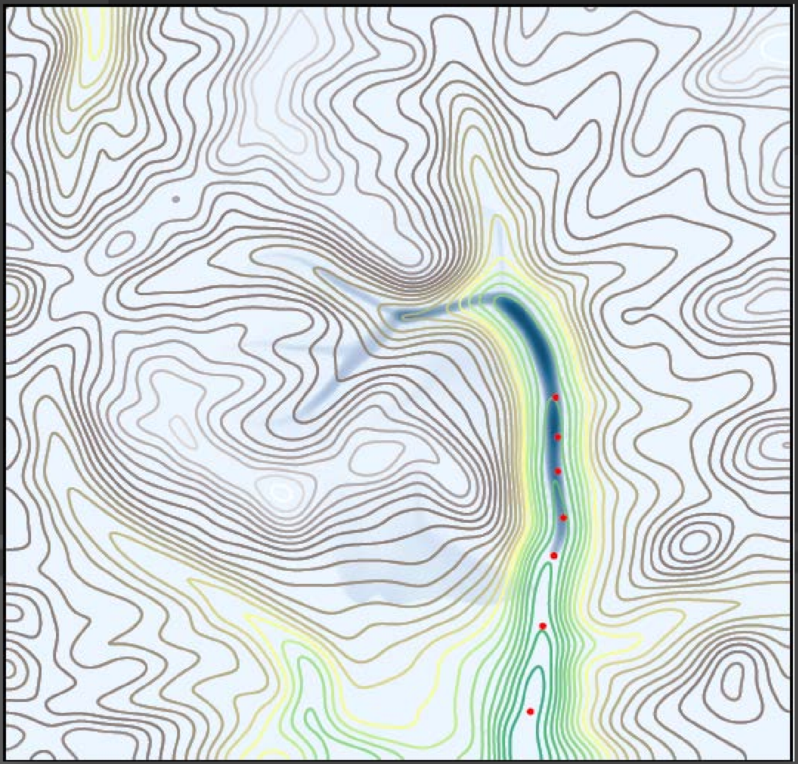
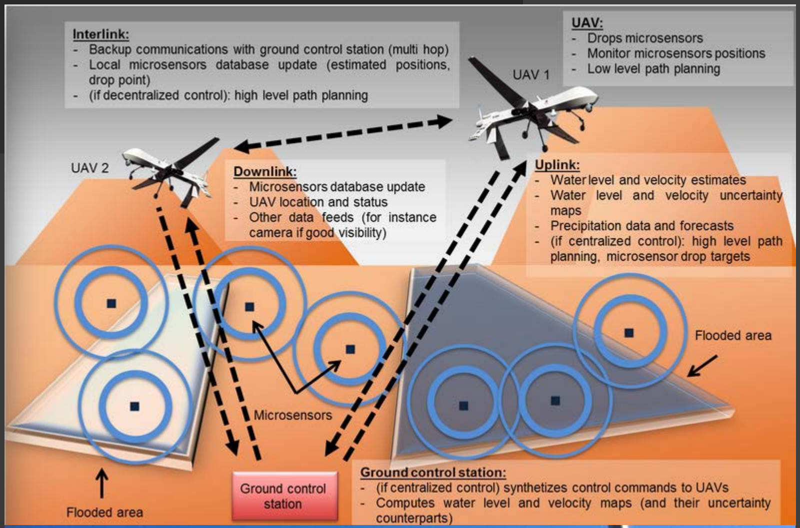
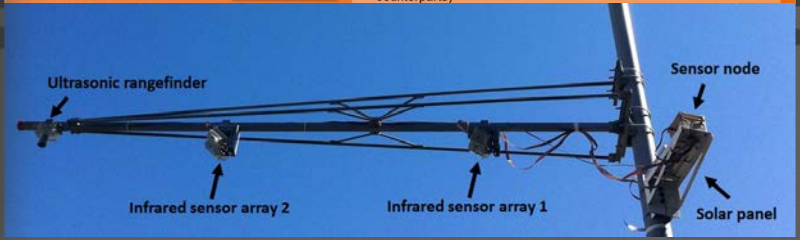
# Real-time flash flood monitoring and forecast using fixed/mobile sensor networks







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**ICT4DM- Mauritius – September 2013**

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# Motivation (floods)

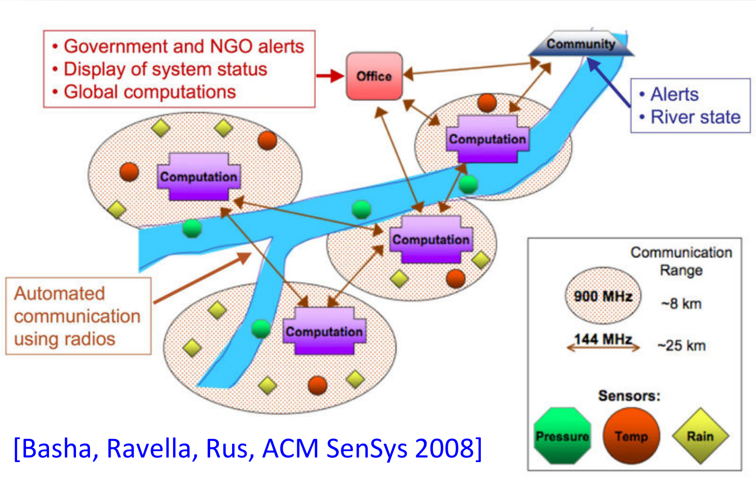
- Floods are one of the most common natural disasters in the world, accounting for more than 50% of all disasters.
- 4000 casualties worldwide, most due to flash floods.
- People not aware of the danger of floods.
- No real-time monitoring to date.
- Generic warnings (“risk of flood”) too vague, not followed by everybody.

# Motivation (floods)

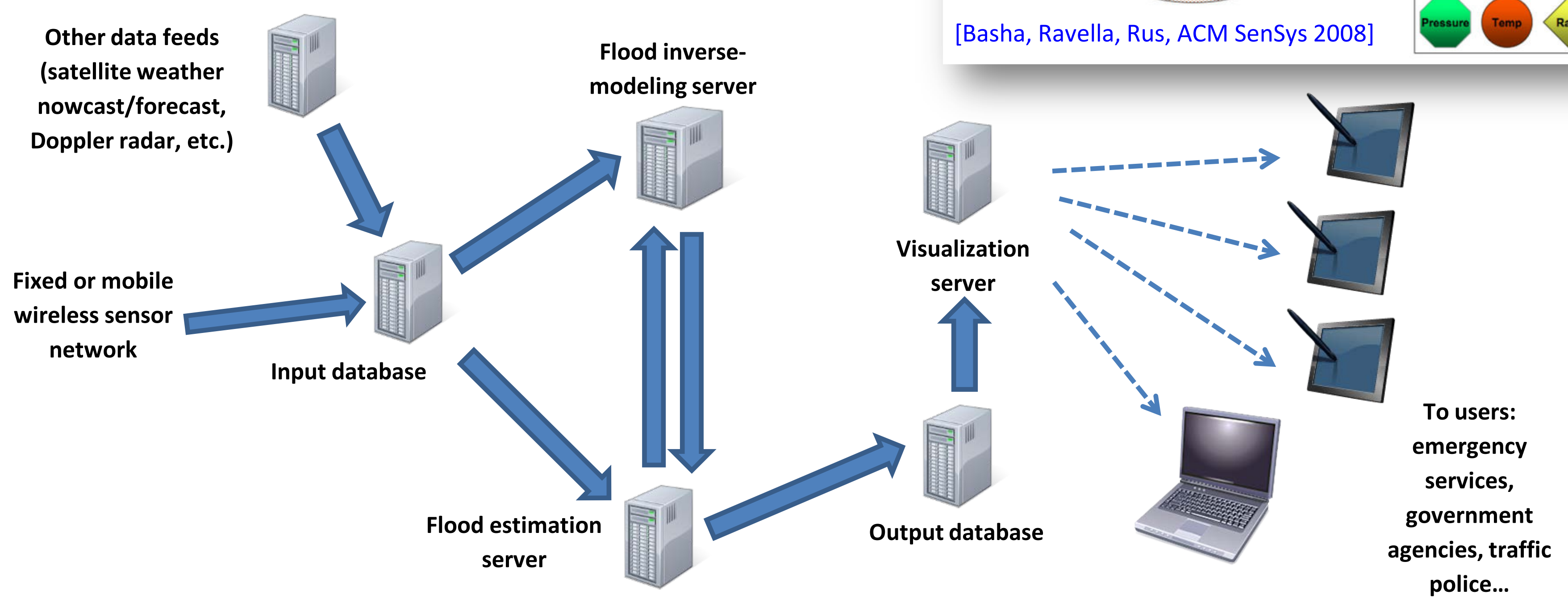
- To date, only limited experiments aimed at sensing floods have been carried out. Defense largely relies on (inaccurate) flood simulations.
- Most notable experiment: Rus et al. (2008, MIT) with fixed water level sensors, in central America.
- This approach can only be used in areas where a river is initially present, excluding all desert areas.

# Generic flood sensing system architecture

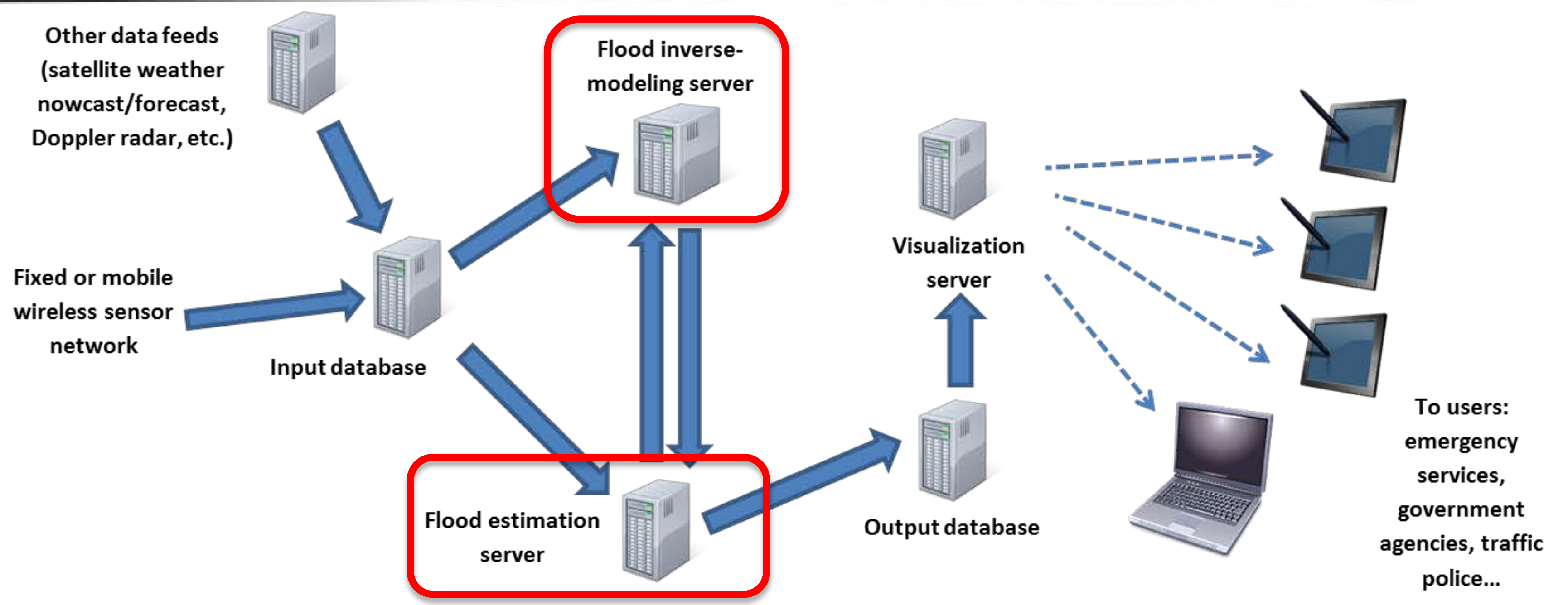
- Sensors: fixed (Eulerian) or mobile (Lagrangian).
- Sensing principle: ultrasound/PIR (city), ultrasound/pressure (river, flood channel), UAV-Lagrangian (desert, large area).



[Basha, Ravella, Rus, ACM SenSys 2008]



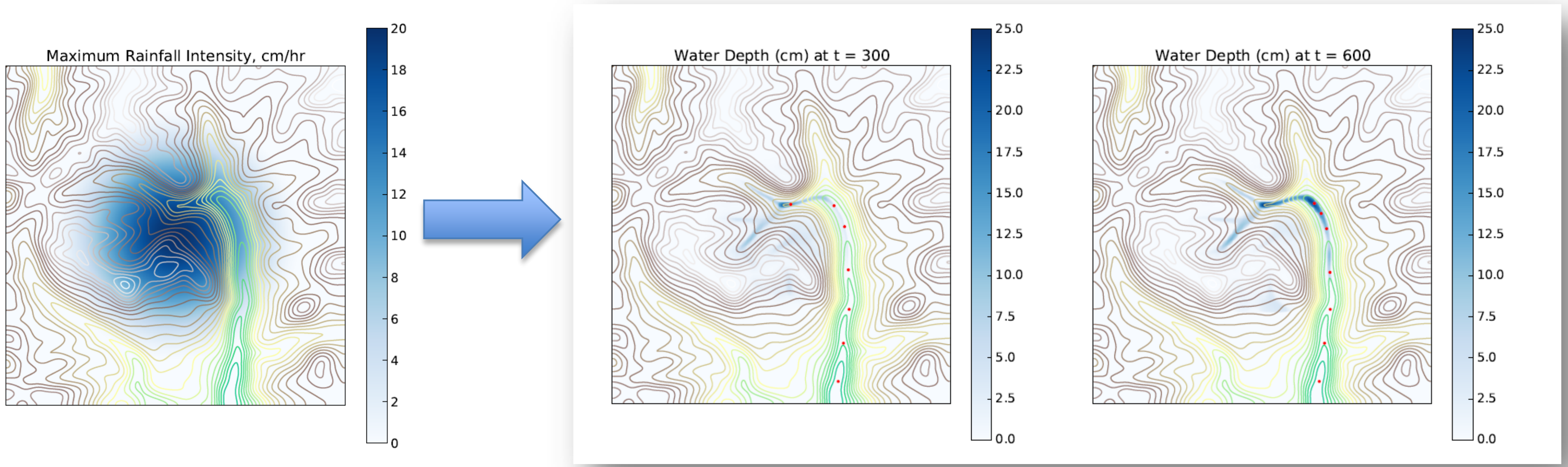
# Flood estimation/inverse modeling



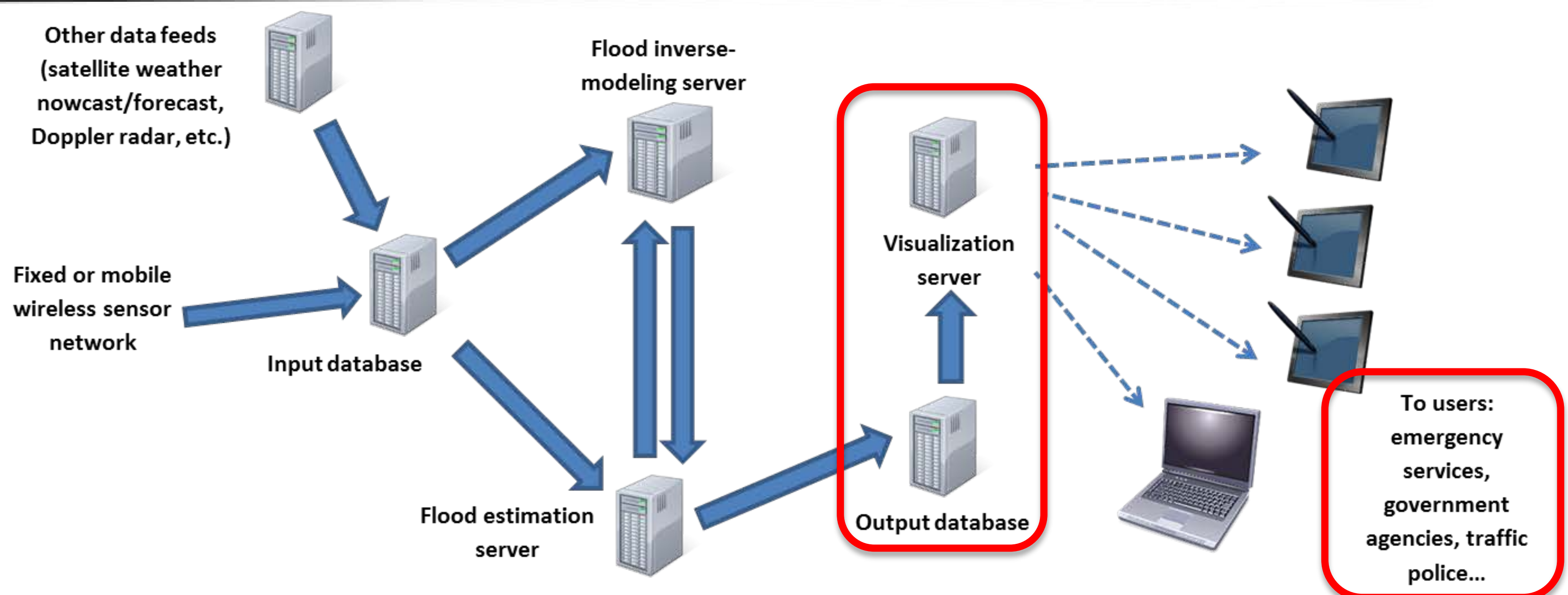

- Standard algorithms can be used to solve the flood estimation problem, such as Ensemble Kalman Filtering (EnKF), Particle Filtering, variational data assimilation, etc.
- Flood inverse modeling is more complex to perform, though it does not absolutely have to be solved in real time: solving in real time the flood inverse modeling problem can improve accuracy, but is not required.

# Flood estimation/inverse modeling

- The flood estimation server and the inverse modeling server require a dynamical model of the flood propagation.
- Models are usually in the form of St Venant equations/ shallow water equations, or can be other hydrological models.
- The models require the definition of the landscape (terrain type, altitude isolines).
- Simulations can be run based on previous flooding events to better calibrate the model parameters (and thus increase the accuracy of the real-time forecast).

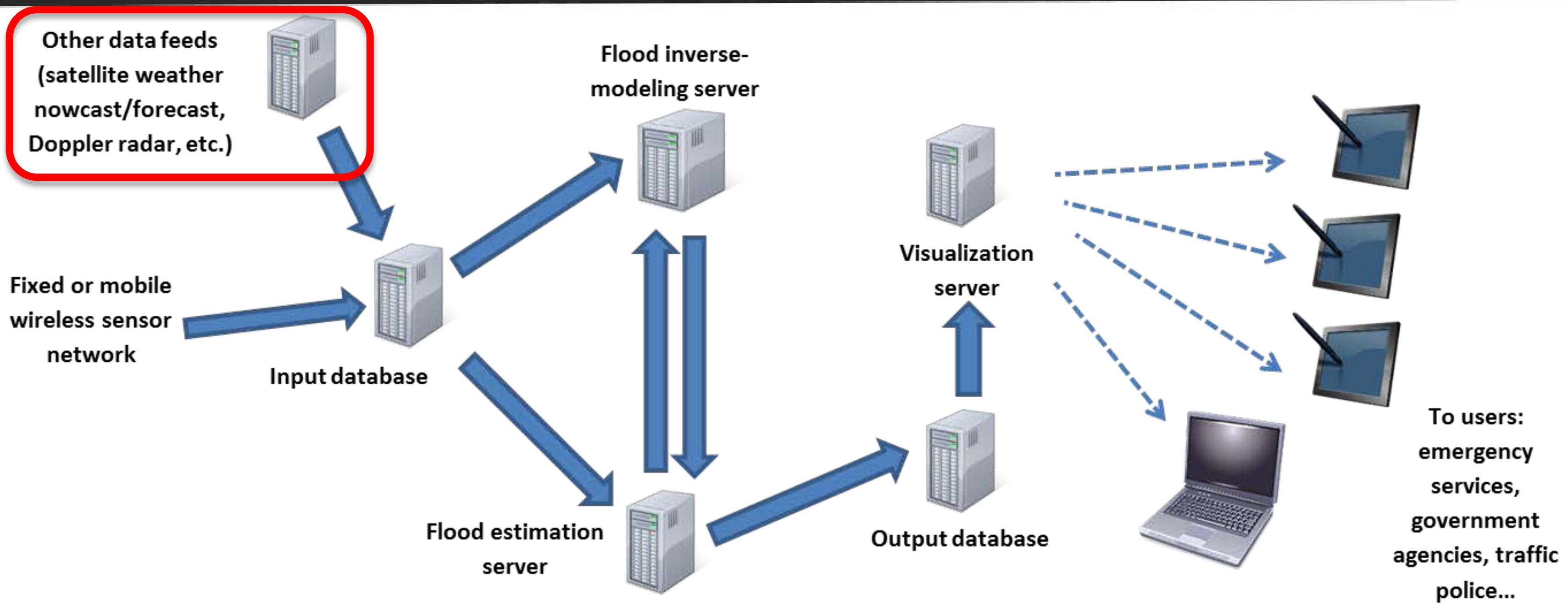


# Visualisation/dissemination



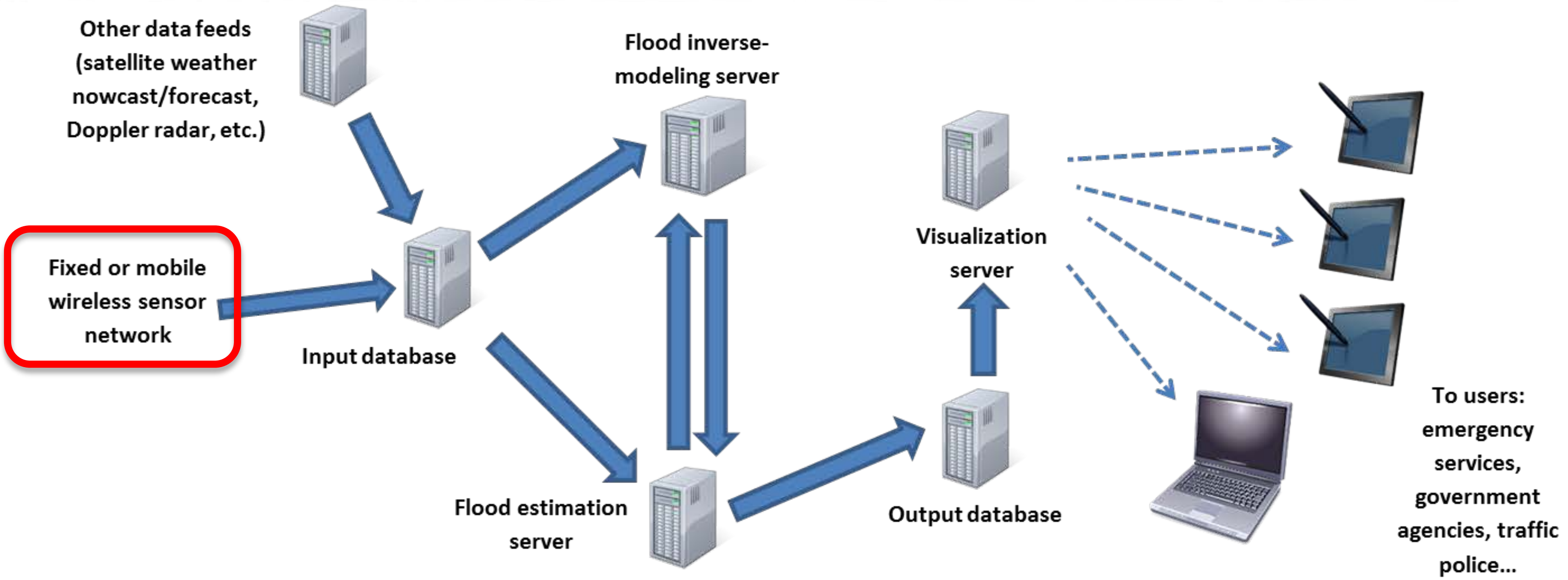

- Output DB and visualization server are straightforward (with new tools such as CartoDB).
- Dissemination to users: network needs to be resilient to outages. For smaller set of users (police/government agencies/emergency services dedicated networks can be used if available).

# Auxiliary data feeds



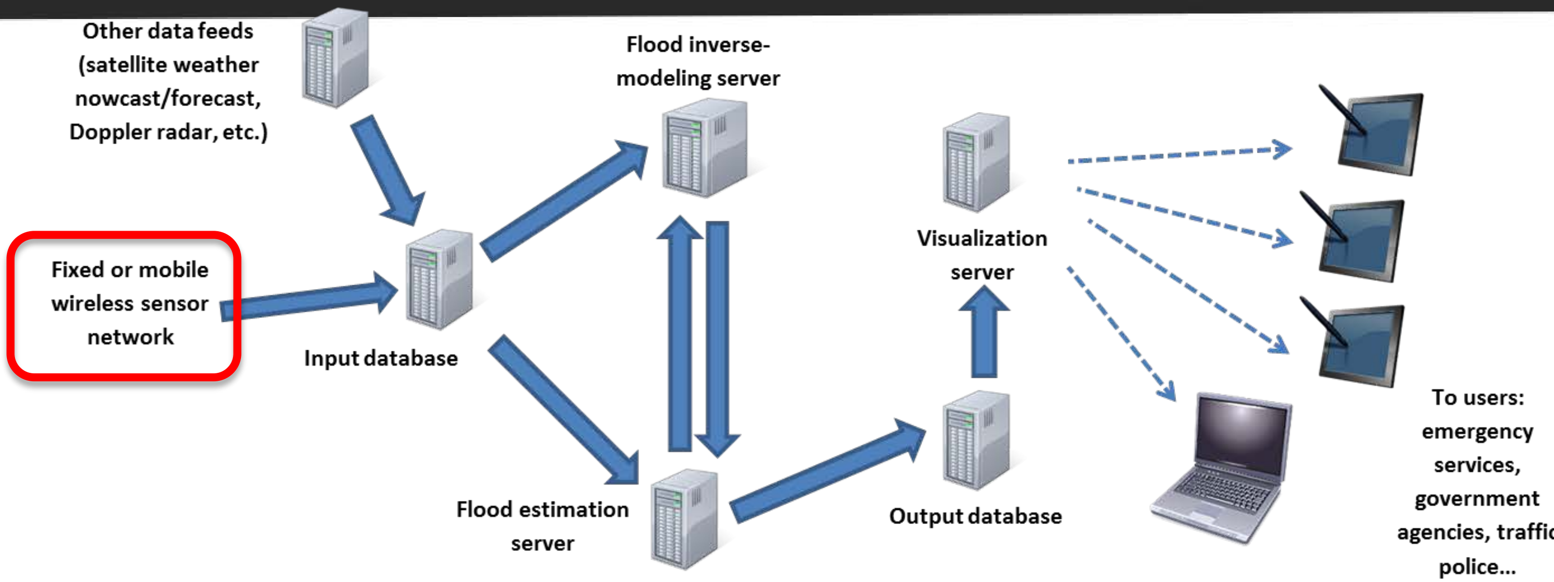

- Any type of weather information is useful: satellite weather nowcast, real-time rain gauge measurements, weather forecasts, weather precipitation data).
- Higher resolution of these feeds will improve the accuracy of flood maps, to a certain extent.

# Main data feeds




- No satellite-based data can be used for flood detection for two reasons:
  - Synthetic aperture radars are too inaccurate (1m vertical resolution), and sensitive to rain
  - Geostationary satellites do not have this capability

# Main data feeds




– **Fixed sensors (Eulerian)**

Pros: cheap (for small areas), straightforward to implement (WSN-based)

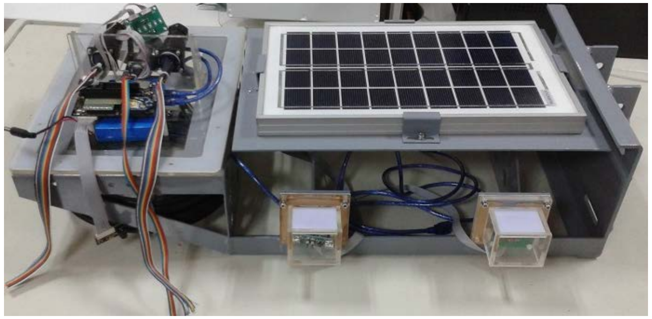
Cons: can only instrument a limited area, sensing capability is lost if the flood occurs in a geographical area area that is not instrumented

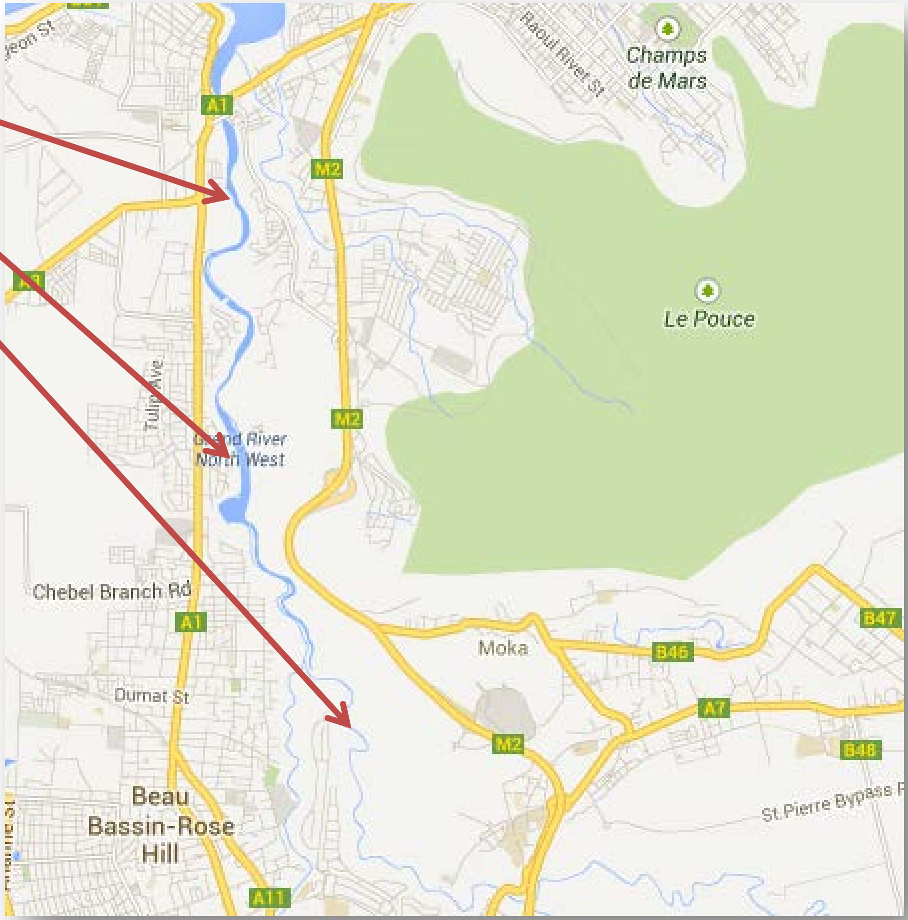
– **Mobile sensors (Lagrangian)**

Pros: cheap (for larger areas), capable to sense any area on demand

Cons: slightly more expensive for small areas, higher level technology

# Fixed sensors: rivers, flood channels

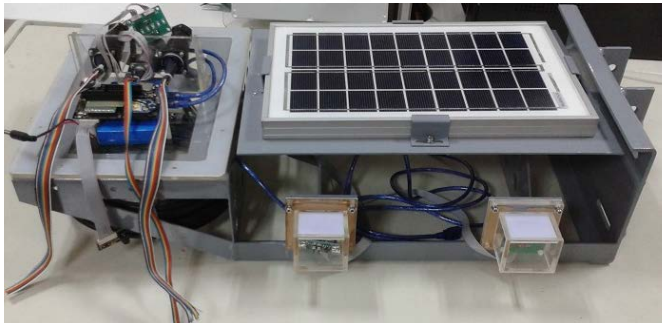


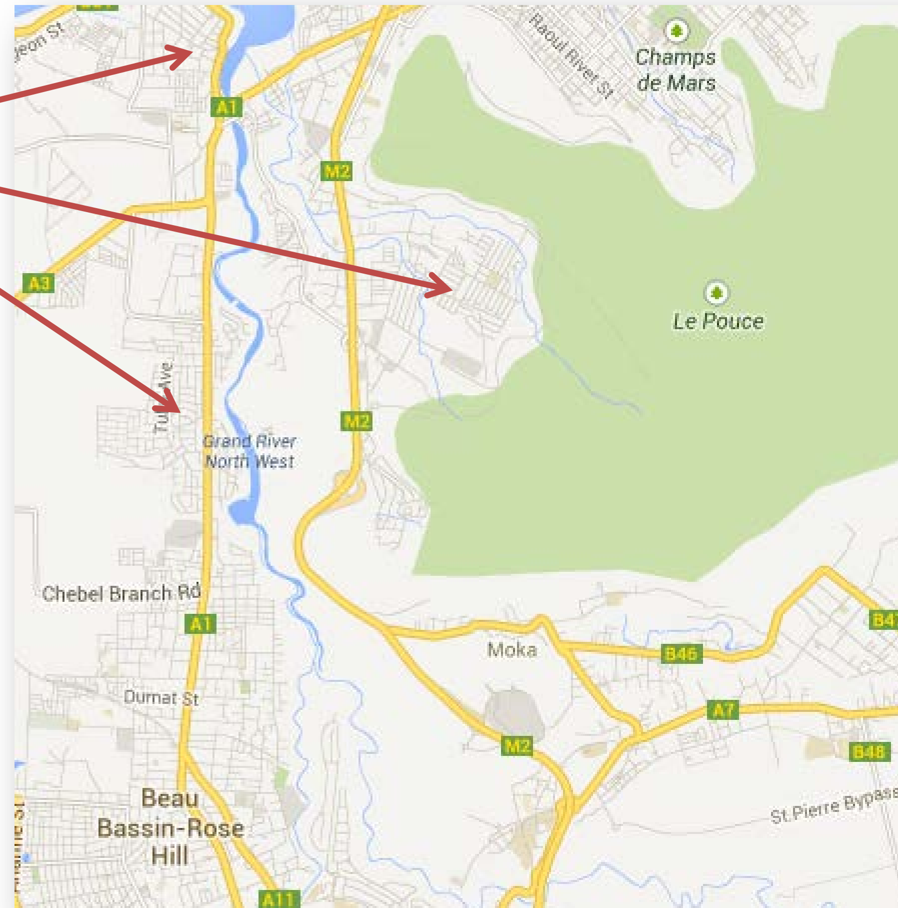



- Radio range: few hundred meters, multi-hop.
- Attached sensor: ultrasonic (bridges), pressure (absolute).
- Pressure sensors are slightly less accurate as they measure a mix of static and dynamic pressure.
- Can be augmented with Lagrangian microsensors (disposable, used only when a flood occurs).
- Solar or grid powered (with battery backup).

[Jiang, Claudel, IEEE Symposium on Industrial Embedded Systems (IEEE SIES), 2013]

# Fixed sensors: smart cities

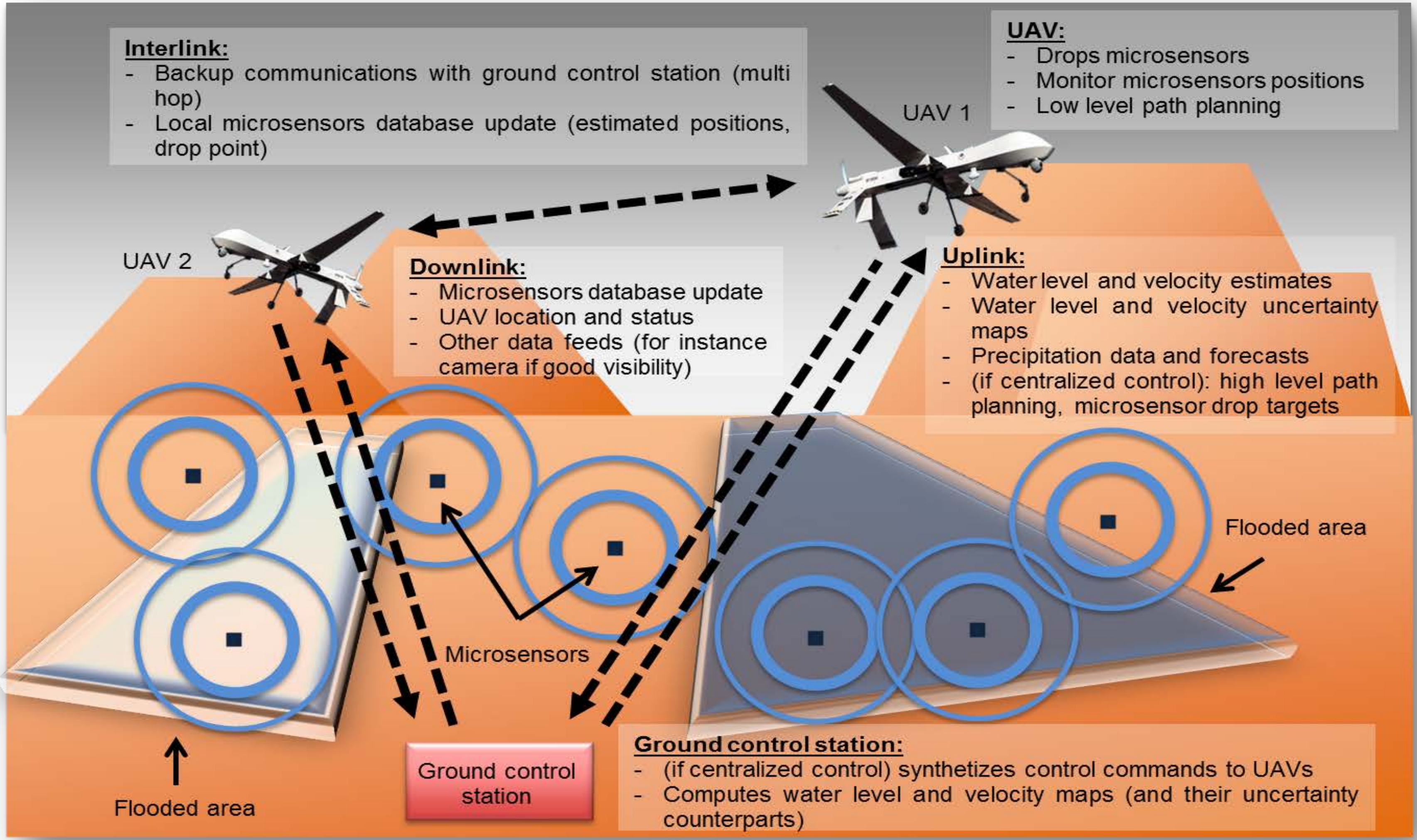





- Radio range: few hundred meters, multi-hop.
- Attached sensors: dual ultrasonic + PIR.
- Double as real-time traffic flow sensors (for day-to-day use).
- Can be similarly augmented with Lagrangian sensors (disposable, used only when a flood occurs).
- Solar or grid powered (with battery backup).

[Jiang, Claudel, IEEE Symposium on Industrial Embedded Systems (IEEE SIES), 2013] [Wariach, Claudel, ACM Sensys, 2013]

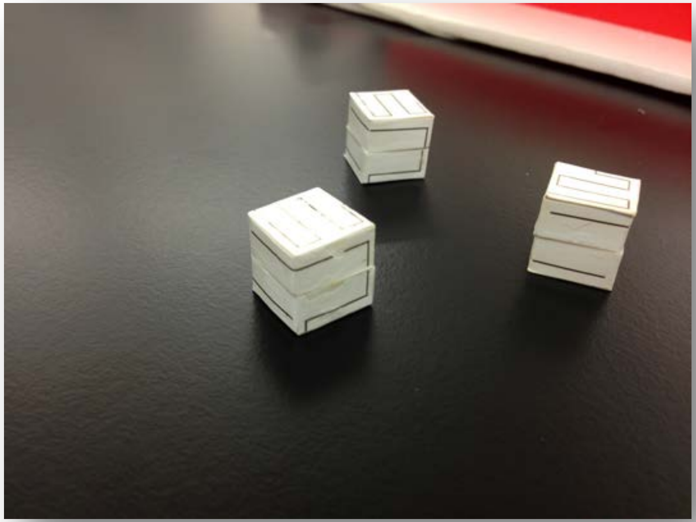
# Mobile sensors: UAV-based sensing

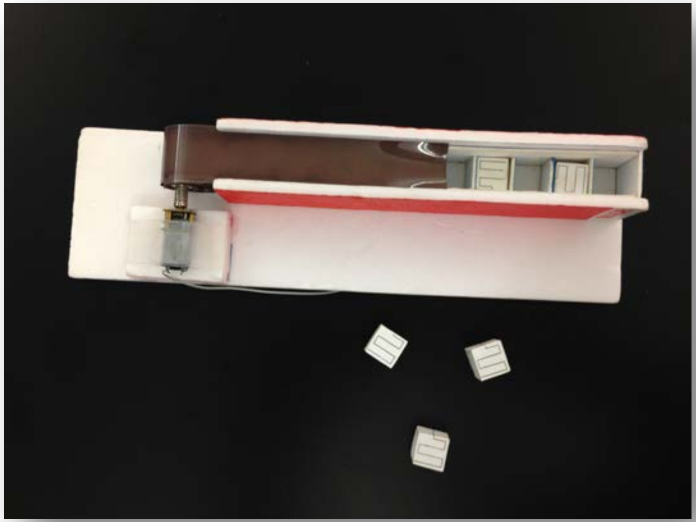



[AbdelKader, Shaqura, Claudel, Gueaieb, Jiang, Claudel, International Conference on Unmanned Aircraft Systems (ICUAS), 2013]

# Microsensor design (IMPACT group, Prof. Atif Shamim, KAUST)

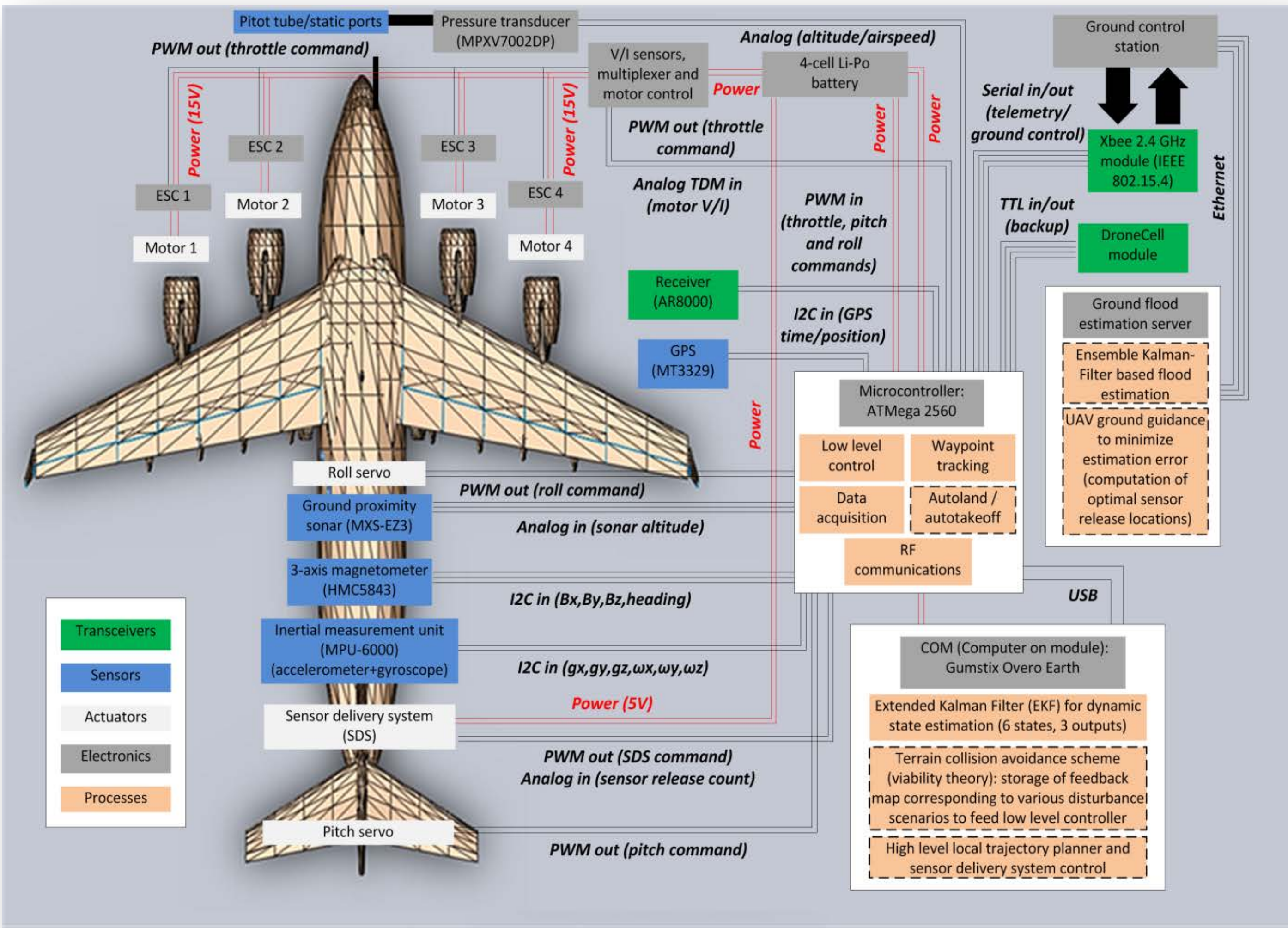
- Chosen technology: printed circuits on paper (PCPs)
  - Cheap, can be printed relatively inexpensively (<1 USD/unit)
  - Antenna is printed on the package (reduces costs, makes emission more isotropic)
  - Absorbs impact more easily
  - Easy to waterproof
  - Can also be used as <u>a disposable contaminant tracking</u> device for monitoring oil-spills/contaminant spills in seawater or freshwater (sharing a single system for two roles)

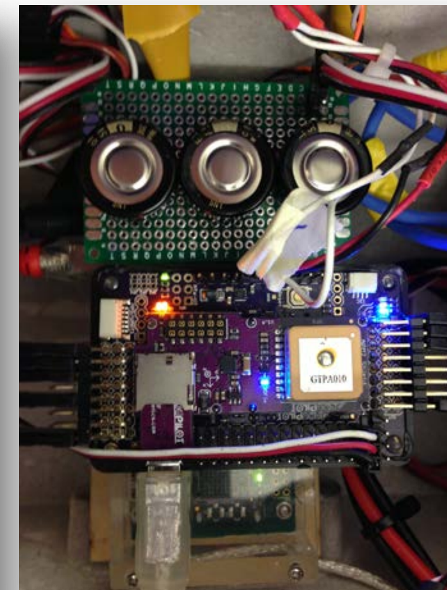




[Farooqui, Claudel, Shamim, IEEE Transactions on Antennas and Propagation, 2013 (submitted)]

# Current UAV system

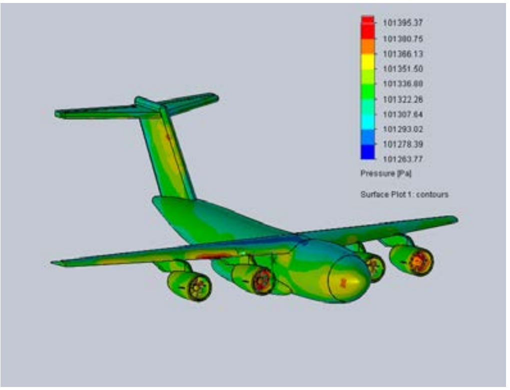


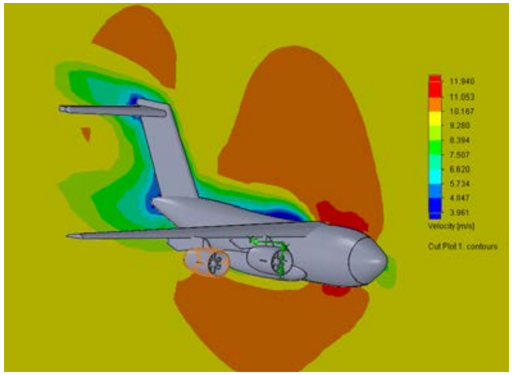



[AbdelKader, Shaqura, Claudel, Gueaieb, Jiang, Claudel, International Conference on Unmanned Aircraft Systems (ICUAS), 2013]

# Field testing

- Numerous flight tests since June 2012
- First live sensor drops expected in December 2013

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## Swarm of drones to give early warning of flash floods

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*A drone monitoring system that tracks flash floods in real time can buy time to escape before the waters hit*

FLASH floods are quick and deadly. At least 13 people died when a surge hit parts of Saudi Arabia earlier this month. Two years earlier, 123 were killed when thunderstorms dumped rain over arid land to the east of the Red Sea port of Jeddah, hitting the city with no warning. A drone monitoring system that tracks floods in real time would sound the alarm before the water hits.

Existing forecasting models are good at predicting roughly when an area might experience the right mix of conditions to create a flash flood, but they can't say precisely when or where a flood will strike. Christian Claudel at the King Abdullah University of Science and Technology outside Jeddah is working on a drone system that could give such cities between 30 minutes and 2 hours of warning, as well as predicting the flood's path.

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High and dry but safe *(Image: Reuters)*

This week's issue

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25 May 2013

# Team

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- Jiming Jiang (Postdoc, electronics, KAUST)
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- 4 MS students

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# Questions?

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