RAPID NHERI
Natural Hazards Reconnaissance

Introduction to the Natural Hazards Reconnaissance (*RAPID*) Facility

Joe Wartman

Director

UCSD-RAPID Workshop

December 2020

NSF Award Number: CMMI 1611820

RAPID Team and Community

Jeff Berman (UW), Site Operation Director
Ann Bostrom (UW), Social Science Advisor
Alex Dioso (APL), Senior Software Engineer
Mike Grilliot (UW), Site Operations Manager
Kurt Gurley (UF), Wind Hazards Specialist
Jennifer Irish (VT), Coast Hazards Specialist
Andrew Lyda (UW), Operations Engineer
Laura Lowes (UW), Struct. and Eq. Eng. Specialist
Scott Miles (UW), Social Science Specialist
Mike Olsen (OSU), Technical Director
Jacqueline Peltier (UW), Operations Specialist
Dan Stromecki (UW-APL), Software Engineer
Troy Tanner (UW-APL), IT and Data Director
Joe Wartman (UW), Director

Community

10+ REU students from 6 institutions
75+ external users
200+ trained investigators

"Our equipment"

RAPID Facility Mission and Values

- The RAPID facility provides investigators with the equipment, software, and support services needed to collect, process, and analyze perishable data from natural hazard events.

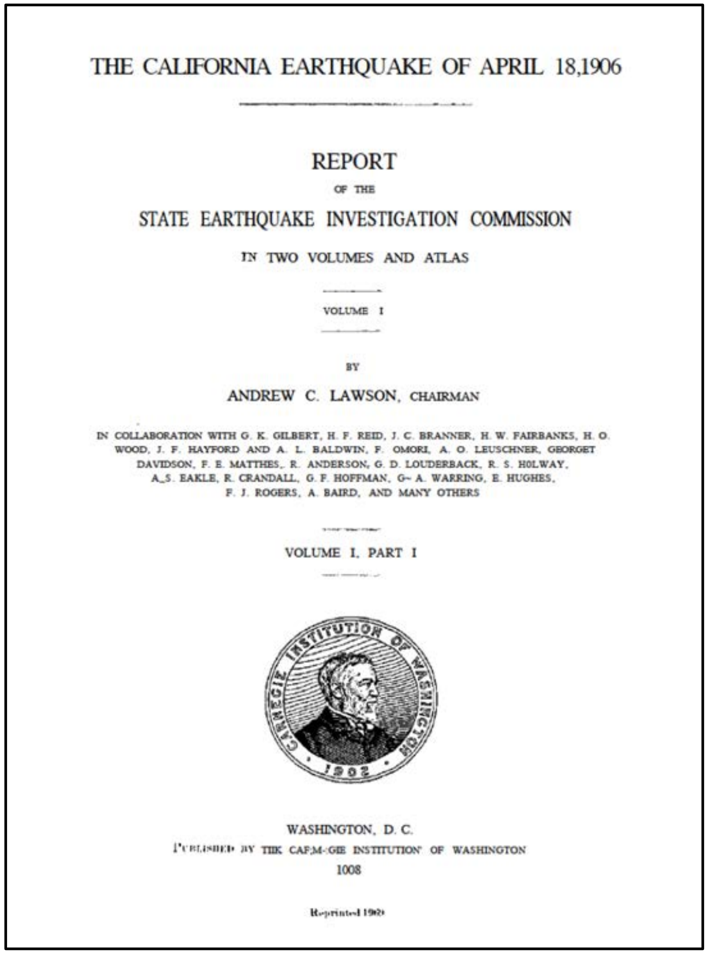
- We promote reconnaissance-based science, shared resources, open data, interdisciplinary research, community engagement, and innovation to reduce the adverse impacts of natural hazards.

RAPID Facility Strategic Activities

To achieve its mission, the RAPID facility engages in the following strategic activities.

- Acquiring, maintaining, and operating state-of-the-art data collection equipment
- Developing and supporting mobile applications (RApp) to support interdisciplinary field reconnaissance
- Providing advisory services and basic logistics support for research investigations
- Facilitating the systematic archiving, processing and visualization of acquired data in DesignSafe-CI
- Training a broad user base through workshops and other activities
- Engaging the public through community outreach and education

1906: The Dawn of Natural Hazard Reconnaissance in the U.S.



THE CALIFORNIA EARTHQUAKE OF APRIL 18,1906

REPORT
OF THE
STATE EARTHQUAKE INVESTIGATION COMMISSION
IN TWO VOLUMES AND ATLAS

VOLUME I

BY

ANDREW C. LAWSON, CHAIRMAN

IN COLLABORATION WITH G. K. GILBERT, H. F. REID, J. C. BRANNER, H. W. FAIRBANKS, H. O. WOOD, J. F. HAYFORD AND A. L. BALDWIN, F. OMORI, A. O. LEUSCHNER, GEORGE DAVIDSON, F. E. MATTHES, R. ANDERSON, G. D. LOUDERBACK, R. S. HOLWAY, A. S. EAKLE, R. CRANDALL, G. F. HOFFMAN, G. A. WARRING, E. HUGHES, F. J. ROGERS, A. BAIRD, AND MANY OTHERS

VOLUME I, PART I

WASHINGTON, D. C.
PUBLISHED BY THE CARNEGIE INSTITUTION OF WASHINGTON
1008

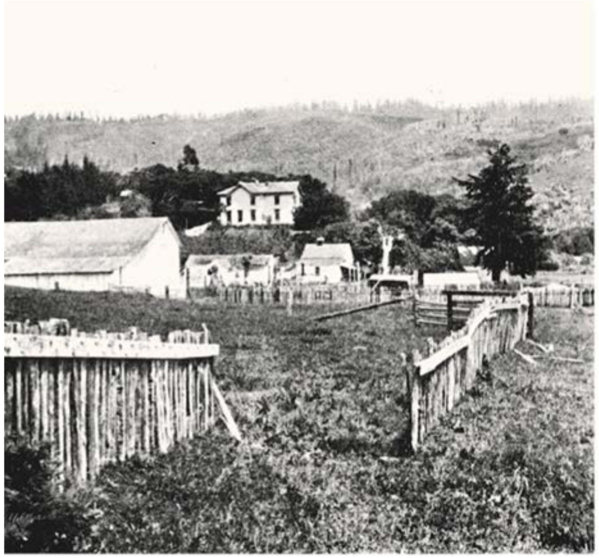
Reprinted [illegible]

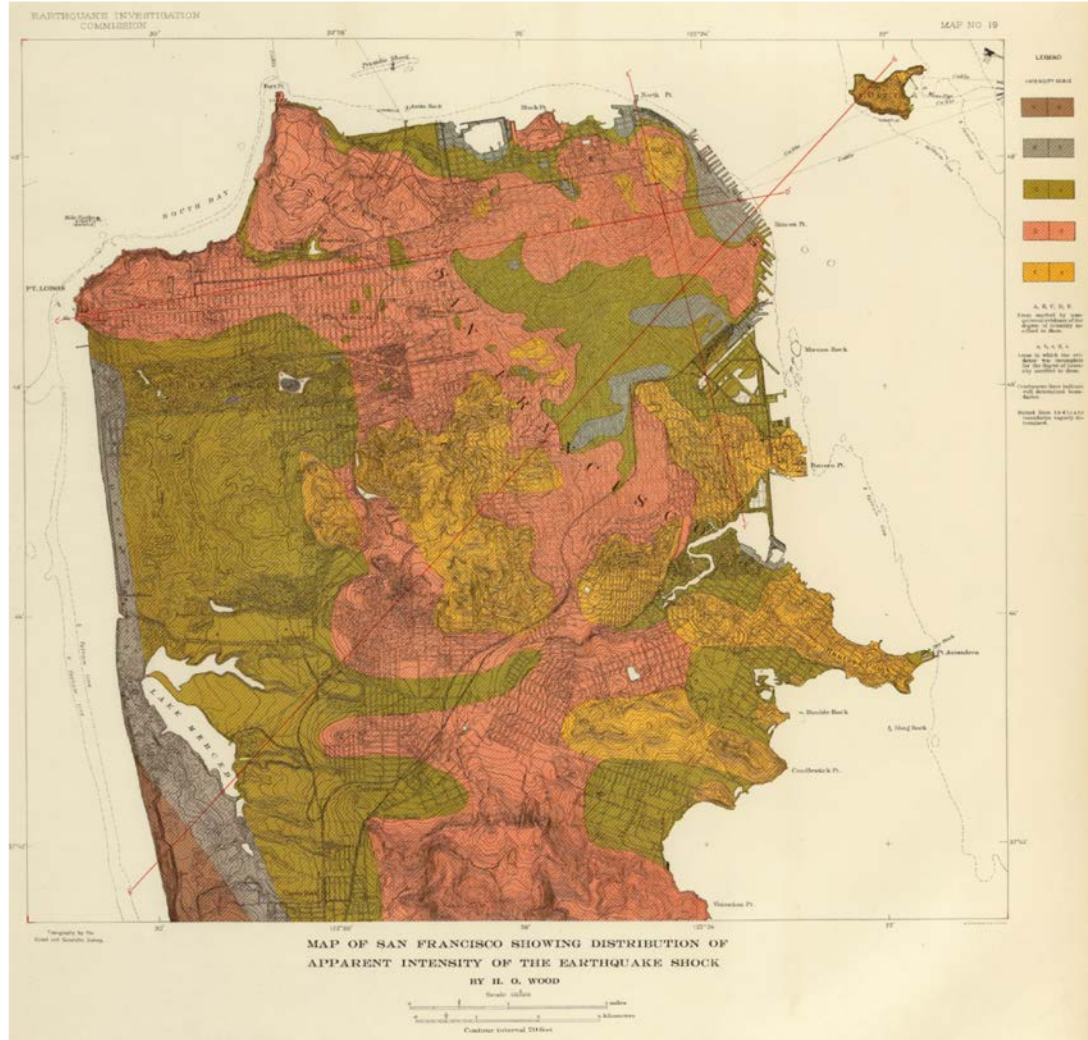
• Three days after the earthquake, Governor Pardee appoints a California State Earthquake Investigation Commission (lead by A. C. Lawson) to unify the work of scientific investigation teams

• "Lawson Report" (1908) - a detailed, benchmark compilation on scientific investigation of the earthquake and the damage it caused

Source: USGS (https://earthquake.usgs.gov/earthquakes/events/1906calif/18april/revolution.php)

1906: The Dawn of Natural Hazard Reconnaissance in the U.S.





• Inspired new, fundamental understanding of earthquakes: e.g. ground movement surveys leads H. F. Ried to introduce the landmark "theory of elastic rebound"

• Post-event mapping across the city begins to provide a coherent story that explains damage concentrations: the notion of "site effects"

Source: USGS (https://earthquake.usgs.gov/earthquakes/events/1906calif/18april/revolution.php)

Value of Natural Hazard Reconnaissance Data

• Data generated by an extreme event is often "perishable" —and thus, must be collected quickly

• Disaster data sets include the real-world complexities (e.g., interplay between natural, human, and built systems) that allow us to better understand and to quantify the socio-technical dimensions related to damage, restoration, and resiliency of the built environment

• Such data is difficult to duplicate in the laboratory

• Once collected, these data can be used to:
  - develop new fundamental discoveries and insights
  - test and verify simulation models
  - reduce uncertainties in probabilistic models

Current Reconnaissance Landscape in the U.S.

GEER

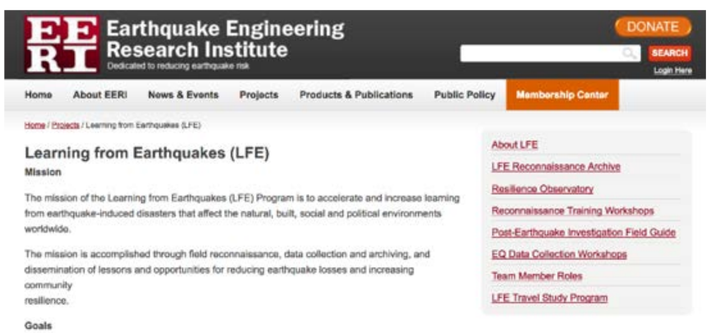
SSEER
SOCIAL SCIENCE
EXTREME EVENTS
RECONNAISSANCE

ISEEER
INTERDISCIPLINARY
SCIENCE & ENGINEERING
EXTREME EVENTS
RECONNAISSANCE

CONVERGE
NHERI

StEER
STRUCTURAL
EXTREME EVENTS
RECONNAISSANCE

\+ NEER and OSEER and SUMMEER…



EERI (and VERT)

And others (e.g., Federal agencies including USGS, NIST and NIH)

NSF RAPID Program Grants

Award Abstract #1904653

RAPID/Collaborative Research: Performance of Low-Rise Large-Volume Buildings in Florida during 2018 Hurricane Michael

NSF Org:	CMMI Div Of Civil, Mechanical, & Manufact Inn
Initial Amendment Date:	November 26, 2018
Latest Amendment Date:	November 26, 2018
Award Number:	1904653
Award Instrument:	Standard Grant
Program Manager:	Joy Pauschke CMMI Div Of Civil, Mechanical, & Manufact Inn ENG Directorate For Engineering
Start Date:	November 15, 2018
End Date:	October 31, 2019 (Estimated)
Awarded Amount to Date:	$32,048.00
Investigator(s):	Justin Marshall jdmarshall@auburn.edu (Principal Investigator) David Roueche (Co-Principal Investigator)
Sponsor:	Auburn University 310 Samford Hall Auburn University, AL 36849-0001 (334)844-4438
NSF Program(s):	ECI-Engineering for Civil Infr
Program Reference Code(s):	036E, 038E, 039E, 040E, 081Z, 1057, 7914, 9150, CVIS
Program Element Code(s):	073Y

Award Abstract #1929304

RAPID: Quantifying Temporal Changes in Rockfall Magnitude-Frequencies for Well-Characterized Rockslopes Shaken by the 2018 Alaska Earthquake

NSF Org:	CMMI Div Of Civil, Mechanical, & Manufact Inn
Initial Amendment Date:	April 4, 2019
Latest Amendment Date:	April 4, 2019
Award Number:	1929304
Award Instrument:	Standard Grant
Program Manager:	Richard Fragaszy CMMI Div Of Civil, Mechanical, & Manufact Inn ENG Directorate For Engineering
Start Date:	April 15, 2019
End Date:	March 31, 2020 (Estimated)
Awarded Amount to Date:	$55,000.00
Investigator(s):	Ben Leshchinsky ben.leshchinsky@oregonstate.edu (Principal Investigator) Joseph Wartman (Co-Principal Investigator) Michael Olsen (Co-Principal Investigator)
Sponsor:	Oregon State University OREGON STATE UNIVERSITY Corvallis, OR 97331-8507 (541)737-4933
NSF Program(s):	ECI-Engineering for Civil Infr
Program Reference Code(s):	036E, 037E, 043E, 1057, 1576, 7914, CVIS
Program Element Code(s):	073Y

Award Abstract #1917298

RAPID/Collaborative Research: Data Collection on Wildfire Urban Interface (WUI) for Schools and Hospitals Following the 2018 California Camp Fire

NSF Org:	CMMI Div Of Civil, Mechanical, & Manufact Inn
Initial Amendment Date:	March 8, 2019
Latest Amendment Date:	May 3, 2019
Award Number:	1917298
Award Instrument:	Standard Grant
Program Manager:	Robin Dillon-Merrill CMMI Div Of Civil, Mechanical, & Manufact Inn ENG Directorate For Engineering
Start Date:	March 1, 2019
End Date:	February 29, 2020 (Estimated)
Awarded Amount to Date:	$38,110.00
Investigator(s):	Erica Fischer erica.fischer@oregonstate.edu (Principal Investigator) Sara Hamideh (Co-Principal Investigator)
Sponsor:	Oregon State University OREGON STATE UNIVERSITY Corvallis, OR 97331-8507 (541)737-4933
NSF Program(s):	HDBE-Humans, Disasters, and th
Program Reference Code(s):	041E, 042E, 7914, 9102, 9179
Program Element Code(s):	1638

Plus other standard NSF proposals and special programs (including CAREER)

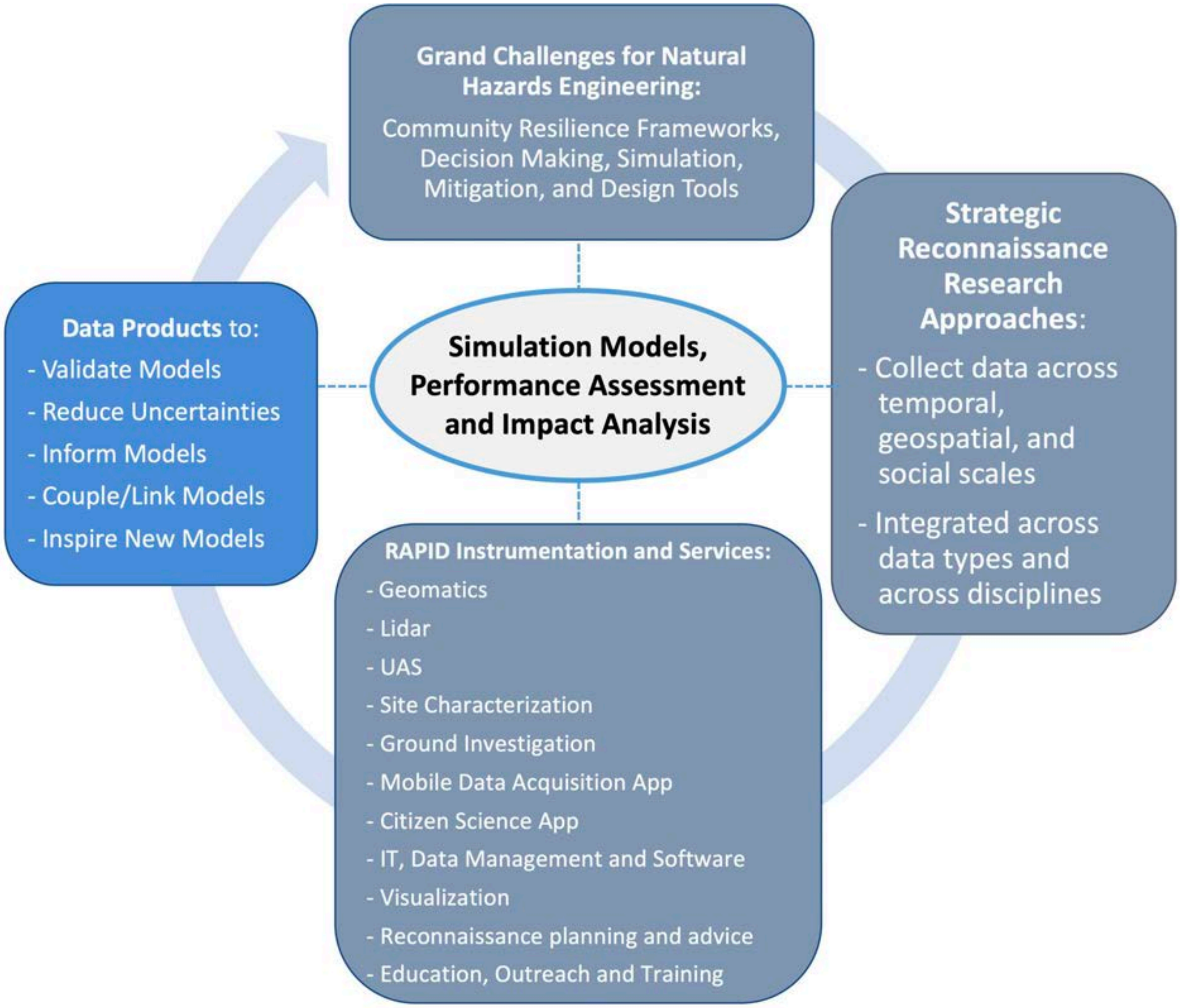
RAPID Facility 2018-2020 Missions

In the past 2.5 years, the RAPID facility supported over 70 natural hazard reconnaissance deployments worldwide, in service to 20 organizations, representing 25+ institutions.

RAPID Facility Science Plan

The principal scientific goal of the RAPID is to:

Inform natural hazards computational simulation models, infrastructure performance assessment, and socioeconomic impact analysis by supporting the collection, development, and assessment of high-quality disaster data sets



RAPID Facility Science Plan

New strategic approaches for natural hazards reconnaissance:

1. Data collection over **time frames** representing conditions and states before, during, and after significant natural hazard events

2. The collection and synthesis of data over **spatial scales** spanning multiple orders of magnitude (i.e., from the site-specific to the regional scales; ~m^2 to ~km^2)

3. Data collection is sensitive to and associated with **social conditions**, and considers the **social processes** that can make populations hard to reach

4. The **collection and synthesis of multidisciplinary data** sets to establish relationships between hazard events, their antecedents, and their broad consequences, ultimately leading to an improved ability to model, manage, and mitigate disaster risk to communities

Wartman et al. (2020) Research Needs, Challenges, and Strategic Approaches for Natural Hazards and Disaster Reconnaissance, *Frontiers in Built Environment*

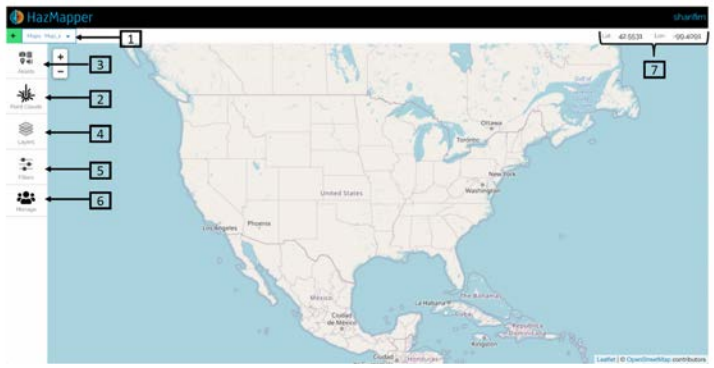
Acquire data over a range of temporal, spatial, and social scales— across disciplines

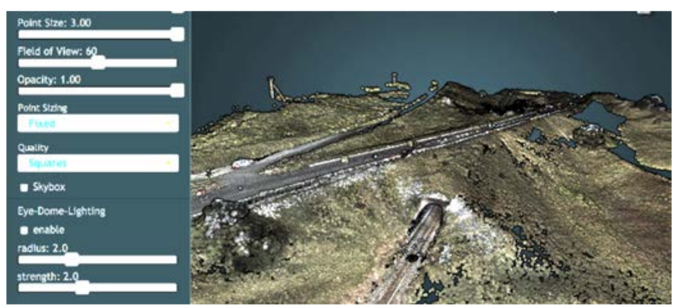
Amanda South, reporter, Newstalk ZB, 8-5-12.

I: Right, let's start with February 22, can you describe your key experiences on that day?

IP: I was actually at home, ironically, because the Christchurch City Council was having its first dedicated earthquake recovery meeting so I would have started work at 1, so I was always haunted by that, but I was in Angus' bedroom getting him off for a nap and I guess the rest is history. The house started to explode around us. I just took him in by body in the middle of the room and things just fell around us. We were in this little bubble in the middle and it was horrific because everyone has that internal counter and you thought 'Oh my god this is going to on too long, it's supposed to stop'. It got angrier and stuff was just erupting in the hallway. I can just remember knowing it was horrific and trying to think about my kid and I can remember my

DESIGNSAFE-CI
A NATURAL HAZARDS ENGINEERING COMMUNITY

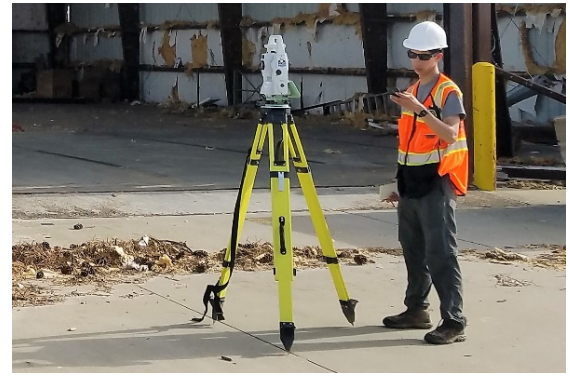




Facility Resources

- Advanced Geomatics Technologies
- Seismic Instrumentation
- Wind and Storm Surge Instrumentation
- Social Science Reconnaissance Equipment
- Ground Investigation
- Imaging Equipment
- Software tools
- Full list:

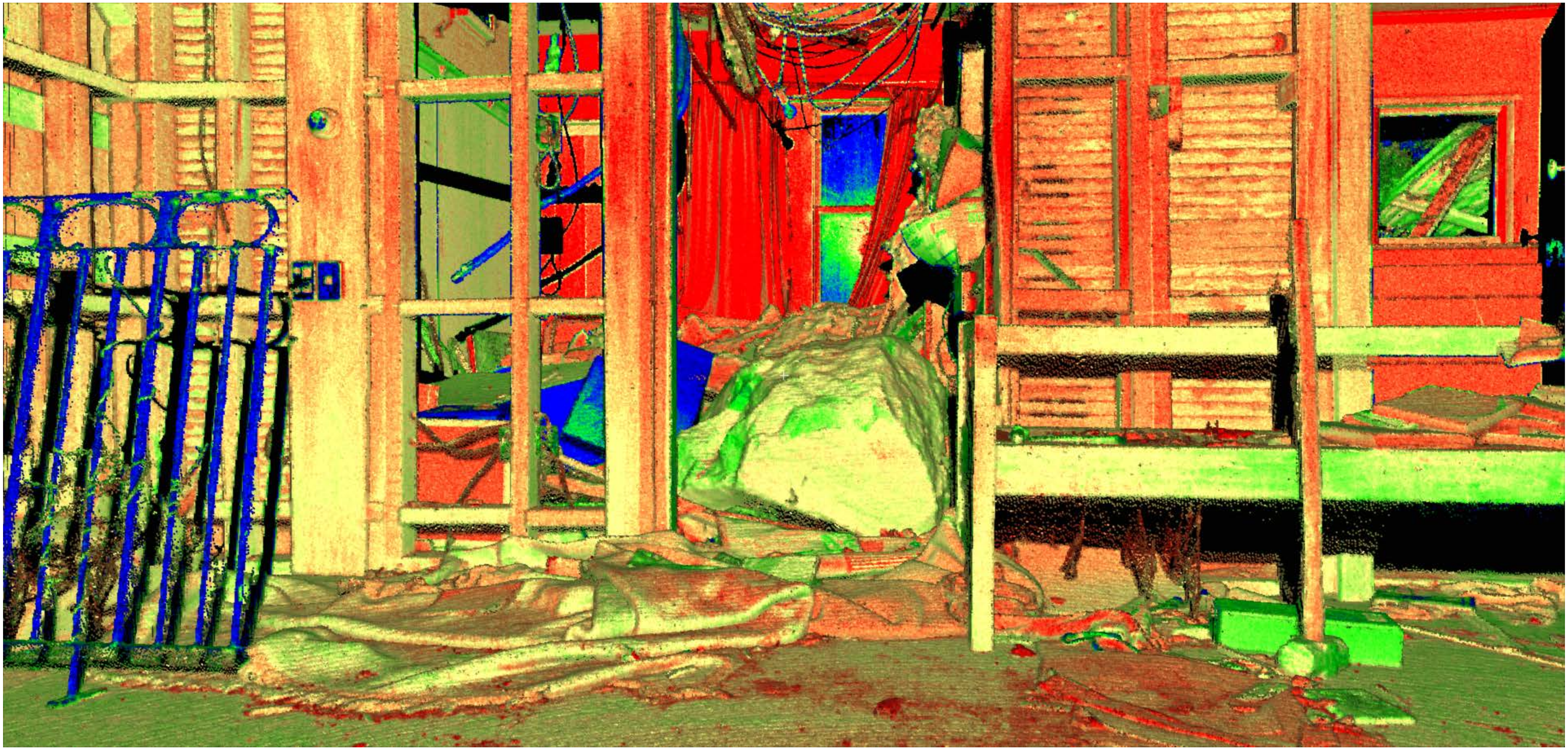
https://rapid.designsafe-ci.org/





3D Laser Scanning\Imaging



- Highly versatile – Collect once, use many times
- Digitally preserve scene at high detail, accuracy
- Applicable across spatial scales

3D Laser Scanning Equipment

Leica BLK360 (x3)

Leica RTC360

- Short, medium and long range systems
- Simple, easy to use interfaces
- Portable and durable
- Streamlined workflows

Leica P50

Maptek LR3

Maptek XR3

Example Data Sets: Large-Scale Tests

Obtain 3D high- resolution point cloud models for NHERI experiments

- Record damage
- Determine precise instrument locations
- Benchmark experiments to field observations
- Develop damage detection and load history determination methods

Surveying Technologies Equipment

Leica Nova TS60I Total Station

Leica GS18T GNSS (x4)

Leica LS15 Digital Level

- Total station with reflectorless, robotics, and imaging capabilities
- GNSS (*GPS*) receiver with improved positioning with obstructions
- High precision digital level

Unmanned Aircraft Systems (UAS) Equipment

- Hobbyist drones: lower resolution data for damage assessment and scouting
- Consumer-grade: aerial photography for SfM and orthomossaics
- Industrial: weatherproof, high-resolution data for SfM
- MiniRanger: lidar system
- New set of RTK versions

Mavic Pro/Air

Phantom 4 Pro+

Inspire 2

Matrice 200 Series

MiniRanger

Phoenix miniRanger lidar drone

- cm-level accuracy
- 9MP global shutter RGB camera
- RTK GNSS
- High quality Inertial Measurement Unit (IMU)
- Abs Accuracy (25H/35Vmm RMSE @100 m range
- 100k shots per second, up to 5 returns per shot
- Real-time data transmission (custom software)
- Flight time: ~20mins (total), Max speed: 40mph
- Fully autonomous, can be mounted on any drone, car, boat and/or even backpacks

Imaging Technologies

- With SfM, imaging is moving to forefront of 3D scene capture and DEM
- Captures context of scene (especially for 3D models)
- High resolution capture across a range of scales
- Immersive digital imaging products

Coastal Equipment

Z-boat (Single Beam Echo Sounder)

Depth: 30cm to 600m
RTK GNSS position
5cm Heave accuracy

True Blue Water Level loggers (x20)

Depth: 0m to 200m
Log rate: Up to 4Hz

RJE Acoustic Beacon (x10)

Used to locate submerged equipment, i.e. True Blue and Aquadopp or others…

Aquadopp Profiler 2 MHz

ADCP up to 10 m depth
Max: 10 m s^{-1} velocity | 23 Hz

Petit Ponar Grab Sampler

Relatively Portable (28 lbs)
6” x 6” (152mm) sample area

Seismic instrumentation

Trillium Compact Seismometer (x6)

Centaur Digital Recorder

IP67	Protected from total dust ingress.	Protected from immersion between 15 centimeters and 1 meter in depth.

Seismometer

- Flat velocity from 20 sec (0.05Hz) to 100Hz

Recorder

- 3 channel, 24 bits per channel
- 8GB Storage
- GPS Receiver
- Can apply bandpass filters and calculated PGA, PGV, PGD in field
- Transfer data with Ethernet, WiFi, SD-card swap

ATOM wireless seismic data acquisition system (x24)

- Passive system (design, but also perform active survey), 24 units, 24-bit
- GPS controlled timing
- Retrieve data with WiFi
- 4GB storage (70, 8-hr days at 4ms sample rate)
- Shear wave data up to 1km deep
- Seisimager software for processing data

Structural Instrumentation

- Nanometrics Titan EA accelerometers
- 4 buildings kits, each with:
  - Three tri-axial accelerometers
  - GPS antenna
  - Cabling
  - Data logger

TitanEA

Ground Investigation Equipment

Hand-held Smart Dynamic Cone Penetrometer

Basic Soil Sampling Kit

SilverSchmidt and RockSchmidt Hammer

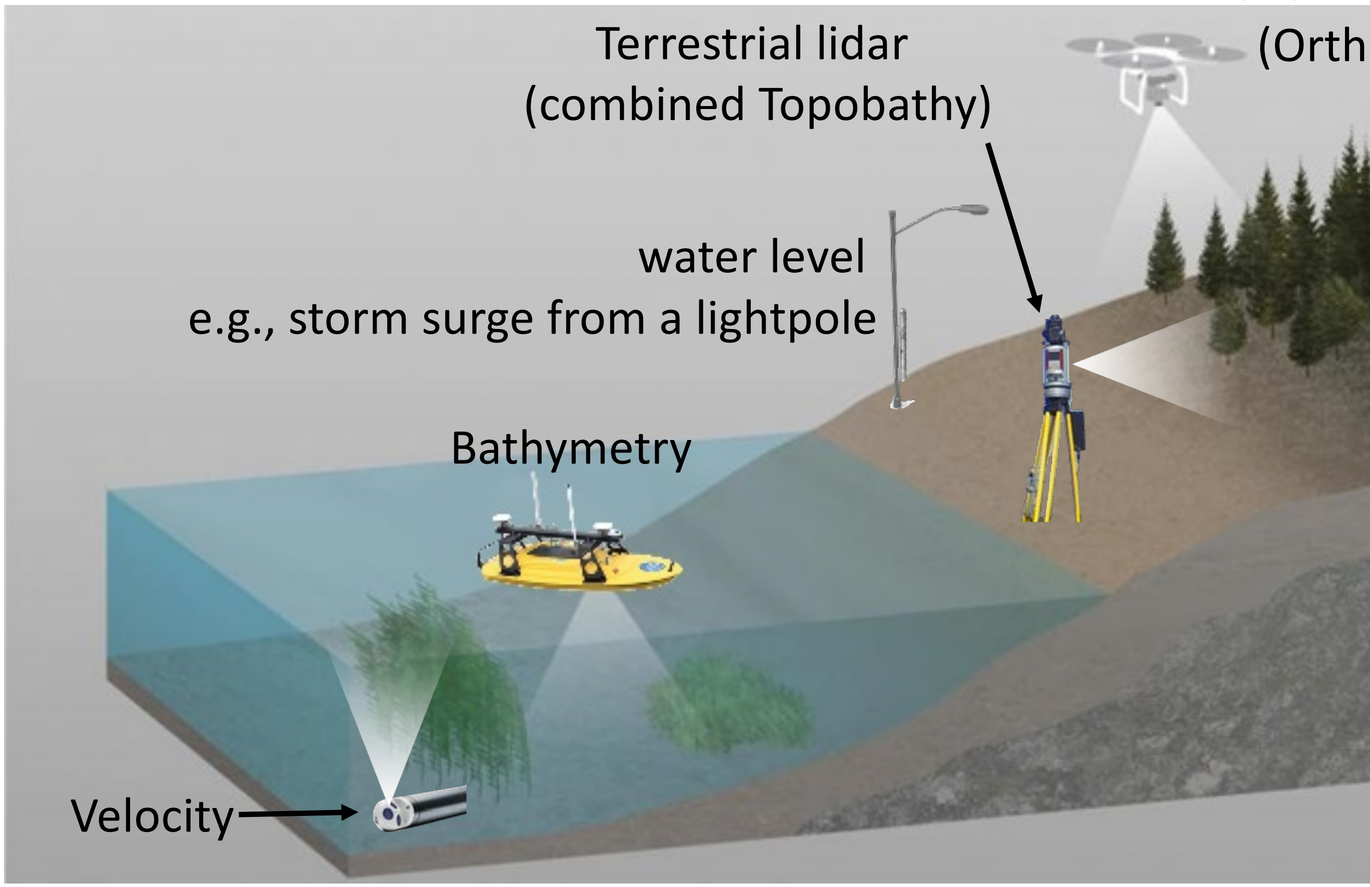
Pocket Penetrometer

Integrating Data

Pre-Event:
Snapshot
of coastal environment

During Event:
Velocity & Water Level

Post-Event:
Change detection



Original figure by Mark Garrison

https://www.hakai.org/blog/stitching-together-data-quilt/

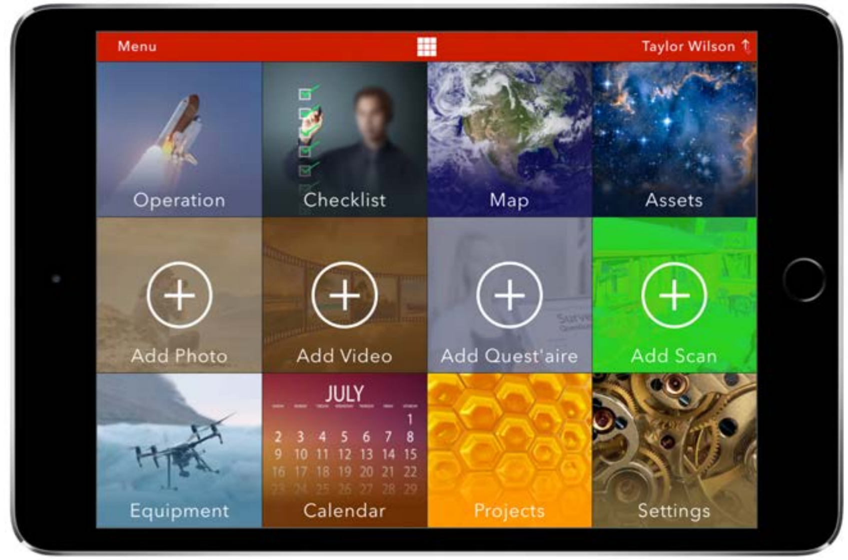
RApp Mobile Software

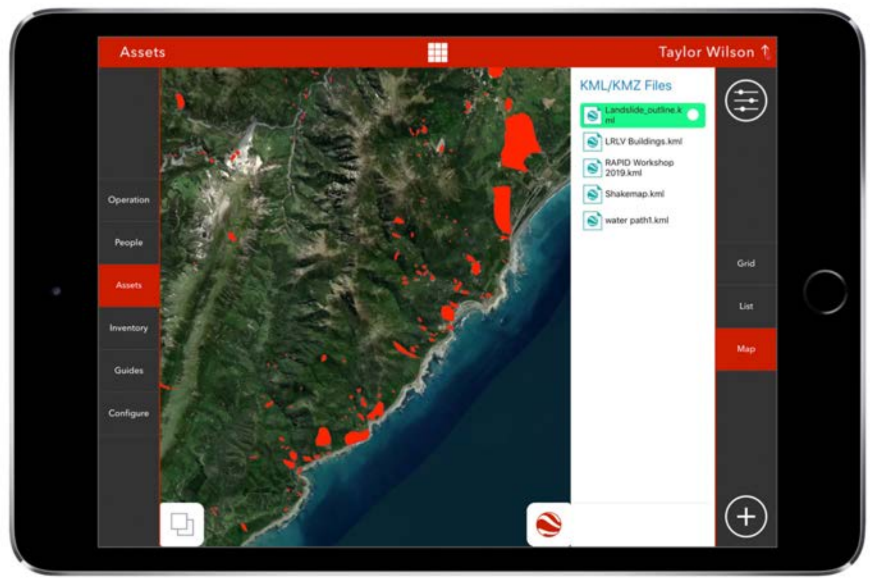
1. RApp mobile application is developed and optimized for GPS-enabled (i.e., cellular capability) I-pads (iOS). These are free to borrow from the RAPID Facility. RApp complies with NSF cybersecurity guidelines. It works offline.

2. RApp features include
- Take photos and record videos and audio
- Checklists
- RAPID instrumentation functions
- Upload KML-formatted maps for offline use
- Questionnaires, and now, *advanced questionnaires*
- Fully customizable

What is next? Based on community input: I-phone version, teams function, and more!

3. RApp was developed to directly interface with Designsafe. Data is synced (and thus backed up) in real-time. Data may be displayed in the Hazmapper web interface.





Mission Highlight: Palu, Indonesia Earthquake (GEER)

RAPID-user interactions

- Within 24 hours of contact, consult with leader on scientific objectives

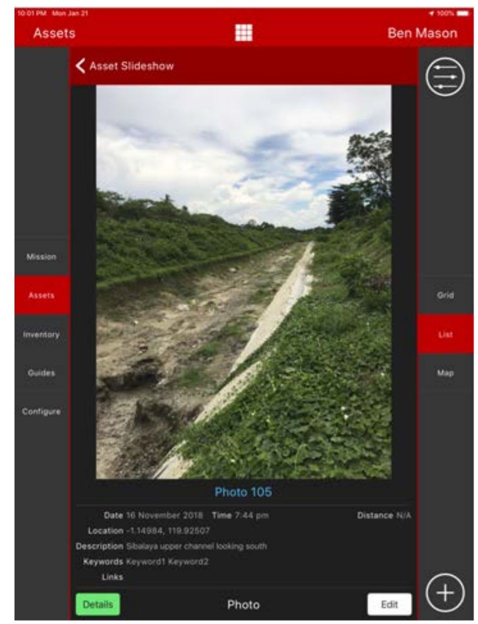
- Science plan: multi-geospatial scale, multidisciplinary data sets

- Set strategy to map multiple km^2 of flowslide with drones, with GPS ground control

- Collect feature data using RApp (auto-upload to DesignSafe)

- Subsurface investigation with portable dynamic cone

- RAPID workshop-trained Assist. Prof. Jack Montgomery leads drone planning/execution in the field



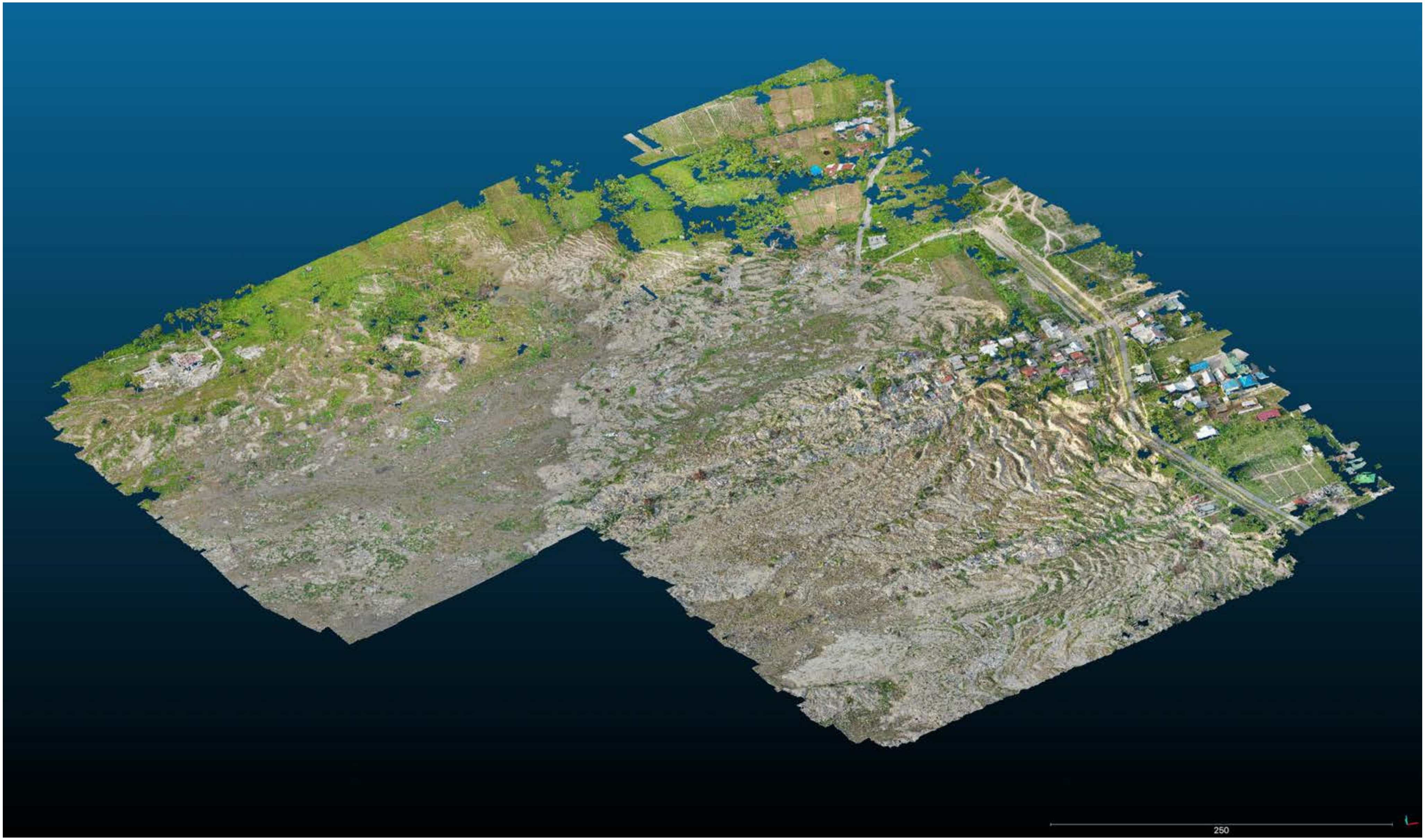
RAPID-Derived Data Products: Palu, Indonesia Earthquake

RAPID-Derived Data Products: Palu, Indonesia Earthquake

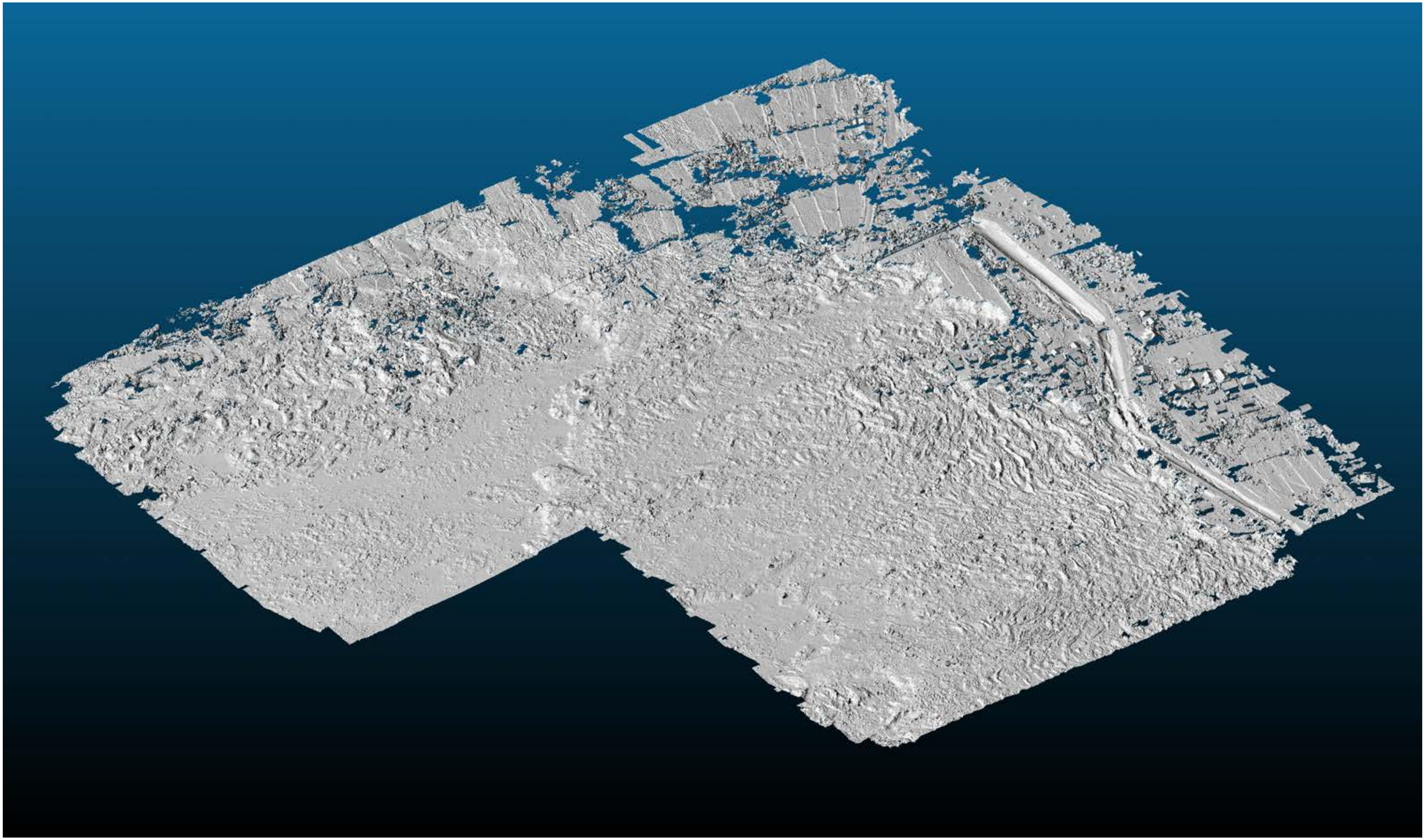
High-resolution (2 cm) orthomosaic mapping across multiple km^2

RAPID-Derived Data Products: Palu, Indonesia Earthquake

Reconnaissance Data Example: 2018 M 7.4 Palu, Indonesia Earthquake



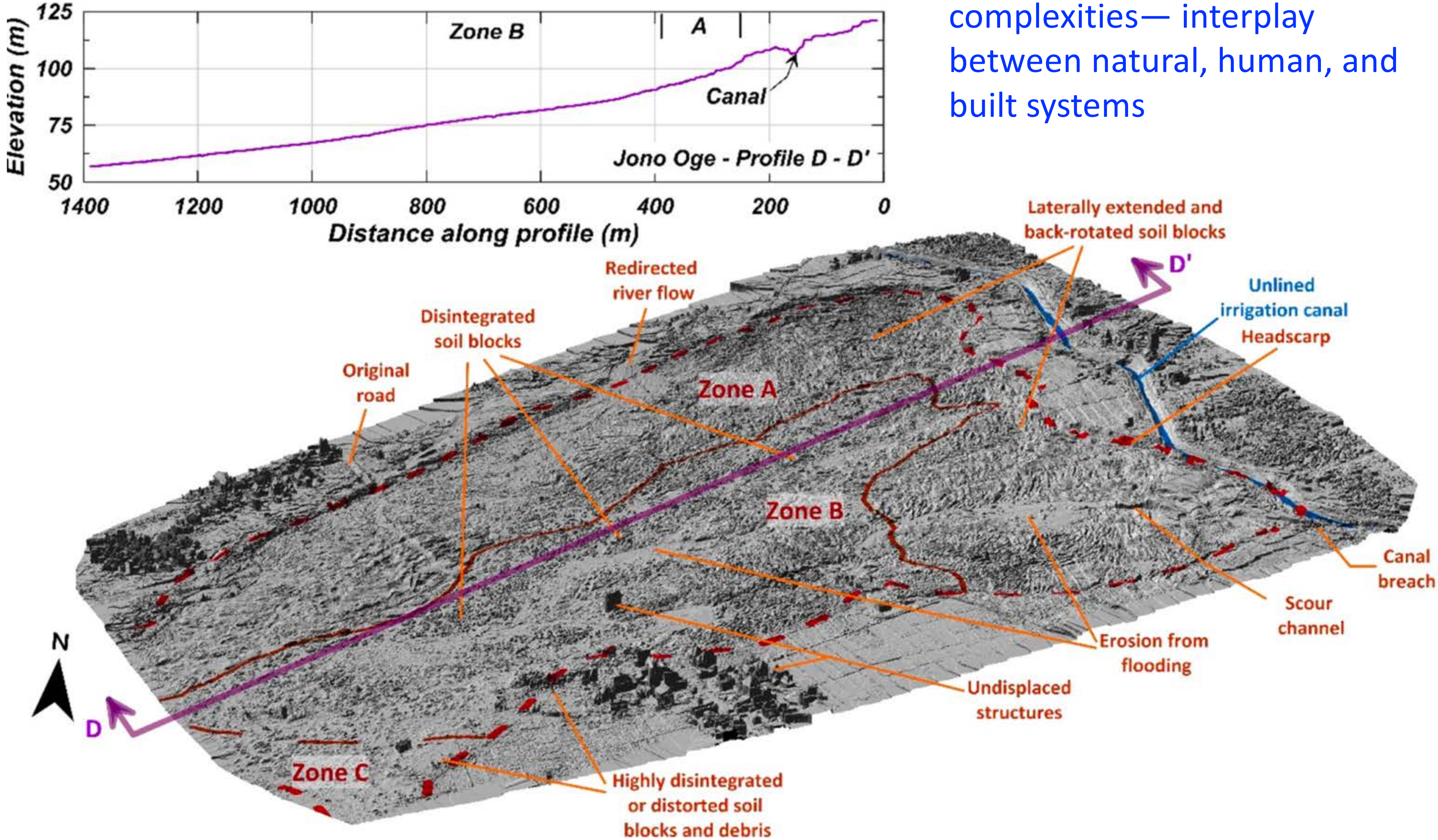
Reconnaissance Data Example: 2018 M 7.4 Palu, Indonesia Earthquake



Digital surface model (10-cm accuracy)

Reconnaissance Data Example: 2018 M 7.4 Palu, Indonesia Earthquake

Capture real-world complexities— interplay between natural, human, and built systems



Mason et al. 2020, *Geomorphology*

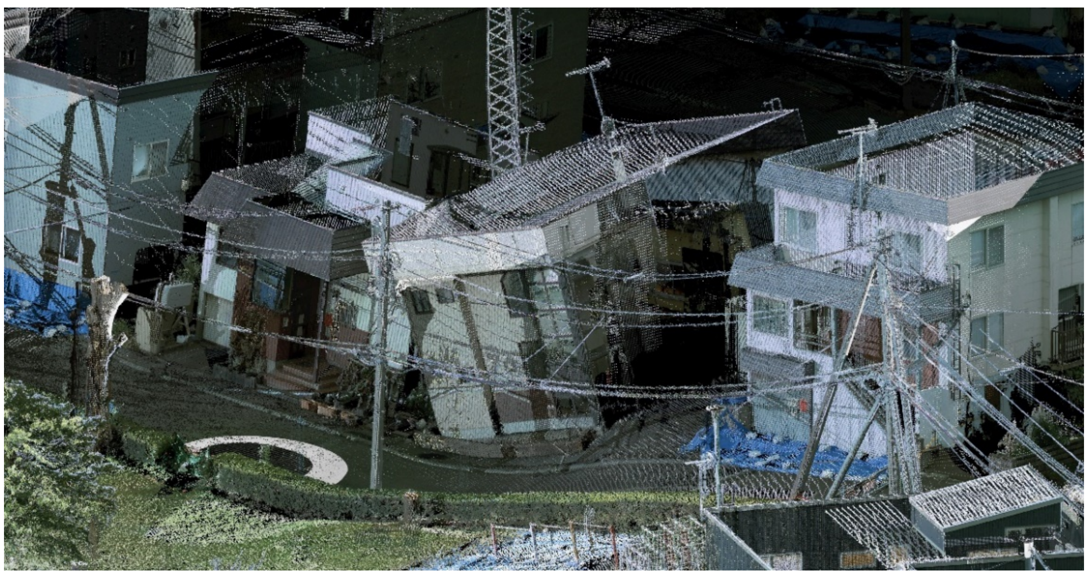
Mission Highlight: M6.6 2018 Tomakomai Earthquake (GEER)

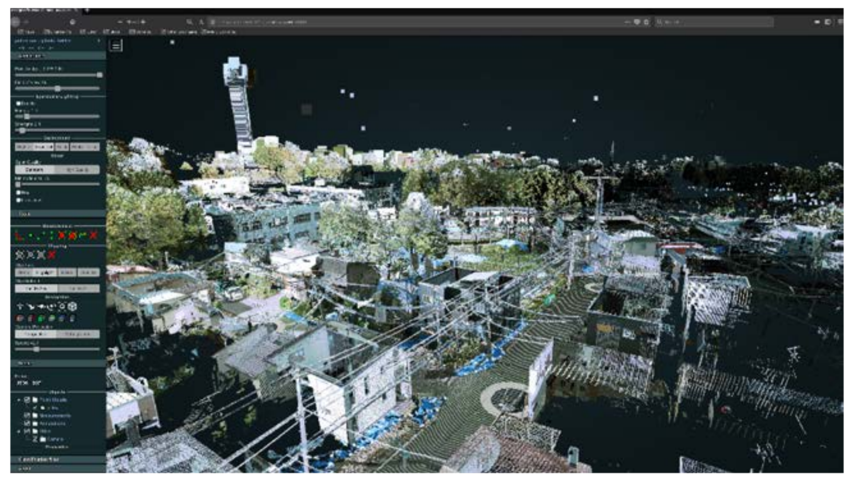
RAPID-user interactions

- Set strategy to capture both rural and urban ground failure settings using long-range (2.4 km) lidar, some surveys from building tops

- RAPID workshop-trained Alex Grant (USGS) and Brad Wham (Univ. of Colorado) lead lidar capture in the field

RAPID-Derived Data Products: Tomakomai Earthquake



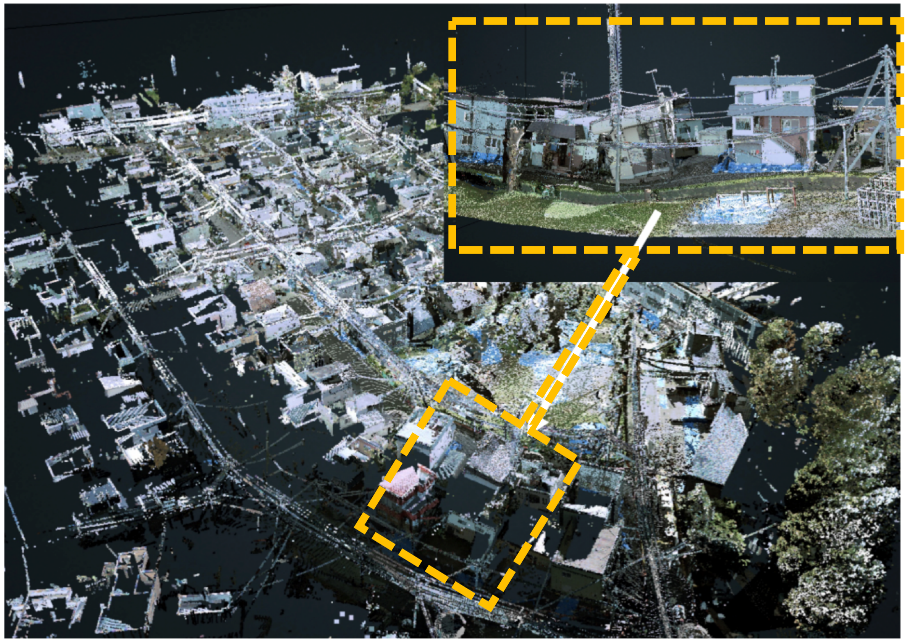


Data products: cm-level accuracy digital model of impacted city

Mission Impact: Tomakomai Earthquake

High-Quantity, High-Quality Dataset

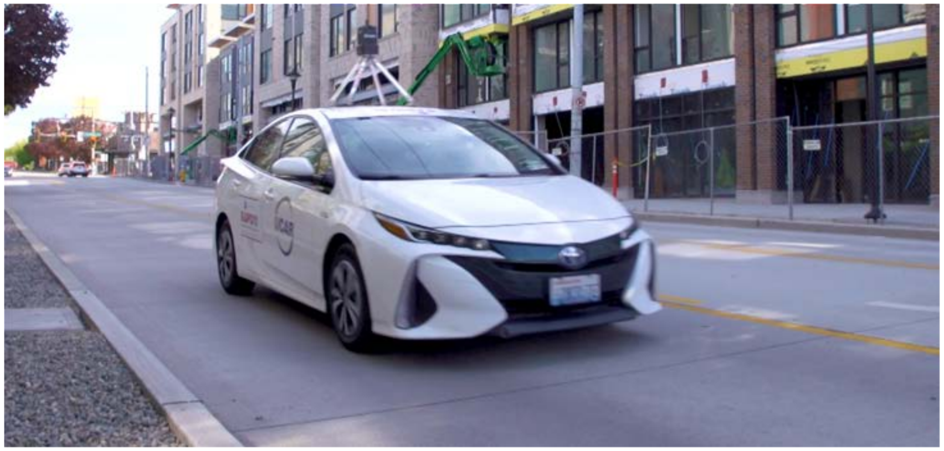
Dozens of soil-structure interaction case histories. Foundation type (mat vs. piles) was a critical factor in building performance



Science plan: Linking Geospatial Scales

Linking geospatial scales: site-specific performance in the context of large scale subsurface trends

Current Project: Covid-19 Seattle Streetview Campaign



- Longitudinal "street view" surveys across a broad socio-economic cross-section of Seattle

- 100-mile sampling route, run every 2 to 4 weeks, and after major policy changes

- Provides a ground-based, record of an urban region *during* and *after* a major pandemic

- Open datasets providing fundamental research insights on:

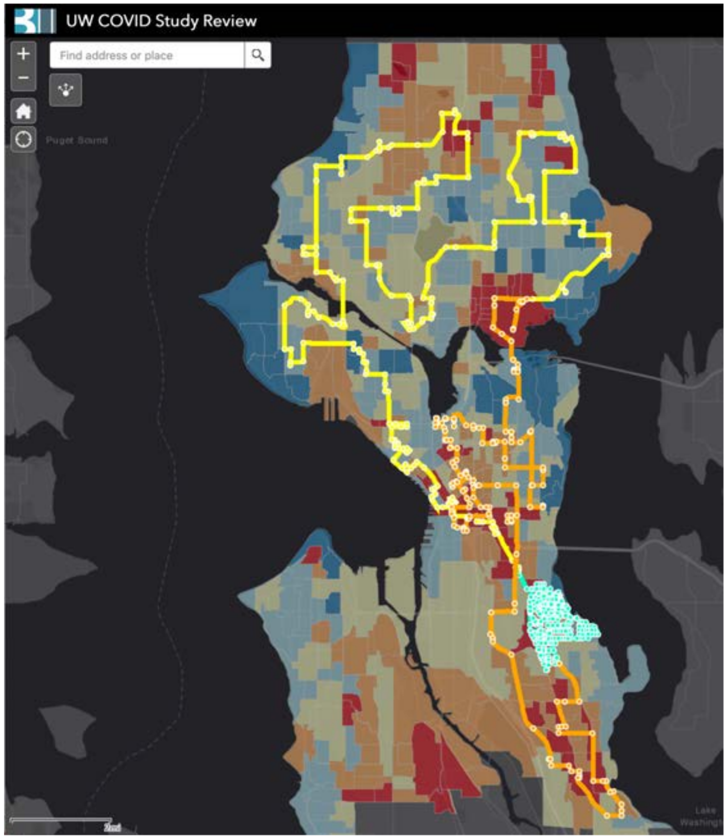
  - Crisis impacts on business operations, transportation networks, and other community assets
  - Rate and quality of recovery, and how this varies locally based on a community's characteristics
  - Response to nonpharmaceutical interventions, and later policy relaxations

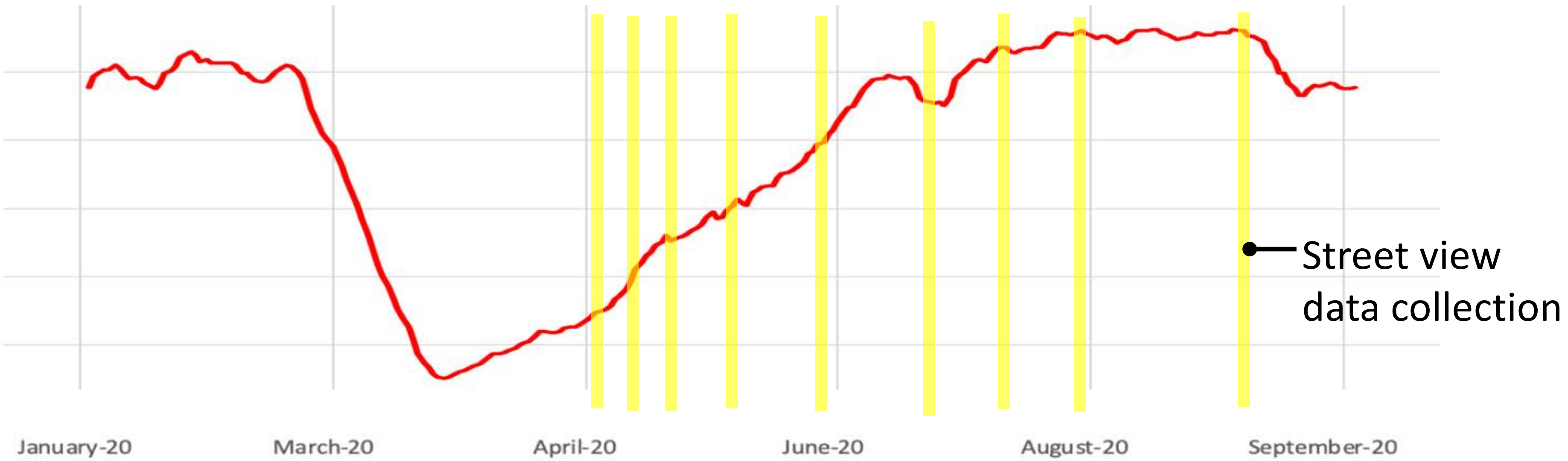
- Processed dataset will also serve as a benchmark for calibrating and validating urban simulation and recovery models

- Additionally, will advance the scientific application of post-extreme event mobile imaging by establishing sampling protocols that may be used to guide other campaigns

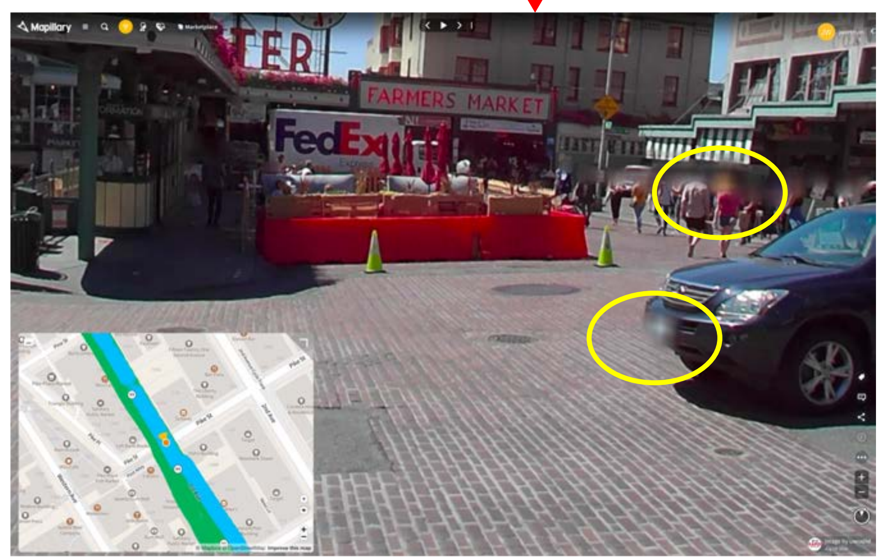
Science plan:

Cross Social- and Time Scale Data Collection

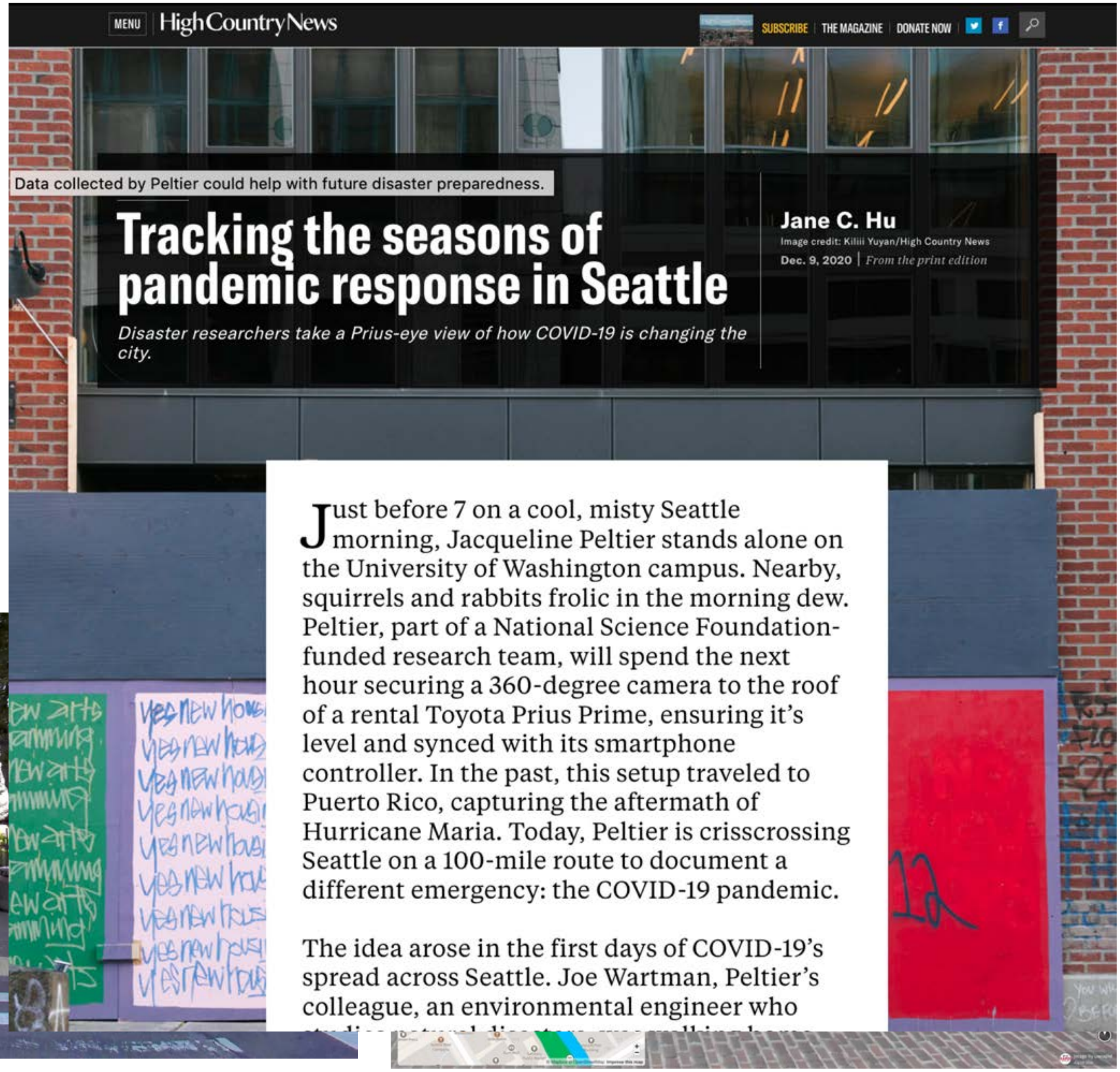




Street View System Products



Street View System Products



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Data collected by Peltier could help with future disaster preparedness.

Tracking the seasons of pandemic response in Seattle

Disaster researchers take a Prius-eye view of how COVID-19 is changing the city.

Jane C. Hu
Image credit: Kiliii Yuyan/High Country News
Dec. 9, 2020 | *From the print edition*

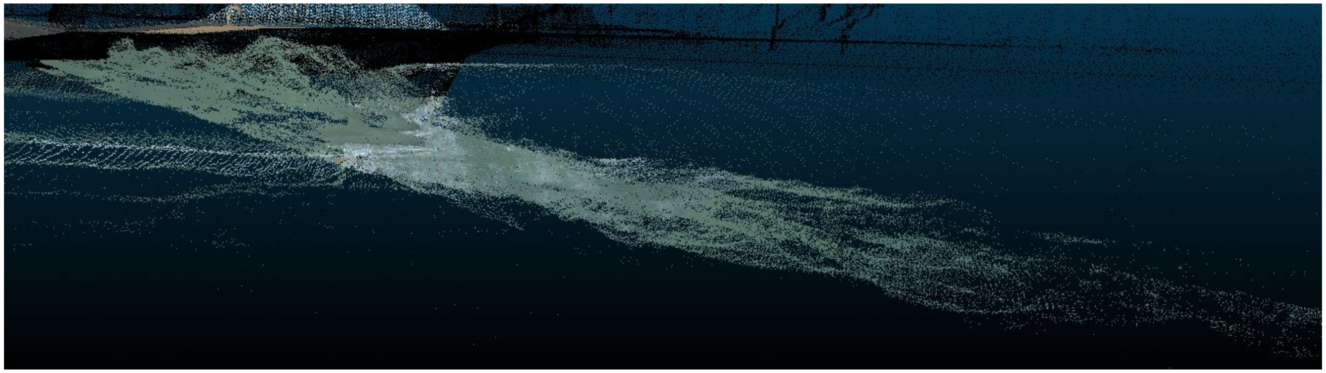
Just before 7 on a cool, misty Seattle morning, Jacqueline Peltier stands alone on the University of Washington campus. Nearby, squirrels and rabbits frolic in the morning dew. Peltier, part of a National Science Foundation-funded research team, will spend the next hour securing a 360-degree camera to the roof of a rental Toyota Prius Prime, ensuring it's level and synced with its smartphone controller. In the past, this setup traveled to Puerto Rico, capturing the aftermath of Hurricane Maria. Today, Peltier is crisscrossing Seattle on a 100-mile route to document a different emergency: the COVID-19 pandemic.

The idea arose in the first days of COVID-19's spread across Seattle. Joe Wartman, Peltier's colleague, an environmental engineer who

Supporting Novel Research Methods in Natural Hazards Science

E.g., Cell-phone video integrated with high resolution DEM to determine, for the first time, flow-slide velocity-time history during the Palu Earthquake

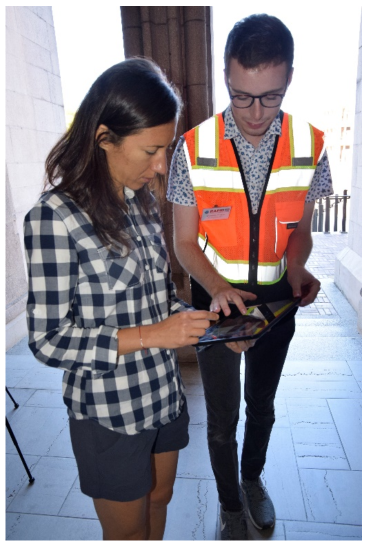
E.g., Application of drone-mounted lidar system to continually image waves in across a wide 3D field

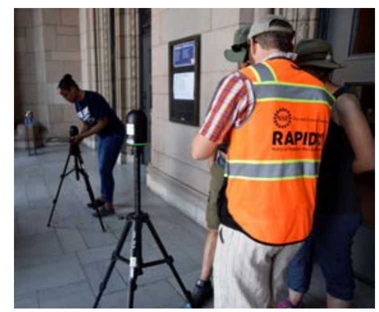


RAPID NHERI NSF

RAPID Training

We have trained over 200 individuals on state-of-the-art reconnaissance data collection





4-Day Intensive Workshop: Participants

- Marketing and Recruitment
  - Workshop flyers sent to multiple listservs
  - Targeted recruitment of participants from minority-serving institutions
  - 69 applicants (students, postdocs, faculty, gov't employees, industry)
- 26 Workshop participants
  - full range of career stages & paths
  - multiple disciplines

2019 RAPID 4-day workshop participants, staff, and REUs

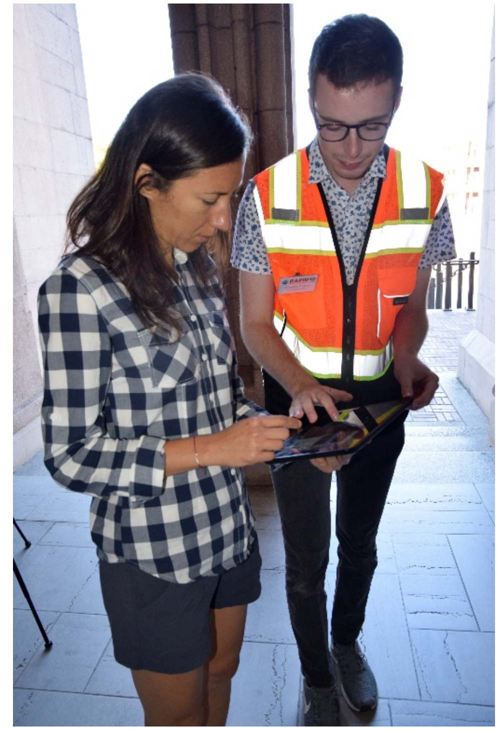
4-Day Intensive Workshop: Activities

- Hands-on training to use equipment and process data.
- 2019 schedule developed using feedback from 2018 workshop attendees as well as observations by facility staff -> more time spent on equipment training.
- Schedule enabled all to train on some of the equipment (Rapp,LiDAR,SfM) and smaller groups to train on specialized equipment (Z-Boat, Seismometers, etc.)

	Tuesday	Wednesday	Thurs A/Fri B	Thurs B/Fri A
8:30 9:00 9:30	**Intro/Facility Updates** (J. Wartman, J. Berman)	**Coastal** Z-boat/Pressure Sensors (M. Grilliot, J. Irish) ***OR*** **Seismic Site Charact. I** Seismometer/ATOM (J. Dafni, C. Wood)	**Terrestrial Lidar Scanning** Site planning Targets + control Hands-on: BLK, TS, Long Range (M. Olsen, M. Grilliot, A. Lyda)	**Structure from Motion** Intro, Flight Planning, Control (J. Wartman)
10:00	15-min Break			
10:30 11:00 11:30 12:00	**RApp** (T. Tanner)			
Lunch				
13:30 14:00	**DesignSafe** (T. Cockerill)	**Streetview** (J. Berman) MOR 110 ***OR*** **Seismic Site Characterization II** Seismometer/ATOM (J. Dafni, C. Wood)	**Terrestrial Lidar Scanning** Hands-on: BLK, TS, Long Range Registration Lite (M. Olsen, M. Grilliot, A. Lyda)	**Structure from Motion** Data Collection, Workflow, Pix4D Lite (J. Wartman)
14:30 15:00 15:30 16:00	**MiniRanger** (J. Dafni, M. Grilliot)			
Formal Sessions end @ 4:30PM each day				
	Social Hour & Dinner 5-7 PM	**Social Hour & Dinner** 5-8 PM	**Office Hours w/ RAPID Staff** 5-8 PM	

4-Day Intensive Workshop: Lidar

Terrestrial Lidar Scanning
- Scanning the UW grad library entrance using Leica BLK 360



4-Day Intensive Workshop

StreetView
- Setup streetview cameras and establish driving route

Structure-from-Motion
- Setup GNSS-GPS
- cameras and establish – review SfM pointcloud

4-Day Intensive Workshop - Impact

- **65%** of teams that took RAPID equipment into the field had one or more team members who had participated in a training workshop.
- **25%** of RAPID users (members of a team that took RAPID equipment into the field) participated in a RAPID training workshop.
- More pre-deployment training results in more effective and more efficient field deployments

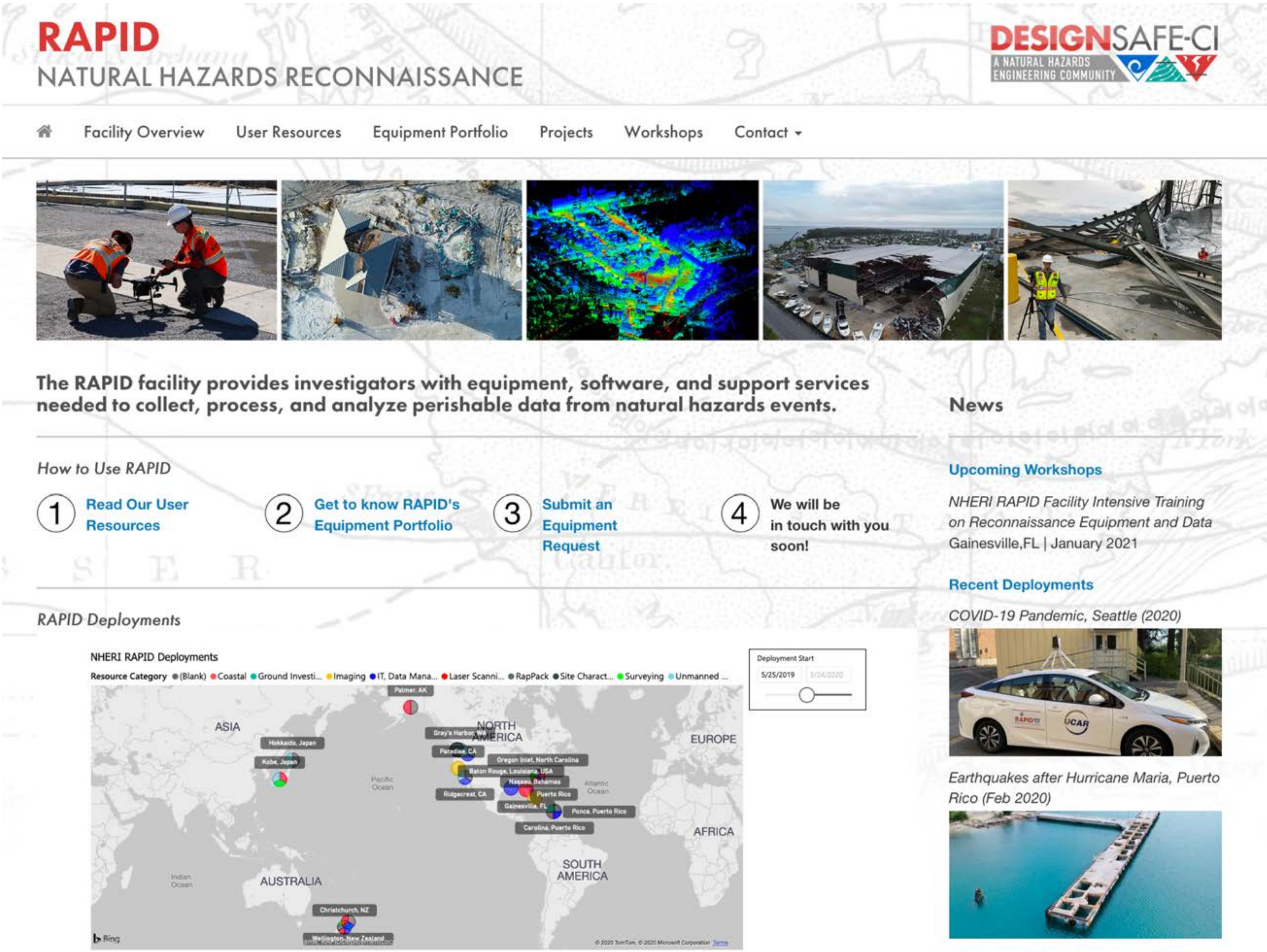
Hands-on summer workshop

Pre-deployment refresher

2-Day Data Processing Workshop

- September 5-6 (actually Y4) at RAPID HQ
- PI's and students from 4 projects:
  - Maria Koliou and graduate student (Texas A&M): E-Defense data collection
  - Graduate student of David Roueche (Auburn U.): Large volume buildings
  - Erica Fischer (Oregon State): Paradise wildfires
  - Navid Jafari (LSU): Hurricane Florence
- Focused on processing and learning from their data sets
- Very well received and productive
- Model for future support for users for data processing

More information..... Google: "UW RAPID"



See also: Berman et al. (2020) Frontiers in Built Environment