# Low-cost High Precision GNSS: Challenges and Opportunities

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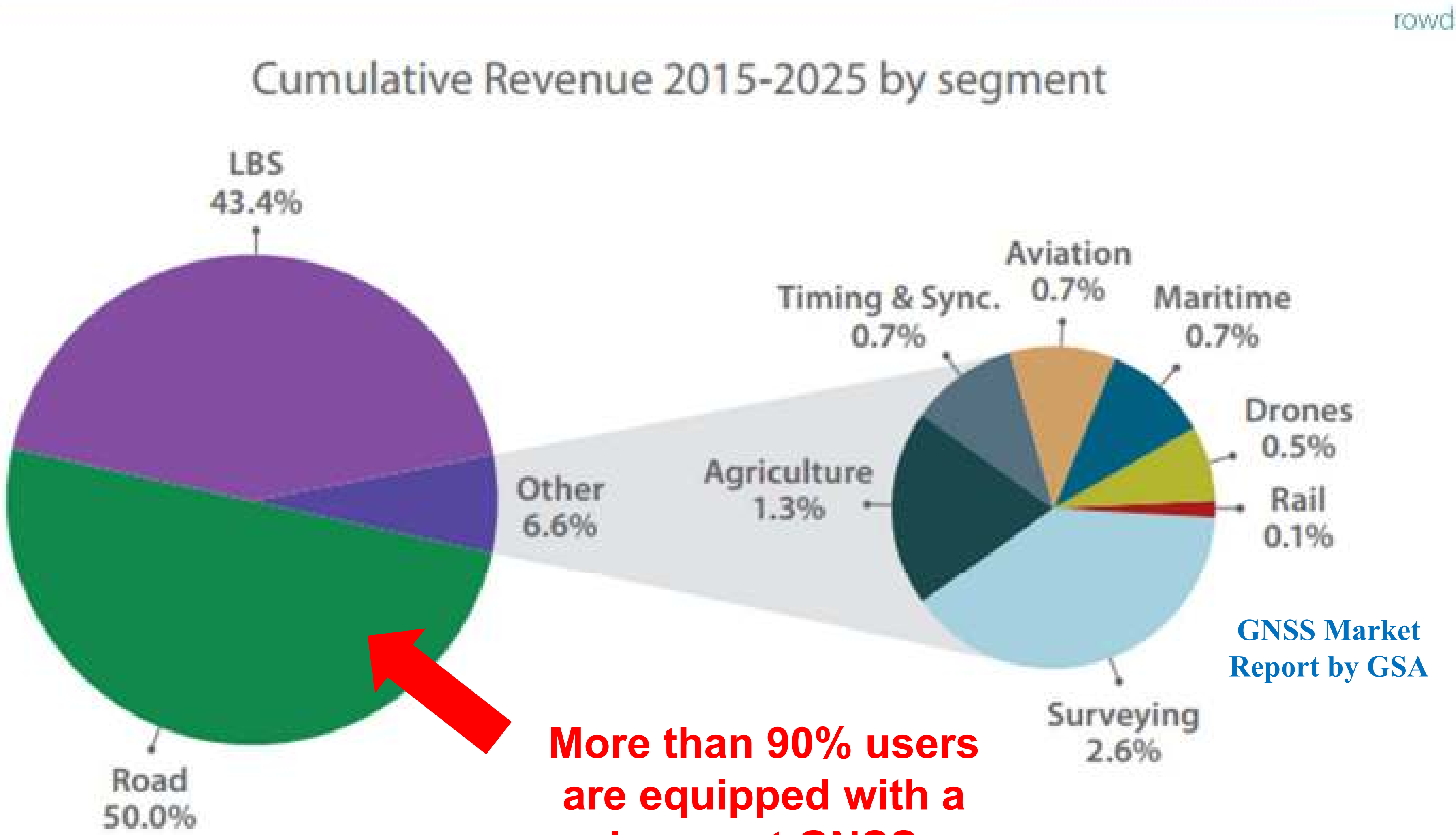
# Outline



- Why low-cost high precision GNSS?
- The challenges
- The opportunities
- Some research efforts at UC
- Looking into the future

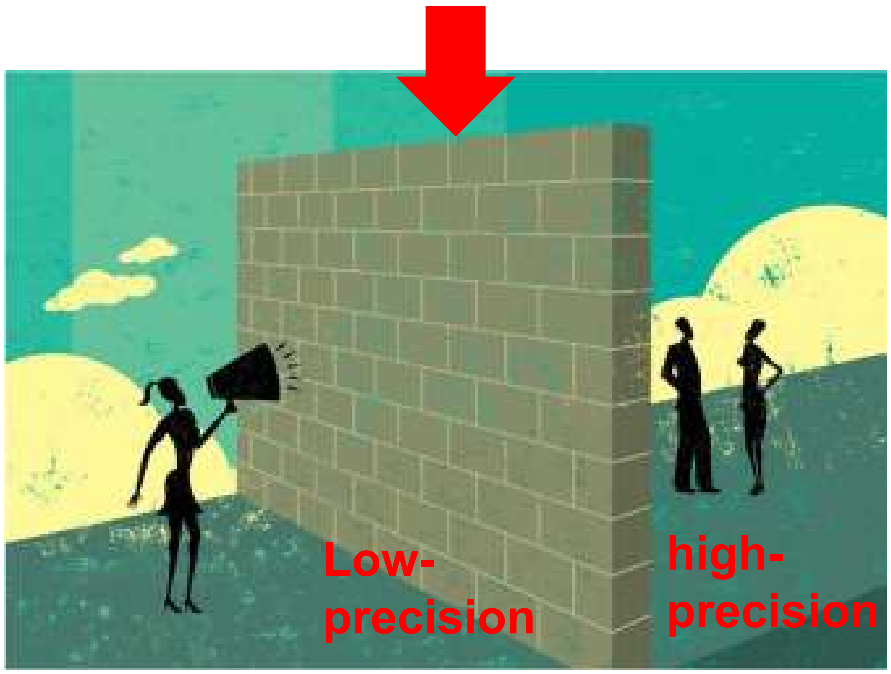
# Why low-cost high precision GNSS?




**More than 90% users are equipped with a low-cost GNSS receiver**

# Historically: Two Separate GNSS Markets for Years

**Consumer market (low-cost)**




**Precision market (professional)**

# Why low-cost high precision GNSS?




**But Today: many mass-market applications also demand high precision**


# Why low-cost high precision GNSS?

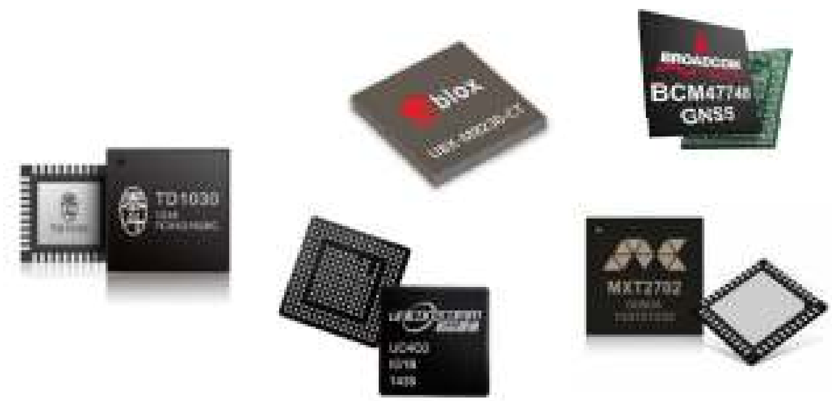


Self-driving cars demand 50cm to cm accuracy

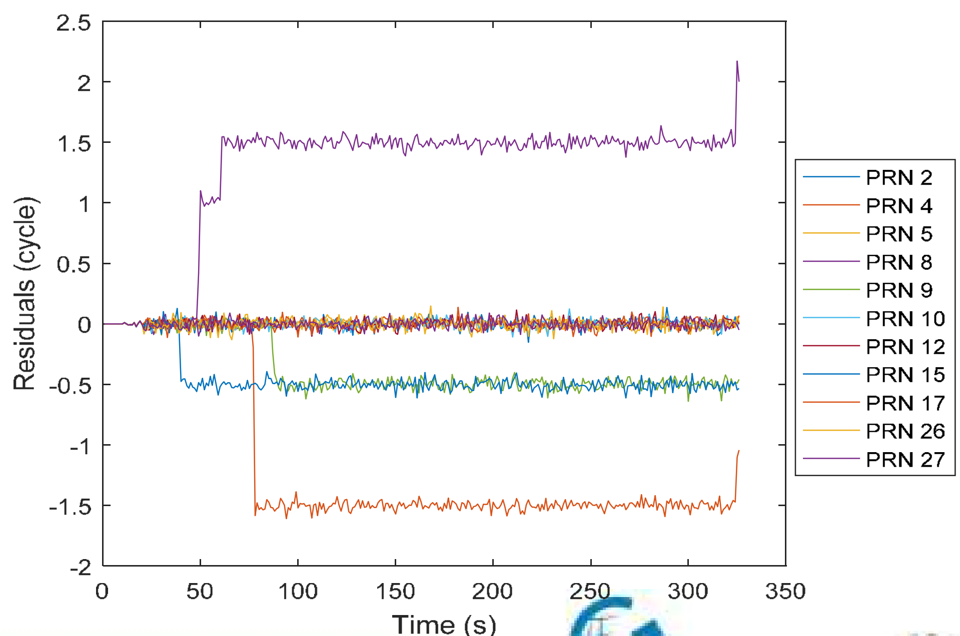
Precise tracking and geo-fencing of share-bicycles

# The Challenges

Consumer-grade GNSS chips are not designed for precision: architecture, hardware, DSP, …

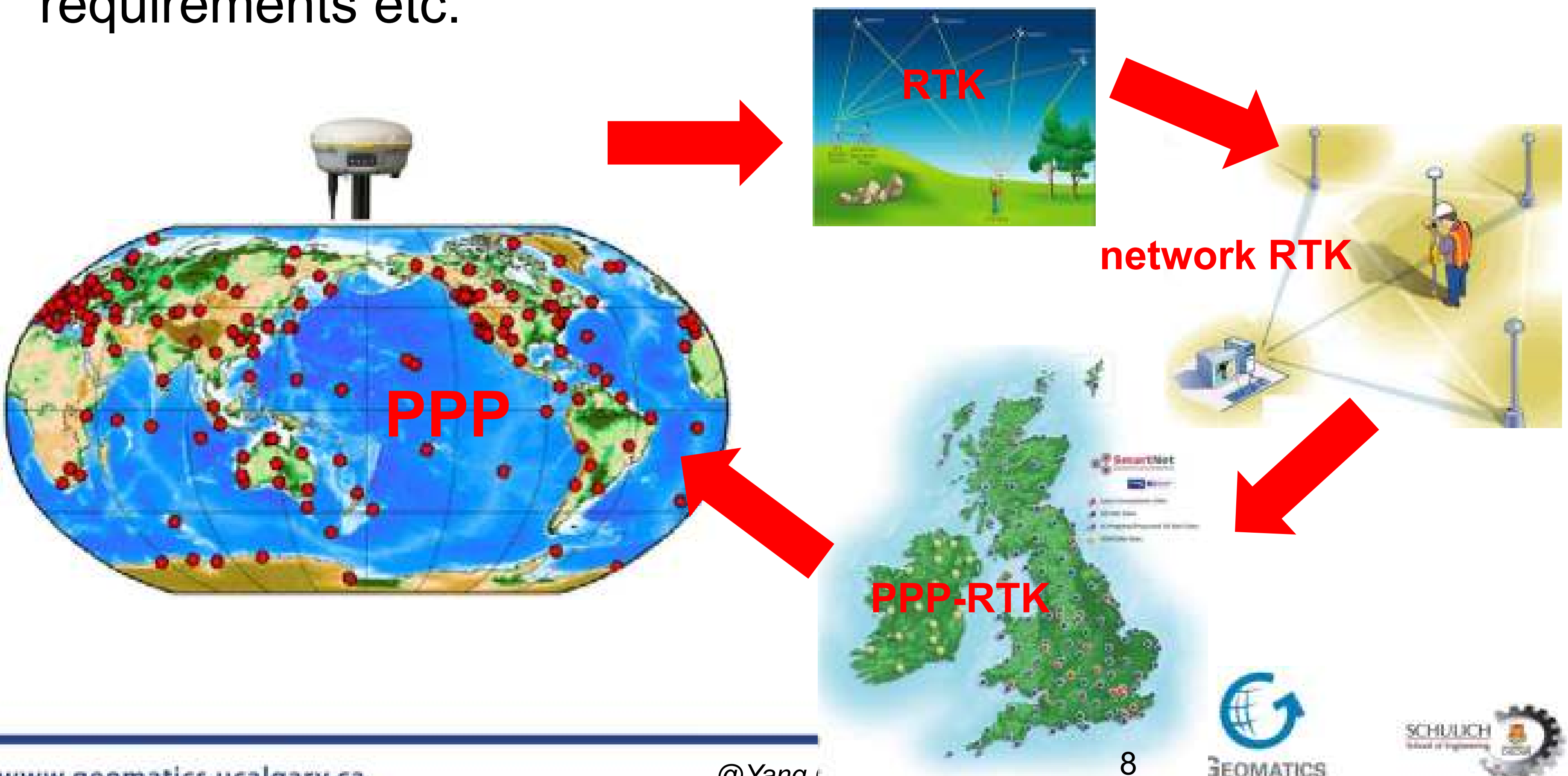



- ✓ High measurement noise level
- ✓ Frequent cycle slips
- ✓ Large multipath
- ✓ Sensitivity to dynamics
- ✓ …



# The Challenges

Existing high-precision GNSS technologies are not designed to work with low-cost GNSS receivers: error modeling, positioning algorithm, operational procedure and environment requirements etc.



# The Challenges

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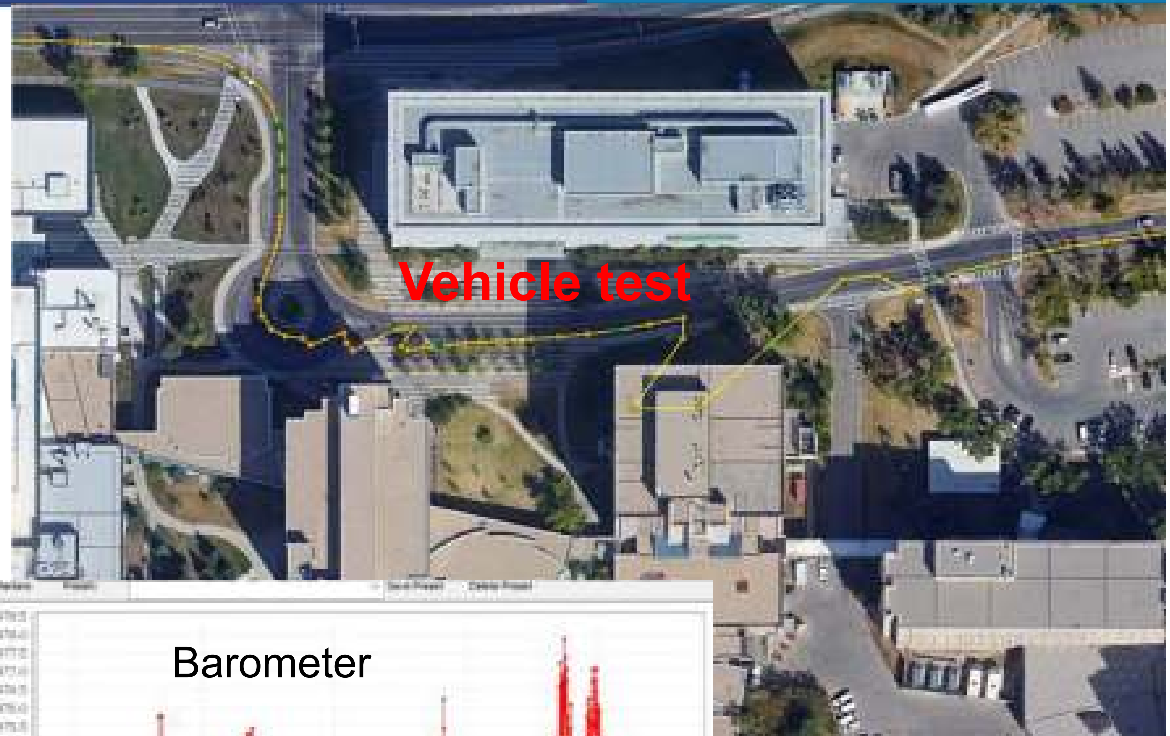
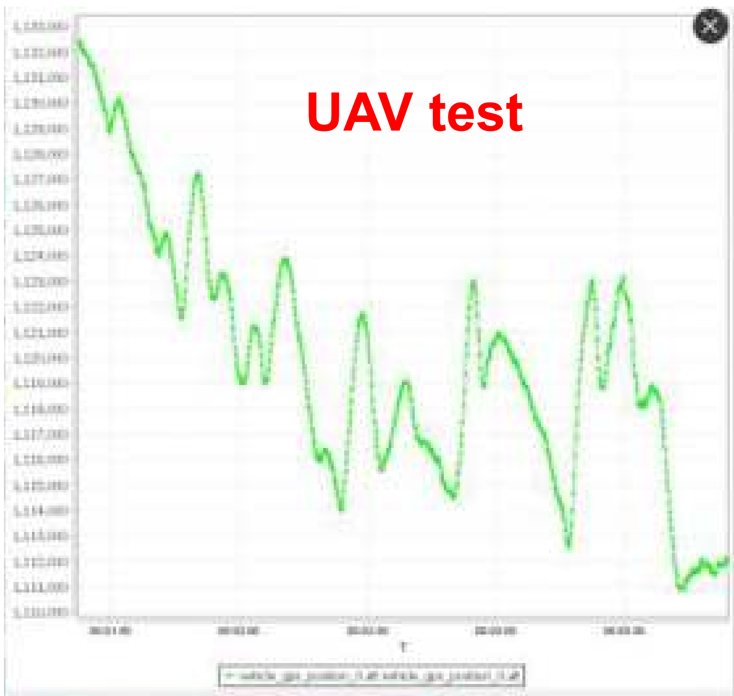
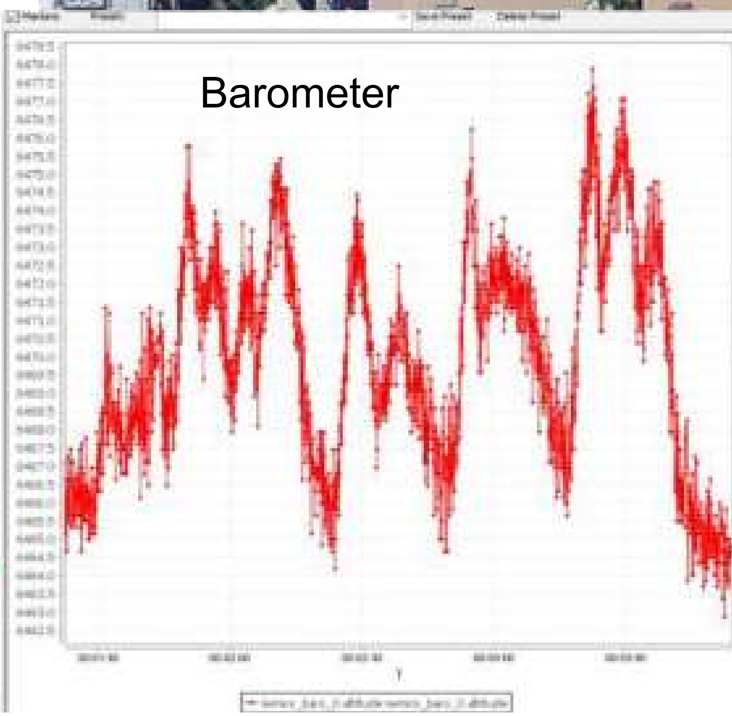
Low-cost RTK



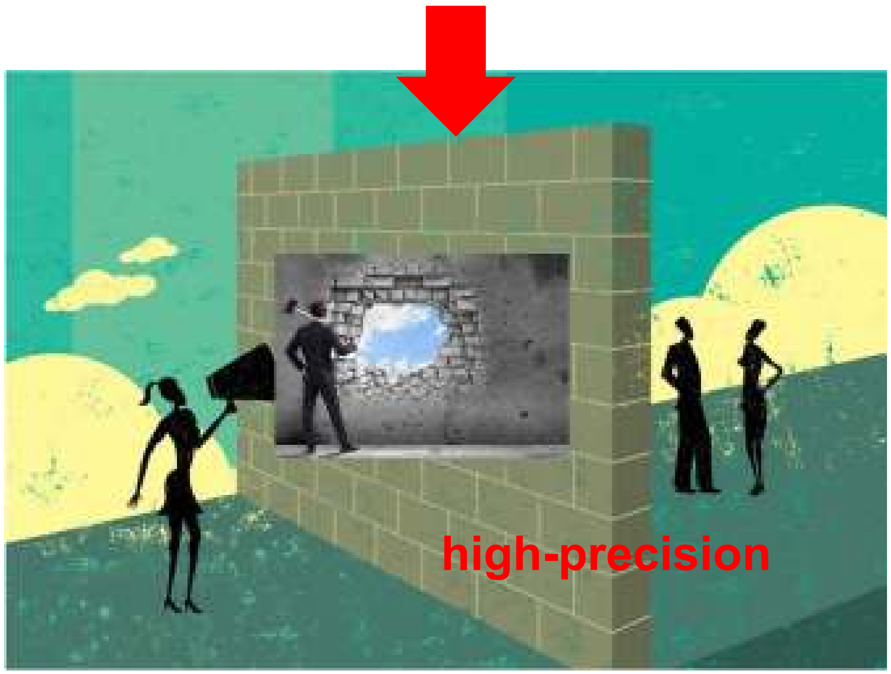




# The Challenges

- ✓ Not just precision requirement important to mass-market application
- ✓ High availability and reliability of "precision" are further significant challenges for mass-market applications, as many of them are safety critical positioning.
- ✓ even existing high-precision GNSS technologies still suffer various limitations and deficiencies with high-grade receivers
- ✓ …

The involvement of Internet giants in the location technology competitive landscape opens new opportunities for precision GNSS

**Consumer market (low-cost)**




**Precision market (professional)**

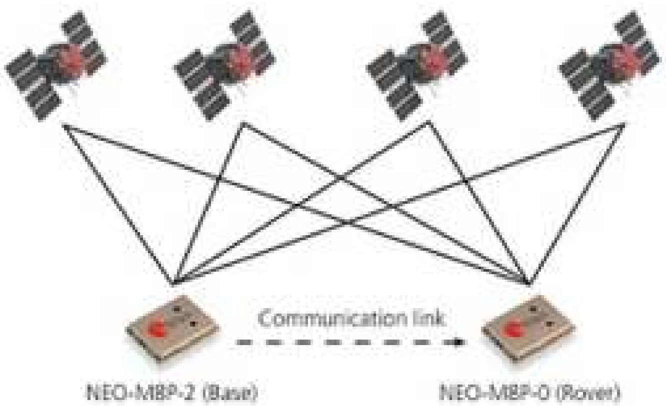
# The Opportunities



Google announced to provide raw GNSS measurements including carrier phase from smartphones (2016)

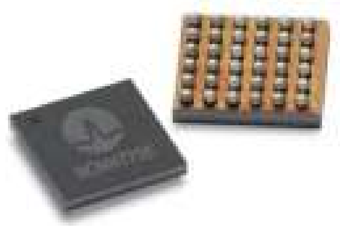
Alibaba Group
阿里巴巴集团

Alibaba launches a joint venture for location-based service business (2016)




u-blox releases RTK product to the mass market (2016)

# The Opportunities



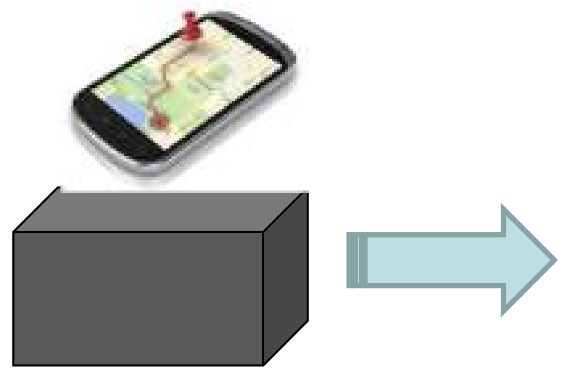
Broadcom announces world's first dual frequency GNSS receiver (2017)


u-blox announces F9 robust and versatile high precision positioning technology for industrial and automotive applications (2018)


Xiaomi released the first smart phone with dual-frequency GPS (2018)

# The Opportunities





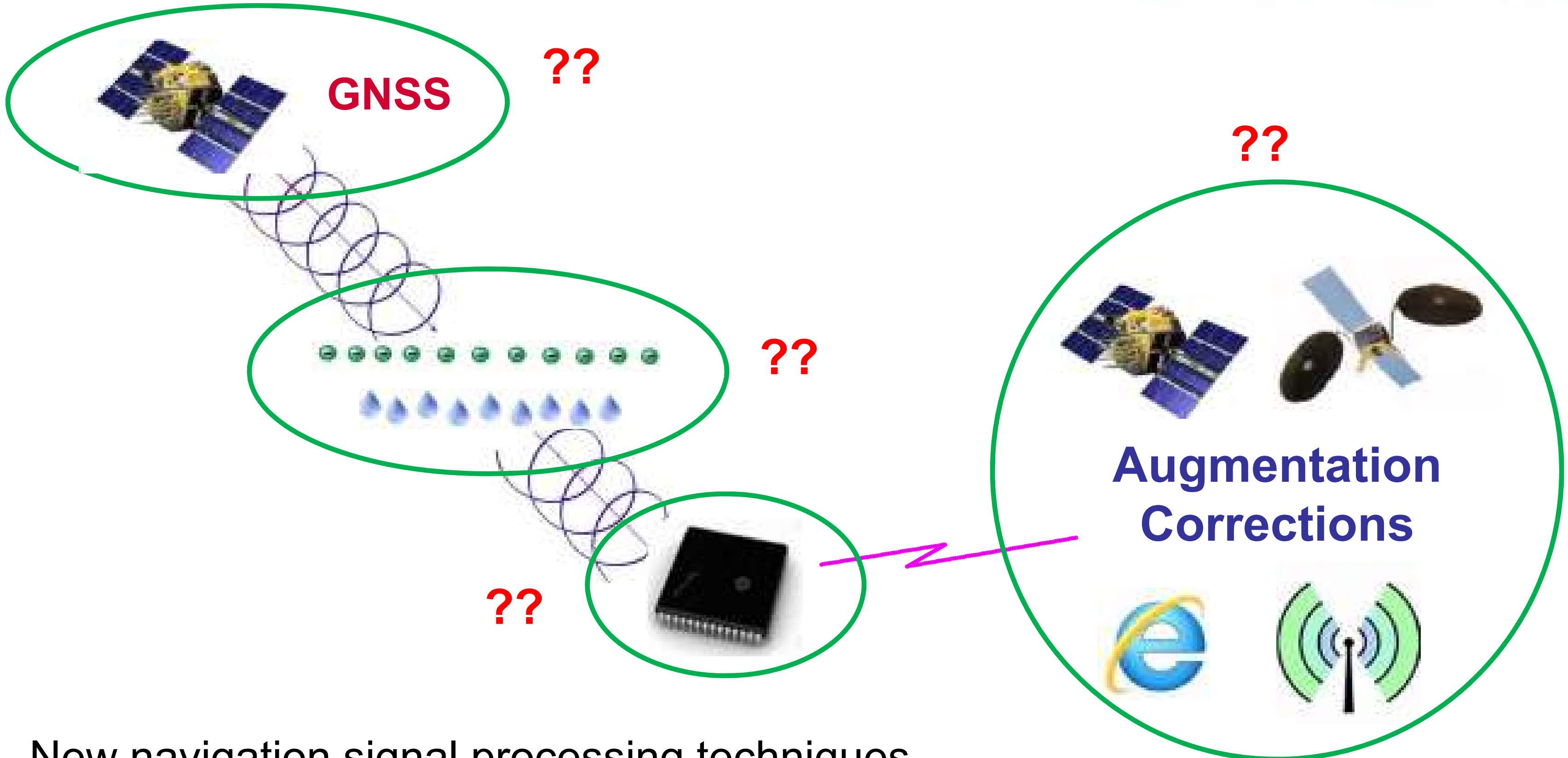
Pseudorange and pseudorange rate
Navigation messages
Accumulated delta range or carrier
Hardware (HW) clock

But little discussion as a black box

Overwhelming work in analyzing raw measurements and position solutions using existing high-precision GNSS techniques

Low-cost high precision GNSS demands technology innovation to address fundamental and essential issues unique to low-cost and mass-market applications, beyond tuned versions of existing high-precision GNSS technologies

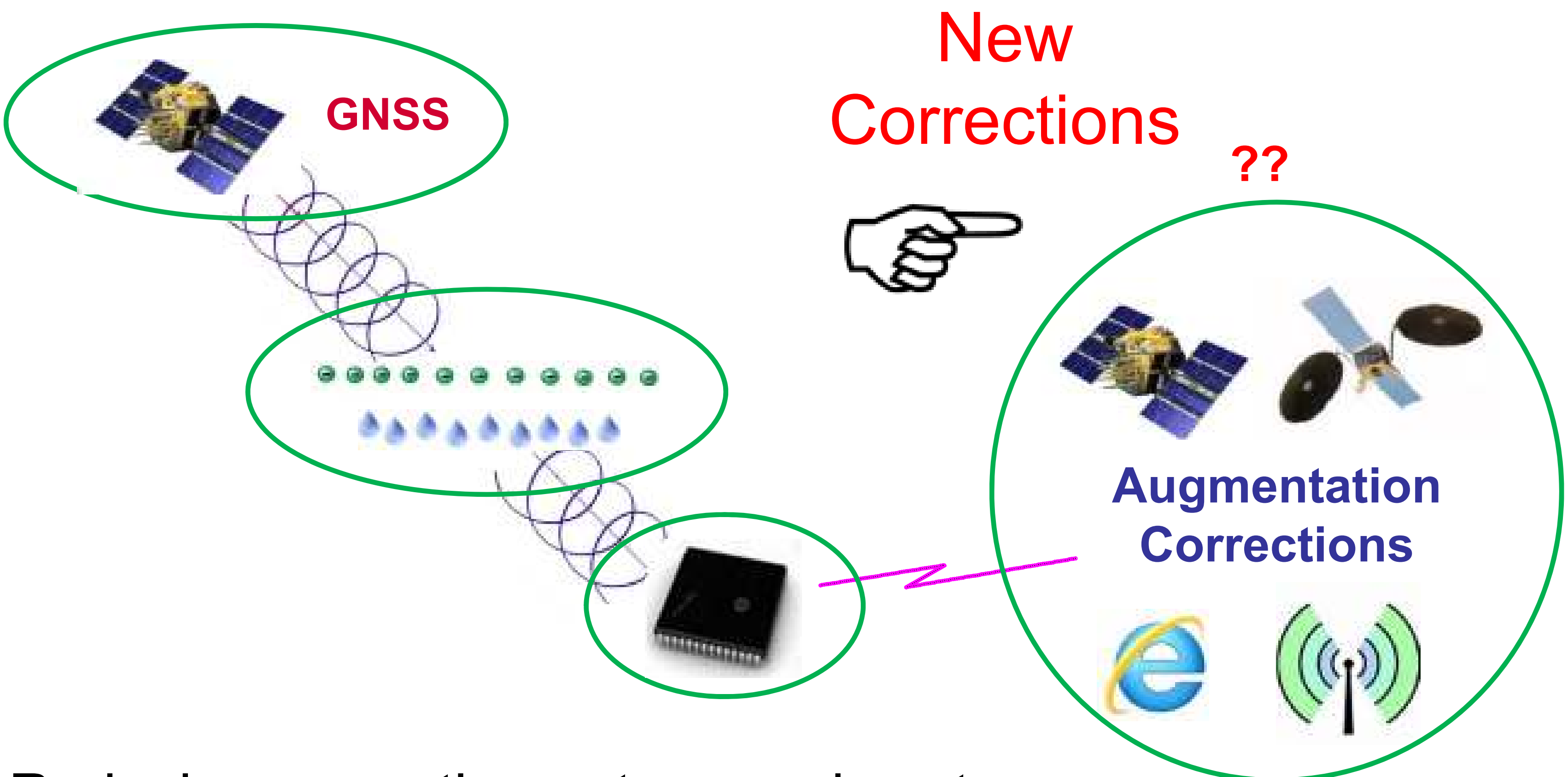
# The Opportunities




- ✓ New navigation signal processing techniques
- ✓ New navigation message, augmentation corrections and services strategies
- ✓ New positioning algorithms
- ✓ New in-sensor bias estimation and calibration
- ✓ …

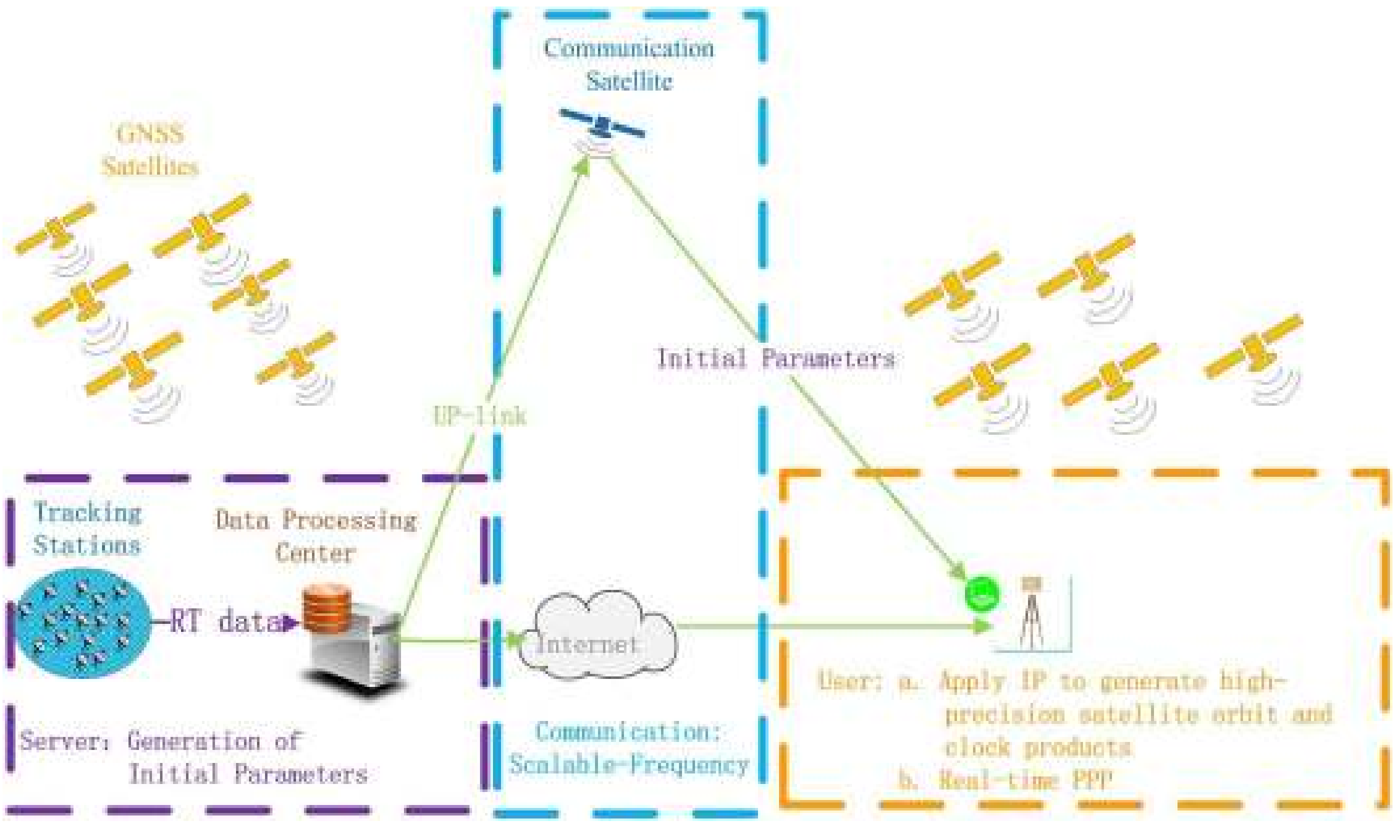
# Some Research Efforts at UC

Existing corrections: high update rate, sensitive to outage




Reducing correction outage and cost

# Scalable Corrections: Initial Parameters (IP)



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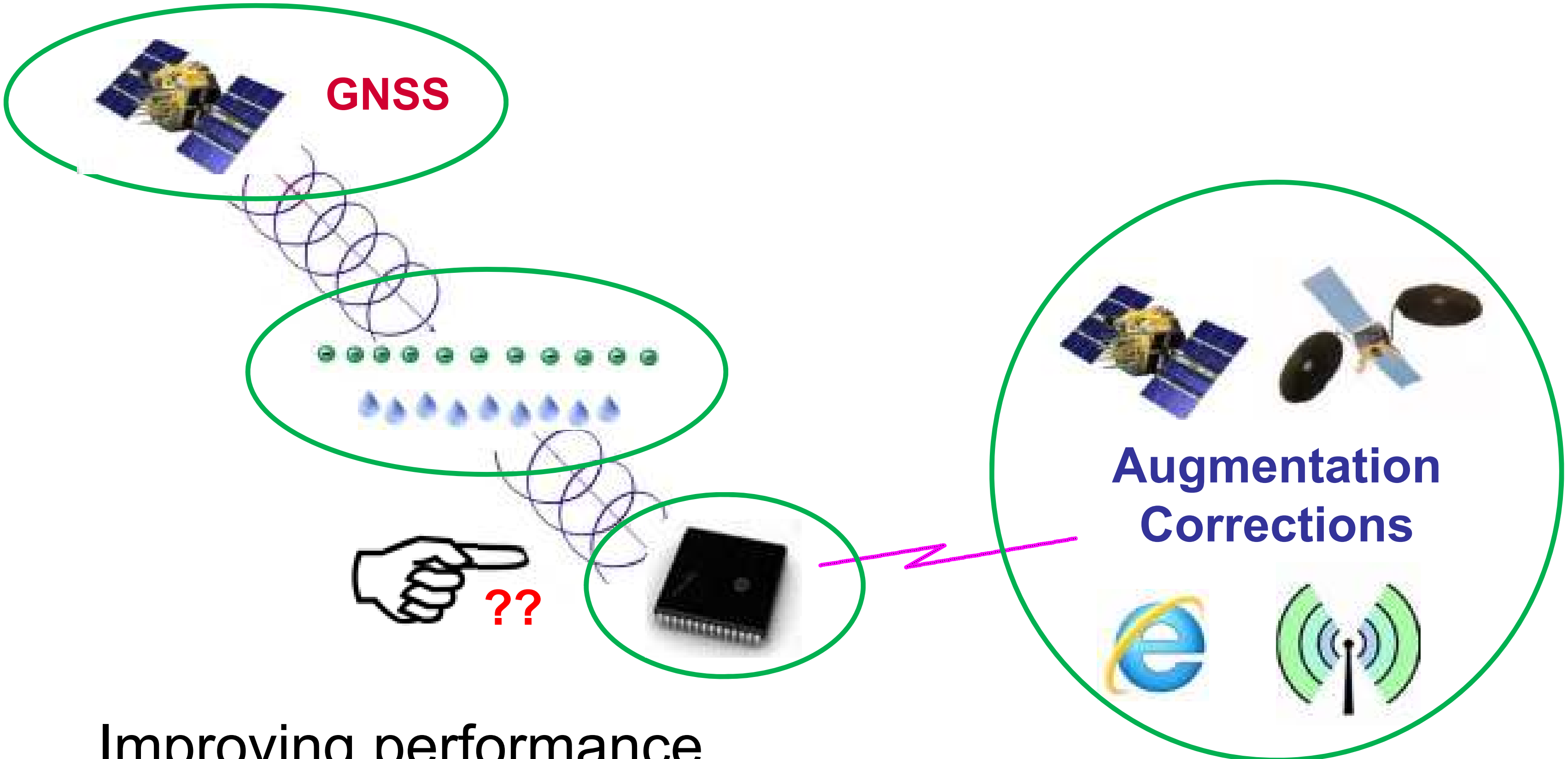
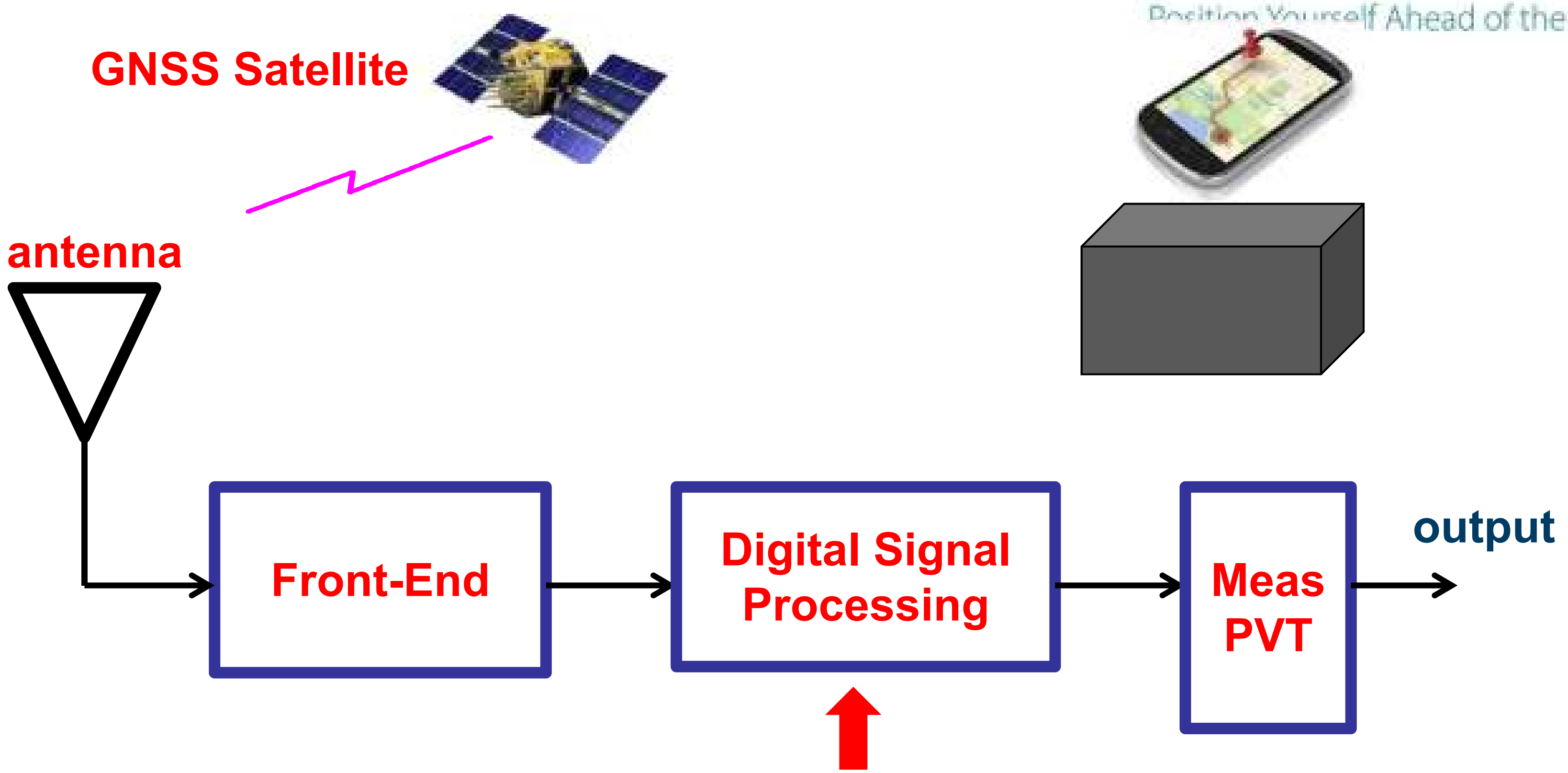



Improving performance of low-cost GNSS receivers

# Some Research Efforts at UC




In-receiver bias analysis, identification, estimation and calibration

# Some Research Efforts at UC



$$P_1 = \rho + c(dT - dt) + d_{orb} + d_{trop} + d_{iono/L1} + b^r_{P1} - b^s_{P1} + \varepsilon(P_1)$$

$$P_2 = \rho + c(dT - dt) + d_{orb} + d_{trop} + d_{iono/L2} + b^r_{P2} - b^s_{P2} + \varepsilon(P_2)$$

$$L_1 = \rho + c(dT - dt) + d_{orb} + d_{trop} - d_{iono/L1} + b^r_{L1} - b^s_{L1} - \lambda_1 N_1 + \varepsilon(L_1)$$

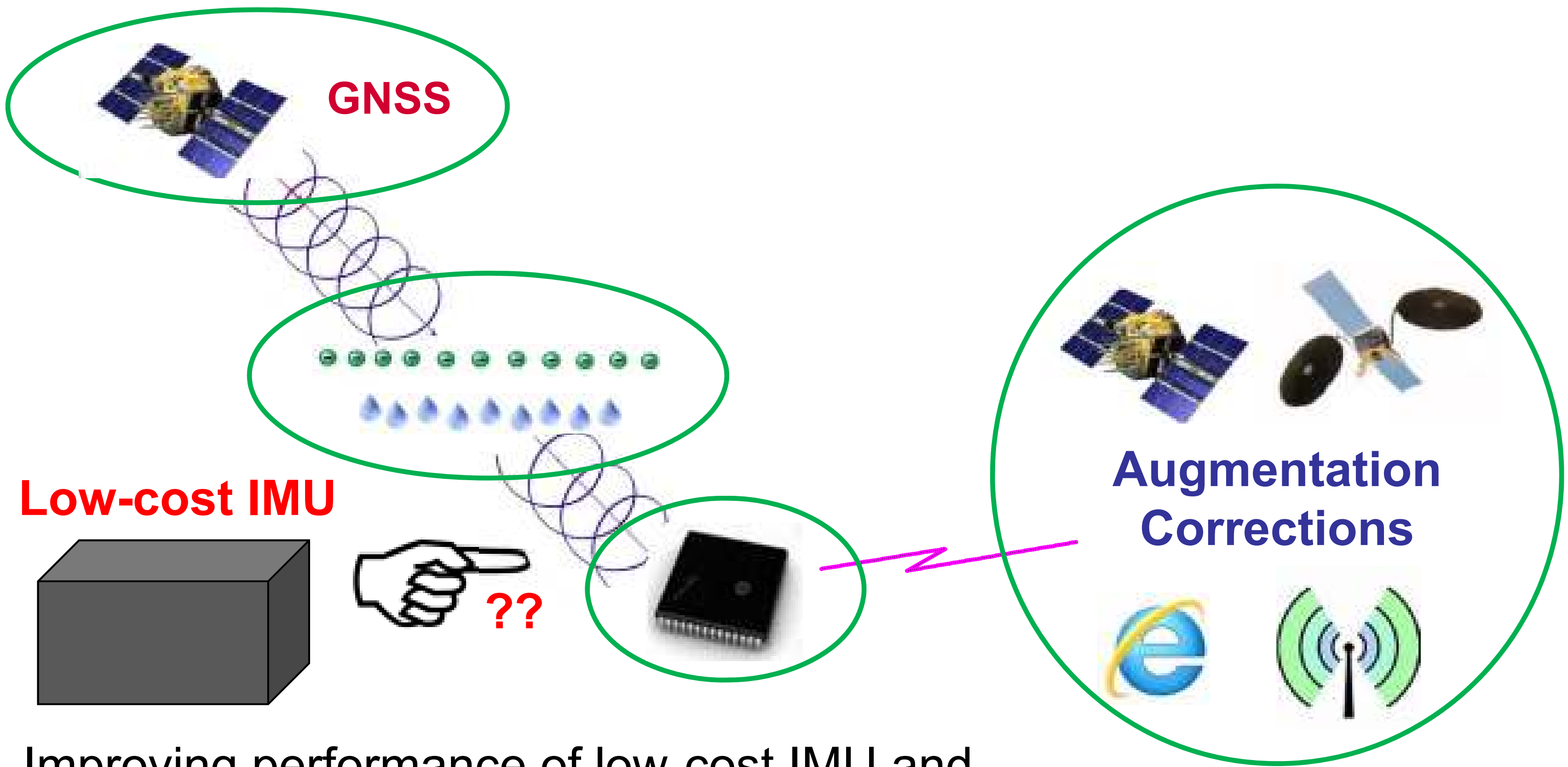
$$L_2 = \rho + c(dT - dt) + d_{orb} + d_{trop} - d_{iono/L2} + b^r_{L2} - b^s_{L2} - \lambda_2 N_2 + \varepsilon(L_2)$$

Lumping together of all bias effects

- ✓ GNSS measurements contain various biases and out-receiver bias identification and estimation are very challenging
- ✓ Most biases are not separable and estimable using GNSS measurements
- ✓ Current bias corrections are often receiver and network dependent

# Some Research Efforts at UC

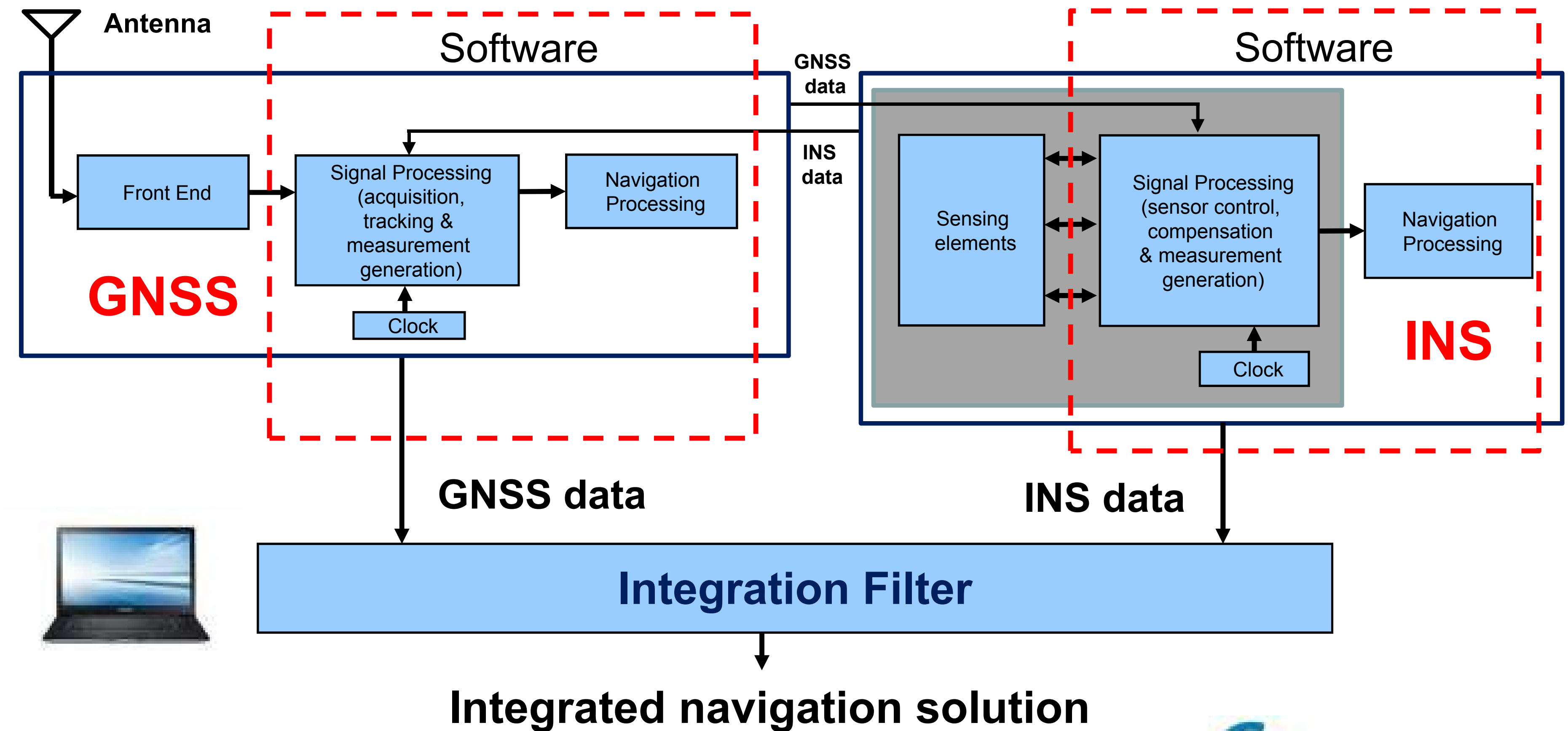





Improving performance of low-cost IMU and integration with GNSS

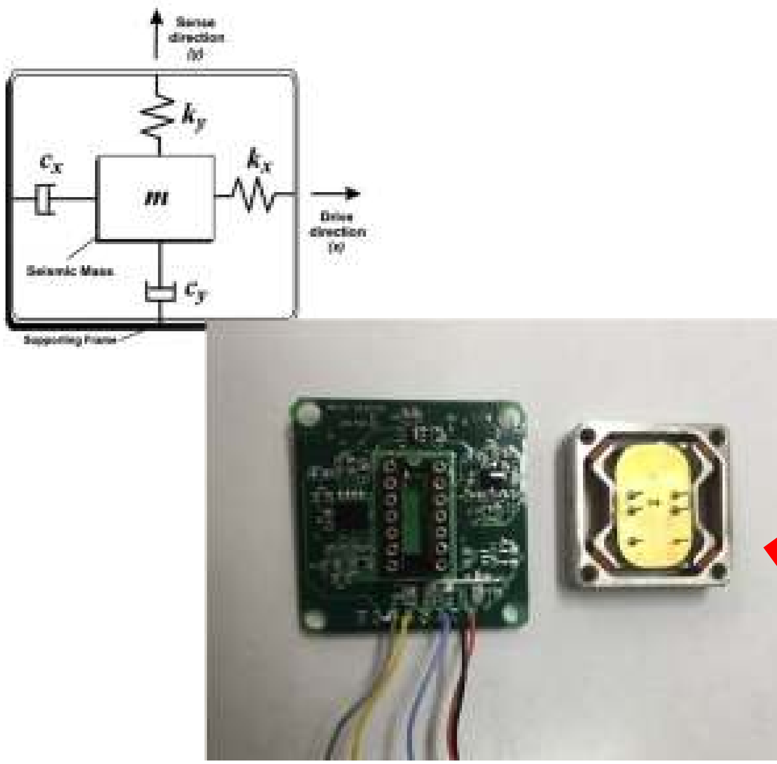
# Some Research Efforts at UC

## Concept of "software-based INS" and ultra-deep integration

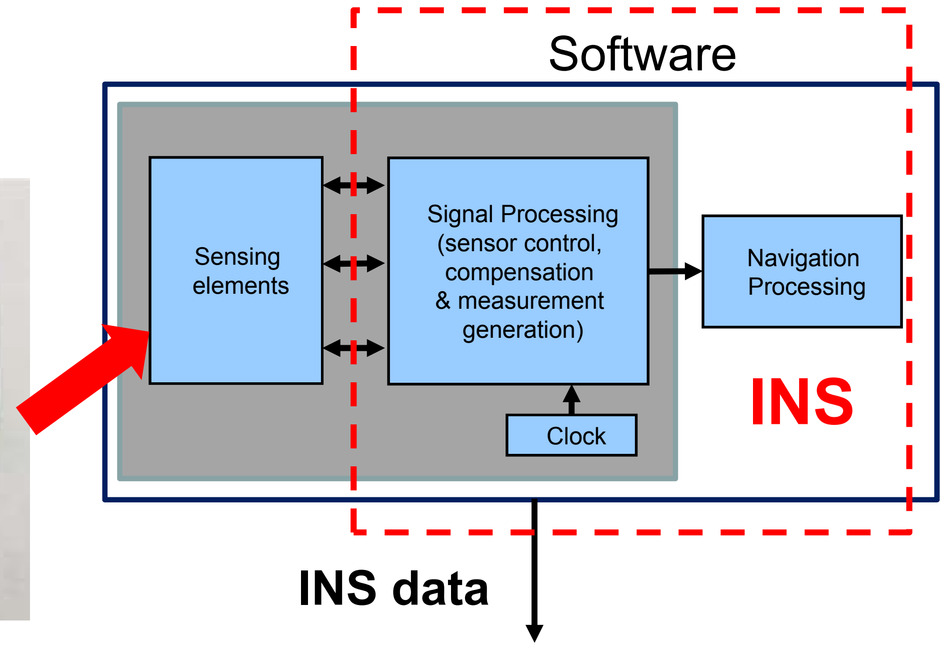


# Some Research Efforts at UC

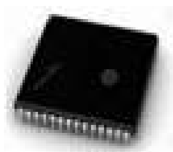
## "software-based INS" implementation




Sense signal acquisition system

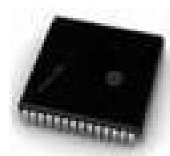


# Looking into the future



**Low-cost**

**High-precision**



Next-generation low-cost high precision GNSS systems and products

High-precision will be available at low-cost and as a core navigation sensor capable of supporting mass-market precise applications