HURRICANE MICHAEL

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DATA REPORT

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PREFACE

The National Science Foundation (NSF) awarded a 2-year EAGER grant (CMMI 1841667) to a consortium of universities to form the Structural Extreme Events Reconnaissance (StEER) Network (see https://www.steer.network for more details). *StEER builds societal resilience by generating new knowledge on the performance of the built environment through impactful post-disaster reconnaissance disseminated to affected communities.* StEER achieves this vision by: (1) deepening structural engineers' **capacity** for post-event reconnaissance by promoting community-driven standards, best practices, and training, as well as their understanding of the effect of natural hazards on society; (2) **coordination** leveraging its distributed network of members and partners for early, efficient and impactful responses to disasters; and (3) **collaboration** that broadly engages communities of research, practice and policy to accelerate learning from disasters. StEER works closely with other extreme event reconnaissance organizations and the Natural Hazards Engineering Research Infrastructure (NHERI) to foster greater potentials for truly impactful interdisciplinary reconnaissance after disasters.

Under the banner of NHERI's CONVERGE node, StEER works closely with the wider Extreme Events Reconnaissance consortium including the Geotechnical Extreme Events Reconnaissance (GEER) Association and the networks for Interdisciplinary Science and Engineering Extreme Events Research (ISEEER), Nearshore Extreme Event Reconnaissance (NEER), Operations and Systems Engineering Extreme Events Research (OSEEER), Social Science Extreme Events Research (SSEER), and Sustainable Material Management Extreme Events Reconnaissance (SUMMEER), as well as the NHERI RAPID equipment facility, the NHERI Network Coordination Office (NCO), and NHERI DesignSafe CI, long-term home to all StEER data and reports.

While the StEER network currently consists of the three primary nodes located at the University of Notre Dame (Coordinating Node), University of Florida (Atlantic/Gulf Regional Node), and University of California, Berkeley (Pacific Regional Node), StEER aspires to build a network of regional nodes worldwide to enable swift and high quality responses to major disasters globally.

StEER's founding organizational structure includes a governance layer comprised of core leadership with Associate Directors for each of the primary hazards as well as cross-cutting areas of Assessment Technologies and Data Standards, led by the following individuals:

- **Tracy Kijewski-Correa (PI),** University of Notre Dame, serves as StEER Director responsible for overseeing the design and operationalization of the network and representing StEER in the NHERI Converge Leadership Corps.
- **Khalid Mosalam (co-PI),** University of California, Berkeley, serves as StEER Associate Director for Seismic Hazards, leading StEER's Pacific Regional node and serving as primary liaison to the Earthquake Engineering community.
- **David O. Prevatt (co-PI),** University of Florida, serves as StEER Associate Director for Wind Hazards, leading StEER's Atlantic/Gulf Regional node and serving as primary liaison to the Wind Engineering community.
- **Ian Robertson (co-PI),** University of Hawai'i at Manoa, serves as StEER Associate Director for Coastal Hazards, serving as a primary liaison to the coastal engineering community and ensuring a robust capacity for multi-hazard assessments.
- **David Roueche (co-PI),** Auburn University, serves as StEER Associate Director for Data Standards, ensuring StEER processes deliver reliable and standardized reconnaissance data suitable for re-use by the community.

ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grant No. CMMI 1841667. Any opinions, findings, and conclusions or recommendations expressed in this material are those of StEER and do not necessarily reflect the views of the National Science Foundation. All authors and editors listed on the cover page participate as volunteer professionals. Thus, any opinions, findings, conclusions or recommendations expressed herein are those of the individual contributors and do not necessarily reflect the views of their employer or other institutions and organizations with which they affiliate.

Data was collected in part using equipment provided by the National Science Foundation as part of the RAPID Facility, a component of the Natural Hazards Engineering Research Infrastructure, under Award No. CMMI: 1611820. StEER is grateful for the partnership with the NHERI RAPID Equipment Facility at the University of Washington and the efforts of Jeff Berman, Joe Wartman and Andrew Lyda in supporting both our primary mission as well as the addition of the RAPID EF's supplemental data.

Special thanks to Spatial Networks for their ongoing partnership and generous support, making available, at no cost, the Fulcrum Community mobile platform for StEER Damage Assessments. StEER also acknowledges its partnership with the Florida State Emergency Response Team for providing assistance in accessing affected regions. StEER further thanks the Virtual Assessment Structural Team members (many who worked anonymously) to gather information on access and conditions on the ground for the FAST, as well as a number of students who assisted with the FAST's preparations:

- Brandon Rittelmeyer, Auburn University
- Nathan Miner, Iowa State University
- Saransh Dikshit, Iowa State University

Special thanks also go to Dr. Marc Levitan of NIST for sharing the simulated windfield data from ARA with the community, which helped StEER define its sampling strategy and mobilize quickly. StEER also wishes to recognize the outstanding collaborations on Slack before and after the storm, especially the collaboration with the University of Florida Coastal Monitoring Program under the leadership of Forrest Masters. StEER expresses its gratitude for the efforts of its team and regrets over the loss of Tower 3 during the landfall of Hurricane Michael. In addition to these collaborations, the sharing of videos, damage reports and briefings via Slack by the entire NHERI community was tremendously helpful and much appreciated.

These collaborations and other exchanges of critical data in the landfall/planning stages benefited greatly from the work of the DesignSafe CI team who continuously supported and responded to StEER's emerging needs, including activating individuals on Slack swiftly.

ATTRIBUTION GUIDANCE

Citing Images, Data or Data Derivatives from this Dataset

The use of images from this published data set and the use of these or any other data to conduct additional analyses or prepare various visualizations or data derivatives should use the full citation information and DOI from DesignSafe (these are available at https://www.steer.network/products).

For a full listing of all StEER products (briefings, reports and datasets) please visit the StEER website: https://www.steer.network/products

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1.0 Event Summary and Team Configuration

On October, 10 2018, Hurricane Michael made landfall just south of Panama City, FL with the National Hurricane Center reporting a minimum pressure 919 MB and maximum sustained winds of 150 mph. Regardless of its place in history, Hurricane Michael caused catastrophic damage from high winds over a wide swath that stretched across much of the FL panhandle and inland into southeastern GA and beyond. Additional details of the hazard characteristics and resulting damage, as distilled from public reports and field observations, respectively, were documented in StEER's prior publications on this event:

Preliminary Virtual Reconnaissance Report (PVRR)	PRJ-2112	https://doi.org/10.17603/DS2RH71
Early Access Reconnaissance Report (EARR)	PRJ-2111	https://doi.org/10.17603/DS2G41M

In response, StEER initiated a coordinated response, working with other groups within the natural hazards engineering community to swiftly deploy a Field Assessment Structural Team (FAST). This FAST broadly assessed the performance of a representative subset of structural typologies in coastal and inland areas. Its teams conducted assessments between October 13-15, 2018. FAST collected data in Florida from Panama City Beach east and south to Indian Pass and north to Marianna. The communities assessed included: Panama City Beach, Panama City (and surrounding communities), Mexico Beach, Port St. Joe, Apalachicola, a few routes out to barrier islands in the region, and the inland communities of Blountstown and Marianna. Detailed forensic investigations were generally not achievable within the scope and time limits of FAST. Instead, focus was directed toward broadly assessing building performance over a large expanse of the impacted area and over a wide range of structural typologies.

Members of the FAST are summarized in Table 1.1 and were organized into two teams:

1. Advance Scout Team
2. Door-to-Door (D2D) Assessment Team (with UAS: Unmanned Aerial Systems)

This organization of effort enabled D2D assessments to be coupled with UAS to ensure that a holistic view of the post-storm condition was captured, while the Advance Scout Team surveyed larger areas for rapid assessment of damage using Applied StreetView (ASV) technology. The Advance Scout Team also recorded spot D2D Assessments of representative performance and identified areas for follow-up assessment based on damage and accessibility. The team collaborated in the field with Bryan Wood of Assurant and David Roueche was assisted by Graduate Student Brett Davis.

Following the reconnaissance effort, a team of student Data Librarians were trained to execute StEER's Data Enrichment and Quality Control (DE/QC) process described in Section 4.1. These Data Librarians are listed in Table 1.2, while the streetview data acquired by the FAST was processed by the individuals listed in Table 1.3 under the supervision of the RAPID EF at the University of Washington.

As part of an independent yet complementary effort, the RAPID EF continued data collection on November 7-8, 2018 in and around Panama City and Mexico Beach, using a variety of technologies including unmanned aerial vehicles, laser scanners and applied streetview technologies. This self-funded initiative generated an additional dataset that complements the data collected by StEER and is thus curated jointly in this project. The individuals forming this second RAPID EF Team are listed in Table 1.3.

Table 1.1: Members of StEER FAST and RAPID EF Team

Team Member	Affiliation	Team Assignment
David Roueche (Lead)	Auburn University	StEER D2D Assessment Team, UAS Operator
John Cleary	University of South Alabama	StEER Advance Scout Team
Kurt Gurley	University of Florida	StEER D2D Assessment Team
Justin Marshall	Auburn University	StEER D2D Assessment Team
Jean-Paul Pinelli	Florida Institute of Technology	StEER D2D Assessment Team
David Prevatt	University of Florida	StEER D2D Assessment Team
Daniel Smith	James Cook University (Australia) and University of Florida	StEER Advance Scout Team
Jeffrey Berman	University of Washington	RAPID EF Team
Jake Dafni	University of Washington	RAPID EF Team
Sean Yeung	University of Washington	RAPID EF Team

Table 1.2: StEER Data Librarians

Name	Affiliation	QC ID
Kevin Ambrose	Auburn University	KMA
Madeline Rihner	Auburn University	MR
Hadiah Rawajfih	Auburn University	HZR
Christian Brown	Auburn University	CVB
Joseph Palmer	Auburn University	JP

Mohammadtaghi Moravej	Walker Consultants	MM

Table 1.3: RAPID EF Data Processing Team	
Jake Dafni	University of Washington
Parker Johnson	University of Washington
Dominic Grasso	Cornell University
Emily Mongold	University of Delaware
Andrew Lyda	University of Washington

2.0 Data Collection Methodology

Teams were assembled to document damage to structures, delineating the effects of wind and storm surge. FAST used its targeted **D2D Assessment Teams** to conduct door-to-door (D2D) damage assessments at predefined clusters in Panama City and Mexico Beach. This was coupled with data collected by UAS, whenever possible (based on FAA restrictions) to provide high resolution aerial imagery to capture roof condition, debris paths, and impacts to surrounding structures. This was further supplemented by the Applied StreetView (ASV) technology operated by the **Advance Scout Team** to quickly gather data throughout the affected region to get a broad assessment of the conditions on the ground. Figure 2.1 provides an overview of the main assessment sites. Descriptions of each site are provided in Table 2.1.

This was then followed by a second round of data collection conducted by the RAPID EF, whose locales and methods are summarized in Table 2.2. Additional details of the methodologies engaged are provided in the following subsections.

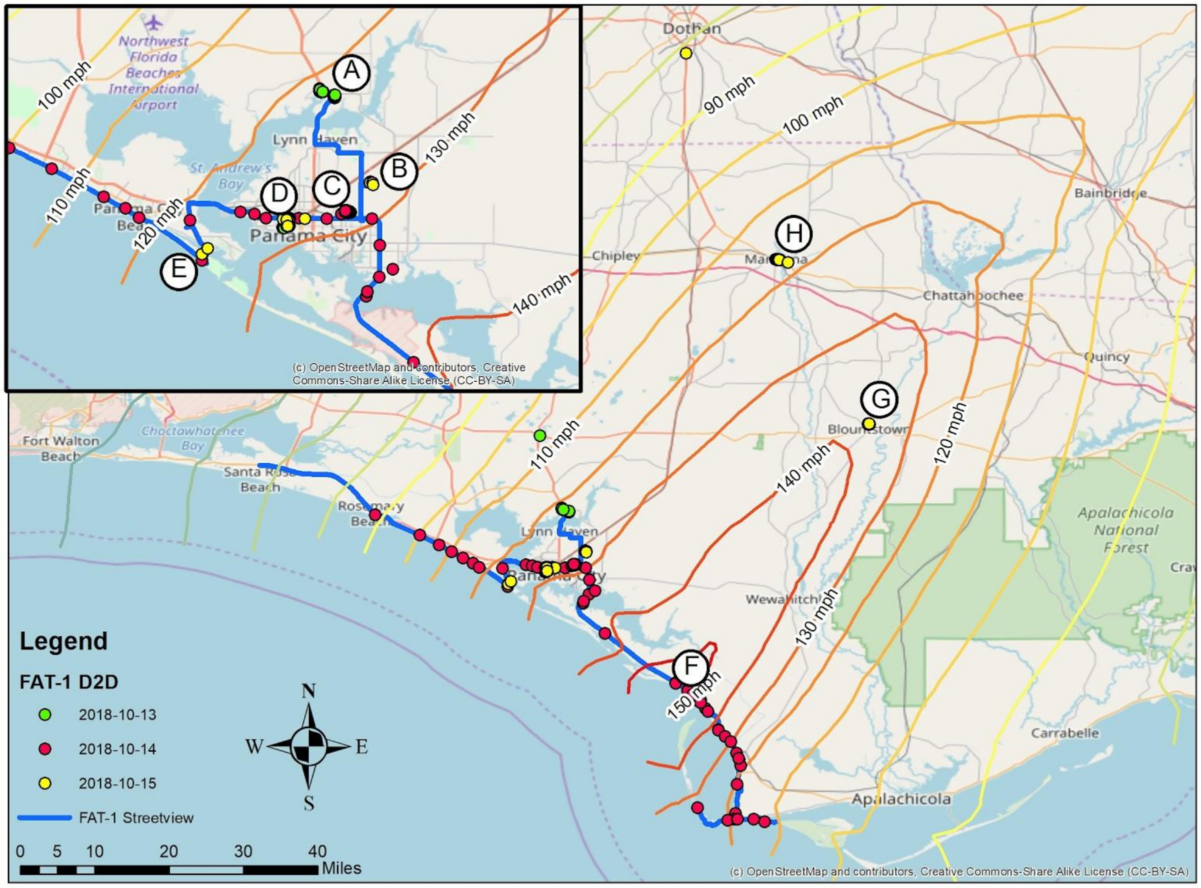


Figure 2.1: Summary of StEER assessments relative to the peak gust wind speeds as estimated by ARA.

Table 2.1: Assessment technologies used by StEER FAST at each site in Figure 2.1

Map ID	Site Name	Primary Structural Typology	Assessment Types
A	Southport	Residential, Religious, Institutional	ASV, D2D
B	Magnolia Hills	Residential	ASV
C	Cedar Crossing	Residential	ASV, D2D, UAV (SfM)
D	Interior Panama City	Light commercial, Institutional	ASV, D2D, UAV (aerial photos)
E	Pirates Cove Marina	Commercial	D2D, UAV (aerial photos)
F	Mexico Beach & Beacon Hill	Residential	ASV, D2D, UAV (SfM)

G	Blountstown	Residential	D2D
H	Marianna	Residential, Commercial	Drive-by, D2D

Table 2.2: Summary of assessment technologies used by RAPID EF

Site ID	Site Name	Site Location	Assessment Types
01	Gulf Aire Drive Neighborhood	Port St. Joe, FL	UAV (Phantom 4)
02	Water Tower	Mexico Beach, FL	UAV (Phantom 4), Laser Scan, Supplementary Photos
03	Oceanside Village	Mexico Beach, FL	UAV (Phantom 4), 360 Camera, GPS
04	Around Panama City	Driving Route	Mobile DJI Osmo
05	Under the Palms	Mexico Beach, FL	UAV (Phantom 4), GPS
06	Waterfront Apartments	Port St. Joe, FL	UAV (Matrice 210), Laser Scan, Supplementary Photos
07	Panama City to Mexico Beach	Driving Route	Mobile DJI Osmo

2.1 D2D Damage Assessments

IMPLEMENTATION: FAST D2D Assessment Team
PUBLIC ACCESS POINT: StEER's Fulcrum Community page

For the clusters of structures that were identified and assessed, based on typology, year of construction, post-Michael performance (as indicated by satellite imagery), and hazard exposure/intensity, D2D assessments were conducted at regular intervals (e.g., every third structure) to provide detailed evaluation of building performance without biasing toward damaged structures. These were documented using the Fulcrum mobile app: *StEER Building - US (Windstorm).* Assessments documented primary structural typologies and component types, construction materials, and damage levels. These were established using direct observation and contact/non-contact measurements accompanied by geotagged photos, videos, and statements from eyewitnesses to establish failure sequences. All data was collected using the library of Fulcrum mobile applications developed by StEER. D2D Assessments, including adopted damage ratings, follow what was eventually published as the *StEER Field Assessment Structural Team (FAST) Handbook* (2019). Appendix A lists the fields acquired by this Fulcrum Application. Note that 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 recorded via audio recordings.

Meanwhile, records of damage to non-building structures were collected in the *StEER Non-Building (Windstorm)* Fulcrum App. Appendix B lists the fields acquired by this Fulcrum Application.

In the process of conducting D2D assessments, FAST members also gathered forensic evidence of hazard intensity using a separate Fulcrum mobile smartphone app: *StEER Hazard Indicator*. Appendix C lists the fields acquired by this Fulcrum Application.

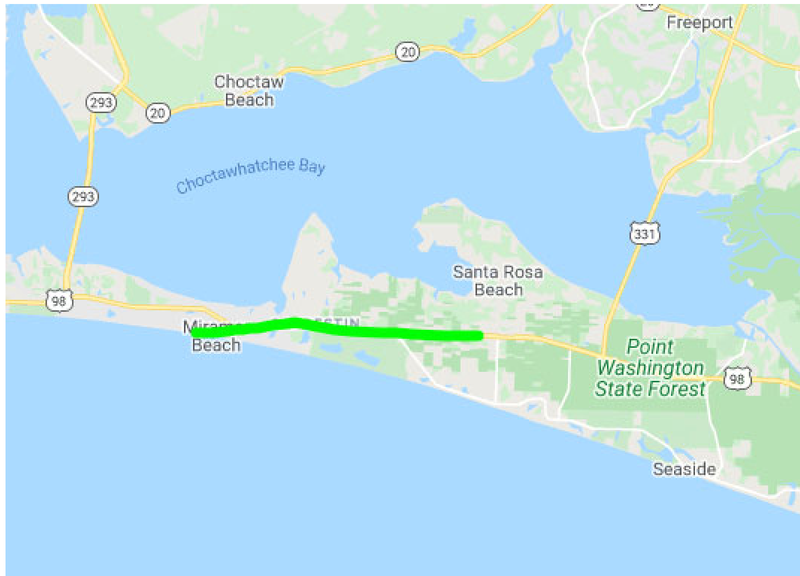
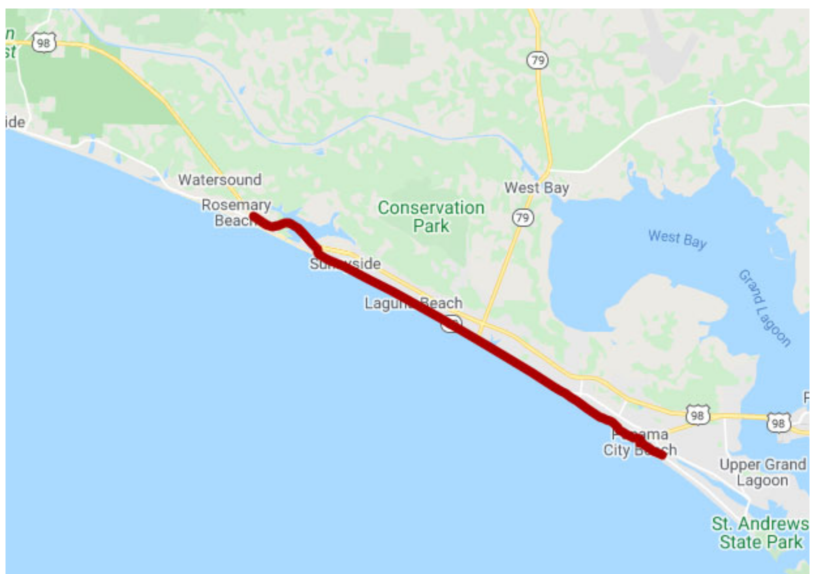
2.2 Applied StreetView Technology

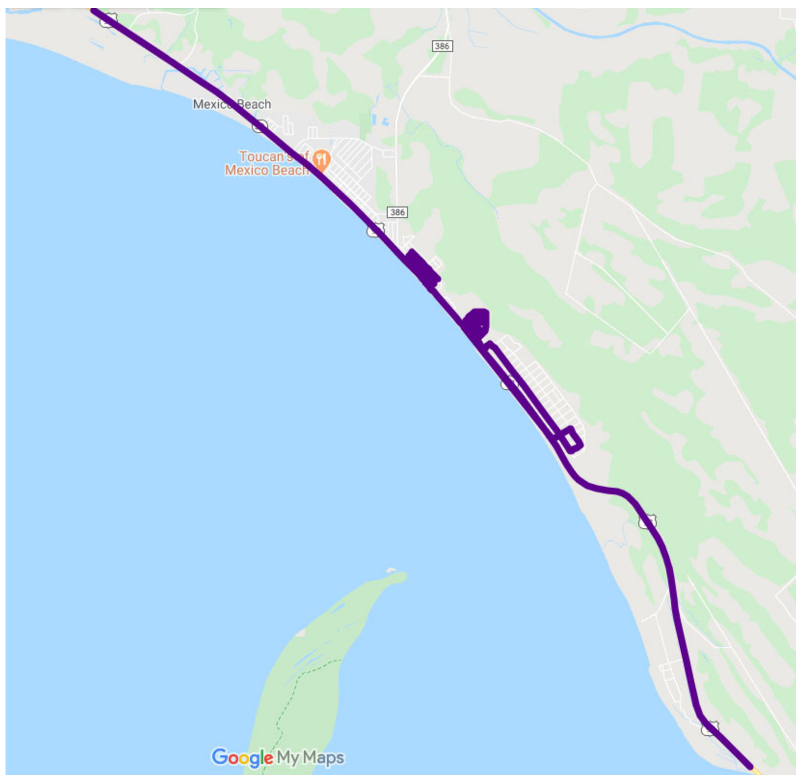
IMPLEMENTATION: FAST Advance Scout Team, RAPID EF Team
PUBLIC ACCESS POINT: RAPID EF Temporary Server and Google Street View

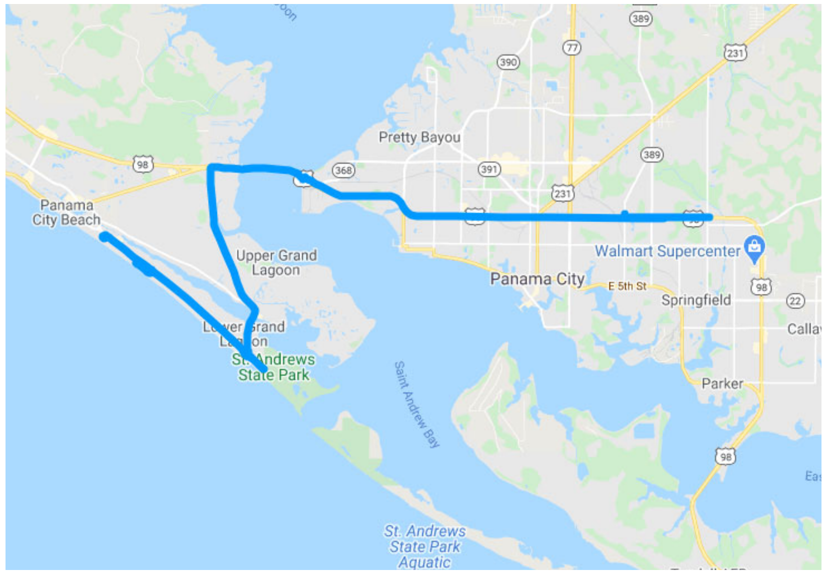
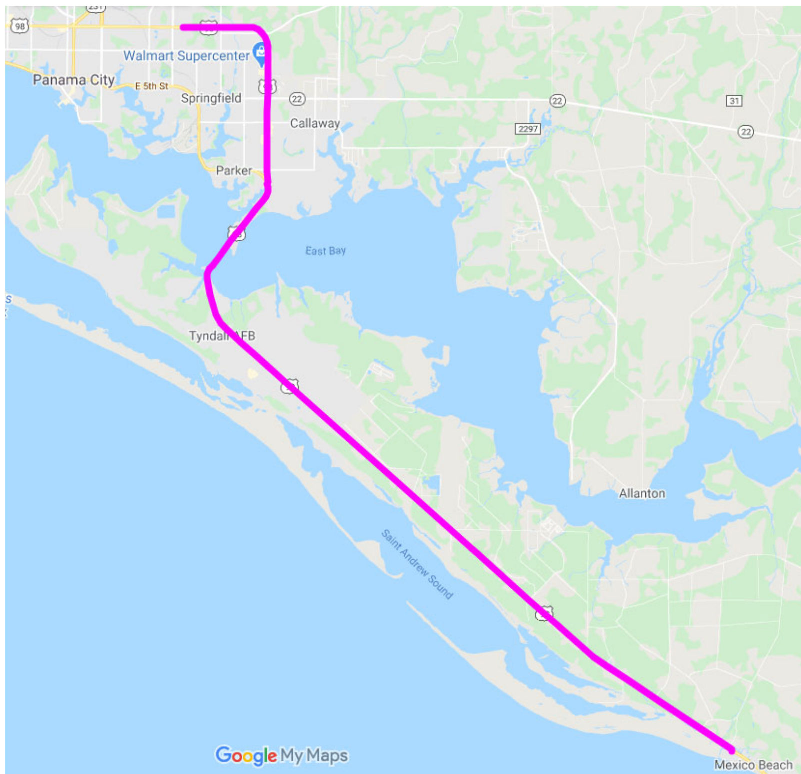
The Advance Scout Team gathered temporally significant 360-degree panoramas, or StreetViews, capturing the damage from both wind and storm surge using the Applied StreetView (ASV) system from the University of Washington NHERI RAPID Experimental Facility (NHERI RAPID EF). The system consists of six cameras mounted together to gather a 360 x 160 degree field of view. Each camera has a resolution of 5 MP, sensor size of 2560 x 1920, and uses fisheye lenses with fixed focus and focal length of 2.8. GNSS-tracking allows for ~2 m image location accuracy. The ASV system used in this investigation records six photographs (one forward, two oblique forward, two oblique backwards, and one upwards) every five meters along the driving route. Maximum resolution for panoramas can reach 8192 x 4096 pixels. The camera module and GNSS receiver were mounted on a car roof and the system was controlled by users inside the vehicle.

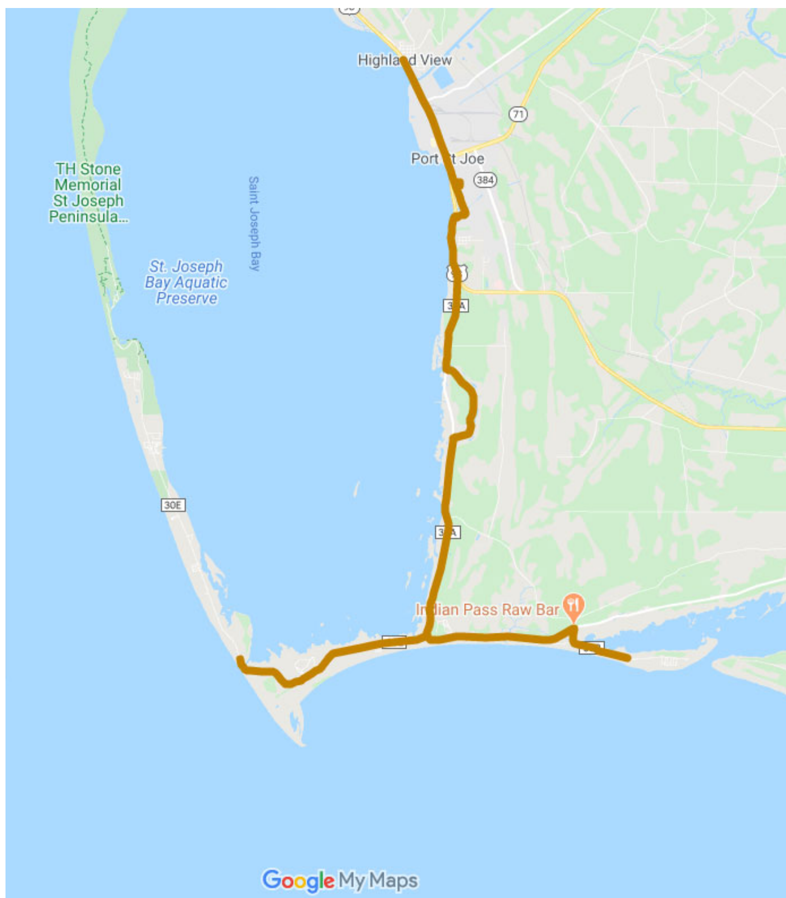
Under this configuration, FAST captured near-continuous coverage of exterior building performance while driving along routes in a broad area from Southport and Lynn Haven to the north of Panama City, Seaside to the west of Panama City Beach, and Port St. Joe along the coast to the east (see Fig. 2.1). The subteam drove primary routes as well as neighborhoods that were targeted for D2D assessment. The team cataloged over 302,000 individual photographs using the ASV system, traveling over 130 miles. See Table 2.3 for details of the specific ASV routes.

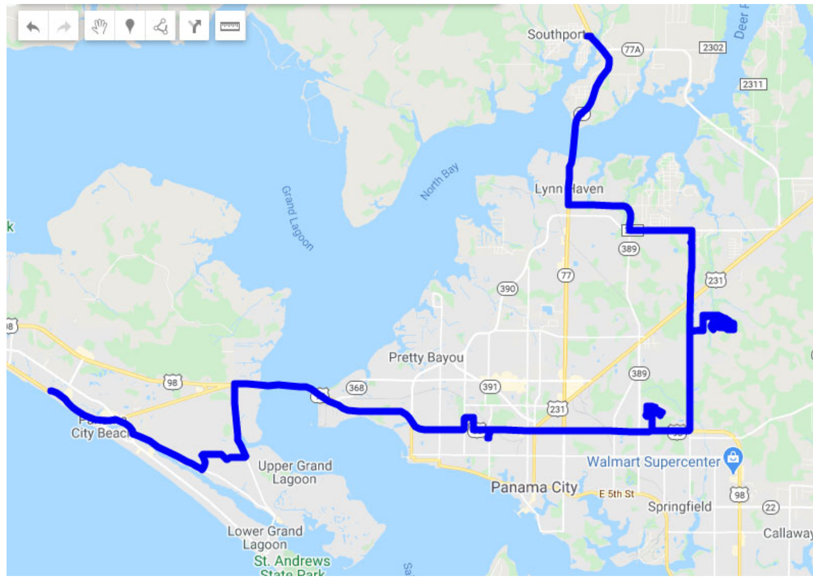
Additionally, the RAPID EF created DJI Osmo+ collections shot while traveling by car between Panama City and Mexico Beach, testing this camera's capabilities to create what is analogous to a street view collection. The Osmo+ camera is a small handheld gimbal mounted, image stabilized, camera capable of videos and geolocated images when synced via app to a user's cell phone. Images and videos were collected on two trips, one around Panama City and another between Panama City and Mexico Beach (see Sites 04 and 07 in Table 2.2).

Table 2.3. Applied StreetView Route Details	
October 14, 2018	
18_10_14_Michael_98_1 (US Route 98)	
18_10_14_Michael_98_2 (US Route 98)	

18_10_14_Michael_MB_1 (Mexico Beach, FL)	
18_10_14_Michael_MB_2 (Mexico Beach, FL)	

18_10_14_Michael_PC_1 (Panama City, FL)	
18_10_14_Michael_PC_2 (Panama City, FL)	

18_10_14_Michael_PSJ_1 (Port St. Joe, FL)	
18_10_14_Michael_PSJ_2 (Port St. Joe, FL)	

October 15, 2018	
18_10_15_Michael_PC_1 (Panama City, FL)	

2.3 Unmanned Aerial Vehicles

IMPLEMENTATION: StEER FAST (D2D Team), RAPID EF Team
PUBLIC ACCESS POINT: N/A

Unmanned Aerial Systems (UAS) were conducted by two groups: members of StEER FAST and a separate UAS Team from the RAPID EF. For the StEER FAST, this technology supplemented the D2D assessments, capturing damage levels over larger geographic areas and to provide a superior vantage point for roof damages. Two unmanned aerial systems were engaged by StEER FAST: a DJI Inspire 2 with a Zenmuse camera and a DJI Mavic Platinum. The UAS were used primarily to capture high-resolution nadir or oblique photographs in a gridded pattern with a minimum of 70% front and side overlap, from which orthomosaics and 3D models can be generated using Structure-from-motion (SfM) photogrammetry methods. In a few sites, specifically the Pirates Cove Marina and the Interior Panama City locations, gridded flight patterns were not possible due to time constraints. Instead, the UAS were used to acquire high resolution aerial photographs from key angles and elevations in order to provide a birds-eye view of the post-storm condition.

The RAPID EF Team UAS collected datasets from five independent sites (See Table 2.2). At Oceanside Village, Under the Palms, and Gulf Aire Drive, high resolution nadir images were collected to help best create orthomosaics of the damaged area. At Water Tower and Waterfront, oblique images were acquired in a gridded collection pattern to create orthomosaics as well as accurate SfM models. A minimum of 60% overlap or more was used to acquire less than 1.5 cm average ground sampling distances (GSD) on all products. Two drone models were used, the DJI Phantom 4 Pro and the DJI Matrice 210 with Zenmuse X4S camera (See Table 2.2). All images are JPG formatted and include required data such as GPS coordinates for future processing.

2.4 Laser Scans

IMPLEMENTATION: RAPID EF Team
PUBLIC ACCESS POINT: N/A

A Leica BLK360 imaging laser scanner was used to collect point clouds near specific targets of interest at two sites (Table 2.2). The scanner collects 3D points with a 360 degree horizontal and 300 degree vertical field of view. Maximum range averages 60 meters and 3D point accuracy is 6 mm at 10 meters.The number and location of scans was planned at the site based on the available site access (relative to both permission and safety), geometry of the structure (due to its line of sight technology), maximum distance between scans, and permissible time. Each scan was conducted at normal resolution to achieve a balance between maximized point density and desired number of scans. The team collected 17 scans at Water Tower and 29 usable scans at Waterfront Apartments. Each scan position took approximately 3-10 minutes. Scan locations were taken in varied conditions including full sunlight, no sunlight, and areas with little usable light inside safe structures. Pictures were taken by the scanner during each scan for point coloration and post processing. Areas with little light do not have usable images. Files from each scan were exported and saved in Leica proprietary BLK format.

2.5 Other Ground-Based Observations

IMPLEMENTATION: FAST (all teams), RAPID EF Team
PUBLIC ACCESS POINT: N/A

While conducting reconnaissance, investigators at times acquired additional photos/videos on their personal mobile devices or GPS cameras. Additional observations/notes similarly recorded outside of the Fulcrum mobile application are included in the Daily Summaries prepared each day by the FAST using the standard StEER template.

The RAPID EF also acquired additional ground-based imagery using an Insta360 camera, as well as a Canon EOS 7D Mark II camera. The Insta360 is a small, pocket sized camera that can be paired with a phone or fit with a micro-SD card to instantly take stabilized, 360 degree images. The camera has a F2.2 aperture and is rated at 24 MP, producing 360 degree images at 6912*3456 pixels. Images are output in proprietary format but can be viewed and exported to JPEG via free app or software.

The Canon imagery is JPG formatted and includes field photos for documentation and photo captures to incorporate into the processed photogrammetric data generated from the UAS surveys conducted by the RAPID EF Team.

3.0 Chronology and Geospatial Distribution of Data Collection

13 October 2018
 	
1. **StEER D2D Assessment Teams:**
    a. Southport
    b. SR77 to Alt-98 through Tyndall Air Force Base
    c. Mexico Beach
    d. Cedar's Crossing
    e. Panama City (center)

14 October 2018 1. **StEER Advance Scout Team:** Panama City down through Tyndall Air Force Base to Mexico Beach, Beacon Hill, Port St. Joe, Apalachicola, and the St. Joseph barrier islands 2. **StEER D2D Assessment (with UAS):** Cedar Crossing, Area surrounding Florida Coastal Monitoring Program (FCMP) Tower 2 (T2) 3. **StEER D2D Assessment Team:** Beacon Hill (along US-98)
15 October 2018 1. **StEER - Advance Scout Team:** Panama City interior and suburbs, including Magnolia Hills and Cedar Crossing 2. **StEER D2D Assessment (with UAS):** Pirates Cove Marina, commercial and institutional district in interior Panama City, Blountstown, FL and Marianna, FL.
7 November 2018 **RAPID EF Team:** 1. Gulf Aire Drive Neighborhood in Port St. Joe, FL 2. Water Tower in Mexico Beach, FL 3. Oceanside Village in Mexico Beach, FL 4. Driving Route: Around Panama City, FL
8 November 2018 **RAPID EF Team:** 1. Under the Palms in Mexico Beach, FL 2. Waterfront Apartments in Port St. Joe, FL 3. Driving Route: Panama City to Mexico Beach, FL

4.0 Data Processing

4.1 Door-to-Door Damage Assessments

Each record in the Fulcrum database underwent StEER's Data Enrichment/Quality Control (DE/QC) process outlined in *Virtual Assessment Structural Team (VAST) Handbook: Data Enrichment and Quality Control (DE/QC) for US Windstorms* (2019). Records were updated by the librarians in Table 1.2 and were immediately available within the Fulcrum Community portal at each stage of the DE/QC Process. As each record completed one of these stages, a code is updated within the record. 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.

For the majority of assessments, at least two data librarians participated in the DE/QC process of each record separately to help catch errors and reduce uncertainties. In addition, the entire dataset underwent a number of macro-level QC checks to identify potential errors, such as filtering the dataset for blank entries in the number of stories, searching for invalid field entries (e.g., 72 was entered for first floor elevation (ft) due to unit error), and more. The complete quality control checklist and workflow for StEER D2D data is still being developed but every effort was made here to find and fix major errors or inconsistencies. Despite the best efforts of the data librarians, there is likely to be small errors in a few records, and there is also uncertainty present due to incomplete data and/or use of engineering judgement. Despite these, additional QC should not be necessary for most research applications, but may be warranted for any analysis particularly sensitive to errors and uncertainties. Consumers of the data are encouraged to conduct additional stages in the DE/QC process in accordance with StEER's *Virtual Assessment Structural Team (VAST) Handbook: Data Enrichment and Quality Control (DE/QC) for US Windstorms* (2019).

For all data captured by *StEER Building - US (Windstorm)* App: The StEER DE/QC process was executed at a minimum to Stage 2 for all individual records, meaning basic attributes such as location, building type, damage ratings, structural wall and roof system, number of stories, and component-level damage ratings were assessed with reasonable confidence. Stage 1 was reserved for general area assessments that broadly described the performance of multiple buildings in an area. Where insufficient information was available to have a reasonable degree of confidence in the Stage 2 fields, a Stage 2e code is used to warn potential users of the data that the information therein may be more incomplete or uncertain than typical records. Where high quality data was available for a given record, typically through overlapping data sources (e.g., audio recordings, on-site photographs, satellite imagery, and/or StreetView), Stage 3 was executed which includes more finer details of the building attributes and structural load path. Table 4.1 summarizes the number of records for which each Stage was executed (see Building column). Once each record was advanced to its respective Stage in the DE/QC process, the final database was downloaded from Fulcrum for curation in DesignSafe in CSV and GeoJSON formats.

In the process of conducting D2D assessments, FAST members also gathered forensic evidence of hazard intensity using a separate Fulcrum mobile smartphone app. Appendix C lists the fields acquired by this Fulcrum Application.

For all data captured by *StEER Non-Building (Windstorm)* App: Minimal enhancement was performed for non-building records in this dataset, but each record was QC'd to ensure validity of the location and other attributes. Table 4.1 summarizes the number of records for which each Stage was executed (see Non-Building column). Once each record was advanced to its respective Stage in the DE/QC process, the final database was downloaded from Fulcrum for curation in DesignSafe in CSV and GeoJSON formats.

For all data captured by *StEER Hazard Indicator* App: Data enhancement was generally minimal in the Hazard Indicator records as well. However, further processing of much of the Hazard Indicator data was completed and presented in Kennedy et al. (2020). Table 4.1 summarizes the number of records for which each Stage was executed (see App 3 column). Once each record was advanced to its respective Stage in the DE/QC process, the final database was downloaded from Fulcrum for curation in DesignSafe in CSV and GeoJSON formats.

Table 4.1: Breakdown of records by DE/QC stage executed

		Number of Records	
Stage	**Brief Description**	**Building**	**Non-Building**
1	The location of the record has been verified and existing attributes QC'd, but the record is unsuitable for further enhancement. This field is generally reserved for general area assessments that are not specific to a single building or structure.	34	3
2	The minimum information required for a completed assessment has been verified or added. For example, the correct building type is assigned, overall damage ratings are confirmed to be in agreement with the quantitative guidelines, and basic building attributes, e.g., number of stories, are identified.	89	2
2e	There is insufficient information to meet the minimum data standards for a complete assessment, or there is considerable uncertainty in assignment of one or more critical fields. If a record is at 2e, it may not be possible or worthwhile to advance into additional stages and caution should be used in conducting analysis that includes this data.	14	0
3	The majority of fields up through Stage 3, as described in the DE/QC handbook, have been	532	0

	completed and validated with reasonable confidence in accuracy and precision.		
3e	Some or all Stage 3 fields have been completed, but lack of data (e.g., only 2 sides of the structure are visible) or other circumstances adds high levels of uncertainty.	69	0

4.2 Applied StreetView Technologies

Individual images from the ASV capture system were processed into seamless panoramas and panorama tiles using the ASV Creator 3 software. Images were filtered using a duplicate remover so that no panorama was within 5 meters of another horizontally or vertically. Images were also leveled and some minor manual cleaning applied. Objects in the images were not blurred during processing. Panoramas are created and uploaded to Google through the G-Publisher option of ASV. The final resolution of the processed panoramas is 8192x4096. The ASV Creator 3 software also generates a set of tiled imagery and a web player that allows any user to set up a virtual streetview server. Images are processed under the web player option and lower resolution StreetView tiles are created for the web player instead of panoramas. The web player requires a server (WAMP/MAMP/LAMP) and is run through a SQL database. Tiles are organized and displayed using the server and software output by Creator 3. Further information and directions for setting this option up can be obtained from NHERI RAPID or ASV. Tile and web player outputs also have the option of incorporating logos and web links for attribution purposes.

The DJI Osmo+ collected JPG images and MOV video files along driving routes around Panama City and between Panama City and Mexico Beach. All files were exported directly from the device via internal micro SD card. The only processing applied to the data was the removal of audio from the video files.

4.3 Unmanned Aerial Surveys

In cases where imagery from a UAS was acquired sufficient to generate other data products, the geolocated dataset is ingested into a standard UAS-compatible photogrammetry desktop application, in this case Pix4DMapper Pro (licensing provided through the NHERI RAPID Experimental Facility at the University of Washington), which:

1. Checks the photo dataset for its integrity and positional accuracy based on the geolocation coordinated in the metadata of each image.
2. Establishes desired coordinate system (ie. WGS 1984 or others) and units of measurement.
3. Establishes options for processing quality, processing speed, data outputs, and other related parameters.

4. Generates data outputs such as point clouds, 3D models, Digital Elevation Models, and Orthomosaics using proprietary Structure-from-Motion algorithms.

Resulting data products can be ingested into a variety of proprietary and non-proprietary software, including Potree (available through DesignSafe Workspace) for points clouds and QGIS (also available through DesignSafe Workspace) for Digital Elevation Models and Orthomosaics. Area, Linear, and Volumetric measurements can also be generated from the point cloud.

4.4 Laser Scans

After field data collection, raw laser scans have to go through several post-processing steps such as filtering to reduce noise and scan registration to accurately combine scans or geolocate them. This process is typically done by software specific to the scanner manufacturer. No post processing of the laser scans is included with this report. To read or process the proprietary Leica file formats of the point clouds will require a Leica software suite. Further information can be obtained from the NHERI RAPID center.

4.4 Other Ground-Based Observations

Media acquired outside of Fulcrum was reviewed to remove poor quality, redundant, ambiguous or irrelevant photos/videos. Time, date and coordinates can be extracted from the metadata of each geotagged photo. Insta 360 images did not undergo any additional post-processing and can be edited, viewed, and exported to usable formats using the free Insta360 Studio or Insta360 Player apps.

5.0 Archived Data Products

This section details the directory structure created in DesignSafe-CI and the contents therein. Directories have an extension (StEER vs. RAPID EF to differentiate the team acquiring the data).

🖿 Directory D0. Planning Documents - StEER
FORMATS = PDF

Pre-deployment briefing used to plan the mission and data collection strategy.

🖿 Directory D1.1 Building Damage Assessments - StEER
FORMATS =CSV, GeoJSON, JPG, .m4a

The folder **Building Damage Assessment Data -- Processed** contains the final enriched and quality controlled dataset (as CSV and GeoJSON) with all the response fields in Appendix A. Not all response fields have values, for reasons described in Section 4.1. Each media file (e.g., photograph, audio file) is linked to a specific record by a unique alpha-numeric string. This unique string is both the filename of the media file, and also listed in the corresponding data field (e.g., photos, audio) for the record it is associated with in the CSV or GeoJSON database. The folder also contains the photo log which provides all available photo metadata for each photograph.

🖿 Directory D1.2 Non-Building Damage Assessments - StEER

FORMATS = CSV, GeoJSON, JPG

The folder **D2D Non-Building Assessment Data** contains the final quality controlled dataset (as CSV and GeoJSON) with all the response fields in Appendix B. Not all response fields have values, due to lack of available information, and certain fields only being applicable to specific non-building assessment types. Each media file (e.g., photograph, audio file) is linked to a specific record by a unique alpha-numeric string. This unique string is both the filename of the media file, and also listed in the corresponding data field (e.g., photos, audio) for the record it is associated with in the CSV or GeoJSON database. The folder also contains the photo log which provides all available photo metadata for each photograph.

🖿 Directory D1.3 Hazard Indicators - StEER

FORMATS = CSV, GeoJSON, JPG

The folder **D2D Hazard Indicator Data** contains the final quality controlled dataset (as CSV and GeoJSON) with all the response fields in Appendix C. Not all response fields have values, due to lack of available information, and certain fields only being applicable to specific hazard indicator assessment types. Each media file (e.g., photograph, audio file) is linked to a specific record by a unique alpha-numeric string. This unique string is both the filename of the media file, and also listed in the corresponding data field (e.g., photos, audio) for the record it is associated with in the CSV or GeoJSON database. The folder also contains the photo log which provides all available photo metadata for each photograph.

🖿 Directory D2.1 Applied Streetview - StEER

FORMAT = JPG, CSV, ANPP (Processed files: SQL, PHP, XML)

This directory contains files organized in folders by route, equivalent to new projects started in the field, each containing different amounts of data. These routes were previously introduced in Table 2.3. Route folders are named using the following format:

YY_MM_DD_Event_XXX_#

corresponding to the Year (YY), Month (MM), Day (DD) of the acquired data for Event=Michael and XXX designates the locale of the route (98=US Route 98, MB=Mexico Beach, FL, PC=Panama City, FL, and PSJ=Port St. Joe, FL) with # as a sequential number used to distinguish multiple routes collected in the same locale on the same day. Within these route folders, there may be one or more folders named:

camera-YYYYYMMDD-HHMMSS

where YYYYMMDD is the Year (YYYY), Month (MM) and Day (DD) the data was acquired and HHMMSS was the time (HH=hour, MM=minute, SS=second) the data capture initiated. Within each camera folder are seven sub-folders: folders 1-6 contain the raw JPG images of the six cameras of the streetview system, one folder for each camera. Folder 7 contains the panorama capture locations, collection tracks, and the log for the photo collection. The panorama locations and tracks are in *.csv files and the log file is in the ASV specific *.anpp format.

DIRECTORY	LOCATION
18_10_14_Michael_98_1	Route 98 (Near Mexico Beach, FL)
18_10_14_Michael_98_2	Route 98 (Near Panama City, FL)
18_10_14_Michael_MB_1	Mexico Beach, FL
18_10_14_Michael_MB_2	Mexico Beach, FL
18_10_14_Michael_PC_1	Panama City, FL
18_10_14_Michael_PC_2	Panama City, FL
18_10_14_Michael_PSJ_1	Port St. Joe, FL
18_10_14_Michael_PSJ_2	Port St. Joe, FL
18_10_15_Michael_PC_1	Panama City, FL

Each route folder also includes the corresponding image products processed through the ASV Creator 3 software. All of the image products are meant for 360 degree StreetView applications and there are two derivatives in this folder. The data is organized into three sub-folders:

1. **panorama-tiles** contains small tiled images used to create large panoramic experiences on a self-contained web server
2. **panoramas** contains single 360-degree panoramic images from each capture location.
3. **player** contains files for hosting a StreetView web player given a server and database.

panorama-tiles contains numerous subfolders, each representing a photo location. Within the subfolders are the JPG images used to create a 360 degree photo player. Directions and metadata for building the players are contained in the player folder. The folder contains SQL, PHP, and XML files used to build a web player. The web player requires a server (WAMP/MAMP/LAMP) and runs through a SQL database using the provided file types. Further information and directions to set up a web player can be provided by ASV or NHERI RAPID. If unable to host StreetViews or web servers, the panoramas folder contains more than 16 thousand single panoramic images as an alternative. The images are 360 degree panoramas and are meant to be hosted on other StreetView services such Google StreetView. The naming structure for these matches with the raw data, following "camera-tour-capture number". The capture number counts up with the photos in the original tour folder, minus duplicates or corrupted images.

🖿 Directory D2.2 OSMO Camera Imagery - RAPID EF

FORMAT = .JPG, .M4V, .MP4

This directory contains imagery for two sites, as listed below. Within each site directory, there are two sub-folders: **Processed Data** and **Raw Data**. The raw data folders contain raw JPG images taken by the DJI Osmo camera during the routes around Panama City or between Panama City and Mexico Beach. Processed data folders contain video files captured along the same routes with audio taken out of the file. All files are meant to represent streetview style collections and no processing besides taking out audio was done on the data.

🖿 **04_Around Panama City_20181107**	Raw: images Processed: videos
🖿 **07_Panama City to Mexico Beach_20181108**	Raw: images Processed: videos

🖿 Directory D3.1 Unmanned Aerial Vehicle - StEER

FORMATS = .JPG, .TIFF, .TFW, .OBJ, .LAS, .P4D

This directory houses UAV data collected by StEER FAST. A subdirectory (7 total) was created for each unique location: ##_Location. The data collection for each site includes the raw images (.JPG). In the case of Cedars Crossing, more than one unmanned aerial system was used to cover different portions of the subdivision. Two subfolders organize the data collected by each system: DJI Inspire or DJI Mavic, respectively covering the east and west sides of the surveyed areas. Within these subfolders, in addition to the raw imagery, processed photogrammetric data products are available in the Processed Data” subfolder. These include:

- .P4D executable file
- Data products including point clouds (.LAS), orthomosaics and Digital Elevation Model (.TIFF with associated .TFW providing georeferencing details)
- Various supporting files, logs and reports documenting the data processing

The table below catalogs the files contained in each site directory, summarizing the location details, number of photos captured by the UAS, along with location details.

DIRECTORY	No. Files	LOCATION DETAILS
🖿 **01_Cedars Crossing**		*Raw images and processed products*
↳ 🖿 Cedars Crossing East		East side of Cedars Crossing Subdivision

↳ ↳ 📁 Raw Data	877	Panama City, FL (30.180994 N, 85.619145 W)
↳ ↳ 📁 Processed Data		
↳ 📁 Cedars Crossing West		West side of Cedars Crossing Subdivision Panama City, FL (30.182692 N, 85.622173 W)
↳ ↳ 📁 Raw Data	392	
↳ ↳ 📁 Processed Data		
📁 **02_Beacon Hill**		*Raw images and processed products*
↳ 📁 Raw Data	879	Port St. Joe, FL (29.917221 N, 85.375908 W)
↳ 📁 Processed Data		
📁 **03_Marina** *Raw images only*	39	Panama City, FL (30.143096 N, 85.748853 W)
📁 **04_Bay County Public Library** *Raw images only*	25	Panama City, FL (30.16889 N, 85.673062 W)
📁 **05_Toyota Scion** *Raw images only*	51	Panama City, FL (30.174604 N, 85.675067 W)
📁 **06_Dothan Christian Church** *Raw images only*	290	Dothan, AL (31.176092 N, 85.402278 W)
📁 **07_Mobile Homes**		*Raw images and processed products*
↳ 📁 Raw Data	181	Panama City, FL (30.167484 N, 85.667947 W)
↳ 📁 Processed Data		

📁 Directory D3.2 Unmanned Aerial Vehicle - RAPID EF
FORMATS = MOV, JPG, .TIFF, .TFW, .OBJ, .LAS, .FBX, .KML, .P4D

This directory houses UAS data collected by the RAPID EF UAS Team. A subdirectory (5 total) was created for each unique location: ##_Location_YYYYMMDD, where YYYY is the year, MM is the month and DD is the day the data was collected. Interior folder structure is divided by raw and processed data. Raw data is further organized by UAV system (Phantom 4, Matrice 210), flight #, and acquired images. Processed data contains project folders and processed photogrammetric data products including:

- .P4D executable project files

- A corresponding folder of the same name with support files and data products including point clouds (.LAS), 3D Mesh files, google earth tiles (.KML), orthomosaics and Digital Elevation Models (.TIFF and associated .TFW georeferencing file).

DIRECTORY	UAS FILES	DESCRIPTION
01_Gulf Aire Drive Neighborhood_ 20181107		
Raw Data	494	Small neighborhood around Gulf Aire Drive, between Mexico Beach and Port St Joe, FL (29.914112 N, 85.374297 W). One flight of raw JPG images. Full processing dataset.
Processed Data		
02_Water Tower_20181107		
Raw Data	352	Water tower and utility area behind Mexico Beach City Hall. Three flights of raw JPG images. No densified point cloud or 3D mesh. (29.945902 N, 85.409833 W)
Processed Data		
03_Oceanside Village_20181107		
Raw Data	1019	On and off beach housing in the Oceanside Village neighborhood of Mexico Beach. Two flights of raw JPG images. No densified point cloud or 3D mesh.(29.950403 N, 85.424442 W)
Processed Data		
05_Under The Palms_MexicoBeach_20181108		
Raw Data	2370	Large area of Mexico Beach, FL extends from the beach, over Under The Palms city park, to 1 km inland. Four flights of raw JPG images. Two product folders, the second has a full processing dataset. (29.937463 N, 85.396619 W)
Processed Data		
06_Waterfront Appartments_20181108		
Raw Data	387	Waterfront apartments between Mexico Beach and Port St Joe, FL. One flight of raw JPG images from Matrice 210. Three product folders, one for rapid orthomosaic, one full processing dataset, and one full dataset incorporating ground imagery from Canon camera. (29.910371 N, 85.373834 W)
Processed Data		

🖿 Directory D4. Laser Scans - RAPID EF
FORMAT = BLK

Ground-based 3D point clouds acquired using a portable Leica BLK 360 laser scanner are organized into subdirectories by site (see Table 2.2). Subfolders include BLK360 folder and scan data. Scan files are not renamed to a standard convention but follow sequentially as collected in the field with name given by scanner (BLK360_ID#_Setup#). Data is raw and unprocessed in BLK format pulled directly from the scanner. Two sites include Water Tower and Waterfront apartments. No location given besides the general working area. Forward further questions to RAPID EF (see Section 6.0 for contact info).

DIRECTORY	Scans	DESCRIPTION
🖿 **02_Water Tower_20181107**	17	3D scans of structure from the fallen Water Tower behind Mexico Beach City Hall. (29.945902 N, 85.409833 W)
🖿 **06_Waterfront Apartments_20181108**	30	3D scans of Waterfront Apartments between Mexico Beach and Port St Joe, FL. Scans taken around apartments from street side and beach side, as well as inside apartments where safe. (29.910371 N, 85.373834 W)

🖿 Directory D5. 360 Camera - RAPID EF
FORMAT = INSP

The folder contains 360 degree images collected by the RAPID EF. A total of 6 images were taken with an Insta360 One camera at a single site within the Oceanside Village location (Table 2.2). The images are stored in a proprietary INSP format with naming convention as follows:

IMG_YYYYMMDD_HHMMSS_###.insp

where HHMMSS is in 24 hour time notation and ### is a sequentially increasing two-digit numerical photo identifier. The images can be viewed with free viewing software available from Insta360, the manufacturer. Contact RAPID EF for further information.

DIRECTORY	FILES
🖿 **03_Oceanside Village_20181107**	6

🖿 Directory D6.1 Other Ground-Based Imagery - StEER
FORMAT = JPG, CSV

This directory contains additional photos captured by investigators outside of Fulcrum. Subdirectories are organized by investigator last name and include attributed photos and a photo log named HM-Photo_Log-PI.CSV where PI is the investigator's initials (DR=David Roueche, JM=Justin Marshall). This log contains a chronological listing of the following attributes for each photo:

A	B	C	D	E
1	2	3	4	5
filename	Date	Time	Lat	Lon

Photos files are named using following convention:

HM-MMDDYY-P####-PI.jpg

where H is an event code (HM = Hurricane Michael), MMDDYY is a six-digit encoding of the month/day/year the photo was acquired, P=photo with #### is a sequentially increasing four-digit numerical photo identifier, and PI is the investigator’s initials (DR=David Roueche, JM=Justin Marshall).

🖿 Directory D6.2 Other Ground-Based Imagery - RAPID EF
FORMAT = JPG

This directory contains additional photo images captured by the RAPID EF team using a Canon EOS 7D Mark II camera. Images were captured at two sites, Water Tower and Waterfront Apartments (see Table 2.2). The file names given by the camera are kept so that the primary identifier is a sequentially increasing four digit number at the end of each file name. The general purpose of the photos was to document the sites. However, the photos were also taken to supplement photogrammetric drone models and some of the folder structure conveys that. Water Tower has two subdirectory folders. Scene contains images taken in a panoramic style to encompass the work site for possible photogrammetric application. Structure contains images of specific structural elements and failures captured by the team. Waterfront Apartments contains only one subdirectory photo with all images from that site. Nearly all of these images were taken with intent to supplement photogrammetric models save for the last seven images of the folder numbered 1772 to 1778.

DIRECTORY	FILES	DETAILS
🖿 **02_Water Tower_20181107**		

↳ Scene	174	Scene capture images for modeling purposes
↳ Structure	28	Specific structural components
06_Waterfront Apartments_20181108		
↳ Canon Photos	734	All site photos

Directory D7 GPS Data - RAPID EF
FORMAT = M00, PDF, X00

This directory contains GPS information gathered by the RAPID EF team at the Oceanside Village and Under The Palms sites (see Table 2.2). Data was collected using Leica GS18 GNSS in a base rover setup over targets laid out across the collection sites. Subdirectory folders for each site reflect this with folders for Base data and Rover data. Base folders contain M00 files of the base collection and PDF files of the OPUS solution for that base location. Rover folders contain M00 files of the rover collection and project folders from the rover collection. All data is considered raw with no processing beyond the OPUS results for the base stations.

Directory D8. Daily Summaries - StEER
FORMAT = PDF

This directory contains daily summaries (2 in total) capturing key observations and illustrative examples of the damage documented by the FAST, using a StEER standard template.

6.0 Contacts

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

D2D Damage Assessments - StEER	**Unmanned Aerial Surveys - StEER**
David Roueche dbr0011@auburn.edu	David Roueche dbr0011@auburn.edu
All Other Data Types	**General Inquiries**
Andrew Lyda awlyda@uw.edu	Tracy Kijewski-Correa tkijewsk@nd.edu

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Appendix A. Buildings - Windstorm App Fields

Column		Column Header	Field	Format	Response Choices/ *Description*	Percentage Filled[1]
A	1	fulcrum_id	Record ID	Text	Auto-populated	100%
B	2	status	Damage State	Single Choice	0=No Damage 1=Minor 2=Moderate 3=Severe 4=Destroyed	100%
C	3	project	Project	Text	Hurricane Michael (2018)	100%
D	4	latitude	Latitude	Decimal	Auto-populated	100%
E	5	longitude	Longitude	Decimal	Auto-populated	100%
F	6	name_of_investigator	Name of Investigator	Text	Andrew Kennedy Brayan Wood Brett Davis David Prevatt David Roueche Daniel Smith Dean Ruark Doug Krafft Erin Koss Jean-Paul Pinelli John Cleary Justin Marshall Keith Cullum Kelly Turner Kurt Gurley Matt Janssen Oscar Lafontaine Tim Johnson	100%
G	7	date	Date	MM/DD/YYYY	Auto-populated	100%
H	8	general_notes	General Notes	Text	*Investigator/Librarian general notes*	0.54%
I	9	assessment_type	Assessment Type	Single Choice	Aerial Drive-by On-site Remote General Area Other	100%

J	10	all_photos	All Photos	Comma separated values	*Photos associated with record*	97.82%
K	11	all_photos_captions	All Photos Captions	Comma separated text	*All photo captions supplied by surveyor (if any*	0.7%
L	12	all_photos_urls	Direct Path to Photo Hosted on Fulcrum	URL	Auto-populated	97.82%
M	13	audio	Audio	Comma separated values	*Surveyor-supplied audio*	0.13%
N	14	audio_url	Direct Path to Fulcrum Entry	URL	Auto-populated	0.13%
O	15	overall_damage_notes	Overall Damage Notes	Text	*Overall damage notes supplied by surveyor/Librarian*	52.99%
P	16	hazards_present	Hazards Present	Multiple Choice (Comma separated text)	Flood Rain Surge Tree-fall Wind Wind-borne debris Unknown Other	99.86%
Q	17	wind_damage_rating	Wind Damage Rating	Single Choice	-1=Not Applicable 0=No Damage 1=Minor 2=Moderate 3=Severe 4=Destroyed	100%
R	18	surge_damage_rating	Surge Damage Rating	Single Choice	0=No Damage or Very Minor Damage 1=Minor 2=Moderate 3=Severe 4=Very Severe 5=Partial Collapse 6=Collapse	99.46%
S	19	rainwater_ingress_damage_rating	Rainwater Ingress Damage	Single Choice	-1=Unknown 0=None Visible 1=Minor Ingress	28.94%

			Rating		2=Moderate 3=Severe 4=Destroyed	
T	20	attribute_notes	Attribute Notes	Text	*Attribute notes supplied by surveyor/Librarian*	2.45%
U	21	address_sub_thoroughfare	House Number	Text	Auto-populated	99.18%
V	22	address_thoroughfare	Street Name	Text	Auto-populated	100%
W	23	address_suite	Suite Number	Text	Auto-populated	0.14%
X	24	address_locality	City/Town	Text	Auto-populated	100%
Y	25	address_sub_admin_area	County	Text	Auto-populated	100%
Z	26	address_admin_area	State	Text	Auto-populated	100%
AA	27	address_postal_code	Zip Code	Text	Auto-populated	99.86%
AB	28	address_country	Country	Text	Auto-populated	99.86%
AC	29	address_full	Full Address	Text	*Address supplied by surveyor/Librarian*	100%
AD	30	building_type	Building Type	Single Choice	Single Family Multi-Family Apartment Assisted Living Center Condominium Detached Garage Government Hotel/Motel Manufactured Home Manufacturing Plant Marina Office Park Shelter Professional Religious Restaurant Retail RV Service Station	99.86%

					Shed Supermarket Warehouse Unknown Other	
AE	31	number_of_stories	Number of Stories	Integer	1-25	97.28%
AF	32	understory_pct_of_building_footprint	Understory Area(% of Building Footprint)	Single Choice	0% - 100%	86.14%
AG	33	first_floor_elevation_feet	First Floor Elevation in Feet	Decimal	0-13	90.90%
AH	34	year_built	Year Built	Integer	*Surveyor-supplied year built*	97.42%
AI	35	roof_shape	Roof Shape	Multiple Choice (Comma separated text)	Complex Flat Gable Gable/Hip Combo Gambrel Hip Mansard Monoslope Unknown Other	95.65%
AJ	36	roof_slope	Roof Slope	Integer	*Surveyor-supplied roof slope*	79.08%
AK	37	front_elevation_orientation	Front Elevation Orientation	Integer	*Surveyor-supplied front elevation orientation*	93.21%
AL	38	structural_notes	Structural Notes	Text	*Structural notes from surveyor*	8.97%
AM	39	mwfrs	Main Wind Force Resisting System	Multiple Choice (Comma separated text)	Roof Diaphragm, wood Roof Diaphragm, steel Roof Diaphragm, concrete Roof Diaphragm, composite Wall Diaphragm, wood Wall Diaphragm, steel Wall Diaphragm, concrete Wall Diaphragm,	79.76%

					masonry Wall, X-bracing Moment Frame Unknown Other	
AN	40	foundation_type	Foundation Type	Multiple Choice (Comma separated text)	Slab-on-grade Cast-in-place concrete piers Ground anchors and strapping Crawlspace Reinforced masonry piers Reinforced masonry stem wall Unreinforced masonry piers Unreinforced masonry stem wall Wood Piers <= 8 ft Wood Piers > 8 ft Unknown Other	62.23%
AO	41	wall_anchorage_type	Wall Anchorage Type	Multiple Choice (Comma separated text)	Anchor bolts with nuts and washers Anchor bolts with missing nuts and washers Metal straps Concrete nails Unknown Other	3.53%
AP	42	wall_structure	Wall Structure	Multiple Choice (Comma separated text)	Wood frame Masonry (reinforced) Masonry (unreinforced) Masonry (unknown) Concrete, tilt-up Concrete, moment resisting frame Steel, moment resisting frame Steel, braced frame Steel, cold form Insulated concrete form (ICF) walls Solid Brick Wythe Unknown Other	87.09%
AQ	43	wall_substrat	Wall	Multiple Choice	Wood, sheathing	65.49%

		e	Substrate	(Comma separated text)	(continuous) Wood, sheathing (corners only) Wood,dimensional planks Insulated sheathing Insulated foam board Non-engineered wood panel Metal panels Not Applicable Unknown Other	
AR	44	wall_cladding	Wall Cladding	Multiple Choice (Comma separated text)	Aluminum siding Brick Curtain wall EIFS Fiber-Cement Board Corrugated steel panels Plywood Siding Stucco Vinyl Siding (standard) Vinyl Siding (high wind rated) Vinyl Siding (unknown) Wood Boards Wood Shake/Shingle Unknown Other	92.53%
AS	45	soffit_type	Soffit Type	Multiple Choice (Comma separated text)	None Vinyl Metal Wood Unknown Other	70.92%
AT	46	front_wall_fenestration_ratio	Front Wall Fenestration Ratio	Single Choice	0%-100%	53.40%
AU	47	front_wall_fenestration_protection	Front Wall Fenestration Protection	Multiple Choice (Comma separated text)	None Unknown Impact Resistant Plywood/OSB Panel Hurricane Shutter Other	38.32%
AV	48	left_wall_fenestration_ratio	Left Wall Fenestration Ratio	Single Choice	0%-100%	50.14%

AW	49	left_wall_fenestration_protection	Left Wall Fenestration Protection	Multiple Choice (Comma separated text)	None Unknown Impact Resistant Plywood/OSB Panel Hurricane Shutter Other	35.60%
AX	50	back_wall_fenestration_ratio	Back Wall Fenestration Ratio	Single Choice	0%-100%	45.79%
AY	51	back_wall_fenestration_protection	Back Wall Fenestration Protection	Multiple Choice (Comma separated text)	None Unknown Impact Resistant Plywood/OSB Panel Hurricane Shutter Othe	35.19%
AZ	52	right_wall_fenestration_ratio	Right Wall Fenestration Ratio	Single Choice	0%-100%	49.32%
BA	53	right_wall_fenestration_protection	Right Wall Fenestration Protection	Multiple Choice (Comma separated text)	None Unknown Impact Resistant Plywood/OSB Panel Hurricane Shutter Othe	36.28%
BB	54	large_door_present	Large Door Present	Multiple Choice (Comma separated text)	Yes No N/A	81.93%
BC	55	large_door_opening_type_front	Large Door Opening Type Front	Multiple Choice (Comma separated text)	None Single garage door (standard) Double garage door (standard) Single garage door (wind-rated) Double garage door (wind-rated) Single garage door (unknown) Double garage door (unknown) Sectional door Roll-up door Other	80.98%
BD	56	large_door_opening_type_left	Large Door Opening Type Left	Multiple Choice (Comma separated text)	None Single garage door (standard)	78.40%

					Double garage door (standard) Single garage door (wind-rated) Double garage door (wind-rated) Single garage door (unknown) Double garage door (unknown) Sectional door Roll-up door Other	
BE	57	large_door_opening_type_back	Large Door Opening Type Back	Multiple Choice (Comma separated text)	None Single garage door (standard) Double garage door (standard) Single garage door (wind-rated) Double garage door (wind-rated) Single garage door (unknown) Double garage door (unknown) Sectional door Roll-up door Other	78.13%
BF	58	large_door_opening_type_right	Large Door Opening Type Right	Multiple Choice (Comma separated text)	None Single garage door (standard) Double garage door (standard) Single garage door (wind-rated) Double garage door (wind-rated) Single garage door (unknown) Double garage door (unknown) Sectional door Roll-up door Other	77.99%
BG	59	roof_system	Roof System	Multiple Choice (Comma separated text)	Steel, cold formed Steel, hot rolled Steel, joists Concrete slab Wood, rafter	86.41%

					Wood, trusses Wood, unknown Unknown Other	
BH	60	r2wall_attachment	Roof to Wall Attachment	Multiple Choice (Comma separated text)	Toe-nails Metal ties Metal straps Bolted connection Welded connection Unknown Other	1.22%
BI	61	r2w_attachment_type	Roof to Wall Attachment Type	Text	*Surveyor-supplied roof to wall attachment type*	0.41%
BJ	62	roof_substrate_type	Roof Substrate Type	Multiple Choice (Comma separated text)	Plywood/OSB Dimensional lumber Metal deck Concrete None Unknown Other	57.07%%
BK	63	roof_cover	Roof Cover	Multiple Choice (Comma separated text)	Asphalt shingles (3-tab) Asphalt shingles (laminated) Built-up with Gravel Built-up without Gravel Clay tiles Concrete tiles Metal shingles Metal, corrugated Metal, standing seam Roll roofing Single ply Wood shake Wood shingle Unknown Other	92.66%
BL	64	secondary_water_barrier	Secondary Water Barrier	Multiple Choice (Comma separated text)	None Closed-cell urethane foam adhesive Fully adhered membrane High performance underlayment Self-adhering membrane over joints Unknown Other	1.90%

BM	65	overhang_length	Overhang Length	Integer	*Surveyor-supplied overhang length*	77.58%
BN	66	parapet_height_inches	Parapet Height in inches	Integer	*Surveyor-supplied parapet height*	70.38%
BO	67	wind_damage_details	Wind Damage Details	Text	*Wind damage notes from surveyor*	22.69%
BP	68	roof_structure_damage_	Roof Structure Damage	Single Choice	0%-100%	95.24%
BQ	69	roof_substrate_damage	Roof Substrate Damage	Single Choice	0%-100%	92.80%
BR	70	roof_cover_damage_	Roof Cover Damage	Single Choice	0%-100%	95.11%
BS	71	wall_structure_damage_	Wall Structure Damage	Single Choice	0%-100%	94.97%
BT	72	wall_substrate_damage_	Wall Substrate Damage	Single Choice	0%-100%	91.85%
BU	73	building_envelope_damage_	Building Envelope Damage	Single Choice	0%-100%	94.70%
BV	74	front_wall_fenestration_damage	Front Wall Fenestration Damage	Single Choice	0%-100%	91.44%
BW	75	left_wall_fenestration_damage	Left Wall Fenestration Damage	Single Choice	0%-100%	88.45%
BX	76	back_wall_fenestration_damage	Back Wall Fenestration Damage	Single Choice	0%-100%	86.28%
BY	77	right_wall_fenestration_damage	Right Wall Fenestration Damage	Single Choice	0%-100%	88.72%
BZ	78	large_door_failure	Large Door Failure	Multiple Choice (Comma separated text)	None Front Left	73.78%

					Back Right All other	
CA	79	soffit_damage	Soffit Damage	Single Choice	0%-100%	54.08%
CB	80	fascia_damag e_	Fascia Damage	Single Choice	0%-100%	80.43%
CC	81	stories_with_ damage	Stories with Damage	Integer	*Surveyor-supplied stories with damage*	79.48%
CD	82	water_induce d_damage_n otes	Water Induced Damage Notes	Text	*Water induced damage notes from surveyor*	9.92%
CE	83	percent_of_b uilding_footpri nt_eroded	Percent of Building Footprint Eroded	Single Choice	0%-100%	31.79%
CF	84	__damage_to _understory	Damage to Understory	Single Choice	0%-100%	36.28%
CG	85	maximum_sc our_depth_in ches	Maximum Scour Depth in inches	Integer	*Surveyor-supplied maximum scour depth*	30.03%
CH	86	__piles_missi ng_or_collaps ed	Piles Missing or Collapsed	Single Choice	0%-100%	39.95%
CI	87	__piles_leani ng_or_broken	Piles Leaning or Broken	Single Choice	0%-100%	39.27%
CJ	88	cause_of_fou ndation_dam age	Cause of Foundation Damage	Multiple Choice (Comma separated text)	Erosion Wave Flood Floating Debris Velocity Scour None Unknown Other	26.22%
CK	89	reroof_year	Reroof Year	Integer	*Surveyor-supplied reroof year*	0.41%
CL	90	retrofit_type_ 1	Retrofit Type 1	Text	*Surveyor-supplied retrofit description*	0.95%

CM	91	retrofit_1_year	Retrofit 1 Year	Integer	*Surveyor-supplied retrofit year*	0.27%
CN	92	retrofit_type_2	Retrofit Type 2	Text	*Surveyor-supplied retrofit description*	0.14%
CO	93	retrofit_2_year	Retrofit 2 year	Integer	*Surveyor-supplied retrofit year*	0%
CP	94	data_librarians	Data Librarian	Text	*Data Librarian Name*	99.32%
CQ	95	qc_progress_code	QC Progress Code	Single Choice	1 1 2 2e 3 3e	100%
CR	96	qc_notes	QC Notes	Text	*Notes from Data Librarians regarding the DE/QC process*	15.22%

[1] Percent filled column ignores any entries defined as “Unknown” or “Unk”.

Appendix B. Non-Buildings - Windstorm App Fields

Column		Column Header	Field	Format	Response Choices/ *Description*	Percentage Filled
A	1	fulcrum_id	Record ID	Text	Auto-populated	100%
B	2	project	Project	Text	Hurricane Michael (2018)	100%
C	3	latitude	Latitude	Decimal	Auto-populated	100%
D	4	longitude	Longitude	Decimal	Auto-populated	100%
E	5	date_of_survey	Date of Survey	MM/DD/YYYY	Auto-populated	100%
F	6	photos	Photos	Comma separated values	*Photos associated with record*	100%
G	7	nb_assessment_type	Assessment Type	Single Choice	Power Infrastructure Bridge Dam Road Other	100%
H	8	nb_damage	Damage	Binary	Yes No	100%
I	9	damage_level	Damage Level	Single Choice	Undamaged Minor Moderate Severe Destruction	100%
J	10	damage_source	Damage Source	Multiple Choice (Comma separated text)	Flood Flood-borne debris Landslide Surge Wind Wind-borne debris Other	80%
K	11	general_notes	General	Text	*General notes by surveyor*	60%

			Notes			
L	12	general_description	General Description of Structure	Text	*General description of structure by surveyor*	60%
M	13	general_description_of_damage	General Description of damage	Text	*General description of damage by surveyor*	40%
N	14	type_pi	Type	Single Choice	Pole Tower Substation Lines	0%
O	15	material_pi	Material	Single choice	Timber Concrete Steel Other	20%
P	16	diameterwidth_in	Diameter or Width in Inches	Decimal	*Surveyor-supplied diameter or width*	0%
Q	17	heightlength_m	Height or Length in Meters	Decimal	*Surveyor-supplied height or length*	0%
R	18	damage_type_power_infra	Damage Type	Single Choice	Undamaged Leaning Fallen Snapped Other	20%
S	19	pi_damage_distribution	Damage Distribution	Single Choice	Isolated Common Uniform Other	20%
T	20	bridge_use	Bridge use	Single Choice	Pedestrian Vehicular Railroad	20%
U	21	material_bridge	Material Bridge	Multiple Choice (Comma separated	Precast Concrete Cast in place Concrete Steel Timber	20%

				text)	other	
V	22	length_or_span_bridge	Length or Span of Bridge	Integer	*Surveyor-supplied length or span of bridge*	20%
W	23	lanes_bridge	Number of Lanes Bridge	Integer	*Surveyor-supplied lanes number of lanes*	20%
X	24	damage_state_bridge	Damage State Bridge	Single Choice	0=Undamaged 1=Light damage, still in use 2=Moderate damage, out of use but repairable 3=Severe damage, structure remains but not repairable 4=Collapsed	60%
Y	25	functional	Functional	Single Choice	Yes No Don't Know	40%
Z	26	material_dam	Material of Dam	Single Choice	Earth Concrete Steel Other	0%
AA	27	length_or_span_dam	Length or Span of Dam in Meters	Decimal	*Surveyor-supplied length or span of dam*	0%
AB	28	height_m_dam	Height of Dam in Meters	Decimal	*Surveyor-supplied height of dam*	0%
AC	29	thickness_dam	Thickness of Dam	Decimal	*Surveyor-supplied thickness of dam*	0%
AD	30	damage_state_dam	Damage State	Single Choice	0=Undamaged 1=Light damage, repairable, maintaining	40%

					function 2=Moderate damage, repairable, minimum loss of function 3=Severe damage, non-repairable, moderate loss of function 4=Destroyed, no longer serves function	
AE	31	qc_id	QC ID	Text	*Name of Librarian*	100%
AF	32	qc_code	QC Progress Code	Single Choice	0 1 1a 1b 1e 2 2e 3 3e 4 9	100%
AG	33	qc_notes	QC Notes	Text	*Summary of modifications made to data in QA/QC process*	20%

Appendix C. Hazard Indicator - Windstorm App Fields

Column		Column Header	Field	Format	Response Choices/ *Description*	Percentage Filled
A	1	fulcrum_id	Record ID	Text	Auto-populated	100%
B	2	_created_at	Created at	MM/DD/YYYY	Auto-populated	100%
C	3	_updated_at	Updated at	MM/DD/YYYY	Auto-populated	100%
D	4	_project	Project	Text	CMMI-1266418	100%
E	5	_latitude	Latitude	Decimal	Auto-populated	100%
F	6	_longitude	Longitude	Decimal	Auto-populated	100%
G	7	name_of_surveyor	Name of Surveyor	Text	Auto-populated	100%
H	8	date	Date	MM/DD/YYYY	Auto-populated	100%
I	9	time	Time	HH:MM	Auto-populated	100%
J	10	photos	Photo	Comma separated values	*Photos associated with record*	87.34%
K	11	hazard_type	Hazard Type	Single Choice	Flood Flood-borne debris Surge Wind Wind-borne debris Other	98.73%
L	12	notes	Notes	Text	*Notes from surveyor*	1.27%
M	13	wind_indicator_class	Wind Indicator Class	Multiple Choice (Comma separated text)	Tree Tower Sign Other	1.27%
N	14	tree_species	Tree Species	Text	*Surveyor-supplied tree species*	0%
O	15	tree_height_ft	Tree Height in Feet	Decimal	*Surveyor-supplied tree height*	0%
P	16	tree_projected_area	Tree Projected Area	Integer	*Surveyor-supplied tree projected area*	0%

Q	17	tree_damage_state	Tree Damage State	Single Choice	Undamaged Small branches torn off Large branches torn off Partially uprooted Uprooted Trunk snapped	0%
R	18	tree_damage_distribution	Tree Damage Distribution	Single Choice	No nearby trees Isolated (<15%) Common (15%-50%) Typical (50%-75%) Uniform (80%-100%) Other	0%
S	19	tree_fall_direction	Tree Fall Direction	Integer	*Surveyor-supplied tree fall direction*	0%
T	20	tower_use	Tower Use	Text	*Surveyor-supplied tower use*	1.27%
U	21	tower_structure_type	Tower Structure Type	Single Choice	Solid Trussed Open Other	1.27%
V	22	tower_material	Tower Material	Multiple Choice (Comma separated text)	Steel Wood Aluminum Concrete Other	1.27%
W	23	tower_height_ft	Tower Height in feet	Integer	*Surveyor-supplied tower height in feet*	1.27%
X	24	tower_damage_state	Tower Damage State	Single Choice	Undamaged Leaning, straight Leaning, plastic hinge Collapsed, anchorage failure Collapsed, member failure Other	1.27%
Y	25	tower_projected_area	Tower Projected Area	Integer	*Surveyor-supplied tower projected area*	0%
Z	26	tower_failure_direction	Tower Failure Direction	Integer	*Surveyor-supplied tower failure direction*	0%

AA	27	sign_use	Sign Use	Text	*Surveyor-supplied sign use*	0%
AB	28	sign_structure_type	Sign Structure Type	Single Choice	Solid Trussed Open Other	0%
AC	29	sign_material	Sign Material	Multiple Choice (Comma separated text)	Steel Wood Aluminum Concrete Other	0%
AD	30	sign_height_ft	Sign Height in Feet	Decimal	*Surveyor-supplied sign height*	0%
AE	31	sign_damage_state	Sign Damage State	Single Choice	Undamaged Leaning, straight Leaning, plastic hinge Collapsed, anchorage failure Collapsed, member failure Other	0%
AF	32	sign_projected_area	Sign Projected Area	Integer	*Surveyor-supplied sign projected area*	0%
AG	33	sign_failure_direction	Sign Failure Direction	Integer	*Surveyor-supplied sign failure direction*	0%
AH	34	site_description	Site Description	Text	*Surveyor-supplied site description*	87.34%
AI	35	horizontal_datum	Horizontal Datum	Single Choice	NAD27 NAD83 WGS84 Other	0%
AJ	36	horizontal_datum_source	Horizontal Datum Source	Single Choice	Digital map GNSS Handheld GPS Mobile device	0%
AK	37	vertical_datum_source	Vertical Datum Source	Single Choice	Differential Levels GNSS (Network) GNSS (Rapid Static) GNSS (RTN) GNSS (Static) Hand Level Tapedown	0%

					Total Station Other	
AL	38	vertical_datum	Vertical Datum	Single Choice	Arbitrary NAVD'88 NGCD'29 PRVD'02 Other	2.53%
AM	39	hwm_objective_point	HWM Objective Point	Single Choice	GNSS BM NGS BM RM RP Other	0%
AN	40	hwm_elevation	HWM Elevation	Decimal	*Surveyor-supplied hwm elevation*	1.27%
AO	41	hwm_elevation_uncertainty	HWM Elevation Uncertainty	Decimal	*Surveyor-supplied hwm elevation uncertainty*	1.27%
AP	42	hwm_elevation_units	HWM Elevation Units	Single Choice	Inches Meter	1.27%
AQ	43	elevation_source	Elevation Source	Single Choice	Differential Levels GNSS (Network) GNSS (Rapid Static) GNSS (RTN) GNSS (Static) Hand Level Tapedown Total Station Other	0%
AR	44	hwm_type	HWM Type	Single Choice	Debris line Debris snag Mud line Present at peak Seed line Wash line Other	1.27%
AS	45	hwm_marker	HWM Marker	Single Choice	Chiseled mark Marker Nail Nail and HWM tag Not marked Paint Stake Tape Other	0%

AT	46	tranquil_stillwater_hwm	Tranquil Stillwater HWM	Binary	Yes No	1.27%
AU	47	hwm_height_above_ground	HWM Height Above Ground	Decimal	*Surveyor-supplied hwm height above ground*	2.53%
AV	48	hwm_description	HWM Description	Text	*Surveyor-supplied hwm description*	1.27%
AW	49	hazard_source	Hazard Source	Single Choice	Wind Flood Surge Other	11.39%
AX	50	debris_type	Debris Type	Single Choice	Sheet Block Pipe Disc Fragment Other	15.19%
AY	51	distance_from_source	Distance From Source	Decimal	*Surveyor-supplied distance from source*	0%
AZ	52	distance_from_source_units	Distance From Source Units	Text	*Surveyor-supplied distance from source units*	0%
BA	53	method_of_distance_estimate	Method of Distance Estimate	Single Choice	Digital map measurement Ground-based measurement device Visual approximation Other	0%
BB	54	debris_description	Debris Description	Text	*Surveyor-supplied debris description*	6.33%