Technical Note V.1.1

MINTS Sensor Description

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Multi-Scale Integrated Sensing and Simulation
https://mints.utdallas.edu/
https://github.com/mi3nts

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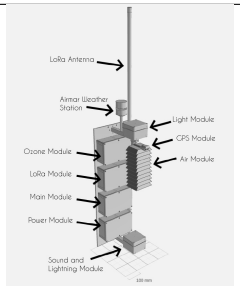
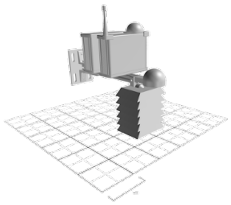
1. Introduction

The Central Node is a stationery sensor system consisting an array of iot sensors which is an extensible platform in which many newer sensors can be adopted into. The source code for the Central Node as well as most mints projects are open source and is available at https://github.com/mi3nts. The central Node consists of an array of sensor listed below:

1. Main Module
2. Airmar Weather Station
3. Light Module
4. Air Module
5. Ozone Module
6. LoRa Module
7. Thunder and Lightning Module
8. Power Module
9. GPS Module

2. Central Node

Sensor Nodes	Central Node	PoLo Node	SoLo Node	Wearable
Sketches			figures/Solo.png	
SBC	Odroid C4	Odroid C4	Odroid C4	Rasberri Pi Zero W
Attached sensors	• IPS7100 • HM3301 • OPCN3 • BME280 • BME680 • SCD30 • MGS001 • AS7262 • APDS9002 • GL001 • GUV001 • SI114x • TM3993 • TSL2591 • VEML6075 • SKYCAM • WIMDA • WIMWV	• IPS7100 • BME280 • SCD30	• IPS7100 • BME280 • SCD30	• IPS7100 • BME280 • SCD30

	• WIMWV • YXXDR • AS3935 • SEN0232 • TB108L • LIBRAD • VK-162 GPS			

Note: SBC refers to Single Board Computer

3. Central Node Data

Data from each Central Node is initially saved as *csv* files.There are two Single board computers(OdroidC4) that record the data from the sensors.Each of the SBC have unique node id's and a group of sensors connected to each of them. A *csv* file is provided for each sensor within a central node per day and is collected under the respective nodeid. In order to maintain a record of the most recent data read, a unique json file is updated for each individual sensor.Upon connection to the internet both the *csv* and *json* files are transferred via *rsync* [**?**]. Upon transmission the data to the graphical dashboards are updated using an *mqtt* [**?**] pipeline.For each day, each sensor will have a single csv file saved inside the respective node, with the following folder structure @ *\home\teamlary\mintsData*.

```
mintsData
    raw
        001e0636e547
            2023
                01
                    04
                        MINTS_001e0636e547_APDS9002_2023_01_04.csv
                        MINTS_001e0636e547_AS7262_2023_01_04.csv
                        MINTS_001e0636e547_BME280_2023_01_04.csv
                        MINTS_001e0636e547_BME680_2023_01_04.csv
                        MINTS_001e0636e547_APDS9002_2023_01_04.csv
                            .
                            .
```

```
                    .
                    .

                    MINTS_001e0636e547_SI114X_2023_01_04.csv
                    MINTS_001e0636e547_TB108L_2023_01_04.csv
                    MINTS_001e0636e547_TMG3993_2023_01_04.csv
                    MINTS_001e0636e547_TSL2591_2023_01_04.csv
                    MINTS_001e0636e547_VEML6075_2023_01_04.csv

mintsData
    raw
        001e06430225
            2023
                01
                    04
                        MINTS_001e06430225_AS3935_2023_01_04.csv
                        MINTS_001e06430225_SEN0232_2023_01_04.csv
                        MINTS_001e06430225_SKYCAM003_2023_01_04.csv
                        MINTS_001e06430225_WIMDA_2023_01_04.csv
                        MINTS_001e06430225_YXXDR_2023_01_04.csv
                        snaps
                            MINTS_001e06430225_SKYCAM003_
                            2023_01_04_16_00_43.png
                            .
                            .
                            .
                            MINTS_001e06430225_SKYCAM003_
                            2023_01_04_18_35_03.png
                            MINTS_001e06430225_SKYCAM_binary003_
                            2023_01_04_16_37_44.png
                            .
                            .
                            MINTS_001e06430225_SKYCAM_binary003_
                            2023_01_04_18_35_03.png
```

In this example, the sensor ID happens to be *001e0636e547*, *001e06430225* which is the unique ID corresponding to the XU4 and N2+ respectively .

3.1 Data Format for Each Sensing Module

3.1.1 Particulate Matter Sensors

IPS7100

dateTime	pc0_1	pc0_3	pc0_5	.....	pm10_0
2023-01-04 00:00:00.059604	64474	18205	11661	.....	5.74317020
2023-01-04 00:00:01.061184	62047	17368	11109	.....	5.57649617
2023-01-04 00:00:02.062446	59468	16571	10640	.....	5.40531891
2023-01-04 00:00:03.063477	56790	15791	10198	.....	5.23171629
2023-01-04 00:00:04.064636	54282	15017	9777	.....	5.06503846
2023-01-04 00:00:05.065186	51981	14281	9377	.....	4.90459504
2023-01-04 00:00:06.066297	49793	13580	9015	.....	4.76209408

The data format of the **IPS7100** *csv* is described on table 1.

Table 1. Data Format used on the **IPS7100** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-02-09 00:00:07.143333	
Particles Counts	pc0_1 to pc10_0	Integer	$\#/Liter$	Particle Counts per *liter* for particle diameters 0.1, 0.3, 0.5, 1.0, 2.5, 5, 10 μm	3272	
Particulate mass fractions	pm0_1 to pm10_0	Float	$\mu g/m^3$	Particle mass fractions for particle diameters 0.1, 0.3, 0.5, 1.0, 2.5, 5, 10 μm	2.56	

HM3301

dateTime	pm1	pm2_5	pm10
2023-01-04 00:00:01.230436	1	1	1
2023-01-04 00:00:11.258133	1	1	1
2023-01-04 00:00:21.270849	1	3	1
2023-01-04 00:00:31.283578	4	7	10
2023-01-04 00:00:41.311695	1	1	1
2023-01-04 00:00:51.324609	1	7	10
2023-01-04 00:01:01.337217	1	1	1
2023-01-04 00:01:11.365143	1	1	1

The data format of the **HM3301** *csv* is described on table 2.

Table 2. Data format used on **HM3301** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:31.283578	
$PM_{1.0}$	pm1	Integer	$\mu g/m^3$		4	
$PM_{2.5}$	pm2_5	Integer	$\mu g/m^3$		7	
$PM_{10.0}$	pm10	Integer	$\mu g/m^3$		10	

3.1.2 Climate Sensors

BME280

dateTime	temperature	pressure	humidity	altitude
2023-01-04 00:00:06.268466	16.81	99540.00	29.00	149.66
2023-01-04 00:00:16.296297	16.81	99542.00	29.00	149.49
2023-01-04 00:00:26.309238	16.80	99537.00	29.00	149.91
2023-01-04 00:00:36.337023	16.80	99538.00	29.00	149.83
2023-01-04 00:00:46.350128	16.80	99539.00	29.00	149.75
2023-01-04 00:00:56.362813	16.79	99539.00	29.00	149.75
2023-01-04 00:01:06.390603	16.79	99539.00	29.00	149.75
2023-01-04 00:01:16.403502	16.77	99538.00	29.00	149.83
2023-01-04 00:01:26.416226	16.77	99540.00	29.00	149.66
2023-01-04 00:01:36.429101	16.78	99542.00	29.00	149.49
2023-01-04 00:01:46.456660	16.78	99539.00	29.00	149.75

The data format of the **BME280** *csv* is described on table 3.

Table 3. Data format used on **BME280** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:06.268466	
Temperature	temperature	Float	$^{\circ}C$		16.81	
Pressure	pressure	Float	$millibars * 100$		99540.00	
Humidity	humidity	Float	%		29.00	
Altitude	altitude	Float	meters		149.66	

BME680

dateTime	temperature	pressure	humidity	gas
2023-01-04 00:00:04.568350	16.94	99.50	31.34	12976.91
2023-01-04 00:00:14.725647	16.93	99.50	31.45	12976.91
2023-01-04 00:00:24.882822	16.93	99.50	31.54	12976.91
2023-01-04 00:00:35.024835	16.93	99.50	31.57	12976.91
2023-01-04 00:00:45.182448	16.92	99.50	31.56	12976.91
2023-01-04 00:00:55.339732	16.92	99.50	31.53	12976.91
2023-01-04 00:01:05.496983	16.91	99.50	31.52	12976.91
2023-01-04 00:01:15.654531	16.91	99.50	31.59	12976.91

The data format of the **BME680** *csv* is described on table 4.

Table 4. Data format used on **BME680** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:04.568350	
Temperature	temperature	Float	$^{\circ}C$		16.94	
Pressure	pressure	Float	hPa		99.50	
Humidity	humidity	Float	%		31.34	
Gas	gas	Float	IAQ		12976.91	

WIMDA

```
dateTime                    barrometricPressureMercury  ........ checkSum
2023-01-04 00:00:04.499788  29.9021                     ........ 1.0126
2023-01-04 00:00:09.997634  29.9050                     ........ 1.0127
2023-01-04 00:00:15.500336  29.9021                     ........ 1.0126
2023-01-04 00:00:20.998336  29.9021                     ........ 1.0126
2023-01-04 00:00:26.498463  29.9021                     ........ 1.0126
2023-01-04 00:00:31.501278  29.9050                     ........ 1.0127
2023-01-04 00:00:36.999337  29.9050                     ........ 1.0127
```

The data format of the **WIMDA** *csv* is described on table 5.

Table 5. Data format used on **WIMDA** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:04.499788	
Pressure Measured By Mercury Barometer	barrometric Pressure Mercury	Float	in		29.9021	
Unit of Pressure for Mercury Barometer	BPMUnits	string			I	
Pressure Measured By Mercury Barometer in Bars	barrometric Pressure Bars	Float	Ba		1.0126	
Unit of Pressure for Barometer	BPBUnits	string			B	
Temperature	airTemperature	Float	$^{\circ}C$		22.2	
Unit of Air Temperature	ATUnits	string			C	

Water Temperature	waterTemperature	Float	C°			
Unit of Water Temperature	WTUnits	string			C	
Relative Humidity	relativeHumidity	Float	%		15.5	
Absolute Humidity	absoluteHumidity	Float	%			
Dew Point	dewPoint	Float	C°		-5.2	
Unit of Dew Point	DPUnits	string			C	
True Wind Direction	windDirectionTrue	Float	Degrees		334.1	
True Wind Direction Unit	WDTUnits	string			T	
Magnetic Wind Direction	windDirectionMagnetic	Float	Degrees		329.2	
Magnetic Wind Direction Unit	WDMUnits	string			M	
Wind Speed Knots	windSpeedKnots	Float	m/s		1.4	
Wind Speed Knots Unit	WSKUnits	string			N	
Wind Speed in Meters Per Second	windSpeedMetersPerSecond	Float	m/s		0.7	
Unit for Wind Speed in Meters Per Second	WSMPSUnits	string			M	
check Sum	checkSum	Integer			78	

3.1.3 CO_2 Sensor

SCD30

dateTime	c02	temperature	humidity
2023-01-04 00:00:08.763232	405	19.44	27.58
2023-01-04 00:00:18.775858	406	19.44	27.53
2023-01-04 00:00:28.803976	405	19.42	27.62
2023-01-04 00:00:38.816727	405	19.44	27.64
2023-01-04 00:00:48.829733	405	19.44	27.59
2023-01-04 00:00:58.857351	406	19.44	27.62
2023-01-04 00:01:08.870275	406	19.41	27.59
2023-01-04 00:01:18.883096	406	19.41	27.67
2023-01-04 00:01:28.911038	407	19.42	27.62
2023-01-04 00:01:38.923842	406	19.42	27.70

The data format of the **SCD30** *csv* is described on table 6.

Table 6. Data format used on **SCD30** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:04.568350	
CO_2	co2	Integer	ppm		405	
Temperature	temperature	Float	$^{\circ}C$		19.44	
Humidity	humidity	Float	%		27.58	

3.1.4 Light Sensors

APDS9002

dateTime	luminance	voltage	raw
2023-01-04 00:00:08.974372	1.01	0.00	0
2023-01-04 00:00:20.521757	1.01	0.00	0
2023-01-04 00:00:32.069220	1.01	0.00	0
2023-01-04 00:00:43.616382	1.01	0.00	0
2023-01-04 00:00:55.163985	1.01	0.00	0
2023-01-04 00:01:06.711284	1.01	0.00	0
2023-01-04 00:01:18.273649	1.01	0.00	0
2023-01-04 00:01:29.821167	1.01	0.00	0
2023-01-04 00:01:41.368623	1.01	0.00	0

The data format of the **APDS9002** *csv* is described on table 7.

Table 7. Data format used on **APDS9002** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:08.974372	
Luminance	luminance	Float			1.01	
Voltage	voltage	Float	V		0.00	
Raw	raw	Integer	%		0	

GL001

```
dateTime                    lightLevel
2023-01-04 00:00:04.784561  23
2023-01-04 00:00:16.331946  22
2023-01-04 00:00:27.879069  21
2023-01-04 00:00:39.441456  19
2023-01-04 00:00:50.989075  20
2023-01-04 00:01:02.536537  18
2023-01-04 00:01:14.083669  17
2023-01-04 00:01:25.631127  15
2023-01-04 00:01:37.178965  15
2023-01-04 00:01:48.741113  15
2023-01-04 00:02:00.288745  15
```

The data format of the **GL001** *csv* is described on table 8.

Table 8. Data format used on **GL001** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:04.784561	
Light Level	lightLevel	Integer			1.01	

GUV001

```
dateTime                    uvLevel
2023-01-04 00:00:07.951263  0
2023-01-04 00:00:19.498775  0
2023-01-04 00:00:31.061110  0
2023-01-04 00:00:42.608385  0
2023-01-04 00:00:54.156001  0
2023-01-04 00:01:05.703240  0
2023-01-04 00:01:17.250637  0
2023-01-04 00:01:28.813349  0
2023-01-04 00:01:40.360622  0
2023-01-04 00:01:51.908080  0
2023-01-04 00:02:03.455638  0
2023-01-04 00:02:15.003021  0
2023-01-04 00:02:26.550561  0
2023-01-04 00:02:38.112896  0
2023-01-04 00:02:49.660179  0
```

The data format of the **GUV001** *csv* is described on table 9.

Table 9. Data format used on **GUV001** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:07.951263	
UV Level	uvLevel	Integer			1.01	

SI114x

```
dateTime                    visible   ir      uv     ........  proximity3
2023-01-04 00:00:02.801268  261       255     0.02   ........  0
2023-01-04 00:00:14.364232  261       254     0.02   ........  0
2023-01-04 00:00:25.911306  261       253     0.02   ........  0
2023-01-04 00:00:37.458465  261       254     0.02   ........  0
2023-01-04 00:00:49.006254  262       253     0.03   ........  0
2023-01-04 00:01:00.553659  261       254     0.02   ........  0
2023-01-04 00:01:12.100631  260       254     0.02   ........  0
2023-01-04 00:01:23.663443  261       254     0.02   ........  0
```

```
2023-01-04 00:01:35.210918   260       253     0.02  ........  0
2023-01-04 00:01:46.758317   260       253     0.02  ........  0
2023-01-04 00:01:58.305905   260       253     0.02  ........  0
2023-01-04 00:02:09.853251   262       253     0.03  ........  0
```

The data format of the **SI114x** *csv* is described on table 10.

Table 10. Data format used on **SI114x** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:02.801268	
Visible	visible	Integer			261	
Infra Red	ir	Integer			255	
Ultra Violet	uv	Foat			0.02	
Proximity1	proximity1	Integer			225	
Proximity2	proximity2	Integer			20131	
Proximity3	proximity3	Integer			0	

TMG3993

```
dateTime                    infraRed   red       green   ......  proximity
2023-01-04 00:00:01.809116  14.00      4.00      5.00    ......  24
2023-01-04 00:00:13.356797  13.00      4.00      5.00    ......  25
2023-01-04 00:00:24.904051  13.00      4.00      5.00    ......  25
2023-01-04 00:00:36.451265  12.00      4.00      5.00    ......  25
2023-01-04 00:00:47.998818  12.00      4.00      4.00    ......  25
2023-01-04 00:00:59.546473  11.00      3.00      4.00    ......  24
2023-01-04 00:01:11.108258  11.00      3.00      4.00    ......  25
2023-01-04 00:01:22.656208  11.00      3.00      4.00    ......  25
2023-01-04 00:01:34.203607  10.00      3.00      4.00    ......  25
2023-01-04 00:01:45.750780  10.00      3.00      4.00    ......  25
2023-01-04 00:01:57.298541  9.00       3.00      3.00    ......  25
2023-01-04 00:02:08.845794  9.00       3.00      3.00    ......  25
2023-01-04 00:02:20.408250  9.00       3.00      3.00    ......  24
2023-01-04 00:02:31.955576  8.00       2.00      3.00    ......  25
2023-01-04 00:02:43.502923  8.00       2.00      3.00    ......  25
```

The data format of the **TMG3993** *csv* is described on table 11.

Table 11. Data format used on **TMG3993** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:01.809116	
Infra Red	infrared	Float			14.00	
Red	red	Float			4.00	
Green	green	Float			5.00	
Blue	blue	Integer			7.00	
Proximity	proximity	Integer			24	

TSL2591

```
dateTime                    luminosity   ir      full .......    lux
2023-01-04 00:00:11.342016  2687083      41      107  .......    2.214639
2023-01-04 00:00:22.889220  2556007      39      103  .......    2.163324
2023-01-04 00:00:34.436582  2490466      38      98   .......    1.998367
2023-01-04 00:00:45.998925  2359391      36      95   .......    1.993330
2023-01-04 00:00:57.546508  2293851      35      91   .......    1.874708
2023-01-04 00:01:09.093538  2162775      33      87   .......    1.823338
```

The data format of the **TSL2591** *csv* is described on table 12.

Table 12. Data format used on **TSL2591** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:11.342016	
Luminosity	luminosity	Integer			2687083	
Infra Red	ir	Integer			41	
Full	full	Integer			107	
Visible	visible	Integer			66	
Lux	lux	Float			2.214639	

VEML6075

```
dateTime                    rawUVA   rawUVB   ..................  index
2023-01-04 00:00:00.801969  0        0        ..................  0.00
2023-01-04 00:00:12.349474  0        0        ..................  0.00
2023-01-04 00:00:23.896498  0        0        ..................  0.00
2023-01-04 00:00:35.444258  0        0        ..................  0.00
2023-01-04 00:00:47.006426  0        0        ..................  0.00
2023-01-04 00:00:58.554261  0        0        ..................  0.00
2023-01-04 00:01:10.101090  0        0        ..................  0.00
2023-01-04 00:01:21.648704  0        0        ..................  0.00
```

The data format of the **VEML6075** *csv* is described on table 13.

Table 13. Data format used on **VEML6075** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:00.801969	
Raw Ultra Violet A	rawUVA	Integer			0	
Raw Ultra Violet B	rawUVB	Integer			0	
Visible Compensation	visibleCompensation	Integer			0	
Infra Red Compensation	irCompensation	Integer			0	
Ultra Violet A	uva	Float			0.00	
Ultra Violet B	uvb	Float			0.00	
UV Index	index	Integer			0	

SKYCAM003

```
dateTime                    cloudPecentage   allRed ..........  cloudBlue
2023-01-04 00:00:04.353794  100.0            127.5  ..........  127.5
2023-01-04 00:05:04.311989  100.0            127.5  ..........  127.5
```

```
2023-01-04 00:10:04.019655   100.0            127.5  ..........  127.5
2023-01-04 00:15:04.216315   100.0            127.5  ..........  127.5
2023-01-04 00:20:03.846723   100.0            127.5  ..........  127.5
2023-01-04 00:25:03.898568   100.0            127.5  ..........  127.5
```

The data format of the **SKYCAM003** *csv* is described on table 14.

Table 14. Data format used on **SKYCAM003** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:04.353794	
Cloud Percentage	cloudPercentage	Float	%		100.0	
All Red	allRed	Float			127.5	
All Green	allGreen	Float			127.5	
All Blue	allBlue	Float			127.5	
Sky Red	skyRed	Integer			-1	
Sky Green	skyGreen	Integer			-1	
Sky Blue	skyBlue	Integer			-1	
Cloud Red	cloudRed	Float			127.5	
Cloud Green	cloudGreen	Float			127.5	
Cloud Blue	cloudBlue	Float			127.5	

3.1.5 Sound and Lightning Sensor

AS3935

```
dateTime                    source   energy   distance
2023-01-04 00:16:17.044439  2        30       63
2023-01-04 00:21:44.338102  2        0        63
2023-01-04 02:16:17.235212  2        30       63
2023-01-04 03:16:17.390213  2        30       63
2023-01-04 04:16:17.302775  2        30       63
2023-01-04 05:16:16.826721  2        30       63
2023-01-04 06:16:16.929995  2        30       63
```

```
2023-01-04 07:51:59.525492   2         0         63
2023-01-04 08:16:16.288806   2         30        63
2023-01-04 09:16:16.331344   2         30        63
2023-01-04 09:24:50.938658   2         0         63
2023-01-04 09:59:29.143407   2         0         63
2023-01-04 10:01:46.432704   2         30        63
2023-01-04 10:16:16.333990   2         30        63
2023-01-04 10:48:05.037363   2         0         63
2023-01-04 11:16:16.772286   2         30        63
2023-01-04 12:16:17.743577   2         30        63
2023-01-04 13:04:12.617759   2         0         63
2023-01-04 13:04:32.671638   2         0         63
```

The data format of the **AS3935** *csv* is described on table 15.

Table 15. Data format used on **AS3935** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:16:17.044439	
Source	source	Integer			2	
Energy	energy	Integer			30	
Distance	distance	Integer	km		63	

SEN0232

```
dateTime                    rawAnalog   rawVoltage   dB
2023-01-04 00:00:02.040488  17          0.08         4.15
2023-01-04 00:00:04.556777  16          0.08         3.91
2023-01-04 00:00:07.057364  15          0.07         3.66
2023-01-04 00:00:09.558081  13          0.06         3.17
2023-01-04 00:00:12.058904  14          0.07         3.42
2023-01-04 00:00:14.559609  12          0.06         2.93
2023-01-04 00:00:17.060362  15          0.07         3.66
2023-01-04 00:00:19.561099  11          0.05         2.69
2023-01-04 00:00:22.061834  19          0.09         4.64
2023-01-04 00:00:24.578352  13          0.06         3.17
2023-01-04 00:00:27.079106  15          0.07         3.66
2023-01-04 00:00:29.579937  18          0.09         4.39
2023-01-04 00:00:32.080686  15          0.07         3.66
```

The data format of the **SEN0232** *csv* is described on table 16.

Table 16. Data format used on **SEN0232** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:02.040488	
Raw Analog	rawAnalog	Integer			17	
Raw Voltage	rawVoltage	Float			0.08	
Sound in dB	dB	Float			4.15	

3.1.6 Ozone Sensor

TB108L

dateTime	ozone	temperature	pressure	voltage
2023-01-04 00:00:03.772092	71.8	30.3	862.8	0.0188
2023-01-04 00:00:17.731681	57.8	30.2	873.4	0.0188
2023-01-04 00:00:31.724246	66.1	30.2	862.9	0.0188
2023-01-04 00:00:45.716841	93.4	30.2	872.5	0.0188
2023-01-04 00:00:59.681053	104.5	30.2	863.2	0.0188
2023-01-04 00:01:13.673615	105.8	30.2	872.8	0.0188
2023-01-04 00:01:27.661576	95.9	30.2	862.2	0.0188
2023-01-04 00:01:41.625811	100.2	30.2	873.3	0.0188
2023-01-04 00:01:55.618314	102.9	30.2	862.2	0.0188
2023-01-04 00:02:09.606005	80.1	30.2	873.3	0.0188
2023-01-04 00:02:23.565577	79.2	30.2	862.9	0.0188
2023-01-04 00:02:37.558110	98.7	30.2	872.5	0.0188
2023-01-04 00:02:51.550699	87.4	30.2	863.3	0.0188
2023-01-04 00:03:05.510434	67.5	30.2	872.7	0.0188

The data format of the **TB108L** *csv* is described on table 17.

Table 17. Data format used on **TB108L** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:03.772092	
Ozone	ozone	Float			71.8	
Temperature	temperature	Float			30.3	
Pressure	pressure	Float			862.8	
Voltage	voltage	Float			0.0188	

3.1.7 Radiation Sensors

LIBRAD

```
dateTime                    countPerMinute   ................ LIBRADCount
2023-01-04 00:00:04.408582  0.0000           ................ 0
2023-01-04 00:00:14.565957  0.0000           ................ 0
2023-01-04 00:00:24.723068  0.0000           ................ 0
2023-01-04 00:00:34.880212  0.0000           ................ 0
2023-01-04 00:00:45.022648  0.0000           ................ 0
2023-01-04 00:00:55.180008  0.0000           ................ 0
```

The data format of the **LIBRAD** *csv* is described on table 18.

Table 18. Data format used on **LIBRAD** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:04.408582	
count Per Minute	countPer Minute	Float			0.000	
Radiation Value	radiation Value	Float			0.000	
Time Spent	timeSpent	Integer			10000	
Radiation Count	LIBRAD Count	Integer			0	

QLMRAD001

dateTime	event
2023-01-04 00:00:00.143675	0063
2023-01-04 00:00:00.146156	0200
2023-01-04 00:00:00.190742	0074
2023-01-04 00:00:00.286839	0056
2023-01-04 00:00:00.293918	0065
2023-01-04 00:00:00.550614	0086
2023-01-04 00:00:00.582952	0050
2023-01-04 00:00:00.636760	0150
2023-01-04 00:00:00.686808	0075
2023-01-04 00:00:00.839238	0229
2023-01-04 00:00:00.903411	0052
2023-01-04 00:00:01.050683	0049
2023-01-04 00:00:01.334357	0738

The data format of the **QLMRAD001** *csv* is described on table 19.

Table 19. Data format used on **QLMRAD001** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:00.143675	
Event	event	Integer			0063	

3.1.8 GPS Sensors

GPSGPGGA2

dateTime	timestamp	latitudeCoordinate	...	stationID
2023-01-04 00:00:01.101081	00:00:01	32.715703500000004	...	0
2023-01-04 00:00:04.083579	00:00:04	32.715704833333334	...	0
2023-01-04 00:00:07.086137	00:00:07	32.715700500000004	...	0
2023-01-04 00:00:10.085323	00:00:10	32.71569783333334	...	0
2023-01-04 00:00:13.082585	00:00:13	32.715699666666666	...	0
2023-01-04 00:00:16.081818	00:00:16	32.715701833333334	...	0
2023-01-04 00:00:19.080205	00:00:19	32.71570366666666	...	0

The data format of the **GPSGPGGA2** *csv* is described on table 20.

Table 20. Data format used on **GPSGPGGA2** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC date	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:01.101081	
Time Stamp	timestamp	hh:mm:ss			00:00:01	
Status	status	string			A	
Latitude Coordinate	latitude Coordinate	Float	Degrees		32.7157035	
Longitude Coordinate	longitude Coordinate	Float	Degrees		-96.7480245	
Latitude	latitude	Float	Degrees		3242.94221	
Latitude Direction	latitude Direction	string			N	
Longitude	longitude	Float	Degrees		9644.88147	
Longitude Direction	longitude Direction	string			W	
GPS Quaity	gpsQuality	Integer			2	
Number of Satellites	numberOf Satellites	Integer			10	
Horizontal Dilution	Horizontal Dilution	Float			1.01	
Altitude	altitude	Float	meters		133.4	
Unit of Altitude	altitudeUnits	string			M	
Unit of Altitude	altitudeUnits	string			M	
Undulation	undulation	Float	meters		-25.2	
Unit of Undulation	undulation Units	Float	meters		-25.2	
	age					
Station ID	stationID	string			0	

GPSGPRMC2

```
dateTime                    timestamp ..... magVariationDirection
2023-01-04 00:00:01.093170  00:00:01  .....
2023-01-04 00:00:04.076470  00:00:04  .....
2023-01-04 00:00:07.078490  00:00:07  .....
2023-01-04 00:00:10.078148  00:00:10  .....
2023-01-04 00:00:13.075355  00:00:13  .....
2023-01-04 00:00:16.074523  00:00:16  .....
```

The data format of the **GPSGPRMC2** *csv* is described on table 21.

Table 21. Data format used on **GPSGPRMC2** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC date	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:01.093170	
Time Stamp	timestamp	hh:mm:ss			00:00:01	
Latitude Coordinate	latitude Coordinate	Float	Degrees		32.7157035	
Longitude Coordinate	longitude Coordinate	Float	Degrees		-96.7480245	
Latitude	latitude	Float	Degrees		3242.94221	
Latitude Direction	latitude Direction	string			N	
Longitude	longitude	Float	Degrees		9644.88147	
Longitude Direction	longitude Direction	string			W	
Speed of Device over Ground	speedOver Ground	Float			0.082	
True Course	trueCourse					
Magnetic Variation	magnetic Variation					
Magnetic Variation Direction	magnetic Variation Direction					

GPGGA

dateTime	UTCTimeStamp	.....	checkSum
2023-01-04 00:00:05.331006	000005	.....	3E
2023-01-04 00:00:10.831074	000010	.....	30
2023-01-04 00:00:15.834106	00001	.....	38
2023-01-04 00:00:21.331956	000021	.....	3A
2023-01-04 00:00:26.834607	000026	.....	3E
2023-01-04 00:00:32.332718	000032	.....	31
2023-01-04 00:00:37.832798	000037	.....	3F
2023-01-04 00:00:42.836016	000042	.....	3E

The data format of the **GPPGA** *csv* is described on table 22.

Table 22. Data format used on **GPGGA** data *csv*

Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC date	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:05.331006	
UTC Time Stamp	UTC TimeStamp	Integer			000005	
Latitude	latitude	Float	Degrees		3242.9427	
Latitude Direction	latDirection Direction	string			N	
Longitude	longitude	Float	Degrees		9644.8815	
Longitude Direction	lonDirection	string			W	
GPS Quaity	gpsQuality	Integer			2	
Number of Satellites	numberOf Satellites	Integer			7	
Horizontal Dilution	horizontal Dilution	Float			1.9	
Altitude	altitude	Float	meters		130.2	
Unit of Altitude	AUnits	string			M	

Geoidal Separation	geoidal Separation					
Geoidal Separation Unit	gSUnits					
	ageOf Differential					
Station ID	stationID	string				
checkSum	Check Sum	string			3E	

YXXDR

```
dateTime                    angularDisplacement   pitch ..... rollOfvessel
2023-01-04 00:00:00.078385  A                     0.6   ..... ROLL
2023-01-04 00:00:05.576478  A                     0.3   ..... ROLL
2023-01-04 00:00:11.076524  A                     0.5   ..... ROLL
2023-01-04 00:00:16.079577  A                     0.1   ..... ROLL
2023-01-04 00:00:21.577380  A                     0.5   ..... ROLL
2023-01-04 00:00:27.080041  A                     0.5   ..... ROLL
2023-01-04 00:00:32.578080  A                     0.3   ..... ROLL
```

The data format of the **YXXDR** *csv* is described on table 23.

Table 23. Data format used on **YXXDR** data *csv*

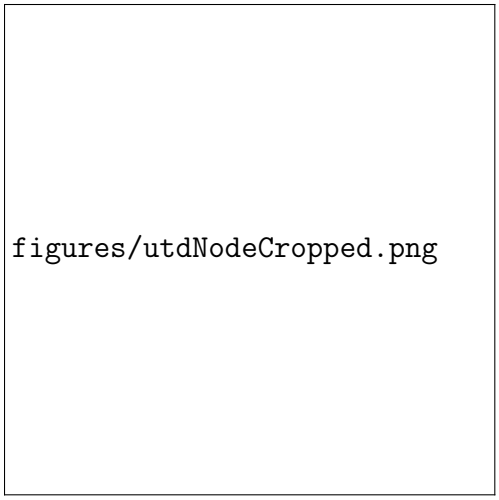
Parameter	Column Name	Format	Unit	Errors	Example	Comments
UTC Time	dateTime	yyyy-MM-dd hh:mm:ss			2023-01-04 00:00:00.078385	
Angular Dispalcement	angular Displacement	Float	Degree		100.0	
Pitch	pitch	Float	Degree		127.5	
Pitch Unit	degrees	Float			127.5	
Pitch of Vessel	pitchOfVessel	Float			127.5	
Roll	roll	Float	Degree		-0.9	
Roll Unit	degrees2	string			D	
Roll of Vessel	rollofVessel	string			ROLL	

References

Appendix C: Stationary Sensing Systems

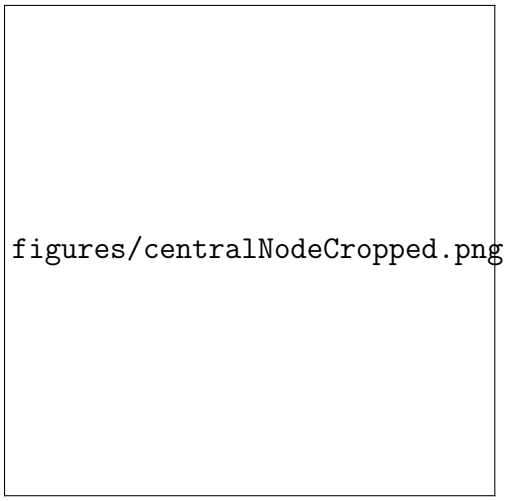
MINTS has been developing multiple sensor systems for a wide range of applications. One subset of such systems is 24/7 Streaming Distributed Sentinels, where the data is provided on a frequent and continuous basis.

1st Generation: UTD Nodes



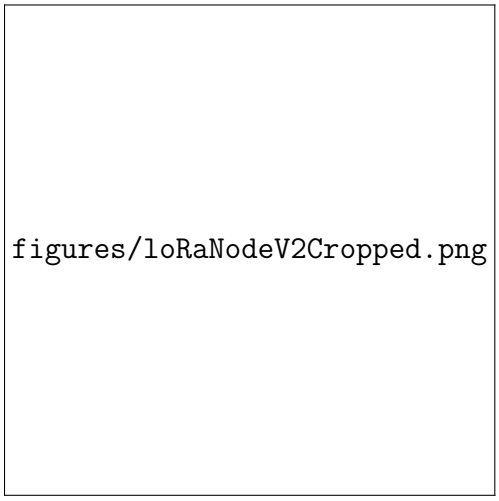
The UTD Node is a stationery sensor system consisting an array of iot sensors which is an extensible platform in which many newer sensors can be adopted into. The UTD Node houses a particulate matter sensor, CO_2 sensor, climate sensor, a set of light sensors as well as an skyward facing camera.

2nd Generation: Central Nodes



Central Nodes are the second generation of UTD Nodes. In addition to providing all the sensors provided by the UTD Node, the Central Node has an expanded light sensing module as well as a radiation sensor, a sound sensor that detects bird calls as well as gunshots, a research grade ozone sensor, a lightning sensor, and remote power management capabilities. Additionally, the Central Node serves as a central gateway for a mesh network of LoRaWAN Nodes described in section 3.1.8.

LoRaWAN Nodes



LoRa is an infant communication technology based on ISM (Industrial, Scientific and Medical) bands which are capable of low power and Long Range applications. LoRaWAN is a Wide Area Network protocol that is designed to embed LoRa technology into a network infrastructure . The LoRa Nodes are designed to make use of LoRaWAN technology with each node a part of a mesh network communicating with one Central Node.

The LoRa Nodes are designed to work without the need of direct power nor internet connectivity. This makes it extremely versatile. The main source of power for the LoRa Nodes is sunlight and thus it consists of two solar panels to harness solar energy.

A LoRa Node consists of a particulate matter sensor and a climate sensor.

Appendix D: MINTS GitHub repositories

- Version 1, 3 firmware:
  https://github.com/mi3nts/minWeNodes
- Version 4 firmware:
  https://github.com/mi3nts/minWeZeroNodes
- UTD Node firmware:
  https://github.com/mi3nts/UTDNodes
- Central Nodes firmware:
  https://github.com/mi3nts/centralHub
- LoRaWAN Nodes firmware:
  https://github.com/mi3nts/LoRaWANNodes