First session on
GPS and Galileo Data Processing: from fundamentals to precise navigation
Lecture Notes(*)

(*) Partially based on
"Global Positioning System; Signals, Measurements, and Performance", P. Misra and P. Enge, Ganga-Jamnua Press, 2004 and on
"GPS data processing: code and phase. Algorithms, techniques and recipes", M.Hernández-Pajares, J.M. Juan, J.Sanz, 2001-2005.

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https://scholar.google.es/citations?user=Tm-DcsMAAAAJ&hl=en

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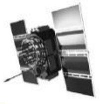

Main Goal: To acquire GPS Fundamental Background & Processing skills

OUTLINE

Outline (2)

Bibliography:

Hernández-Pajares, M. et al., *Introduction to GNSS Data Processing*, 1998-2015 http://newg1.upc.es/lectures/legad/

Hernández-Pajares, M., J.M. Juan, J.Sanz, *GPS data processing: Code and Phase Algorithms, Techniques and Recipes*, 2002-2008, http://newg1.upc.es/lectures/legad/docs/LeGAD-00.Book-English_v8b.pdf

Hofmann-Wellenhof, Lichtenegger and Wasle, *GNSS, Global Navigation Satellite Systems, GPS, GLONASS, Galileo and more*, Springer, Wien, NewYork, 2008.

P. Misra and P. *Enge,Global Positioning System; Signals, Measurements, and Performance*, Ganga-Jamnua Press, 2004.

Parkinson B.W., J.J.Spilker (eds), *Global Positioning System: Theory and Applications, Vols. I & II*, Progress in Astronautics and Aeronautics, Vol. 163 & 164, 1996.

Seeber G., *Satellite Geodesy*, de Gruyter ed., 1993.

GPS World: http://www.gpsworld.com

Inside GNSS: http://www.insidegnss.com/

Teacher coordinates:

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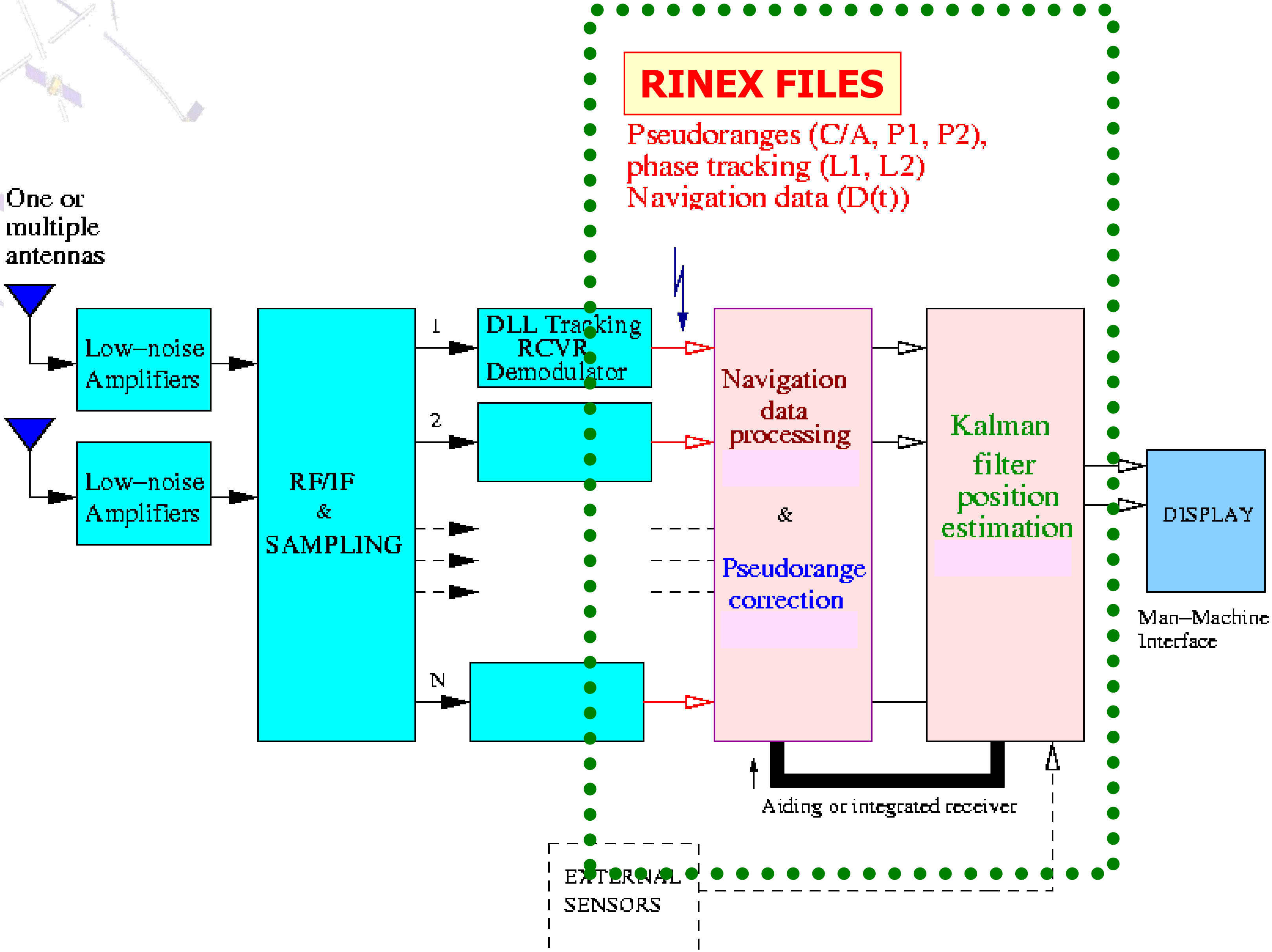
Part of this course is based on the book edited by UPC:

GPS data processing: code and phase. Algorithms, techniques and recipes.

These slides show some exercises and examples whose data files (with actual GPS data) and corresponding software (with source code) are provided in the book.

Summary

- **Introduction.**
- **GPS measurements and their combinations.**
- **Satellite coordinates.**
- **The model.**
- **Navigation equations.**
- **Code and phase differential positioning.**
  - Floating versus fixing ambiguities.


RINEX FILES
Pseudoranges (C/A, P1, P2),
phase tracking (L1, L2)
Navigation data (D(t))
One or
multiple
antennas
Low–noise
Amplifiers
Low–noise
Amplifiers
RF/IF
&
SAMPLING
1
2
N
DLL Tracking
RCVR
Demodulator
Navigation
data
processing
&
Pseudorange
correction
Kalman
filter
position
estimation
DISPLAY
Man–Machine
Interface
Aiding or integrated receiver
EXTERNAL
SENSORS

Specific Objectives:

- To learn about GPS observables (code and phase), their characteristics, properties, combinations and applications.
- To learn how to calculate satellites orbits and clocks from navigation message. To know the achievable precision.
- To learn how to model pseudodistance for code and phase measurements. This includes calculation of: 1) Coordinates at emission epoch, 2) Ionospheric delay (Klobuchar model), 3) Tropospheric delay, 4) relativistic correction, 5) clocks offsets and satellite instrumental delays, 6) phase wind-up, etc.
- To learn how to set and solve the navigation equation system using least-squares or Kalman filter (algorithm level).
- To know how to use phase differential positioning: Floating and fixing ambiguities.

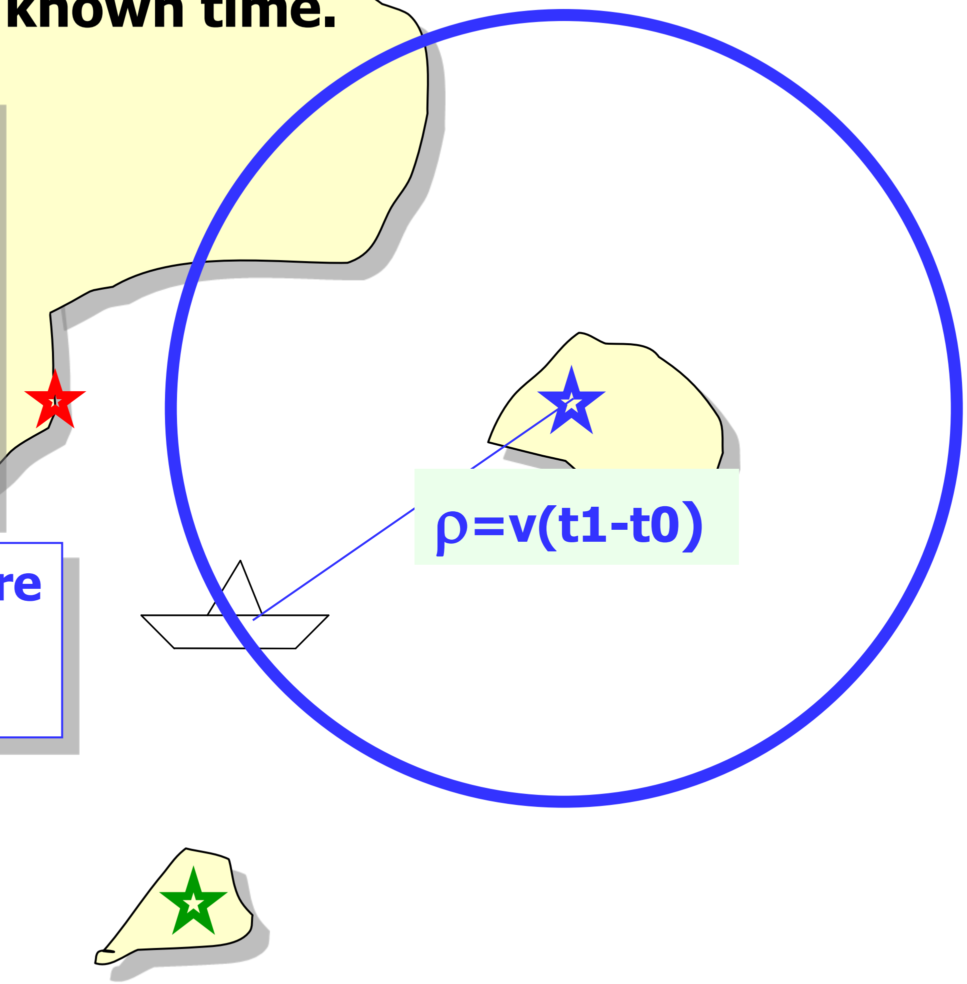
To get tools and skills to process and analyze GPS data.
To implement algorithms for satellite navigation.

Introduction

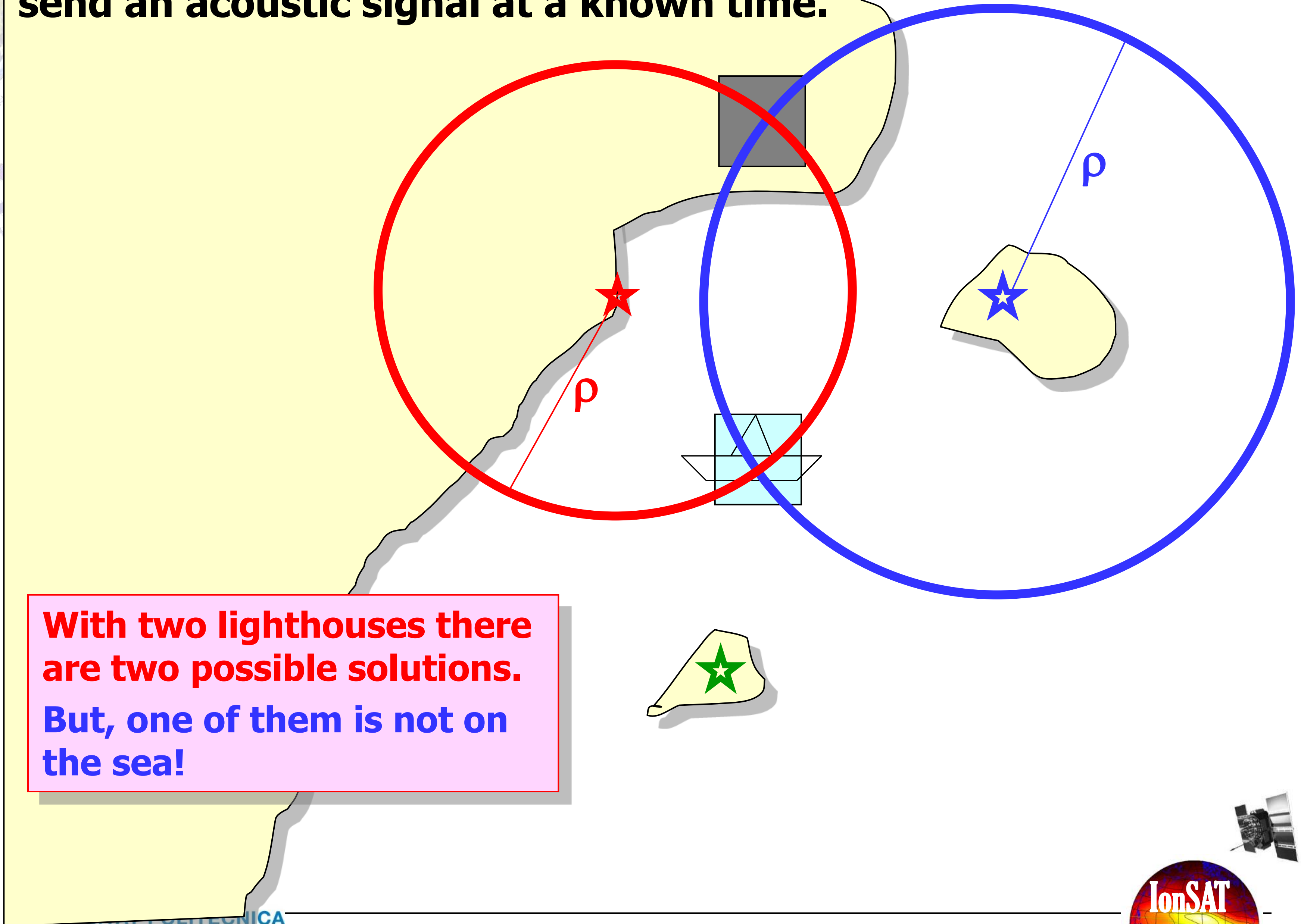
A ship determines its location from a set on lighthouses that send an acoustic signal at a known time.

Knowing the emission time "t0" in the lighthouse and the reception time "t1" in the ship, the traveling time "t1-t0", and the geometric range "ρ=v(t1-t0)" may be computed.

With only one lighthouse there is a whole circumference of possible locations



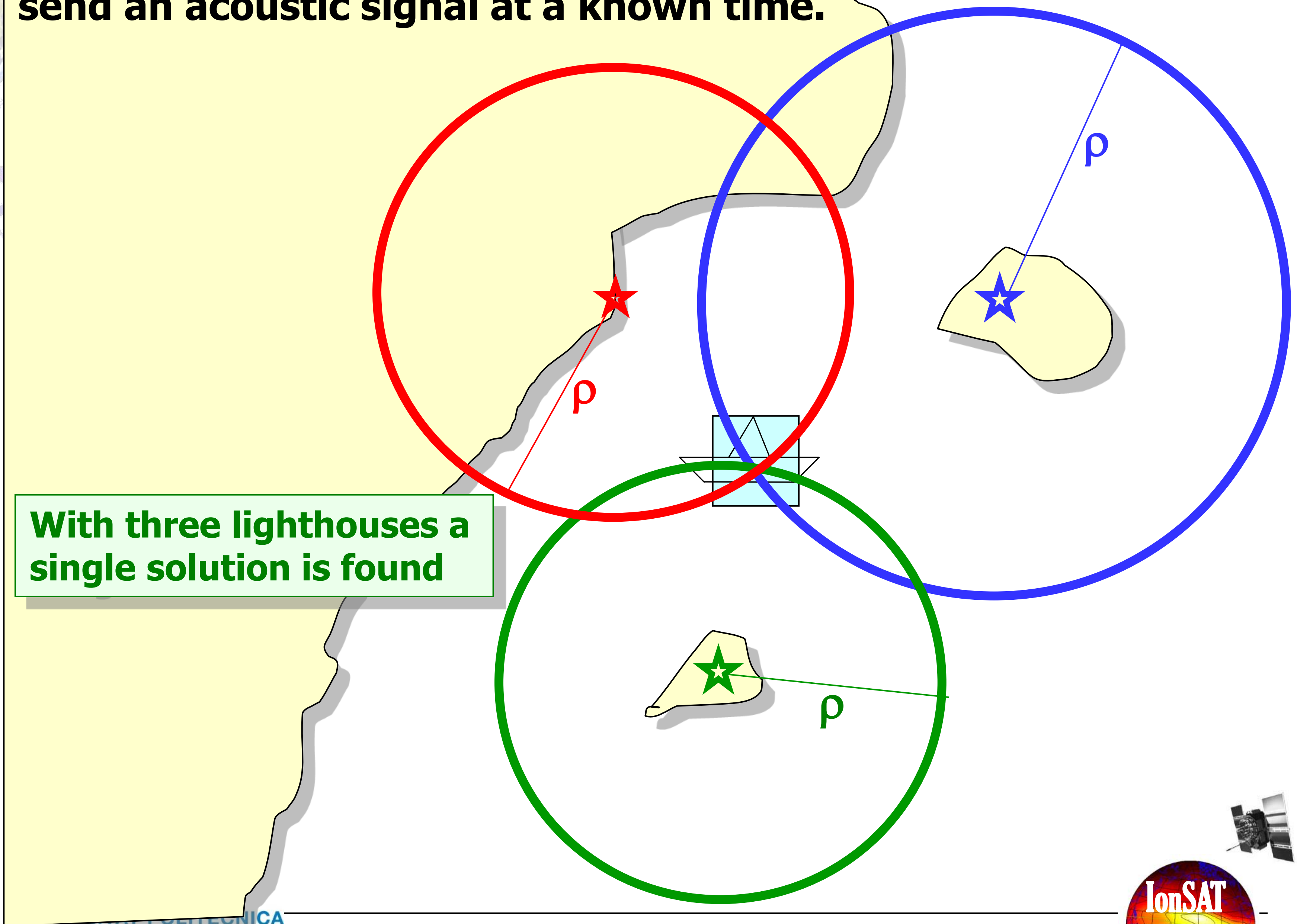
A ship determines its location from a set on lighthouses that send an acoustic signal at a known time.



With two lighthouses there are two possible solutions.

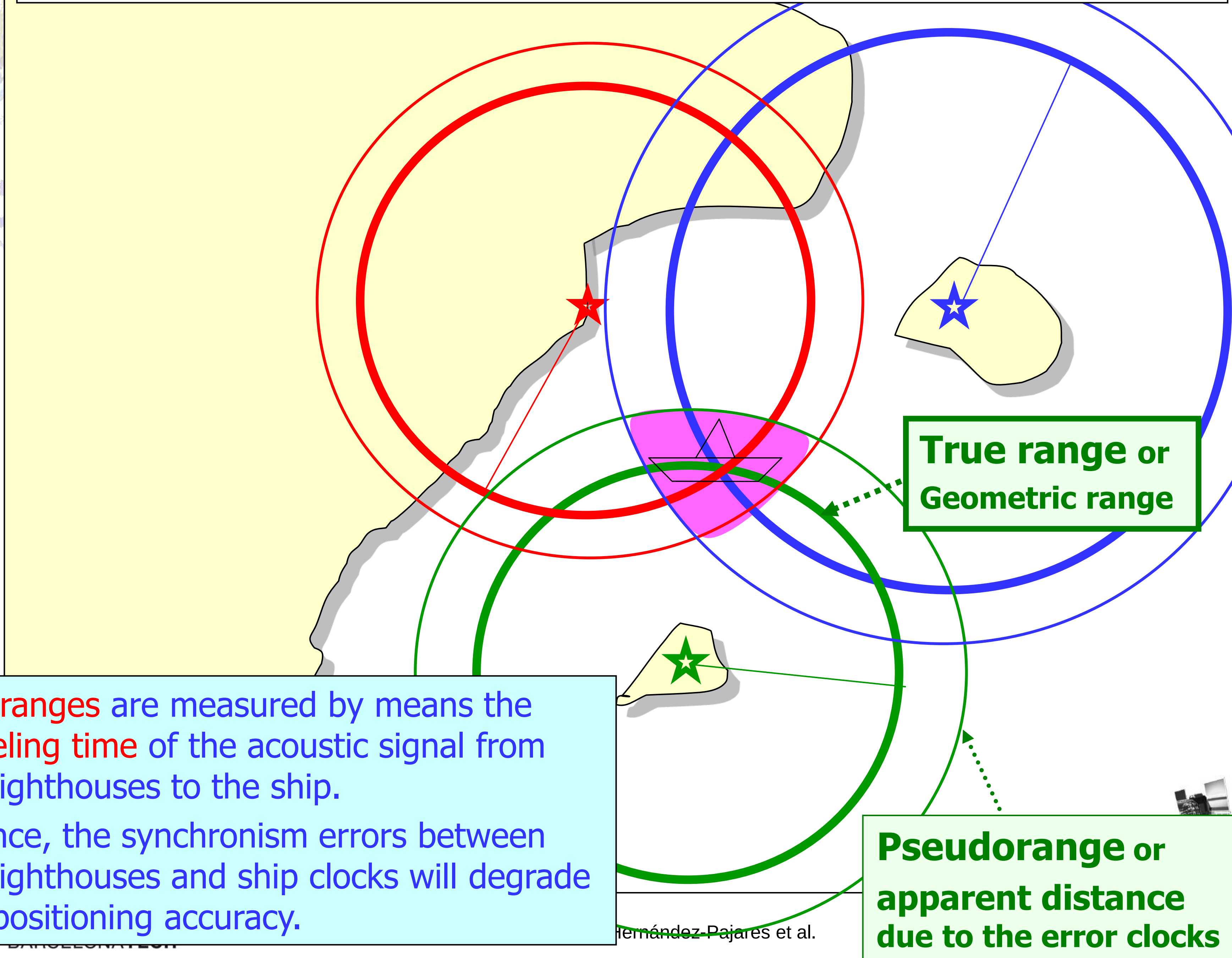
But, one of them is not on the sea!

A ship determines its location from a set on lighthouses that send an acoustic signal at a known time.



With three lighthouses a single solution is found

Errors in the clocks (lighthouses and ship) synchronism affects the accuracy

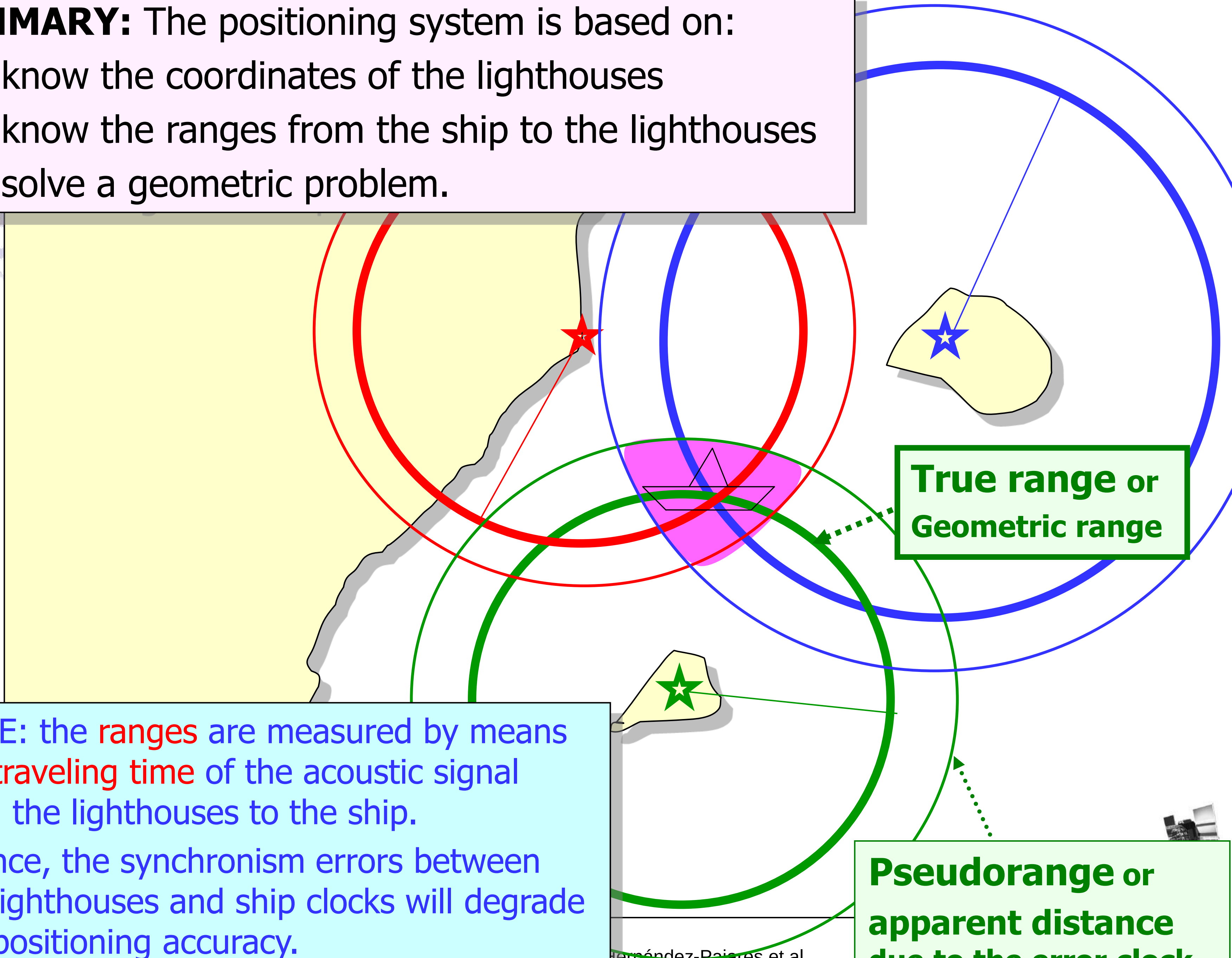


The ranges are measured by means the traveling time of the acoustic signal from the lighthouses to the ship.

Thence, the synchronism errors between the lighthouses and ship clocks will degrade the positioning accuracy.

SUMMARY: The positioning system is based on:

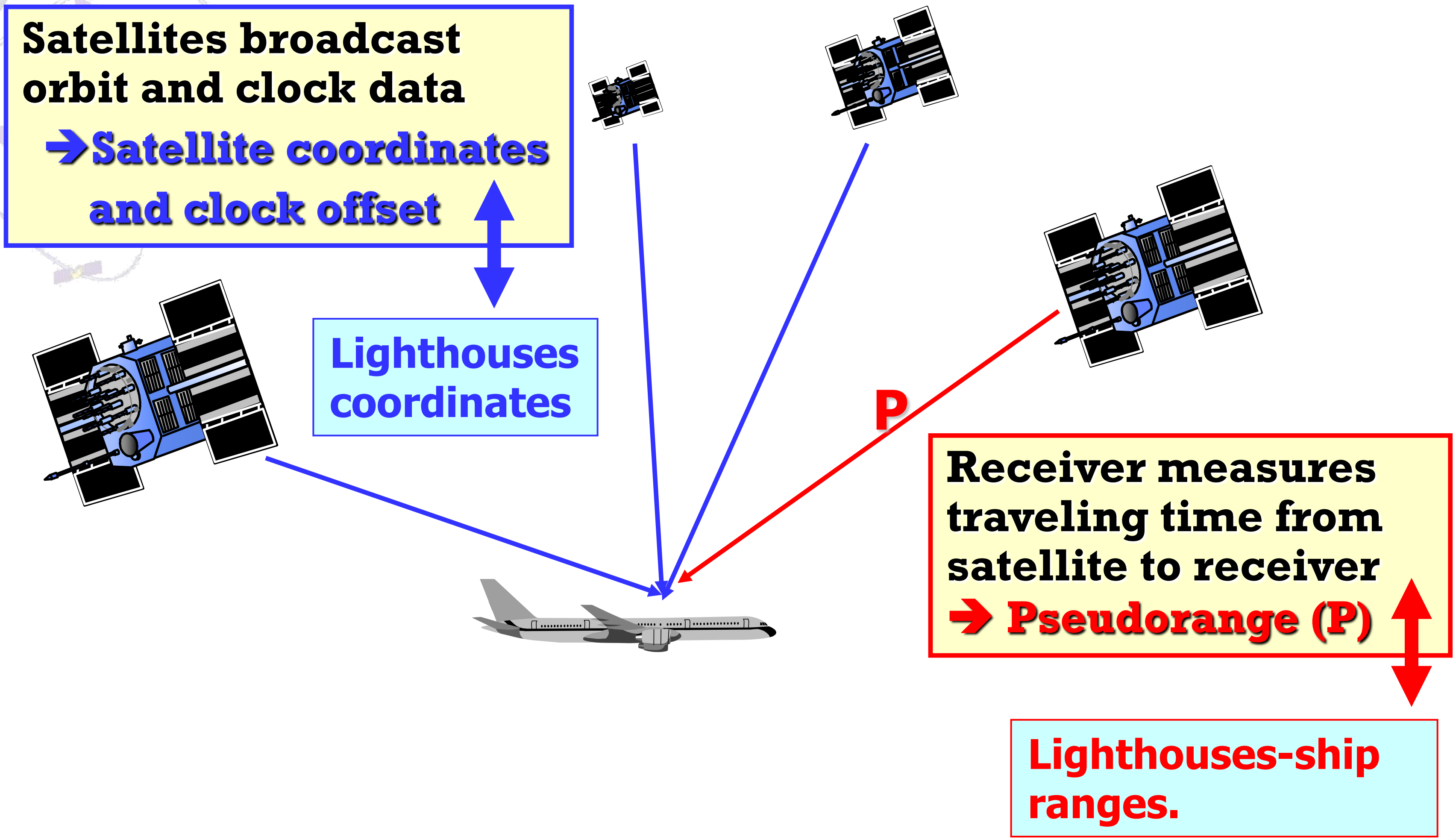
- To know the coordinates of the lighthouses
- To know the ranges from the ship to the lighthouses
- To solve a geometric problem.



NOTE: the ranges are measured by means the traveling time of the acoustic signal from the lighthouses to the ship.

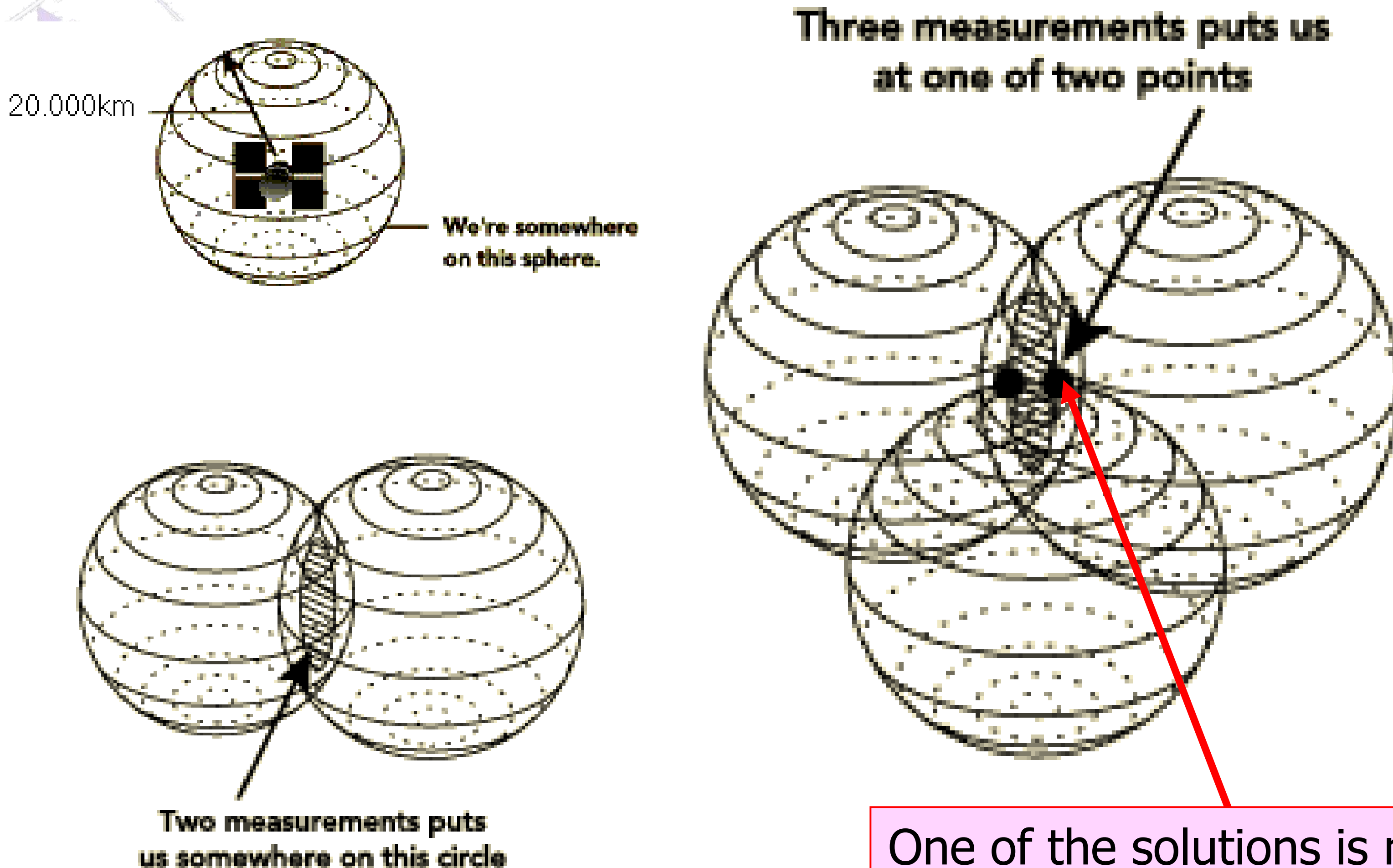
Thence, the synchronism errors between the lighthouses and ship clocks will degrade the positioning accuracy.

How GPS Works



Thence, the receiver coordinates are found **solving a geometrical problem**: from sat. coordinates and ranges

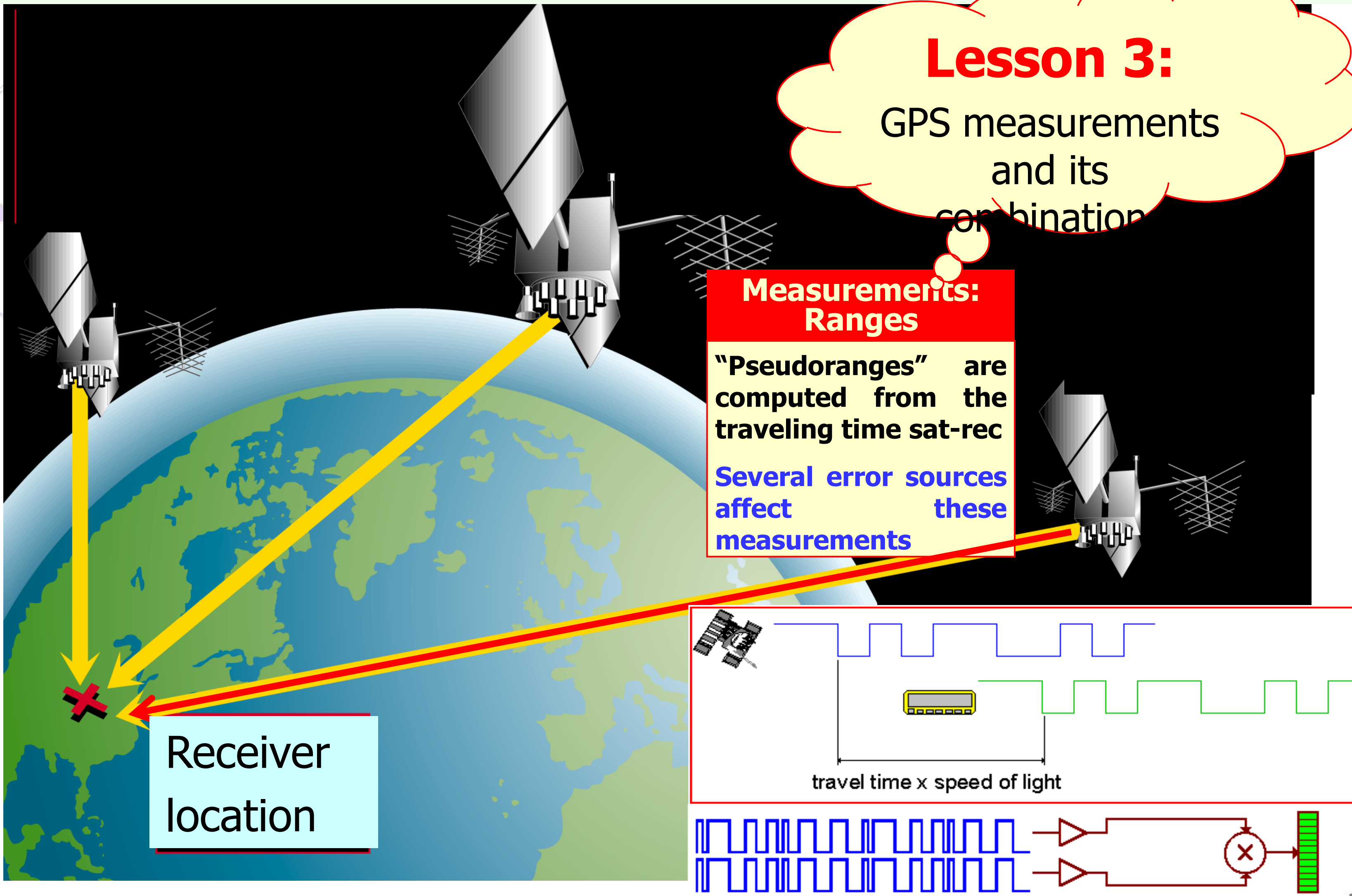
How GPS Works



One of the solutions is not on the Earth surface.

How GPS Works

How GPS Works



Lesson 3:

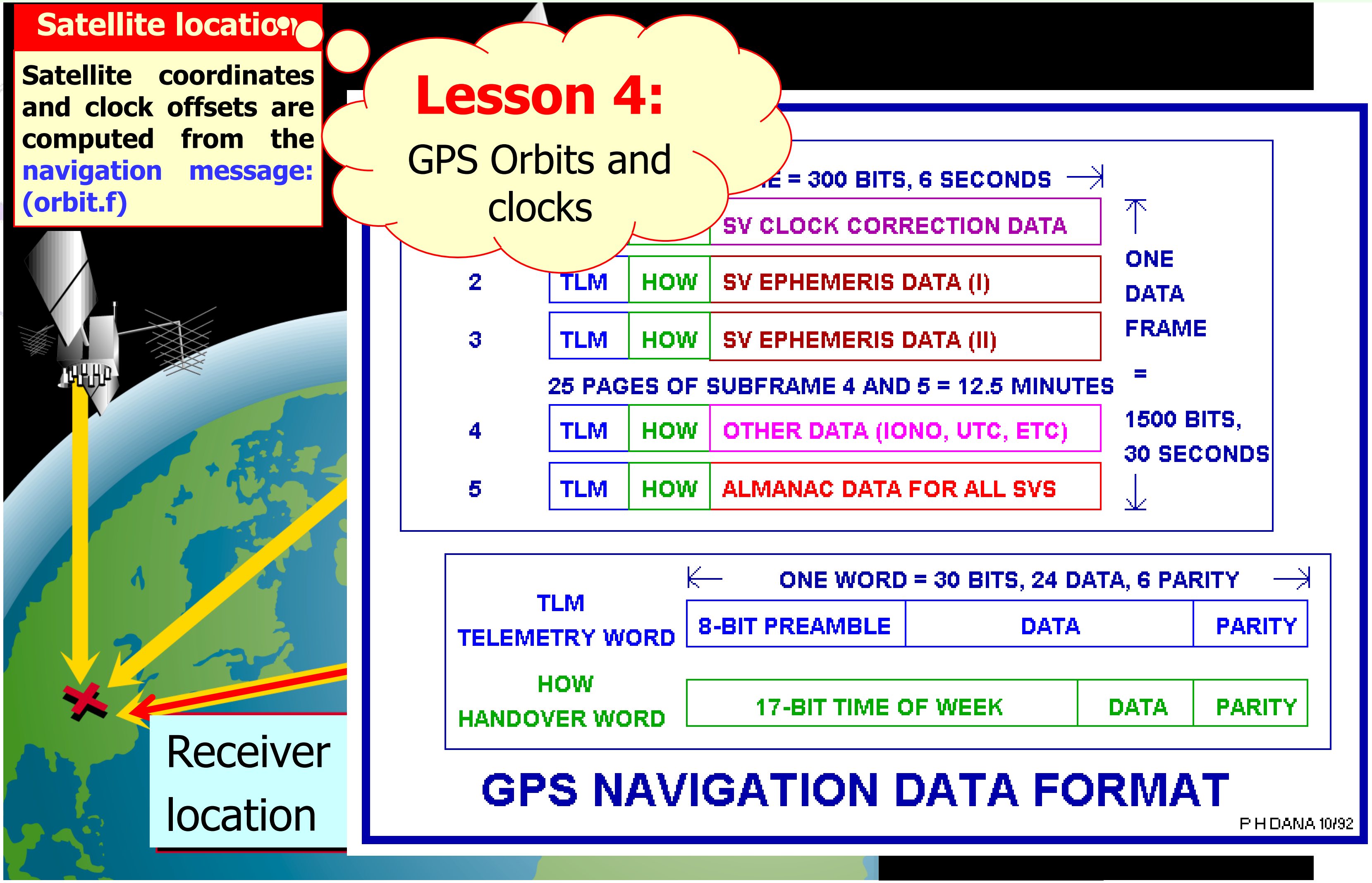
GPS measurements and its combination

Measurements: Ranges

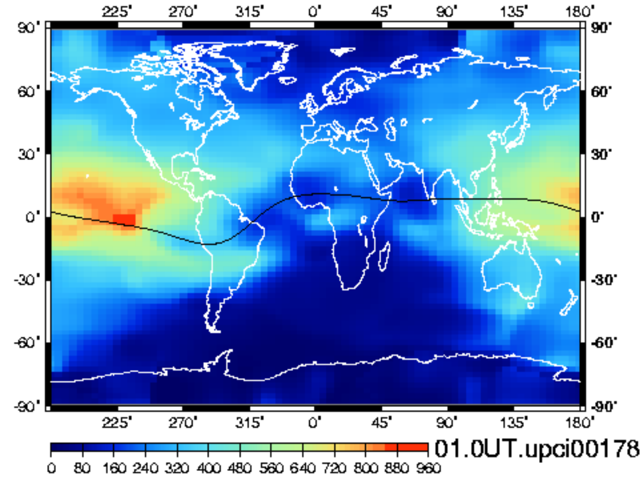
"Pseudoranges" are computed from the traveling time sat-rec

Several error sources affect these measurements

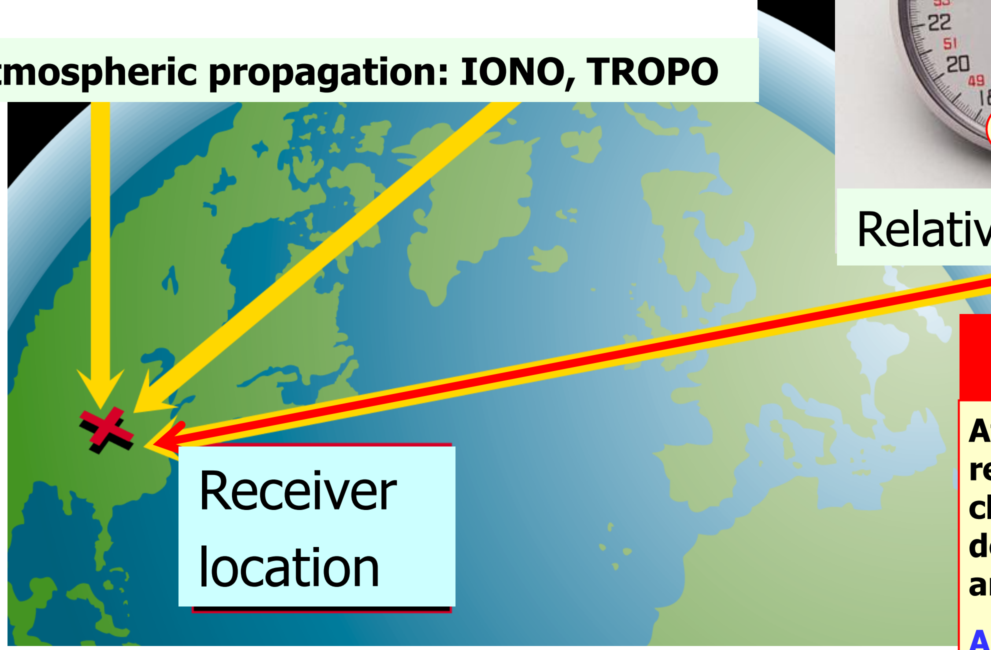
How GPS Works



GPS Works



Atmospheric propagation: IONO, TROPO



Relativistic

Lesson 5:

GPS measurements modeling (code)

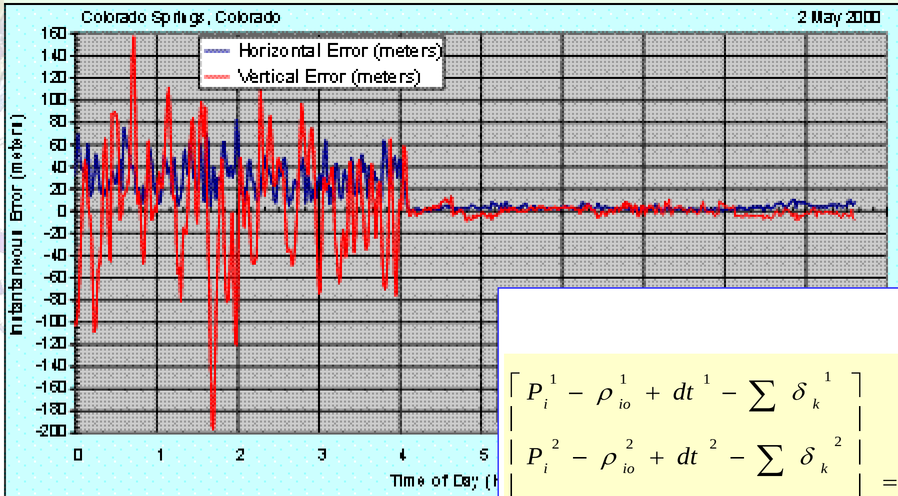
Receiver location

- **MODEL:**

Atmospheric propag., relativistic effects, clocks and instrum. delays are modeled and removed.

And the navigation equations are built

How GPS Works



$$
\begin{bmatrix} P_i^1 - \rho_{io}^1 + dt^1 - \sum \delta_k^1 \\ P_i^2 - \rho_{io}^2 + dt^2 - \sum \delta_k^2 \\ \dots\dots \\ P_i^n - \rho_{io}^n + dt^n - \sum \delta_k^n \end{bmatrix} = \begin{bmatrix} \frac{x_{io} - x^1}{\rho_{io}^1} & \frac{y_{io} - y^1}{\rho_{io}^1} & \frac{z_{io} - z^1}{\rho_{io}^1} & 1 \\ \frac{x_{io} - x^2}{\rho_{io}^2} & \frac{y_{io} - y^2}{\rho_{io}^2} & \frac{z_{io} - z^2}{\rho_{io}^2} & 1 \\ & \dots\dots\dots & & \\ \frac{x_{io} - x^n}{\rho_{io}^n} & \frac{y_{io} - y^n}{\rho_{io}^n} & \frac{z_{io} - z^n}{\rho_{io}^n} & 1 \end{bmatrix} \begin{bmatrix} \Delta x_i \\ \Delta y_i \\ \Delta z_i \\ cdt_i \end{bmatrix}
$$

Lesson 6:

Solving the navigation Equations

Navigation equations

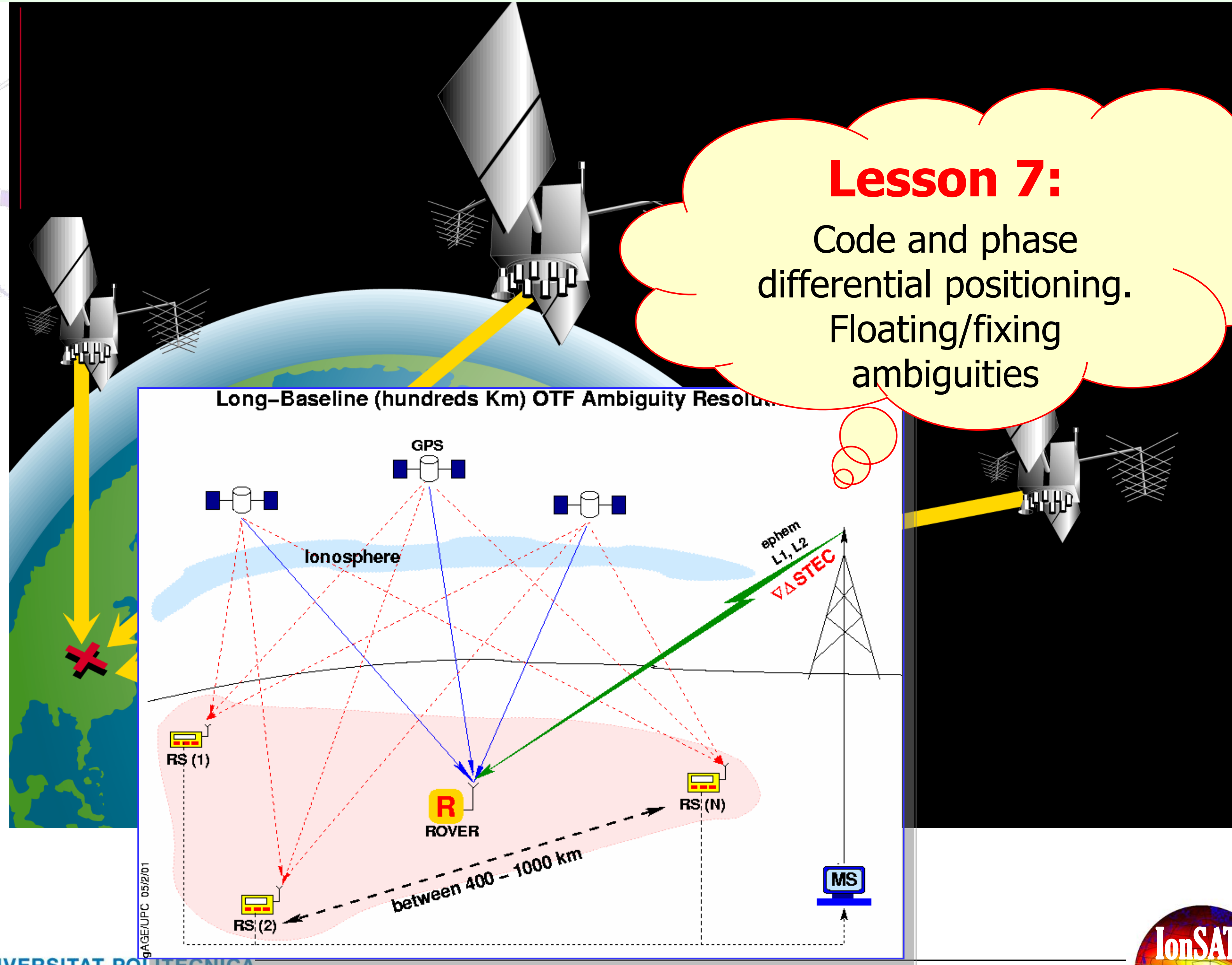
The geometric problem is linearized, and Weighted Least Mean Squares or Kalman filter are used to compute the solution.

MODEL:

Atmospheric propag., relativistic effects, clocks and instrum. delays are modeled and removed.

And the navigation equations are built

How GPS Works



Lesson 7:

Code and phase differential positioning. Floating/fixing ambiguities