MODULE 1

From Bats to Geiger; the History of LiDAR-Enabling Technologies
• What do bats, H.G. Wells, Einstein, WWII, Sputnik, and the space and nuclear races have to do with LiDAR?

• Discuss how modern LiDAR systems were made possible by the convergence of enabling technologies
THE PERFECT ECHOLOCATION SYSTEM
What is echolocation?

Man-made echolocation:

- Radar
- Lidar
- Sonar

These are considered active sensors
Aerial Laser Scanner

- Device that captures 3D data of large areas of surface and above-surface features by illuminating the target with laser energy
Modern LiDAR System Components

Sensor Head (the laser)
• Generates and “steers” the beam
• Oscillating or rotating mirror
• Frequencies up to 500kHz and greater now
Modern LiDAR System Components

Airborne GPS

- Satellite-based radio-navigation system used to derive the precise $x$, $y$, $z$ position of the sensor
**Inertial Measurement Unit (IMU)**

- An electronic device that uses accelerometers and gyroscopes to measure gravitational forces, orientation, and acceleration
Chiroptera (bat)

- Uses sonar
- Use a toroidal coordinate system for orientation
- Use polarized light to calibrate internal compass
Light Polarization

Sun at zenith = horizontal polarization

Sun at sunset/sunrise = vertical polarization

Bat compass orientation
The Bat Coordinate System

Neural IMU
Torus

• “Superstring” physics (shape of the universe)
• Most efficient particle accelerators
• Bacteriophages
• Transformers
• Human magnetic field
WAR OF THE WORLDS AND OTHER CATALYSTS
“This intense heat they project in a parallel beam against any object they choose, by means of a polished parabolic mirror...”

War of the Worlds
H.G Wells
1897
Light Amplification by Stimulated Emission of Radiation

Theory advanced by Albert Einstein in 1917

\[ E_2 - E_1 = \Delta E = hv \]
Death Rays and Lasers

- 1930’s scientists stumble upon radar while trying to develop a “death ray”
- 1950’s – theories on operational laser were kicked around and the first maser was built using microwaves
- 1960 – First laser (ruby) built
• Ancient Greeks, Romans, and Chinese played with tops for centuries

• 1740 – idea of artificial horizon

• 1750’s – gyroscope invented to observe the rotation of the Earth
• 1930’s – Robert Goddard begins experimenting with gyroscopic guidance

• WWII starts an arms race and the improvement of gyroscopic guidance systems
Global Positioning System

- 1957 – Soviet Union launches Sputnik
- The space race begins in earnest
By monitoring Sputnik’s radio signal, physicists at Johns Hopkins’s Applied Physics Laboratory realized they could pinpoint the location of the satellite by measuring the Doppler shift.

The Doppler effect: a change in frequency of a wave relative to the wave source with respect to the observer.
Global Positioning System

- 1960 – First working US Navy TRANSIT satellite launched. Full system operational by 1964
- Considered one of the precursors to the Global Positioning System
PARALLEL WORLDS
Development and application of these technologies, for the most part, occurred in parallel.

GPS 1957
Lasers 1897
IMU 1740

55 million B.C.
Lasers/LiDAR - Lightspeed Timeline

- **1897**: Martians
- **1960**: Laser
- **1963**: Laser Rangefinder Testing
- **1971**: Laser Maps Moon
- **1970’s – 1980’s**: NASA Airborne LiDAR
IMU - Lightspeed Timeline

- 1740: Serson’s Speculum
- 1750’s - Gyroscope
- 1944: V2 Rocket Gyro
- 1962: Minuteman
- 1961 - 1975: Apollo Program
- 1990’s: Tech Declassified
THE CRITICAL INTERSECTION OF TECHNOLOGY
FROM RELICS TO HIGH-SPEED TECH
• Technology was met with some skepticism:
  • “It’s not accurate”
  • “It’s not reliable”
  • “It will never replace photogrammetrically-derived Digital Elevation Models (DEM)s”
  • It will blind forest animals?
The First Statewide LiDAR Program

2000 - 2007

Phase I — Blue
Phase II — Orange
Phase III — Green
The First Statewide LiDAR Program

• Up until this point:
  • NC received (on average) an updated Flood Study for one county per year
  • ~55% of the NC Flood Insurance Rate Maps (FIRMs) were at least 10 years old
  • NC established the statewide LiDAR program to update elevation data, flood studies and maps
The First Statewide LiDAR Program

- At the conclusion of the program:
  - All 100 counties were mapped with new LiDAR elevation data (53,819 sq miles)
  - ~ $19,000,000 in annual savings to flood insurance holders due to re-delineation of flood zones and unmapped areas
THE STATE OF LIDAR TODAY
LiDAR Today

Static Scanners

Mobile Scanners
LiDAR Today

Topographic Scanners

Source: Teledyne Optech

Bathymetric Scanners

Source: Teledyne Optech
## LiDAR Today

<table>
<thead>
<tr>
<th>DEM Models</th>
<th>Oil &amp; Gas Exploration</th>
<th>BIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>Mining</td>
<td>Cell Network Planning</td>
</tr>
<tr>
<td>Forestry</td>
<td>Archeaology</td>
<td>Autonomous Vehicles</td>
</tr>
<tr>
<td>Flood Models</td>
<td>Viewshed Analysis</td>
<td>Watershed Delineation</td>
</tr>
<tr>
<td>Land Classification</td>
<td>Solar Energy Planning</td>
<td>Robotics</td>
</tr>
<tr>
<td>River Surveys</td>
<td>Glacier Monitoring</td>
<td>Meterology</td>
</tr>
<tr>
<td>Utility Mapping</td>
<td>Accident Scene Map</td>
<td>Law Enforcement</td>
</tr>
<tr>
<td>Transportation Mapping</td>
<td>Architecture</td>
<td>Military</td>
</tr>
<tr>
<td>Pollution Modeling</td>
<td>Gaming</td>
<td>Astronomy</td>
</tr>
<tr>
<td>Coastline Management</td>
<td>Historical Records</td>
<td>Surveying</td>
</tr>
</tbody>
</table>
LiDAR Today – NC Refresh

NC County Phases
- Phase 1 - 2014 (USGS)
- Phase 2 - 2014 (NC)
- Phase 3 - 2015
- Phase 4 - 2016
- Phase 5 - 2017
LiDAR Today – NC Refresh

New QL2 Data
NC Refresh – Next?

High Resolution Topographic Refresh
Phase 4

Legend
- Phase 4 Counties

Legend
- Phase 4 Counties

NC Refresh – Next?
Well...sort of...
QUESTIONS?