



Risk-informed Governance and Innovative Technology for Disaster Risk Reduction and Resilience

Module 2.1: Extending Our Reach, Expanding Our Capabilities

Contents

1. Unmanned Vehicles
2. Using Unmanned Vehicles to Support DRR and Resilience
3. Robotics
4. Sensing Systems

Learning Outcomes

At the conclusion of this Session, Participants will be able to:

- Recognize pre- and post-disaster scenarios where drone technologies, robotics, or remote and in-situ sensing technologies can provide informational and operational support.
- Understand the current and planned operational capacity of robots, notably as it pertains to search and rescue efforts.
- Request and utilize space imagery in order to plan more resilient recovery efforts.

- **Unmanned Vehicles**
- **Robots**
- **Remote Sensing Systems**

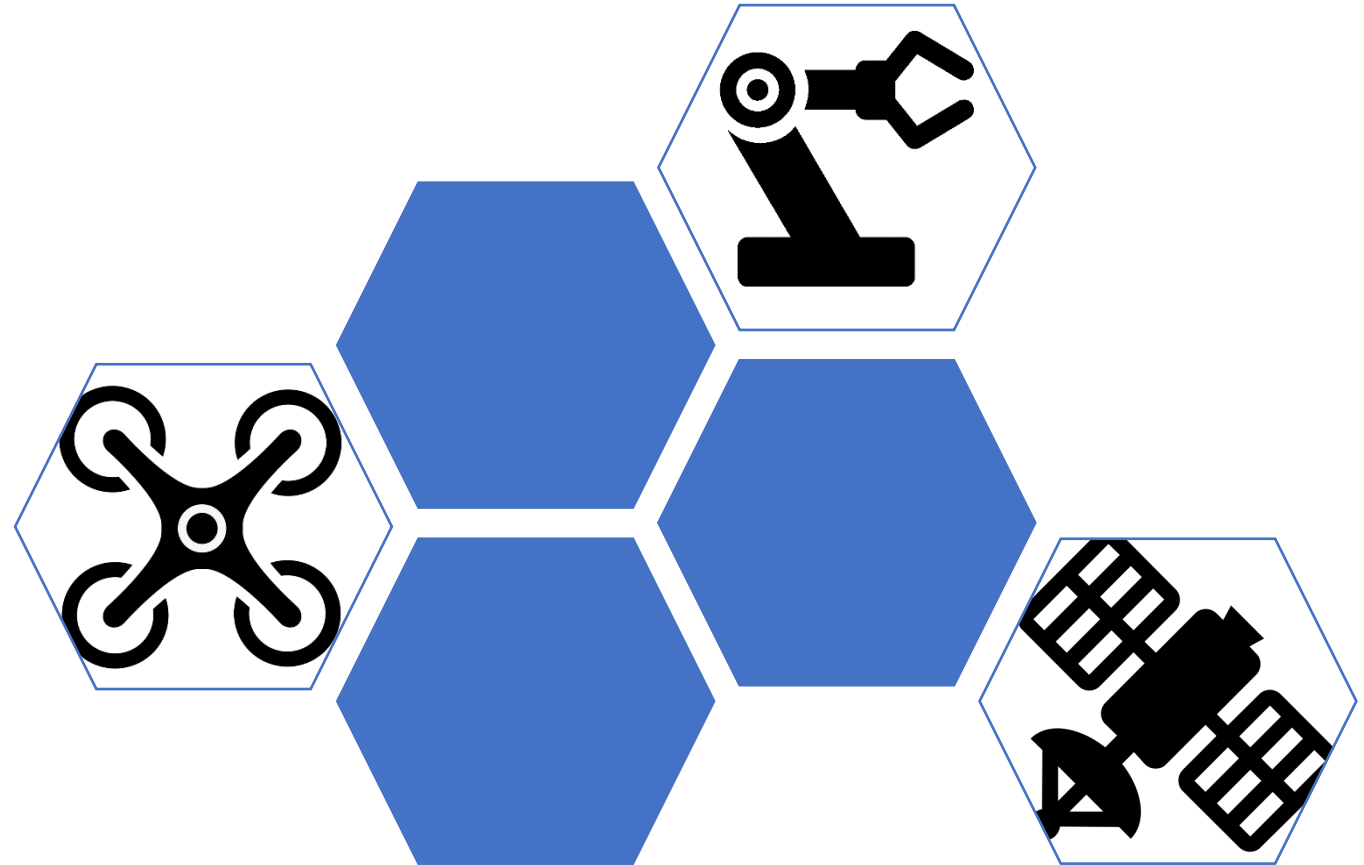


Image: In observance of the International Day for Mine Awareness and Assistance in Bunia in the Democratic Republic of the Congo (DRC), a peacekeeper from Indonesia is demonstrating the operation of a landmine clearance robot to a local population.

Image credit: United Nations Photo, April 4, 2007.

1. Unmanned Vehicles

An unmanned vehicle is one that, whether powered or unpowered, is capable of traveling by one or more modes of transport but has no human operator physically on board.

May be:

- **Remotely piloted**
- **Semi-autonomous**
- **Fully-autonomous**



Image: Drone used to assess crops.
Image credit: Kay Ledbetter, 2017.

1. Unmanned Vehicles

■ Sales & Use Trends Worldwide

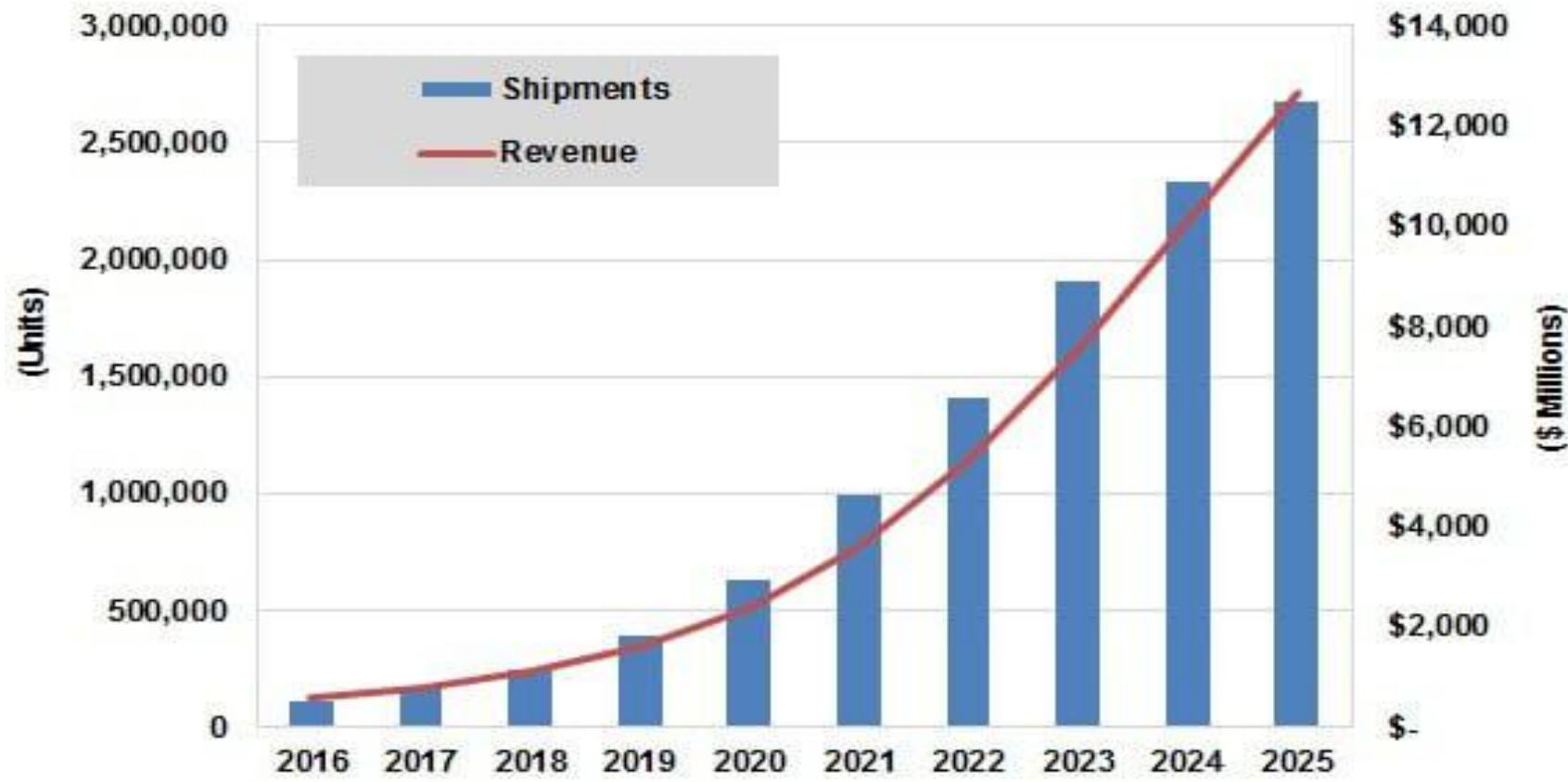


Image: Commercial drone hardware unit shipments and revenue, actual and projected, worldwide 2016-2025. Image credit: Tractica. 2019. Drones for Commercial Applications. <http://bit.ly/2VqubCl>.

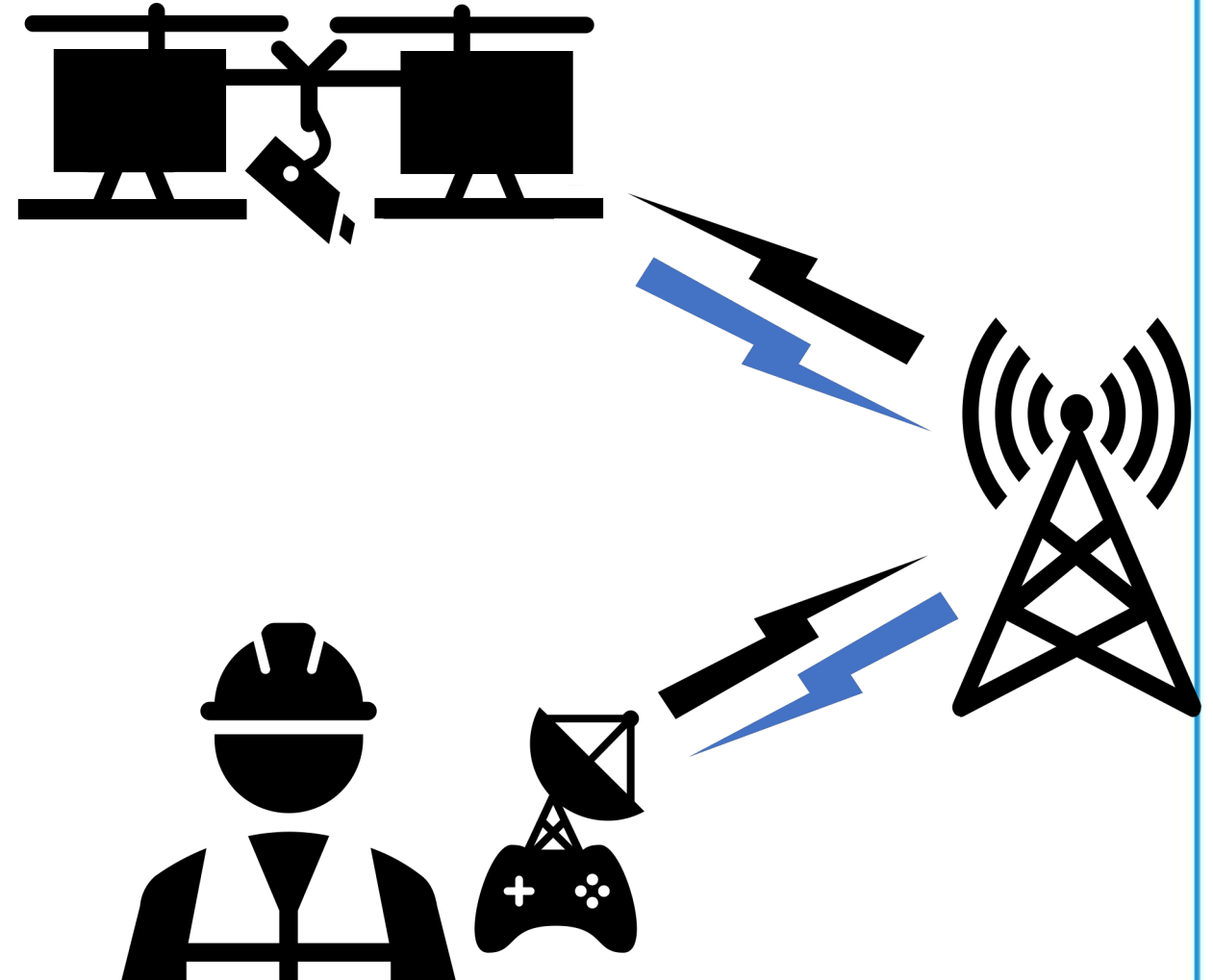
1. Unmanned Vehicles

■ Systems

System Components:

1. The Unmanned Vehicle
2. The Operator
3. The control Center
4. The Control Link
5. The Payload

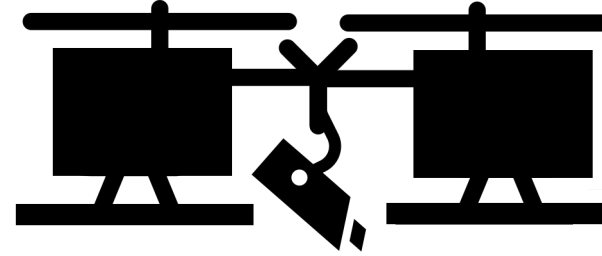
Image: Scientific research facility.
Image credit: Michael Pereckas, 2008.



1. Unmanned Vehicles




Domains

- Air
- Ground
- Water (surface)
- Water (submerged)
- Space



1. Unmanned Vehicles

Activity: Choose the Best UAV

| | Pros | Cons |
|----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Multi-Rotor UAV  | <ul style="list-style-type: none"> • Accessibility • Ease of use • Vertical Takeoff and Landing • Hover flight • Good camera control • Can operate in a confined area | <ul style="list-style-type: none"> • Short flight times • Small payload capacity |
| Fixed-Wing UAV  | <ul style="list-style-type: none"> • Long endurance • Large area coverage • Fast flight speed | <ul style="list-style-type: none"> • Launch and recovery needs a lot of space • No Vertical Takeoff / Landing • No hover flight • Harder to fly, more training needed • Expensive |
| Single-Rotor UAV  | <ul style="list-style-type: none"> • VTOL and hover flight • Long endurance (with gas power) • Heavier payload capability | <ul style="list-style-type: none"> • More dangerous • Harder to fly, more training needed • Expensive |

Search for additional information on different types of Unmanned Aerial Vehicles using the engine provided
 Hybrid VTOL. <http://bit.ly/2MRuowg>.

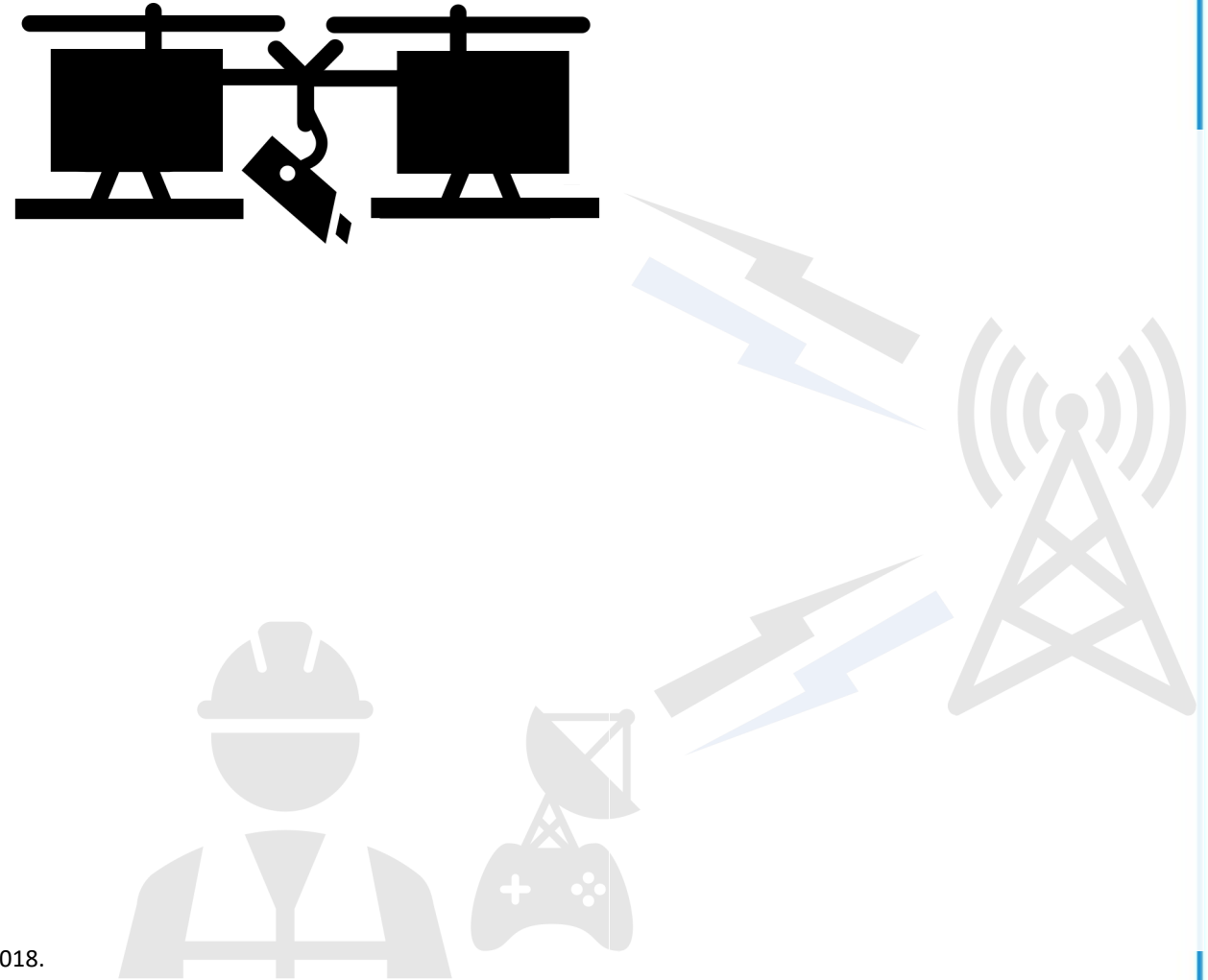
1. Unmanned Vehicles

■ Power Source

- Energy Accumulator
- Photovoltaic Solar Cells
- Internal Combustion Engine
- Wind
- Lighter-Than-Air Gas
- Rocket Fuel (dry)
- Rocket Fuel (liquid)



Image: Lyra autonomous 'Wave Glider' vehicle used to monitor fish stocks. Image Source: Cefas, 2018.
<http://bit.ly/35ROWwa>.



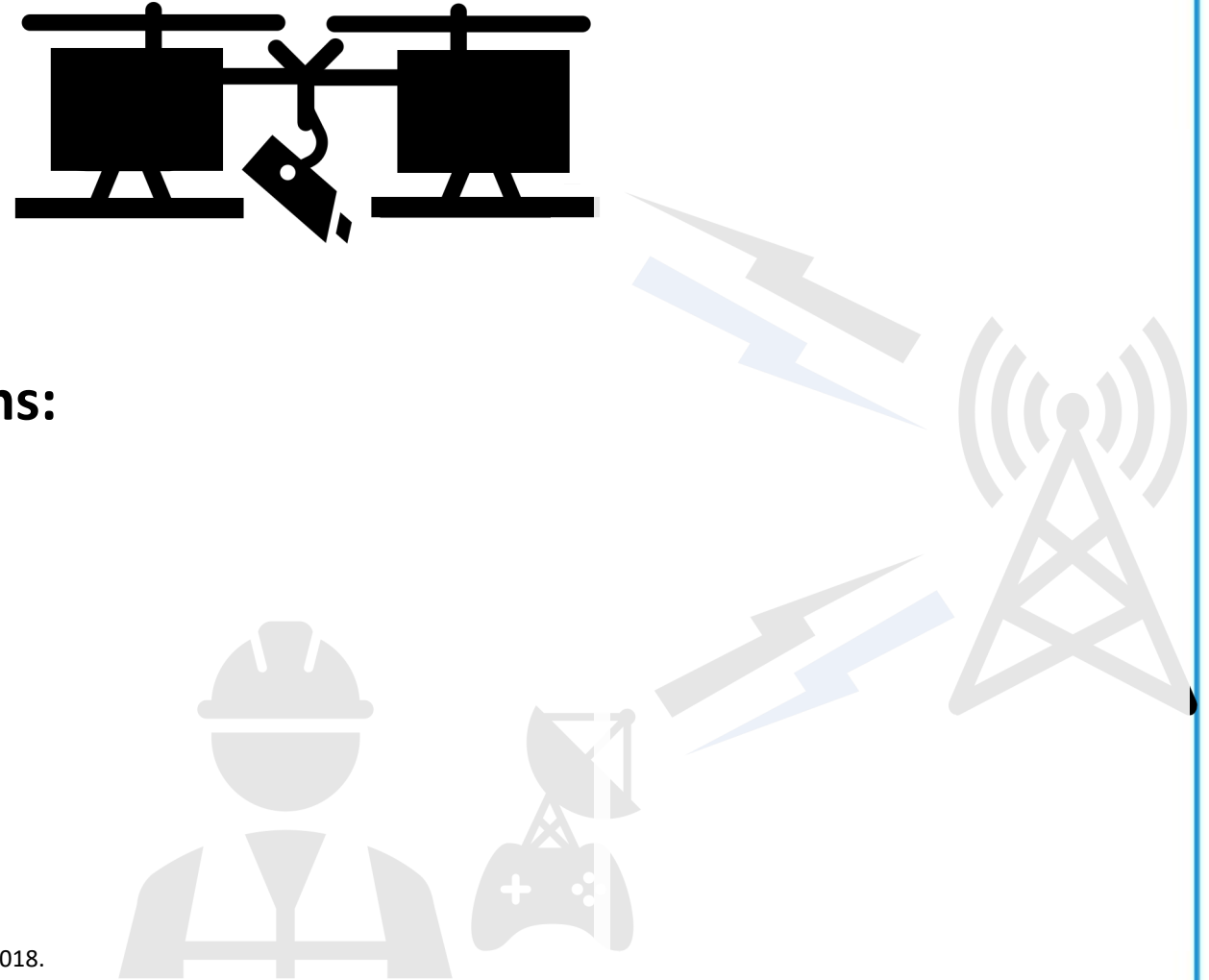
1. Unmanned Vehicles

■ Computing

Onboard computer

- ‘Intelligence’ on autonomous vehicles
- Control vehicle movement
- May use onboard sensors
- Examples of Operational Control Programs:
 - Obstacle Avoidance
 - Fly-away Protection
 - Self-level
 - Altitude hold
 - Follow-me
 - GPS Waypoint Navigation
 - Orbit

Image: Lyra autonomous ‘Wave Glider’ vehicle used to monitor fish stocks. Image Source: Cefas, 2018.
<http://bit.ly/35ROWwa>.



1. Unmanned Vehicles

Sensors

- Vehicle's operational conditions
 - Position
 - Movement
 - Environment
- Vehicle health and status
 - Power source
 - Signal strength
- Called "Degrees of Freedom" (DOF)

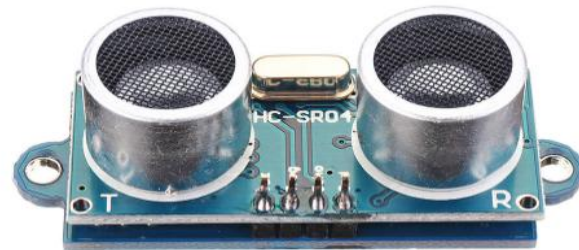
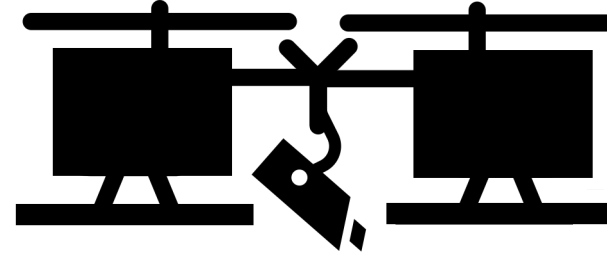


Image: UAV obstacle avoidance sensor.



1. Unmanned Vehicles

■ Communications

- Receives commands
- Transmits data
- Often determines vehicle range
- Components:
 - Transmitter
 - Receiver
 - Antennae
 - Power source

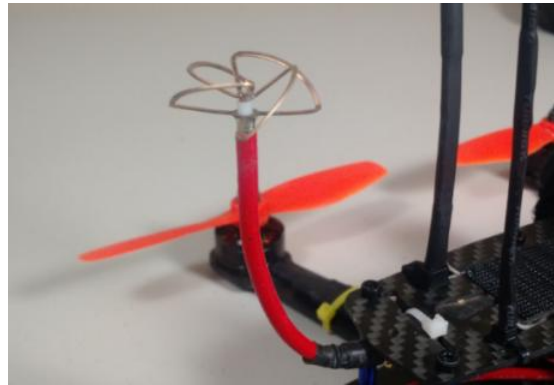
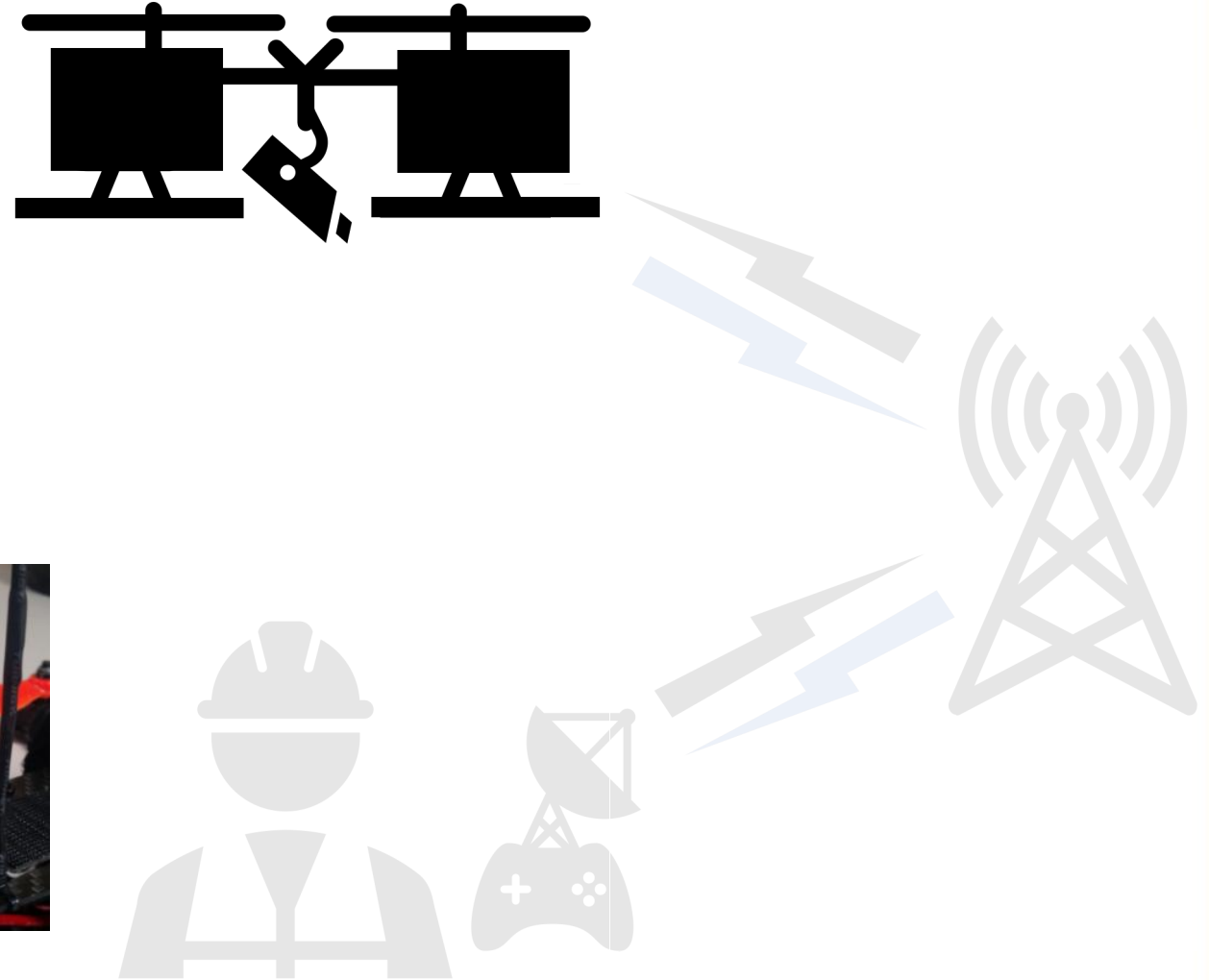


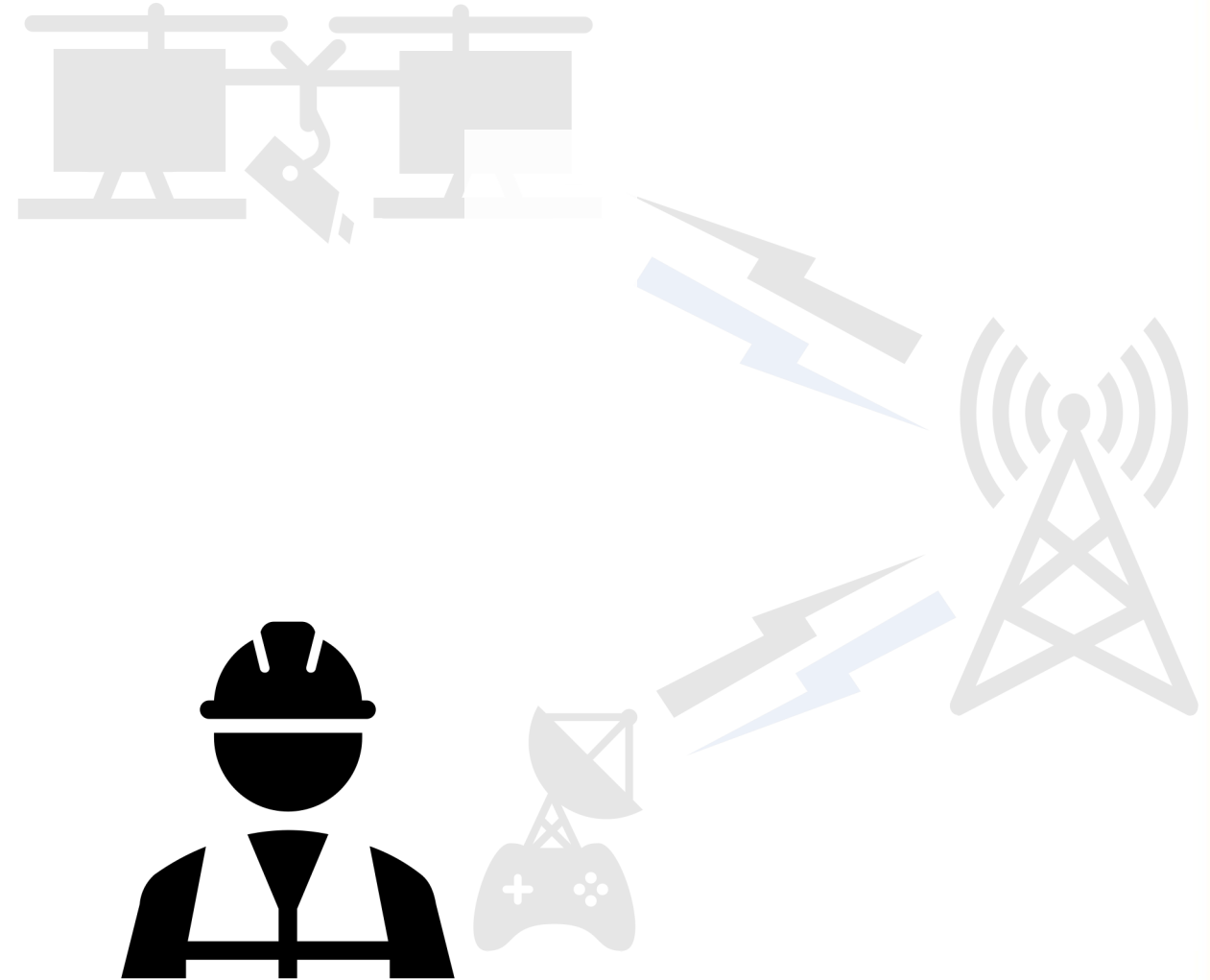
Image: UAV 'Mushroom' antenna. Image Source: Propwashed, 2019. <http://bit.ly/33FE2YI>



2. The Operator

Modes of Operation

- Piloted Operation
- Direct Automation
- Flight Path
- Autonomous Operation



3. The Control Center

- Device or Facility
- Informs operator of conditions
- May use 'point of view' perspective
- May integrate user device
- Control may be:
 - Within Visual Line of Sight
 - Beyond Visual Line of Sight

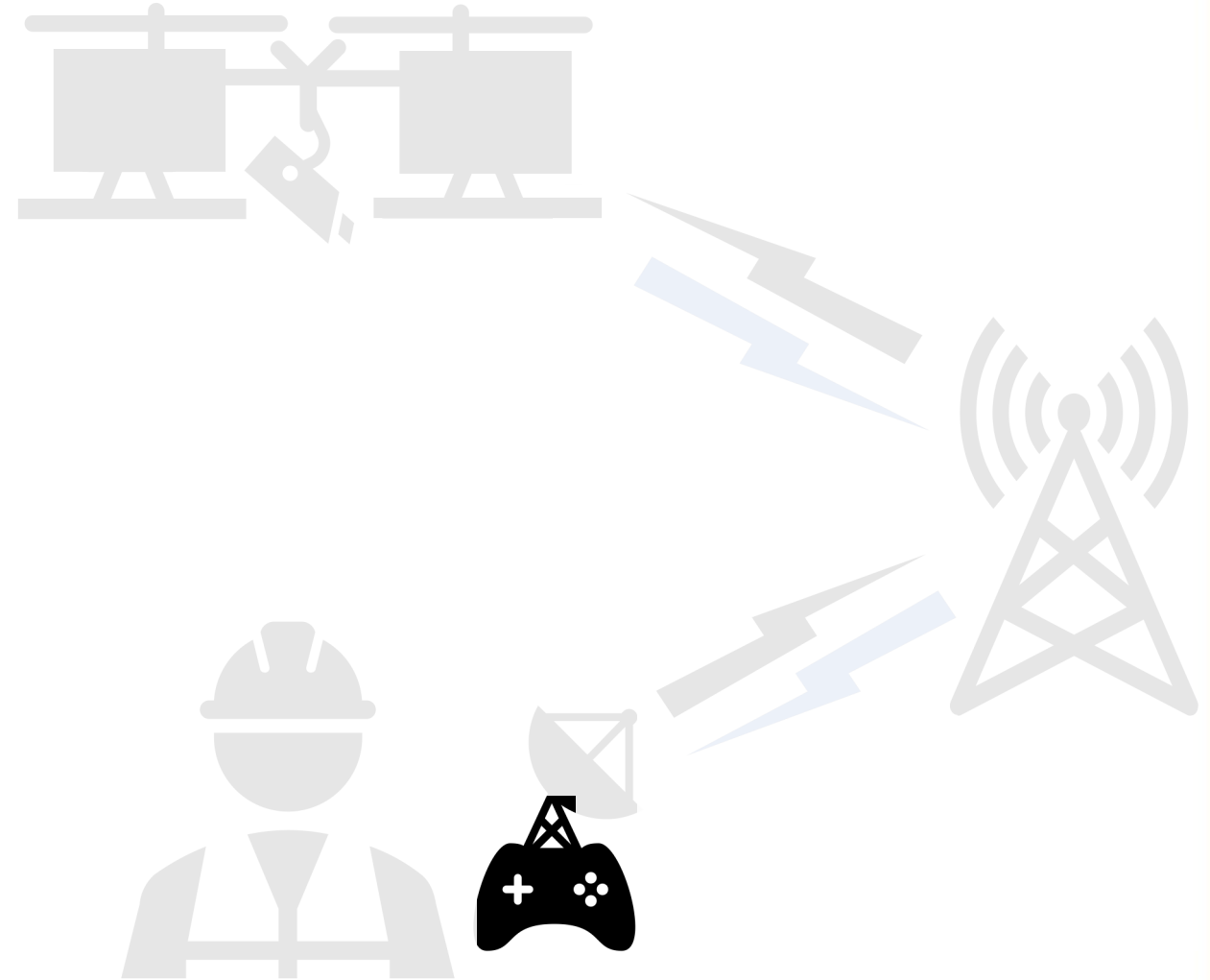
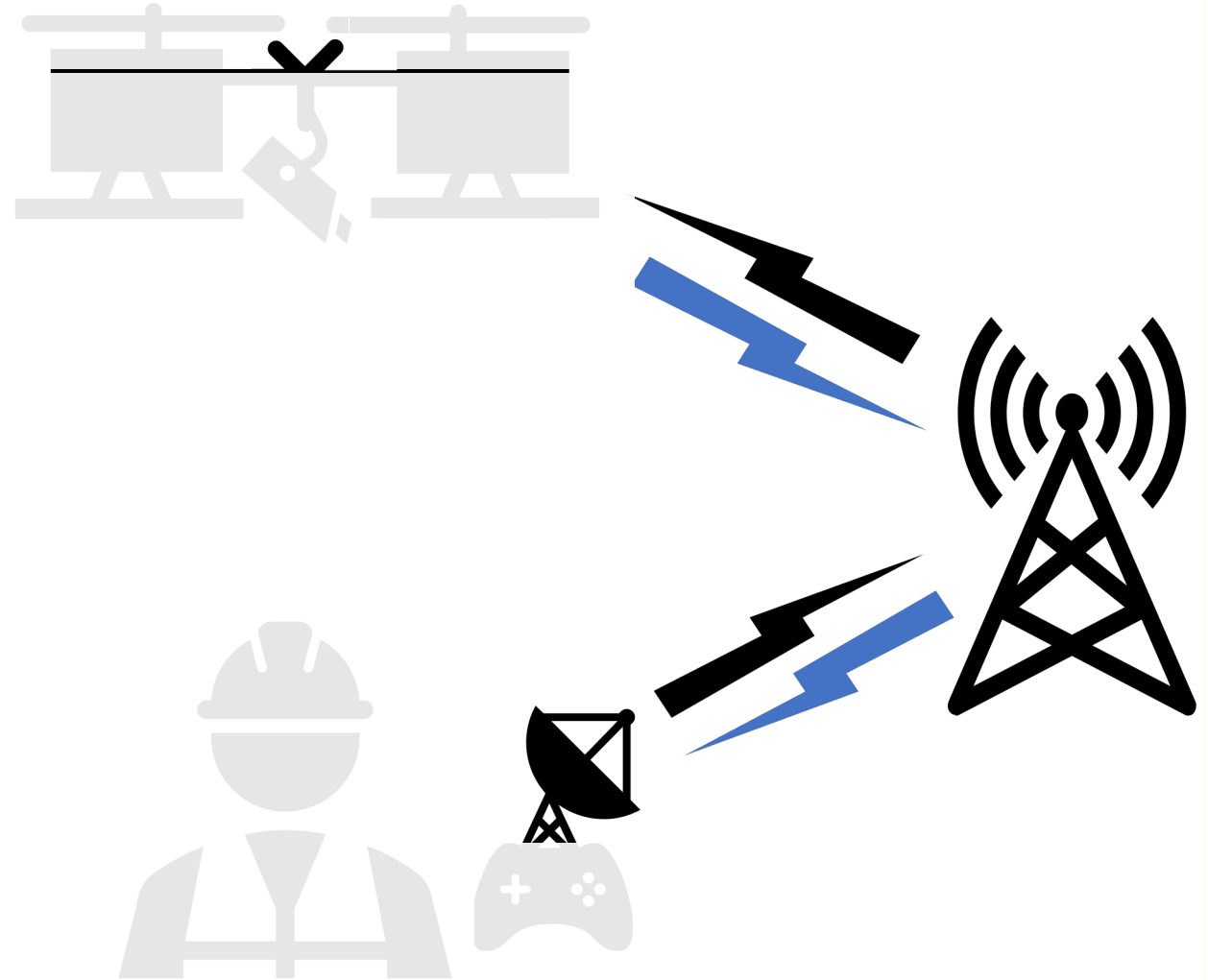


Image: Silent Falcon drone control center. Image Source: Albuquerque Journal, 2018. <http://bit.ly/2OTaGBw>

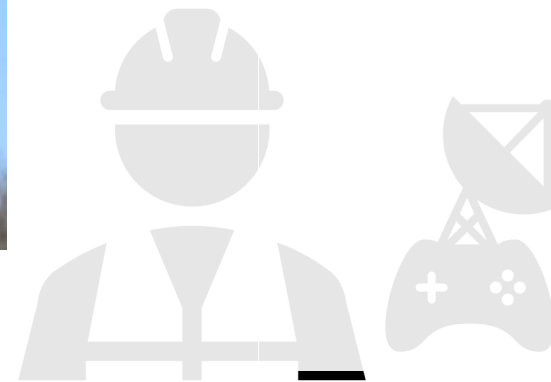
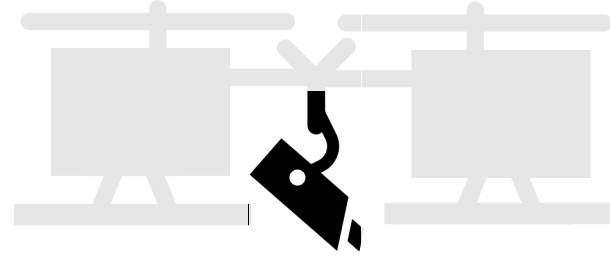
4. The Control Link

- Enables communication between control center and onboard computer
- Repeaters may be used to extend range
- 5G will expand capabilities
- Transmission:
 - Ground control
 - Remote network system
 - Relay



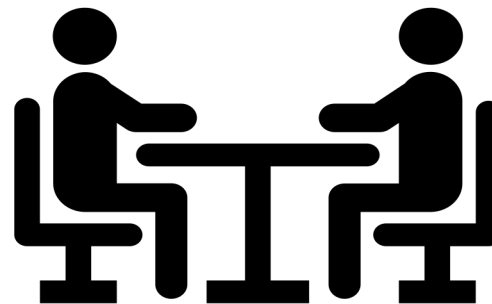
1. Unmanned Vehicles

5. The Payload



- Sensing Equipment
- Material to Deliver
- Communications Equipment
- Operational Equipment

Group Work and Activities



■ Discussion 1: Using Unmanned Vehicles to Do Our Work

- Why would an emergency management stakeholder choose to use a UAV such as drones to deliver relief supplies instead of delivering the supplies in person?
- What conditions would make UAV such as drone delivery of relief supplies impractical?

2. Using Unmanned Vehicles to Support DRR and Resilience

■ Supporting DRR and Resilience

- Hazard Mapping, Monitoring, and Detection
- Situational Awareness, Decision Support, and Damage Assessment
- Communications Infrastructure Support
- Operational Functions
 - Delivery of Supplies, Equipment, and People
 - Firefighting
 - Search and Rescue

2. Using Unmanned Vehicles to Support DRR and Resilience

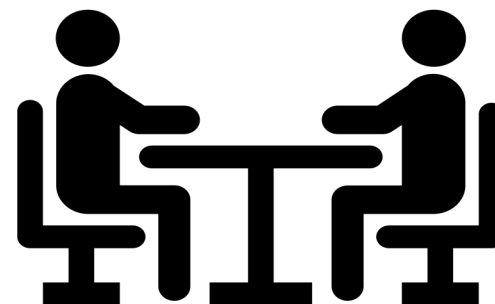
■ Hazard Mapping, Monitoring, and Detection

- These activities require significant manpower and resources
- Unmanned vehicles are particularly well-suited to advance mapping, monitoring, and detection capabilities
- Coupled with GIS / analysis capabilities, unmanned vehicle technologies are transforming hazard mapping, monitoring, and detection
- Can monitor
 - Hazard vulnerability
 - Demographics / population movements
 - Agriculture
 - Infrastructure



Image: UAV measuring riverine water levels.
Image credit: Bandini, 2017. <http://bit.ly/2PsOO03>.

Group Work and Activities



■ **Discussion 2: Benefits of Using Unmanned Vehicles for Hazard Mapping, Monitoring, and Detection**

- What advantages do unmanned vehicles have over traditional methods when it comes to these three functions?
- Participants may have additional thoughts to offer?

2. Using Unmanned Vehicles to Support DRR and Resilience

Case Study: Hazard Mapping in the Maldives

- **Problem:** Risk from sea level rise and storm surge in Maldives is extreme.
- **Need:** Mapping is key to understanding risk and supporting decision-making.
- **Obstacle:** Population geographically-dispersed, equipment and expertise not always equally distributed or available.
- **Solution:** Training and equipment (commercial-grade UAVs) provided to support distributed hazard mapping capabilities.



Images: Residents of Faafu Atoll participate in UAV Training, April 2018..
Image credit: NDMA Maldives, 2018.

Case Study: Hazard Mapping in Fiji

- **Problem:** Extensive risk and high community vulnerability.
- **Need:** Better understanding of risk areas in vulnerable communities.
- **Obstacle:** Economically-depressed population, and a lack of relevant risk assessment skills and resources.
- **Solution:** Mapping assistance and training using commercially-available UAVs



Image: Map of Maunivatu Settlement, in Suva Fiji. Image Source: We Robotics, 2018.

2. Using Unmanned Vehicles to Support DRR and Resilience

Case Study: Ocean Gliders Improve Hurricane Forecasts

- **Problem:** Uncertainties associated with seasonal hurricane risk prediction capabilities
- **Need:** Expanded set of ocean data (salinity, temperature, density, conductivity)
- **Obstacle:** Very large geographic area to be monitored
- **Solution:** Multiple UUVs that constantly monitor ocean conditions along pre-established routes

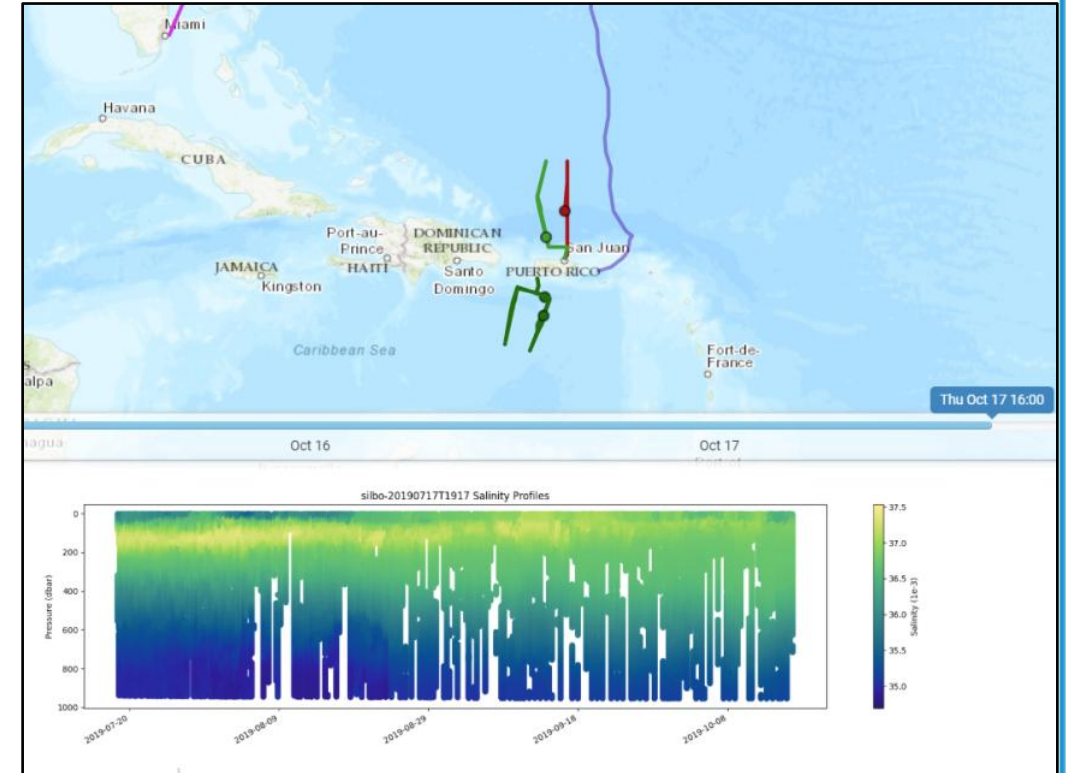


Image: Pathway and data report from ocean glider operating in the Caribbean, October 2019. Image Source: Integrated Ocean Observing System, 2019.



■ Case Study: Saildrones Commercialize DRR Data Collection

- **Problem:** Data on ocean currents, temperatures, depths, and other factors relevant to DRR is very incomplete
- **Need:** Data available across large areas of the ocean
- **Obstacle:** Financial costs, logistical problems, and human risks associated with ocean data collection are high
- **Solution:** Environmentally sustainable, low-cost, autonomous ocean sampling USV



Video: Saildrones – Cutting Edge Technology for Ocean Research. Video Length: 4:29.

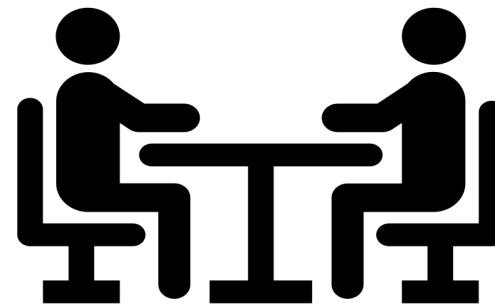
■ Situational Awareness, Decision Support, and Damage Assessment

- Response and recovery information requires current / reliable data
- Unmanned vehicles well-suited for many situational awareness / damage assessment missions
- Many advantages:
 - Cost
 - Speed
 - Data quality
 - Feasibility
 - Safety



Image: Drone hovering over a prescribed forest burn in the United States.
Image Source: Desert Research Institute, 2019.

Group Work and Activities



■ **Discussion 3: Advantages of Using Unmanned Vehicles for Disaster Assessments**

- What advantages do drones offer disaster management stakeholders in terms of supporting situational awareness or collecting damage assessment data?
- How have unmanned vehicles supported disaster assessment in your country?

Case Study: Typhoon Haiyan

- **Problem:** Disaster assessments difficult and/or unsafe due to extent of damages and security concerns
- **Need:** Rapid access to information to support response planning and prioritization efforts
- **Obstacle:** Limited access to commercial and satellite data, geographic obstacles, limited local expertise and hardware
- **Solution:** Private-sector donation of UAV hardware and expertise



Image: Carigara District Hospital as captured by the Huginn X1 UAV
Image Source: Danoffice IT, 2013.

2. Using Unmanned Vehicles to Support DRR and Resilience

■ Case Study: Christchurch Cathedral

- **Problem:** Damage to iconic cultural heritage site in important urban economic zone undergoing concurrent recovery activities
- **Need:** Detailed imagery of damaged historic building and surrounding development zone
- **Obstacle:** Dangerous conditions, proximity to people and structures.
- **Solution:** UAV flight data integrated with both reconstruction and economic development plans



Upper Image: Drone footage of the Christchurch Cathedral. Lower Image: Christchurch City Council development plans overlaid on drone-generated imagery. Source: Pix4D, 2019.

2. Using Unmanned Vehicles to Support DRR and Resilience

■ Case Study: Hurricane Florence

- **Problem:** Response organizations wish to communicate ongoing hazardous flooding conditions to hurricane-impacted population
- **Need:** Detailed location-specific information about flooding conditions, especially as it affects transportation infrastructure
- **Obstacle:** Ongoing hazardous conditions, near constant need for data, large assessment area
- **Solution:** Trained UAV teams deployed prior to disaster onset



Image: Drone footage of flooding in North Carolina after Hurricane Florence. Image Source: NC Department of Transportation, 2019.

Case Study: Hurricane Pam

- **Problem:** Significant amount of damage to housing stock, but poor understand of what that damage is and where it is located.
- **Need:** Rapid access to information to support recovery planning and prioritization efforts
- **Obstacle:** Limited access to commercial and satellite data, geographic obstacles, limited local expertise and hardware
- **Solution:** Collaborative effort to organize and conduct UAV flyovers

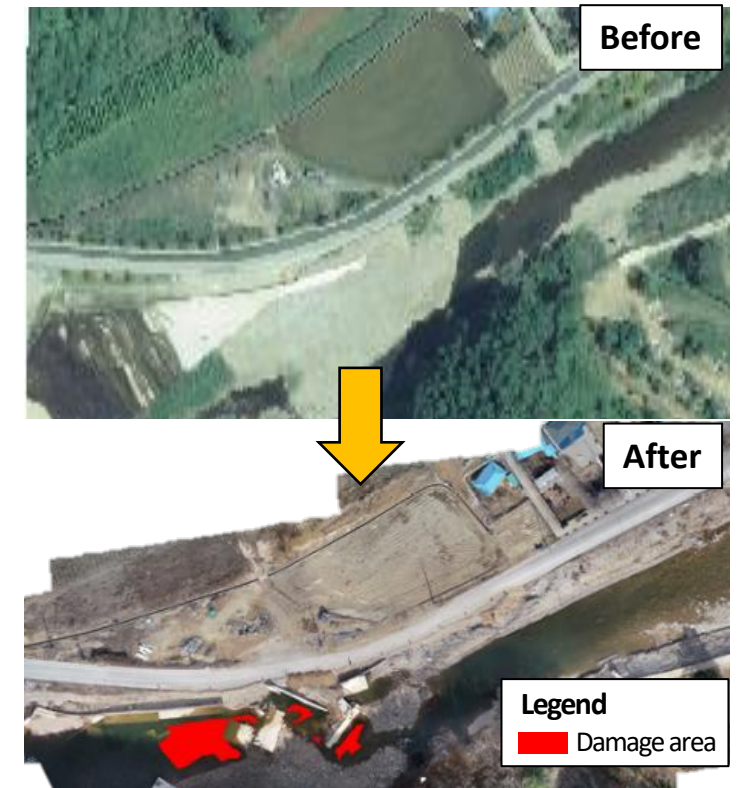
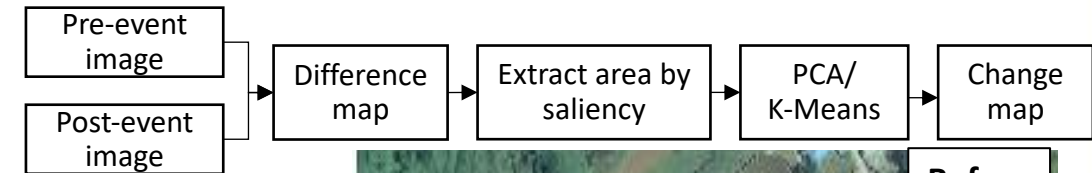


Image: UAV-informed damage assessment map of Vanuatu following Hurricane Pam. In this map, red structures are heavily damaged, blue structures moderately damaged, and yellow structures undamaged. Source: Matt Irwin, Mapping Cyclone Pam's destruction with drones.

2. Using Unmanned Vehicles to Support DRR and Resilience

Case Study: Damage Mapping in South Korea

- **Problem:** Damage from typhoon Mitag in South Korea in 2019
- **Need:** Mapping is key to understanding damage and supporting decision-making.
- **Obstacle:** Difficulty grasping the exact site situation due to limited human access.
- **Solution:** UAVs enable the collection of damage site information for areas where human access is difficult.



Upper image: Aerial image in Uljin before typhoon; Lower image: Damage map in Uljin after typhoon.
 Upper image Source: National Geographic Information Institute, 2019;
 Lower image Source: Yonsei University, 2020.

2. Using Unmanned Vehicles to Support DRR and Resilience

Impact-based forecasting and damage assessment for cyclone Gita

- **Problem:** Between 10 to 13 February 2018, tropical cyclone Gita hit several countries in the Pacific.
- **Need:** The cyclone was predicted well in advance.
- **Obstacle:** Governments could prepare for the impacts and plan countermeasures
- **Solution:** Tonga's post disaster needs assessment was carried out using drones

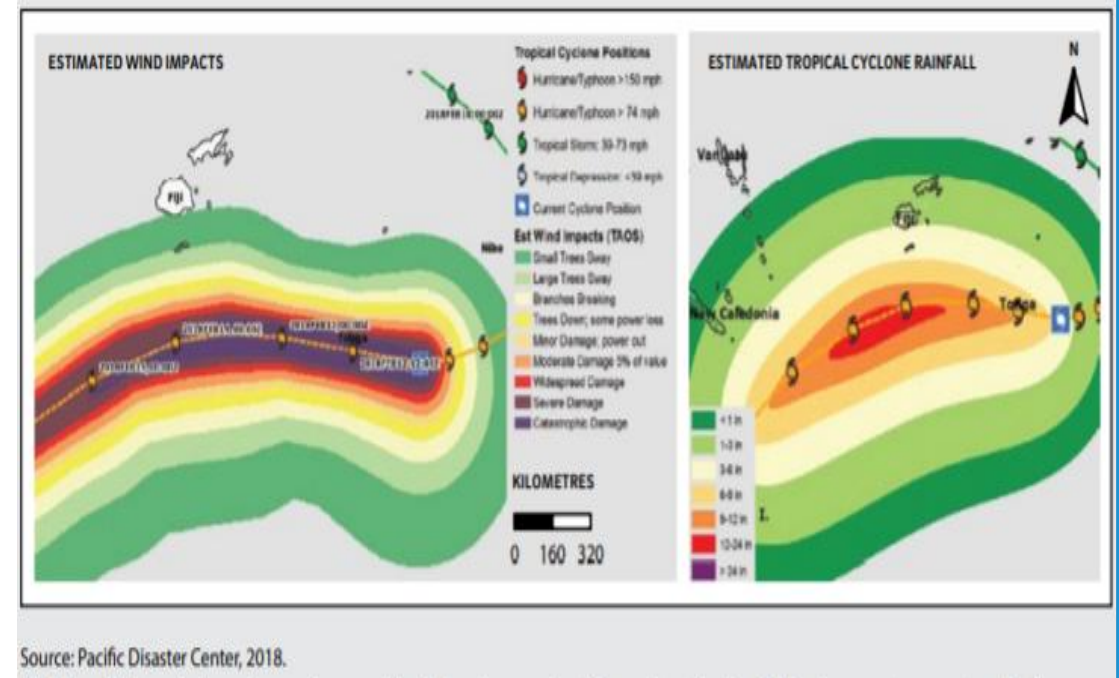


Image: <https://www.unescap.org/sites/default/files/APDR%202019%20Chapter%204.pdf>

Post-Disaster Environmental Assessment

- Identification and monitoring of conditions hazardous to:
 - Humans
 - Animals
 - The environment
- Supports:
 - Search & rescue
 - Response planning
 - Remediation
 - Long-term recovery planning

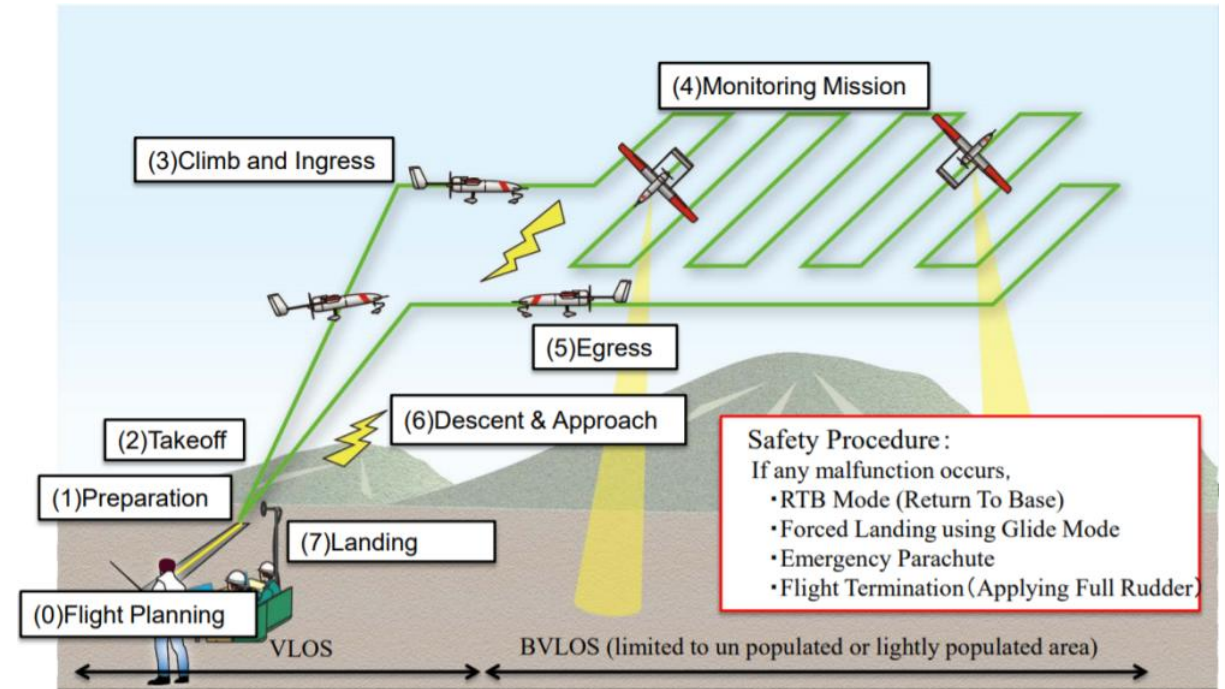


Image: Flight plan of UAV used to monitor radiation following the Fukushima Daiichi Reactor Meltdown.
Image Source: Tatsuo Torii, 2015.

2. Using Unmanned Vehicles to Support DRR and Resilience

- **Case Study: UAV Monitoring of Radiation Following the 2011 Great East Japan Earthquake**
- Identification and monitoring of conditions hazardous to:
 - Humans
 - Animals
 - The environment
- Supports:
 - Search & rescue
 - Response planning
 - Remediation
 - Long-term recovery planning



Upper Image: Still photo from a March 15 mission over the damaged reactor; Lower Image: the AUH.
Upper Image Source: Alexis Madrigal, 2011; Lower Image Source: Tatsuo Torii, 2015.

Communication Infrastructure Support

- Communication is a critical emergency management function
 - Responder to responder
 - Responder with public
 - Public to public
- Enables coordination / awareness
- Modes:
 - Landline / cellular voice
 - Cellular data
 - Wi-Fi
 - UHF / AM / FM / Shortwave
 - Microwave
 - Bluetooth

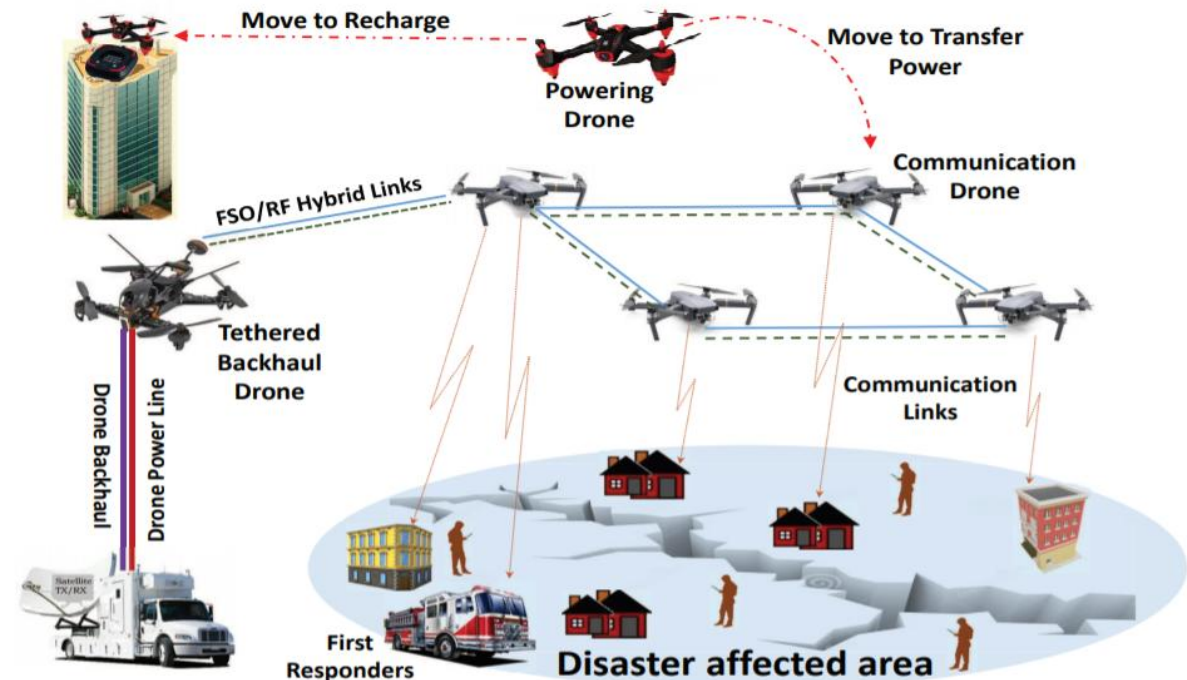


Image: Diagram of drone-supported communications network deployed after a disaster.
Image Source: Selim, Mohammed and Ahmed Kamal. 2018. <http://bit.ly/2BA7liY>

2. Using Unmanned Vehicles to Support DRR and Resilience

■ Case Study: Tethered Communications UAV

- **Problem:** Damaged communication infrastructure, non-existent communication infrastructure, inadequate communication system capacity
- **Need:** Rapidly-available communication infrastructure support
- **Obstacle:** Cost, difficulty, and limits of land-based temporary infrastructure options
- **Solution:** Tethered UAV-based communication network



Image: Elistair tethered drone.
Image Source: Elistair, 2019.

2. Using Unmanned Vehicles to Support DRR and Resilience

■ Case Study: AT&T “Cell on Wings” (COW)

- **Problem:** Damaged cellular network infrastructure, non-existent communication infrastructure, inadequate communication system capacity
- **Need:** Rapidly-available communication infrastructure support
- **Obstacle:** Extreme weather conditions, reconstruction delays
- **Solution:** UAV-based mobile network components



Image: Cell on Wings (COW) Weather Hardened UAV.
Image Source: AT&T, 2018.

2. Using Unmanned Vehicles to Support DRR and Resilience

■ Delivery of Relief Supplies, Equipment, and People

- Transportation often impacted by disasters
- Transportation can also be impeded by security issues
- Unmanned vehicles alleviate many of these issues in the early days of a disaster response
- Application for resilience building as well – e.g., strengthening public health



Image: A medical professional holds a package delivered by a Zipline drone.
Image Source: Zipline, 2019. <http://bit.ly/2ME4trS>.

2. Using Unmanned Vehicles to Support DRR and Resilience

■ Case Study: Vaccine Delivery in Vanuatu

- **Problem:** Public health needs remain unmet in remote parts of the country
- **Need:** Vaccines and other medications
- **Obstacle:** Transportation options are not conducive to delivery of vaccines and medication
- **Solution:** UAV equipped to carry and monitor a climate-controlled package used to quickly transport vaccines



Video: Vanuatu vaccine delivery pilot program footage.
Image Source: UNICEF, 2018.

2. Using Unmanned Vehicles to Support DRR and Resilience

Case Study: Drones Fly Disaster Relief in Puerto Rico

- **Problem:** Communities in remote locations have ongoing public health requirements requiring outside delivery of supplies and equipment
- **Need:** Reliable delivery mechanisms
- **Obstacle:** Distance and vulnerable infrastructure
- **Solution:** Alternative delivery mechanisms using long-distance UAV flights



Image: Medical package loaded onto UAV in Puerto Rico during pilot testing program.
Image Source: Butschli, Jim, 2018. <http://bit.ly/2BLvOIL>.

Case Study: Malawi Drone Corridor

- **Problem:** Poor capacity to harness drone delivery capabilities in underdeveloped areas
- **Need:** Drone research and development
- **Obstacle:** Lack of permissions, policies, and area to test drone use
- **Solution:** Designated test bed to enable relevant stakeholders to discover new and innovative uses of UAV deliveries



Image: People observe a UAV involved in the Drone Corridor program.
Image UNICEF, 2018. <https://uni.cf/2BBkOXM>.

2. Using Unmanned Vehicles to Support DRR and Resilience

■ Search and Rescue

- **Unique challenges and risks**
- Several benefits using unmanned vehicles:
 - Enhanced ability to see through clouds, smoke, vegetation
 - Better vantage
 - Ability to search large areas
 - Assisted route planning
 - Information on structural integrity
 - Heavy-lift of rescuers or survivors



Image: The Rega Search and Rescue Drone, which operates autonomously and can search for victims over a several kilometers for several hours at a time.
Image David Neld, 2019. <http://bit.ly/2JfitGI>.

2. Using Unmanned Vehicles to Support DRR and Resilience

■ UAVs in Extreme Search and Rescue Environments



Video: Search and Rescue in Extreme Environments
Video Source: DJI, 2017.

2. Using Unmanned Vehicles to Support DRR and Resilience

Case Study: South Korea “Skyship” Platform

- **Problem:** Disaster survivors need to be located in the initial hours of event
- **Need:** Ability to quickly locate and identify survivors
- **Obstacle:** Searching disaster areas takes considerable time and manpower
- **Solution:** Integrated system of mobile signal sensors, air and land-based drones, and survivor information.

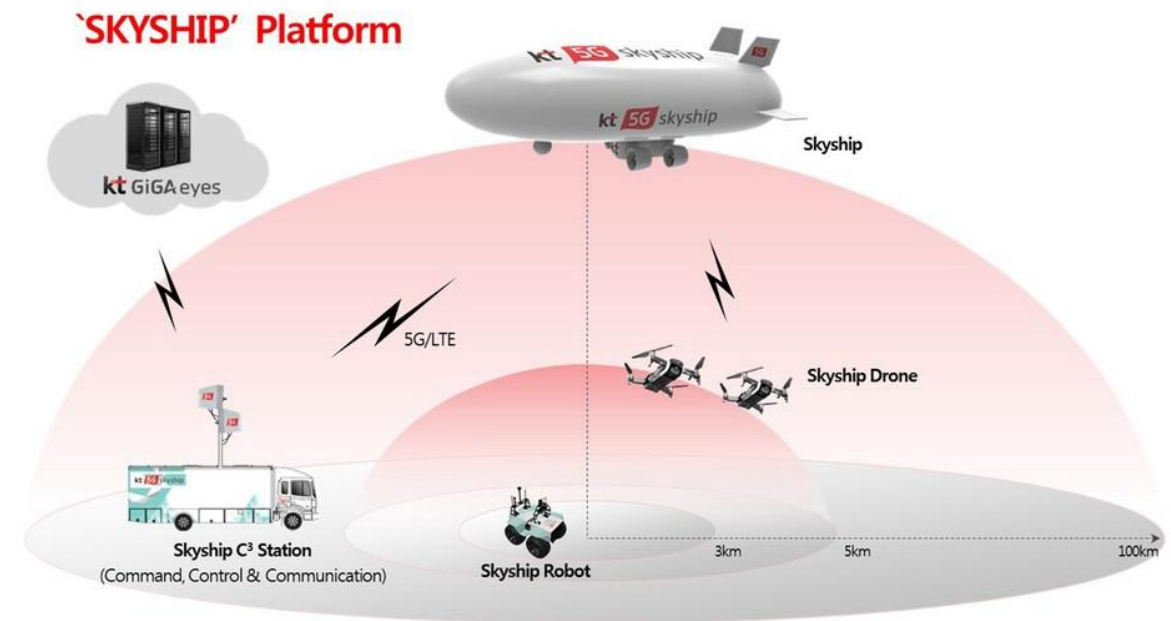
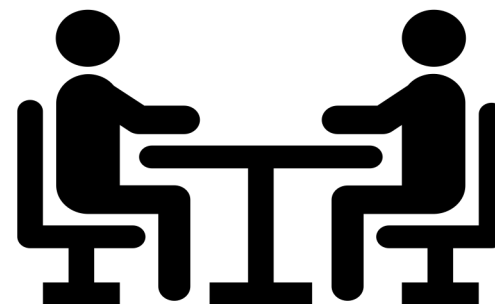


Image: Diagram of the SKYSHIP platform.
Image Source: KT Corporation, 2018.

Group Work and Activities



■ **Activity 4: Drone Footage of Rescue Efforts**

- Watch the following video, which details the extraction of a cadaver during search and rescue operations in Tacloban City, Philippines, following Typhoon Haiyan: <http://bit.ly/2B7puEN>
- How does the high vantage of this UAV improve on search and rescue efforts, if at all?
- What does this video indicate about the scope of search and rescue operations? How does this impact the planning process, if at all?
- Alternate video: <http://bit.ly/35XXcdZ>
 - Programming and using a UAV to conduct a search and rescue mission

2. Using Unmanned Vehicles to Support DRR and Resilience

■ Firefighting

- Fire risk to humans is extensive – over 300,000 deaths per year
- Firefighting risk is also dangerous
- Unmanned vehicle use by fire departments / EMS increasing
- UAV modifications for fire response:
 - Thermal cameras
 - Infrared cameras
 - Extinguisher tanks
 - Mist distributors
 - High-definition cameras



Image: UK Firefighter deploying a drone during an exercise.
Image Source: Peter Van Der Schaft, 2018. <http://bit.ly/35ZdlzT>.

Case Study: Aerones Firefighting Drone

- **Problem:** Fires are not always located in easy-to-access locations
- **Need:** Ability to fight fires at very high elevations with little setup time
- **Obstacle:** Apparatus limits are currently about 29 meters, and take time to set up
- **Solution:** UAV-based firefighting system that is able to reach great heights quickly and deploy fire suppression chemicals and foams



Video: Aeronne firefighting UAV demonstration.
Image Source: Aerones, 2019.

Case Study: SmokeBot

- **Problem:** People and animals are often trapped by fires
- **Need:** Ability to find survivors
- **Obstacle:** Conditions are difficult and dangerous to navigate and work in
- **Solution:** Land-based unmanned vehicle equipped with multiple sensors

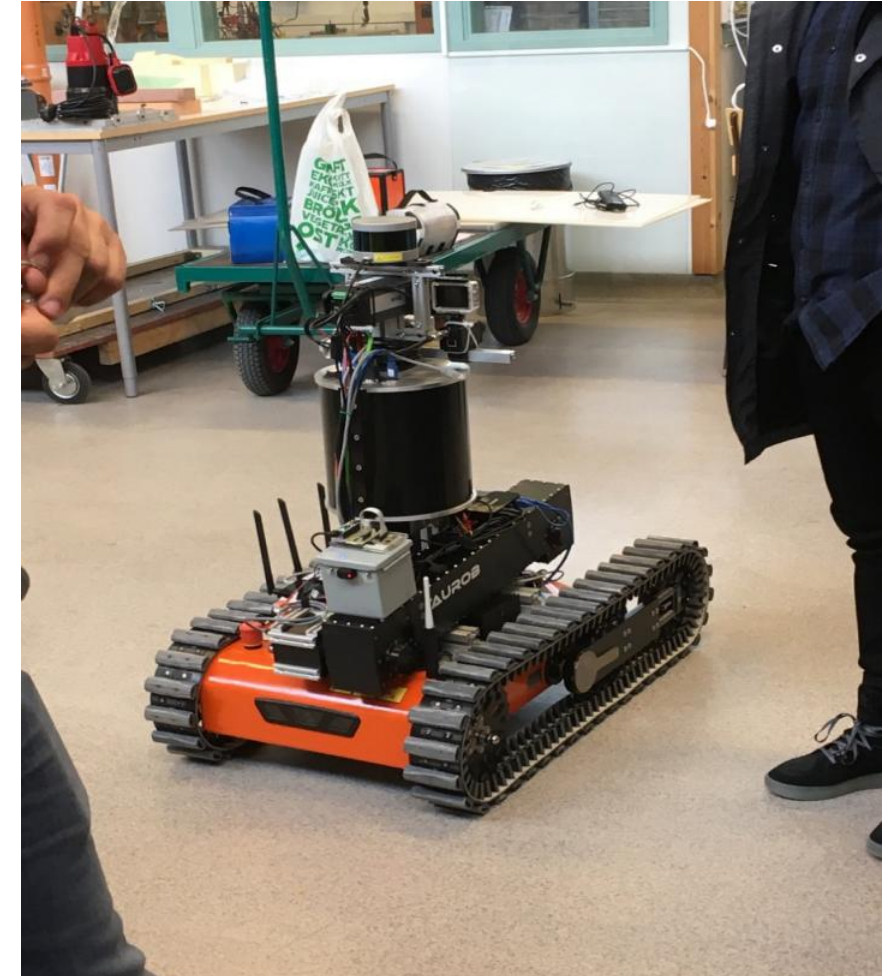


Image: Version 2 (current) of the SmokeBot.
Image Source: SmokeBot, 2019.

■ Case Study: Firefighting Robot System

- **Problem:** Many fires have qualities that make conditions extremely dangerous for firefighters
- **Need:** Ability to fight large fires remotely
- **Obstacle:** Large fires require a large amount of extinguishing capacity, and up-to-the-minute intelligence
- **Solution:** Multi-robot system that provides firefighting, hose-laying, and surveillance capabilities



Video: Mitsubishi Heavy Industries Firefighting Robot System, 2019.

■ Robot

- Ancient roots, Slavic etymology: robota - “forced labor” or “servitude”
- Robots do work that humans:
 - Find tedious
 - Consider too risky to do
 - Cannot do
- **5 requirements:**
 - Autonomous
 - Exists in the physical world
 - Can sense its environment
 - Can act on the data it receives
 - Can achieve a goal

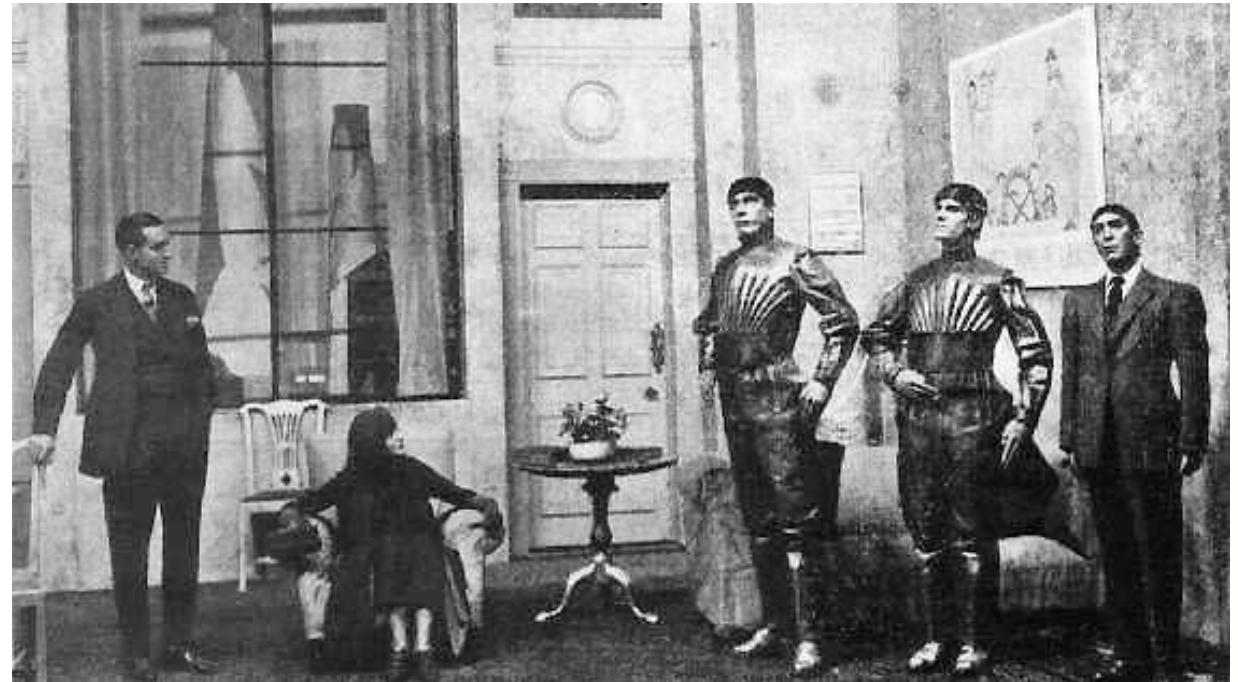


Image: Scene from *Rossum's Universal Robots*, a play by Czech playwright Karel Capek.

■ Advantages

- Robots are more accurate than humans (they can follow an instruction precisely)
- Robots are more consistent than humans (they can perform the same operation over and over with little variance)
- Robots perform tasks faster
- Robots don't tire (they can produce the same quality of output)
- Robots need only good ventilation and proper regulation of dust and moisture levels in their work environment, and can perform tasks in many hazardous environments
- Robots don't demand salaries or other forms of compensation
- Robots work with little supervision

■ Disadvantages

- Robots often take away jobs from humans
- Robots can overheat if worked nonstop
- Robots are expensive
- Robots are often limited in utility to their programming
- Robots do not gain experience



Image: In observance of the International Day for Mine Awareness and Assistance in Bunia in the Democratic Republic of the Congo (DRC), a peacekeeper from Indonesia is demonstrating the operation of a landmine clearance robot to a local population. Image credit: United Nations Photo, April 4, 2007.

■ Hazard Assessment and Monitoring



Video: "Sunfish" robot was successful in assessing damage to the Fukushima Daiichi nuclear power plant following the 2011 GEJE, performing tasks that would have had fatal consequences to humans.

■ Case Study: Fukushima Power Plant Damage Assessment

- **Problem:** Remediation of nuclear contamination required to address ongoing environmental crisis
- **Need:** Accurate imagery from reactor core to inform recovery process
- **Obstacle:** Obstructions from debris, toxic conditions
- **Solution:** Specially designed robot equipped for physical obstructions and environmental hazards

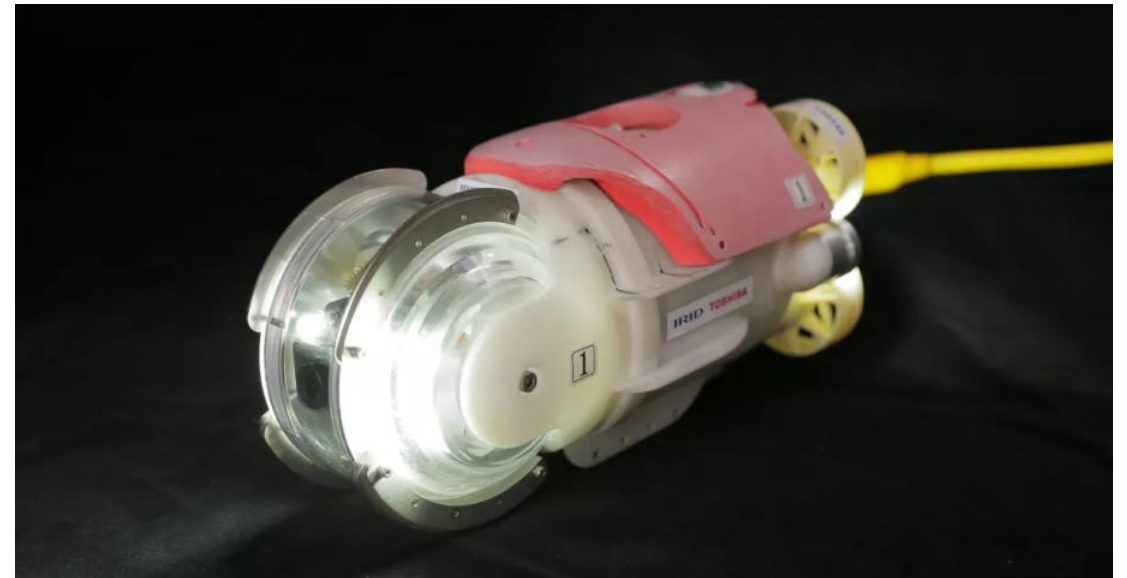


Image: Mini-Manbo, or "Little Sunfish".
Image Source: Shuji Kajiyama, 2018.

■ Case Study: Robobees

- **Problem:** Weather monitoring and storm prediction requires significant hardware
- **Need:** Hyper-local weather data
- **Obstacle:** Limited number of sensors
- **Solution:** Design robots that are so small, many can be deployed for relatively little investment

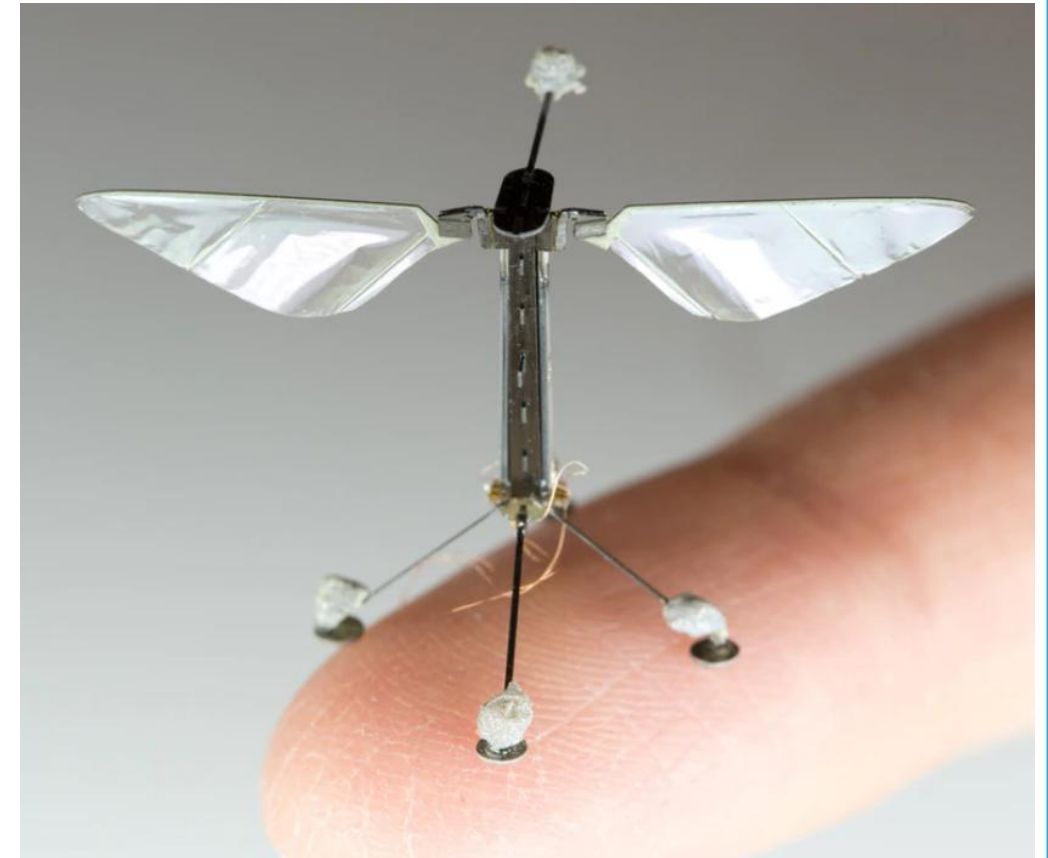


Image: Robobee.
Image Source: Wyss Institute, 2019.

Supporting Response Operations

Robot design driven by function



Image: Humanoid Robot HRB-2, during a disaster debris navigation demonstration at the International Robot Exhibition in Tokyo, 2015.
Image Source: International Straits Times, 2015. <http://bit.ly/31A2lWg>.



Image: Colossus, a firefighting robot that supported firefighting operations at Notre Dame during the 2019 fire, and which was partly credited with saving the structure from total destruction.
Image Source: NY Post, 2019. <http://bit.ly/2Pf1Puq>.

■ Case Study: WALK-MAN

- **Problem:** Hazards exist in the post-disaster environment.
- **Need:** Access to the source of hazards, such as a gas shutoff valve in a damaged building
- **Obstacle:** Explosion hazards or debris
- **Solution:** Agile robot with human capabilities



Video: WALK-MAN Operating in a Damaged Building.
Image Source: IIT, 2018.

■ Case Study: SnakeBot

- **Problem:** Victims may be located in collapsed structures
- **Need:** Victims must be located and assessed
- **Obstacle:** disaster debris and extreme confinement make reaching victims quickly very difficult
- **Solution:** Snake-shaped robot is able to bypass most obstructions much faster than a human or canine

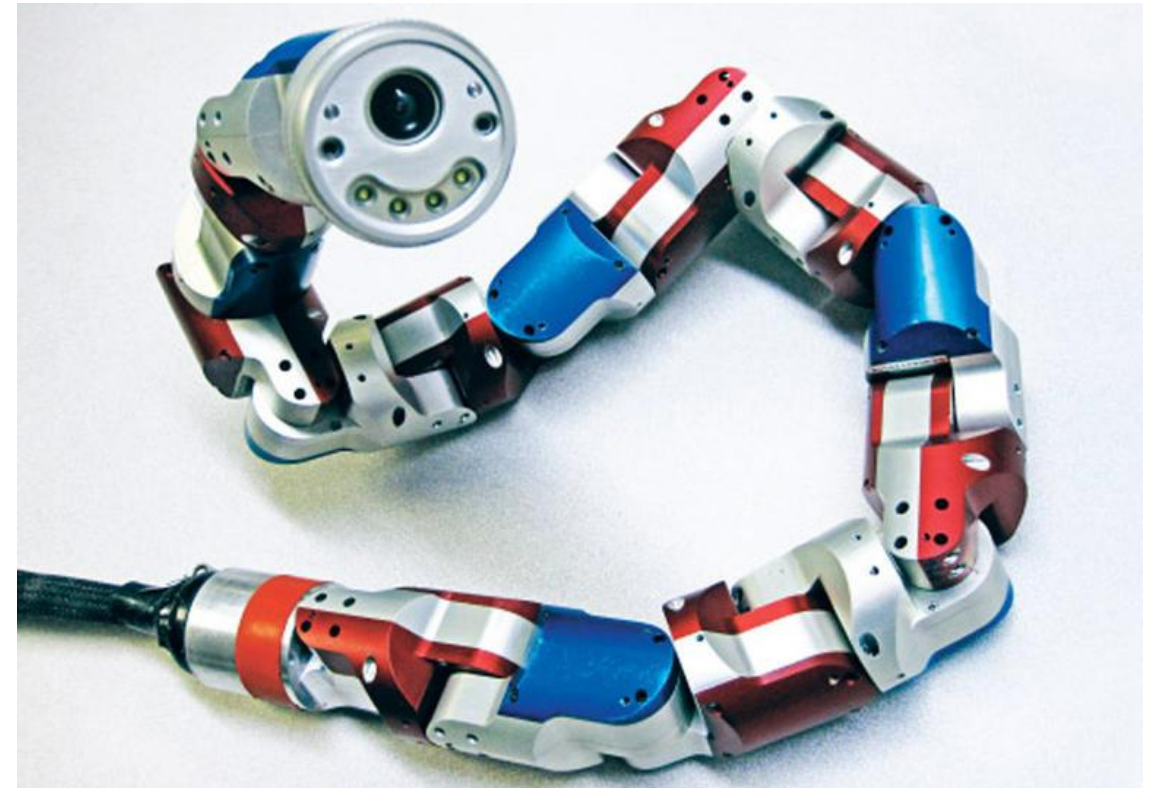


Image: SnakeBot.
Image Source: ZDNet, 2018.

■ Case Study: Growing Search & Rescue Robot

- **Problem:** Victims may be located in collapsed structures
- **Need:** Victims must be located and assessed
- **Obstacle:** disaster debris and extreme confinement make reaching victims quickly very difficult
- **Solution:** Soft robots able to bypass most obstructions without getting stuck

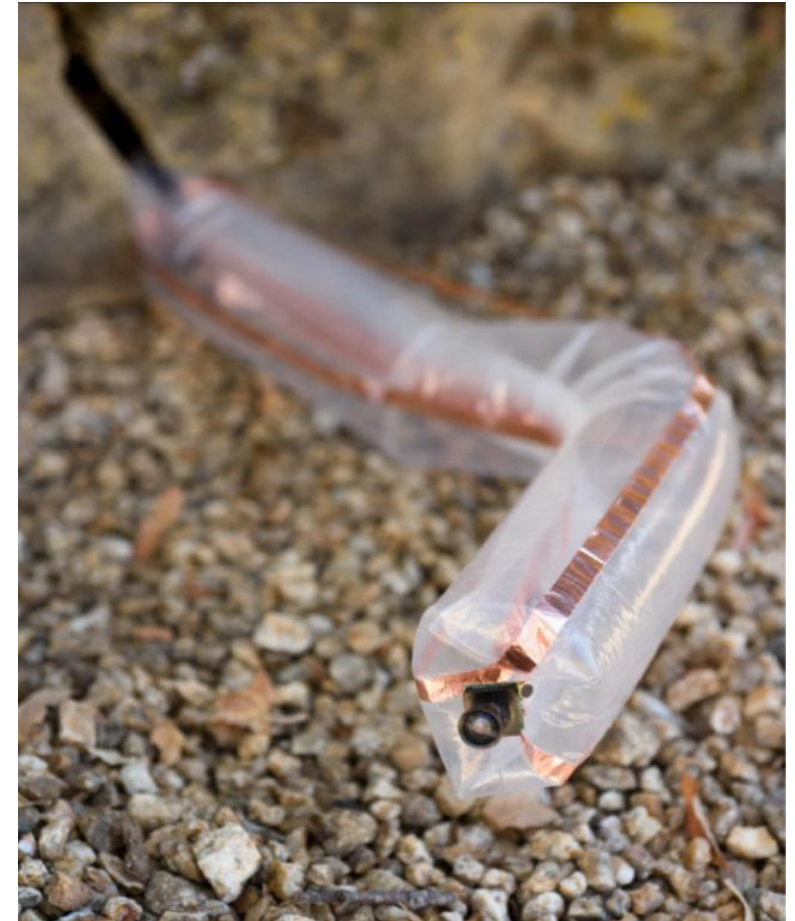


Image: Growing robot prototype showing camera-tipped tendril.
Image Source: Kubota, 2017.

■ Sensing Systems

- Remote Sensing
- In-Situ Sensing
- Proximal Sensing

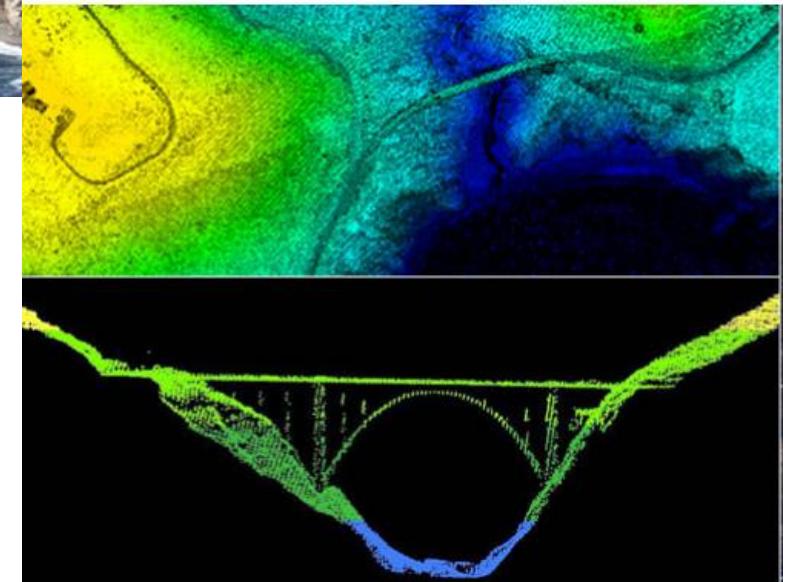


Image: Camera and LiDAR imagery of a bridge in California, USA.
Image Source: NOAA, 2019.

4. Sensing Systems

Passive and Active Sensors

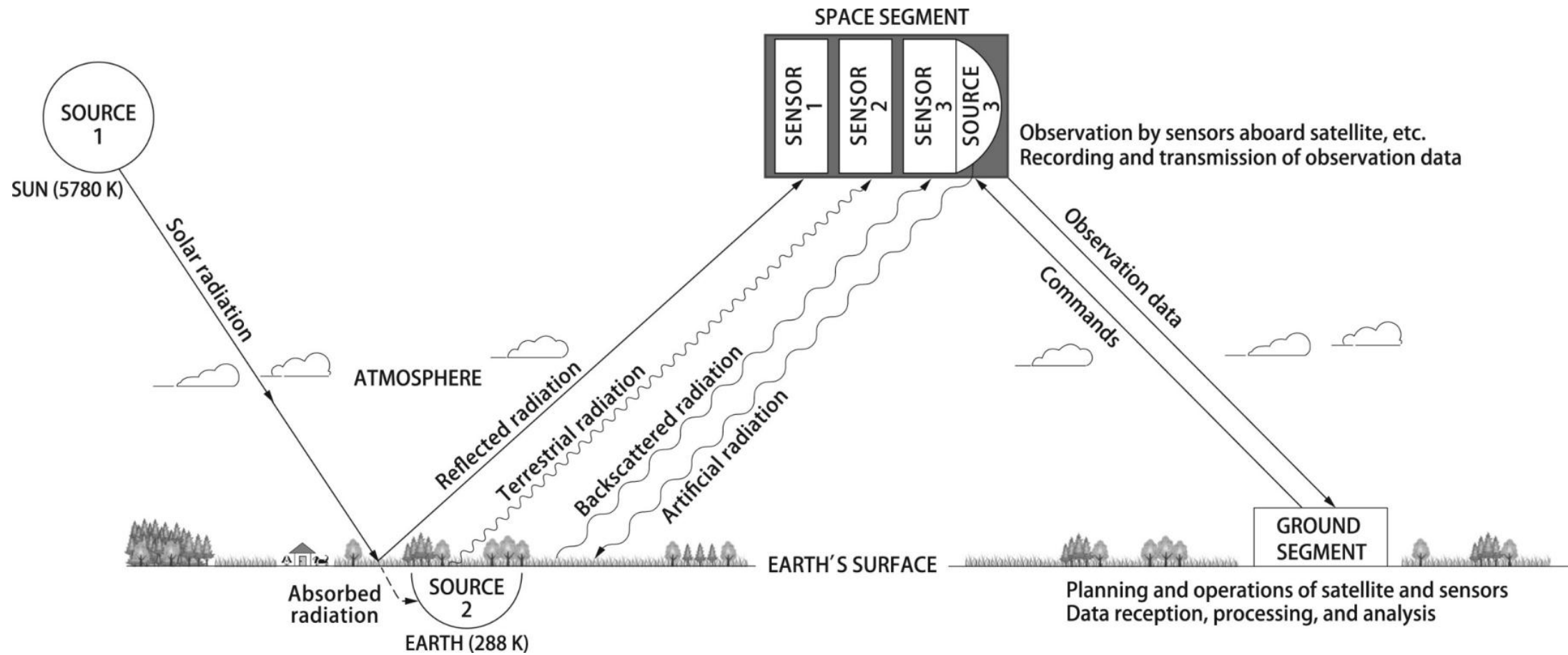


Image: Sensors 1 and 2 are passive, while sensors 3 and 4 are active.
 Image Source: P.J. Curran. 1985. Components of Satellite Remote Sensing.

■ Sensor Examples

Active

- LiDAR
- Laser Altimeter
- Radar
- Ranging Instrument
- Scatterometer
- Sounder

Passive

- Accelerometer
- Hyperspectral Radiometer
- Imaging Radiometer
- Radiometer
- Sounder
- Spectrometer
- Spectroradiometer

EO versus SEO

EO

- In Europe, all-encompassing (remote, in-situ)
- In US, differences in use, more often to mean space-based methods

SEO

- Accelerometer
- Hyperspectral Radiometer
- Imaging Radiometer
- Radiometer
- Sounder
- Spectrometer
- Spectroradiometer

■ Case Study: Copernicus

- **Problem:** Hazards, urbanization, climate change, and other factors influence development
- **Need:** Sustainable development planning
- **Obstacle:** Access to data
- **Solution:** Pool and provide open access to space-based data collected by ESA Satellites

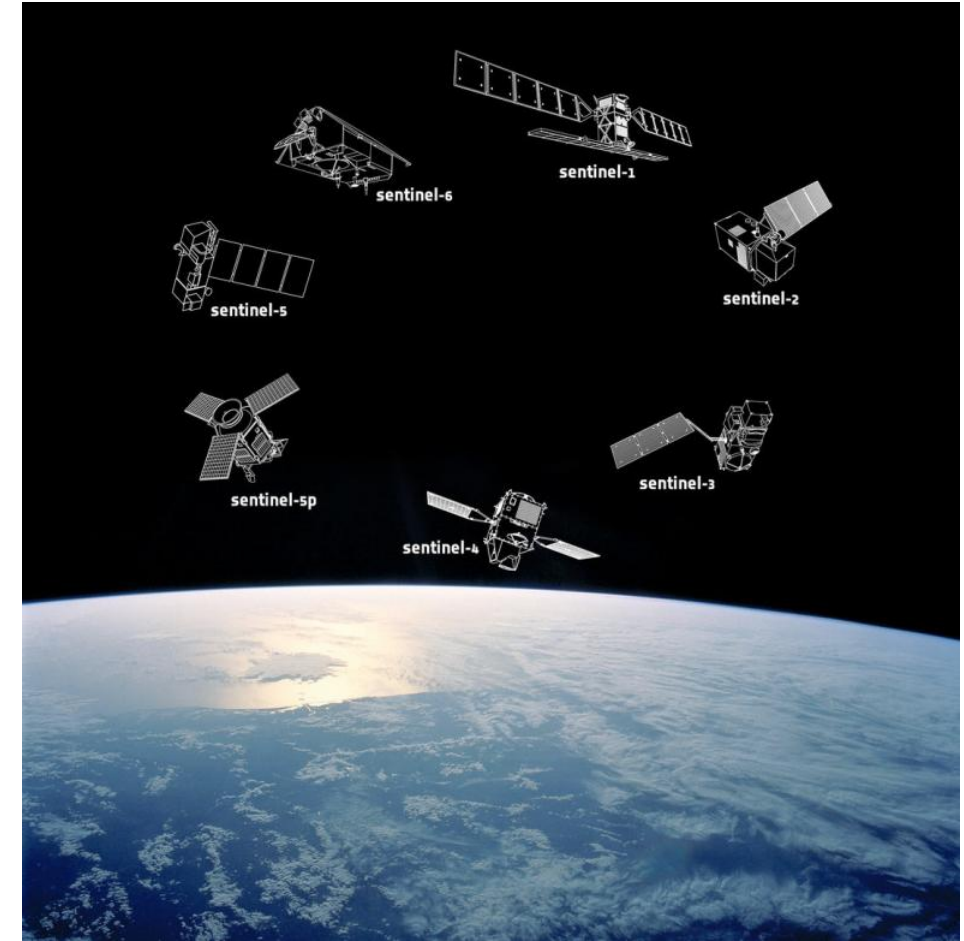
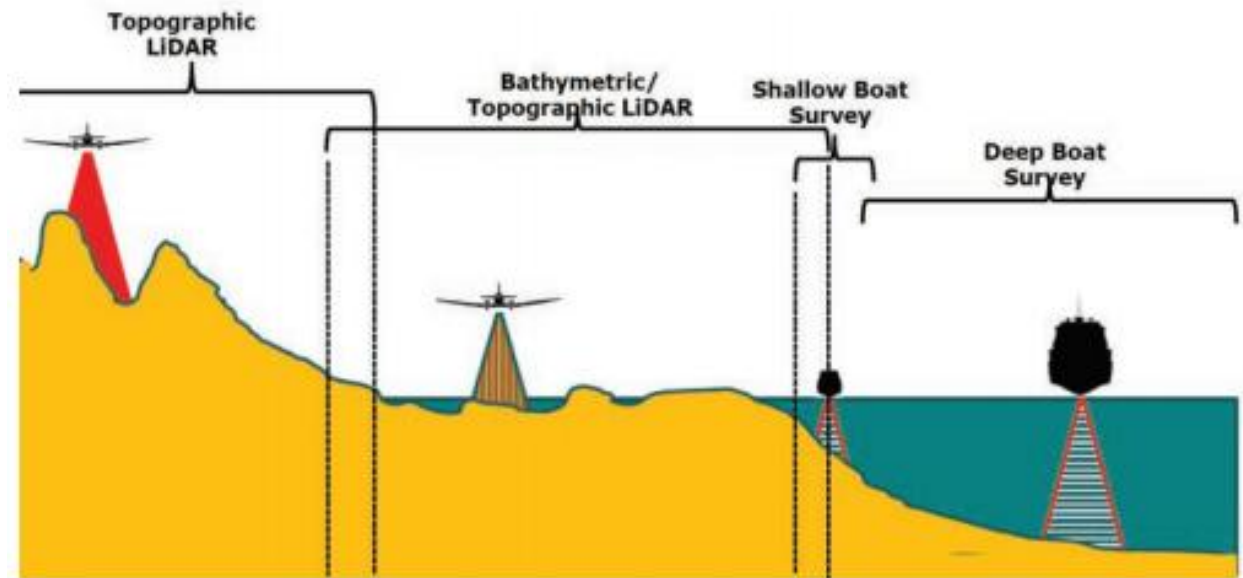
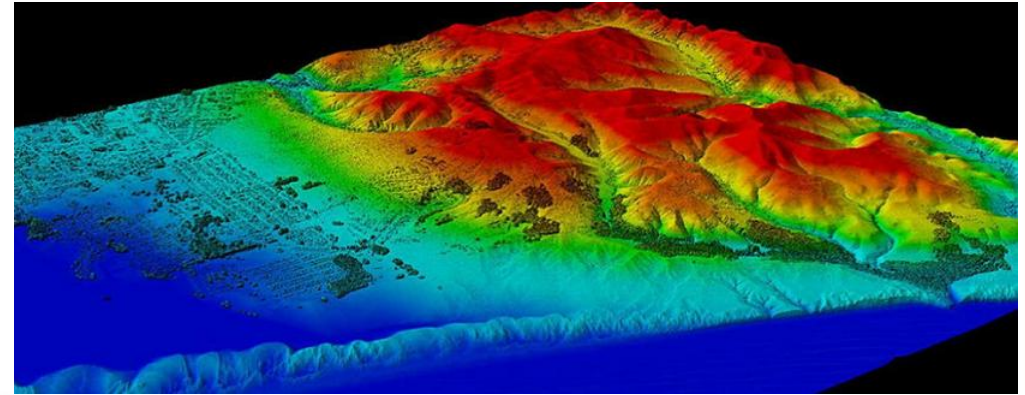


Image: Rendering of the different Copernicus program sentinels.
Image Source: ESA, 2019.

4. Sensing Systems

■ LiDAR

- Light Detection and Ranging (LiDAR)
- Measures distances (height/depth)
- Uses pulses of light from a laser, and a scanner



Upper Image: LiDAR image created with data collected by NOAA's National Geodetic Survey. Source: NOAA National Ocean Survey. Lower Image: Diagram of technologies used to obtain elevation data. Image Source: Australian AID, 2013.

ALIRT Support in Haiti

- **Problem:** High quantities of debris resulted from earthquake induced collapse
- **Need:** Information on the location and quantity of debris
- **Obstacle:** Quantities of debris exhaust ground-based assessment resources
- **Solution:** Satellite-based LADAR scanning provides accurate estimates quickly

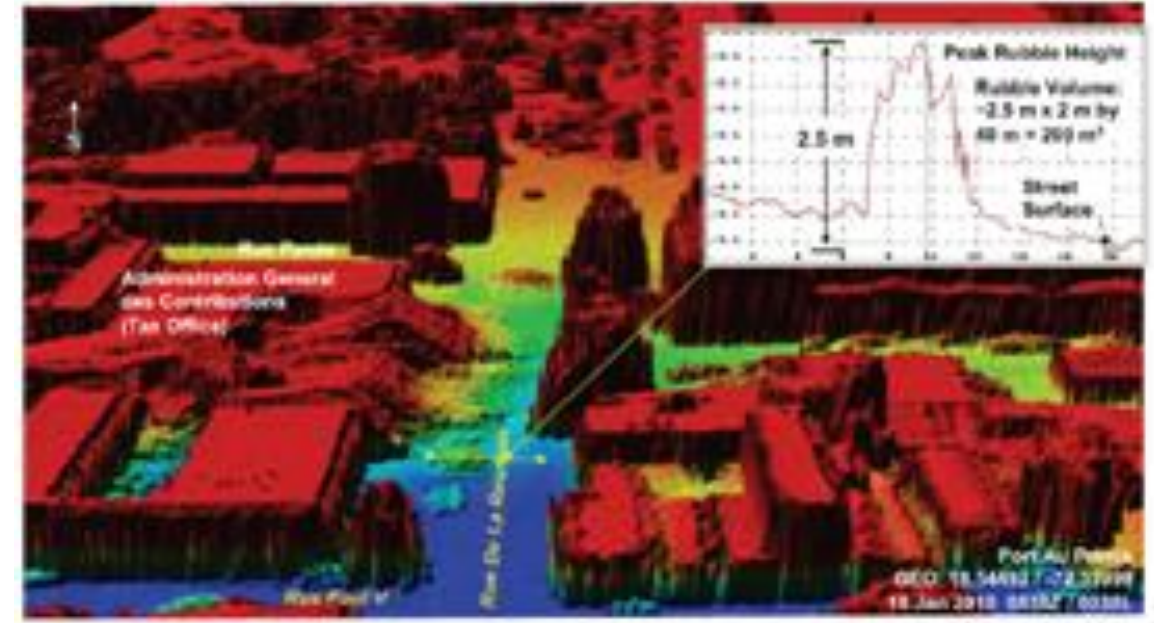


Image: In Haiti, ALIRT's direction and precise measurement of height and slope helped inform which type of vehicles may navigate obstructions. The inset depicts a section across the Rue de la Reunion in which the peak debris height is 2 meters above the street surface. Image Source: Massachusetts Institute of Technology, 2011.

■ Synthetic Aperture Radar (SAR)

- Visual form of RADAR
- Three modes:
 - Stripmap
 - ScanSAR
 - Spotlight
- Can see through most atmospheric obstructions
- Can capture data day or night

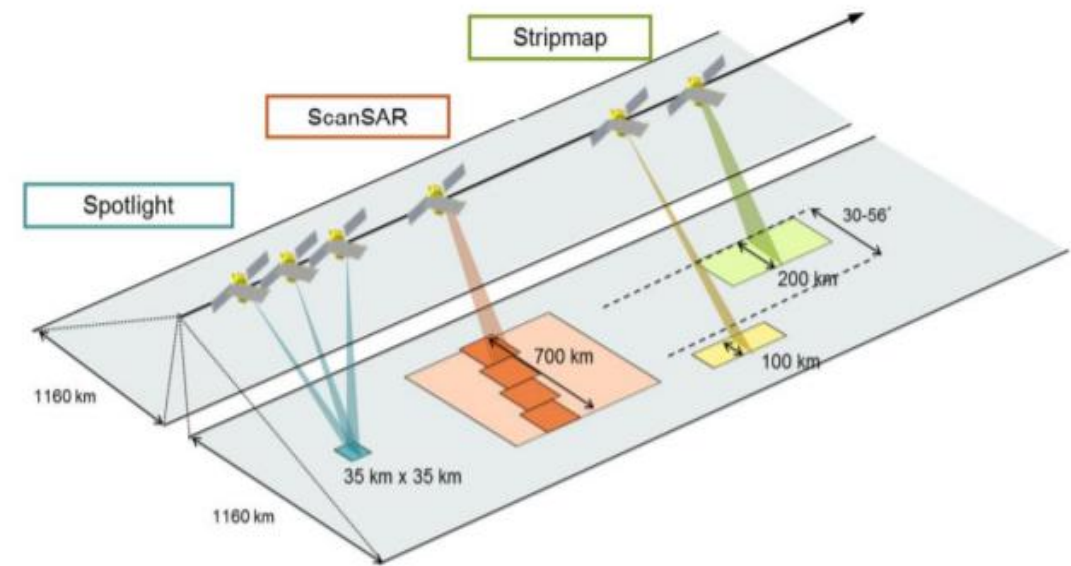


Image: Illustration of the three forms of SAR capture.
Image Source: JAXA 2019.

Case Study: Indoor LiDAR Mapping

- **Problem:** Responders do not always know their way around buildings during rescues or responses
- **Need:** Accurate indoor maps
- **Obstacle:** Traditional mapping of buildings is human resource intensive and often not done
- **Solution:** Indoor LiDAR system that scans an entire building in about 1 hour.

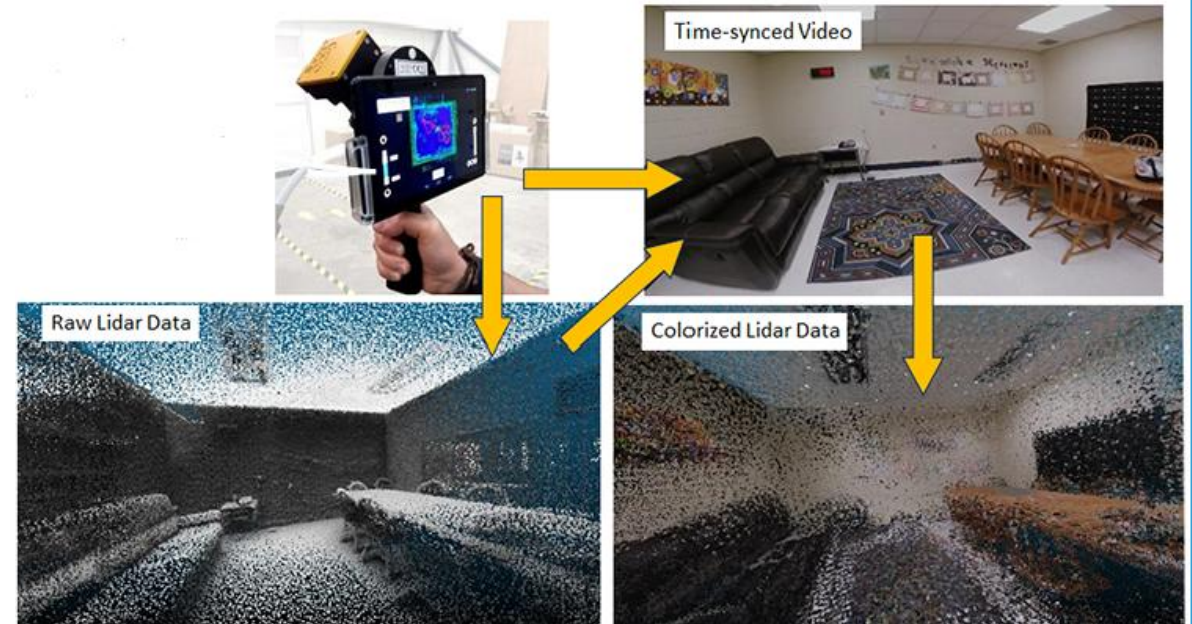
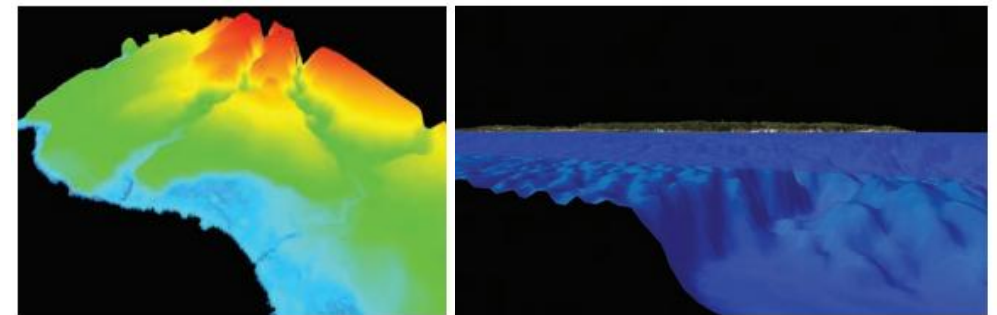
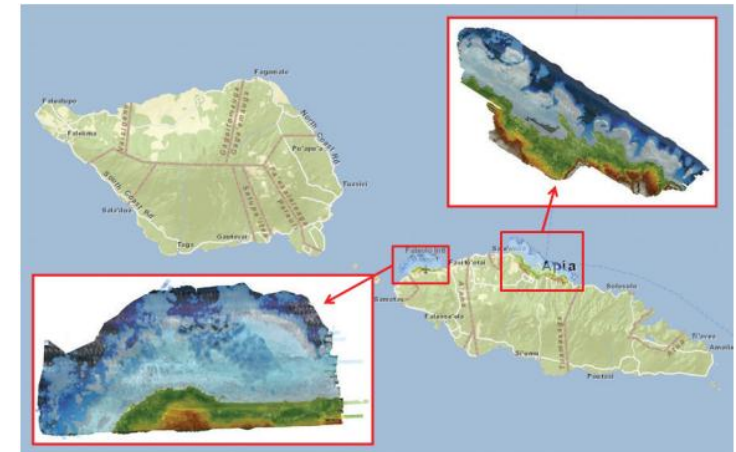


Image: Overview of the Indoor LiDAR Building Mapping project
Image Source: Kanowitz, 2019.

Case Study: Samoa LiDAR Mapping

- **Problem:** Low lying coastal communities are at high risk from storm surge and tsunami, exacerbated by sea-level rise
- **Need:** Accurate elevation data to guide planning efforts
- **Obstacle:** Ground-based surveys have moderate accuracy and do not provide complete coverage; also may be outdated
- **Solution:** Aircraft-produced LiDAR scans of topography and bathymetry around populated low-lying areas.

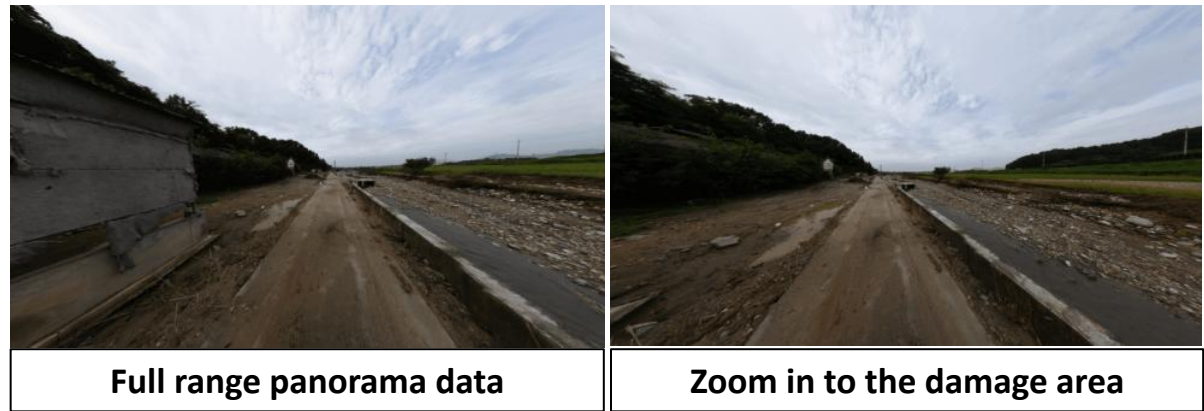
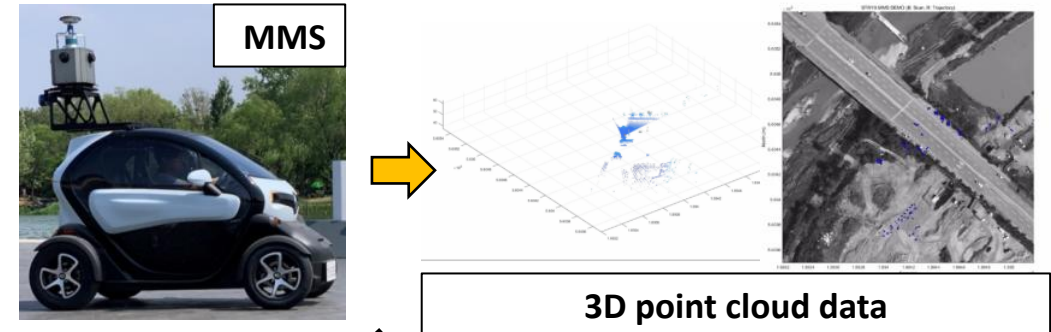


Top: Map showing extent of LiDAR capture in Samoa and digital elevation models (DEM) of the two areas captured; Bottom Left: A 3D digital elevation model of the area surrounding Apia, with red indicating highest elevation; Bottom Right: A 3D perspective of the seafloor off the coast of Upola. Images Source: Australian AID, 2013.

4. Sensing Systems

Case Study: MMS (Mobile Mapping System)

- **Problem:** Sporadic damage caused by heavy rain in 2020
- **Need:** Rapid and accurate on-site maps
- **Obstacle:** Traditional mapping methods take a lot of time to collect precise data.
- **Solution:** MMS collects detailed information on the site by acquiring various types of data based on various sensors.



Images: Damage situation data in Icheon after heavy rain in 2020.
Image Source: Stryx Inc., 2020

4. Sensing Systems

Case Study: Wildfire Detection in Indonesia

- Problem:** Recurrent wildfires in Asia impacting populations and contributing to global carbon levels
- Need:** Monitoring and detection of wildfire 'hotspots'
- Obstacle:** Large area requiring monitoring; difficulty determining if a hotspot is an actual fire risk
- Solution:** Satellite-based data analysis conducted and shared with wildfire management stakeholders in each country in Asia

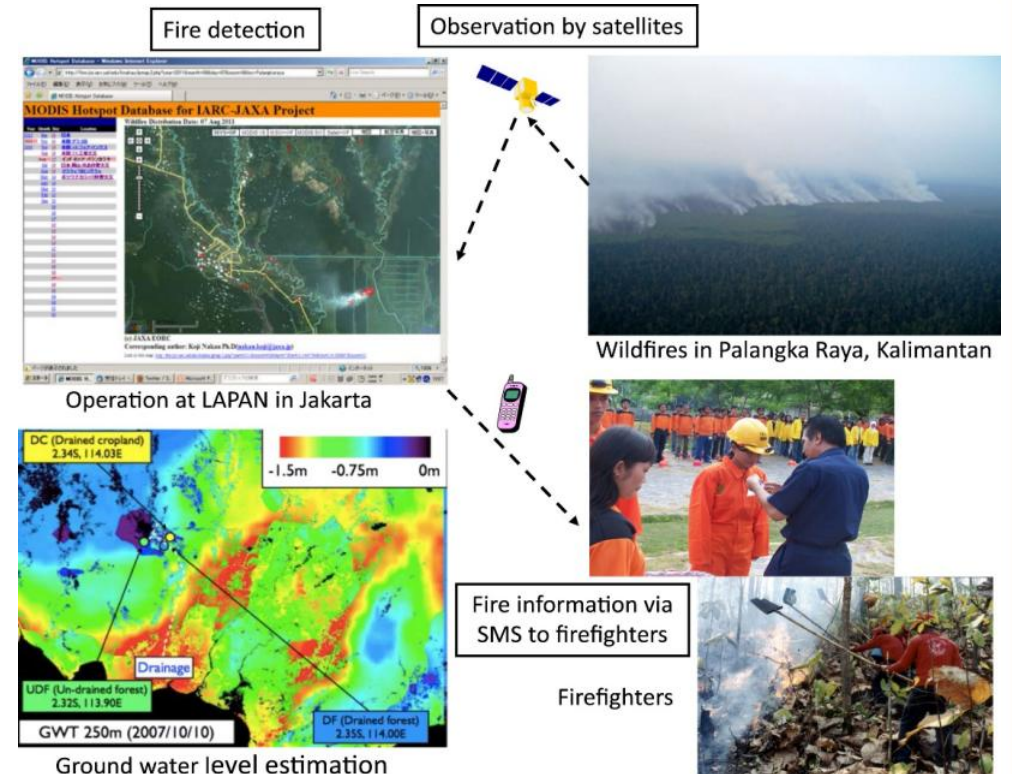


Image: Fire detection and control system of the JST/JICA project on wildfire and carbon management in a peat forest in Indonesia. The photos in the upper right and middle right are provided courtesy of A. Usup of Palangka Raya University; the lower right, the National Park, Wildlife and Plant Conservation Department, Thailand. The fire detection system in the upper left was developed by K. Nakau of Hokkaido University. The ground water level estimation system in the lower left was provided by W. Takeuchi of the University of Tokyo.

■ Case Study: FINDER

- **Problem:** Victims trapped under debris must be identified and rescued quickly
- **Need:** Information confirming the presence and location of victims
- **Obstacle:** Detecting humans through debris is difficult, and no system can locate victims in any condition or scenario
- **Solution:** Radar systems able to detect a human heartbeat through mixed or solid concrete



Image: The Finding Individuals for Disaster and Emergency Response (FINDER) system being used in Nepal to assist in rescue efforts after the April 25, 2015, earthquake.
Image Source: NASA, 2015.

■ Case Study: 2010 Russia Heatwave

- **Problem:** Heatwaves do not impact all areas in a uniform manner, thereby requiring prioritization of resources based on need
- **Need:** Location-specific data showing areas of highest exposure
- **Obstacle:** Assessment of rapidly-changing conditions over very large geographic areas is not possible using earth-based systems
- **Solution:** Satellite-based sensors that measure temperature

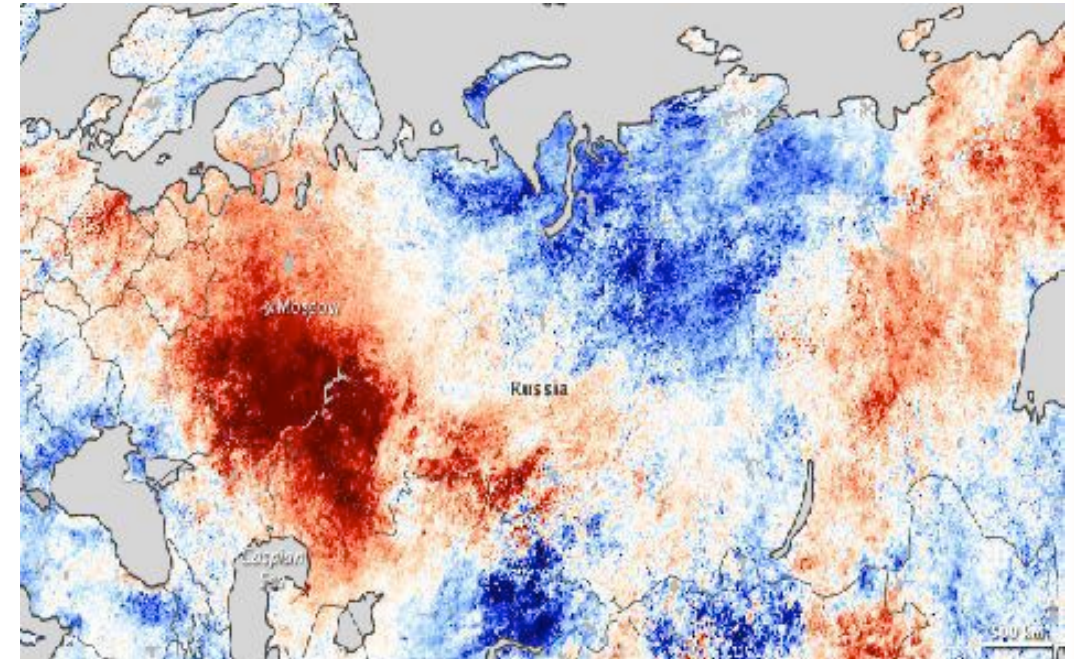


Image: Map of temperature anomalies in Russia during the 2010 heatwave.
Image Source: NASA, 2010.

4. Sensing Systems

■ Case Study: Measuring Displacement During the 2018 Indonesia Earthquake

- **Problem:** Resilience of recovery efforts following a major seismic event is contingent on accurate risk data
- **Need:** Land displacement and deformation data
- **Obstacle:** Land deformation data requires accurate before and after data across the entire affected area
- **Solution:** ESA partnership surveys post-disaster land and compares with pre-disaster data to create relevant impact products

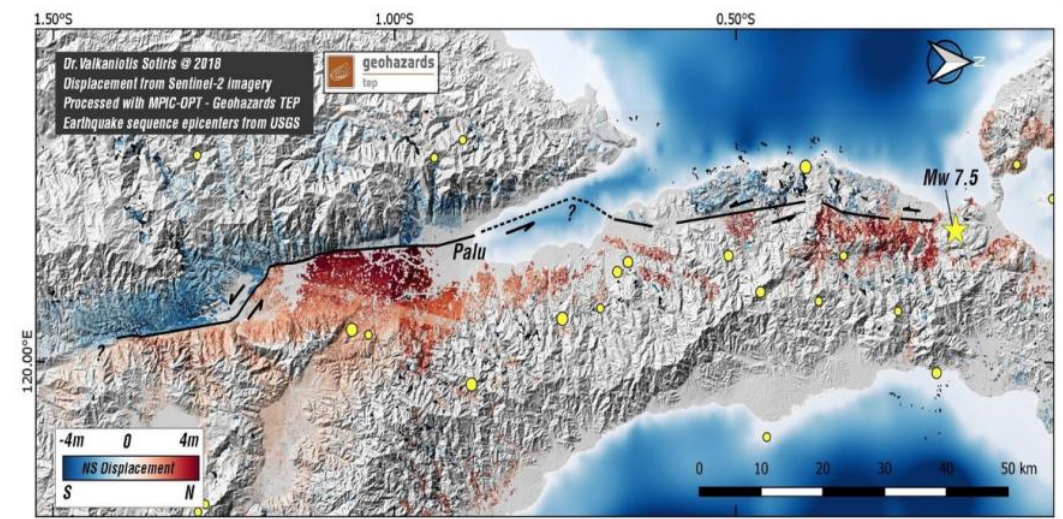
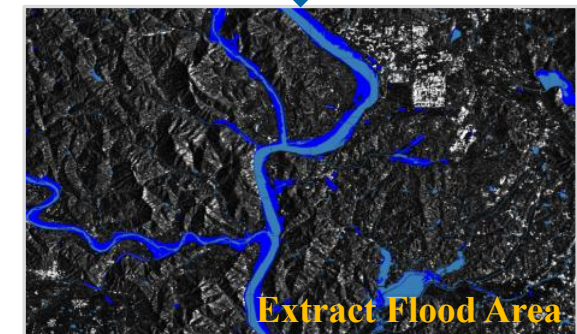
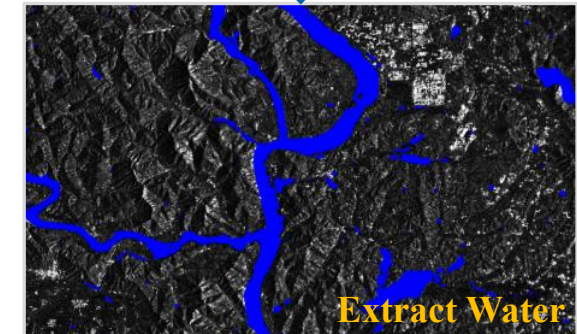
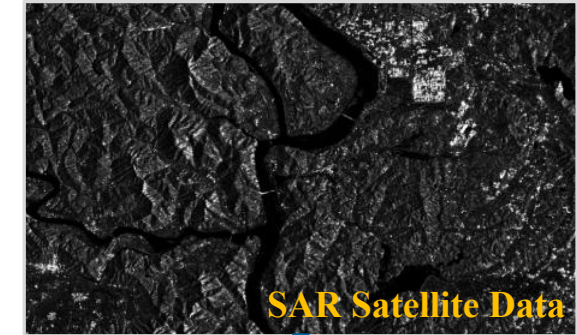


Image: Map of land displacement in Indonesia following the 2018 earthquake..
Image Source: ESA, 2018.

4. Sensing Systems

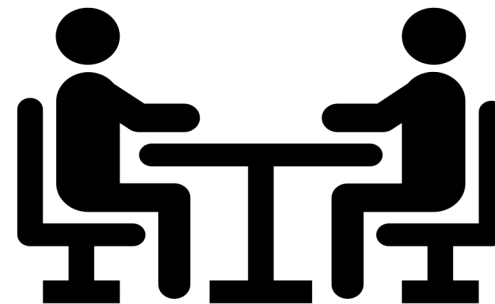
■ Case Study: Extracting Flood Areas via SAR Imaging During 2020 Heavy Rain

- **Problem:** Flood areas from heavy rain should be identified.
- **Need:** Surface data in the area where the disaster occurred.
- **Obstacle:** When using general optical images, it is difficult to identify all surfaces in the area due to clouds.
- **Solution:** Extraction of flood-caused areas through cloud-free SAR data.



Images: SAR Image and Flood Area
Source: Seoul National University.

Group Work and Activities



■ Discussion 5: Value of LiDAR Program Data

- Divide the participants into up to 7 groups.
- Assign each group 1 or 2 of the products developed in the Samoa LiDAR program.
- Using your knowledge or internet research, develop a list of ways the assigned datasets may be used to support DRR planning efforts.

Key Readings

- American Red Cross, et. Al. 2015. Drones for Disaster Response and Relief Operations. April. <http://bit.ly/2VcAmdE>.
- Paganini, Marc, and Ivan Petiteville. 2018. Satellite Earth Observation in Support of the SDGs. European Space Agency. <http://bit.ly/35Dim0X>
- United Nations. 2019. Asia-Pacific Disaster Report 2019 – specific chapter – Technological innovations for smart resilience (<https://www.unescap.org/sites/default/files/APDR%202019%20Chapter%204.pdf>)



Thank you