RAPID: STRUCTURAL WIND ENGINEERING RECONNAISSANCE OF HURRICANE HARVEY

A Supplement to **Collaborative Research: Geotechnical Extreme Events Reconnaissance (GEER) Association: Turning Disaster into Knowledge**

DATA REPORT

	
(right to left) Kennedy, Kijewski-Correa, Taflanidis, Zhang and Sun at Bayside, TX	*(left to right) Wood, Peterman, Liao at Aransas County Airport*
	
Wirkijowski, Hu, Leite, Ji, Xian, Zhou, Gong, Feng, Yu at Holiday Beach, TX	*Liang, Dao, Allen, Moser, Cai, Womble at Rockport, TX*

Prepared by Tracy Kijewski-Correa (Lead Investigator)
In collaboration with Team Leads Jie Gong, Andrew Kennedy, J. Arn Womble
and Team Members Steve Cai, John Cleary, Thang Dao, Fernanda Leite, Daan Liang, Kara Peterman, Chao Sun, Alexandros Taflanidis and Richard L. Wood

Funded through a subcontract to the University of Notre Dame from the University of California, Berkeley as part of an NSF supplement to [Geotechnical Extreme Events Reconnaissance (GEER)] (PI, Jonathan Bray) under award CMMI 12-66418. The team gratefully acknowledges Richard Fragaszy and Joy Pauschke for their support.

This report provides a detailed summary of the data collected and ultimately curated in the NHERI DesignSafe platform.

1. RECONNAISSANCE TEAM

Hurricane Harvey was the first Category 4 hurricane to make landfall in the US in over a decade, the first storm of this intensity to hit Texas since 1961, and what was to be the first in a sequence of major hurricanes to strike US territory in the 2017 season. As illustrated in Figure 1, the storm made landfall August 25, 2017 at the northern end of San Jose Island about 5 n mi east of Rockport, Texas at 0300 UTC as a Category 4 hurricane with sustained winds of 115 kt and a minimum central pressure of 937 mb. The hurricane then made a second landfall on the Texas mainland 3 hours later, with 105 kt winds and an estimated central pressure of 948 mb, southeast of Refugio on the northeast coast of Copano Bay west of Holiday Beach. The highest observed sustained winds on land were 96 kt near Aransas Pass, with the highest observed gust being 126 kt near Rockport. The combined effect of the surge and tide produced maximum inundation levels between 6 and 10 ft above grade to the north and east of landfall, in the back bays between Port Aransas and Matagorda, including Copano Bay and Aransas Bay.

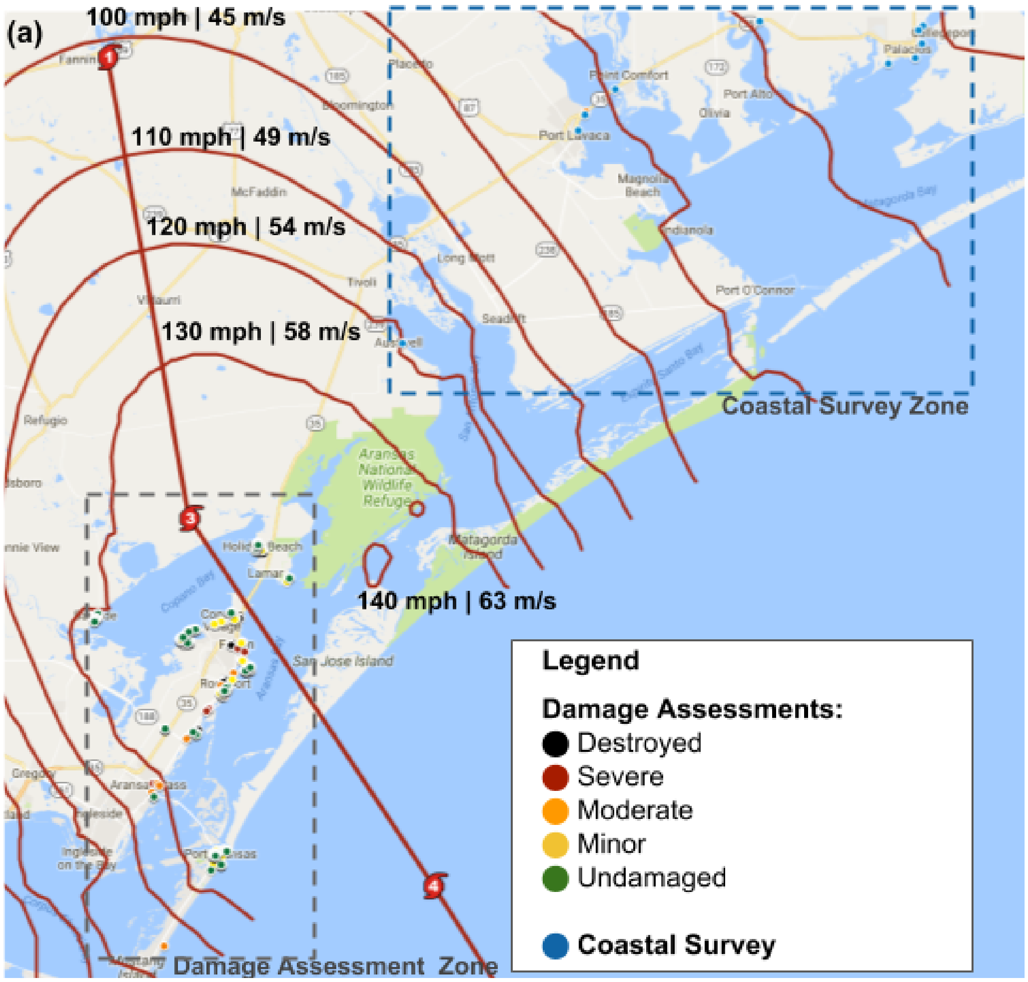


Figure 1. Map of landfall region of Hurricane Harvey with storm track superimposed, denoting regions where assessments were acquired. Damage Assessments color coded by overall damage rating; Coastal Survey points also denoted. Wind field contours (red) are derived from ARA report (supplied by Mark Levitan of NIST).

In response, a structural wind and coastal engineering reconnaissance team was assembled through a supplement to the NSF-supported Geotechnical Extreme Events Reconnaissance (GEER) Association (CMMI 12-66418, PI Jonathan Bray University of California, Berkeley) to document the damage induced by Hurricane Harvey. Tracy Kijewski-Correa (University of Notre Dame) served as coordinator of this team, under the leadership of Ellen Rathje (University of Texas at Austin) who was the overall coordinator for the three GEER teams deploying in response to this event. A call for participants was circulated across the community and teams were formed based on availability, balancing the expertise, equipment and prior hazard experience across the team members. The response was ultimately led by four sub-teams deploying in three waves, with some Floridian personnel initially intended to join these teams redirecting to conduct surveys after Irma struck their home state. Personnel who collaborated in the field to gather the reconnaissance data are summarized in Table 1. Following the reconnaissance effort, a team of student Data Librarians were trained to execute the Quality Assurance and Quality Control (QA/QC) process described in Section 3.2. These Data Librarians are listed in Table 2.

Table 1. Team Members and Dates of Field Work

Dates: September 8-10, 2017			
Team Member	**Affiliation**	**Team Assignment**	**File Coding**
Tracy Kijewski-Correa	University of Notre Dame	Field Coordinator (Wind Team 1, lead)	TK
Andrew Kennedy	University of Notre Dame	Coastal Scout Team (lead)	AK
Alexandros Taflanidis	University of Notre Dame	Coastal Scout Team	AT
Chao Sun	Louisiana State University	Wind Team 1	CS
Kara Peterman	University of Massachusetts Amherst	Wind Team 1	KP
Richard L. Wood	University of Nebraska-Lincoln	Wind Team 1	RW
John Cleary (Collaborator)	University of South Alabama/Metal Building Manufacturers Association	Wind Team 1	JC
Support Team:	Yijun Liao (Graduate Student Researcher, University of Nebraska-Lincoln), Zhiming Zhang (Graduate Student Researcher, Louisiana State University)		

Local UAS Teams (Texas A&M Corpus Christi):	**Team 1:** Dr. Michael Starek, Jacob Berryhill **Team 2:** Dr. Jinha Jung, Dr. Anjin Chang, Dr. Junho Yeom		
September 11-13, 2017			
Team Member		**Team Assignment**	**File Initials**
Jie Gong	Rutgers University	Mobile LiDAR Team (lead)	JG
Fernanda Leite	University of Texas at Austin	Mobile LiDAR Team	FL
Support Team:	Yi Yu (Graduate Student, Rutgers University), Xuan Hu (Graduate Student, Rutgers University), Zixiang Zhou (Graduate Student, Rutgers University), YuanShen Ji (Graduate Student, University of Texas at Austin)		
Unfunded Collaborators:	Siyuan Xian (Graduate Student, Princeton University), Kairui Feng (Graduate Student, Princeton University), Dominic Wirkijowski (Graduate Student, Rutgers University)		
September 15-17, 2017			
Team Member		**Team Assignment**	**File Initials**
Arn Womble	West Texas A&M University	Wind Team 2 (lead)	AW
Thang Dao	University of Alabama - Tuscaloosa	Wind Team 2	TD
Daan Liang	Texas Tech University	Wind Team 2	DL
Steve Cai	Louisiana State University	Wind Team 2	SC
Douglas Allen (Collaborator)	Simpson Strong-Tie	Wind Team 2	DA
Additional Unfunded Collaborators:	Charles Moser (Simpson Strong-Tie)		

Table 2. Data Librarians		
Name	**Affiliation**	**QC ID**
Andrew Bartolini	University of Notre Dame (also Logistics Coordinator)	AB
Matthew Musetich	University of Notre Dame	MM
Brendan Woods	University of Notre Dame	BW

2. METHODOLOGY

2.1 Survey Classes

Teams were assembled to document damage to structures, delineating the effects of wind and coastal hazards, using the following survey classes.

2.1.1 Coastal Surveys

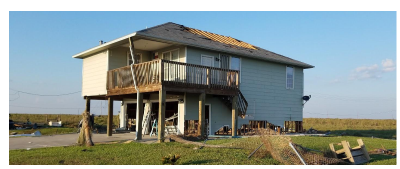
Coastal Surveys were conducted to establish high water marks and inundation extent, as inferred from debris lines, damage levels, displaced objects and first-hand accounts. Runup and maximum still water elevations were determined from debris fields and eyewitness accounts. Elevations were measured from local still water level using one of two methods: (1) rod and level and (2) laser rangefinder with angular measurement from horizontal. Most measurements were taken down to the still water level.

2.1.2 Damage Assessments

Damage Assessments were conducted door-to-door for a detailed evaluation of building condition, including primary structural typologies, construction materials, and component damage levels. These were established using direct observation and contact/non-contact measurements accompanied by geotagged photos, videos, and statements from homeowners to establish failure sequences. Wind hazard intensity was mapped using observation-based data products from ARA (supplied by NIST) -- see contours in Figure 1.

A standardized damage assessment instrument was created and programmed as a Fulcrum mobile application. The instrument fields were based upon prior instruments developed by team members Kennedy and Kijewski-Correa, as well as the Fulcrum application used by Krupar, Roueche, Smith & Lombardo in their initial Harvey reconnaissance. The customized App then steps through major assessment categories, beginning with building classification. Any visible mitigation measures are also noted. All records receive a **Total Damage Rating,** as well as component-level damage ratings. The **Total Damage Rating** scale for low-rise (less than 3 stories), single- and multi-family residential structures (majority encountered in field reconnaissance) is defined in Table 3. Other building types were rated in accordance with the HAZUS-MH Hurricane technical manual.

Wind Team 1 members unable to use this application were provided with hard copy forms that were later encoded into the Fulcrum database and photos acquired by GPS camera were uploaded and attached to the Fulcrum database entry. Wind Team 2's members all used the Fulcrum application. The Fulcrum application automatically records date/time, GPS coordinates and street address of the property; for hard copy surveys, locations were derived from pins recorded by the surveyor's handheld GPS unit or from the geotagged photos acquired by the surveyor's GPS camera. Appendix A lists the fields acquired by the Fulcrum Application, while Appendix B contains the corresponding hardcopy instrument that was later coded into the Fulcrum Application's database to unify the dataset. Note that the response categories for roof cover and wall cover/cladding were expanded for Team 2's survey based on regional construction practices observed by Wind Team 1, thus multiple updates to the Fulcrum Application were deployed during this campaign (see "Version" data field in Appendix A).

Table 3. Total Damage Rating Scale	
4/X=Destroyed Complete roof failure and/or failure of wall frame. Loss of more than 50% of roof sheathing.	
3=Severe damage (major impacts to structural load path) Major window damage or roof sheathing loss. Major roof cover loss. Some roof structure failure.	
2=Moderate damage (load path preserved, but significant repairs required) A few roof sheathing panels damaged. Roof cover loss < 50%.	
Minor damage (damage confined to envelope) Up to one door or window failure. Some wall cladding and soffit failure noted. Up to 15% roof cover loss.	
Undamaged No visible damage.	

2.1.3 Stationary Scans

Different portable stationary scanning technologies were used in the reconnaissance: ground-based LiDAR scanner (Faro Focus S-350 LiDAR scanner with 350 meter range) operated by Wind Team 1 and a Leica BLK360 imaging laser scanner, a Faro Focus 3D scanner, and a Google Tango phone operated by the Mobile LiDAR Team. Both the Leica BLK360 and Faro S-350 data were acquired through a three step process of scan planning, data acquisition, and data processing. The planning phase considers the scanning positions and positioning of registration targets if there is a need and placement of survey control points. The overall purpose is to determine an optimum number of scans and their positions such that the scans can be accurately registered to maximize coverage with minimal occlusions. At a site of interest, the number of scans conducted was a function of the available site access (relative to both permission and safety), geometry of the structure (due to its line of sight technology), and permissible time. In the data acquisition phase, terrestrial scanners often record the 3D information of the targeted objects, and a built-in function will automatically register all the points from a single scan to the local coordinate system of the scanner.

The Faro scans were collected using parameters of 1:4 density with 4x oversampling to minimize noise in the dataset while minimizing acquisition time. Each Faro scan position was approximately 8-14 minutes. The resultant from each scan is a point cloud in its relative coordinate system. Similar to the Faro scans, the Leica BLK360 data collection also consisted data collection at the site and data registration. The number and location of scans was planned at the site based on available site access, direct line of sight to the areas of interests, and maximum distance between each scans. Each scan was conducted at normal resolution to achieve a balance between maximized point density and desired number of scans. Each scan position took approximately 3-10 minutes. The distance between scans was less than 20 feet. After each scan, an iPad-based application performed automated registration to link the current scan to previous scans. In most cases, the auto-registration was correct. In a few cases, manual registration was performed to link scans in the same area of interest. The scan locations did not have direct sunlight to avoid both overheating the laser scanners and overexposing the images. After registration of several scans in a specific area of interest, the result was a point cloud and a spherical 360 color image.

2.1.4 Mobile Scans

Mobile LiDAR data collection starts with mission planning and staging which is mainly concerned with GPS outage-related planning. The van-mounted mobile LiDAR system (consisting of a Velodyne HDL32 LiDAR scanner, a Ladybug Panoramic Camera, and an Applanix navigation system) was calibrated prior to driving the unit down the identified street or coastline. All trajectory solutions were derived with the Applanix SmartBase technique, which leverages GPS base station data from surrounding CORS stations and a temporary base station set up by the team. The resulting data includes 3D point clouds, GPS/IMU data, and camera data. The mobile LiDAR system produces 3D point clouds, GPS/IMU data, and camera data, which are extensively post-processed to generate georeferenced point cloud and imagery data. Each georeferenced point cloud corresponds to a driving path, and a total of 38 driving paths were acquired over the landfall area, as visualized in Figure 2. The distance of each path varies from 1 mile to more than 6 miles.

Figure 2. Map of landfall region of Hurricane Harvey with colored lines indicating each of the 38 unique drive paths executed by the mobile LiDAR unit.

2.1.5 Unmanned Aerial Surveys

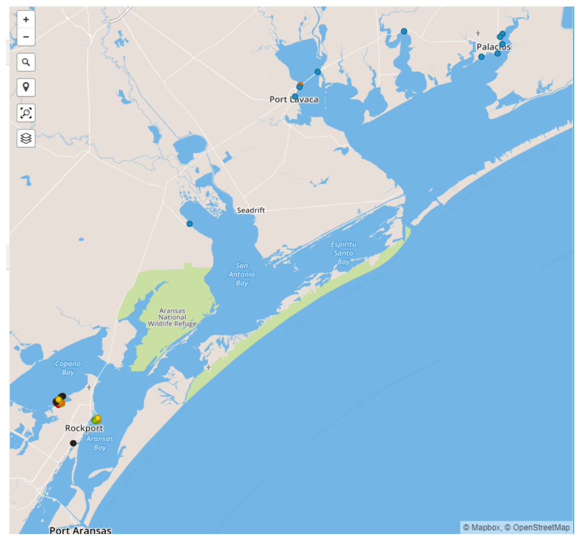
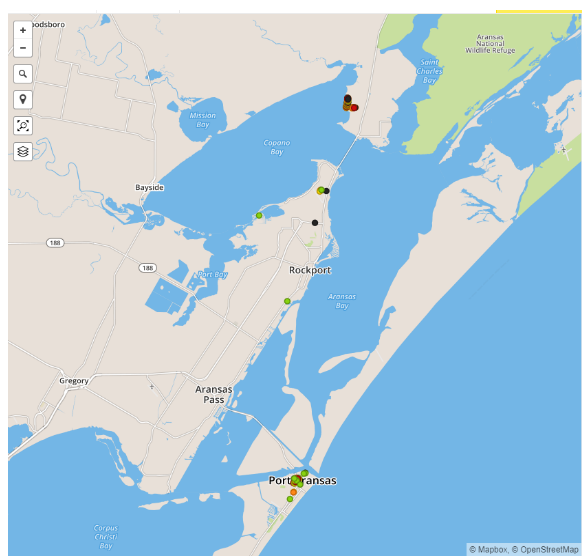
Unmanned Aerial Surveys (UAS) were conducted post-Hurricane Harvey at three locations to help categorize structural damage and to provide a superior vantage point for roof damages. The UASs at Holiday Beach and Salt Lake recorded damage around the shoreline of Copano Bay, while the third in Port Aransas recorded damage just inland of the Gulf of Mexico. Two teams, both from Texas A&M University, Corpus Christi, acquired the imagery at these three sites. A DJI Phantom 4 Pro was used to fly all UAS missions. A summary of each surveyed site now follows:

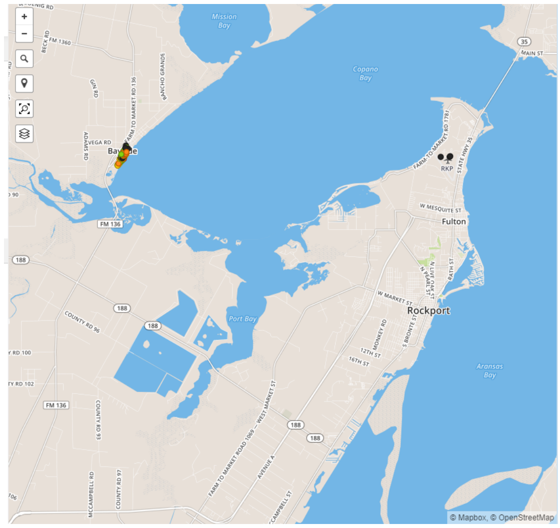
- **Holiday Beach:** The Holiday Beach area is located in Aransas County, TX, facing the southeast side of Copano Bay. Team 2's UAS in Holiday Beach produced two types of data: Digital Surface Models (DSM) and photo orthomosaics.
- **Salt Lake:** The Salt Lake area is located in Aransas County, TX, facing south Copano Bay and across the peninsula from Fulton/Rockport. Team 1's UAS in this community included photos, orthomosaics, and georeferenced point clouds. The area covered was centered around the entrance to Salt Lake.

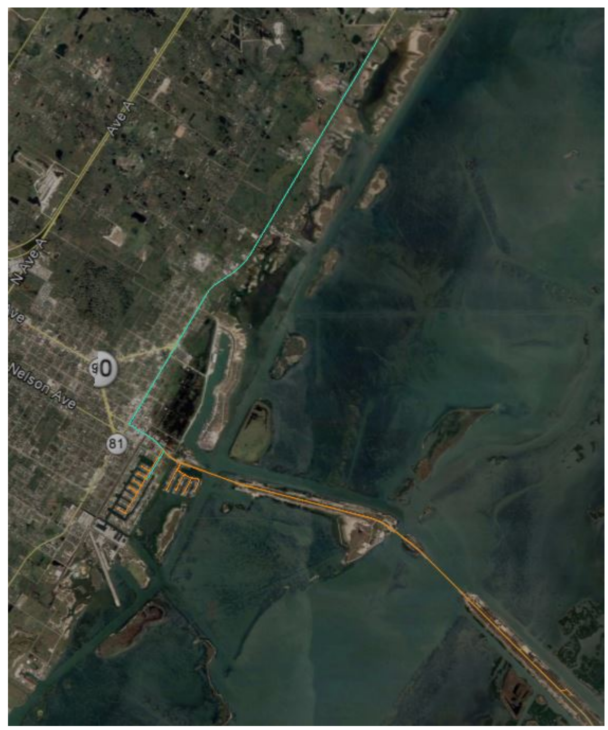
- **Port Aransas:** Port Aransas is located in Aransas County, TX, on the thin barrier called Mustang Island separating the Gulf of Mexico and Corpus Christi Bay. Team 1's UAS here included two separate orthomosaics and georeferenced point clouds.

2.2 Chronology and Geospatial Distribution of Data Collection

The geographic focus of the damage assessments is visually depicted in Figure 1, with Table 1 again summarizing the individuals participating on each team. Table 4 provides a detail of the chronological sequence of the reconnaissance.

Table 4. Summary of Reconnaissance Efforts in Hurricane Harvey	
September 8, 2017 **Coastal Scout Team:** Measured high water marks east of Rockport to Palacios (Hynes Bay, Lavaca Bay, Vaes Bay) **Wind Team 1:** Rockport (southwest edge of Copano Bay around Salt Lake, Key Allegro)* *includes stationary scan of Rockport Marine Inc.	
September 9, 2017 **Wind Team 1 & Coastal Scout Team:** Rockport (Holiday Beach), Aransas County Airport, Port Aransas (Cut-Off Road to Avenue A, along Cotter Ave.), Rockport and Port Aransas (assorted marina facilities)* *includes stationary scans of Nueces County Water Control/Boat Works and Sea Gull Condos in Port Aransas **UAS:** Rockport (southwest edge of Copano Bay around Salt Lake), Holiday Beach, Port Aransas (parallel to coast along dunes)	

September 10, 2017 **Wind Team 1 & Coastal Scout Team:** Bayside; stationary scan of Aransas County Airport Hangar	
September 11, 2017 **Mobile Scan 1:** Holiday Beach (includes stationary scan of single family homes with wind and surge damage)	
September 11, 2017 **Mobile Scan 2:** Rockport (Copano Ridge Road area, includes stationary scan at west end of Copano Ridge Road)	

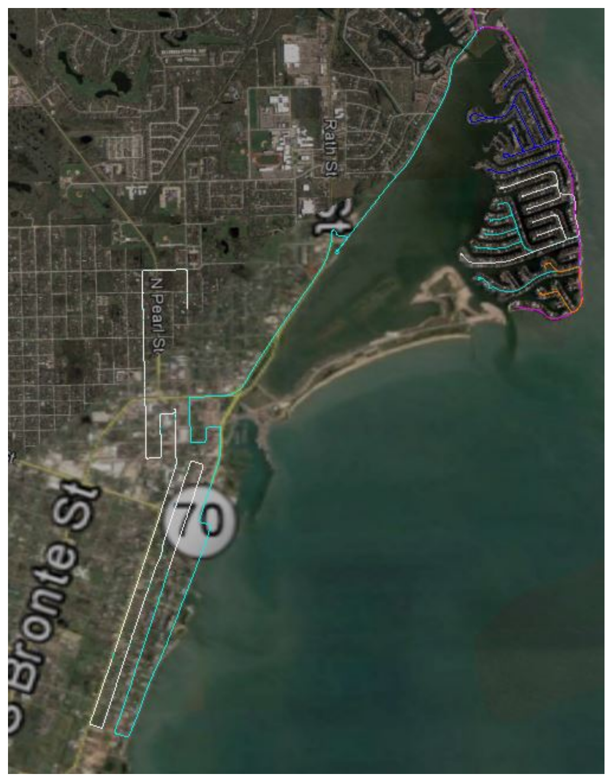
September 12, 2017 **Mobile Scan 1:** Port Aransas	
September 12, 2017 **Mobile Scan 2:** Aransas Pass (Sea View Dr. area)	

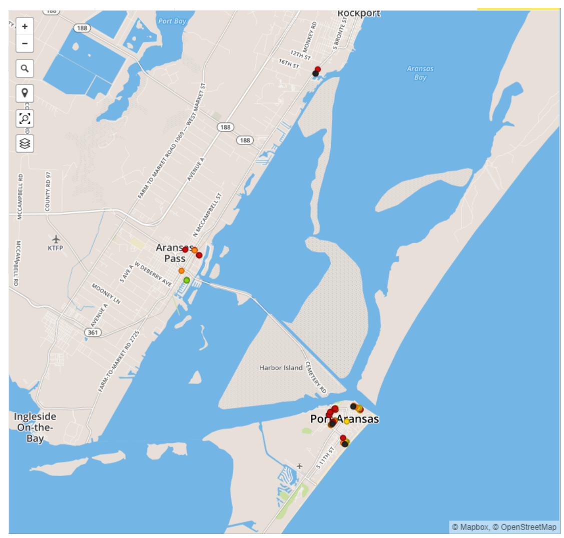
September 12, 2017

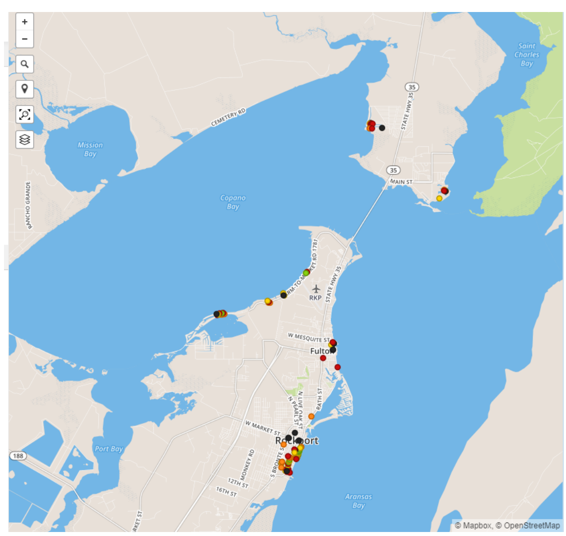
Mobile Scan 3: Bayside

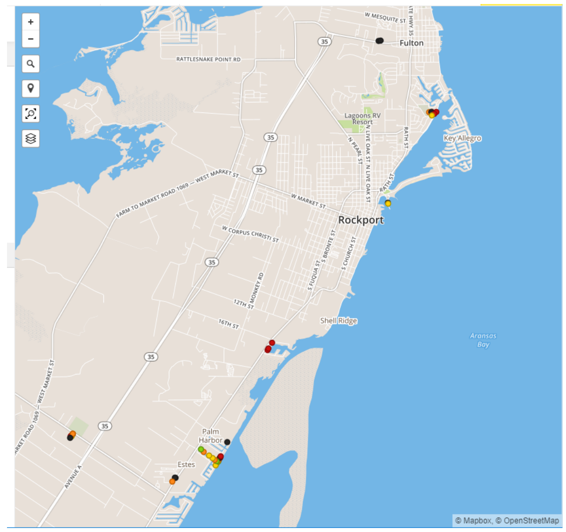
September 13, 2017

Mobile Scan 1: Rockport (Key Allegro)



September 13, 2017 **Mobile Scan 2:** Lamar (Front Street area)	
September 15, 2017 **Wind Team 2:** • Aransas Pass neighborhood just west of Intracoastal Waterway south of Hwy. 361 • Port Aransas • Aransas Pass along North Railroad Avenue • Rockport (Cove Harbor)	

September 16, 2017
 	
Wind Team 2:
• Rockport area
    ○ south of Downtown, along S. Magnolia, S. Austin, and S. Water Streets
    ○ S. Church Street at E. 2nd to E. 3rd Streets
    ○ Southeast edge of Copano Bay, Copano Ridge Road between Ridge Harbor Drive and Loop 1781
    ○ Loop 1781 north of Aransas County Airport and east of Copano Bay
• Reserve Lane south of Goose Island State Park
• Holiday Beach
	

September 17, 2017 **Wind Team 2:** ● Rockport area ○ Highway 188 west of Highway 35 ○ South Church Street ○ Neighborhoods along Ocean Drive (along waterfront) ○ Cove Harbor ○ Rockport Marina ○ North Broadway between Key Allegro and Rockport Cemetery ● Fulton (Highway 35, TXDoT Facility)	

3. DATA PROCESSING

3.1 Coastal Surveys

For all locations, elevations were determined in NAVD88 using mean sea level (MSL) corrections from VDATUM. Each site was manually assigned an identifier by their surveyor using the following format:

HH-MMDDYY-SXXXX-AK

where HH=Hurricane Harvey, MMDDYY is the date of the survey as month, day, year (e.g., 090817), S=site, XXXX = 4-digit site number, sequentially increasing and resetting daily (e.g., 0020), and PI=initials of investigator (AK).

3.2 Damage Assessments

While Fulcrum assigns a unique identifier to each record, hard copy assessments were manually assigned an identifier by their surveyor using the following format:

HH-MMDDYY-SXXXX-PI

where HH=Hurricane Harvey, MMDDYY is the date of the survey as month, day, year (e.g., 090717), S=site, XXXX = 4-digit site number, sequentially increasing and resetting daily (e.g., 0020), and PI=initials of investigator (e.g., AT, see Table 1).

The entire Fulcrum Database was migrated into a Fulcrum Community account to allow for immediate public access and the ability to crowdsource additional assessments from those outside the team. Once all hardcopy assessment forms and corresponding geotagged photos were migrated into the Fulcrum Database, the database was downloaded in its entirety as a CSV file with accompanying photographs for curation. Then each record in the Fulcrum database underwent the Quality Control/Quality Assurance process developed by David

Rouche (Auburn University) for the subsequent Hurricane Irma/Maria reconnaissance missions. Records were updated in real-time within the Fulcrum Community portal as they underwent each stage of the QC/QA Process.

The process was divided into three stages:

1. Verify existing inputs for basic building attributes and overall damage state

   Check surveyor name, record date, consistency between GPS coordinates & reported street address, proofreading of any entries in app's notes field, verify total damage rating

2. Add or update missing information in the app for parameters that should be available through photographs or public sources such as appraiser websites, Zillow, NOAA Aerial Imagery

   Update year of construction, number of stories, roofs shape, roof cover, wall cover/cladding, wall framing, opening protection, garage door, first floor height, number of stories, damage cause, post-event functionality, component damage levels

3. Verify, update or add information that was not captured in the field and may not be available or applicable for all buildings (e.g., use of hurricane straps)

As each record completed one of these stages, a code is updated in the record (see "QC Code" field in Appendix A). A QC notes field is also provided for the Data Librarian to include any relevant information regarding changes made to the record in the process. Once the process was completed, the final database is downloaded from Fulcrum for curation in DesignSafe in CSV and GeoJSON formats.

Table 5. QC Codes and Descriptions

Code	Description
0	No QC performed
1a	Stage 1 – completed, no errors identified
1b	Stage 1 – completed, errors identified and corrected
1c	Stage 1 – incomplete, errors identified but not resolved
2a	Stage 2 – completed, damage ratios added, visible building details added
2b	Stage 2 – completed, but some fields are blank and need further review

While conducting Damage Assessments, surveyors may acquire additional photos, videos or recorded observations/notes that were captured outside of the Fulcrum App. These are also curated, as discussed in Section 4. Damage assessments may also be accompanied by additional observations (from measurements and interviews) that may be entered in the notes field of the Fulcrum Application or captured through voice recordings or handwritten notes.

These are transcribed in Field Journals discussed in Section 4 (Directory D7. Dissemination Products).

3.3 Stationary Scans

After field data collection, the raw scans have to go through several post-processing steps such as filtering to reduce noise and scan registration. Functionalities inherent to each scanners technology automatically register all the points from a single scan to a common global or universal coordinate system (UCS). To achieve a UCS, the scans were first manually placed aligning survey targets or natural features such as planes and edges (e.g., walls, columns, ground surfaces, etc.) and optimized using cloud-to-cloud technology. While filtering is commonly used to reduce noise, no filtering or cleaning techniques were performed on the Faro scans, as this can vary by application for further LiDAR point cloud data processing.

3.4 Mobile Scans

Post-processing of mobile LiDAR data includes forward and backward trajectory processing with base station data, stitching and georeferencing the point cloud data, georeferencing the imagery data, and QA/QC focused on strip/lever arm/boresight adjustment and benchmarking against known points or targets. All trajectory solutions are derived with the Applanix SmartBase technique which leverages base station data from surrounding CORS stations and a temporary base station set up by the team. The geo-referencing process and QA/QC are performed using the software developed by the Mobile LiDAR Team. The final datasets include trajectory data, geo-referenced point cloud data, and street-level imagery data. The projection systems used for all datasets collected by the Mobile LiDAR Team were Texas State Plane in US Survey Feet units. NAD83 was used for the horizontal datum; NAVD88 was used as the vertical datum.

3.5 Unmanned Aerial Survey

Geolocated photos were the prime dataset acquired for subsequent creation of photogrammetric products like:

1. Processed orthomosaic photo geotiffs stitched together from many separate UAV photographs
2. Digital Point Clouds obtained by photogrammetry from many separate UAV photographs
3. Digital Surface Models (DSM) of the terrain and buildings.

To generate these, the geolocated dataset is ingested into a standard UAS-compatible photogrammetry desktop application, in this case Pix4D Mapper Pro (v. 3.3.29), which was used for the following basic processing:

- Check the photo dataset for its integrity and positional accuracy based on the geolocation coordinated in the metadata of each image.
- Establish desired coordinate system and units of measurement. In this case, all data are in UTM14N Meters with elevations being ellipsoidial WGS84.
- Establish options for processing quality, processing speed, data outputs, and other related parameters.
- Generate data outputs such as point clouds, 3D models, digital surface models, and orthomosaics.

Resulting point clouds can be rendered by standard software such as Pix4D Mapper Pro for an even more photorealistic model, the point cloud can become a 3-dimensional mesh. Area, linear, and volumetric measurements can be taken from the point cloud and DSM.

Note that the UAS data is not georeferenced to survey-grade accuracy. As such, the global accuracy is 1 to 5 meters, but the relative accuracy within the orthomosaics and point clouds is sub-meter, as summarized in Table 6.

Table 6. Resolutions on Photogrammetric Products		
Site	**Photogrammetric Product**	**Finest Resolution**
Holiday Beach	orthomosaic geotif	2.13 cm
Holiday Beach	digital surface model	4.26 cm
Port Aransas (North)	orthomosaic geotif	2.61 cm
Port Aransas (South)	orthomosaic geotif	2.71 cm
Salt Lake	orthomosaic geotif	2.72 cm

4. ARCHIVED DATA PRODUCTS

This section details the directory structure created in DesignSafe-CI and the contents therein.

🖿 Directory D1. Damage Assessments

FORMATS = CSV, GeoJSON, JPG, PNG

The raw Fulcrum database of Damage Assessments (both those directly recorded via Fulcrum and those recorded in hardcopy and manually input into Fulcrum), prior to QA/QC processing, is archived as a zip file in the folder **Damage Assessment Data -- Original.** The folder **Damage Assessment Data -- Quality Controlled** contains the final quality assured dataset (as CSV and GeoJSON) for *771 Building Assessments* with all the response fields in Appendix A. All referenced photos are contained in **HH-DA-PHOTOS.**

🖿 Directory D2. Surface Imagery

D2.1 Photographs

FORMAT = JPG, PNG

This directory contains a folder (Photos) that catalogs additional photos captured by investigators outside of Fulcrum or other formal damage assessment. Photos from each investigator were reviewed to remove poor quality, redundant, ambiguous or irrelevant photos/videos and renamed by a standard convention:

HH-MMDDYY-P####-PI.JPG

where HH = Hurricane Harvey, MM is the month (=09), DD is the day (e.g., 10), YY is the year (=17), P=photo, #### is the photo number (sequentially updated and reset daily), and PI are the initials of the investigator acquiring the image (see Table 1).

D2.2 Videos
FORMAT = MP4

This directory also contain a folder (Videos) that contains a sequence of videos filmed while driving various routes in the landfall area. Each video clip is named by a standard convention:

HH-MMDDYY-V####-PI.MP4

where HH = Hurricane Harvey, MM is the month (=09), DD is the day (e.g., 10), YY is the year (=17), V=video, #### is the video number (sequential), and PI are the initials of the investigator acquiring the video (see Table 1). The folder "GPS Route" contains the waypoints for the route traversed while shooting these videos (in multiple formats: DXF, GDB, GPX, KMZ, APS, TXT).

D2.3 Logs
FORMAT = XLSX
A photo log (HH-PHOTO-LOG) contains a chronological listing of the following attributes of each photo:

A	B	C	D	E	F	G	H
1	2	3	4	5	6	7	8
File Name	Date Taken	Time Taken	Latitude	Longitude	Site ID	Location	Description

Time, date and coordinates were extracted from the metadata of each geotagged photo. On those that were missing GPS locations due to malfunction of the camera, the GPS locations were approximated by using the coordinates of photos taken in the same locale. The Site ID (if assigned) follows the format in Section 3.2. The investigator acquiring the image or a Data Librarian provide a description of each image and the location (community or city) where the image was acquired.

A video log (HH-VIDEO-LOG) contains a listing of the GPS files documenting the routes traveled when videos were acquired, followed by a chronological listing of the following attributes of each video clip:

A	B	C	D	E
1	2	3	4	5
File Name	Format	Date Taken	Location	Description

The investigator acquiring the video provided a description of clip and the location (community or city) where the video was acquired.

🖿 Directory D3. Coastal Survey

D3.1 High Water Levels
FORMAT = XLSX

The excel file named ‘HH-Coastal Survey’ contains a listing of high water levels identified from coastal surveys. The contents of each column are itemized below:

Column		Header	Description
A	1	Site ID	Format: HH-MMDDYYYY-S####-AK
B	2	Date	Date data was acquired
C	3	Latitude	Coordinates for location of measurement
D	4	Longitude	
E	5	Wave?	Measurement influenced by wave action? 2=Definitely, 1=Possibly, 0=Unlikely
F	6	Location	Nearest community or other physical landmark
G	7	Elevation (m)	High Water Mark (m) with respect to NAVD88
H	8	Method	Measurement Method: ROL = Rod and Level, LRF = Laser Rangefinder
I	9	Error (m)	Estimated Error (m)
J	10	Photos	Photographs documenting High Water Level at this location (if any)
K	11	Description	Notes or other descriptions of measurement/photos

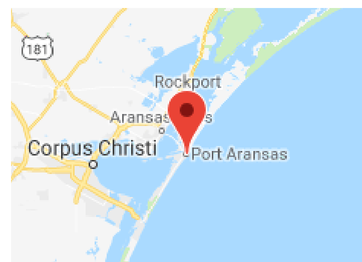
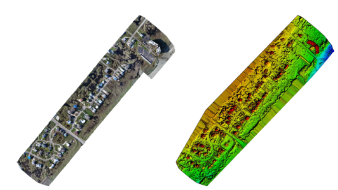
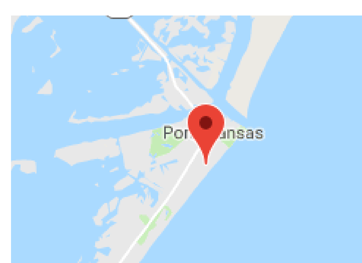
D3.2 Photos
FORMAT = JPG
This directory also contains photos acquired during the Coastal Surveys and referenced in the accompanying spreadsheet. Files are named according to the convention:

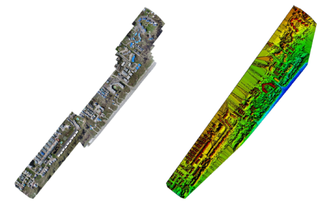
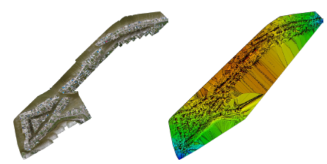
HH-MMDDYY-P####-PI.JPG

where HH = Hurricane Harvey, MM is the month (=09), DD is the day (e.g., 08), YY is the year (=17), P=photo, #### is the photo number (sequentially updated and reset daily), and PI are the initials of the investigator who acquired the image (see Table 1).

Directory D4. Unmanned Aerial Survey
FORMATS = JPG, TIF, TFW, PRJ, LAS, PDF, TXT

A directory is named for each UAS site. Each contains subdirectories for Orthomosaic, DSM, and Point Cloud photogrammetric products, which may include a number of supporting files, and Photos, which contains the original (unprocessed) photos acquired in the UAS flights. These are accompanied by two standalone files: the PDF and TXT files summarizing process that generated these data. The only exception is Holiday Beach, for which only the final orthomosaic and DSM geotiffs are available. A summary of the curated data is provided below.

File/Folder	Format	Description	Visual Summary
Port Aransas			
↳ **Port Aransas North**		**Start Point:** (27.827839, -97.054561)	
Photos	.JPG	Unprocessed photos	
Orthomosaic	.TIF .TFW .PRJ	Orthomosaic Geotiffs and supporting files	
DSM	.TIF .TFW .PRJ	Digital Surface Models and supporting files	
Point Cloud	.LAS	Digital Point Clouds	
17_09_09_PortA_North_Process_report	.PDF	Process Report	
17_09_09_PortA_North_Process	.TXT	Processing log	
↳ **Port Aransas South**		**Start Point:** (27.81982, -97.064419)	
Photos	.JPG	Unprocessed photos	
Orthomosaic	.TIF .TFW .PRJ	Orthomosaic Geotiffs and supporting files	
DSM	.TIF .TFW .PRJ	Digital Surface Models and supporting files	
Point Cloud	.LAS	Digital Point Clouds	

17_09_09_PortA_South_Process_report	.PDF	Process Report	
17_09_09_PortA_South_Process	.TXT	Processing log	
Salt Lake		**Start Point:** (28.066124, -97.109145)	
Photos (Area 1, Area 2)	.JPG	Unprocessed photos	
Orthomosaic	.TIF .TFW .PRJ	Orthomosaic Geotiffs and supporting files	
DSM	.TIF .TFW .PRJ	Digital Surface Models and supporting files	
Point Cloud	.LAS	Digital Point Clouds	
17_09_09_Salt_Lake_Rockport_Process_report	.PDF	Process Report	
17_09_09_Salt_Lake_Rockport_Process	.TXT	Processing log	
Holiday Beach			
Orthomosaic	.TIF	Orthomosaic Geotiff	
DSM	.TIF	Digital Surface Model	

Directory D5. Stationary Scans
FORMATS = FLS, LAS, e57, RCP,

Ground-based 3D point clouds acquired using portable stationary laser scanning units are organized into subdirectories by date/investigator, named using the following convention:

HH-MMDDYY-G3D-PI

where HH=Hurricane Harvey, MMDDYY is the date the dataset was acquired as month, day, year (e.g., 090817), G3D= ground-based three-dimensional data, and PI=initials of investigator (see Table 1). As there are two sets of stationary scanning data, acquired by different hardware, two different types of data are cataloged in these folders.

Three of the curated folders contain data collected by Wind Team 1 and corresponding files named by a similar convention:

HH-MMDDYY-G3DXXXX-PI.e57 or .las

Where XXXX = four-digit image tile number sequentially increasing and resetting daily (e.g., 0002). Descriptions of the scans at each location are provided in the following table.

The fourth curated folder (HH-091117-G3D-FL) contains a single project file (.rcp) that groups together multiple scan files (.rcs) files collected by the Mobile LiDAR Team. Project and scan files are not renamed to a standard convention to preserve file names assumed by the project file when it was created. Note: Autodesk® ReCap can be used to interact with this data.

File/Folder	Format	Description
🖿 **HH-090817-G3D-RW**		
Rockport Marine Inc., Rockport, TX	**Location:**	(27.992496, -97.07631)
HH-090817-G3D0001-RW	.e57, .las	SW corner
HH-090817-G3D0002-RW	.e57, .las	NE corner (near)
HH-090817-G3D0003-RW	.e57, .las	SW along road
HH-090817-G3D0004-RW	.e57, .las	S - between buildings
HH-090817-G3D0005-RW	.e57, .las	SE along road
HH-090817-G3D0006-RW	.e57, .las	E along TX-35 business (south)
HH-090817-G3D0007-RW	.e57, .las	E along TX-35 business (north)
HH-090817-G3D0008-RW	.e57, .las	North of structure
🖿 **HH-090917-G3D-RW**		
Nueces County Water Control, Port Aransas, TX	**Location:**	(27.829861, -97.064206)
HH-090917-G3D0001-RW	.e57, .las	Front view
HH-090917-G3D0002-RW	.e57, .las	Interior
HH-090917-G3D0003-RW	.e57, .las	Rear 1
HH-090917-G3D0004-RW	.e57, .las	Rear 2

HH-090917-G3D0005-RW	.e57, .las	Boat Works
Sea Gull Condos, Port Aransas, TX	**Location:**	(27.839915, -97.059663)
HH-090917-G3D0006-RW	.e57, .las	URM façade failure (south side)
📁 **HH-091017-G3D-RW**		
Hanger Damage Aransas County Airport	**Location:**	(28.091321, -97.043043)
scans conducted clockwise		
HH-0910917-G3D0001-RW	.e57, .las	NE
HH-091017-G3D0002-RW	.e57, .las	E - north
HH-091017-G3D0003-RW	.e57, .las	E - south
HH-091017-G3D0004-RW	.e57, .las	SE corner
HH-091017-G3D0005-RW	.e57, .las	South wall
HH-091017-G3D0006-RW	.e57, .las	SW corner
HH-091017-G3D0007-RW	.e57, .las	W - south
HH-091017-G3D0008-RW	.e57, .las	W - north
HH-091017-G3D0009-RW	.e57, .las	NW corner
HH-091017-G3D0010-RW	.e57, .las	North wall
📁 **HH-09117-G3D-FL**		
holiday beach scan 1	.rcp	Scan of single family homes with wind and storm surge damage in Holiday Beach, acquired with Leica BLK360
Holiday beach scan 1 Support.zip	.zip	Contains all .rcs, .rch, .rcc, .llt, .diff supporting files for the scans referenced by the project file
📁 **HH-09117-G3D-JG**		
Site 1 (3 files)	.las	Residential construction in Holiday Beach (Sailfish Drive), curated as 3 part scan
Site 2 (1 file)	.las	Residential construction at west end of Copano Ridge Rd in Rockport

🖿 Directory D6. Mobile Scans

FORMAT = LAS, XML, PGR, EXE

Mobile LiDAR team generates a vast amount of data including static scans, dashboard video, geo-referenced panoramic photos, and mobile scan data. The latter are considered most appropriate and feasible for transfer/curation in DesignSafe. These are organized into two subdirectories: one for **Imagery** and the other for **Point Clouds**. The subsequent table summarizes the files contained in DesignSafe.

The **Imagery** folder contains a compressed format for panoramic photos along with an executable file (Ladybug_1.15.3.23_x24.exe) for viewing and extracting the photos. Each navlog file name indicates the path number on a particular day of data collection. Due to the size of the photos, each path may also be divided into multiple segments. For example, the "navlog03-01-000005.pgr" file in the folder of 09-11-2017 indicates it contains the imagery collected on 09/01/2017 along the path of navlog03-01 and it is actually the fifth segment of the imagery on that path. Once the executable file is installed, users can view and extract the imagery by running the program called "LadybugCapPro.exe". Rather than downloading and executing this script, users may interact with an alternative way of organizing this data, developed using overleaf and potree. It is accessible at the link below and a screen shot of this interface is provided in Figure 3, where zooming in further will allow the clusters (with numbers indicating the number of images at that site) to further discretize ultimately to individual points along a driving path that the user can click to obtain street view imagery:
https://s3.amazonaws.com/rutgersharvey/Leaflet/debug/vector/ladybug_09112017.html.

The mobile scan data is contained in the **Point Cloud** folder where files are organized by date and trajectory. For example, the Harvey0913PH7G_0001_1.las indicates the Harvey LiDAR data collected on 09/13/2017 along the path of PH7. The "G" indicates it is the 'G' segment on the Path 7. IN most cases, the las files are produced in a way to ensure that there are no more than 20 million points in each file. A more user friendly interface to view the data will soon be available at the following link.
https://s3.amazonaws.com/rutgersharvey/RutgersHarveyCenter/index.html

File/Folder	**Format**	**Description**	**File Details**
🖿 **Imagery**			
↳🖿 **091117**	.XML, .PGR	Navlog files	navlog01 to navlog23
↳🖿 **091217**	.XML, .PGR	Navlog files	navlog01 to navlog19
↳🖿 **091317**	.XML, .PGR	Navlog files	navlog01 to navlog08
Ladybug_1.15.3.23_x24.exe			
🖿 **Point Clouds**	.LAS	Point Cloud	Scans on 9/11/17, 9/12/17 and 9/13/17

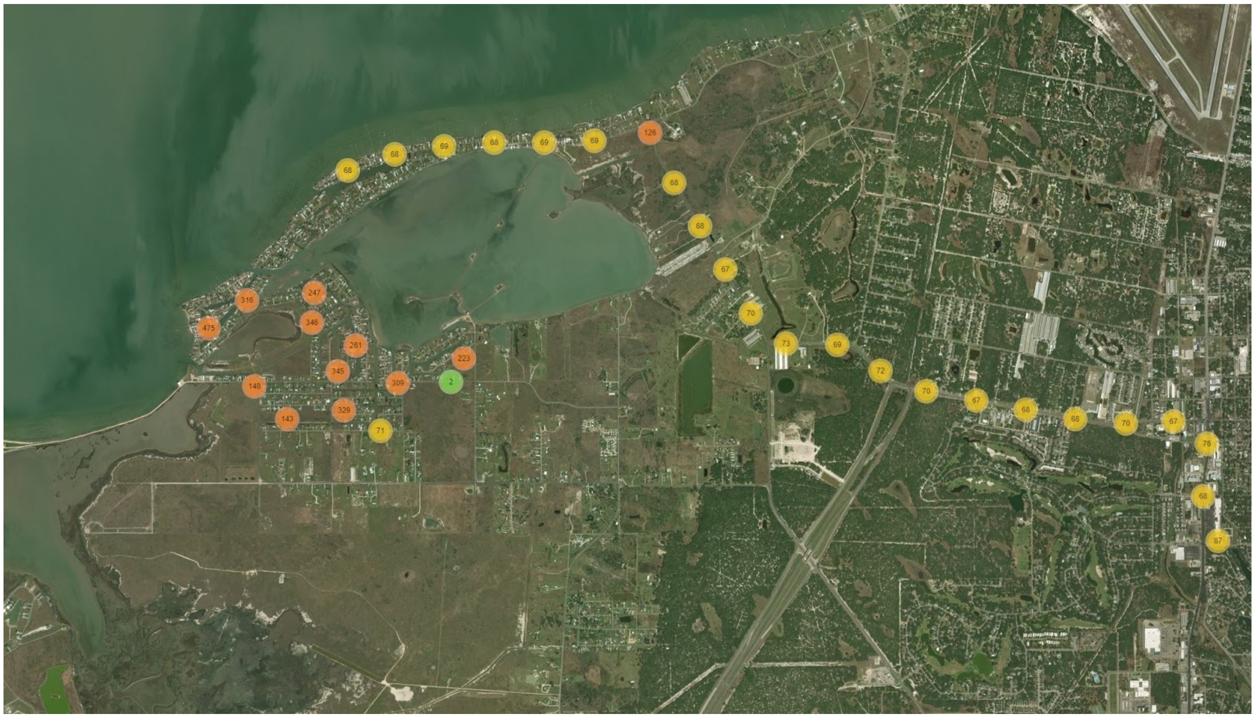


Figure 3. Screen capture of alternative data visualization platform using overleaf and potree, showing clusters of mobile LiDAR data collected along driving path around Salt Lake adjacent to Copano Bay in Rockport, TX. Zooming in further will cause each cluster to eventually break into individual points at which users can interact with photographic data.

Directory D7. Dissemination Products

D7.1 Field Notes

FORMAT = DOCX

Investigator field journals containing notes, general observations and other measurements captured in notebooks or voice recordings are named according to the following convention:

HH-JRN-PI

where HH=Hurricane Harvey, JRN = journal and PI=initials of investigator as defined in Table 1.

D7.2 Publications

FORMAT = PDF

Publications that had already been submitted at the time of curation are included in this subdirectory. Full bibliographic information is summarized in the following table:

Filename	Author(s)	Title	Venue
Forensics Paper_Harvey.PDF	T. Kijewski-Correa, J. Gong, A. Kennedy, J. A. Womble, C.S. Cai, J. Cleary, T. N. Dao, F. Leite, D. Liang, K. Peterman, C. Sun, A. Taflanidis and R. L. Wood	Performance of Low-Rise Construction Under Wind and Coastal Hazards During the Landfall of Hurricane Harvey	Proceedings of Forensic Engineering 8th Congress, November 29-December 2, 2018, Austin, TX
CCFSS Final Manuscript.PDF	Adrianna M. Early, M. Ebrahim Mohammadi , Richard L. Wood, Kara D. Peterman	Behavior of Cold-Formed Steel Metal Industrial Buildings	Proceedings of Wei-Wen Yu International Specialty Conference on Cold-Formed Steel Structures 2018, November 7-8, 2018, St. Louis, MO
Cleary_IISE 2018_Paper_Final.PDF	John Cleary	Structural Damage after Hurricane Harvey: Initial Observations and Lessons Learned	Proceedings of Institute of Industrial and System Engineers, May 19-22, 2018, Orlando, FL
NHERI Newsletter. PDF	Marti LaChance	Hurricane Season 2017: A Coordinated Reconnaissance Effort	NHERI Quarterly, March 2018 (p. 2-3, 6)

8. CONTACTS

For inquiries on specific sets of data, please contact the following individuals:

Coastal Survey	**Damage Assessments**
Andrew Kennedy Email: Andrew.B.Kennedy.117@nd.edu Phone: 574-631-6686	Tracy Kijewski-Correa Email: tkijewsk@nd.edu Phone: 574-631-2980
Stationary Scans	**Mobile Scans**
Richard L. Wood Email: rwood@unl.edu Phone: 402-472-1916	Jie Gong Email: jg931@soe.rutgers.edu Phone: 848-445-2881
Unmanned Aerial Survey	
Michael Starek Email: michael.starek@tamucc.edu | Phone: 361-825-3978	

APPENDIX A. STRUCTURAL DAMAGE FIELDS

Column		Column Header	Field	Format	Response Choices/ *Description*
A	1	fulcrum_id	Record ID	Text	Auto-populated
B	2	latitude	Latitude	Decimal	Auto-populated
C	3	longitude	Longitude	Decimal	Auto-populated
D	4	name_of_surveyor	Name of Surveyor	Text	Alex Taflanidis Chao Sun Daan Liang Douglas Allen John Cleary Kara Peterman Richard Wood Steve Cai Thang Dao Tracy Kijewski-Correa
E	5	date_of_survey	Date of Survey	MM/DD/YYYY	Auto-populated
F	6	type_of_disaster	Type of Disaster	Single choice	Hurricane
G	7	site_id	Site Identifier (Paper Survey)	Text	From paper survey, when applicable: HH-MMDDYY-SXXXX-PI
H	8	project	Project	Text	CMMI-1266418
I	9	photos	Photos	Comma separated values	*Photos associated with record*
J	10	photos_caption	Captions	Comma separated text	*Photo captions supplied by surveyor (if any)*
K	11	photos_url	Direct Path to Fulcrum Entry	URL	Auto-populated
L	12	total_damage_rating	Overall damage rating	Single Choice	0=No Damage 1=Minor 2=Moderate 3=Severe 4=Total
M	13	gps_pin	GPS Pin (Paper Survey)	Integer	*Pin on handheld GPS for those using paper surveys*

N	14	street_address_sub_thoroughfare	House Number	Text	Auto-populated
O	15	street_address_thoroughfare	Street name	Text	Auto-populated
P	16	street_address_suite	Suite Number	Text	Auto-populated
Q	17	street_address_locality	City/Town	Text	Auto-populated
R	18	street_address_sub_admin_area	County	Text	Auto-populated
S	19	street_address_admin_area	State	Text	Auto-populated
T	20	street_address_postal_code	Zip Code	Text	Auto-populated
U	21	street_address_country	Country	Text	Auto-populated
V	22	street_address_full	Complete postal address	Text	Auto-populated
W	23	building_use	Building Usage	Single Choice	Business Hotel Industrial Multi-Family Single Family
X	24	building_use_other	Building Usage (Other)	Text	*Surveyor-supplied structural usage*
Y	25	number_of_stories	Number of Stories	Integer	1-10
Z	26	age_yrs	Age in Years	Integer	*At the time of assessment, based on year home was built*
AA	27	attached_garage	Attached Garage?	Binary	Yes No
AB	28	roof_shape	Roof Shape	Multiple Choice (Comma separated text)	Complex Flat Gable Gambrel Hip
AC	29	roof_shape_other	Roof Shape (Other)	Text	*Surveyor-supplied roof shape*

AD	30	roof_cover_format	Roof Cover Format	Single Choice	Continuous Surface Panels Shingles Tiles
AE	31	roof_cover_format_other	Roof Cover (Other)	Text	*Surveyor-supplied roof cover format*
AF	32	roof_cover_material	Roof Cover Material	Single Choice	Asphalt Clay LW Concrete Reinforced Concrete Metal Slate Wood
AG	33	roof_cover_material_other	Roof Cover Material (Other)	Text	*Surveyor-supplied roof cover material*
AH	34	roof_framing	Roof Framing	Single Choice	CF Steel Metal Joist Structural Steel Wood
AI	35	roof_framing_other	Roof Framing (other)	Text	*Surveyor-supplied roof framing*
AJ	36	structural_wall	Structural Wall	Single Choice	CF Steel Concrete LB Masonry RC Structural Steel Wood Frame
AK	37	structural_wall_other	Structural Wall (other)	Text	*Surveyor-supplied structural wall*
AL	38	wall_covercladding	Wall Cover/ Cladding	Single Choice	Aluminum Siding Brick Veneer Curtain Wall Hardie Board Siding Metal Stucco Vinyl Siding Wood Siding
AM	39	wall_covercladding_other	Wall Cover/ Cladding (other)	Text	*Surveyor-supplied wall cover/cladding*
AN	40	structure_elevated	Elevated Structure?	Binary	Yes No

AO	41	height_above_grade	Height Above Grade [m]	Integer	*Lowest structural member [m]*
AP	42	shuttersstorm_panels	Shutters/Storm Panels Used?	Binary	Yes No
AQ	43	hurricane_clips	Hurricane clips used?	Binary	Yes No N/A (not visible, unknown)
AR	44	damage_cause	Damage Cause	Multiple Choice (Comma separated text)	Freshwater Flood Surge Tree Wind
AS	45	damage_cause_other	Damage Cause (other)	Text	*Surveyor-supplied damage cause*
AT	46	roof_cover_dmg	Roof Cover Damage	Single Choice	0% - 100%
AU	47	roof_sheathing_dmg	Roof Sheathing Damage	Single Choice	0% - 100%
AV	48	roof_framing_dmg	Roof Structure Damage	Single Choice	0% - 100%
AW	49	wall_cover_dmg	Wall Cover Damage	Single Choice	0% - 100%
AX	50	wall_sheathing_dmg	Wall Sheathing Damage	Single Choice	0% - 100%
AY	51	wall_framingstructure_dmg	Wall Framing/Structure Damage	Single Choice	0% - 100%
AZ	52	windows_dmg	Windows Damage	Single Choice	0% - 100%
BA	53	garage_door_dmg	Garage Door Damage?	Binary	Yes No N/A
BB	54	patio_doors_dmg	Patio Door Damage?	Binary	Yes No N/A
BC	55	entry_doors_dmg	Entry Doors Damage	Binary	Yes No
BD	56	structure_usable	Can structure be used for	Binary	Yes No

			intended purpose?		
BE	57	notes	General Notes	Text	*General comments from surveyor*
BF	58	qc_id	Data Librarian Name	Text	BW MM TK
BG	59	qc_code	QC Code	Single Choice	2a 2b
BH	60	qc_notes	QC Notes	Text	*Summary of modifications made to data in QA/QC process*

APPENDIX B. STRUCTURAL DAMAGE ASSESSMENT FORM

SITE ID	HH-	MM	DD	17-S	# # #	-	PI	**GPS PIN #**	
Latitude:	Can transcribe later			**Longitude:**	Can transcribe later				
Address:				**Community:**					
Photo Range:				**Camera:**					
Classification									
No. of Stories:		**Age:**		**Attached Garage:**	Y	N			
Building Use	S-Family	M-Family	Business	Industrial	Hotel	Other			
Roof Shape	Gable	Gambrel	Hip	Complex	Flat	Other			
Roof Cover	A. Shingle	W. Shingle	Metal	Slate	Tile: Cl Co	Other			
Roof Framing	Wood	Metal Joists	Str. Steel	CF Steel	CIP	Other			
Structural Wall/ Wall Framing	Wood Framed	Load Bearing Masonry	Structural Steel	CF Steel	RC	Other			
Wall Cover/ Cladding	Brick Veneer	Siding: V W A HB	Stucco	Curtain Wall	Metal	Other			
Mitigation Measures & Damage									
Elevated above Grd?	Y	N	**If yes, elev. low. str. member:**		m				
Shutters/St-Panels?	Y	N	DK	**Hurricane Clips?**	Y	N	DK		
Damage Cause	Wind	Surge	FW Flood	Rain	Tree				
Total Damage:	0	1	2	3	X	**Occupiable?**	Y	N	DK
Component Damage Level:						**Damage to:**			
Roof Cover	0%	25%	50%	75%	100%	**Garage Door?**	Y	N	N/A
Roof Sheathing	0%	25%	50%	75%	100%	**Patio Doors?**	Y	N	N/A
Roof framing	0%	25%	50%	75%	100%	**Entry Doors?**	Y	N	N/A
Wall Cover	0%	25%	50%	75%	100%	**Notes:**			
Wall Sheathing	0%	25%	50%	75%	100%				
Wall Framing	0%	25%	50%	75%	100%				
Windows	0%	25%	50%	75%	100%				