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Report on Crowd Observatories

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Acronyms and Abbreviations

CDI	Crowd Dynamics International Limited
EC	European Commission
EMT	Executive Management team
FZJ	Forschungszentrum Julich Gmbh
GA	Grant Agreement
INRIA	Institut National De Recherche En Informatique Et Automatique
KPIs	Key Performance Indicators
ONH	Onhys
PO	Project Officer
UL	University of Leeds
ULM	Universität Ulm
URJC	Universidad Rey Juan Carlos
WP	Work-package

Executive Summary

This document is a redacted version of deliverable D4.1 to enable it to be unrestricted. A restricted, confidential version of D4.1 has also been produced which contains confidential information linked to the crowd observatories and is available on request to the project coordinator by project officer and project reviewers.

This report focuses on the first set of observatories for CrowdDNA, looking specifically at the movement of people in an environment where the movement is uninhibited by controlled experiments. The intention is to create a data set for predicting crowd movement which once applied will enhance crowd safety. Through the identification of a range of event types through categorisation, a target list if observatories were contacted. Due to the annual nature of festival season, the focus was placed on pursuing festival observatories to maximise the number of festival seasons for observation throughout the duration of the CrowdDNA project. A systematic approach was taken to secure the observatories.

Scenarios and types of data to be captured were specified for each observatory type prior to attending, with specific ones being relevant to the festivals. This helped to inform what equipment would be required for data capture and the methodology as to how to capture it. The chosen approach was a combination of photo, video, body motion, Xsens suits, IoT tracking, mobile phone tracking and camera counters. The data capture methodology posed some production considerations and presented the requirement for a common framework to ensure GDPR compliance, as well as legal and ethical considerations.

The installed observatories took place between the 17th June and 20th August 2022, with one festival in France (Hellfest) and three in the UK (Tramlines, Bloodstock and ArcTanGent), all with varying capacities and curation. For each observatory, a detailed account of the data capture process is documented within this report, including maps, photos, and video file references. Observations made on site at each of the festivals has facilitated a feedback report to the owners and operators based on findings (issued separately to this report) but included in bullet point form within this report.

The data captured at each of the observatories may under-go further analysis than what is included in this report to generate algorithms for predicting crowd movement and in turn, increase crowd safety. Learnings from participating in the data capture exercises at observatories can be applied to all observatories moving forward and if required, more extensive data capture can take place at festivals in the 2023 season.

1. Introduction

1.1. Purpose of Observatories

The purpose of the observatories is to capture data of people movement in an environment where the movement is free and uninhibited by the control of a laboratory experiment. The intention is to gather data on the instinctive way in which people move within crowded environments and use these observations to predict crowd movement.

1.2. Goals of Observatories

- Create a data set of people movement within a range of crowded environments.
- Map the movement of people within a crowded environment and determine algorithms from the mapped movement.
- Use the algorithms to predict crowd movement, compare the predictions against the data to determine the accuracy of the algorithm.
- Make observations between data sets for similarities in crowd movement across observatories.
- Create an open-source data set for crowd management companies, event planners, health and safety advisors (etc.) to be able to reference.
- Increase crowd safety.

2. Observatories Strategy

This section outlines the approach taken in identifying the types of events and venues that should be considered as part of the observatories study.

2.1. Range of Observatories

A process of identification of suitable event types has been conducted to categorise and appropriately quantify each typology and its possible size, scale, and the types of crowding conditions that are likely to be seen at each. It is crucial that a suitable profile of event types covering a broad range of events across the events industry is collated, so that the maximum number of different crowding behaviours can be assessed.

Identification of the different event typologies has taken place in coordination with other project partners, and these are presented in the figure below.

Figure 2.1 - Event Types

The taxonomy of each of typologies identified has been detailed, considering the possible size and scale, anticipated level of crowding, and the behaviours that could be seen at each event. This task has helped refine the profile of typologies and scope the range of behaviours which need to be studied. Table 2.1 below shows a taxonomy of event types for CrowdDNA observatories.

Table 2.1 - Taxonomy of Event Types

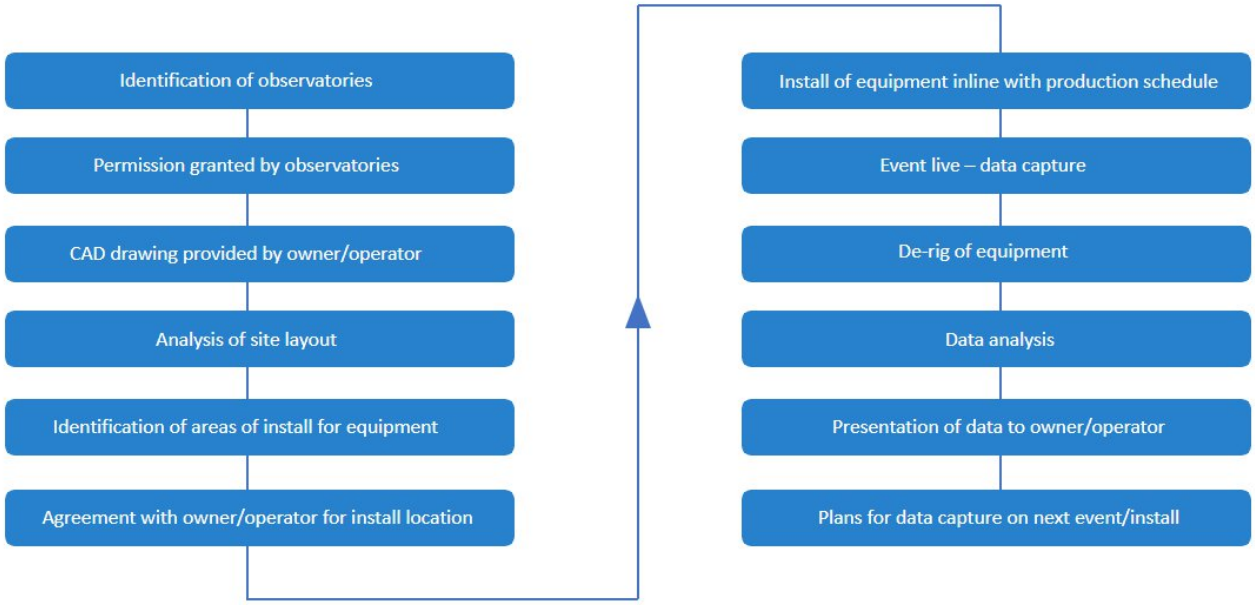
Category Number	Category Name	Examples	Size	Capacity	Density	Behaviour
1	Stadium	Stade De France, Wembley	very large building with outer concourses	20,000-100,000	high	one identity happy to be at high density, move together, hooliganism
2	Concert Arena	O2 Arena, Manchester Arena	large building with small outer spaces	5,000-20,000	medium/high	happy to be at high density, groups move or sit together
3	Theatre/Cin	Bataclan, Opera	small/mediu	1,000-	low	seated crowd, slow moving,

	ema	House	m building	3,000		entry queues
4	Music Festival	Glastonbury, Tomorrowland	wide area with concentrated stages	10,000-100,000	high	standing crowds, high density, one identity
5	Temporary Outdoor Event/Fair	Winter Wonderland, Motor Show, Air Show	wide/small area with concentrated kiosks	100-5,000	medium/high	standing crowds, medium density
6	Conference -Exhibition	EXPO, EXCEL London, Palais des Festivals	large area with concentrated kiosks	1,000-5,000	low	standing crowds, low density
7	Train Station	London Euston	small area with street furniture	200-2,000	medium	standing crowds, medium density
8	Airport	Heathrow, Charles de Gaulle	medium size area with inner concourses	1,000-5,000	low	standing crowds, low density
9	City Centre/public space	Shopping street	medium size area with street furniture	100-1,000	low/medium	standing crowds, low/medium density
10	City centre event	Christmas Market/Local Festivals/New year's Eve	narrow area with street furniture	1,000-200,000	medium/high	standing crowds, low/medium density
11	University	Campus site or busy student areas	large campus/city centre student area	100-1,000	low/medium	student groups moving together, busy before/after lectures or in buildings
12	Night-time Economy Venues	Mayfield Depot FABRIC	Warehouse/ Old train station	10,000	medium/high	Standing crowds, busy key areas and plenty of crowd movement
13	Theme Park/Attractions	Thorpe Park, Disneyland Paris	Park area with indoor and outdoor entertainment and rides	Up to 55,000	medium/high	Moving crowds, queues, congested areas

2.2. Approach to setting up observatories

To select and set up effective and robust observatories at related events, several steps must be considered. This process has been identified and is presented in the flowchart below.

Figure 2.2 - Approach Flowchart



To allow for observatories to be set up and report in a timely manner, the following key milestones have been defined:

- 2021-22 – Scoping of potential observatories
    - Identify and approach venues
    - Agree dates and observation set-up
- 2022 – Festivals in summer
    - Conduct initial observations
    - Help identify data gathering requirements and issues faced
- 2022-2023 – Alternative types of venues
    - Conduct second round of observations across different venue types
    - Consider initial observations lessons learnt
- 2023 – Refine and repeat festival data gathering

2.3. Number of Each Category Targeted

In order to provide a reliable sample of events, considering the range of different sizes and event conditions, a number of each event/venue type will need to be targeted. For the purposes of this study an appropriate number of events which allows a robust analysis, is in the order of 4 to 5 events under each category.

2.4. Potential Observatories Contacted

Following the approach outlined in this section, a number of appropriate events/venues have been contacted. This list of events/venues is a 'living list' and will be updated as new events are approached and confirmed.

Table 2.2 - Events/Venues Contacted

Venue Category	Event/Venue	Location	Situation
Stadium	Velodrome	France	Confirmed
Concert Arena	AO Arena	Manchester, UK	Awaiting Response
	NEC	Birmingham, UK	Awaiting Response
	O2 Arena	London, UK	Awaiting Response
	02 Academy Brixton	London, UK	Awaiting Response
Theatre/Cinema	Tramlines	Sheffield, UK	Confirmed
	Hellfest	Clisson, France	Confirmed
Music Festival	ArcTanGent	Bristol, UK	Confirmed Attended August 2022
	Bloodstock	Burton-upon-Trent, UK	Confirmed Attended August 2022
	Damnation	Manchester	Confirmed Attending Nov 2022
	FOCUS Wales	Wrexham	Agreed to participate
	NASS	Somerset, UK	Confirmed but cancelled due to COVID
	Tramlines	Sheffield, UK	Confirmed Attended July 2022
Temporary Outdoor Event/Fair	Winter Wonderland	London, UK	In conversation for Nov 2022 – Jan 2023
Airport	Heathrow Airport	London, UK	Awaiting Response
	Gatwick Airport	London, UK	Awaiting Response
	Manchester Airport	Manchester, UK	Awaiting Response
	Stansted Airport	London UK	Awaiting Response
	East Midlands Airport	Derby, UK	Awaiting Response
Night-time Economy Venues	Printworks	London, UK	Awaiting Response
	The Drumshed	London, UK	Confirmed, not attended

			due to permanent venue closure.
Theme Park/Attractions	Mayfield Depot	Manchester, UK	Confirmed
	Magazine London	London, UK	Awaiting Response
	Broadwick Live	Various, UK	Awaiting Response
	Evolution	London, UK	Awaiting Response
	Alton Towers	Stoke-on-Trent, UK	Awaiting Response
	Thorpe Park	London, UK	Awaiting Response
	Legoland	Windsor, UK	Awaiting Response
	Chessington World of Adventures	London, UK	Awaiting Response
	Dreamland	Margate, UK	Awaiting Response

3. Data Gathering

This section identifies the data gathering requirements and techniques needed to effectively capture and quantify crowd flow conditions and specific behaviours seen in the crowd observatories.

3.1. Scenarios/Use Cases to be Observed

Across the observatories, a variety of different crowd movement behaviours can be expected. Many of these are likely to be present across many or all event typologies, but present in different conditions and contexts. A variety of different data capture options will need to be considered to allow these behaviours to be quantified.

The main scenarios and use cases under which data capture will be required have been identified, considering all anticipated behaviours and aspects of people flow expected within the observatories. These are listed in the table below.

Table 3.1 - Scenarios/Use-cases for Data Capture

Scenario/Use Case	Data Capture
Large scale crowd movement	Mass movement of people through a large event, venue, public space, transportation hub
Queueing	Queue behaviour at various locations including ticket purchase, bars, merchandise, food concessions etc.
Main gateway of an entertainment environment	Ingress and egress of people through an entertainment environment
Stage (internal)	Dense crowd movements influenced by performed music within a structure
Stage (external)	Large scale dense crowd movements influenced by performed music outdoors
Person in crowd wearing body suit with pressure pads	1) Readings from the pressure suit 2) Movement of the individual wearing it through a crowd 3) The cascade effect of other people surrounding the individual
Walk-through experience	Cameras to track movement through a series of multiple rooms or spaces
Every-day use of transportation hubs	1) Movement throughout transportation hubs at various times of day 2) Bottle-neck areas such as security, ticket gates, passport control
Mass movement of people through entertainment venues	Movement of people through festivals and venues, capturing busiest times through key areas; gates, bars, stages, etc.
Mass movement of people through entertainment venues	Movement of people through festivals and venues, capturing busiest times through key areas; gates, bars, stages, etc.

The identified scenarios/use cases for data collection which are most relevant and need to be considered at each observatory type have been identified and are presented below.

Table 3.2 – Scenarios/Use Cases by Event

Event Typology	Scenario/Use Case
Stadium	Queueing Main gateway of an entertainment environment Person in crowd wearing body suit with pressure pads Mass movement of people through entertainment venues
Concert Arena	Queueing Main gateway of an entertainment environment Stage (external) Person in crowd wearing body suit with pressure pads Mass movement of people through entertainment venues
Theatre/Cinema	Queueing
Music Festival	Large scale crowd movement Queueing Main gateway of an entertainment environment Stage (internal) Stage (external) Person in crowd wearing body suit with pressure pads Mass movement of people through entertainment venues
Temporary Outdoor Event/Fair	Large scale crowd movement
Conference-Exhibition	Queueing Main gateway of an entertainment environment Walk-through experience
Train Station	Everyday use of transportation hubs
Airport	Everyday use of transportation hubs
Night-time Economy Venues	Main gateway of an entertainment environment Stage (internal) Person in crowd wearing body suit with pressure pads Mass movement of people through entertainment venues
Theme Park/Attractions	Large scale crowd movement Queueing Main gateway of an entertainment environment

3.2. Types of Data to be Gathered

Each scenario/use case identified will require specific types of data to be gathered. The main types of such data have been detailed with input from across the research partners.

The primary data type will be video, recorded at static cameras, or on person, and may be recorded or live streamed. Other methods may also be utilised. These are listed in full below.

3.2.1. Video

High quality video recording required, ambition to use cameras with 4k resolution. This is needed to effectively monitor and scrutinise movement of individuals or groups in large, crowded spaces or low-light events.

For any video recorded, a video log should be produced summarising key details of each video recorded has been produced. This acts as a point of reference, allowing key video files to be easily identified for analysis, and is shown in the example below.

Table 3.1 - Video Capture Log

Original Name	Video Name	Date	Time	Length	Location	Description	Observations
GH010005	Tramlines_Friday_Bag_Check_Gate1	22/07/2022	12:17	00:10:00	GATE 1	Capture taken at bag check at gate 1, taken as gates opened at midday on Friday	
GH010006	Tramlines_Fri_Ingress_Gate1_1	22/07/2022	12:30	00:00:55	GATE 1	Captures of crowds ingressing to the festival site at the beginning of the day, camera is positioned away from the Gate 1 entrance, towards the festival site	
GH010007	Tramlines_Fri_Ingress_Gate1_2	22/07/2022	12:31	00:06:40	GATE 1		
GH010008	Tramlines_Fri_Ingress_Gate1_3	22/07/2022	12:39	00:09:00	GATE 1		
GH010009	Tramlines_Fri_Adj_Pinchpoint_Afternoon_1	22/07/2022	14:05	00:11:47	Pinchpoint	Crowd movement between Arena 2/3 (Right) and Arena 1 (Left) - captured towards the end of Shed 7 performance on Main Stage. Camera postion is adjacent to the main pinchpoint	
GH020009	Tramlines_Fri_Adj_Pinchpoint_Afternoon_2	22/07/2022	14:16	00:11:47	Pinchpoint		

Hellfest Observatory used the following kit:

- 1 camera aca1300-60gc + focal len = 6 mm (for sensor format 2/3") HF6XA-5M ~58° HFoV
- 1 camera aca1300-60gc + focal len = 25 mm (for sensor format 2/3") HF25XA-5M ~15° HFoV
- Camera were fixed in height above the crowd using articulating arm and clamp. They were inaccessible during festival for security reasons (location was shared with pyrotechnical equipment)
- With GiGE interface, camera were fully operated through ethernet.
- Data captured on a PC, compressed, stored and transferred to a NAS drive.
- 20 fps (limited by network capacities)

Figure 3.1 – Camera acal

UK Festival Observatories used the following kit:

- GoPro Hero 8
- Fixed lens
- 30 fps at 1080p
- 12-megapixel sensor (4000 by 3000 pixels)
- Video stabilisation from HyperSmooth 2.0

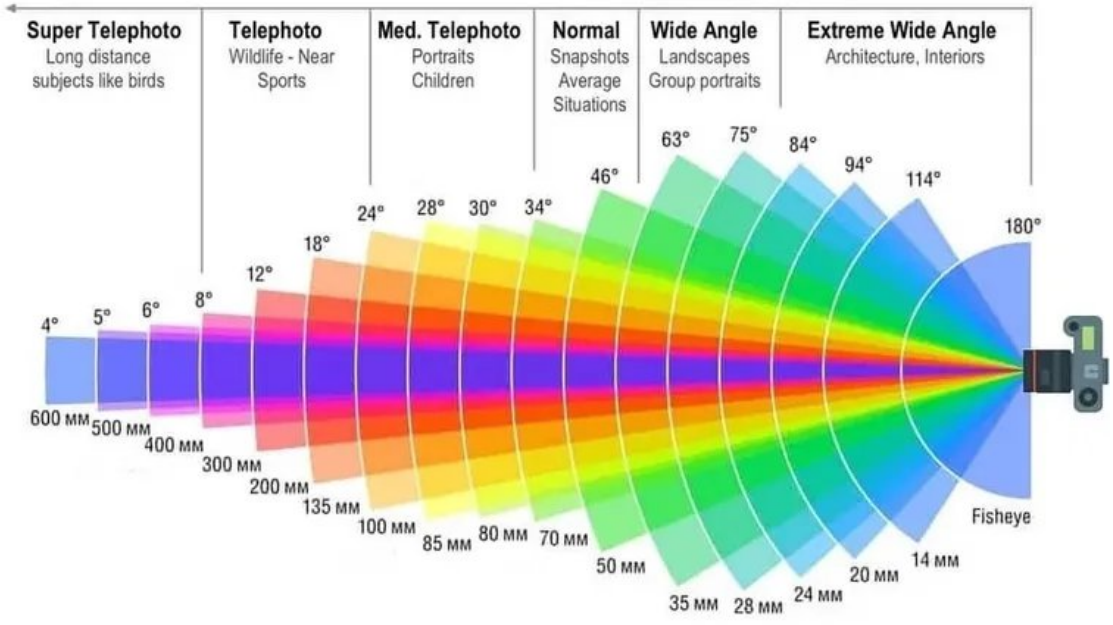
- Data captured on SD card and backed up to hard-drive
- Multi-angle video content and single location content
- Fixed locations – on tripods
- Roaming – walk through of the site

Figure 3.2 – GoPro Hero 8

Other equipment considered for observatories:

- Wide angle/360-degree camera
- Thermal camera required for night-time? Does it provide useful data?
- Angle of cameras will change based on lens used (Figure 3.1)
    - Wide angle lens may only require 3 corner points and one centre point to capture the same area as a fixed lens in four corners and one in the centre
- Footage distortion likely to occur? Do we have capabilities to process this?
- Single camera footage vs multi angle for different purposes

Figure 3.3 – Type of lenses



3.2.2. Photos

Photos are to be taken to compliment other data capture and allow feedback to given to the observatories themselves:

- Smart phone photos of for orientation, general observations, and camera angles for video data capture. Roaming photos and fixed location photos.
- Stills taken from video footage

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- Marketing photos provided by the observatory.

3.2.3. Body Motion

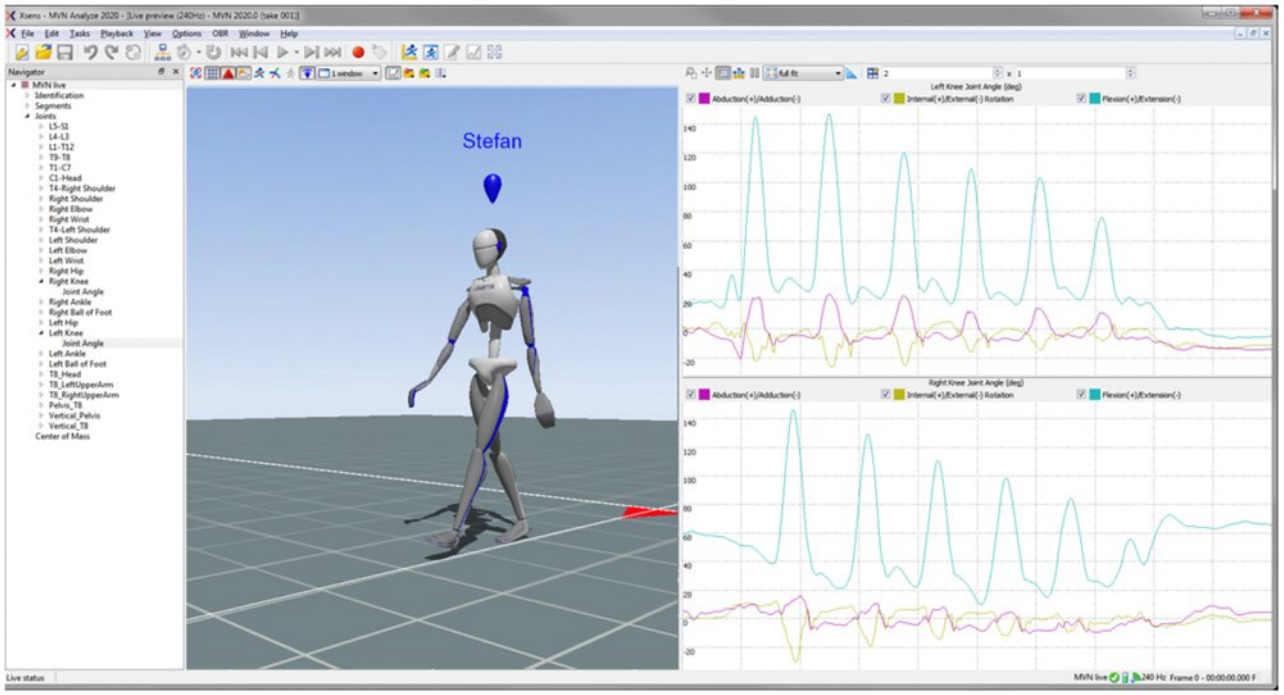
We use the 3D motion capturing (MoCap) system MVN Link by Xsens to track the full body motion of a person in the crowd (Schepers, Giuberti, & Bellusci, 2018). While optical MoCap Systems need a free line of sight between the tracking points on the body and a set of cameras, the Xsens MoCap system uses inertial measurement units (IMU) as sensors. These IMUs measure the acceleration, the angular rate and the magnetic field strength and a line of sight between the body and a camera is not necessary. Therefore, capturing of the full body motion is even possible in dense crowds.

Each MVN Link suit (as shown in Figure 3.) is equipped with 17 IMU sensors on predefined independently moving body segments. The measurement can be triggered manually, and the recorded data is stored locally on a device in the suit. Thus, the measurement is self-contained, and the data can be downloaded afterwards.

After performing a calibration procedure and taking detailed body dimension measurements, the MVN Analyse software then calculates the full body motion based on a biomechanical model from the measured data set (see example in Figure 3.). The processed data then includes the orientation, position, velocity, acceleration, angular velocity, and angular acceleration of each body segment as well as the angles of joints and the location of the centre of mass. The data can be exported either as xml-file or as biomechanical c3d-file.

Figure 3.4 –Xsens MVN Link Lycra suit (left) and Associated IMU Sensors (right) (Xsens, 2022)

Figure 3.5 – Example View of MVN Analyse Software Showing an Avatar Representing Biomechanical Data Recorded by Xsens Mocap &Sample Graphs of Data Captured (Xsens, 2022)



3.2.4. IoT Device Tracking

IoT tracking consists in detecting the presence of mobile devices (such as phones, smart watches, wireless earphones, etc.) near sensor terminals (Figure 3.6) when their WiFi or Bluetooth systems are turned on (thereby emitting regular wireless signals). These signals contain identifying data (MAC address) that allows to follow the rough evolution of the position of the device over time.

This technology is thus adapted to a measurement of the flows of movements of a crowd, making it possible to approximate at the individual scale which is the path followed on a broad spatial and temporal scale. The tracking system we used was delivered by the INOCESS company in France (https://www.inocess.com/).
Let's note some particularities of this type of tracking, and of the one we used in crowd observatories:

- There is limited correspondence between devices and people. Only a proportion of the population has a mobile terminal with WiFi and/or Bluetooth enabled. It is also possible that the terminal switches on and off. On the other hand, a person may possess multiple such devices as well (e.g. phone and watch and earphones). Finally, note that a MAC address may change over time (e.g. around every fifteen minutes for Apple devices), making it impossible to track a device over a large period of time. The quantification of the flows is therefore subject to the estimation of the proportion of active terminals.
- The position estimation is coarse. In a basic way, the detection of a terminal makes it possible to know that it is close to a sensor terminal. The accuracy of the positioning is equivalent to the dimensions of the collection zone of a terminal, ranging from a few meters to a few dozen meters. More precise information requires the use of several sensors in the same area and a calibration procedure. We have only looked for a coarse positioning in the experiments related to CrowdDNA.
- The tracking of a terminal identified by its MAC address violates the RGPD laws protecting privacy. Indeed, it allows to potentially know the paths of an individual on large scales of time and space. However, it is easy to encrypt this information in an irreversible way, and to limit the tracking to small scales of space and time, not allowing to trace the identity of the wearer. This is further helped in a sense by the frequent MAC address changes of the devices, essentially subdividing paths into many sub paths which, from the point of view of the reconstruction system, may or may not be related. Thus, the technology we use: 1) encrypts the sensed MAC addresses directly at the source, on the sensor, to

avoid storing clear MAC addresses, 2) is limited to tracking on the studied crowd observatory, and 3) changes the MAC address encryption parameters regularly (once a day), on top of the devices' own MAC changing, to prevent cross-checking over several days, or over several locations if the device was used in another space frequented by the owner.

The many unknowns involved in this system make it such that no counting is possible, and precise tracking of individuals is not feasible either. The purpose of this technology is rather to determine the rough proportions of crowds which move between well distinct zones of a monitored area (such as the paths in green in Figure 3.8, where major trajectories could be found between a few different rooms and the entrance of a building). As such, if zones of specific interest can be identified, then it is possible to infer the preferred paths and travel times between them. In crowd observatories, this technology has been useful in trying to understand, even roughly, the flows around a specific observation point where other data collections methods were employed.

Figure 3.6 - Nextent eKo Bluetooth/WiFi Sensor (Image Courtesy of Inocess)

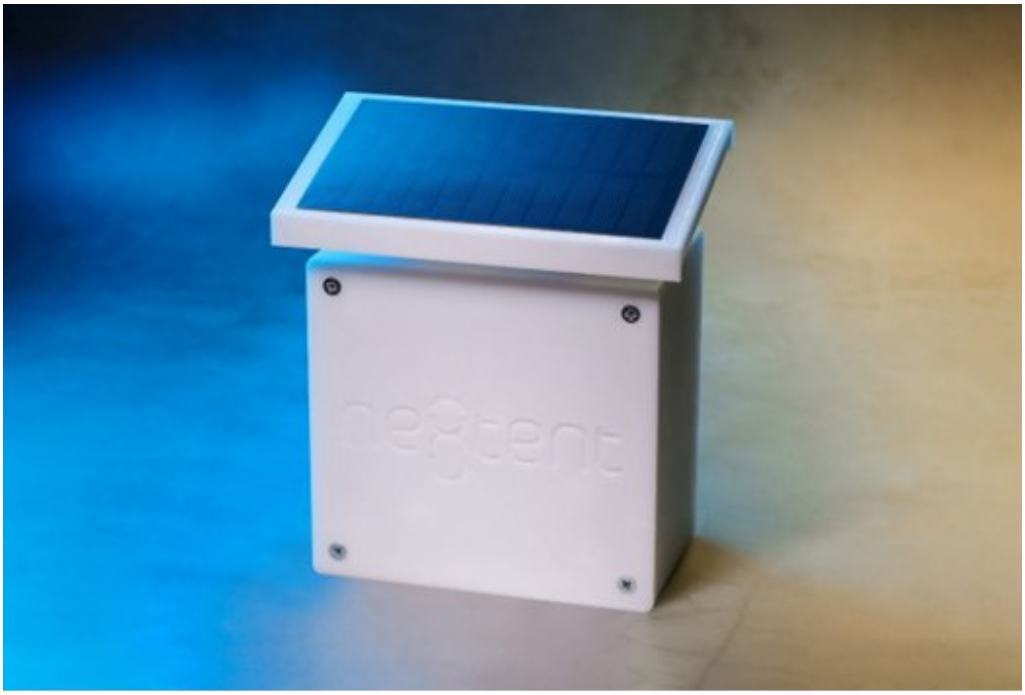


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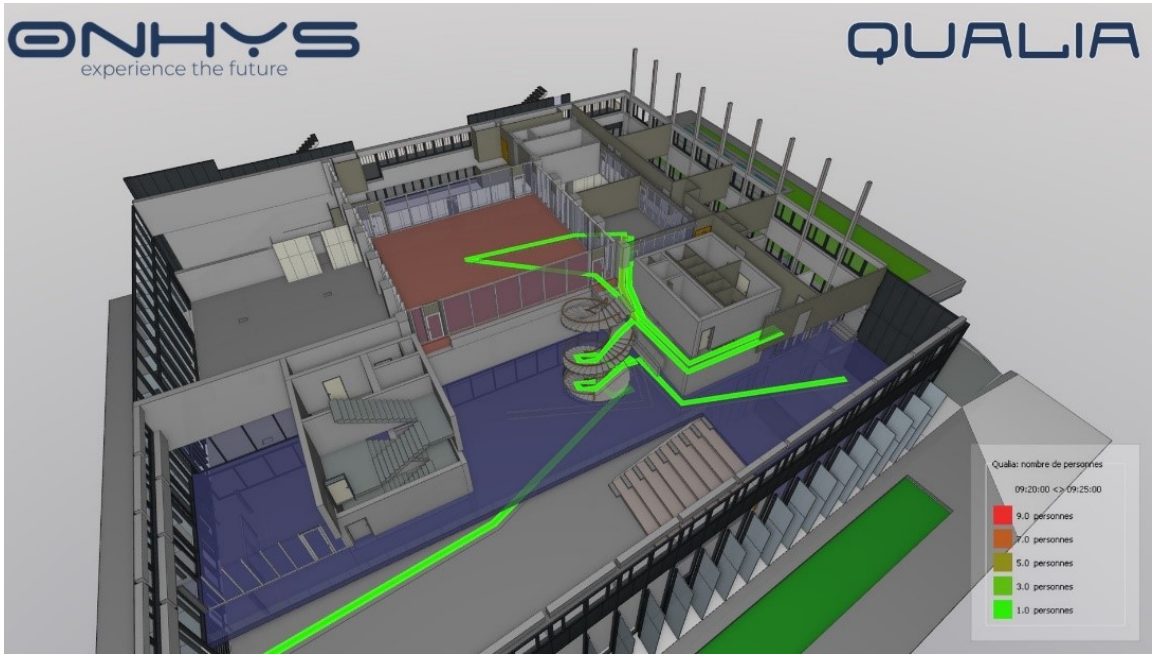
Figure 3.7 - Main Visitor Paths Reconstructed from IoT Tracking Data inside a Building



3.2.5. Mobile phone tracking

Cell phone tracking consists of detecting the presence of phones near sensor terminals that emit a regular signal when their Wifi or Bluetooth systems are turned on. This signal contains identifying data (MAC address) that allows to follow the evolution of the position of the device over time.

This technology is thus adapted to a measurement of the flows of movements of a crowd, making it possible to know at the individual scale which path is followed on a broad spatial and temporal scale. The tracking system we used was delivered by the INOCESS company in France (https://www.inocess.com/)

The particularities of this type of tracking, and of the one we used in crowd observatories:

- The tracking is partial: only a proportion of the population has a mobile terminal with Wifi and/or Bluetooth enabled. It is also possible that the terminal switches on and off. Finally note that MAC address may change over time, making impossible to track a device over a long timeframe. The quantification of the flows is therefore subject to the estimation of the proportion of average active terminal.
- The position estimation is coarse. In a basic way, the detection of a terminal makes it possible to know that it is close to a sensor terminal. The accuracy of the positioning is equivalent to the dimensions of the collection zone of a terminal, ranging from a few meters to a few dozen meters. More precise information requires the use of several sensors in the same area and a calibration procedure. We have only looked for a coarse positioning in the experiments related to CrowdDNA.
- The tracking of a terminal identified by its MAC address violates the RGPD laws protecting privacy. Indeed, it allows identification of the movements of an individual on large scales of time and space. However, it is easy to encrypt this information in an irreversible way, and to limit the tracking to small scales of space and time, preventing the identity of the wearer to be traced. Thus, the technology we use: 1) encrypts the sensed MAC addresses directly at the source, on the sensor, to avoid storing clear MAC addresses, 2) is limited to tracking on the studied crowd observatory, and 3) changes the MAC address encryption parameters regularly (once a day) to prevent cross-checking over several days, or over several locations if the device was used in another space frequented by the owner.

In crowd observatories, this technology has been useful in trying to understand, even roughly, the flows around a specific observation point.

3.2.6. Counting systems

Other types of data are available to get information on number of people in the space without directly recorded using sensors. Examples are:

- Redemption data from ticket company for ingress (does not include staff, crew and talent).
- Ticket gate data for permanent venues/transport hubs
- Daily attendance data as reported by the event/venue
- RFID data (e.g. purchases made on a card)

Other counting methods that can be used are:

- Camera counter sensors such as thermal kinetic sensors
- Video counters
- Beam Counters
- Thermal Counters

For scenario/use case and type of data a capture method has been proposed, as listed below. Limitation regarding each method have been identified.

Table 3.2 - Data Capture Method

Scenario	Data Capture	Methodology	Potential Limitations
Large scale crowd movement	Mass movement of people through a large event, venue, public space, transportation hub	1) Tethered drone footage 2) Live stream down to a laptop to store video content on a hard drive for data analysis	1) Expensive 2) Weather conditions
Queueing	Queue behaviour at various locations including ticket purchase, bars, merchandise, food concessions etc.	Fixed camera filming at busiest times	1) Weather conditions
Main gateway of an entertainment environment	Ingress and egress of people through an entertainment environment	Fixed camera(s) to capture queue movement, movement through the gate, and movement beyond the gate	1) Weather conditions 2) Exposure issues at night
Stage (internal)	Dense crowd movements influenced by performed music within a structure	1) Fixed camera taking aerial footage 2) Multi-angle cameras to give 360 coverage of the crowd	1) Weather conditions 2) Exposure issues at night
Stage (external)	Large scale dense crowd movements influenced by performed music outdoors	1) Fixed camera(s) taking footage 2) Angle of camera(s) will vary depending on stage design and access 3) Fixed camera positioned at Front of House	1) Exposure issues at night 2) Lighting effects and strobes make footage unusable
Person in crowd wearing body	1) Readings from the pressure suit	1) Focused area 2) Camera positions directly	1) Matching the pressure-pad data to the

suit with pressure pads	2) Movement of the individual wearing it through a crowd 3) The cascade effect of other people surrounding the individual	above the crowd. 3) Person wearing a body suit and a brightly coloured hat to help with visualisation when processing data.	video content 2) Exposure due to lighting effects
Walk-through experience	Cameras to track movement through a series of multiple rooms or spaces	Cameras fixed to capture each room. Timestamps on footage so speed of movement through spaces can be calculated	Exhibition obstructs some viewpoints resulting in missing data
Every-day use of transportation hubs	1) Movement throughout transportation hubs at various times of day 2) Bottle-neck areas such as security, ticket gates, passport control	Fixed cameras at key locations	1) Permission 2) Security considerations 3) No fly zone – drones cannot be used
Mass movement of people through entertainment venues	Movement of people through festivals and venues, capturing busiest times through key areas; gates, bars, stages, etc.	RFID chips in wristbands	1) Expensive 2) Data ownership 3) Wi-fi reliability for festivals
Mass movement of people through entertainment venues	Movement of people through festivals and venues, capturing busiest times through key areas; gates, bars, stages, etc.	Mobile phone tracking	1) GDPR compliance issues 2) Mobile phone signals on festival sites are often unreliable so may impact on the data

3.3. Production Considerations

Data collection on-site requires careful consideration of the provision of facilities and utilities which are crucial to the ability to effectively collect data at an event. These considerations are as follows:

- Site Wi-Fi
    - Partitioned Wi-Fi to avoid lag
    - 4G/5G Wi-Fi back-up solutions
    - Weather implications on Wi-Fi
    - No Wi-Fi at all
    - No 3G/4G/5G at all
- Power
    - Access to power
    - Recharging roaming equipment
    - Getting power to a fixed position
    - Necessary equipment/cables

    - Proximity of power: the requirement for a runner and/or mobile charging solution
    - Power outage due to generator failure
- Fixed Equipment
    - Integration with festival/observatories build schedule
    - Rigging and de-rigging of equipment
    - Tickets required for plant machine operation
    - Equipment inaccessible throughout event
    - Requires constant power
    - Data download required
- Access Requirements
    - Need suitable crew accreditation and necessary H&S training for install/de-rig of equipment
    - Media passes required for roaming footage capture
    - Camera operators required throughout the weekend
    - Privacy Policies updates
    - Signs displayed detailing participation in the project
- Footage Capture
    - Exposure – stage lighting affecting exposure (e.g. strobes)
    - Equipment failure
    - Data download failure
    - Damage to equipment (e.g., from extreme weather conditions)
    - Loss of SD cards/external HDDs
- Liability
    - Public Liability and Equipment Liability insurance.
    - Consideration as to where liability lies if subcontractors install kit.
    - Determine whether insurance is required for if data download fails.

4. Legal & Ethical Aspects

4.1. Common framework (GDPR)

The General Data Protection Regulation (GDPR) gives, over Europe, a general framework and a set of rules on privacy. GDPR has an impact on crowd observatories, since CrowdDNA aims at recording videos there, that may contain identifiable faces, for instance.

The key principles at the heart of the law should inform every step of a privacy management in crowd observatories. We review the 7 key principles of GDPR below to explain we adjusted personal data processing to satisfy this legal framework:

4.1.1. Lawfulness, fairness and transparency

This principle implies, for example, that any processing of personal data must be subject to the prior consent of those concerned to allow the use of their personal data. In the context of a crowd observatory, this is generally not possible, because the population is too large to allow the collection of such consents.

To satisfy this principle, we use certain national clauses that allow us to refrain from collecting personal consent:

- In view of the nature of the data collected, in our case videos of a crowd where individuals are difficult to recognize anyway, and the first data processing step is to filter out video sequences where people would be easily recognized.
- In view of the purpose of the data collection, which is to allow public research that benefits the security of mass events
- On the condition of maximizing access to information that informs about the data collection on site, through visible displays for example.

4.1.2. Purpose limitation

The purpose of the data collection in crowd observatories is to allow research on crowd behaviors and the development of technologies to assist mass event organizers in improving safety. Data should never be utilized out of this purpose. The purpose of data collection is part of contracts with crowd observatories.

4.1.3. Data minimization

Data collection should be strictly limited to the purpose as defined above. For CrowdDNA video database, that could for example mean that video resolution is adjusted so that crowd behaviors remain visible in images while we limit the identification of individuals in images at the same time by downsizing resolution.

4.1.4. Accuracy

The data collection is subject to manual verification to ensure that data, for instance, is not corrupted, or damaged.

4.1.5. Storage limitation

Any storage of personal data should be limited: in accessibility, in size and in time. Four crowd observatories, applying the data minimization principle, we attempt to delete personal data. If successful, only privacy-free data will be kept with no limitation of time.

4.1.6. Integrity and confidentiality (security)

Crowd observatories data management follows the principles defined on the data management plan of the CrowdDNA projects, using secured storage systems with access controls. Internally, for example at INRIA, the data management and processing are subject to a security analysis document, supervised and validated by internal experts.

4.1.7. Accountability

CrowdDNA is capable of providing proof that the principles above are followed in our procedures. For instance, at INRIA, the internal ethical board (COERLE) is informed and validates the data collection and management procedures we follow, and is responsible for ensuring the procedures are followed.

4.1.8. Privacy Policies

Observatories that are participating in the CrowdDNA project are advised to update their privacy policies to include a short piece of information about their involvement in the project and a link and/or contact details for the project.

4.1.9. Participation Signage

Signs outlining brief details about CrowdDNA and the observatories participation in the project should be displayed on site. Preferably a QR code should be included for ease of access to the CrowdDNA website.

4.2. Legal Contracts with Observatories

4.2.1. Hellfest

The experiments conducted at Hellfest have been the subject of an agreement between INRIA and Hellfest. In particuler, the agreement list the number of actions to inform the public about the presence of CrowdDNA for experiments. Fig. 4.3 illustrates the signs put at the entrance of the festival, as well as T-shirts wore by the team.

Figure 4.1– (Left) Signs at the entrance of the festival; (Right) T-shirts wore by our staff during festival

4.2.2. Tramlines & ArcTanGent

Observatories are required to update their privacy policies to state their involvement in the CrowdDNA project. The privacy policy needs to link to the CrowdDNA website. During participation, observatories are required to display signs stating their involvement in CrowdDNA with a link or QR to the CrowdDNA website. Examples below from Tramlines and ArcTanGent:

Figure 4.2 - (Left) Sign Displayed at Tramlines; (Right) Sign Displayed at ArcTanGent (in multiple places)

Descriptions: Signs stating participation in CrowdDNA.
Intentionally blurred images for the purpose of this report.

Figure 4.3 - ArcTanGent Privacy Policy extract

Research Participation

ArcTanGent is participating in a European-wide research project call CrowdDNA. CrowdDNA is a collaborative project between 7 organisations from 4 European countries funded by the European Commission (EU H2020). It aims to enable a new generation of "crowd technologies"; a system that prevents deaths, minimizes discomfort, and maximises efficiency in the management of crowds.

This project has been selected in the FET Open call as a research and innovation program by the European Union Horizon 2020 (EU H2020) for the period of November 2020 to October 2024.

More information can be found here: www.crowddna.eu or you can contact the lead partner via the contact form: Contact – CrowdDNA

Contact Us
Please contact us at info@arctangent.co.uk if you have any questions, requests, or complaints regarding the use of your personal data.

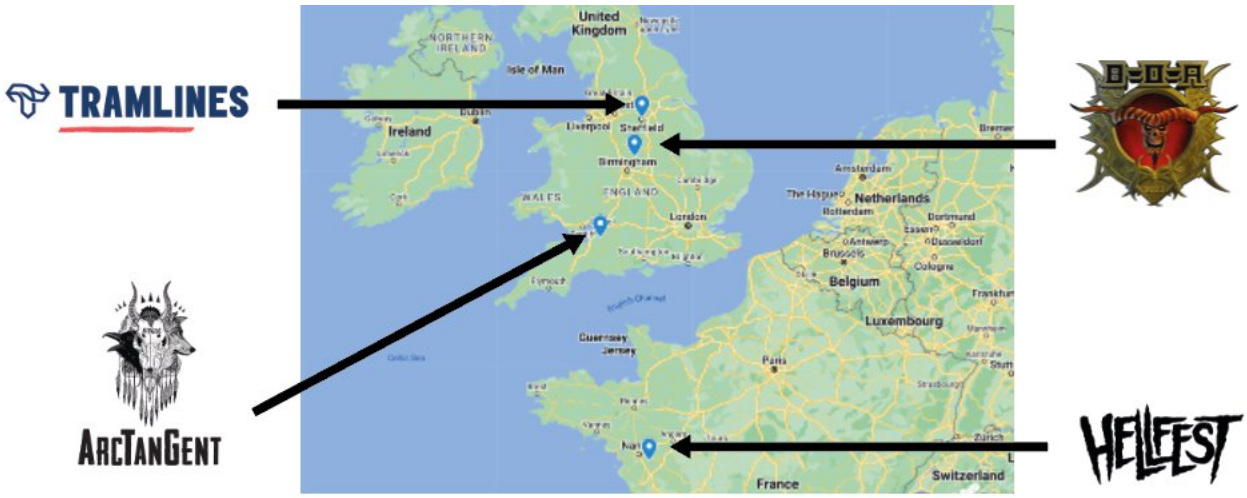
5. Installed Observatories

5.1. Schedule/summary

The following observatories have been installed at festivals during 2022:

- Hellfest 17th – 26th June 2022 (two weekends) – data capture took place on 17th – 19th June 2022
- Tramlines 22nd – 24th July 2022 – data capture took place on the 22nd and 23rd July 2022
- Bloodstock 11th – 14th August 2022 – data capture took place on the 12th August 2022
- ArcTanGent 17th – 20th August 2022 – data capture took place on the 18th August 2022

Figure 5.1 - CrowdDNA Observatory Locations, Summer 2022



Further details on data gathered, photographs and site observations are available in the restricted version of the deliverable as these details are commercially sensitive.

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5.2. HellFest

5.2.1. Description

Hellfest is Europe's largest extreme music festival, and takes place in Clisson, Loire Atlantique, France, usually between mid and late June. The 2022 edition was the fifteenth, coming after two years of cancellation due to the global SarsCov2 pandemic: the 2022 edition was particularly long, taking place over 2 consecutive weekends from June 17th to 19th, then from June 23^{h} to 26th as a result.

The festival gathers about 70,000 people per day, 60,000 paying festival-goers, 5,000 volunteers, and the rest as guests of the festival, but also mostly technicians and professionals working directly for the festival. The festival includes 6 music stages, playing in pairs, allowing a continuous broadcast of concerts on 3 active stages simultaneously. Each stage is dedicated to a specific style of metal music. CrowdDNA's observations have all been on the "Warzone" stage, which curates hardcore metal.

5.2.1. Plan of site

Figure 5.2 - Bloodstock Illustrated Map

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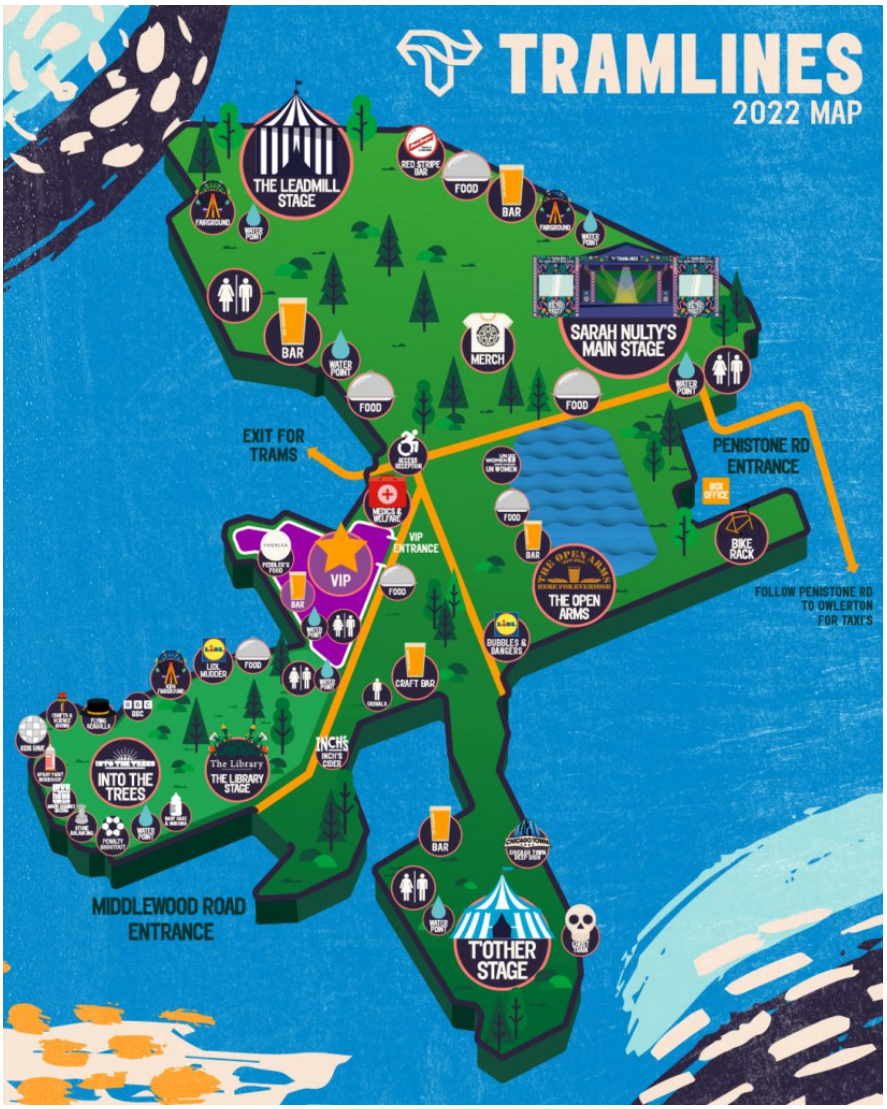
5.3. Tramlines

5.3.1. Description

Tramlines Festival is held in Sheffield, UK on the 22nd - 24th July 2022. The festival was curated and organised by a panel comprising local venue owners, promoters, and volunteers. The name of the festival is inspired by the city's tram network. Tramlines held its first festival in 2009, which attracted 35,000 fans across Sheffield city centre. It has now moved to Hillsborough Park attracting 40,000 people each day (120,00 in total). Tramlines has five stages which host a combination of live music, comedy, a pop-up cinema, and a dedicated family area.

5.3.2. Plan of site

Figure 5.3 - Bloodstock Illustrated Map



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5.4. Bloodstock

5.4.1. Description

Multi award-winning Bloodstock Open Air (B-O-A) is the UK's biggest independent metal festival. Held at the picturesque location of Walton on Trent in Derbyshire, UK since 2005. Originally held indoors for one day with two stages, the festival started in 2001 at the Derby Assembly Rooms and has expanded over the years. It became an outdoor event in 2005. Bloodstock hosts 5 stages, across 4 days and has a capacity of around 18,000 people.

5.4.2. Plan of site

Figure 5.4 - Bloodstock Illustrated Map

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5.5. ArcTanGent

5.5.1. Description

ArcTanGent is an award-winning independent festival founded in 2013, which takes place in Somerset, UK every August. With a licensed capacity of 12,000, ArcTanGent attracts an international audience and line-up. Winner of the "Best Small Festival" in the UK Festival Awards, ArcTanGent curates around 135 bands, across 5 stages over 4 days. The greenfield camping festival is unique in its curation of math-rock, post-rock, noise-rock, leftfield, experimental music.

5.5.2. Plan of site

An illustrative plan of the ArcTanGent site is shown in Figure 5.6

Figure 5.5 - ArcTanGent Site Map

Figure 5.5 - ArcTanGent Site Map

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6. Concluding Remarks

A range of data was collected across four festivals, one in France (Hellfest) and three in the UK (Tramlines, Bloodstock and ArcTanGent). The data captured included Xsens suits, video, photography, and general observation. From the data captured, CrowdDNA can analyse crowd movement within a festival observatory in order to better understand the forces under which crowds are exerted, the flow of the crowds and how the temporary environment influences movement. From these learnings, advice can be given to the observatories to increase crowd safety and a detailed data set can be obtained from processing the video content and Xsens data. This set of observatories also provided learning to the project team on how better to capture data at observatories in the future.

By way of summary:

- Each of the festivals whilst similar in their outdoor, multi-day format differed significantly due to demographic, curation, and participation levels. This has created unique data sets for comparison.
- There is no measurable way to conclude on how crowd movement is affected/changed by the influence of alcohol which it is assumed many partake in at the festivals.
- UK Festivals: The data captured is in shorter lengths due to battery life and the requirement to be mobile around the site. For 2023 and beyond, filming an entire day in each location would provide interesting data sets. However, this poses further production and logistics requirements, as well as expense.
- Attending the festival observatories in 2023 and beyond with increased kit and further direction on content to be captured would help to create a more in-depth data set.
- Returning to each of the observatories for the duration of the project (if viable) would provide an opportunity to compare data year on year, and further into the project, apply some of the learnings in a real-time environment.