THE WORLD'S FIRST GPS MOOC

& WORLDWIDE LAB USING SMARTPHONES

Frank van Diggelen, Per Enge

Stanford PNT

11-13 November 2015

What's a MOOC? "Massive open online course"

Free online course, Video-lectures, interactive quizzes, Pioneered at Stanford (Sebastian Thrun)

Udacity, EdX, Coursera

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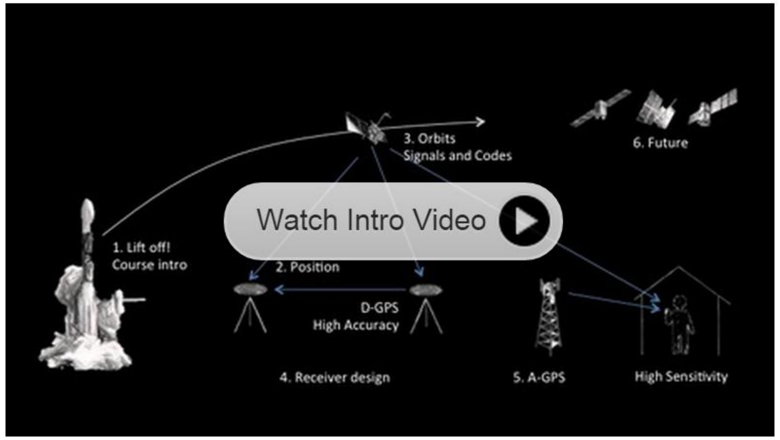
GPS: An Introduction to Satellite Navigation, with an interactive Worldwide Laboratory using Smartphones

Explore the fundamentals of the Global Positioning System (GPS) and how it works by conducting "backyard" laboratory experiments on your own mobile device. Learn the basics of satellite navigation and witness the power of a network with planet-wide coverage. Gain a deeper understanding of GPS and its role in our lives, while interacting with a worldwide community of learners and backyard scientists.



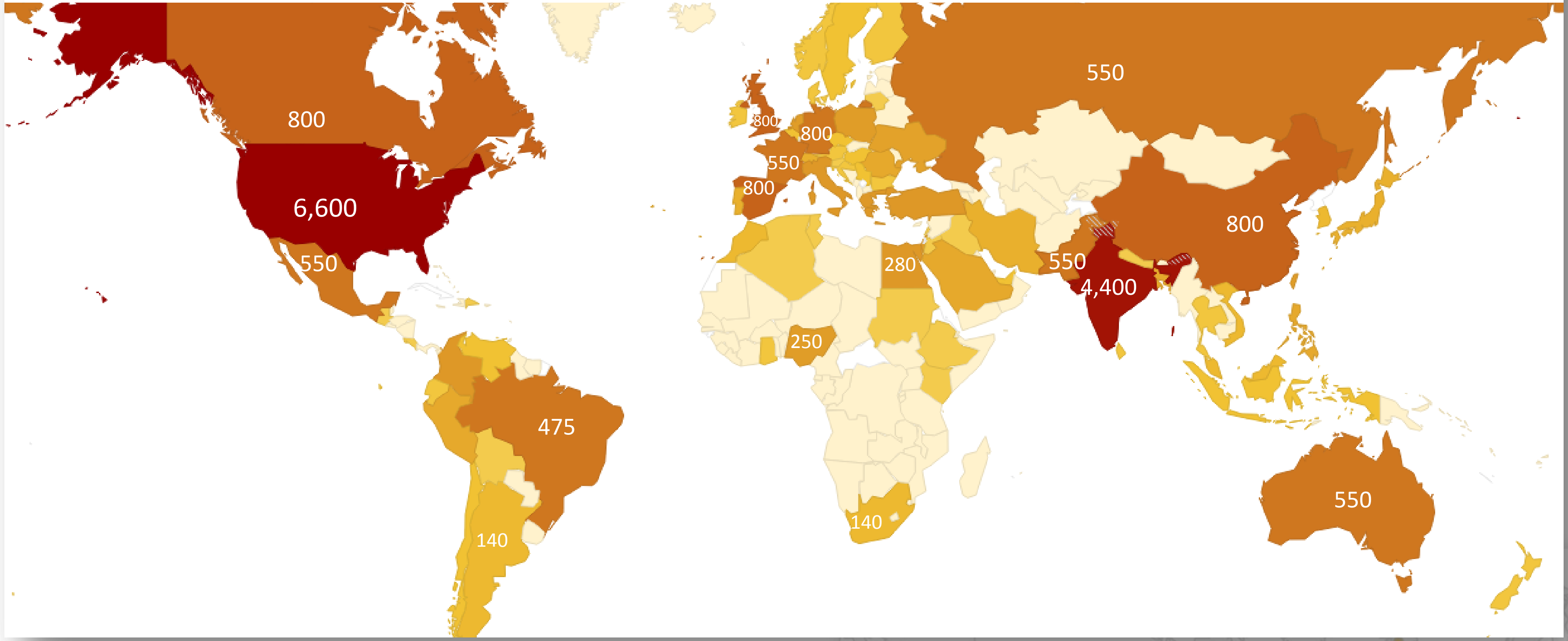
Instructors

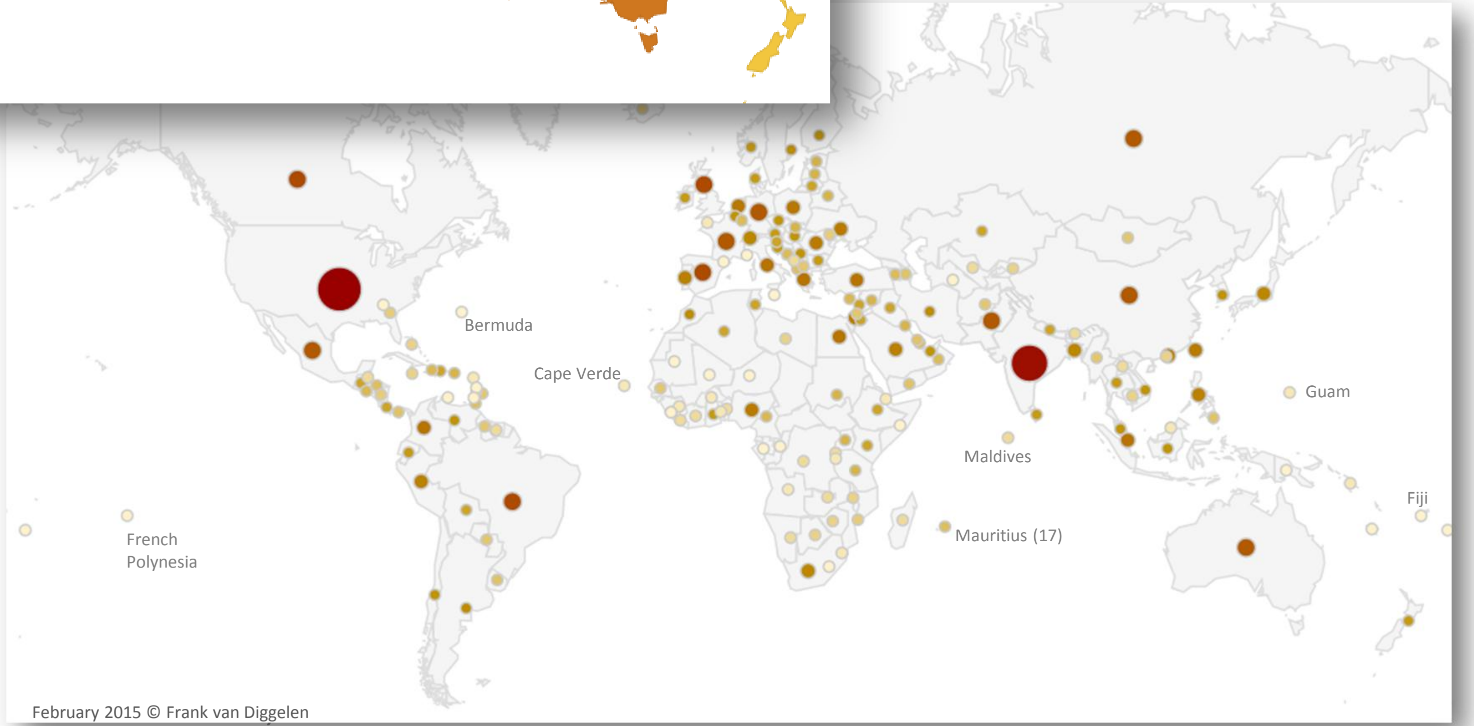
Per Enge
Stanford University

Frank van Diggelen
Stanford University

Stanford University

GPS MOOC Registration: 31,000 people from 192 countries.





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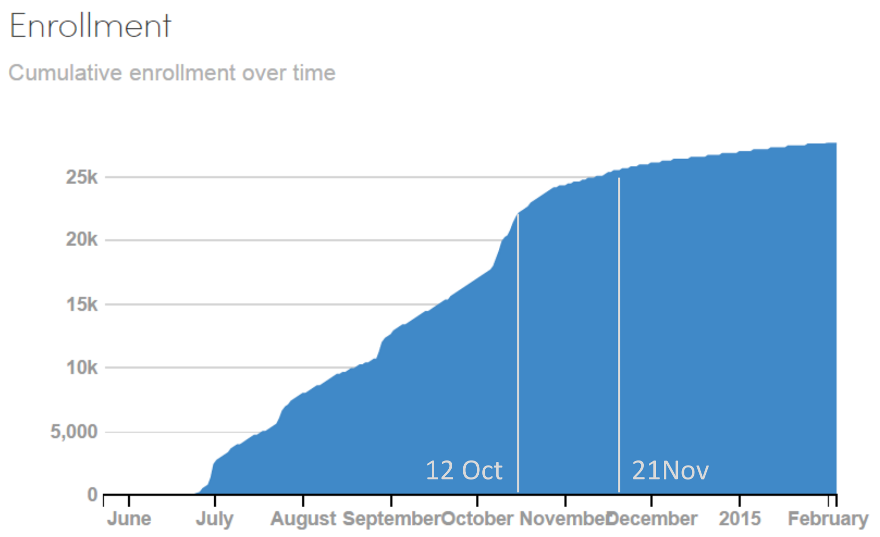
PARTICIPATION, OVER TIME

31,000 registrants (ongoing)

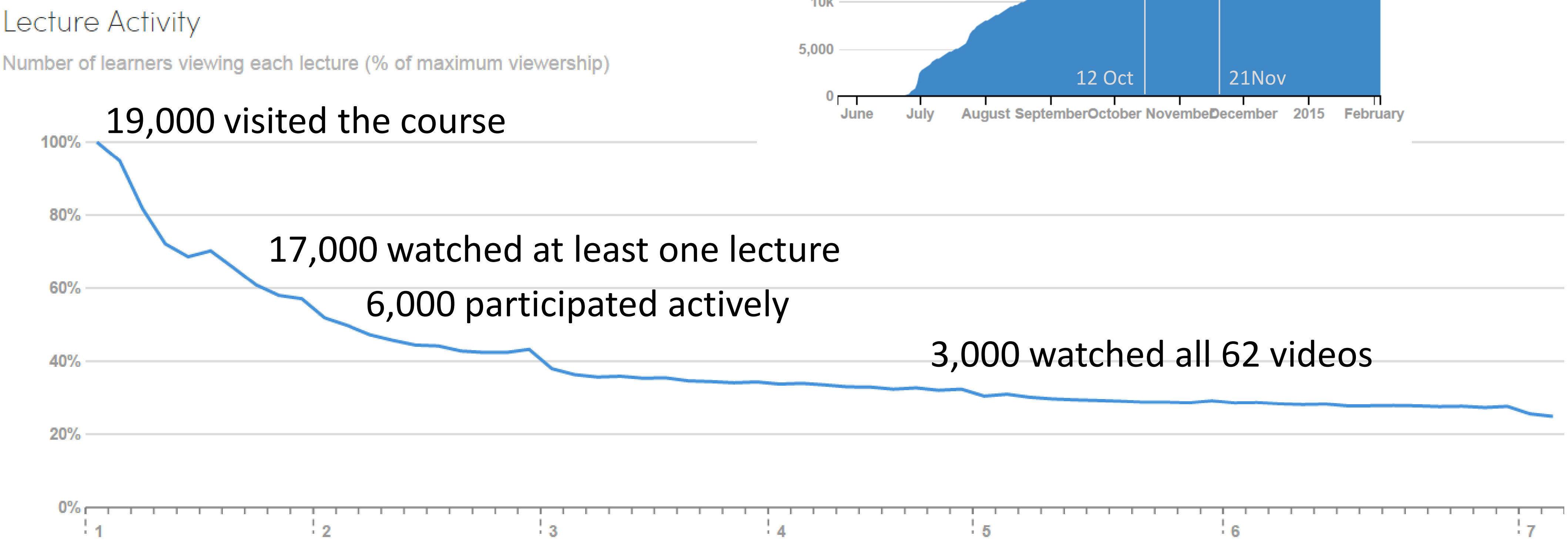


19,000 visited the course

17,000 watched at least one lecture

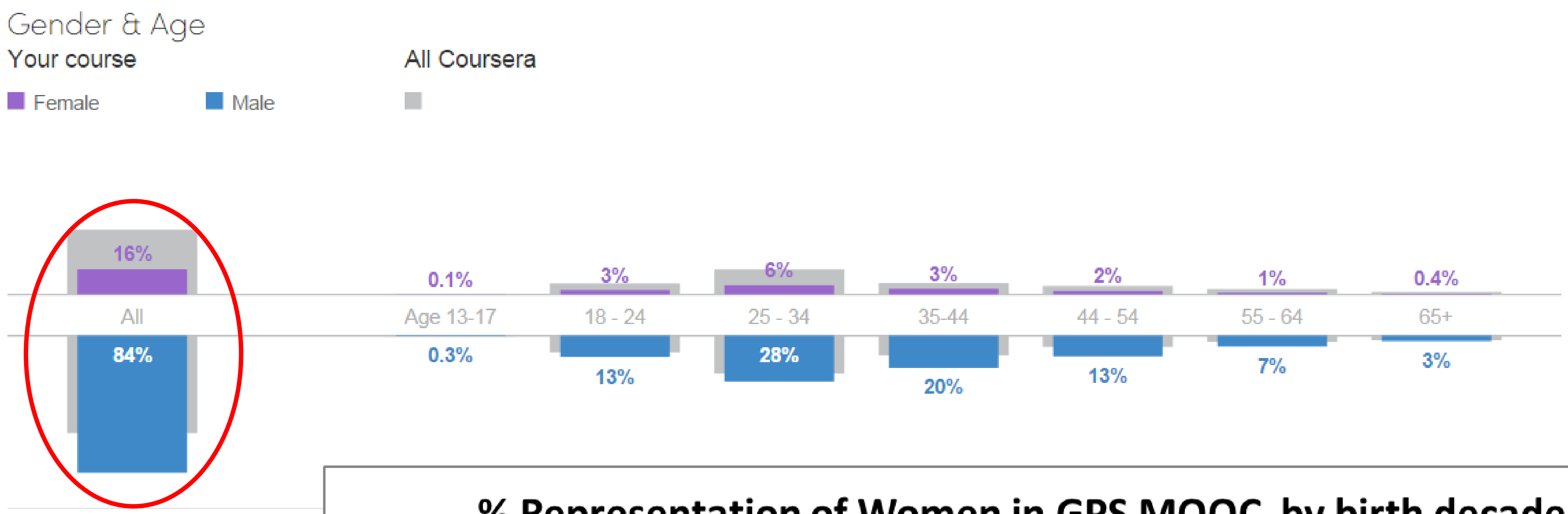
6,000 participated actively

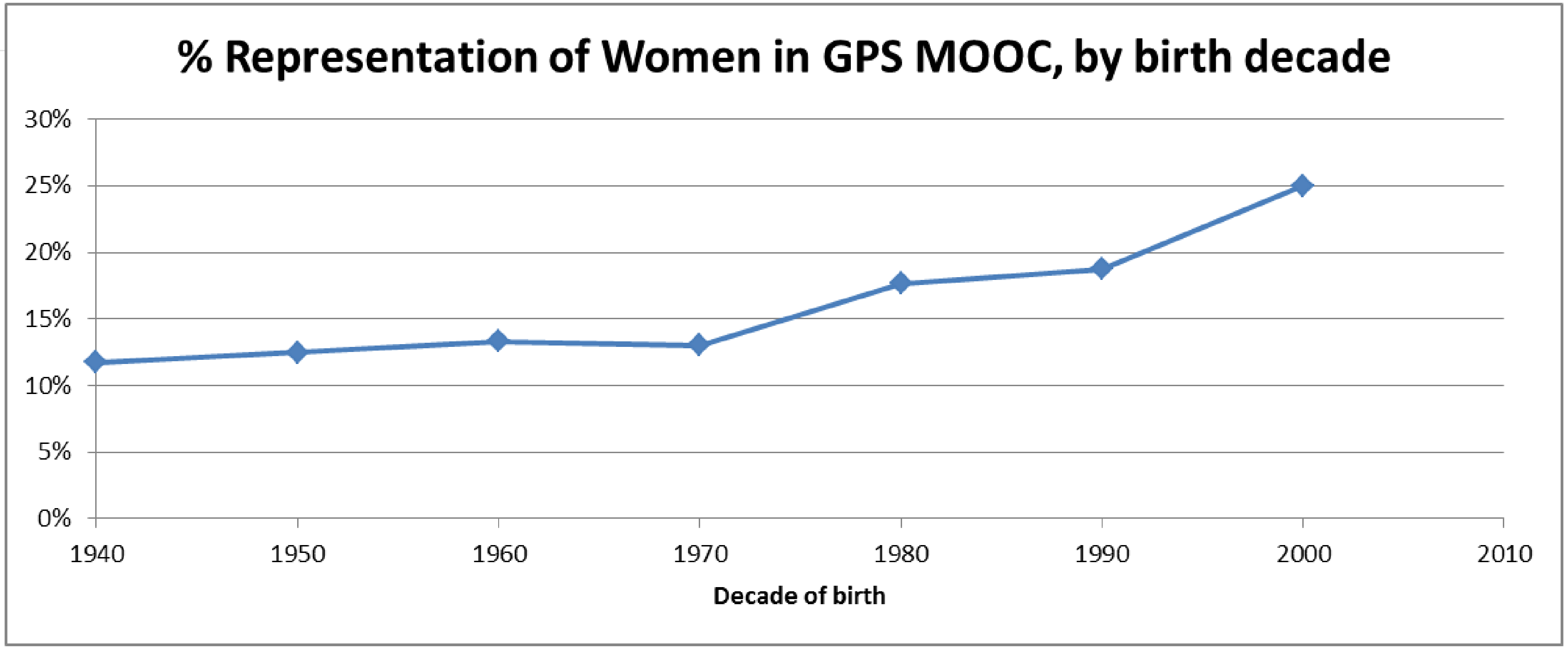
3,000 watched all 62 videos



1,700 participated in the labs

in 100 countries





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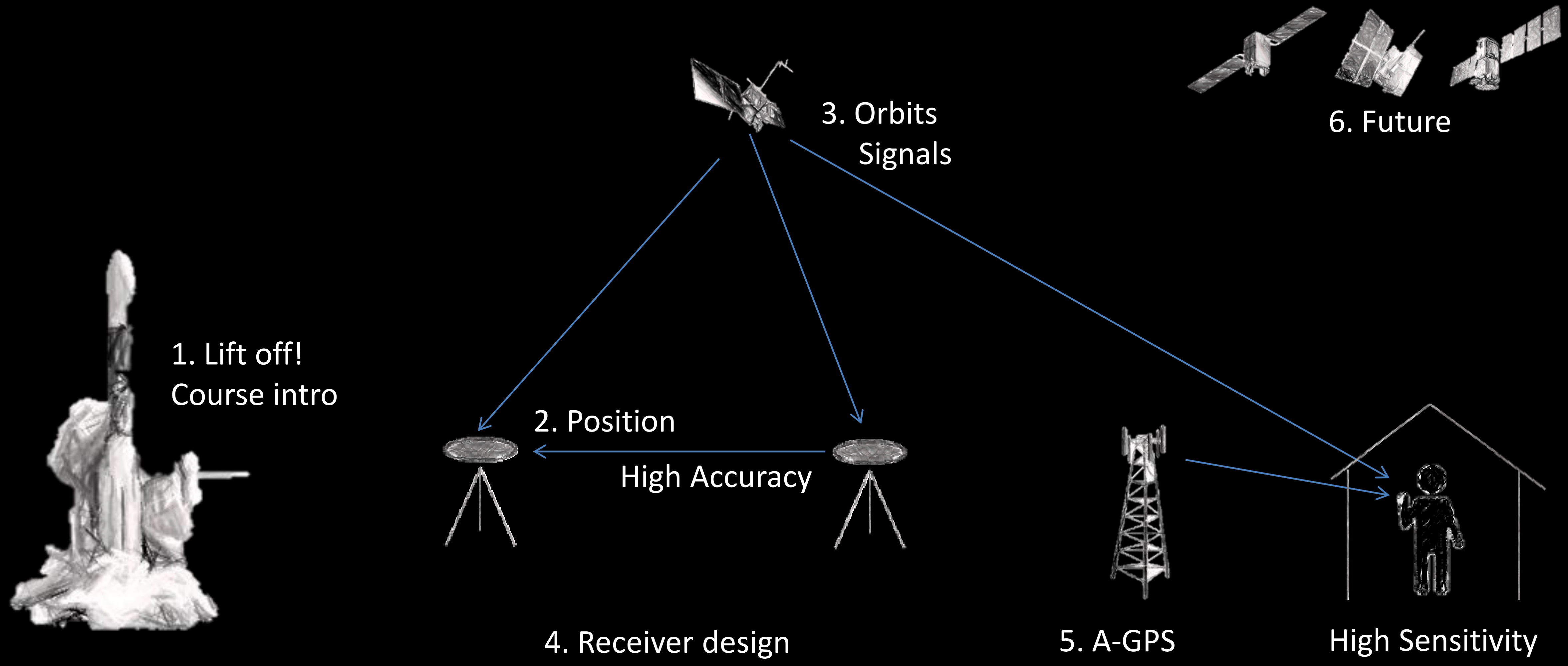
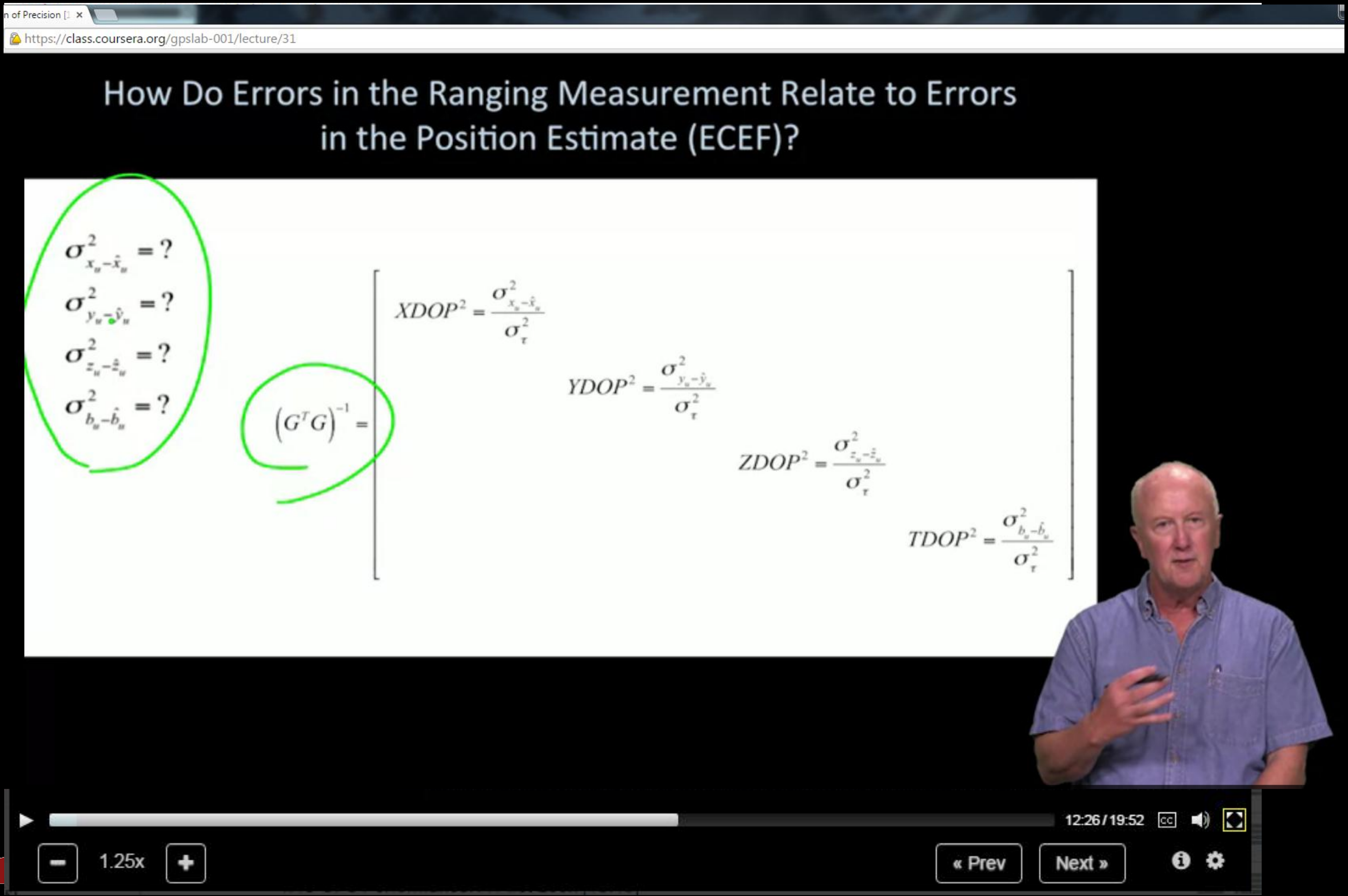
Course outline, by week




GPS MOOC recording


n of Precision [1
https://class.coursera.org/gpslab-001/lecture/31
How Do Errors in the Ranging Measurement Relate to Errors in the Position Estimate (ECEF)?
$\sigma^2_{x_u-\hat{x}_u} = ?$
$\sigma^2_{y_u-\hat{y}_u} = ?$
$\sigma^2_{z_u-\hat{z}_u} = ?$
$\sigma^2_{b_u-\hat{b}_u} = ?$
$(G^T G)^{-1} = \begin{bmatrix} XDOP^2 = \frac{\sigma^2_{x_u-\hat{x}_u}}{\sigma^2_\tau} & & & \\ & YDOP^2 = \frac{\sigma^2_{y_u-\hat{y}_u}}{\sigma^2_\tau} & & \\ & & ZDOP^2 = \frac{\sigma^2_{z_u-\hat{z}_u}}{\sigma^2_\tau} & \\ & & & TDOP^2 = \frac{\sigma^2_{b_u-\hat{b}_u}}{\sigma^2_\tau} \end{bmatrix}$
12:26 / 19:52
1.25x
« Prev
Next »

Labs, carried out worldwide, using smartphones

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GPS Worldwide Lab A (multipath and accuracy)

First, in an open area away from buildings, you will record your GPS position and note the er
Then in another location, this time in a city or town, in a place with buildings, you will record
new GPS position and again note the error.

All instructions are posted at: http://www.gps-lab.org/labs.html. Be sure to first submit you
in Quiz Format before you submit here.

* Required

What was the error when you took the GPS reading in an open area away from buildings *
Estimate the error, by comparing what your GPS shows in "map view" to your known location

- 0 - 2 meters
- 2 - 5 meters
- 5 - 10 meters
- 10 - 20 meters
- 20 - 50 meters
- 50 - 100 meters
- 100 - 200 meters
- Over 200 meters

GPS Worldwide Lab B (satellite visibility)

Go outside when one of these two satellites passes close to your location, and record the satellite elevation that you observe.

All instructions are posted at: www.gps-lab.org/labs.htm. Be sure to first submit your data
Format before you submit here.

* Required

Which GPS satellite did you see *
Pick one of the two specified in the lab (if you see both, choose the one with higher

- Satellite 4
- Satellite 18

Highest observed elevation for this satellite, to nearest 10 degrees *

- 90
- 80
- 70
- 60
- 50
- 40
- 30 or lower

Your Latitude *
Enter degrees and decimals (e.g. 37.893), excluding the + or -

Hemisphere: North or South *

GPS Worldwide Lab C (signal strength)

Measure C/No value outside, and indoors. Estimate the RF losses of your
losses through the building.

All instructions are posted at: www.gps-lab.org/labs.html. Be sure to first
Quiz Format before you submit here.

* Required

Enter the average C/No value of the strongest three satellites, outdoors (U
See the lab instructions for help

Compute the RF losses, compared to our nominal design (Units: dB). This lab description. *
x = 45 - (average outdoor C/No entered above)

Enter the average C/No value of the strongest three satellites, indoors (Un
If your receiver does not track three satellites, enter zero

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Lab A, Accuracy

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GPS Worldwide Lab A (multipath and accuracy)

First, in an open area, and then in a city or town in a place with buildings, please record your GPS position and note the errors.

* Required

GPS error, in an open area *
Estimate the error, by comparing GPS to your known

- 0 - 2 meters
- 2 - 5 meters
- 5 - 10 meters
- 10 - 20 meters
- 20 - 50 meters
- 50 - 100 meters
- 100 - 200 meters
- Over 200 meters

Your Latitude *
Enter degrees and decimals (e.g. 37.893), excluding
37.20717

Hemisphere: North or South *
- N
- S

Your Longitude *
Enter degrees and decimals (e.g. 122.930), excludin
121.85124

Hemisphere: East or West *
- E
- W

What was the error when you took a GPS reading in the city/town, near buildings? *
Estimate the error, by comparing what your GPS shows in "map/satellite view" to your known location

- 0 - 2 meters
- 2 - 5 meters
- 5 - 10 meters
- 10 - 20 meters
- 20 - 50 meters
- 50 - 100 meters
- 100 - 200 meters
- Over 200 meters

City or Town name, and Country (Please use Roman characters, for example Pune instead of पुणे, Beijing instead of 北京)
example:Beijing, China. For US, please add state, example: Miami, FL, USA
San Jose, CA, USA

What are the heights of the buildings around you? *
Estimate the height of most of the tall buildings around you (count the floors or stories)

- 1 floor
- 2-3 floors
- 4 - 10 floors
- 11 - 20 floors
- 21 - 50 floors
- Over 50 floors

Latitude (where you were in the city/town) *
Enter degrees and decimals (e.g. 37.893), excluding the + or -
37.33439

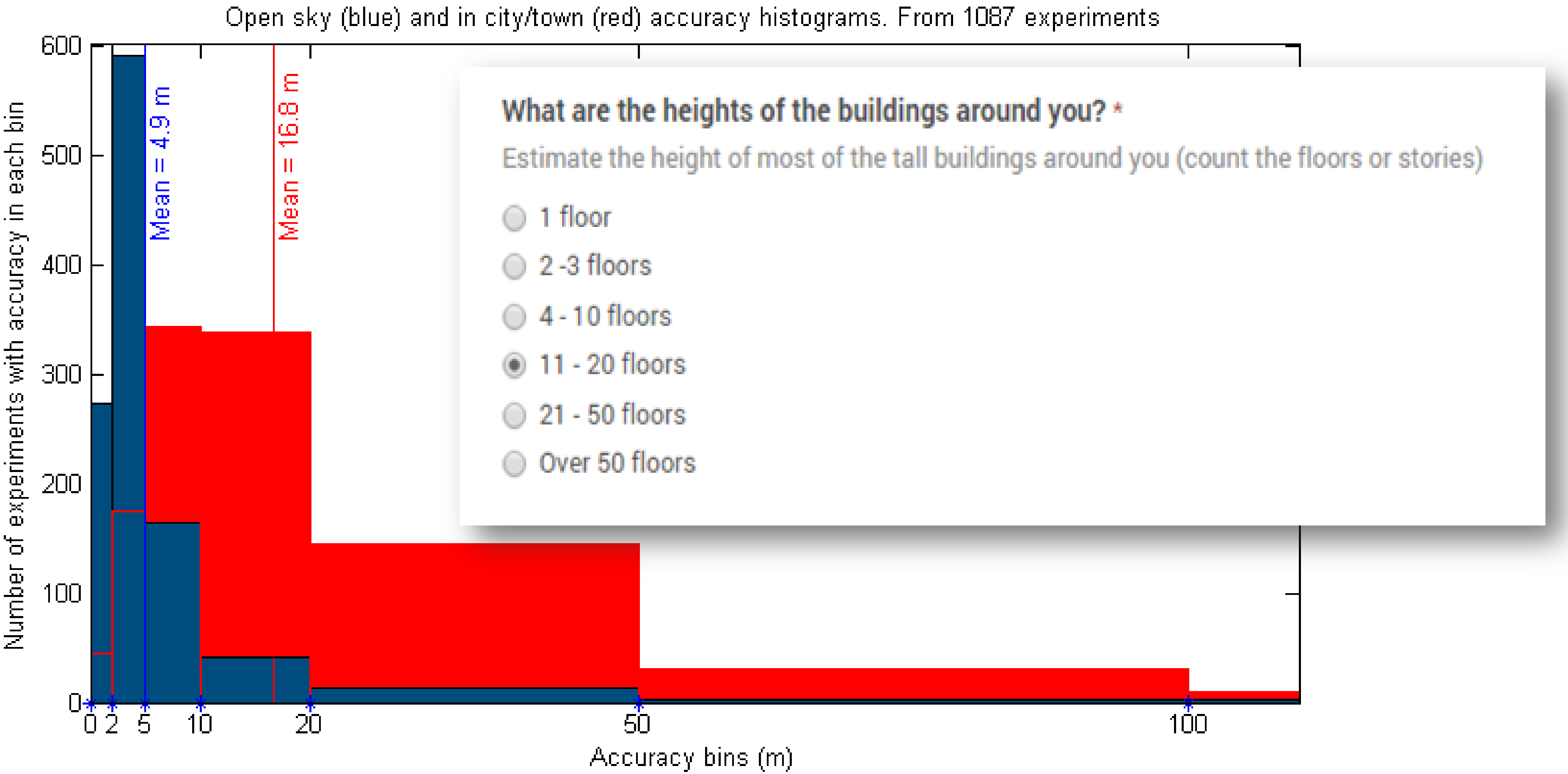
Hemisphere: North or South *
- N
- S

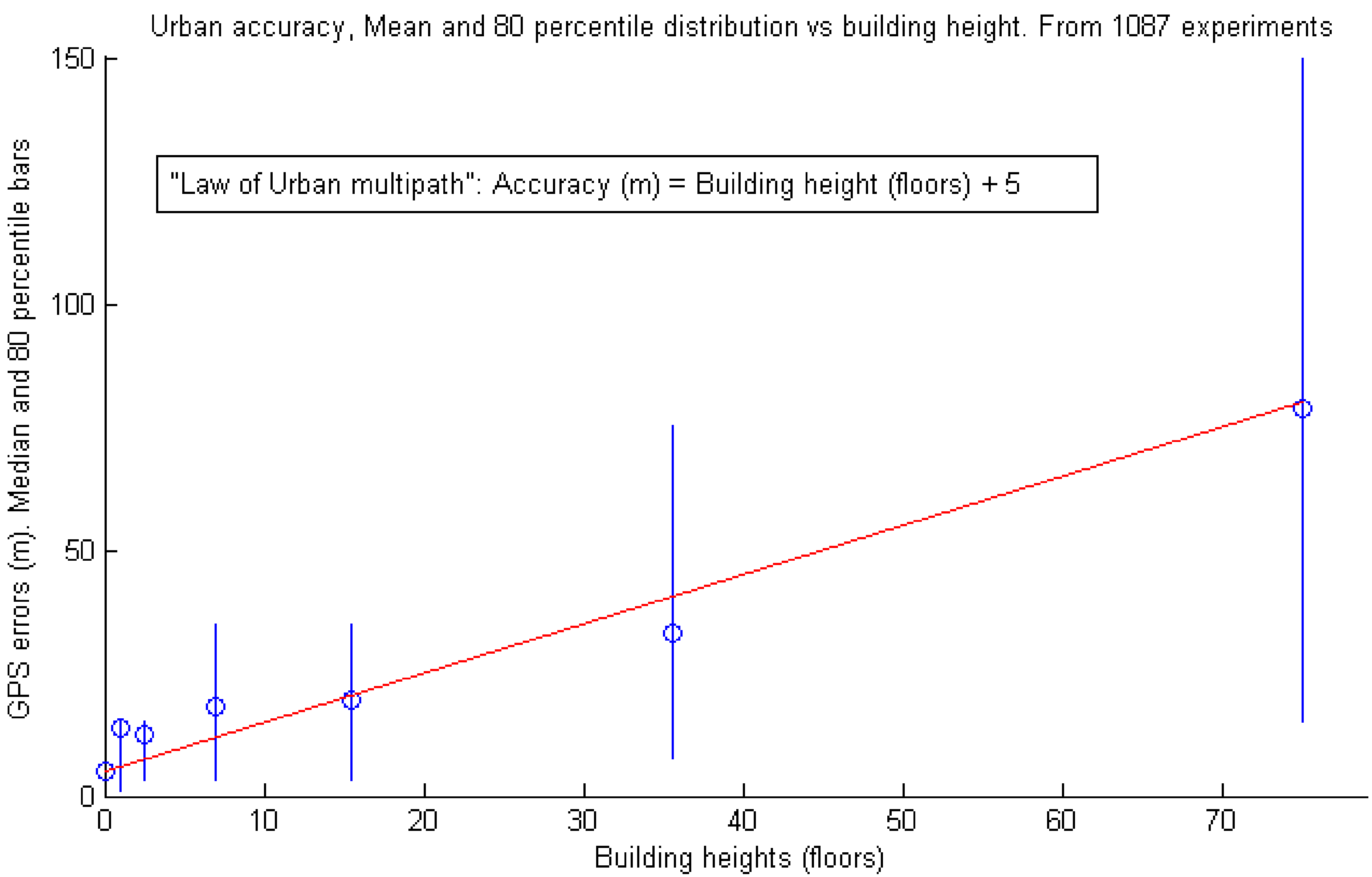
Longitude (where you were in the city/town) *
Enter degrees and decimals (e.g. 122.930), excluding the + or -
121.89440

Hemisphere: East or West *
- E
- W

Submit

Lab A, Results





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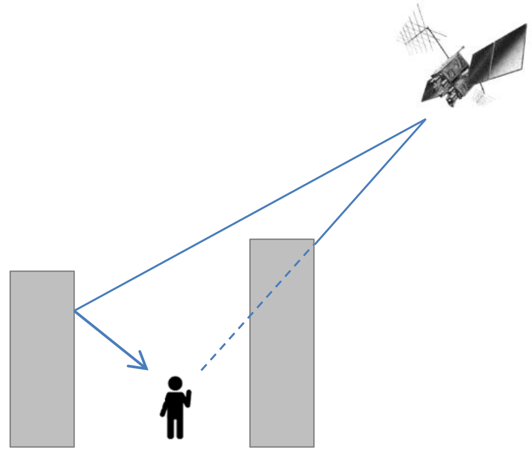
Law of Urban Multipath?



(1) Mean Accuracy (m) = Building height (floors) + 5

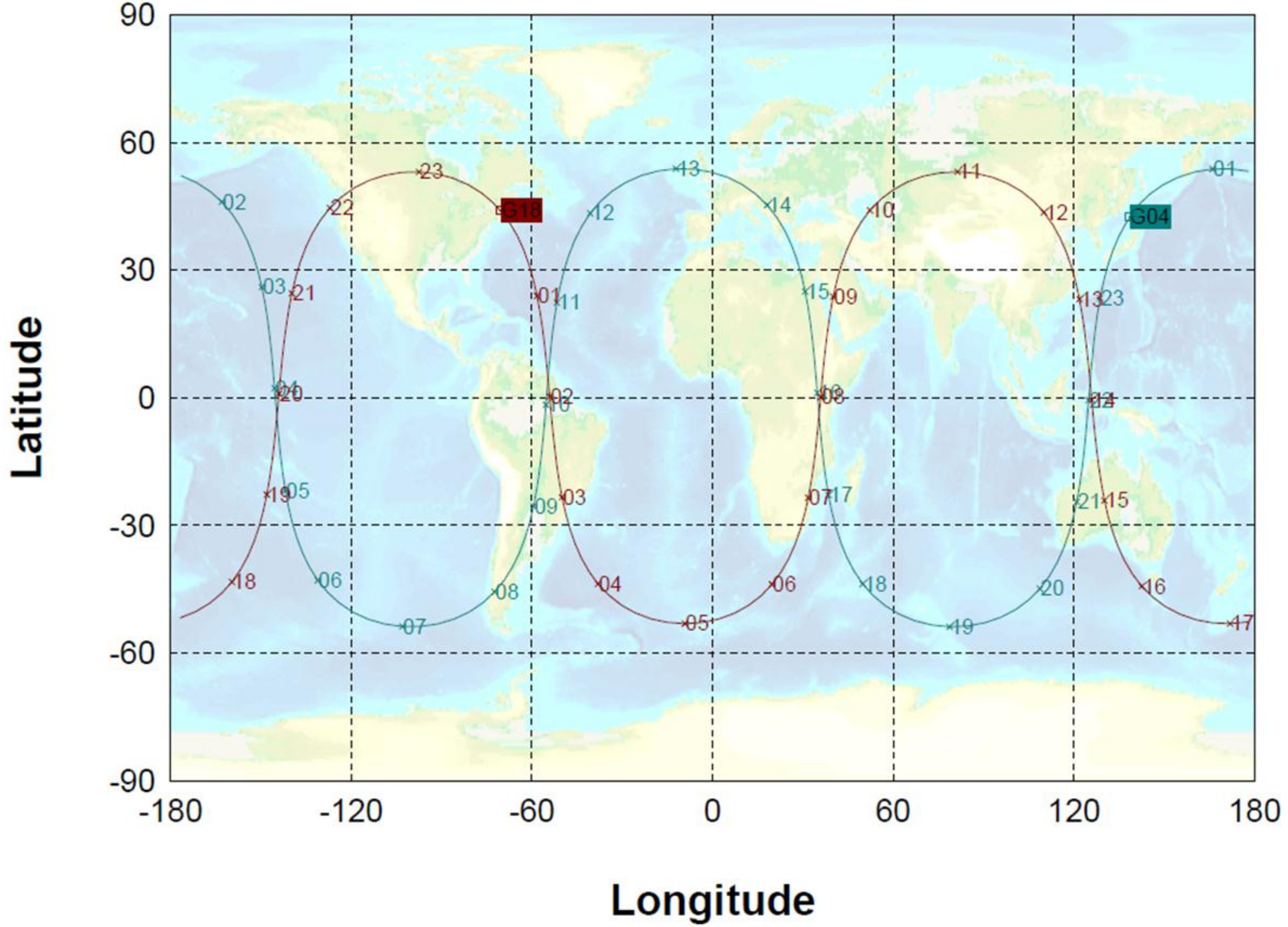
(2) Accuracy = *f*(height of buildings , distance between buildings)

(3) Accuracy = *h**height + *d**distance + *e*

NEXT STEP:

Go out and discover if there is an *h, d,* and *e* that matches the experimental data

Lab B, Predict and track a satellite



Time 11/1/2014 00:00 - 11/2/2014 00:00 (UTC+0.0h) Satellites 2 GPS 2 [current.alm (10/14/2014)]

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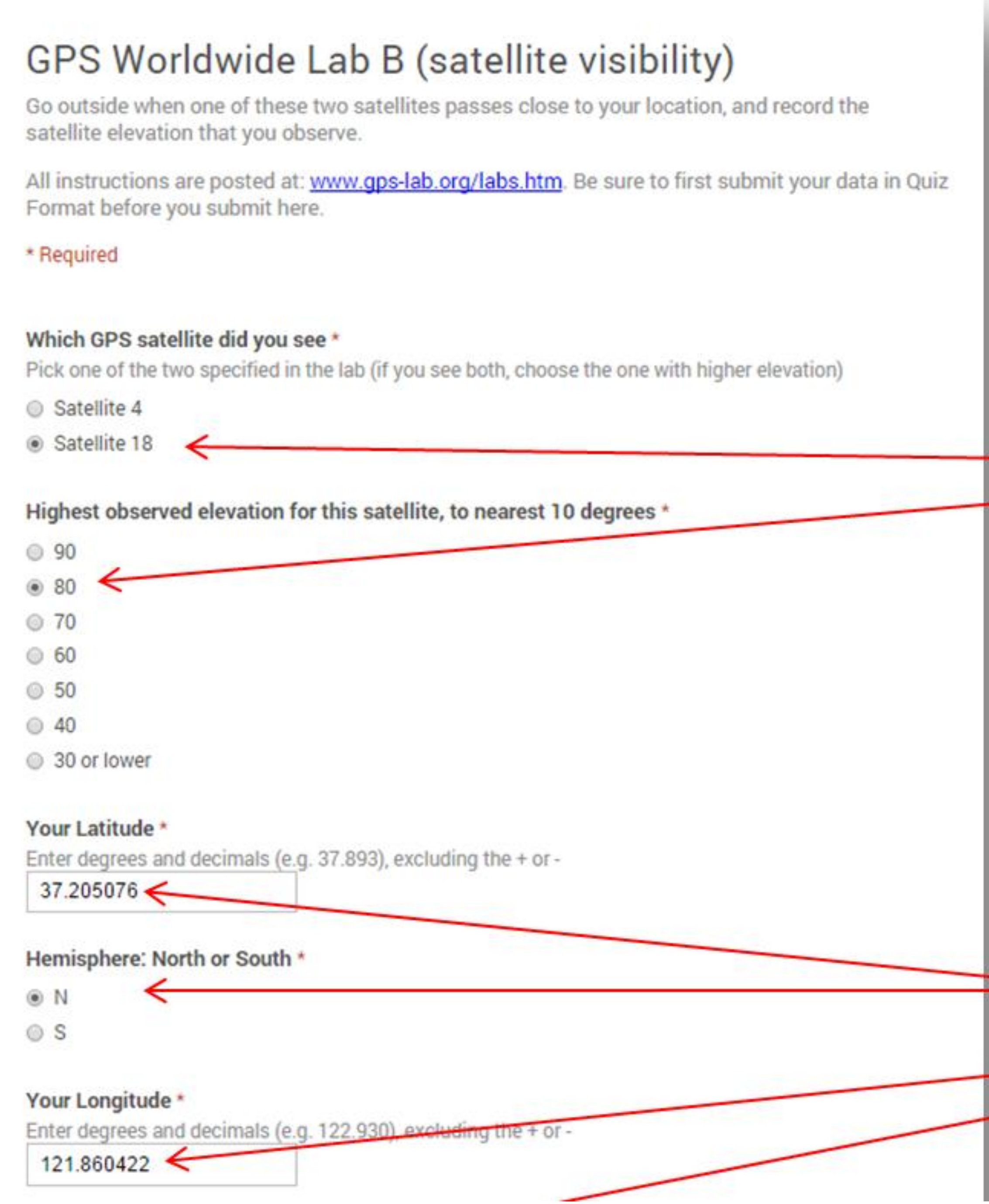

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* Required

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- ○ Satellite 4
- ◉ Satellite 18

Highest observed elevation for this satellite, to nearest 10 degrees *

- ○ 90
- ◉ 80
- ○ 70
- ○ 60
- ○ 50
- ○ 40
- ○ 30 or lower

Your Latitude *

Enter degrees and decimals (e.g. 37.893), excluding the + or -

37.205076

Hemisphere: North or South *

- ◉ N
- ○ S

Your Longitude *

Enter degrees and decimals (e.g. 122.930), excluding the + or -

121.860422

App = AndroiTS GPS Test

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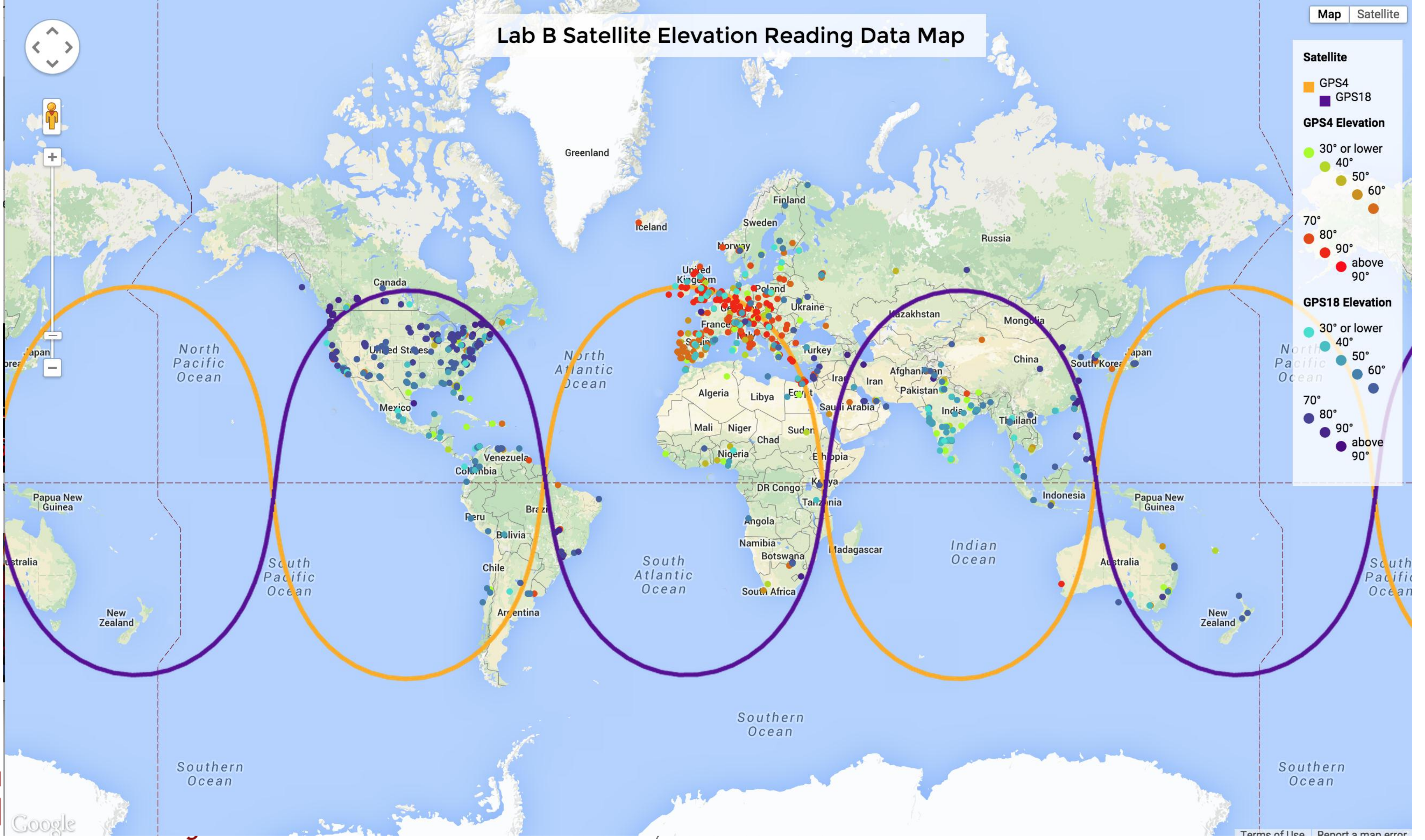
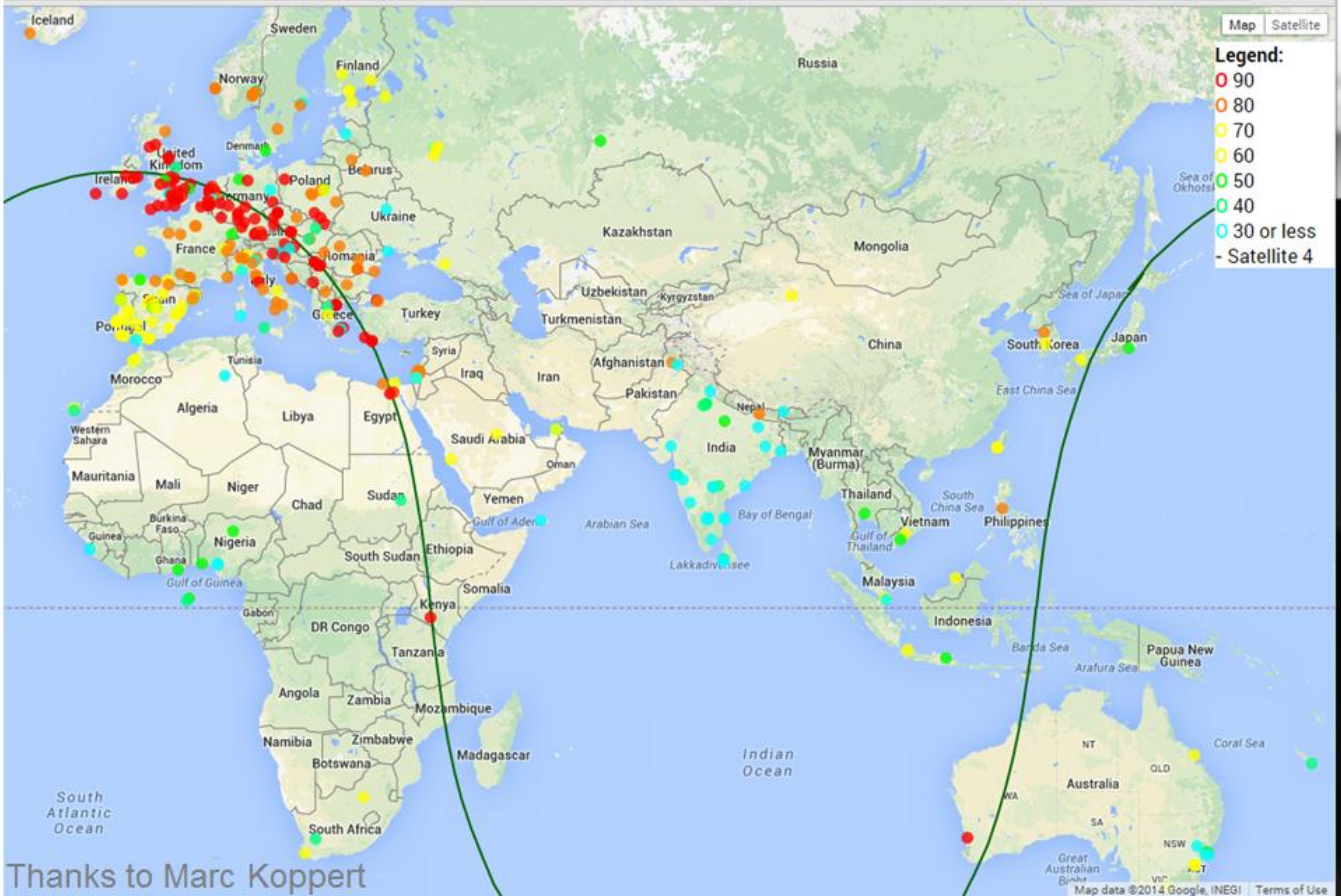
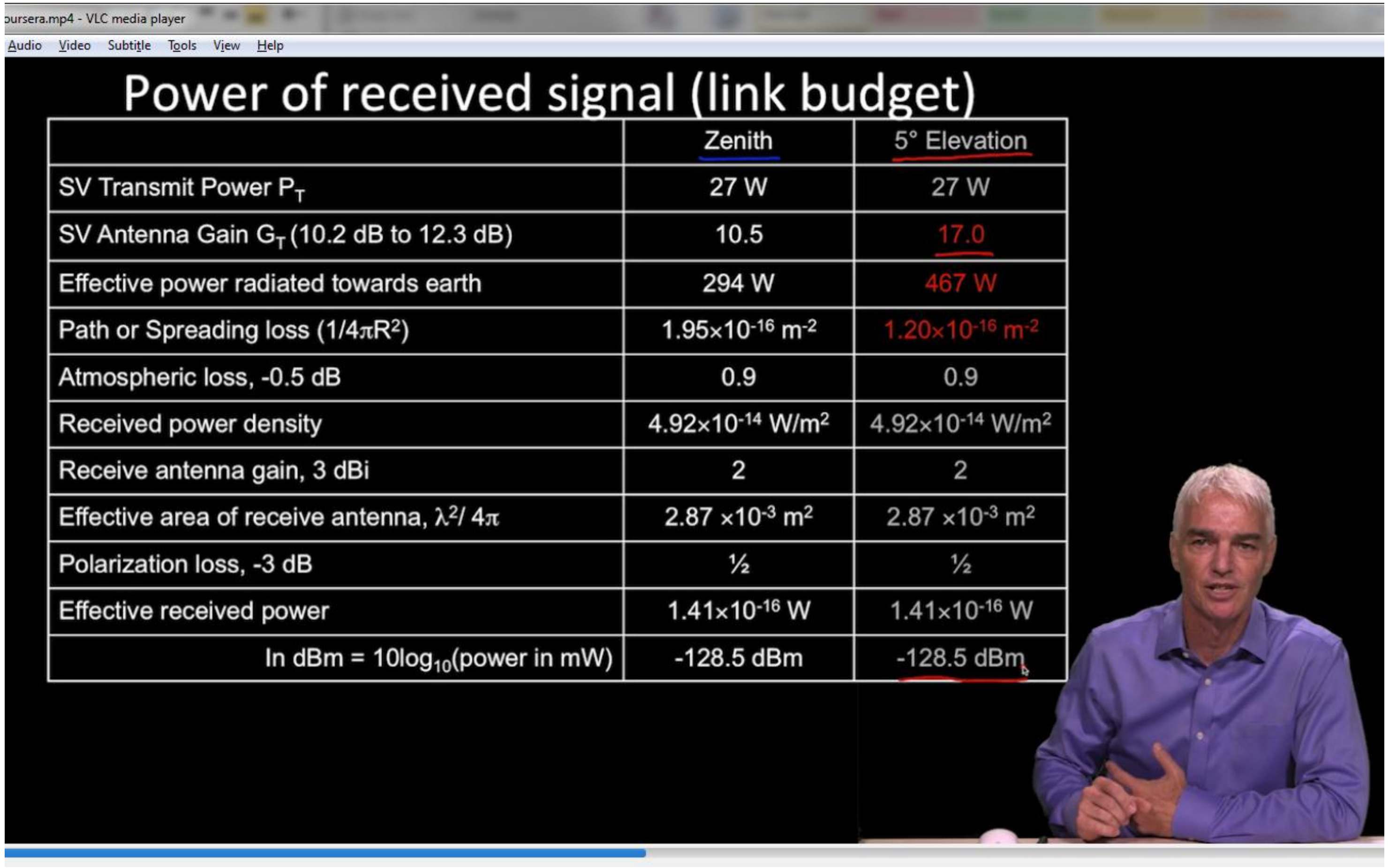
Lab B Satellite Elevation Reading Data Map





Thanks to Marc Koppert

Lab C, Signal strength & RF losses



Power of received signal (link budget)

	Zenith	5° Elevation
SV Transmit Power P_T	27 W	27 W
SV Antenna Gain G_T (10.2 dB to 12.3 dB)	10.5	17.0
Effective power radiated towards earth	294 W	467 W
Path or Spreading loss ($1/4\pi R^2$)	1.95×10^{-16} m^{-2}	1.20×10^{-16} m^{-2}
Atmospheric loss, -0.5 dB	0.9	0.9
Received power density	4.92×10^{-14} W/m^2	4.92×10^{-14} W/m^2
Receive antenna gain, 3 dBi	2	2
Effective area of receive antenna, $\lambda^2/4\pi$	2.87×10^{-3} m^2	2.87×10^{-3} m^2
Polarization loss, -3 dB	½	½
Effective received power	1.41×10^{-16} W	1.41×10^{-16} W
In dBm = $10\log_{10}$(power in mW)	-128.5 dBm	-128.5 dBm

14	T_{eff}		**296.4**	K	Friis's formula
15	No	-203.9		dBW/Hz	=10*LOG10(k*Teff)
16	Signal Strength at antenna	-128.5		dBm	Minimum signal strength in IS-GPS 200, see Module 4-3
		-158.5		dBW	=dBm - 30
17	C/No	45		dB-Hz	SS (dBW)-No(dBW/Hz)

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Lab C

14	T_{eff}		296.4	K	Friis's formula
15	No	-203.9		dBW/Hz	=10*LOG10(k*Teff)
16	Signal Strength at antenna	-128.5		dBm	Minimum signal strength in IS-GPS 200, see Module 4-3
		-158.5		dBW	=dBm - 30
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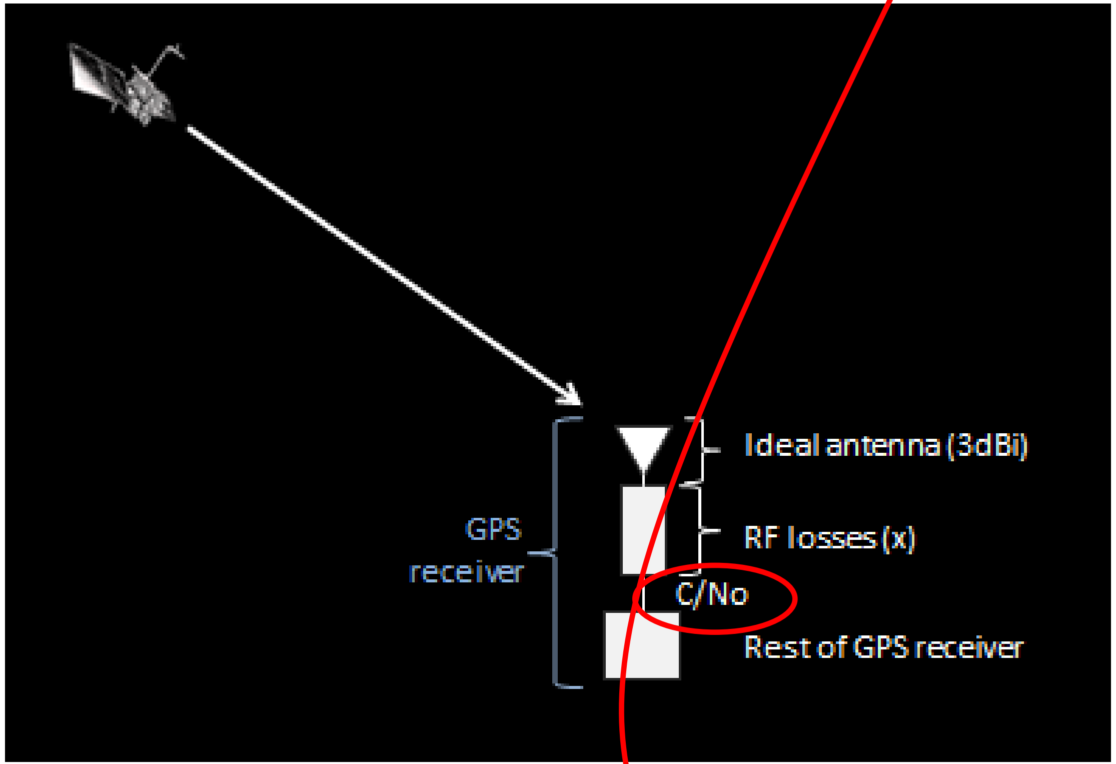
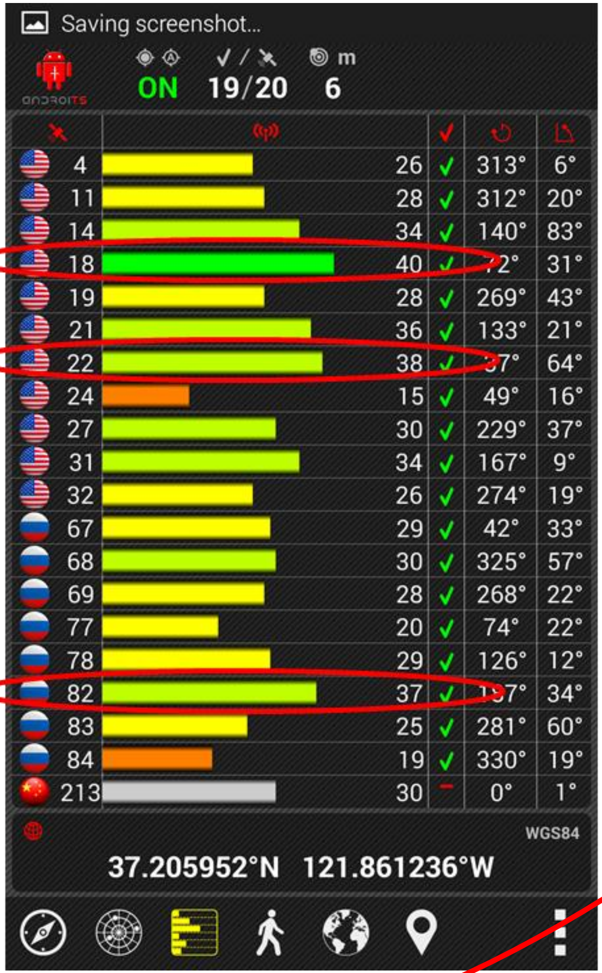


Ideal – Measured = RF loss of phone

= 45 dB.Hz – 38 dB.Hz

= 7 dB



C/No (dB-Hz)

40

38

37

Average = 38.3

App = AndroiTS GPS Test

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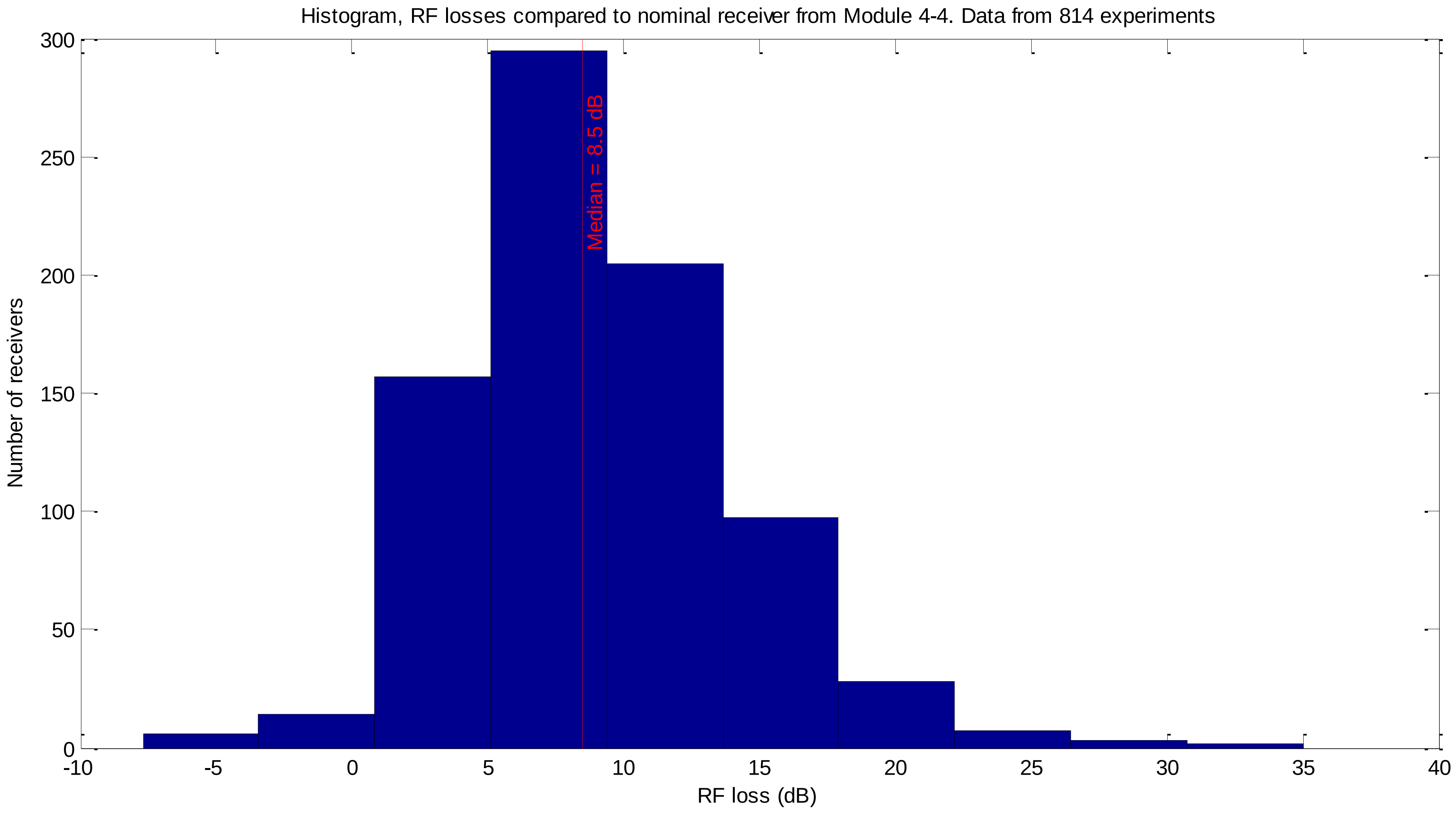
Lab C, Results



GNSS RF loss in smartphone: 8.5 dB $\pm$ 5 dB, (median $\pm$ 1σ)

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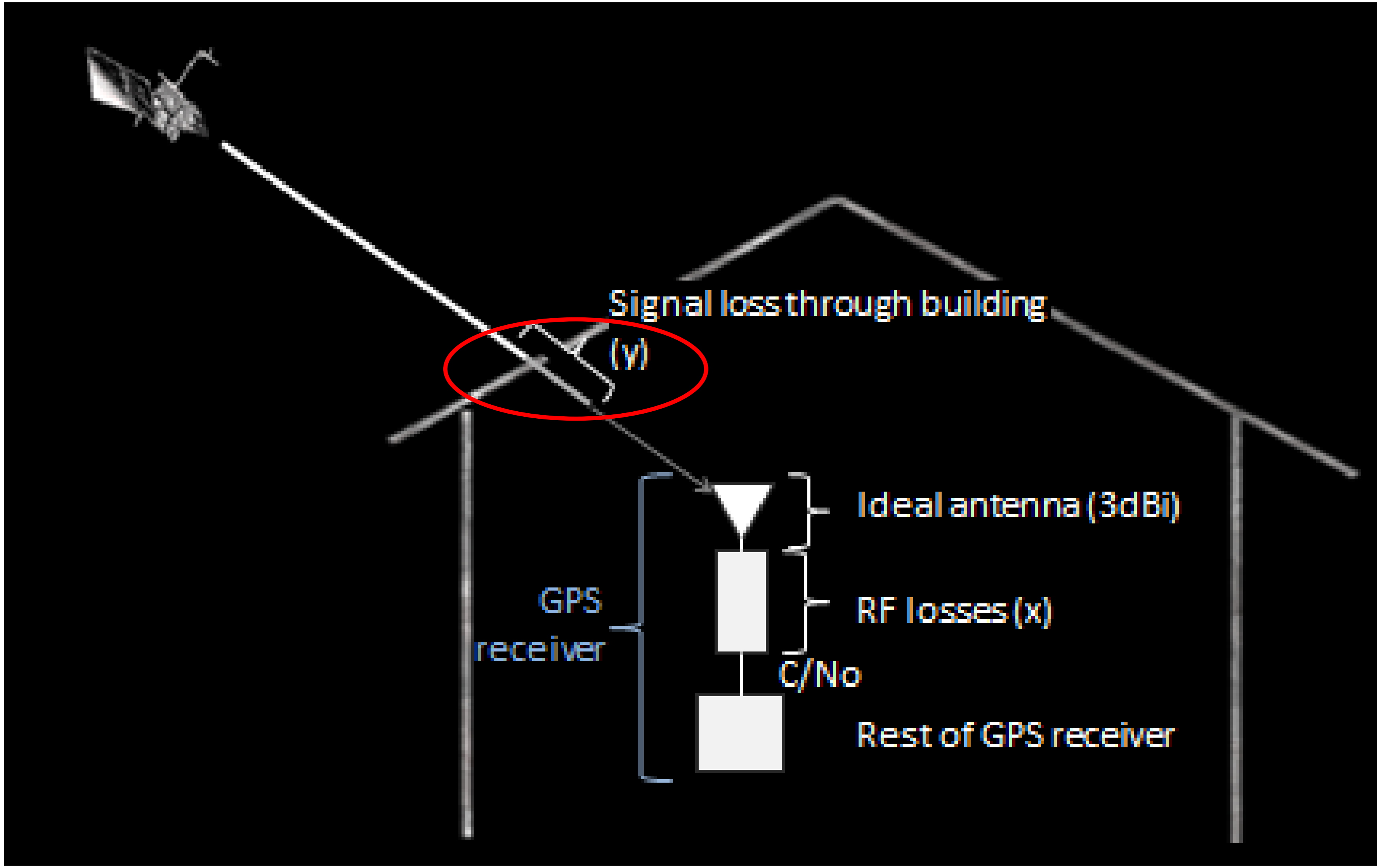
Lab C, part 2: now that you know x, measure y



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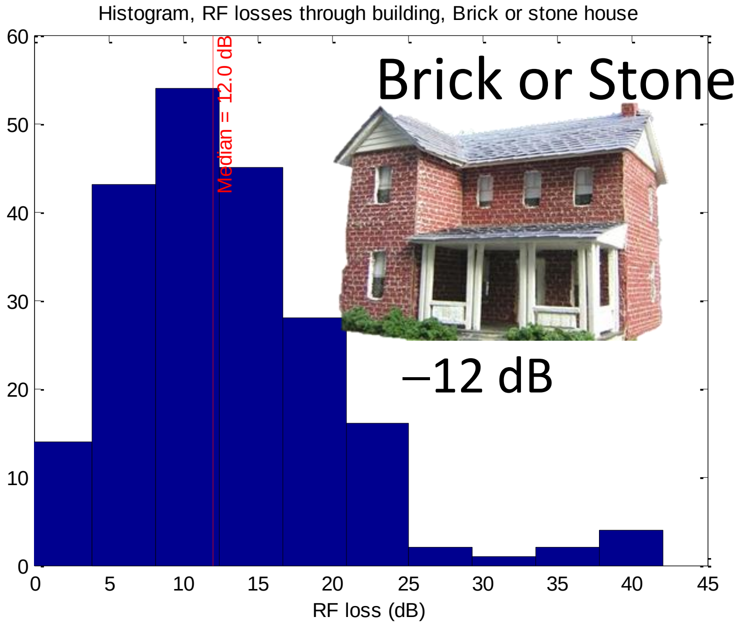
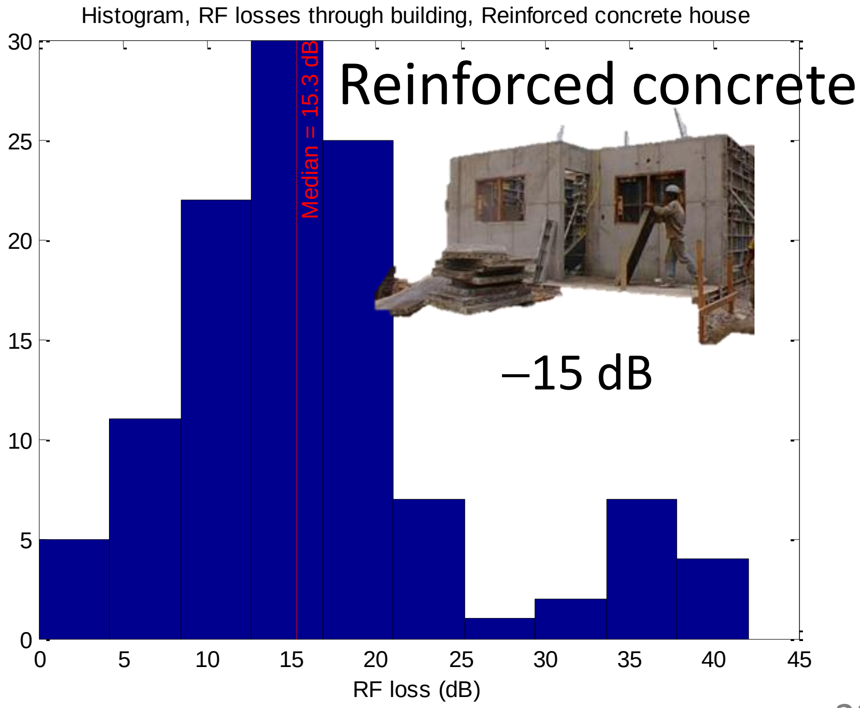
Histograms:
RF losses through different types of buildings





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Online Quizzes & Final Exam

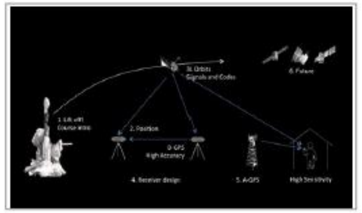
DECEMBER 21, 2014

Online Course
Statement of Accomplishment

WITH DISTINCTION

JAVIER DE SALAS

HAS SUCCESSFULLY COMPLETED A FREE ONLINE OFFERING OF THE FOLLOWING COURSE PROVIDED BY STANFORD UNIVERSITY THROUGH COURSERA INC.



GPS: An Introduction to Satellite Navigation, with an interactive Worldwide Laboratory using Smartphones

This course explores the fundamentals of the Global Positioning System (GPS). Students learn the basics of satellite navigation and gain a deeper appreciation of its role in our lives. Optionally, they conduct experiments using GPS-enabled smart phones.

PER ENGE
PROFESSOR OF AERONAUTICS AND ASTRONAUTICS
STANFORD UNIVERSITY

DR. FRANK VAN DIGGELEN
BROADCOM FELLOW & VP OF GPS TECHNOLOGY, BROADCOM CORP.
CONSULTING PROFESSOR, STANFORD UNIVERSITY

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What we (as teachers) learned

- Use Google Forms
- The World $\neq$ Silicon Valley
- We get valuable info. from simple questions & many participants
- The Labs are more than pedagogical,

  they produce real and valuable research results – even without trying!

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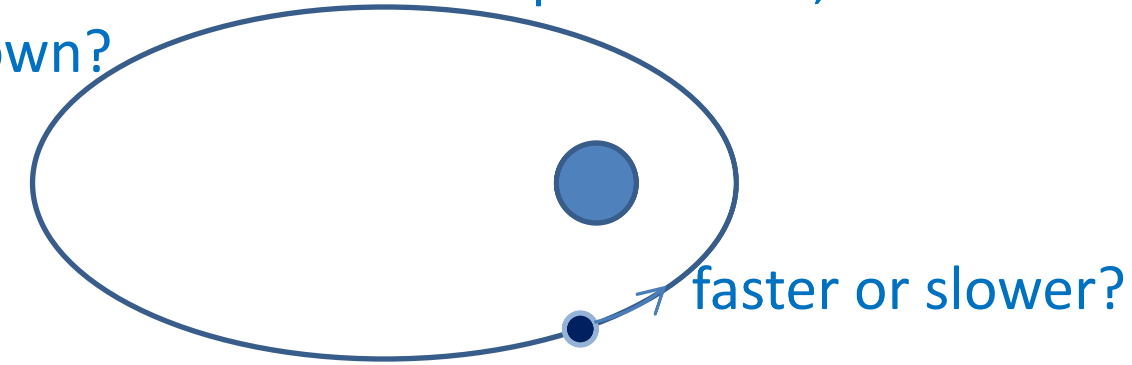
What’s next (at Stanford)

- AA272C, Stanford graduate class: Introduction to GPS
- “Flip” the MOOC
  - videos are pre-class assignments
  - use class time in a more tutorial manner

Example 1) instead of “Here are Kepler’s 3 laws”, a question:
A satellite gets closer to the Earth in an elliptical orbit; does it speed up or slow down?



Example 2) One Venus year = 225 Earth days
What is the highest above the horizon that you could ever possibly see Venus?

What's next (online)

- The MOOC is still there on Coursera –
  - register, login, and watch the videos (current activity 150 people/wk)

- On-demand MOOC (available 2016)
  - More ambitious labs

    e.g. Received C/No vs Foliage type

    other ideas?

    email us: frankvan@stanford.edu
    penge@stanford.edu

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