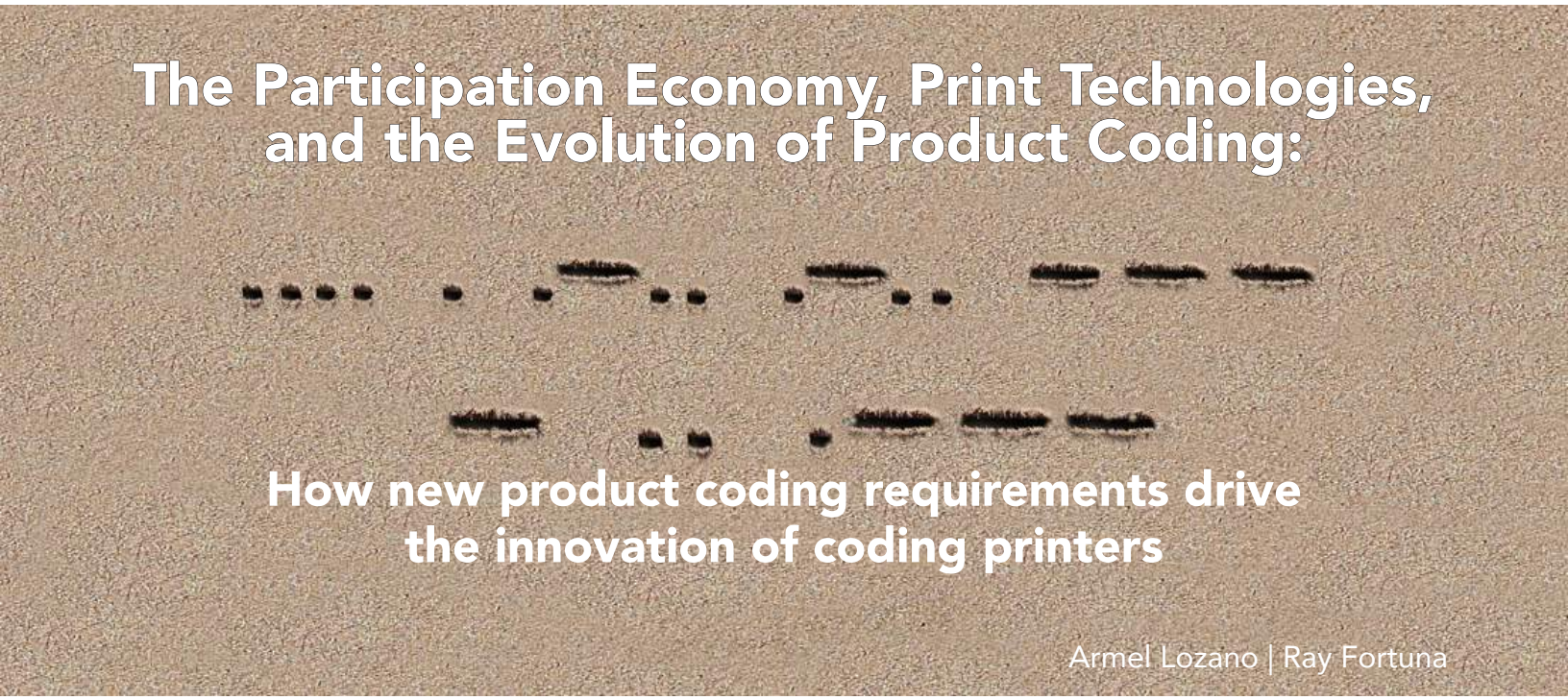
The Participation Economy, Print Technologies, and the Evolution of Product Coding:



How new product coding requirements drive the innovation of coding printers

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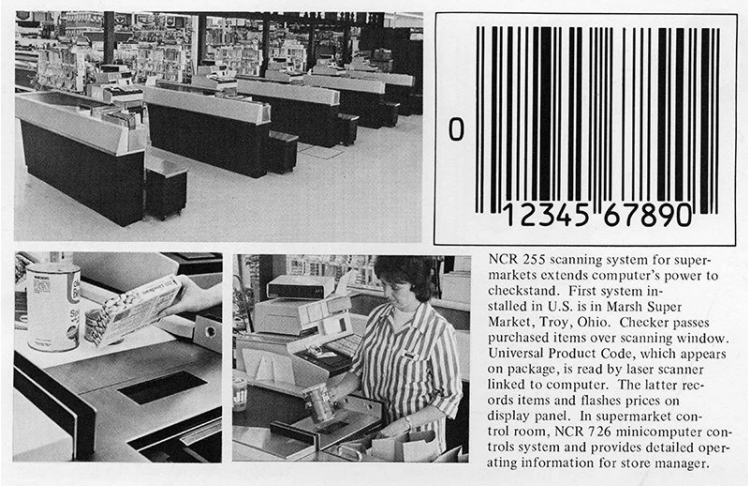
MapleJet FUNAI

Marking and coding began as a way for producers of goods to keep track of their products throughout the product life cycle. Codes were comprised of a short series of alphanumerics that were regionally accepted as a method of identifying goods producers and their products. Marking and coding is not new, in fact, some of the earliest livestock coding tools are up to 170 years old.

Remember the livestock branding iron?

Beginning in 1949, Joseph Woodland searched for an automatic way to capture data. His idea was to use lines and spaces in a similar way that Morse Code uses dashes and dots. While relaxing on the beach, Woodland used his fingers to write a Morse Code message in the sand. At each dash, he drew a long vertical line and left blank spaces where the dots were, and the first linear bar code came into existence (Brown, 2001).

In June of 1974, the first machine readable code, called a Universal Product Code (UPC), was scanned on a pack of Wrigley's gum at Marsh's Supermarket in Troy, Ohio (Brown, 2001). The age of machine coding was born, but not without significant challenges. UPC barcodes were severely limited in several ways: the amount of data stored in the barcode was limited to 6-12 characters (each character being a single digit ranging from 0-9) and the lack of redundancy in the code meant that a UPC code with minor print imperfections could render the code useless.



The first item marked with the Universal Product Code (UPC) was scanned at the checkout of Troy's Marsh Supermarket. Courtesy of Yale University Press

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Today's 2D codes are capable of tracking individual products (Track and Trace), engaging directly with consumers (Marketing), and combating the counterfeit of high-end goods (brand protection).

The Market

Today, every product contains some type of code, but coding plays an especially important role in Fast-Moving Consumer Goods (FMCG) also known as Consumer Packaged Goods (CPG). Codes may be regulatory, quality control measures, or even ways to directly engage with customers. Custom codes cannot be printed with the typical flexography methods used to create full color product packaging. The result is that codes must be applied to packaging dynamically during production.

In 2020, the global coding market was valued at $3.4B, with an estimated value of $4.7B in 2026, which results in a CAGR of 5.5% (Analysts, 2022). Package coding generally falls into one of three (3) categories based on the packaging that is being coded. These categories are (at a high level): Primary Packaging, Secondary Packaging, and Tertiary Packaging.

Types of Packaging

Safety Packaging
- Packaging to ensure product safety and sterility
- Normally used in pharmaceuticals

Primary Packaging
- Material that will likely come in direct contact with the product

Bulk Packaging
- Packaging designed to hold groups of primary packaging in predefined quantities
- Usually used for distribution/wholesale

Retail Ready Packaging
- A special type of Bulk Packaging containing pre-printed colorful designs for the purpose of holding primary packaging when the primary packaging is not easily stacked.
- Designed to be placed directly on store shelves

Secondary Packaging
- Partially pre-printed kraft (cardboard) box that protects primary and retail-ready packaging during shipment. Also called a "Shipping Crate"

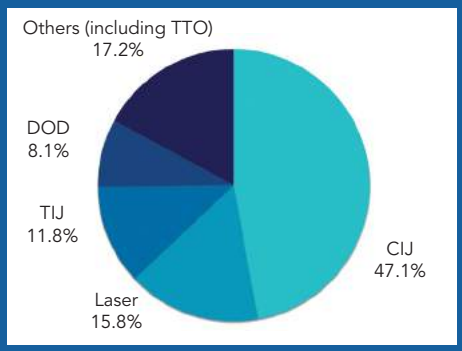
Tertiary Packaging
- Packaging for logistics. Secondary packaging that is palletized and shrink wrapped for shipping.

Code contents generally fall into two categories: 1) Alphanumerics and 2) Machine codes.

Coding is dominated by several major printing technologies in the primary packaging space. These technologies are:

1) Continuous Ink Jet
2) Laser
3) Thermal Ink Jet
4) Thermal Transfer Overprint

The 2022 market breakdown of each printer type is as follows (Technavio, 2022).



2022 Technology Market Share (Technavio, 2022)

Many code types exist. Each performing a specific function and each having different requirements.

Expiration

- Used to identify the useful life of a product and product batch
- Alphanumerics only
- Mark height: Up to three (3) lines of 1/8" (3mm) text

Serialization Track & Trace

- Used to uniquely identify each product. Common in the pharma industry to trace individually shipped units throughout the manufacturing and supply chain. Every package contains unique identifiers specific to the product contained in that single package. Used primarily when product defects are identified.
- Alphanumerics
  Machine codes (2D)
- Mark height: 1/8" – 1/2" (3mm - 12mm)

Lottery Ticket

- Unique 2D or QR codes for the purposes of issuing a "golden ticket."
- Alphanumerics
  Bar Codes
  2D Codes
- Mark height: Varies

Point of Sale

- UPC-A
  Contains only Global Trade Item Number (GTIN) ref. GS1
- Alphanumerics
  Bar Codes
  Limited to 12 digits
- Mark height: 1/2"-1" (12mm - 25mm)

Company operations can benefit from denser codes like the data matrix, which can store up to 2,335 alphanumeric characters or 3,116 numbers (GS1, 2018), as opposed to UPC-A codes that contain 12 digits.

With 2D codes, important operational information can now be dynamically coded onto products that have variable features, such as weight-based products like meats, fruits, and cheese. Point of sale locations that are properly equipped to read dense codes can now charge the appropriate amount for the product without using a cashier "lookup" function, increasing the throughput of each cash register.

2D codes might also contain expiration data which would enable the point-of-sale scanning station to automatically warn consumers that a product may be approaching the end of its useful life. According to Jenny Chang, a senior writer specializing in Saas and B2B software solutions, 41% of supply chain specialists have expressed interest in data analysis technology (Chang, n.d.).

While operational considerations were the initial driving force (of the 2D codes), customer behavior is also shifting, particularly with the millennial generation. This behavior is referred to as the "Participation Economy" (Garton, 2013).

The Participation Economy

This new generation of customer no longer wants to just purchase and consume items, but instead interact with products. This is evident by behaviors in social media (posting a picture of a new car and giving the car a name), reaction and unboxing videos, crowdsourcing venues like Go-Fund-Me, and product reviews via websites like Yelp (Garton, 2013).

Millennial buyers are willing to spend more on a product when a bond can be formed with the product and manufacturer. Creating this bond requires addressing consumer concerns such as sustainability, fair animal/labor practices, and even company stances on social issues; only then will they engage with the product, but once engaged, millennials are notoriously loyal to products that exist within their value system.

Due to rapidly shifting coding demands, GS1.org, the authority in coding, has released their "Sunrise 2027" plan. This plan calls for the end of the UPC code by 2027. 2D barcodes allow for a single, standardized way to meet both supply chain needs and evolving consumer requirements (GS1 US, n.d.).

Several large retailers recently participated in pilot programs implementing 2D codes. Even though each retailer sought to achieve different goals, a single common 2D code successfully performed each function. The retailers (and desired goals) include:

Walmart	Supply chain management
Proctor and Gamble	Intelligent packaging/Customer engagement
Pepsi	Lottery/cash giveaways as part of their UEFA Championship League Sponsorship in the UK (Just-Drinks.com, 2021)
Woolworths	Forecasting, inventory management, and overall efficiency

In short, the adoption of a single 2D code provides the mark data density to achieve various operational and marketing goals with the same code. Recall that the UPC-A code only contains the information to scan SKU pricing, which lacks the traceability needed beyond the cash register.

Who Benefits From 2D Codes?

Production Manager

Benefit
Incorporate 2D codes to enable cradle-to-grave visibility on products.

New Challenges
Evolving product codes incorporate additional data, which requires a "denser" mark.

Action
Ensure that coding technologies can generate custom codes without slowing down production lines.

Enable downstream consumers to decode new machine "language."

Benefit
Simplify Point-of-Sale (POS) codes to register dynamic data that increases the speed of scanning, simplifies pricing changes, and automates inventory management.

New Challenges
Ensure checkout registers can process a variety of codes other than UPC-A.

Action
Utilize the GS1 Barcode Capabilities Test Kit to test and modify point-of-sale scanning capabilities.

Store Manager

Marketing Team

Benefit
Enable customized consumer experiences and engagement to further develop brand loyalty.

New Challenges
Develop and manage large databases of unique codes (by region or individual customer) to provide a customized experience.

Action
Segment markets and develop value statements for each to create uniquely engaging customer experiences. Experiences must be accessible to mobile devices to create deeper consumer engagements.

Benefit
Utilize dynamic codes to direct consumers to corporate statements regarding raw material sustainability, fair labor practices, and social positions.

New Challenges
Develop digital statements/repositories to concisely convey comprehensive social practice guidelines and mission statements linked to scannable 2D codes.

Action
Develop a marking methodology to direct consumers to applicable mission statements that coincide with consumer interests.

Corporate Management

"While the transition to 2D barcodes is still in its infancy, we understand that benefits around sustainability, traceability, supply chain visibility and meeting the needs of consumers are creating a great deal of interest across industry."

Walmart

Marcia Mendez,
Senior Program Manager

"2D barcodes on products will be an important new gateway to digital experiences."

P&G

Kelly Schlafman,
Director of Intelligent Packaging

"At Woolworths we plan to build on the potential of these barcodes to offer customers valuable information on provenance, quality and sustainability. As we work towards a better tomorrow with our suppliers, 2D barcodes can help us communicate a product's verified sustainability credentials to customers."

Roberto Olivares,
Senior Project Manager

"The way in which we interact with products has changed – and technology has to keep up. Sunrise 2027 will allow industries to move toward a single, standardized barcode that will create efficiencies for businesses and trading partners as well as increase consumer engagement and satisfaction."

GS1

Gena Morgan,
Vice President of Standards

A quick summary of the current primary printer technologies, and their key characteristics, is provided below. For more comprehensive printer descriptions, see Appendix A.

Performance Characteristics		Laser	CIJ	TIJ	TTO
	Capital Investment:	High	Medium	Low	Medium
	Resolution	Highly customizable	Low	High	High
	Throw Distance	~2"-6" (50mm-152mm) (typ.)	~1/2" (12mm)	~1/4" (6mm)	Must make contact with substrate
	Print Speed	Highly dependent on message contents	Highly dependent on message contents	Consistent high speed	Consistent medium/high speed
	Alphanumerics Speed	High	High	High	Medium/High
	Machine Code Speed	Low	Low	High	Medium/High
	Speed Impact of Coverage	High	High	Low	Low
	Cost per Mark	N/A	Low	High	Low
	Curved Substrates:	Yes	Yes	No	No
	Recessed Substrates:	Yes	Yes	No	No

Maintenance & Misc.			Laser	CIJ	TIJ	TTO
	Daily/ Weekly	Task	Clean cooling vents	Top off makeup solution	Install/wipe cartridge	Change ribbons
		Difficulty	Easy	Easy	Easy	Challenging
	Monthly / Yearly	Task	Replace filters	Factory maintenance	None	Clean/replace print engine
		Difficulty	Easy	Difficult	N/A	Difficult
		Changing Inks	Laser matched to substrate	Difficult	Simple	Challenging
		Energy Consumption	High	Low/Medium	Low	Medium
		Security Ink Compatible	No	Yes	Yes	No
		Chemical VOC Release	None	High	Minimal	None

A note about sustainability:

The cost per mark is not the only expense to consider when choosing a coding technology. Some technologies are inherently worse for nature than others.

Recycling of consumable waste, energy utilized for operation, and the airborne release of potentially dangerous chemicals should also be considered carefully.

It is our planet that pays this price.

Before diving into how the different printers operate, a discussion on "coverage" is required. In this paper, coverage is defined as the amount of ink placed within a certain sized marking window (expressed as a percentage.)

Example:

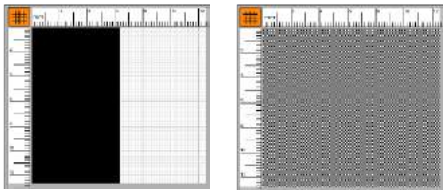
Marking window: ½" (12mm) tall and 1" (25mm) long
Resolution: 600 dpi (vertical) ; 300 dpi (horizontal)

Marking window pixels:
600DPI * ½" * 1" * 300DPI = 90,000 total possible pixels.

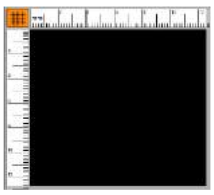
If 45,000 pixels are placed within this window, coverage is calculated as:
45,000 printed pixels/90,000 possible pixels * 100% = 50% coverage.

In other words, 50% of the total available pixels now contain a droplet to form the desired mark.

Approximate coverage calculations for various printed marks are listed below for reference:



Partial Coverage: 50%

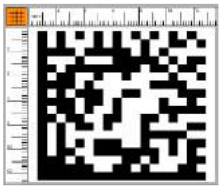


Blackout Coverage: 100%

Lot/Exp Coverage: 8.2%

UPC-A Coverage: 26.2%

QR Coverage: 41.3%



Datamatrix Coverage: 48.3%

Coverage is important when considering how different print technologies deposit ink, primarily as it relates to maximum printing speeds and consumable utilization.

So now that we've seen that the market is shifting, how are current print technologies affected by the denser marks?

Technology	Effects of Coverage	Challenges Due to Code Evolution	Results
Laser	High	» Slowed production lines	» Higher coverage results in lower maximum print speed
CIJ	High	» Slowed production lines » Low resolutions	» Higher coverage results in lower maximum print speed » Large drop size degrades code scannability due to poor edge sharpness
TIJ	Low	» Short ink throw distance » Highest cost per mark (consumables)	» Cannot print on round/recessed substrates. » Larger, more dense, codes require additional consumables at a cost
TTO	Low	» Must make contact with the substrate » Limited production speed	» Cannot print on round/recessed substrates » Not suitable for high-speed primary processes

Significant evidence exists that coding is about to evolve quickly. Unfortunately, no existing solutions have the ability to fully address this anticipated customer demand for engagement and information.

This evolution presents unique (and significant) challenges for the existing coding technology in use today.

If comparing the technologies as-is, Thermal Inkjet (TIJ) is in the best position to make the transition with the exception of two very important challenges:

- **Short throw distance**
- **High cost per mark**

What if a high-resolution, long throw, high-speed printer with a low cost of operation were possible? This is the question that MapleJet and Funai began to ask.

It was for this reason that MapleJet and Funai partnered to pair the 10mm throw Zion cartridge with the ultra-stable, easy to use active bulk delivery system, Hx Ultro. These two products, used in conjunction, lower cost per mark and broaden the range of acceptable applications.

Considering these advancements, the thermal inkjet summary table changes significantly:

		Traditional TIJ	Long-throw with Bulk
Performance Characteristics	Capital Investment	Low	Low
	Resolution	High	High
	Throw Distance	~1/4" (6mm)	~1/2" (12mm)
	Print Speed	Consistent high speed	Consistent high speed
	Alphanumerics Speed	High	High
	Machine Code Speed	High	High
	Speed Impact of Coverage	Low	Low
	Cost per Mark	High	Low
	Curved Substrates	No	Yes
	Recessed Substrates	No	Yes

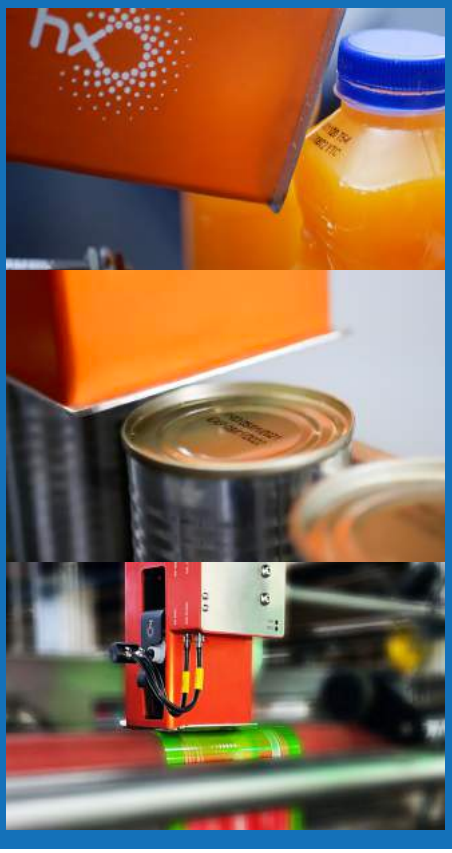
			Traditional TIJ	Long-throw with Bulk
Maintenance & Misc.	Monthly / Yearly	Task	Install/wipe cartridge	Install/wipe cartridge
		Difficulty	Easy	Easy
	Monthly / Yearly	Task	None	None
		Difficulty	N/A	N/A
		Changing Inks	Simple	Simple
		Energy Consumption	Low	Low
		Security Ink Compatible	Yes	Yes
		Chemical VOC Release	Minimal	Minimal

Hx Ultro's smart bulk ink delivery system (US Patent Pending), consisting of precision ink pressure regulation and accurate pump ink feed, is the industry's most compact and reliable active ink system. The system comes with various volumes of ink reservoirs packed inside a cassette customized for easy ink changeover, minimizing line interruption.

The extended throw distance of Zion combined with Hx Ultro's solid, easy-to-use bulk ink delivery system enables thermal inkjet to perform in applications previously reserved for only CIJ and Laser. The low impact of coverage on TIJ assures that, as codes continue to evolve, thermal inkjet printers will be ready for the challenge.

Final Words

There will always be applications, such as ultra-high-speed bottle marking, that will never be suitable for TIJ. The same can be said for marks that are larger than 2" (50mm) tall. Thermal inkjet is not being presented as a cure-all, but instead a viable option for most new primary applications. TIJ ink portfolios are rapidly expanding with the focus on fast-drying, long open-time solvent inks. Custom-tuned inks designed for long-throw cartridges are now a reality and may be a new solution to an old problem, which is to print high-resolution codes on curved or uneven surfaces.



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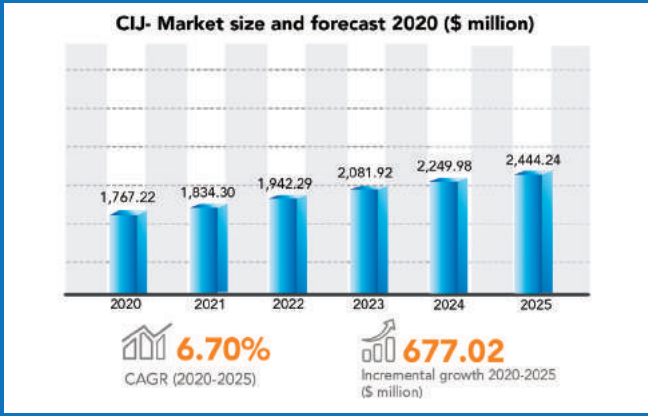
Appendix A

CIJ CONTINUOUS INKJET PRINTER



CIJ - Market size and forecast 2020-2025 (Technavio, 2022)

METHOD OF OPERATION

A garden hose stream is a good example of a continuous flow from a CIJ nozzle except CIJ nozzles are tiny (less than .005 inch or about 1/10 millimeter). The ink stream naturally breaks into separate drops due to Plateau–Rayleigh flow instability.

The CIJ formed ink drops are either deflected by an electric field towards the desired location on the substrate or collected for reuse in a trough on the head. The continuous recycling of ink drops means that ink solvents will need to be replenished as they escape into the atmosphere over time.

PROS

- ~25/54"- 15/32" (10-12mm) throw distance
- Very fast single line text (1,600FPM)
- Lower cost consumables

CONS

- Medium capital cost ($6.5k-$13k)
- Low resolution
- Affected by coverage: 2D/QR codes can be very slow
- Potential for high VOC release (ink dependent)
- Must run 24/7 (8,670 hours)
- Requires service after approximately 2,500 hours (~3x/year)
- Service requires a factory technician
- Spare unit often required to minimize unplanned downtime
- Message content affects maximum speeds
- Customer perception: Difficult to own/ operate, but necessary if the product is uneven

TIJ TRADITIONAL THERMAL INKJET PRINTER

PROS

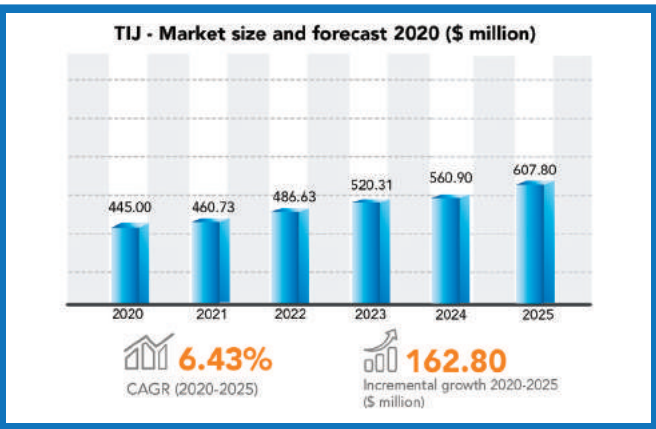
- Not affected by coverage
- Low equipment capital cost
- No engine maintenance. Replacing the cartridge replaces the engine
- Message content does not affect speed
- Extremely high resolution
- Easy to switch substrates/inks

CONS

Cost significantly reduced with Hx Ultro active bulk ink delivery

Now up to 1/2" (10-12mm) with Zion long-throw cartridges

- Highest cost per mark (non-bulk)
- ~1/4" (6mm) typical throw distance
- Customer perception: "Bulk ink delivery is unpredictable"
- Limited to small print swaths (1/2"-1" or 12mm - 25mm)

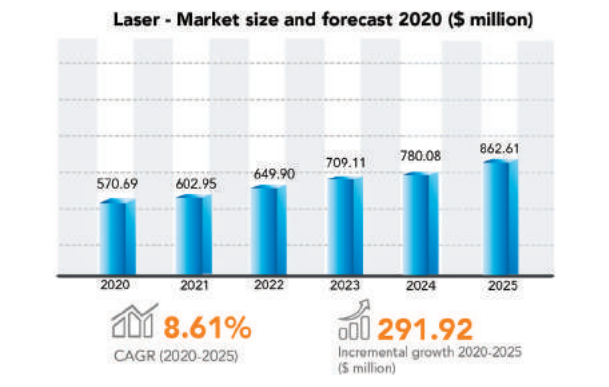


TIJ - Market size and forecast 2020-2025 (Technavio, 2022)

METHOD OF OPERATION

Tiny resistors create heat that nucleates the ink to create a bubble. As the bubble expands, some of the ink is pushed out of a nozzle onto the substrate. When the bubble "pops" (collapses), a vacuum is created. This pulls more ink into the print head from the cartridge. A typical typical industrial print head has 300 or 600 tiny nozzles, and all of them can fire a droplet simultaneously.

LASER LASER PRINTER



Laser- Market size and forecast 2020-2025 (Technavio, 2022)

METHOD OF OPERATION

Lasers turn very focused light into heat to create a mark using three (3) different methods:

1. Ablation – Removing the top layer of a material to expose lower layers (paper, wood, leather, and other organic materials).
2. Etch – Rapidly heating and cooling concentrated areas causing brittle substrates to crumble under stress (glass).
3. Thermal distortion – Annealing or color bleaching a substrate (metal and some plastics).

PROS

- ~6" (152mm) focal distance (varies by lens and beam diameter) – Permits "long- throw"
- No consumables (except air filters) – Low utilization cost
- Very fast, one-line alphanumerics (up to 600 marks/minute on PET and cardboard)

CONS

- High capital cost:
  - CO2: $25k-$50k
  - Fiber: $25k-$75k
  - Diode: Up to $100k
- Must be matched to substrate – Switching substrates can be expensive
- Affected by coverage: Barcodes up 10s per code (metals/glass) – Graphics and coding drastically increase time per mark generated
- Special safety equipment required
- Customer perception: "Laser radiation is scary"
- Message contents affect maximum speed

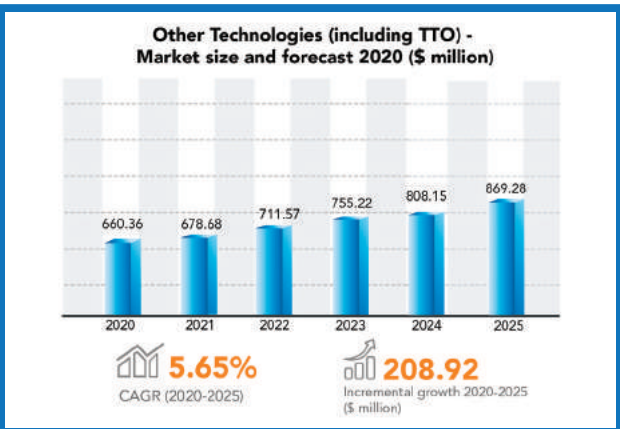
TTO THERMAL TRANSFER OVERPRINTER

PROS

- Excellent print quality
- High opacity and edge sharpness (big factors in barcode grading)
- Prints on a wide variety of non-porous substrates
- Wide variety of transfer ribbon widths
- High rub resistance

CONS

- Ribbons are wasteful, especially if the full width of the ribbon is not used
- Not "high speed" relative to laser, CIJ, and TIJ
- Common complaint: Ribbons break easily if substrate is not flat/controlled well
- Does not grayscale well (rasterizes)
- Mature technology with little room for further development
- Ribbons need to be destroyed manually if the printed data is/was sensitive
- Requires "warm up" before using



PALM, VIJ, and TTO - Market size and forecast 2020-2025 (Technavio, 2022)

METHOD OF OPERATION

In thermal transfer overprinting (also know as TTO), a temperature-sensitive thermal transfer foil made of wax, resin or a mixture of these is passed between the print head and the print medium. The thermal print head has hundreds or thousands of individually controllable heating elements, depending on size and resolution. When a heating element is activated and thereby heated, the ink layer on the thermal transfer foil melts: the ink is permanently transferred to the medium.

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