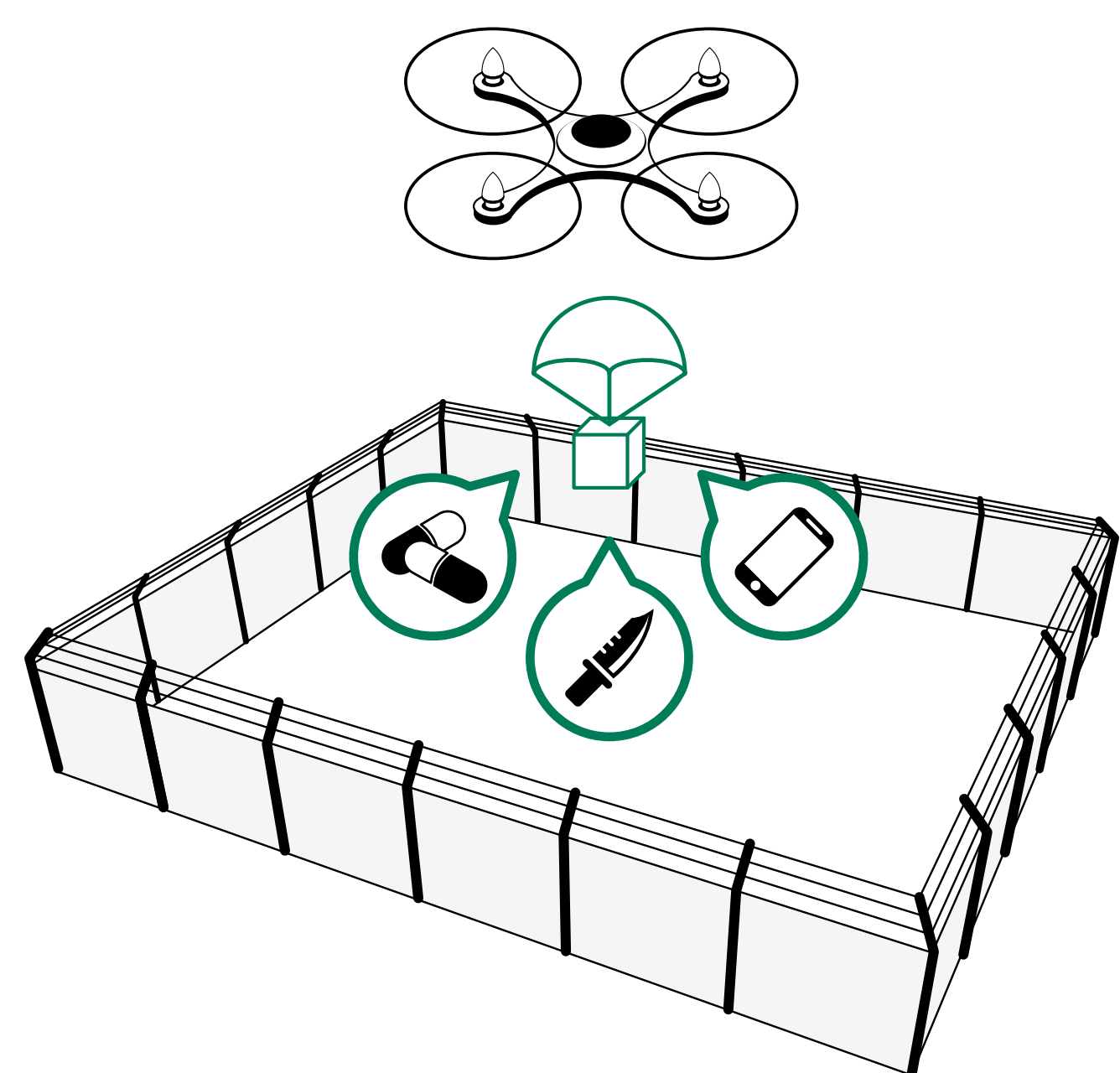




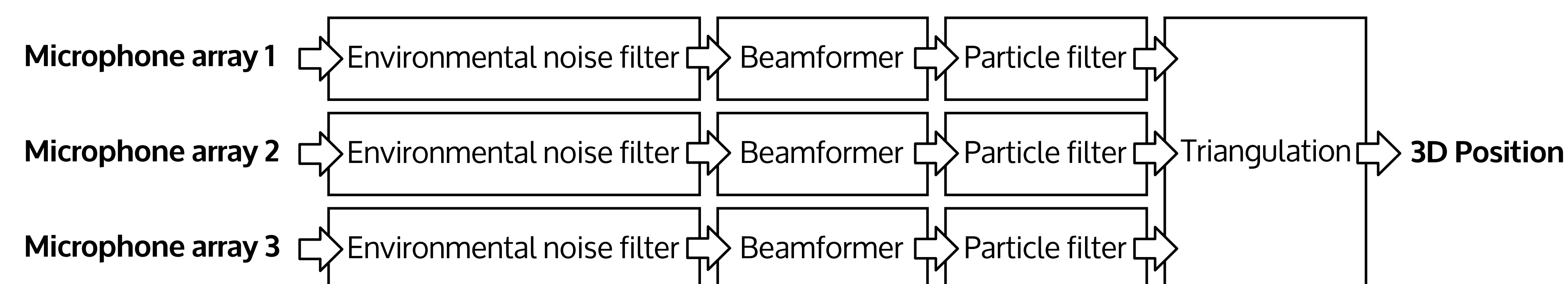
Drone Intrusions in Restricted Areas



- Inexpensive and easy-to-pilot drones are now available on the market
- Intrusions in restricted areas are common, especially over prison yards ("A new report from the FAA lists 583 separate drone incidents reported from August 2015 through January 2016" [1])
- There is a significant increase in the number of packages dropped using drones, which often contain drugs, weapons, cell phones, etc. ("The Prison Officers Association said hundreds of illicit packages are being flown in" [2])
- There is an urgent need for efficient drone detection and localization systems, either to perform live interception or to collect dropped packages afterwards

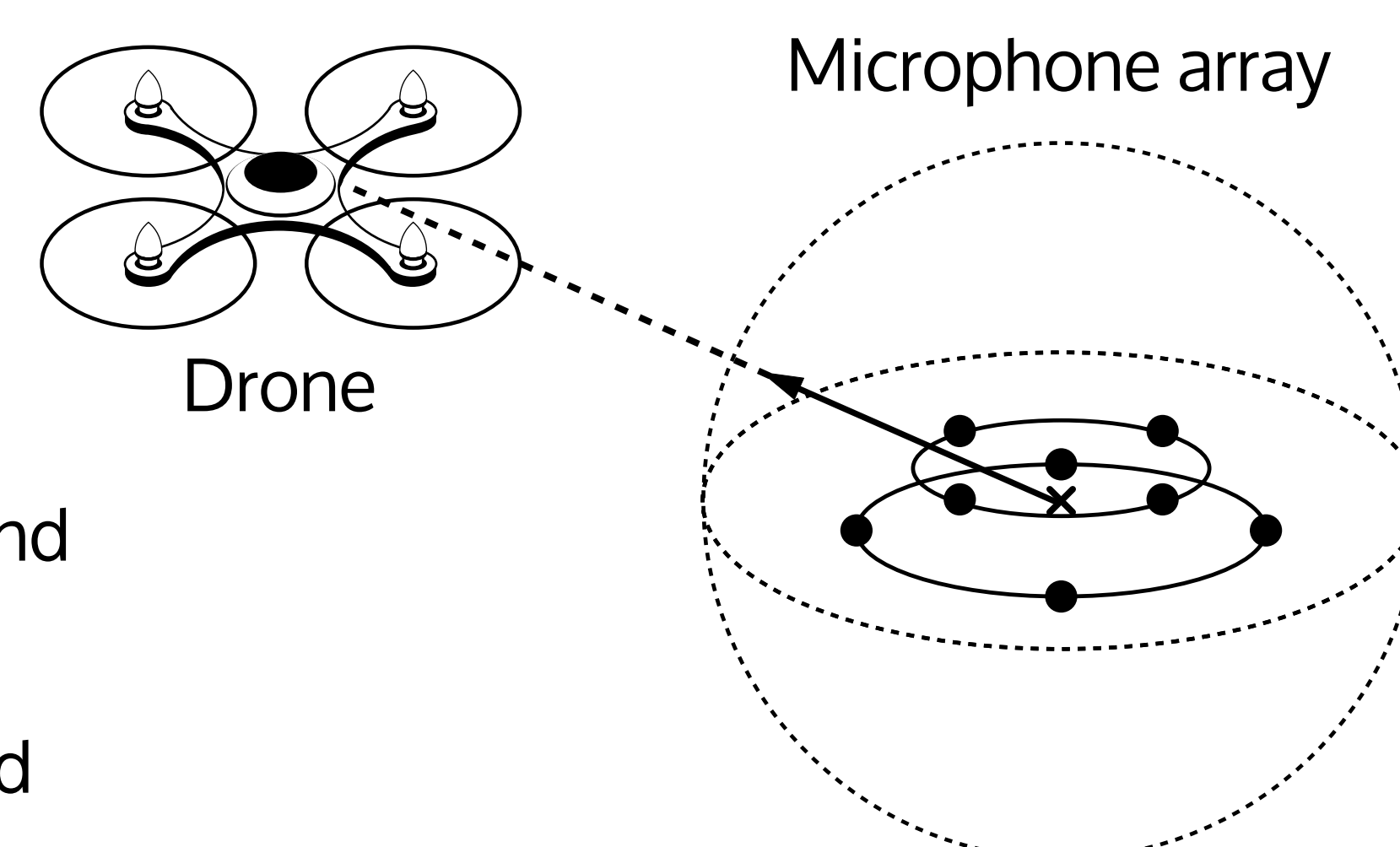
Methodology

Overview of the system

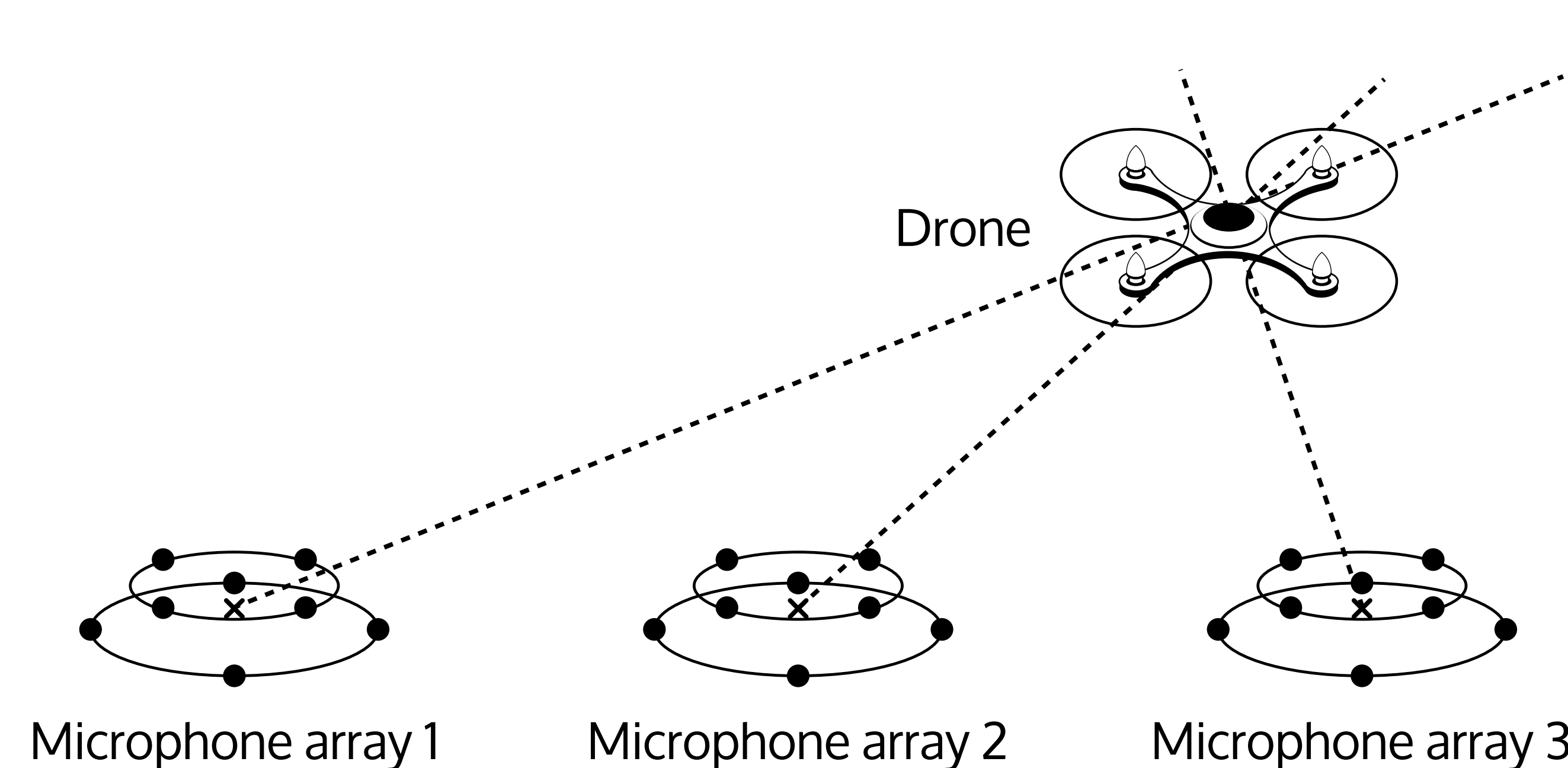


Sound source direction localization using a single microphone array

- The propellers of UAVs generate noise with a fundamental frequency and harmonics
- The direction of arrival of sound introduces a time delay of arrival on each pair of microphones of the array
- A virtual sphere around the microphone array is scanned and the most probable direction of arrival is obtained
- A particle filter is used to smooth the directions and discard sporadic false detections



Sound source absolute localization using multiple microphone arrays



- Microphone arrays are spaced with a significant distance to observe the near field effect when the drone is far away in the sky
- Triangulation is performed to obtain the absolute position of the drone from the known position of the microphone arrays and the measured direction of arrival of the sound from each array

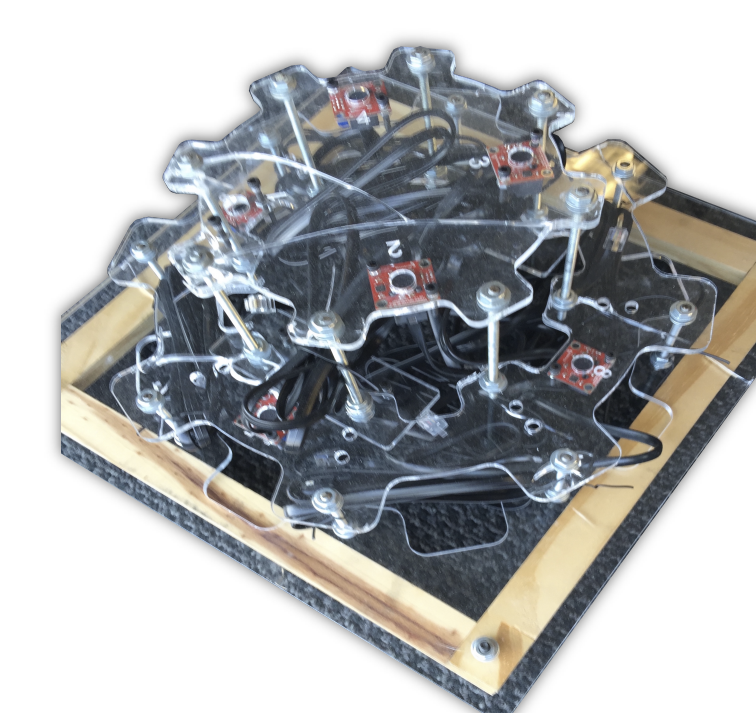
Existing Sensors for Drone Detection and Localization

<p>Radar</p> <p>Most existing radars are designed for large targets Sensitive to clutters and birds</p>		<p>Wi-Fi</p> <p>Not effective for autonomous drones</p>	
<p>Camera</p> <p>Limited field of view and limited detection ability at night, even for IR camera May misclassify birds or planes</p>		<p>Eagles</p> <p>Eagles can be trained to intercept drones, but remains an impractical solution</p>	

Results

Hardware

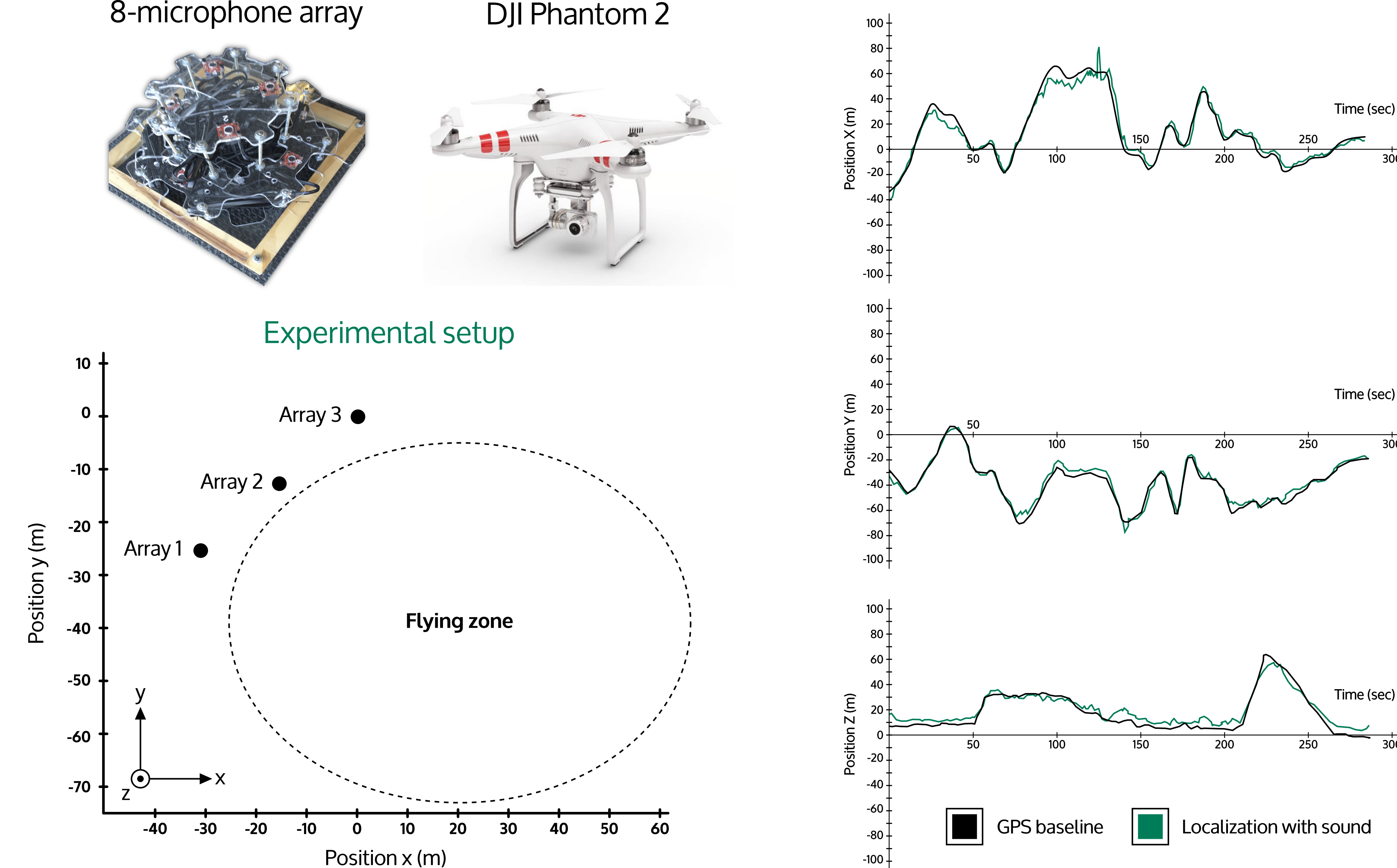
8-microphone array



DJI Phantom 2



Theoretical and measured positions



References

- [1] Bagot, M., "Drone smuggling at prisons is rocketing as criminal gangs fly in drugs and phones," *Mirror*, December 13, 2015
- [2] Brandom, R., "The FAA logged more than 500 drone incidents in six months," *The Verge*, March 25, 2016

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