The Global Language of Business

2D in Retail – Tier 3.1 Test Report

2D Barcode Scanning: Co-Located Symbols

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1 Introduction

Globally, stakeholders are adopting 2D barcodes that contain more data encoded in different data structures (syntaxes). At the same time, retail environments have deployed high-volume point-of-sale (POS) solutions capable of scanning 2D barcodes. The environment is poised to enable 2D on retail packaging for POS processes. However, details on scanning system capabilities and best practices for scanning 2D barcodes in retail are currently unclear. Unbiased, independent data is required to support:

- Retail scanner improvements
- Key retail sector questions
- Scalable, interoperable solutions that leverage the data carrying capacity of 2D barcodes

GS1 is working with retail scanner manufacturers and conducting tests to quantify the performance of 2D barcodes in retail POS scenarios. This report covers the third iteration of this testing.

The University of Memphis Automatic Identification Lab has been engaged to conduct this unbiased, independent testing using robotic equipment and representative high-volume, bi-optic POS scanners. To establish common baselines of performance and unbiased test data, a series of tests were performed on a variety of barcodes to understand how they scan.

The first tier of testing, Tier 1, focused on linear and 2D barcodes with only a Global Trade Item Number (GTIN) contained within them. This test determined the baseline scanning performance of 2D barcodes to compare against current EAN/UPCs on-pack.

Tier 2 testing was an incremental challenge for the scanner solution providers, requiring them to decode linear and 2D barcodes containing GTIN + additional data.

- **Note:** The full Tier 1 report was published in May 2022. The Tier 2 report was published in July 2022, and both can be found, alongside other 2D barcode resources, at *https://www.gs1.org/industries/retail/2D-barcodes*.

As industry transitions to 2D barcodes, items will need to be marked with both an EAN/UPC and a GS1 DataBar retail family or 2D barcode, as 2D readiness will vary at POS and in other scanning environments.

Tier 3 testing aims to determine how co-located barcodes (see Figure 1-1) perform in POS retail scanning environments and to answer four important questions:

1. How well do the scanning systems handle multiple barcodes on-pack?
    a. Will the host POS system understand that the GTINs from multiple barcodes are from the same package and prevent a double scan?
2. How should the barcodes be placed in relation to each other for optimised scan results?
3. Can POS scanners identify linear and 2D barcodes encoded with GS1 data structures and differentiate non-GS1 encodings?
4. Is the decode time between multiple barcodes on a single product acceptable to retailer host systems?

Figure 1-1. Example of a co-located barcode test card

The tests were designed to evaluate if recent software updates made to bi-optic scanners from major manufacturers are sufficient for the decoding of co-located linear and 2D barcodes at retail speeds. One of the five scanners under test had no software updates and represents how an unchanged scanner would react to co-located barcodes.

The testing included:

- Linear and 2D barcodes encoded with both GS1 data structures (i.e., plain, GS1 element string, GS1 Digital Link URI syntax) and non-GS1 encodings (e.g., unformatted data, generic marketing QR Code with a URI, etc)
- Linear and 2D barcodes containing a GTIN with additional data (e.g., expiration date and batch/lot number)
- Co-located barcodes positioned adjacent or stacked with varying spacing
- Variables including barcode orientation, speed, angle and distance from the scanner

Tier 2 testing confirmed that updated scanner software could convert barcodes encoded with GS1 Digital Link URI syntax to GS1 element string syntax. This ensured retailer POS systems can process GS1 Digital Link URI syntax without requiring out of cycle scanner and system upgrades. The syntax conversion capability was included in the Tier 3 software update.

After initial data collection and analysis for Tier 3, it was determined that scanner software was not performing as expected and updates and modifications were necessary. Findings were shared with solutions providers who responded quickly to develop updates to address the issues. After the software updates were verified, testing was restarted and incremented to Tier 3.1.

This report covers the full Tier 3.1 test results.

2 Executive summary

In a controlled environment, updated scanner software can process co-located barcodes encoded with GS1 data structures at required retail self-checkout AND high-volume checkout speeds of 40 to 70 items per minute. As a result of these findings, brand owners, solution providers, and retailers can feel confident that pilot tests that leverage updated scanner software will have a high probability of success.

This report is the result of the collaborative efforts of solution providers in the barcode label software sector, the printing and retail scanning sectors, the University of Memphis and GS1. The scanner tests described herein were designed to support solution providers, brand owners and retailers in the transition to 2D barcodes with GS1 data structures at retail point-of-sale (POS).

Like Tiers 1 and 2 of our testing, this testing was done in a controlled lab environment. Testing was performed on five commercial retail POS barcode scanners from three manufacturers. Tier 1 tested baseline performance. Tier 2 answered the initial questions related to scanning of 2D barcodes with GTIN and additional information. Tiers 3 and 3.1 focused on answering the following important questions:

- How well do the scanning systems handle multiple barcodes on a single trade item?
  - The test results show that, in a controlled environment, scanning systems are capable of processing multiple barcodes at the highest practical retail scanning speeds.
  - Test results proved software updated POS scanners will "beep" once and prevent double charges or scans when multiple barcodes are on-pack. The common software solution added a label identification header to all barcode data delivered to the host POS system.
- How should the barcodes be placed in relation to each other for optimised scan results?
  - When minimum barcode quiet zones are maintained, testing shows that 2 barcodes with between 15 mm and 50 mm separation provide the best overall performance for speed and scan rates.
- Can POS scanners identify linear and 2D barcodes encoded with GS1 data structures and differentiate non-GS1 encodings?

  - Scanning systems are capable of distinguishing between GS1 data structures and non-GS1 encodings in 2D barcodes, allowing the retailer to have confidence that the right barcode can be identified for the right purpose.
- Is the decode time of multiple barcodes on a single product acceptable to retailer host systems?
  - Yes, scanning rates for multiple barcodes that are placed within 50mm of each other are fast enough that retailer host systems should be able to make timely, informed decisions. The test results also show that the retail scan rates of 40 to 70 items per minute (IPM) are achievable when barcodes are co-located within 50mm of each other.

● **Important:** The solution providers, the University of Memphis, and GS1 all agree that retail store pilots are necessary to continue vetting POS scanner improvements. Co-located barcodes that are scanned on systems where software and configuration updates have not yet been made **will not achieve the same results and may lead to duplicate scans** from a single item.

3 Methodology

Like the previous Tier 1 and Tier 2 tests, Tier 3.1 testing was an iterative process where sample barcodes were subjected to a series of incremental tests selected to allow the research team to isolate and analyse the impacts of various real-world variables (e.g., distance between barcodes, angle of barcode relative to the scanner, which camera was doing the decoding, etc.). The selection of the variables and the number of permutations of each variable were made with input from various GS1 workgroups and discussions with solution providers, brands and retailers.

The primary test design considerations were:

- The barcodes needed to encode GTIN plus additional data attributes (GTIN+) in the format required by the symbology (barcode) and syntax.
- The use of consistent and repeatable printing methods and materials ensured quality was representative of real-world barcodes. Barcodes were printed on standard width 6X3 inch labels using thermal transfer printers with wax ribbon or on a colour LaserJet printer for the digital watermark test cards.
- The use of the current-generation retail scanners listed below. All scanners were reset to factory default settings and then had Tier 3.1 software updates and specific configurations applied (i.e., data formatting, communications ports, etc.).
  - Datalogic (9400i and 9800i)
  - NCR (RealScan 7879)
  - Zebra (MP7000, MP7001)
- The test data must be as statistically robust as previous tests.

● **Note**: In this report the scanners are given aliases (Alpha#. Beta#, Delta#, etc.). The aliases are the same as in previous Tier 1 and 2 reports.

3.1 Test profile overview

Tier 3.1 testing, similar to Tier 1 and 2, used a variety of testing scenarios (called 'test profiles' in this document) that were determined through a series of beta tests, historic tests and use of rules and standards outlined in the GS1 General Specifications. Test profiles are detailed below. For Tier 3.1, thirty-eight tests were run to understand how co-located barcodes would read when the scanner parameters were altered from Tier 2 (see B Annex: Test profiles). The thirty-eight tests were of nineteen unique test profiles, each run under two different barcode decoding (i.e., auto-discrimination) configurations.

Both the variation of parameters in the test setup and the variation of barcode characteristics are important to ensure a robust understanding of how a range of barcodes will perform outside of the lab environment. Below is an outline of the parameter variations that were used in the Tier 3.1 testing. A detailed spreadsheet of the barcodes is available as an appendix to this report. (see A Annex: Tier 3.1 barcodes).

The nineteen **test profiles varied by**:

1. Distance (~12.5 mm and 55 mm from scanner horizontal and vertical surfaces)
2. Horizontal offsets (scanner optimal scan location, optimal +25 mm, optimal -25 mm)
3. Speed (from 150 mm/s to 1,200 mm/s)
4. Pause (movement/travel @ 1200 mm/s with 0.25 second stop)
5. Tilt angle from horizontal (0º, 45º, 90º)
6. Clockwise rotation in plane (0º, 45º, 90º, 180º)
7. Barcode decoding algorithms that were activated/enabled in the scanners
    a. Linear and 2D barcodes (EAN-13, UPC-A, GS1 DataBar Expanded Stacked, GS1 DataMatrix, Data Matrix (GS1 DL URI) QR Code (GS1 DL URI))
        i. Configuration 1: EAN/UPC, GS1 DataBar Expanded Stacked, GS1 DataBar Omnidirectional, Data Matrix and QR Code
        ii. Configuration 2: EAN/UPC, GS1 DataBar Expanded Stacked, GS1 DataBar Omnidirectional, Data Matrix, QR Code, ITF-14, PDF417, Code 128, ISBN, digital watermark

Co-located barcode **test cards varied by**:

1. Symbology combinations
2. Data encoded
3. Position of symbols (both adjacent and stacked) see Figure 3-4
    a. Near (<15 mm spacing)
    b. Mid (between 15 mm and 50 mm spacing)
    c. Far (between 100 mm and 150 mm spacing) (Maximum separation distance based on test card size)
4. Number of barcodes on a test card (1, 2, or 3)

3.2 Test rig design

Tier 3.1 used the same test rig (see Figure 3-1) that was used in Tier 2. Five tabletop bi-optic, imager-based scanners were used for the test. Custom Microsoft .NET software and a simple database were developed for collecting scan data. All scanners were configured with physical RS-232 serial or USB serial connections and a computer with multiple serial ports.

To ensure timing consistency, photoeye sensors were tied to the computers and the custom software was configured to capture the photoeye events. Each computer had only one scanner and one photoeye connected. The leading edges of the scan windows and sensors were optimised to each scanner/sensor combination. Finally, the scan path for the samples was adjusted to comply with specific test profiles.

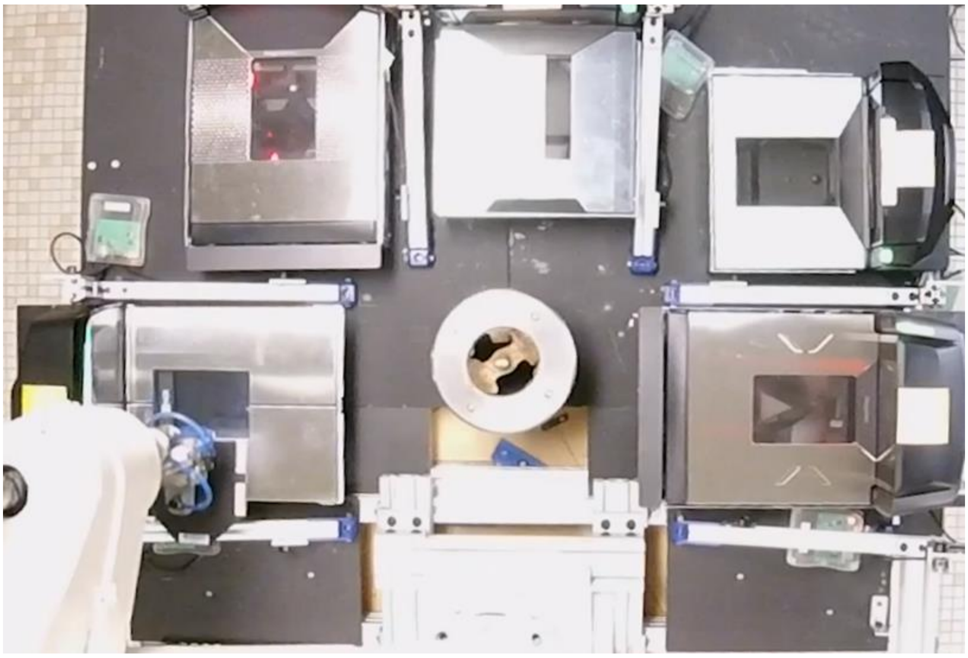

Figure 3-1 Scanning setup with robotic arm and POS scanners

The determination of the optimal test paths was conducted by determining the 2D barcode read zones for each scanner and then overlaying them so that a single common read zone was generated (see Figure 3-2 below). That is to say that the reading zone used for ALL scanners was only that zone which was common to ALL of the specifications for ALL of the scanners tested.

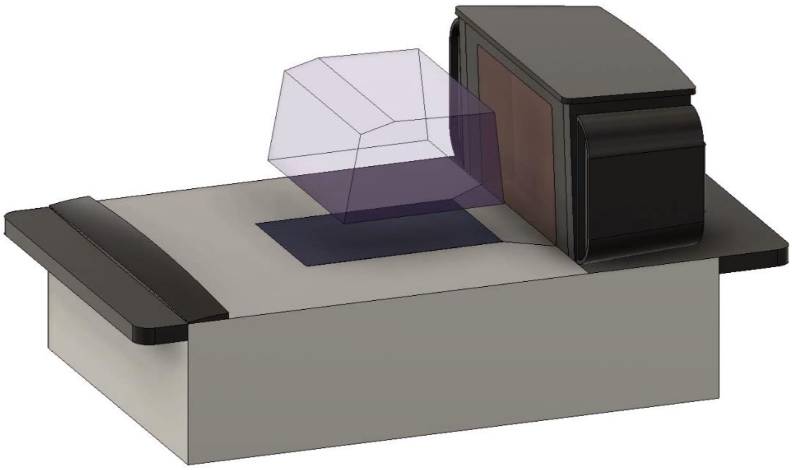

Figure 3-2 Optimal common 2D scanning envelope (transparent shape)

Once the optimal common path was determined, locating fixtures were created to ensure proper robot positioning. Scanner-specific horizontal plates and common 45º and 90º plates were created to aid in the positioning on the scanners (see Figure 3-3 below).

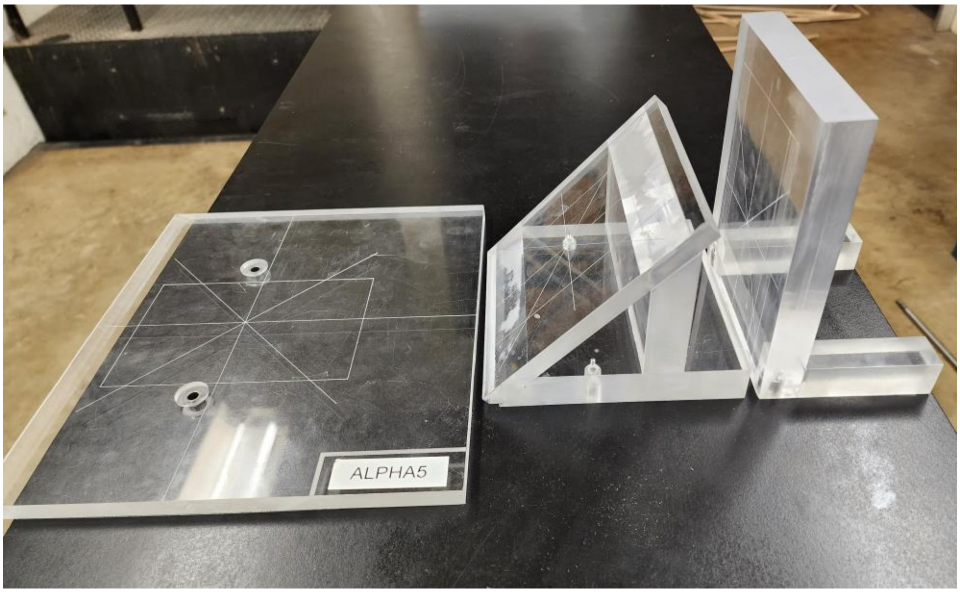

Figure 3-3 Robot positioning fixtures

3.3 Sample preparation

All test barcodes were mounted on fibreboard test cards. With the exception of their 6-inch width (to maximize the separation of the co-located symbols), the Tier 3.1 test cards were otherwise based on the Tier 1 and 2 cards. Unique card identifiers were associated to each test card to allow for the definitive identification (ID) of the test cards themselves. Barcodes were verified to report their print quality, which was additional data used to correlate and analyse scan results (see C Annex: Barcode verification data).

Figure 3-4 Example of Tier 3.1 test cards

The barcodes tested in Tier 3.1 were:

- Linear barcodes:
  - UPC-A (control, plain syntax) – EAN/UPC and benchmark
  - EAN-13 (control, plain syntax) – EAN/UPC
  - GS1 DataBar Expanded Stacked (GS1 element string syntax) - GS1 DataBar ES
- 2D barcodes:
  - GS1 DataMatrix (GS1 element string syntax) – GS1 DM
  - Data Matrix (GS1 Digital Link URI syntax) - DM

  - Data Matrix (Non-GS1 syntax and data) – DM Non-GS1 data
  - QR Code (GS1 Digital Link URI syntax) – QR Code
  - QR Code (Non-GS1 syntax and data) – QR Code Non-GS1 data
  - Digital watermarks (GTIN in proprietary format) - DW Prop
    - Digital watermarks formats are not global, open standards but can carry GS1 identification such as GTIN, and are referred to as a “proprietary format” in this report.
- For GS1-based encodings/syntaxes, data element combinations include:
  - GTIN, batch/lot number and expiration date
  - GTIN, batch/lot number, expiration date and domain name
  - GTIN, batch/lot number, expiration date and packaging component number
  - GTIN, batch/lot number, expiration date, packaging component number and domain name
  - GTIN, batch/lot number, expiration date and packaging component number
  - GTIN, batch/lot number, expiration date, packaging component number and domain name

Cards were grouped into the following categories shown in Table 3-1.

Table 3-1 Card grouping descriptions

Group	Description	Group	Description
1	DM & EAN	9	QR Code Non-GS1 data & UPC/EAN
2	GS1 DM & UPC-A	10	QR Code & Noise x4
3	QR Code & UPC-A	11	GS1 DM & GS1 DataBar ES
4	QR Code & EAN	12	DW Prop*
5	QR Code Non-GS1 data & UPC-A	13	GS1 DM & UPC-A
6	DW Prop* & GS1 DM	14	DW Prop* & UPC-A
7	QR Code Non-GS1 data & QR Code	15	Benchmark symbol
8	DW Prop* & DM	16	QR Code & EAN

* ”Prop” indicates a proprietary data encoded structure.

3.4 Testing process

Testing was conducted by a single robot that would pick up a single test card, present the unique test card identification (ID) number to an optical character recognition (OCR) scanner and then pass the test card with the barcodes over each of the five bi-optic POS scanners.

Scanning speed was maintained by the robot and the scan path was repeatable to within about 0.01 mm at any given point. The robot ran at the defined speed required for each test profile. Every test card was run through the test profiles ten times to maximise our ability to analyse the resulting data and to ensure that we could identify any anomalous runs.

The programmed robot was responsible for managing the test profiles, including card pick-up, rotation and tilt angle. Optical photoeye sensors detected the card entering the scanner and triggered the data acquisition system timers.

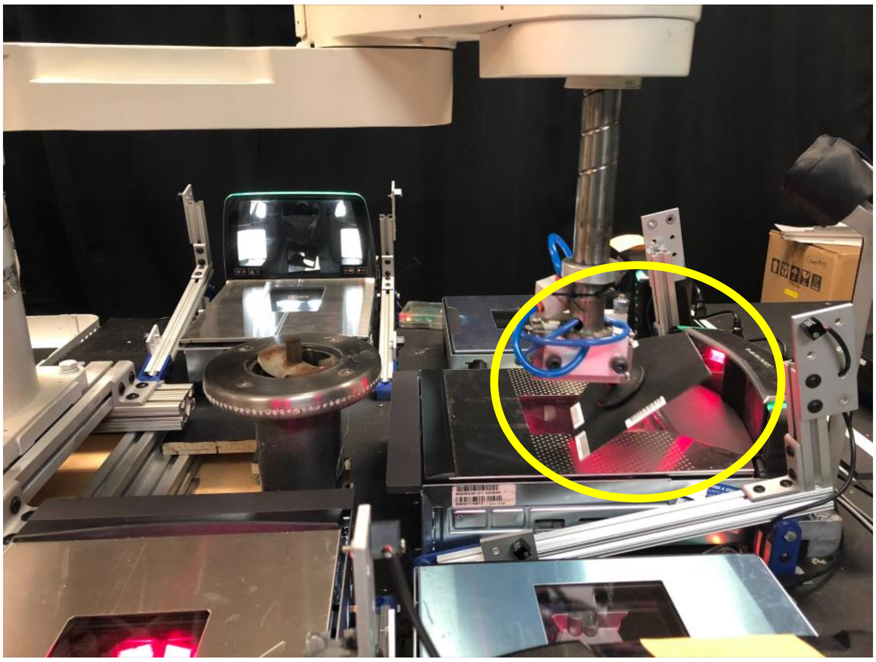

Figure 3-5 Bi-optic scanner with a card presented at 45° angle from horizontal

The scan count, scan time (time from trigger to data transmission time) and scanner decode data were all captured. Decoded data was compared to the expected data, based on the identification of the test card's carrier ID. All data was stored on local test lab servers.

3.5 Limitations

Tier 3.1 testing passed the test cards over each scanner within a consistent field of view (scan window) that was normalized across all scanners. These fields of view are optimised for single barcodes but are not necessarily optimised for co-located 2D barcodes.

- **Important:** This limitation may have impacted the Tier 3.1 data due to the nature of the tests and the fact that the cards were manually produced with a 0.5 mm variation in barcode positioning on the cards. However, this placement variation only impacted those cards in which the outer limits of symbol placement were being tested and adds to the argument that extreme distancing of co-located symbols will result in inconsistent results at the point-of-sale (POS).

4 Test results and observations

Tier 3.1's tests were designed to answer the most pressing questions coming from industry:

1. How well do the scanning systems handle multiple barcodes on-pack?
   a. Will the host POS system understand that the GTINs from multiple barcodes are from the same package and prevent a double scan?
2. How should the barcodes be placed in relation to each other for optimised scan results?
3. Can POS scanners identify linear and 2D barcodes encoded with GS1 data structures and differentiate non-GS1 encodings?
4. Is the decode time of multiple barcodes on a single product acceptable to retailer host systems?

Before answering the above questions, a global solution provider community came together with GS1 to develop solutions to identify and optimise how the data would be delivered to the host POS system from multiple barcodes on a common package. Of the 40 ideas proposed, the solution provider community selected three solutions for testing. In the Tier 3.1 testing the scanner solution providers delivered new software that incorporated the most versatile of the three solutions. The chosen solution approach allows scanners to identify multiple sets of data from each scanned barcode in a way that ties each set of data accurately to the product/package it was scanned from (e.g., GTIN for UPC-A and same GTIN + additional data from a QR Code using GS1 Digital Link URI syntax).

Question 1: How well do the scanning systems handle multiple barcodes on-pack and will the host POS system understand that the GTINs from multiple barcodes are from the same package and prevent a double scan?

Section 4.1 through 4.6 answer the question of how well the scanning systems handle multiple barcodes on-pack. All scanners could deliver data from both barcodes at required retail throughputs of 40 to 70 items per minute (IPM). The average combined decode time for the scanners to deliver both sets of GS1 data was approximately 0.603 seconds, when movement/travel time is excluded. For a 72 IPM scan rate, a product is in a retail associate's hands for an average of 0.833 seconds. The 0.602 second scan time means there will be no required slowdown to the retail checkout process, as the scanners are responding faster than a retail associate can reasonably move the flow of products.

Co-located barcode scan rates were divided into first and second barcode measurements (the order in which the barcodes were delivered to the host system). Results were affected by barcode separation, as robotic paths challenged the scanners field of view. At highest speeds, the scanners decode algorithms were also challenged. When the robotic path presents barcodes to the scanner within the scanning window, and when the co-located barcodes are between 15-50mm from each other, the results showed excellent horizontal scan plane results (between 95%-100%) and very good vertical scan plane results (above 88%).

There was a concern expressed by some constituents that an increase in the number of barcode decoding algorithms that are enabled on a scanner could slow down processing speeds of the tested scanners. In Tier 1 and Tier 2 tests, results did not show any correlation between the number of decoding algorithms that were enabled and the decode time of the barcodes under test, even with fourteen barcode decoding algorithms enabled at the same time. Despite having strong data from the prior tests, this testing profile was still included in the Tier 3.1 testing. Despite the added complexity of multiple symbols being presented side-by-side, there was **still no discernible difference in the average scan rates or decode times for the first barcode** when co-located barcode (2 or 3 barcodes) test cards were run.

Regarding the concern around the host POS system understanding that the GTINs from multiple barcodes are from the same package (and to prevent a double scan), the scanner solution providers implemented a common solution that added a label identification header to all barcode data delivered to the host POS system within a predetermined time window. If the test card had more than one barcode carrying a GS1 data structure, then every decoded data structure received the same identification header ensuring the host POS system could identify that the data was from the same package.

The scanner software generates host messages that contain common **label identification** for all **GS1 data encoded** (i.e., plain, GS1 element string and GS1 Digital Link URI) with **symbology identifiers**. Note that how the data displays is based on the scanner software, so symbology identifiers and other elements may appear differently than what is seen in other systems. An example extract of data that shows each of these parts of the host messages are represented:

- S08$n00007715G00952182201112
- S08$n00007715Dg]d2010095218220111210ABC123<GS>17271231
  Photoeye event (next pass with same test card and scanner)
- S08$n00007106G00952182201112
- S08$n00007106Dg]d2010095218220111210ABC123<GS>17271231

The tested systems showed that data that came from the same label or package could be reliably correlated to the correct package, which is a capability that, when implemented, should ensure the host POS system doesn't double charge a customer. The proof-of-concept work that enabled our Tier 3.1 testing is expected to be able to be tailored to any retailer's needs.

In summary, the high-level answer to Question 1 is that some software updates to the scanner under test were needed and that, once implemented, these software changes ensured that the updated scanners that were tested will support co-located barcodes on a single package in the retail scanning environment without a need to replace the hardware.

Question 2: How should the barcodes be placed in relation to each other for optimised scan results?

While many of the test results were affected by the separation distances for the co-located barcode test profiles, section 4.4 through 4.6 focus specifically on the placement of the barcodes in relation to each other.

All barcodes require minimum amounts of space around them (called a "quiet zone"). These quiet zones exist because the decode algorithms need to be able to identify where the edges of the barcode are.

The data revealed that a barcode separation between the minimum quiet zone and 50 mm performed well across all tests. When the separation between two barcodes exceeded 100 mm, the co-located barcode scan rate dropped below acceptable levels. Anything greater than 100 mm barcode separation translated into poor scan rates and it should be expected that this would create challenges for a retail associate at a POS terminal.

Question 3: Can POS scanners identify linear and 2D barcodes encoded with GS1 data structures and differentiate non-GS1 encodings?

An important new feature that the scanner solution providers implemented is the ability to identify linear and 2D barcodes that are encoded with GS1 data structures and to be able to differentiate non-GS1 encodings. Section 4.7 focuses on this new capability.

Test cards included examples of Data Matrix and QR Codes with non-GS1 data structures both in combination with linear or 2D barcode encoded with valid GS1 data structures. The results show that the four scanners that received the software update correctly differentiated all barcodes encoded with non-GS1 data structures.

NOTE: The BETA3 scanner (which was the one scanner that was not updated with any software changes) demonstrated why retailers today often disable the POS scanner's ability to read QR Code and Data Matrix, as it sent data from non-GS1-encoded barcodes that the host POS system would likely not recognise. This is an important learning for retailers, who will need to ensure that their systems are updated before attempting to enable the reading of 2D barcodes. If scanner software is not updated, system delays may occur and manual intervention may be required.

Question 4: Is the decode time of multiple barcodes on a single product acceptable to retailer host systems?

Section 4.2 provides insight about the decode time of multiple barcodes on a single product. The decode times are acceptable to retailer host systems.

To understand the data, it is important to note that the first barcode scan time clock starts when the test system's photoeye (switch) detects the card before it crosses the scanner and continues to count until the scanner decodes and delivers the first barcode's data to the test system's thin client computer (acts as the host POS system). The second barcode scan time clock starts when the first barcode's data is delivered to the thin client computer and stops when the second barcode's data is delivered. Therefore, the scan time includes all the movement/travel time for the test card's barcodes.

We determined the actual decode time required for multiple barcodes on a single product by observing when the time difference between movement/travel time hits a minimum, as the effect of moving the second barcode into the scanner field of view had been minimised.

Results showed the data from the second barcode is delivered to the host POS system between 90 ms and 200 ms after the data from the first barcode , depending on the scanner. This is excellent news, as the host POS system should have time to deliver the information needed and this will ensure that the retail associate doesn't have to consciously wait to determine how to handle an item that may need additional attention (e.g., an item that should be pulled due to expiration or recall).

Additional observations include:

- Rotation of the test cards did not have a significant impact on the scan rates
- The presence of non-GS1 data did not have a significant impact on the read rates
- It was assumed that the linear (EAN/UPC) barcodes would be decoded first when a linear and 2D barcode enter the scanner field of view. This assumption was made because scanning algorithms for these linear barcodes have been optimised over the span of 45 years. However, **testing results showed that, at retail POS speeds, the linear or 2D barcode that enter the scanners field of view first was most often decoded first.**

4.1 Throughput at normal retail speeds, based on first barcode decoded

Based on retail stakeholder feedback collected during the Tier 2 study, GS1 estimates that a range of 40 IPM to 70 IPM is a very robust estimate of practical scanning throughput in retail stores. Using 70 IPM and assuming the average item size plus a practical scanning gap of 250 mm, the resulting barcode/package velocity is ~315 mm/s. At the low end of the range (40 IPM), the resulting barcode/package velocity is ~167 mm/s.

Within these speed ranges, the scanners all performed well on both 1D and 2D barcodes, with only a marginal decrease in times and scan rates when presented with multiple barcodes. (the robotic cell manages the barcode test card velocity as it moves/travels across the bi-optic scanners.)

The data show that, when barcodes are presented to the scanner within the scanning window and when the co-located barcodes are between 15-50mm from each other, both barcodes can be scanned and delivered to the host POS system within an acceptable amount of time. Additionally, adding the 0.25 second pause resulted in a significant performance improvement. For the Tier 3.1 testing, any use of the term “best practice” in this document is intended to mean:

- Stacked or adjacent barcodes placed between 15mm and 50mm apart from each other
- Barcodes are faced towards either horizontal or vertical camera
- Scan paths ensure all symbols are in the scanner’s field of view

Table 4-1 shows the potentially-achievable throughput (IPM) when scanning co-located barcodes that are placed between 15-50mm apart and at retail speeds. The results have been broken down to show the throughput rates for both the horizontal and vertical scan planes.

Table 4-1 Average throughput (IPM) by scanner for listed velocities

	Horizontal plane				Vertical plane			
Scanner	150 mm/s	300 mm/s	400 mm/s	1200 mm/s + pause	150 mm/s	300 mm/s	400 mm/s	1200 mm/s + pause
ALPHA2	63	100	117	144	47	80	95	145
ALPHA5	72	105	120	132	44	68	79	105
BETA3	41	65	78	88	44	65	76	73
DELTA0	42	66	76	90	35	58	70	89
DELTA1	48	83	102	143	41	75	86	146
Average	51	81	95	120	41	68	80	111

4.2 Barcode decode scan time across all tested speeds

The data show that the average scan time to deliver the first barcode to the host POS system when co-located barcodes exist on a package, including those that are greater than 100 mm apart, will still average around 0.5 seconds when excluding movement/travel time. When movement/travel time at the slowest throughput speed is included, the average decode time is around 1 second. See Table 4-2 for the scan time for the first barcode decoded. The most accurate measure of a true, combined imaging/decoding/transmit time for the first barcode for each scanner is, therefore, the set of times shown in the 288 IPM column of table 4-2 (which is highlighted in green).

Additional time to deliver the second barcode results is a measure that starts when the first barcode's data has been received by the host POS system. In co-located barcode scenarios, all barcodes must be scanned to ensure any relevant data is captured. For example, if the GTIN-only linear barcode is scanned first, any additional attributes will be delivered only by scanning the co-located 2D barcode. This is very significant as the time duration can dictate the host POS system's efficiency. Results showed the data from the second barcode is delivered to the host POS system within 200 ms after the delivery of the first barcode's data, ensuring that the retail associate does not have to consciously wait to determine if an item needs additional attention (e.g., pulled due to expiration or recall).

Table 4-3 and Figure 4-1 show the scan time to the second barcode, for all tested speeds. The reader should keep in mind that at the slower speeds, the time between when the system sees the test card and the time that the first barcode is in the read zone will be a significant component of the times seen. Additionally, all times are only relative to a specific scanner as specific efforts were not made to normalize the exact timing between the sensor and the beginning of the scan envelope of the scanners. The green zone in Figure 4-1 highlights when the travel time influence is minimal and reveals the actual additional scan time to deliver the second barcode. The reader may notice that BETA3 has longer scan read times, this scanner did not receive any update to the software and is still operating under a legacy configuration. If the currently installed bi-optic configurations are not updated, performance similar to BETA3 can be anticipated once co-located barcodes are introduced into the supply chain and reading of 2D symbols is enabled at these POS terminals.

Table 4-2 Time to first barcode by speed and scanner (milliseconds)

Scanner	36 IPM 150 mm/s	72 IPM 300 mm/s	96 IPM 400 mm/s	144 IPM 600 mm/s	192 IPM 800 mm/s	288 IPM 1200 mm/s	250 IPM 1200 mm/s + pause
ALPHA2	776.6	486.2	411.7	325.4	297.6	279.4	301.7
ALPHA5	623.0	415.1	355.1	296.0	269.5	238.1	270.2
BETA3	1092.0	637.3	519.5	404.9	391.3	365.6	388.8
DELTA0	1120.1	669.1	566.7	438.7	384.3	387.5	422.0
DELTA1	1131.3	639.6	520.4	397.1	338.5	289.8	344.9

NOTE: All above times include time of package movement/travel, which is why the slower throughput times are so much larger than the higher-throughput times.

Table 4-3 Additional time to deliver second barcode results, by speed and scanner (milliseconds)

Scanner	36 IPM 150 mm/s	72 IPM 300 mm/s	96 IPM 400 mm/s	144 IPM 600 mm/s	192 IPM 800 mm/s	288 IPM 1200 mm/s	250 IPM 1200 mm/s + pause
ALPHA2	189.1	112.7	100.3	90.3	84.6	84.1	108.2
ALPHA5	214.9	160.1	147.0	142.9	139.3	129.9	186.9
BETA3	401.2	296.8	266.3	228.9	203.2	203.6	301.3
DELTA0	268.7	227.4	209.5	190.5	179.6	169.3	229.3
DELTA1	183.1	120.6	101.9	89.6	89.5	87.5	110.1

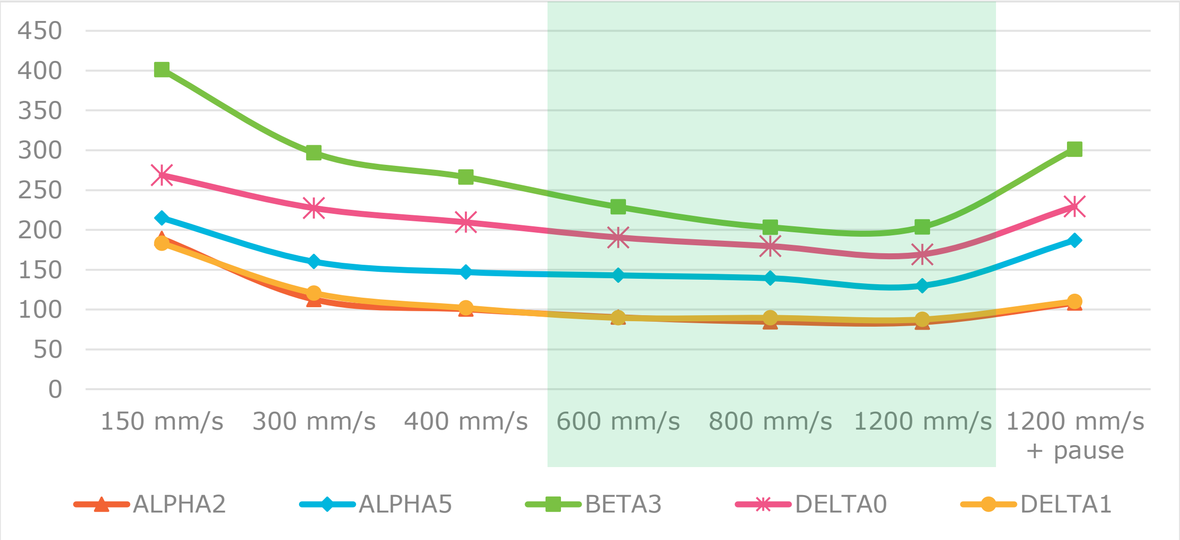

Figure 4-1 Time to second barcode (milliseconds)

4.3 Scan rates for barcodes encoded with GS1 data structures across all tested speeds

Figure 4-3 shows scan rates that are currently possible when barcodes are presented to scanners within their specified field of view and when barcodes are placed between 15mm and 50mm apart.

The figure has been broken out into individual barcode trend lines and shows the scan rates as a percentage of passes in which the scanners found and decoded the barcode in a single scanner optical plane. Tests included in the below chart were limited to either fully horizontal or vertical (tests with the card at a 45º tilt were excluded as there is no way to attribute a scan to an individual scanner plane’s camera).

The scan rate data reveals several important findings:

1. The data shows that, while there is a slight reduction in performance for 2D barcodes when compared to linear barcodes, the performance is still reasonable and is not expected to adversely affect the retail scanning experience.

2. The scanners had predominantly positive results until the speeds exceeded realistic retail checkout speeds.
3. QR Code scan rate continues to be better than other 2D barcodes, which is consistent with our Tier 2 findings.
   a. The Data Matrix family scan rate is lower than QR Code, however multiple retailers around the world have successfully adopted GS1 DataMatrix for fresh food application and have not experienced a drop in productivity.
4. Co-located barcodes printed within standard size limits perform similarly across all tests.
5. Adding the 0.25 second pause resulted in a significant performance improvement.
   a. This unique test card movement scenario was included in our testing because the inclusion of a pause is representative of many consumer and checkout operator's natural movements.
   b. The exceptional results from the testing of this scenario (which correlates to a theoretical throughput of 250IPM) add confidence to the results that we expect from real-world, in-retailer pilots.
6. Average scan rates for the 2D barcodes are:
   a. Lower than the scan rates of linear barcodes, which was expected.
   b. Similar on both the horizontal and vertical planes of scan.
   c. Similar regardless of whether the scanner must interpret GS1 Digital Link URI data or not.

These findings indicate two things. First, there is still room for improvements to 2D decoding algorithms. Second, the presence of a second barcode has a minimal impact on scanner performance.

This section shows the results when barcodes are presented to the scanner at test profile heights, rotations and speeds within the scanning window and when the co-located barcodes are between 15-50mm from each other. It should be noted that there was no discrimination in barcode trend lines as to whether the indicated barcode was scanned first or second, which may result in some skewing of rates.

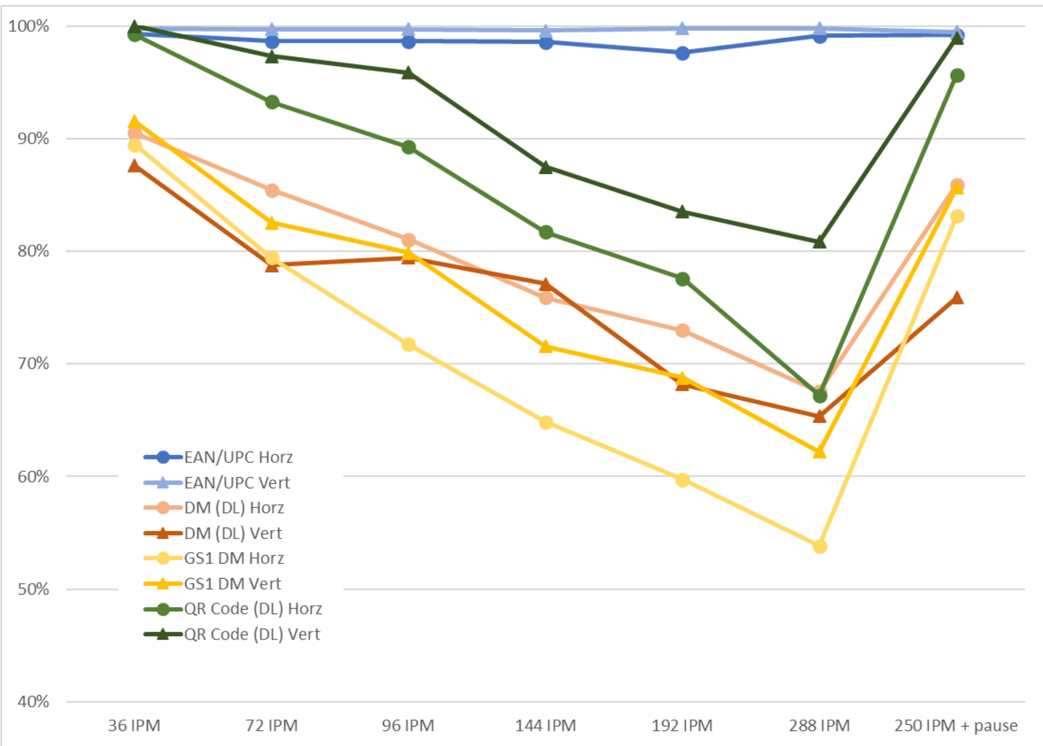

Figure 4-3 Average scan rate by speed and barcode for all tested speeds

4.4 Scan rates of co-located linear and 2D barcode types across all tested speeds

This challenging test has the test cards being exposed to all test profile detailed in Section 3.1. Tables 4-4 and 4-5 show the scan rate for test cards where a linear (EAN/UPC, GS1 DataBar) barcode was paired with a 2D barcode with valid GS1 data structures (GS1 element string or GS1 Digital Link URI), but where the two barcodes were separated by the largest spacing (“far”). It should be noted that there was no discrimination in these tables as to whether the 2D barcode was scanned first or second, which may result in some skewing of rates.

Data shows that the first barcode scan rates went down marginally and the second barcode scan rates dropped more significantly when compared to the best practice scan rates. This revealed that barcodes that are over 100mm apart are unlikely to scan at acceptable retail speed, making positioning of co-located barcodes critical.

- Note: DELTA1 was performing correctly but was removed from Table 4-4 and 4-5 due to intermittent data transmission issues in later testing that resulted in data losses and therefore inaccurate overall scan rates.

Table 4-4 Scan rate for first barcode with co-located linear and 2D barcodes

Scanner	36 IPM 150 mm/s	72 IPM 300 mm/s	96 IPM 400 mm/s	144 IPM 600 mm/s	192 IPM 800 mm/s	288 IPM 1200 mm/s	250 IPM 1200 mm/s + pause
ALPHA2	92.1%	91.4%	90.9%	90.2%	89.6%	88.9%	92.9%
ALPHA5	92.2%	96.7%	97.1%	97.1%	96.3%	95.7%	98.6%
BETA3	97.9%	95.6%	94.0%	91.7%	89.9%	88.0%	96.9%
DELTA0	96.5%	95.9%	94.6%	92.7%	91.1%	89.6%	95.5%

Table 4-5 Scan rate for second barcode with co-located linear and 2D barcodes

Scanner	36 IPM 150 mm/s	72 IPM 300 mm/s	96 IPM 400 mm/s	144 IPM 600 mm/s	192 IPM 800 mm/s	288 IPM 1200 mm/s	250 IPM 1200 mm/s + pause
ALPHA2	61.5%	57.8%	55.4%	51.7%	48.9%	46.9%	58.7%
ALPHA5	81.5%	70.3%	66.3%	58.4%	52.0%	45.2%	76.7%
BETA3	62.9%	52.4%	46.8%	33.9%	26.8%	23.4%	66.9%
DELTA0	71.7%	62.5%	55.7%	46.8%	41.8%	37.0%	66.1%

4.5 Rotation in plane and tilt angle comparison

The effect of barcode rotation in plane and tilt angle toward vertical cameras were explored and shown to have a minimal effect on scan rates with the exception of the scenarios where the co-located barcodes were spaced over 100 mm apart. The barcode rotations and tilt angles were tested across varied surface offset and velocity settings. This test was designed to isolate and identify any concern with the direction or tilt of the barcode as it passes over the scanner. Rotating the barcode test card in plane did not appear to significantly impact the scan rate within a symbology. The variations shown in Figure 4-4 are more attributable to spacing than the rotation.

Figure 4-4 shows the results, plotted by scan rate against the rotation or tilt that was applied to the test card.

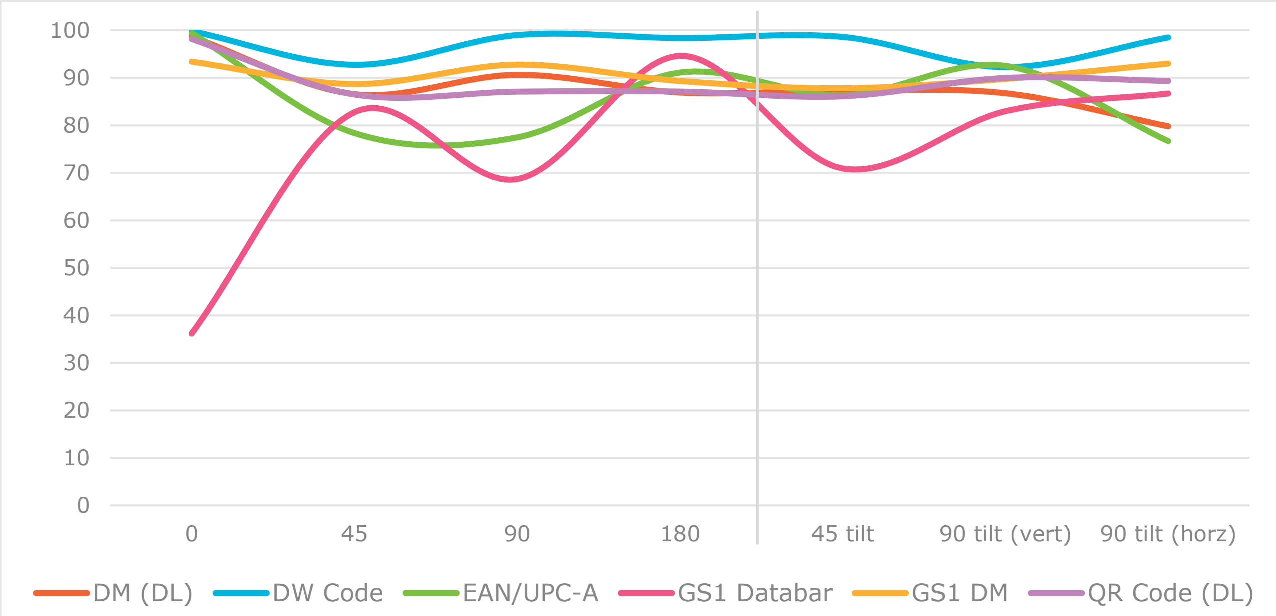

Figure 4-4 Representative sample* of barcode scan rate by rotation and tilt scan rate across all tested speeds (%) (* sample is without BETA3, at 150mm/s at all barcode spacings)

The “90 tilt (horz)” category in Figure 4-4 (above) refers to the card’s orientation relative to the scanner. In the course of running the tests and analysing the data it was realized that the “90 deg. tilt” test had the card in the equivalent of the “0 deg.” horizontal test. What this did was push the wider barcode samples out of the functional scan windows for most of the scanners, resulting in artificially low results. Figure 4-5 (below) shows the card’s physical orientation to the scanners.

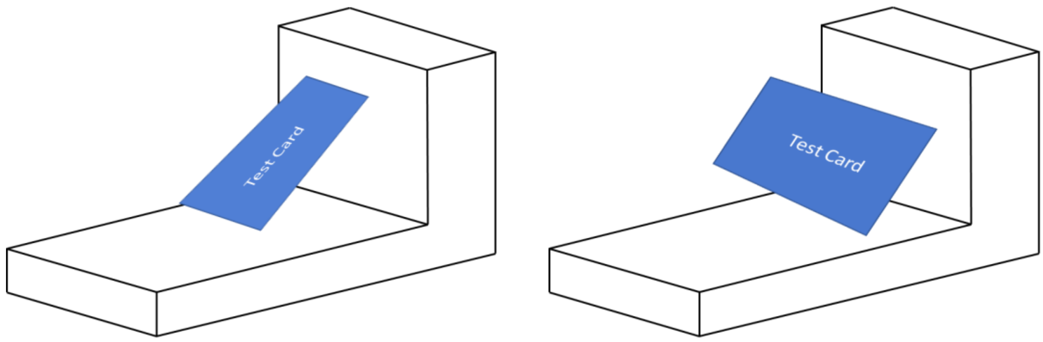

Figure 4-5. Test card orientations for “90 deg. tilt (vert)” (left) and “90 deg. tilt (horz)” (right).

4.6 Scan rate comparison for co-located barcode separation, across all tests (150 to 1200 mm/s)

As previously discussed, there were three levels of separation of the co-located barcodes used in the testing:

- Stacked or side by side samples less than 15 mm or “near”.

Figure 4-6 Sample of a near card

- Stacked or side by side samples between 15 mm and 50 mm or "mid".

Figure 4-7 Sample of a mid-separation card

- Side by side samples over 100 mm apart or "far".

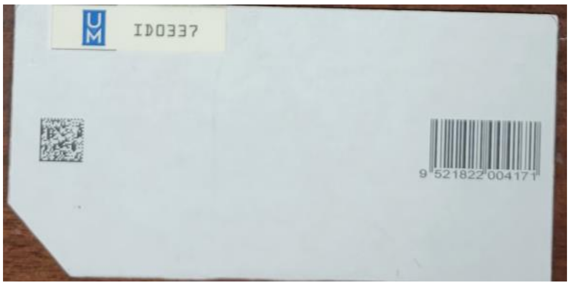

Figure 4-8. Sample of a far card (maximum separation distance based on test card size)

As explained earlier in this report, all GS1 barcodes require minimum amounts of space around them, called quiet zones. The three spacing were selected to learn more about scanner performance and to define some of the "best practices" that might be shared with industry.

All of the test cards were exposed to all test profiles (heights, rotations, speeds, …) detailed in Section 3.1 to determine optimal co-located barcode relative positioning.

The data shows excellent barcode scan rates for the first barcode for all separations. However, second barcode scan rates dropped below acceptable levels for barcodes that are over 100 mm apart. The co-located, 100 mm apart barcode cards performed poorly in the horizontal axis when the test included optimal +/- 25 mm paths. This means that, unless the retail associate passes the item's barcodes over a very specific area of the scanner field of view, the second barcode will not be effectively captured. This can result in missed data or double scan of the item.

Barcode separations up to 50 mm performed well across all tests, when considering the combination of scan rates for both barcodes.

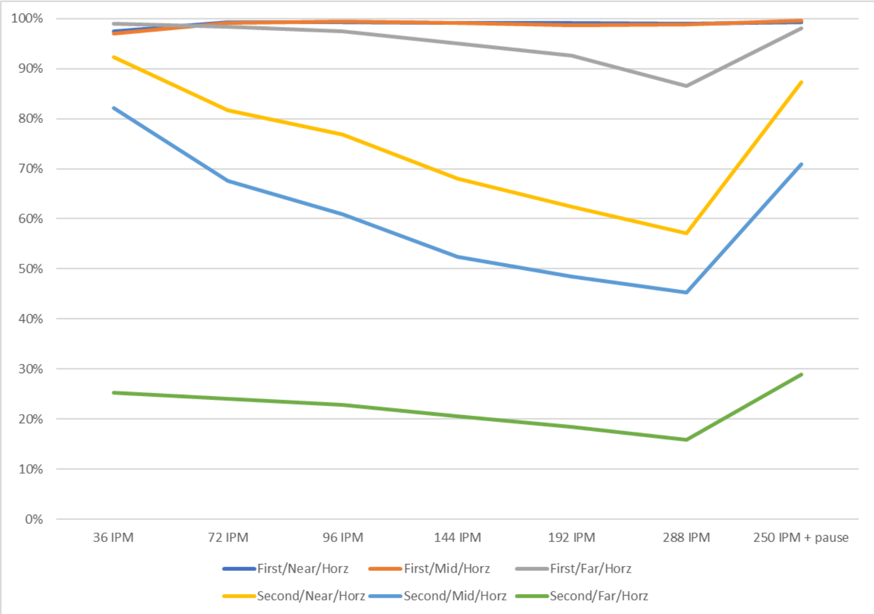

Figure 4-9 Horizontal scan rate by barcode separation

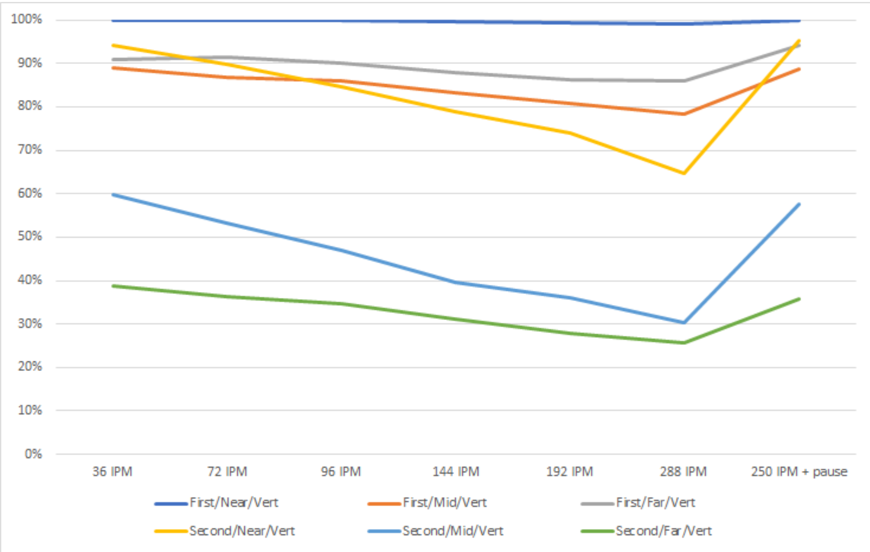

Figure 4-10 Vertical scan rate by barcode separation

Figure 4-11 breaks out the tests where the tilt of the barcode was at 45º between the two cameras (horizontal and vertical). The result of this tilt is that there is no reasonable method for determining which camera (horizontal or vertical) decoded the barcodes. In fact, for some samples it is altogether possible that each camera decoded one of barcodes, depending on their distance to the camera and where within the fields of view of each camera the actual barcode landed. Even accounting for this scenario, missed and duplicate scans of a single test card were not experienced.

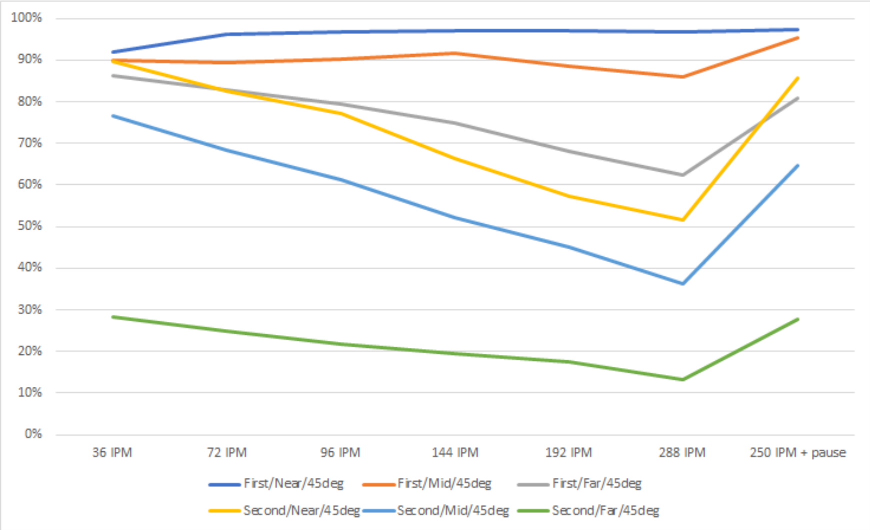

Figure 4-11 45º tilt scan rate by barcode separation

4.7 Barcodes encoded with non-GS1 data structures

As previously mentioned, there were barcodes not containing GS1 data structures included in the Tier 3.1 testing. There were also two levels of auto-discrimination configuration programmed into the scanners.

1. Configuration 1: EAN/UPC, GS1 DataBar Expanded Stacked, GS1 DataBar Omnidirectional, Data Matrix and QR Code
2. Configuration 2: EAN/UPC, GS1 DataBar Expanded Stacked, GS1 DataBar Omnidirectional, Data Matrix, QR Code, ITF-14, PDF417, Code 128, ISBN, digital watermark

Test cards with one barcode encoded with a GS1 data structure and one barcode with non-GS1 data structures were tested to confirm that for those scanners where the configuration/software was updated, non-GS1 data was being properly filtered out. The data show that this functionality is working correctly where applied and that there is no difference in scan rates between Configuration 1 and Configuration 2. This means that the auto-discrimination functionality did not impact scan rates. Additionally, the data show that the time to report the data from the second barcode is still in line with what was seen with GS1 data structures, which indicates that there is no significant impact when filtering is enabled to only pass-through data from GS1-structured barcodes.

Test data included both Data Matrix and QR Codes with non-GS1 data structures, both in combination with valid GS1 data structures and where both barcodes contained non-GS1 data structures. Digital watermarks were included in the data to show how the scanners performed when attempting to decode a digital watermark in addition to linear or 2D barcodes containing GS1 data structures. Digital watermark formats are not globally open standards but can carry GS1 identification such as GTIN.

Figure 4-12, below, shows the scan rates at differing speeds for the second barcode being decoded. Previously it was mentioned that non-GS1 data was being filtered out. **Read rates of 0% are desirable** in Figure 4-12, as the capability of distinguishing between GS1 data structures and non-GS1 encodings in 2D barcodes allows the retailer to have confidence that the right barcode can be identified for the right purpose. The reason BETA3 is showing scan rate data is that the scanner was not updated to differentiate between GS1 data structures in barcodes vs. non-GS1 data structures in barcodes. BETA3 represents what would happen if retailers simply enabled QR Code and Data Matrix without any software updates to unlock the capability to isolate barcodes carrying non-GS1 data.

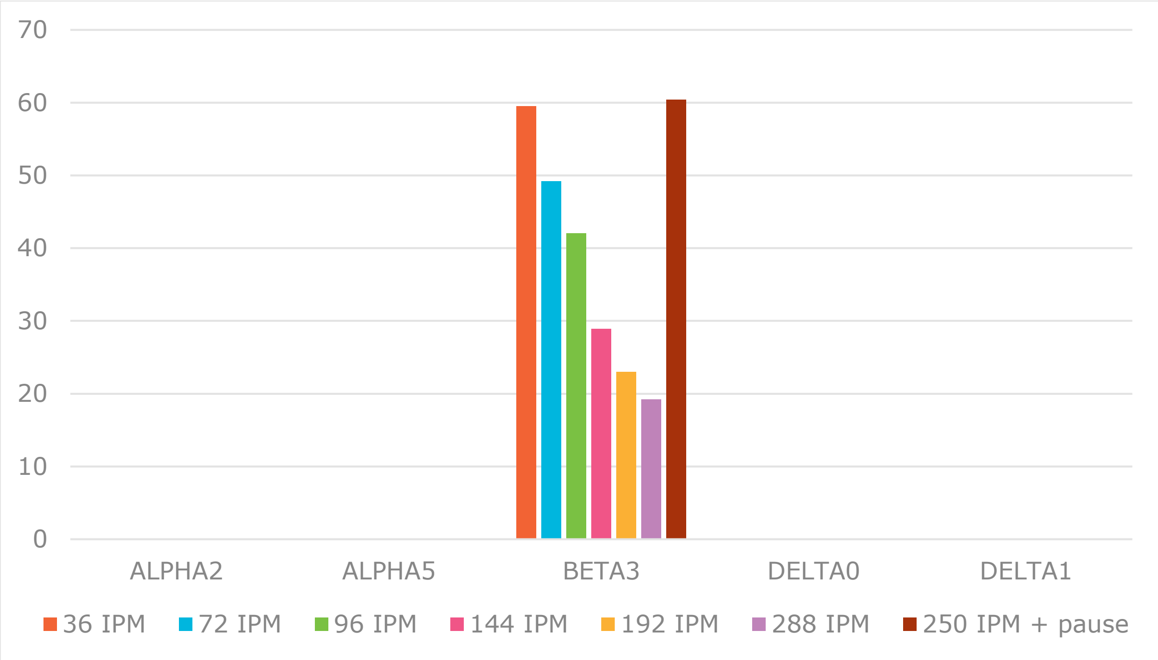

Figure 4-12 Non-GS1 syntax second barcode decoded Scan Rate encoded with non-GS1 data structures - all tests (one barcode with GS1 data structures and one barcode with non-GS1 data structures)

4.8 Scan rates by barcode decode order

One of the items of interest was the determination of the sequence that the scanners were processing the barcodes. Before the testing began, it was assumed that the linear barcodes would be decoded first. During the testing, we decided to try to determine if the data was able to provide any insights into this topic. The data revealed that at retail speeds**, linear barcodes (EAN/UPC) are not favoured over 2D barcodes**. However, as card movement/travel time speeds increased the strength of the scanner's EAN/UPC decode algorithms causes the decode rate to increase over every other barcode type. See Table 4-6,

Table 4-6 First barcode decoded percentage breakdown (150 – 1200mm/s)

Scanner	36 IPM 150 mm/s	72 IPM 300 mm/s	96 IPM 400 mm/s	144 IPM 600 mm/s	192 IPM 800 mm/s	288 IPM 1200 mm/s	250 IPM 1200 mm/s + pause
EAN/UPC-A	44.7%	49.1%	51.2%	54.2%	56.1%	57.8%	51.4%
QR Code (DL)	24.2%	22.1%	21.2%	20.0%	19.3%	18.7%	21.0%
GS1 DM	16.2%	15.0%	14.5%	13.7%	13.0%	12.7%	14.5%
DM (DL)	7.7%	6.5%	5.9%	5.1%	4.8%	4.4%	5.9%
DW Code	4.7%	4.7%	4.6%	4.5%	4.4%	4.2%	4.6%
GS1 DataBar	2.5%	2.7%	2.6%	2.6%	2.4%	2.2%	2.6%

The rate at which the first barcode is decoded appears to align with both the barcode population and the barcode seen first. Therefore, more testing needs to be undertaken to determine if there's an advantage to placing the 2D barcode in a certain position relative to the linear barcode.

Figure 4-13 Co-located barcode with QR Code (GS1 Digital Link URI) leading the UPC-A

5 Conclusions and recommendations

Conclusions

Tier 3.1 lab testing shows that co-located barcodes can be introduced into the retail environment with existing scanner hardware that is fitted with necessary software updates, and that such updates should not negatively impact current retail processes. However, retail store pilots are necessary to confirm these findings.

Real-world implementations will allow retailers to continue to extract the GTIN information for price lookup and will also introduce additional value-added functionality such as expiration date or batch/lot number when embedded in 2D barcodes containing GS1 data structures.

The scanner manufacturers agreed that the rigors of the Tier 3.1 tests were a challenging representation of the retail POS scan environment and verified that the scanners with these updates could perform the following functions for co-located barcodes at expected retail speeds and throughputs:

- Capture, filter for and deliver GS1 data (including extended elements such as batch/lot and expiry data), while ignoring non-GS1 data, at retail scanning speeds.
- Ensure co-located barcode data containing GS1 elements on a single package are correctly associated with the scanned item (ensuring proper price look-up for that single item, no double scans), with additional data being delivered in under 200ms from the moment of initial scan.
- Enable additional decode algorithms with no significant impact on decode times or scan rates, even in the presence of co-located barcodes on the same package.

Recommendation for additional testing

From the scan rates by barcode decode order test (section 4.8) whether the leading barcode is always decoded first could guide symbol placement recommendations that would help brands and retailers design packaging based on which barcode they deem should be scanned first. The majority of high-volume POS scanners have a right to left scanning motion which was utilized in these Tiered tests. Additional tests need to be undertaken to evaluate the potential of recommending where the 2D barcode should be positioned in relation to the linear barcode as a best practice.

It is important to note that the data in this Tier 3.1 report does not include any additional optical disturbances surrounding the barcodes (label graphics, reflective surfaces, curved surfaces, etc) or other retail scanner types.

Therefore, the University of Memphis and GS1 have planned a next phase of testing to:

- Determine if the 2D barcode should be placed in a certain position relative to the linear barcode
- Expand the co-located barcode testing to include "real-world analogue" challenges (e.g., label graphics, curved surfaces, varying X-dimension combinations, reflective surfaces, etc.)

- Expand the testing to other retail scanning solutions (e.g., presentation and hand-held scanners – see Figure 5-1)

Note: Future tests (even beyond the above) will need to be done to understand how earlier generations and other manufacturers' bi-optic scanner solutions decode the Tier 3.1 barcode test cards. We are hopeful that those scanner manufacturers who have been involved with the testing in this report will be able to accurately extrapolate the data from this Tier 3.1 testing to their own prior-generation scanners, as such extrapolation will allow the existing install base of scanners to be more accurately evaluated for updateability.

Scanner manufacturers, the University of Memphis and GS1 recommend that **retail store pilots are now needed to continue the learning and vetting of POS scanner improvements**, and that such pilots should begin with earnest around the world. It is also important to note that a lab robot cannot truly simulate human motions, and we expect that retail pilots will better reflect operational conditions and other factors present in a live environment.

Figure 5-1 An example of a presentation (left) and handheld (right) scanner.

A Annex: Tier 3.1 barcodes

During the Tier 3.1 test, 48 cards were tested. The barcodes varied in:

- 1D barcodes
  - UPC-A (control, plain syntax)
  - EAN-13 (control, plain syntax)
  - GS1 DataBar Expanded Stacked (GS1 element string syntax)
- 2D barcodes:
  - GS1 DataMatrix (GS1 element string syntax)
  - Data Matrix (GS1 Digital Link URI syntax)
  - Data Matrix (Non-GS1 data)
  - QR Code (GS1 Digital Link URI syntax)
  - QR Code (Non-GS1 data)
  - Digital Watermarks (GTIN in proprietary format)
    - Digital watermarks formats are not globally open standards but can carry GS1 identification such as GTIN, therefore a proprietary format or structure.

- Encoded data element combinations include:
  - GTIN, batch/lot number and expiration date
  - GTIN, batch/lot number, expiration date and domain name
  - GTIN, batch/lot number, expiration date and packaging component number
  - GTIN, batch/lot number, expiration date, packaging component number and domain name
  - GTIN, batch/lot number, expiration date and packaging component number
  - GTIN, batch/lot number, expiration date, packaging component number and domain name

Below image show a sample of the barcodes created for the test on the test card carriers. No barcode from outside of the GS1 system (e.g., Code 39, MaxiCode, JAB Code, etc.) were used in this testing.

Figure A-1 Barcode test cards

The table below shows the different barcodes and the characteristics of the barcodes.

- **Note:** The data encoded was a GTIN + attributes unless the barcode were a QR Code or Data Matrix, in which case a GS1 Digital Link URI was encoded to comply with the minimum requirements.

Table A-1 Tier 3.1 test card barcodes

CardID	Grp	Filter1	Filter2	Filter3	Filter4
ID0329	1	DM	EAN	DM & EAN	Trunc-Near
ID0330	1	DM	EAN	DM & EAN	Mid
ID0332	1	DM	EAN	DM & EAN	Mid
ID0333	1	DM	EAN	DM & EAN	Near
ID0337	1	DM	EAN	DM & EAN	Far
ID0341	1	DM	EAN	DM & EAN	Near
ID0317	2	GS1 DM	UPC-A	GS1 DM & UPC-A	Trunc-Near
ID0318	2	GS1 DM	UPC-A	GS1 DM & UPC-A	Mid
ID0319	2	GS1 DM	UPC-A	GS1 DM & UPC-A	Near
ID0320	2	GS1 DM	UPC-A	GS1 DM & UPC-A	Mid
ID0338	2	GS1 DM	UPC-A	GS1 DM & UPC-A	Far
ID0358	2	GS1 DM	UPC-A	GS1 DM & UPC-A	Near
ID0301	3	QR Code	UPC-A	QR Code & UPC-A	Mid
ID0302	3	QR Code	UPC-A	QR Code & UPC-A	Near
ID0303	3	QR Code	UPC-A	QR Code & UPC-A	Mid
ID0304	3	QR Code	UPC-A	QR Code & UPC-A	Near
ID0340	3	QR Code	UPC-A	GS1 DM & UPC-A	Far
ID0309	4	QR Code	EAN	QR Code & EAN	Near
ID0310	4	QR Code	EAN	QR Code & EAN	Near
ID0311	4	QR Code	EAN	QR Code & EAN	Mid
ID0312	4	QR Code	EAN	QR Code & EAN	Mid
ID0339	4	QR Code	EAN	QR Code & EAN	Far
ID0305	5	QR Code Prop	UPC-A	QR Code Prop & UPC-A	Near
ID0313	5	QR Code Prop	EAN	QR Code Prop & EAN	Mid
ID0325	5	DM Prop	UPC-A	DM Prop & UPC-A	Near
ID0328	5	DM Prop	EAN	DM Prop & EAN	Near
ID0315	6	WM Prop	GS1 DM	WM Prop & GS1 DM	Near
ID0322	6	QR Code Prop	GS1 DM	QR Code Prop & GS1 DM	Near
ID0323	6	DM Prop	GS1 DM	DM Prop & GS1 DM	Near
ID0306	7	QR Code Prop	QR Code	QR Code Prop & QR Code	Near
ID0314	7	DM Prop	QR Code	DM Prop & QR Code	Near
ID0335	7	WM Prop	QR Code	WM Prop & QR Code	Near
ID0324	8	WM Prop	DM	WM Prop & DM	Near
ID0326	8	QR Code Prop	DM	QR Code Prop & DM	Near
ID0334	8	DM Prop	DM	DM Prop & DM	Near
ID0300	9	QR Code Prop	QR Code	UPC-A	QR Code Prop & QR Code
ID0308	9	DM Prop	QR Code	EAN	DM Prop & QR Code
ID0336	9	WM Prop	QR Code	UPC-A	WM Prop & QR Code
ID0307	10	QR Code	Noise x4	QR Code & Noise x4	
ID0327	10	GS1 DM	Noise	GS1 DM & Noise	
ID0342	10	GS1 DM	Noise x4	GS1 DM & Noise x4	
ID0343	11	GS1 DM	DataBar ES	GS1 DM & DataBar	Near
ID0344	11	QR Code	DataBar ES	QR Code & DataBar	Near
ID0316	12	DM Prop	GS1 DM	WM Prop	DM Prop & GS1 DM
ID0321	13	GS1 DM	UPC-A	GS1 DM & UPC-A	Near
ID0345	14	WM Prop	UPC-A	WM Prop & UPC-A	Near
ID0346	15	UPC-A			
ID0357	16	QR Code	EAN	QR Code & EAN	Near

B Annex: Test profiles

Thirty-eight different test profiles, summarised in the table below, were run to analyse and understand the scan rates of different barcodes. The parameters that were adjusted are explained as follows:

1. The number of enabled barcode decode algorithms varied from a limited selection, only looking for expected barcodes (Config1), to the full suite of test, which included the enabling of all decoding algorithms for all barcodes turned on within the scanner. The following symbologies were enabled as the full suite of test (Config2) in all scanners: Data Matrix, QR Code, GS1 DataBar Expanded Stacked, GS1 DataBar Omnidirectional, EAN/UPC, ITF-14, PDF417, Code 128, Code 39, ISBN, digital watermark
2. When the barcode symbol was passed in front of the scan window, the height or distance from the scan window was tested at 12.5, 55mm.
3. Horizontal offsets (scanner optimal scan location, optimal +25 mm, optimal -25 mm)
4. The barcodes were passed in front of the scan window at the following speeds: 150 mm/s, 300 mm/s, 400 mm/s, 600 mm/s, 800 mm/s, 1200 mm/s and at 1500mm/s + a 250ms pause.
5. The barcodes were presented at different tilt angles from parallel to the scan window: 0°, 45°, and 90°.
6. Within the parallel presentation to the scan window, the barcodes were rotated clockwise: 0°, 45°, 90°, and 180°.

The full test matrix is shown in Table B-1, below.

Table B-1. Test Matrix

Auto Discriminate	Horizontal Offset (mm)	Vertical Offset (mm)	speed mm/s	Tilt Angle from Horizontal	CW Rotation in Plane	Test ID
Config 1	0	12.5mm & 55mm	all (150, 300, 400, 600,1200 & 1500 1/4 pause)	0	0	test8
					45	test9
					90	test10
					180	test11
				45	0	test13
				90	0	test15
Config 1	Nominal + 25	12.5mm & 55mm	all	0	0	test24 (8)
					45	test25 (9)
					90	test26 (10)
					180	test27 (11)
				45	0	test28 (13)
				90	0	test29 (15)
Config 1	Nominal - 18 (towards hood)	12.5mm & 55mm	all	0	0	test30
					45	test31
					90	test32
					180	test33
				45	0	test34
				90	0	test35
				90	horizontal	test48
Config 2 (full monty)	0	12.5mm & 55mm	all	0	0	test16 (8)
					45	test17 (9)
					90	test18 (10)
					180	test19 (11)
				45	0	test21 (13)
				90	0	test23 (15)
Config 2 (full monty)	Nominal + 25	12.5mm & 55mm	all	0	0	Test36 (24)
					45	Test37 (25)
					90	Test38 (26)
					180	Test39 (27)
				45	0	Test40 (28)
				90	0	Test41 (29)
Config 2 (full monty)	Nominal - 18 (towards hood)	12.5mm & 55mm	all	0	0	Test42 (30)
					45	Test43 (31)
					90	Test44 (32)
					180	Test45 (33)
				45	0	Test46 (34)
				90	0	Test47 (35)
				90	horizontal	Test49(48)

C Annex: Barcode verification data

All barcodes used in the testing were validated on a barcode verifier to discover the barcodes quality based on the GS1 General Specification Section 5.12 Barcode production and quality assessment. Only barcodes that received a 1.5 (C) and above were acceptable for testing.

Table C-1. Verification data for all cards and symbols

Card ID	Symbology	Data	Overall ANSI Grade
300a	QR Code	https://examplebrand.com/123456789mQR5	4.0/08/660
300b	QR Code	https://dalgiardino.com/01/00952172101187/10/ABC123?17=271231	4.0/10/660
300c	UPC-A	952172101187	4.0/05/660
301a	QR Code	https://dalgiardino.com/01/00 9 52172104140/10/ABC123? 17=27123 1&243=1234	3.0/07/660
301b	UPC-A	952172104140	4.0/05/660
302a	QR Code	https://dalgiardino.com/01/00952172103136/10/ABC123?17=271231&243=1234	4.0/10/660
302b	UPC-A	952172103136	4.0/05/660
303a	QR Code	https://dalgiardino.com/01/00 9 52172102122/10/ABC123? 17=27123 1	4.0/07/660
303b	UPC-A	952172102122	4.0/05/660
304a	QR Code	https://dalgiardino.com/01/00952172101118/10/ABC123?17=271231	4.0/15/660
304b	UPC-A	952172101118	4.0/05/660
305a	QR Code	123456789QR1	4.0/08/660
305b	UPC-A	952153101151	4.0/05/660
306a	QR Code	https://dalgiardino.com/01/00952172731155/10/ABC123?17=271231	4.0/10/660
306b	QR Code	https://examplebrand.com/123456mQR3	4.0/08/660
307	QR Code	https://dalgiardino.com/01/00 9 52172000206/10/ABC123? 17=27123 1	4.0/10/660
308a	QR Code	https://dalgiardino.com/01/09521722001195/10/ABC123?17=271231	4.0/10/660
308b	Data Matrix	https://dalgiardino.com/01/00952172103174/10/ABC123?17=271231	4.0/10/660
308c	EAN-13	https://dalgiardino.com/01/09521721001158/10/ABC123?17=271231	4.0/05/660
309a	QR Code	https://dalgiardino.com/01/00 9 52172103174/10/ABC123? 17=27123	4.0/10/660
309b	EAN-13	9521721003176	4.0/10/660
310a	QR Code	https://dalgiardino.com/01/09521721001158/10/ABC123?17=271231	4.0/08/660
310b	EAN-13	9521721001158	3.9/05/660
311a	QR Code	https://dalgiardino.com/01/09 5 21720204185/10/ABC123? 17=27123 1&243=1234	4.0/10/660
311b	EAN-13	9521720204185	4.0/05/660
312a	QR Code	https://dalgiardino.com/01/09521720202167/10/ABC123?17=271231&243=1234	4.0/12/660
312b	EAN-13	9521720202167	4.0/05/660
313a	QR Code	https://examplebrand.com/123456mQR1	4.0/08/660
313b	EAN-13	9521207301154	4.0/05/660
314a	QR Code	https://dalgiardino.com/01/00952172831169/10/ABC123?17=271231	4.0/10/660
314b	Data Matrix	123456789DM3	4.0/10/660
315	GS1 Data Matrix	0100952190000011 10ABC12317271231	4.0/09/660
316a	GS1 Data Matrix	0100952161831163 10ABC12317271231	4.0/09/660
316b	Data Matrix	https://examplebrand.com/123456mDM2	4.0/09/660

Card ID	Symbology	Data	Overall ANSI Grade
317a	GS1 Data Matrix	0100952161105189 10ABC12317271231	4.0/12/660
317b	UPC-A	952161105189	3.7/05/660
318a	GS1 Data Matrix	0100952161104144 10ABC12317271231	4.0/10/660
318b	UPC-A	952161104144	4.0/10/660
319a	GS1 Data Matrix	0100952161103130 10ABC12317271231	4.0/12/660
319b	UPC-A	952161103130	3.9/05/660
320a	GS1 Data Matrix	0100952161102126 10ABC12317271231	4.0/15/660
320b	UPC-A	952161102126	4.0/10/660
321a	GS1 Data Matrix	0100952161101112 10ABC12317271231	4.0/07/660
321b	UPC-A	952161101112	3.5/05/660
322a	GS1 Data Matrix	0100952161731159 10ABC12317271231	4.0/10/660
322b	QR Code	https://examplebrand.com/123456mQR2	4.0/08/660
323a	GS1 Data Matrix	10095216183116300000000000000000	4.0/10/660
323b	Data Matrix	https://examplebrand.com/123456mDM2	4.0/10/660
324	Data Matrix	https://dalgiardino.com/01/00952190000035/10/ ABC123?17=271231	4.0/09/660
325a	Data Matrix	123456789DM1	4.0/10/660
325b	UPC-A	952183201166	3.9/05/660
326a	Data Matrix	https://dalgiardino.com/01/00952182531158/10/ ABC123?17=271231	4.0/10/660
326b	QR Code	https://examplebrand.com/123456789mQR4	4.0/08/660
327	GS1 Data Matrix	0100952161000200 10ABC1 23172712 31	4.0/10/660
328a	Data Matrix	https://examplebrand.com/123456mDM1	4.0/10/660
328b	EAN-13	9521832001160	4.0/05/660
329a	Data Matrix	https://dalgiardino.com/01/09521822005185/10/ ABC123?17=271231	4.0/10/660
329b	EAN-13	9521822005185	3.8/05/660
330a	Data Matrix	https://dalgiardino.com/01/09521822004140/10/ ABC123/21/392874?17=271231	4.0/10/660
330b	EAN-13	9521822004140	4.0/05/660
~~331a~~	~~Data Matrix~~	~~https://dalgiardino.com/01/09521822003136/10/ ABC123/21/392874?17=271231~~	~~0.0/10/660~~
~~331b~~	~~EAN-13~~	~~9521822003136~~	~~4.0/05/660~~
332a	Data Matrix	https://dalgiardino.com/01/09521822002122/10/ ABC123?17=271231	4.0/10/660
332b	EAN-13	9521822002122	4.0/05/660
333a	Data Matrix	https://dalgiardino.com/01/09521822001118/10/ ABC123?17=271231	4.0/07/660
333b	EAN-13	9521822001118	3.5/0.5/660
334a	Data Matrix	https://dalgiardino.com/01/00952182831166/10/ ABC123?17=271231	4.0/10/660
334b	Data Matrix	123456789DM3	4.0/10/660
335	QR Code	https://dalgiardino.com/01/00 9 52190000028/10/ABC123? 17=27123 1	1.7/09/660
336a	QR Code	https://dalgiardino.com/01/00 9 52190000042/10/ABC123? 17=27123 1	1.9/08/660
336b	UPC-A	952190000042	1.9/05/660
337a	Data Matrix	https://dalgiardino.com/01/09 5 21822004171/10/ABC123? 17=27123 1	0.0/08/660
337b	EAN-13	9521822004171	4.0/10/660
338a	GS1 Data Matrix	0100952161104175 10ABC1 23172712 31	4.0/08/660
338b	UPC-A	952161104175	4.0/06/660
339a	EAN-13	9521720202204	4.0/06/660
339b	QR Code	https://dalgiardino.com/01/09 5 21720202204/10/ABC123? 17=27123 1&243=1234	0.0/08/660

Card ID	Symbology	Data	Overall ANSI Grade
340a	QR Code	https://dalgiardino.com/01/00 9 52172105178/10/ABC123? 17=27123 1	0.0/08/660
340b	UPC-A	952172105178	4.0/06/660
341a	Data Matrix	https://dalgiardino.com/01/09 5 21822003136/10/ABC123/2 1/39287 4?17=271231	4.0/10/660
341b	EAN-13	9521822003136	4.0/05/660
342	GS1 Data Matrix	010095216100021710ABC1 23172712 31	4.0/10/660
343a	GS1 Data Matrix	010952141712018710ABC1 23172712 31	4.0/10/660
343b	GS1 Data Matrix	010952141712018710ABC1 23172712 31	4.0/10/660
344a	GS1 Data Matrix	010952142161221010ABC1 23172712 31	4.0/10/660
344b	QR Code	https://id.gs1.org/01/0952142 1 612210/10/ABC123? 17=271231	4.0/10/660
345	UPC-A	952190085001	4.0/05/660
346	UPC-A	952110000022	4.0/10/660
357a	QR Code	https://dalgiardino.com/01/00 9 52172101156/10/ABC123? 17=27123 1	0.0/08/660
357b	UPC-A	952172101156	4.0/06/660
358a	Data Matrix	https://dalgiardino.com/01/00 9 52182201112/10/ABC123? 17=27123 1	0.0/08/660
358b	UPC-A	952182201112	4.0/06/660