# Where in the World Am I?
# The Nuts and Bolts of the Global Positioning System

OLLI at UNT
lecture presented by:
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## Bibliography

There is a lot of information available about GPS, but most of it falls into one of two categories:
- Very high level descriptions which don't really describe much about how it really works
- Very detailed descriptions which are difficult to follow without a strong mathematical background

I have attempted to put together a presentation that hopefully falls somewhere in the middle, presenting enough of the real "nuts and bolts" to give a solid understanding of the principals upon which GPS works, as well as important specific techniques used, but avoiding getting bogged down with incomprehensible math.

In doing this, and fitting the resulting talk into 90 minutes or less, I had to make a difficult decision. Either I needed to forego trying to explain some key technologies, such as the code-multiplexing spread-spectrum radio signals and the way receivers measure transmission delays, or I needed to leave out discussions about how various sources of errors are handled. I ultimately chose the latter option, believing that focusing on the core technology was more interesting and would better satisfy curiosity about how GPS "really works."

**Presentation Download**

The entire presentation, including my speaker's notes reminding me of what to talk about, can be downloaded using this link:
https://drive.google.com/uc?export=download&id=1KEMu5XVhLKBpGPkoFFeW61dX8VV3gXBP

If just clicking on the link (or perhaps doing a "Ctrl-click") does not work, the link can be copied into any web browser to trigger the download.

The downloaded file is 84 pages long (one page per slide), so if you choose to print it out, be sure to have plenty of paper on hand! At the end, after the "Questions" slide, there are 19 additional slides, with notes, which were cut from the presentation due to time constraints. These cover additional topics related to error correction, and provide some more detail on the ECEF coordinate system and Keplerian orbital parameters.

**Primary Source Materials**

*Global Positioning System: Signals, Measurements, and Performance* by Pratap Misra and Per Enge. ISBN 0-9709544-1-7, published by Ganga-Jamuna Press. Information about this book is available online at https://www.gpsTextBook.com, and the book may be ordered there, or found on Amazon. Warning: This is a textbook intended for senior or graduate level engineering classes, and is not easily digestible. It is also priced like a college textbook (i.e., not cheap).

An equally important source was a series of 65 video lectures by two Stanford professors, Per Enge (co-author of the above-referenced book) and Frank van Diggelen.  These are available on YouTube at https://www.youtube.com/playlist?list=PLGvhNIiu1ubyEOJga50LJMzVXtbUq6CPo.  The 65 lectures vary in length from 2 minutes up to about 30 minutes each.  This is a very thorough and complete explanation of the ins-and-outs of GPS technology.  Though the material is presented in detail, it is surprisingly understandable without deep prior knowledge of the mathematics or science involved (with a few exceptions).  If you have the interest and time for this series, I strongly recommend it.

**Other Useful Online Material**

https://www.youtube.com/watch?v=btzFoBncPF4  24 minute video on How GPS works.  Good information on the various segments of GPS system, especially including the control segment, which was not covered in my OLLI presentation.  A bit of information on error corrections is also included, but, unfortunately, the explanations on how these errors are handled are oversimplified to the point of inaccuracy.

https://www.youtube.com/watch?v=6m0xGwkYYy0&t=631s – 12 minute video – similar high-level description of how GPS works, including practical use of a device (as shown in the OLLI presentation) that does all position calculations, and outputs NMEA-formatted data.

https://www.telesens.co/2017/07/17/calculating-position-from-raw-gps-data/ - White paper describing the processes of calculating position from GPS satellite data in some detail.  Thorough discussion of the basic math techniques involved, including sample computer code.  Difficult to follow without a solid familiarity with linear algebra concepts (i.e., vectors and matrices).

https://hikingguy.com/how-to-hike/how-does-gps-work-gps-for-dummies/ - Nice overview of GPS technology.  This does not get into too many details of how it actually works, but it touches on a wide range of issues.

https://www.gps.gov/technical/icwg/#current – Index of current official interface specifications for GPS.  From this page, the main specification document, https://www.gps.gov/technical/icwg/IS-GPS-200N.pdf, may be downloaded.  More useful as a reference document than a tutorial, it is interesting to see the specifics of things like the format of the Navigation messages.  The entire web site at https://www.gps.gov is worth perusing.