Singapore Land Authority Uses 3D Reality Modeling and Mapping to Generate the First Country-scale Digital Twin, Promoting a Smart, Sustainable Nation

- *Singapore 3D Mapping Program is a key digital transformation project to create and provide core geoinformation that supports a sustainable, resilient, and smart nation.*
- *Singapore Land Authority (SLA) initiated this project to update the 2014/2015 national 3D map to deliver accurate, reliable, consistent 3D data to multiple government agencies and stakeholders.*
- *The project required capturing and processing more than 160,000 aerial images, spanning 720 square kilometers, and 25 terabytes of ground surface data, covering all public roads in Singapore.*
- *SLA's success was predicated on using 3D reality modeling and mapping technology in a connected data environment to generate a nationwide digital twin.*

A Nationwide Open-source 3D Mapping Initiative
The world's second most densely populated and land-scarce nation of Singapore has seen significant development of vertical buildings and infrastructure to accommodate the lack of horizontal space, making effective use of land space paramount to the country's development. To optimize land resources and promote economic and social growth, Singapore Land Authority (SLA) initiated the first nationwide 3D mapping program in 2012 to map the entire country with rapid data capture technologies. They performed aerial and street mobile mapping and delivered the country's first national 3D map of Singapore in 2014/2015. The 3D map has been used by government agencies in their policy formulation, planning, operation, and risk management. However, as a dynamic country with rapid development and complex land use, the 2014/2015 snapshot is no longer adequate to support government and stakeholder needs.

In 2019, SLA initiated a second mapping to detect the changes over time and update the original map with improved accuracy to reflect the country's dynamic urban development. The scope of the work included performing cadastral surveys, managing and ensuring precise positioning of national infrastructure, and creating a current national 3D digital map. The project required aerial mapping of the entire country, and mobile street mapping of all public roads in Singapore. In addition to capturing the data and generating the updated map, SLA set an objective of "capture once, use by many" to maximize accessibility to the map, making it available as an open-source 3D national map for projects among government agencies, authorities, and consultants. "We embrace the open standard exchange format and the eventual data developed once, used by many," said Hui Ying Teo, senior principal surveyor at SLA.

Data Processing, Interoperability, Security, and Sustainability
A large-scale, urban digital data capture and reality modeling initiative, the project presented survey and data processing challenges, compounded by data interoperability difficulties among the numerous agencies using varying legacy systems. Furthermore, with national security

paramount, the entire project had to be managed within a secure processing facility but then made available in a cloud-based environment to share with and support government agencies and infrastructure projects. With a long-term sustainable vision, SLA sought to generate a reality mesh of the current existing conditions, integrating aerial imagery and point cloud data through local offline processing to deliver an accurate and reliable 3D map that could then be accessible through and open-source platform and continually updated over time.

As a government mapping agency, SLA continually faces challenges generating, managing, and sharing national large-scale datasets, which requires capital investment and maintenance of advanced IT infrastructure to accommodate mapping, modeling, and collaborative workflows. "Other non-Bentley applications have been explored, but none had the strength to process the scale of the project," stated Teo. SLA realized that they needed integrated reality modeling and mobile mapping technology to securely process the voluminous data from multiple sources into a sustainable nationwide dynamic, 3D digital twin, accessible in a controlled, cloud-based environment to the government and stakeholders.

Leveraging Bentley's 3D Reality Modeling and Mapping Technologies
SLA captured more than 160,000 high-resolution aerial images over a 41-day period and selected ContextCapture to process them into a 0.1-meter accurate nationwide 3D reality mesh. Using Orbit 3DM to incorporate more than 25 terabytes of local street data, they integrated the point clouds into the model and, based on the model, generated a sustainable nationwide digital twin available via a secure, open-source platform. The sheer processing capability, interoperability, and flexibility of Bentley applications facilitated the generation of the first country-scale 3D reality mesh and enabled SLA to successfully provide controlled access in a user-friendly format to serve different users and their requirements. "Bentley's strength in interoperability enables the production of a 3D mesh, optimized for visualization or analysis with 3D software, 3D GIS, or web applications," added Teo.

Using ContextCapture provided the flexibility to work locally or over the cloud, with multi-engine processing to efficiently process the huge amount of data. Integrating Orbit 3DM helped SLA establish a connected data environment that advanced national 3D reality mapping of Singapore, supporting a digital context and digital workflows among different agencies with access to a single accurate, reliable, and consistent data source. "Bentley Orbit 3DM is an enabler to manage the large volume of point clouds and imagery, and bridge data sharing with other users with scalable cloud resources to support the long-term sustainable mapping program that SLA envisions," said Teo.

Leveraging Bentley's applications, SLA delivered an accurate 3D reality mesh to achieve a breakthrough in national scale mapping that can be continually enhanced with 3D building and transportation models, machine learning, and artificial intelligence, providing the framework for the development of a digital twin.

Digital Twin Drives Smart National Development
Compared to traditional topographic surveys, the national aerial and street mobile mapping resulted in significant savings. SLA estimated a one-time cost of SGD 35 million to map the whole nation via conventional methods, but using Bentley applications, they saved SGD 29 million and generated the nationwide 3D reality mesh in just eight months, compared to two years using traditional methods. Implementing the "capture once, use by many" digitalization strategy provides an annual potential savings for the government of at least SGD 13 million based on a refresh cycle once every three years. "Digital context, such as the nationwide reality mesh model, will give access of 3D information to agencies working on the same project and, at the same time, plan and review inputs from one another collectively," said Teo. The open-source digital mapping solution facilitates new collaborative workflows and increases availability of national scale maps by 60%, enabling early planning within a shorter period of time at lower costs.

SLA's national 3D mapping is an enabler for digital transformation and development of Singapore into a smart, resilient, and sustainable nation. The reality mesh, complemented with building and transportation models' attributes, will elevate the model's intelligence as Singapore's digital twin to support core 3D functions targeted at analytics, automation, and visualization. The vision of the Singapore digital twin is a sustainable one with a robust mission to capture and update the city assets, unlock the unlimited intangible benefits of digitalization, and drive smart national development. "Bentley's comprehensive suite of software provided the means to process, manage, edit, and share digital geodata effectively, empowering SLA's digital transformation journey and unlocking unlimited imagination," concluded Teo.

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Caption: In 2019, Singapore Land Authority initiated a second mapping to detect the changes over time and update a mapping created in 2012 with improved accuracy to reflect the country's dynamic urban development. The project required aerial mapping of the entire country, and mobile street mapping of all public roads in Singapore.
Image courtesy of Singapore Land Authority.
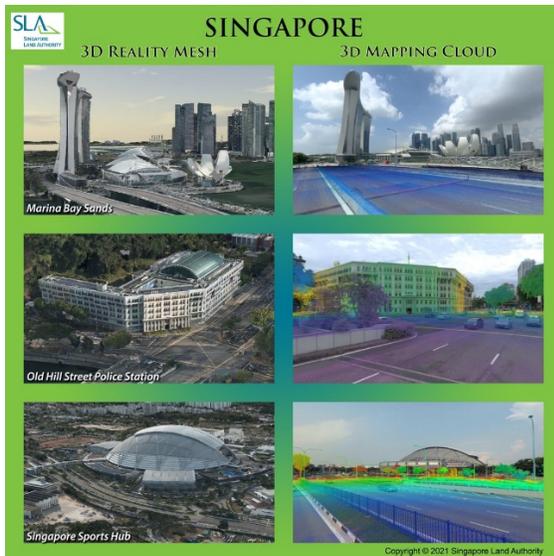
Caption: Singapore Land Authority captured more than 160,000 high-resolution aerial images over a 41-day period and selected ContextCapture to process them into a 0.1-meter accurate nationwide 3D reality mesh.
Image courtesy of Singapore Land Authority.