



1. INTRODUCTION

This document is a specification for the Digital Matter Yabby LoRaWAN GPS device. Contact info@digitalmatter.com for more information.

1.1. Revision History

Date	Version	Changes
2018-04-26	1.0	Initial release
2019-02-25	1.1	Added man down beacon parameter to downlink 1
2019-03-08	1.2	Added downlinks 10 and 11
2019-03-11	1.3	Updated downlinks 8 and 9

2. DEVICE BEHAVIOUR

The Yabby's behaviour can be configured by setting a variety of parameters using a USB programming adapter, or by sending a subset of those parameters during a downlink message. The details of these parameters can be found on the [product support website](#).

2.1. Uplink

The Yabby uses an accelerometer to detect movement, allowing it to decide when an asset is in-trip, and when it is stationary. This allows it to schedule the battery-hungry GPS fixes and transmissions as infrequently as possible, to maximize battery life. Each time a status update is scheduled the Yabby will attempt a GPS fix, then transmit the results (whether the fix succeeded or not). You can configure the Yabby to transmit a status update:

- Periodically (ie. 24-hour heartbeat)
- At configured times of the day
- At the start of a regular or after-hours trip
- During the trip
- At the end of the trip
- When the 'Man Down' status changes

2.1.1. Device Statistics

The Yabby transmits a device statistics message once every 3 days, to allow monitoring of device activity and associated battery usage. The device statistic messages can be disabled to prevent tracking disruption in regions where the transmit duty cycle restrictions are a bottleneck (868 MHz regions can limit transmissions to 1 every 3 minutes).

2.2. Downlink

LoRaWAN potentially allows for a downlink with every regular data uplink, but most networks will only allow a few per day. When a parameter update is sent down to the Yabby, it responds with an application layer acknowledgement uplink as soon as possible. In some

regions, this could take several minutes. If the next uplink received is not the expected acknowledgement, the downlink should be resent.

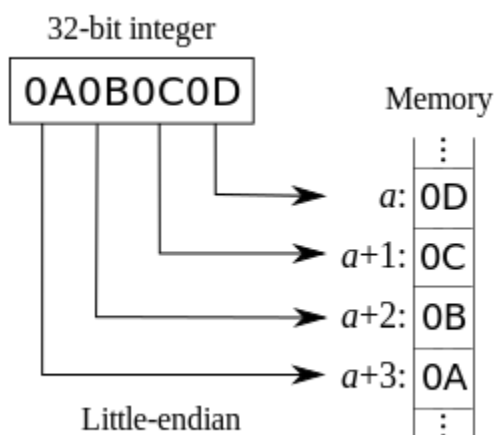
3. MESSAGES

3.1. Number Formats

3.1.1. Little Endian

Except where noted, all data in the payloads is LITTLE ENDIAN. Be aware of this when converting data fields that consist of more than one byte from the data payload.

<https://en.wikipedia.org/wiki/Endianness#Little>



3.1.2. Signed (Negative) Numbers

When a field is specified as *signed*, it is represented in 'two's complement' form. Be aware of this when converting signed fields from the data payload. Where unspecified, assume that fields are unsigned.

https://en.wikipedia.org/wiki/Two's_complement

3.2. Uplink

LoRaWAN uplink payloads can be as small as 11 bytes in some regions (for the longest-range transmissions). The packet headers already include the device serial number, and a 'port number' from 1 to 223, which we will use as a message type.

3.2.1. Uplink Port 1: GPS Data Record

Offset	Description
0 (INT32)	32 bit latitude, signed , LSb = 0.000'000'1°. To convert, first calculate the signed integer value, then divide by 10 million to get a floating-point value.
4 (INT32)	32 bit longitude, signed , see above
8.0	0: Out of trip, 1: In-trip
8.1	Last fix failed

8.2	Man down (no movement for configured period)
8.3 - 8.7	Reserved
9.0 - 9.2	Heading, LSb = 45°, rounded to nearest
9.3 - 9.7	Speed, LSb = 5 km/h, rounded down
10 (BYTE)	Battery voltage, LSb = 25 mV, rounded down

Example: 53AB783C0421F98E04CAB3

- 53AB783C little endian
 - 3C78AB53 in hex
 - 1014541139 in decimal
 - 101.4541139°
- 0421F98E little endian
 - 8EF92104 in hex
 - 2398691588 in decimal (unsigned)
 - -1896275708 in decimal (signed)
 - -189.6275708°
- 04
 - 00000100 in binary
 - 0 - not in trip
 - 0 - last fix did not fail
 - 1 - man down
 - 00000 - reserved bits
- CA
 - 11001010 in binary
 - 010 - 2 x 45 = 90°
 - 11001 – 25 x 5 = 125 km/h
- B3
 - 179 x 25 = 4475 mV

3.2.2. Uplink Port 2: Downlink Ack

Offset	Description
0.0 - 0.6	Sequence number (identifies downlink to server)
0.7	0: Downlink rejected, 1: Downlink accepted
1	Firmware major version
2	Firmware minor version

Example: D30102

- D3
 - 11010011 in binary
 - 1010011 - sequence number 83
 - 1 - downlink accepted
- 0102
 - Firmware 1.2

3.2.3. Uplink Port 3: Device Statistics

Offset	Description
0.0 - 0.3	Initial battery voltage, LSb = 100 mV, 4V offset
0.4 - 1.6	Tx count, LSb = 32 Tx attempts
1.7 - 3.3	Trip count, LSb = 32 trips
3.4 - 4.5	GPS Successes, LSb = 32 fixes
4.6 - 5.5	GPS Failures, LSb = 32 failed fixes
5.6 - 6.6	Average GPS fix time, calculated over successful fixes only, seconds
6.7 - 7.7	Average GPS fail time, calculated over failed fixes only, seconds
8.0 - 8.7	Average GPS freshen time per successful fix, seconds
9.0 - 9.6	Wakeups per trip
9.7 - 10.7	Uptime, LSb = 1 week

Example: 8BF3DC7B9438984278B85E

110.7	5E	B8	78	42	98	38	94	7B	DC	F3	8B	0.01
0101111010111000011110000100001010011000001110001001010001111011110111001111001110001011												
010111101011100001111000010000101001100000111000100101000111101110111001111001110001011												
189	56	120	133	96	226	327	6073	1848	11			

- $11 \times 0.1 + 4.0 = 5.1$ V when battery was inserted
- $1848 \times 32 = 59136$ transmissions
- $6073 \times 32 = 194336$ trips
- $327 \times 32 = 10464$ GPS fixes
- $226 \times 32 = 7232$ GPS failures
- 96 s spent per successful GPS fix, not including freshen time
- 133 s wasted per failed GPS fix attempt
- 120 s spent freshening GPS ephemerides per successful GPS fix
- 56 wakeups per trip
- 189 weeks uptime

3.2.4. Example JavaScript Decoder

```
// Decode an uplink message from an array of bytes to an object of fields
function Decoder(bytes, port)
{
  var decoded = {};

  if (port === 1)
  {
    decoded.type = "position";

    decoded.latitudeDeg = bytes[0] + bytes[1] * 256 +
                          bytes[2] * 65536 + bytes[3] * 16777216;
    if (decoded.latitudeDeg >= 0x80000000)
      decoded.latitudeDeg -= 0x100000000;
    decoded.latitudeDeg /= 1e7;

    decoded.longitudeDeg = bytes[4] + bytes[5] * 256 +
                           bytes[6] * 65536 + bytes[7] * 16777216;
    if (decoded.longitudeDeg >= 0x80000000)
      decoded.longitudeDeg -= 0x100000000;
    decoded.longitudeDeg /= 1e7;

    decoded.inTrip = ((bytes[8] & 0x1) !== 0) ? true : false;
    decoded.fixFailed = ((bytes[8] & 0x2) !== 0) ? true : false;
    decoded.manDown = ((bytes[8] & 0x4) !== 0) ? true : false;

    decoded.headingDeg = (bytes[9] & 0x7) * 45;

    decoded.speedKmph = (bytes[9] >> 3) * 5;
    decoded.batV = bytes[10] * 0.025;
  }
  else if (port === 2)
  {
    decoded.type = "downlink ack";

    decoded.sequence = (bytes[0] & 0x7F);
    decoded.accepted = ((bytes[0] & 0x80) !== 0) ? true : false;
    decoded.fwMaj = bytes[1];
    decoded.fwMin = bytes[2];
  }
  else if (port === 3)
  {
    decoded.type = "stats";

    decoded.initialBatV = 4.0 + 0.100 * (bytes[0] & 0xF);
    decoded.txCount = 32 * ((bytes[0] >> 4) + (bytes[1] & 0x7F) * 16);
    decoded.tripCount = 32 * ((bytes[1] >> 7) + (bytes[2] & 0xFF) * 2
                              + (bytes[3] & 0x0F) * 512);
    decoded.gpsSuccesses = 32 * ((bytes[3] >> 4) + (bytes[4] & 0x3F) * 16);
    decoded.gpsFails = 32 * ((bytes[4] >> 6) + (bytes[5] & 0x3F) * 4);
    decoded.aveGpsFixS = 1 * ((bytes[5] >> 6) + (bytes[6] & 0x7F) * 4);
    decoded.aveGpsFailS = 1 * ((bytes[6] >> 7) + (bytes[7] & 0xFF) * 2);
    decoded.aveGpsFreshenS = 1 * ((bytes[7] >> 8) + (bytes[8] & 0xFF) * 1);
    decoded.wakeupsPerTrip = 1 * ((bytes[8] >> 8) + (bytes[9] & 0x7F) * 1);
    decoded.uptimeWeeks = 1 * ((bytes[9] >> 7) + (bytes[10] & 0xFF) * 2);
  }

  return decoded;
}

```

3.3. Downlink

LoRaWAN downlink payloads can be as small as 11 bytes in some regions (for the longest-range transmissions). The packet headers already include a 'port number' from 1 to 223, which we will use as a message type. The Yabby sends an explicit acknowledgement uplink (port 2) on reception of a downlink. It sends the acknowledgement only once, on its next uplink attempt. The uplink includes a sequence number to help identify the specific downlink being acknowledged, despite any queuing / buffering in the network. 'Confirmed' and 'unconfirmed' downlinks are handled in the same way.

3.3.1. Downlink Port 1: Set Trip Parameters

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1 (BYTE)	Max time between fix attempts out of trip ('heartbeat'), 1-127: 1-127 mins, 129-255: 1-127 hours, default 24 hours
2 (BYTE)	Trip end timeout, LSB = 10s without accelerometer detecting movement, 0 disables trip tracking entirely (heartbeats only), default 5 mins
3 (BYTE)	Time between fix attempts in-trip during work hours, 1-127: 1-127 seconds, 129-255: 1-127 minutes, 0 or 128 disables, default 10 mins
4 (BYTE)	Time between fix attempts in-trip after hours, 1-127: 1-127 seconds, 129-255: 1-127 minutes, 0 or 128 disables, default 10 mins
5.0	Fix on start of trips during work hours, default true
5.1	Fix on end of trips during work hours, default true
5.2	Fix on start of trips after hours, default true
5.3	Fix on end of trips after hours, default true
5.4	Optimise GPS for trip tracking (download all ephemerides), default true
5.5	Disable stats messages (uplink port 2), default 0 (message enabled)
5.6	Disable wakeup filtering during work hours, 1: only apply accelerometer wakeup threshold and count, 0: apply threshold, count, and filter, default 0
5.7	Disable wakeup filtering after hours, 1: only apply accelerometer wakeup threshold and count, 0: apply threshold, count, and filter, default 0
6 (BYTE)	Accelerometer wakeup threshold, 1-8: 63-504 mG, default 126 mG
7 (BYTE)	Accelerometer wakeup count, 1-96: 10-960 ms, default 80 ms, current firmware will round down to a multiple of 80 ms
8 (BYTE)	Man Down timeout, 1-127: 10-1270 min, 129-255: 12-1524 hours, others disable, default 60 min
9.0 - 9.1	Man Down fix on set, 0: no fix, 1: single fix attempt, 2: retry fix attempts if network not ready (ie. join failed - uplinks are still unconfirmed), default 0
9.2 - 9.3	Man Down fix on clear, see above
9.4 - 9.7	Reserved, set to zero

10 (BYTE)	Man Down beacon period ('heartbeat') when Man Down is active, overrides default 'heartbeat' if enabled, 1-127: 1-127 mins, 129-255: 1-127 hours, default 0 (disabled), supported from version 1.4
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3.3.2. Downlink Port 2: Set After-Hours 1

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1 (BYTE)	Start of after-hours period on Monday, LSb = 7m30s since 00:00 local time, setting to end time indicates no after-hours period, default 0
2 (BYTE)	End of after-hours period on Monday, LSb = 7m30s since 00:00 local time, setting to start time + 1 indicates a 7m30s after-hours period, set start time to 00:00 and end time to 24:00 to indicate the whole day is after-hours, default 0
3 (BYTE)	Start of after-hours period on Tuesday, see above
4 (BYTE)	End of after-hours period on Tuesday, see above
5 (BYTE)	Start of after-hours period on Wednesday, see above
6 (BYTE)	End of after-hours period on Wednesday, see above
7 (BYTE)	Start of after-hours period on Thursday, see above
8 (BYTE)	End of after-hours period on Thursday, see above

3.3.3. Downlink Port 3: Set After-Hours 2

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1 (BYTE)	Start of after-hours period on Friday, LSb = 7m30s since 00:00 local time, setting to end time indicates no after-hours period, default 0
2 (BYTE)	End of after-hours period on Friday, LSb = 7m30s since 00:00 local time, setting to start time + 1 indicates a 7m30s after-hours period, set start time to 00:00 and end time to 24:00 to indicate the whole day is after-hours, default 0
3 (BYTE)	Start of after-hours period on Saturday, see above
4 (BYTE)	End of after-hours period on Saturday, see above
5 (BYTE)	Start of after-hours period on Sunday, see above
6 (BYTE)	End of after-hours period on Sunday, see above

3.3.4. Downlink Port 4: Set Time Zone

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)

0.7 - 1.1	Reserved, set to zero
1.2 - 2.1	Offset of normal time zone from UTC, LSb = 15 minutes, signed , default 0
2.2 - 2.5	Daylight saving time shift, LSb = 15 minutes, 0 disables, default 0
2.6 - 3.0	Start of DST Nth day of month, 1: First day, ..., 5: Fifth day, 6: Last day, 0: Use absolute date instead of relative '2 nd Sunday of October' style
3.1 - 3.5	1-7: Monday-Sunday, or 1-31: Day of month (absolute date), local time
3.6 - 4.1	1-12: January-December
4.2 - 5.2	Offset from 00:00 local time, LSb = 15 mins, signed , can select hours in previous days like '02:00 on Friday before last Sunday of October local time' would need Offset = (2hr - 48hr) * 4 = -184
5.3 - 5.5	End of DST Nth day of month, 1: First day, ..., 5: Fifth day, 6: Last day, 0: Use absolute date instead of relative '2 nd Sunday of October' style
5.6 - 6.2	1-7: Monday-Sunday, or 1-31: Day of month (absolute date), local time
6.3 - 6.6	1-12: January-December
6.7 - 7.7	Offset from 00:00 local DST, LSb = 15 mins, signed , can select hours in previous days like '02:00 on Friday before last Sunday of April local DST' would need Offset = (2hr - 48hr) * 4 = -184

3.3.5. Downlink Port 5: Set GPS Parameters 1

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Require 3D GPS fixes, default false
1 (BYTE)	Max time to wait for initial coarse GPS fix, 45-127: 45-127 seconds, 129-255: 1-127 minutes, default 3 mins
2 (BYTE)	Max time to wait for fine GPS fix, 1-127: 1-127 seconds, 129-255: 1-127 minutes, 0 or 128 disables, default 5 s
3 (BYTE)	Target accuracy for the fine GPS fix wait, LSb = 1m, default 20 m
4 (BYTE)	Required PDOP for valid GPS, 25-100: 2.5 to 10.0, default 10.0
5 (BYTE)	Required position accuracy for valid GPS, 5-100: 5-100 m, default 75 m
6 (BYTE)	Required speed accuracy for valid GPS, 8-55: 2.88-19.8 km/h, default 10 km/h
7 (BYTE)	Discard first N GPS points to allow solution to settle, 0-32: 0-32 positions, default 3

3.3.6. Downlink Port 6: Set GPS Parameters 2

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero

1 (BYTE)	Daily GPS on-time budget, 45-127: 45-127 seconds, 129-255: 1-127 minutes, 0 or 128 for unlimited on-time budget, default unlimited
2 (BYTE)	Max time to spend looking for 1 st satellite, 1-255: 5-1275s, 0 disables signal validator, default 1 min
3 (BYTE)	Max time to spend looking for 2 nd satellite, 0-255: 0-1275s, default 1 min
4 (BYTE)	Max time to spend looking for 3 rd satellite, 0-255: 0-1275s, default 1 min
5 (BYTE)	Max time to spend looking for 4 th satellite, 0-255: 0-1275s, default 1 min
6.0 - 6.4	Satellite detection margin adjustment, signed , -16-15: -16-15 dB, >=0 requires stronger signal, <0 allows weaker signal, 0 is default
6.5	Enable Autonomous Aiding, default off
6.6 - 6.7	Reserved, set to zero
7 (BYTE)	GPS statistical model, 0: Portable, 2: Stationary,3: Pedestrian, 4: Automotive, 5: Sea, 6: Air 1G, 7: Air 2G, 8: Air 4G, default 4
8 (UINT16)	Approximate maximum error from Autonomous Aiding calculations, 5-1000: 5-1000 m, 0: automatic, default: 100

3.3.7. Downlink Port 7: Set LoRaWAN Channels

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1.0 - 1.3	Minimum data rate to use when ADR is disabled, default is 0 (DR0)
1.4 - 1.7	Maximum data rate to use when ADR is disabled, default is 2 (DR2)
2 - 10	Uplink channel mask, set bits are enabled channels, LSb of the 1 st byte is channel 0, MSb of the 9 th byte is channel 71, set all zeros (default) for the region-specific defaults

The Yabby will spread its transmissions out over the allowed data rates in such a way as to equalize the time spent on-air at each data rate. For the default setting of DR0-DR2, this gives a 16 / 30 / 54% split between the three data rates, and maximizes the gateway's capacity. However, the relative range of the three data rates are 100, 75, and 50% respectively. When ADR is enabled, the network server controls the data rate instead.

The uplink channel mask should be left 0 (default) in regions where the network join channels are fixed. In these regions, the gateway will tell the Yabby which channels to use, during the Join procedure.

In regions where the join channels are not specified (US902-928, AU915-928), you should set the channel mask to avoid continued transmission on unused channels. In these regions the gateway will usually not tell the Yabby which channels to use, resulting in significant packet loss if the mask hasn't been programmed.

3.3.8. Downlink Port 8: Set LoRaWAN Join / App EUI

Offset	Description
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0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Set JoinEUI, 0: Use default JoinEUI, 1: Use supplied JoinEUI, default 0
1 - 8	JoinEUI, non-zero, big endian , i.e. default JoinEUI 70-B3-D5-70-50-00-00-04 is encoded with first byte as 0x70 and the second byte 0xB3

The acknowledgement will be transmitted **once** on the existing JoinEUI, and then the Yabby will switch to the new JoinEUI. It continues to use the already provisioned NwkKey and AppKey, which cannot be programmed over the air.

Note that:

- In LoRaWAN 1.0, the JoinEUI is known as the AppEUI
- In LoRaWAN 1.1, changing the JoinEUI resets three cryptographic counters:
 - RJCount1
 - DevNonce
 - JoinNonce
- So after changing the JoinEUI in 1.1, you must reset the counters on the join server

3.3.9. Downlink Port 9: Set Advanced LoRaWAN Options

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1 (BYTE)	Days between network joins, 0 disables, default 7
2.0 - 2.1	ADR support, 0: Never, 1: When out-of-trip, 2: Always, default never
2.2 - 2.3	Reserved, set to zero
2.4 - 2.7	Initial frame repetitions (NbTrans/Reps), 1-15, default 1
3.0 - 3.3	Initial MaxCount0, sets uplinks between Rejoin0 attempts in LoRaWAN 1.1 OTAA, uplink interval equals $2^{(4+MaxCount0)}$, default 15
3.4 - 3.7	Initial MaxTime0, sets approx. time between Rejoin0 attempts in LoRaWAN 1.1 OTAA, uplink period equals $2^{(10+MaxTime0)}$ s, default 15
4.0 - 4.3	Initial ADRAckLimitExp, sets uplinks between ADR confirmation requests, uplink interval equals $2^{ADRAckLimitExp}$, default 6 (limit is 64)
4.4 - 4.7	Initial ADRAckDelayExp, sets uplinks between ADR backoff steps, uplink interval equals $2^{ADRAckDelayExp}$, default 5 (delay is 32)
5 (INT8)	Maximum Tx power limit, signed , -128-127: -128 to 127 dBm EIRP, default 127 (no limit)
6 (BYTE)	Random Tx delay, 0: disabled, 1-127: 1-127 seconds, 129-255: 1-127 minutes, default disabled

Fields from offset 2.4 onwards are supported from firmware version 2.0. For a detailed description of these parameters, please see the *Configuration and Usage Guide* on the support website.

3.3.10. Downlink Port 10: Set Scheduled Upload Parameters

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	0: Single fix attempt, 1: Retry fix attempts if network not ready (i.e. join failed - uplinks are still unconfirmed), supported from firmware version 2.0 onwards, unconfigured default is no attempts
1 (BYTE)	Local time* of scheduled upload time 1, 1-192: 00:07:30-24:00:00 (7.5 min intervals), +- 5 minutes randomization, default 0 (disabled)
2 (BYTE)	Local time* of scheduled upload time 2, see above
3 (BYTE)	Local time* of scheduled upload time 3, see above
4 (BYTE)	Local time* of scheduled upload time 4, see above
5 (BYTE)	Local time* of scheduled upload time 5, see above
6 (BYTE)	Local time* of scheduled upload time 6, see above
7 (BYTE)	Local time* of scheduled upload time 7, see above
8 (BYTE)	Local time* of scheduled upload time 8, see above
9 (BYTE)	Local time* of scheduled upload time 9, see above
10 (BYTE)	Local time* of scheduled upload time 10, see above

*Local time takes time zone and daylight savings offset into account (configurable in Downlink 4).

The scheduled upload feature allows for heartbeats to be scheduled, rather than setting an upload interval. Each upload will occur within a 5 minute offset (i.e. scheduled upload at 13:00 could occur anywhere between 12:55 and 13:05). Up to 12 upload times may be configured per day. The first 10 upload times are configured with this downlink.

This downlink is supported from firmware version 1.4 onwards.

3.3.11. Downlink Port 11: Set Scheduled Upload Parameters (continued)

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1 (BYTE)	Local time* of scheduled upload time 11, 1-192: 00:07:30-24:00:00 (7.5 min intervals), +- 5 minutes randomization, default 0 (disabled)
2 (BYTE)	Local time* of scheduled upload time 12, see above

*Local time takes time-zone and daylight savings offset into account (configurable in Downlink 4).

The scheduled upload feature allows for heartbeats to be scheduled, rather than setting an upload interval. Each upload will occur within a 5 minute offset (i.e. scheduled upload at 13:00 could occur anywhere between 12:55 and 13:05). Up to 12 upload times may be configured per day. The 11th and 12th upload times are configured with this downlink.

This downlink is supported from firmware version 1.4 onwards.

4. CONTACT INFORMATION

For the latest version of this document plus other product information please visit our website at www.digitalmatter.com/support, or contact DM at info@digitalmatter.com.