Final Workshop on J-RAPID-Nepal
June 21-22, 2016, Kathmandu

Damage Mapping of April 2015 Nepal Earthquake using Small UAV

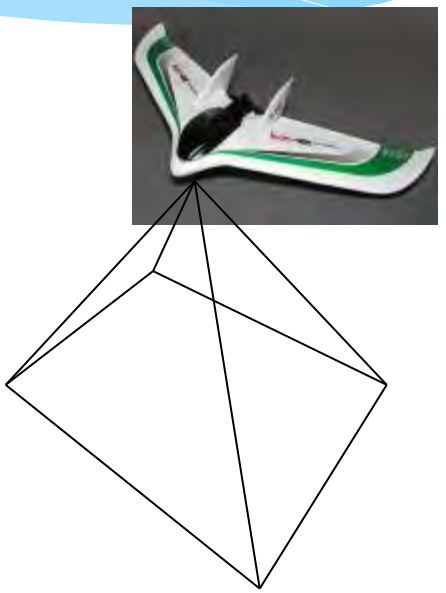
Hiroshi Inoue[*1], Tsuneo Ohsumi[*1], Hiromichi Fukui[*2], Ramesh Guragain[*3], **Gopi Krishna Basyal**[*3], Suresh Chaudhary[*3], Sujan Raj Adhikari[*3]

*1 National Research Institute for Earth Sci. and Disaster Resilience
*2 Chubu University
*3 National Society for Earthquake Technology-Nepal (NSET)

Outline

NSET presents

1. Overview of earthquake damage
2. Background of the proposal
3. Original Plan
4. UAV regulation and permission



NIED presents

5. Survey report

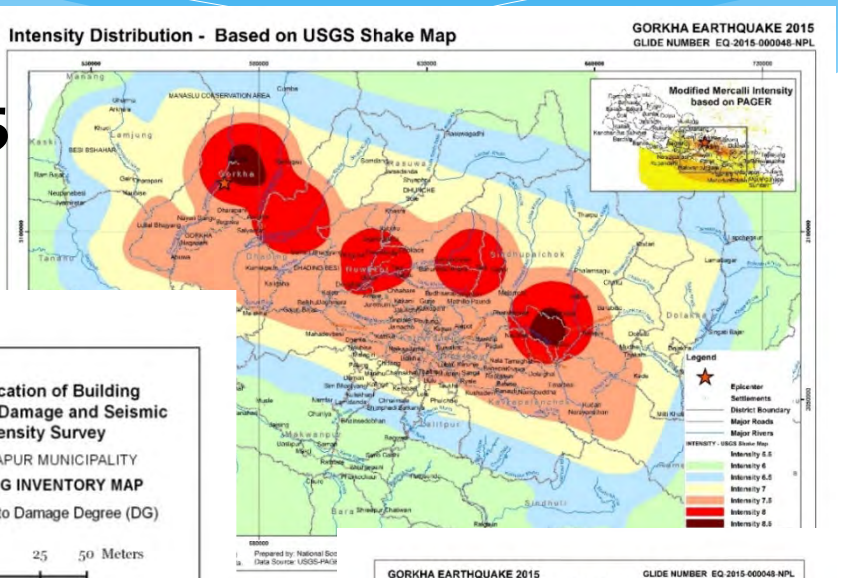
   Sankhu,Chautara (Heli), Langtan(UAV), Charikot(Heli)

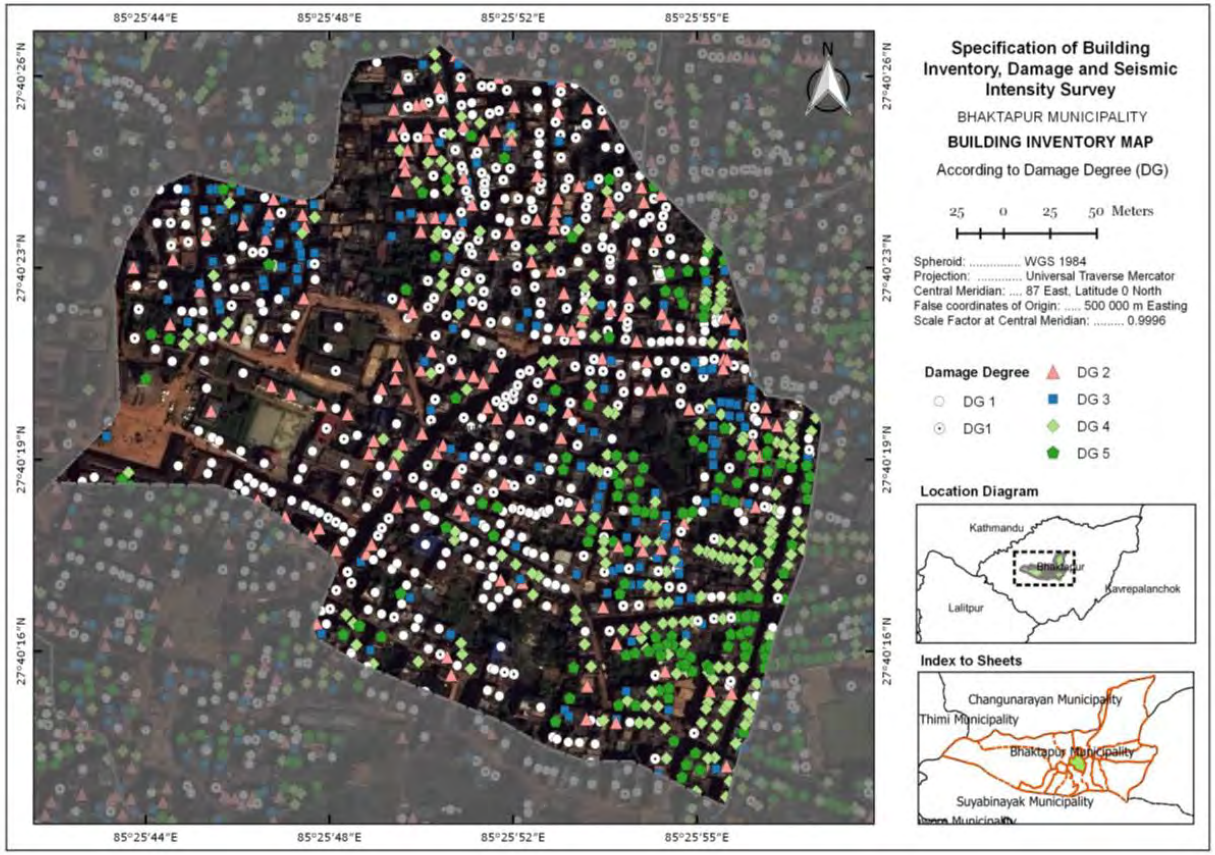
   Khokana, Bungmati, Bhaktapur, Bhainsepati(UAV)

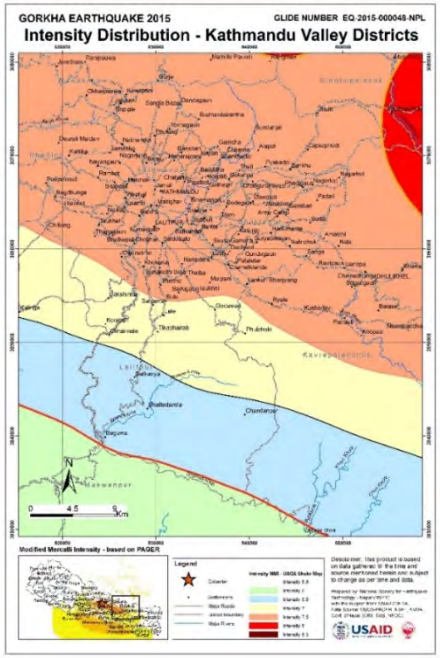
6. Discussion
7. Conclusion

Overview of earthquake damage

Intensity Map based on USGS, 2015 April 25 Gorkha Nepal Earthquake







Background of the proposal

NSET's damage mapping and motivation

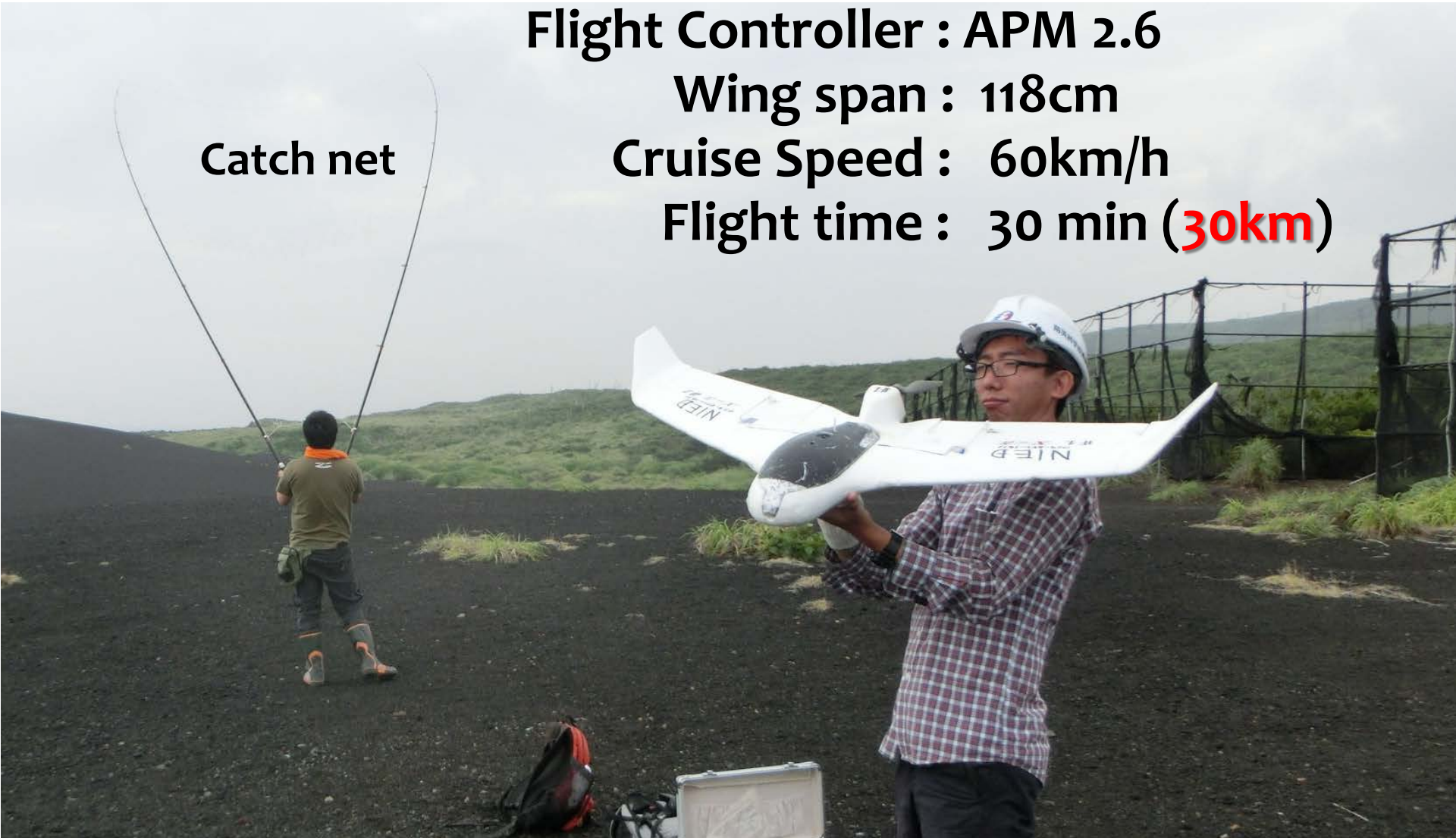
* Building damage survey – in earthquake hit areas (200,000 buildings),
* Rapid assessment is required quickly for planning purpose – relocation, shelter, displace, evacuation sites identification, possible open spaces etc.
* Proposed for UAV survey for planning and quick extract of data using UAV, low cost, high resolution information of damaged area.
* Building damage assessment with oblique photographs – identification of damage grade
* Proposed low-altitude aerial photo surveys

Going Low Altitude for High Resolusion

Camera On	Ground Altitude	Resolution	Can identify damage level down to
Satellite	300 km-	1 - 10m	5 : Total Collapse
Plane/Heli	300m-3km	0.1 - 1m	4 : Heavy Damage
UAV	30m-300m	3 – 30 cm	3 : Moderate Structural/ High Non-structural Damage
Pole	3m-10m	0.3 – 1 cm	1 or 2 : Non or Minor Structural Damage
Human	1.5 m	0.1 - 1cm	1 or 2 : Non/Minor Structural Damage

Our UAV is a fixed-wing plane

Long-range and Safety



Safety is of paramount importance to fly UAVs over inhabited areas, not to make another disaster

One crash every hundred flight is unavoidable in current technology of small UAV


Fixed-wing plane

Less chance to injure people because

1 Made of soft material
2 Break itself to absorb shocks
3 Propeller is facing rear
4 Glides to fall in case of trouble
5 Less flights due to longer range


Multicopter

More chance to injure people because

1 Made of hard and sharp material
2 Not designed to break
3 Propellers are exposed
4 Simply falls in case of trouble
5 More flights due to shorter range

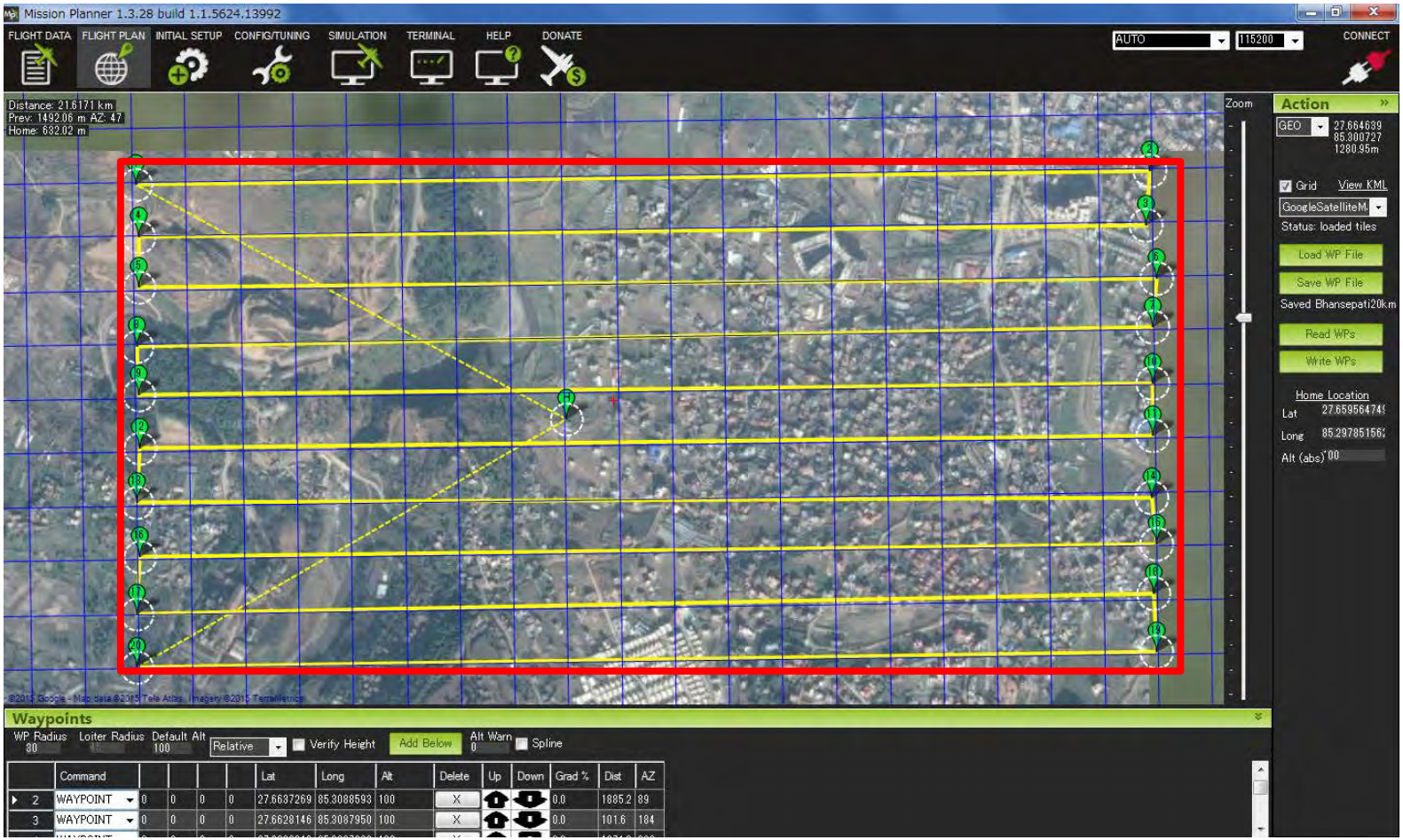
Hand Launch and Net Catch

Take-off

Landing

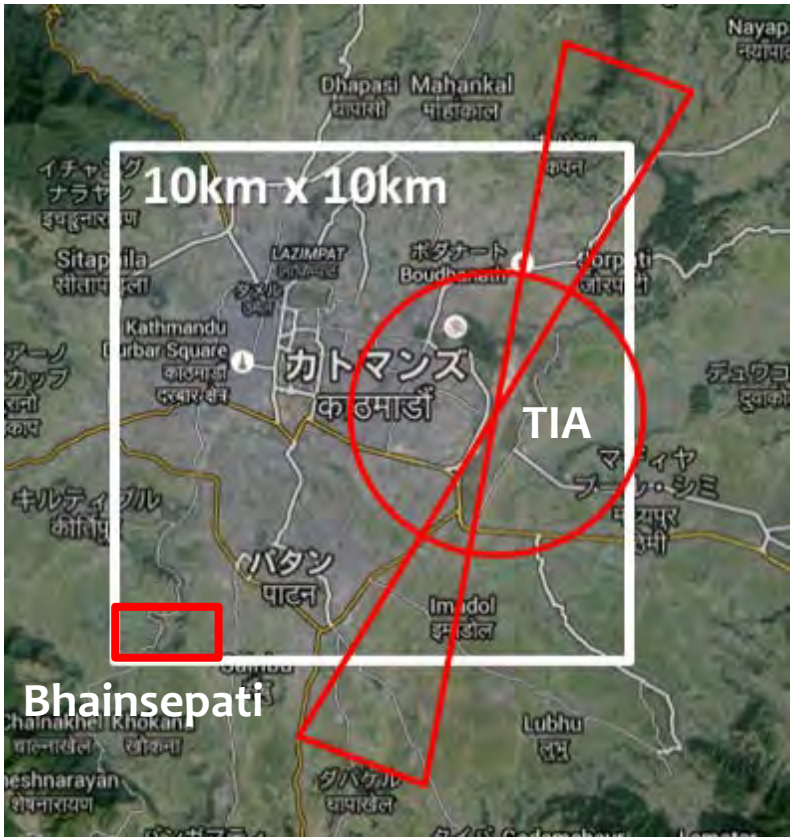
An example mission in Bhainsepati, Lalitpur

2 km² area in one flight of 22km (22 minutes) at 150m ground altitude, 100m lane interval



Original Plan

Central 100 km² Area of Kathmandu Valley to be surveyed by 2km² x 50 flights in non-rainy 10 full working days



- Jun 1- UAV permission
- Jun 15- Pilot survey in Bhainsepati
- Jun 20- Full-scale survey in Kathmandu Valley
- Jul 31 Completion of UAV survey in Central KV
- Aug 31 Preliminary damage map of a part of central KV

UAV: Legal Provisions and Permit Process in Nepal

MoHA on behalf of GoN, issued UAV Flight Procedure, 2015

1. Submit documents to CAAN

- A Filled form with UAV details
- Request Letter
- Copy Map of Operation area/plan
- No Objection, Recom' tion from Concerned Authorities
- Security Clearance

2. Process from CAAN

- Permission from MoHA,
- Permission from Nepal Army, Nepal Police, Armed Police Force
- Permission from MoIC
- Permission from TIA

General Permission

3. Submit Flight details to CAAN

Individual permission

Flight under coordination with local police, and presence/ consent/ liaison with govt. CAAN

Time-line of UAV permission to our J-Rapid project

2015

May, NIED-NSET-KVDA collaboration

May 31, Approached to KVDA

Jun 1, JICA Letter to KVDA

- Letter to MoUD by KVDA –

Jul 16, Request from MoUD to MoHA, MoD, MoCTCA

- Responses from Security forces –

Aug 18, Response from MoUD to KVDA

Oct 28, Response from CAAN

Nov 21, Response from MoIC

Dec 4, Permission from MoHA

Feb 22, 2016 Final Permission from CAAN to KVDA (before 6AM)

Jun 7, 18, 19, Flights in Khokana, Bhakutapur, and Bhainsepati

Survey plan loses values every month

Sankhu, Chautara Heli

Langtang UAV

Survey plan loses value every month

Charikot Heli

UAV was finally allowed in KV, but only before 6AM

To avoid plane bird-strike, because,
1) Birds are surprised by UAV to fly,
2) It takes one hour to settle down,
3) The first flight of TIA is at 7AM.

Sunrise in Kathmandu

Jan 6:56	July 5:18
Feb 6:42	Aug 5:34
Mar 6:13	Sep 5:49
Apr 5:39	Oct 6:04
May 5:15	Nov 6:25
Jun 5:08	Dec 6:47

(on 15 of the months)

Only one flight in May, Jun, and July is possible

Our UAV flight path was tangled
Going nowhere

We had to switch the target to study technical feasibility of quick damage mapping applicable to Nepal for future disasters

by

1. Experimental UAV survey in KV, and outside KV

2. Helicopter survey in Sankhu, Chautara, Charikot

3. Proposing alternative methodology

4. UAV Seminar and Training for the future

Heli Survey 1, Aug 20, 2015

Kathmandu

Sankhu

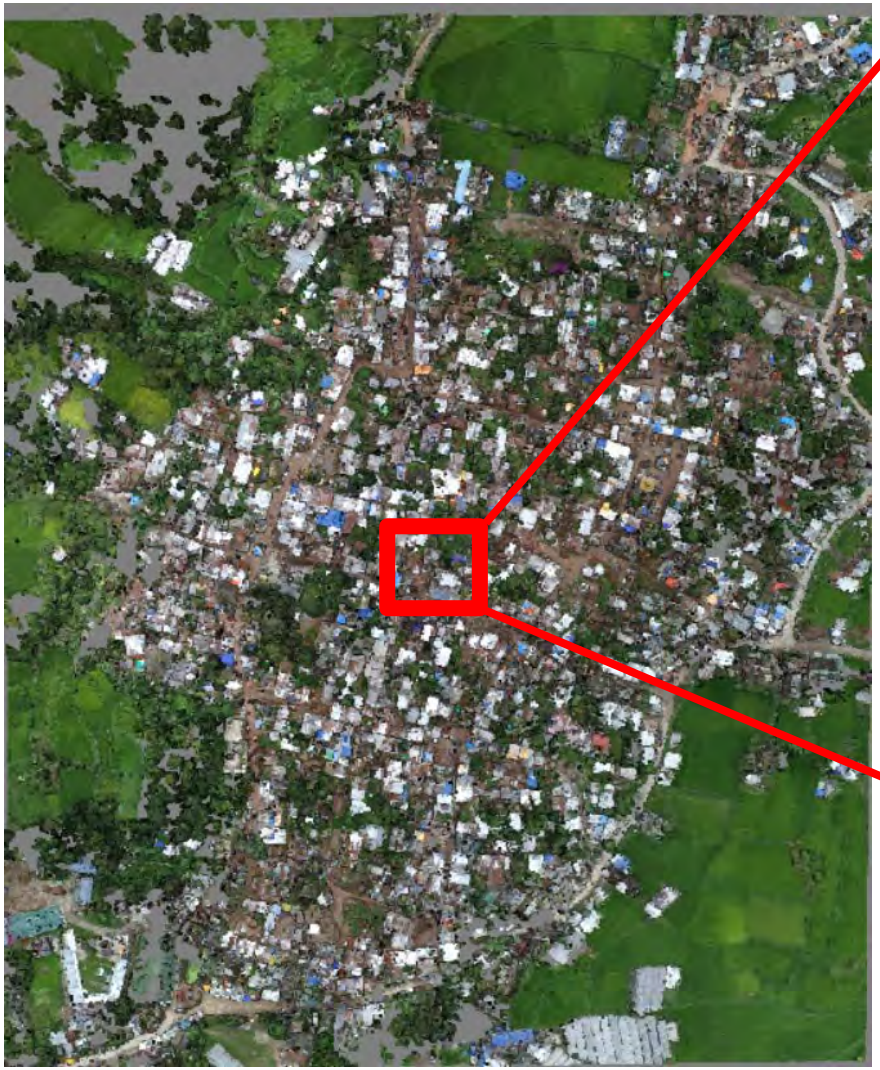
Chautara

Sankhu Oblique photos by Ricoh GR

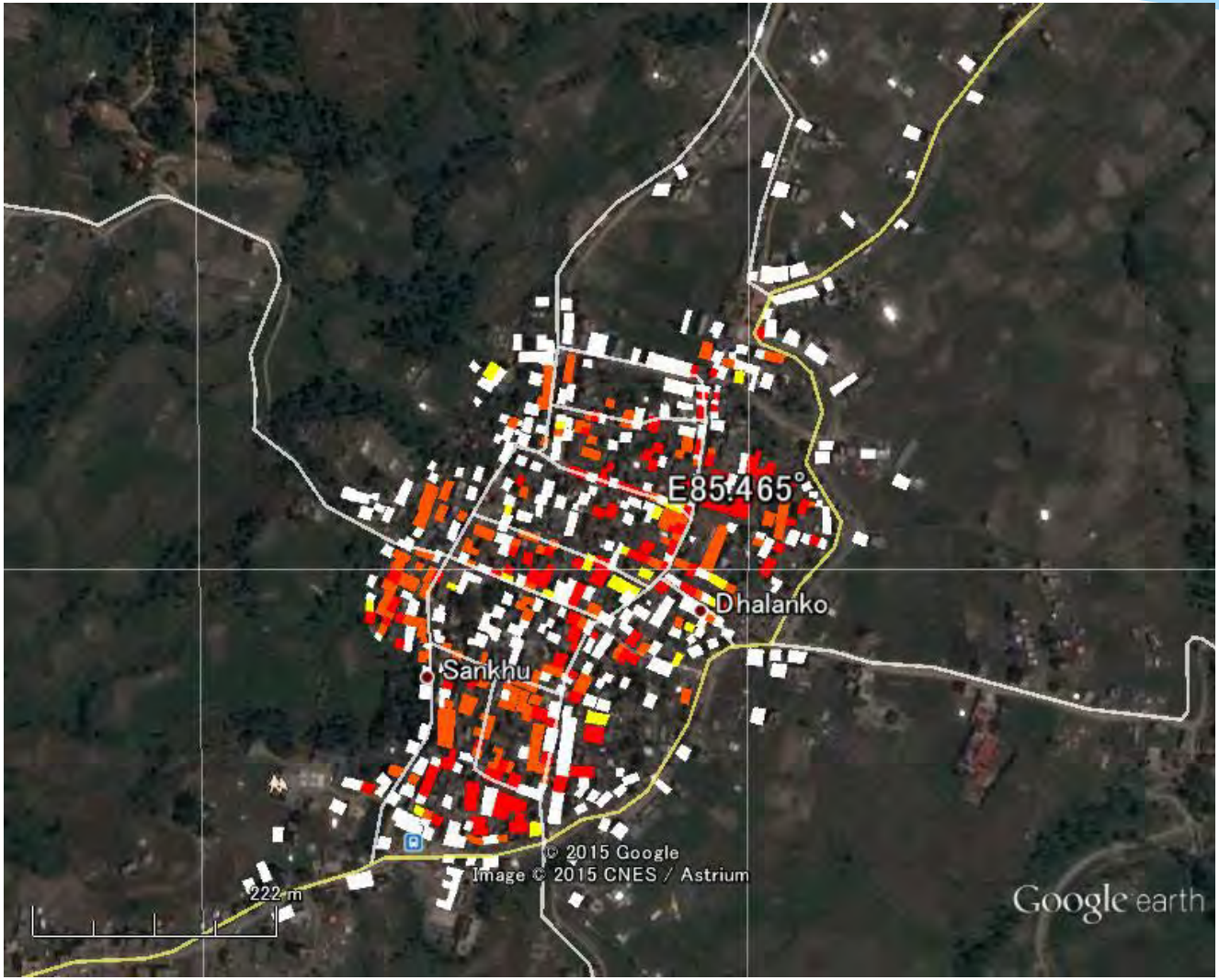
Aug 20, 2015

Sankhu Ortho Mosaic Photo

Aug 20, 2015



Original UAV photos were used by Ohsumi, et al (2015), “Investigation of building damage and ground truth verification of satellite data from the Kathmandu Valley related to the 2015 Gorkha Earthquake, Earth, Planets and Space: submitted.”



EMS-98
- No Damaged
- Level 1 -3
- Level 4
- Level 5

Chautara Heli Survey

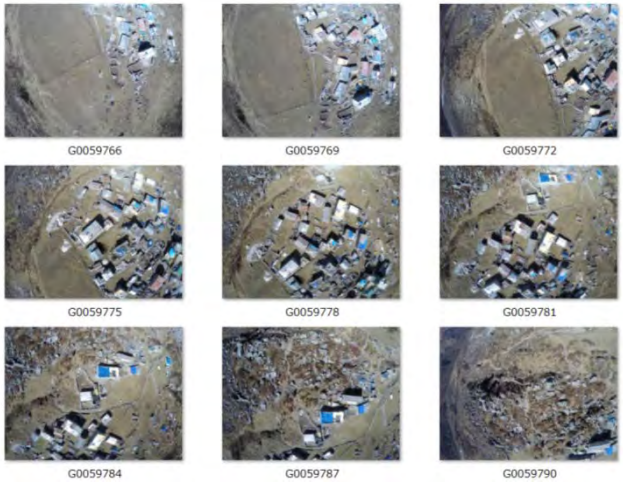
Original Oblique Photo

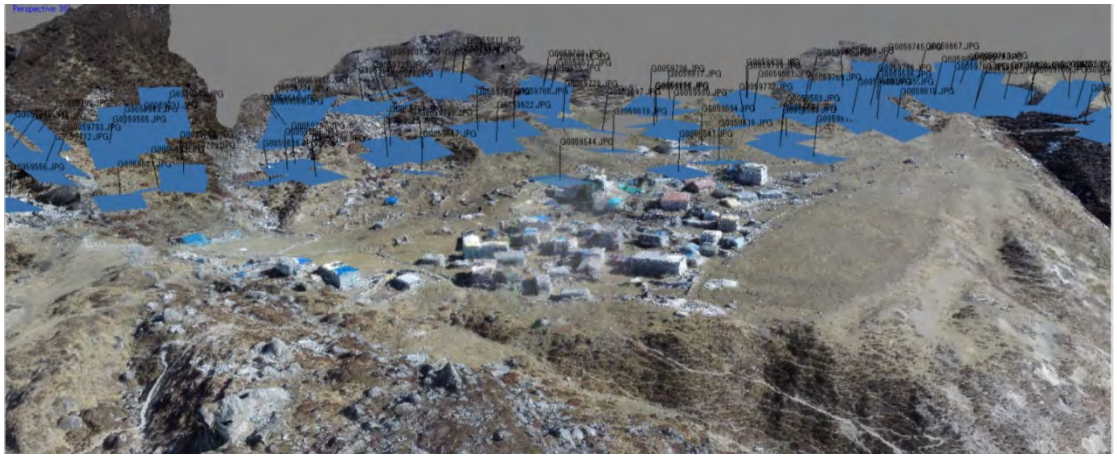
3D Model(DSM)

First UAV survey, October 2015

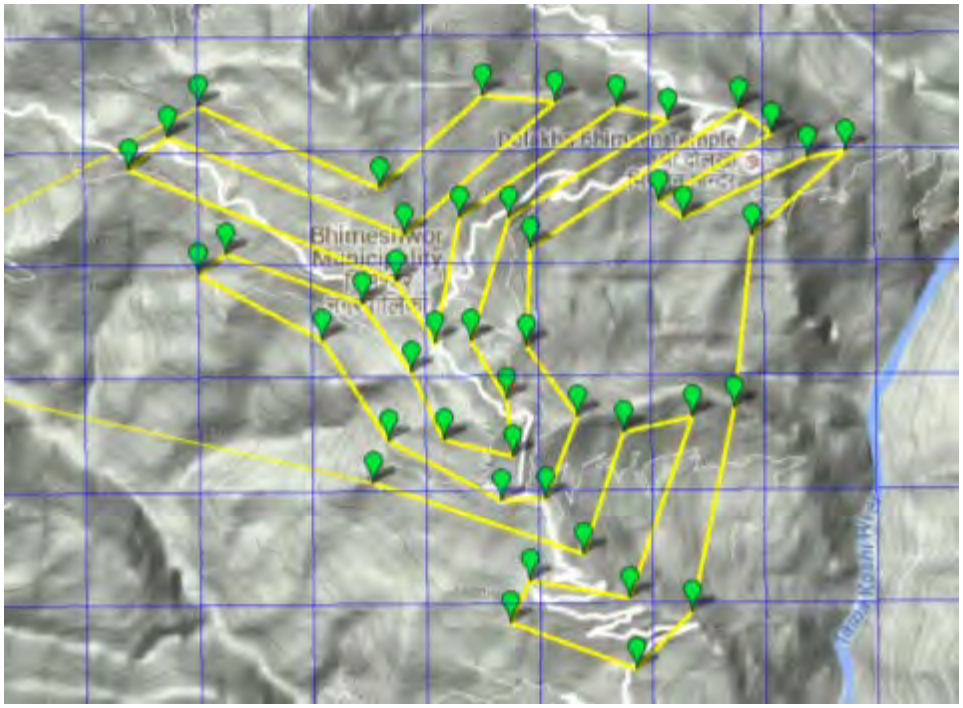
J-Rapid Langtang project by Nagoya Univ. and Kathmandu Univ.

UAV survey in Langtang, October 2015





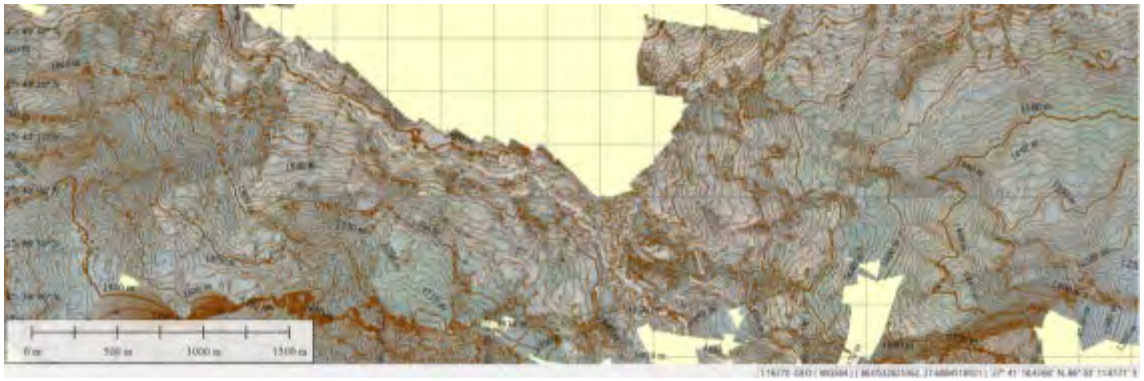
Heli survey in Charikot, March 2016 for topo mapping

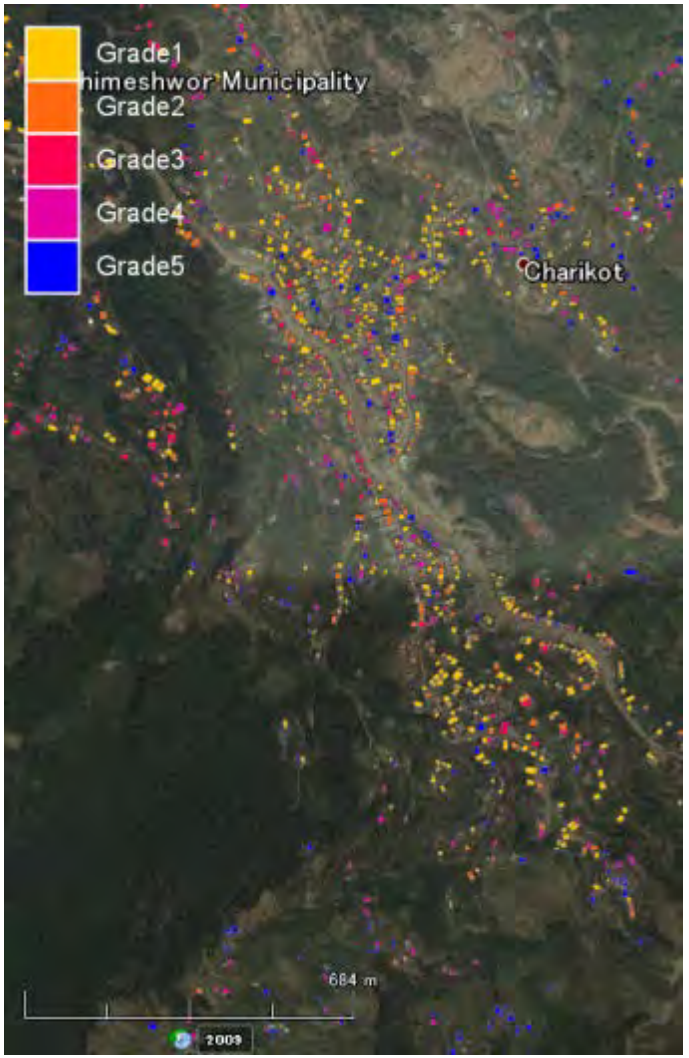


To assess topography effects on damage where NSET made damage survey on the ground

Charikot DSM to be compared with damage

Mar22, 2016

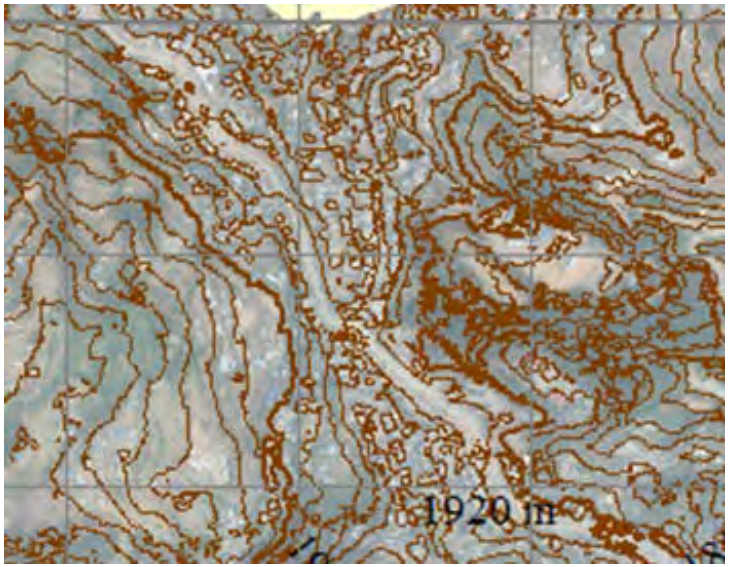




DSM in great detail

Nepal 1/25,000 Charikot

Heli DSM (500m AGL)



Enables to identify slope and curvature in great detail to assess topo hazards.

GCP measurements (accurate coordinates) are not necessary for the purpose, i.e., no need to wait for more detailed topo-sheets published by the mapping agency

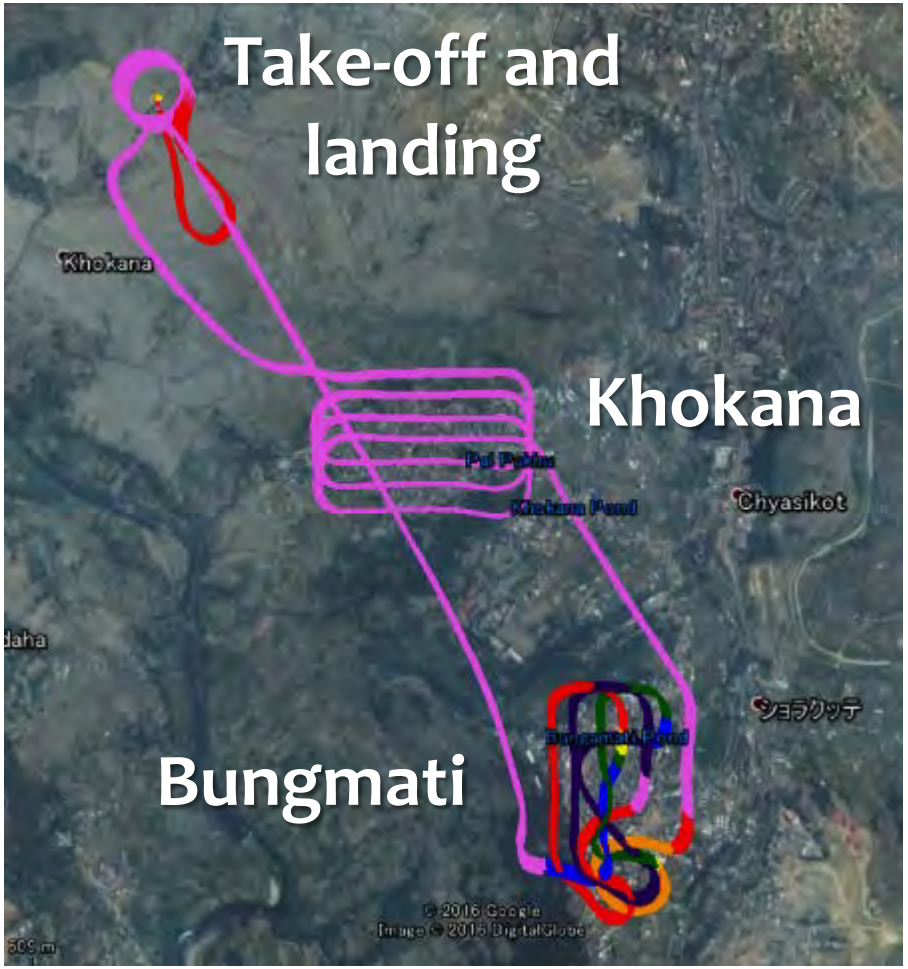
2nd UAV survey, June 7, 2016

Khokana and Bungmati, Lalitpur

AM 5:30 – 6:00

Take-off

Landing



Khokana and Bungmati UAV photos from 100m AGL

Jun 7, 2016, AM5:30- 6:00

Khokana

Bungmati

To be compared to the damages right after the earthquake

Jun 7, 2016

Ground truth

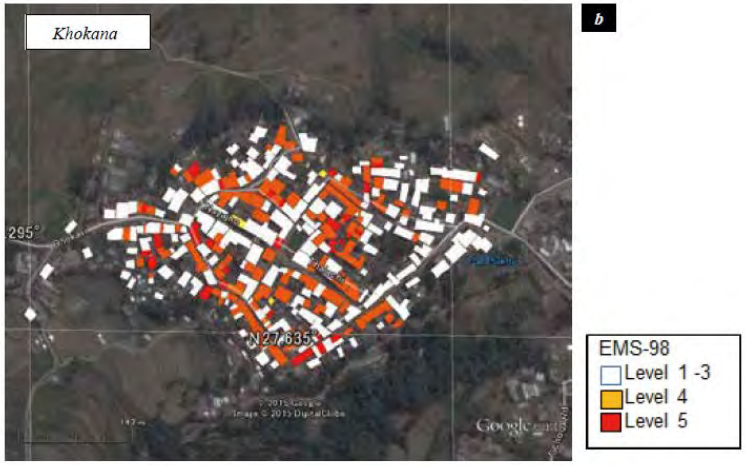
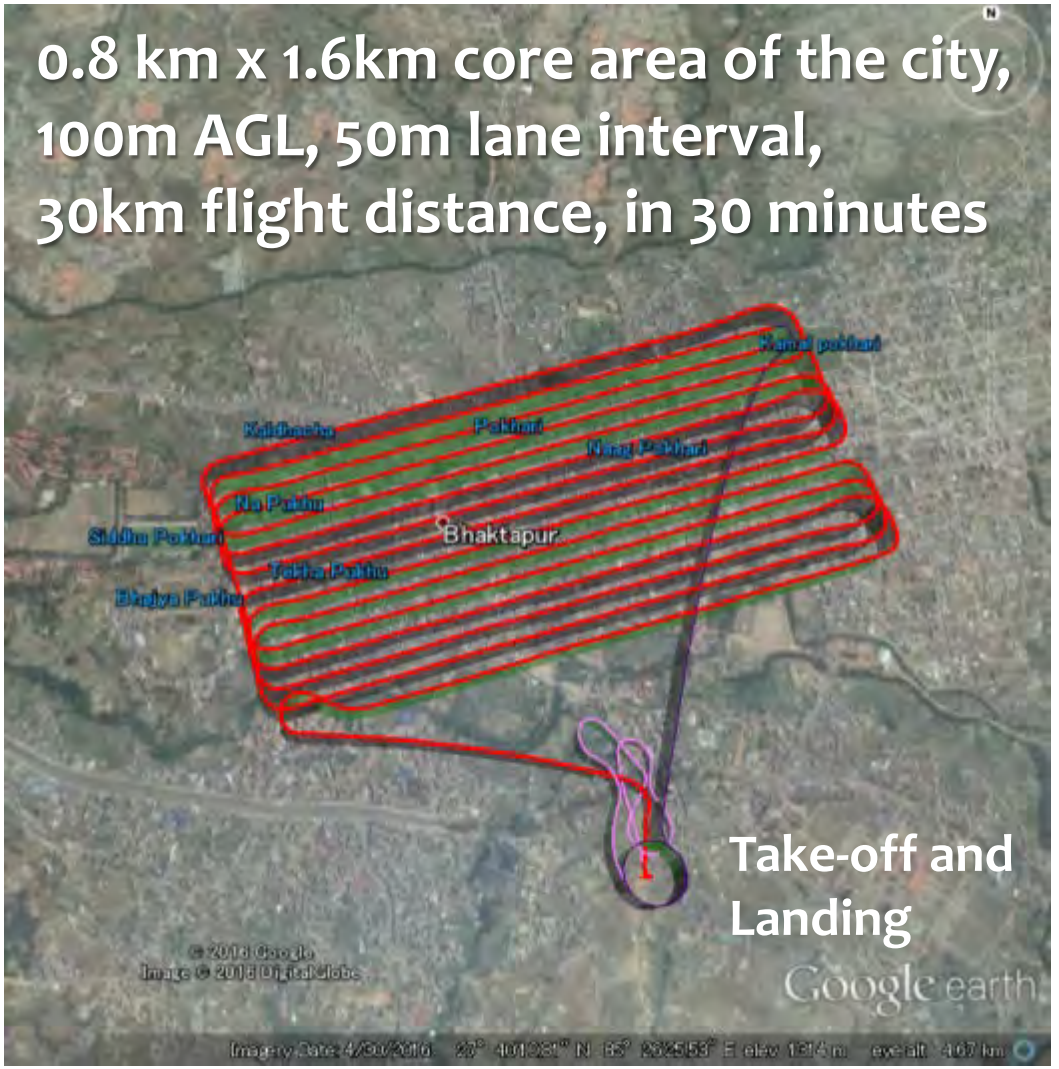


Fig. 7.4 Survey of damage extent for every house in Sankhu and Khokana [5), 6)].

	EMS-Level 1	EMS-Level 2-3	EMS-Level 4	EMS-Level 5
RC	67	0	4	0
%	94%	0%	6%	0%
BC	54	0	17	2
%	74%	0%	23%	3%
BM Well	7	0	4	0
%	64%	0%	36%	0%
BM	39	3	75	28
%	27%	2%	52%	19%

UAV survey, June 17, AM5:30-6:00, 2016 in Bhaktapur



UAV survey, June 17, AM5:30-6:00, 2016 in Bhaktapur

Cloudy weather

G0032270.JPG

G0032271.JPG

G0032272.JPG

G0032273.JPG

G0032274.JPG

G0032279.JPG

G0032277.JPG

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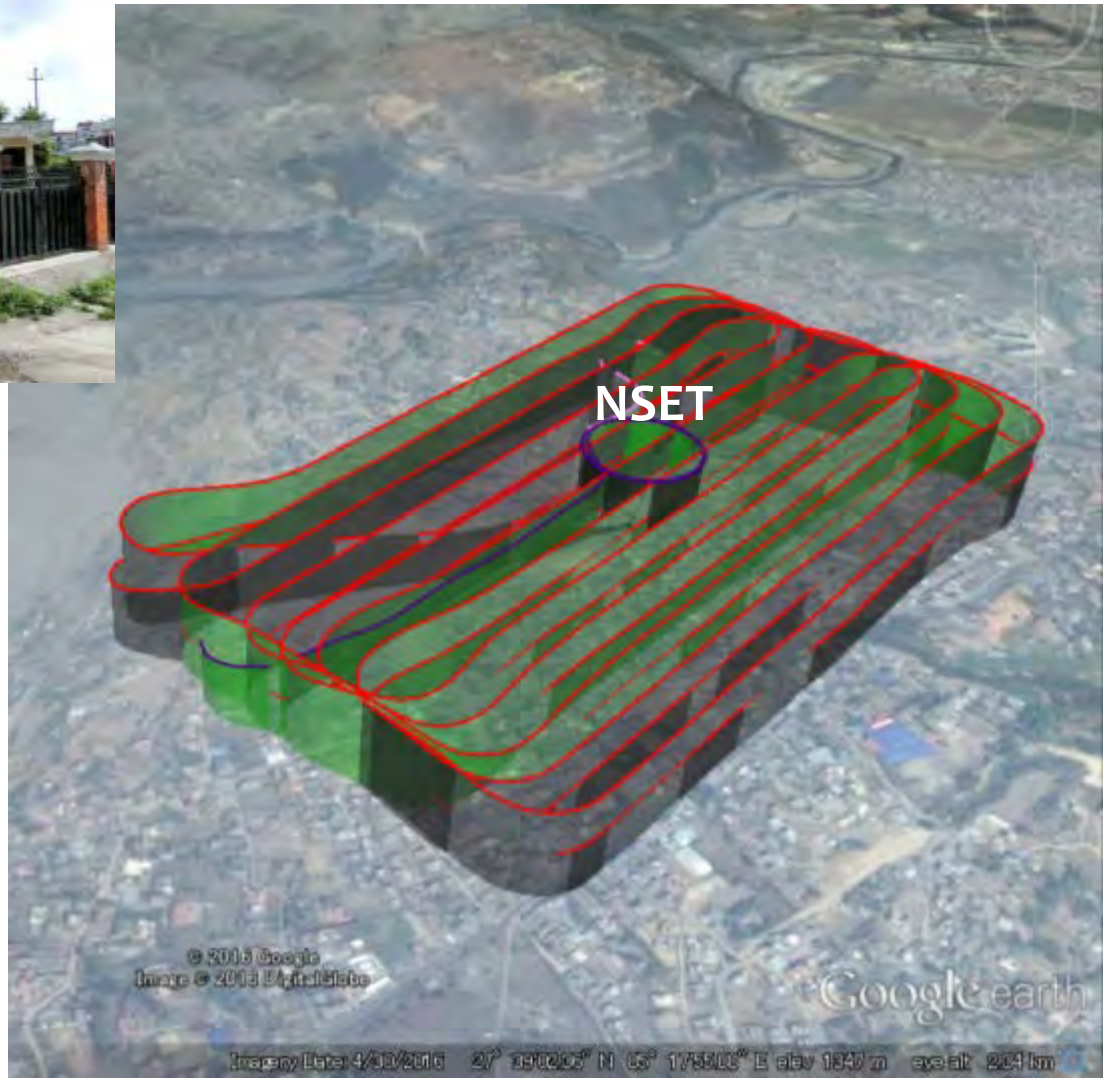
UAV survey, June 18, AM5:30-6:00, 2016 in Bhainsepati

Take-off and land on NSET building



UAV survey, June 18, AM5:30-6:00, 2016 in Bhainsepati

Cloudy weather

Under insufficient light condition (before 6AM), flying the lower altitude does not make the better quality due to shaking caused by the faster image flow.

Discussion

Biggest challenge was UAV permission

It took too long and too much efforts to obtain the UAV flight permission even for the purpose of damage assessment by a government agency.

➔You need to wait for months after a disaster.

(or predict earthquakes few months in advance)

UAV is allowed to fly only before 6 AM in Kathmandu Valley

➔ Only single 30 minutes flight per day after sunrise, under insufficient light condition, only in May, June and July.

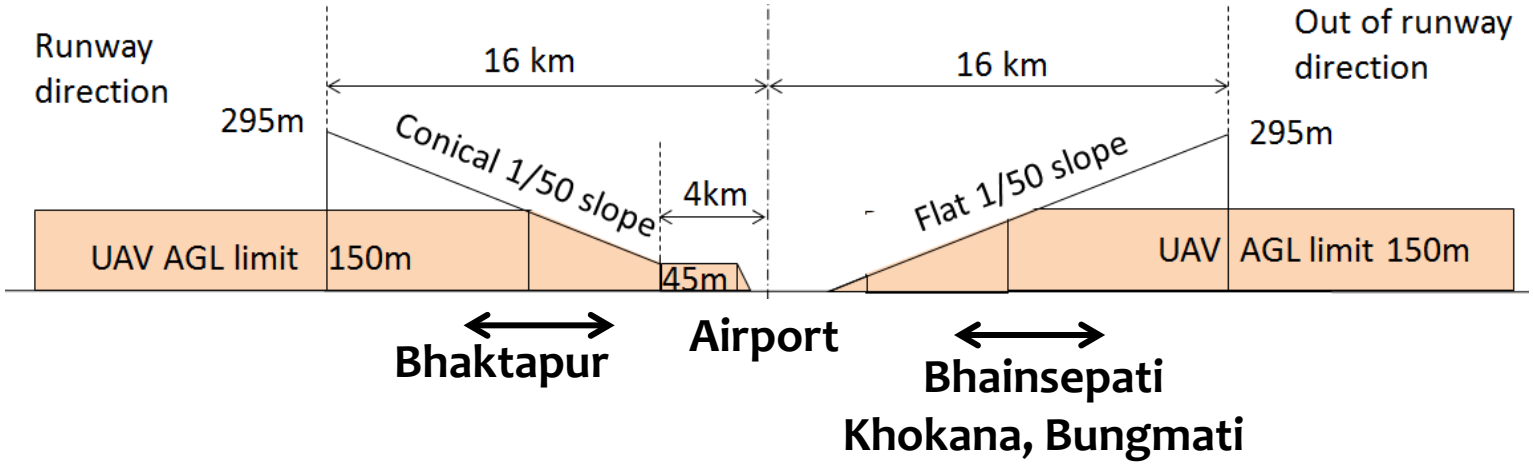
How to more quickly assess the damage if another disaster occurs tomorrow

Desired UAV permission

1) **Nepali government streamlines the process of application and permission, or provides a whole-year permission to a particular agencies for a particular purpose.**

2) **CAAN defines "no-UAV height" near the airport only above which special permission is required.**

Japanese regulation of height limit of UAV for your reference.
No "before 6AM" rule in Japan

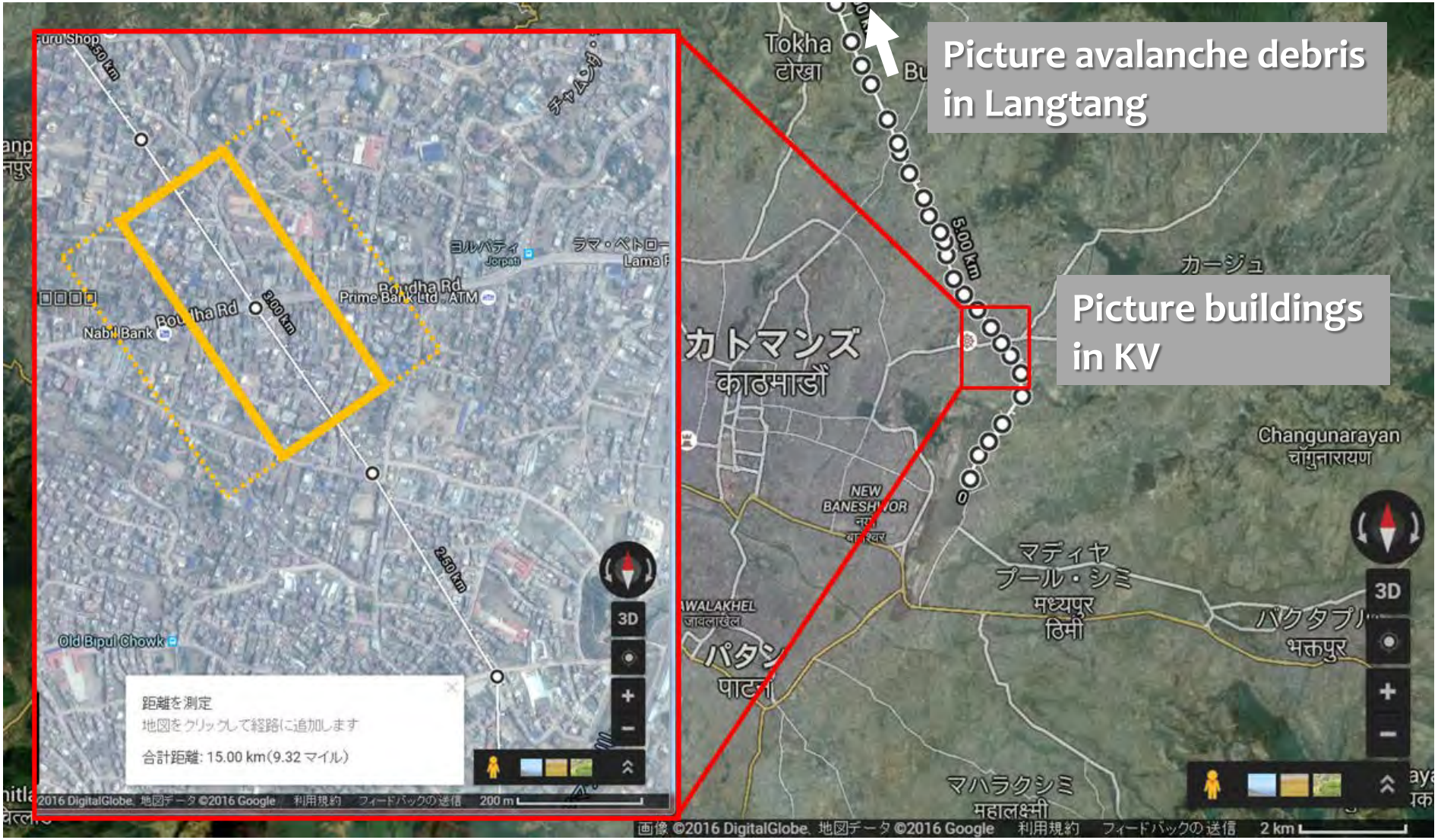


How to quickly assess the damage by the next disaster

Helicopter is only the choice
GoPro on heli is a good option

Why GoPro? Heli can carry high res. full frame cameras. Because GoPro is easy to attach and operate, no need to ride heli, ultra-wide lens, waterproof, and available everywhere

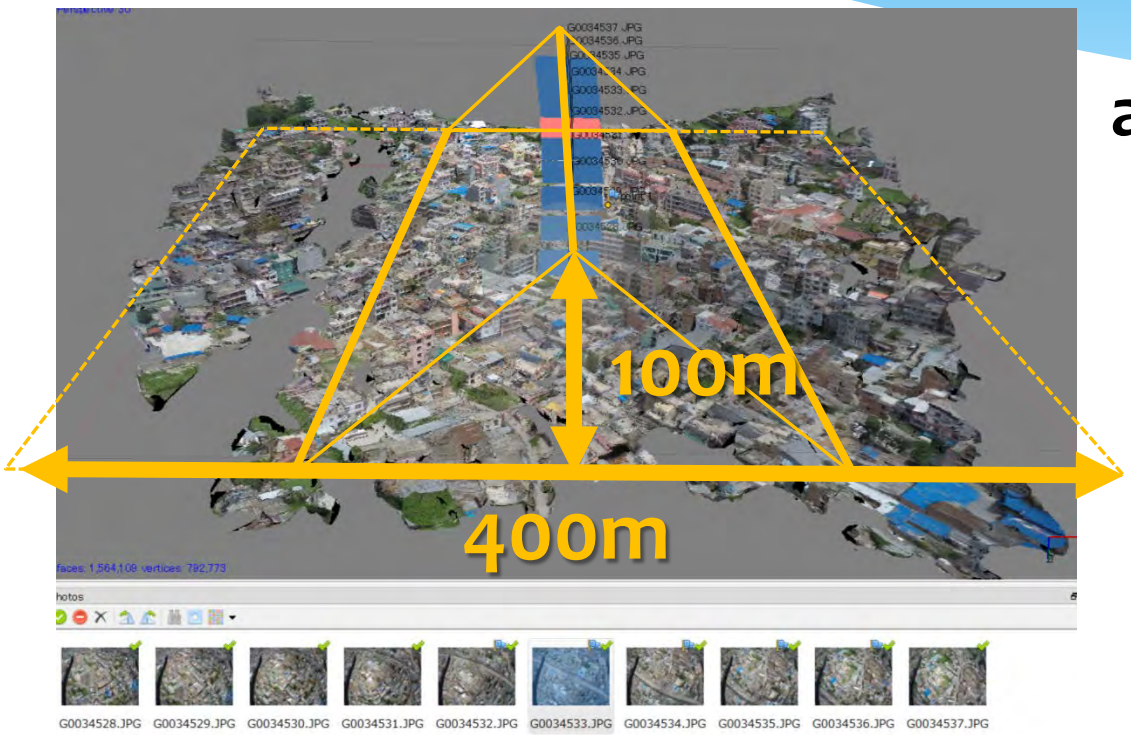
Heli GoPro Test Survey
June 19, 2016



Example result of Heli GoPro Survey

Boudha Road

Heli GoPro Damage Mapping (proposal)



altitude	width
100m x 4 =	400m
150m x 4 =	600m

Attach GoPro to every helicopter of disaster relief mission, or even search and rescue mission for quick damage assessment.
(coordination required, CAAN's approval required)

Lesson from Kumamoto Earthquake April 14 and 16, 2016

Many people evacuated and stayed long in shelters, because they were hit by two big earthquakes in two days, similar to Nepali experience.

⇒ Even quicker 'quick inspection' is needed

It took many days or months to assess the damages of houses for government's compensation for each household.

⇒ Quicker damage survey is needed

However, number of engineers is limited.

How to accelerate the process of earlier recovery

Triage of damage survey

Prioritizing the areas of dispatching engineers, by preliminary quick photo survey using Heli, UAV, Car, Motorbike with GoPro

SensFLy eBee™

Another challenge: How to quickly view the damages of hundreds of buildings

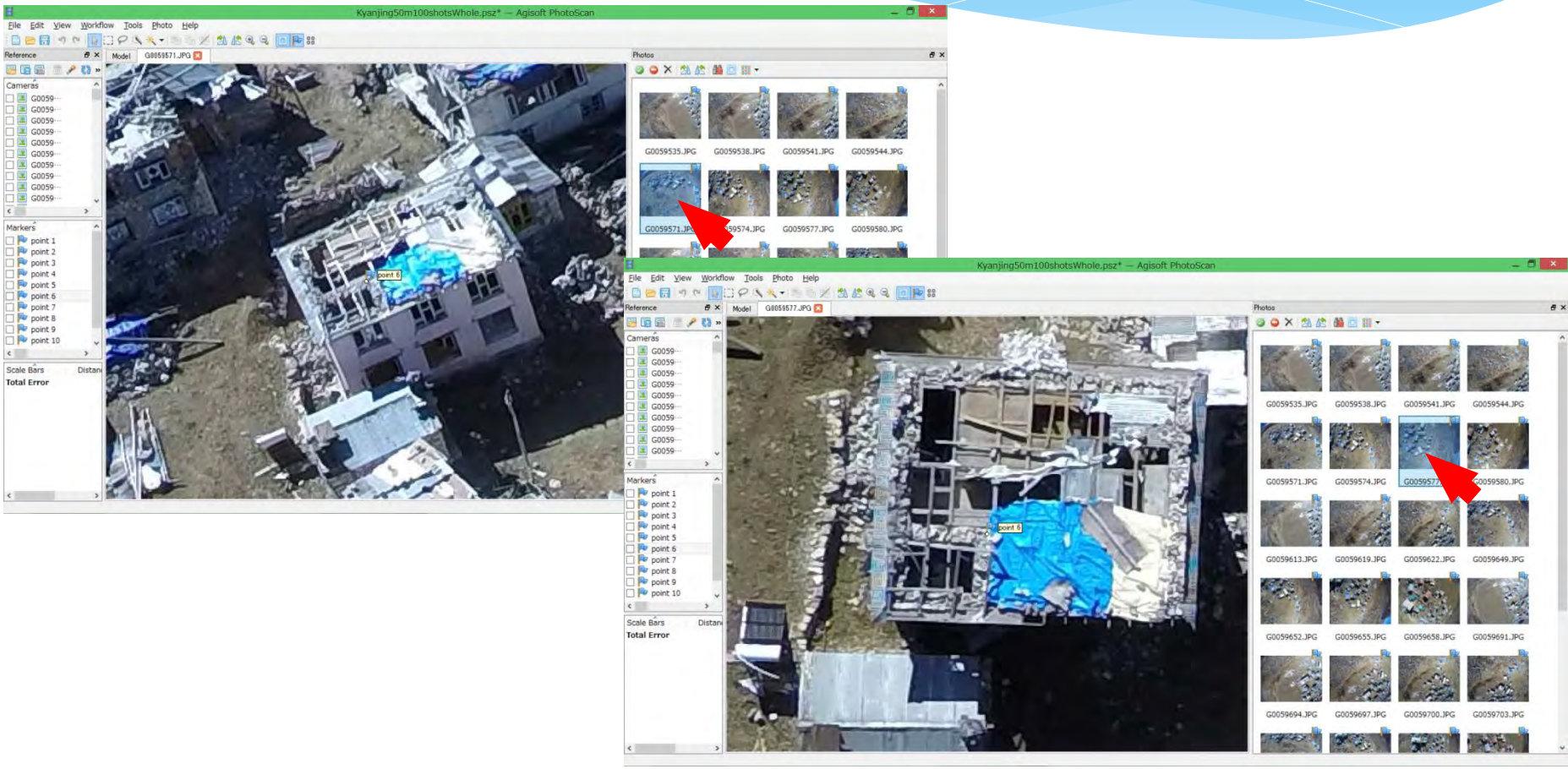
Ortho-mosaic photo is useful for mapping , but not useful for damage assessment because it shows only roofs.

3-D model is useful to measure the heights, but not useful for damage assessment because of low resolution and eformation.

Original oblique photos are best to see the damage

But, how to identify each buildings in hundreds of photos?

PhotoScan™ is a useful tool for the purpose,



But we need a simper tool without time-consuming data processing by PhotoScan

Conclusions

- **UAV is supposed to be a useful tool to assess the damage and monitoring rehabilitation of Nepal from the Gorkha earthquake.**
- **The system of UAV regulation and permission of Nepal should be streamlined, especially for quick damage assessment.**
- **Helicopter is currently the best alternative. A method of data collection should be standardized.**
- **Efficient way of browsing oblique photos of individual buildings in hundreds of photos should be developed**

Future plan

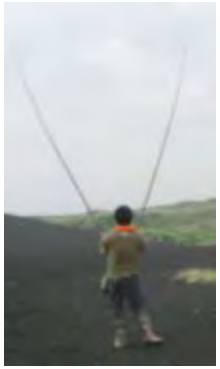
1) **UAV survey in Singati, Dolakha (permission is expected)**
2) **Process the data for mapping buildings and topos**
3) **Establishing "Heli-GoPro" method**

Our last accivity in Nepal under J-Rapid

UAV operation training

for future possibility of
utilizing UAV in Nepal

Friday, June 24 at
Kathmandu University Campus
AM 11:00-12:00 Seminar
PM 1:30-4:00 Assembling, Configuration,
Mission planning, and demo flight



Dherai dherai dhanyabaad
Domo arigato

KVDA ChubuU. NIED NSET

6AM after the flight, Jun 7, 2016, in Khokana