers (SRE), traditional system admins, data scientists, and others. The objective here was two-fold. First, it was important to understand, for each role, their most pressing day-to-day concerns, what motivated them, how they measured success, and what would make Operate First of interest to them. Second, to keep things simple, identifying and combining roles that largely shared motivations and concerns made it easier to focus engagement efforts.

Quality engineers who write testing frameworks and tests have an increasing amount of overlap with more traditional **developers** of applications and other code. Both are motivated by improving customer and internal user experiences, especially when doing so involves solving novel problems. They measure success with metrics such as satisfaction of and adoption by their constituencies as well as productivity and code quality metrics. Operate First serves these goals by encouraging and enabling software design that builds in operational capabilities while keeping the person who needs to operate the software in mind.

From an operational perspective, the focus is shifting away from traditional sysadmin roles that deal mainly with maintaining and upgrading hardware and software infrastructure using tools like scripts and configuration management. While those tasks continue, **site reliability engineers (SREs)** spend a significant amount of time on development tasks such as adding new features, improving scalability, and automating. SREs interact extensively with cloud APIs, whether on premises or in a public cloud. SREs aim to do more with less; the ratio of SREs to the number of managed clusters is one important metric, as is their uptime.

In addition to developer and operations personas, the **data scientists and data engineers** in the OpenDataHub community have also been early adopters of Operate First. OpenDataHub is a blueprint for building an Artificial Intelligence (AI)-as-a-Service platform that integrates a variety of open source machine learning tools, including Kubeflow, Kafka, Seldon, PyTorch, and Jupyter notebooks on Red Hat OpenShift Container Platform.

For these data-focused audiences, Operate First provides:

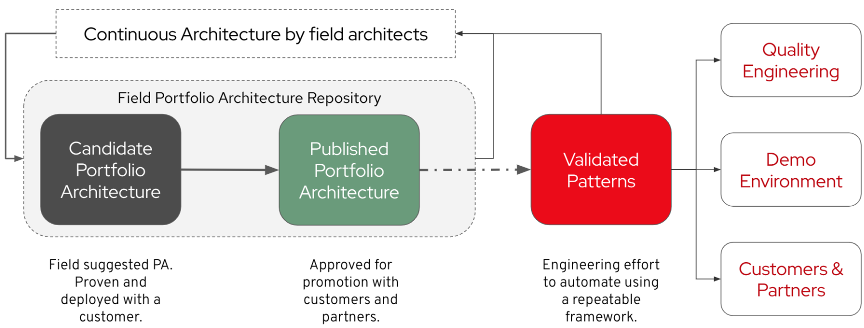
- A cluster to develop and run AI applications
- GitHub organizations to share and collaborate on open source projects
- Custom image pipelines to publish reproducible experiments
- Real production operations data for tackling machine learning problems in AIOps

Furthermore, operating a subset of OpenDataHub at scale creates an opportunity to document best practices, which can, in turn, be fed into Red Hat OpenShift Data Science, the managed cloud service offering based on OpenDataHub. Just as the open source development model forms a virtuous cycle when working as intended, Operate First can lead to a beneficial circle for operational knowledge and supporting code.

The ultimate goal of Operate First is to free software users from having to make a false choice. It brings the power of the open source development model to operationalizing software. Fully operationalized software is software that maintains the flexibility of open source software that isn't tied to a single cloud provider, while also simplifying and improving the Day Two operations of that software.

Portfolio architectures

Portfolio architectures document proven architectures by providing a common process, visual language, and tool set. They effectively "package" architectural knowledge associated with a repeatable pattern that has been validated through actual real world deployments.



Extended portfolio architecture life cycle. Source: Red Hat.

The general process for creating portfolio architectures at Red Hat is to identify an adoption pattern that's a combination of Red Hat products and often other technologies that have been shown to be effective in multiple customer deployments and which solve a specific, common problem (or cluster of problems). A given portfolio architecture consists of architecture diagrams, a slide deck and associated video presentation, a solution brief, and blog articles.

The architectures are created using the open source diagrams.net[37] tool and are publicly available on GitLab.[38]

High-level logical diagrams provide the overall landscape while more detailed schematics explicitly show the relationships between blocks.

Validated patterns

Validated patterns are a natural progression from portfolio architectures and other reference architectures.

They contain all the code needed to help build an edge software stack to make getting to a proof of concept faster. A typical pattern will include both a datacenter and one or more edge Kubernetes-based clusters. All steps are fully automated through GitOps processes to automate deployments consistently and at scale. Users can then modify the pattern for their own specific application. Furthermore, the associated user communicate improvements—providing another example of the open source development model being applied to both initial deployment and ongoing operations of a complex, distributed software stack.

Unlike static reference architectures, the validated patterns are continuously tested against current product releases so that your deployment is kept up to date—reducing risk while using the latest capabilities.

Validated patterns also consider other aspects, such as security, that may not be part of the architecture per se but are important to consider as part of any software deployment. For example, secrets management and identity management are essential parts of most

[37] https://diagrams.net

[38] https://gitlab.com/redhatdemocentral/portfolio-architecture-examples

complex deployments but are often left off of “marketectures” or even reference architectures in order to focus on the essential elements.

Managed services

But the choice doesn’t have to be between running software on-prem or buying into a given cloud provider’s native services—a choice that may not make it easy to migrate or replicate an application on a different cloud provider’s platform. You also have the option of consuming services that someone else is integrating, operating, and delivering for you. And, with open source technologies, you can have a consistent experience across hybrid cloud environments.

If we focus on developers, they ultimately just want infrastructure and services that they can consume as needed. Is there a reasonable way to give them what they want without *needing* to operate their own platforms? There is.

Red Hat Director of Product Marketing, Managed Application Services Coco Jaenicke puts it this way:

> Managed cloud services—functionality that is hosted and managed in the cloud—provide a clean separation of the service’s features and effort that goes into administering the service. They provide the best of both worlds if you are looking at them through the lens of a development team under pressure—they provide the technology you want with none of the hassles of acquiring hardware, managing uptime, or updating software...
>
> Another persona that is very interested in cloud services is anybody who's leading the business unit, the line of business, the person who is focused on delivering business outcomes and

> getting apps to market so that they can offer more to their customers. They're going to see cloud services as a way to up the velocity, get there faster and spend resources on building business applications, not on supporting infrastructure.

The distinction between on-prem platforms and managed services isn’t just that you don’t need your own site reliability engineer to be on pager duty in case the platform breaks. It’s also that someone with experience, the provider of the service, has made choices about how, not only a service component, say, a message broker like Kafka gets configured and started. That someone also chooses how all the other components that Kafka needs to run get configured and started as well. (Kafka enables applications, systems, and services to communicate with each other and exchange information. But the specifics aren’t important to this example.)

Those who have used Apache Kafka know that you need more than just the broker to build applications. You need interfaces, metrics, monitoring, discovery, connectors and more. A Kafka managed service will have made (informed) decisions about which projects to include and how. This delivers a curated Kafka experience that makes Kafka much easier and more efficient to use.

Technologies like operators can simplify some of this on-prem but it’s still more like driving a stick shift than an automatic.

At the same time, unlike many services native to a specific cloud provider, open source managed services can be delivered across a number of different cloud providers. A company can also decide to run the same software on-prem if they decide they need more flexibility to meet some unusual requirement.

Ultimately it comes down to choice and what tradeoffs a given technology consumer *wants* to make.

Improving the overall experience

So far we've been primarily discussing aspects of packaging physical goods and software that are primarily functional. How do we use packaging to sell and deliver a useful product? How do we protect that product? How do we use it? These are table stakes really—the minimum needed to put a product in the hands of a customer and have it be useful.

With this as a starting point, we now move into the realm of the experiential. There was less to be said about software here until recently. This is partly because, for much of its history, computer software was a utilitarian business tool. But it's also because consumer goods had a good century head start in the packaging game. Packaging features that have long been recognized as important parts of how consumers buy and use products have only recently gained serious attention in the software world.

Inform

We begin by turning the discussion to how packaging informs. This is inevitably wrapped up with the broader ways in which packaging communicates and even becomes part of how people think about, feel about, and use a product. But we'll start with those aspects of communication that are most about communicating facts rather than building more subjective experiences.

Informational packaging was originally pretty bare-bones. A bag might have "flour" printed on it or a soap wrapper the manufacturer's name.

General store in US c. 1900. Note the relatively limited amount of labeling.

The object being sold might have been expected to do its own communicating. This largely remains the case at a farmers market, produce section, or butcher today. A price is likely on display and there may be a sign telling you the variety of tomato or cut of meat on offer. But not much else.

Historically, selling was also largely an interactive exchange between a buyer and a seller. A bazaar is the classic example, but even a nineteenth century general store usually involved a customer asking for and receiving goods through an intermediary, the shopkeeper. To the extent that buyers needed additional information, they asked.

This model began to change in the early twentieth century.

The shift to self-service

Piggly Wiggly, founded in 1916 in Memphis, Tennessee by Clarence Saunders, is often credited with being the first true self-service grocery store. At the time of its founding, grocery stores did not allow their customers to gather their own goods. Instead, a customer would give a list of items to a clerk, who would then go through the store himself, gathering them. Piggly Wiggly introduced the innovation of allowing customers to gather their own goods. This cut costs, allowing for lower prices.[39]

Chain store retail was taking off during the same general period with the Great Atlantic and Pacific Tea Company (later A&P), established in 1859, and other small, regional players including Piggly Wiggly. In the late 1930s, A&P began consolidating its thousands of small stores into larger supermarkets, often replacing as many as five or six stores with one large, new one. Similar transformations occurred among all the major players; in fact, most

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[39] http://www.groceteria.com/about/a-quick-history-of-the-supermarket/

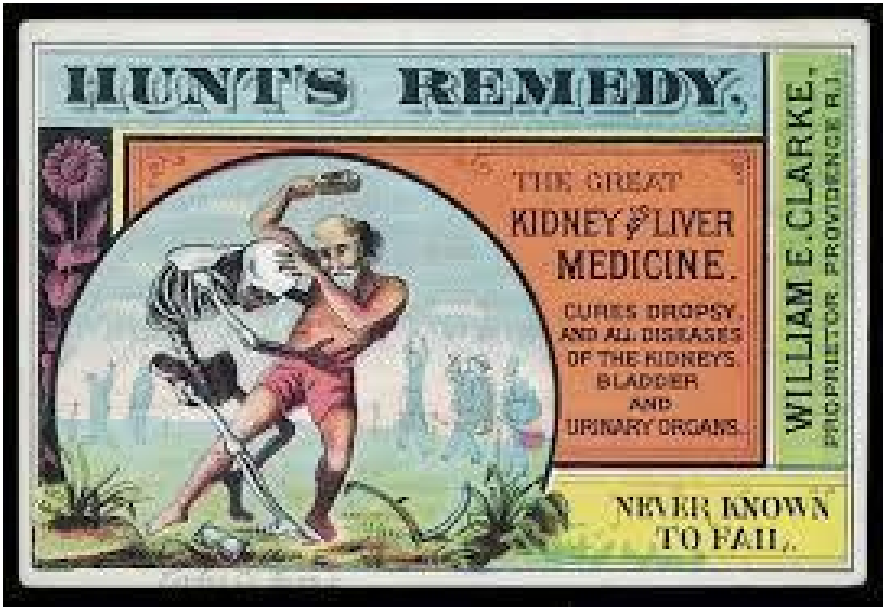
national chains of the time saw their store counts peak around 1935 and then decline sharply through consolidation. This consolidation coincided with the introduction of self-service at A&P in 1936.

Compare photographs of food stores or general stores before and after self-service and the difference is striking. In the after photos, the boxes and cans are designed to grab the consumer's attention both graphically and with information about their content.

A&P, 246 Third Avenue, Manhattan, 1936. Note the prominent ads for A&P's private brands. Source: Wikimedia, released into the public domain by the New York Public Library.

Of course, it helps if the information being communicated is true.

For example, a patent medicine like Hunt's Remedy presented itself as the "Great Kidney and Liver Medicine" that "cures dropsy and all diseases of the kidney, bladder, and urinary organs." It was "never known to fail." Norman's Snake Oil liniment promised "instantaneous relief" and to cure "all aches and pains with the strength of a thousand snakes."



The Pure Food and Drug Act of 1906 was the first in a series of consumer protection laws enacted by the US Congress in the twentieth century; it led to the creation of the Food and Drug Administration. Among other purposes the law was intended to ban mislabeled food and drug products. It also required that active ingredients be placed on the label of a drug's packaging and that drugs could not fall below established purity levels.

However, in United States v. Johnson in 1911, the United States Supreme Court ruled that the misbranding provisions of the Pure Food and Drug Act of 1906 did not pertain to false curative or therapeutic statements; rather, it only prohibited false statements as to the identity of the drug. Congress responded in 1912 with the Sherley Amendments, which prohibited false and fraudulent claims of health benefits.

In their own way, computer software products have often made almost equally outrageous promises. Given that, in theory, missing functionality is just an update away, it can be tempting to make claims that reflect aspirations rather than reality. Furthermore, especially before the widespread use of open source made it easier to test and examine software, it could also be expensive and time-consuming to figure out if products worked as advertised.

A familiar example of government-mandated information on packaging today is the nutrition facts label. In the US, this was mandated by the Food and Drug Administration in 1990. In addition to the nutrition label, products may also display certain nutrition information or health claims on packaging. These health claims are only allowed by the FDA for eight diet and health relationships based on proven scientific evidence.

Packaging can also convey information about what a product is used for, how to use it (and how not to use it!), claims relative to other products, and which other products from the company you might like to use with this one.

Take, for example, a box of Barilla spaghetti sitting on a shelf. One panel tells us how to "get the best from your pasta, cooking the Italian way" in three steps. Another panel tells us what's inside and the net weight of the contents. The flip side advertises claims such as "part of a healthy diet" and "non-GMO ingredients." A stamp informs that the contents of this box are best used by January 2022 and includes some identifying information that is probably relevant to the company for recalls and other purposes.

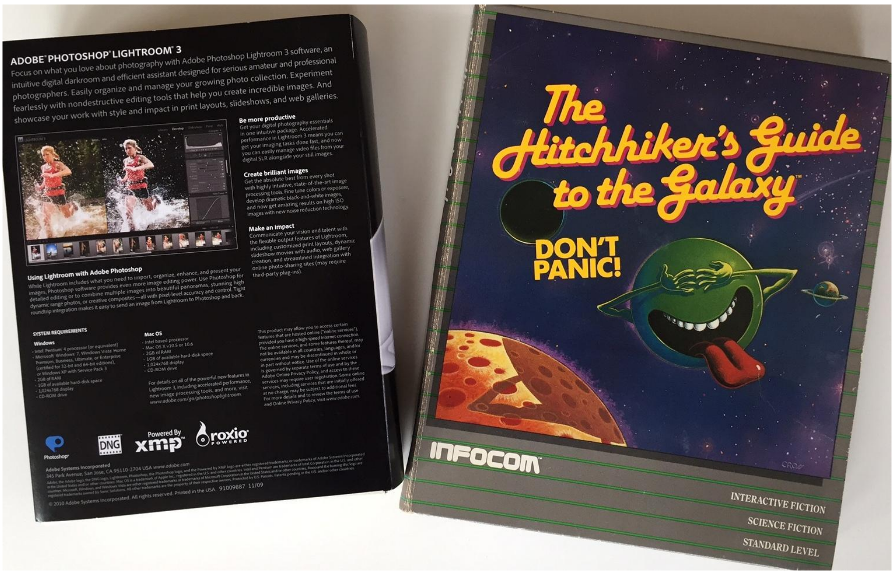
Typical canned food label showing branding, informational content, instructions, ingredients, nutrition facts label, and UPC.

In years past, we'd also expect to have seen some part of a human-readable price label added by a retailer. Today, though, that information is often on the shelf rather than the individual box or can.

In part, that's because there's now a barcode. This is still information, of course. But it's information that is used as part of the retail system rather than by the consumer directly.

As Margalit Fox wrote in The New York Times in 2011: "On a summer morning in 1974, a man in Ohio bought a package of chewing gum and the whole world changed. At 8:01 a.m. on June 26 of that year, a 10-pack of Wrigley's Juicy Fruit gum slid down a conveyor belt and past an optical scanner. The scanner beeped, and the cash register understood, faithfully ringing up 67 cents. That purchase, at a Marsh Supermarket in Troy, Ohio, was the first anywhere to be rung up using a barcode." (To be a bit more precise, this was the first commercial use of the Universal Product Code (UPC) specifically.)

Software packaging can be directly informational as well whether the information is for a human looking at a package or packaging system or (as is increasingly the case), it's in a form that can be interpreted and acted upon by the software itself.



The trivial example of human-readable information in software packaging comes from shrink-wrapped software boxes. A typical box would tell you what sort of computer the software was written for and minimum specs for the hardware and operating system. The relatively expensive boxed software of the early microcomputer era would also throw in manuals, reference cards, and other content that would help people use the program stored on the enclosed diskettes. Early PC software boxes were often designed to stand out from the competition but, over time, retailer demands led to more standardized sizes and shapes.

Better information through bits

However, the more interesting discussion concerns how the bits themselves can be packaged to convey information describing the software, what's needed to run it, and how to install it. The trend over time has been to make software more self-contained and enable the informational content to take direct action rather than simply being a set of instructions for a human to follow.

An early step down this path is the archive utilities that have existed in many operating systems. In the Unix world, the best known is tar, an archive format that collects files, directories, and other file system objects into a single stream of bytes, which can then be written out as a structured set of files. The tar utility (as mentioned earlier in the context of container layers) was first introduced in the Seventh Edition of Unix in January 1979, replacing the tp program. Like most other archive utilities, tar could also compress the contents of the archive, thereby reducing the amount of disk space required to store it and the time needed to transmit it over a phone line or network.

In the PC world, the first widely-known and used archive utility to also compress files was ARC, written by Thom Henderson of System Enhancement Associates (SEA) in 1985. ARC was especially popular on hobbyist bulletin board systems (BBS), both because it packaged all the files associated with a program into one download and because compression reduced the time needed to download files using modems on telephone lines that could only transmit a few hundred characters per second. A few years later, after a nasty and controversial lawsuit, ARC largely gave way to PKWare's ZIP format, developed by Philip Katz using some of SEA's code, which had been made public but not under an open source license. The ZIP format remains in wide use today although programs are more likely to be packaged up in different ways, as we shall see.

Archive utilities were fine as far as they went. They put all the necessary files in one place and then transferred them to disk in a structured way so that they were laid down in a way the main program expected when it was run. For example, they might place documentation in a specific directory rather than putting all of a program's files in a big jumble. However, unpacking an archive did nothing to customize the installation for a particular system or a particular user. That required an installer.

Installers and package managers

Installers have often been one-off affairs. There's been some standardization within various operating systems. But installers have often failed to provide a consistent experience when loading a program onto a system, a consistent way to determine and load the software on which a program depended, or a consistent way to update a program over time. Traditional installers were (and are) often something of a hack.

Package managers were the response, mostly on systems running Linux, to automate the process of installing, upgrading, configuring, and removing programs in a consistent manner. Originally written by Red Hat's Erik Troan and Marc Ewing in 1997, RPM is an early example. Other examples include yum, and its successor DNF, for RPM-based distributions,[40] and apt, for Debian-based distributions like Ubuntu.

DNF can resolve dependencies and perform other checks on package installations (as can apt). When DNF finds dependencies that are not installed it can source those dependencies from an online repository ("repo") and install them before installing the desired package.

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[40] RPM is itself technically a package manager but yum and DNF build on it to provide more sophisticated package management features such as resolving dependencies and taking the appropriate actions in response.

To their detriment, neither Microsoft Windows nor MacOS ever introduced a package manager although others have written package managers for MacOS. (Most notably, Homebrew. Because MacOS is built on a BSD Unix foundation, it's amenable to package management in the Linux vein.)

Today, mobile app stores such as Apple's can also be thought of as a form of package management although they're based on a very different model that is conceptually more related to containers.[41]

Package managers were and continue to be an extremely useful tool for managing Linux systems. But with the availability of both container technology and new approaches to configuration management, it's now possible to embed information that makes installing and running software an even more consistent and more automated experience.

Dockerfiles

The revolution that the docker project originally brought to the container technology space was largely in two areas. First, as mentioned earlier, docker created the de facto standards for the runtime and layered image format that were later rolled into OCI.

The docker project also contributed the notion of a Dockerfile and a comprehensive CLI to interact with it. A Dockerfile describes how you would build a new image using a series of commands.

In this way, information needed to run an application or service can be embedded into a container together with the minimum software layers that they need to perform a task.

[41] Containers effectively act as a form of application virtualization, which was an area of active development in the aughts but never really gelled as a mainstream concept.

Configuration management and playbooks

Once you move into highly automated and highly scalable CI/CD environments, efficiency and velocity become especially important. So long as container image and runtime requirements are met, organizations have a lot of flexibility to pick technologies that meet efficiency and velocity and security requirements—without losing the benefits of standardized containers.

Automation and the delivery of complete applications to computer systems didn’t start with containers nor does it end there today. As my former colleague Mark Lamourine said in a podcast:[42]

> It started out when I was the young cub sysadmin, we'd have a set of manual procedures that started out as things in our head: Set the network, set resolv.conf, set the hostname, make sure time services were running.
>
> When you only had a short list of these things, it wasn't really a big deal. You'd go to each machine, you'd spend 15 minutes making it fit into your network, and then you'd hand it off to some developer or user.
>
> Over time, we realized that we were doing an awful lot of this and we were hiring lots of people to do this, so we needed to write scripts to do it. Eventually, people started writing configuration management systems, starting with Mark Burgess and CFEngine.
>
> The idea was that we were doing these tasks manually. We started automating them, but we were automating them in a custom way.

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42 http://bitmason.blogspot.com/2015/02/podcast-configuration-manangement-with.html

> Then people recognized patterns and said, “We can do this. There's a pattern here that we can automate, that we can take one step higher.” That led to these various systems which would make your machines work a certain way.

Over time the configuration management space evolved with different systems following different philosophies and becoming tailored to the approaches of different types of users.

More fundamentally, there’s been something of a shift away from traditional configuration management tools—although they’re still widely used. This stems, in part, from the growing scale of many software deployments. The shift from monolithic applications that are long-lived and monolithic to short-lived microservices, as we discussed earlier, is another important factor.

One example of a more modern approach to automation is provided by Ansible, which has become extremely popular. It’s popular for a variety of reasons, not least of which is that it’s easy to get productive quickly.

It’s a simple IT automation engine that automates cloud provisioning, configuration management, application deployment, intra-service orchestration, and many other IT needs.

Designed for multi-tier deployments, Ansible models an IT infrastructure by describing how all of the systems interrelate, rather than just managing one system at a time.

It uses no agents—which is to say that Ansible does not require installing any components on a managed host—and no additional custom security infrastructure, so it's easy to deploy. Most importantly, it uses a very simple language (YAML, in the form of Ansible Playbooks) that allows automation jobs to be described in a way that approaches plain English. Ansible’s playbooks provide a language to describe the policy for successful configuration and deployment of remote systems. In this way, a playbook can be used to configure and deploy thousands of remote hosts at the click of a button.

Ansible also provides a mechanism to evaluate the success or failure of a particular task in the playbook. A failed task can result in the playbook halting and providing feedback to the user about which host failed. In this way a playbook can enforce a policy (such as who has access to an application) across multiple hosts.

Ansible fits naturally into a Kubernetes environment. Standard Ansible tooling can automate and orchestrate applications across both new and existing platforms allowing teams to transition without having to learn new skills. With the k8s module, an Ansible user can manage applications on Kubernetes, on existing IT, or across both with one simple language.

With respect to modern packaging, this shows how, thanks to standardization and by building on existing automation approaches, further innovations around automation have increased efficiency and speed even further.

While, like many terms in the general space, precise definitions can be elusive, Infrastructure-as-Code is one common way to talk about standardized, repeatable automation. It builds on many configuration management, automation, and DevOps concepts but it can be thought of as bringing new thinking to the space that's better aligned with large-scale software-defined infrastructures.

Creating an Experience

In a sense, we've been dancing around the edges of a central goal, which is a better outcome, either from the perspective of the consumer, the seller, or both.

But what does better mean?

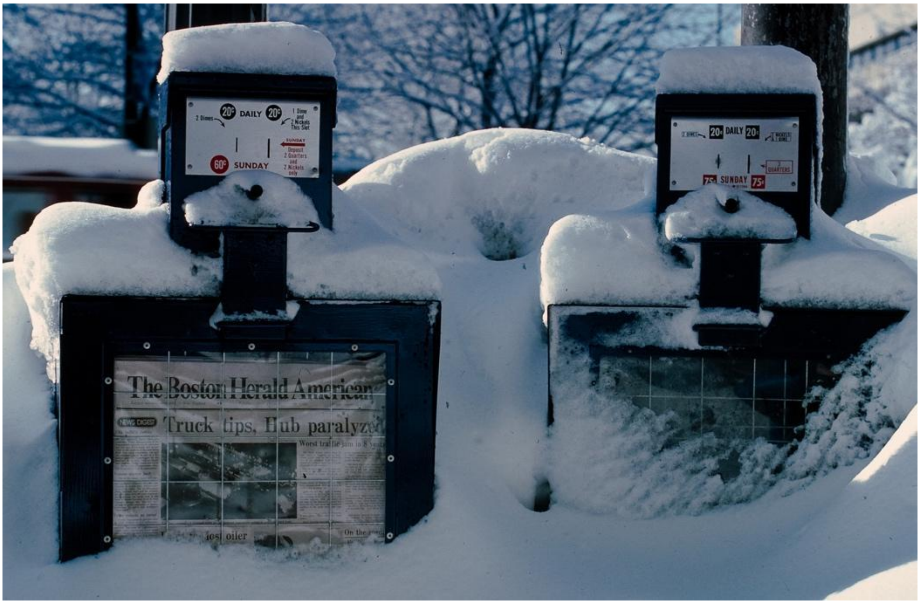
Bundling

Some aspects of "better" can certainly be related to what gets sold and how. The idea of bundling, in some respects a superset of product packaging, is one example of this. By making the customer an all or nothing offer, a bundle prevents a customer from picking and choosing only the parts they want and negotiating the price of individual line items.

We touched on this earlier in the context of products as an integrated and curated set of parts. Auto makers have become masters of the bundling game when it comes to options. You want those heated leather seats? Sure. But you need to take the alloy rims and the upgraded trim kit too.

But bundling is really a broader concept and there's perhaps no more canonical example historically than newspapers.

Newspapers bundle various news topics like syndicated and local news, sports, and political reporting, along with advertising, classifieds, weather, comic strips, shopping coupons, and more. Many of the economic woes of the newspaper can be traced to the splitting of this bundle. Craigslist took over the classifieds—and made them mostly free. Online severed the connection between news and local ads. While ads run online as well, the economics are something along the lines of print dollars devalued to digital dimes.



Newspapers are a classic example of a bundle that creates a product from parts that may not be individually viable. Source: Gordon Haff.

As NYU professor Clay Shirky wrote in 2008:[43]

> For a long time, longer than anyone in the newspaper business has been alive in fact, print journalism has been intertwined with these economics. The expense of printing created an environment where Wal-Mart was willing to subsidize the Baghdad bureau. This wasn't because of any deep link between advertising and reporting, nor was it about any real desire on the part of Wal-Mart to have their marketing budget go to international correspondents. It was just an accident. Advertisers had little choice other than to have their money

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43 https://www.edge.org/conversation/clay_shirky-newspapers-and-thinking-the-unthinkable

> used that way, since they didn't really have any other vehicle for display ads.

Over the years, many tech companies have attempted to force customers to buy a bundle. Wanted phone service from the old AT&T (and it’s not like you had a choice)? You had to rent a phone from the local Bell operating company. You could have it in any color you wanted so long as that color was black (but it *was* solidly built).

In computer and related office equipment businesses, the bundle was typically some combination of hardware, software, services, and supplies. One of the primary motivations was to prevent a competitor from cherry-picking some aspect of your business to compete against. However, bundles also made possible less obvious subsidies and pricing models. For example, when IBM and Xerox tied the sale of supplies like punched cards and paper to their leased machines, this effectively gave them a way to meter usage and price discriminate between high volume users and low volume ones.

Tying has played a part in a number of the tech industry’s antitrust cases. That’s because, as in the case of the local newspaper, a dominant position in some market greatly increases the power of a company to enforce a bundle without worrying about what competition might do in response.

The central issue of United States v. Microsoft in 2001 was whether Microsoft was allowed to bundle its flagship Internet Explorer browser software with its Microsoft Windows operating system. Bundling them together was alleged to have been responsible for Microsoft's then-victory in the browser wars as every Windows system came with a copy of Internet Explorer out of the box. (The outcome of the case was complicated but Microsoft eventually agreed to a settlement.)

Other examples include Data General v. Digidyne in which Data General, then a maker of minicomputers (what we'd call servers today), was forced to sell its RDOS operating system to Digidyne to run on its "clone" hardware.

Most recently, there has been the ongoing squabble over digital rights management (DRM) in printer cartridges. This is an attempt by printer manufacturers to limit the use of third-party ink cartridges in their printers. This is one of the clearest examples of cross-subsidies. Low-end printers are sold at or below cost. They're profitable only because of ink sales—which, of course, the manufacturer doesn't get if you buy someone else's ink.

But there's another view of bundling that ties back to product packaging and user experience.

Bundles, like other aspects of packaging, are prescriptive. They can be seen as a response to *The Paradox of Choice*, a 2004 book by American psychologist Barry Schwartz, in which he argues that consumers don't seem to be benefitting psychologically from all their autonomy and freedom of choice. Whether or not one accepts Schwartz' disputed hypothesis, it's certainly the case that technology options can sometimes seem to proliferate endlessly with less and less real benefit to choosing one tech over another.

Indeed, from the perspective of a newspaper or magazine reader, one of the advantages of certain aspects of the newspaper bundle is that it delivers a curated news experience for one predictable price. A limited number of publications—including *The Wall Street Journal*, *The New York Times*, and *The Economist*—have demonstrated that there's still some market for this even in an online world.

Indeed, *The New York Times*, which has achieved some success with its digital subscriptions, has experimented with new forms of bundling. In its 25.03 issue in early 2017, *Wired* magazine described how the *Times* has been developing new products such as Cooking, Real Estate, and Watching as part of its Beta Group. (The acquisition of the gadget review site Wirecutter made for the newest product to be brought into Beta.) Collectively, it's a form of bundling for a digital subscription age.

There are numerous other examples of bundles whose components are not as attractive to some consumers and other users in their fully disaggregated state.

Some bundles of financial instruments have gotten a bad rep for good reason. In part it was poorly structured bundles of loans known as collateralized debt obligations (CDOs) that exacerbated the 2008 subprime mortgage crisis. The complexity of these bundles was one factor that obscured how risky they, in fact, were.

However, bundles are ubiquitous throughout the financial industry because they can also reduce risk or otherwise hedge against unforeseen events. Mutual funds are bundles of individual stocks, bonds, and other investments. They allow investors (for a fee) to buy into a more diversified portfolio than they would otherwise be able to. Other instruments allow airlines to hedge against fuel price increases. (Airlines generally prefer to focus on being profitable as an airline, not by speculating on oil prices.) Interest rate swaps can better line up incoming and outgoing cash flows and minimize certain types of market exposure, such as currency fluctuations.

Bundling can also be another aspect of delivering an integrated and tested experience. The manufacturer of those DRMd printer cartridges is being more than a bit disingenuous when they say that they're doing it for your own good. Nonetheless, having visibility and control over the supply chain and manufacturing of all the components that will be used together as part of a product and process reduces the likelihood that sub-par parts will make their way in. (Though you often pay a premium for this assurance.)

Furthermore, bundling simplifies the transaction and the support after the transaction. To return to Clay Shirky and newspapers, successful a la carte pricing models for unbundled short-form writing, such as a single article or a blog post, have proven elusive. Micropayments in the "give me a nickel to read this story" vein have failed time and time again. Way back in 2000, Shirky argued that this was because "users want predictable and simple pricing. Micropayments, meanwhile, waste the users' mental effort in order to conserve cheap resources, by creating many tiny, unpredictable transactions. Micropayments thus create in the mind of the user both anxiety and confusion, characteristics that users have not heretofore been known to actively seek out."[44] This transaction cost argument sounds a lot like the paradox of choice.

But there are no formulas for bundles and pricing. People say that they hate being "nickeled and dimed." Yet, they may not like that monthly subscription bill for a service they don't use much either. Consumers widely grouse about cable bills that include hundreds of channels that they never watch. Start adding up streaming services that need to be individually paid for and lack a common interface and people complain about that too.

The overall consumer preference does seem to favor subscriptions for many things. Certainly, domestic mobile phone usage has mostly moved to fixed monthly bills. Streaming music services have come to dominate individual song or album purchases. The total bill matters of course, but the evidence suggests that, by and large,

[44] http://www.openp2p.com/pub/a/p2p/2000/12/19/micropayments.html

consumers prefer the predictability of subscription billing and the reduced need to make as many ongoing purchase decisions. They know they can always cancel even if they often don't. Which makes subscriptions often attractive for vendors; a trial period is a good way to capture new customers and, even when a customer doesn't use a subscription much, they often fail to cancel.

The situation at large end-user companies is more mixed. Most of the major software they use have ongoing support contracts even if they aren't subscription products as such. Software-as-a-Service is usually subscription in some manner, often with tiered or per-seat pricing of some sort. However, the major public cloud providers are mostly priced based on pay-per-use and these services like Amazon Web Services and Microsoft Azure have become increasingly popular.

The best we can probably say is that both individuals and companies tend to have preferences for how they pay for a given good. And that preference may reflect customary practice as much as it does logic.

The unboxing experience

Ultimately, whether it's software or something else, there's a need that's being fulfilled and the packaging should be in service of that goal. But that's not to say that packaging is purely about getting a consumer to some goal as efficiently as possible—though that's certainly part of it.

Signs of the evolution of packaging from the utilitarian to the experiential are everywhere.

Unbox a computer a couple of decades ago and, if you were lucky, you might find a sheet of paper easily identifiable as a "Quick Start" guide. (Which itself was an improvement over simply needing a field engineer to swing by.)

Today the unboxing experience of consumer goods like Apple's iPhone has become almost a cliché, but it's no less real for that. In the words of Grant Wenzlau, SVP of Story at Day One Agency, "Packaging is no longer simply about packaging the object—it is about the unboxing experience and art directing. This is where the process starts for designers today: you work backward from the Instagram image to the unboxing moment to the design that serves it."

The idea of creating an experience around acquiring a product isn't new.

One of the clear antecedents in retail comes from Harry Gordon Selfridge, the American retail magnate who founded the London-based department store Selfridges.

Selfridge promoted the notion of shopping for pleasure rather than necessity (at his Oxford Street store of course.) As Erika Rappaport writes: "Gordon Selfridge marketed his new store by promoting shopping as a delightful and respectable middle-class female pastime… In writing about the store's opening, [one] paper's reporter loudly proclaimed that, at Selfridges, 'Shopping' had become an 'Amusement.' Whether imagined as an absolute need, a luxurious treat, a housewife's duty, or a feminist demand, shopping was always a pleasure."[45]

Selfridges housed elegant restaurants with modest prices, a library, reading and writing rooms, special reception rooms for French, German, American and "Colonial" customers, a First Aid Room, and a Silence Room, with soft lights, deep chairs, and double-glazing, all

[45] *The Gender and Consumer Culture Reader*

intended to keep customers in the store for as long as possible. Staff members were taught to be on hand to assist customers, but not too aggressively, and to sell the merchandise.[46]

A Selfridges Christmas display. Shopping as experience. Source: Selfridges.

Over time, the idea of thinking about user experience more broadly took hold. One could point to Frederick Winslow Taylor's early twentieth century research into how workers interact with their tools as a precursor to the science behind how we think about user experience today. Peter Drucker, who once graced the cover of *Business Week* as "the man who invented management," wrote that Taylor "was the first man in recorded history who deemed work deserving of systematic observation and study. On Taylor's 'scientific management' rests, above all, the tremendous surge of affluence in the last seventy-five years which has lifted the working masses in the developed countries well above any level recorded before, even for the well-to-do."

[46] https://en.wikipedia.org/wiki/Harry_Gordon_Selfridge

Beyond interfaces to experiences

The modern focus on user experience is often connected to Donald Norman whose 1986 *The Design of Everyday Things* is a classic of the field. However, Norman himself says that early user experience thinking was too narrow in scope. In the expanded 2013 edition of his earlier book, he writes: “The first edition of the book focused upon making products understandable and usable. The total experience of a product covers much more than its usability: aesthetics, pleasure, and fun play critically important roles. There was no discussion of pleasure, enjoyment, or emotion. Emotion is so important that I wrote an entire book, *Emotional Design*, about the role it plays in design.”

Software has a (deserved) reputation for historically paying scant heed to usability. But especially once graphical user interfaces became widespread, designers started paying more attention to user interface (UI) design and then user experience (UX) more broadly.

One can even observe the evolution from UI to UX through the lens of book titles. In 1992, Bruce Tognazzini, then Human Interface Evangelist at Apple, published *Tog on Interface* which mostly focused on things like user learning curves and interface consistency. By fifteen years later, Bill Buxton of Microsoft was publishing *Sketching User Experiences*, which focuses on higher-level attributes:

> Despite the technocratic and materialistic bias of our culture, it is ultimately experiences that we are designing, not things. Yes, physical objects are often the most tangible and visible outcomes of design, but their primary function is to engage us in an experience—an experience that is largely shaped by the affordances and character embedded into the product itself.

> Obviously, aesthetics and functionality play an important role in all of this.

Part of this experience is rooted in how easily software is acquired, prepared for use, and operated for however long it's needed. As analyst Stephen O'Grady wrote in his 2012 post "Do Not Underestimate the Power of Convenience:"[47]

> One of the biggest challenges for vendors built around traditional procurement patterns is their tendency to undervalue convenience. Developers, in general, respond to very different incentives than do their executive purchasing counterparts. Where organizational buyers tend to be less price sensitive and more focused on issues relating to reliability and manageability, as one example, individual developers tend to be more concerned with cost and availability—convenience, in other words.

[47] http://redmonk.com/sogrady/2012/12/19/convenience/

Open source: A vision for the future

Ultimately, open source managed services, an approach like Operate First, and associated tools such as operators are ingredients to help open source thrive in a world where large cloud providers often dominate. Open source can do so by overcoming key challenges.

Simplicity is a challenge because it runs counter to developer and, especially open source developer, instincts to offer more choices, more options. It runs counter to a preference to let users select among alternatives in a sort of Darwinian free-for-all. How many desktop environments are available for Linux again?

Simplicity doesn't come naturally to open source. There's usually no central authority carving out unnecessary features and holding firm to a streamlined architectural vision.

Simplicity isn't inherent in all cloud options either. At this point navigating the Amazon Web Services catalog of services is a daunting task. But, to the degree that open source software projects can simplify installation, simplify configuration, and simplify ongoing operations, they'll see even more adoption. Containers and automation tools such as Ansible are making great strides to abstract away a lot of the complexity around software provisioning and configuration.

Integration has been one of the biggest challenges to adopting open source software over time. Tight integration would seem to fly in the face of an ethos of independence from specific technology tracks and specific vendors.

But it's not a binary choice.

Consider the technological innovation happening around containers and DevSecOps. On the one hand, this creates enormous possibilities for new types of applications running on a dynamic and flexible platform. And this continues to happen. But it doesn't preclude *also* having an integrated (but extensible) container platform.

And for many organizations, channeling and packaging the rapid change happening across a plethora of open source projects isn't easy—and can end up being a distraction from the ultimate business goals. With container formats, runtimes, and orchestration increasingly standardized through the OCI and CNCF (where Kubernetes is hosted), there's increasing interest from many ops teams in deploying a tested and integrated bundle of these technologies.

If you consider the differences between perceptions about open source as it was starting to become important to businesses and today, one of the big changes is **confidence** around open source security, support, and reliability. Much of this was, in fact, often not hard to find early on but it was at best patchy. The confidence provided by enterprise open source packaging is one aspect that has led to the shift in perception.

This shift comes from how the open development model allows entire industries to agree on standards and encourages their brightest developers to continually test and improve technology. Developing software in collaboration with users from a range of industries, including government and financial services, provides valuable feedback that guides security-related discussions and product feature implementations. Collaborating with communities to solve problems is the future.

This collaboration brings additional benefits. As Paul Cormier, the CEO of Red Hat, wrote:[48]

> This commitment to contribution translates to knowledge, leadership, and influence in the communities we participate in. This then translates directly to the value we are able to provide to customers. When customers encounter a critical issue, we are as likely as anyone to employ the developers who can fix it. When customers request new features or identify new use cases, we work with the relevant communities to drive and champion those requests. When customers or partners want to become contributors themselves, we even encourage and help guide their contributions.

Open source software suppliers also put a wide range of processes and services in place to further enhance confidence in open source software. Modern security means shifting from a strategy that is built around minimizing change to one that is optimized for change.

Enterprise open source software also requires code review and testing methodologies, a supply chain that's secured by digitally signing all released packages and distributing them through secure channels, and a dedicated product security team (such as we maintain at Red Hat) that analyzes threats and vulnerabilities against all our products every day and provides relevant advice and updates.

Finally, **Experience** is where the rubber hits the road. Everything comes down to delivering an experience through the software and the way in which it is packaged.

Open source brings freedom. Open source brings flexibility. Open source brings choice. Open source brings independence.

[48] https://www.redhat.com/en/about/blog/what-makes-us-red-hat

But open source participants also must keep their eyes on delivering those attributes to users with the minimum of friction. This means moving beyond thinking about software in the traditional sense—and instead enabling the streamlined delivery of digital services.

The innovation taking place in cloud-native development today provides many options to make this approach a reality. And the open source development model has proven to be hugely successful. But there remains the need to focus on and embrace packaging principles to deliver a simplified and enhanced user experience. A better experience.