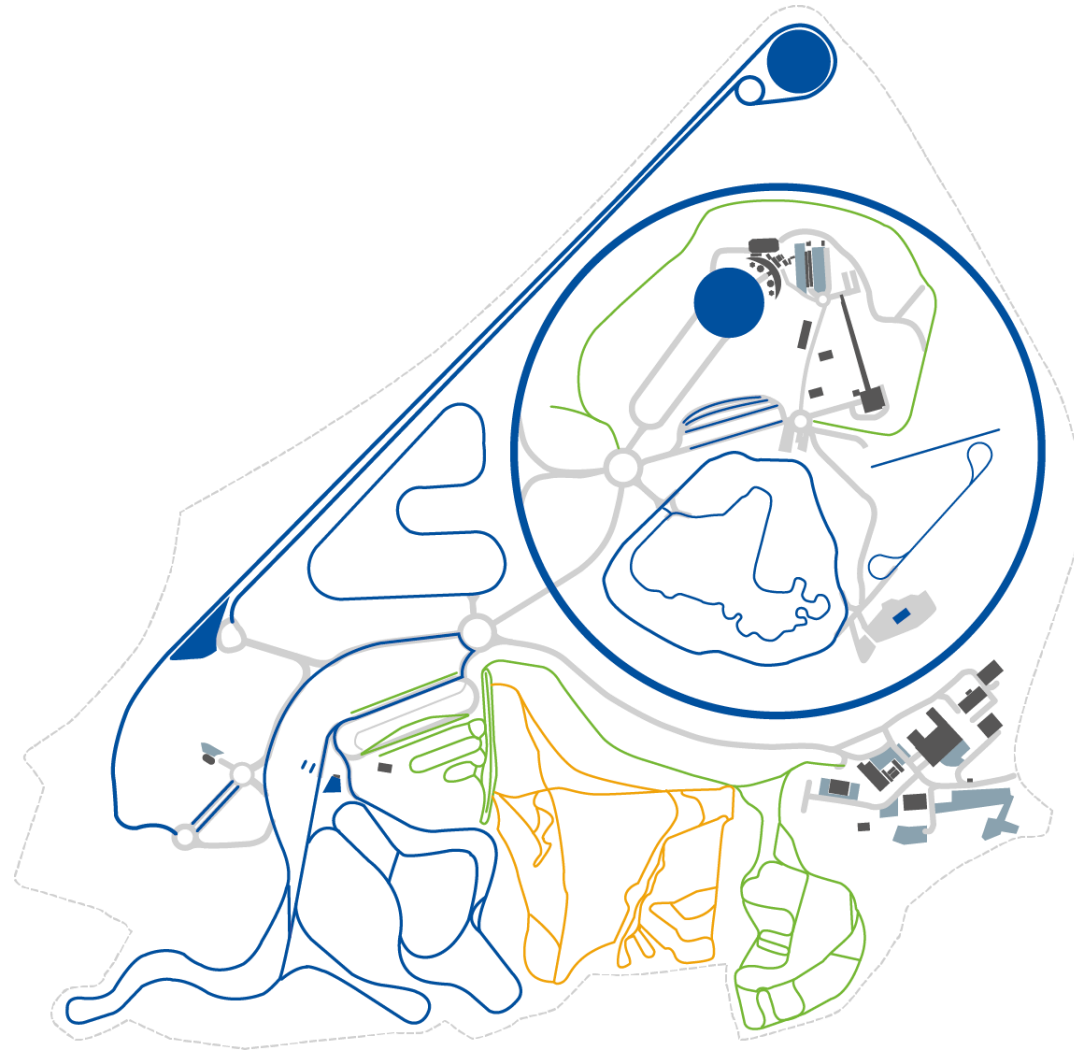
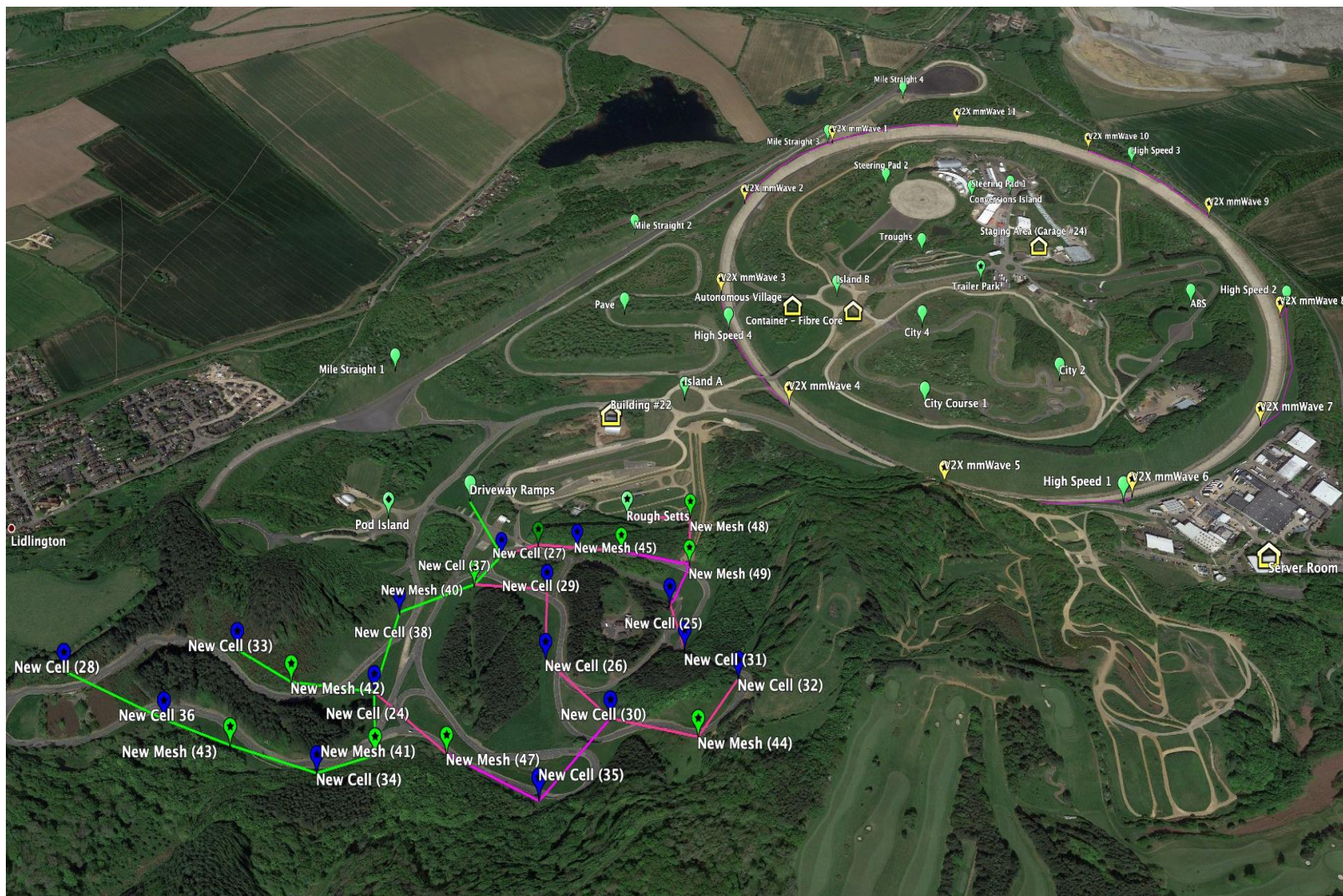


Millbrook

April 2019



Hyper Dense Small Cell Networks



Deployment Summary

- 89 eNodes/gNodes on 59 Sites
- 22 mmWave Sectors on 11 Sites
- 19km of Fibre to 23 sites
- 54 mmWave Backhaul links
- Test Track Coverage: ~70km

Envisioned, Designed, Constructed and made Operational in 9 months

- Poles
- Power
- Fiber and mmWave Mesh Backhaul

Our Vision

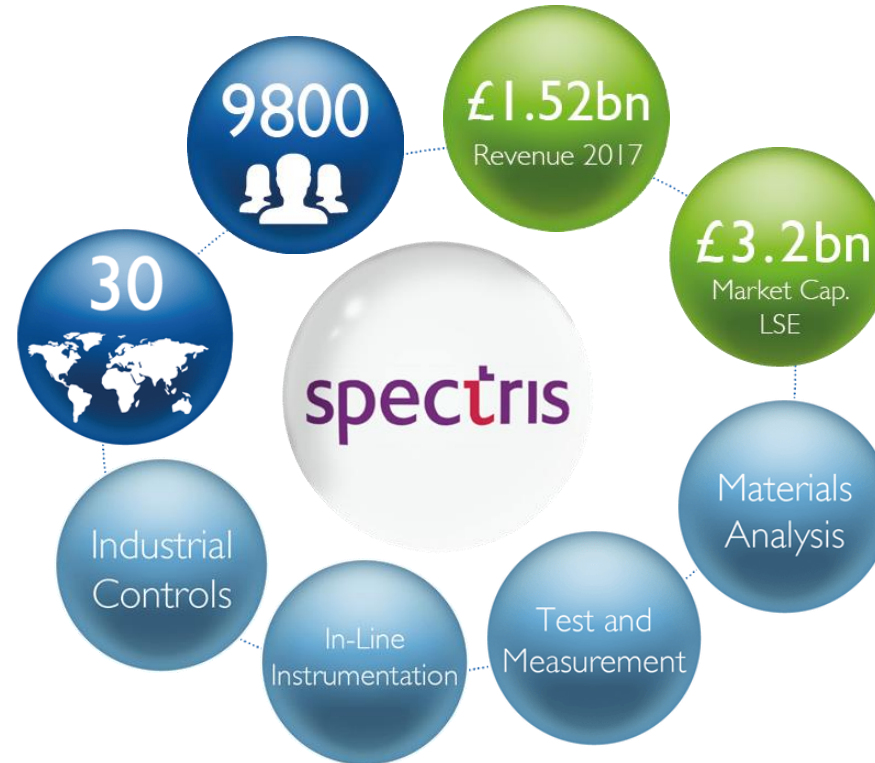
Our vision is to be a
leading global provider of
test services
to the industries that we
serve

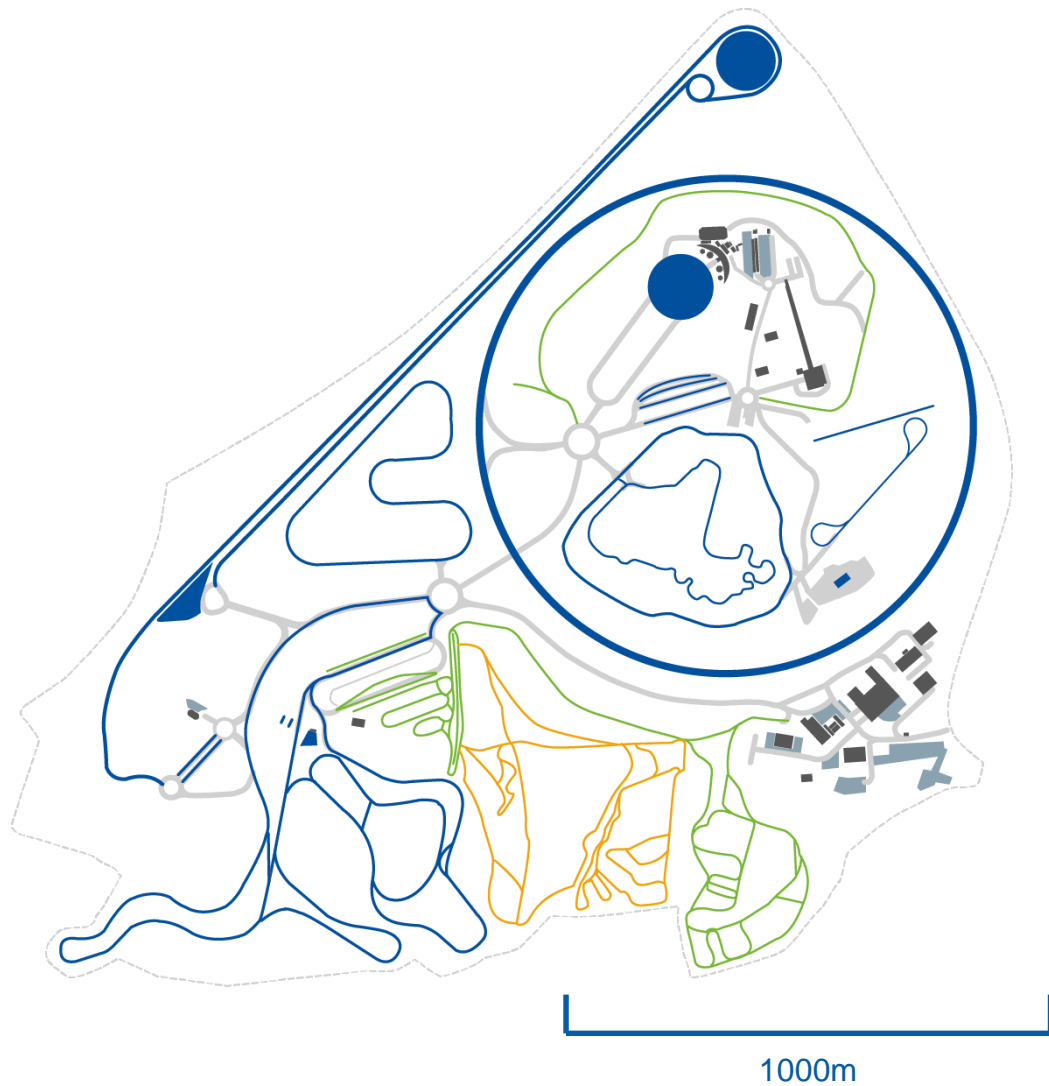
We will realise this vision
through a relentless focus
on our Priorities



Spectris

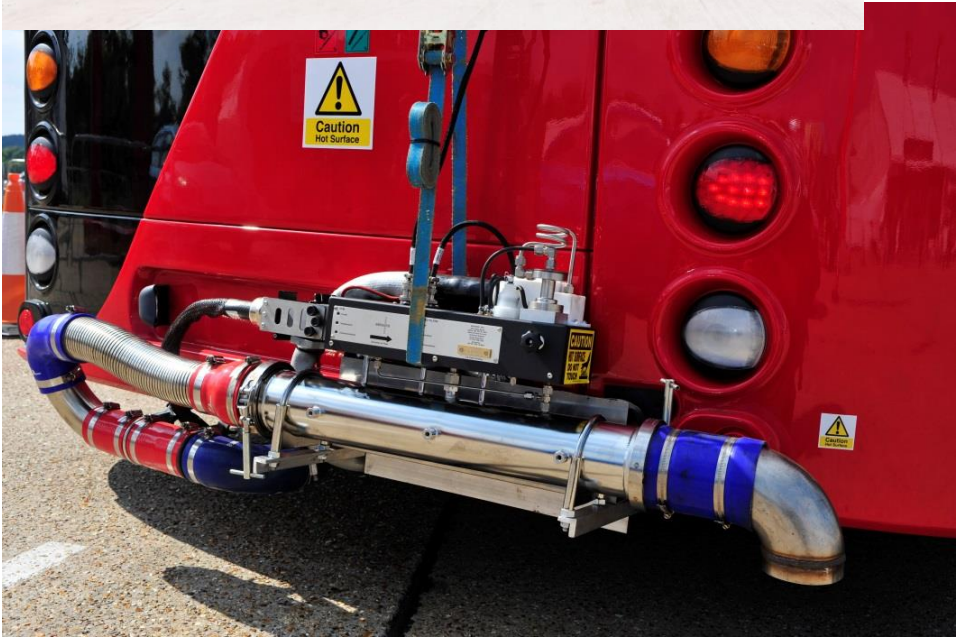
Millbrook is part of the Test and Measurement business segment of Spectris plc







Track Testing – UK



Hills.....



High Speed.....



All types of vehicles.....



Digital.....



- The video can be found here
- <https://www.youtube.com/watch?v=X1zylSRWslg&t=10s>

Foliage.



October 2017



Innovate UK

Peter Stoker
Millbrook Proving Ground Limited
Millbrook Proving Ground
Station Lane
Millbrook
MK15 2JQ

File Ref: 104033

Application number: 99121-569160

Date: 19 October 2017

Dear Mr Stoker

Competition: Connected and Autonomous Vehicles Test Bed

Project Title: The Millbrook-Culham Test and Evaluation Environment: A semi-controlled urban CAV Test Bed

I am pleased to inform you that subject to the terms and conditions of this letter Innovate UK, the operating name for Technology Strategy Board, an Executive Non-Departmental Public Body created under the Science and Technology Act 1965 and established by Royal Charter (English Company Number RC000818) whose registered office is at North Star House, North Star Avenue, Swindon, SN2 1UE ("Innovate UK"), is prepared to make a contribution under



DCMS 5G Testbeds & Trials Programme Briefing - London

Monday, 30 October 2017

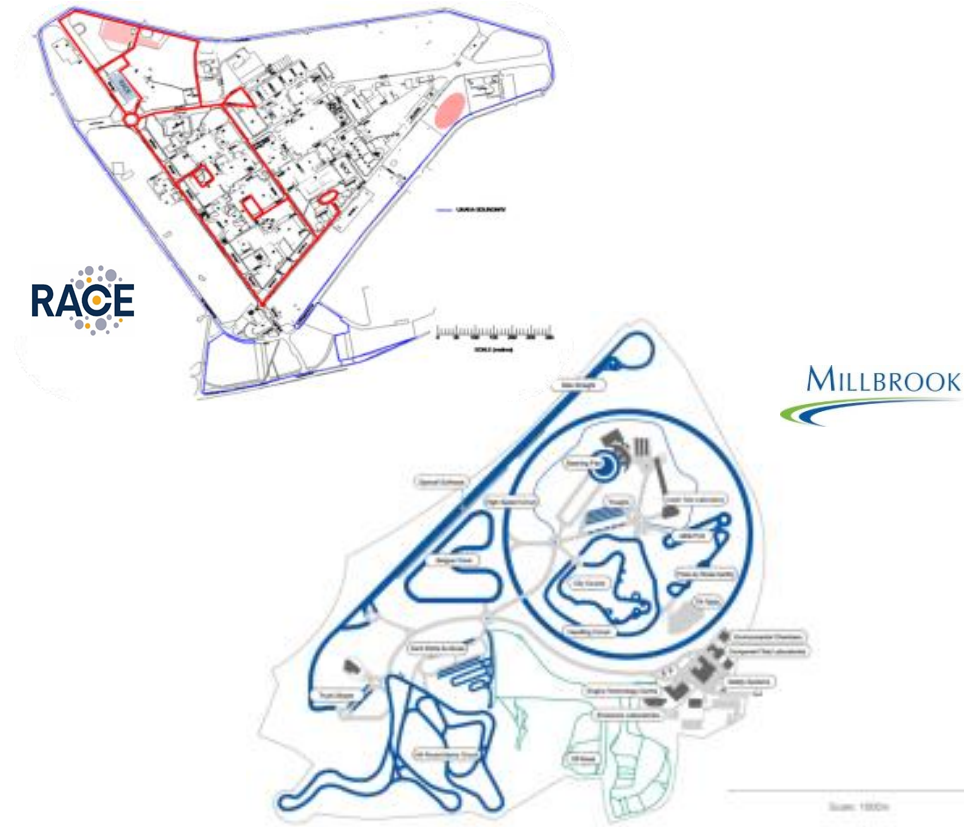
BMA House

Agenda

09:30	<i>Arrival and Registration</i>
10:00	Welcome - Knowledge Transfer Network
10:10	5G Testbeds & Trials Programme – DCMS
10:30	5GT&T Phase 1 Competition – DCMS
11:00	Q&A
11:15	Competition process and eligibility - Innovate UK
12:00	Q&A
12:15	<i>Networking Lunch</i>
13:15	Delegate elevator pitches and networking Facilitated by Knowledge Transfer Network
15:30	Wrap up and close - Knowledge Transfer Network



UK's controlled urban CAV testbed



Peter Stoker
Vehicle Chief Engineer
T: +44 1525 842 519
e: peter.stoker@millbrook.co.uk





UK's controlled urban CAV testbed

1. Your Project

- Test services to the CAV industry
- New test facilities / 5G emulation
- Already testing CAV's / components

2. What's innovative about it?

- Open to all players
- Link to UK testbeds via Meridian
- No IP threat or compromise

3. The services you can offer?

- Development, trials, test, demonstration
- Vehicles, components and systems
- 80km tracks, 900 acres. Endless scenarios

4. The customers you seek?

- Start up's, SME's, OEM's, consortia
- On or off road testing. Static or dynamic
- City, urban, interurban users



5G Testbeds & Trials Projects in the UK

Smart Tourism

Tourism

This testbed will focus on delivering enhanced experiences for tourists using Augmented Reality (AR) and Virtual Reality (VR), 3d motion tracking, and 4k 360° content streaming technology, in major attractions in Bath and Bristol, including the Roman Baths and Millennium Square.

5G RuralFirst

Rural, agriculture and broadcast

The project will explore a variety of potential benefits, from improving how farms grow crops and look after livestock, to making industrial equipment more efficient and reliable, to improving residents' quality of life by better connecting them to TV, radio and online content.

AutoAir

Dense deployment, CAVs

AutoAir will aim to make 5G technologies available for the validation and development of Connected and Autonomous Vehicles at the UK's premiere vehicle proving ground at Millbrook



5G Rural Integrated Testbed (5GRIT)

Rural, including farming and tourism

5GRIT will be trialling innovative use of 5G technology across a range of rural applications, such as smart agriculture, tourism and providing internet services to poorly-connected communities

Liverpool 5G Testbed

Healthcare in an urban setting

the project will see high value technologies including low-cost open source 5G networks, artificial intelligence, virtual reality and IoT deployed across deprived communities in the Liverpool city region testbed.

Worcestershire 5G Consortium

Manufacturing and security

the Consortium will explore a range of use cases including increased productivity in manufacturing, machinery fault detection, remote training, and 'security by design'.

The AutoAir Consortium



4G LTE and 5G NR
RAN



Neutral Host Network
Operator



mmWave Mesh &
High Speed
Access



5G NR Phy & Core,
and BF Antennas



4G and 5G Core
Networks



Vehicle Proving Ground



Network Planning,
Analysis



5G Antennas

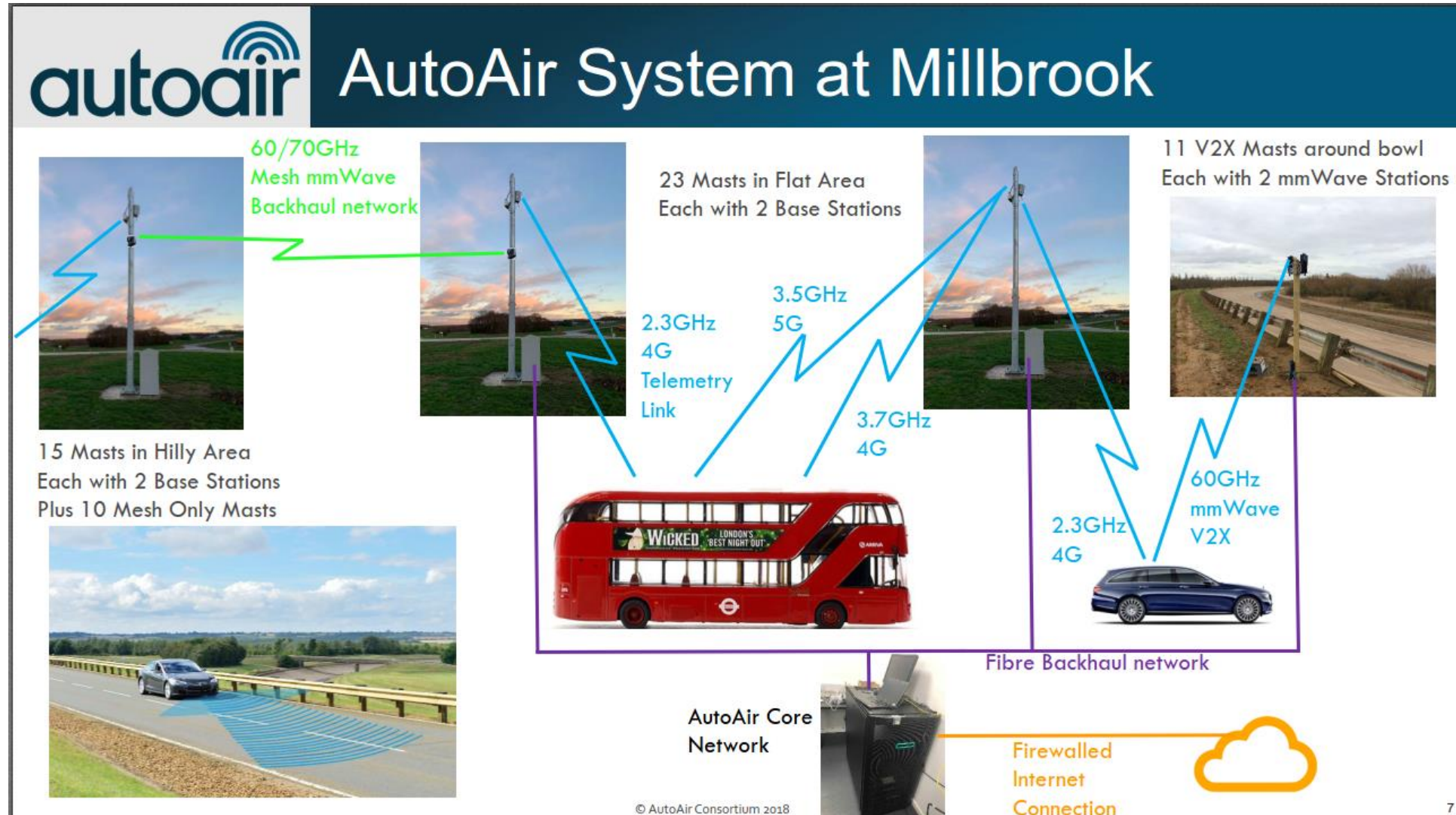
Guiding principles

AutoAir is focused on R&D in a number of core “5G technology” areas

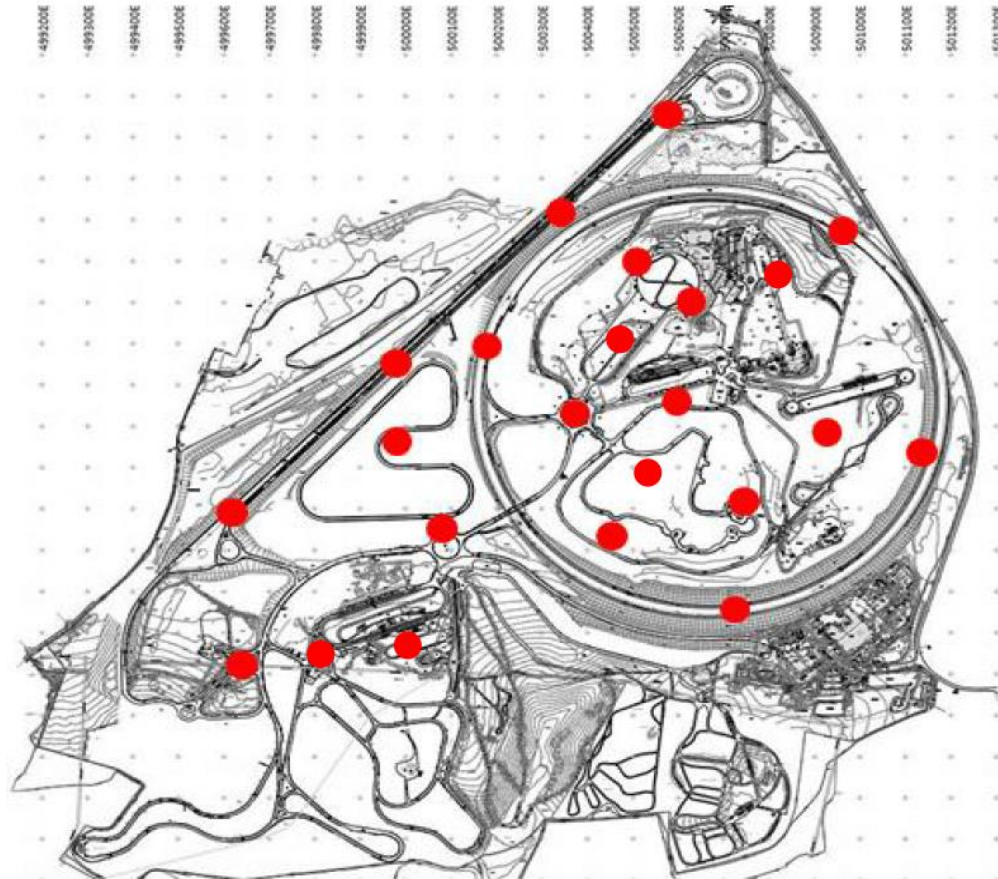
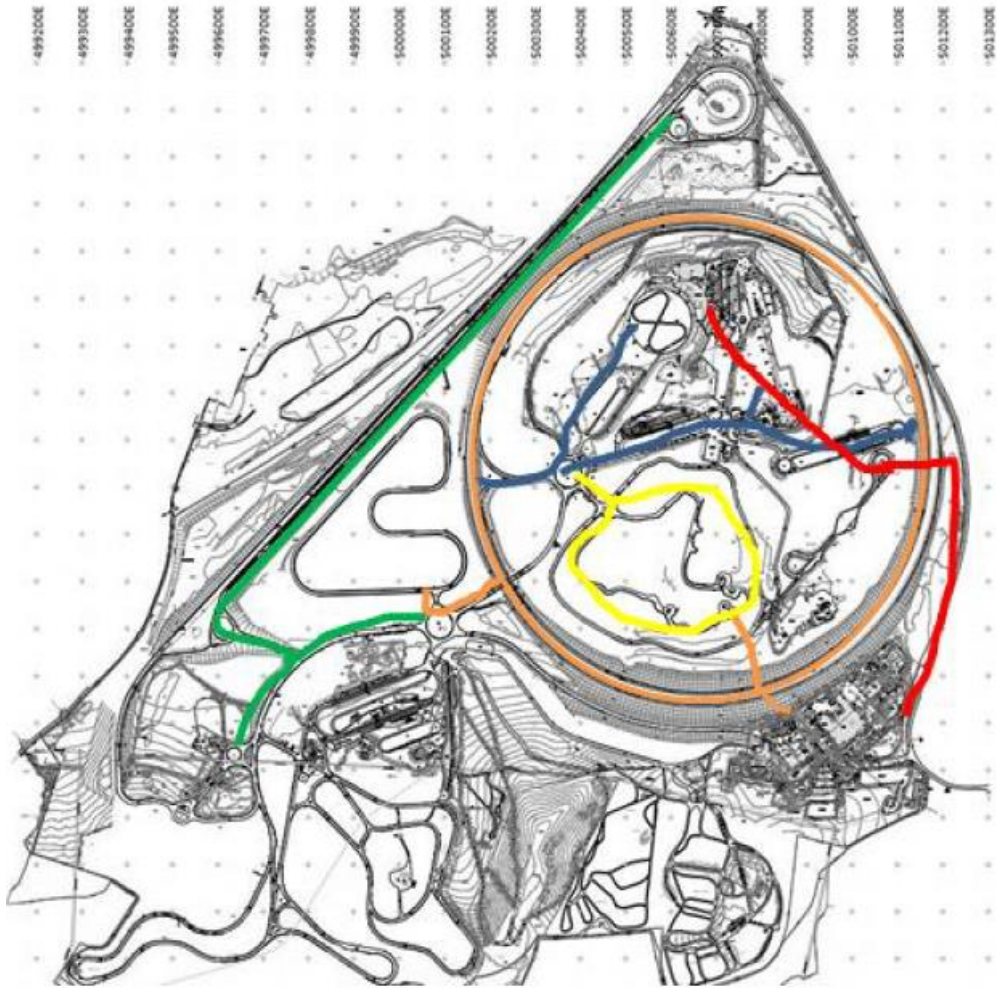
- Use of **5G TDD Frequency Bands** (2.3, 3.4-3.8, 57-71 GHz)
- **Hyper-Dense** Small Cell Networks and Architectures
- 5G Small Cell Antenna Technologies (**Mini-Massive MIMO**)
- “**Software Defined**” eNodeB (LTE) and gNodeB (NR) 5G Small Cells
- **High Speed Mobility using mmWave** capable of delivering Gbit/s services at 160mph
- **Extended range mmWave** Mesh Backhaul for Fibre backhaul extension in 66-71 GHz.
- **Mobile Edge Computing (MEC)** for V2V and V2I CAV connectivity for real-time services
- **Neutral Host and Network Slicing** for hosting multiple public and private networks
- **Economic Analysis of “5G Connected Highways”**



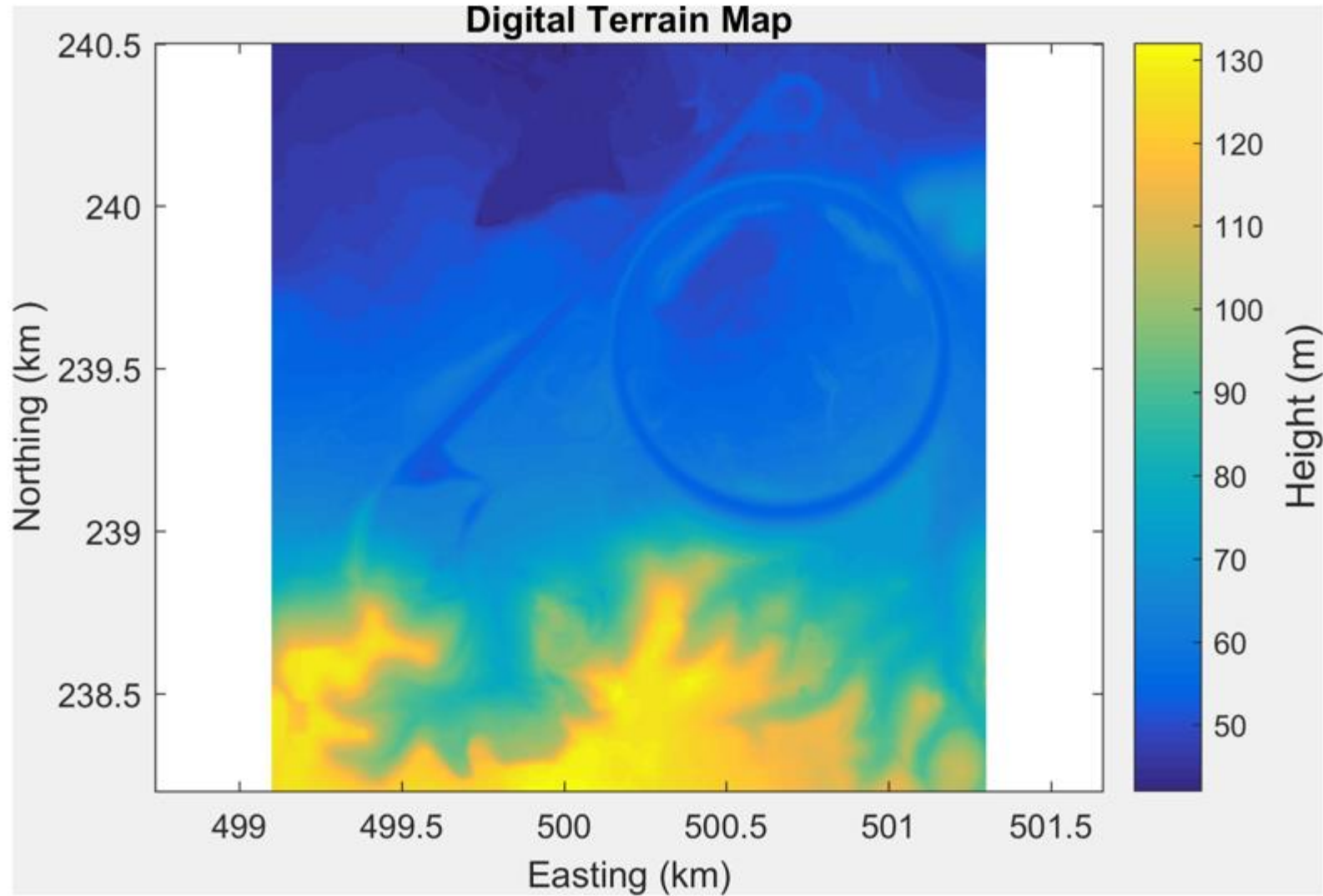
What do we have?



The first plans

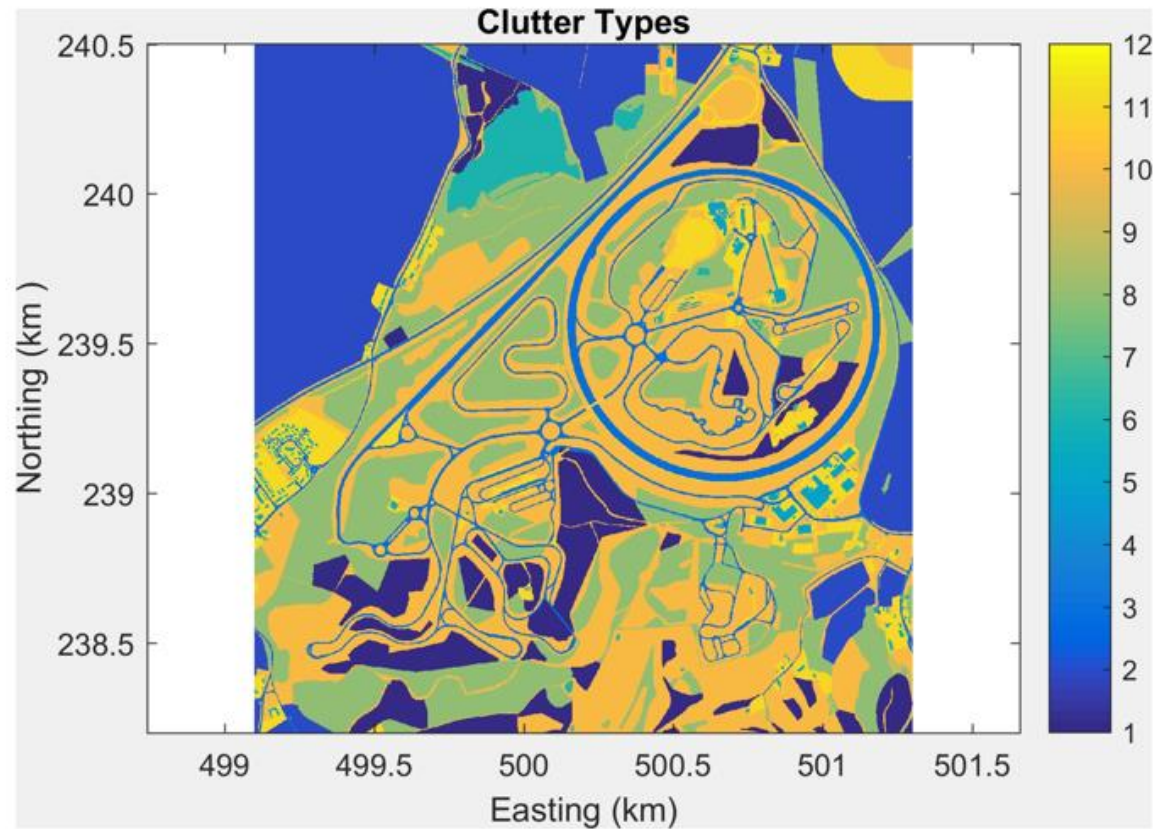


Collaboration with Ordnance Survey



Clutter....

- There are 12 clutter types identified

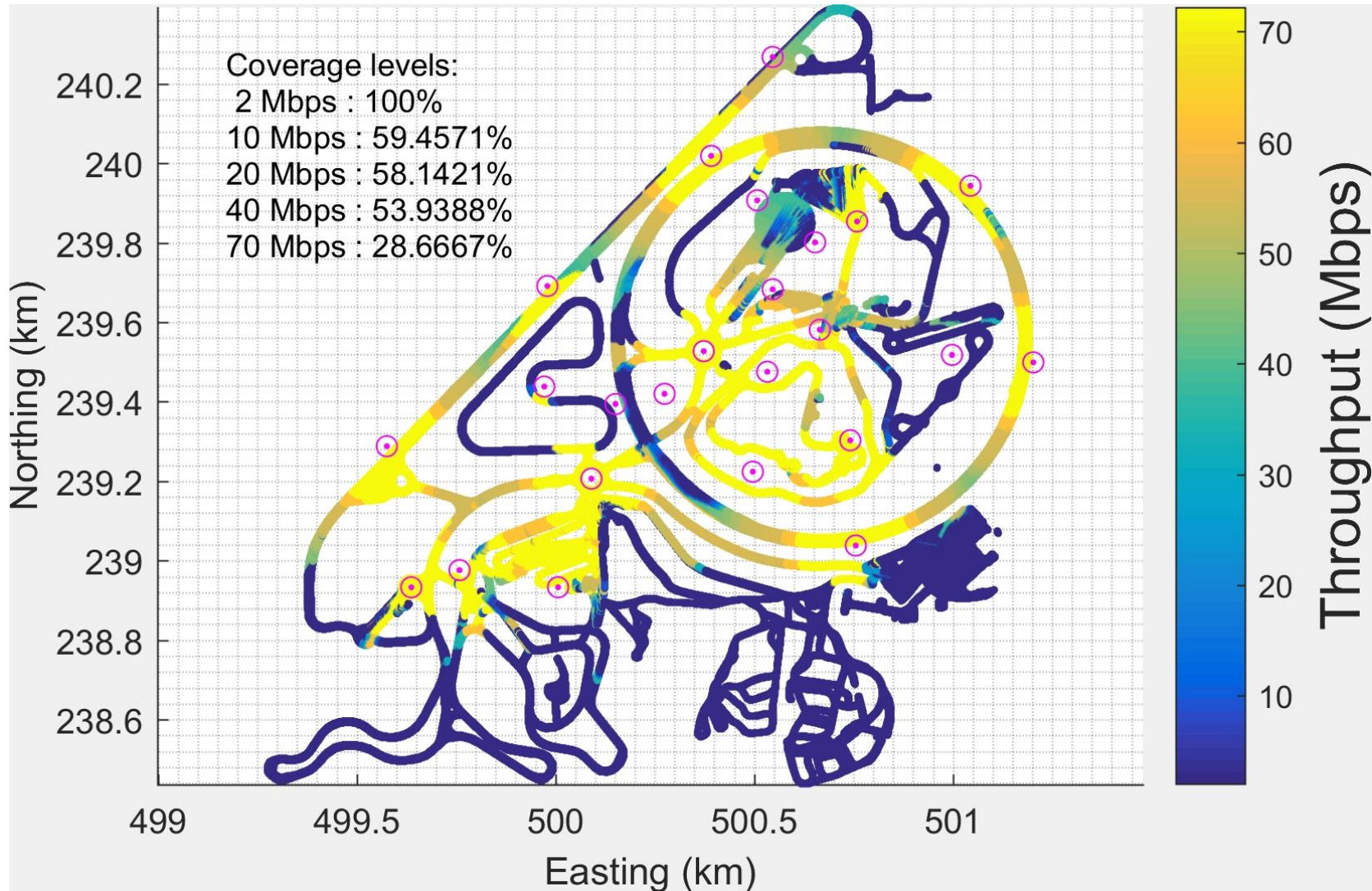


Clutter Type	Clutter Code
Coniferous Trees	1
Farm land	2
Transport	3
Pylon	4
Building	5
Inland Water	6
Glasshouse	7
Non-Coniferous Trees	8
Open Marsh Mud and Foreshore/Sand	9
Open Flat Grass	10
Open Flat Manmade	11
Infrastructure	12

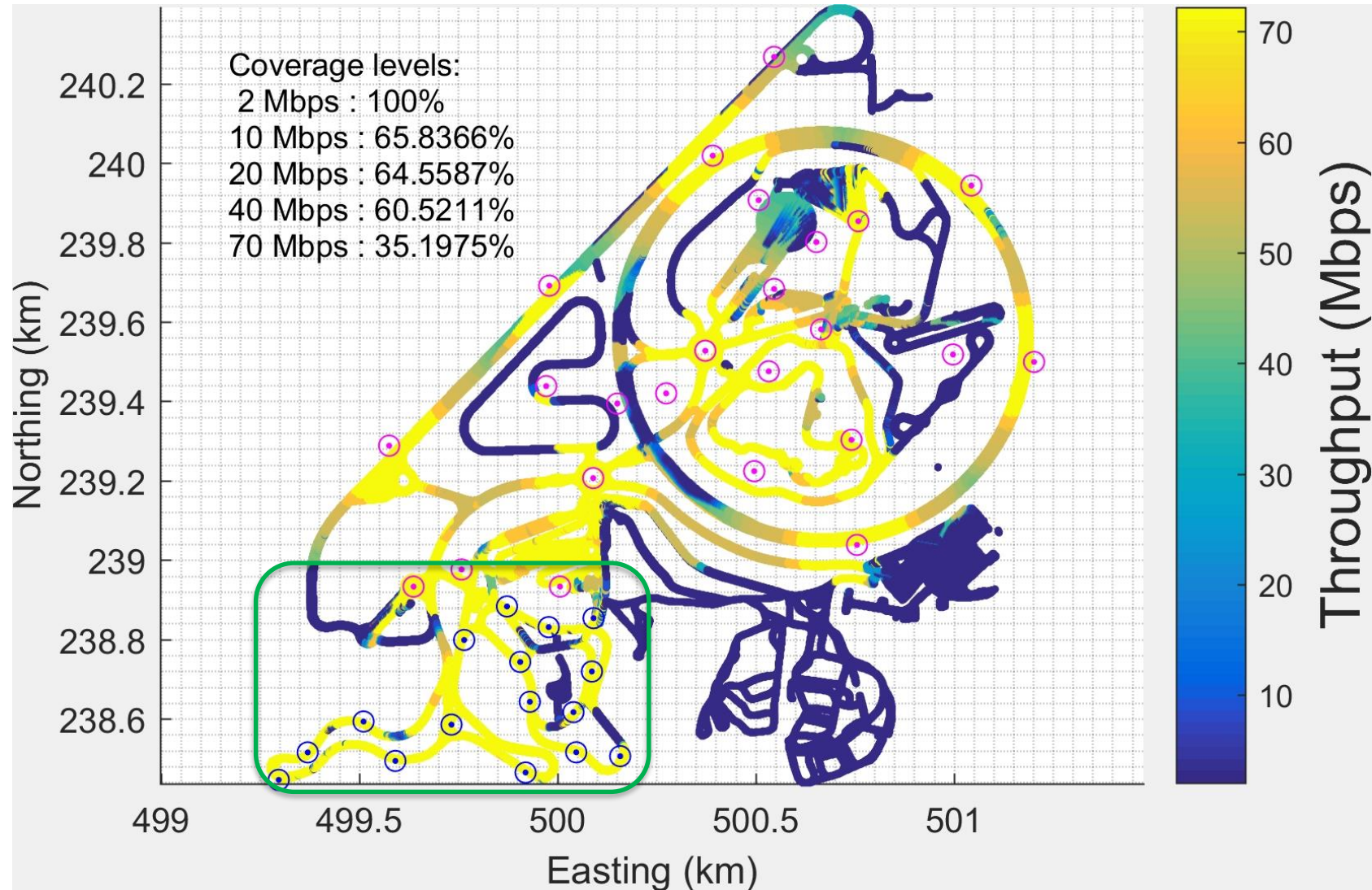
CAD Models to Polygons



Initial simulations




Planning for Hills



Millbrook

Building Locations

Legend

 Buildings



Millbrook

4G Cell Sites

Legend

- Cell Sites (Flat Area)
- Cell Sites (Hilly Area)



4G Sites

38 Cell Sites, each with
1x AirHarmony1000 (Band 40: 2300-2400MHz)
1x AirSpeed1000 (Band 48 3550-3700MHz)

NB Mile Straight 3 and High Speed 1-4 have
2x AirHarmony1000 (Band 40: 2300-2400MHz)
2x AirSpeed1000 (Band 48 3550-3700MHz)
For optimised High-Speed Bowl performance

Millbrook High Speed Bowl

60GHz mmWave V2X Sites plus fibre feeds from relevant cell sites

Legend

- Cell Sites providing V2X power & fibre
- V2X Fibre
- V2X mmWave sites (2 units per site)



V2X High Speed Bowl Sites

11 V2X Sites evenly around 3.2km bowl
Each with
2x BWT DN101LC 60GHz mmWave units
Aligned towards and away from traffic direction
10Gbps fibre backhaul over Millbrook network
to ATLAS server co-located with AutoAir core

Millbrook Hilly Area

4G Cell and mmWave Mesh Sites

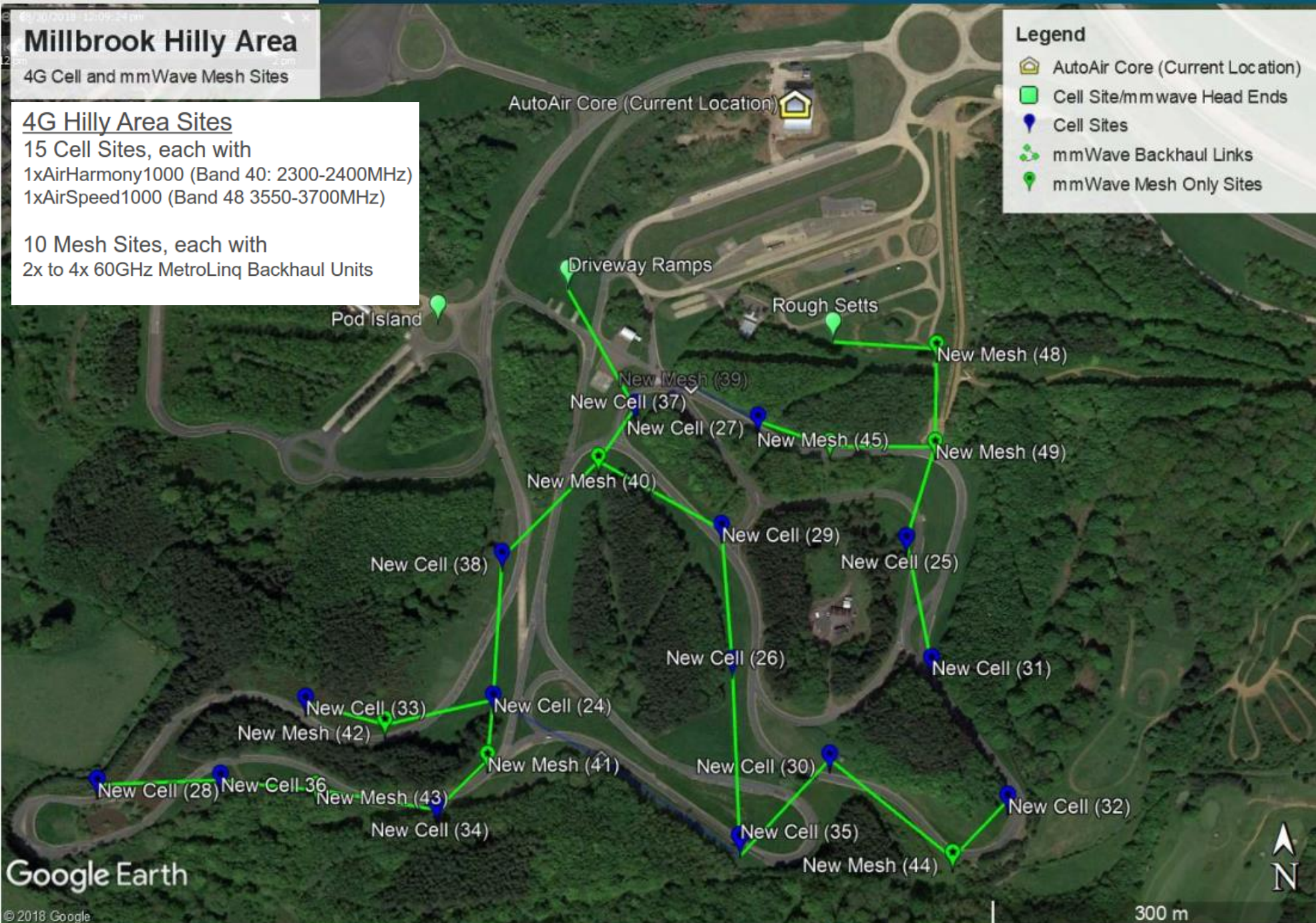
4G Hilly Area Sites

15 Cell Sites, each with
1xAirHarmony1000 (Band 40: 2300-2400MHz)
1xAirSpeed1000 (Band 48 3550-3700MHz)

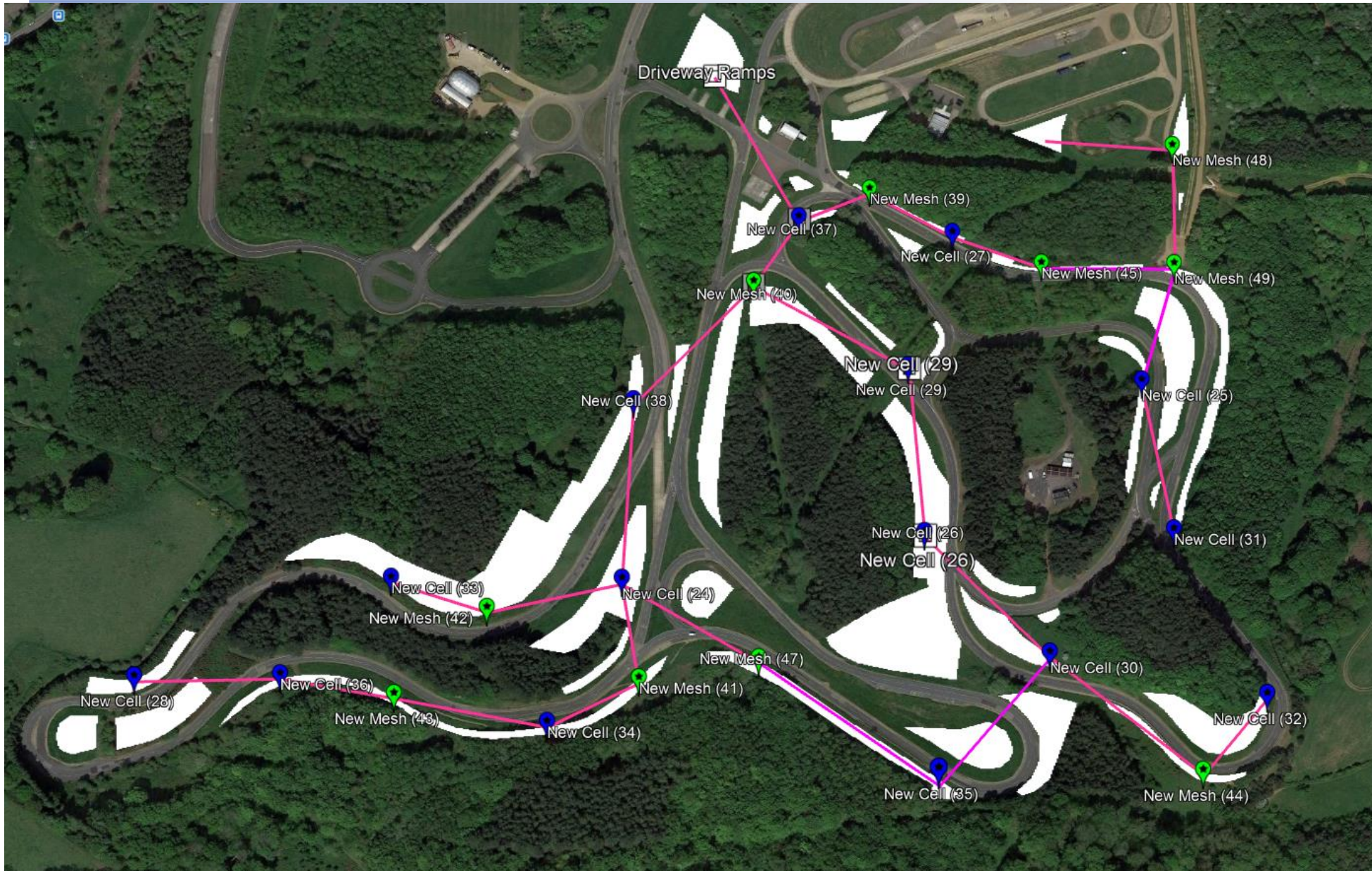
10 Mesh Sites, each with
2x to 4x 60GHz MetroLinq Backhaul Units

Legend

- AutoAir Core (Current Location)
- Cell Site/mm wave Head Ends
- Cell Sites
- mmWave Backhaul Links
- mmWave Mesh Only Sites

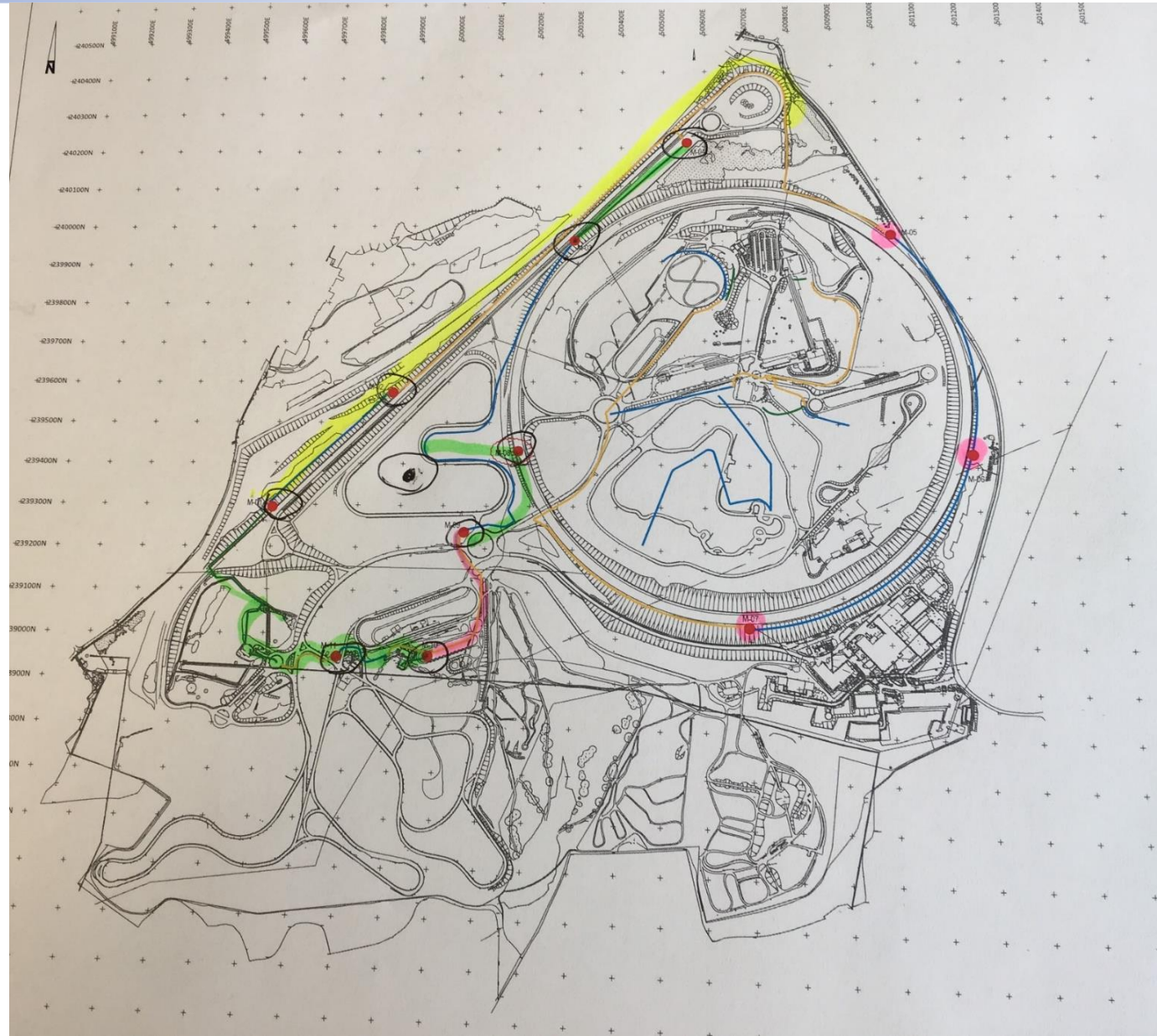


Go / No go areas





Marked up prints..... And status report!

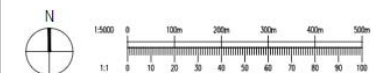
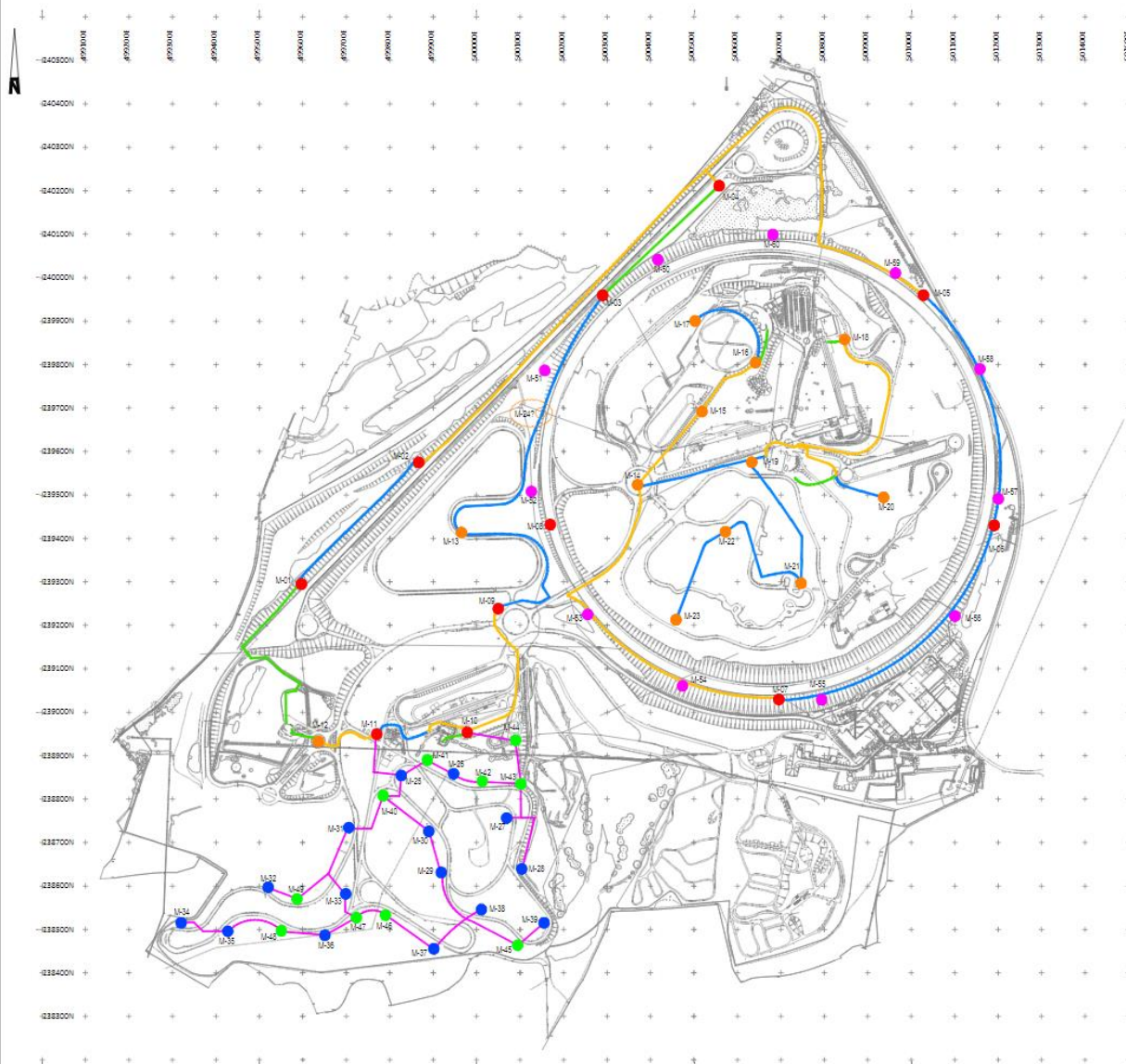


Green- trench & duct finished.

Pink- Areas that will be completed this weekend.

Yellow- Surface ducting should be finished by Friday 5th Oct

Black circles- mast bases completed.



PHASE 1

MAST No.	MPG SITE ID	TYPE	EASTING (KM)	NORTHING (KM)	MAST/POST TYPE
M-01	MILE STRAIGHT 1	SMALL CELL	499575.989	239288.0879	TYPE 4
M-02	MILE STRAIGHT 2	SMALL CELL	499579.832	239591.2761	TYPE 4
M-03	MILE STRAIGHT 3	SMALL CELL	500291.928	240018.9341	TYPE 1
M-04	MILE STRAIGHT 4	SMALL CELL	500548.712	240287.8801	TYPE 4
M-05	HIGH SPEED 3	SMALL CELL	501044.338	239943.8166	TYPE 3
M-06	HIGH SPEED 2	SMALL CELL	501202.822	239499.1828	TYPE 3
M-07	HIGH SPEED 1	SMALL CELL	500756.051	239030.0768	TYPE 3
M-08	HIGH SPEED 4	SMALL CELL	500162.787	239592.5369	TYPE 3
M-09	ISLAND A	SMALL CELL	500090.688	239206.4834	TYPE 4
M-10	ROUGH SETTS	SMALL CELL	500006.895	238933.1517	TYPE 5
M-11	DRIVEWAY RAMPS	SMALL CELL	499788.774	238976.1482	TYPE 4

PHASE 2

MAST No.	MPG SITE ID	TYPE	EASTING (KM)	NORTHING (KM)	MAST/POST TYPE
M-12	POD ISLAND	SMALL CELL	499637.445	238933.0282	TYPE 5
M-13	PAVE TRACK	SMALL CELL	499972.087	239438.2128	TYPE 2
M-14	ISLAND B	SMALL CELL	500375.327	239527.3591	TYPE 4
M-15	TROUGHS	SMALL CELL	500546.795	239683.0294	TYPE 4
M-16	STEERING PAD 1	SMALL CELL	500883.444	239801.2442	TYPE 4
M-17	STEERING PAD 2	SMALL CELL	500808.003	239606.949	TYPE 4
M-18	CONVERSIONS ISLAND	SMALL CELL	500759.184	239683.712	TYPE 4
M-19	TRAILER PARK	SMALL CELL	500865.32	239681.3193	TYPE 4
M-20	ABS TRACK	SMALL CELL	500997.969	239517.9456	TYPE 4
M-21	CITY COURSE 2	SMALL CELL	500741.995	239302.9688	TYPE 4
M-22	CITY COURSE 3	SMALL CELL	500833.215	239475.8744	TYPE 4
M-23	CITY COURSE 1	SMALL CELL	500486.768	239223.8853	TYPE 4

PHASE 1A

MAST No.	MPG SITE ID	TYPE	EASTING (KM)	NORTHING (KM)	MAST/POST TYPE
M-24	NEW CELL 37	SMALL CELL	499822	238882	TYPE E
M-25	NEW CELL 27	SMALL CELL	499938	238892	TYPE D
M-26	NEW CELL 26	SMALL CELL	500074	238744	TYPE D
M-28	NEW CELL 31	SMALL CELL	500096	238836	TYPE C
M-29	NEW CELL 28	SMALL CELL	499916	238830	TYPE D
M-30	NEW CELL 29	SMALL CELL	499904	238782	TYPE D
M-31	NEW CELL 38	SMALL CELL	499703	238722	TYPE D
M-32	NEW CELL 33	SMALL CELL	499532	238590	TYPE C
M-33	NEW CELL 24	SMALL CELL	499698	238592	TYPE F
M-34	NEW CELL 28	SMALL CELL	499382	238516	TYPE C
M-35	NEW CELL 36	SMALL CELL	499486	238520	TYPE D
M-36	NEW CELL 34	SMALL CELL	499648	238490	TYPE D
M-37	NEW CELL 38	SMALL CELL	499928	238455	TYPE D
M-38	NEW CELL 30	SMALL CELL	500006	238546	TYPE E
M-39	NEW CELL 32	SMALL CELL	500160	238520	TYPE C

MAST No.	MPG SITE ID	TYPE	EASTING (KM)	NORTHING (KM)	MAST/POST TYPE
M-40	NEW MESH 40	MESH	499789	238812	TYPE B
M-41	NEW MESH 39	MESH	499874	238884	TYPE A
M-42	NEW MESH 45	MESH	500002	238830	TYPE A
M-43	NEW MESH 49	MESH	500100	238832	TYPE B
M-44	NEW MESH 48	MESH	500100	238922	TYPE A
M-45	NEW MESH 44	MESH	500114	238486	TYPE A
M-46	NEW MESH 47	MESH	499816	238524	TYPE A
M-47	NEW MESH 41	MESH	499712	238522	TYPE A
M-48	NEW MESH 43	MESH	499538	238608	TYPE A
M-49	NEW MESH 42	MESH	499643	238551	TYPE A

NOTES:

- 1 - FOR CABLE TERMINATION & POWER DISTRIBUTION CABINET - SEE TECHNICAL DOCUMENT ISSUED BY JOHN FORRESTER 20/07/2010.
- 2 - SEE SPECIFICATION DOCUMENT FOR CABLE TYPE FOR EACH POWER SUPPLY.
- 3 - FOR MAST REFERENCE AND POWER SUPPLY DETAILS SEE HWD DRAWING 15-2197-E-105

LEGEND:

- PIRE ONLY TRENCH
- POWER ONLY TRENCH
- SHARED FIBRE & POWER TRENCH
- HILL ROUTE TRENCH
- PHASE 1 8M METAL MAST
- PHASE 1A 8M WOODEN CELL MAST
- PHASE 1A 8M WOODEN MESH MAST
- PHASE 2 8M METAL MAST
- PHASE 3 8M V2X MAST
- M-XX MAST REFERENCE

T	15-09-19	TENDER ISSUE
REV	DATE	DESCRIPTION
1 Dunsdale Rd Eaton Bray, Bedfordshire LU2 1RD		
Tel: 01525 222747 Fax: 01525 222747		
Email: info@hwd.co.uk		
Drawn By	LCH	Job No: 15-2197 Scale: 1:5000 @ A1
Client	 Millbrook Paying Grounds Ltd Willesden, Greater London Tel: 0181 618 4040 www.millbrook.co.uk	
Project	CCAV WIRELESS NETWORK	
Title	POWER TO MASTS SITE INFRASTRUCTURE LAYOUT ALL PHASES	
Orig No	15-2197-E105	



Ducts, trenches and bases



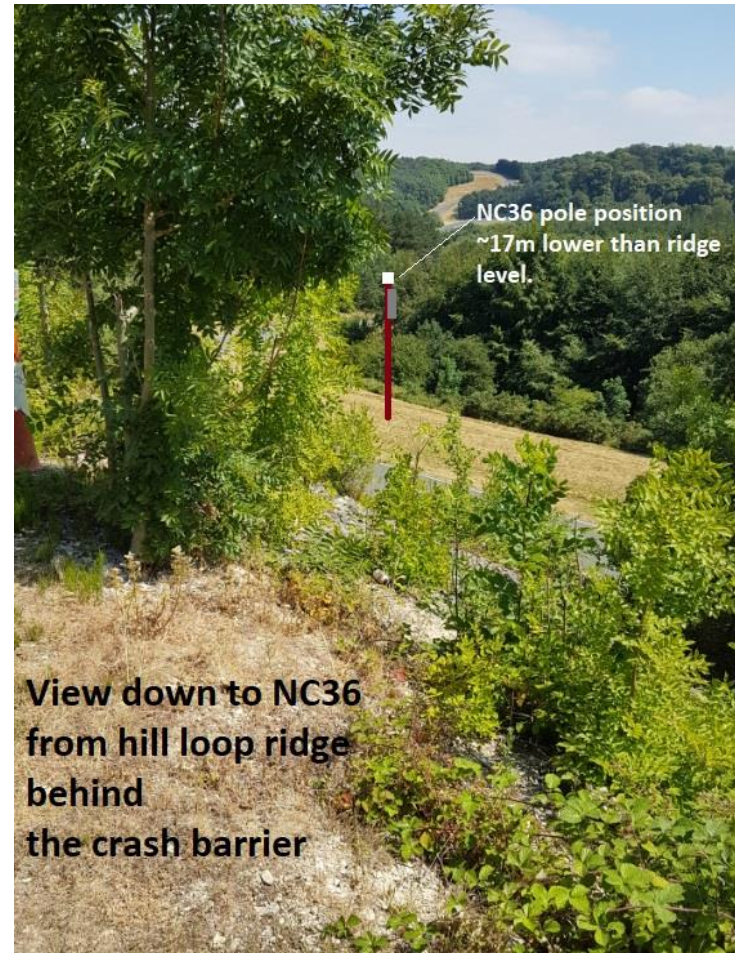
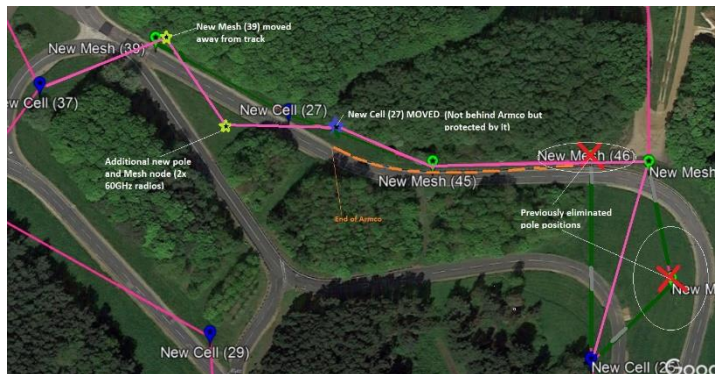
Ducts, trenches and bases



Hard at work



Refining the positions on foot – summer 2018!



Equipping the masts



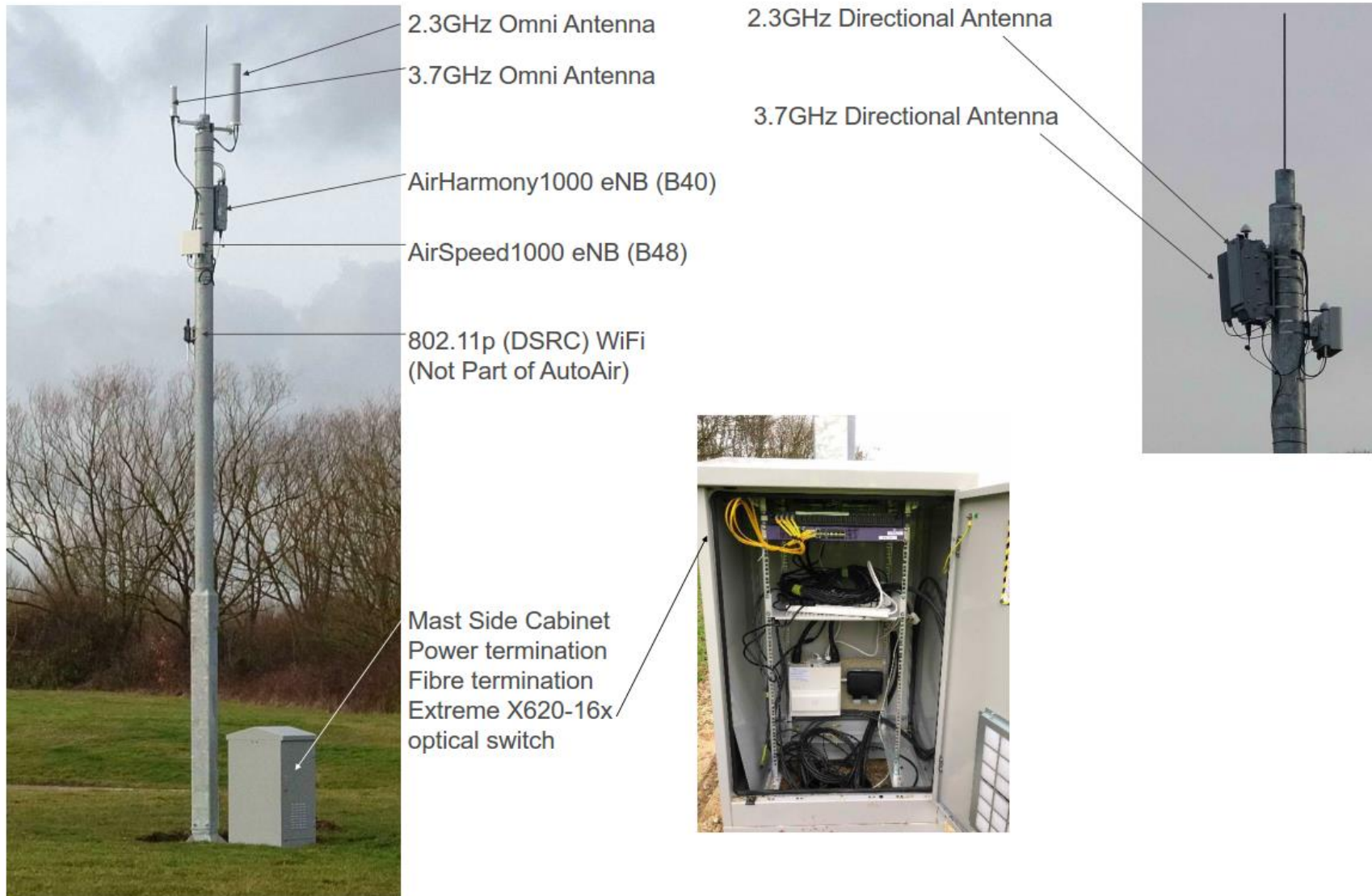
Lowering, Drilling, Equipping and Erecting Flat Area Masts



Posts

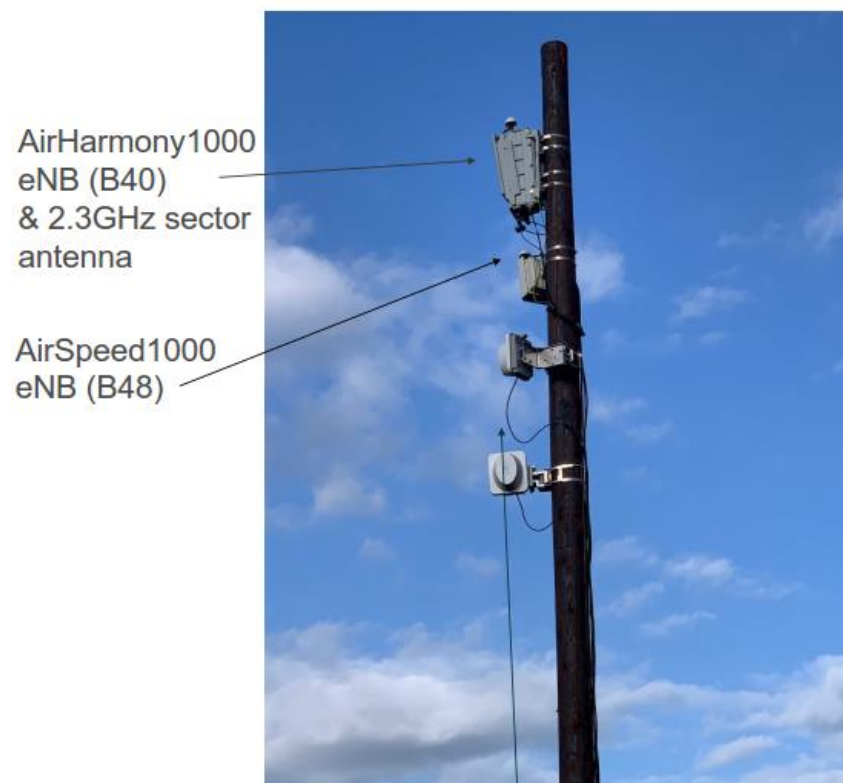


Metal masts (sample!)



Winch Down Masts
8m Metal masts on concrete plinth
Altron AW1859/8HD
Requires winch DW2500/59

Wooden Posts (sample!)



4G Cell Site

1xAirHarmony1000 (Band 40: 2300-2400MHz)
1xAirSpeed1000 (Band 48 3550-3700MHz)
2xMetroLinq 60GHz mmWave Backhaul

4G mmWave Mesh Site

2x to 4xMetroLinq 60GHz mmWave Backhaul

Post Mounted Cabinet

Power Supplies
Local Router

mmWave Posts



2x DN101LC mmWave
Distribution Nodes

→ Traffic direction

← Against Traffic direction

Post Mounted cabinet
Power and fibre termination
Power supplies

Incoming fibre & power
From nearest Cell Site cabinet

Trackside Installation

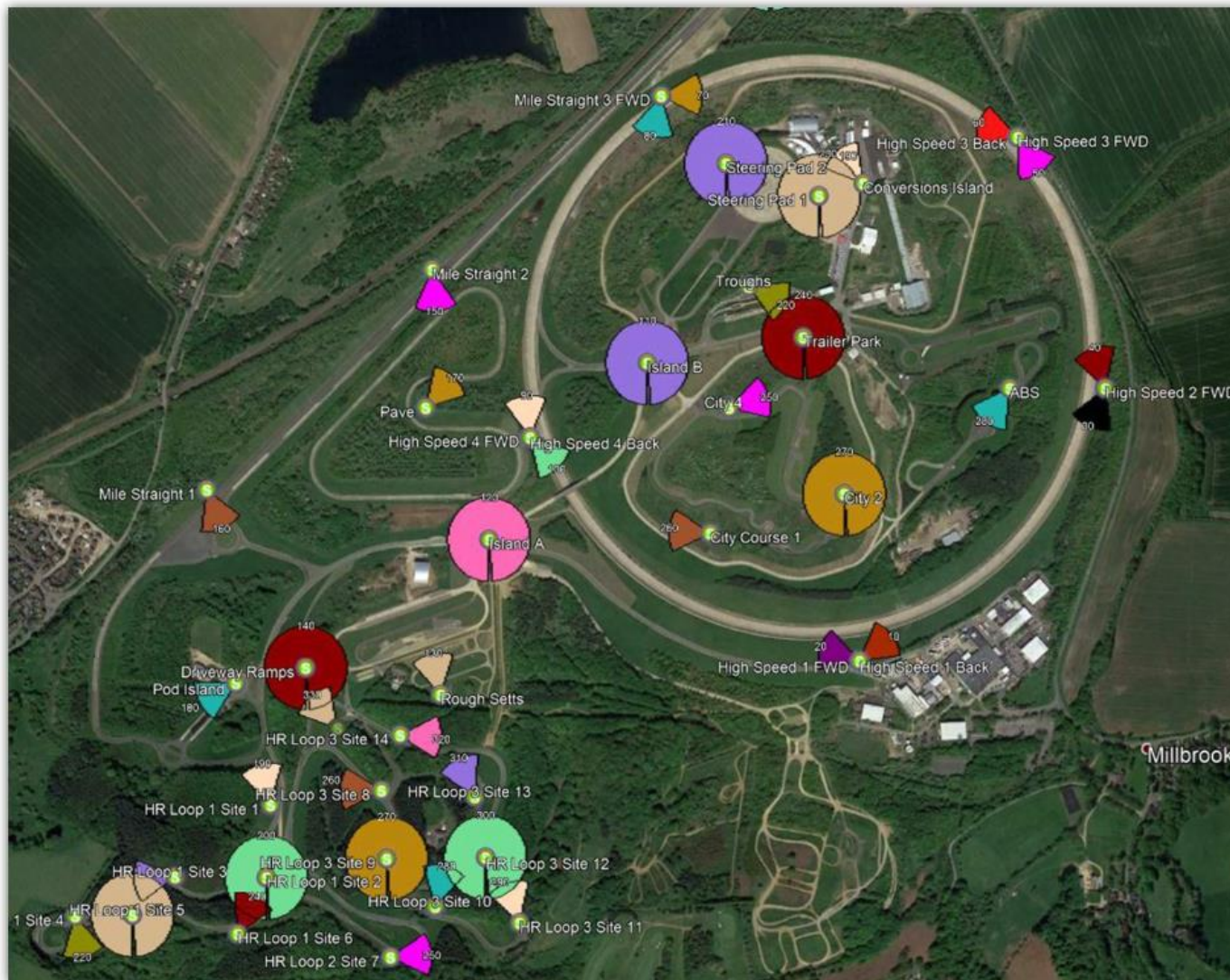


V2X Network in use
TN201 unit mounted on vehicle



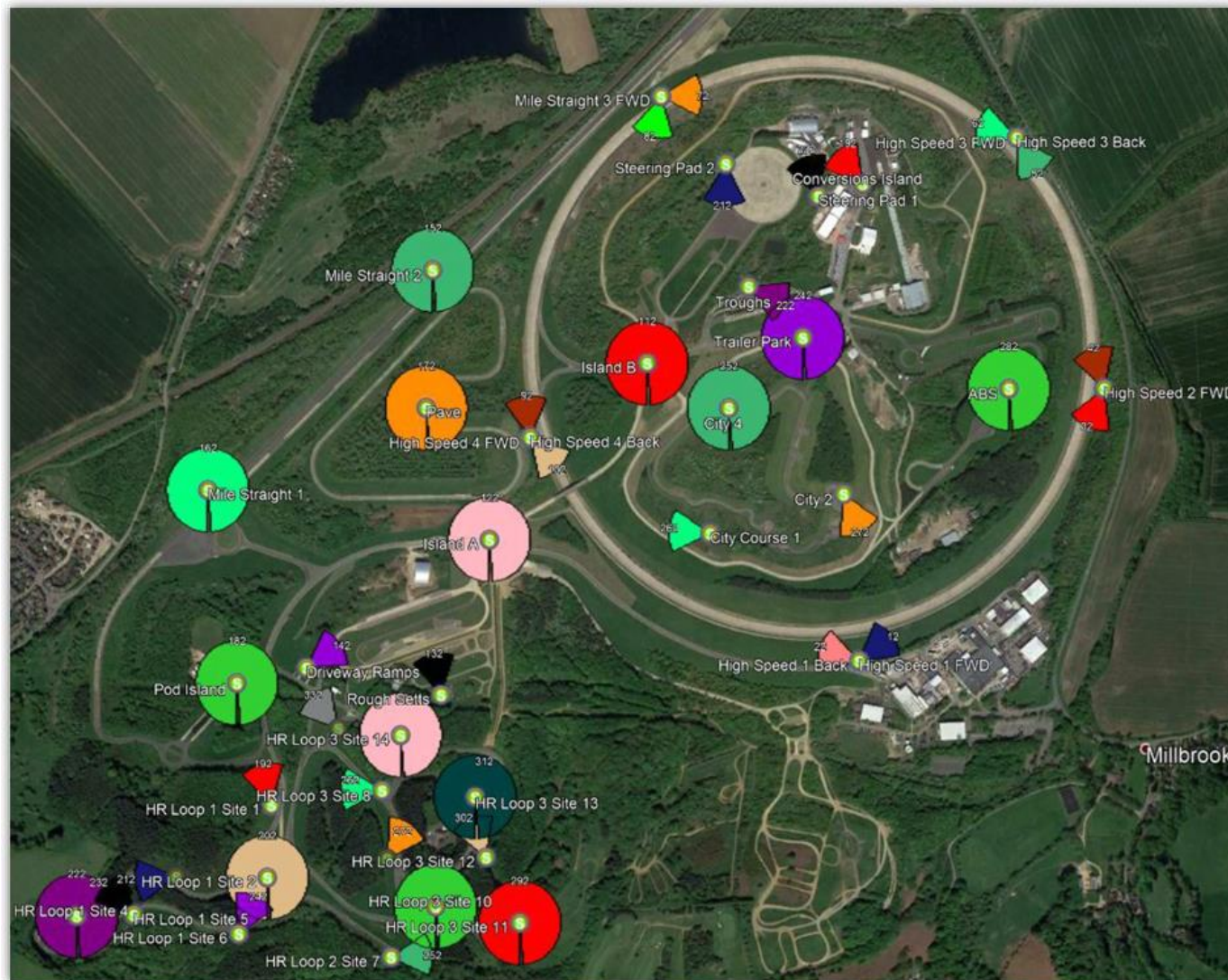
V2X Network in use
McLaren 570S passing units

2.3GHz small cells



eNB Name	Longitude	Latitude	PCI	Band	Azimuth	Angle	Tx Power	Mech. Tilt
ABS	-0.528242	52.044667	280	Band 40	218	65	30	8
City 4	-0.535683	52.044356	250	Band 40	76	65	30	8
Conversions Island	-0.532122	52.047967	190	Band 40	324	65	30	8
Driveway Ramps	-0.546908	52.040167	140	Band 40	0	360	30	0
High Speed 1 FWD	-0.532225	52.040278	10	Band 40	55	65	30	0
High Speed 1 Back	-0.532225	52.040278	20	Band 40	290	65	30	0
High Speed 2 FWD	-0.525708	52.044667	40	Band 40	345	65	30	8
High Speed 2 Back	-0.525708	52.044667	30	Band 40	205	65	30	8
High Speed 3 Back	-0.528031	52.048711	50	Band 40	150	65	30	8
High Speed 3 FWD	-0.528031	52.048711	60	Band 40	290	65	30	8
High Speed 4 Back	-0.540958	52.043878	90	Band 40	355	65	30	0
High Speed 4 FWD	-0.540958	52.043878	100	Band 40	140	65	30	0
Island B	-0.537853	52.045078	110	Band 40	0	360	30	8
Mile Straight 1	-0.549528	52.043033	160	Band 40	160	65	30	8
Mile Straight 2	-0.543553	52.046578	150	Band 40	177	65	30	8
Mile Straight 4	-0.534608	52.051422	200	Band 40	0	360	30	0
Rough Setts	-0.543331	52.039733	130	Band 40	350	65	30	8
Steering Pad 1	-0.5333	52.047767	230	Band 40	0	360	30	0
Steering Pad 2	-0.535761	52.048289	210	Band 40	0	360	30	0
Trailer Park	-0.533714	52.045489	240	Band 40	0	360	30	0
Troughs	-0.535158	52.046311	220	Band 40	117	65	30	8
Mile Straight 3 FWD	-0.537481	52.049378	80	Band 40	196	65	30	8
Mile Straight 3 Back	-0.537481	52.049378	70	Band 40	90	65	30	8
City 2	-0.532631	52.042967	270	Band 40	0	360	30	0
City Course 1	-0.536183	52.042333	260	Band 40	277	65	30	8
Island A	-0.542047	52.042233	120	Band 40	0	360	30	8
Pave	-0.543725	52.044356	170	Band 40	45	65	30	8
Pod Island	-0.548758	52.039922	180	Band 40	244	65	30	8
HR Loop 1 Site 1	-0.547839	52.037957	190	Band 40	348	65	30	8
HR Loop 1 Site 2	-0.547949	52.036789	200	Band 40	0	360	30	0
HR Loop 1 Site 3	-0.550369	52.036801	210	Band 40	266	65	30	8
HR Loop 1 Site 4	-0.553014	52.036168	220	Band 40	170	65	30	8
HR Loop 1 Site 5	-0.551497	52.036185	230	Band 40	0	360	30	0
HR Loop 1 Site 6	-0.548708	52.035881	240	Band 40	28	65	30	8
HR Loop 2 Site 7	-0.544657	52.035505	250	Band 40	88	65	30	8
HR Loop 3 Site 8	-0.5449	52.03819	260	Band 40	275	65	30	8
HR Loop 3 Site 9	-0.544761	52.037092	270	Band 40	0	360	30	0
HR Loop 3 Site 10	-0.543474	52.03632	280	Band 40	16	65	30	8
HR Loop 3 Site 11	-0.541237	52.036059	290	Band 40	345	65	30	8
HR Loop 3 Site 12	-0.542136	52.037113	300	Band 40	0	360	30	0
HR Loop 3 Site 13	-0.542425	52.038088	310	Band 40	337	65	30	8
HR Loop 3 Site 14	-0.544405	52.039083	320	Band 40	96	65	30	8
HR Loop 3 Site 15	-0.546063	52.039194	330	Band 40	322	65	30	8

3.7GHz small cells



eNB Name	Longitude	Latitude	PCI	Band	Azimuth	Angle	Tx Power	Mech. Tilt
ABS	-0.528242	52.044667	282	Band 43	0	360	25	0
City 4	-0.535683	52.044356	252	Band 43	0	360	25	0
Conversions Island	-0.532122	52.047967	192	Band 43	324	65	20	8
Driveway Ramps	-0.546908	52.040167	142	Band 43	58	65	20	8
High Speed 1 FWD	-0.532225	52.040278	12	Band 43	55	65	20	8
High Speed 1 Back	-0.532225	52.040278	22	Band 43	290	65	20	8
High Speed 2 FWD	-0.525708	52.044667	42	Band 43	345	65	20	8
High Speed 2 Back	-0.525708	52.044667	32	Band 43	205	65	20	8
High Speed 3 Back	-0.528031	52.048711	52	Band 43	150	65	20	8
High Speed 3 FWD	-0.528031	52.048711	62	Band 43	290	65	20	8
High Speed 4 Back	-0.540958	52.043878	92	Band 43	355	65	20	8
High Speed 4 FWD	-0.540958	52.043878	102	Band 43	140	65	20	8
Island B	-0.537853	52.045078	112	Band 43	0	360	20	8
Mile Straight 1	-0.549528	52.043033	162	Band 43	0	360	20	8
Mile Straight 2	-0.543553	52.046578	152	Band 43	0	360	20	8
Mile Straight 4	-0.534608	52.051422	202	Band 43	72	65	20	8
Rough Setts	-0.543331	52.039733	132	Band 43	350	65	20	8
Steering Pad 1	-0.5333	52.047767	232	Band 43	343	65	20	8
Steering Pad 2	-0.535761	52.048289	212	Band 43	185	65	20	8
Trailer Park	-0.533714	52.045489	242	Band 43	0	360	25	0
Troughs	-0.535158	52.046311	222	Band 43	117	65	20	8
Mile Straight 3 FWD	-0.537481	52.049378	82	Band 43	196	65	25	0
Mile Straight 3 Back	-0.537481	52.049378	72	Band 43	90	65	25	0
City 2	-0.532631	52.042967	272	Band 43	157	65	20	8
City Course 1	-0.536183	52.042333	262	Band 43	277	65	20	8
Island A	-0.542047	52.042233	122	Band 43	0	360	25	0
Pave	-0.543725	52.044356	172	Band 43	0	360	25	0
Pod Island	-0.548758	52.039922	182	Band 43	0	360	25	0
HR Loop 1 Site 1	-0.547839	52.037957	192	Band 43	348	65	25	0
HR Loop 1 Site 2	-0.547949	52.036789	202	Band 43	0	360	25	0
HR Loop 1 Site 3	-0.550369	52.036801	212	Band 43	266	65	25	0
HR Loop 1 Site 4	-0.553014	52.036168	222	Band 43	0	360	25	0
HR Loop 1 Site 5	-0.551497	52.036185	232	Band 43	321	65	25	0
HR Loop 1 Site 6	-0.548708	52.035881	242	Band 43	28	65	25	0
HR Loop 2 Site 7	-0.544657	52.035505	252	Band 43	88	65	25	0
HR Loop 3 Site 8	-0.5449	52.03819	262	Band 43	275	65	25	0
HR Loop 3 Site 9	-0.544761	52.037092	272	Band 43	36	65	25	0
HR Loop 3 Site 10	-0.543474	52.03632	282	Band 43	0	360	25	0
HR Loop 3 Site 11	-0.541237	52.036059	292	Band 43	0	360	25	0
HR Loop 3 Site 12	-0.542136	52.037113	302	Band 43	341	65	25	0
HR Loop 3 Site 13	-0.542425	52.038088	312	Band 43	0	360	25	0
HR Loop 3 Site 14	-0.544405	52.039083	322	Band 43	0	360	25	0
HR Loop 3 Site 15	-0.546063	52.039194	332	Band 43	322	65	25	0

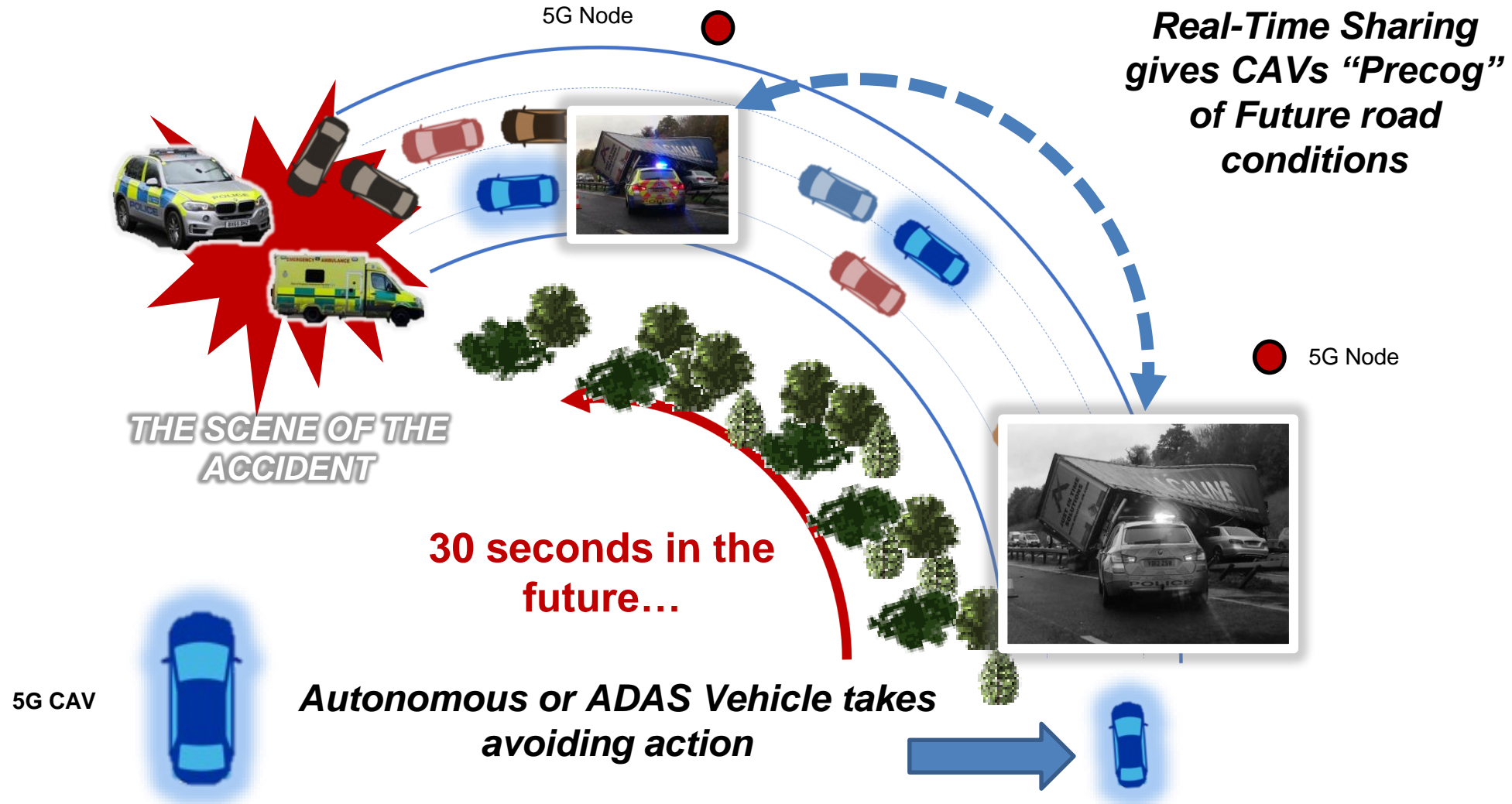
5G CAV Use Cases: See the Road Ahead...

- **“5G Connected Highway”** could enable real-time information to be shared between Connected and Autonomous Vehicles (CAVs)
 - Vehicle to Vehicle
 - Infrastructure to Vehicle
- This shared information / data streams enables the use of “Autonomous” driving modes and improved ADAS on 5G connected highways.
- Level 4 or 5 Autonomous Vehicles are significantly “Safer” if they know the state of the road ahead and behind, and create a better “map” of other vehicles on the road.



How can we share information between CAVs in real time?

5G CAV Use Cases: Real-Time Data Sharing



Launch!

- The video can be found here
- <https://www.youtube.com/watch?v=X1zyISRWslg&t=10s>

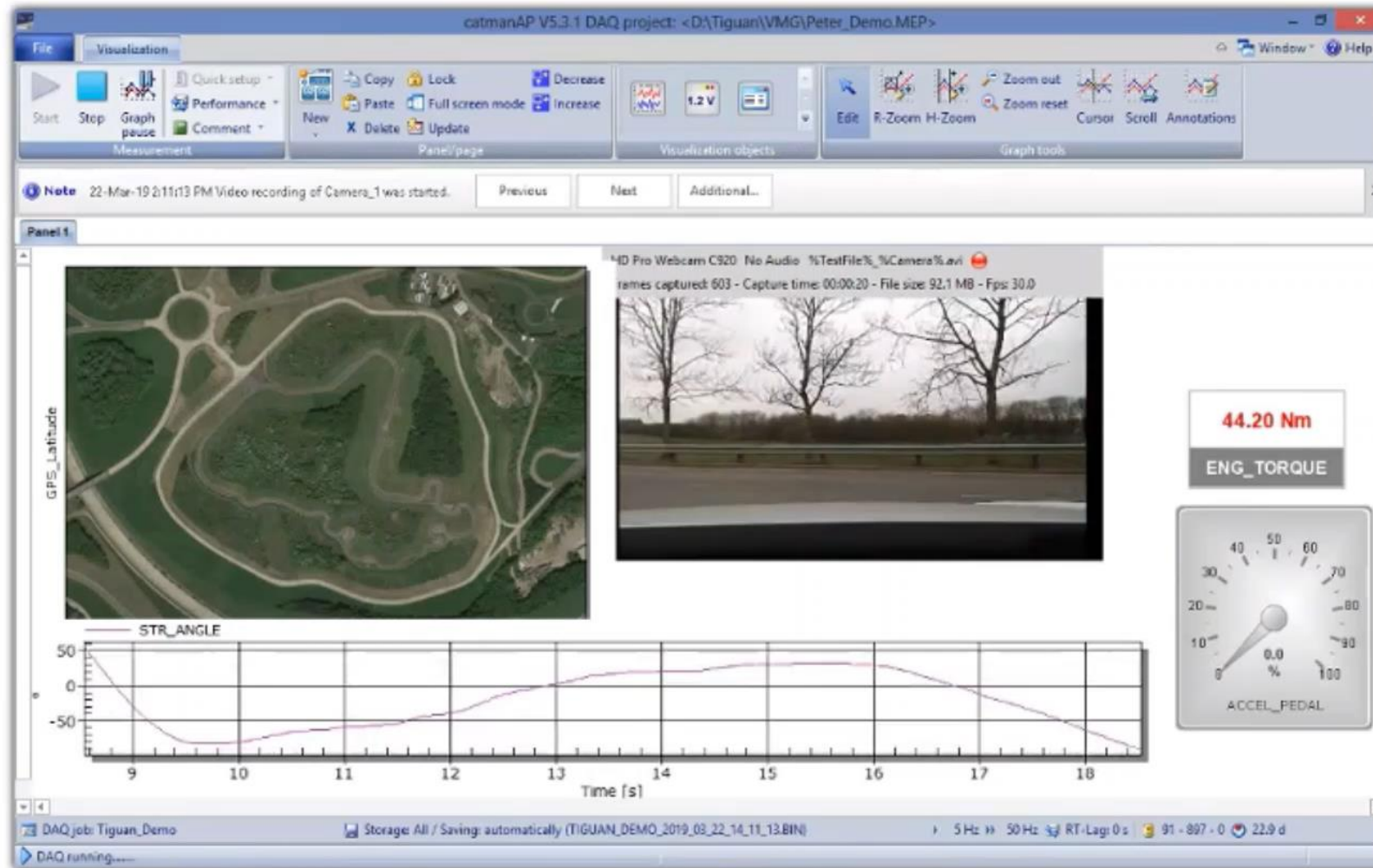
4G/5G Small Cells around Millbrook



Hyper Dense Small Cell Networks



Live demo and reporting





www.millbrook.co.uk