Who owns the space under cities? The attempt to map the earth beneath us

The space under cities is getting busier – from transport excavations to billionaire's mega-basements. So how to keep track of what's down there?

A tunnel under Los Angeles built by Elon Musk's Boring Company. Photograph: The Boring Company

Just over a year ago I was sent a photograph of a tunnel-boring machine in a dirt lot in Los Angeles. The caption read: "Elon Musk is about to start digging."

The message was from Wayne Chambliss, a geographer in southern California, who tends to be prescient in such matters – and indeed, Musk's freshly minted Boring Company soon set its machine loose, ripping through the subsurface soil under the SpaceX headquarters in Hawthorne to create a short tunnel.

This pet project – to test a private mass-transit system based on Hyperloop technology that would magnetically propel small pods and cars through LA's underbelly – has now

become a serious challenge to the famously traffic-snarled city's failure to create viable public transit.

The company's website suggests "roads must go 3D" and Musk has stated "in theory, you could have hundreds of levels of tunnel" as more thoroughfares are required. As so often with Musk's projects, the company is treating subterranean space as a *tabula rasa* – or in this case, *tubula rasa* – to be played in for profit.

Indeed, in most major cities, just as you can't expect commercial planes to stop flying over your house through aerial highways, you also can't prevent public transport routes being dug out underneath it. Outside Melbourne, Australia, for example, the government is currently preparing to bore underneath 260 properties – including more than 100 homes – to build a road tunnel. Homeowners received a letter explaining that their "sub-stratum" land was being sequestered – without compensation.

In London, a city with 150 years of trenching, digging and boring to its name, the chaos is reaching new depths. According to Newcastle University's Global Urban Research Unit, more than 4,600 basements have been granted planning permission in the last decade – in just seven of London's 32 boroughs.

The space under London is now getting so busy that the Ordnance Survey, Future Cities Catapult and the British Geological Survey have joined forces to create a new initiative called Project Iceberg, which will attempt to aggregate cities' subterranean data. In London it will include transport tunnel information, geological records and maps of 1.5m km (0.9m miles) of underground utilities and four million kilometres of telecommunications lines.

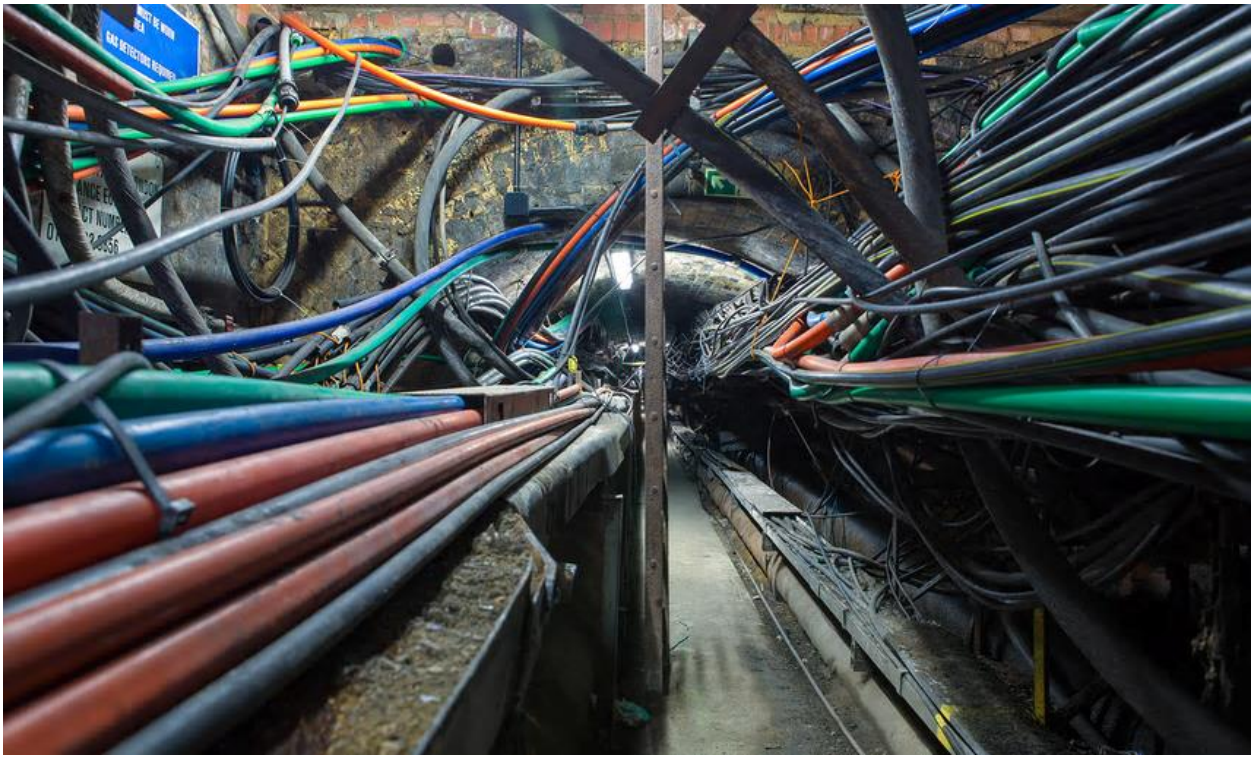
Los Angeles does not have the same degree of vertical complication as a much older city like London, and the city council seems to be tentatively backing Musk's new private transit tunnels. But Musk's vision of underground dominance presents us with another thorny problem: what complications arise from passing the underground into the hands of private industry? And should the state be allowed to cede subterranean land to a billionaire to build a private transport system?

From heaven to hell – with caveats

Historically, the foundation of property law in the US and UK was enshrined in the Latin phrase "*Cuius est solum, eius est usque ad coelum et ad inferos*" – which roughly translates as: "Whoever owns the soil, holds title up to the heavens and down to the depths of hell."

Subterranean scholar Dr Marilu Melo of the University of Sydney explains that not all countries behave this way. In Mexico, for example, “property rights are effectively superficial, they do not extend volumetrically into the earth,” she says.

Even in places that have traditionally been ardent defenders of private property, however, once human beings took to the air and started tunnelling underground, the old heaven to hell ideal began to require caveats. In Australia, although pre-1891 land titles went “to the centre of the Earth”, those issued after 1891 extend down just 15 metres (49 feet). The new Melbourne tunnels will edge right up to this legal vertical limit.



“Land prices tend to force private construction downwards, especially where there are planning limits on upward expansion,” says the Ordnance Survey’s Rollo Home.

There has been a growing concern in London over “iceberg architecture”, where the volume of subterranean expansions can quickly eclipse the “host” architecture in size. The Newcastle researchers separate the London basements it studied into what sounds like fast-food drink sizes: “standard”, “large” and “mega”.

In the “mega” category, they found that on average owners pulled almost 1,700 cubic metres of dirt from under their houses. Many of the basements contained cinemas, gymnasiums, pools, wine cellars and panic rooms. One even included plans for a subterranean beach with an accompanying waterfall. Kensington and Chelsea and

Westminster councils have now taken steps to curb the maximum depth of such projects.

The Ordnance Survey has suggested that £5.5bn ($7bn) is spent every year on exploratory excavation just to figure out what's underground, and according to a 2013 Mayor of London report, £150m of damage is done every year to underground utilities because of a lack of information. Underground urban planning of an extension of a tube line, for instance, requires knowledge of where sewer and water systems, electricity and utility tunnels, bunkers, foundations, basements, cellars, vaults, passageways, archaeological remains, data centres, basements, and other transport tunnels are located. Most cities have a "dial before you dig" hotline because there is no central holding place for data about underground space.

Enter Project Iceberg. The goal is to serve as a framework for data on all of these underground elements, from which a comprehensive visualisation can be built. The resulting map would need to be an all-inclusive spatial database, but how volumetric cartography might look is not yet imagined. It could perhaps be something like Bruno Imbrizi's real-time 3D tube map that went viral in 2013. Or the framework could feed an augmented reality engine, so that aiming a phone camera at the ground would reveal what is underneath.

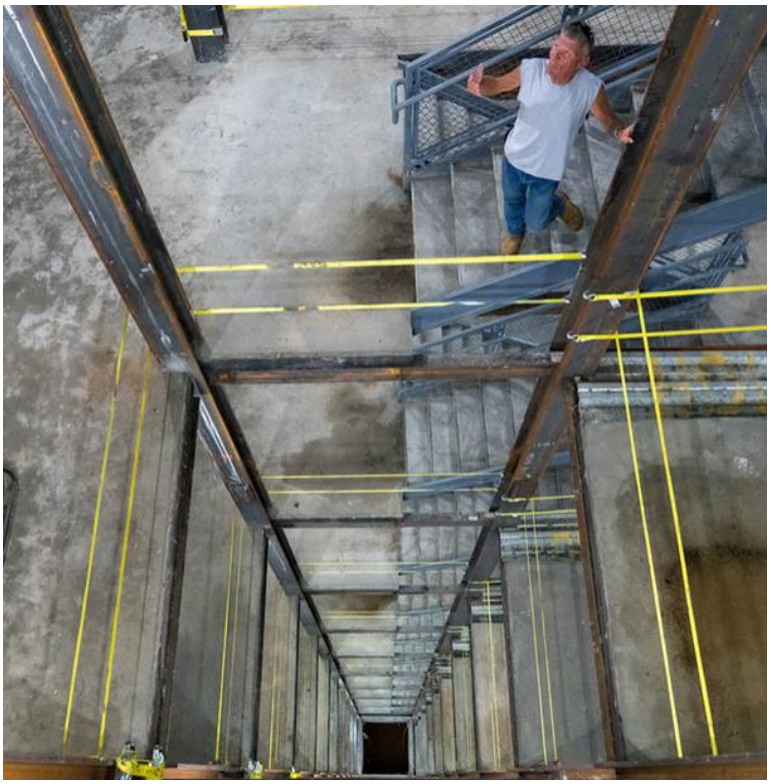
Singapore, Helsinki and Hong Kong are model cities for developing underground masterplans – and it is no coincidence that tightly controlled and regulated cities hold better data in this regard. Private developers digging and burrowing into cities like Los Angeles and London make this immensely more complicated – as does the need for secrecy on many underground projects.

The underground is, after all, where we hide things. When Westminster tube station was built, much of it had to be "planned by omission", a guide told me. Engineers would submit plans and the government would send them back with suggestions for different routes – refusing to explain why. Land registry data later confirmed what anti-secrecy journalists like Duncan Campbell had suspected all along: the existence of a network of covert tunnels connecting government buildings in Westminster. The government, in short, wasted loads of public money denying the existence of something that it had secretly spent a great deal of public money building in the first place.

Further clandestine excavations spring to mind: tunnels under borders used to smuggle people and contraband; shipping containers stockpiled with food buried in the wee hours by doomsday preppers. Given London's history of furtive diggers – like William Lyttle, the Mole Man of Hackney, who burrowed under his house for 40 years – it doesn't seem a stretch to imagine a TfL boring machine punching through the side of a fallout shelter dug without permission.

Nowhere left to hide

Although it is an open project, Iceberg researchers have suggested creating a hidden vault layer in the 3D map, where secret data could be locked away from general view. Yet as was clear in the Westminster example, the absence of data *is* data in a comprehensive archive. Given this, both governments and criminals who wish to keep their underground infrastructure under wraps may find it difficult to do so in the coming age of volumetric transparency. We have little virtual privacy left; within decades, all spatial privacy may evaporate, too.



The US government has been trying to map the subsurface of the Earth from outer space, by measuring differences in the gravity field at the Earth's surface. An Air Force project undertaken more than 20 years ago on a tunnel in Texas was able to capture "reasonably accurate readings of the tunnel's size, shape, variable depth, and orientation", as Chambliss told attendees of the recent annual American Association of Geographers conference in New Orleans. This could soon enable a planetary-scale survey of the underground, revealing new tunnels, bunkers, silos, and compounds. His recommendation to the assembled geographers: "Dig now."

Many are. In Sweden, which already has 65,000 known shelters for a population of just under 10 million people, the government has begun building new bunkers. Seoul in South Korea has more than 3,000 large public shelters. In the plains of Kansas, I recently visited two cold war-era Atlas intercontinental ballistic missile (ICBM) silos being redeveloped into "Survival Condos for the wealthy.

If we are to take control of the subsurface, we need to have an holistic view of the subsurface
Rollo Home

Meanwhile, the US Defense Advanced Research Projects Agency (Darpa) is currently funding a "subterranean challenge", soliciting bids for techniques to enhance "situational awareness" of global underground spaces, with a $2m prize. The challenge is to create machines that can make their way through tunnel systems, urban undergrounds and natural caves. Robots will need to climb, crawl, squeeze and sense their way through these environments, with an eye towards future use in dangerous or hostile underground environments that human bodies can't access. These robots will effectively become our subterranean avatars, and their deployment will mean that there really is nowhere left to hide.

"If we are to take control of the subsurface, we need to have an holistic view of the subsurface," says Home. But who is to wield that control? For almost 200 years – since Marc Brunel's invention of the tunnelling shield, which protects workers as they inch forward during excavation – human beings have almost exclusively excavated using money from the public purse. Only two years ago, for example, more than £9bn of public money was used in Switzerland to tunnel 35 miles through the Alps, down to depths of almost 2.4km.

Underground has long been a space of public investment, communal infrastructure, exploration and, when required, secret assembly. In many ways subterranean environs have been more democratic than the surface of the Earth, as depicted in Gabriel Tarde's 1896 utopian novel The Underground Man, in which in which people not only survive but thrive after a "fortunate disaster" forces human kind to burrow.

But as we rush to render our underground world in three dimensions, increasingly it appears we are backing – tacitly or otherwise – private ownership and comprehensive surveillance. The mayor of Chicago, Rahm Emanuel, has just handed Musk's Boring Company a contract to build a Hyperloop to shuttle people from O'Hare International Airport to the city centre.

Although Musk's company will build the tunnel, the city will own it and lease it back to Musk for use, and Musk has also stated that (unlike in Melbourne) no land will be seized to build it. Both sound like good caveats, but neither dilute the fact that this will be a private, for-profit, transport system – not public transport.

Just like our drone-filled skies, the undergrounds of the future appear to be just another territory for the rich and powerful to colonise the rich and powerful , a process that may replicate and compound the inequalities of the present. This may be cause enough to throw a wrench into Musk's tunnel-boring machines. Metaphorically speaking, of course.