Deployment of Solar-powered Water Purification System in Puerto Rico

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LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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MIT Lincoln Laboratory

DoD Federally Funded Research and Development Center

Massachusetts Institute of Technology

MIT Lincoln Laboratory, Lexington, Massachusetts

Mission: Technology in Support of National Security

Key Roles: System architecture engineering
Long-term technology development
System prototyping and demonstration

Mission Areas:

- Air and Missile Defense
- Homeland Protection
- Air Traffic Control
- Communication Systems
- Cyber Security
- Advanced Technology
- Space Control
- ISR Systems and Technology
- Tactical Systems
- Engineering

Humanitarian Assistance and Disaster Response Work at Lincoln Laboratory

Increase national security through sustained and measurable impacts in domestic and foreign humanitarian assistance and disaster relief

Core Mission Areas

Disaster Relief

2017 Hurricane Harvey

Coordinated response efforts across the enterprise

Complex Humanitarian Emergencies

Atmeh Refugee Camp, Syria

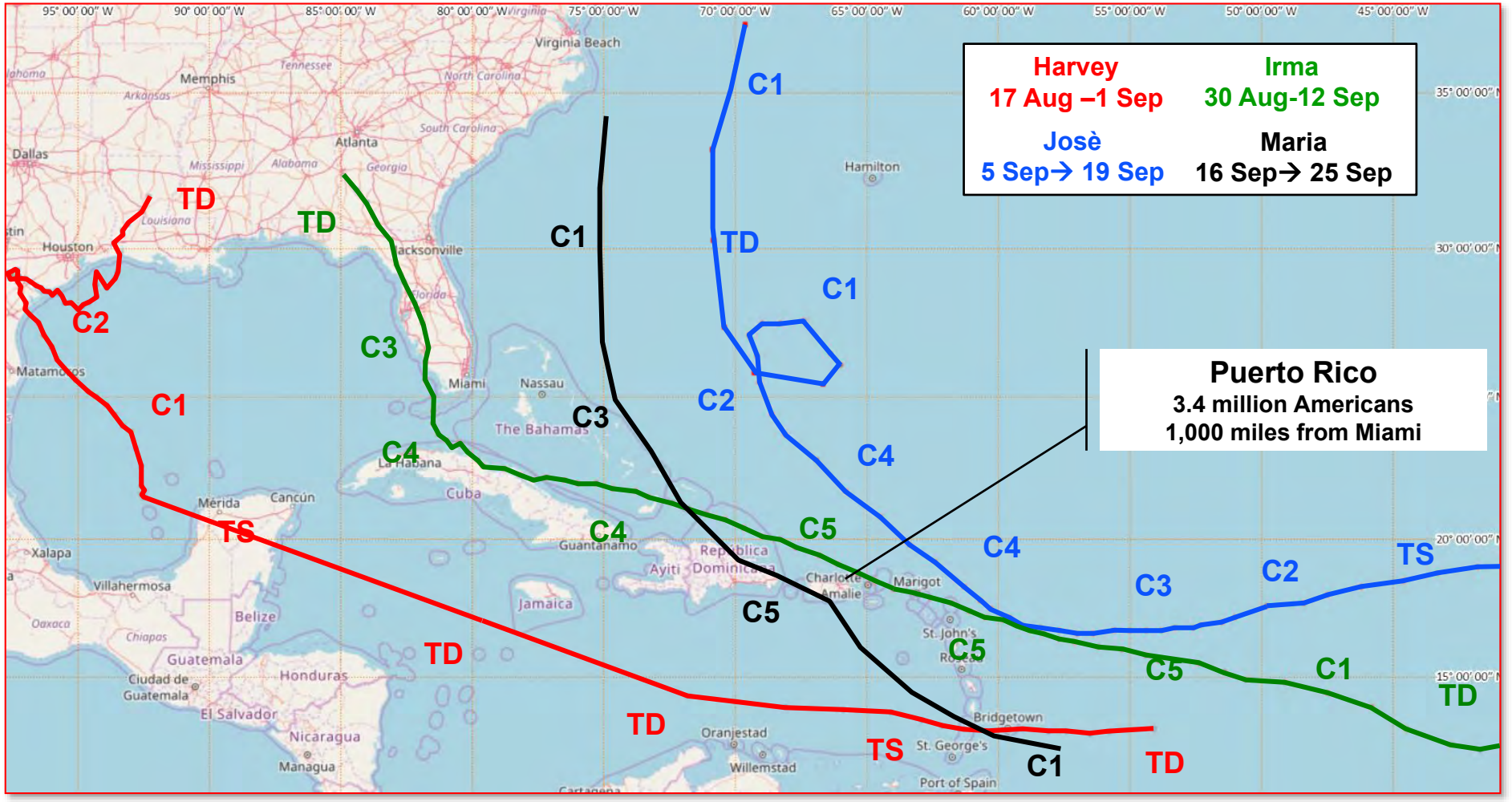
Security & problem solving in challenging environments

Technology Thrusts

- **Advanced sensing**
- **Situational awareness tools**
- **Decision support systems**
- **Resilient communications**
- **Modeling and simulation**

HADR = Humanitarian Assistance and Disaster Relief

2017 Hurricane Paths

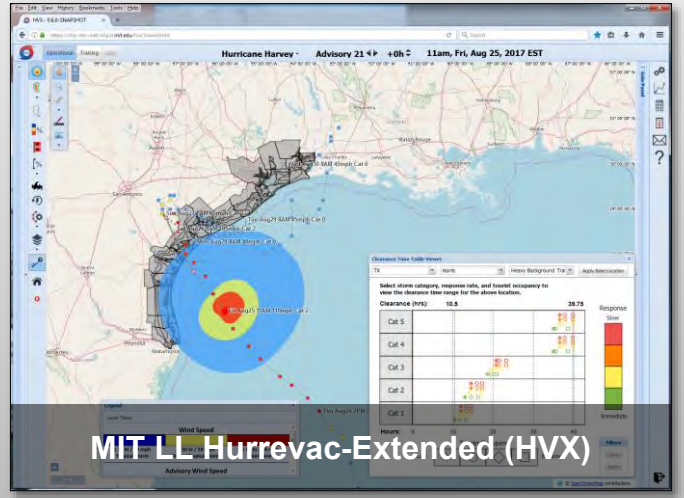


TD: Tropical Depression
TS: Tropical Storm
C1: Category 1 Hurricane
C5: Category 5 Hurricane (strongest)

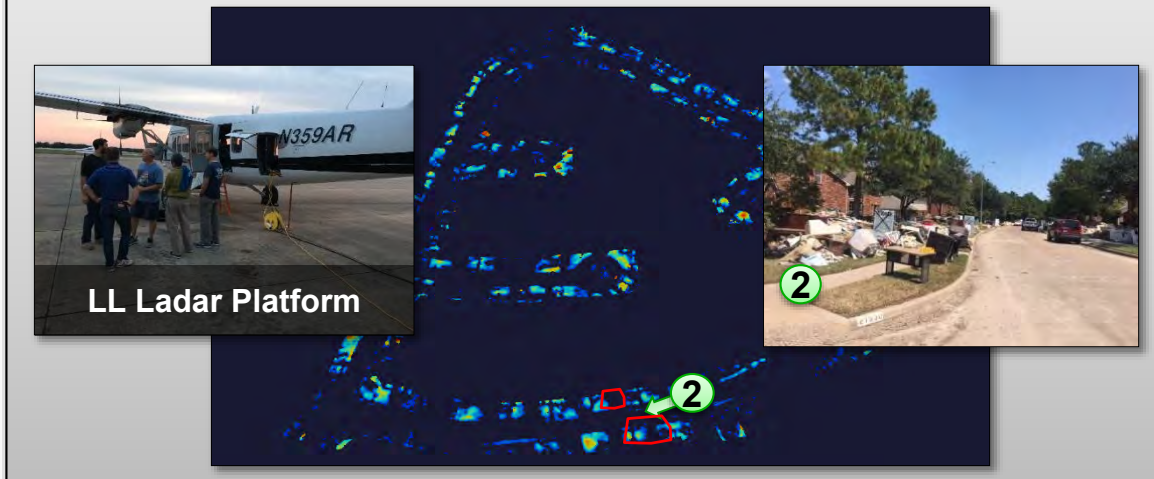
One of the most severe hurricane seasons on record

Lincoln Laboratory's U.S. Support for 2017 Hurricane Response

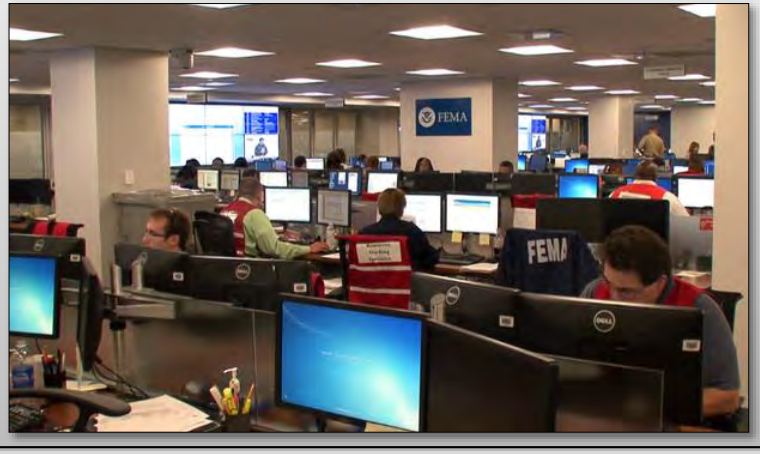
Hurricane Situational Awareness Tools



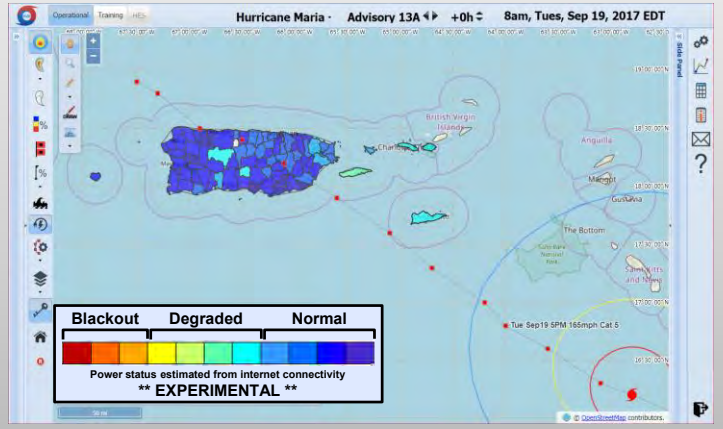
Ladar-based Debris Quantification



FEMA NRCC Technical Support



Real-time Power Outage Detection (Prototype)

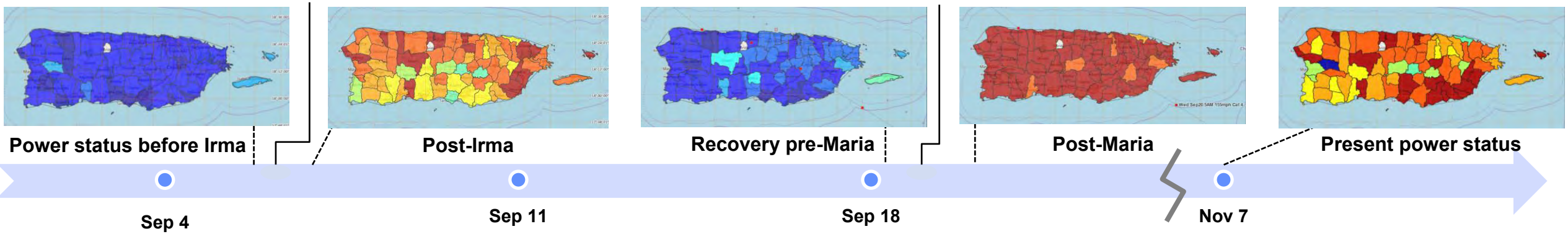


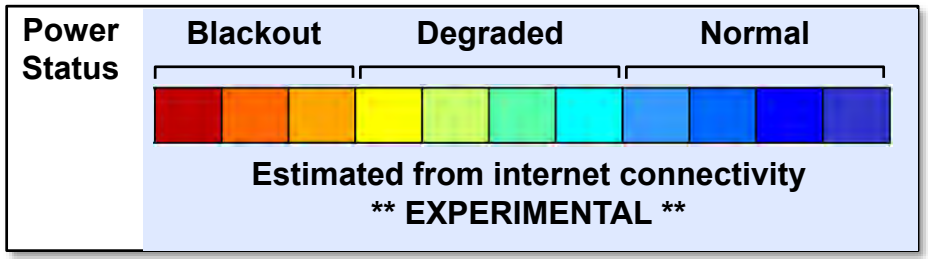
NRCC = National Response Coordination Center

Timeline: Devastation of Puerto Rico's Power Grid

Sep. 6: Hurricane Irma strikes Puerto Rico

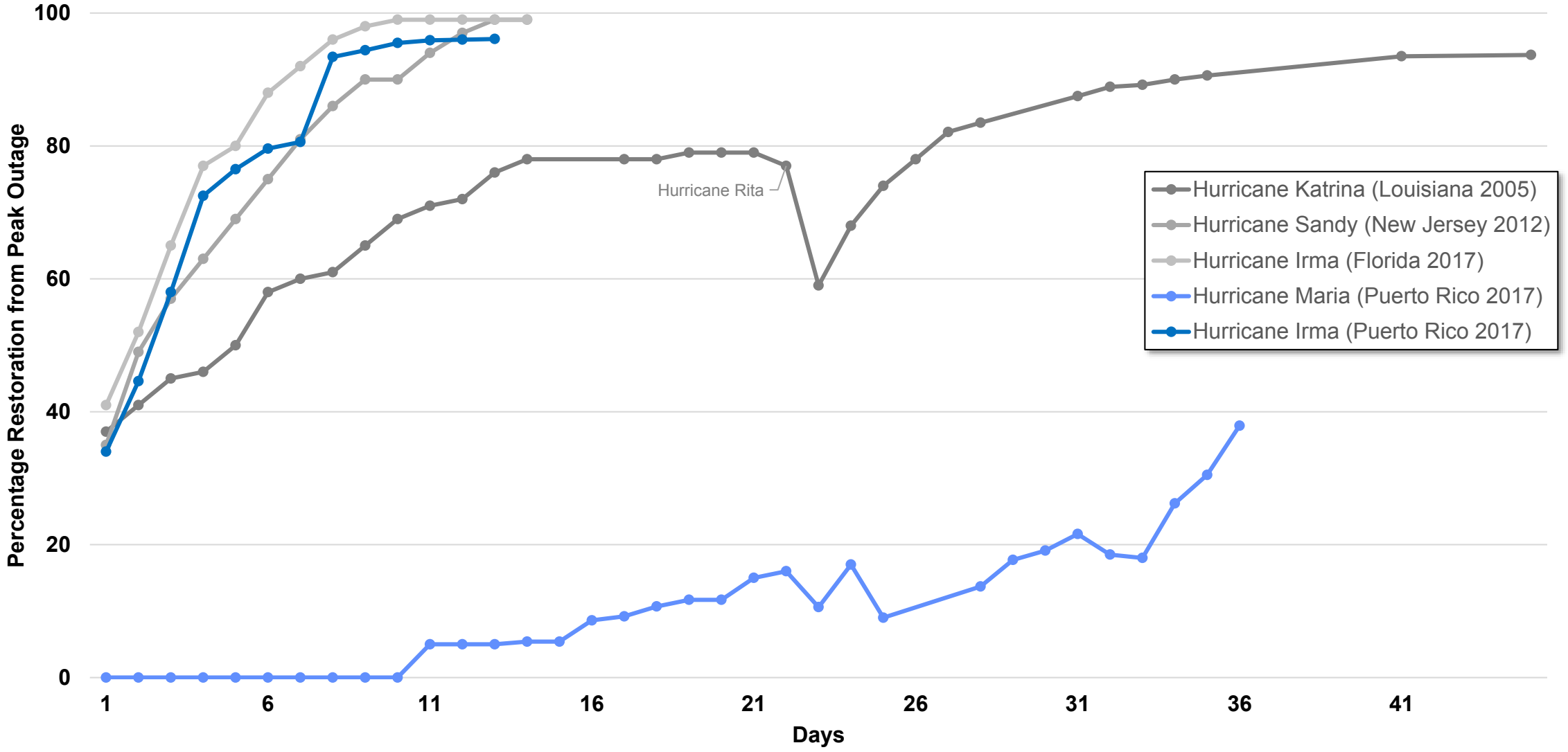
Sep. 20: Hurricane Maria strikes Puerto Rico





3.4 million Americans without power.
~25% restored as of November 7.

Challenging Power Restoration in Puerto Rico



Department of Energy, Infrastructure Security and Energy Restoration (ISER)
https://energy.gov/oe/downloads/hurricanes-nate-maria-irma-and-harvey-situation-reports

Greatest Need Resulting from Power Loss Is Water Purification

- Water treatment plants lack power
- Multiple sources of water pollution after the storm
  - Backed-up sewage systems; standing sewage water
  - Dead animals
  - Gasoline and chemicals in flood water
  - Tree and building debris
- People drinking from untreated water sources
  - Lakes, mountain streams
- Water-borne disease outbreak
  - Leptospirosis in Loíza and Carolinas (75 cases, 10 deaths)
  - Unrecorded deaths in Corozal

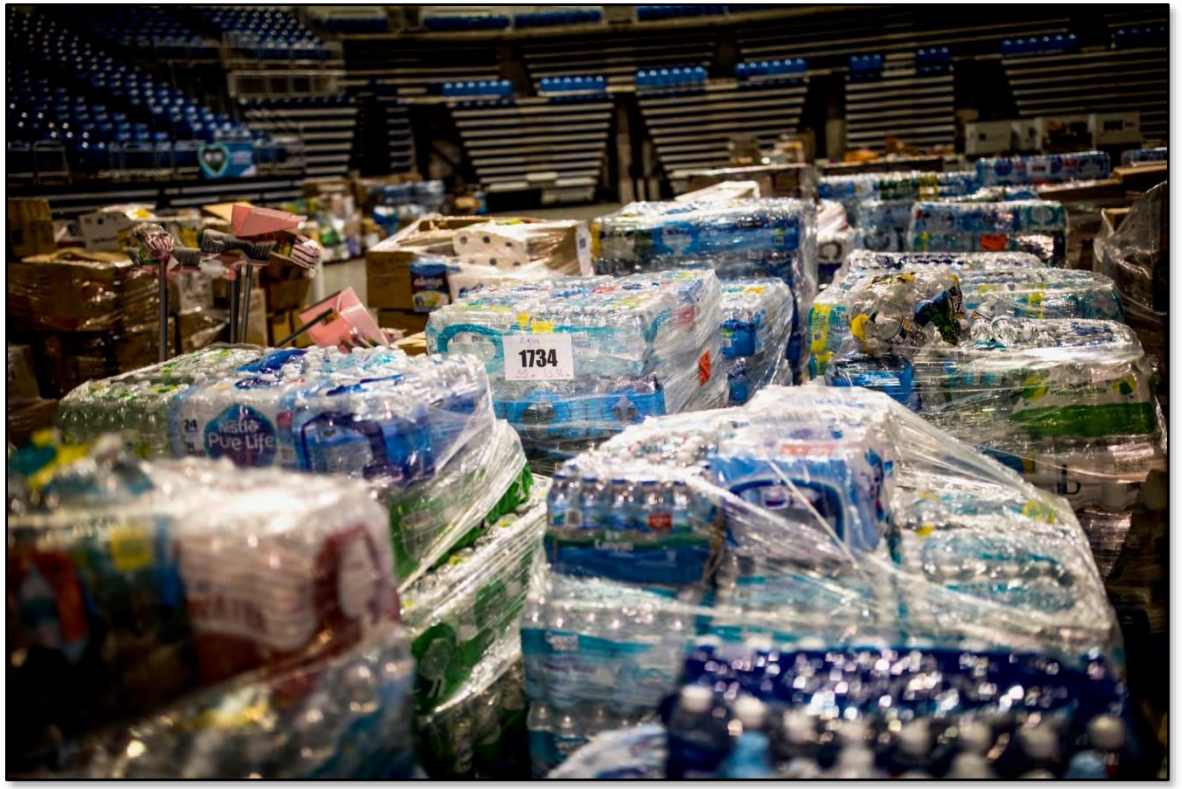
Loíza after Hurricane María

Water Distribution is Logistically Challenging

Stats for 10,000 people per day

- World Health Organization (WHO) minimum sustainment drinking and cooking standard: 5 liters (1.3 gal.) / person / day
- Significant bottled water cost and trash
  - 80,000 bottles / 56 pallets per day
  - $19,000 per day for bottles
  - Seven C-130 resupply flights per day

1st Armored Division Combat Aviation Brigade resupplying isolated village in Puerto Rico



Supplies at the Joint Field Office

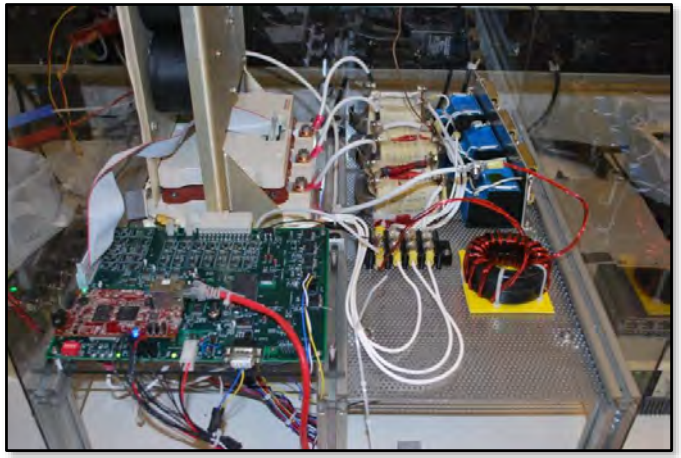
Prior IHS-Roddenberry Water Treatment System Design

- **Purifies 500 – 1,000 gallons per day**
- **Deployed in Haiti, Nepal, Phillipines**
- **Required fuel resupply**
- **Multiple stages with redundancy**
  - **Commercial air-transportable**
  - **Puralytics Shield technology customized for mass-production**

Deployment videos: https://www.youtube.com/user/eldeion/videos

Energy Systems Group Relevant Experience: DoD Tactical Power

Example Hybrid System Deployment



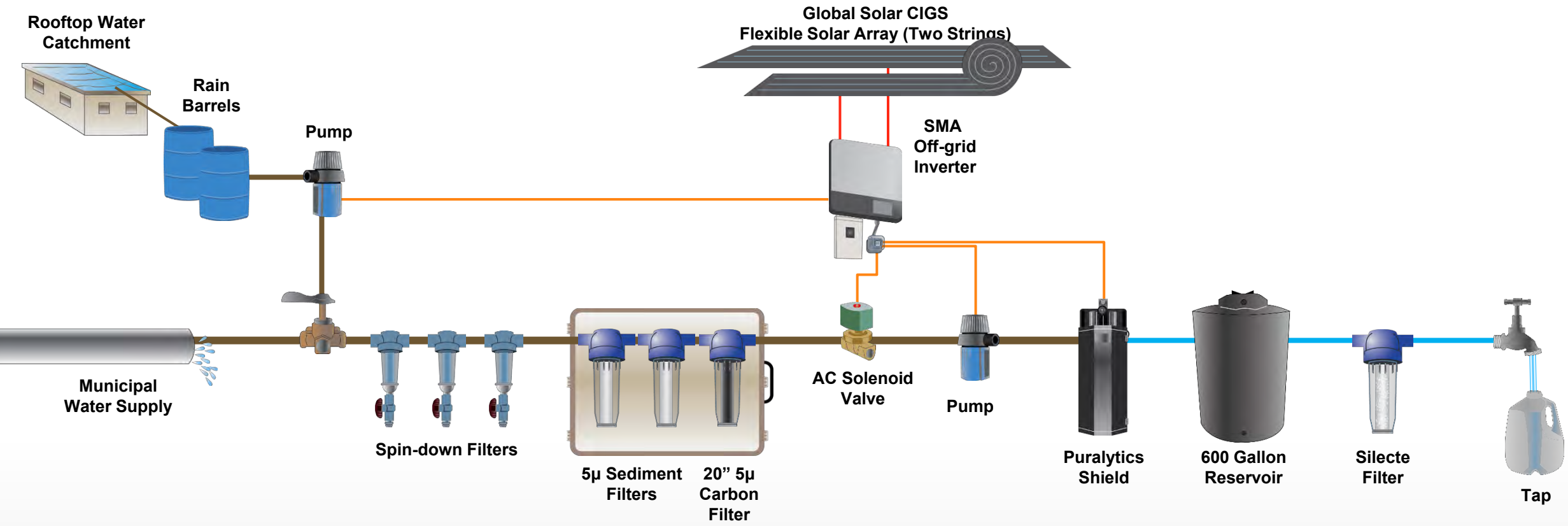
Hybrid System Prototype

- Developed technology for future small hybrid systems in austere locations
  - Power reliability is paramount, every load is critical
  - Equipment operates in harsh environments (arctic, jungle, desert, etc.)
  - Equipment operates in combat scenarios and alongside heavy machinery
    - Damage and loss of cabling is likely
- Operated by troops with modest training

Energy Systems Group Relevant Experience: Modular Aid and Power Pallet (MAPP) Prototype

- Can be assembled with no training
- Supplies AC or DC power

Water Aid & Renewable Power (WARP) System Design



- Eliminates need for tri-fuel generator
- Requires no grid power
- Operates on cloudy, rainy days
- Uses portable, rugged solar modules
- Avoids use of large, expensive batteries
- Simple installation

CIGS: Copper Indium Gallium diSelenide thin-film solar modules

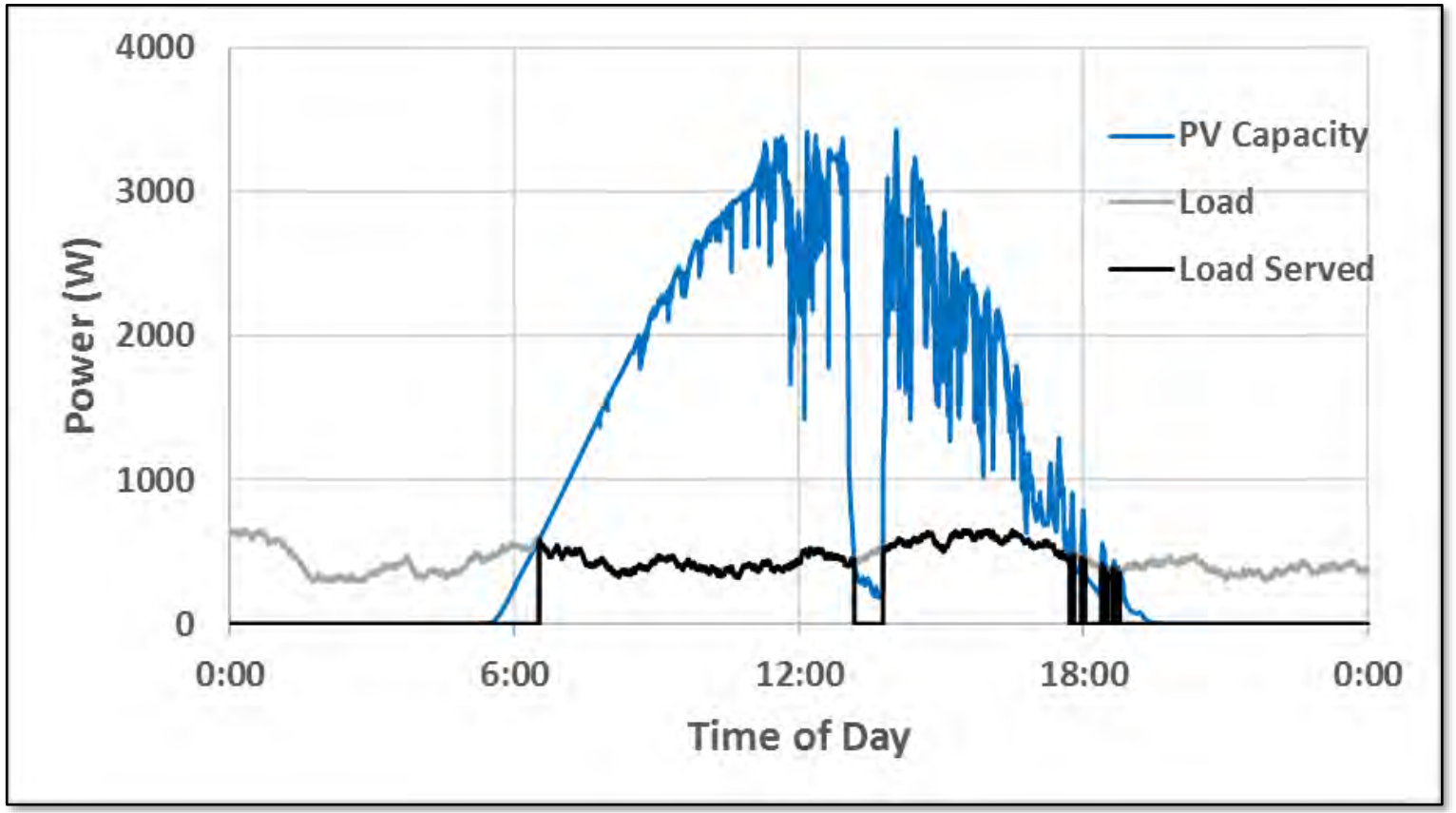
Concept illustration, not to scale

Off-grid, Battery-less Solar Operation

- **Power inverter must track the load's power demand, not the sun's energy supply**
- **Shuts off when solar capacity is insufficient**
  - **Avg. 9 hours of operation daily**

Flexible Solar Modules

Power Inverter with Secure Power Supply



Solar is abundant, so over-size for reliable operation and avoid need for batteries

Timeline for Preparation and Deployment

MIT-LL joins FEMA NRCC

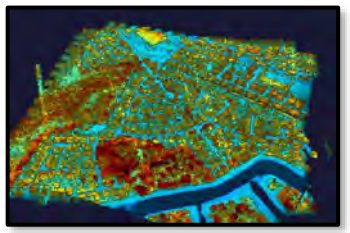
Hurricane Irma strikes Puerto Rico

Site identification at Joint Field Office

Site assessment #2: Culebra Island

Solar sys. installation

System operational



MIT-LL airborne imagery & power sensing for Texas

Hurricane Maria strikes Puerto Rico

Planning, design, & test

Site assess. #1: Utuado

Site assessment #3: Loíza

Water sys. installation

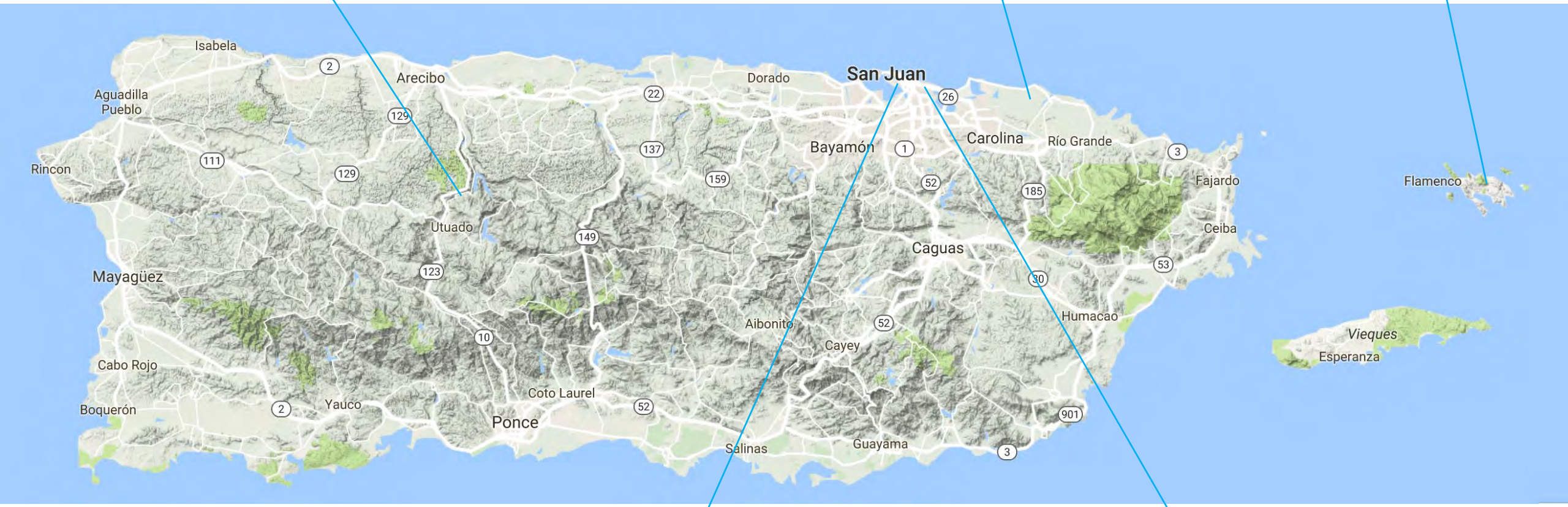
Aug 28 | Sep 4 | Sep 11 | Sep 18 | Sep 25 | Oct 2 | Oct 9 | Oct 16 | Oct 23 | Oct 30

Puerto Rico

Site assessment #1: Rio Abajo, Utuado

Site assessment #3: Loíza

Site assessment #2: Culebra Island



Joint Field Office (Convention Center)

Deployment team's house

Site Assessments

#1: Sector 315, Rio Abajo, Utuado

- 100 residents remaining
- Resupplied by shopping cart roped across river
- Press, fire dept., and FEMA presence

#2: Culebra Island

- 1,800 residents
- Strong municipal leadership
- Distributed cistern water supply
- FEMA resupply every three days
- Stockpiled, guarded supplies
- Organized rationing

#3: Loíza

- Boys & Girls Club serves 600 people
- Leptospirosis outbreak
- Water supply didn't meet EPA standards before hurricanes
- Standing sewer water

Site Assessment Results

Selection Criterion	Site #1: Sector 315, Rio Abajo, Utuado	Site #2: Culebra Island	Site #3: Loíza, Boys & Girls Club
1. Fresh water access	Intermittent mountain streams	Piped from Viejas Island	Intermittent city water
2. Centralized community distribution		Distributed cisterns, polluted pipes	
3. Community size: 500-1,000	100	1,800	600
4. Unshaded space for solar	Mountainous, wooded, landslides		
5. Structure for electronics			
6. Community engagement	Locals preoccupied with survival & home repair		
Support strategy	Continue small-scale local resupply	Army / FEMA to provide homes with water filtration straws	Install IHS-Roddenberry / MIT-LL water treatment system + water catchment

Good match for WARP* system

Potential issues for WARP system

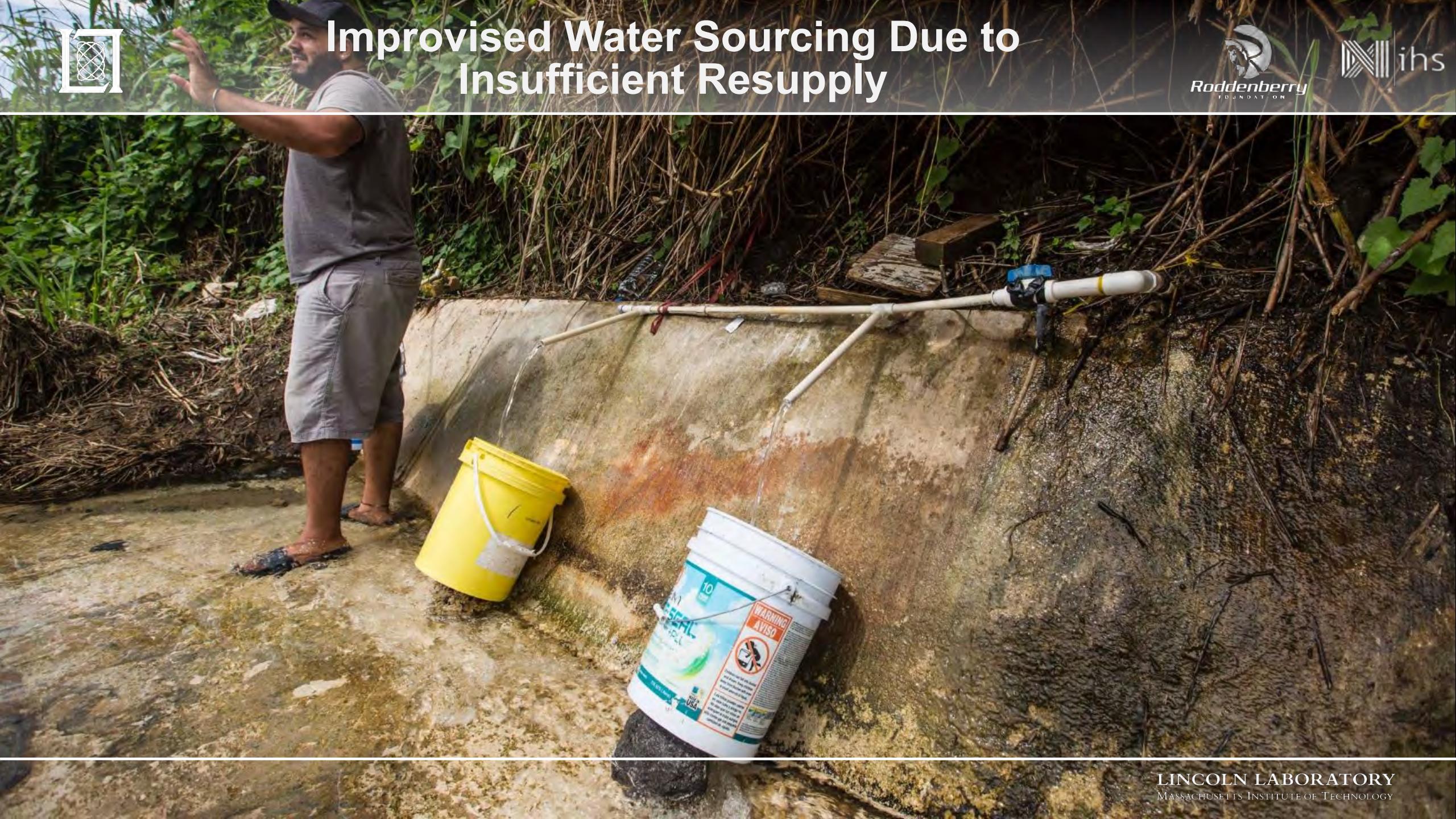
Poor match for WARP system

*WARP: Water Aid and Renewable Power system

Outline

- System overview
- Site assessment
- Observations
- Team
- Installation & lessons learned
- Results & next steps

Improvised Water Sourcing Due to Insufficient Resupply



Sewage Water Inundated Portion of Loíza

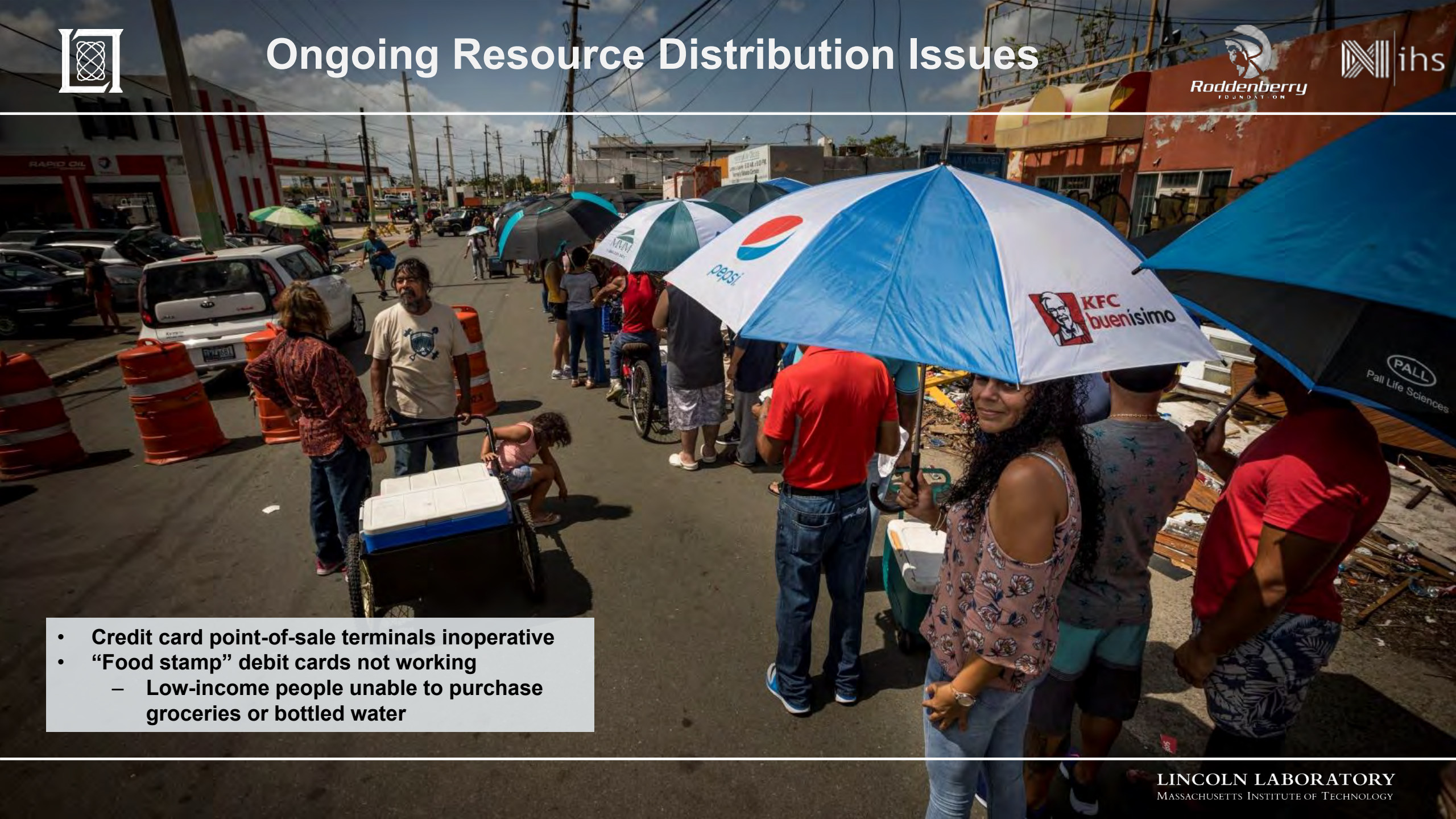
Including Two Club Buildings

Desperate Conditions at Culebra Hospital

- 1 doctor; 7 nurses on 36-hour shifts
- Medical supplies destroyed
  - Resupplied only after 38 days
- Black mold growing in emergency room
- Backup water cistern inoperative
  - Cockroaches; no additional purification

Widespread Residential Damage in Loíza

Ongoing Resource Distribution Issues



- Credit card point-of-sale terminals inoperative
- "Food stamp" debit cards not working
  - Low-income people unable to purchase groceries or bottled water

Extensive Power System Damage

Loíza

Extensive Power System Damage

Río Grande

Little Power Restoration Activity Observed

October 14 – 22, 2017

- Two local power utility repair crews seen during deployment
- Hundreds of distribution poles damaged or destroyed

Local utility crews seen during trip

Widespread Destruction of Forests

- Roads cleared prior to our arrival
- Trees stacked for blocks along highway and streets

No Power for 40+ Days, but Puerto Ricans' Attitudes Were Positive

Observations

October 14 – 22, 2017

- Water resupply still an issue
  - Contaminated municipal water, FEMA bottled water, or untreated water from mountain stream
  - FEMA still identifying communities that haven't received potable water supply
- Standing sewage and flood waters
- Medical facilities: desperate conditions at Culebra Island hospital
- Low-income homes destroyed: roofs and top floors missing
- Long lines for water and ice
  - Three hour wait for two bags of ice
  - Lack of powered points of sale for credit cards and "food stamp" debit cards
    - A serious hindrance for access to food and safe water for the poor
- Total devastation of the power system
  - Virtually no power restoration work observed
- Road travel is not an issue: roads cleared, gas available
- Security not an issue: good police presence, gates & barred windows on most homes
- The Puerto Ricans we met were resolute

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Deployment Partners

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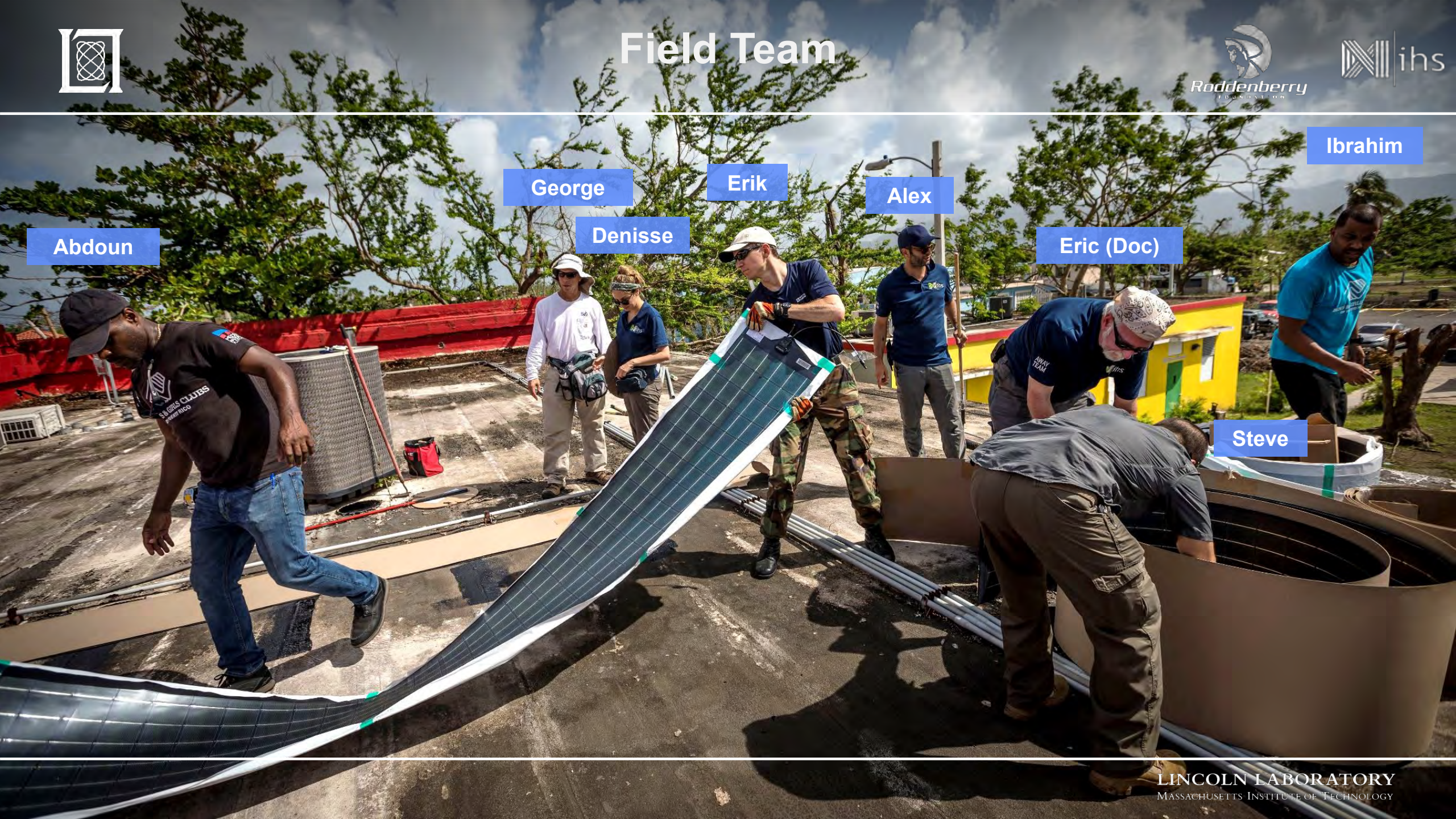
ihs infinitum humanitarian systems

GEO Innovation
Engineering a Sustainable Future

Roddenberry FOUNDATION

Field Team



Field Team

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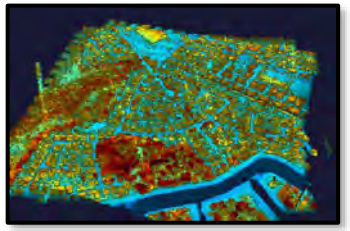

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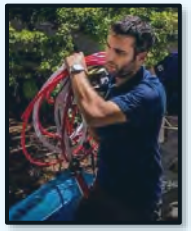

Water sys. installation

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Installed Rugged Solar Photovoltaic Array

Copper Indium Gallium diSelenide (CIGS) thin-film, flexible solar

Power System Installation

Local staff participated in every assembly step

Trained facilities engineer on data collection system

George trained staff on system installation and maintenance

Installing the off-grid solar inverter

Assembly of Water Treatment, Plumbing, and Storage By IHS-Roddenberry and Boys & Girls Club Volunteers

Large particle spin-down filters

Taps installed at front of Loíza Club

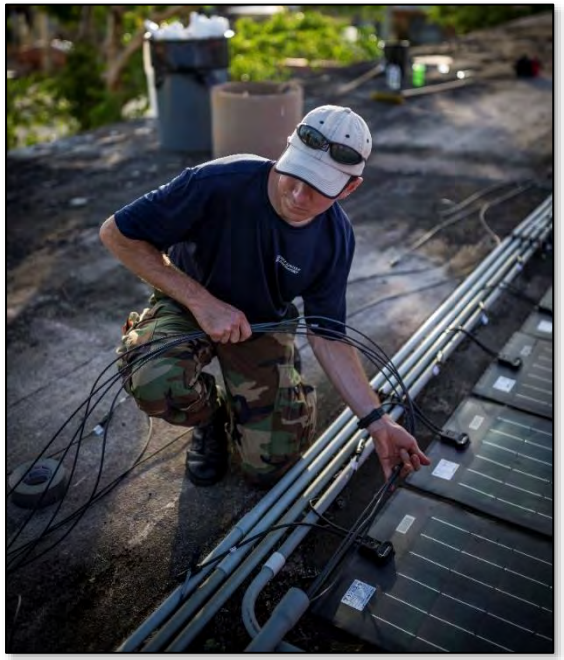
Plumbing work

600 gallon food-grade clean water reservoir

Lessons Learned

Don’t ship equipment into a disaster zone; carry everything with you

Inspect all parts at home,
even commercial off-the-shelf parts



Assemble cables on-site
(multiple connectors failed
and difficult to route)

Do integrated design of power sources and prioritized loads (inverter-Shield integration issues)

Build in redundancy
(UV ligh ballast failed)

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Producing Safe Drinking Water for 600 People Per Day, Indefinitely

Electronics:

- Solar power inverter
- Data collection system
- Pump
- Puralytics Shield

Pre-plumbing taste test

Safe drinking water for Americans

Solar-powered Clean Water

Tap Opening Ceremony

October 25

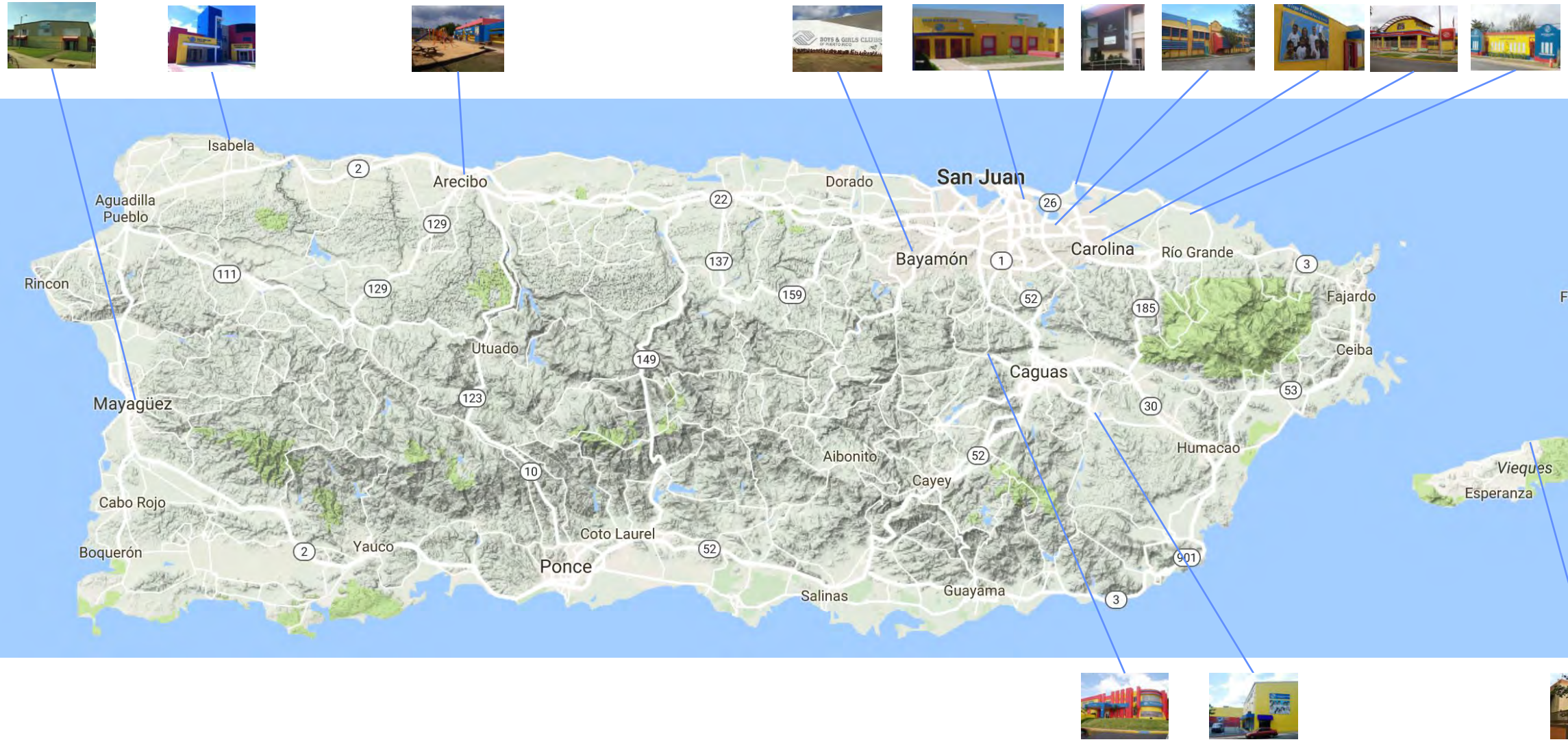
Next Steps

- Boys & Girls Club staff and volunteers to install rainwater catchment system
- Boys & Girls Club staff to install system #2 at Las Margaritas
  - MIT-LL spare parts + private funding committed
- IHS-Roddenberry and MIT-LL to revisit Loíza site in January
  - Provide 1 year of consumables
- IHS-Roddenberry planning to install water purification at all 13 Boys & Girls Clubs

  ihs-i.com/puerto-rico-ongoing-mission
- Lincoln Laboratory developing next-generation Water Aid & Recovery Power (WARP) system
  - Possibly incorporate other capabilities
    - Communal food preparation, charging stations for phones, lanterns, and cooling
  - Joint training exercise in CONUS

System #2 donor: Greg Olsen

Boys and Girls Clubs of Puerto Rico



Potential Power + Water + Food Partnership

MIT-LL / IHS-Rodenberry / World Central Kitchen

MIT Lincoln Laboratory

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