

DIGITAL UNDERGROUND

A Framework For Reliable Three-dimensional
Underground Utility Mapping For Urban
Planning

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Team

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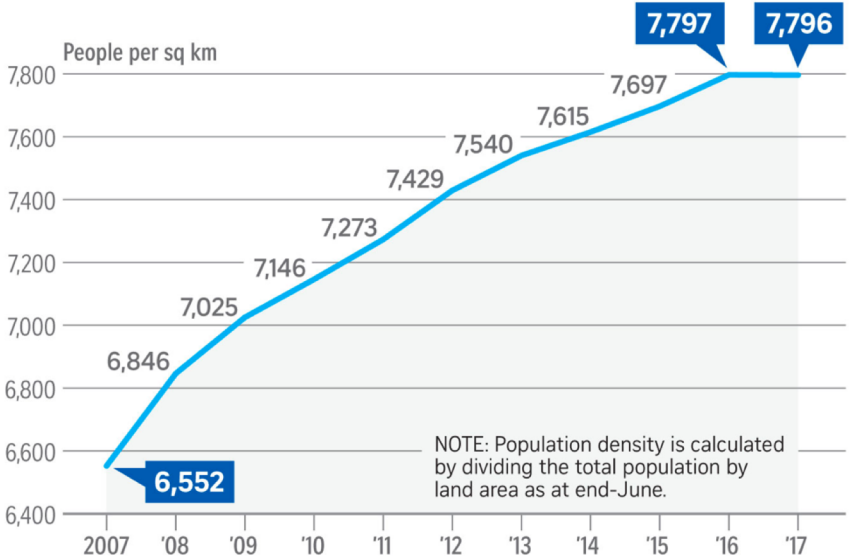
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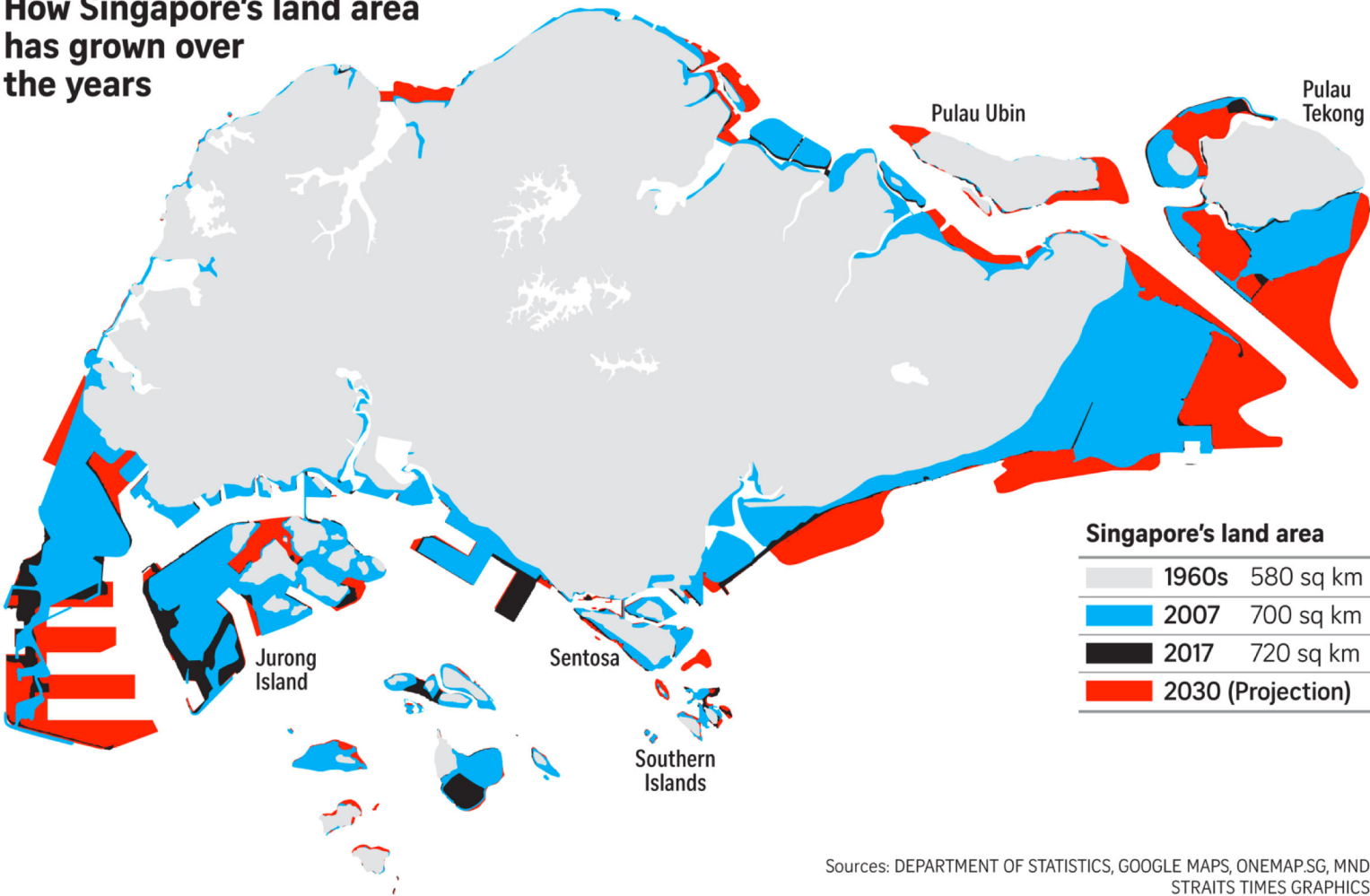


FINDING SPACE FOR THE FUTURE

Population density over a decade



How Singapore's land area has grown over the years



Finding space for the future

To use our space more efficiently, the Government is looking to launch its Underground Master Plan in 2019. Here are some subterranean ideas that are being explored.

Substations

Electrical substations, which are essential for providing electricity to estates, currently occupy small tracts of land at the ground level, even though they are connected to the underground cabling network. To save space, these can be housed underground, and can still be serviced through access points with a smaller footprint.

Bus interchange

The new Bidadari housing estate will be home to Singapore's first underground air-conditioned bus interchange below Housing Board flats. Slated for completion by 2019, it will sit below a carpark and a garden, and will likely cater to five bus services.

Road and rail networks

To enhance our living environments, future major road and rail networks, especially those that will cut through built-up areas, will be located underground. This reduces the impact of noise and dust on homes.

Deep Tunnel Sewerage System

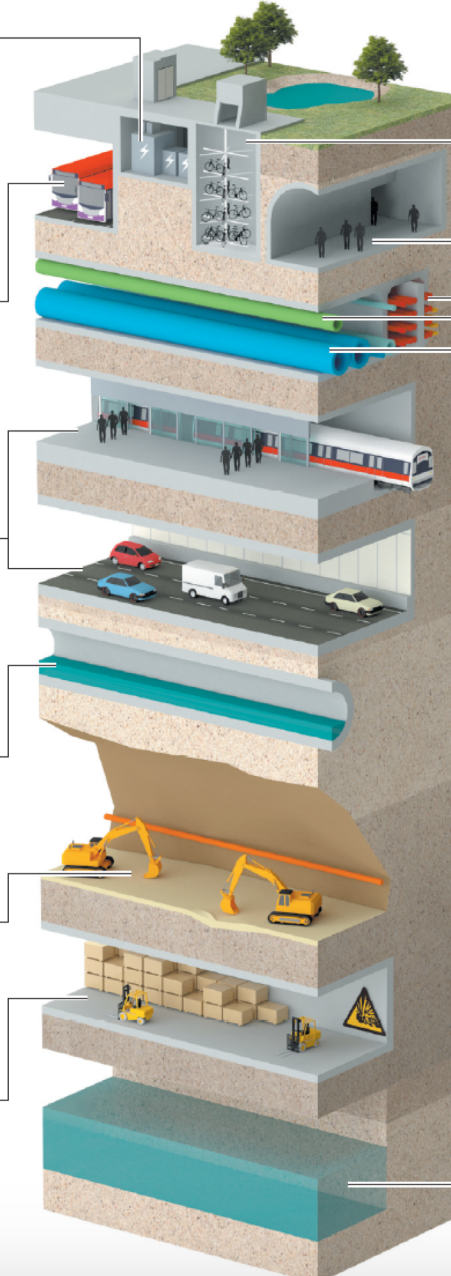
This is a network of tunnels that operates on gravity, and transports sewage and waste water across the island to two centralised water reclamation plants.

Jurong Rock Caverns

The Jurong Rock Caverns under Jurong Island is for petrochemical storage. In phase one, its five caverns are as high as nine storeys, saving approximately 60ha of land.

Ammunition facility

The underground ammunition facility built under a quarry in Mandai in 2008 stores ammunition and explosives. It frees up land about half the size of Pasir Ris town.



SecureMyBike

In Admiralty, the Land Transport Authority completed the first automated underground bicycle parking space, known as SecureMyBike. Users can leave their bikes at kiosks located above ground, which then houses them in storage cells extending up to 10m underground.

Pedestrian links

Underground pedestrian links make it easier to connect between buildings or cross busy streets. For a more extensive underground pedestrian network, the Urban Redevelopment Authority offers an incentive scheme to co-fund the construction of selected linkages in Orchard Road and the Central Business District.

Common Services Tunnel

More than just space-saving measures, underground pipes are less prone to external wear and tear. The Common Services Tunnel in Marina Bay is a creative way of housing all utilities together. This frees up land, with lesser maintenance disruptions on the roads.

Waste disposal

In housing estates, trash can be carried away to a centralised bin centre through a suction force via underground pipes, using pneumatic waste conveyance systems. Such a waste disposal network can be seen in an HDB estate in Yuhua, removing the need for refuse workers to manually collect waste from each block.

Air-conditioning pipes

Chilled water used for air-conditioning could be supplied centrally through an underground network of pipes, known as a district cooling system. This is already done in Marina Bay, and the authorities are looking to implement them in the Punggol Digital District.

Reservoirs

Water can be stored in underground reservoirs, with the national water agency PUB currently looking into an idea that can free up significant parcels of land for development. The 17 reservoirs currently occupy 3,700ha, or around 5 per cent of Singapore's total land.

NOTE: Illustration not drawn to scale

Source: URA STRAITS TIMES GRAPHICS



Underground access to
Downtown MRT Station

Straits View



Underground access to
future Shenton Way MRT Station



Towards
Marina Bay MRT Station

Park Street





Masterplan of Singapore's underground spaces ready by 2019

Ms Hwang said the URA is working towards having a more complete 3D map of the underground spaces and infrastructure here.

National Development Minister Lawrence Wong told The Straits Times that the Government has to take stock of what is underground, including pipes and power grids.

"We have to take stock and have a good database of information, and are compiling it as a central repository so we have a good basis plan," he said.

article source: Straits Times, <https://www.straitstimes.com/politics/masterplan-of-spores-underground-spaces-ready-by-next-year>

Singapore

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Brand Spotlight



Proposed law will allow Govt to acquire specific stratum of underground space

By YVONNE LIM



source: Today Online, <https://www.todayonline.com/singapore/proposed-law-will-allow-govt-acquire-specific-stratum-underground-space>

Construction work ruptures gas pipe near Lau Pa Sat

By ROBIN CHOO



Boon Tat Street was cordoned off because of the gas leak, but gas supply to the area was not affected. Photo: Robin Choo

source: Today Online, <https://www.todayonline.com/singapore/construction-work-ruptures-gas-pipe-near-lau-pa-sat>

HOW RELIABLE IS TODAY'S MAP OF UNDERGROUND UTILITIES?

Information may not match reality

- Inaccurate locations
- As-designed instead of as-built
- No geo-referencing
- Inconsistent depth information
- Incomplete
- Not up to date

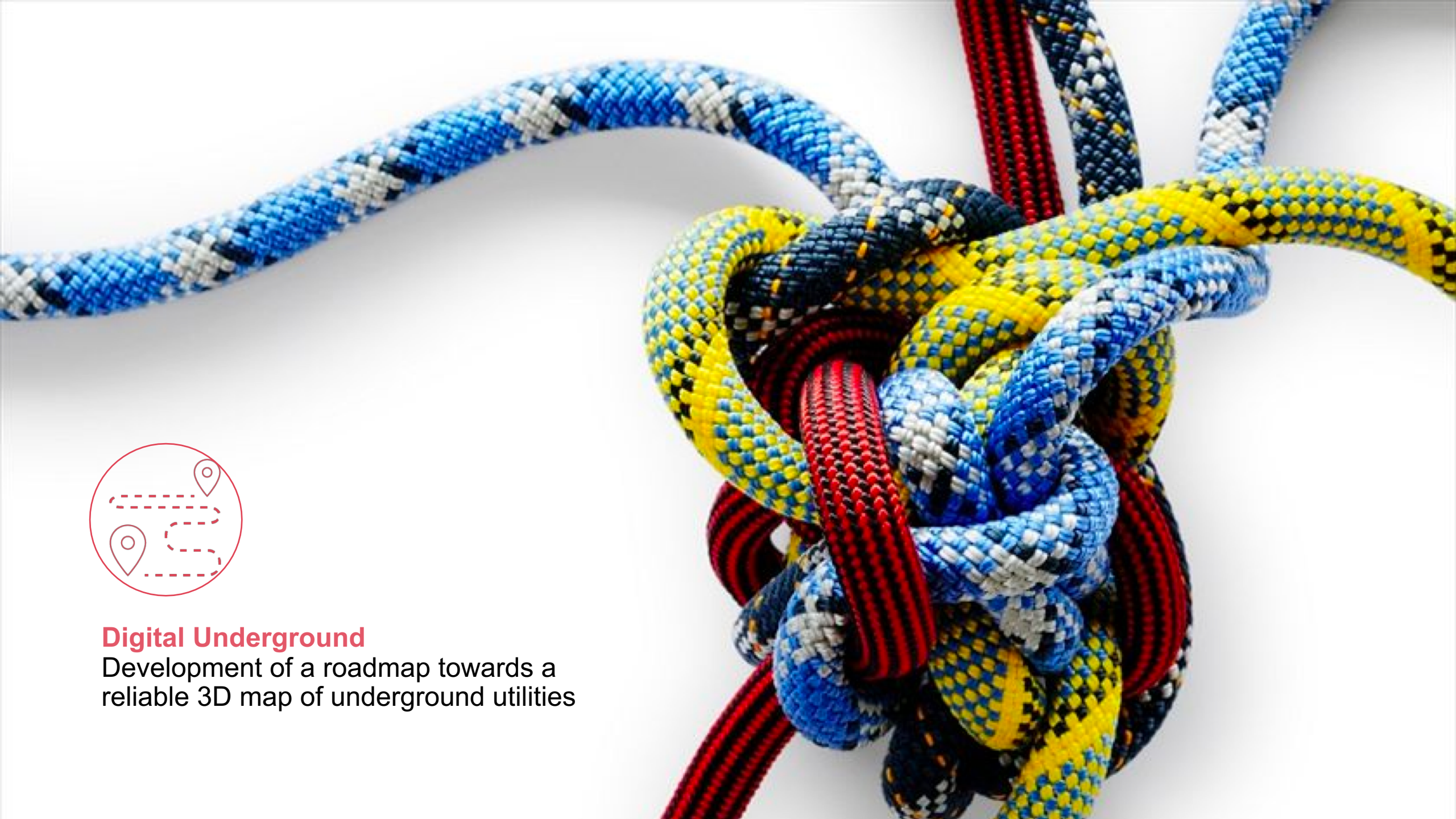
Information may not fit purpose

- 2D or 2.5D instead of 'true' 3D
- Lacks rich semantics

Information is not accessible, interoperable, and usable

- Inconsistent representation
- Many formats (GIS, CAD, paper)
- Accessing data is not straightforward



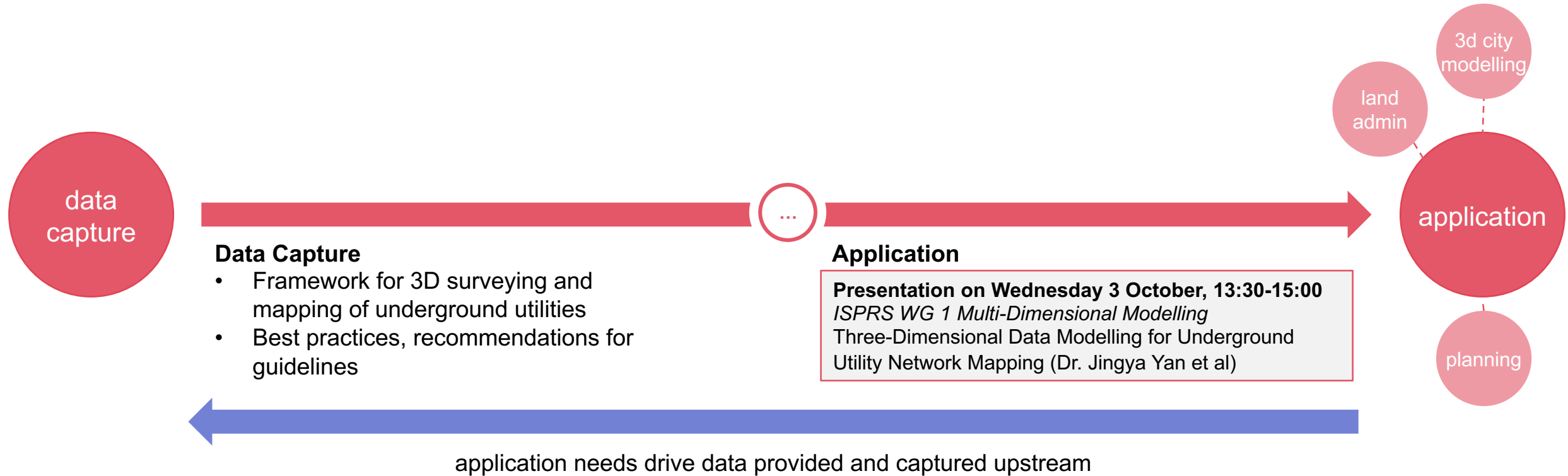


Digital Underground

Development of a roadmap towards a reliable 3D map of underground utilities

BRIDGING THE GAP BETWEEN DATA CAPTURE AND APPLICATION

Understanding, demonstrating, and recommending a feasible workflow



A FRAMEWORK FOR 3D MAPPING UNDERGROUND UTILITIES

An overview of data capture methods, describing

- Operation (surveying + mapping)
- Expected output and quality
- Conditions under which it can feasibly operate and produce reliable data
- Practical considerations for deployment

Purpose

- Application in Singapore
- To support decision making by surveying contractors, commissioning entities and policy makers

Approach

- Initial focus on mapping existing utilities
- Desktop research (market analysis and scientific literature)
- Pilot studies in realistic environments
- “Whole Ecosystem Approach” - emphasize government and industry collaboration

Industry collaborators



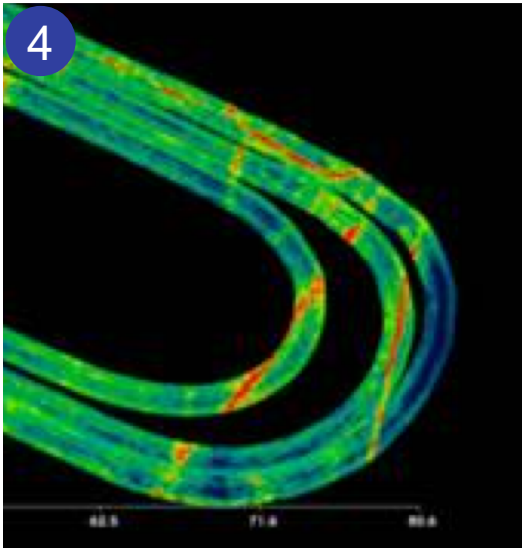
Government collaborators



DIGITAL
UNDERGROUND

DATA CAPTURE METHODS FOR UNDERGROUND UTILITY SERVICES

	Method	Use case	Typical (primary) data
1	Conventional surveying	Open pit	Sparse point trajectory
2	Laser & photogrammetry	Open pit	Dense point cloud
3	Ground penetrating radar	Buried	B-scan radargram -> point trajectory
4	3D ground penetrating radar	Buried	C-scan radargram -> point trajectory
5	Gyroscope / IMU	Buried, newly built	Dense point trajectory
6	Marker tagging	Buried	Sparse point trajectory



credit: T. Baker Smith



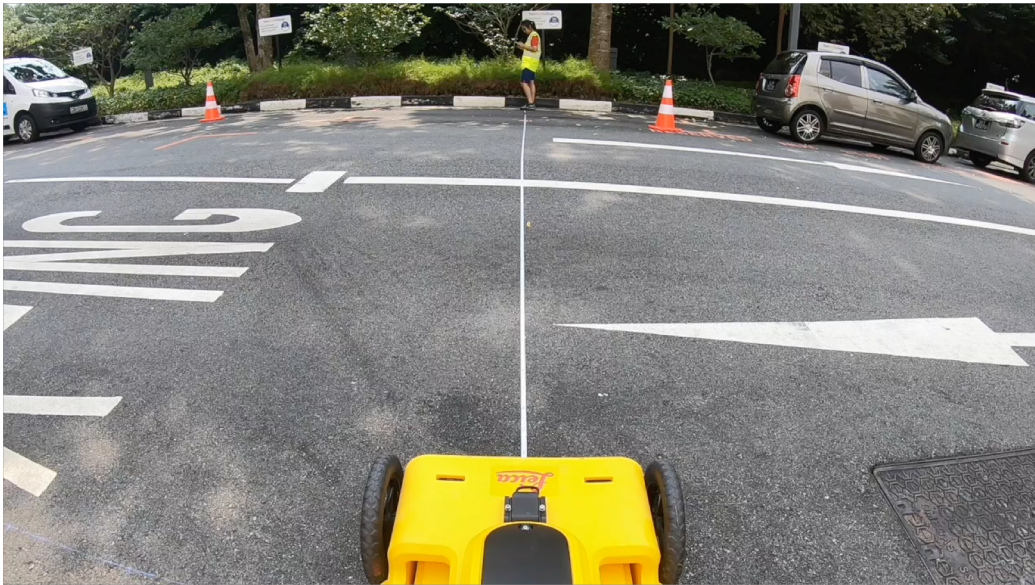
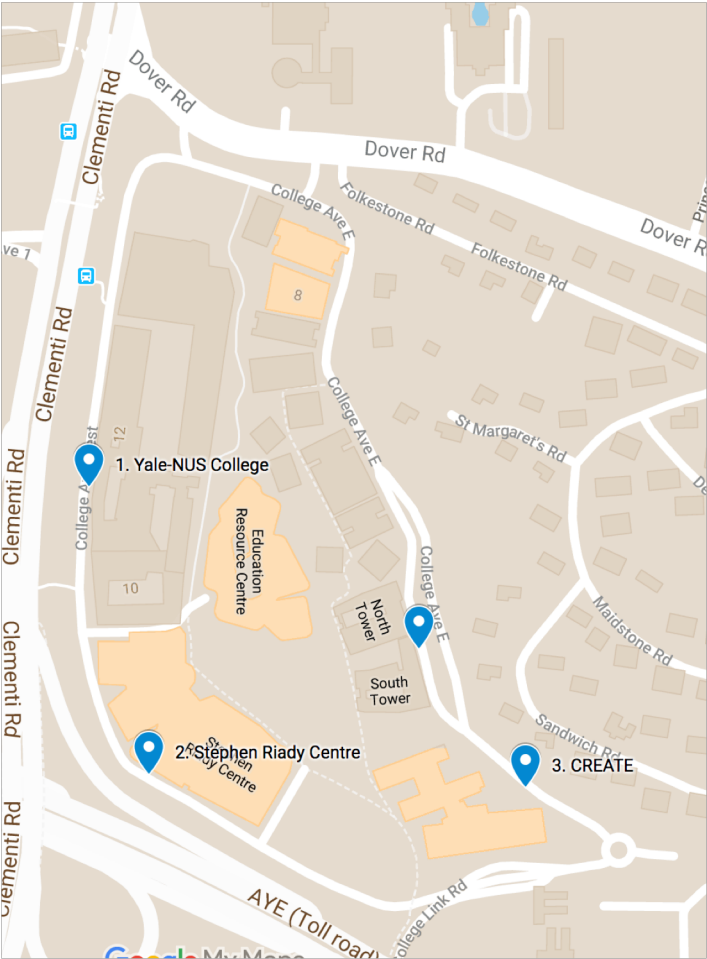
credit: University of Illinois at Urbana-Champaign



credit: Eliot solutions

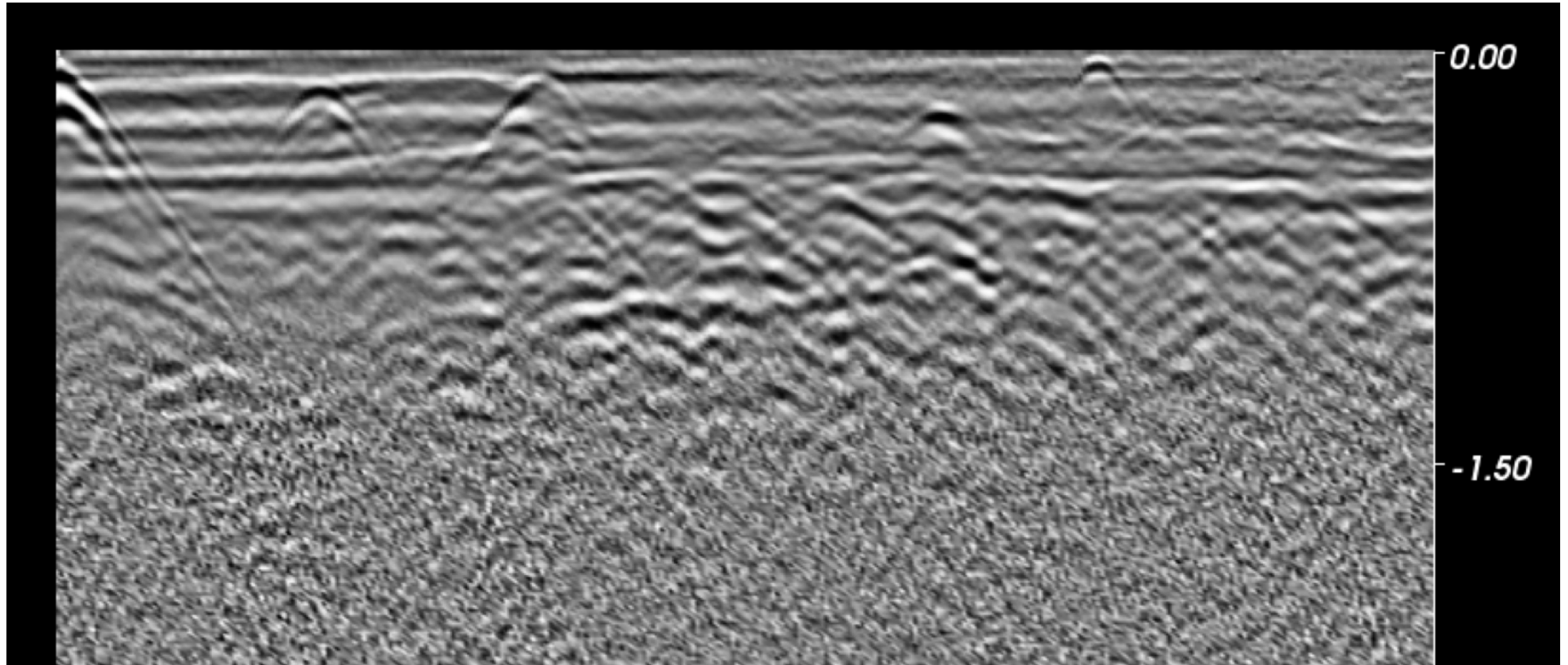
GROUND PENETRATING RADAR

Pilot study in progress - NUS University Town



GROUND PENETRATING RADAR

Early sample of primary data



GYROSCOPIC MAPPING

Pilot study - Woodlands Industrial Park



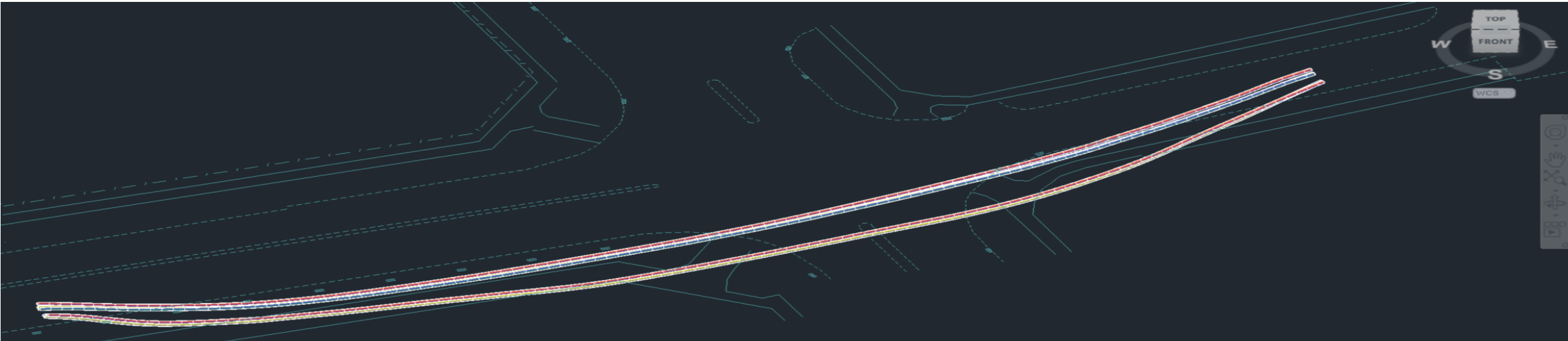
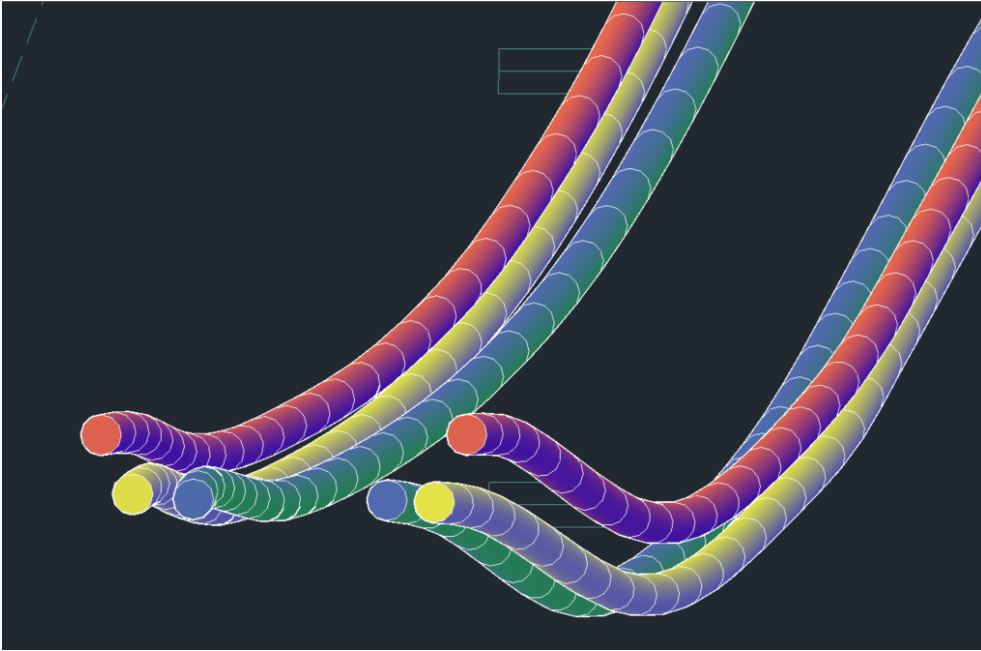
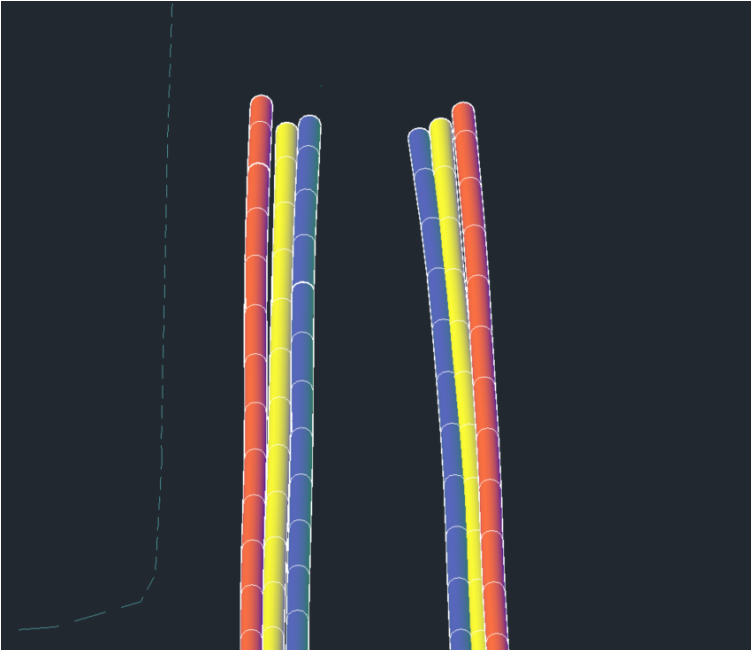
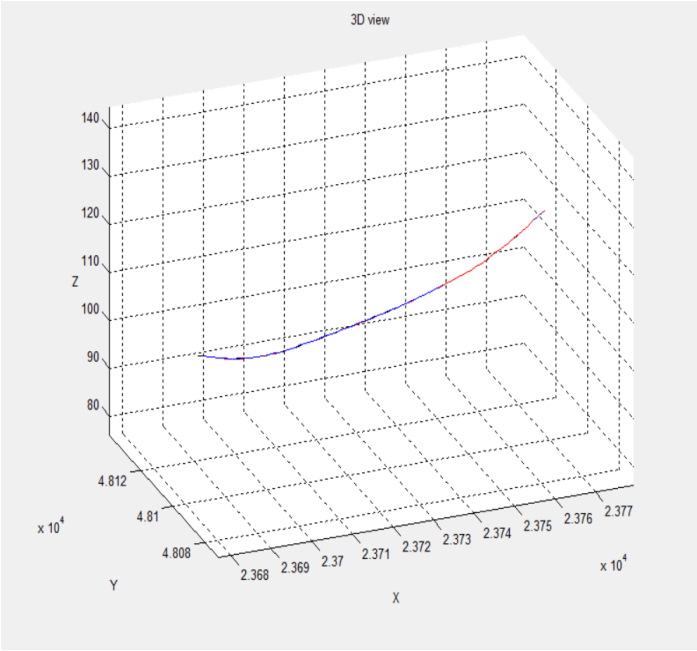
GYROSCOPIC MAPPING

Data capture



GYROSCOPIC MAPPING

Mapping results



SOME EARLY CONCLUSIONS

We can't simply recommend a single mapping method

- The best moment to map a utility will always be when it is exposed and visible
- Alternatives are needed nonetheless (i.e. for trenchless construction, existing services, and shifting services)
- Unclear yet if GPR technology can be an economically viable method
- New or “non-GIS” applications (e.g. BIM) => new information requirements => different mapping techniques (e.g. point cloud based)

Pros and cons of a “Whole Ecosystem Approach”

- It is the only way forward
- Collaboration can be slow, complicated, and time-consuming

Back to our roadmap: The mapping workflow is just a small piece of the puzzle

- How to improve technology adoption and the required competencies?
- How to manage, store and share the information?
- How to organize data governance?

RIGHT NOW - RAMPING UP FOR FUTURE PILOTS...



Thank you! See you in SG?

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