3D Mountain Modeling
using Aerial Images, Aerial LiDAR data, and Satellite Data

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Acknowledgement and references

Asia Air Survey Co., Ltd.
http://www.ajiko.co.jp/en/

Mr. Nobuhiro Usuki, Mr. Masanori Takigawa, Mr. Tomoaki Eguchi, Mr. Naoki Nishimura

Japan Space Imaging Corporation
http://www.spaceimaging.co.jp/en/

Mr. Keiichi Aramoto, Mr. Yunqing Li

Mt. Fuji Sabo Office, CBR, MLIT (Ministry of Land, Infrastructure, Transport and Tourism)
http://www.cbr.mlit.go.jp/fujisabo/en/index.html

JAXA (The Japan Aerospace Exploration Agency)
http://global.jaxa.jp/

3D Mountain Modeling
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- Introduction
- 3D Modeling using Aerial Photogrammetry
- 3D Modeling using Aerial LiDAR
- 3D Modeling using Satellite Images
- 3D Mt. Fuji Survey Project
- Summary

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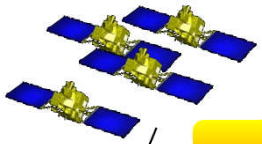
Geoinformarics Lab., Shibaura Institute of Tech.

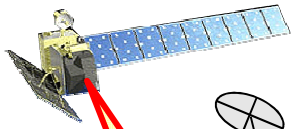
Remote sensing

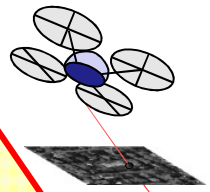
ALOS data processing

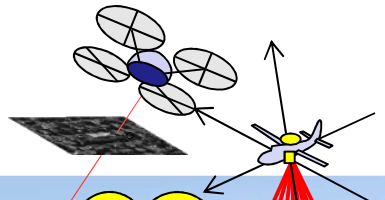


Photogrammetry

- 3D urban mapping
- Landslide analysis





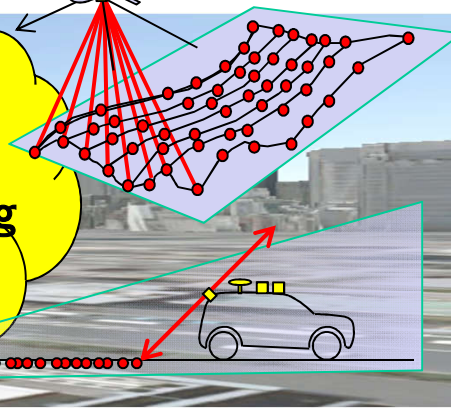


Positioning

Seamless positioning (QZSS, Indoor GPS)

Navigation & Browsing

Mapping



LiDAR

- Pointcloud visualization
- Mapping for Robots

GIS

Spatial recommendation service

Survey

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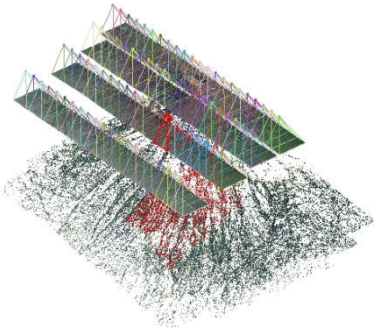
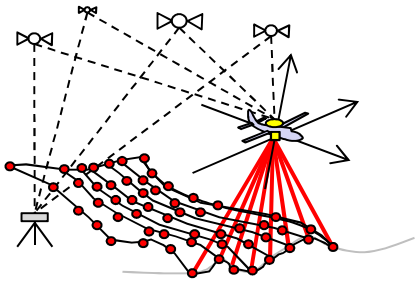
Introduction

3D Mountain Modeling using Aerial Images, Aerial LiDAR data, and Satellite Data



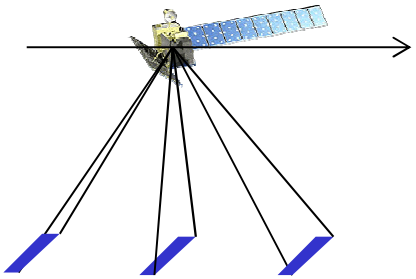
Aerial Photogrammerty

15cm accuracy



Airborne Laser Scanning

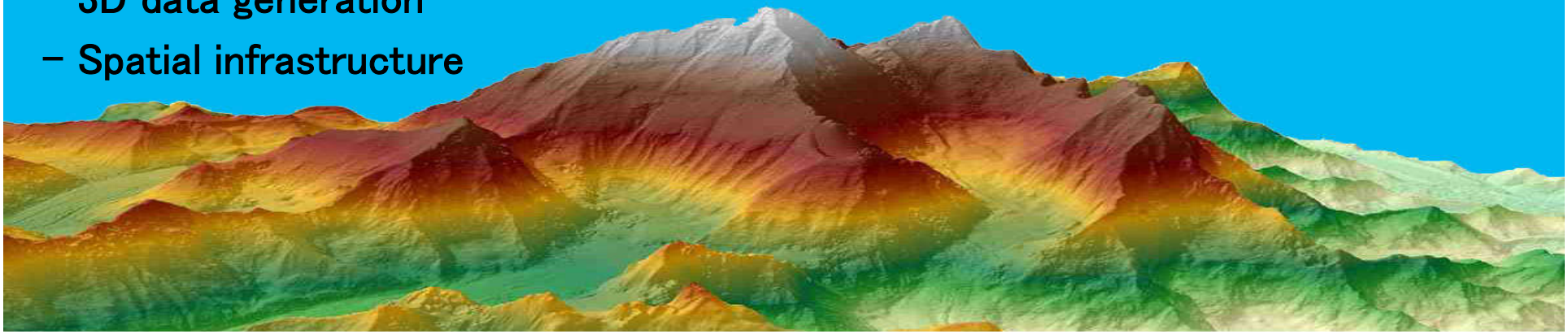
15cm accuracy



Satellite imaging

3m accuracy

- 3D measurement systems
- 3D data generation
- Spatial infrastructure



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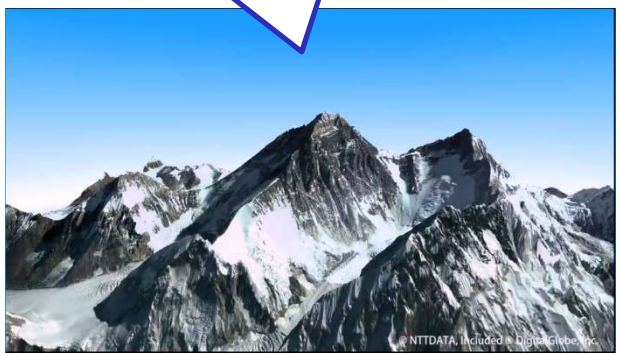
After 3D Everest Measurement ?

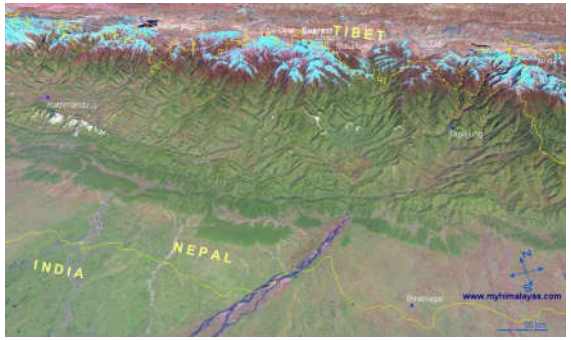
Spatial infrastructure can be used for various fields

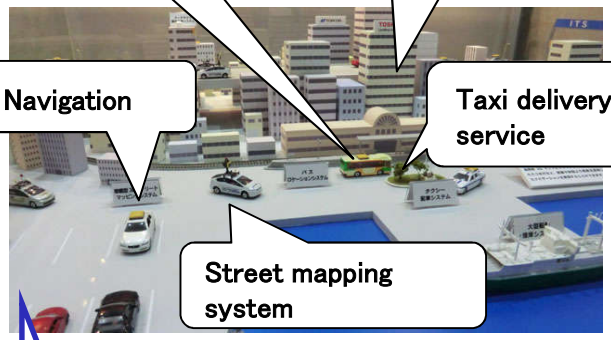
8848m !

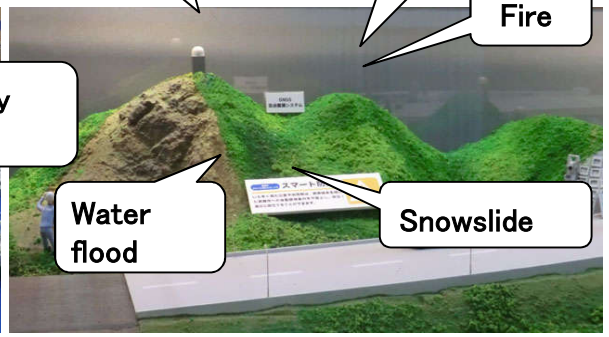


+

- GNSS ref. points
- Precise Geoid map
- 3D map

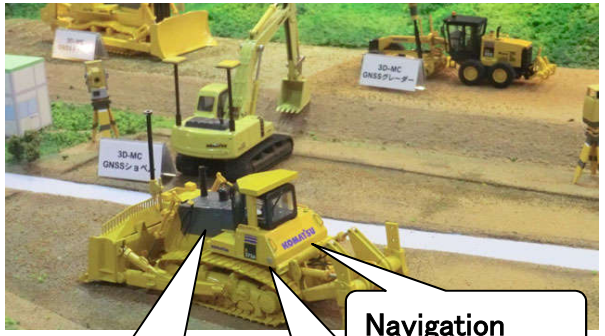






Transportation | **Disaster**

Agriculture | **Construction**



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SABO

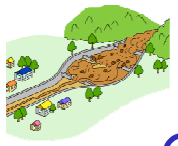
Act on Sediment Disaster Prevention

Sediment disasters are triggered by various natural phenomena and conditions

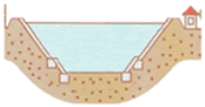
- Earthquake
- Torrential Rain
- Volcanic Area

SABO facilities

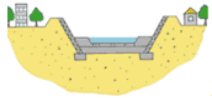
Debris barrier (dam)



Sediment-retarding basin



Revetment



Protected riverbed

Prevention

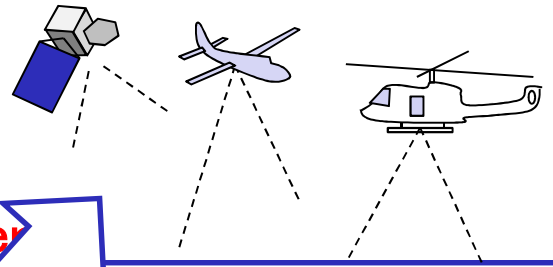
Sediment disaster

- Debris Flow
- Landslide
- Slope Failure
- Avalanche
- Volcanic disasters

When an unstable slope collapses, a debris avalanche is formed, and debris is transported away from the slope

Monitoring

Large scale surveys



Evacuation

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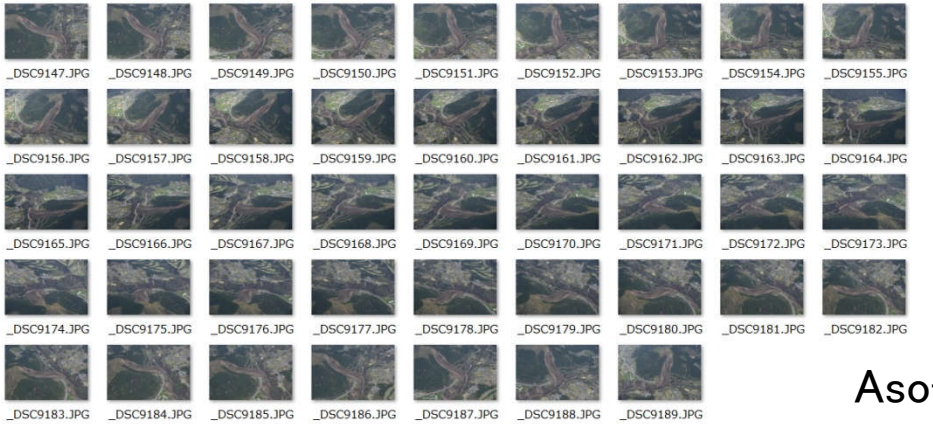
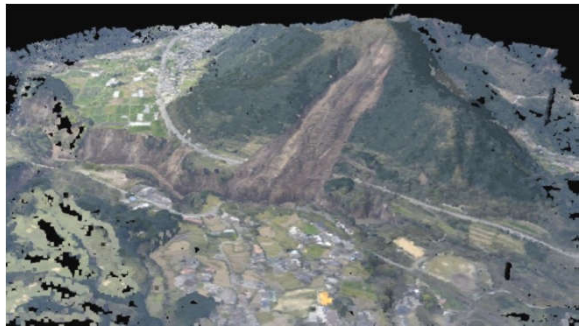
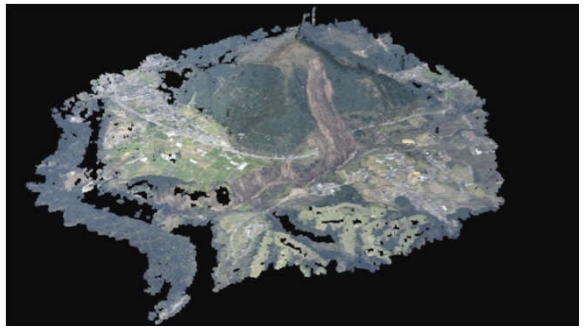
Landslide in Kumamoto Earthquake

Structure from Motion using Aerial Images



Aso-ohashi Bridge





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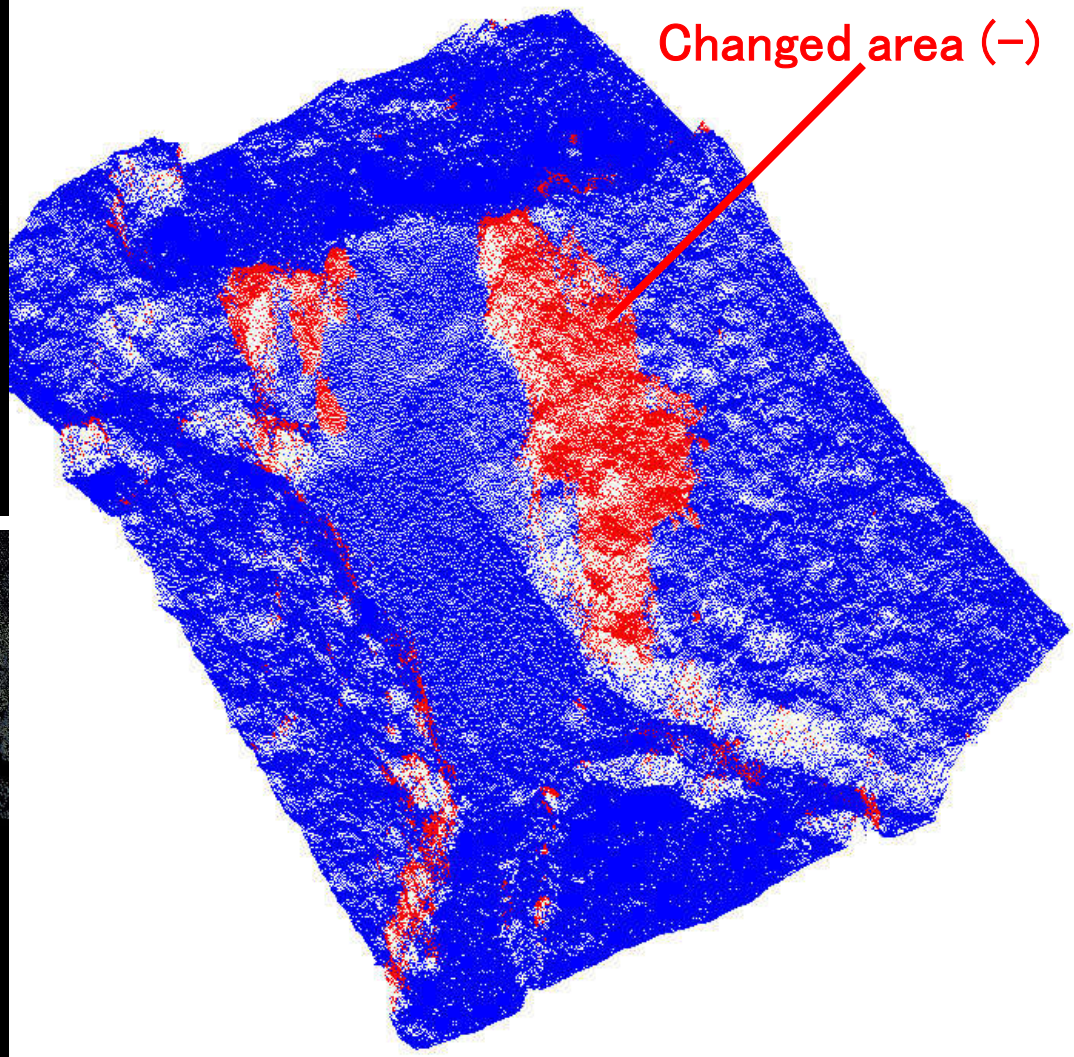
Change Detection in Landslide

Can achieve “Volumetric change detection” using 3D data



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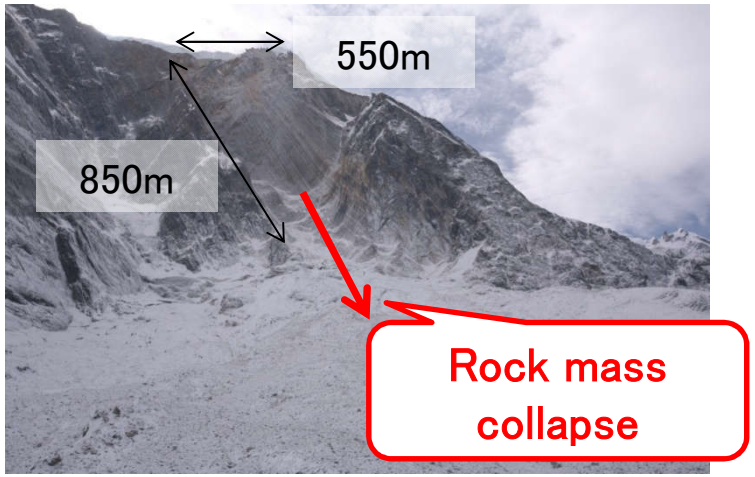
Surveys after Flash Flood Disaster in Nepal

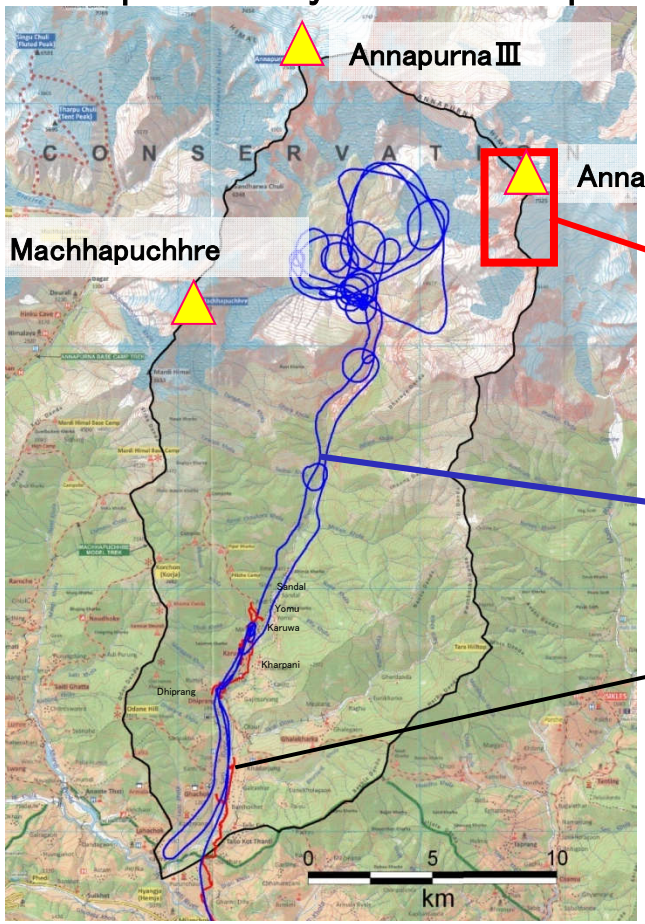
アジア航測株式会社

Seti Khola, Nepal 3-8 June 2012

NPO Nepal-Japan Friendship Association for Water Induced Disaster Prevention (NFAD)
International Sabo Association (ISA), Sabo Frontier Foundation (SFF)
Asia Air Survey CO.,LTD.



Helicopter survey around Annapurna Ⅳ



3D measurement is required for SABO survey

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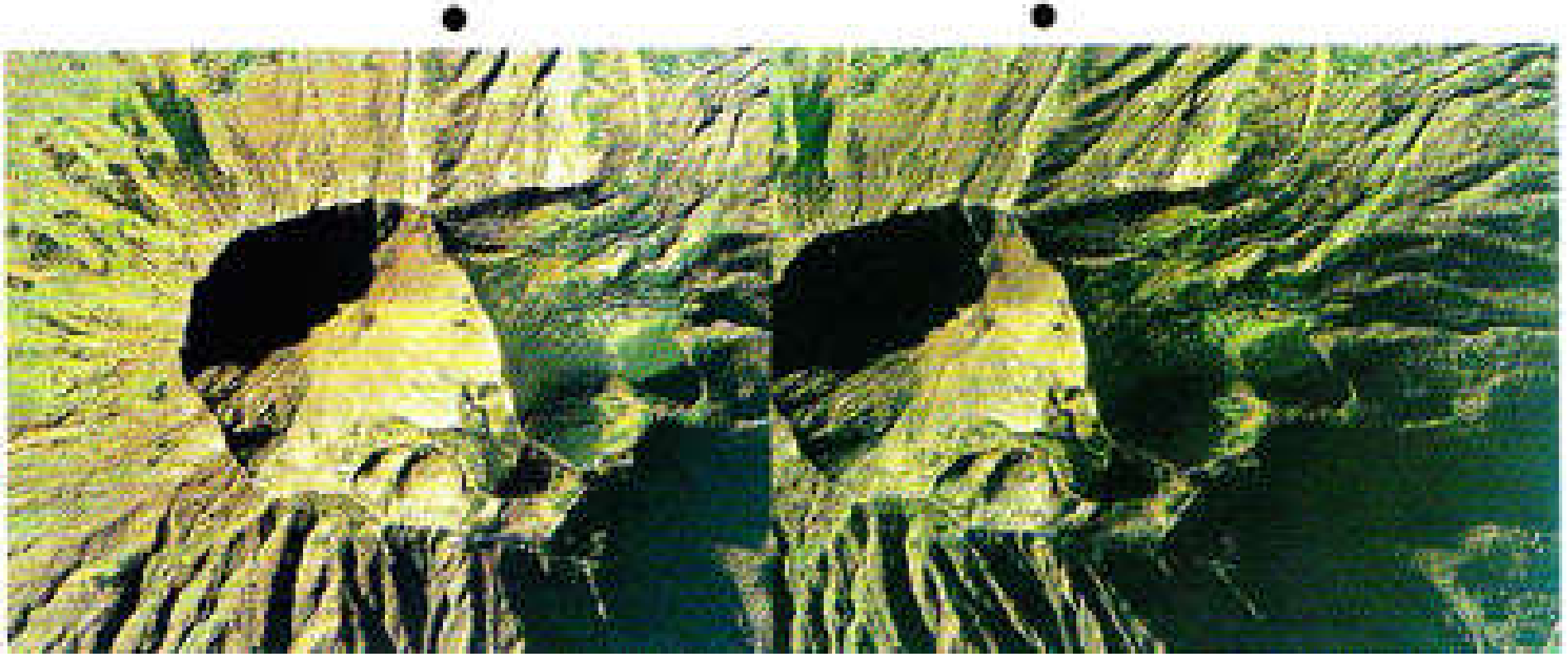
Stereoscopic Vision

for **Left** eye

for **Right** eye



Can see 3D object !

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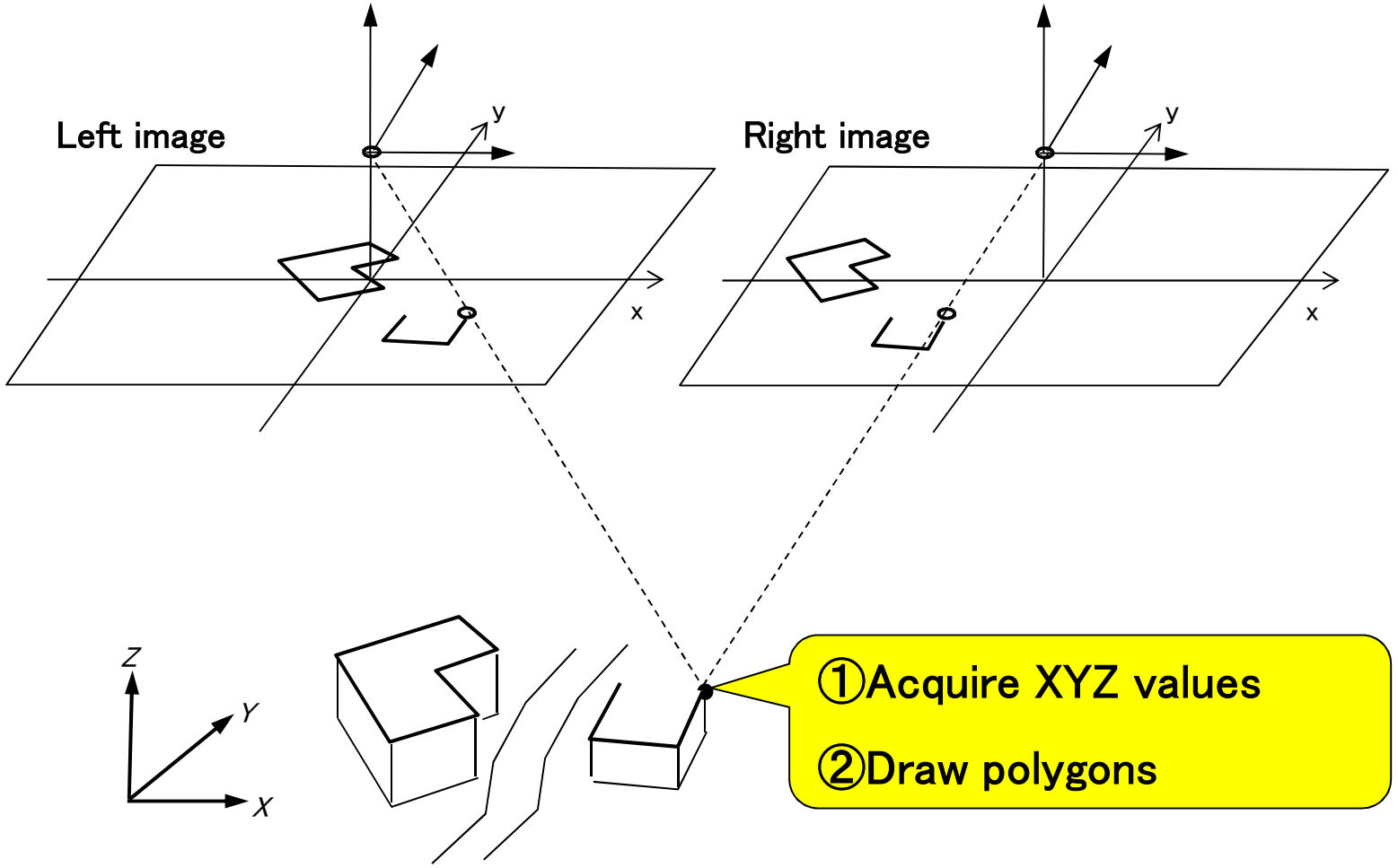
Basic Theory of Image-based Measurement

Can measure 3D data based on Stereoscopic Vision



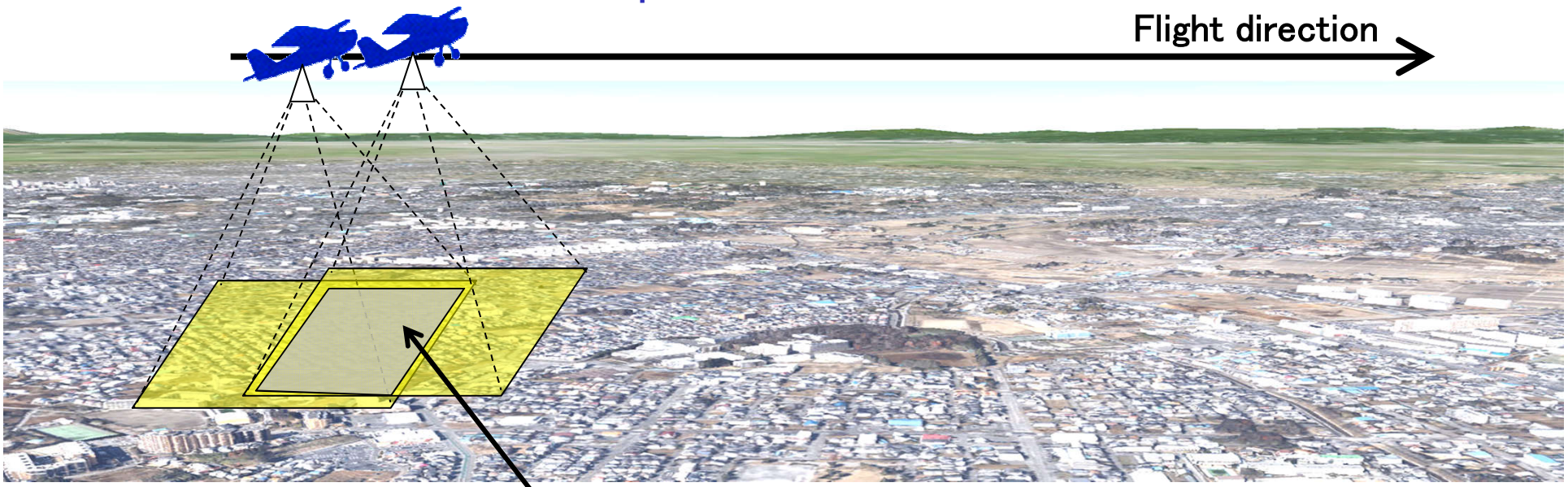
How to acquire images ?

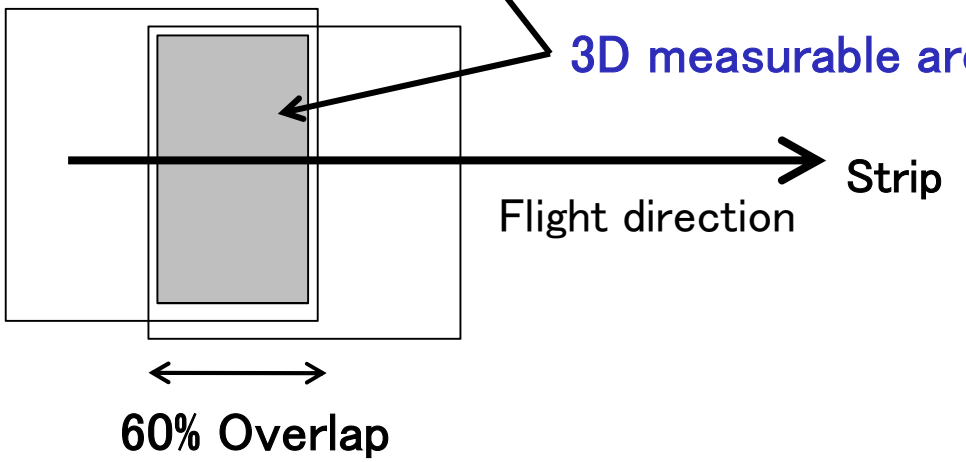
Aerial Photogrammerty

- Can not cover a wide area with a image
- Can not reconstruct 3D data using a image

Aerial Photogrammerty

60% overlap for Stereo Measurement





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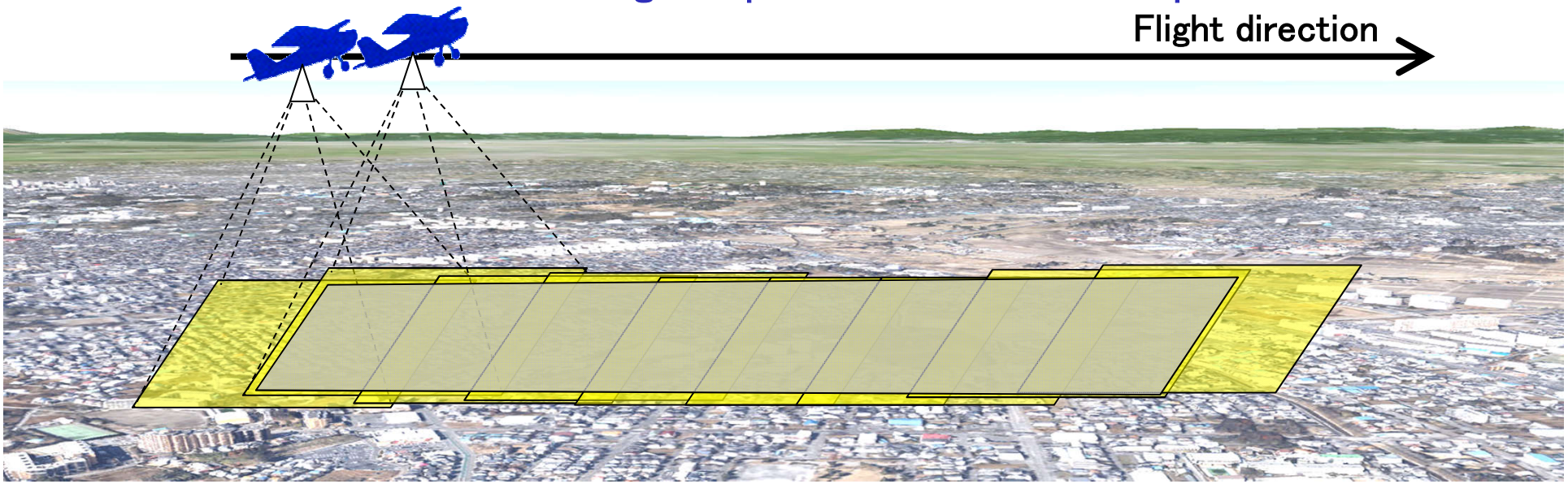
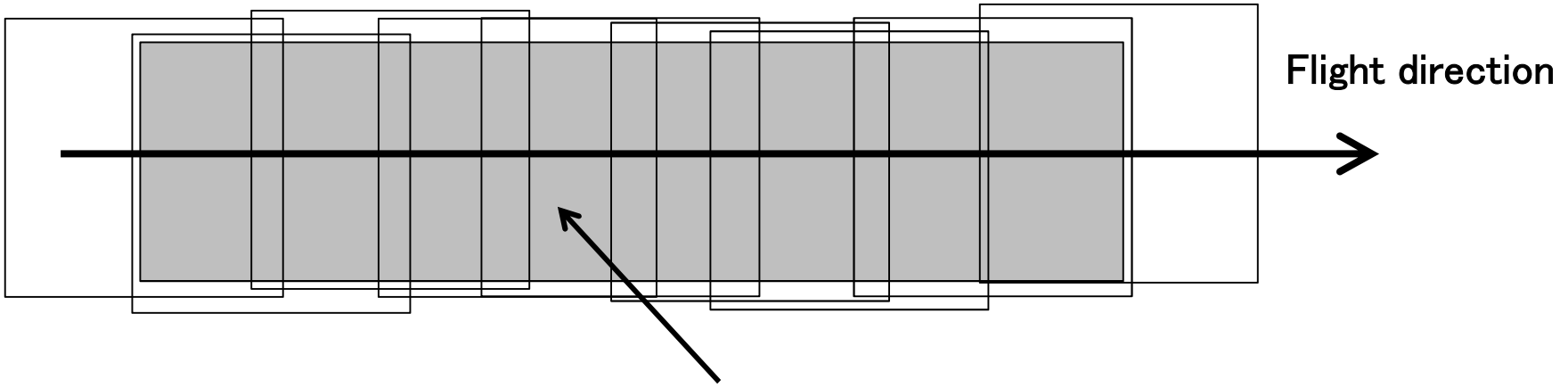
Aerial Photogrammerty

Continuous image acquisition with 60% overlaps





3D measurable area

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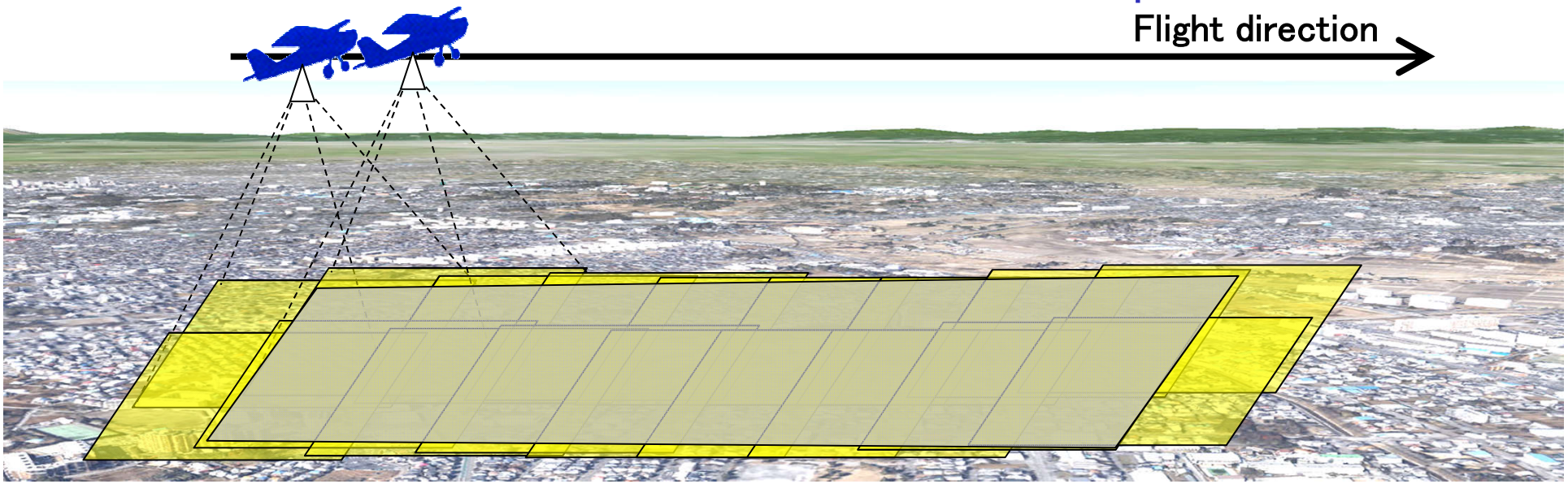
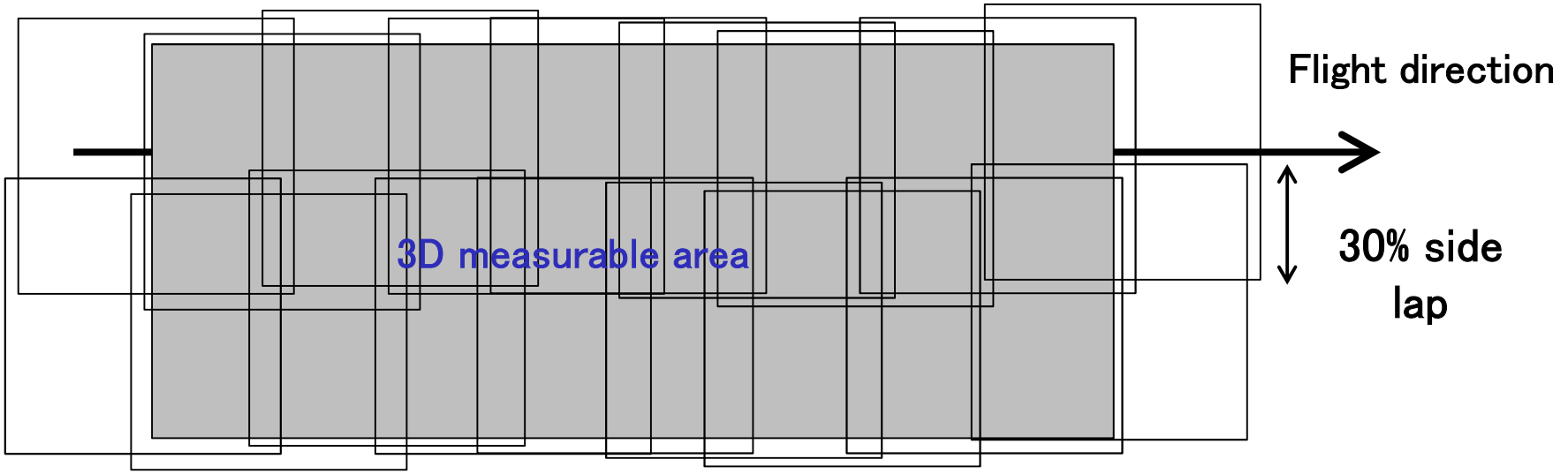
Aerial Photogrammerty

Wide area can be covered with some strips





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Aerial Camera

Precise, High resolution, Multi spectral(, and Expensive)

Area camera

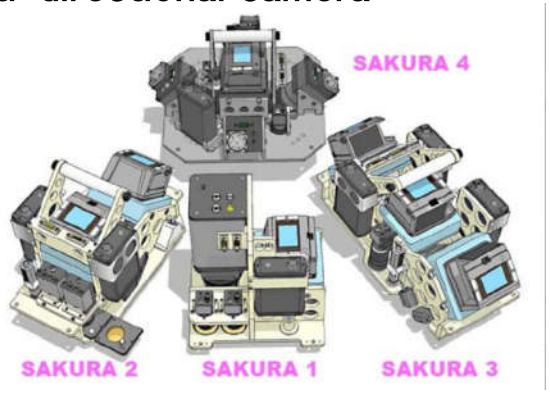
DMC, Intergraph

Ultracam eagle, Microsoft

Linear array camera

ADS80, Leica

Multi-directional camera



Nakanihon Air Service Co.,Ltd.

- High resolution
  100～200 mil. pixels
- High spectral resolution
  11～12 bit

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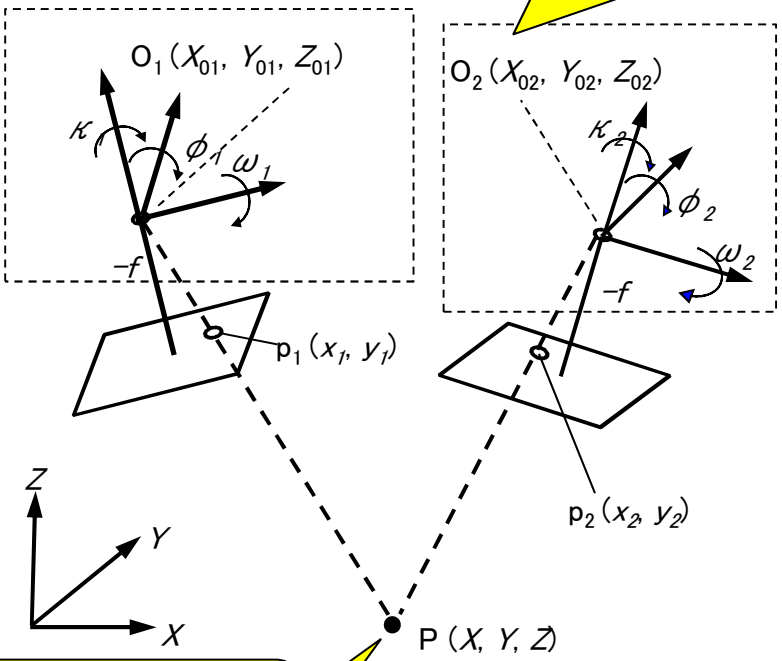
Photogrammetry

Mathematical “Stereoscopic Vision”

①Prepare two images

②Interior and exterior parameter estimation



③3D measurement based on Forward intersection

Focal length : f

Points in images : (x_1, y_1), (x_2, y_2)

Ground point : (X,Y,Z)

Principal point : (X_{oi}, Y_{oi}, Z_{oi}), i=1,2

Camera rotation : $(\omega_i, \phi_i, \kappa_i)$, i=1,2

Co-linear equation

$$x = -f\frac{a_{11}(X-X_0)+a_{21}(Y-Y_0)+a_{31}(Z-Z_0)}{a_{13}(X-X_0)+a_{23}(Y-Y_0)+a_{33}(Z-Z_0)}$$

$$y = -f\frac{a_{12}(X-X_0)+a_{22}(Y-Y_0)+a_{32}(Z-Z_0)}{a_{13}(X-X_0)+a_{23}(Y-Y_0)+a_{33}(Z-Z_0)}$$

here,

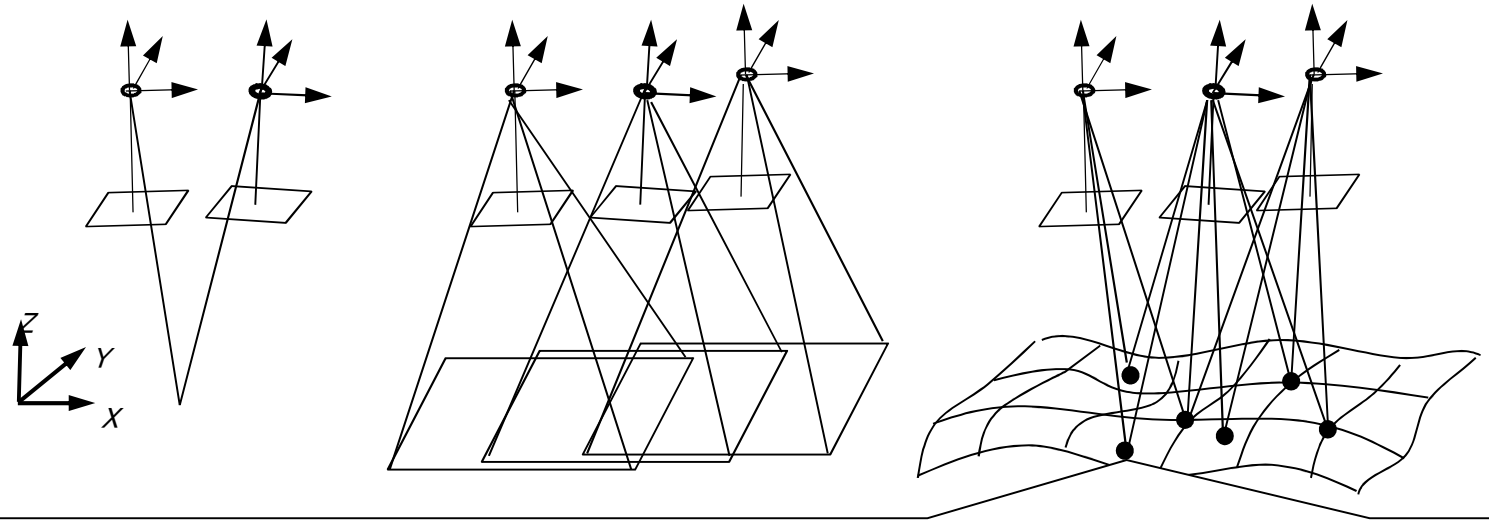
$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & -\sin\omega \\ 0 & \sin\omega & \cos\omega \end{pmatrix} \begin{pmatrix} \cos\varphi & 0 & \sin\varphi \\ 0 & 1 & 0 \\ -\sin\varphi & 0 & \cos\varphi \end{pmatrix} \begin{pmatrix} \cos\kappa & -\sin\kappa & 0 \\ \sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} x' \\ y' \\ z' \end{pmatrix}$$

$$= \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \cdot \begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = \mathbf{R} \cdot \begin{pmatrix} x' \\ y' \\ z' \end{pmatrix}$$

Exterior Orientation

Relative orientation ⇨ **Absolute orientation**

Determines position and orientation of camera in absolute coordinate system from projections of calibration points in scene



Ground Control Point (GCP)

GCP installation

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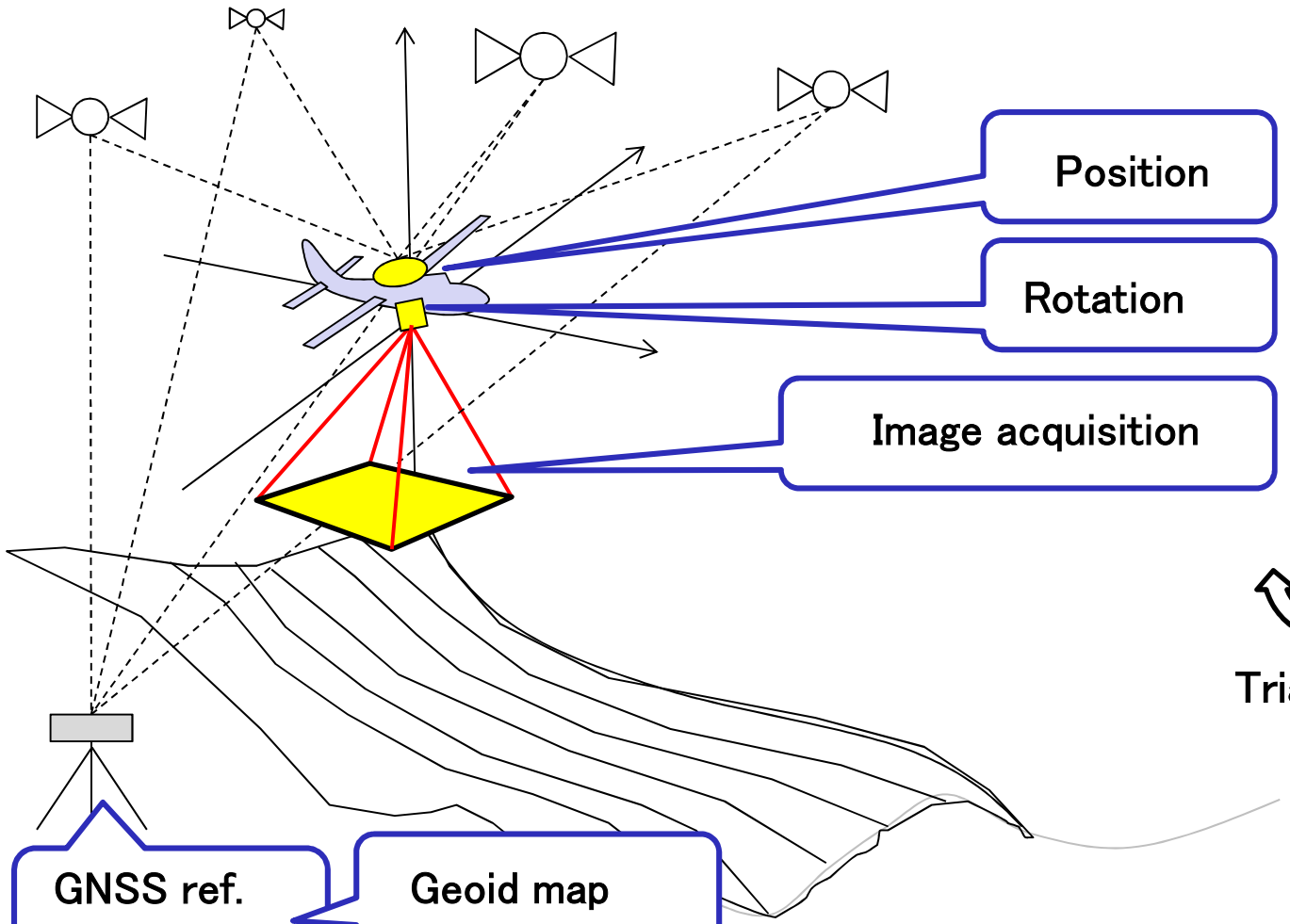
Aerial Photogrammetry

Image acquisition + Position/rotation estimation



Base stations and geoid map are required for aerial photogrammetry

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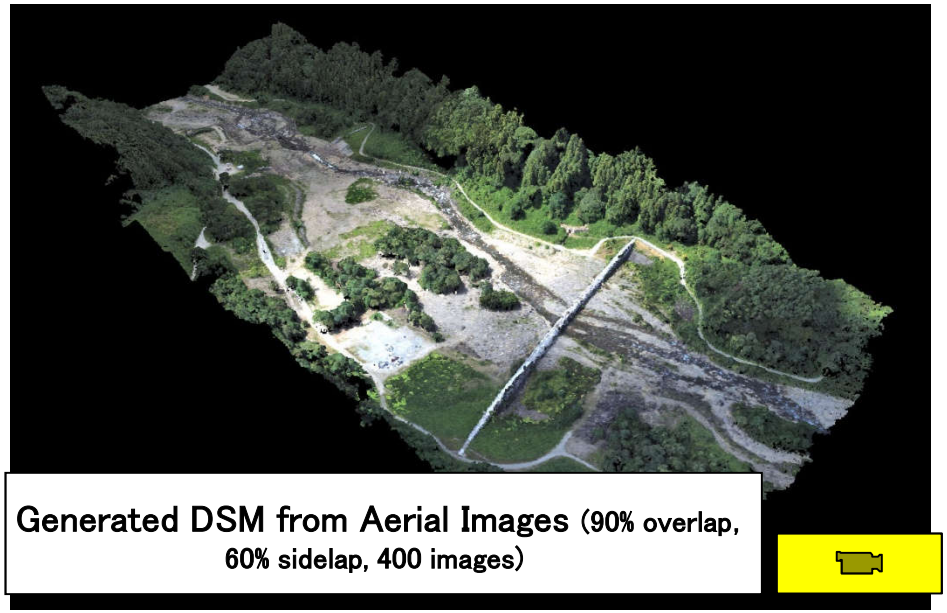
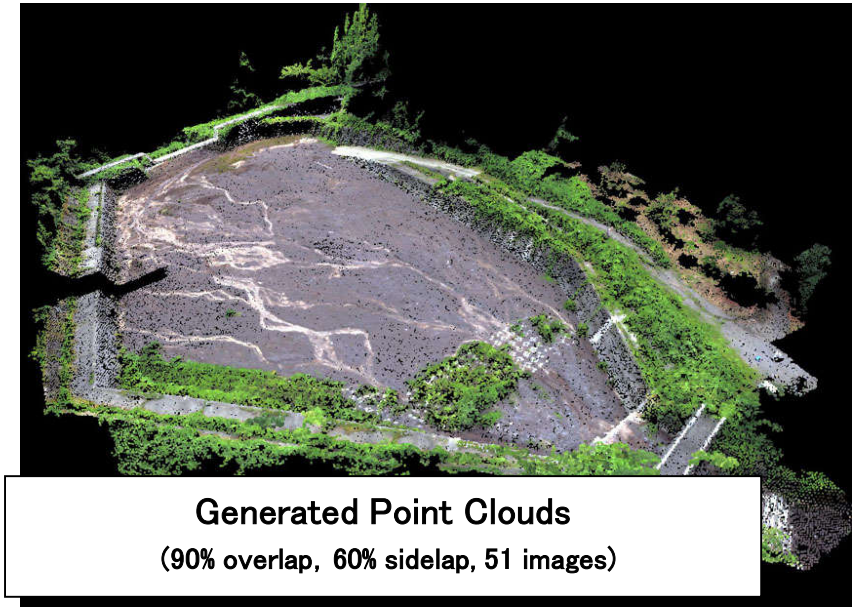
Point Cloud Generation using Aerial Images

Mapping for SABO Infrastructure Inspection



Generated DSM from Aerial Images (90% overlap, 60% sidelap, 400 images)



Generated Point Clouds
(90% overlap, 60% sidelap, 51 images)

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Drone vs. Helicopter vs. Airplane

		Drone	Helicopter	Airplane
Cost	Small area	○ Low	Medium	× High
	Large area	× High	Medium	○ Low
Resolution		Depend on flight height		
Availability		× Urban ○ Rural △ Mountain × Higher mountain	○ Urban ○ Rural ○ Mountain × Higher mountain	○ Urban ○ Rural ○ Mountain ○ Higher mountain

Airplane is better platform for Photogrammetry in higher mountain area

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タイトル

Text

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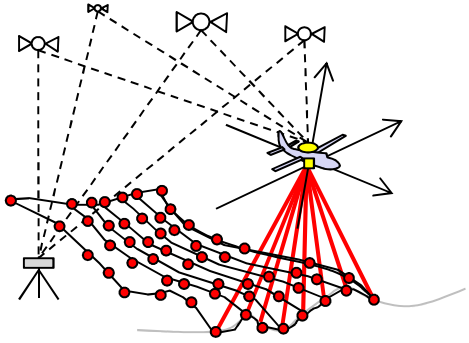
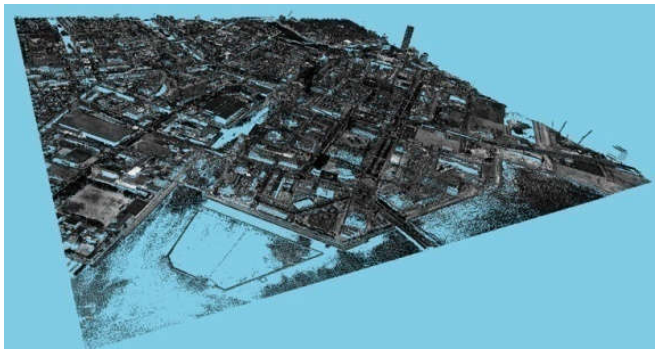
Laser Scanning Systems

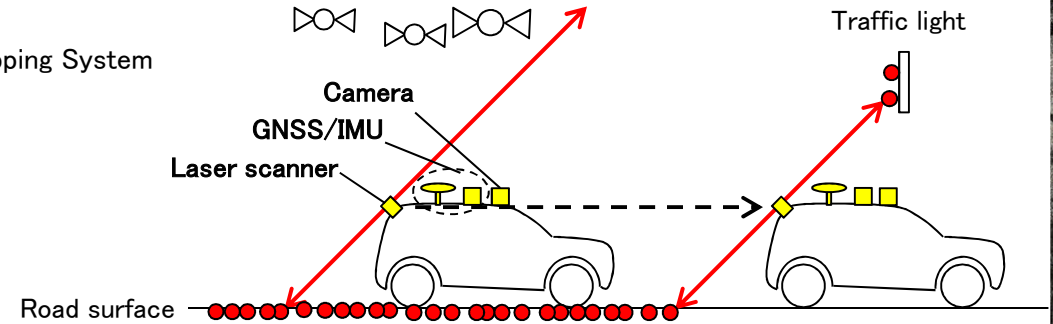
High resolution, High accuracy, and High speed

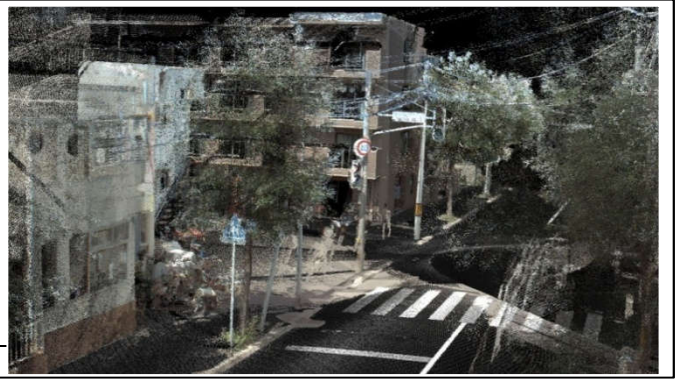
ALS
Airborne Laser Scanner





MMS
Mobile Mapping System





TLS
Terrestrial Laser Scanner

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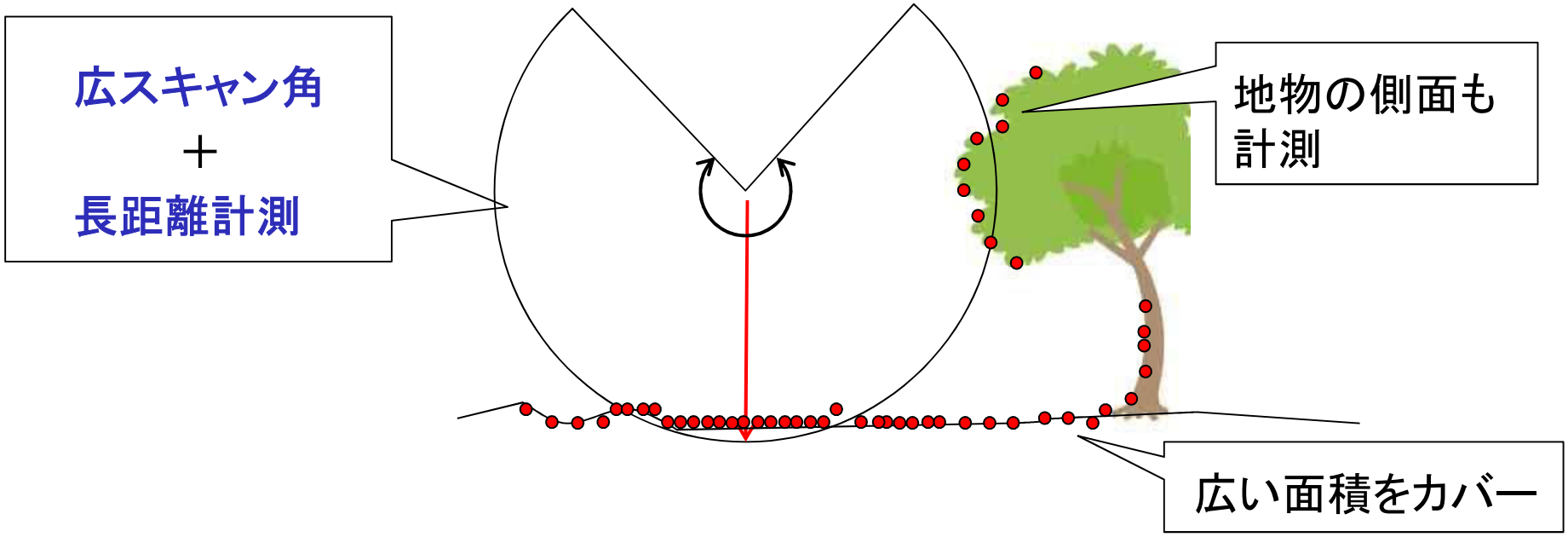
RIEGL JAPAN

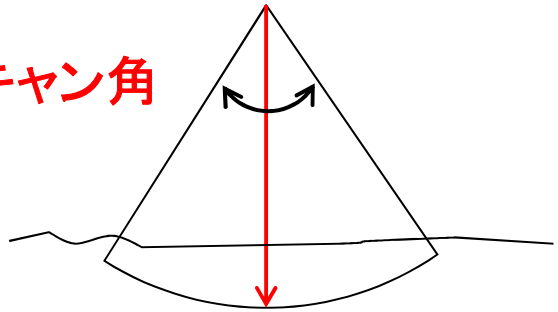
低空からの空撮範囲が広い

広スキャン角＋長距離計測でできること

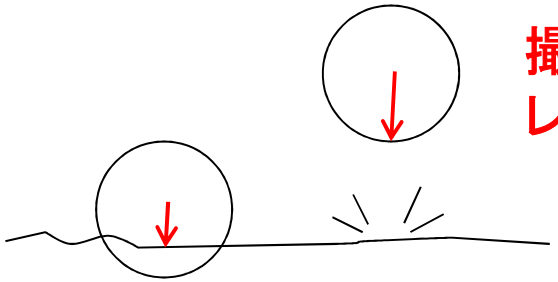


一般的な航空LiDAR

狭スキャン角



安価なスキャナ



撮影高度を上げると
レーザーが届かない

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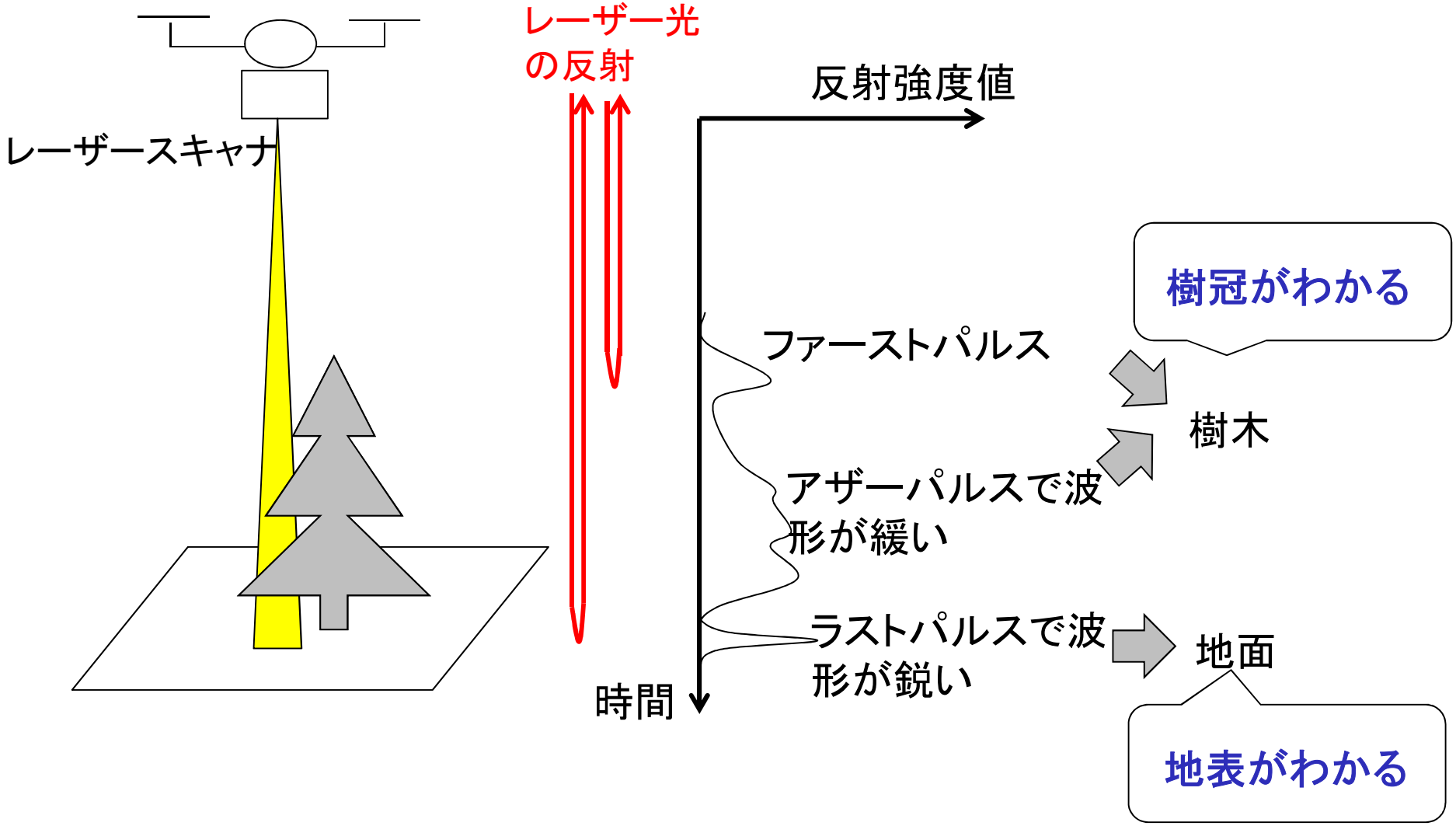
レーザー波形解析（航空LiDAR計測）

pp.128

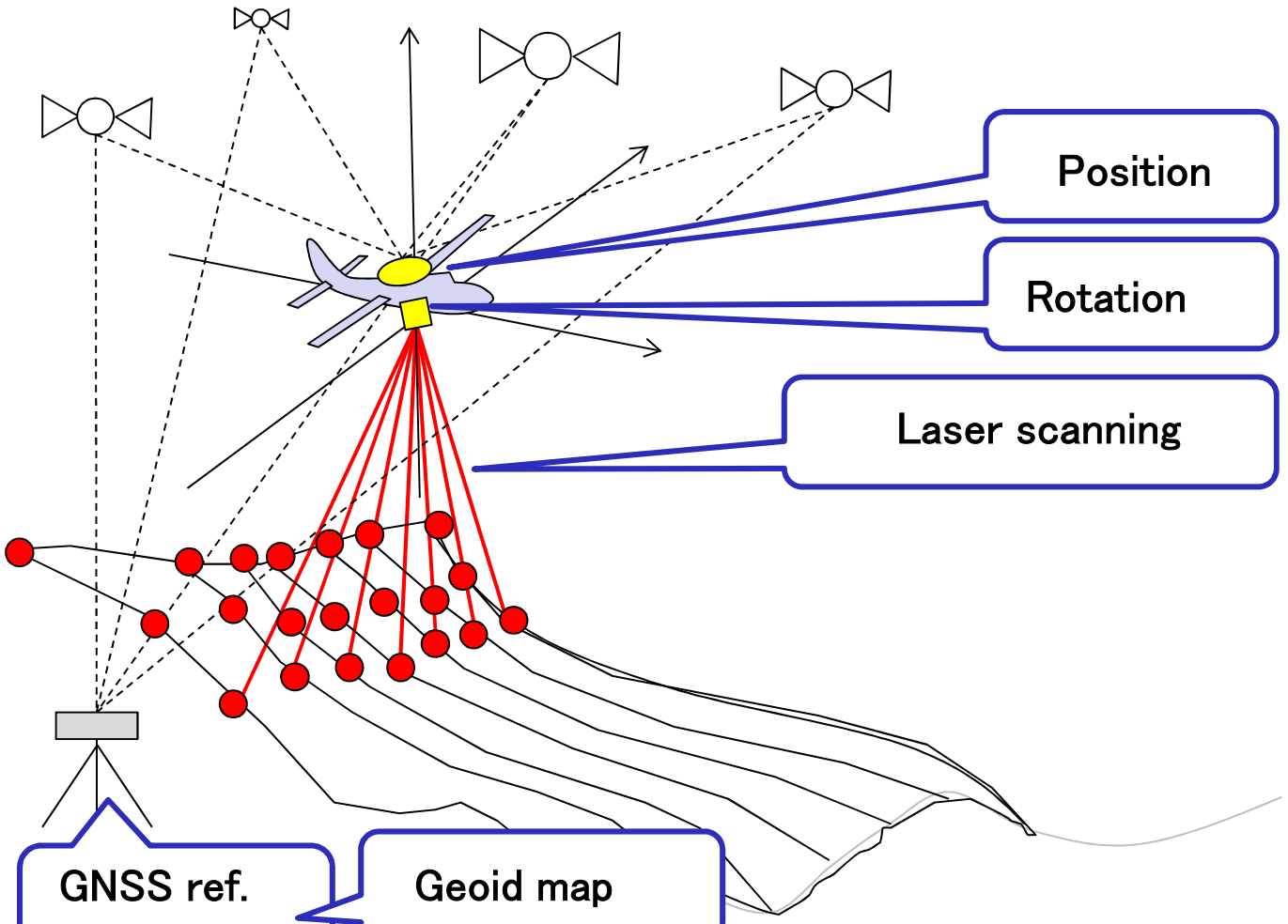
レーザーの反射波の到達順位を解析する → 計測物体の分類



NAKAGAWA Masafumi : mnaka@shibaura-it.ac.jp

Aerial LiDAR

Laser scanning + Position/rotation estimation



Position → Kinematic GNSS

Rotation → IMU

Laser scanning → Laser scanner

GNSS ref. points → Kinematic GNSS

Geoid map

Base stations and geoid map are required for aerial LiDAR

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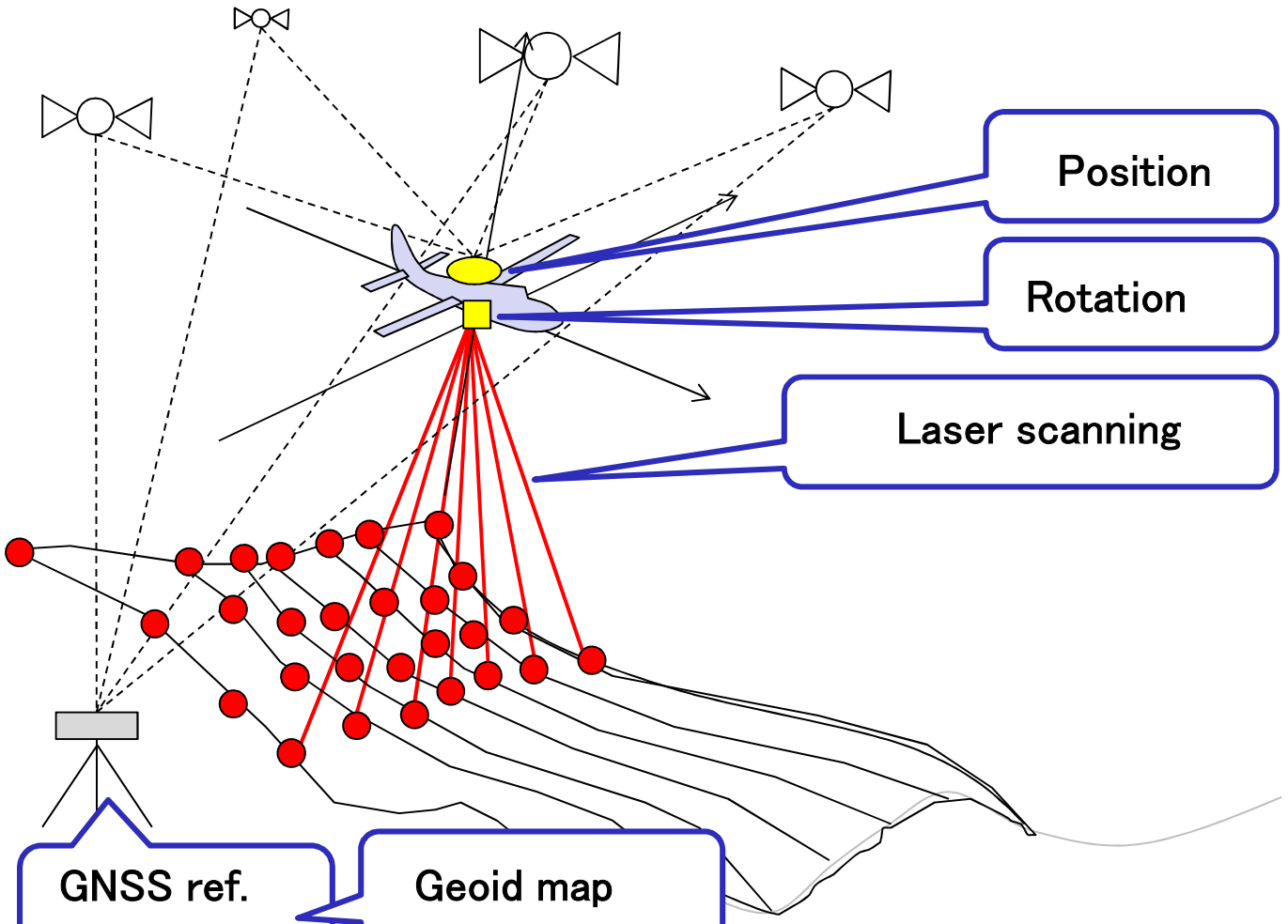
Aerial LiDAR

Laser scanning + Position/rotation estimation



Position → Kinematic GNSS

Rotation → IMU

Laser scanning → Laser scanner

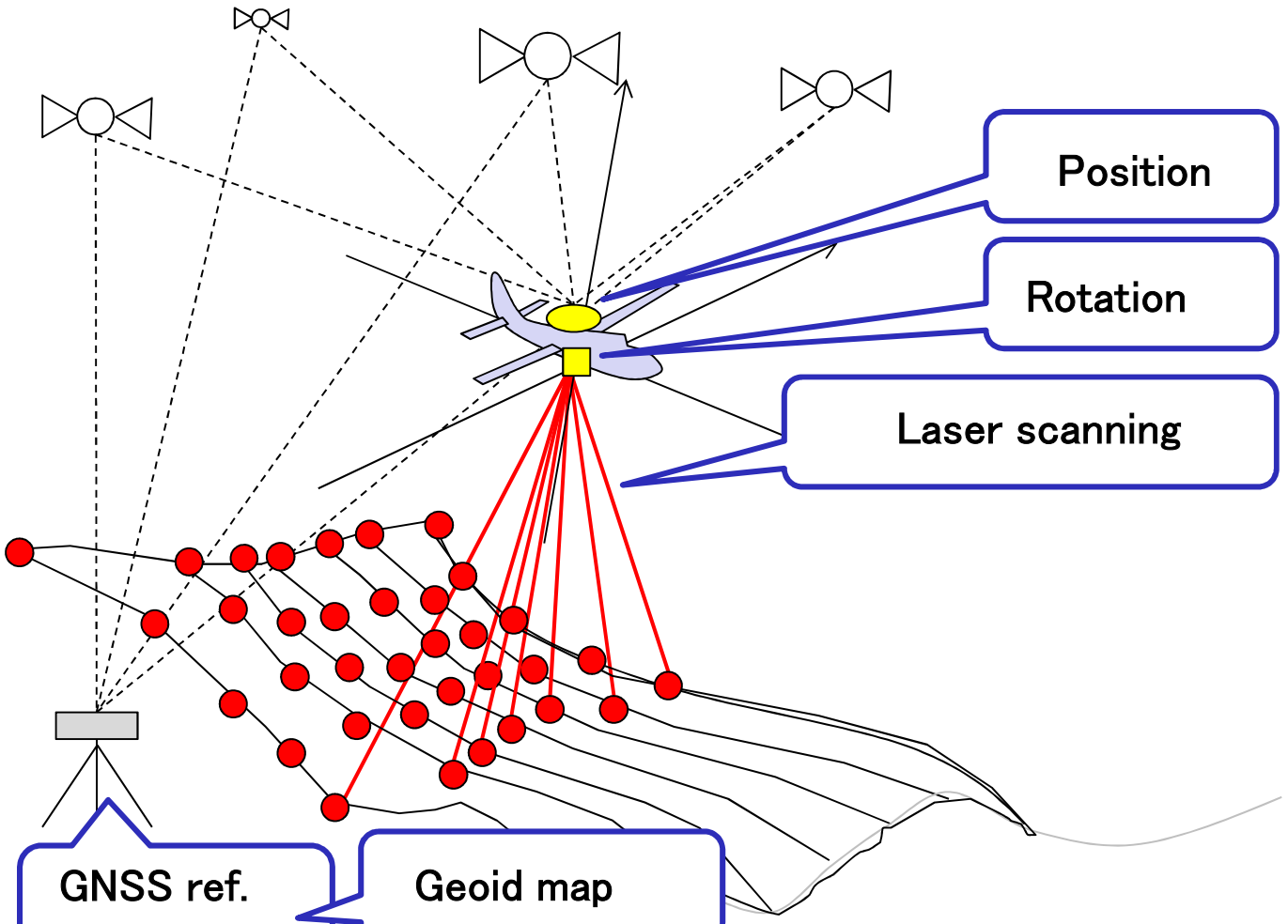
GNSS ref. points → Kinematic GNSS

Geoid map

Base stations and geoid map are required for aerial LiDAR

Aerial LiDAR

Laser scanning + Position/rotation estimation



Base stations and geoid map are required for aerial LiDAR

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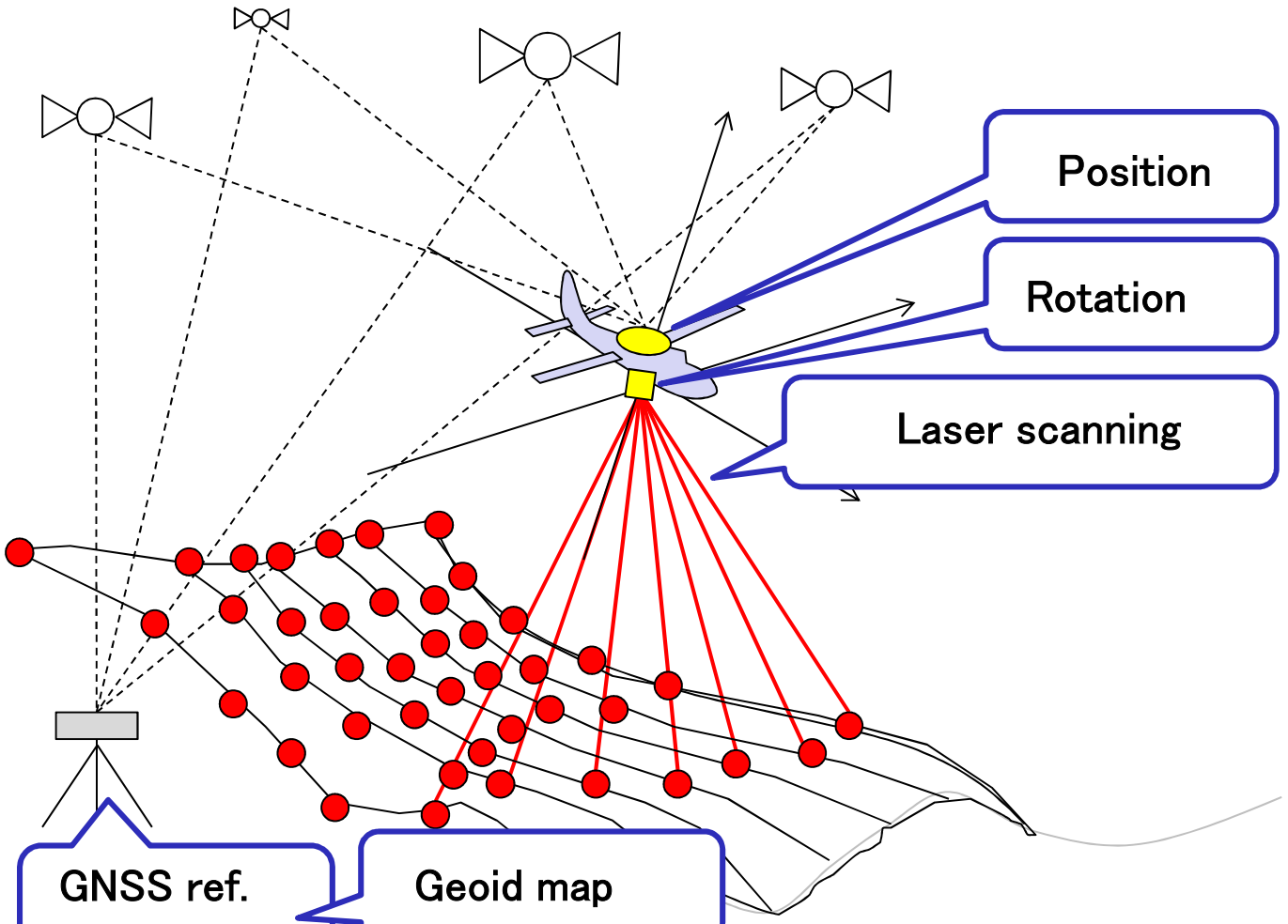
Aerial LiDAR

Laser scanning + Position/rotation estimation



Base stations and geoid map are required for aerial LiDAR

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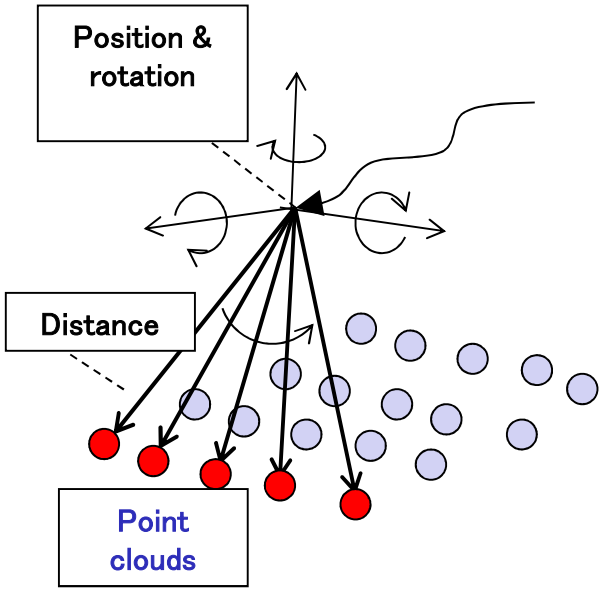
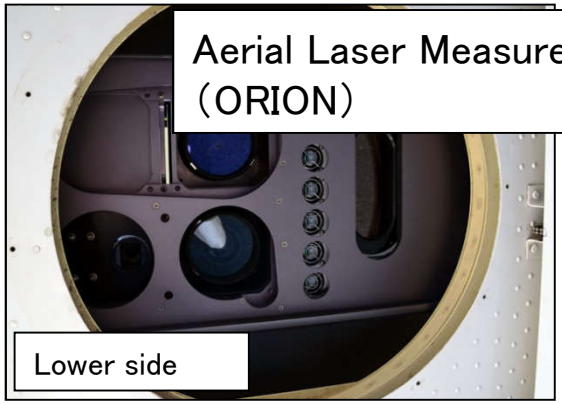
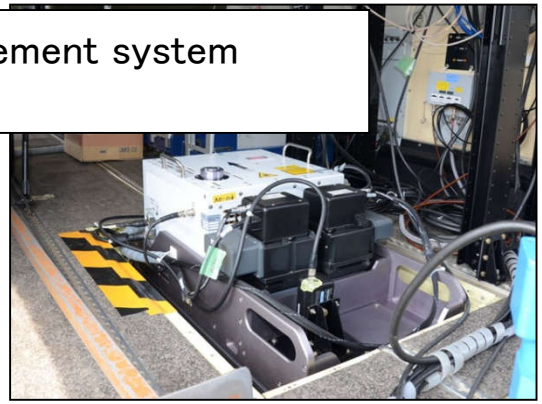
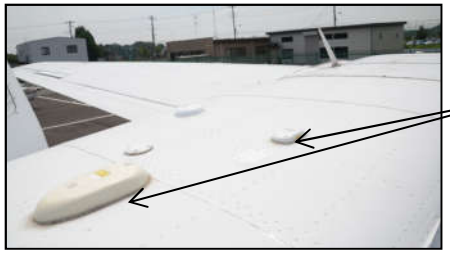
Aerial LiDAR

Laser scanning + Position/rotation estimation



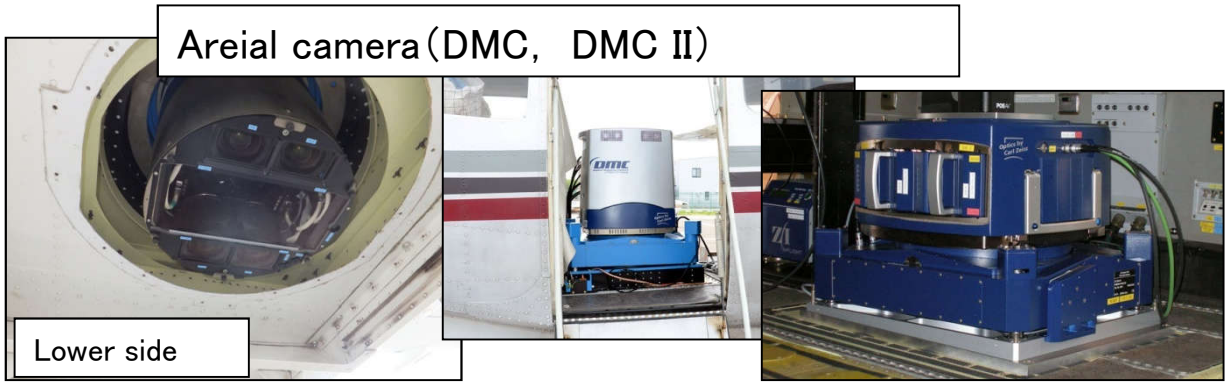






Data source :
ASAHI Co.,Ltd.

AERO



Ultra Long Range TLS

Suited for measuring snowy and icy terrain

http://www.geocom.cl/assets/6000_2.jpg

RIEGL VZ-6000

- 15mm accuracy
- Max. Range [m]: 6000
- Laser Class 3B

Main Applications

Glacier & Snowfield Mapping

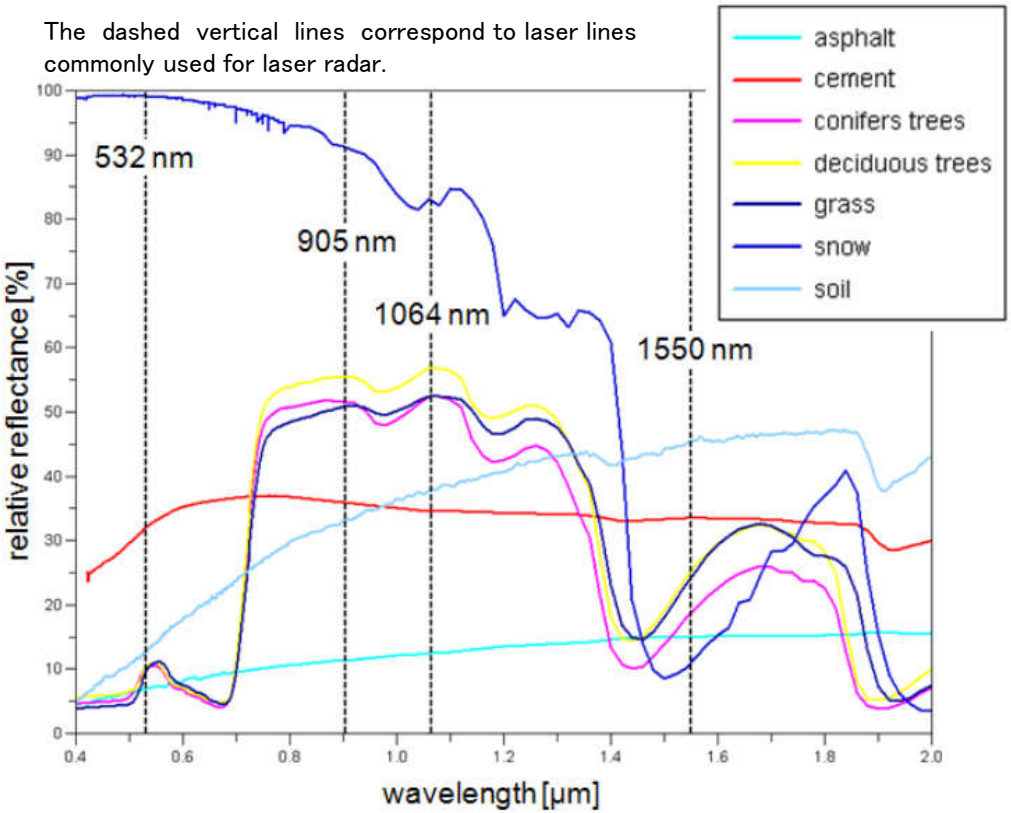
Topography & Mining

Civil Engineering, Archaeology

Reflectance vs. wavelength for different materials

(based on data courtesy to Baldridge, Hook, Grove, & Rivera, 2008, speclib.jpl.nasa.gov)

The dashed vertical lines correspond to laser lines commonly used for laser radar.

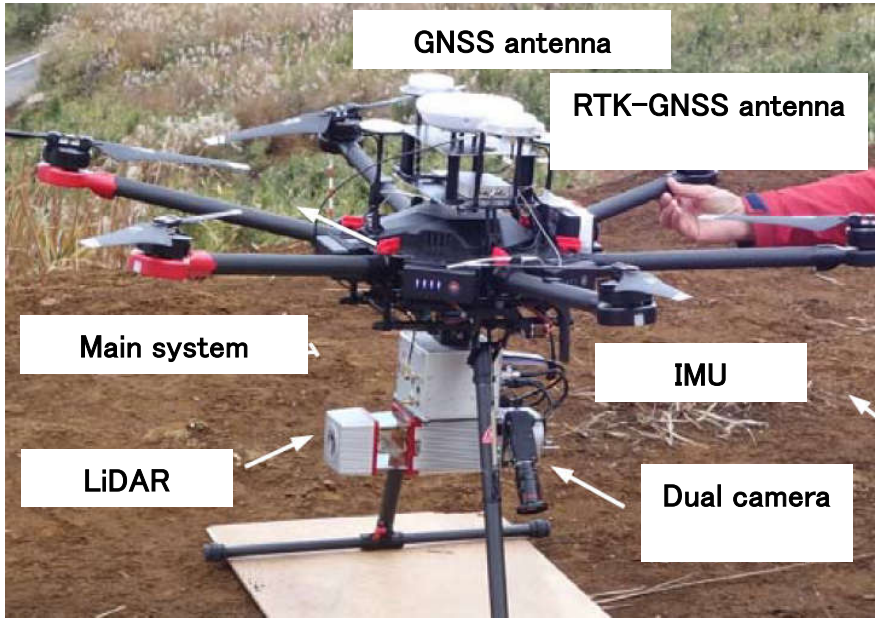


Martin Pfennigbauer, et al., Multi-Wavelength Airborne Laser Scanning

http://www.riegl.com/uploads/tx_pxpriegldownloads/Paper_ILMF_2011_RIEGL_Multiwavelength_ALS.pdf

Measurement Systems for Ground Survey

Drone LiDAR



Backpack LiDAR

Phoenix－RIEGL mini VUX

Leica pegasus backpack

? Weight

? Battery

? Temperature

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3D Mountain Modeling
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- Summary

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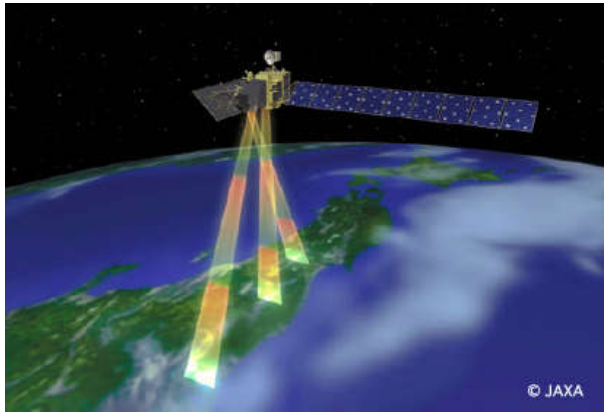
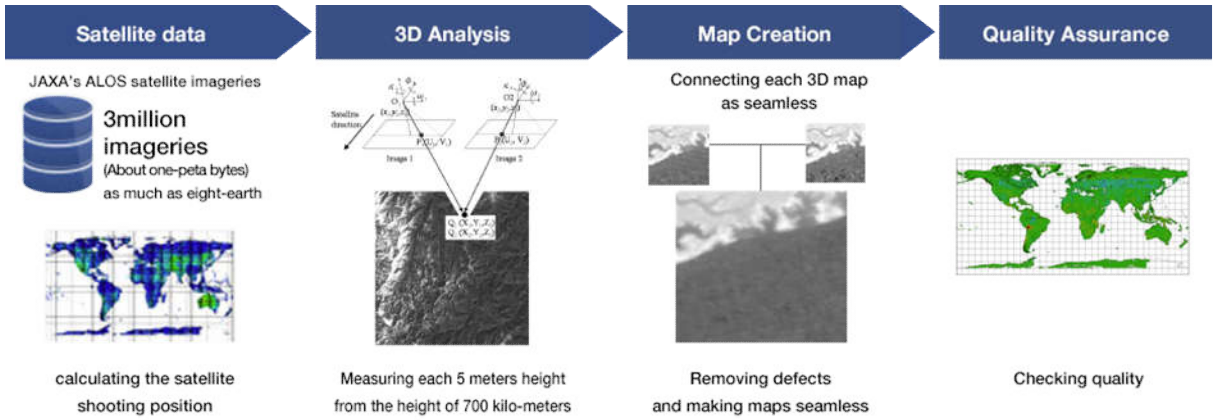
AW3D

World 3D Map using Satellite Images

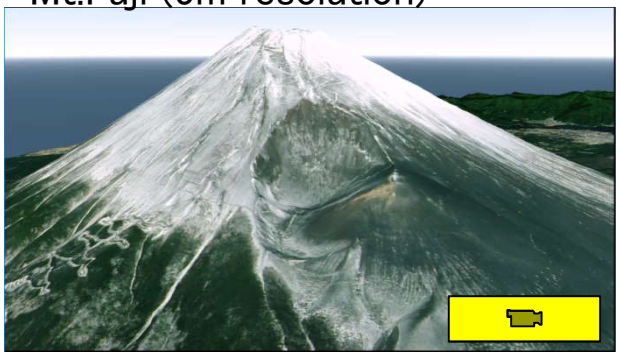
AW3D® http://www.aw3d.jp/en/ NTT DATA RESTEC



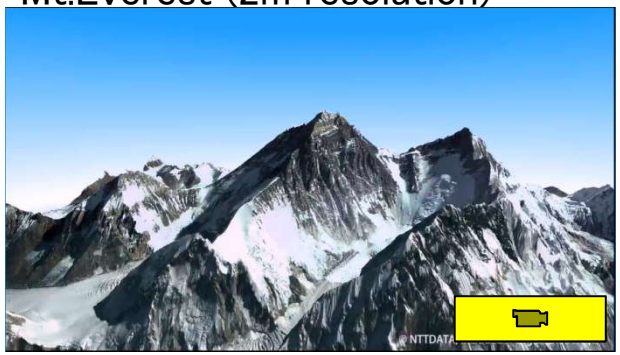


Tokyo (AW3D Metro)

Mt.Fuji (5m resolution)



Mt.Everest (2m resolution)



Height accuracy: 3m (standard deviation)

How to generate 3D data ?

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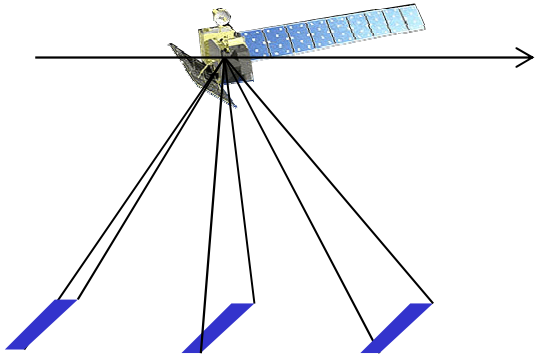
ALOS (Advanced Land Observing Satellite, 2006-2011)

- PALSAR
- AVNIR-2
- *PRISM*

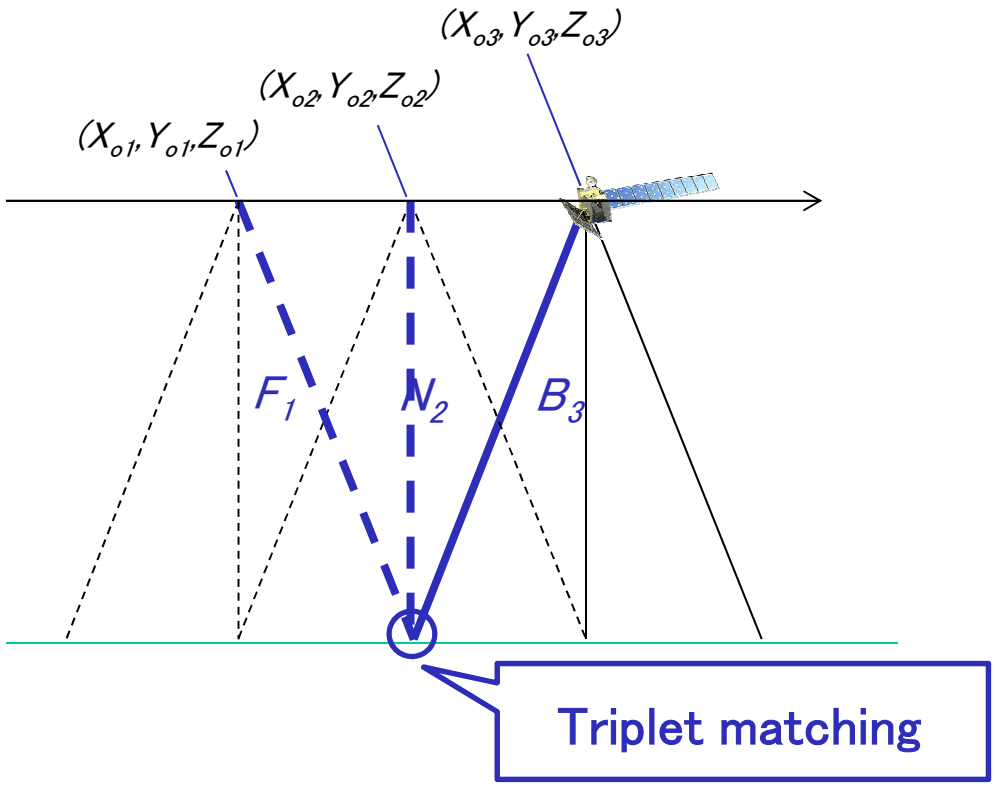
  Panchromatic Remote-sensing Instrument for Stereo Mapping



Optical sensor with three linear CCD in parallel, three linear images can be acquired at the same time.

Three Line Sensor

- Seamless linear images
- Triplet stereo images
- High resolution



PRISM can acquire triplet stereo imageries for 3D map generation

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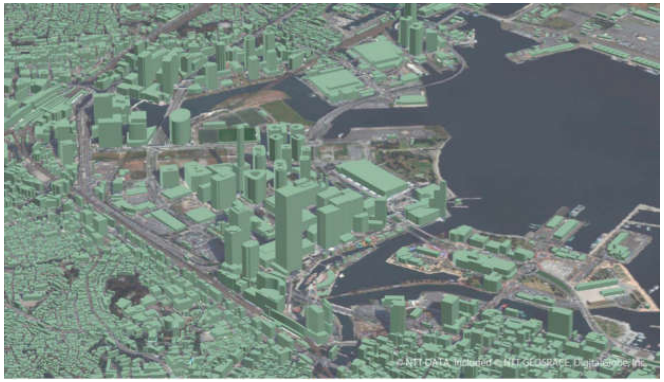
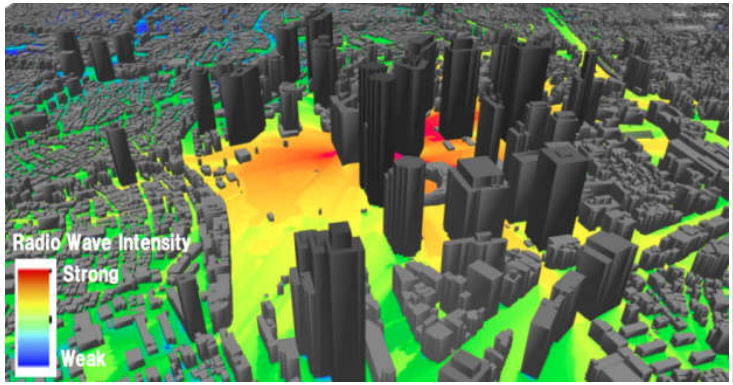
Case Studies using AW3D

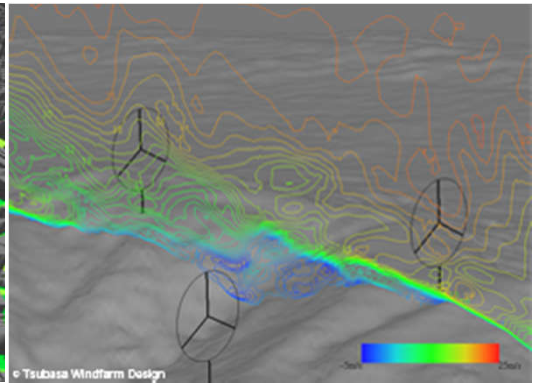
http://www.aw3d.jp/en/casestudy/case10-2/



Urban map



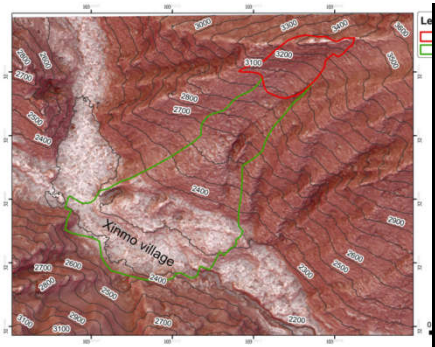
Signal propagation simulation

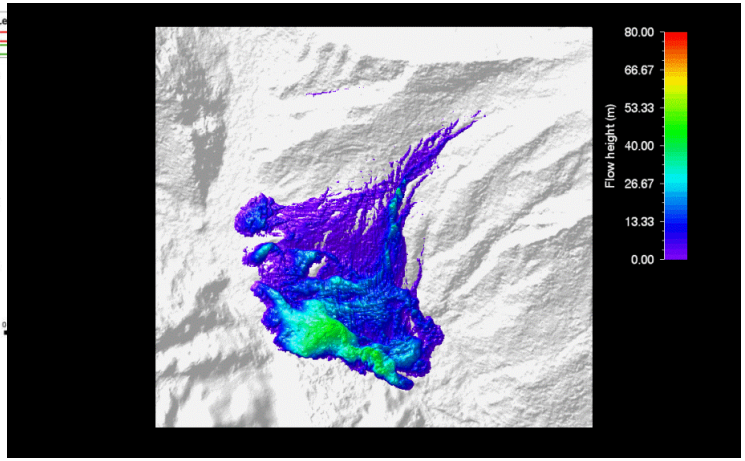


Selection of Wind Turbine Best Location

Hazard map

Landslide runout distance simulation





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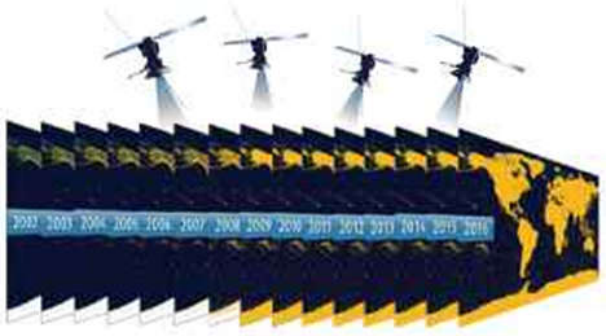
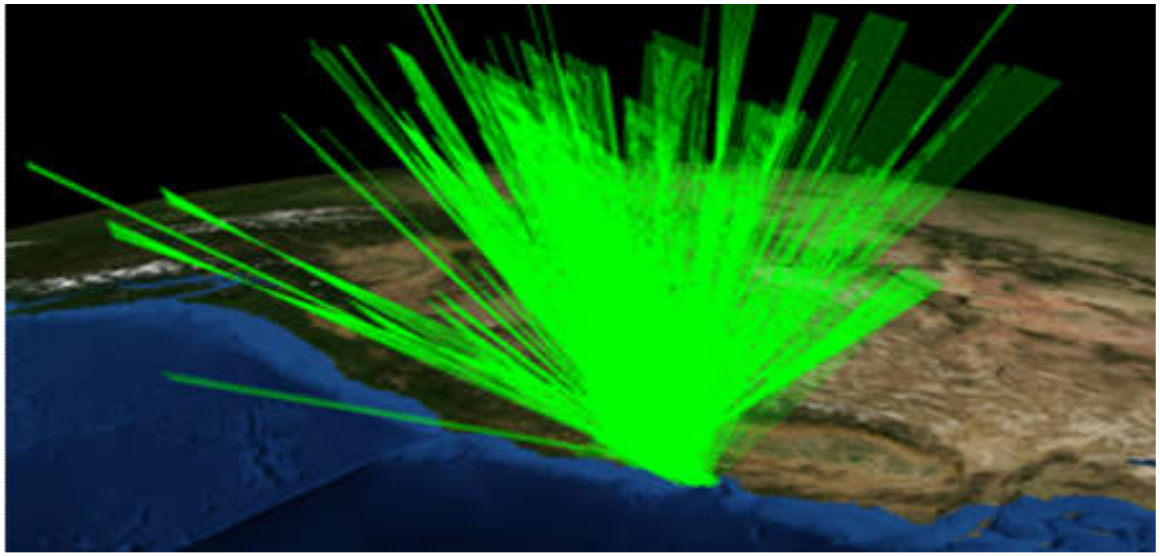
VRICON

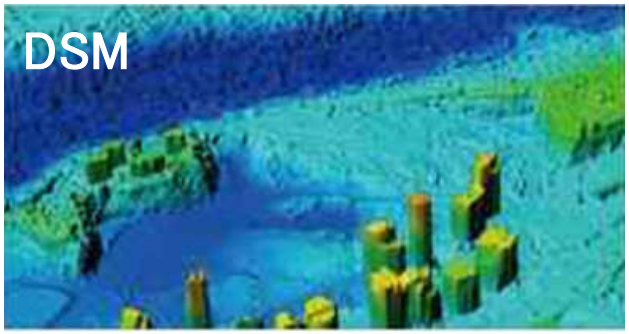
Stereo-photography and massive data processing

VRICON https://www.vricon.com/



20 scenes (3～5 years) are required for 3D modeling





0.5m resolution, 3m accuracy

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3D Mountain Modeling
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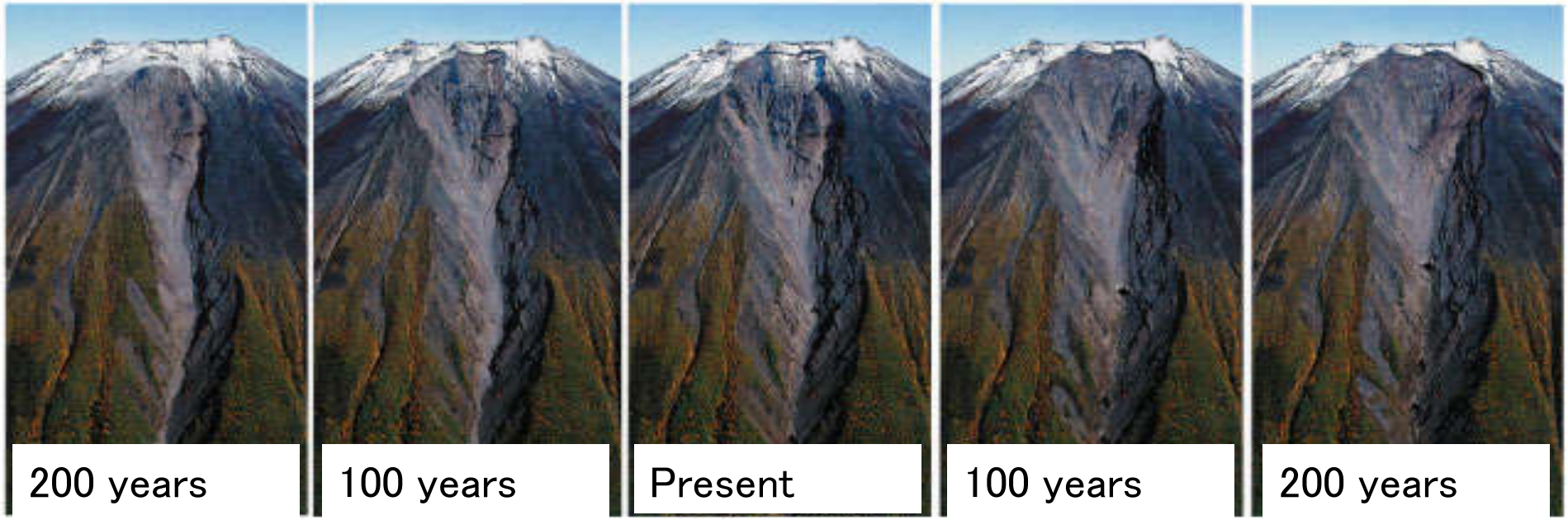
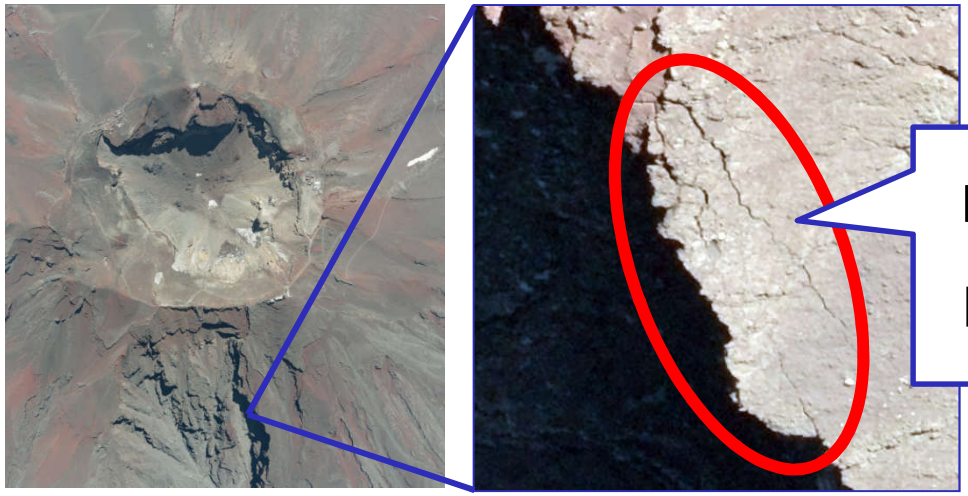
3D Mt. Fuji Survey Project with Asia Air Survey



http://sakuya.ed.shizuoka.ac.jp/sbosai/fuji/wakaru/020_art_08.jpg



Detect 3D cracks

➡ Predict rock mass collapse

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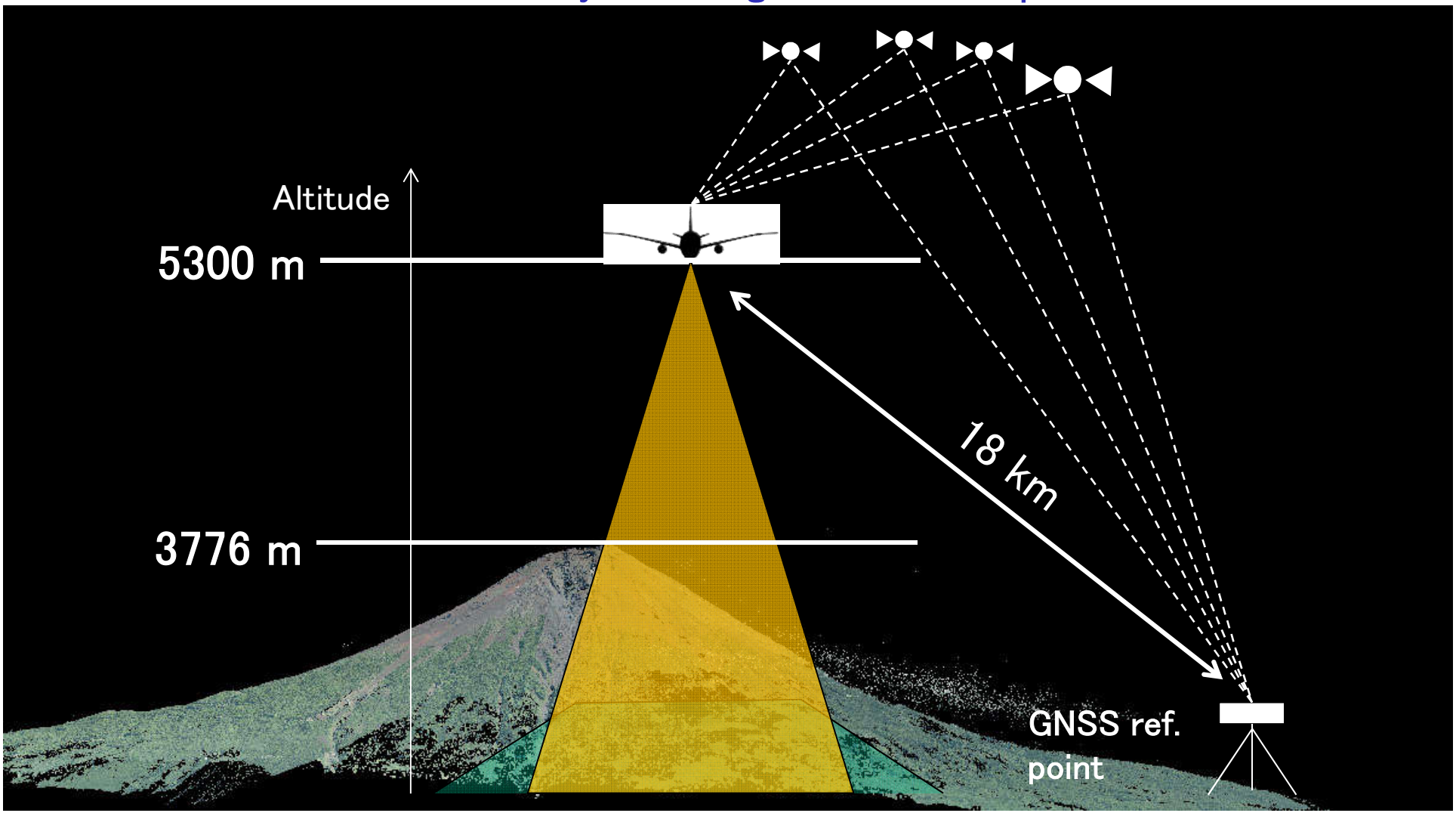
Survey plan

Aerial survey in the highest area in Japan



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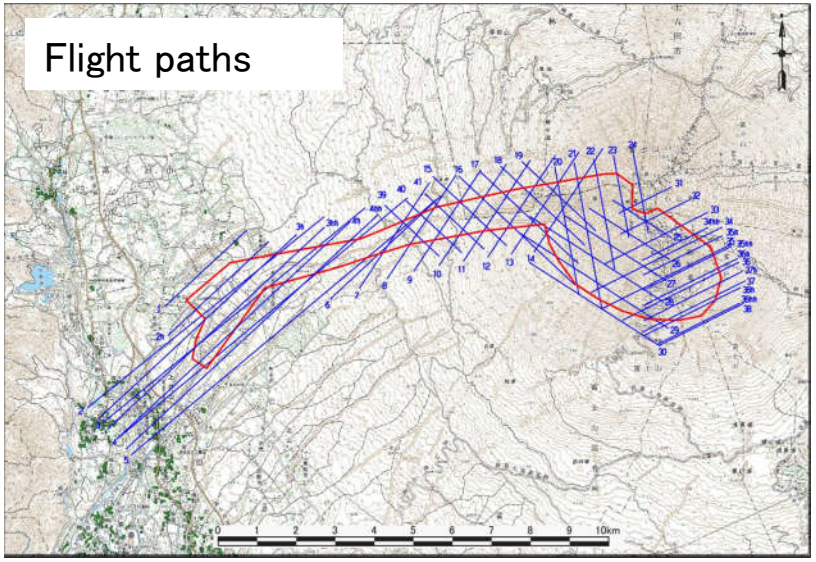
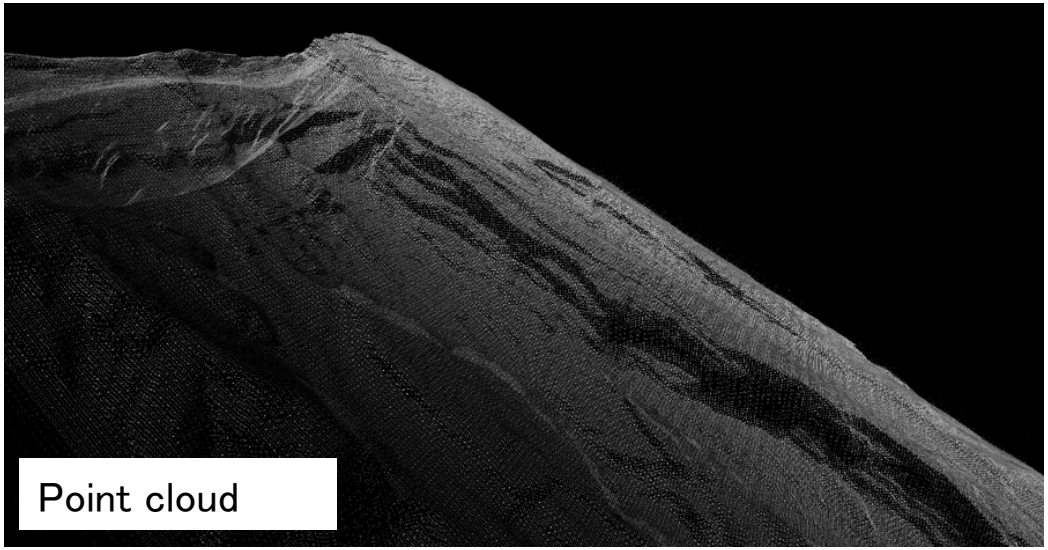
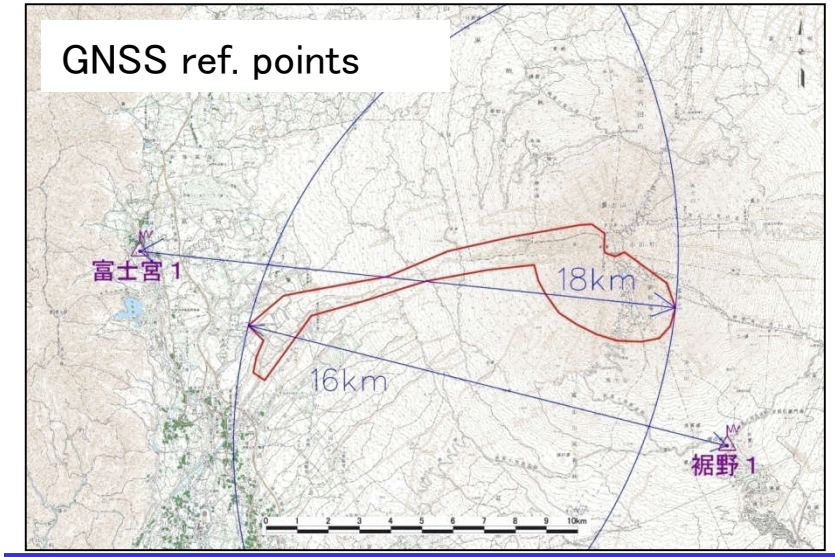
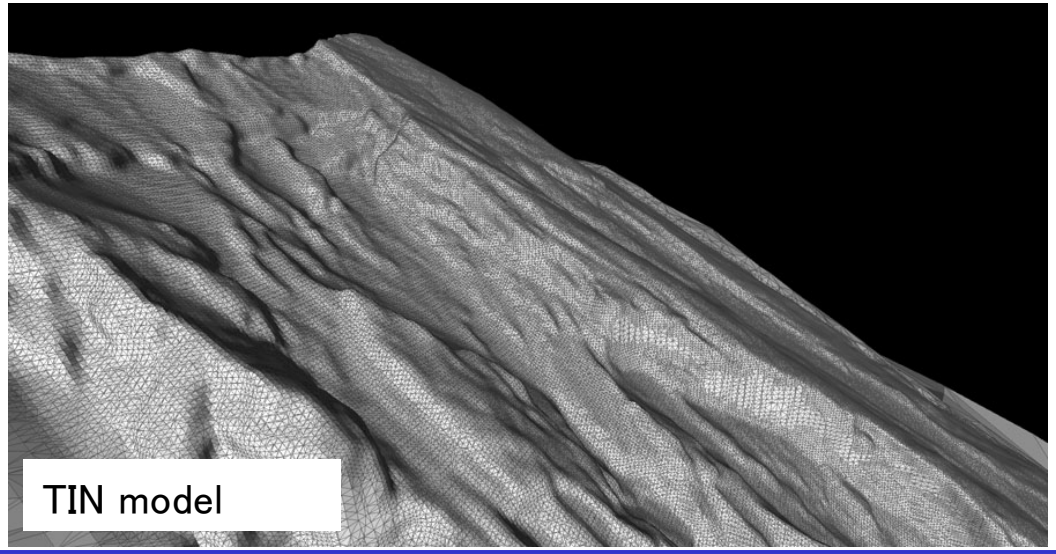
Acquired data (Aerial LiDAR)

100 cm resolution









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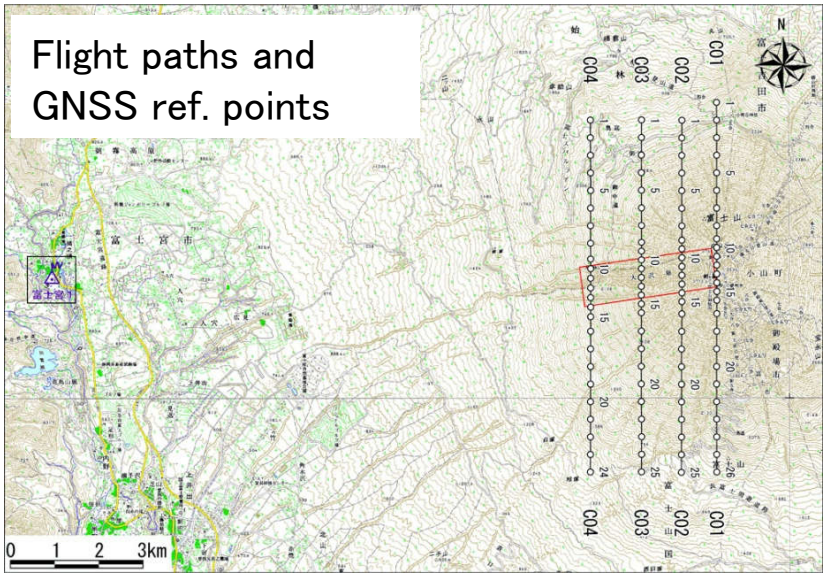
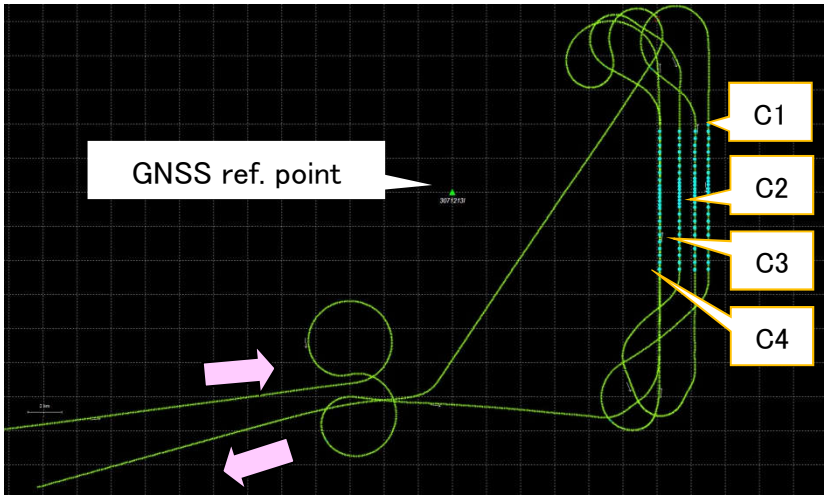
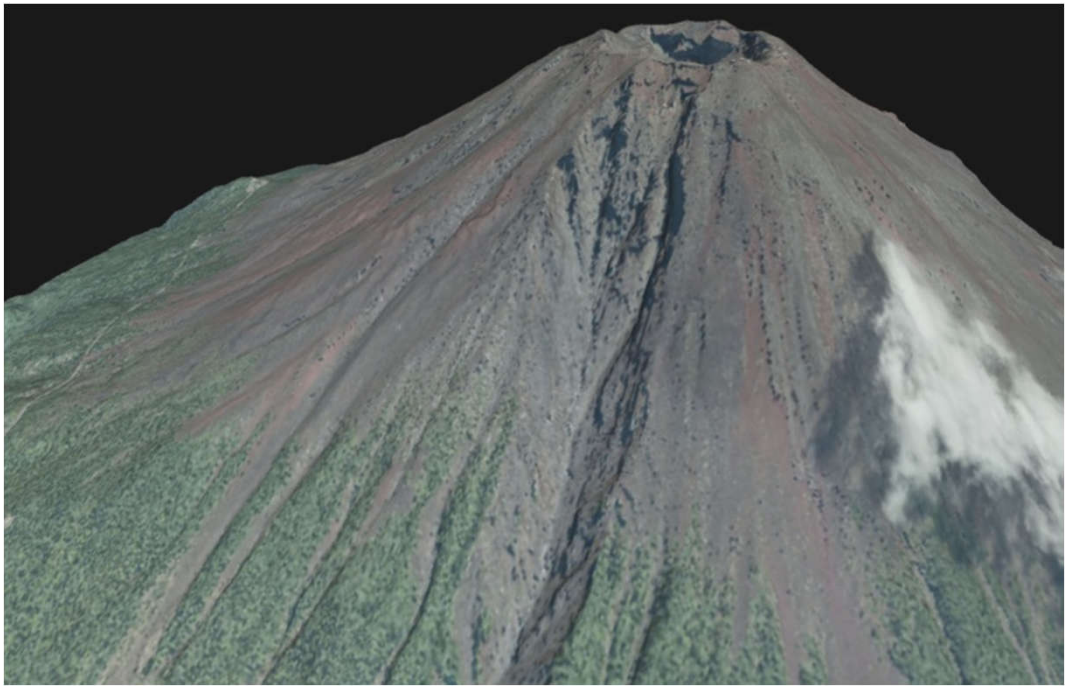
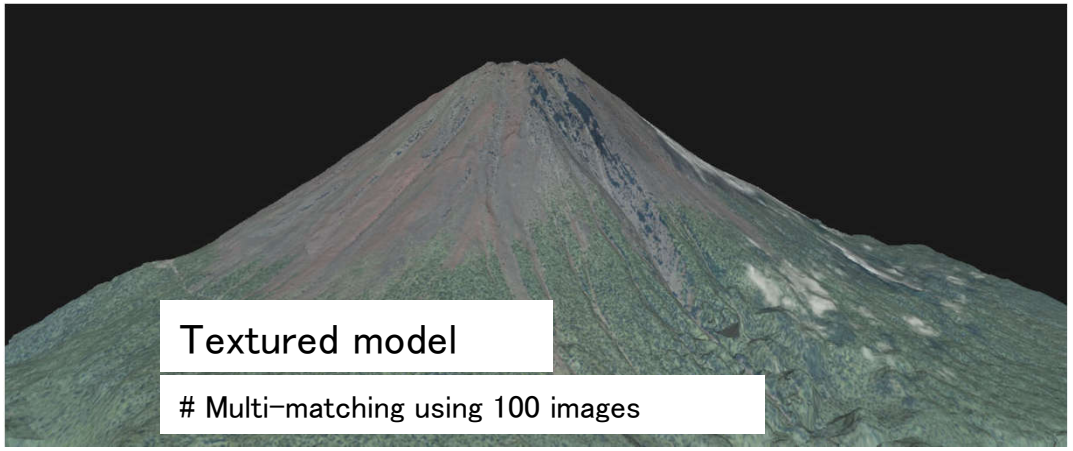
Acquired data (Aerial Photogrammetry)

10 cm resolution



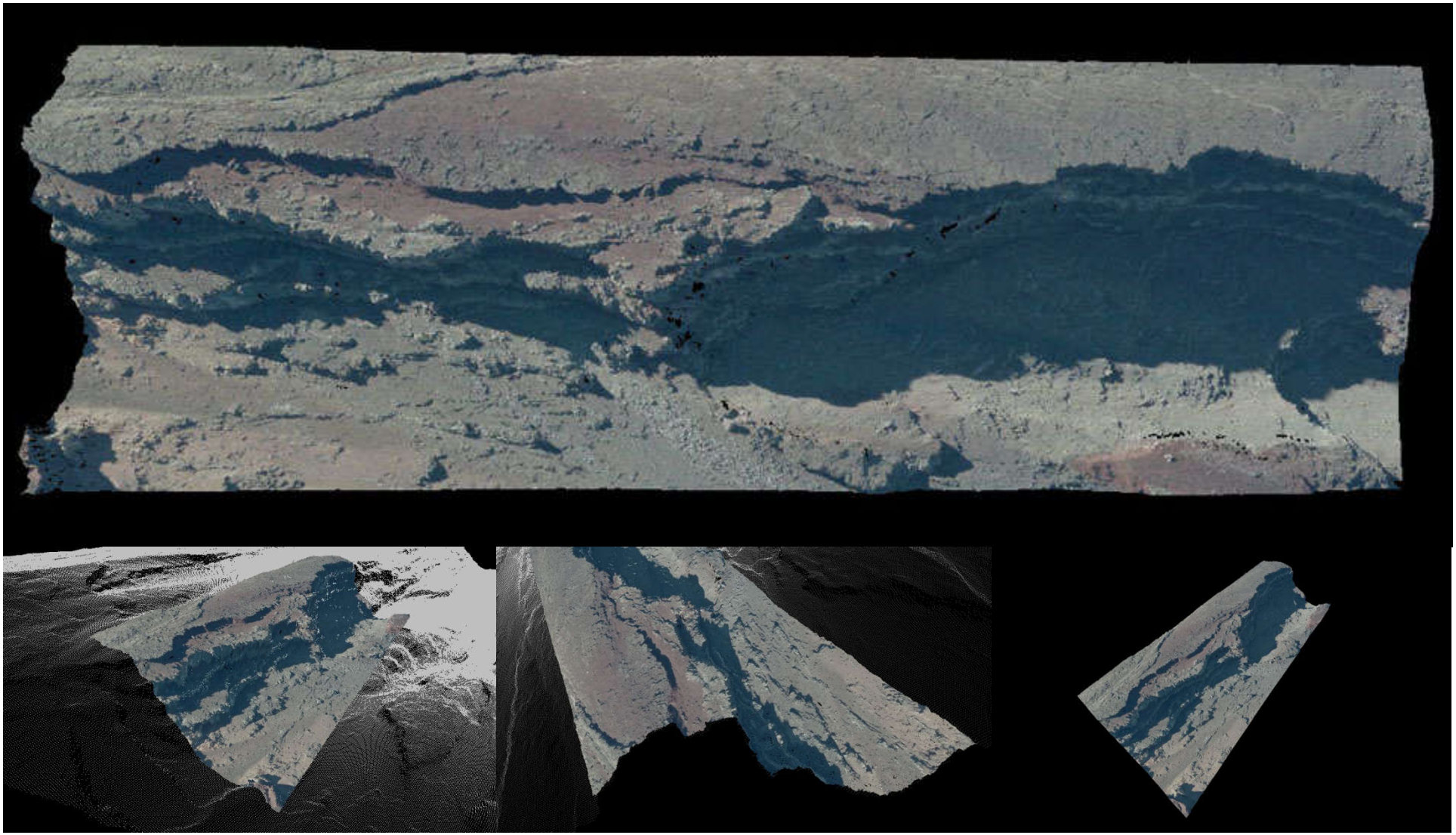






Dense Point Cloud for Crack Detection

Crack classification using intensity, distance, and slope



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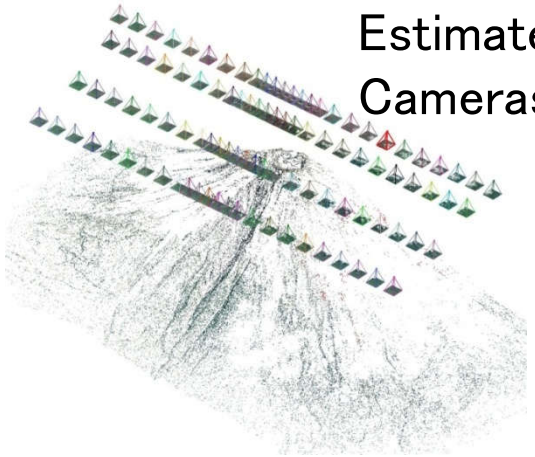
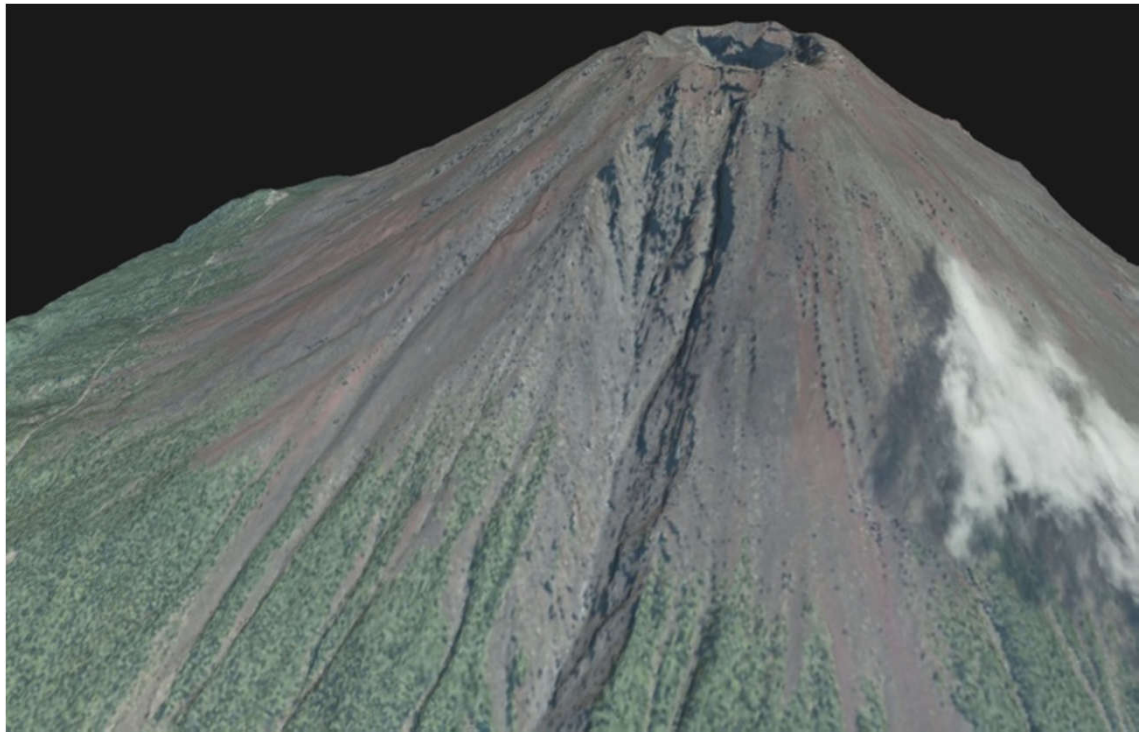
3D Data Generation using Aerial Images

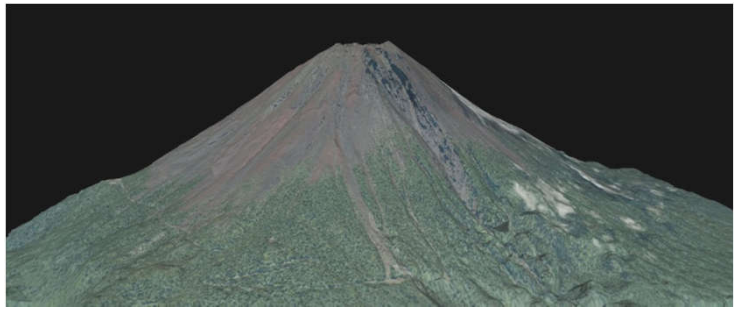
3D terrain surface model using 100 aerial images

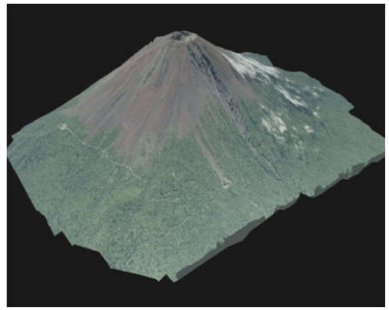


Estimated Cameras

- Image Match: 1389 s
- 3D reconstruction: 143 s
- Dense reconstruction: 378 s







3D terrain surface model using 100 aerial images

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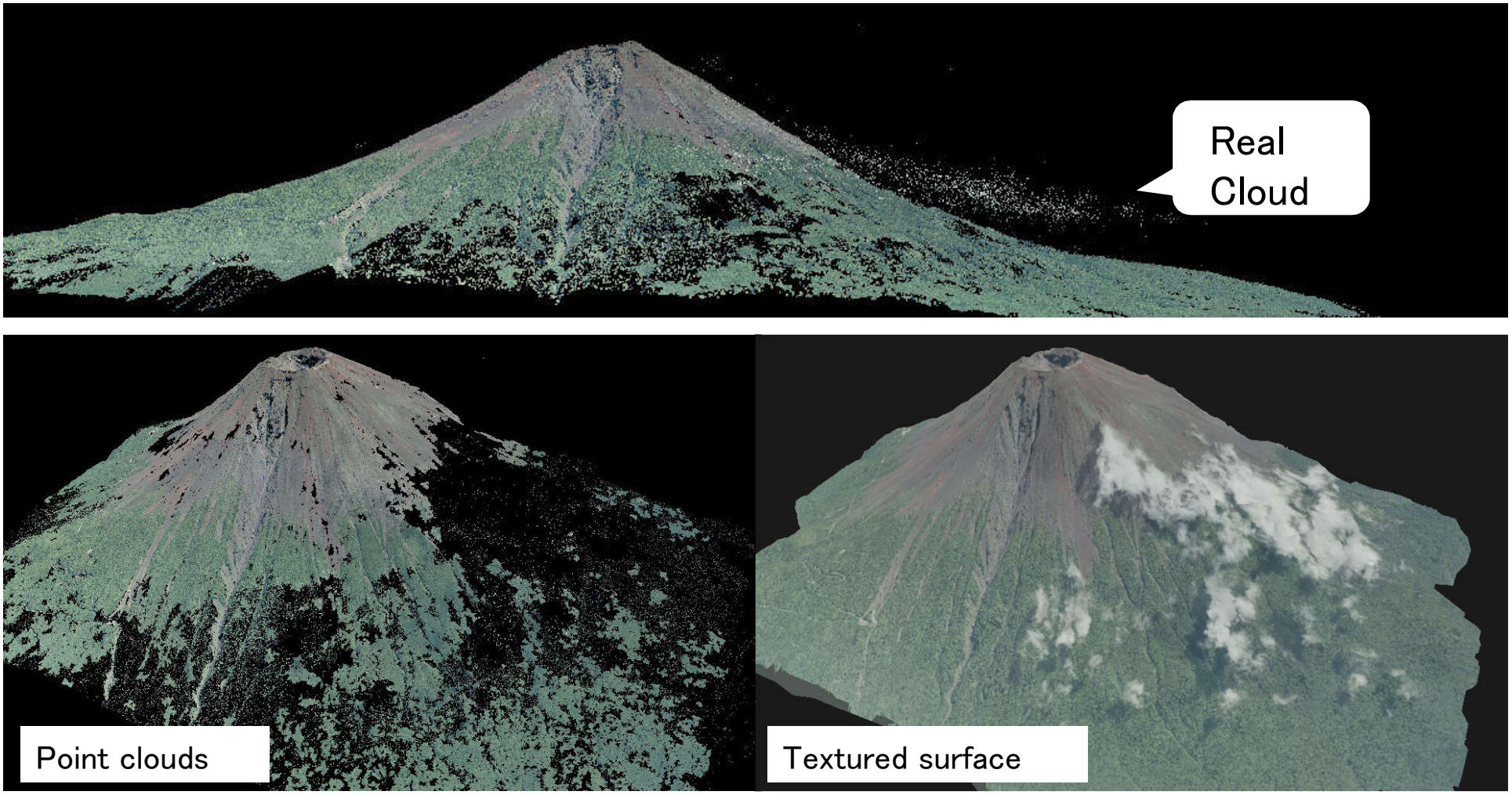
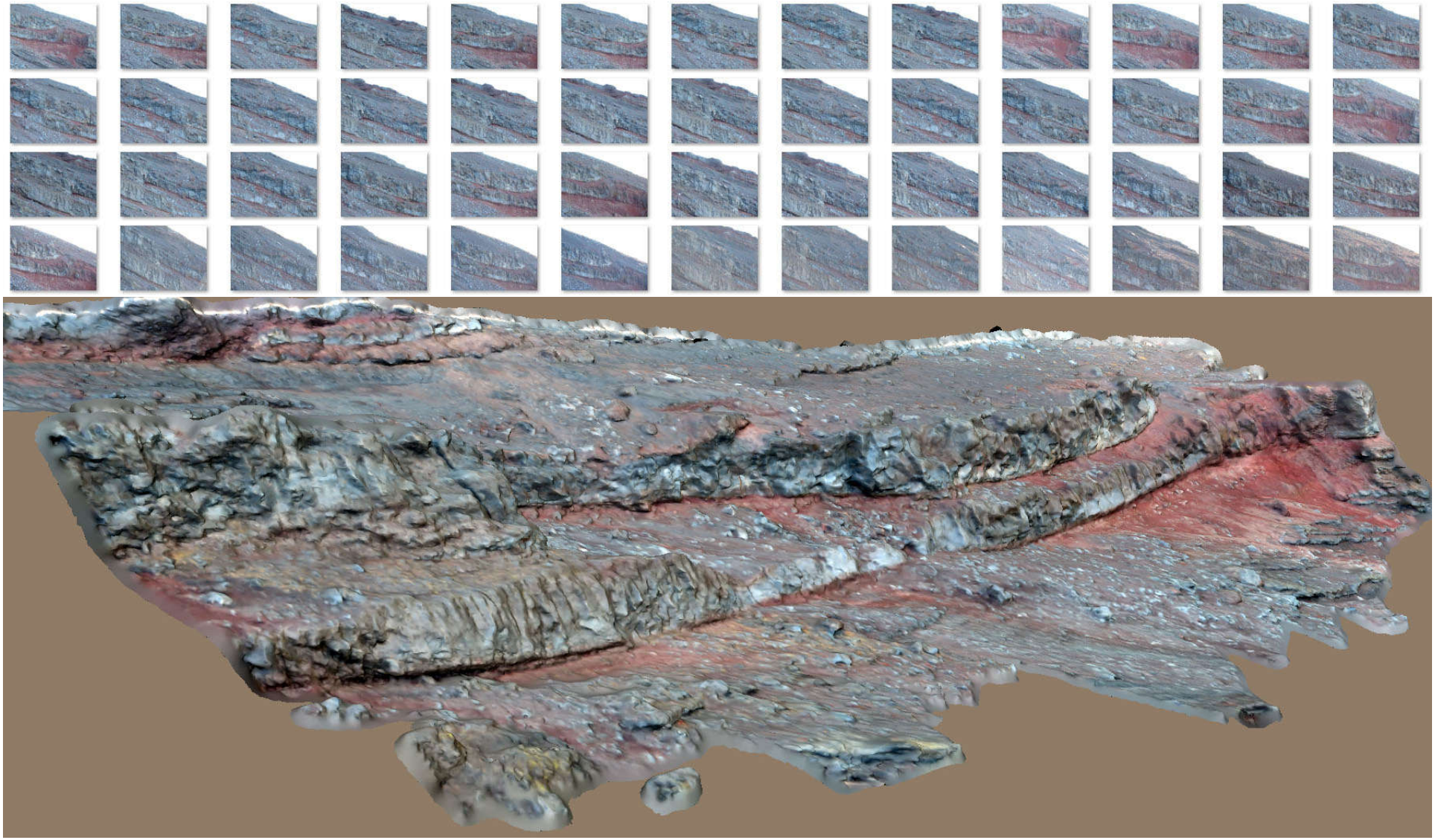
Technical Issue in Image Matching

“Cloud” in Point Clouds



3D Modeling using Ground Survey Data

Cover the details of ground surfaces



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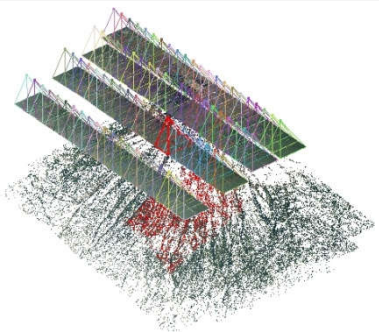
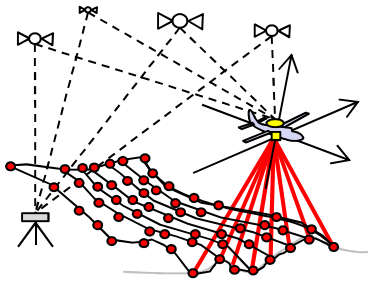
3D Mountain Modeling using Aerial Images, Aerial LiDAR data, and Satellite Data

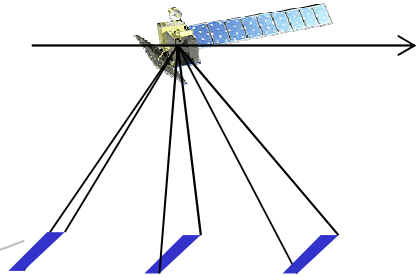
3D measurement systems, 3D data generation, and the Mt.Fuji SABO project



Aerial Photogrammerty



Airborne Laser Scanning



Satellite imaging

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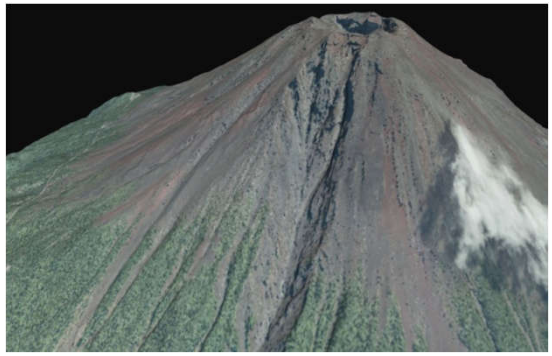

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- GNSS ref. points
- Precise Geoid map
- 3D map

Spatial infrastructure can be used for various fields

Transportation

Disaster

Agriculture

Construction

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