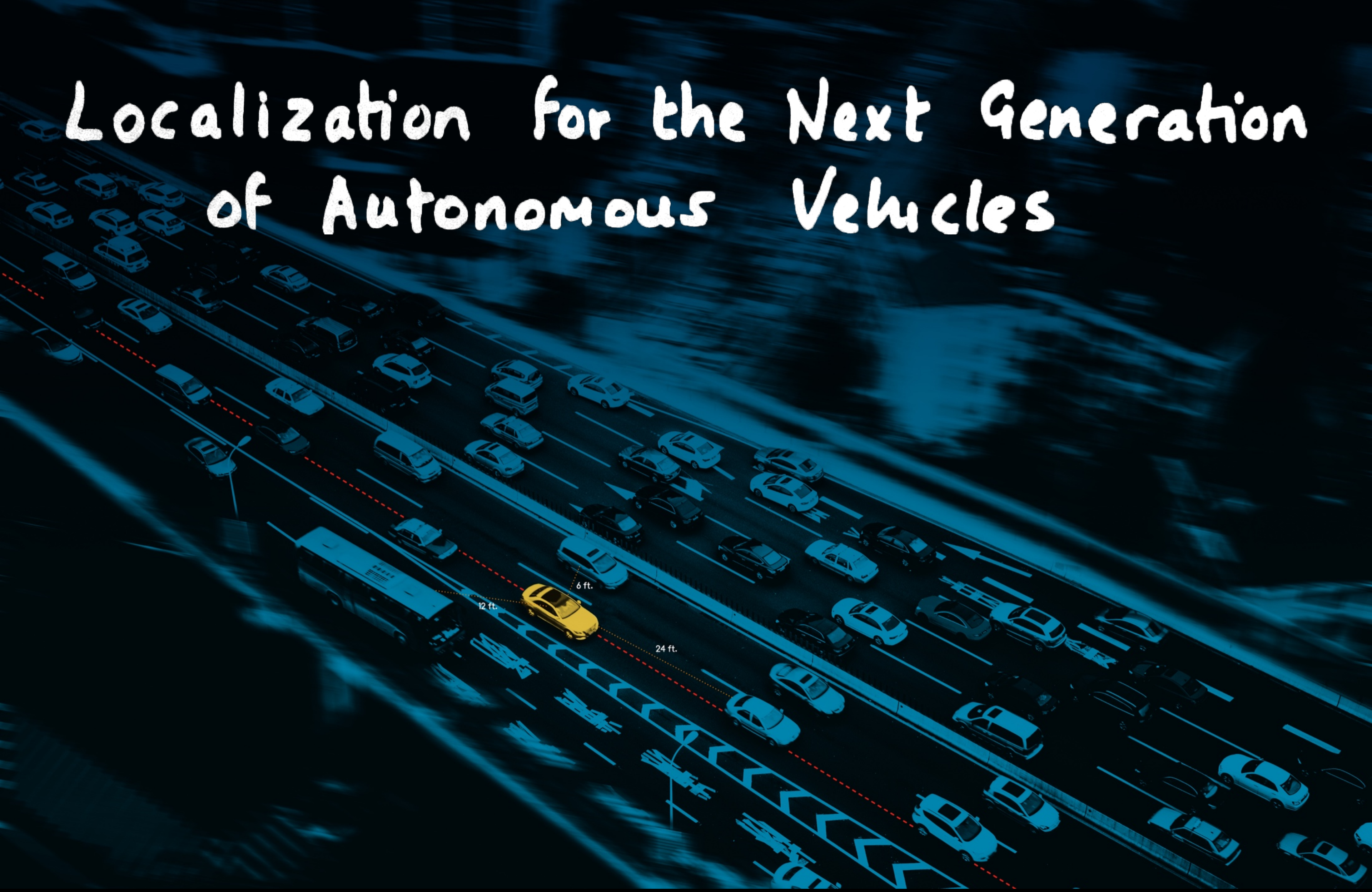
Localization for the Next Generation of Autonomous Vehicles



Fergus Noble CTO

Swift Navigation

- Autonomy is arriving

- Autonomy is arriving
- Autonomous vehicles need centimeter positioning to navigate

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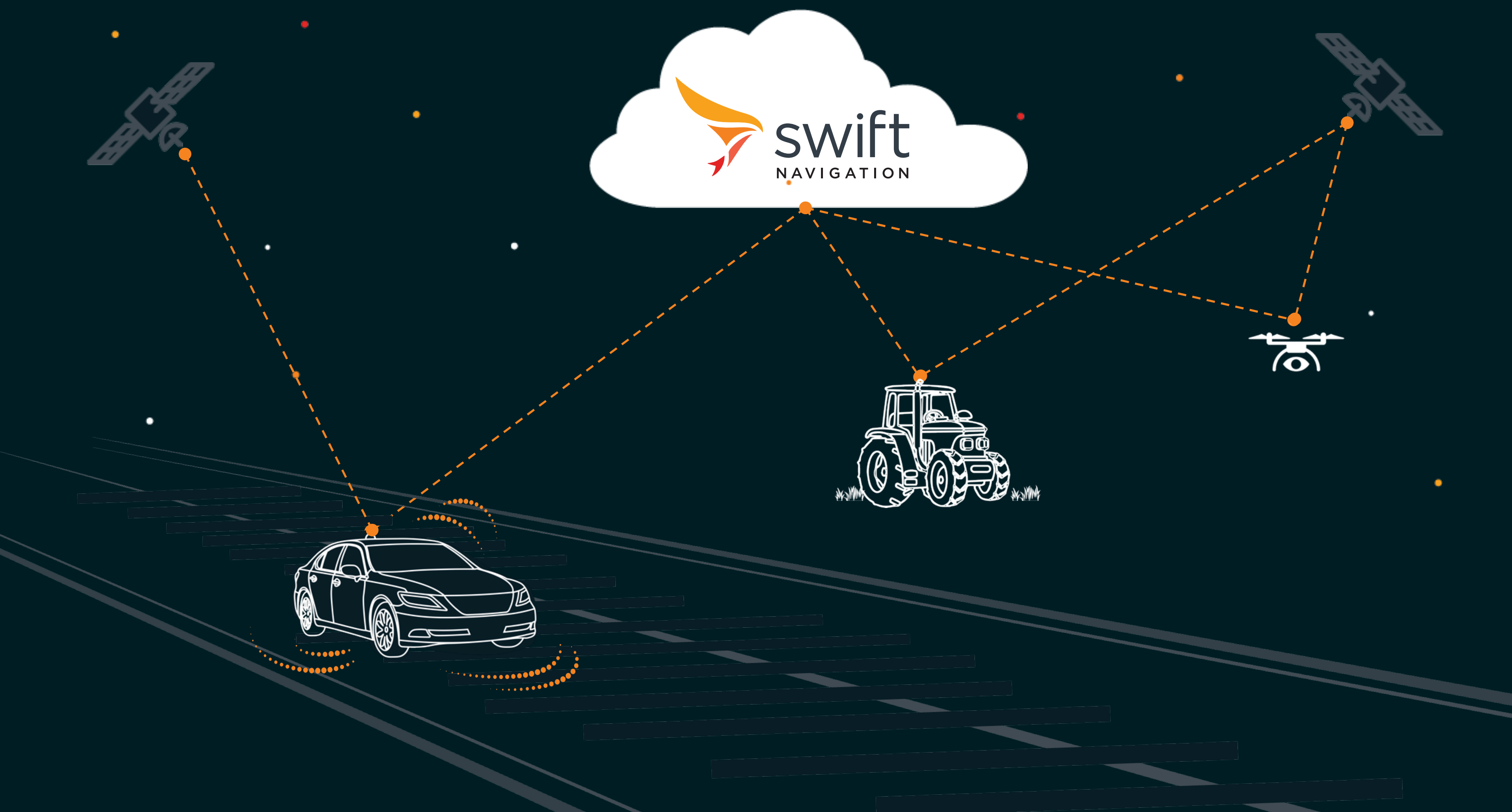
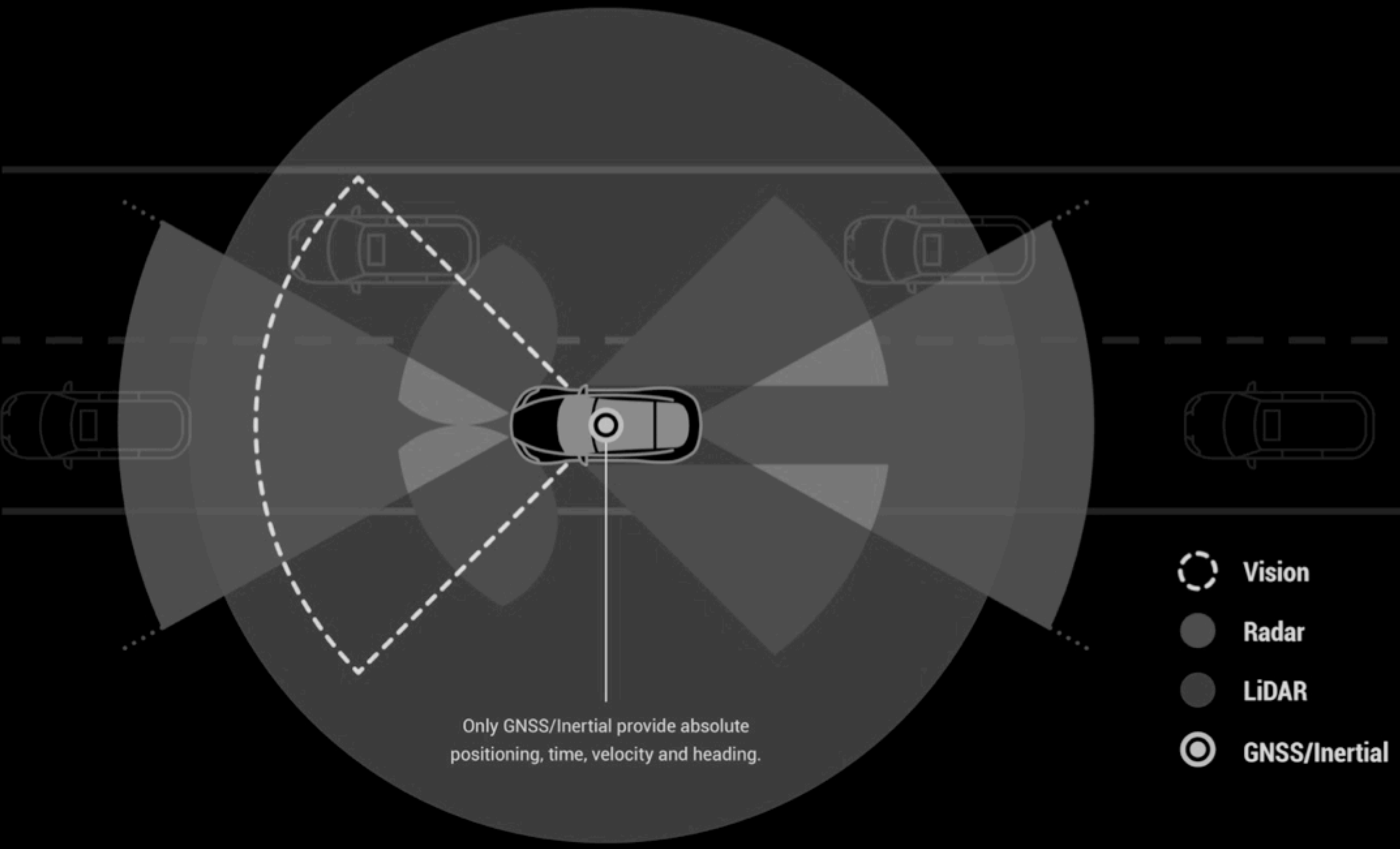
- GPS is the only way to acquire absolute location, but it is inaccurate

- Autonomy is arriving
- Autonomous vehicles need centimeter positioning to navigate
- GPS is the only way to acquire absolute location, but it is inaccurate
- An advanced centimeter-accurate GPS is required for autonomy



5 KEY SENSORS

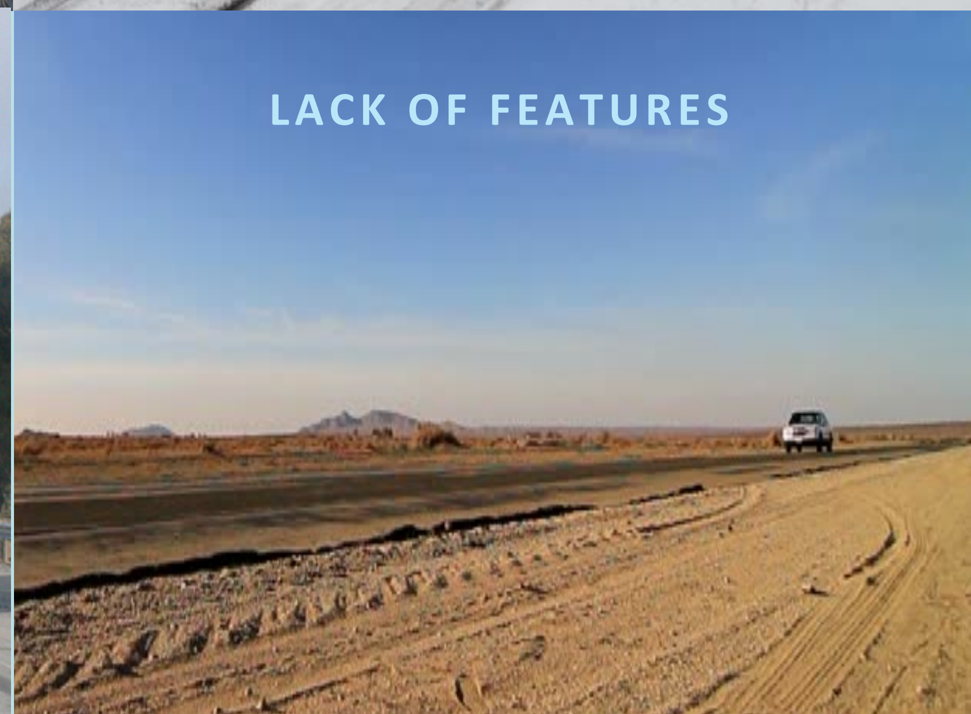


LACK OF LANE MARKINGS

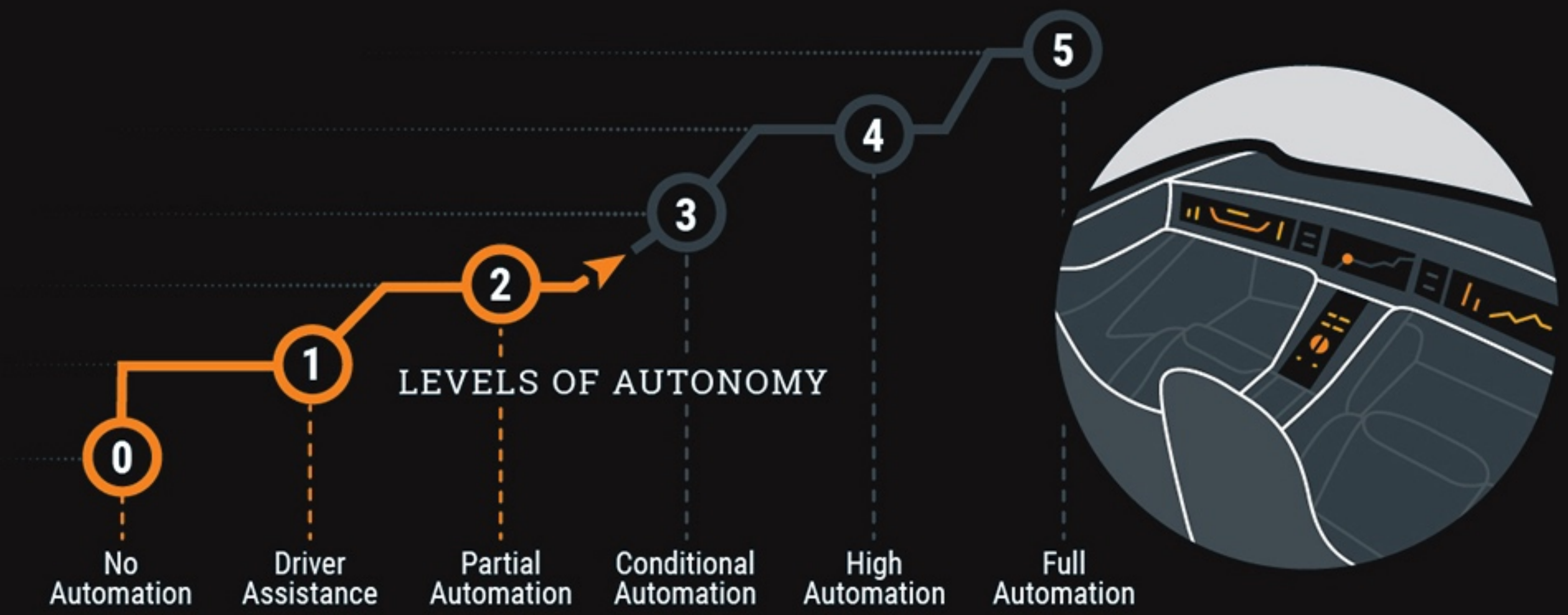
INCLEMENT WEATHER

LANE AMBIGUITY

LACK OF FEATURES

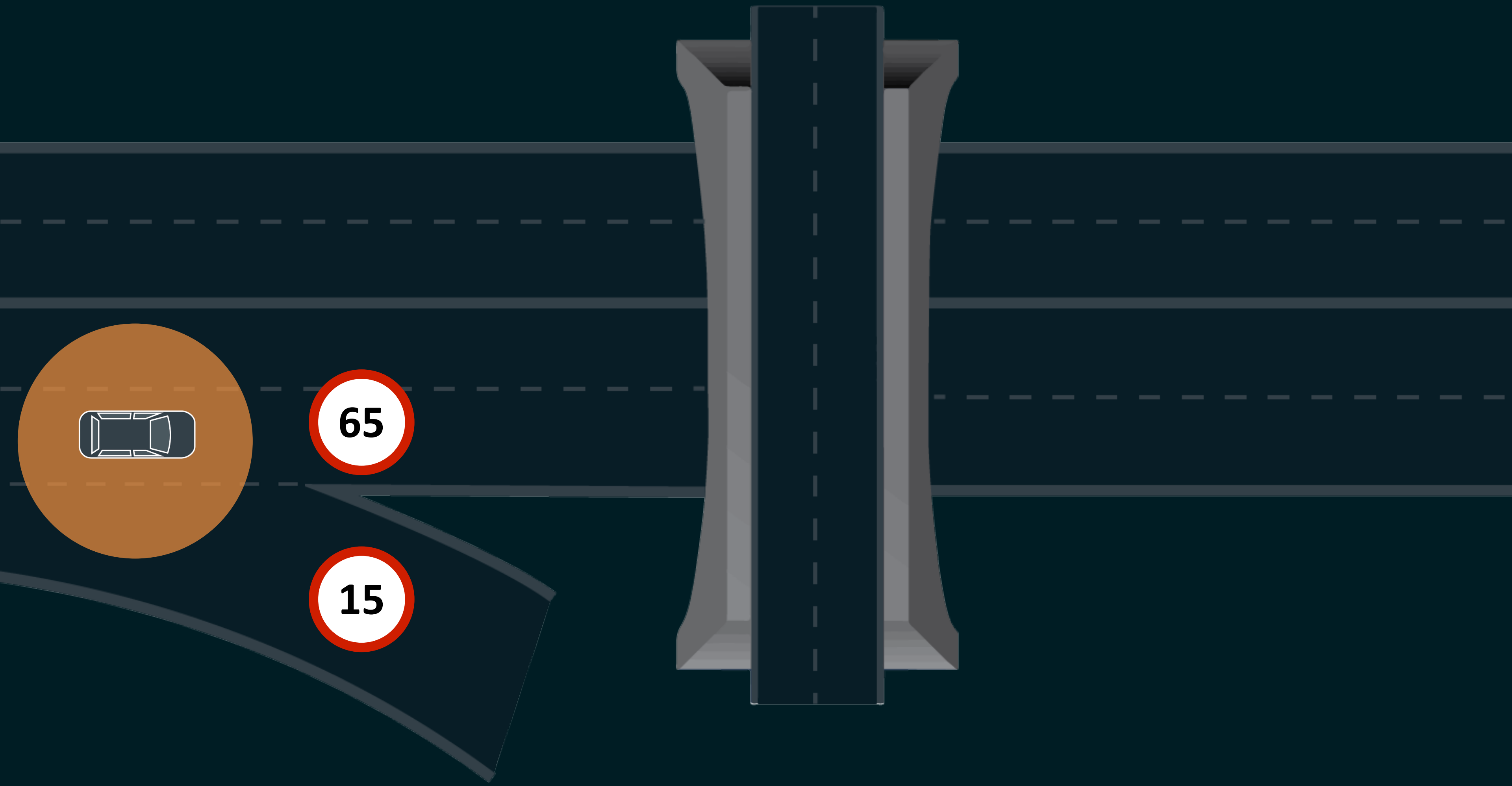


5 LEVELS OF AUTONOMY



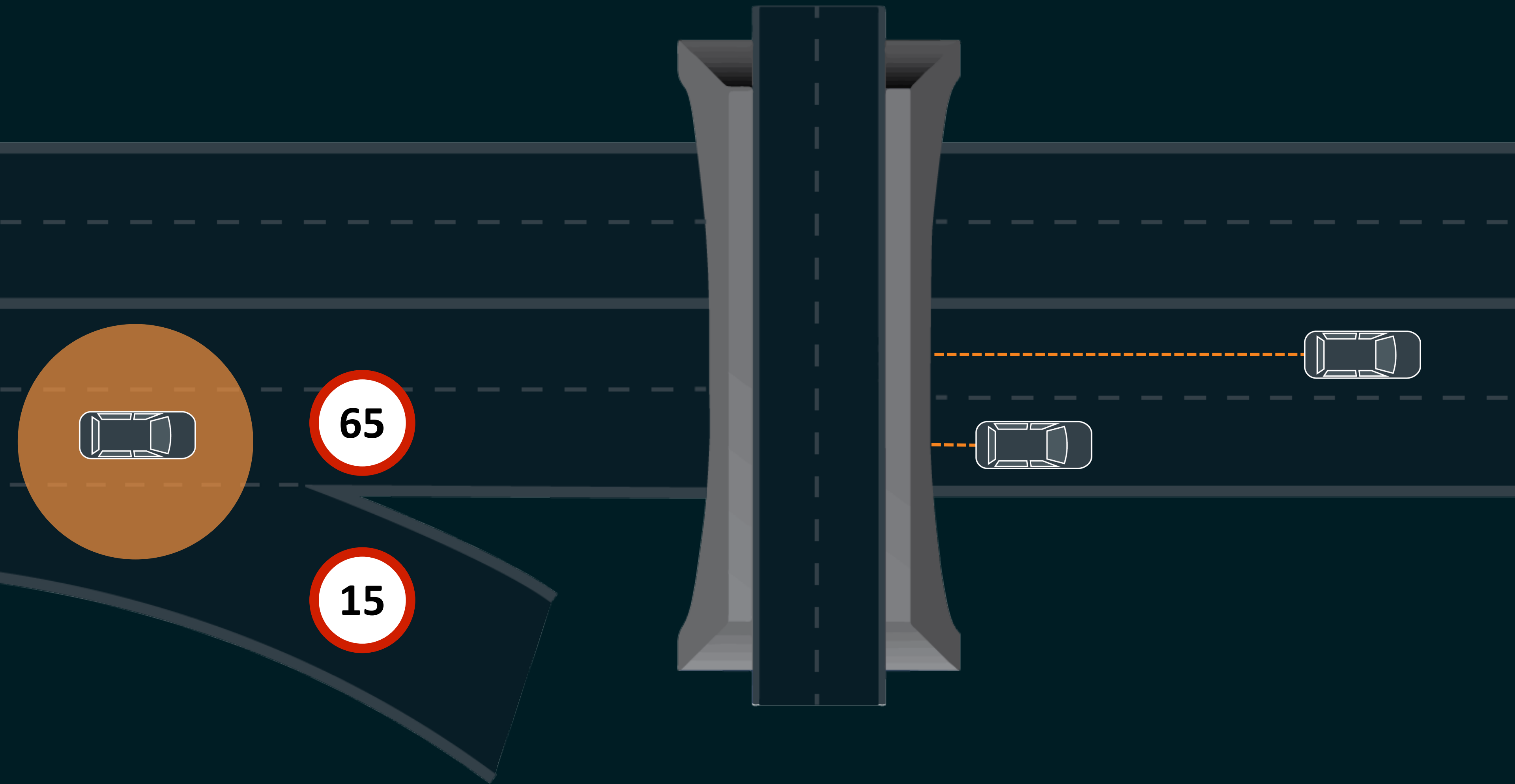
AUTONOMY REQURIES

- **HIGH PRECISION**



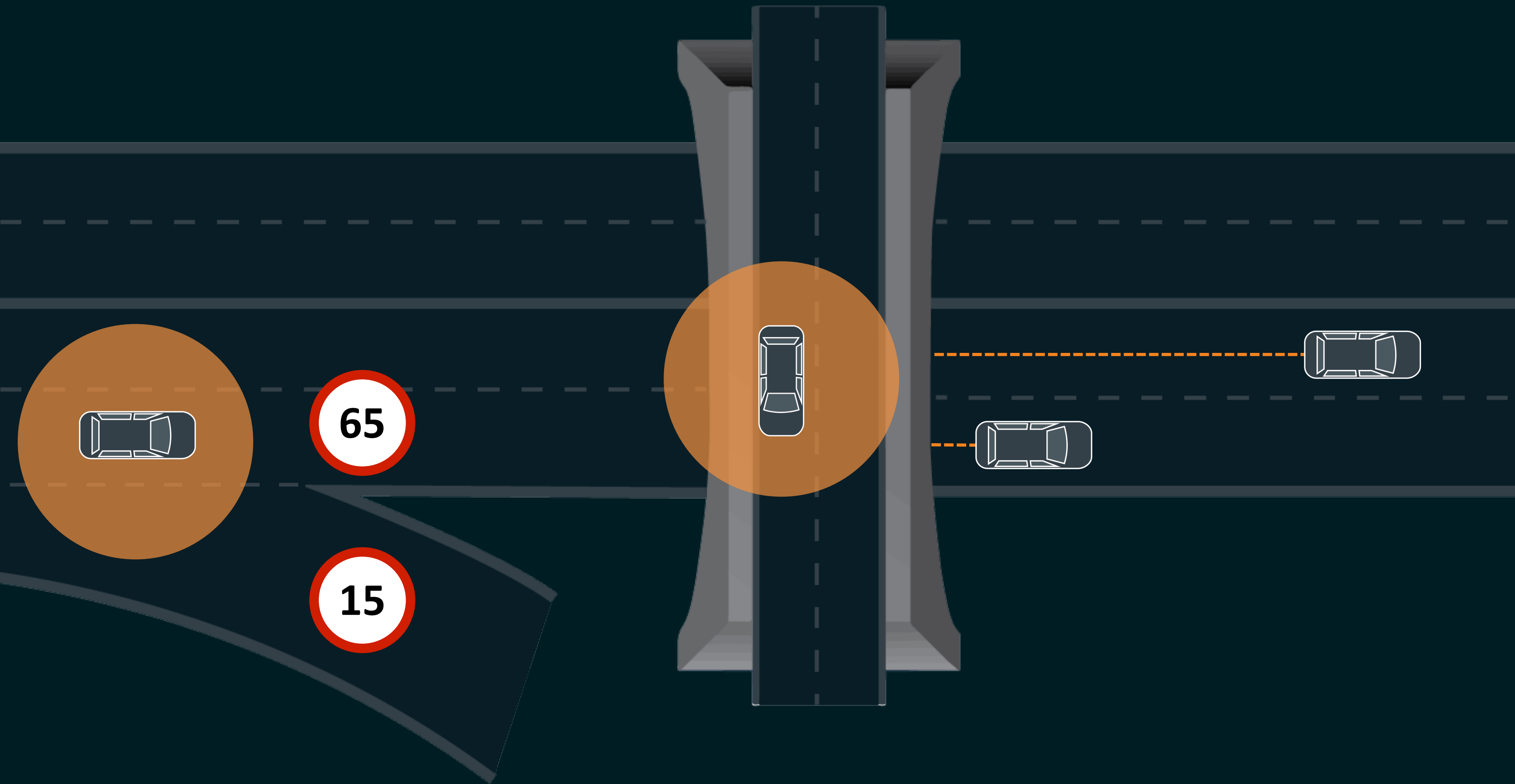
AUTONOMY REQURIES

- **HIGH PRECISION**
- **AVAILABILITY**



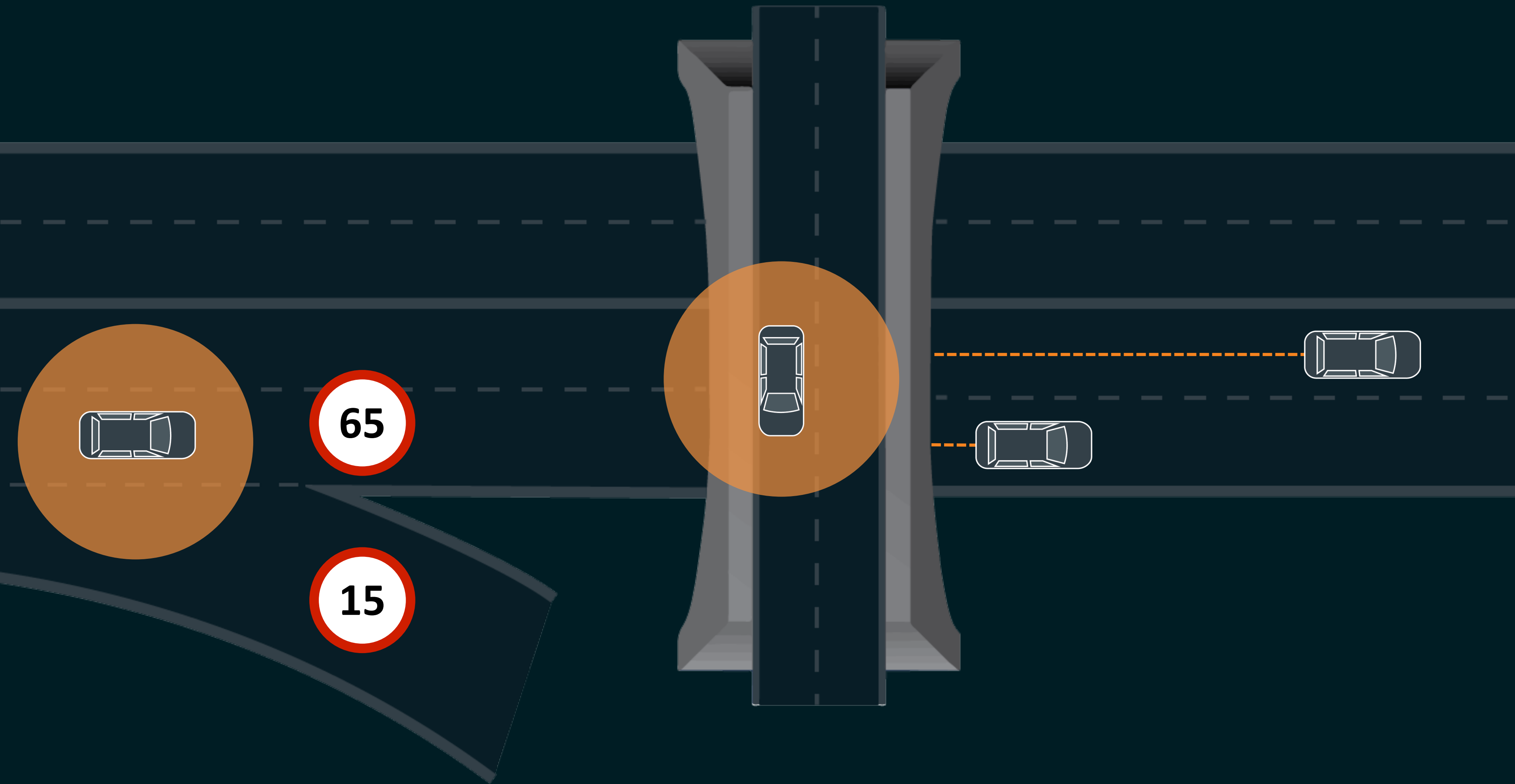
AUTONOMY REQURIES

- **HIGH PRECISION**
- **AVAILABILITY**
- **INTEGRITY**



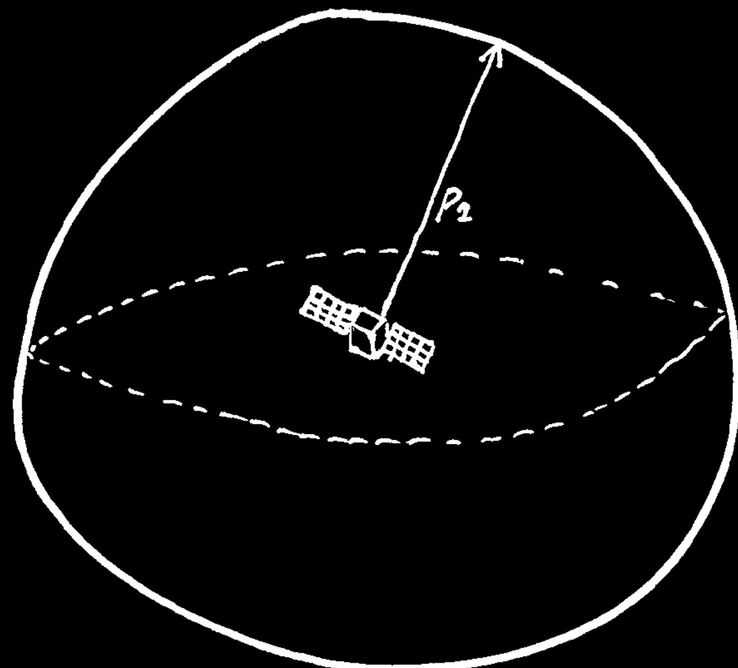
AUTONOMY REQURIES

- **HIGH PRECISION**
- **AVAILABILITY**
- **INTEGRITY**
- **LOW COST**

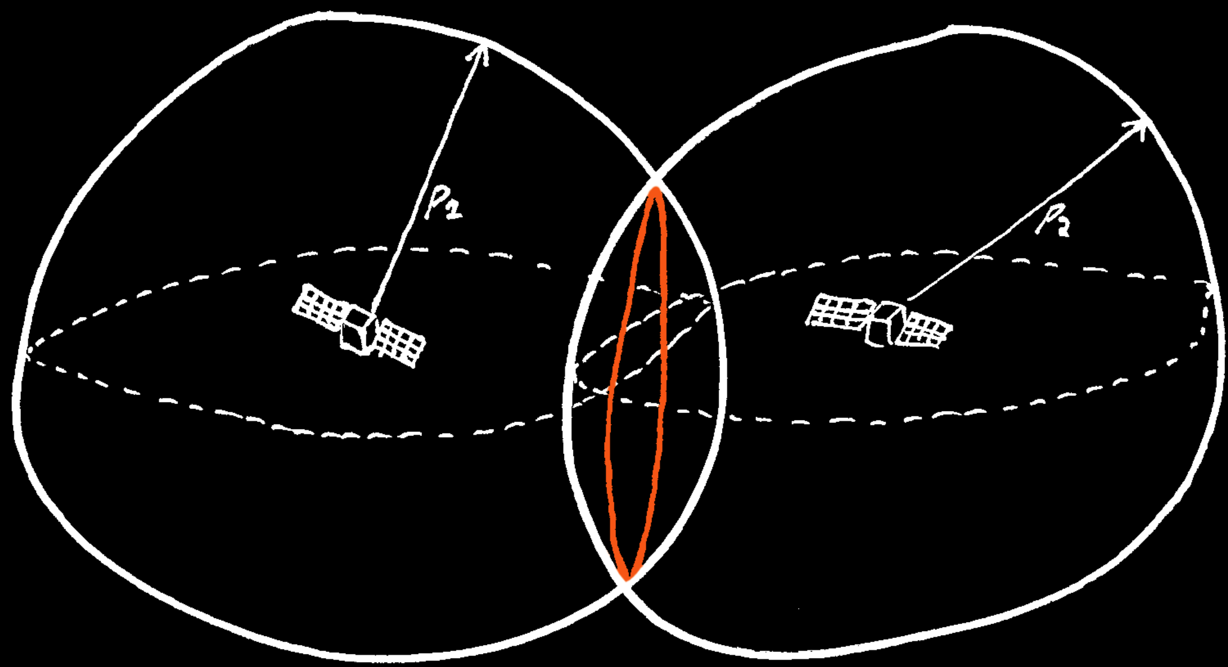


How does GPS work?

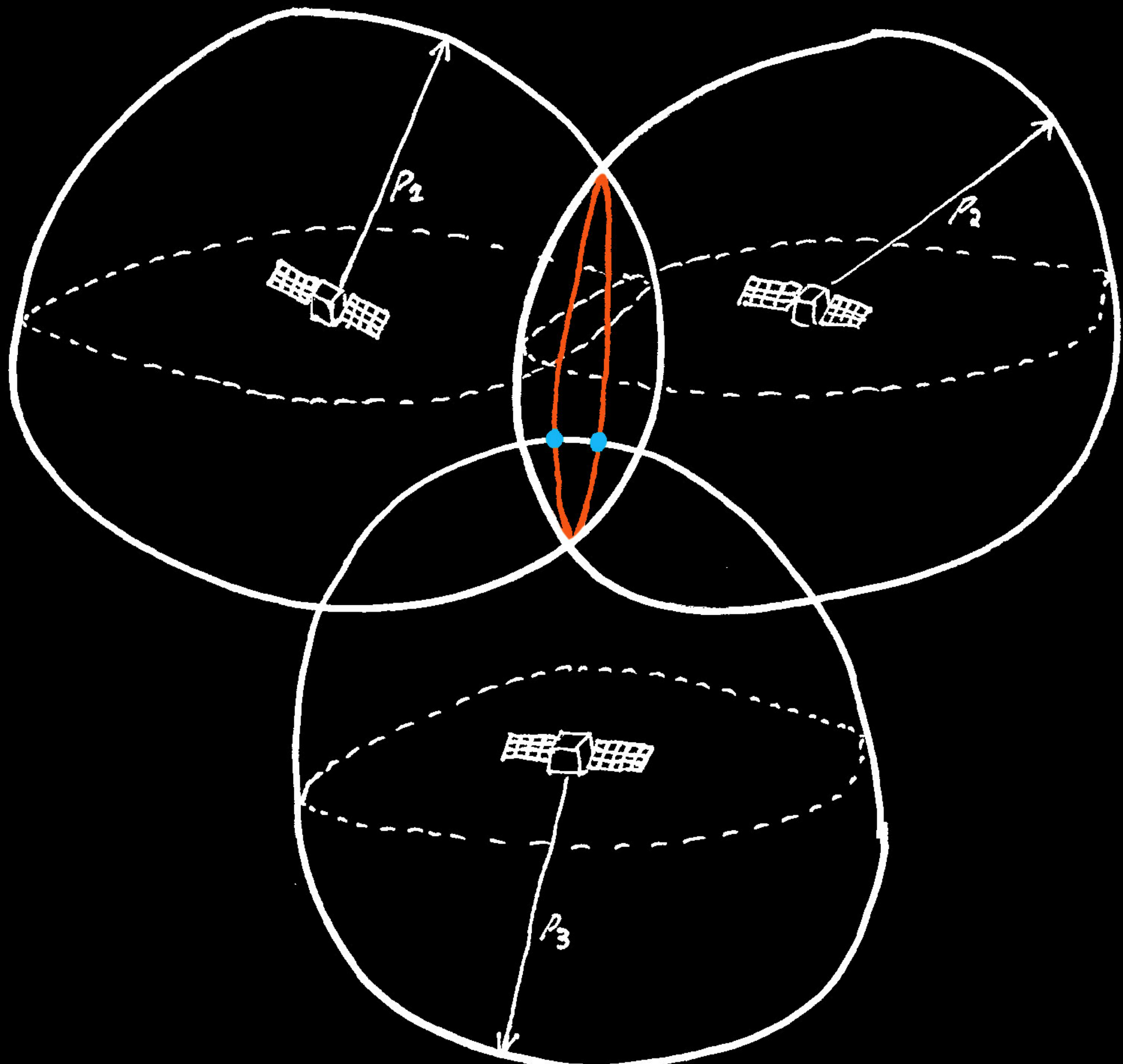
Solving for position



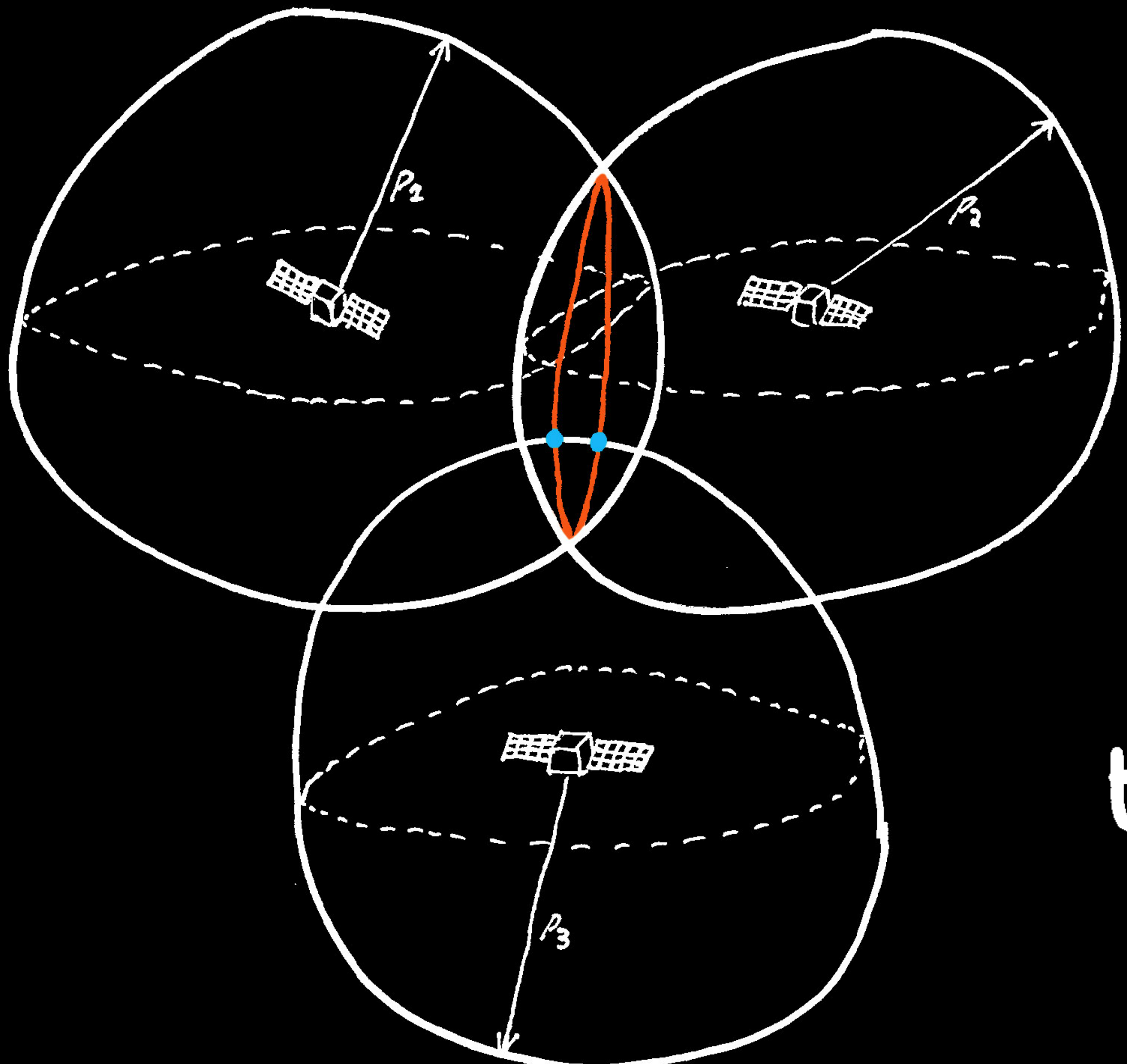
Solving for position



Solving for position



Solving for position



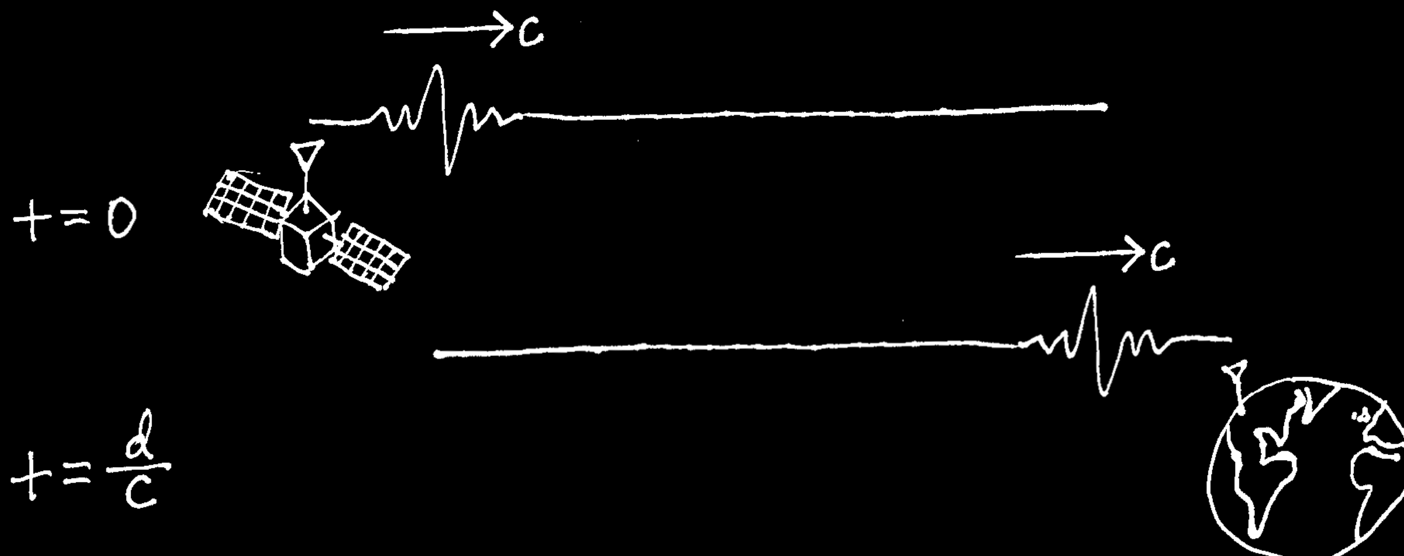
t?

How can we measure the distance to the satellite?

distance ⇔ time

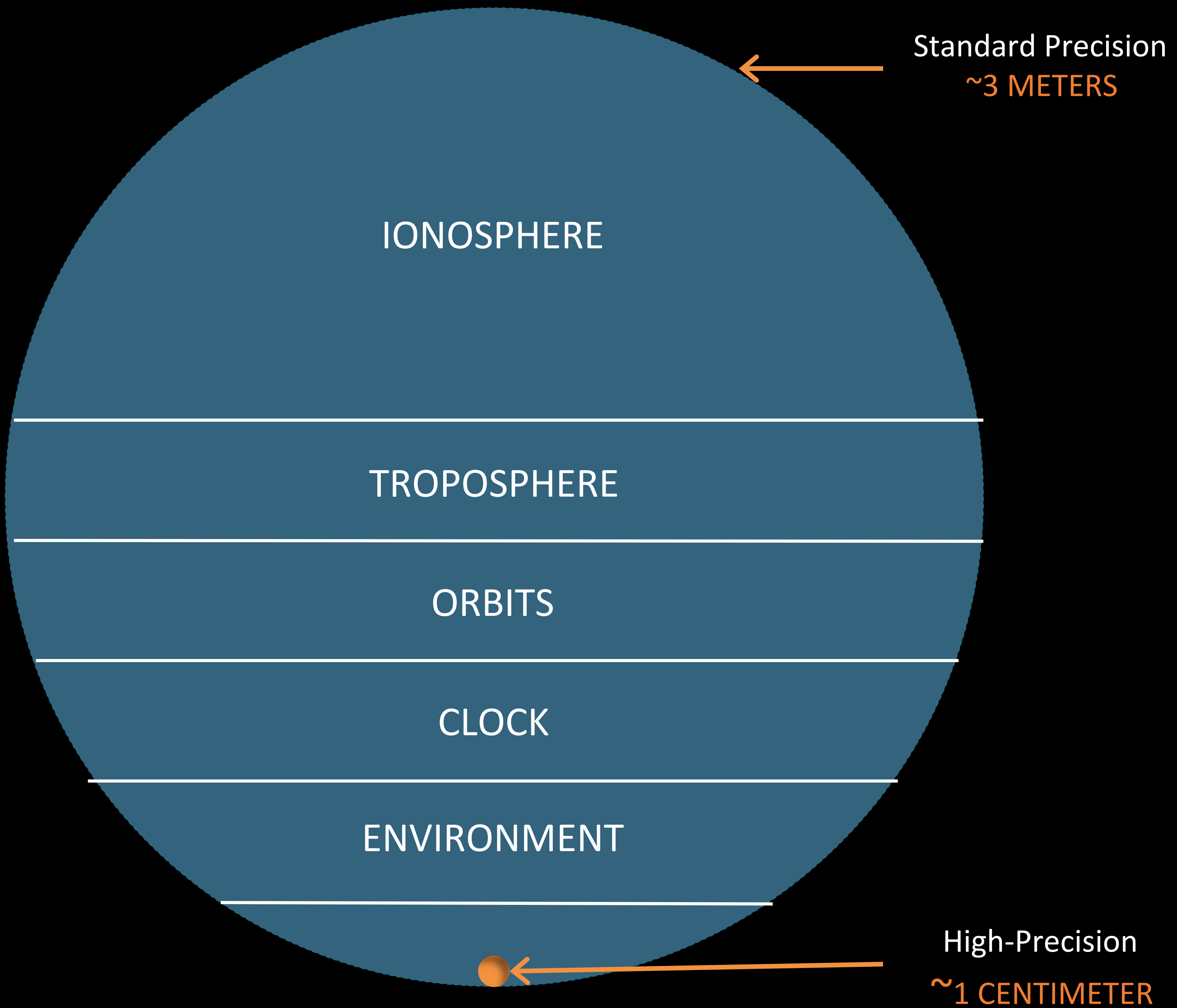
d t

$$d = ct$$



Sources of error

HIGH-PRECISION GPS

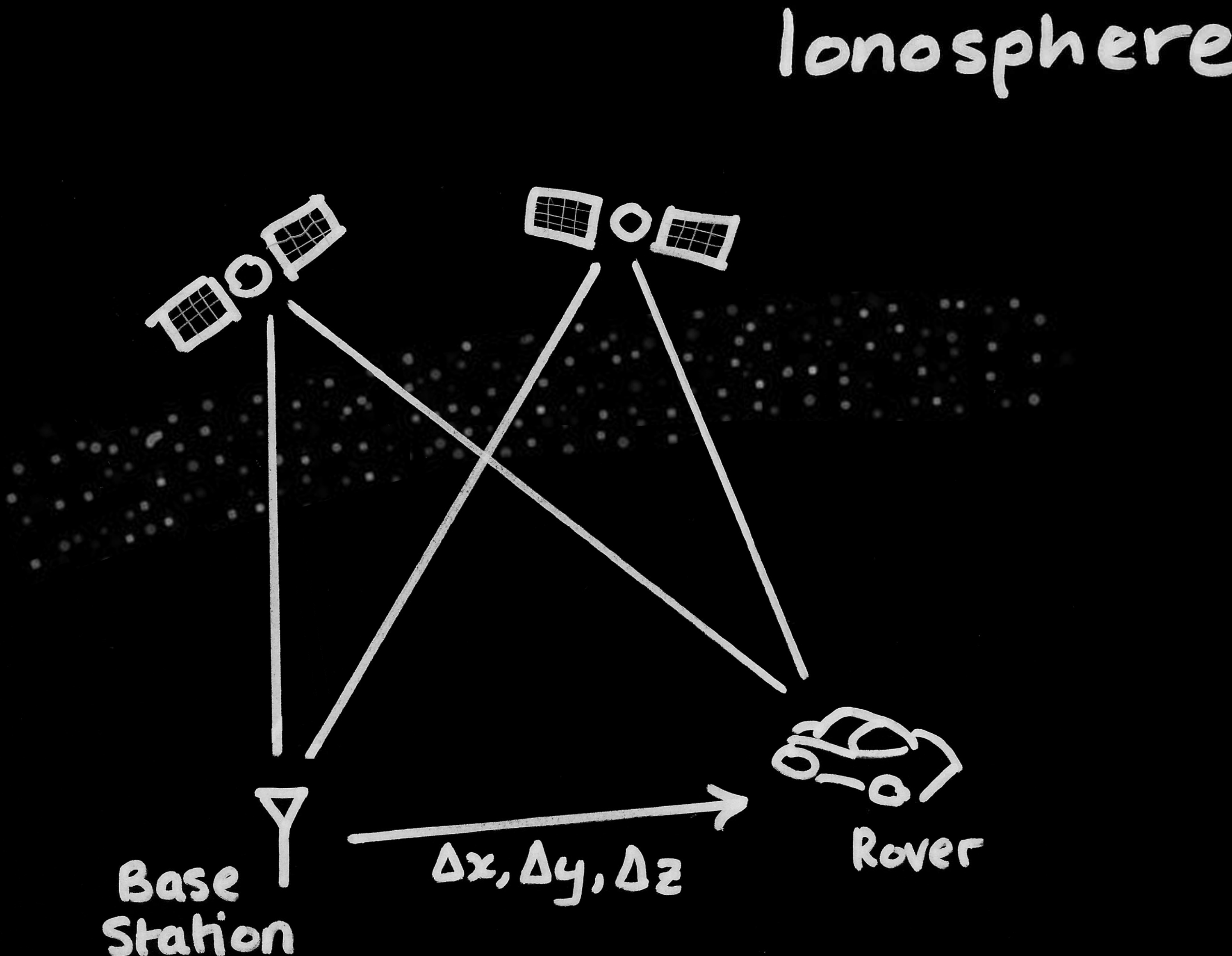


Real Time Kinematic

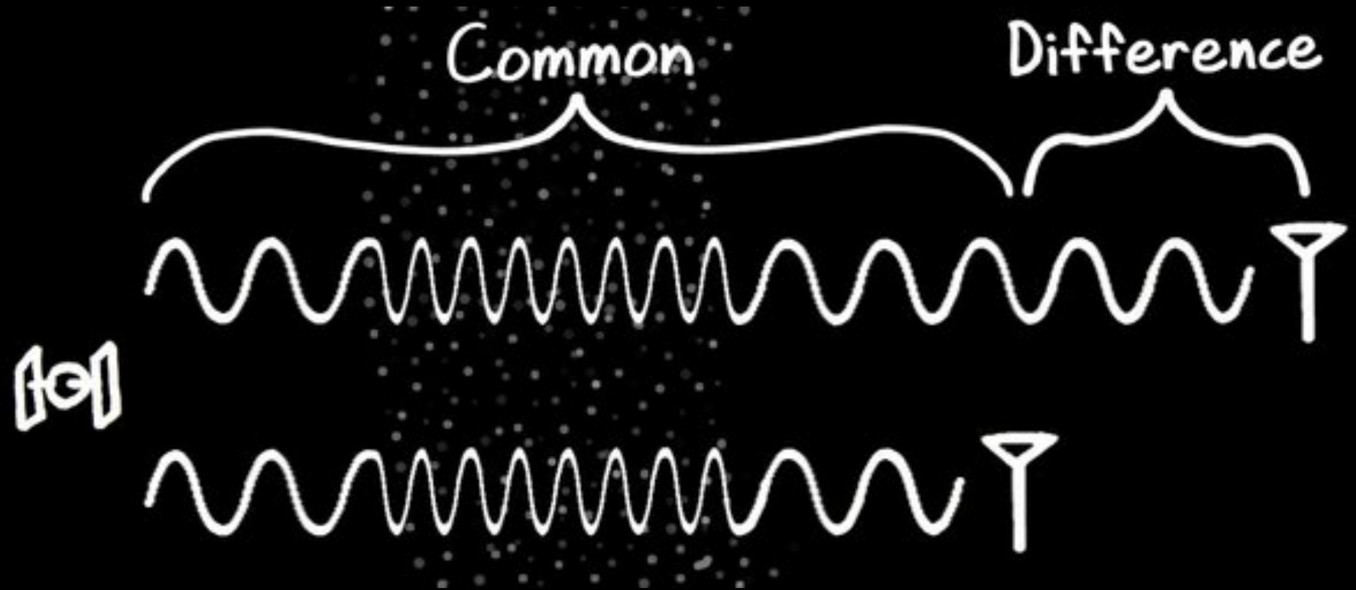
⇓

1) Differential

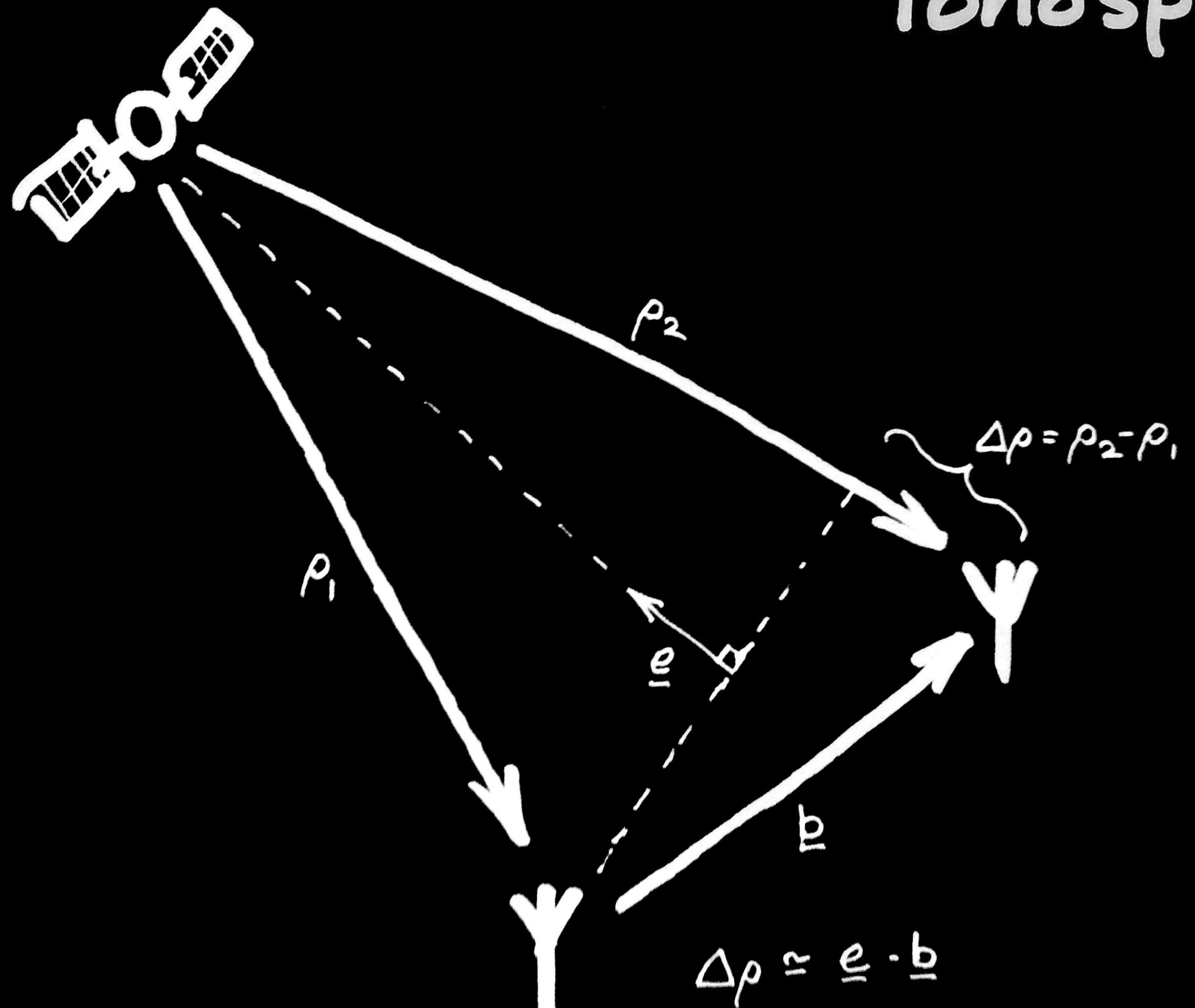
2) Carrier-phase


Ionosphere
Base Station
Δx, Δy, Δz
Rover

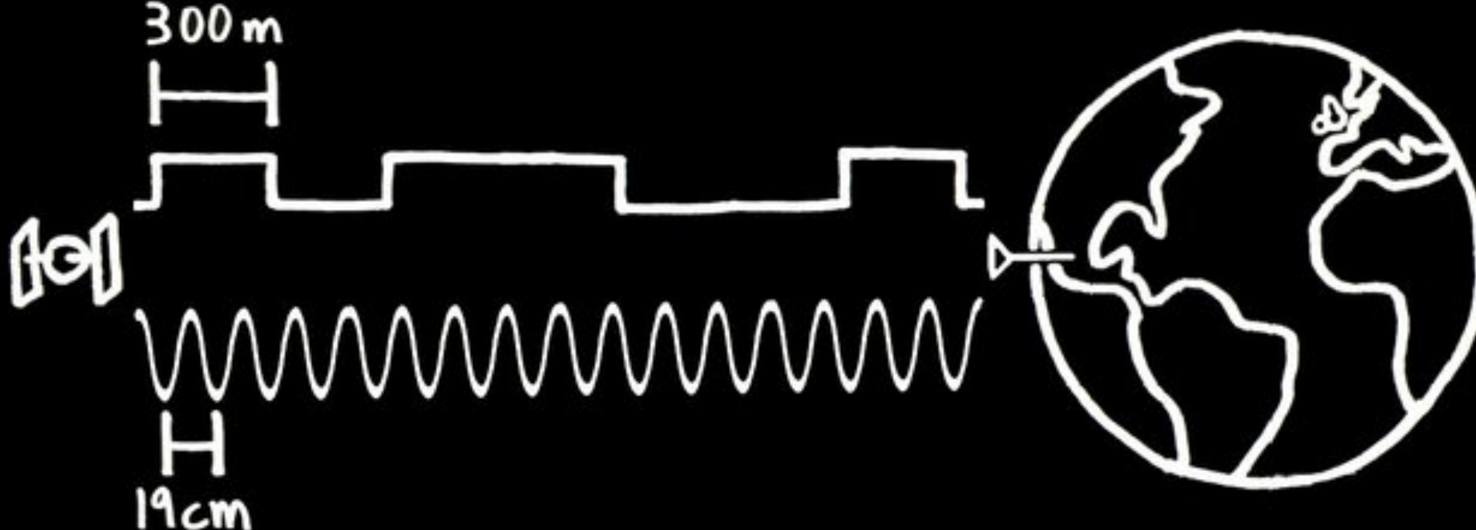
Ionosphere



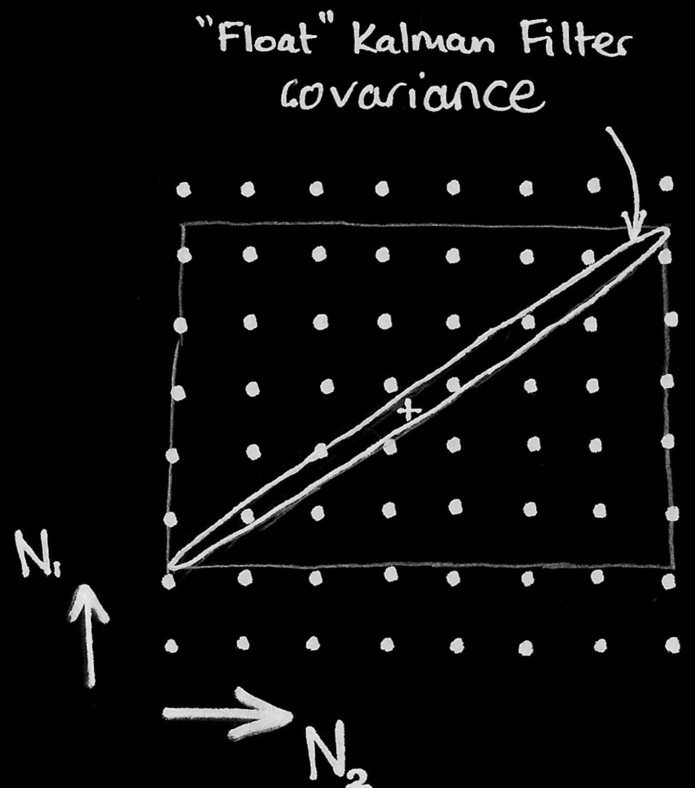
Ionosphere



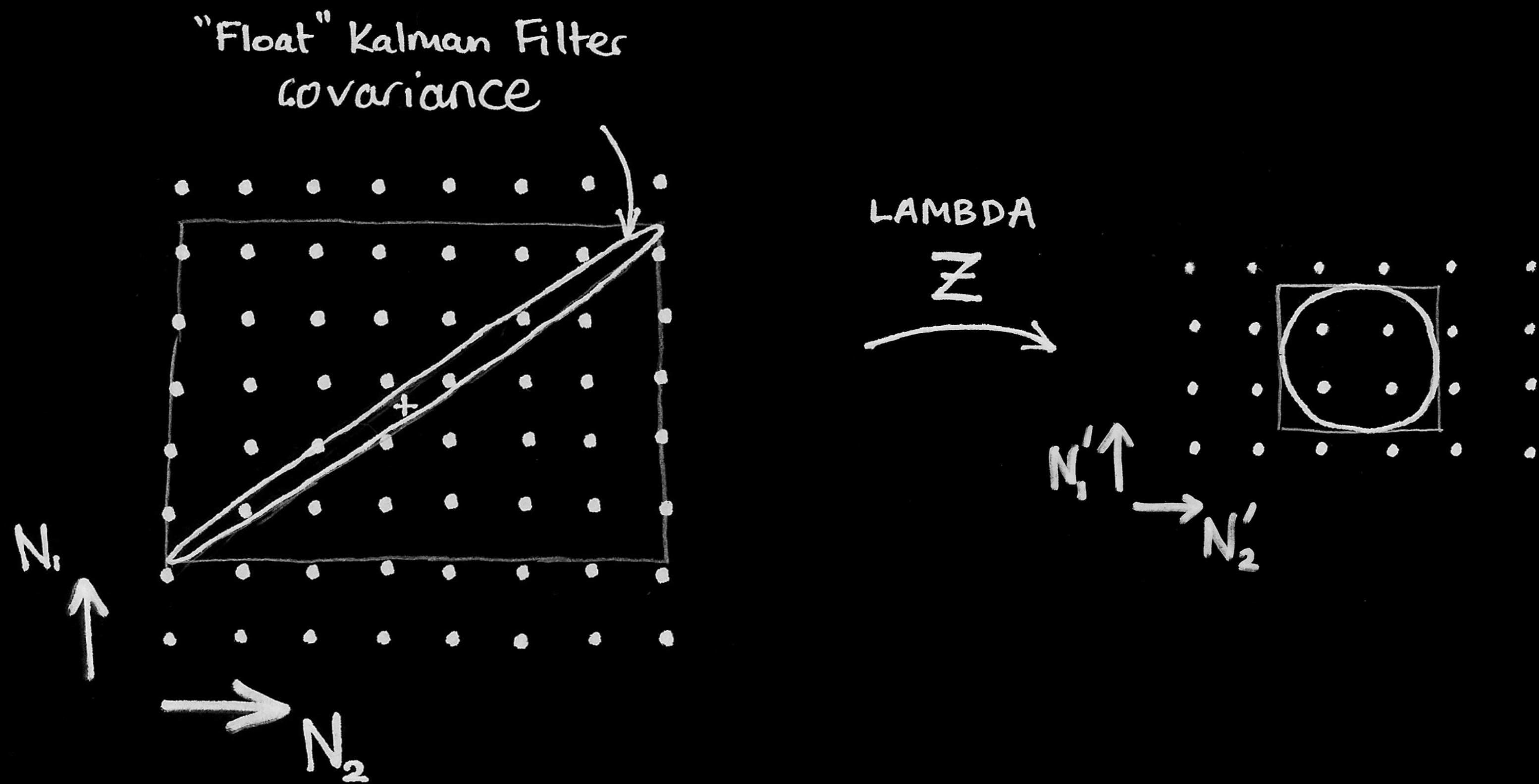
Measurement Precision



Measurement Precision

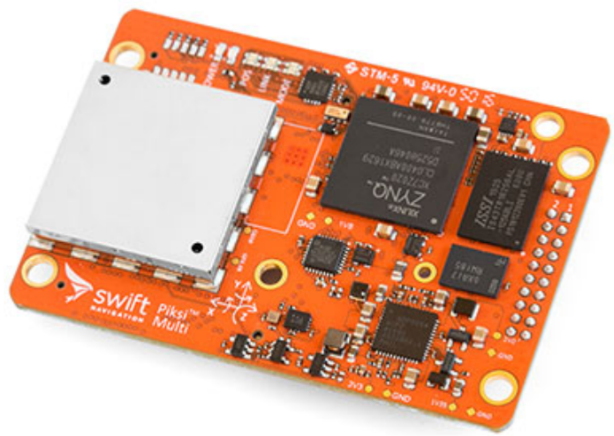


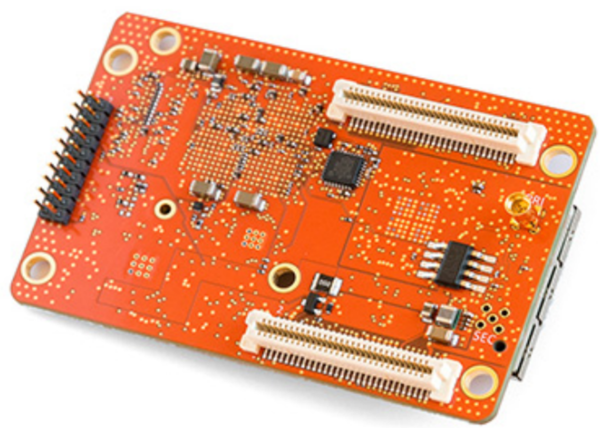
Measurement Precision



Introducing Piksi™ Multi

swift NAVIGATION





Fast RTK convergence times measured in seconds, not minutes

Improve results with centimeter-accurate positioning

Open platform featuring powerful FPGA & dual core processor

UART, CAN, USB & Ethernet interfaces

Breakthrough price of $595

GPS L1/ L2
Hardware-ready for GLONASS, BeiDou, Galileo

Small form factor compatible with common GNSS modules

Designed for rapid prototyping & ease of use

Introducing Duro™

Meet Duro

Duro is a ruggedized version of the Piksi Multi RTK GNSS receiver. Built to be tough, Duro is ideal for agricultural, robotics, maritime and outdoor industrial applications. Duro is designed for integration into existing equipment. This easy-to-deploy GNSS sensor is protected against weather, moisture, vibration, dust, water immersion and the unexpected that can occur in outdoor long-term deployments.

Centimeter-accurate positioning

Military-grade, rugged enclosure

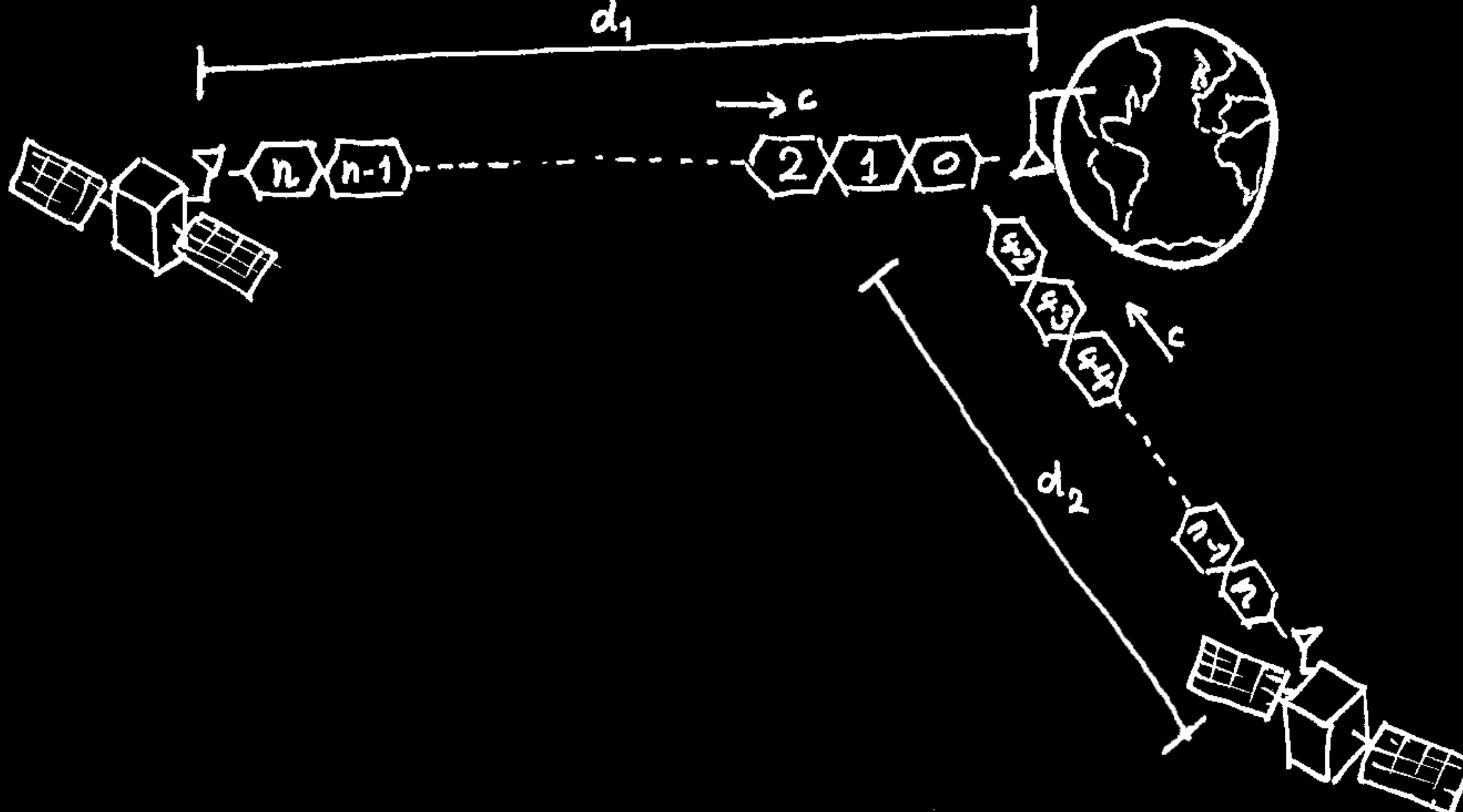
Easy to deploy, ready out of the box

Weatherproof design, sealed connectors

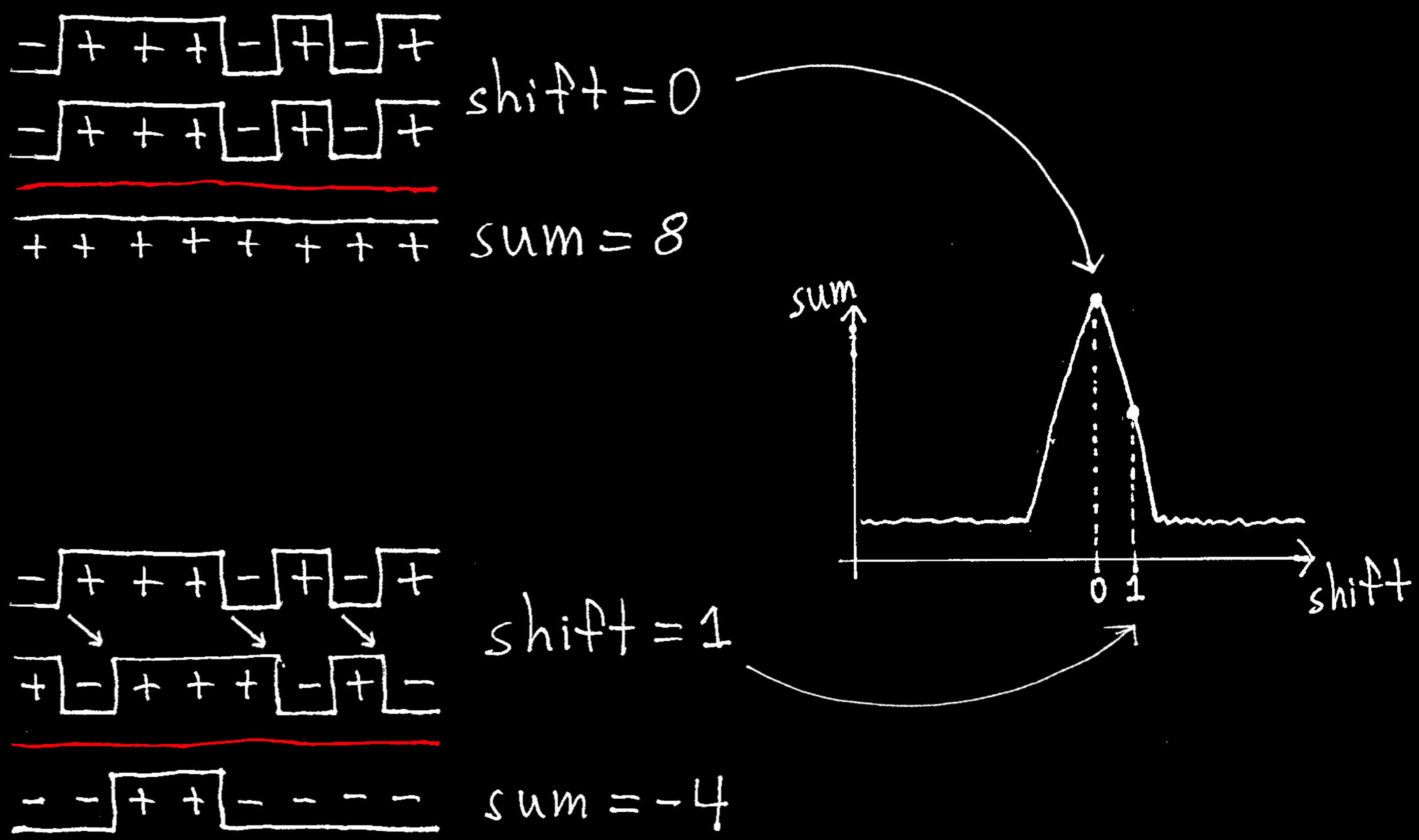
38,300

Source: National Safety Council, 2015 Motor Vehicle Fatalities

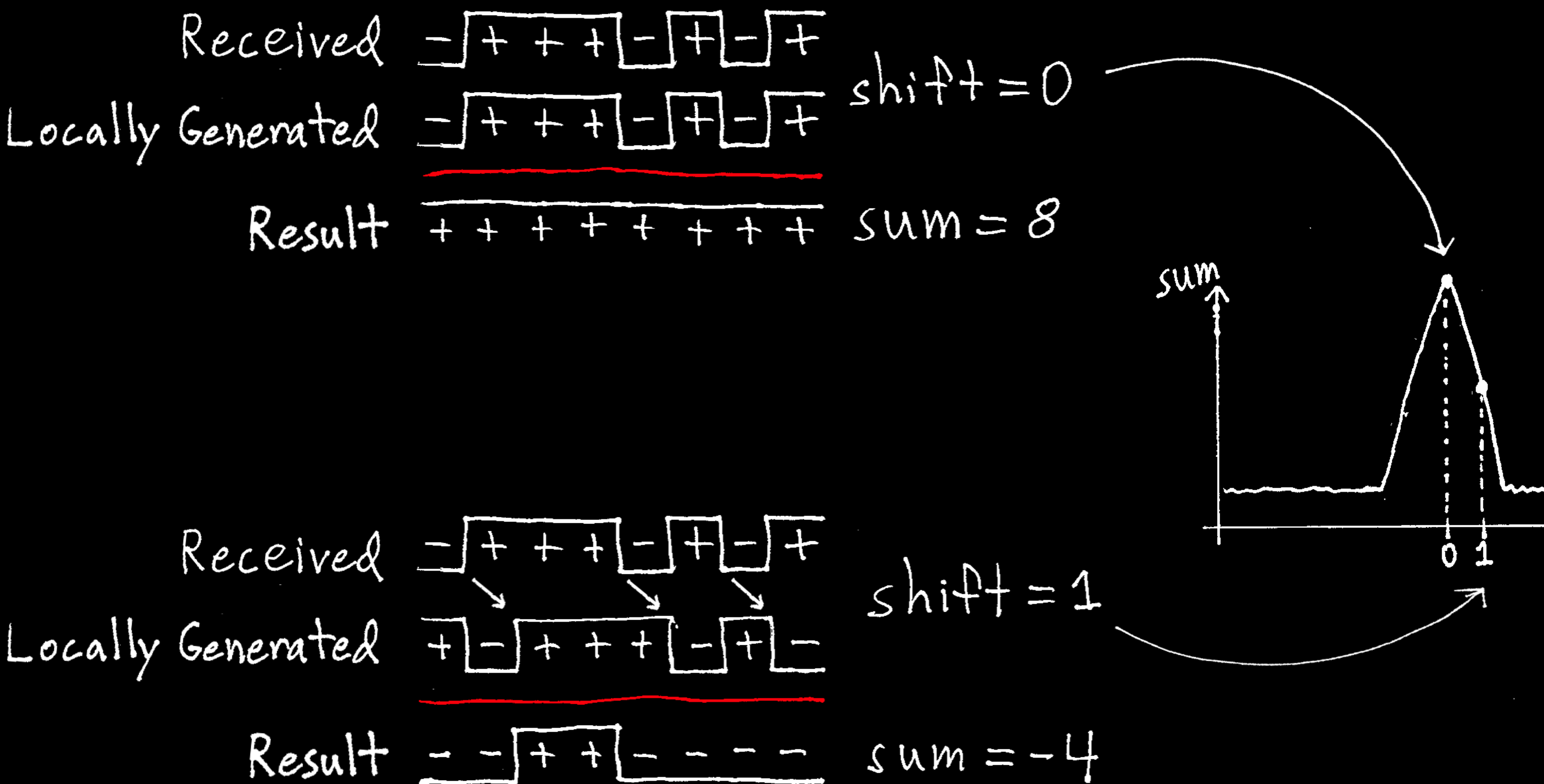
Appendix


d_1
c
n
n-1
2
1
0
c
d_2
n-1
n

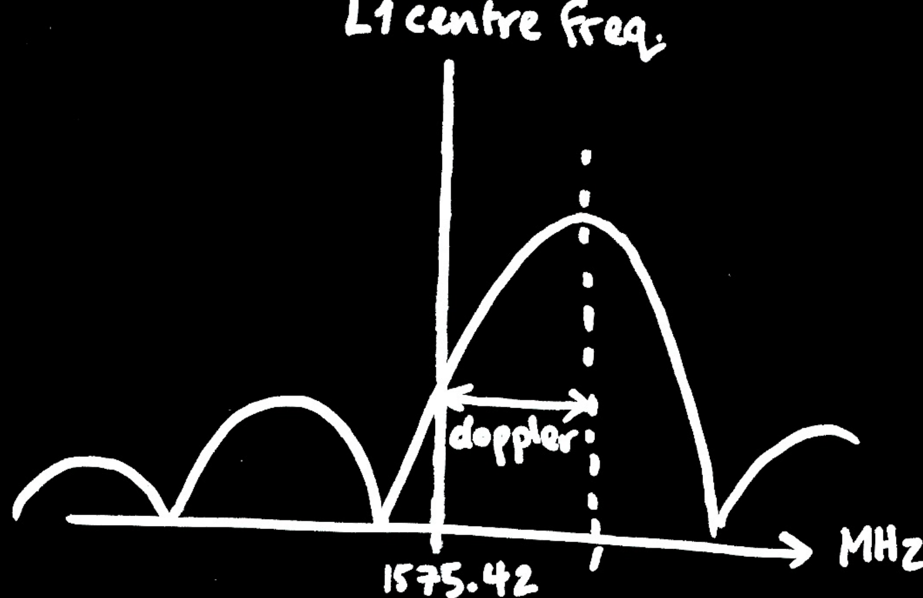
Measuring the code phase



Measuring the code phase

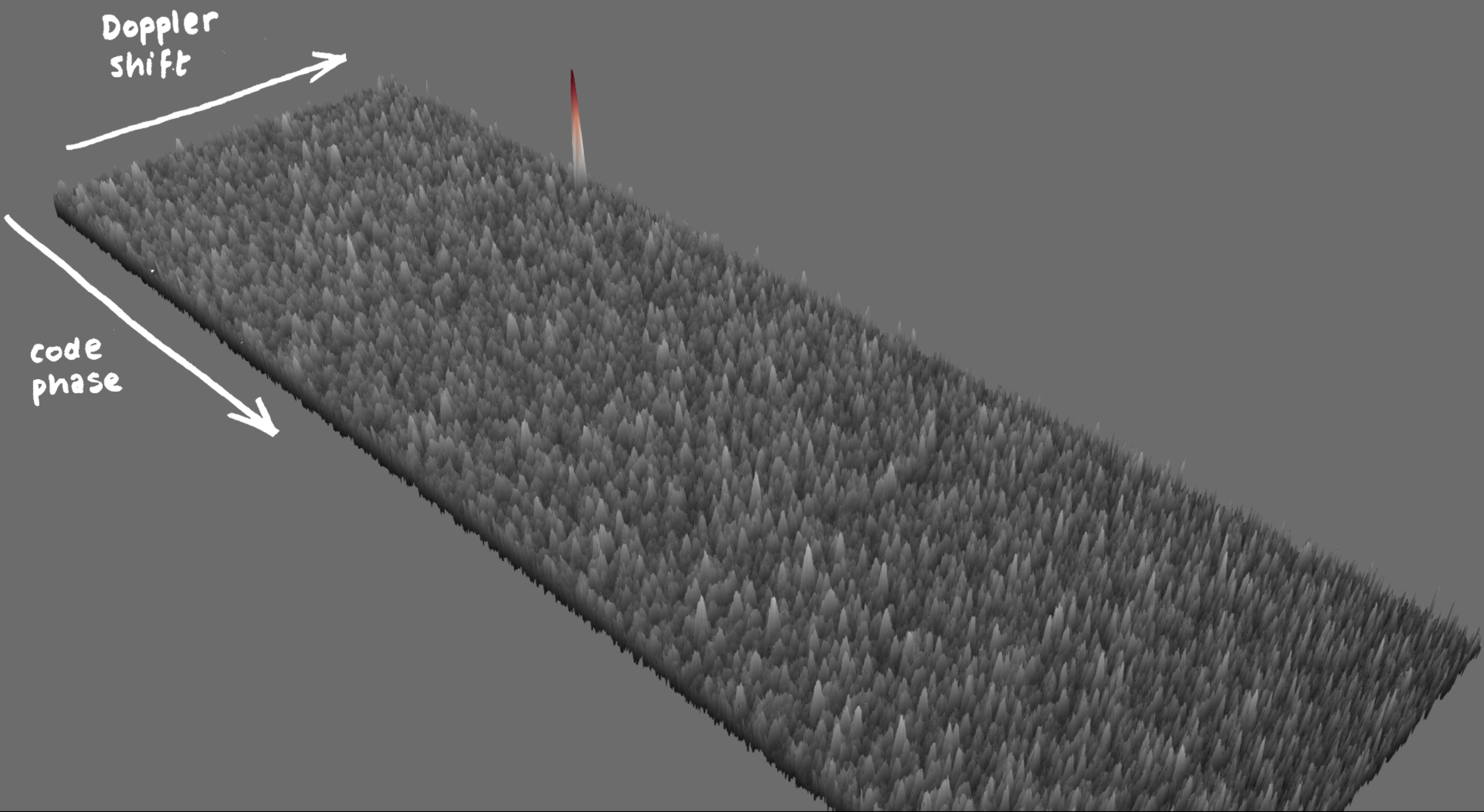


Doppler shift

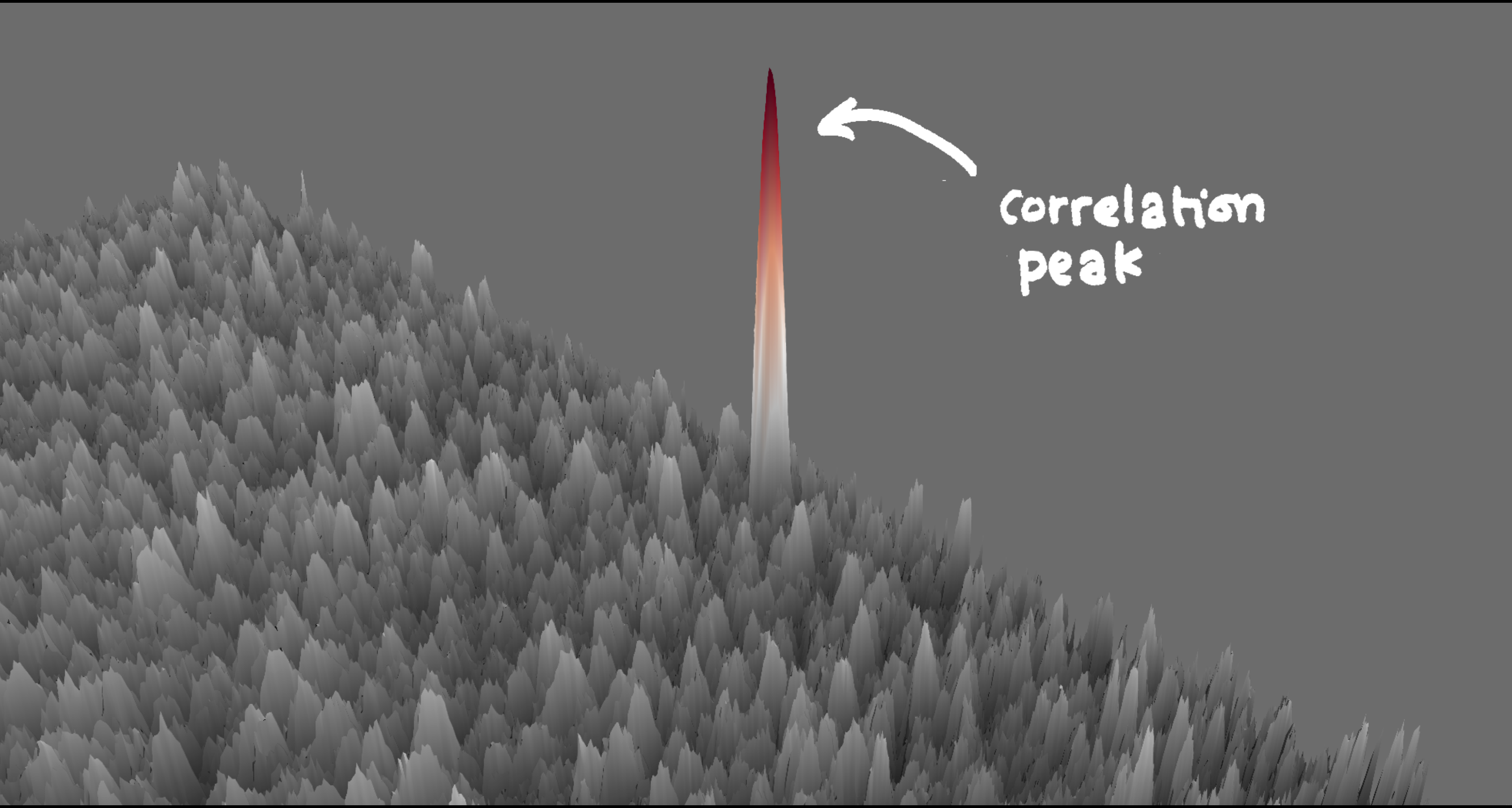


Acquisition

Acquisition

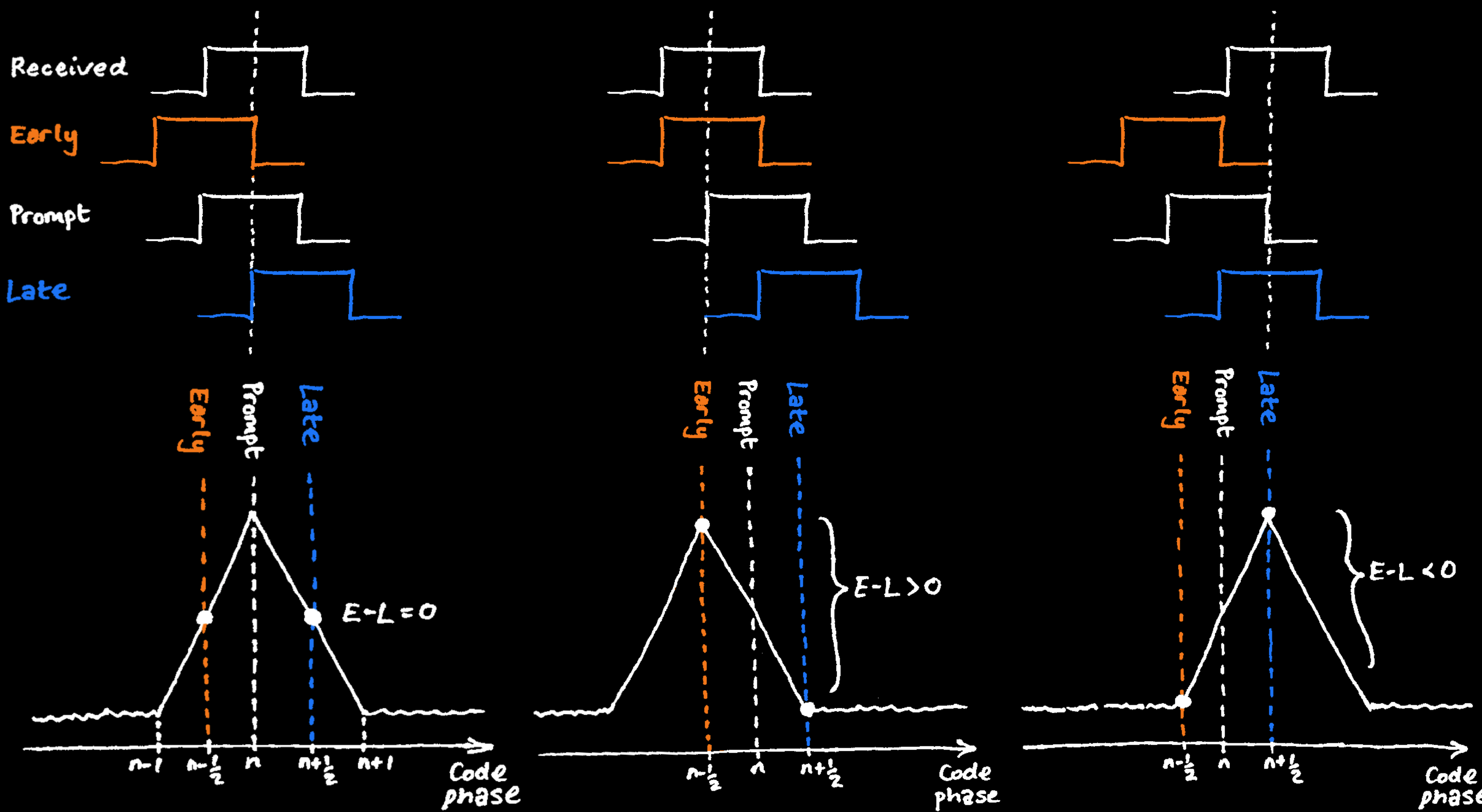


Acquisition

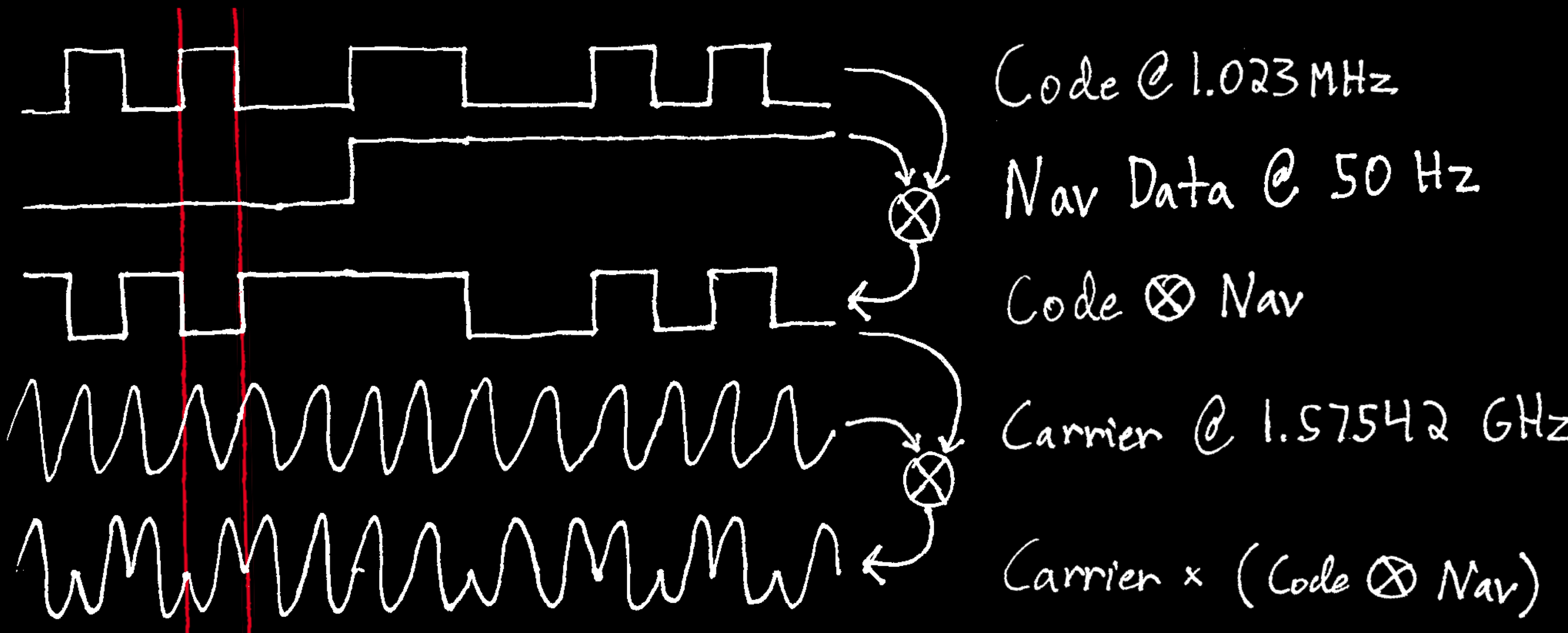


Tracking

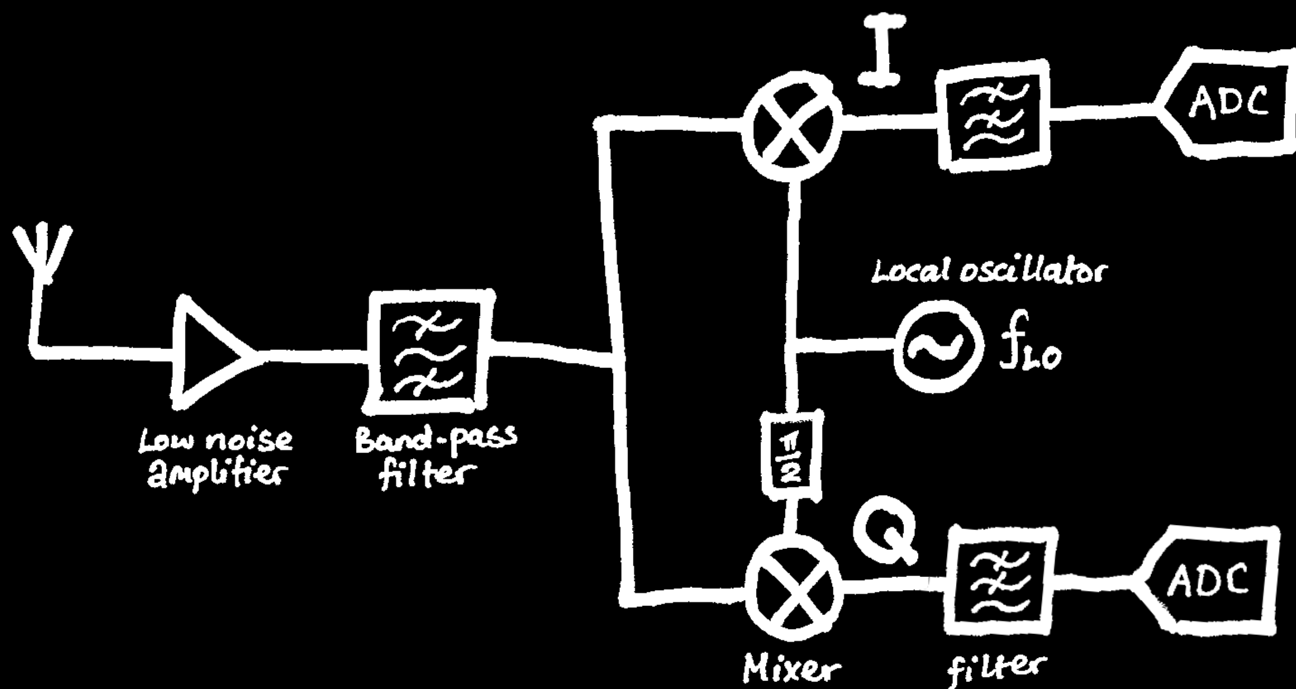
Tracking


Received
Early
Prompt
Late
Early
Prompt
Late
E-L=0
n-1
n-½
n
n+½
n+1
Code phase
E-L>0
E-L<0

Signal structure



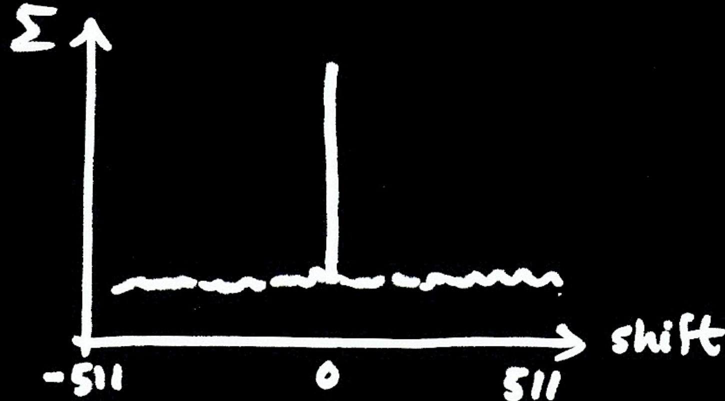
Analog Frontend



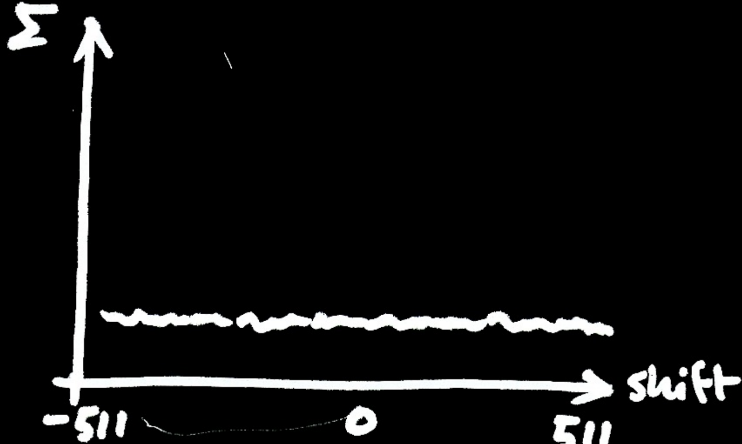
$$\cos\theta\cos\phi = \frac{\cos(\theta-\phi)+\cos(\theta+\phi)}{2}$$

Gold codes

length $= 2^n - 1$

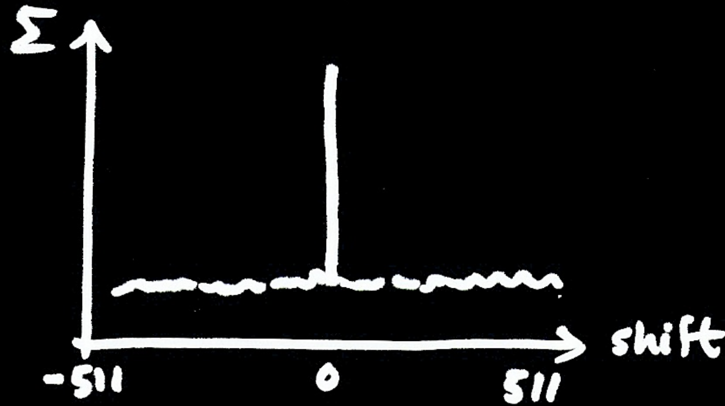


Autocorrelation

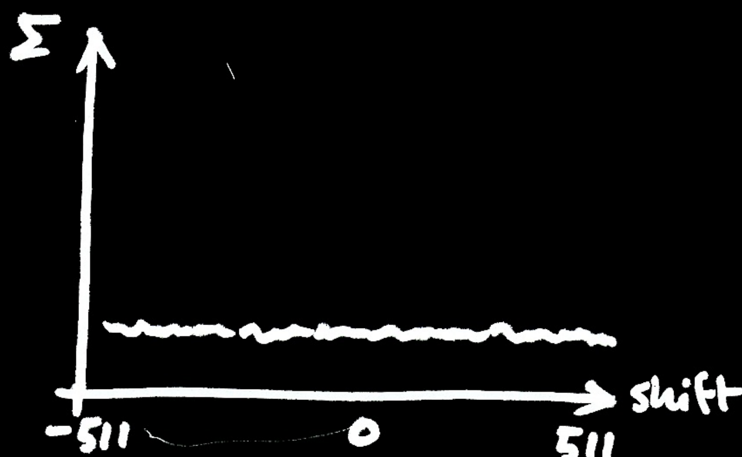


Cross-correlation

Receiving from multiple satellites



sat A code ★ sat A code



sat A code ★ sat B code