ETH Eidgenössische Technische Hochschule Zürich

DARCH
Institut für Denkmalpflege
und Bauforschung

Next Generation SMART Cities: The role of Geomatics

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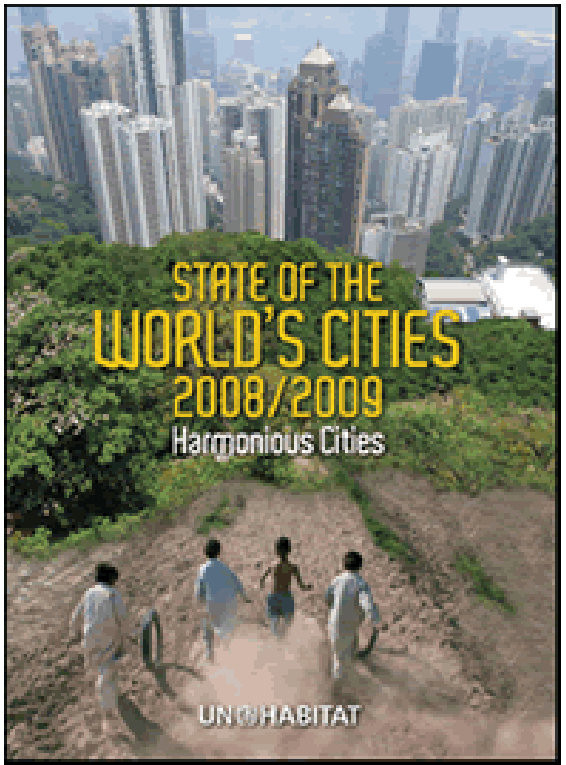
Future Cities Laboratory (FCL), Singapore, www.futurecities.ethz.ch

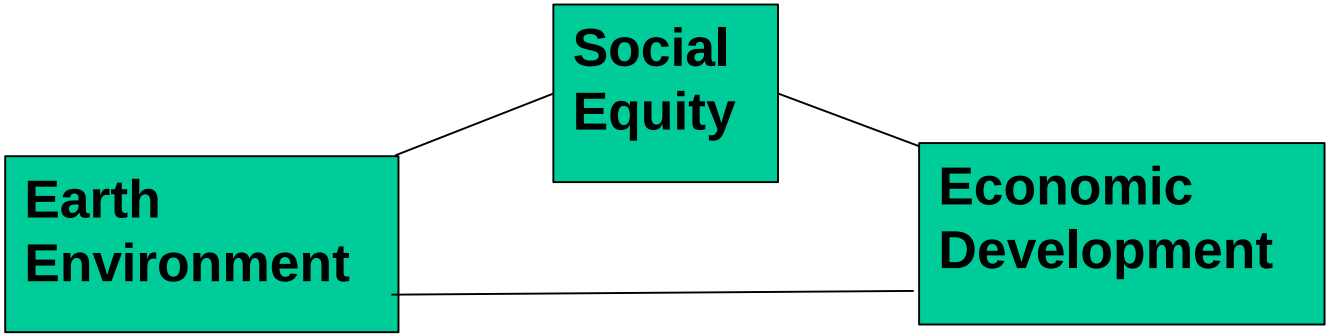
1. **Smart cities/spatial intelligence**
2. **Geomatics technologies: 3D/4D modeling**
3. **Example: SEC-FCL project**
4. **Conclusions, perspectives**

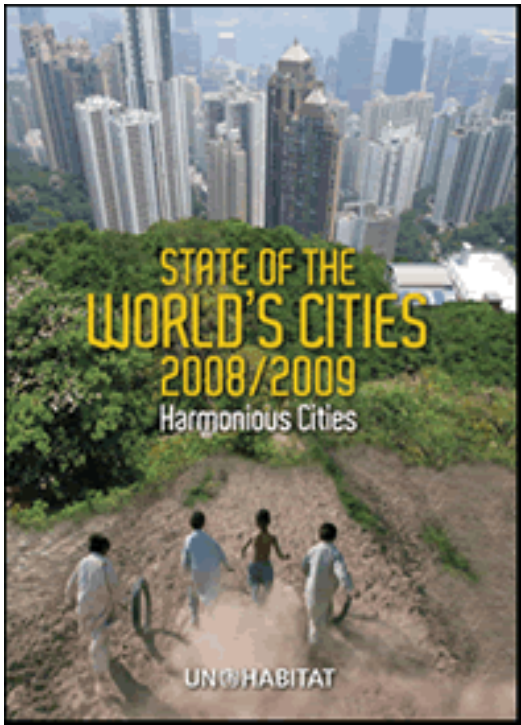


Cities / megacities

Problem

- Urban growth is most rapid in the developing world, where cities gain an average of 5 million residents every month.
- City growth: Harmony among the spatial, social, economical and environmental aspects of a city and between their inhabitants becomes of paramount importance.
  This harmony hinges on 3 key pillars:





→ **Balance through sustainability**

Smart cities (6 axes model)
- smart
  economy, **mobility**, **environment**, **people**, **living**, **governance**

'Smart' city: Investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development, a high quality of life, with a wise management of natural resources, through participatory governance.

A lively and liveable Singapore:
Strategies for sustainable growth
(Inter-Ministerial Committee on Sustainable Development, 2009)

Goals for 2030

- **Energy** – greater efficiency and diversification; reduce energy intensity by 35%
- **Waste** - towards zero landfill; improve recycling rate to 70%
- **Water** – towards self-sufficiency; reduce consumption to 140l per capita per day
- **Air Quality** – reduce annual mean for ambient fine Particular Matter to 12mueg/m3
- **Clean, Blue and Green Environment** – increase green park space to 0.8ha per1,000 population and more
- **Capability and Expertise** – Singapore as outstanding knowledge hub
- **Environment. responsible community** – part of people and business culture

Singapore CREATE program
(Campus for Research Excellence And Technological Enterprise)

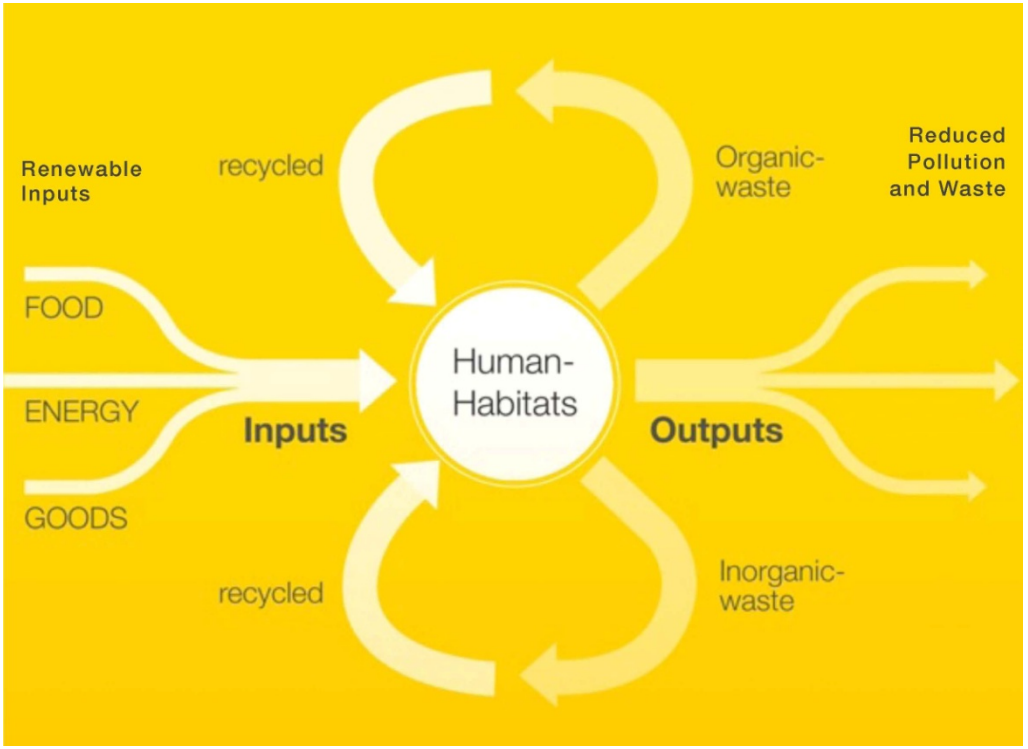
5 research centers:

+ **ETH Zurich** (**SEC-FCL**: Singapore/ETH Center for Global Environmental Sustainability- Future Cities Laboratory)
+ MIT
+ Technion
+ TU Munich
+ Hebrew University of Jerusalem

SEC-FCL

URBAN METABOLISM

- Understand the city as a dynamic system
- Read and model this system in terms of Stocks and Flows
- Recognize Urban Stocks as basic elements of the urban metabolism and as locally available resources



STOCKS AND FLOWS

PEOPLE

URBAN SOCIOLOGY
CHRISTIAN SCHMID / MARC ANGÉLIL / LAI-CHOO MALONE-LEE / CHYE KIANG HENG / KEE YONG LIM / ...

ENERGY

LOW EXERGY
HANSJÜRG LEIBUNDGUT / LINO GUZZELLA / ANDREA DEPLAZES / LUDGER HOVESTADT / THAM KWOK WAI ...

WATER

LANDSCAPE & ECOLOGY
CHRISTOPHE GIROT / JANET HERING / PERRY P J YANG / MICHAEL SAUNDERS / WUN JERN NG / ...

MATERIALS

DIGITAL FABRICATION
FABIO GRAMAZIO / MATTHIAS KOHLER / ...

TRANSFORMING AND MINING URBAN STOCKS
FRANZ OSWALD / LAI-CHOO MALONE-LEE / CHYE KIANG HENG / ERWIN VIRAY / PERRY P J YANG / WEN JING HSU / ...

CAPITAL

TERRITORIAL ORGANIZATION
MARC ANGÉLIL / LAI-CHOO MALONE-LEE / CHYE KIANG HENG / ERWIN VIRAY / ADRIAN DAVID CHEOK / ...

SPACE

MOBILITY ANDTRANSPORTATION INFRASTRUCTURE
KAY AXHAUSEN / HENRY FAN / YIIK DIEW WONG / ...

URBAN DESIGN STRATEGIES
KEES CHRISTIAANSE

INFORMATION

SIMULATION PLATFORM
ARMIN GRÜN / GERHARD SCHMITT / LUC VAN GOOL / TAT JEN CHAM / ADRIAN DAVID CHEOK / IAN MCLOUGHLIN / CHYE KIANG HENG / LEONG KEONG,... ...

What is the goal of the Simulation Platform?

a) Find new methods for better understanding of ever growing amounts of urban data

b) Make this knowledge available to decision makers, urban planners and stakeholders

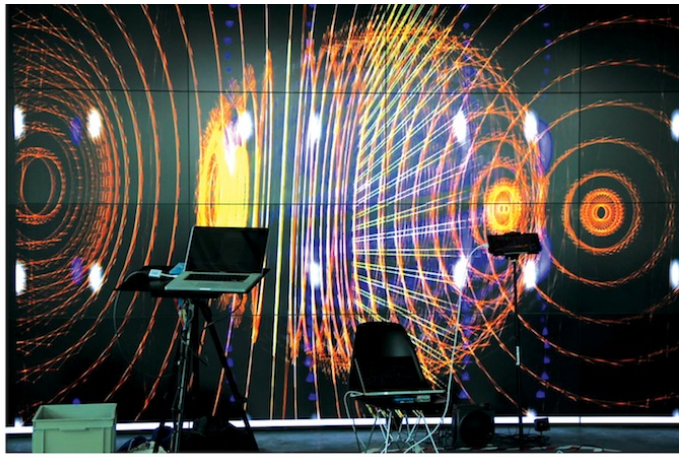
What is the Value Lab?

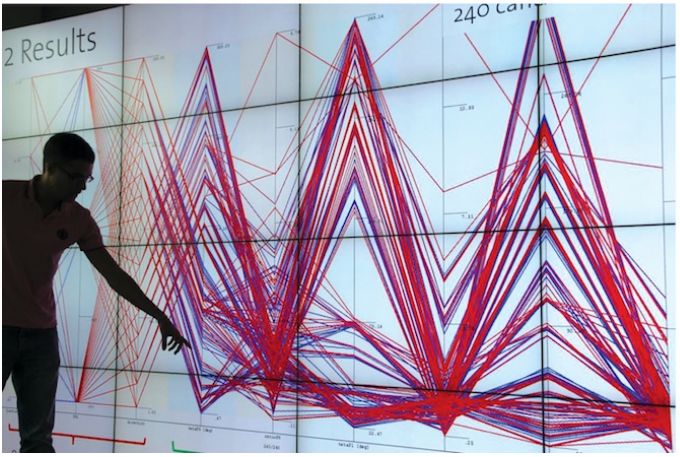
The Value Lab is the physical collaborative environment where the new methods are validated and applied

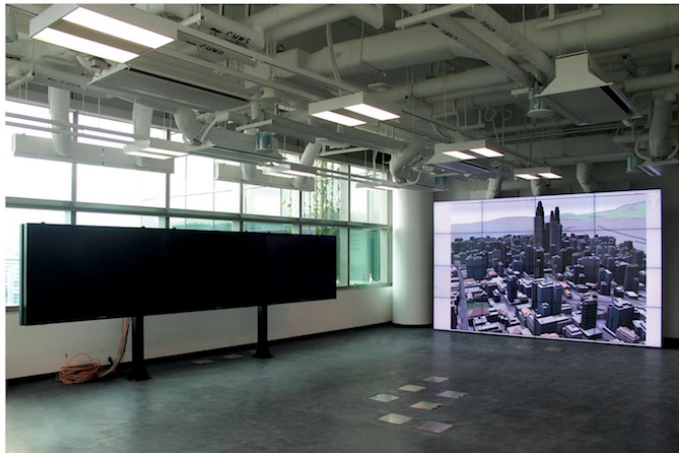
Interface to the external world

SEC-FCL Value Lab Asia

- 3 x 82" Touch Display Wall
- 4 x 50" Mobile Touch Tables
- 4 x 4 Video Wall (40 Mpi)







Geospatial Technologies

Data acquisition : Many new platforms and sensors (space, aerial, terrestrial)

Data processing : Powerful computing devices („cloud processing“),
fast/automated processing (on-line, real-time results)

Data administration & analysis: SIS technology

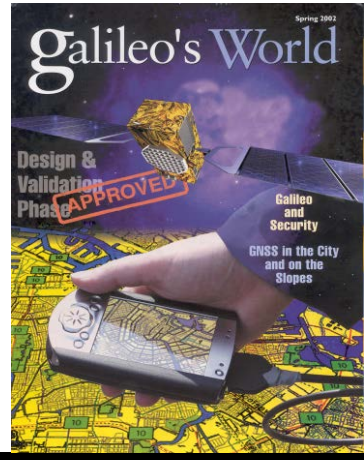
Data representation: Visualization (3D cartography), VR, animation

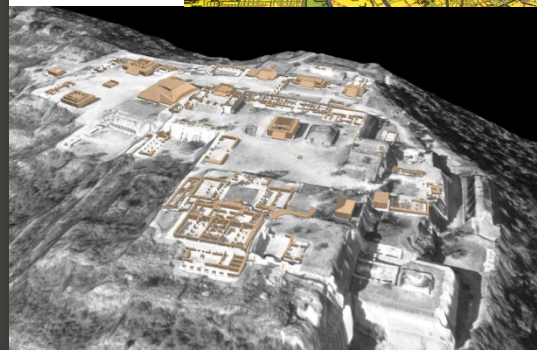
Data access and dissemination: Web-based technologies

Applications. Beyond mapping: Cultural Heritage, LBS, environmental monitoring, hazards, security, risk, business, tourism, simulation, animation (geogames, movies, TV), etc.

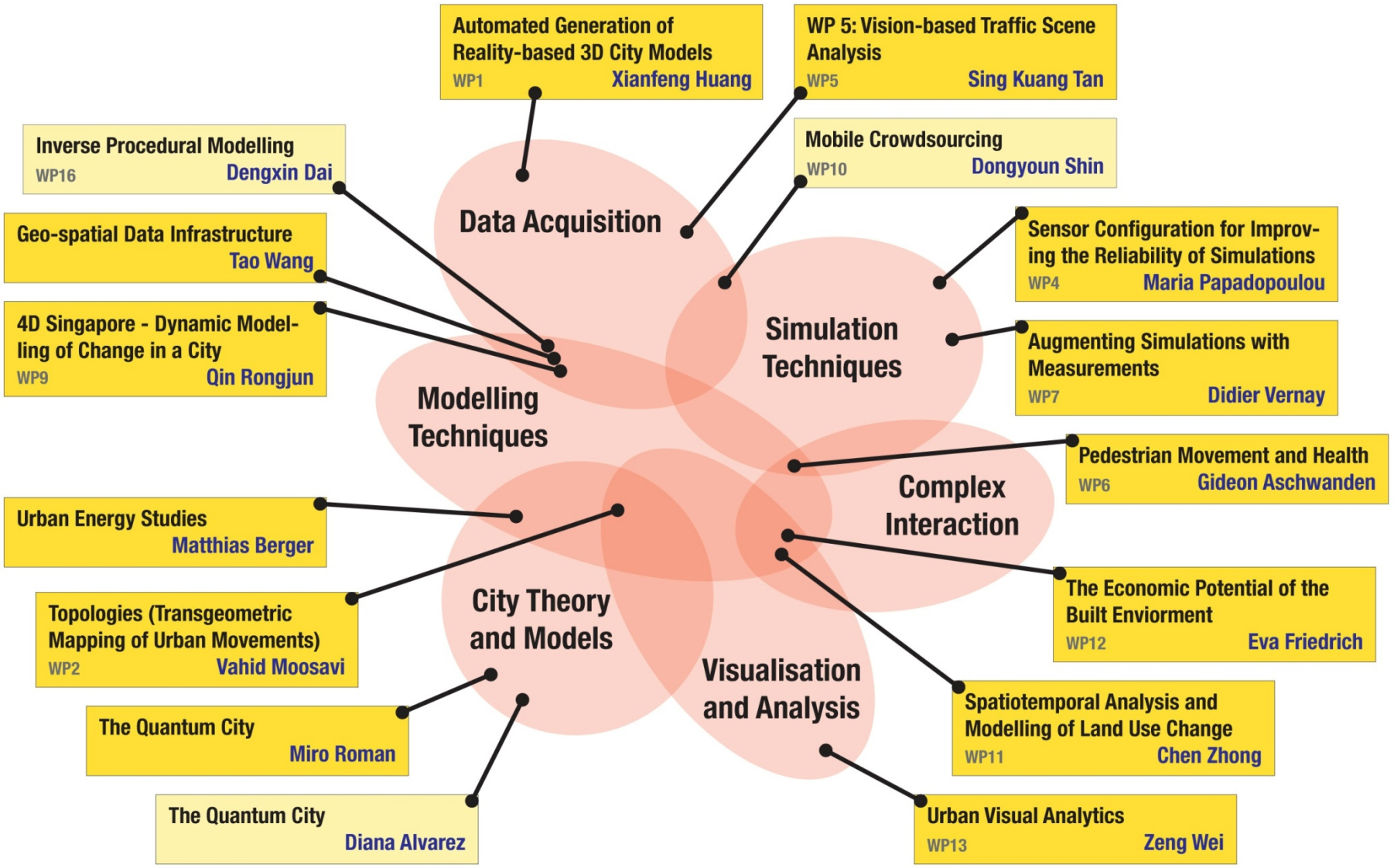
Geomatics technologies

+ GPS/IMU
+ DSMs/DTMs
+ 3D/4D city models
+ Facility management
+ Mobile Mapping Systems
+ Imagery: satellite, aerial, terrestrial
+ Maps, plans
+ Historic data
+ LBS, “smart” apps
+ Sensors in WEB 2.0
+ Sensors in smart buildings
+ GIS/SIS
+ Visualization/simulation/animation





Simulation platform – Research workpackages



Reality-based modeling of cities

We use satellite, airborne and terrestrial imagery and laser-scans to develop new methods and software tools for realistic reality-based modeling of cities.

ETH Zurich via CyberCity Modeler

Required: **Models for landscape (terrain), buildings, infrastructures, vegetation, etc.**

BIM – Building Information Models

For individual buildings, but also for whole cities

Contain **- geometry**

- topology

- semantics

- appearance

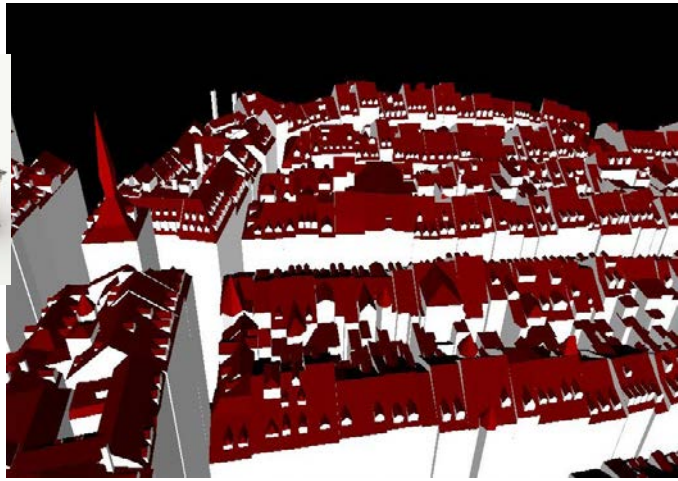
Used for

Analysis of lifecycles of building stocks and flows:

Determining “flows”: 4D city models, updating, processes

Florence, Italy

Applications of 3D city models



Traditional

- environmental monitoring
- planning (buildings, roads, location)
- mobile communication, LBS
- energy (solar), natural hazards
- tourism, real estate
- architecture, landscape engineering
- monument preservation

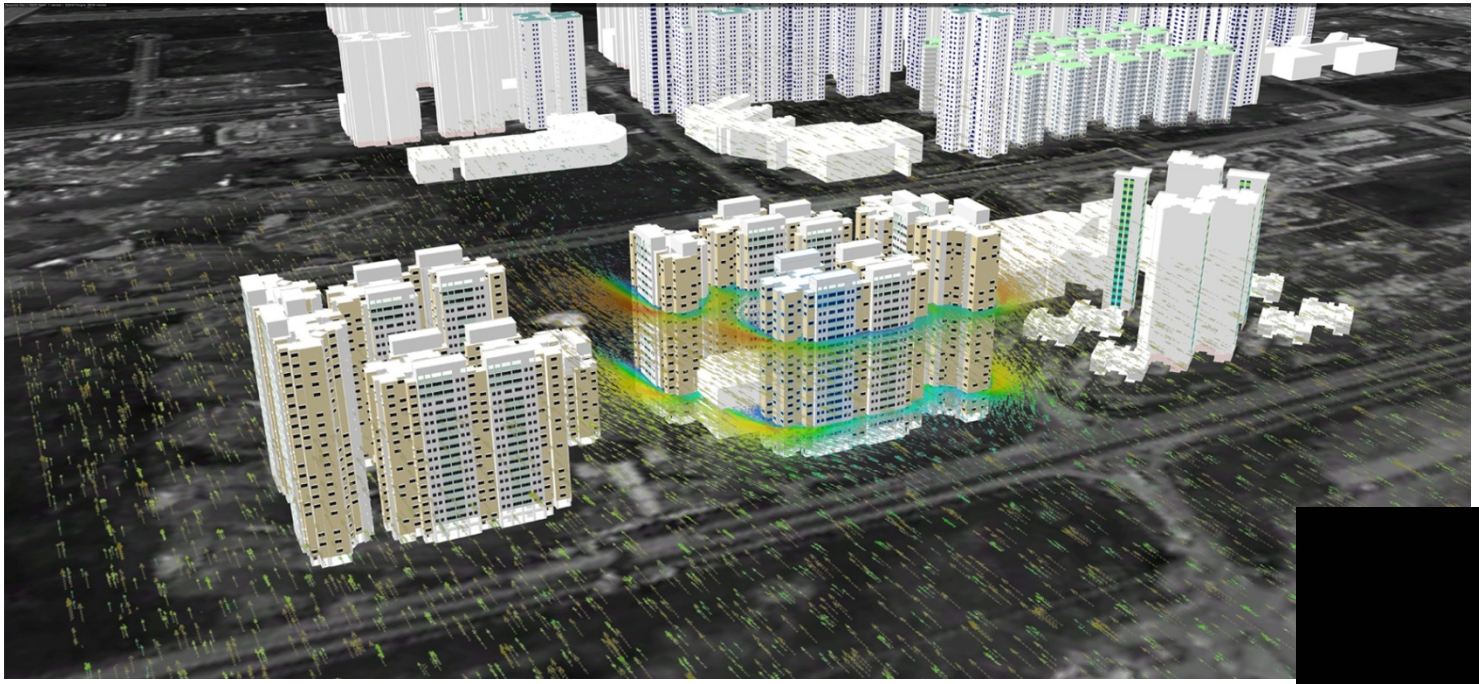
New

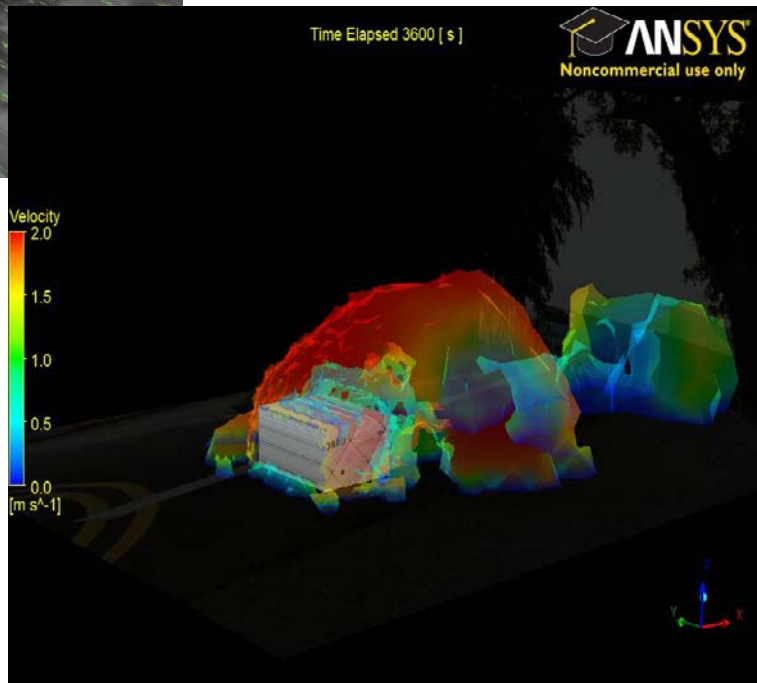
- smart homes
- insurances (risk transports, etc.)
- 3D car navigation
- homeland security
- police, firesquad, traffic and crowd control

Singapore FCL – requested data

+ DTM, DSM at different resolutions
+ Master plans in vector format
+ Land use map, drainage pattern
+ Buildings: coordinates, building type, number of floors above and below ground, number of flats and rooms, roof type and shape, type of ownership, value (insured value/ market value), status of protection as heritage, life cycle of the lot/buildings, age
+ Thermal building data
+ Historical plans/cadastre
+ Census data 2010 with location
+ School catchment areas
+ Navteq road network
+ Trip matrices for tourists, Malayan commuters and lorries/heavy vehicles
+ Georeferenced post codes
+ climate/weather data, temperature of ground at various depths, annual temperatures of rivers and ocean

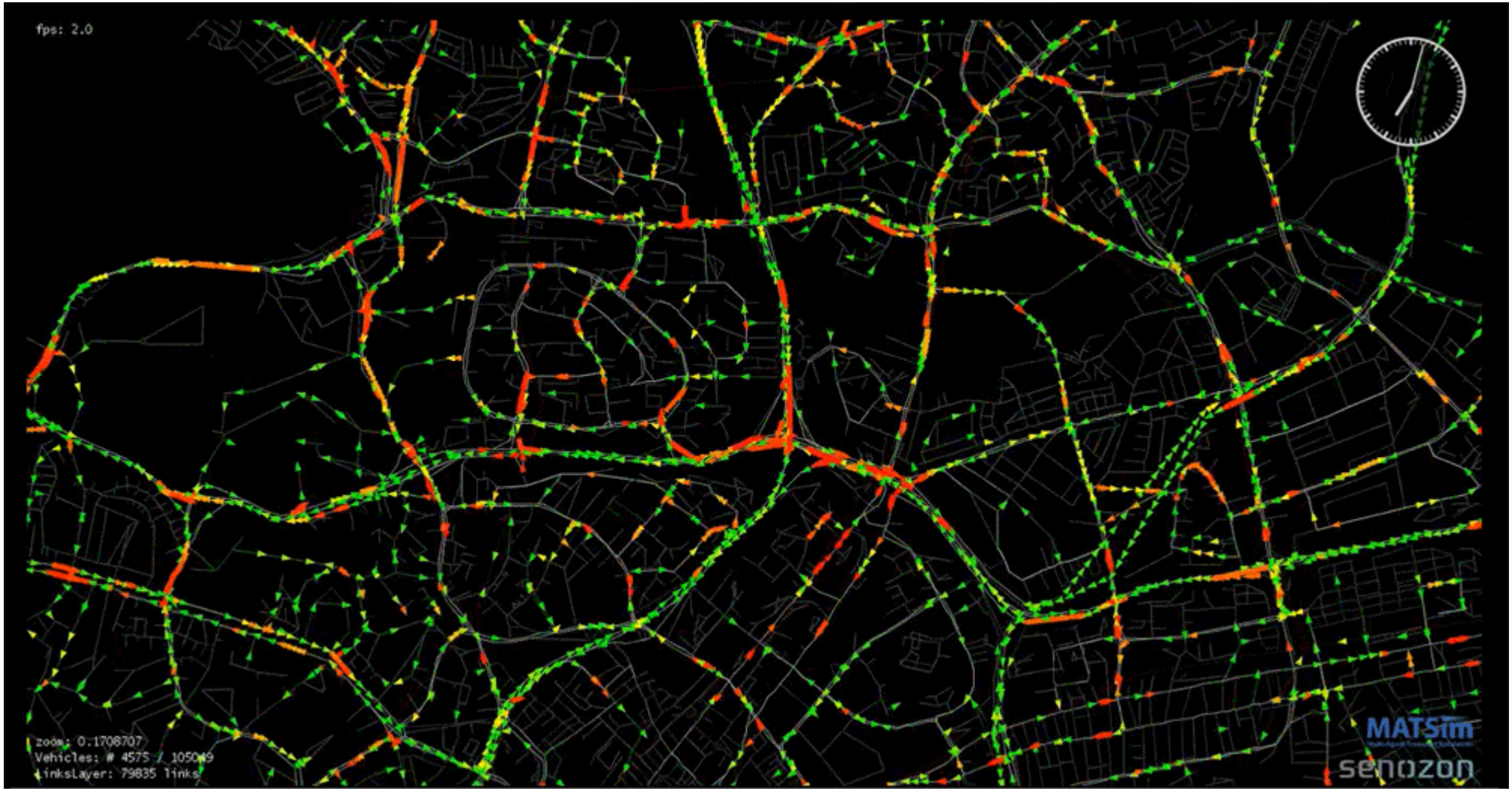
Airflow around buildings





Multi-agent Transport Simulation with matsim

Central business district



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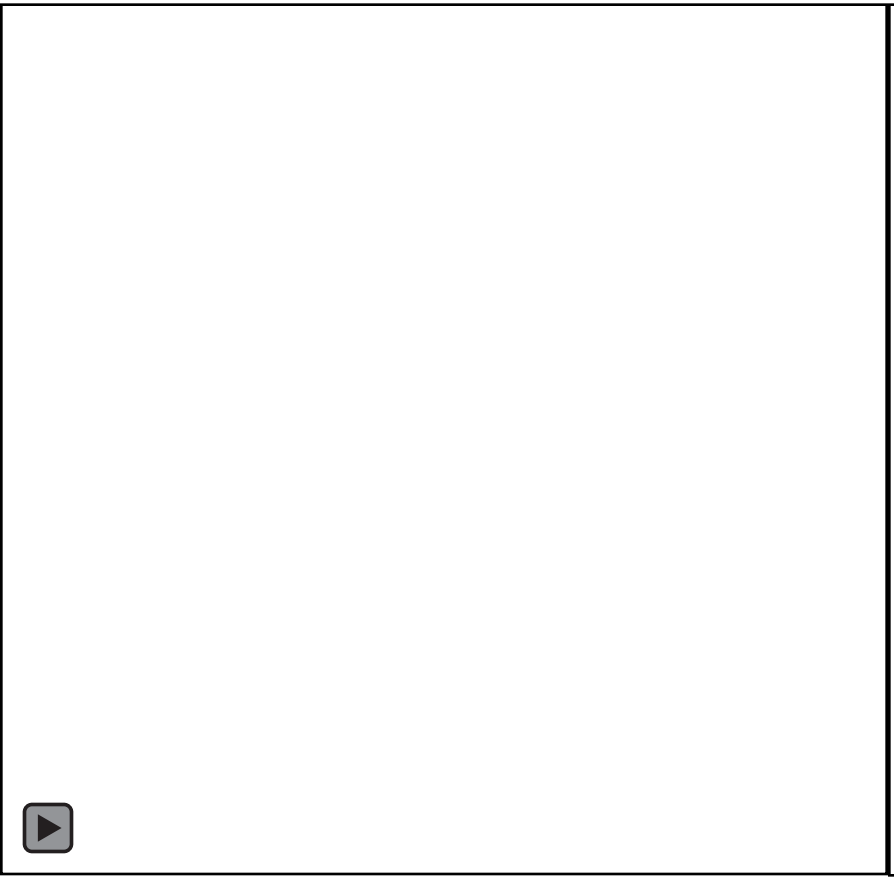
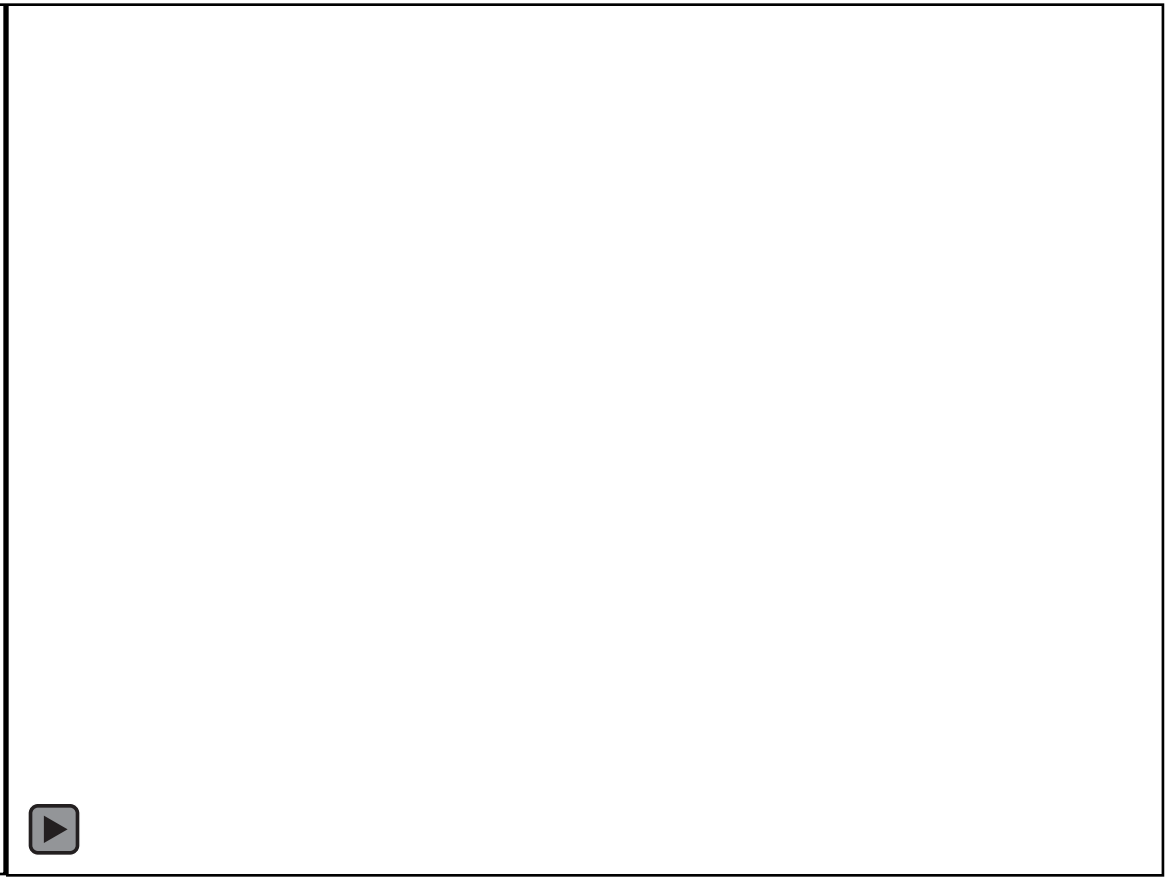
Urban Modeling - Pedestrian Flow





By Eva Maria Friedrich & Gideon Aschwanden

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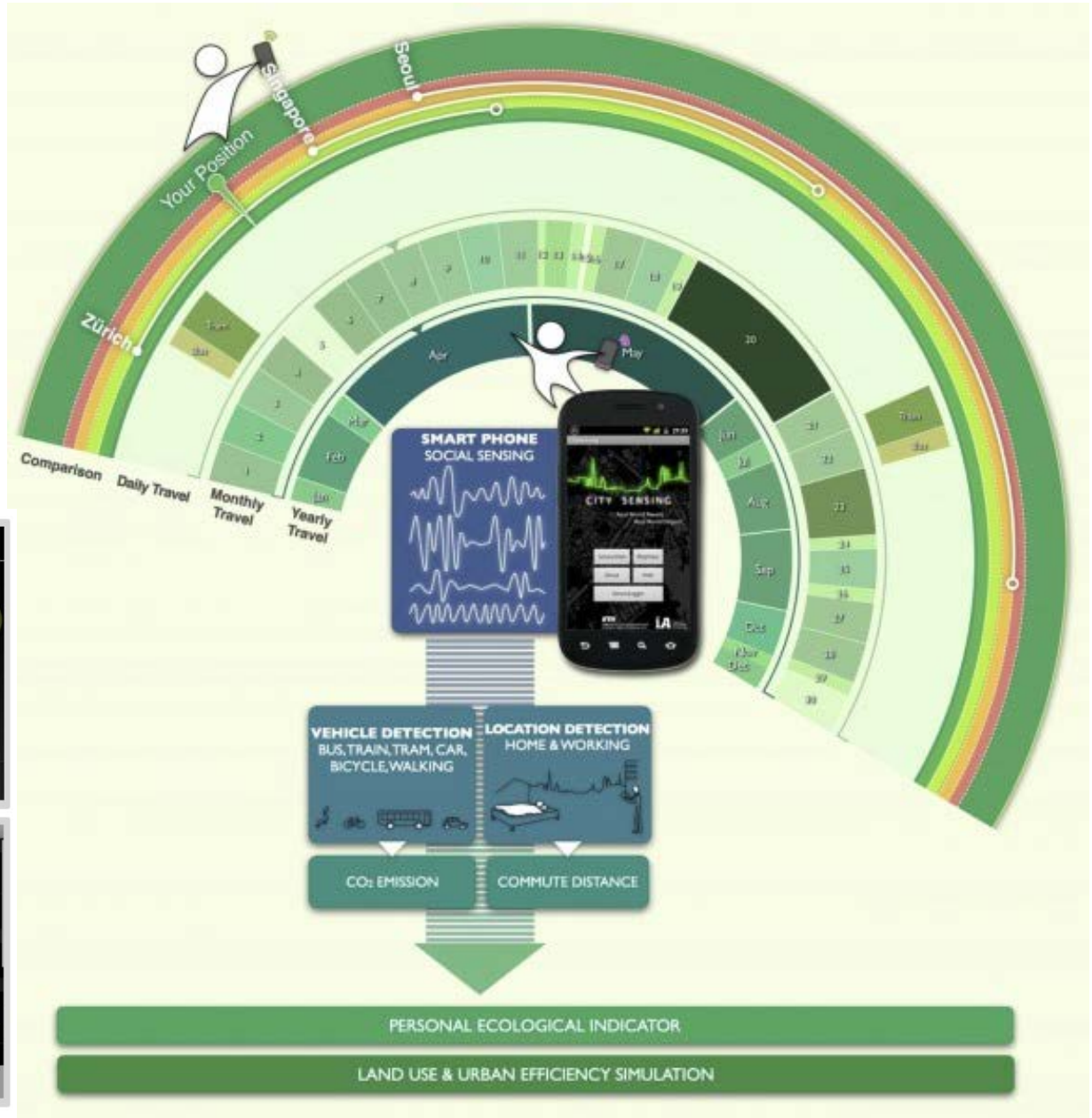
Interactive 3D Augmented Reality of Urban Cities on Mobile Devices

Mobile Social Sensing

(of individual user)



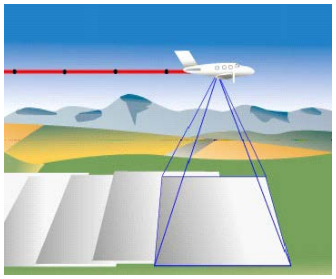
Crowdsourcing urban data collection using smartphone

Imaging platforms

+ spaceborne images

+ Stratospheric platforms

+ aerial images



+ model helicopter/ balloon images

+ terrestrial images

500-700 km

altitude

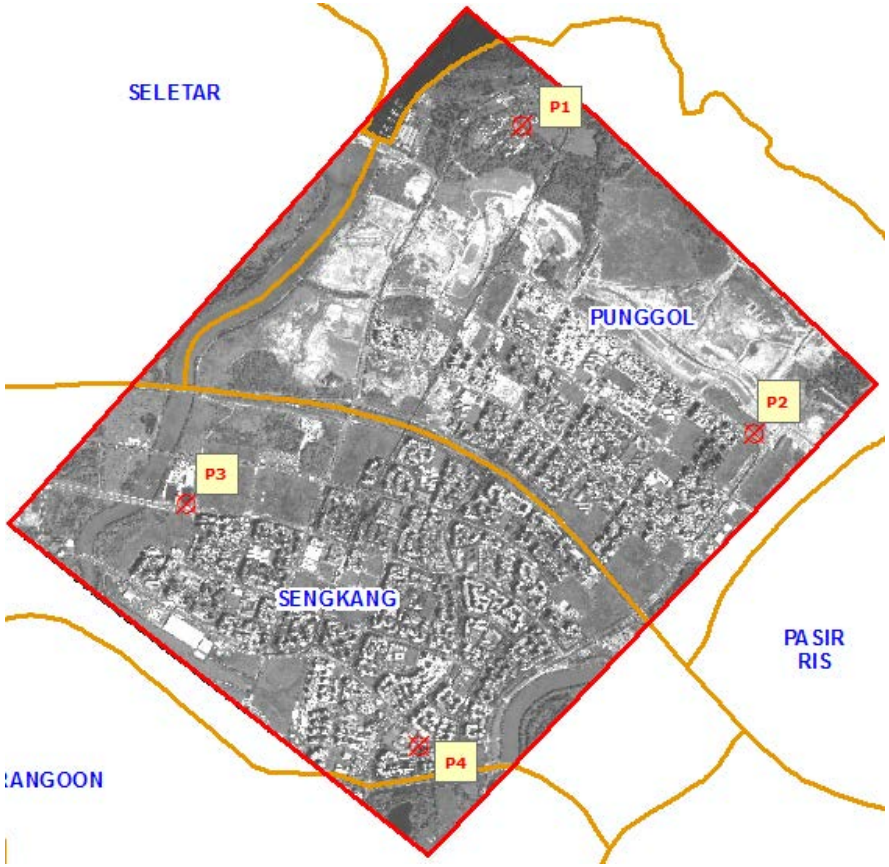
1-10 m

Singapore – 3D city models from satellite images

IKONOS, WV-2 stereos

Singapore – HRSI stereos

WV-2 Punggol



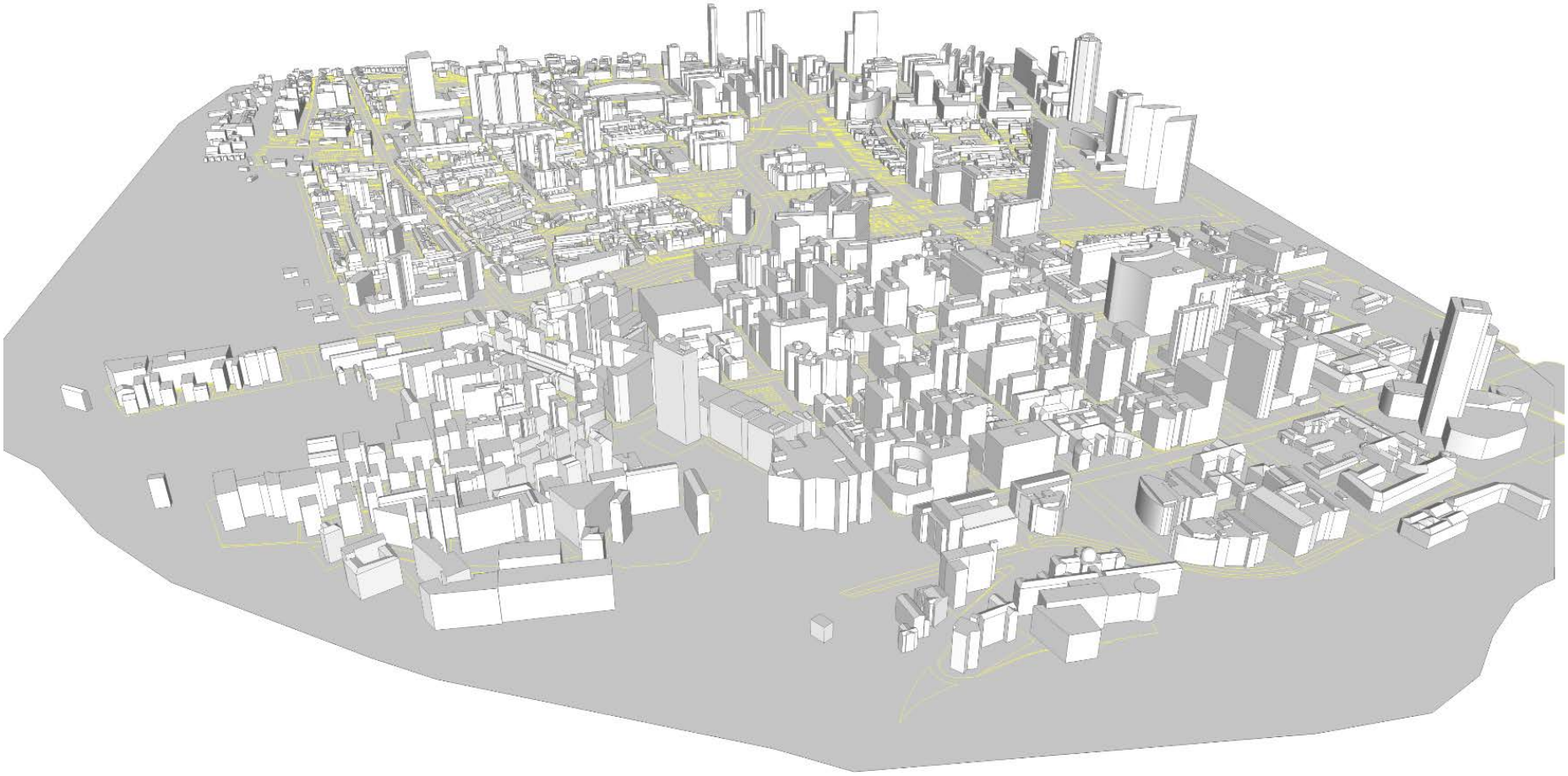
IKONOS Little India, Geelong

Building and Terrain Model – Little India

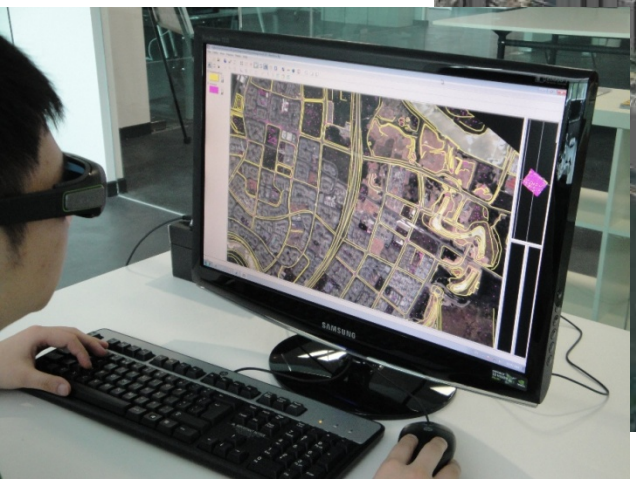
Overlay cadastral map

Rochor

3 clips



Punggol 3D

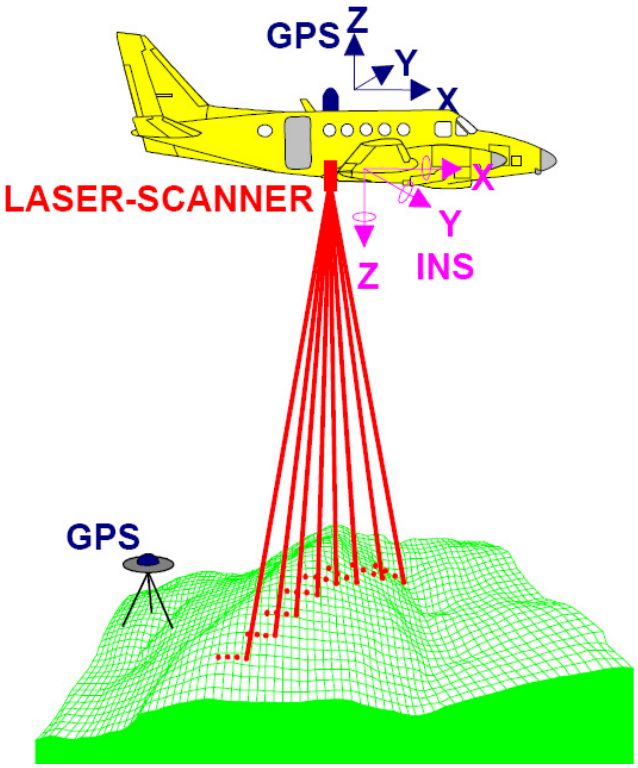


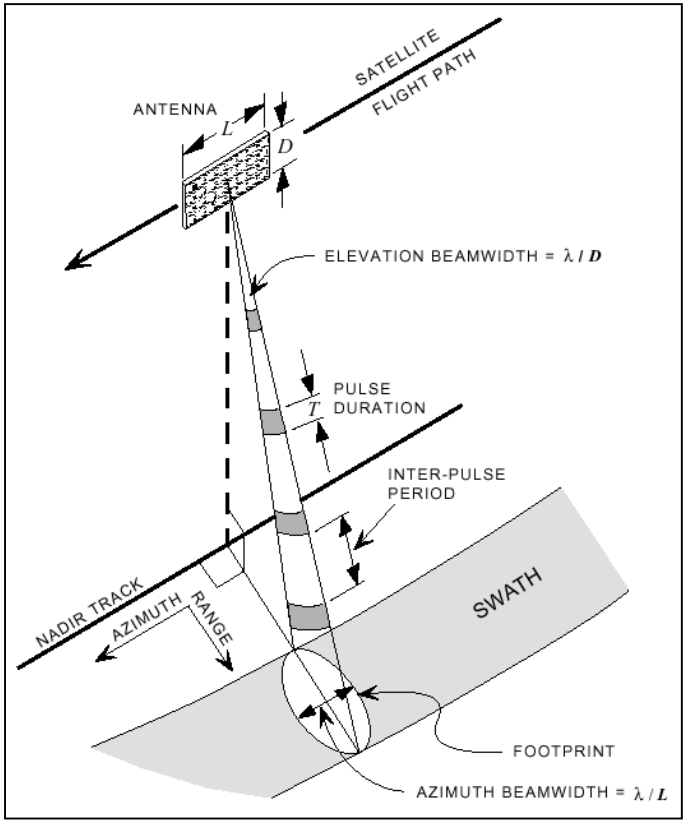
Aerial Sensing

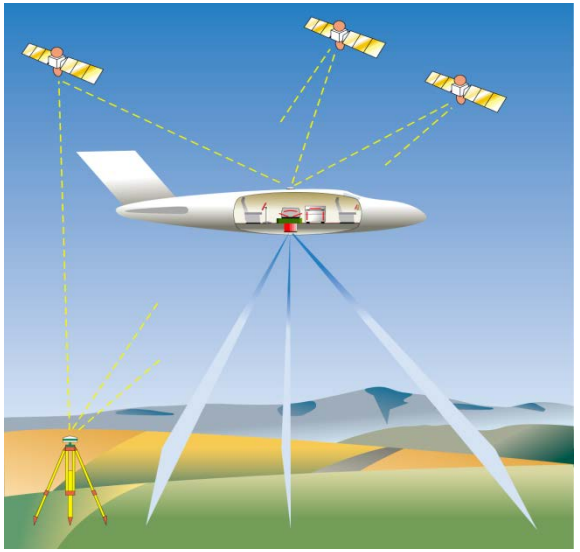
Optical cameras (analogue, digital)

Laserscanners (LiDAR), GPS/INS

Radar, InSAR

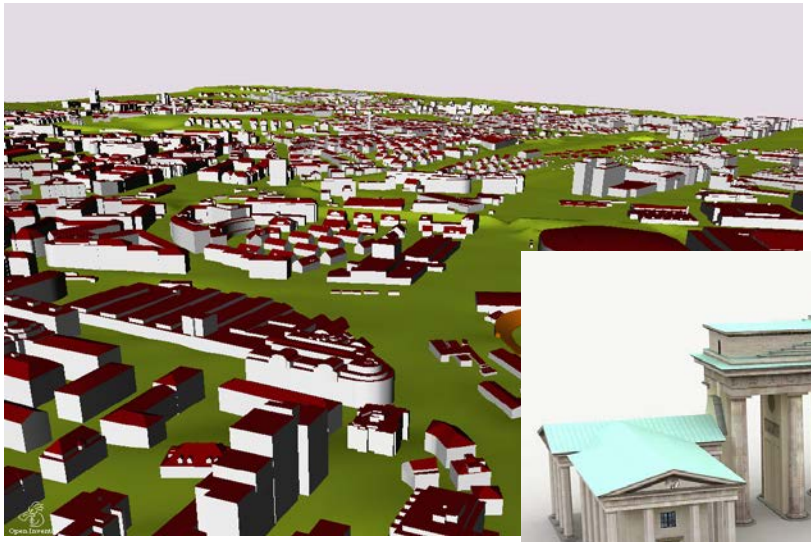


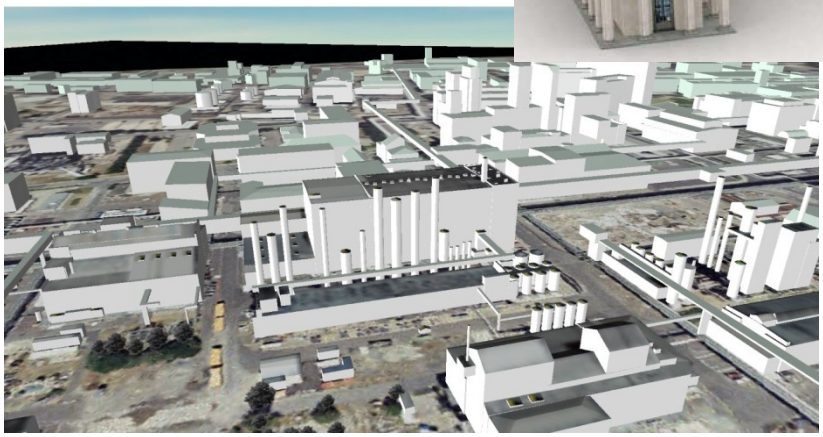




Das Produktion Model
mit einer Optik und einer Focalebene

3D / 4D City Models - CyberCity Modeler





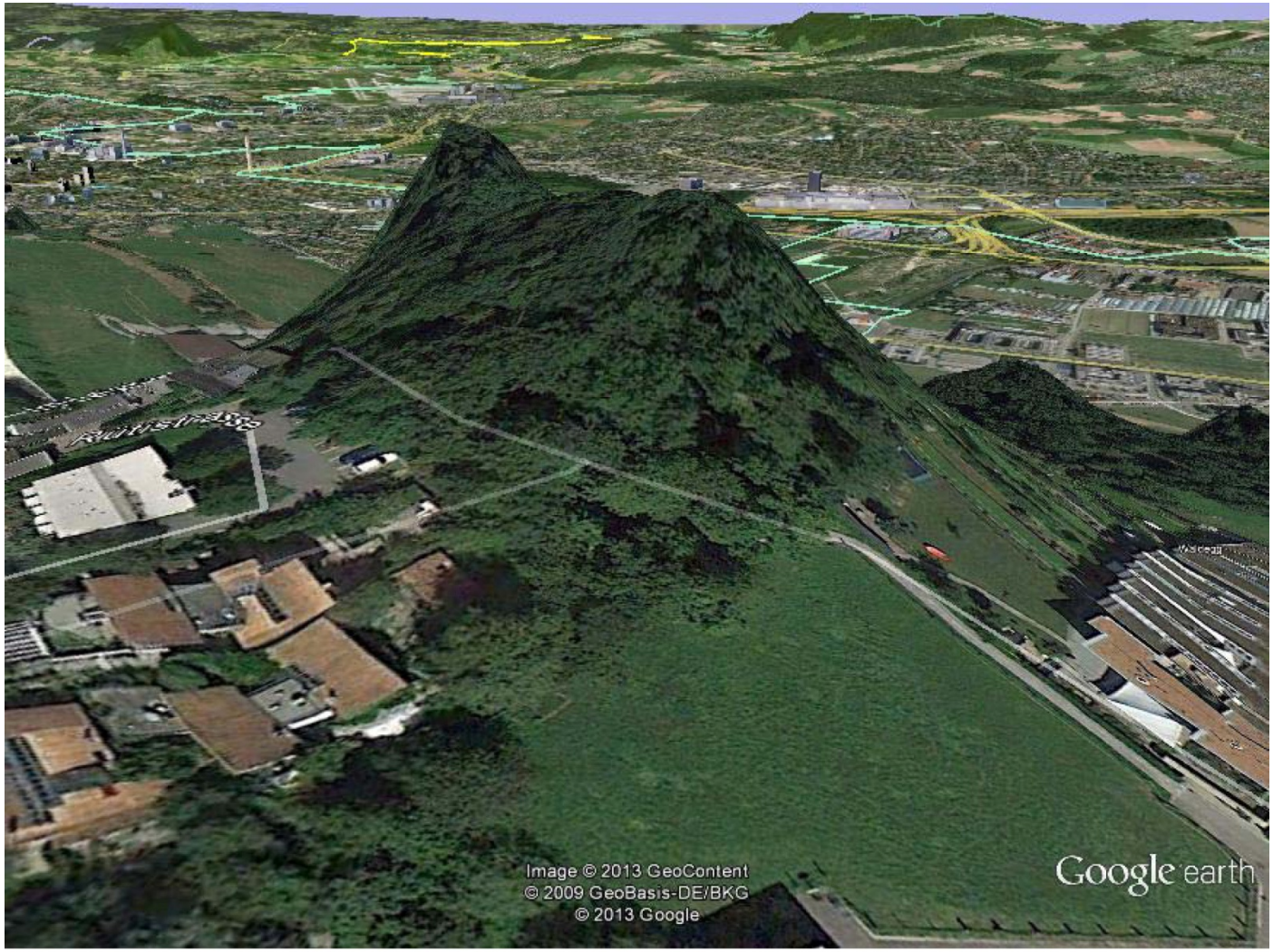
3D Hamburg: Integration into Google Earth

Google Hamburg

Courtesy

CyberCity AG

3D LANDMARKS for car navigation



Zurich Gockhausen
in Google Earth

The problem of quality control – what is the accuracy and completeness of these models?

- How accurate are the models in terms of geometry, topology and texture (appearance/perception)?

- How do the different techniques compare to each other?

⟹ No quantitative studies !

SEC-FCL project – UAV over NUS campus

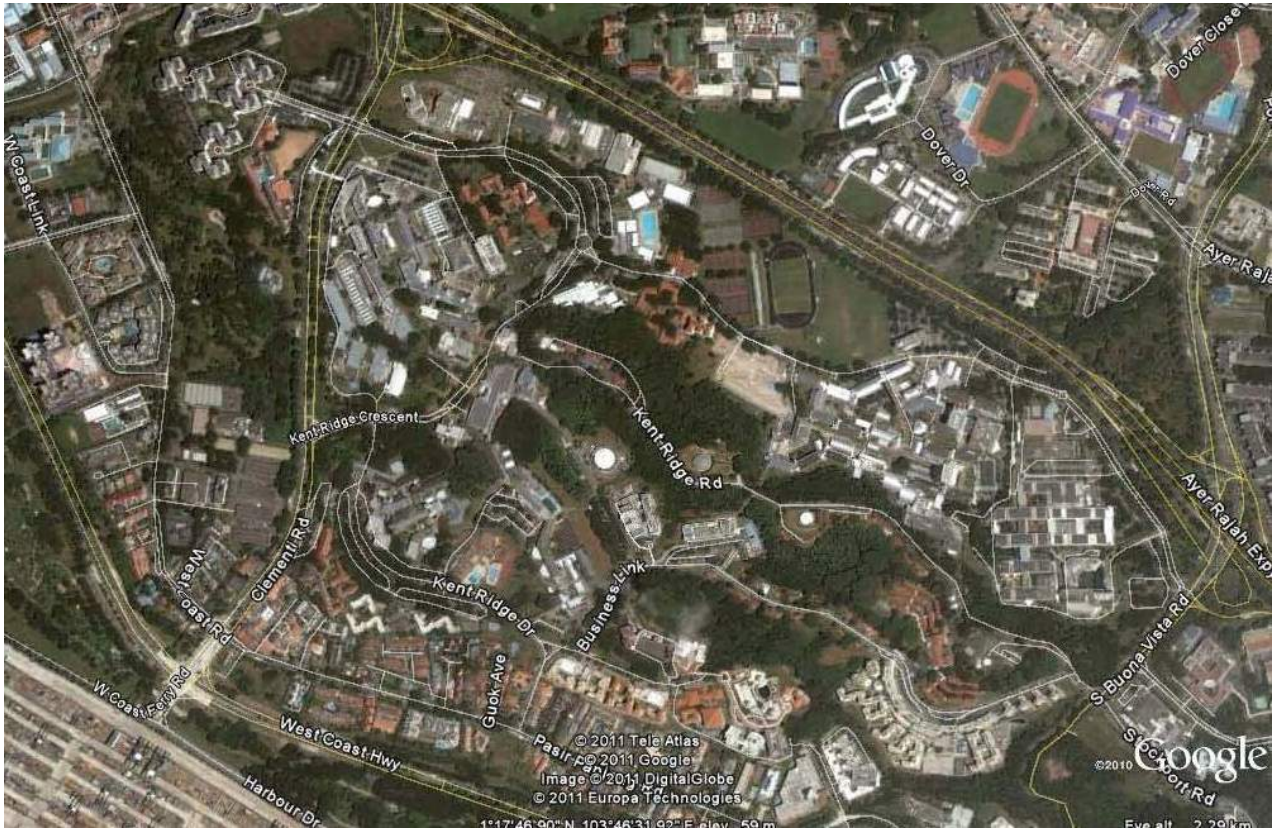
Prime Minister of Singapore Lee Hsien Loong, National Day Rally 2012, UAVs as a key breakthrough technology for the next 20 years: **”UAVs will have many uses in the future – civilian and military”.**

AscTec Falcon 8
500 g load
max 20 min flight time
max 10 m/s wind speed
redundancy through 8 rotors
GPS, height sensor, compass, IMU
max. Total weight 1,8 kg

UAV photogrammetry

SEC-FCL project – UAV over NUS campus

Singapore – **E**TH **C**entre for Global Environmental Sustainability
Future **C**ities **L**aboratory (Simulation Platform)



SEC-FCL UAV NUS campus flight
Take-off and landing stations

CREATE
take-off

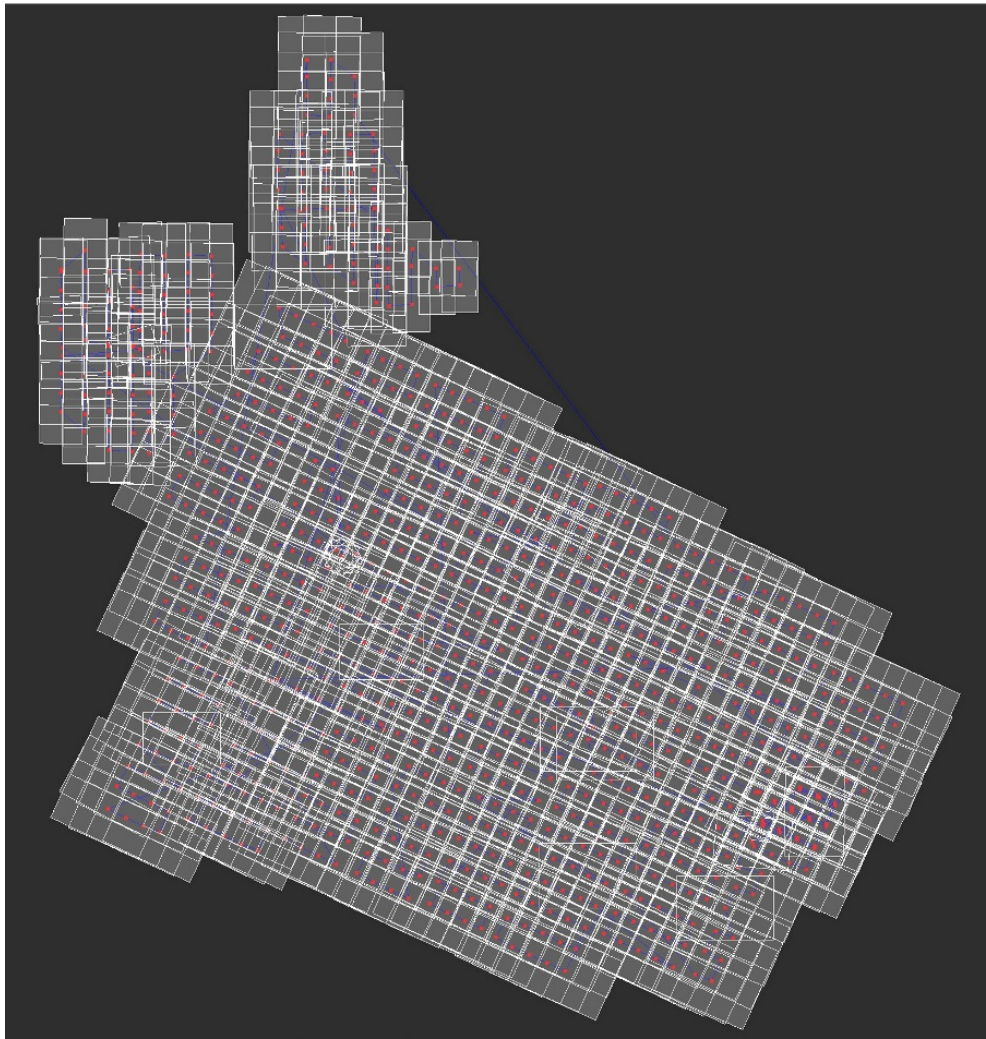
Falcon roof
landing

Education Resource Centre

CREATE Tower

SEC-FCL project – UAV over NUS campus

Singapore – **E**TH **C**entre for Global Environmental Sustainability
Future **C**ities **L**aboratory (Simulation Platform)

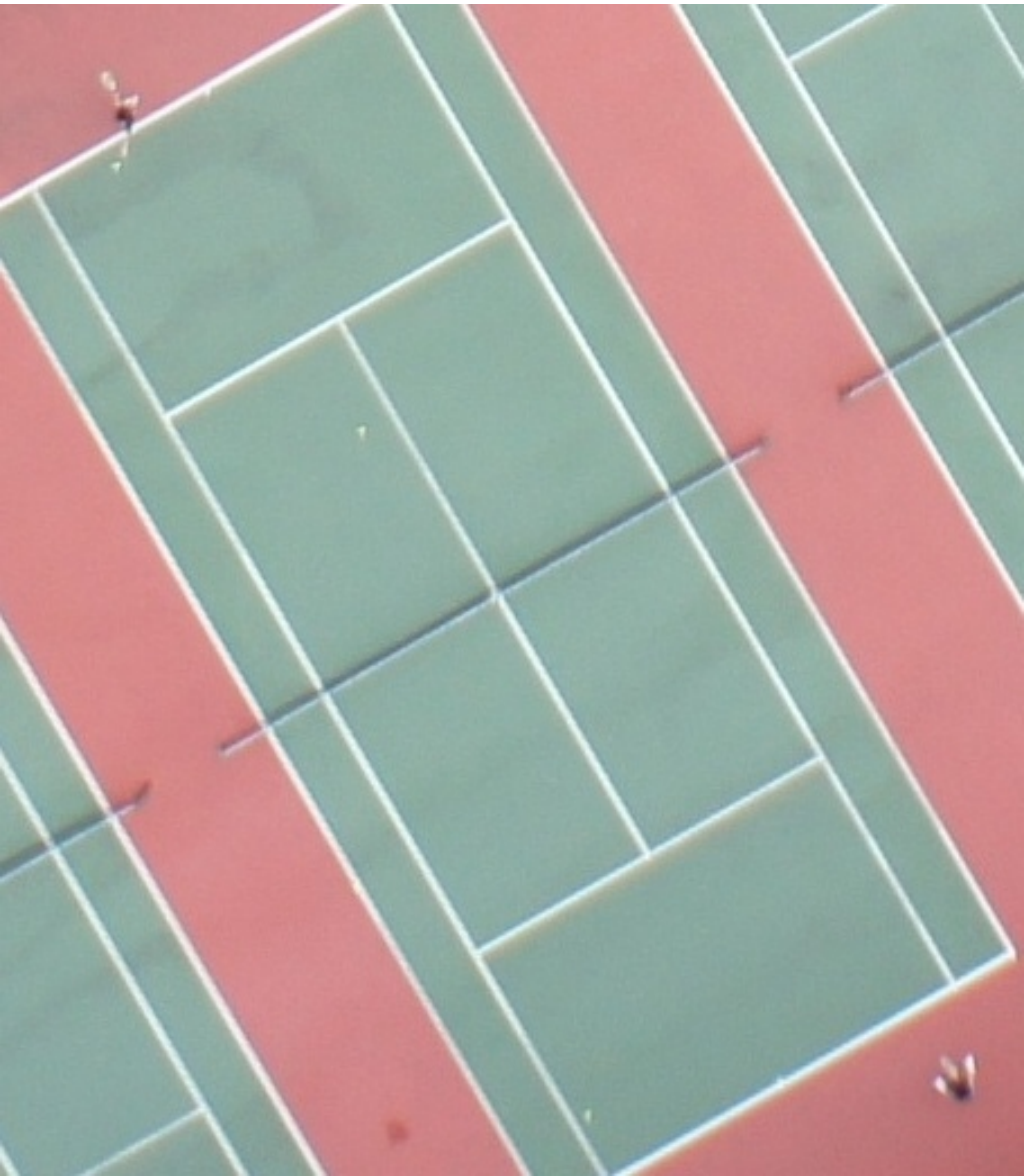


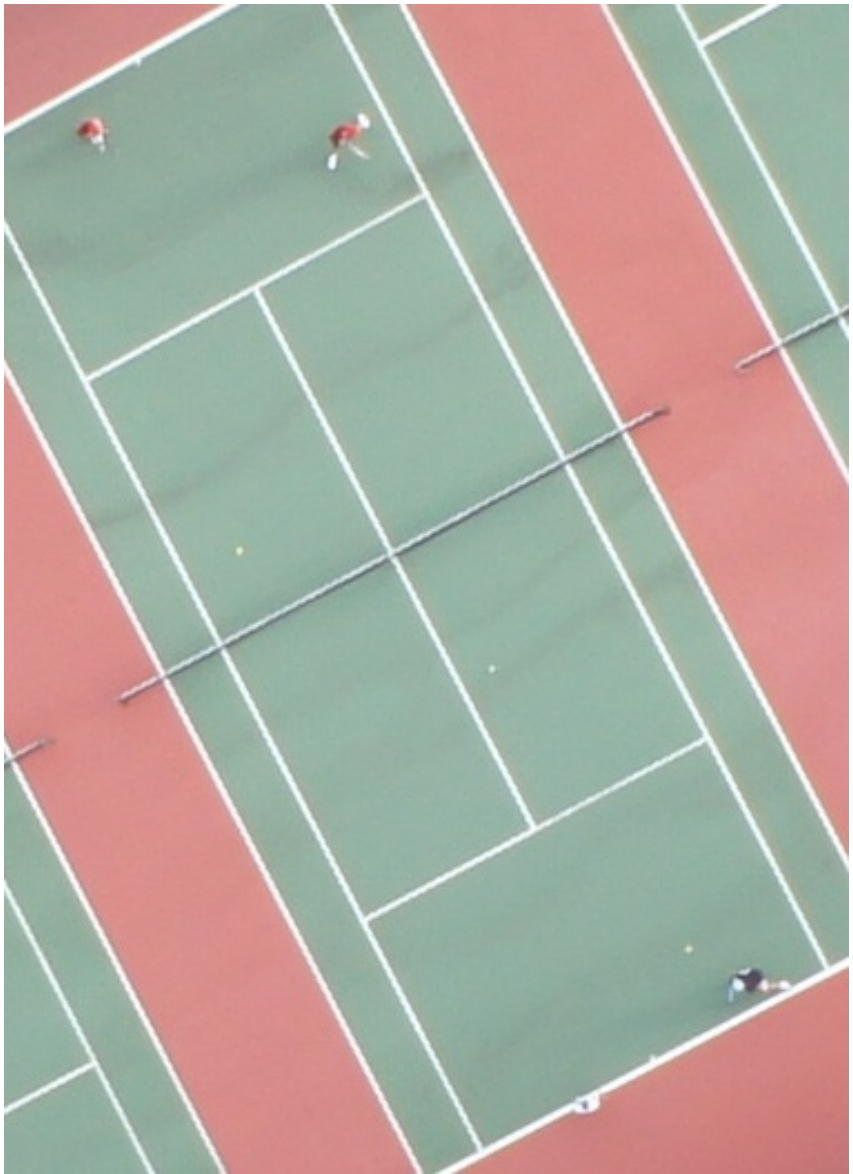
4x4 image block University Hall

4x4 block

P-Centres total block

NUS tennis courts, tennis balls





Data Processing

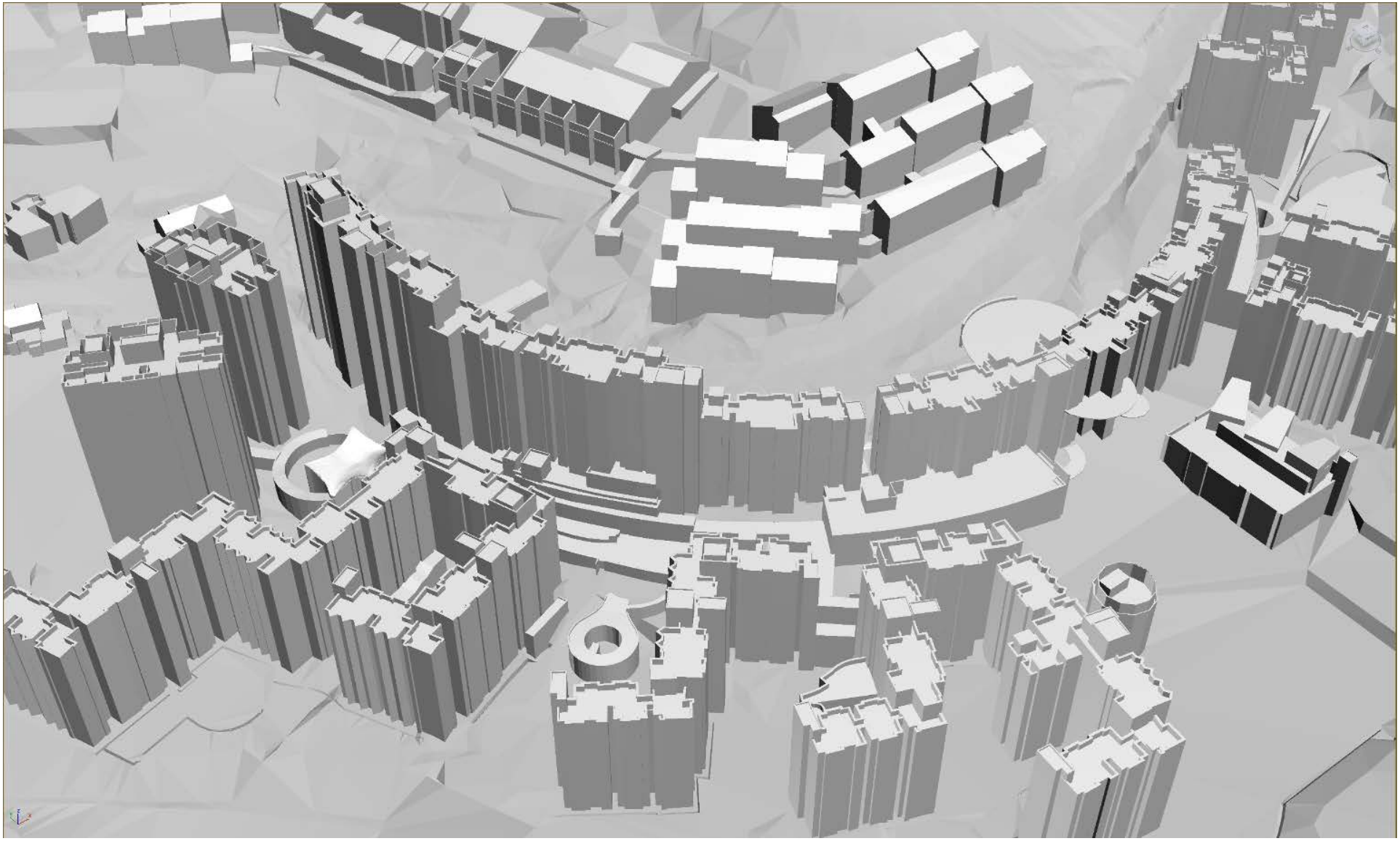
- Georeferencing: GCPs by GPS (datum)
  Image triangulation/bundle adjustment
- Model generation: DTM, man-made objects, natural features (trees, etc.)
  Photo texture: Roofs, terrain

Tree models

Problem: Model content definition

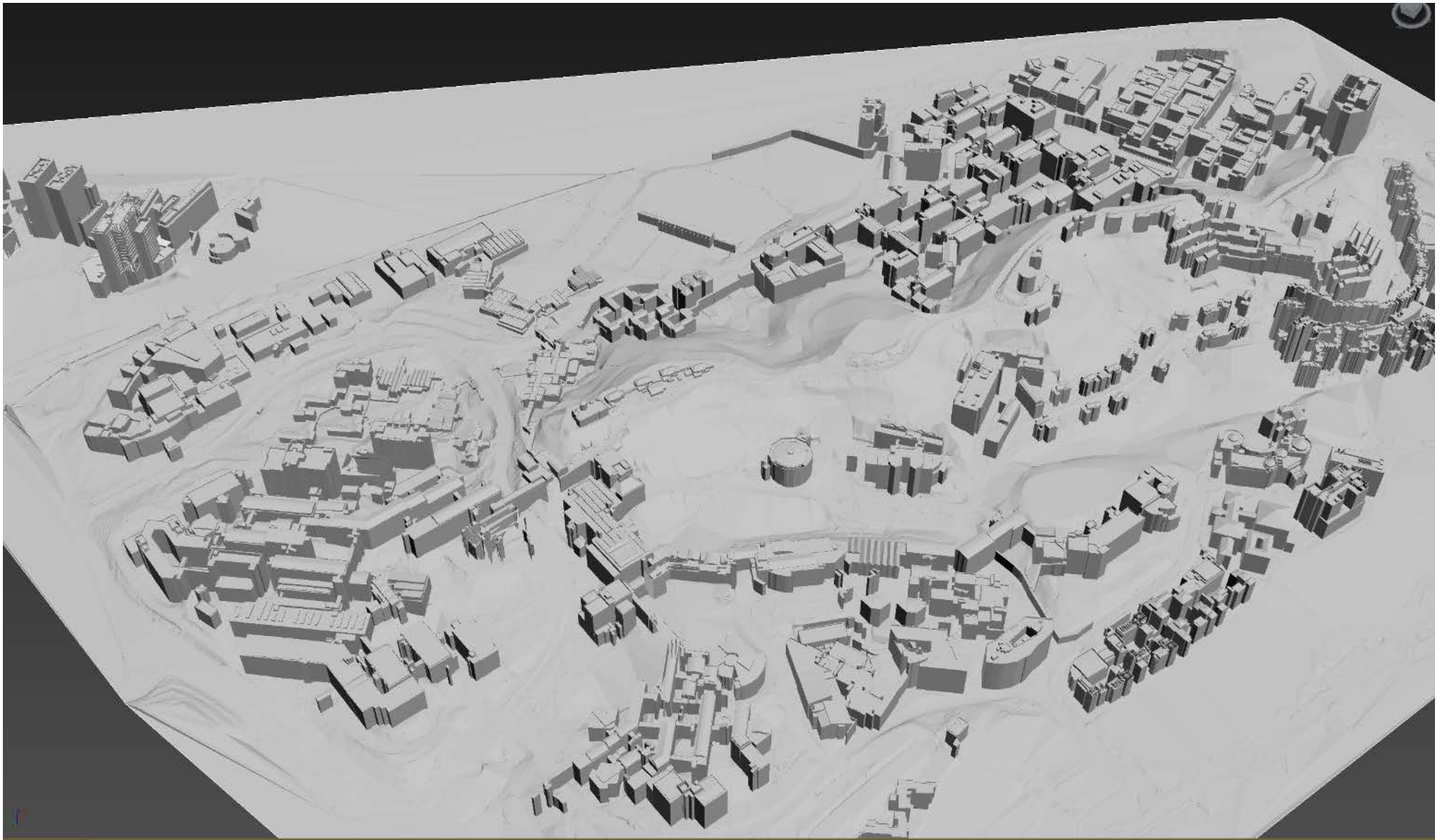
NUS Campus

NUS Campus: Model resolution



NUS Campus: Overview

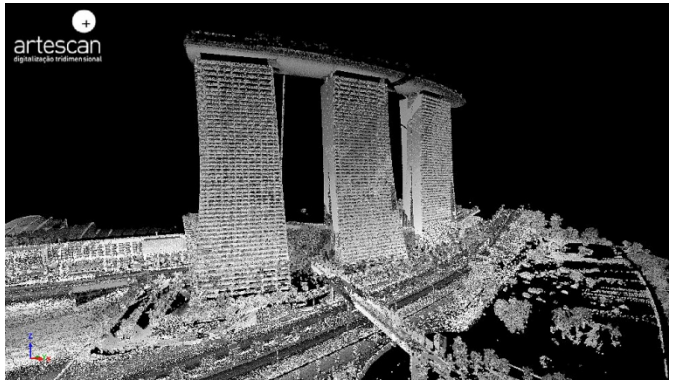
Flyover geometry

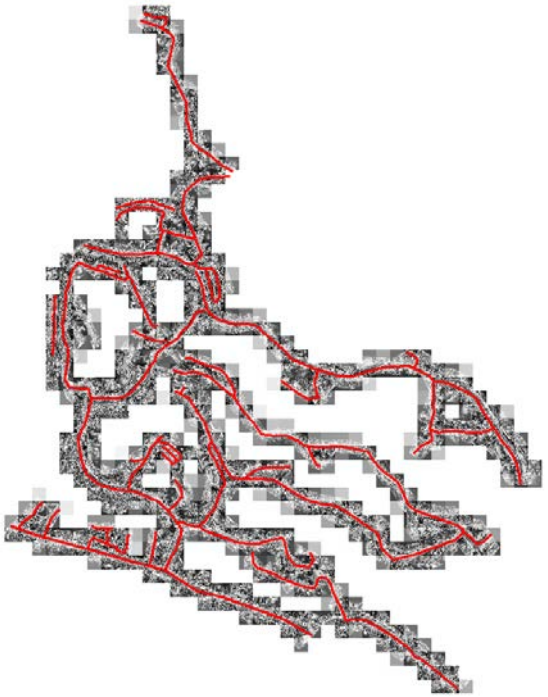


Model view: University Town

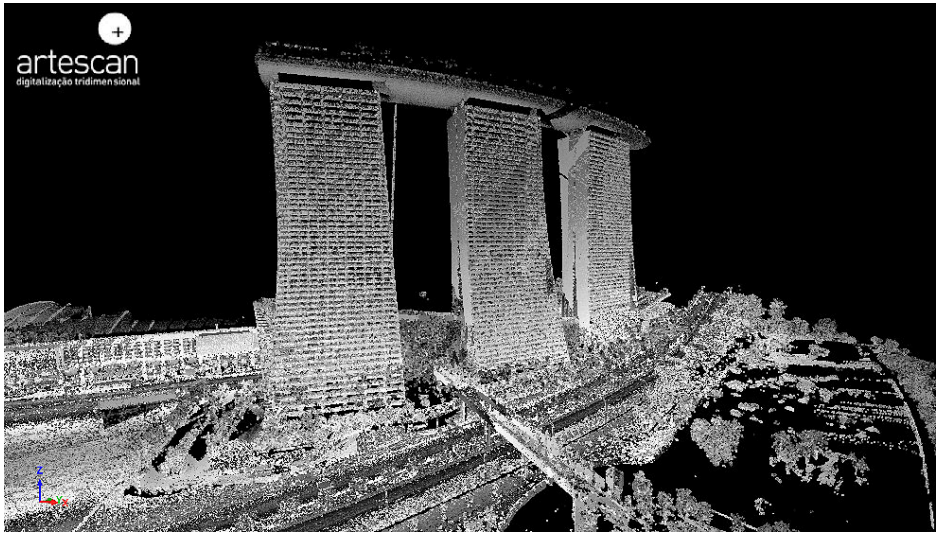
Combination of

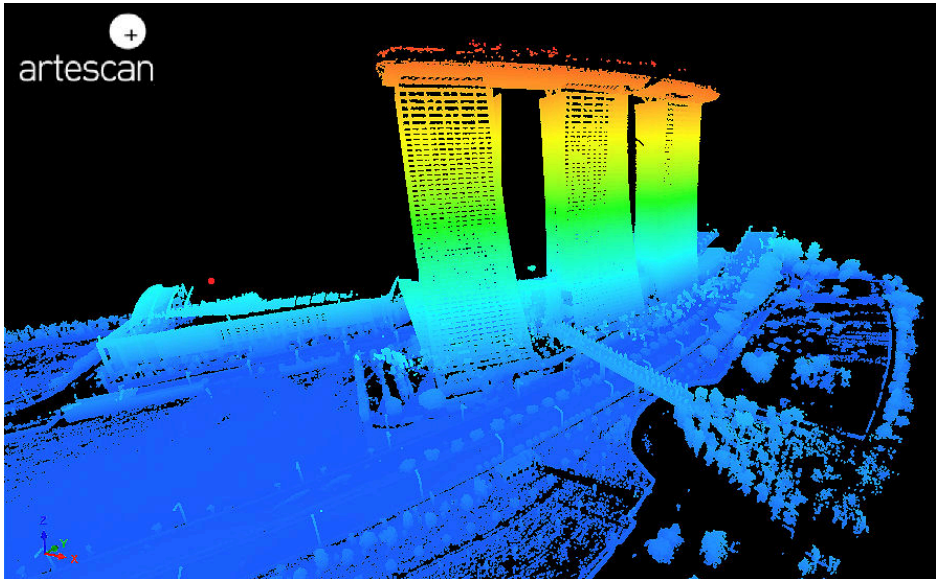
- 847 UAV images
- MMS point clouds
- terrestrial images





Singapore Mobile Mapping (flood simulation)



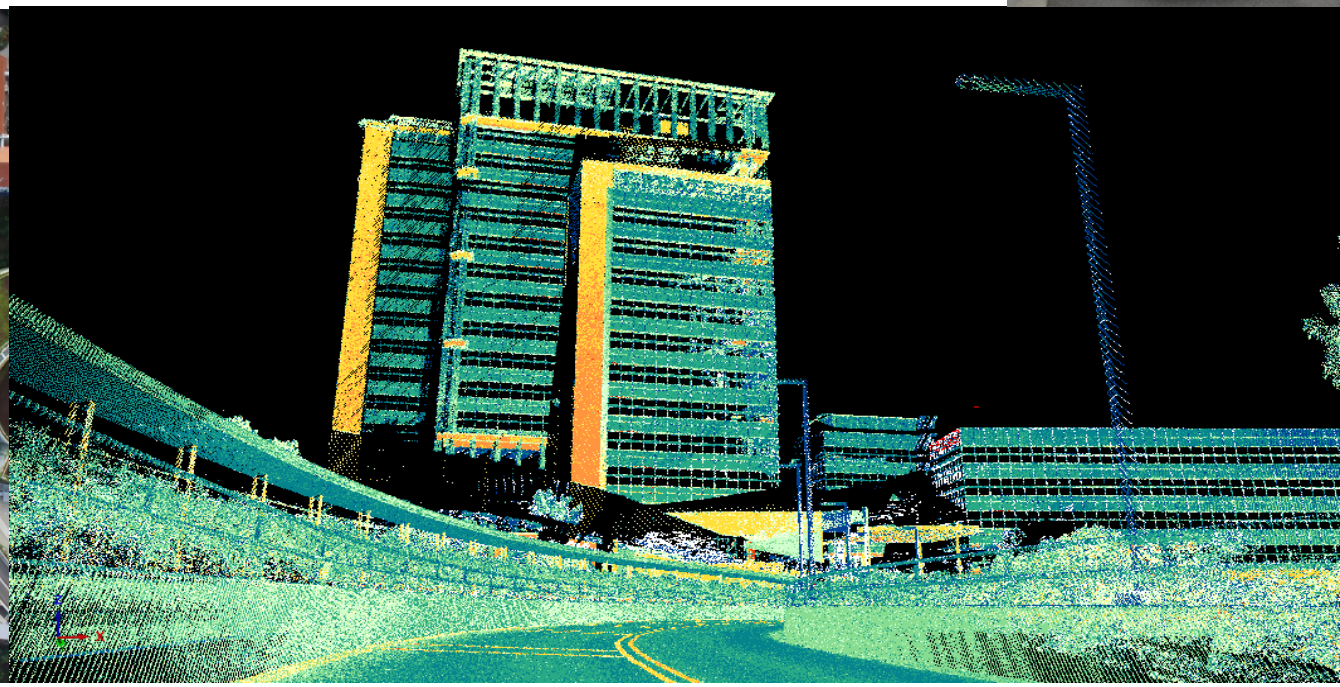


NUS (CREATE) building reconstruction

raw data

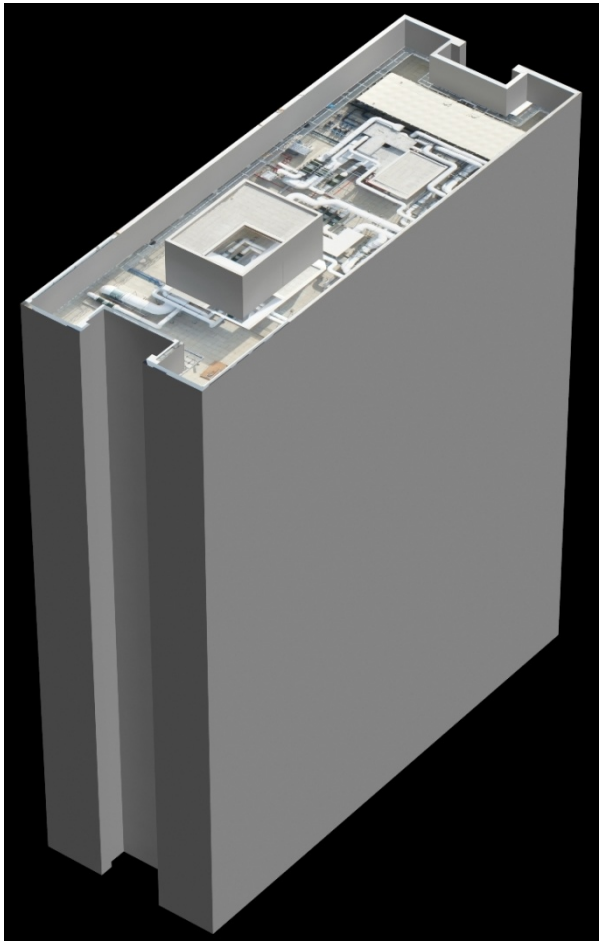
UAV images

MMS laserscans

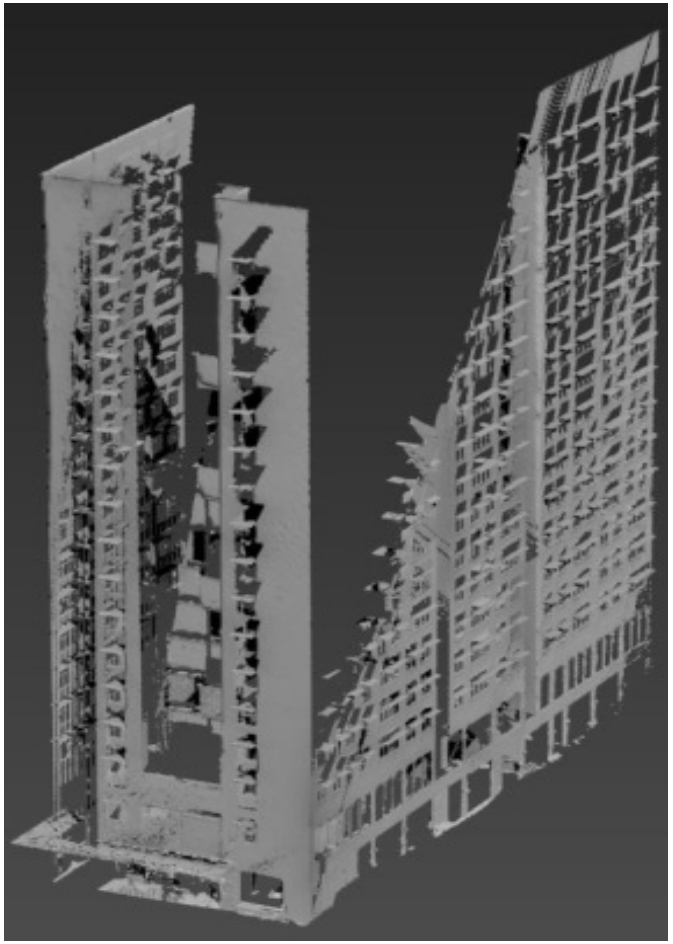


NUS building reconstruction

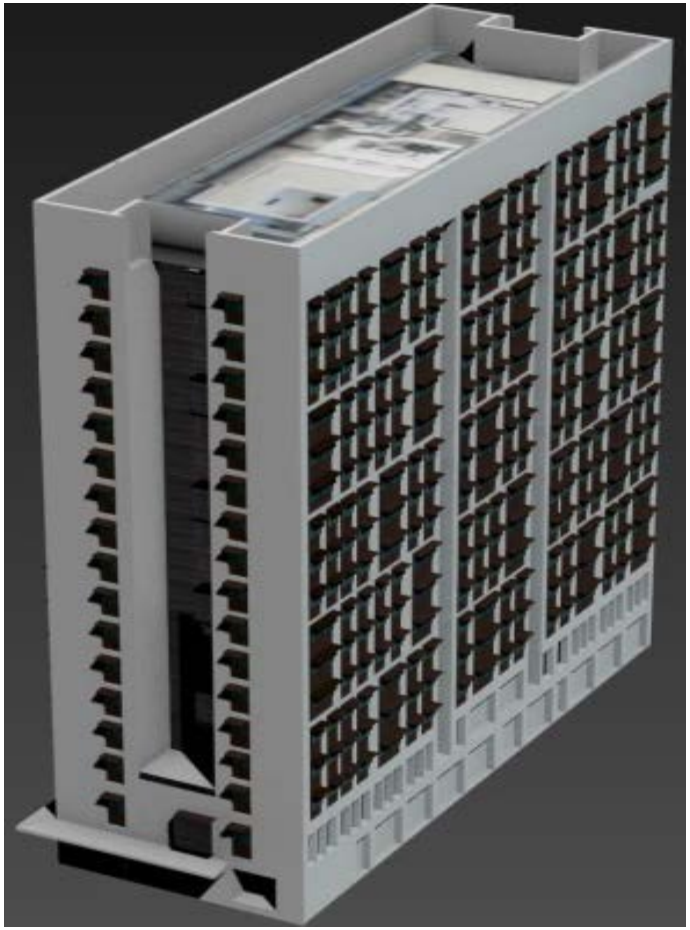
UAV images and MMS laserscans



Roof from UAV images



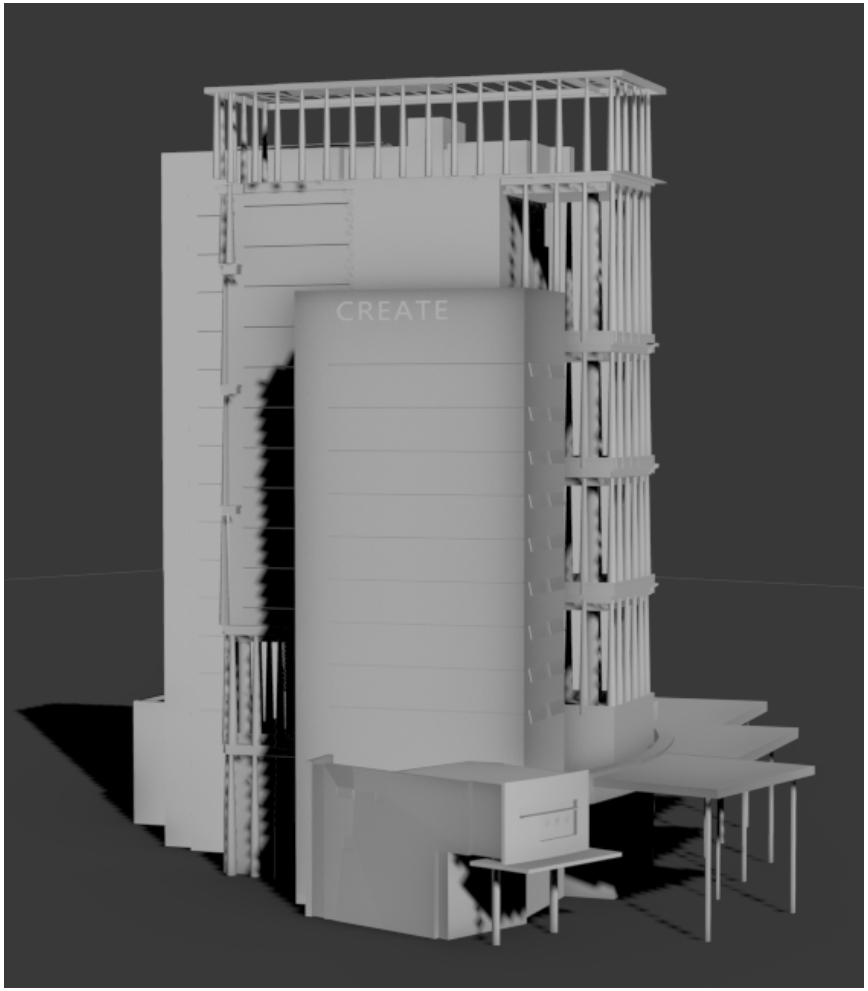
Wrapped point cloud

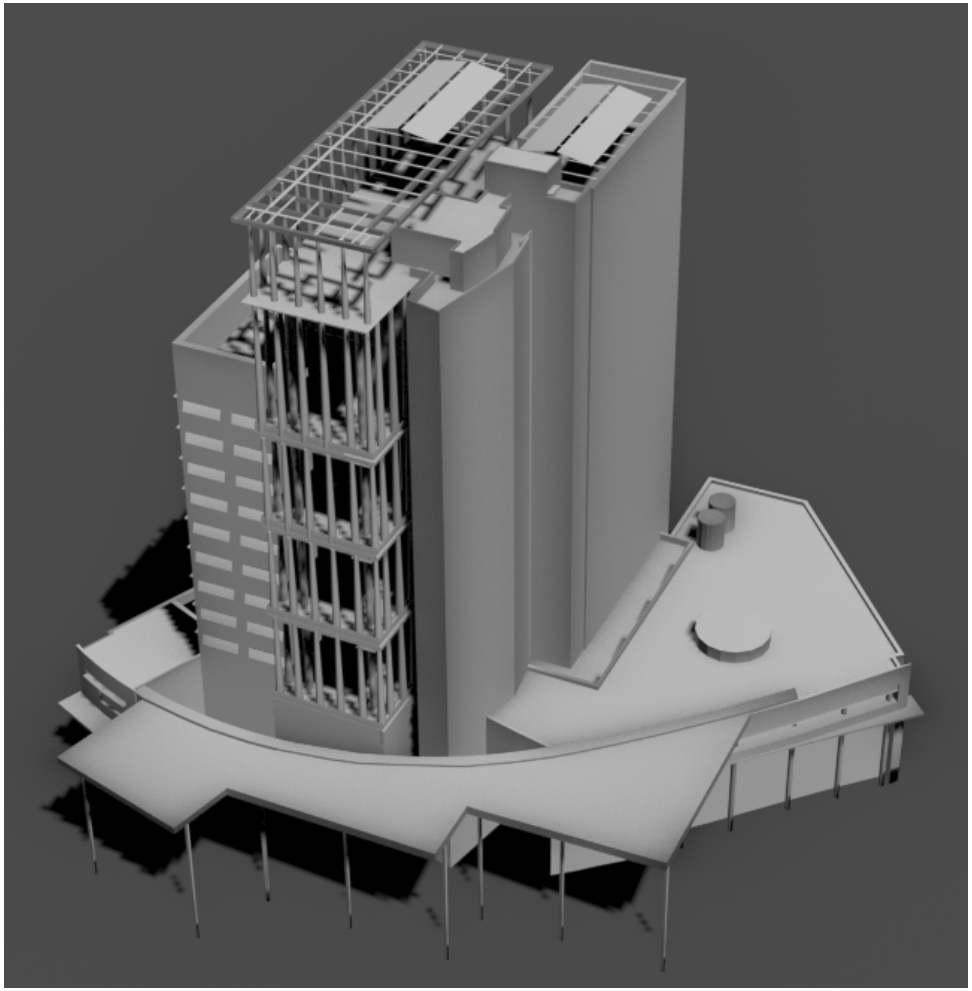


Complete Model

NUS CREATE) building reconstruction

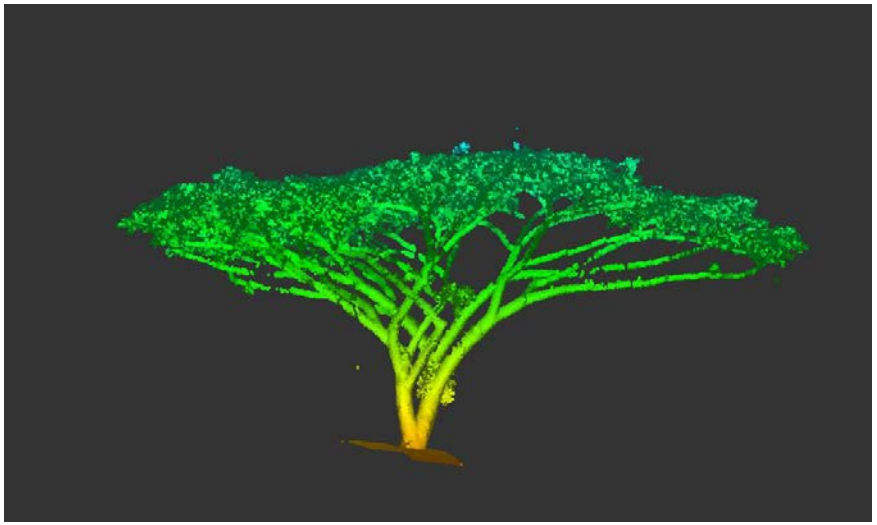
From UAV images and MMS laserscans





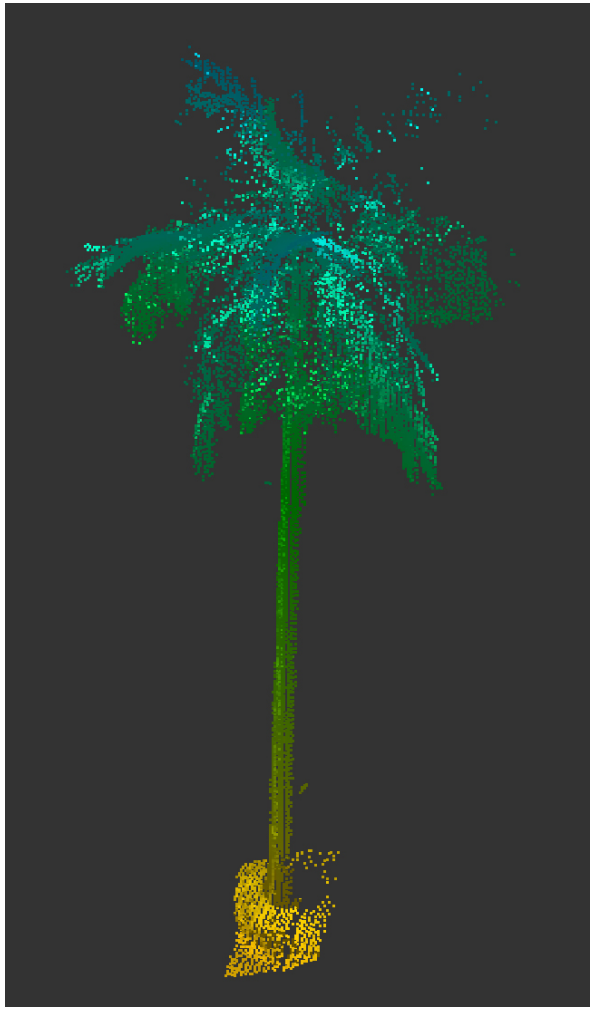
Tree modeling from terrestrial laser-scans

Rain Tree

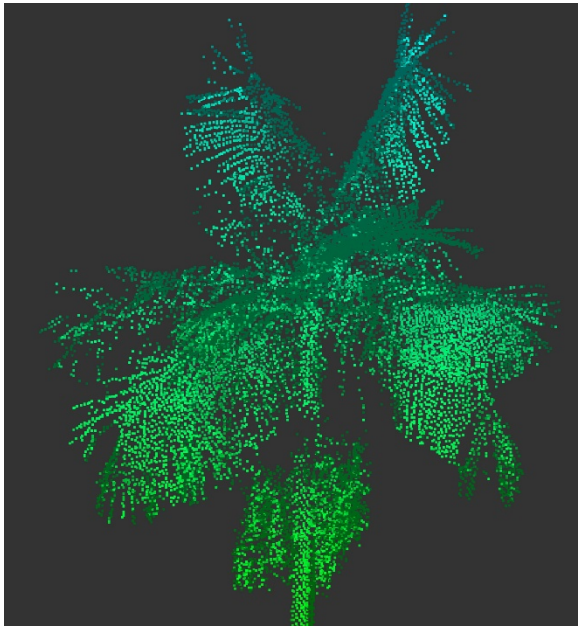


1. ***Pointools Edit.*** Separate point cloud of a tree from the whole scene
2. ***Geomagic Studio.*** Wrap the tree points into triangular mesh
3. ***3ds Max***. Draw spline lines manually along the stems: skeleton of the tree
4. ***3ds Max***. Generate columns along the spline lines using the tool “loft”
5. ***3ds Max***. Texture the loft as stems and the left triangles as canopy, using images captured in the field.

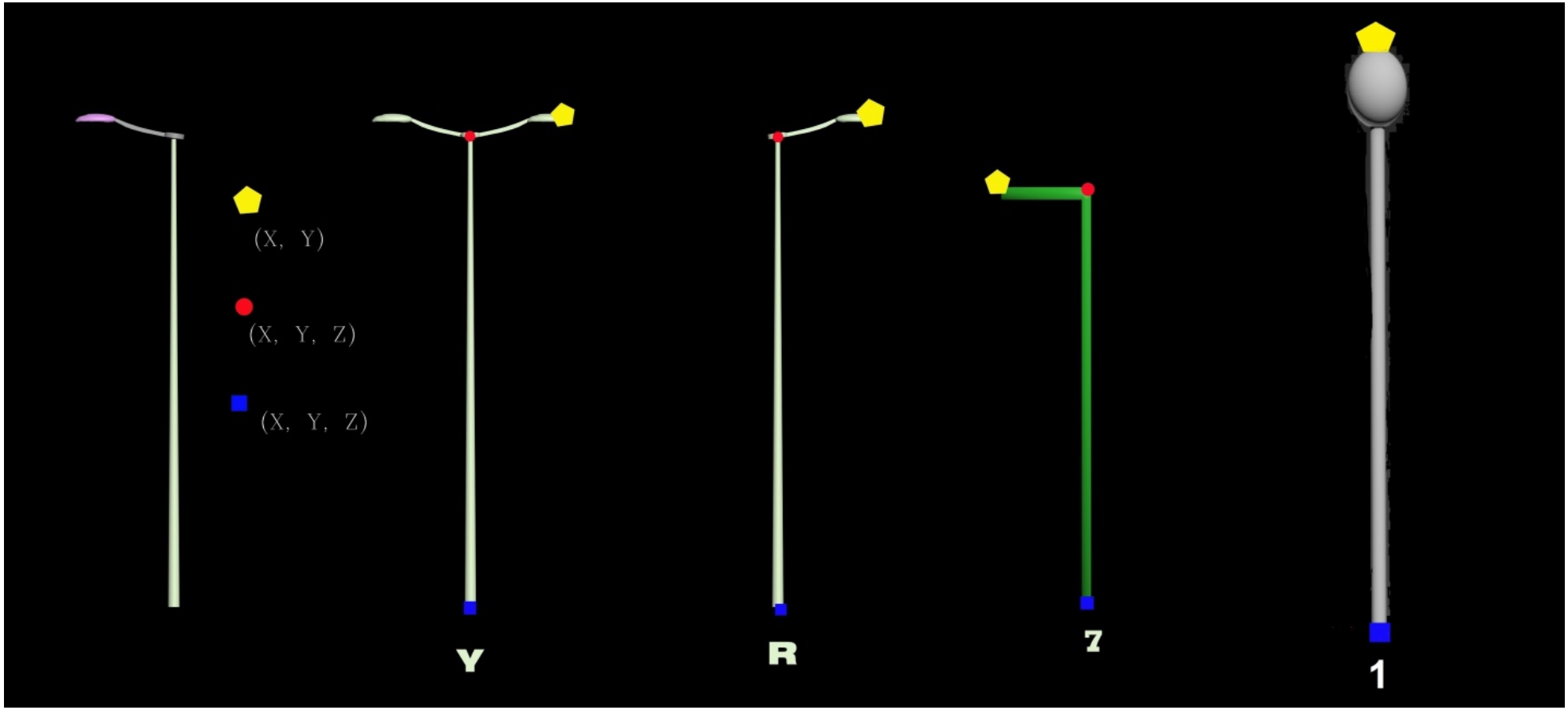
Tree modeling from terrestrial laser-scans



Palm tree



Light pole models (900)



Multi-sensor data

(1) Vertical aerial UAV images at 5 cm footprint

(2) Oblique UAV images (in planning)

(3) Raw point clouds from MMS

(4) Terrestrial images from off-the-shelf cameras

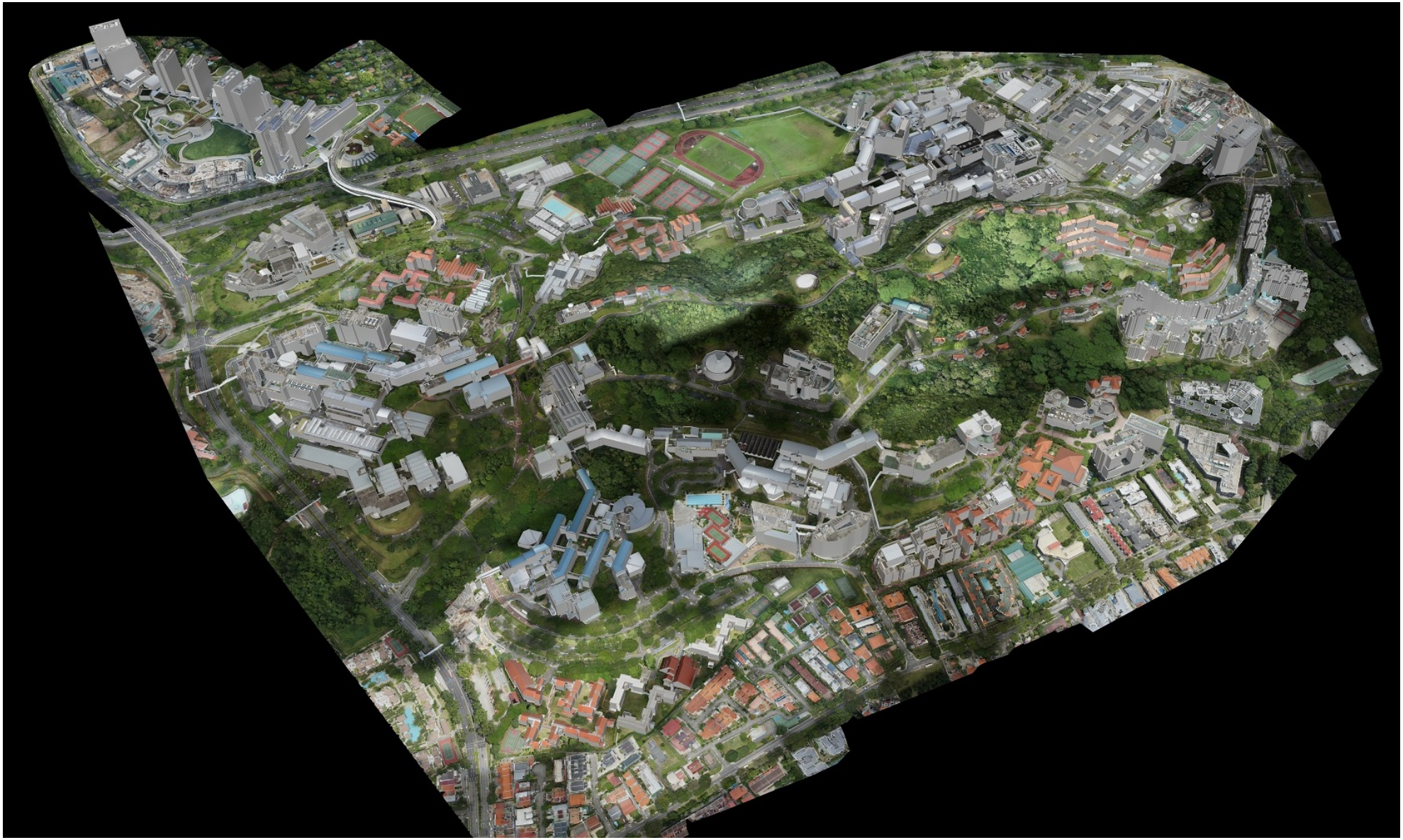
(5) Ground Control Points (GCPs)

(6) Existing data (maps)

Output

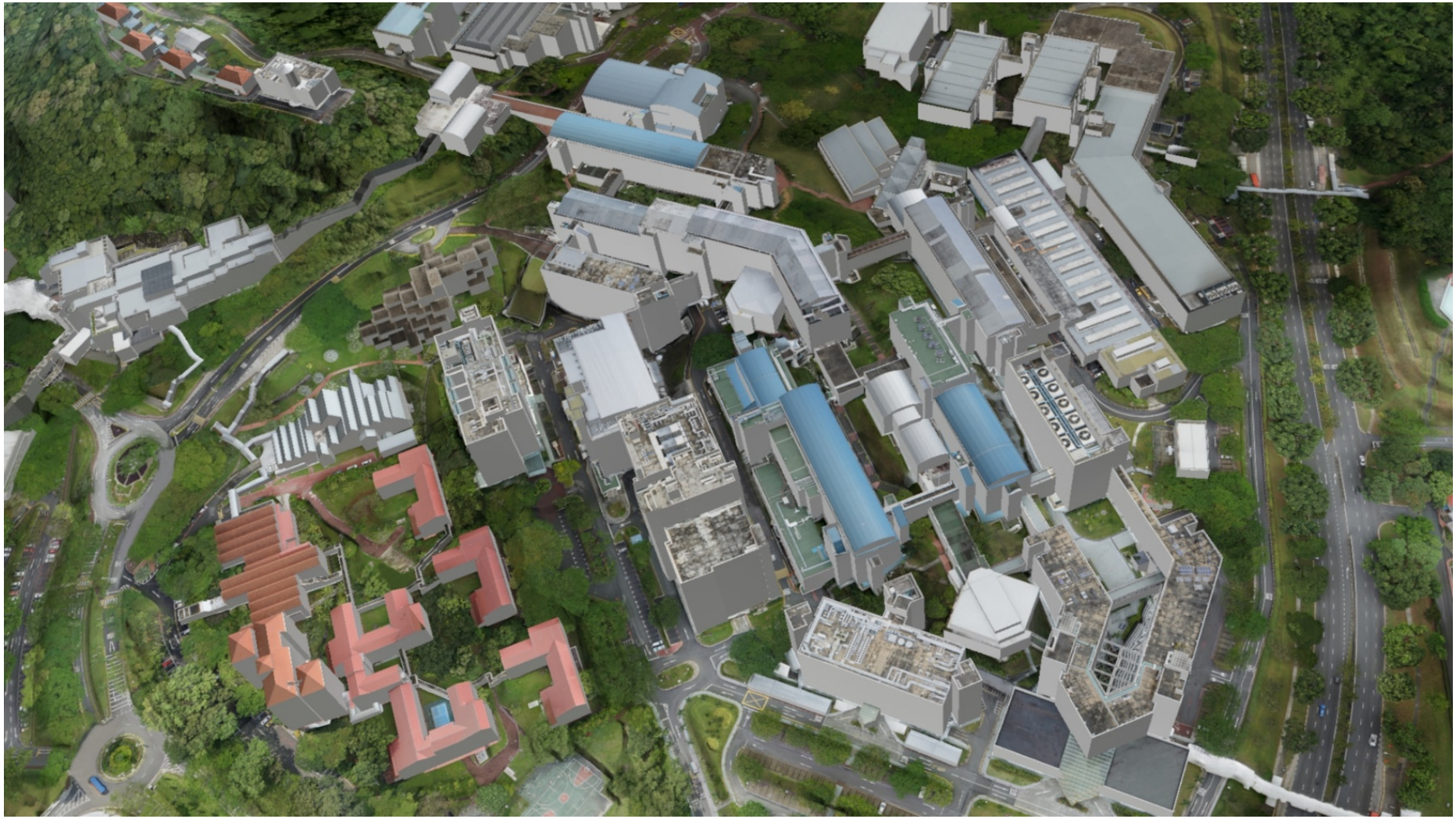
3D hybrid site model, achieved by integration of these input data

NUS model - overview



CREATE building

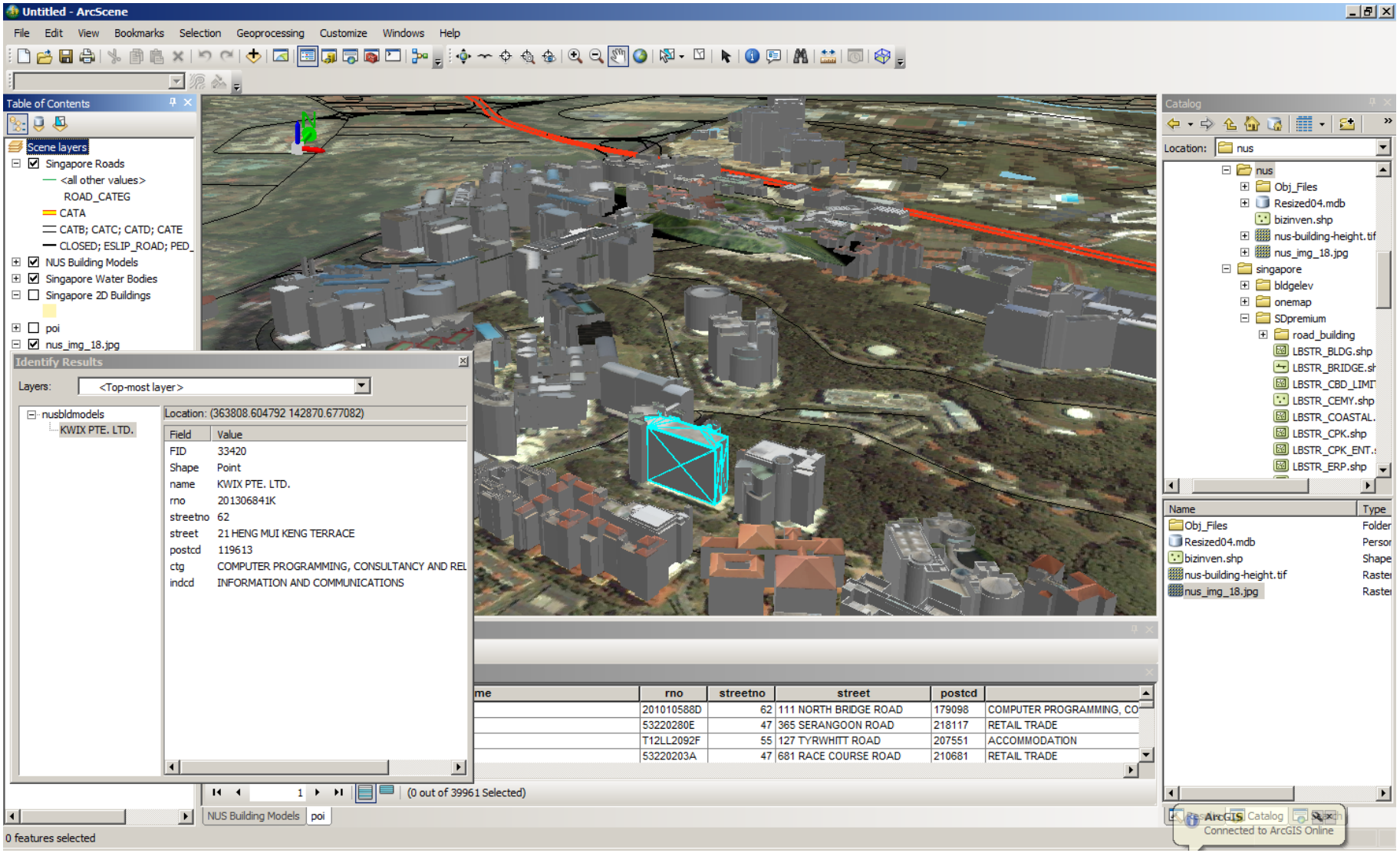
Model view: Engineering section



Engineering section

GIS integration

Model geometry 576 MB obj/745 MB 3Dmax
Model texture 4.15 GB bmp/tiff



Potential UAV projects of Singapore Gov. Agencies

National Environment Agency (NEA):

- Real-time detection and tracking of oil spills
- Detection and 3D measurement of water pools where Dengue fever mosquitos reside
- Micro-climate modeling, city hot spots

Urban Redevelopment Authority (URA):

- Building and tree (vegetation) models for smart city management

Public Utilities Board (PUB):

- DSM generation for flood modeling. Generation of 3D façade models for water entrance analysis

Singapore Land Authority (SLA):

- Base map data in 3D
- 3D change detection

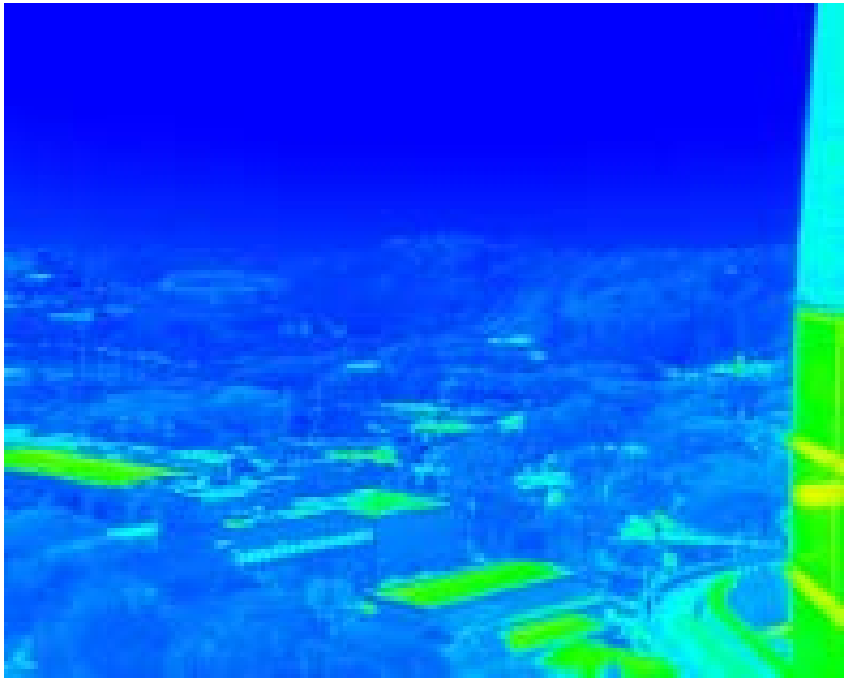
NParks, Botanic Garden

- 3D GIS-based model, with tree health analysis (Garden management)

Detecting breeding grounds of Dengue mosquitos

Thermal Imaging Test

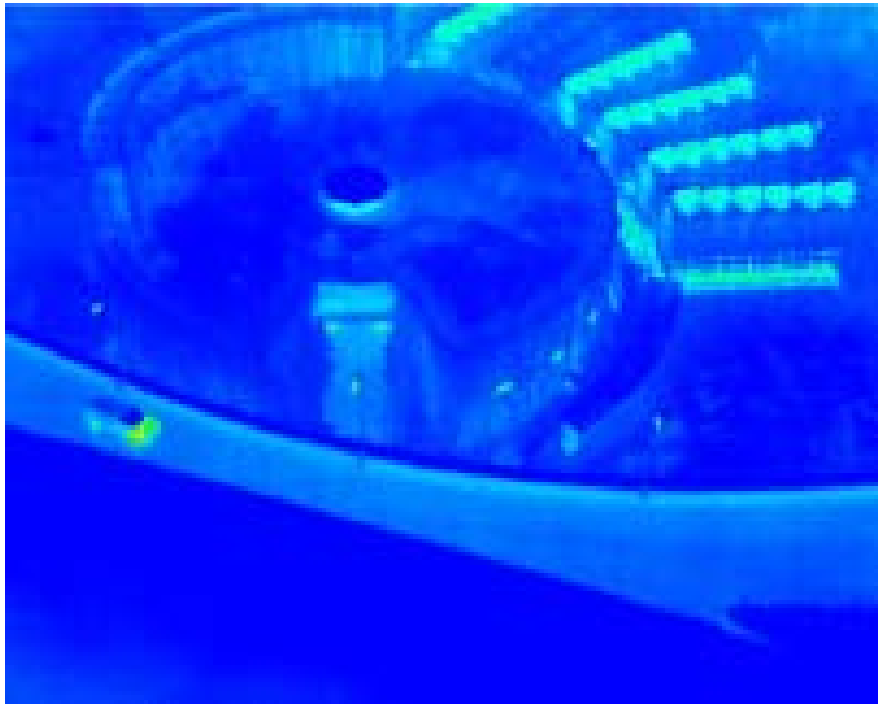
Camera: FLIR, 640x480 pi, 14bit
Platform: Falcon-8



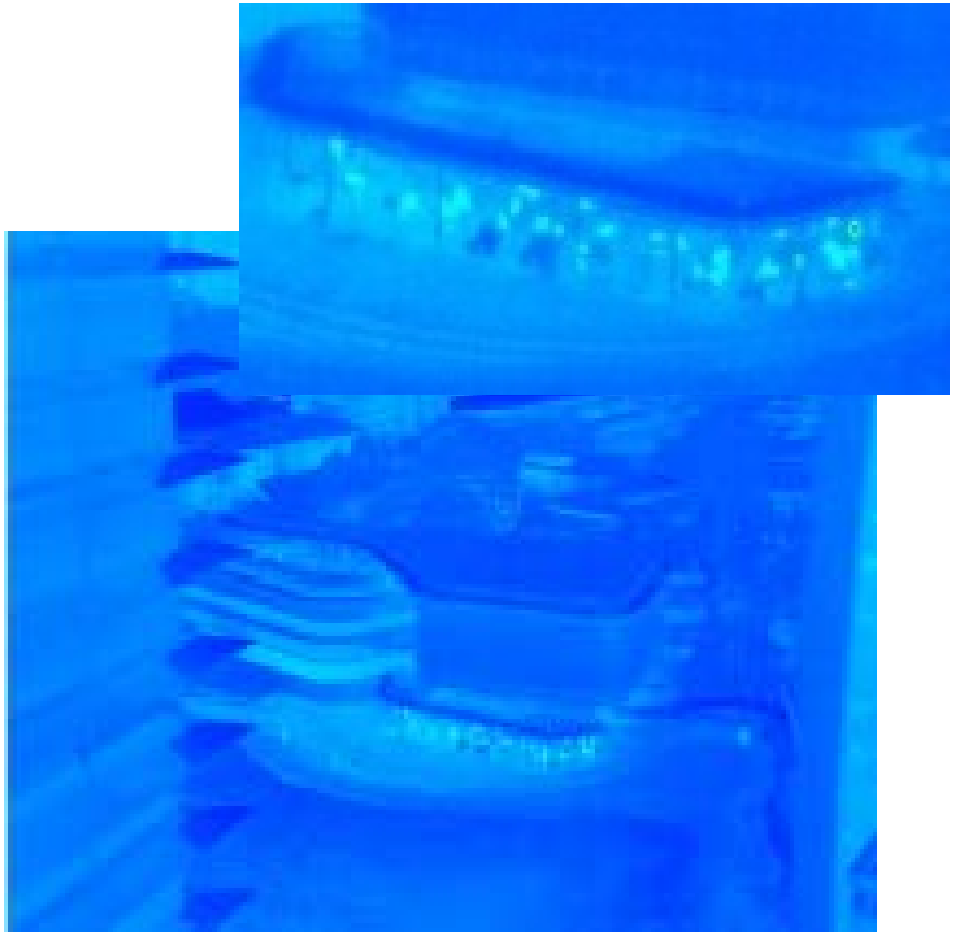
Daylight recording

Night recording

Night recordings



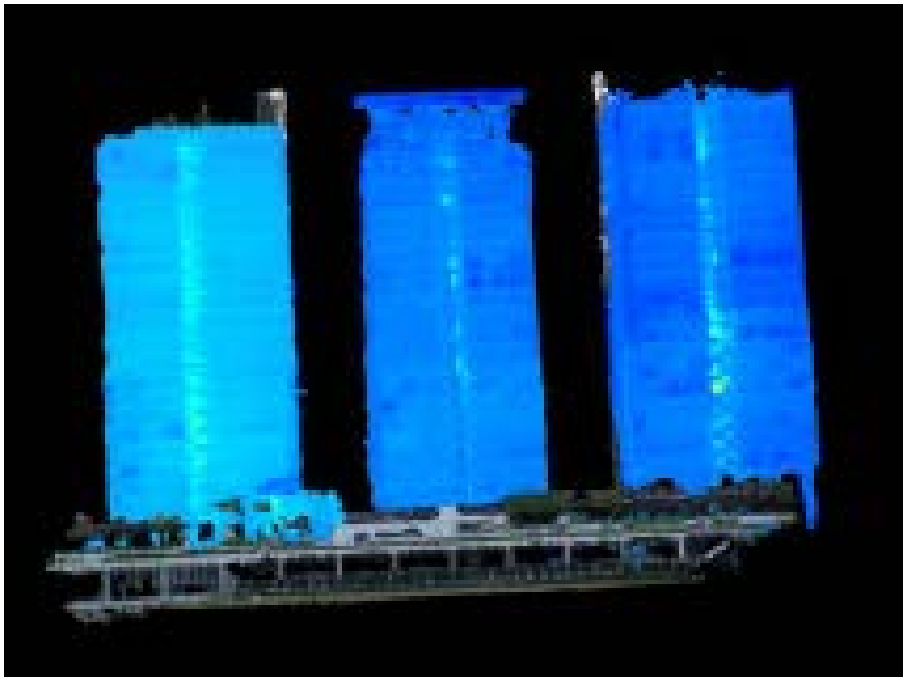
Missing fan. Car engine



Students at STARBUCKS

3D thermal building model

Point cloud



Thermal model

Schabolovoskaya Tower

Built 1919-1922

Radio station for international connections of the young Soviet state

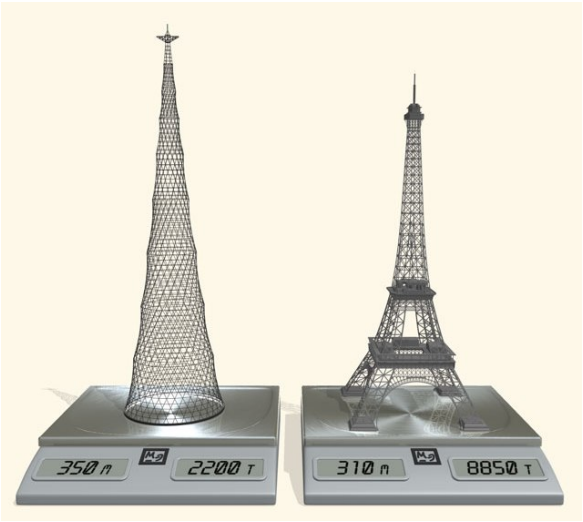
First version: 350 m high, with Lenin's permission

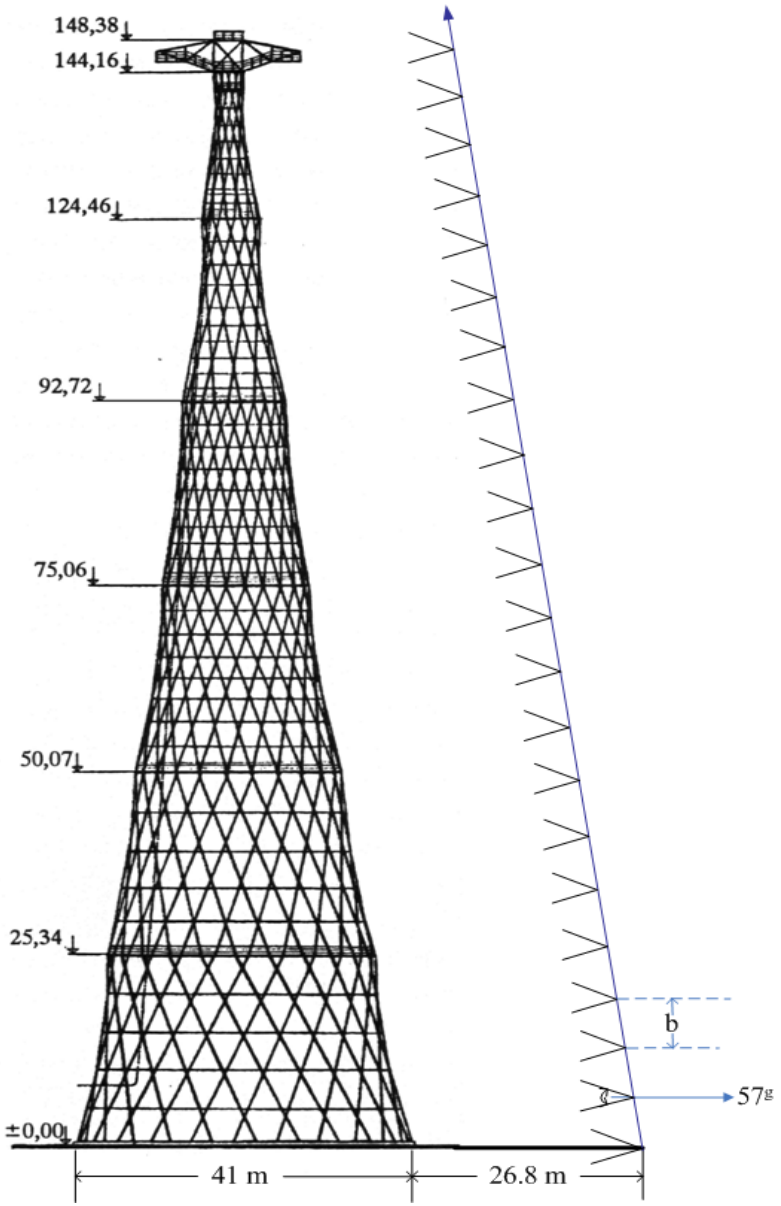
After 1939: TV antennas

Today: Belongs to Russian State TV

Restricted accessibility

Transmitters for mobile communication



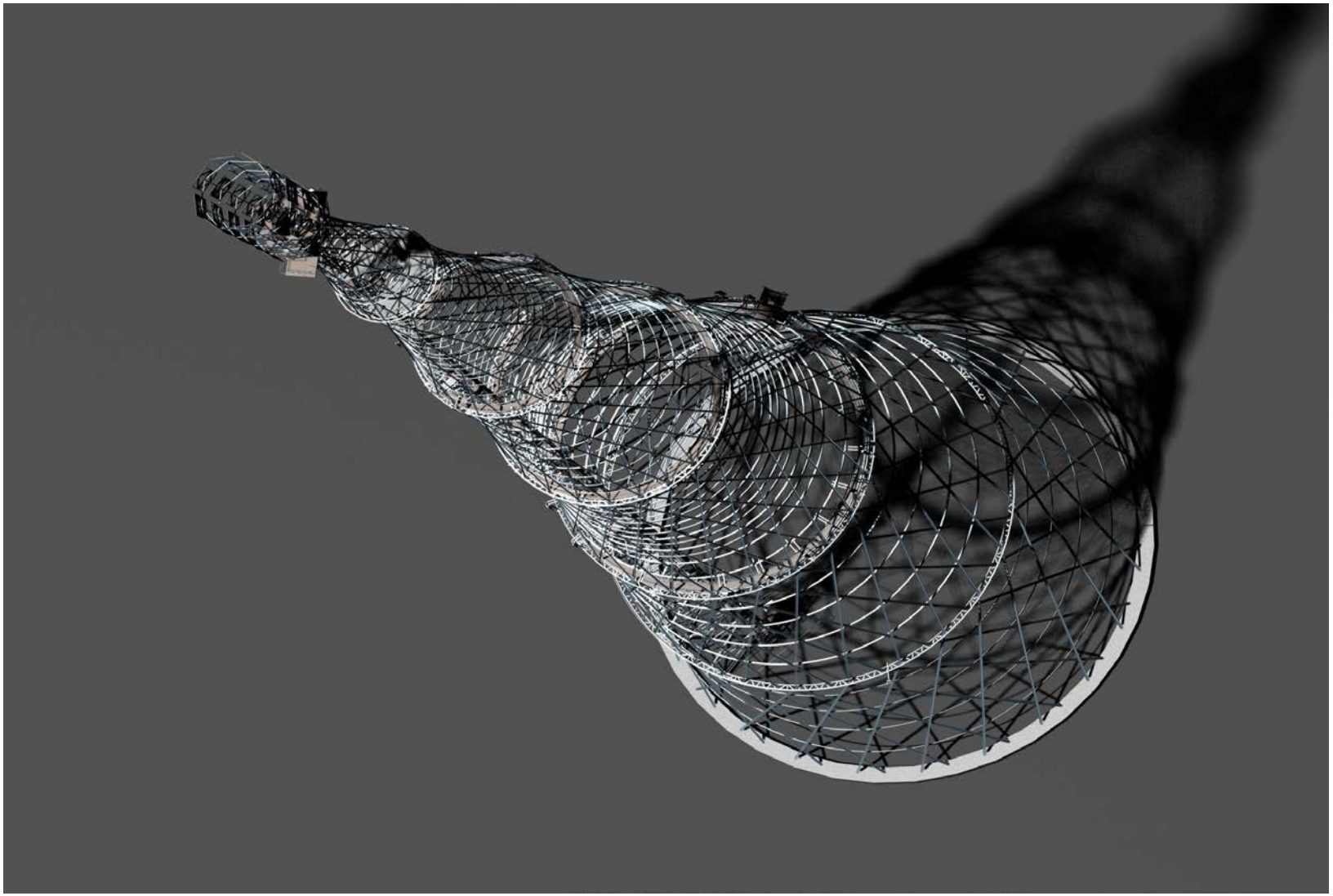


Network design:

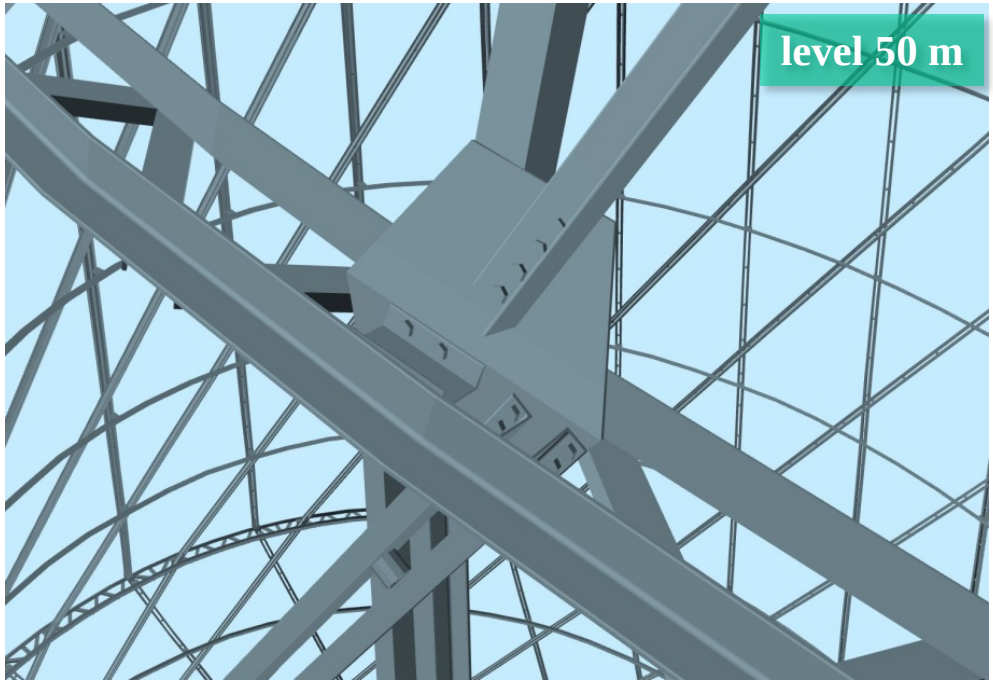
80%l > b = 7.7m

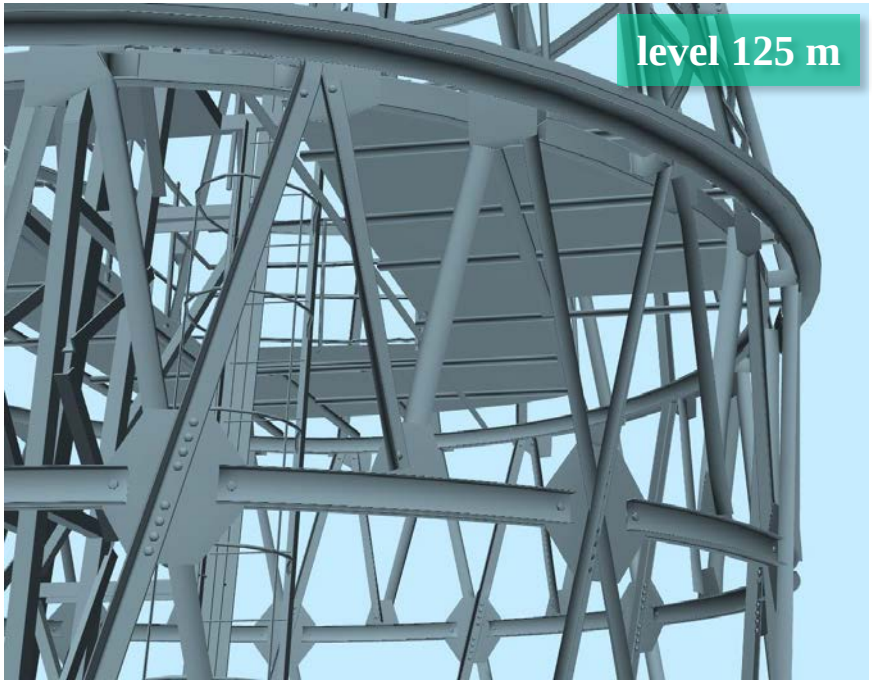
- 20 images per strip
- 160 images in total

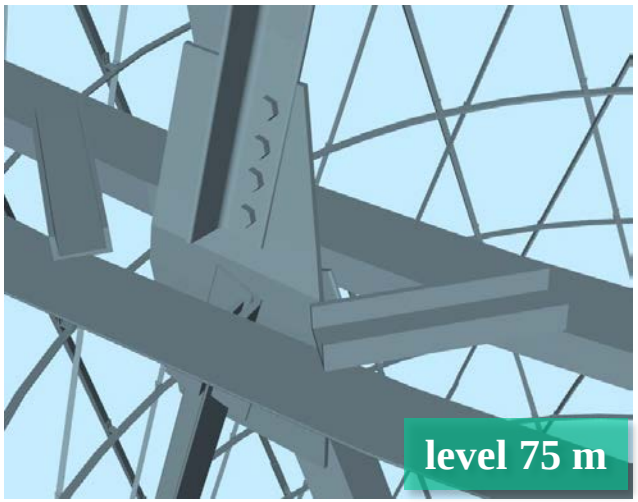
Final model, derived from laserscans



Modeling of junctions, examples

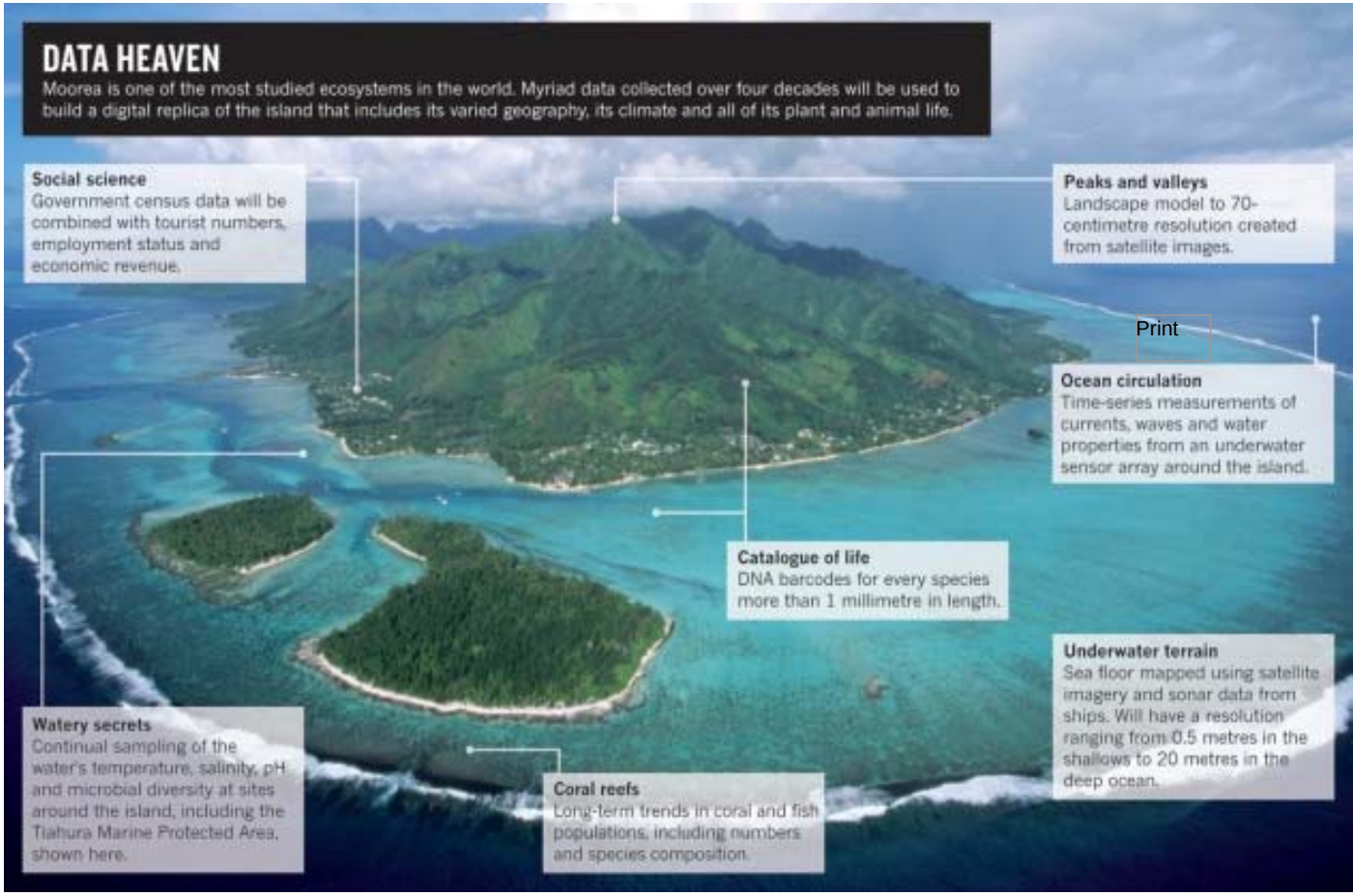






Moorea Island Avatar - Ecological modeling

(mooreaidea.org)



***NATURE* | NEWS**

Tropical paradise inspires virtual ecology lab

Digital version of Moorea will provide a way to experiment with an entire ecosystem.

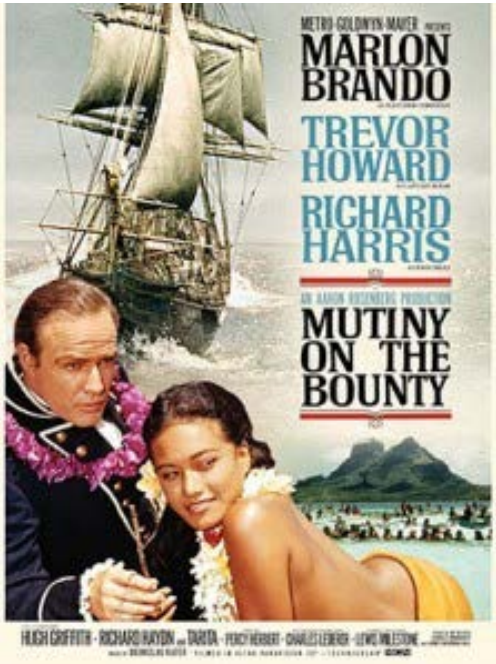
Daniel Cressey

14 January 2015

Tetiaroa - Island Avatar

“Tetiaroa is beautiful beyond my capacity to describe. One could say that Tetiaroa is the tincture of the South Seas.”

Marlon Brando



Moorea 3D model

Conclusions

+ **New tools** available for documentation, analysis and dissemination of environment: *Sensors, processing software, visualization, SIS, Internet*
+ **Multi-sensor, multi-resolution approach** helps in getting results of better quality, completeness and higher level of automation
+ Perception of world and mapping is changing

➡ **New concepts for 3D mapping/modeling** required

Crowd-sourcing, Big Data, data mining, cloud computing