# StEER: Structural Extreme Event Reconnaissance Network

## HURRICANE MICHAEL:
## FIELD ASSESSMENT TEAM 1 (FAT-1)
## EARLY ACCESS RECONNAISSANCE REPORT (EARR)

Members of FAT-1

Members of FAT-1 (taken by UAV)


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# Executive Summary

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. Surface observations near the eyewall measured peak wind gusts of at least 130 mph at 10 m height, but gusts may have been higher as several observation stations were damaged and stopped reporting. 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. Best estimates of the hurricane wind field indicate that design wind speeds for many structures were exceeded for a sizable region near Mexico Beach and further inland. Heavy storm surge inundated regions from Tyndall Air Force base down through Mexico Beach (8-12 ft storm surge inundation reported), Port St. Joe, Apalachicola, and the barrier islands. The extent of damage required a coordinated response from the structural engineering community, which began with the deployment of a Field Assessment Team (FAT-1) that was subdivided into an Advance Scout Team, a UAV team, and Door-to-Door (D2D) assessment teams.

This Early Access Reconnaissance Report (EARR) provides an overview of Hurricane Michael, StEER's event response, and preliminary findings based on FAT-1's collected data. FAT-1 broadly assessed the performance of a representative subset of structural typologies in coastal and inland areas. Its teams conducted assessments October 13-15, 2018. The extent of the assessments 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.

In general, FAT-1 observed widespread wind- and surge-induced damage from Panama City Beach down to Apalachicola, with extensive joint wind- and surge-induced damage in Mexico Beach.

- **Structural Wind Damage:** Structural wind damage was widely observed in Panama City but was still highly variable, with adjacent buildings often exhibiting highly disparate levels of damage. In Panama City Beach, and inland areas such as Marianna and Blountstown, structural damage was more isolated but roof cover and wall cladding damage was still frequently observed. In coastal regions, including Mexico Beach and Port St. Joe, multiple buildings were destroyed by the high winds but destruction was still not uniform.
- **Storm Surge Damage:** Storm surge was most prevalent from Mexico Beach down into to the Big Bend, including Apalachicola. Structural surge-induced damage was mostly confined to an approximately 1-mile stretch of Mexico Beach and portions of Port St. Joe. Washout of roads and coastal features was documented in multiple areas
- Anecdotally, the most extreme levels of damage were observed in older (pre-2002) structures, while newer structures generally performed much better. However, roof cover and wall cladding damage was still commonly observed even in newer structures. Failures were frequently observed in both engineered and non-engineered buildings.

All observations and findings provided in this report should be considered preliminary and are based on the limited scope of FAT-1. Many coastal and inland communities could not be sampled within the scope and timeline of FAT-1 and should be included in future assessments. Specific recommendations of areas worthy of further investigation by the community are offered at the conclusion of this report.

# Introduction

StEER's response to Michael had a two-fold objective. The first being the swift capture of perishable data through a coordinated strategy to improve our understanding of the performance of coastal construction under this event. The second viewed this response as an opportunity to prototype the protocols, procedures, policies and workflows that StEER will be developing over the next two years in collaboration with the Natural Hazards Engineering research community, the Natural Hazards Engineering Research Infrastructure (NHERI), and other members of the Extreme Events Reconnaissance Consortium.

The first product of the StEER response to Hurricane Michael is this **Early Access Reconnaissance Report (EARR)**, which is intended to:

1. provide an overview of the storm, particularly as it relates to the wind and storm surge that damaged structures
2. overview StEER's event strategy in response to this storm
3. summarize the activities, methodologies and preliminary findings of the StEER's first Field Assessment Team (FAT-1)
4. Identify potential areas of interest for future field assessment teams and recommendations for future research regarding this event.

It should be emphasized that all results herein are preliminary and based on the rapid assessment of data within days of its collection. As such, the records have not yet been processed by the StEER Quality Assurance protocol. Damage ratings discussed herein are based largely on the judgement of the surveyor on the ground without access to additional aerial imagery and will be updated when the full dataset is released on DesignSafe under Project ID PRJ-2113. The raw data is now available for viewing in the Fulcrum Community page: https://web.fulcrumapp.com/communities/nsf-rapid

# Meteorological Background

Hurricane Michael was upgraded to a tropical storm on October 7, 2018, but was not initially expected to become a catastrophic storm (Fig. 1). However, in only three days, it grew from a tropical storm to a Category 4 hurricane at landfall, making it one of the most powerful storms in US history. Hurricane Michael made landfall on October 10, 2018, in the Florida Panhandle, near Mexico Beach. At the time of landfall, the Category 4 hurricane was moving forward at approximately 14 mph, with maximum sustained wind speeds of 155 mph and a minimum central pressure of 919 MB (Fig. 2). When using minimum sea level pressure as a metric for intensity, Michael's landfall pressure of 919 millibars was the third-lowest on record in the United States, trailing only the Labor Day Hurricane of 1935 (892 millibars) and Camille in 1969 (900 millibars). Perhaps more noteworthy was the speed of Michael's intensification as it moved over the warm waters of the Gulf of Mexico: sea surface temperatures along Michael's track were approximately 0.75-1.5°C warmer than average. This aided Michael in intensifying from a 35 mph tropical depression to a 145 mph hurricane in approximately 72 hours.


**Figure 1:** Projected path of Hurricane Michael (Source: National Hurricane Center)

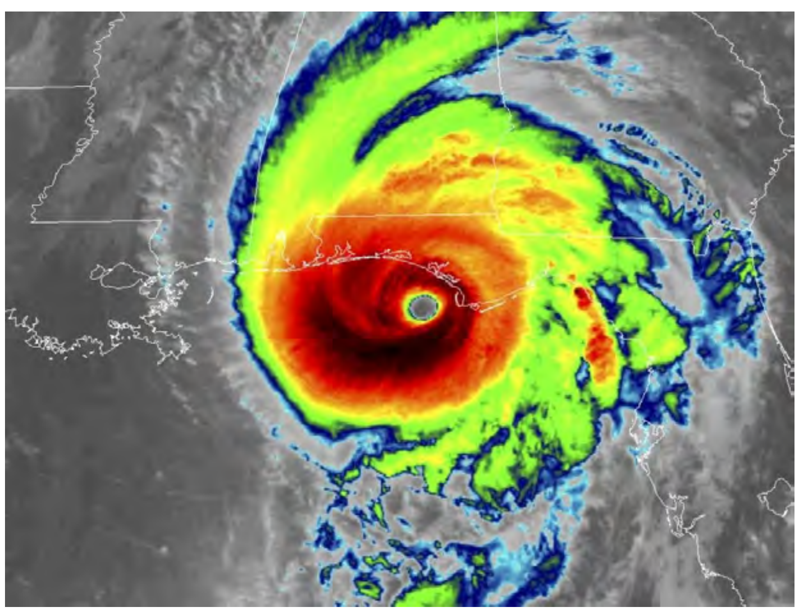

**Figure 2:** Infrared satellite image captured at approximately 11:40 am EDT as Hurricane Michael approached the Florida coastline as a Category 4. (Source: NOAA via Associated Press)

As seen in Figure 3, projected maximum wind gusts along the Florida coastline varied from 40 mph to 140 mph, although the National Hurricane Center reported wind speeds as high as 155 mph. At any given point however, the maximum wind speed and direction from which it occurs is a function of the distance to the hurricane eyewall, the local terrain surrounding the point, and the presence of any convective features within the hurricane wind field. The hurricane gradually weakened as it traveled across land, but was still a Category 3 as the eye passed from Florida to Georgia, with measured sustained wind speeds reaching 115 mph. Although it quickly deteriorated in a matter of hours, tropical storm-level winds were experienced by the Carolinas, as well as in Northern Georgia.

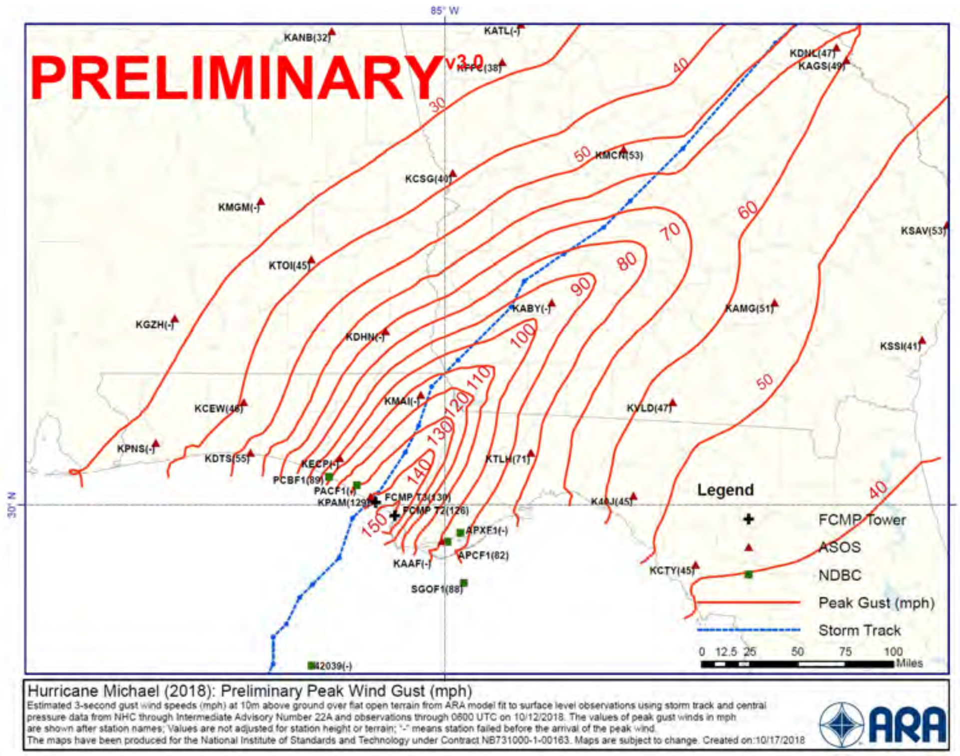


**Figure 3:** Estimated 3s peak wind gust by ARA (assumes open terrain and 10 meter height) (Courtesy of NIST)

The *Independent* referenced the National Hurricane Center in reporting that the storm surge ranged from 8 to 14 ft in areas from Mexico Beach to Apalachee Bay, a location noted for storm surge potential even from less-intense tropical cyclones. There in Apalachee Bay, Michael's storm surge produced a peak inundation of 7.72 feet above ground level, easily surpassing the previous record of 6.43 feet above ground set during Hurricane Dennis in July 2005. Predicted storm surge levels based on ADCIRC (EHzergih$GMVGyepexmsr) simulations by the Coastal Emergency Risk Assessment (CERA) are visualized in Figure 4 and measurements at Mexico Beach (Fig. 5) affirm maximum storm tide levels of over 14 feet. The depth of inundation with strong waves riding on this storm surge completely destroyed many homes with insufficient freeboard, making storm surge a particularly damaging hazard in this hurricane.

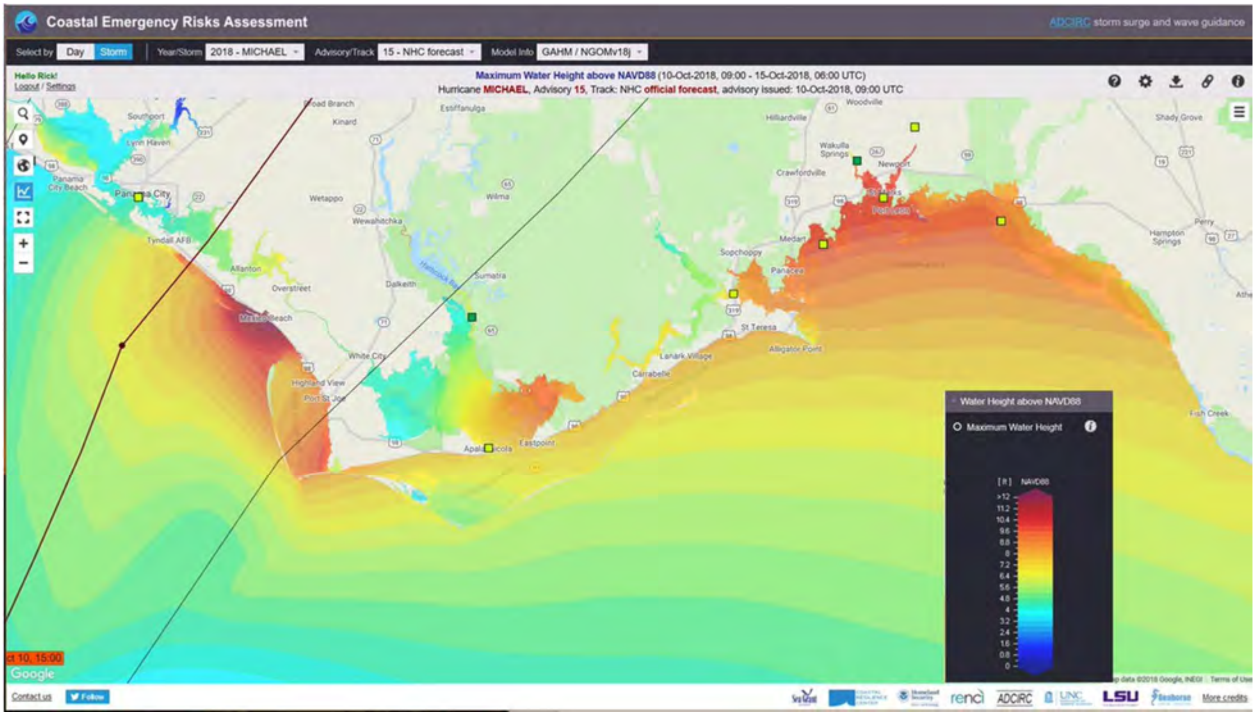


**Figure 4:** Storm surge projections for Michael (Source: Coastal Emergency Risks Assessment)

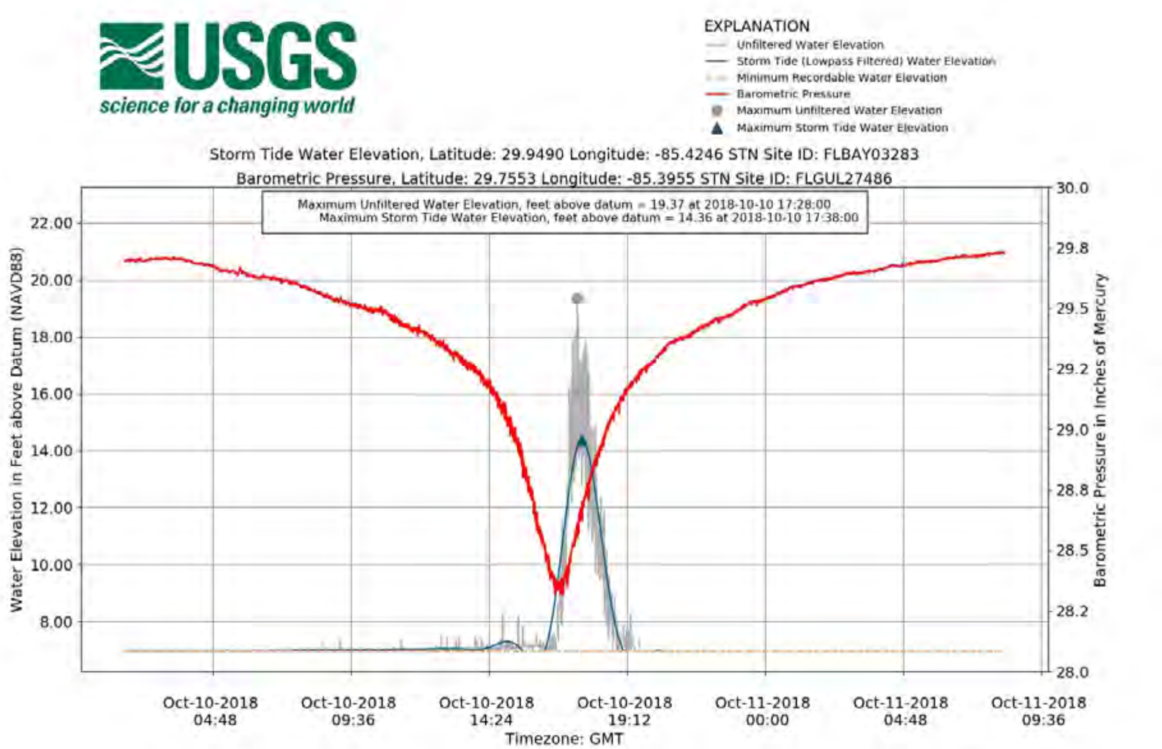


**Figure 5:** Processed storm surge data at Mexico Beach Pier, Bay County, FL (Source USGS: https://stn.wim.usgs.gov/STNServices/Files/105217/Item)

As reported by the Weather Channel, Michael spread heavy rains from the Florida Panhandle to the mid-Atlantic/New England, though rainfall totals could have been far worse had Michael not been such a fast moving storm. Still, there were 204 reports of flash flooding attributed to Michael in the 48-hour period ending 8 am EDT Oct. 12, spanning from Georgia to New Jersey. Major flash flooding occurred in Danville, Farmville, Richmond and Roanoke, among other locations in Virginia, prompting flash flood emergencies from the National Weather Service. Water rescues were performed in Danville, where the measured rainfall of 6.00 inches on October 11 broke the local record for rainfall in one day. The most notable rainfall totals were outside of Florida, with 9.62 inches near Black Mountain (NC), 8.04 inches in Bowling Green (VA), 7.39 inches near Jefferson (SC), 7.10 inches in Salisbury (MD), 6.75 inches near Boone (NC) and 6.48 inches near Powder Springs (GA). The highest total in Florida was 5.26 inches at Sumatra (see Fig. 6). Other areas in Georgia and Alabama experienced rainfall in the 7-8 inches range, according to satellite imagery from NASA (see Fig. 6).

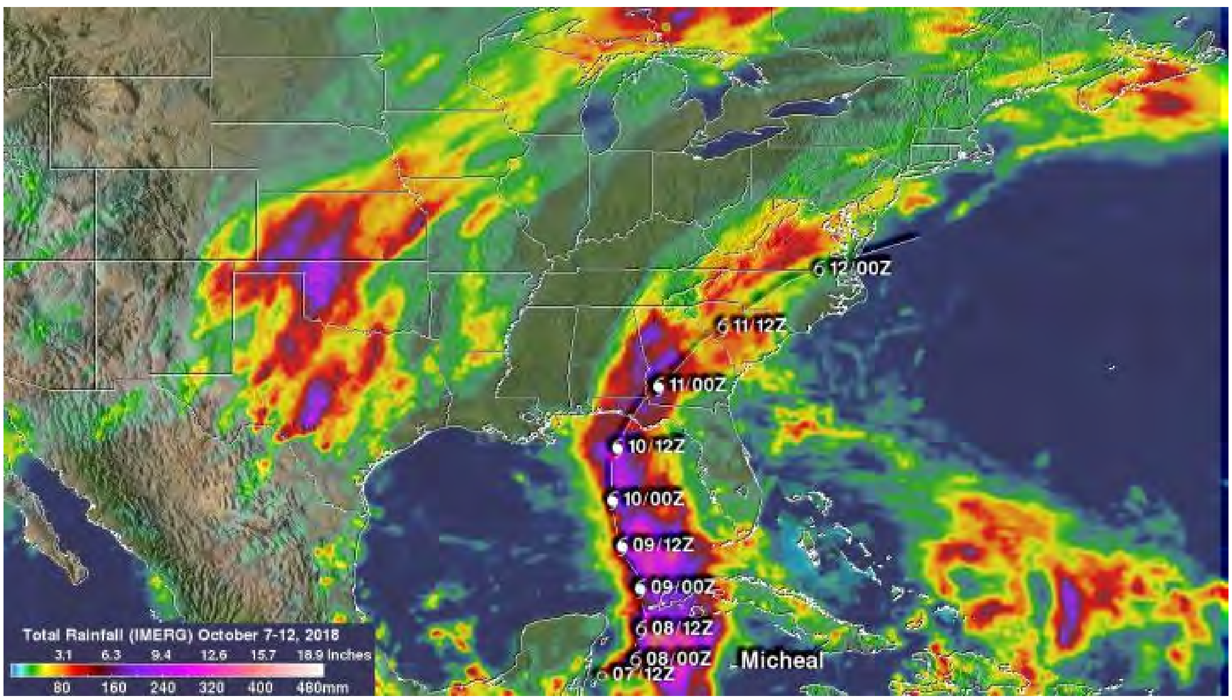


**Figure 6:** Rainfall levels occurring October 7-12, with those in the Southeastern US mostly due to Hurricane Michael. (Image created by NASA/JAXA)

# StEER Response Strategy

FAT-1 collected data in Florida between October 13-15, 2018 from Panama City Beach east and south to Indian Pass and north to Marianna using the following technologies:

- UAV (DJI Mavic Platinum and Inspire 2);
- Door-2-Door (D2D) damage assessments with a customized Fulcrum App; and
- Vehicle-mounted Applied Streetview (ASV) camera.

The StEER's preferred response strategy centers on pre-identifying clusters of structures based on typology, year of construction, terrain conditions or other factors, and conducting D2D assessments on every third structure within each cluster to avoid biasing. The D2D assessments were then coupled with UAS coverage to ensure a holistic view of the post-storm condition was captured, while the AS camera was able to cover larger areas for rapid assessment of damage.

Detailed forensic investigations were generally not achievable within the scope and time limits of FAT-1. Instead, focus was provided on broadly assessing building performance over large expanse of the impacted area and over a wide range of structural typologies. If recommended, future StEER deployments or RAPID-style grants can focus on specific typologies or regions. Specific, hypothesis-driven research is generally outside of the scope of StEER, although data collected by StEER can be used for these purposes in some cases.

# Local Codes & Construction Practices

Florida relies on two codes to regulate building construction: (1) the Florida Residential Code and (2) the Florida Building Code. While the Florida Residential Code provides regulations and guidance for the construction of one and two-family dwellings, the Florida Building Code addresses all other buildings and structures. The Florida Building Code released in 2010 was primarily based on 2009 International Building Code, which did not incorporate the specifications of ASCE 7-10. Since 2012, ASCE 7-10 served as the foundation of the Florida Building Code. According to the latest version of Florida Building Code (2017), wind loads on buildings must be calculated using Chapters 26-30 of ASCE 7. Design wind speeds should be determined from the maps given in Figures 1609.3(1), 1609.3(2), and 1609.3(3) of the 2017 Florida Building Code, Sixth Edition. Figure 7 illustrates the design wind speeds from ASCE 7-16 for the landfall region, with exact values reported for Panama City, FL.

In 2000, while Florida was preparing to enact the first statewide building code, legislation created the so-called "Panhandle Exemption," which exempted areas of the Panhandle from some of the more strict wind design requirements. **These exemptions only applied to buildings located at least one mile inland.** The exemption primarily related to wind-borne debris requirements. While the rest of the state was subject to wind-borne debris requirements for design wind speeds greater than 120 mph, wind-borne debris requirements in the Panhandle extended only one mile from the coast. In 2006, following Hurricane Ivan, the exemption was repealed under Legislation HB 7A (2007).

The FL Coastal Construction Control Line (CCCL) is another important part of Florida's regulatory environment and was implemented in this region in the late 1970s. The CCCL delineates that area of the beach-dune system that is expected to be subject to severe fluctuation resulting from a 100-year storm event. The 100-year storm elevation requirements for habitable structures located seaward of the coastal construction control line ensure that the lowest horizontal structural member of the building is placed at an elevation above the predicted breaking wave crest, termed the 100-year storm elevation. All major structures are required to be designed to resist the predicted forces associated with a one hundred-year storm event. In Bay County, the 100-year storm elevation varies between 17.1 ft and 17.4 ft relative to the National Geodetic Vertical Datum. In Mexico Beach, the CCCL approximately aligns with US-98, meaning structures seaward of US-98 should be constructed with the lowest horizontal structural member at an elevation of at least 17.1 ft NGVD.

# Reconnaissance Methodology

FAT-1 used its targeted **D2D Assessment Teams** to conduct door-to-door (D2D) damage assessments at predefined clusters in Panama City and Mexico Beach. UAS was deployed by the U**AV Team** in tandem 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 supplemented by the ASV camera 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 7 provides an overview of the main assessment sites. Descriptions of each site are provided in Table 1.

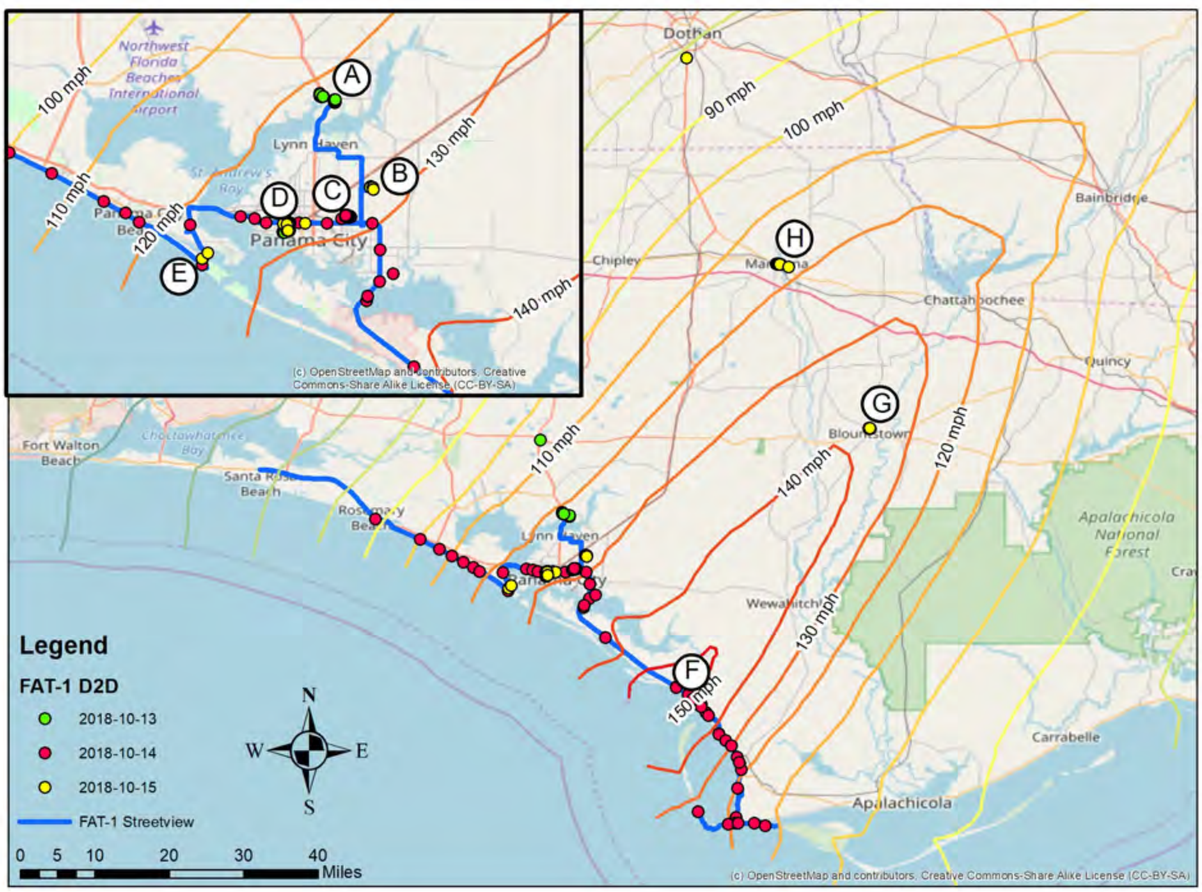


**Figure 7:** Summary of StEER assessments relative to the peak gust wind speeds as estimated by ARA.

**Table 1:** Summary of assessment technologies used at each site indicated in Figure 7

| 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 |

## D2D Assessments

D2D Damage Assessments enable a detailed construction classification and evaluation of condition/component damage levels. These were recorded using a Fulcrum mobile smartphone application acquiring geotagged photos and other relevant metadata from the surveyor's mobile device. The App development was informed by the experience of the 2017 Hurricane Season and reorganized into a Fulcrum project, allowing FAT members to select assessment forms customized for buildings, non-buildings, or hazard indicators.

FAT emphasis is placed on documenting the performance of as many buildings as possible in a short amount of time, while still capturing the minimal depth of information needed for a useful assessment. This information includes 1) collecting clear photographs from multiple perspectives, 2) accurately geo-locating the assessments, 3) filling out site-specific fields which require on-site forensic investigation, and 4) noting unique features of structures that would affect windstorm performance and not be otherwise visible from UAS data. To avoid biasing, D2D damage assessments were conducted on every third house within the pre-identified cluster.

A large portion of D2D data enrichment comes from VATs analyzing data submitted by FATs once the file synchronizes with the backside Fulcrum database. VATs are charged with 1) creating uniform damage rating standards from the variable assessments of individual FAT investigators, 2) conducting a detailed QA/QC process, 3) enriching each entry with more detailed classification of the structure and assessments of overall/component damage due to wind and storm surge, and 4) oversee the migration of this data into DesignSafe in accordance with uniform data standards.

## Unmanned Aerial Surveys

The UAS engaged in this deployment included one 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 (Fig. 8). In a few sites, specifically the Pirates Cove Marina and the Interior Panama City locations, gridded flight patterns were not able to be used 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.

**Figure 8:** Preliminary 3D model of a portion of the Cedar Crossing subdivision, created using Structure from Motion photogrammetry.

## Applied StreetView Imaging

The Advance Scout Team, consisting of Dr. Daniel Smith from James Cook University and the University of Florida and Dr. John Cleary from the University of South Alabama, gathered high-level impressions of damage from both wind and storm surge using ASV rapid surveying technology (Fig. 9), recording spot observations of representative performance using the Fulcrum App, and identifying areas for follow-up assessment based on damage and accessibility. The team covered 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.

ASV imagery provides an efficient platform to rapidly collect the perishable data in the field. In typical primary post-disaster reconnaissance where photo documentation is instigated by a human surveyor, it is inevitable to end up with fairly subjective dataset due to interests and expertise of data collectors. However, the ability of the ASV cameras to capture the entire external view of the scene can considerably reduce the chance of missing valuable post-disaster information and enable a more robust set of data for processing afterward. The ASV system used in this investigation records seven photographs (one forward, two oblique forward, two oblique backwards, and one upwards) every five meters that the vehicle drives. The team 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. The images collected from the ASV system will be stitched together into seamless street views that will be made available on DesignSafe under project PRJ-2113.


**Figure 9:** ASV system deployed on vehicle (Source: John Cleary).

# Observations by Region

Observations of damage and conditions in the regions assessed by FAT-1 (see Fig. 7) are now summarized.

## Southport

D2D assessment was conducted in Southport by FAT-1 on October 13, 2018 near Bridge St. and Railroad Ave. and along Mary Jo Ave. The D2D assessment included 22 residential buildings, 1 commercial building, and 1 institutional building (church); those sustaining damage had preliminary overall wind damage ratings of minor (N=9) and moderate (N=12). Preliminary analysis of D2D data in the sampled clusters indicates damage predominantly driven by wind and largely to the roof cover and building wall envelope of single-family homes (Fig. 10). Severe and consistent tree damage with several trees impacting structures near the Southport Elementary campus (Fig. 11) was observed. The two churches near the Southport Elementary campus were reported to experience more severe wind damage, with one experiencing partial wall collapse on the north-facing gable end, and the other experiencing loss of the metal roofing system. South of Southport Elementary, consistent building envelope damage to most structural typologies with isolated structural failures was observed.

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| **Accessibility:** As of Oct 17, no reports of road closures or accessibility restrictions are reported in Southport. On Oct 13, FAT-1 reported no major issues with access to Southport. |
| **Site Conditions:** As of Oct 17, Gulf Power, the company that serves Southport, reported no outages. Real-time power outage information can be found here. Drone footage of Southport taken on Oct 12 can be found here. |

**Figure 10:** Damage to roof cover and building wall envelope observed in Southport

**Figure 11:** Example of tree damage observed in Southport

## Panama City Beach

D2D assessments were conducted in Panama City Beach, Laguna, and Rosemary Beach by FAT-1 on October 14, 15, and 17 near US Highway 30 and US Highway 98. Assessments were mostly conducted between Front Beach Rd. and US Highway 98. The assessed sites are concentrated from E. Lakeshore Dr. in Laguna Beach to St. Thomas Dr. in Panama City Beach. Three commercial buildings, 2 hotels, 2 residential buildings, and 3 buildings specified as 'other' were surveyed in the D2D assessment; those sustaining damage had preliminary overall wind damage ratings of minor (N=5), moderate (N=4), and severe (N=2). Preliminary analysis of D2D data indicates damage predominantly driven by wind, which include moderate to substantial roof and wall damage. These can be described by loss of sheathing, soffit damage, gutter damage, and shingle/tile loss (Fig. 12). Damage was also observed to wood-framed buildings that were under construction at the time of the storm (Fig. 13).

Collapse of three metal buildings associated with marinas were assessed in Panama City Beach (Figs. 14-15). While there is no doubt of the intensity of the wind speeds in Panama City Beach, forensic investigation revealed many connections of steel framing to their footings that were corroded to be point of significant loss of section and strength. In particular these conditions are likely to occur where the structures are located along the water and exposed to the environmental conditions salt air in marine locations.

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| **Accessibility:** As of 10/24/2018, no road closures were in effect in Panama City Beach. Traffic through Panama City Beach remains heavy. |
| **Site Conditions:** As of 10/24/18, running water, power and telecommunications are restored in Panama City Beach. Despite some substantial damage, all Bay County wastewater treatment plants are operational. The boil water order has been lifted for Panama City Beach and areas to the north. A countywide burn ban has been set in place that asks residents not to burn any waste or debris outside. |

**Figure 12:**  (left) Commercial building in Panama City Beach sustaining severe wind damage. (Right) Multifamily building under construction sustaining minor wind damage in Panama City Beach.

**Figure 13:** Construction sites in Panama City Beach sustaining moderate wind damage.

**Figure 14:** Collapse of a storage building (left) with corrosion and material loss in columns and baseplates (right).

**Figure 15:** Partial collapse of a metal building marina in Panama City Beach.

## Interior Panama City

D2D assessments were conducted in interior Panama City by FAT-1 on October 14 and 15, 2018 near US Highway 98. Assessments span a wide geographic region but are concentrated from 10th St. to 15th St. between Degama Ave. and Florida Ave. The D2D assessment included 12 commercial buildings, 1 government building, 1 institutional building, 3 residential buildings, and 5 buildings specified as 'other'; those sustaining damage had preliminary overall wind damage ratings of minor (N=3), moderate (N=8), severe (N=8), and destroyed (N=1). Preliminary analysis of D2D data in the sampled clusters indicates damage predominantly driven by wind with consistent structural failure to older, non-engineered buildings. There was regular cladding and roof cover damage to modern, non-engineered buildings. Some engineered buildings also were observed with cladding and roof cover damage. Figures 16-20 provide a sampling of observed damage to different typologies in interior Panama City.

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| **Accessibility:** Roads are temporarily closed throughout the city due to utility work (including Baldwin Rd. in Panama City east of SR77). Morning traffic is heavy along US-98 coming into Panama City from the west, but generally stays moving. Traffic can be heavy at times along US-98 south of Panama City towards Port St. Joe as it often becomes single lane. Traffic is at standstill trying to come out of Panama City around curfew (7pm) as everyone tries to leave at the same time. Commute through and out of Panama City in all directions can be twice as long as normal. |
| **Site Conditions:** As of 10/23/18 9:30 PM, the county reports that water is being restored to many of the county's wholesale customers in Panama City. Intermittent loss will occur as |

crews find and repair leaks. A boil water order is still in effect in Panama City except for Lynn Haven. See this website for current conditions.

Gulf Power had a goal of restoring power to 95% of customers by Wednesday, 10/24/18. Outage maps indicate intermittent power outages still in effect. The city is collecting about 25% of residential garbage (blue cans) each day. Low hanging power lines or debris in the roadway will not be collected until it is safer to do so.


**Figure 16:** Commercial structure in Interior Panama City Sustaining minor wind damage.


**Figure 17:** Commercial structure in Interior Panama City Sustaining moderate wind damage.

**Figure 18:** Commercial structure in Interior Panama City Sustaining severe wind damage.


**Figure 19:** Severely damaged roof at Family of God Baptist Church at 901 US-98 BUS, Panama City (Captured by: Tim Johnson)

**Figure 20:** Failure of roof cover and exterior wall of a gymnasium at the Bay County Prep Academy (Lat: 30.16902, Long: -85.67445).

## Cedar’s Crossing

D2D assessments were conducted in Cedar’s Crossing (neighborhood in northeast Panama City) by FAT-1 on October 13-14, 2018 near US Hwy 98 (southbound) and US Hwy 389 (westbound). Surveys span residences from Cedar’s Crossing (southbound road) to Tracy Lynn St. (northbound road). D2D Assessments encompassed 40 residential buildings; those sustaining damage had preliminary overall wind damage ratings of undamaged (N=1), minor (N=27), moderate (N=10), and severe (N=2). Preliminary analysis of D2D data in the sampled clusters indicates damage predominantly driven by wind. There was no major structural damage to homes built after 2007; homes experienced varying levels of roof cover and roof cladding loss, with a few garage door failures (Fig. 21). Pre-2007 homes experienced more prominent roof cover and cladding damage (Fig. 22), with some tree-fall damage (Fig. 23). Damaged roofs and failed soffits resulted in damage from water ingress, as there were no secondary water barriers.

**Figure 21:** Garage door failures in residential homes in Cedar’s Crossing.

**Figure 22:** Damage to roof cover and roof sheathing in residential homes in Cedar’s Crossing.

**Figure 23:** Example of tree damage in Cedar's Crossing.

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| **Accessibility:** Traffic is still heavy along routes accessing the area. As of 10/17/18 9:00 PM, this region remains under curfew between 6:30 PM-6:30 AM. |
| **Site Conditions:** Power, water and telecommunication status generally align with those of Panama City. As of 10/24/2018, Gulf Power outage map still indicated power outages in Cedar's Crossing. |

## Tyndall Air Force Base

StEER did not attempt to access Tyndall Air Force Base, but significant damage to a number of buildings was observed from US-98, including several large aircraft hangars (Fig. 24), on-base housing, and experimental laboratories.

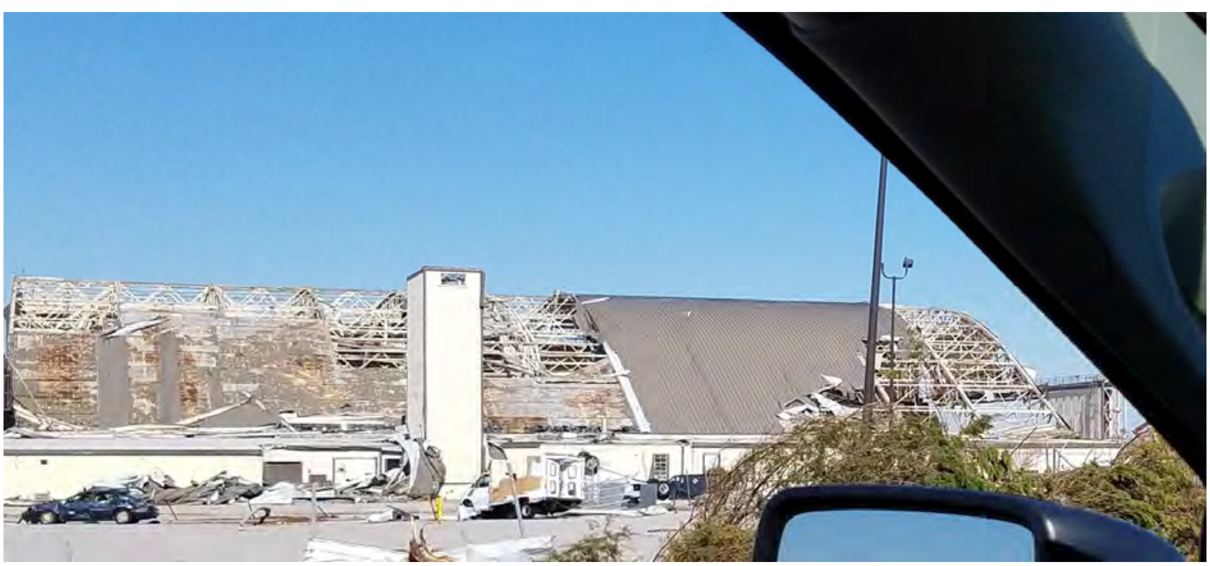

**Figure 24:** Severe wind damage observed to a large aircraft hangar on the Tyndall Air Force base, with almost complete failure of the corrugated metal roof cladding system.

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| **Accessibility:** Only credentialed base members are allowed access. |
| **Site Conditions:** Unknown. |

## Mexico Beach

D2D assessment was conducted in in Mexico by FAT-1 on October 13, 2018 along US Hwy 98 from S. 36th St. to Bay St. D2D Assessments cataloged 41 residential buildings and 1 building specified as ‘other’; those sustaining damage had preliminary overall wind damage ratings of minor (N=21), moderate (N=5), severe (N=5), and destroyed (N=6). In addition, those sustaining damage had preliminary overall storm surge/flood damage ratings of minor (N=2), moderate (N=2), very severe (N=1), and collapse (N=4). Preliminary analysis of D2D data in the sampled clusters indicates damage driven by both wind and storm surge. Mexico Beach suffered heavy but highly non-uniform damage (Figs. 25-27). Newer buildings performed well, while older buildings had the highest damage rates. Several new homes close to the coast appeared to be undamaged (Fig. 28). Storm surge had the highest impact between N. 8th and S. 42nd St. along US-98, with minimal storm surge impacts observed elsewhere. Several cases of entire buildings swept off foundations and moved considerable distances due to storm surge were observed (Fig. 29).

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| **Accessibility:** As of 10/23/2018, checkpoints were put in place limiting access to Mexico Beach to federal, state and local emergency officials, credentialed volunteers, contractors, insurance agents, and residents. See https://myescambia.com/recoverbaycounty for more information and a map of checkpoint locations. |
| **Site Conditions:** Portions of US-98 are washed out (Fig. 30), limiting travel. Debris cleanup is still ongoing. Duke Energy supplies power to Mexico Beach and began restoration on October 22, but no timeline for power restoration has been made available yet. |

**Figure 25:** Example of storm surge damage in Mexico Beach. High water mark, 8” short of the 8 ft ceiling, slab is elevated 5” above ground level so surge height estimated 93” AGL.

**Figure 26:** Severe damage to a masonry building observed in Mexico Beach (likely due to storm surge).

**Figure 27:** Example of total destruction of residential construction in Mexico Beach.


**Figure 28:** Newer buildings with minor damage in Mexico Beach.

**Figure 29:** (left) Home pushed on to US-98 by storm surge; (right) Home pushed into multi-family residential complex by storm surge in Mexico Beach.

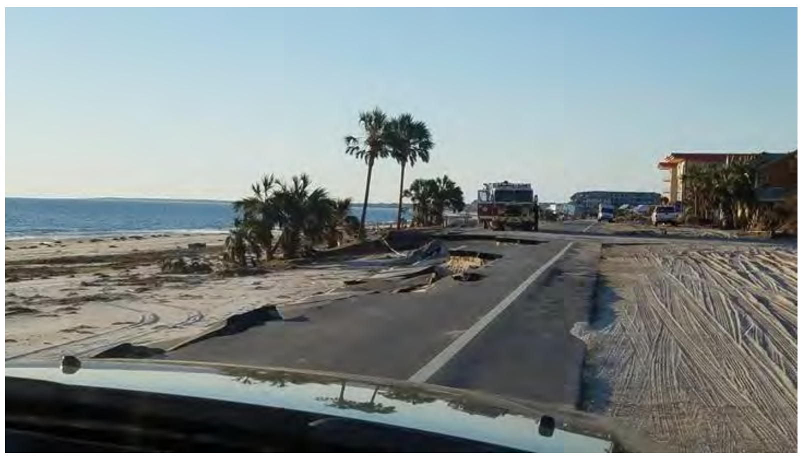

**Figure 30:** Road washout near US Hwy 98 in Mexico Beach (Latitude: 29.935440, Longitude: -85.400476).

D2D assessments were also conducted on a sample of single family residential structures in a neighborhood just northwest of the intersection of Highways 98 and 386 in Mexico Beach along Magnolia Dr. and Pine St. The structures assessed in this area were only subjected to wind damage. None of the houses were directly on the beach, but were on the other side of Highway 98. Based on discussion with the residents, the storm surge did rise up close to the houses, but due to their elevation the surge did not reach the homes. In one location between two houses, a portion of lower terrain served as the flow channel for the surge but did not reach any of the homes beyond those on Highway 98. The variability in performance was significant in this area as were the ages of the homes: some very recently completed, while others were older. Eight structures were assessed in this grouping with the overall wind damage classification as follows: 1 destroyed, 1 moderate damage, 5 minor damage and 1 undamaged. The undamaged home was recently constructed (within 3 months) based on discussions with a resident. According to the property database, the destroyed home was constructed in 1995. The home with moderate damage had significant siding loss, loss of fascia and significant water ingress damage. The range of damage in this region is illustrated by Figures 31 and 32.

**Figure 31:** Examples of minor damage to homes assessed near the intersection of Highways 98 and 386 in Mexico Beach.

**Figure 32:** Examples of moderate (left) and severe (right) damage to homes assessed near the intersection of Highways 98 and 386 in Mexico Beach.

## Beacon Hill

D2D assessments were conducted on October 14, 2018 in the Beacon by the Sea community in the Beacon Hill area. This community was selected for assessment due to the close proximity to the location of the Florida Coastal Monitoring Program (FCMP) Tower 2 which recorded data throughout Hurricane Michael. In addition to a number of single family residences, an assisted living center facility was also assessed for damage. The damage surveys included D2D sampling surveys of 15 structures; damage observations and photographs were recorded using the Fulcrum app. Additional overhead photography was also collected using UAS-mounted high-resolution cameras. Of the 15 structures surveyed, three were undamaged (N=3) and twelve had minor wind damage (N=12).

Based on discussions with the residents who were available, the homes have been built within the last five years, with some of the houses less than two years old. The primary forms of damage to these houses were loss of fascia boards and soffit damage, both under the eaves and under the entryways. There were also cases of minor shingle loss. Figure 33 shows examples of the fascia loss and shingle loss. Figure 34 shows typical examples of soffit damage observed in the neighborhood. In discussions with several of the homeowners present, even when significant soffit damage and complete loss of attic insulation were documented (Fig. 34), significant water intrusion did not occur. While it was less common, there was siding damage to a few of the homes in the community, including vinyl, cement fiber and wood shake cladding systems. By far the most significant siding damage was seen in the assisted living facility adjacent to the community. Examples of siding loss are shown in Figure 35.


**Figure 33:** Typical fascia damage of homes in the Beacon by the Sea Community.

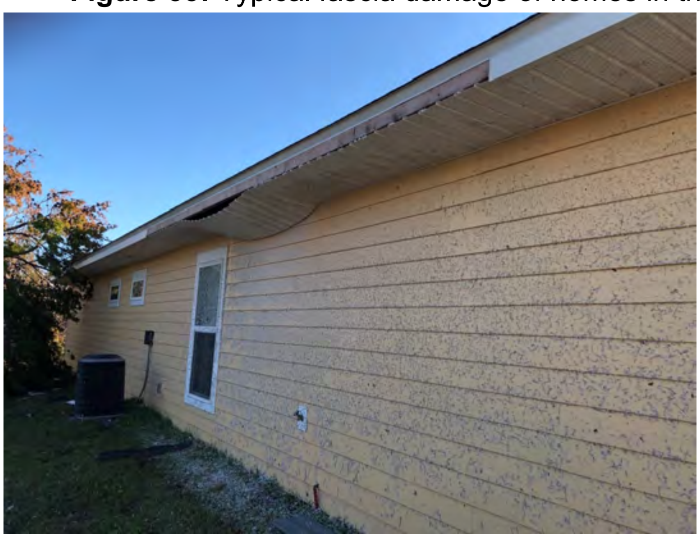
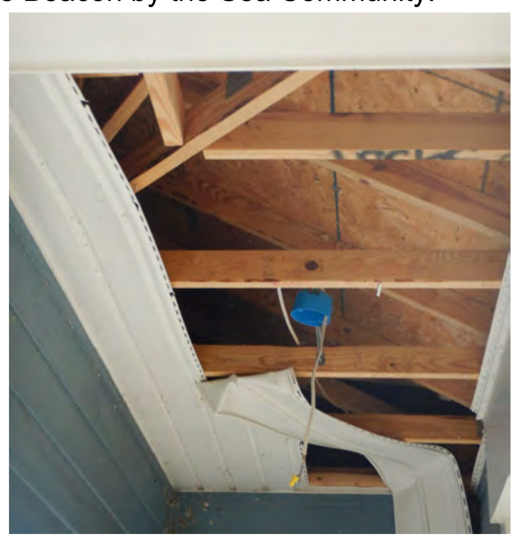

**Figure 34:** Typical soffit damage to homes in the Beacon by the Sea community.

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| **Accessibility:** As of 10/19/2018, there were no restrictions to entering the neighborhood. Downed power lines over the entrance may limit the size of the vehicle that can enter the neighborhood. |
| **Site Conditions:** As of 10/22/2018, power, water, telecommunications and other lifelines had not been restored. |

**Figure 35:** Examples of siding loss in an assisted living facility (left) and single family residence (right) in the Beacon by the Sea community.

## Port St. Joe

Surge high water mark of 72” was measured at Port St. Joe as shown in Figure 36. Wind damage was also severe in Port St. Joe, generally trending toward moderate and minor moving farther South. In general, it was seen that the surge footprint extended much farther south than the high-wind footprint. A surge-induced bridge failure (Fig. 37) was observed on 30A just South of Country Club road. New homes (less than 5 years old) along Four J’s Rd. and Kaelyn Ln., less than a mile northeast of FCMP T2, performed very well. All were single-story, most with gable roofs, and with a mix of wall cladding and roof cover materials. Most had engineered wood panels installed to protect glazed openings. Isolated roof cover and wall cladding damage was observed. Vinyl siding failed more frequently, typically in small lengths. Fascia damage was common. Conversations with multiple homeowners revealed no significant water ingress through the building envelope, even to homes with soffit damage (Fig. 38).

**Figure 36:** Surge high water mark (72”) in Port St. Joe.

(a)

(b)

**Figure 37:** Surge-induced bridge failure on 30A South of Port St. Joe: (a) buckled road surface; (b) scour at abutment support.


**Figure 38:** Residential structure in Port. St. Joe with solar panels intact (left) and minor vinyl soffit damage to front elevation (right), windows were covered with plywood.

## Blountstown

D2D assessments were conducted at Blountstown inside the Calhoun County by FAT-1 on October 15, 2018. The surveyed sites are concentrated on Marie Ave., NE Lambert St., Church St. and NE Charlie Johns St. A total of 13 residential buildings and 1 church building were surveyed in the D2D assessment; those sustaining damage had preliminary overall wind damage ratings of minor (N=7), moderate (N=3), and severe (N=1). Preliminary analysis of D2D data indicates damage predominantly driven by wind and tree fall (Figs. 39-40), which includes moderate to substantial roof and wall damage. These can be described by loss of sheathing, soffit damage and shingle/tile loss.

**Figure 39:** Damaged electricity conductor present in a building near Lambert Ave. in Blountstown.

**Figure 40:** Residential building sustaining severe damage due to tree fall at NE Lambert St. in Blountstown.

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| **Accessibility:** As of 10/19/2018, there were no restrictions to entering Blountstown. |
| **Site Conditions:** As of 10/22/2018, power, water, telecommunications and other lifelines have been restored, although temporary outages have been reported as additional repairs are made. |

## Marianna

D2D assessments were conducted in Marianna in Jackson County by FAT-1 on October 18, 2018. The surveyed sites are concentrated on Lafayette St., Market St. and US 90. A total of 7 commercial buildings were surveyed in the D2D assessment; those sustaining damage had preliminary overall wind damage ratings of minor (N=1), severe (N=2) and destroyed (N=2). Preliminary analysis of D2D data indicates damage predominantly driven by wind which includes moderate to substantial roof and wall damage.

Tree-fall was widespread in and around Marianna. Roof cover damage was frequently observed in both newer and older buildings. The most significant structural damage was observed to historic buildings in downtown Marianna, where unreinforced masonry walls collapsed (Figs. 41 and 42) and/or portions of the roof structure were damaged (Fig. 43). Buckling was observed at the base of columns supporting a gas station canopy (Fig. 44), and several large signs were also destroyed in and around downtown Marianna.


**Figure 41:** Commercial building (Edward Jones investments) with wall collapsed and roof structure damaged on Lafayette St. in Marianna.


**Figure 42:** Commercial buildings with masonry walls collapsed and roof structure damage on Lafayette St. in Marianna.


**Figure 43**. Commercial building (Mowery Elevators) sustaining severe roof damage on Lafayette St. in Marianna.


**Figure 44:** Exxon station sustaining column and roof damage at US 90 in Marianna.

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|---|
| **Accessibility:** As of 10/18/18, there were no restrictions on entering Marianna. |
| **Site Conditions:** At the time of assessment, approximately 83% of the power in Jackson County was out. As of 10/23/18, 93% of cellular service has been restored, the current power outage level was 62%, and a boil water advisory is in effect. |

# Damage to Transportation Infrastructure

A majority of closures that were reported in the P-VAT report have been lifted as they constituted cautionary closures due to high winds or water or debris over the roadways/bridges. The remaining closures or loss of access are mostly due to sustained damage. The damage could be categorized as follows: damage to roadways due to raised water levels that resulted in washing out the subgrade (Figs. 45-47) or those due to high levels of storm surge (and potentially waves in some locations) that resulted in failure of bridges spans, approaches, and abutments (Fig. 48).

**Accessibility:** US Highway 98 remains closed as of 10/17/2018 5:00pm ET both North and Southbound into Port St. Joe. Highway 30A is also closed connecting Port St. Joe to St. Joseph Peninsula along with Highway 30E. A bridge along Highway 30A has been severely damaged due to washout under the northern abutment. US Highway 98 remains closed as of 10/17/2018 5:00pm ET due to multiple washouts.

**Figure 45:** Road washout on Highway 30E (Cape San Blas Rd) on Saint Joseph Barrier Island (Latitude: 29.680619, Longitude: -85.366115).

**Figure 46:** Road wash out US Hwy 98 (Big Bend Scenic Byway Coastal Trail) (Latitude: 29.772736, Longitude: -84.793465) (Source: ESRI StoryMap).

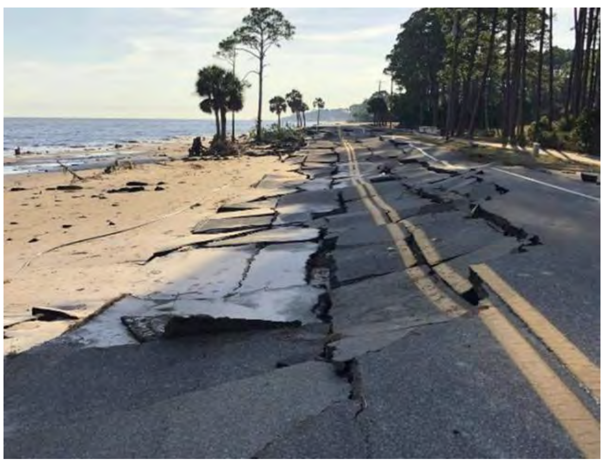

**Figure 47:** Road washout US Hwy 98 near Carrabelle (Latitude: 29.827057, Longitude: -84.696981) (Source: ESRI StoryMap).

**Figure 48:** Bridge approach washout on Highway 30A Bridge near Saint Joseph Bay (Latitude: 29.754006, Longitude: -85.303750).

# Damage to Power Infrastructure

Most of the areas remain without the power, but utility crews are working to restore the power. The damage to the power infrastructure is observed at the level of transmission (high voltage) (Fig. 49), distribution poles (lower voltage), and also access points at individual housing locations. The damages observed seem to be a combination of the bending and shear failure at the base of the poles (Fig. 50), or snapping of the tip of the pole were the attachments are connected (Fig. 51). There are cases of one pole failure leading to a domino effect in multiple poles. Some of the failures may be as a result of not only the high winds but also the impact from flying debris from adjacent structures or fallen trees or branches of trees (Fig. 52). The damage to the transmission towers seems more sporadic but may cause more widespread blackouts. The damage to the individual housing attachments have also been reported.

**Figure 49:** Destroyed transmission tower near North Tyndall Parkway, Springfield (Latitude: 30.160519, Longitude: -85.591164).

**Figure 50:** Damaged electric pole near West 15th St., Panama City (Latitude: 30.175136, Longitude: -85.663061).


**Figure 51:** Damaged electric pole near West 15th St., Panama City (Latitude: 30.175136, Longitude: -85.663061).

**Figure 52:** Damaged electric pole near Oakshore Dr., Parker (Latitude: 30.110311, Longitude: -85.60216) (Credit: Dean Ruark)

# Recommendations for Further Study

FAT-1 primarily focused assessments on 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. Preliminary review of assessments logged by the team in these areas, in addition to observations by the team members as they traveled throughout the impacted areas, have led to the following recommendations for future study.

Suggested targets for more comprehensive investigation of wind impacts:

1. **Performance of roof cover systems**: Poor roof cover performance was observed in most of the areas assessed, even in regions that did not experience the highest wind speeds. Studies should encompass all roof cover systems including standing seam, corrugated metal, asphalt shingle, and tile. Most buildings with damage did not appear to have secondary water barriers.
2. **Effects of wind-driven rain through building cladding elements:** Water penetration was observed in a number of engineered and non-engineered buildings, including a public library. Particular focus should be given to buildings of Category III or IV importance levels.
3. **Performance of steel structures:** Multiple collapsed steel buildings were observed, including in some areas where surrounding buildings sustained only minor damage.
4. **Performance of schools:** School campuses were observed to have a number of structural and envelope failures to buildings. Such failures directly affect large segments of the community for many months, with indirect effects (e.g., opportunity loss, resetting of social structure) potentially impacting future life paths of many students and teachers.
5. **Probabilistic performance of residential structures:** More careful examination should be conducted on the probabilistic performance of the residential inventory, delineated by year of construction and building code in effect at time of construction, including documenting the effects of the panhandle exemption.
6. **Inland Assessments:** Comprehensive assessments should extend to more inland areas of the Florida panhandle but also into Georgia. FAT-1 only briefly documented structural performance in Marianna and Blountstown. The majority of the inland areas have not been assessed in detail but sustained significant damage.
7. **Performance of historical buildings:** The wind performance of historic structures, particularly unreinforced masonry buildings, should be examined. The destruction of entire historical business districts can alter the identity of communities and towns such as Marianna.
8. **Performance of marine structures:** Consideration should be given to inspections and evaluation of dry docks, marina storage facilities, and covered sheds. Failures have regularly occurred in past hurricanes, raising concerns over their design philosophy and service life given the aggressive (corrosive) environments they are situated within. While most are private property and not occupied by humans, they can result is substantial losses and instigate debris that can affect surrounding construction.

9. **Power infrastructure:** A structural and network assessment of the electrical distribution system should be conducted to identify potential design improvements that could enhance network resilience during future hurricanes.

Suggested targets for more comprehensive investigation of storm surge impacts:

1. **Performance within Regulatory Environment:** Performance of structures relative to the Florida Coastal Construction Control Line should be documented, including estimated surge heights relative to the as-constructed and the mandated first floor elevation.
2. **Effective Coastal Construction Practices:** An overall evaluation of construction practices that fared well in the storm's significant storm surge should be documented, including establishing freeboard requirements, evaluation of a wide range of foundation types and depths, effectiveness of breakaway construction, and the effects of sheltering on surge-induced forces on structures.

Other non-structural topics that StEER recommends for further investigation include:

1. Evaluation of evacuation decisions with regards to two key factors:
    a. The prevalent public opinion that the Florida panhandle is largely exempt from any major hurricane landfalls.
    b. The rapid intensification of Hurricane Michael (similar to Hurricane Harvey) and the reduction in time available for the public to make decisions whether to evacuate once the storm became a major hurricane. All residents who spoke to FAT-1 Team members indicated they would not choose to stay in event of another hurricane. However, Panama City and the surrounding areas are located relatively far away from preferred evacuation areas (i.e., it is 100 miles from Tallahassee, FL). Thus once Michael intensified so rapidly, the residents did not have sufficient time to make it safely to their preferred evacuation locations and feared being in transit during landfall.
2. The impacts of climate change on Hurricane Michael, and whether rapid intensification events in the Gulf of Mexico (such as Hurricane Harvey in 2017), should be regarded as the new normal, which could have important implications for emergency management preparations, evacuation protocols, and risk communications to the public.

# Acknowledgements

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StEER further thanks the Virtual Assessment Team members (many who worked anonymously) to gather information on access and conditions on the ground for FAT-1, as well as a number of students who assisted with FAT-1's preparations and the gathering of additional data to support the authorship of this EARR:

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

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The sharing of videos, damage reports and briefings via Slack by the entire NHERI community was tremendously helpful and much appreciated. These collaborations and 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. We particularly appreciate the assistance of Tim Cockerill for helping team members get activated on Slack swiftly.

StEER also acknowledges the Florida State Emergency Response Team for providing assistance in accessing affected regions.

# About StEER

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. StEER's mission is to deepen the structural natural hazards engineering (NHE) community's capacity for reliable post-event reconnaissance by: (1) promoting community-driven standards, best practices, and training for RAPID field work; (2) coordinating official event responses in collaboration with other stakeholders and reconnaissance groups; and (3) representing structural engineering within the wider extreme events reconnaissance (EER) consortium in geotechnical engineering (GEER) and social sciences (SSEER) to foster greater potentials for truly interdisciplinary reconnaissance. StEER also works closely with the NSF-supported Natural Hazards Engineering Research Infrastructure (NHERI) RAPID facility and cyberinfrastructure Reconnaissance Portal to more effectively leverage these resources to benefit StEER missions.

StEER relies upon the engagement of the broad NHE community, including creating institutional linkages with dedicated liaisons to existing post-event communities and partnerships with other key stakeholders. While the 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 with overseeing the design and operationalization of the network.
- **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 Assessment Technologies, guiding StEER's development of a robust approach to damage assessment across the hazards.
- **David Roueche (co-PI),** Auburn University, serves as StEER Associate Director for Data Standards, ensuring StEER processes deliver reliable and standardized reconnaissance data.

StEER's response to Hurricane Michael preceded the formation of its official policies, protocols and membership, which are still in active development. All policies, procedures and protocols described in this report should be considered preliminary and will be refined with community input as part of StEER's operationalization in 2018-2019.

# StEER Event Report Library

## 2018

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