

# MODULE 1

From Bats to Geiger; the History of LiDAR-  
Enabling Technologies





# OVERVIEW

- 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



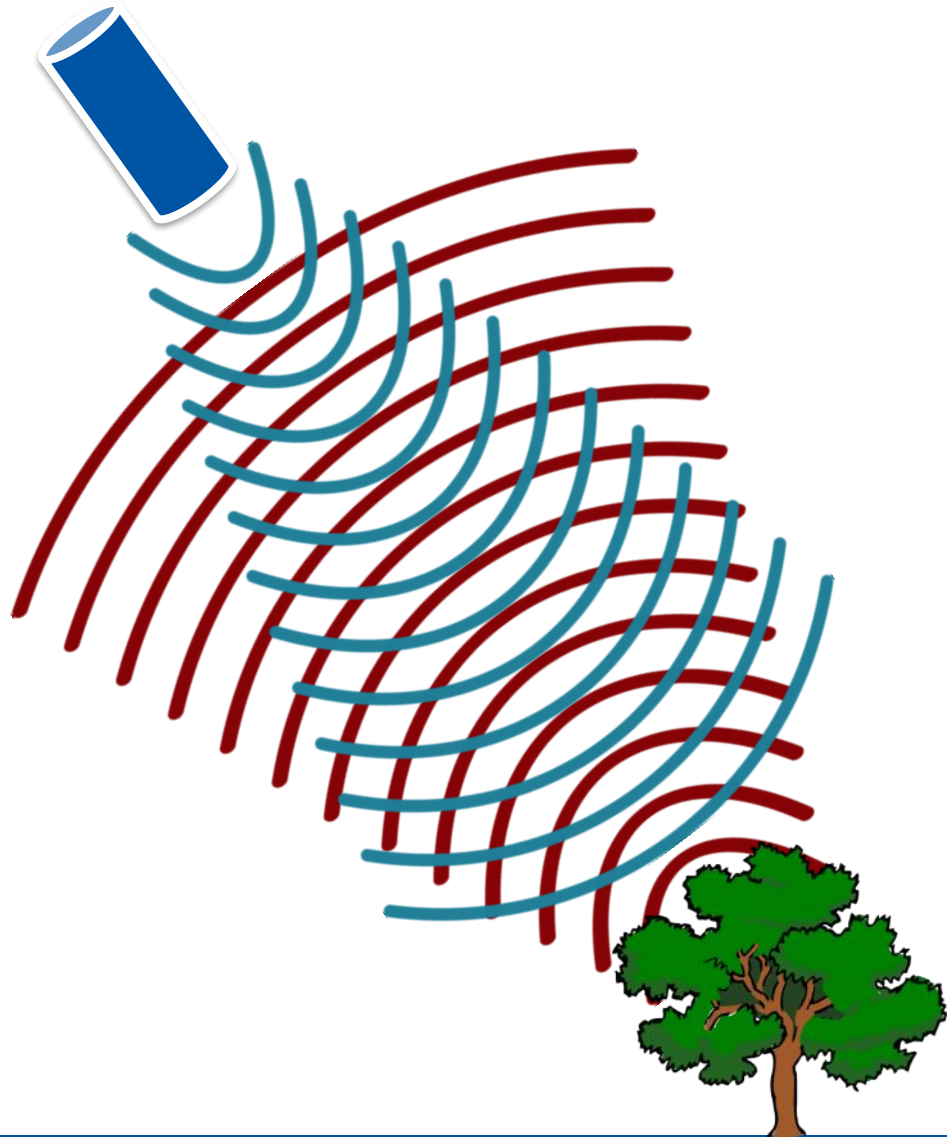


# What is echolocation?

## Man-made echolocation:

- Radar
- Lidar
- Sonar

These are considered active sensors

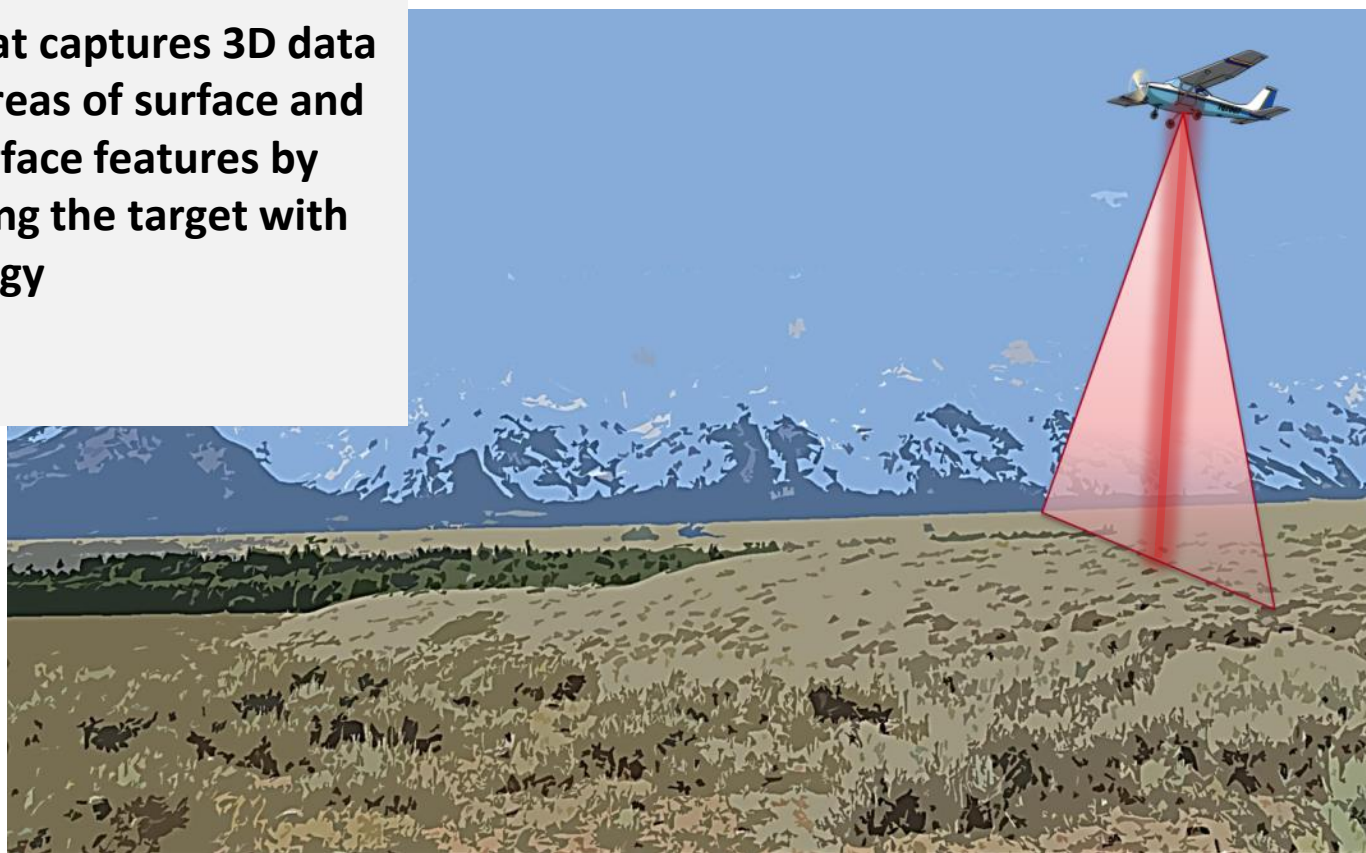




# Modern LiDAR System Components

## Aerial Laser Scanner

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

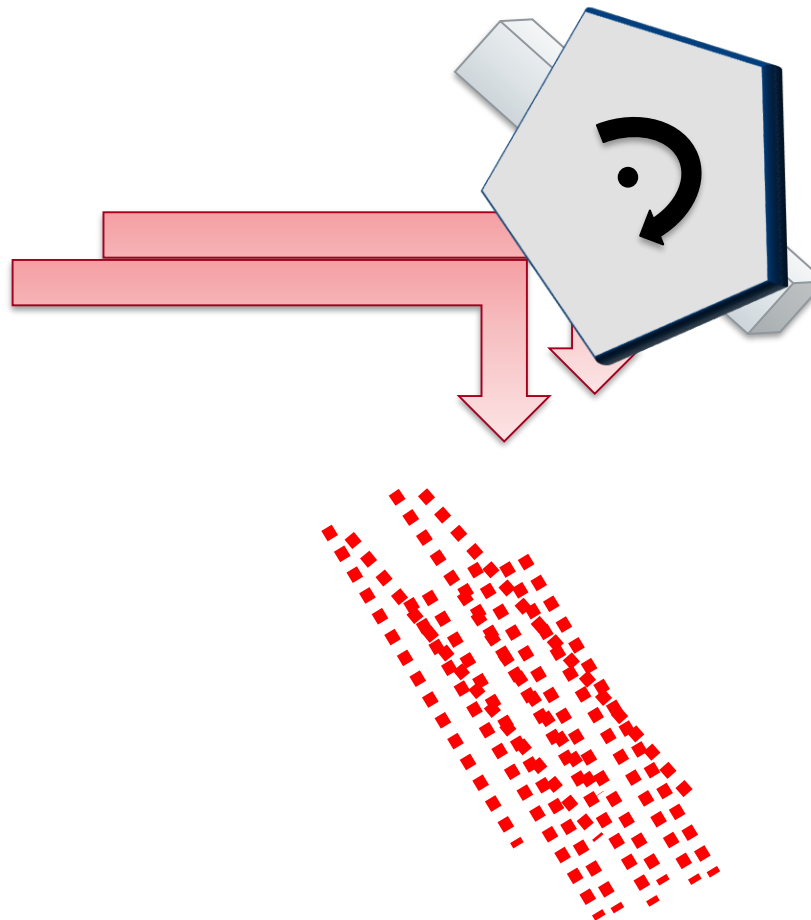




# Modern LiDAR System Components

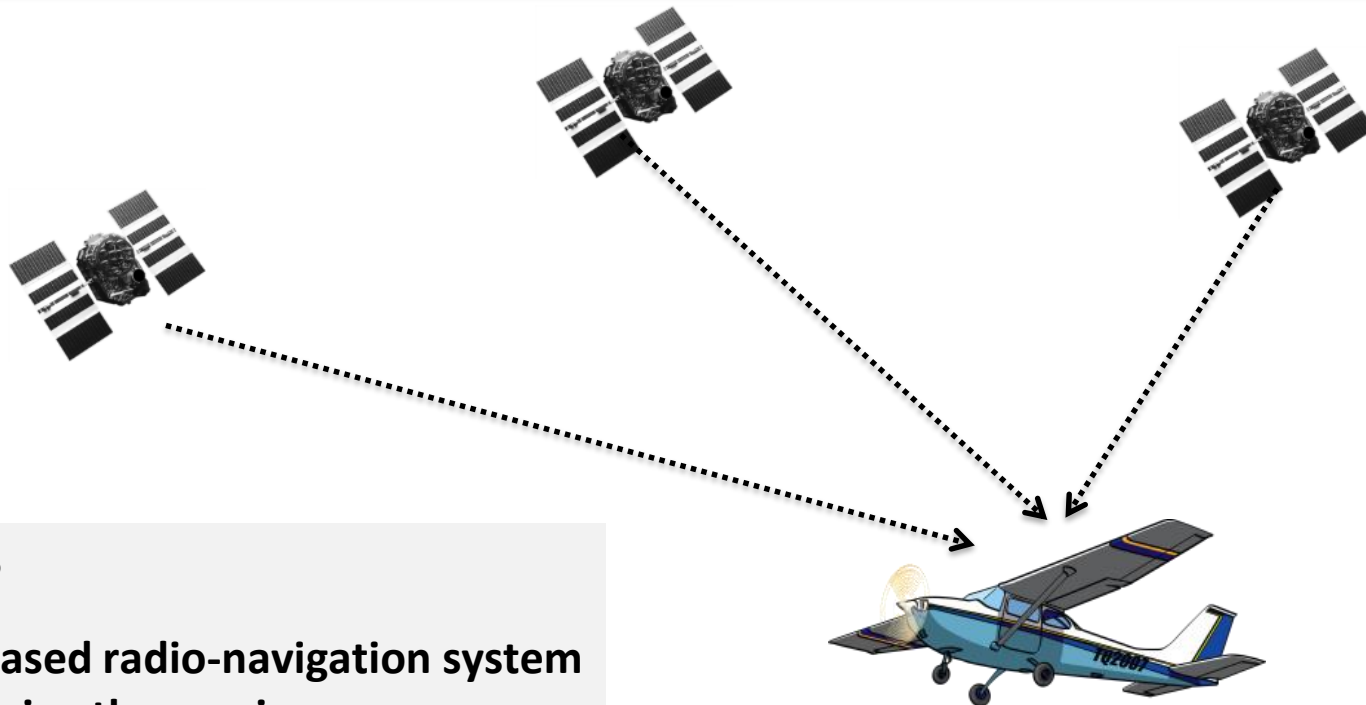
## Sensor Head (the laser)

- Generates and “steers” the beam
- Oscillating or rotating mirror
- Frequencies up to 500kHz and greater now



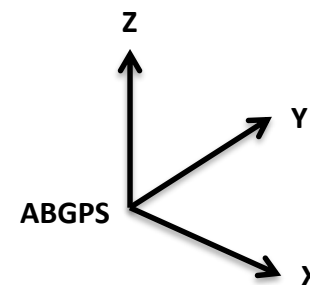


# Modern LiDAR System Components



## Airborne GPS

- Satellite-based radio-navigation system used to derive the precise  $x$ ,  $y$ ,  $z$  position of the sensor

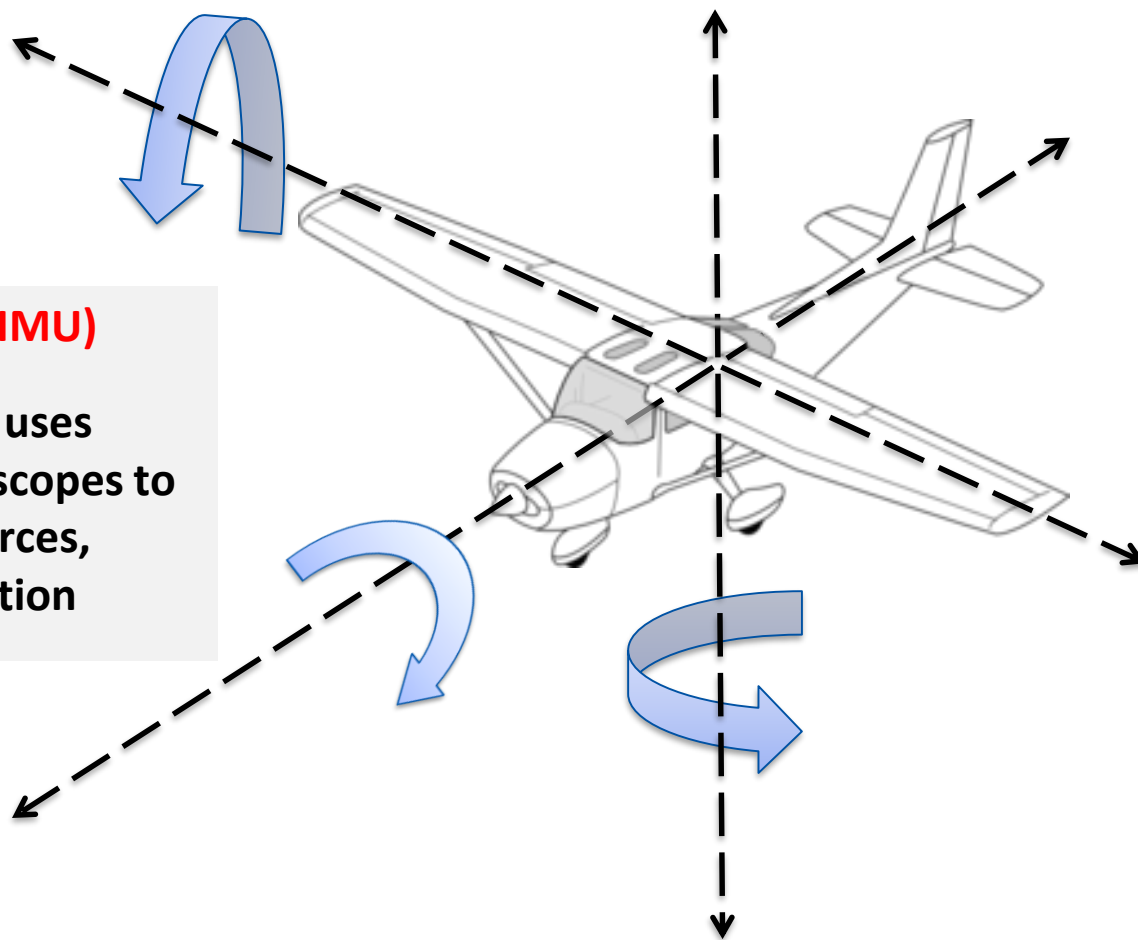




# Modern LiDAR System Components

## Inertial Measurement Unit (IMU)

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



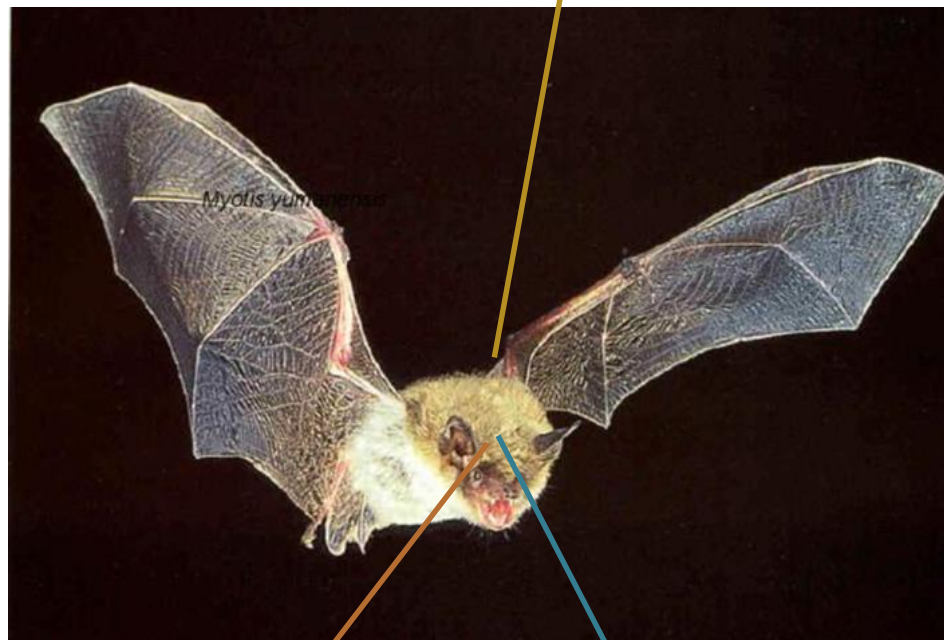




# The perfect echolocation system

## Chiroptera (bat)

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



Active Sonar

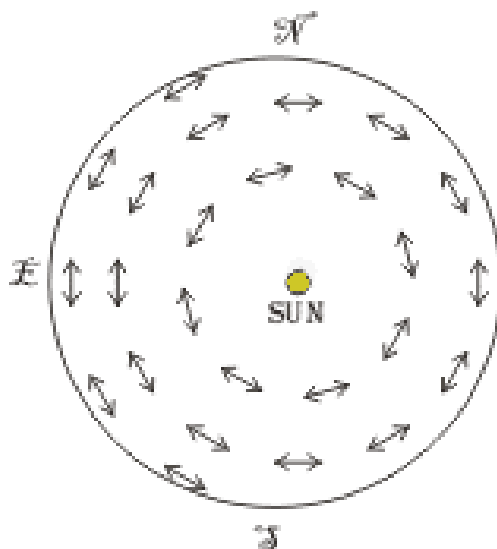
Compass  
Calibration

Neural IMU

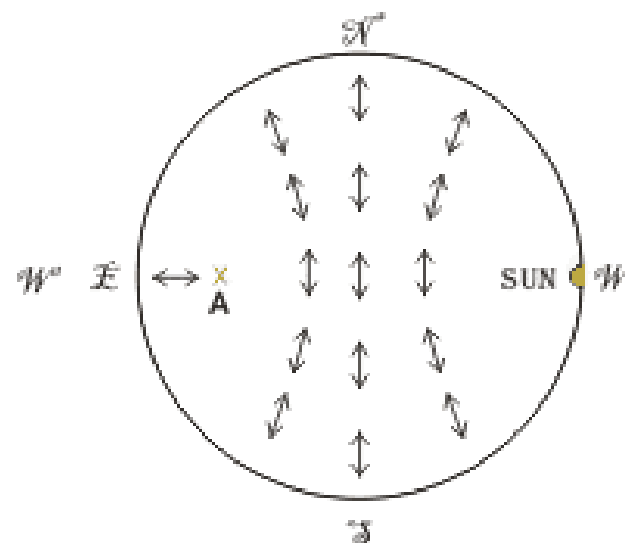


# Light Polarization

Sun at zenith =  
horizontal polarization



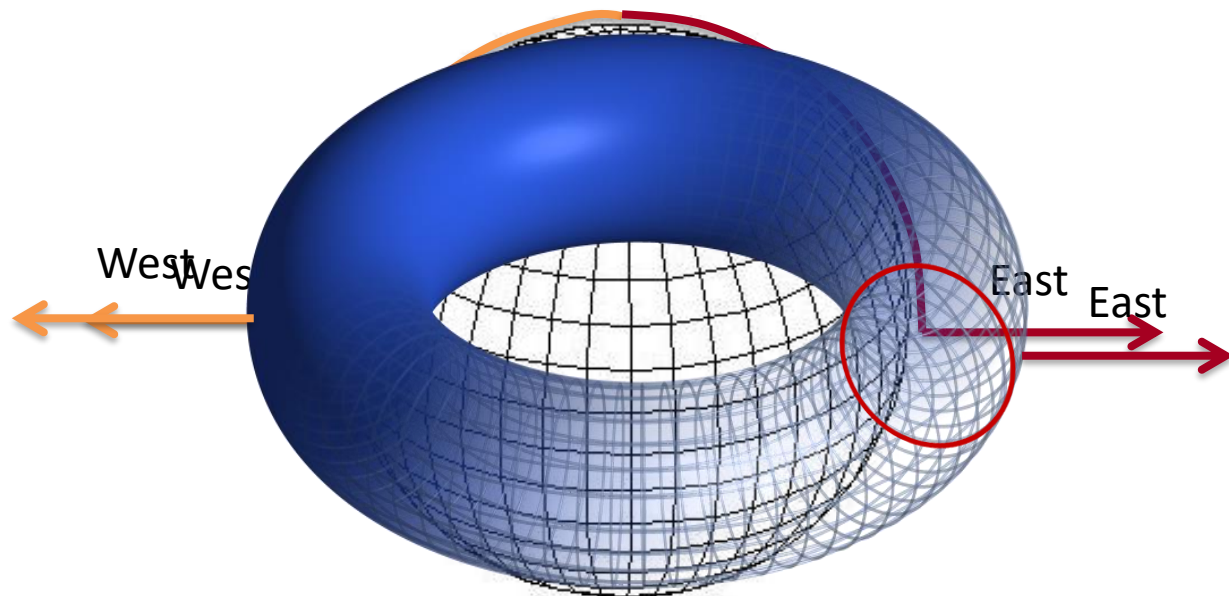
Sun at sunset/sunrise =  
vertical polarization



Bat compass  
orientation



# The Bat Coordinate System



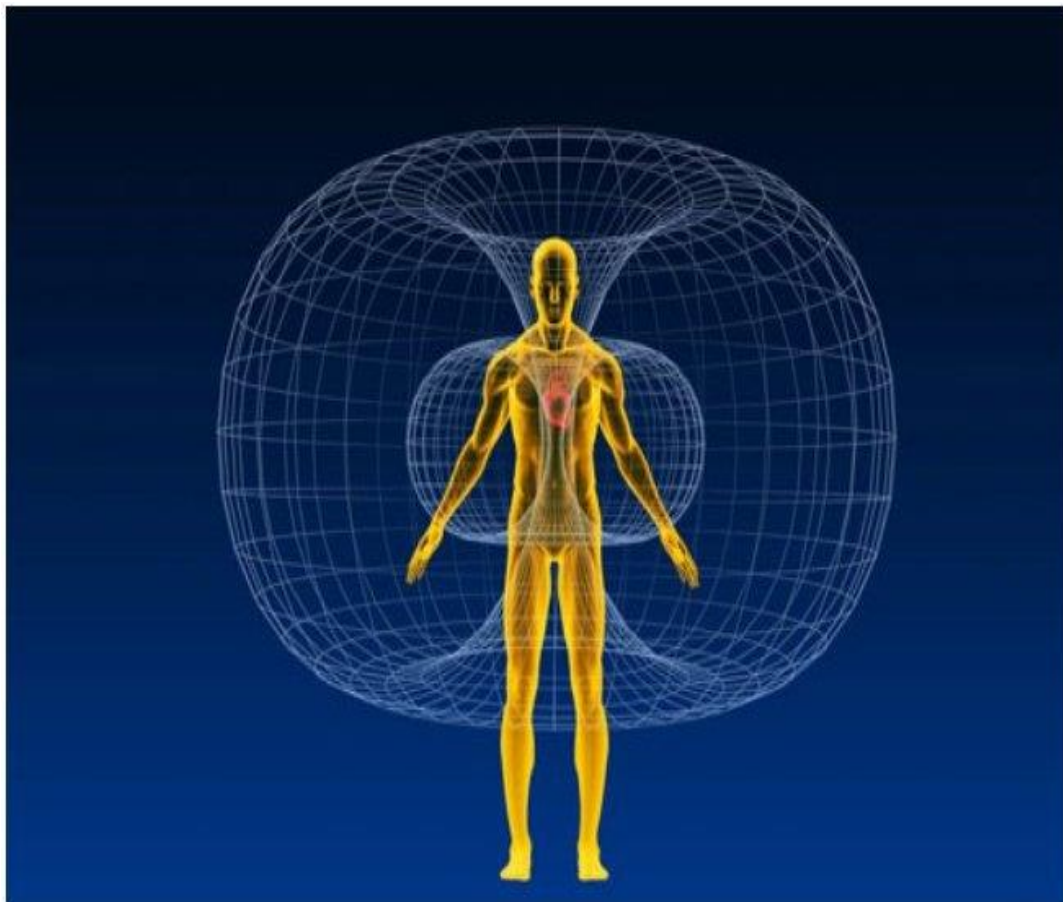
Neural IMU



# Going Down the Google Rabbit Hole

## Torus

- **“Superstring” physics (shape of the universe)**
- **Most efficient particle accelerators**
- **Bacteriophages**
- **Transformers**
- **Human magnetic field**



# WAR OF THE WORLDS AND OTHER CATALYSTS





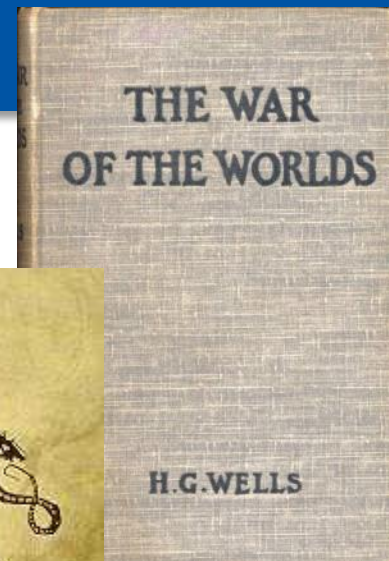
# The Heat Ray

**“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**



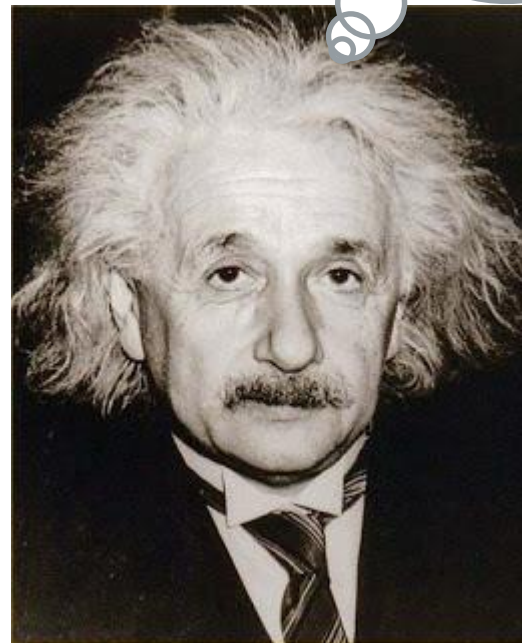


# Lasers

$$E_2 - E_1 = \Delta E = h\nu$$

**Light Amplification by  
Stimulated Emission of  
Radiation**

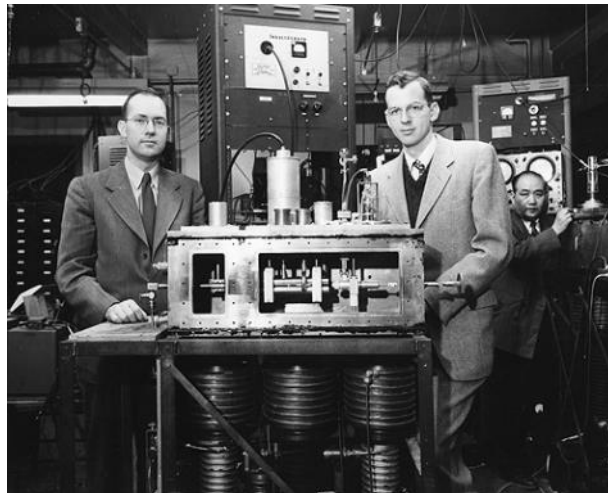
**Theory advanced by Albert  
Einstein in 1917**





# 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**



The first maser



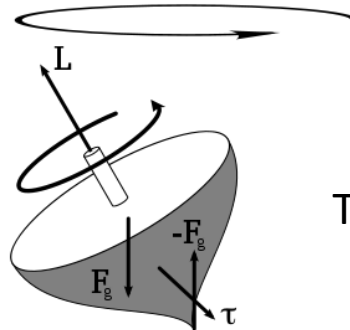
The first laser





# Tops and Gyroscopes

- **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**



The simple, toy top



The gyroscope



# Inertial Measurement Systems

- **1930's – Robert Goddard begins experimenting with gyroscopic guidance**
- **WWII starts an arms race and the improvement of gyroscopic guidance systems**

Robert Goddard in Roswell, NM



WWII V2 Rocket





# Global Positioning System

- 1957 – Soviet Union launches Sputnik
- The space race begins in earnest



**The Weather**  
 Paris: Today's forecast, Cool. Friday, mainly mist. Yesterday's temperature, 48-65. 10-18 Celsius, wind, 10-18. (Sun.). Today's probable temperature, Max. 65. 18-20 Celsius.  
 London: Main and misty rain. Fair and. Yesterday's temperature, 55-65. 13-17 Celsius. 16-22 Celsius.  
 Chassell (Crested) (Siberia).  
 New York: Cool, windy, occasional rain. Yesterday's temperature, 50-65. 10-18 Celsius.

Established in Europe 1887

NEW YORK

## Herald Tribune

European Edition

PARIS, MONDAY, OCTOBER 7, 1957

Established in New York 1942

London	4 A. 20	10 20
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Berlin	2 15	11 15
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Phnom Penh	2 15	11 15

### U.S. Views Satellite as Russian Victory

#### Fights Flare In Warsaw for Fourth Night

By William J. Humphreys  
 Warsaw, Oct. 6. — Chaos between riot police and civilians erupted at Thursday by university students battling for the right of free speech, tonight ranged up and down the principal thoroughfares of Warsaw for the fourth consecutive night.

At the same time, 24000 Cardinal Wyspianski, Roman Catholic bishop of Lublin, said that the Polish people should not be misled by Soviet propaganda that while he could understand their "right," they had to remember "that our country is in a particularly difficult situation."

These statements to the cardinal's remarks on the occasion of the university's scheduled reopening, but the impression that he was warning that the anti-headed protests might push Poland into necessary steps of war.

Official reports said that a total of 150 have been arrested since the rioting, several seriously injured persons have been hospitalized. At least there has been no official confirmation of any fatalities, although there have been mentions in Poland.

Toughly main challenge to Polish government authorities was staged in front of Stalin's sprawling architectural gift to the people of Poland—the Palace of Peace and Culture.

#### Russians Work on New One It May Get Down With Instruments

By B. J. Cutler  
 Moscow, Oct. 6.—The Soviet Union is working on a new satellite designed to return to earth instruments intact.

This was disclosed today by Yevgeny Fedorenko, scientist in charge of Russia's upper-atmosphere research program, who already has been today's first artificial satellite into its orbit around the earth.

The statement came as the nation's newspapers and radio stations erupted in a series of programs over Friday's successful launching of the satellite and first launch that the Soviet Union had made in the field of satellite launching.

From all major newspapers, it was clear that the Kremlin was trying to convert the scientific achievement into a propaganda victory. Its purpose, to convince the world that such progress was possible only "under the wise leadership of the Communist Party," as "Pravda" wrote.

Details had been revealed among the hundreds of thousands of words printed about the satellite, there were almost none about its technical details. It

This photograph, made from an altitude of 143 miles during recent rocket tests in the United States, provides background for artist's conception of the American man-made satellite in flight. Area in the background is of Southwestern United States and northern Mexico.

#### Braves Nip Yanks, 7-5, In Tenth

Series Made 2-2 By 3-Run Rally

By Tommy Holmes  
 St. Louis, Oct. 6. — Right-hander, of the Braves, led off a spin in the tenth inning today and the home run he hit into the right-field bleachers clinched a seventh win, the "good team" of New York, 7-5, and again won the 1957 World Series.

#### 23-In. Sphere Looping World at 18,000 M.P.H.

Soviet Satellite's Predicted Orbit

That the Eisenhower administration may be alarmed by an expansion of Congressional criticism resulting primarily in a major Congressional investigation of American military policy in Moscow City yesterday afternoon was indicated by a statement from the State Department.



# Global Positioning System

*The Doppler effect: a change in frequency of a wave relative to the wave source with respect to the observer*

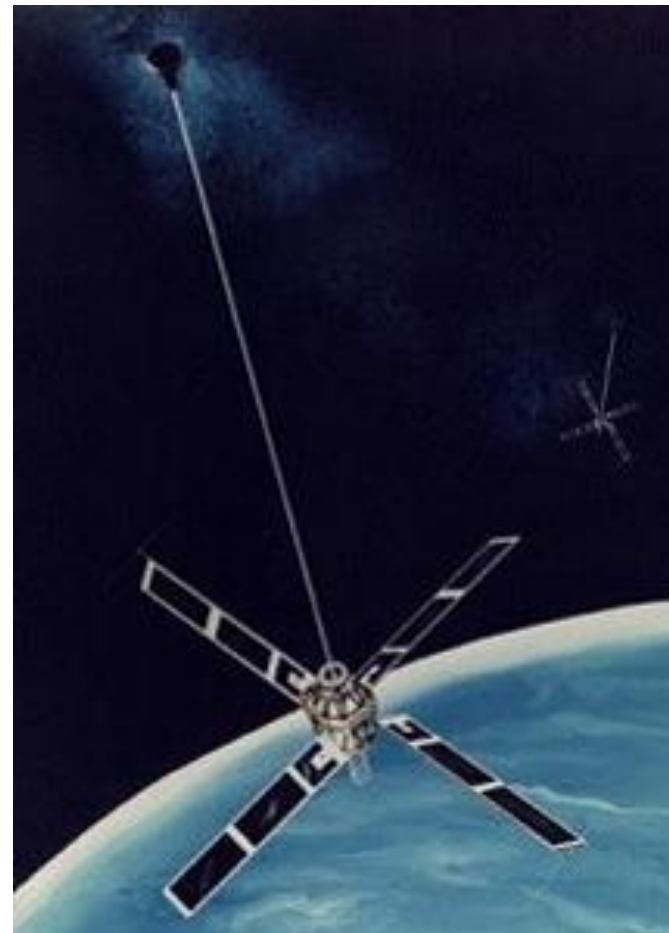
**By monitoring Sputnik's radio signal, physicists at Johns Hopkin's Applied Physics Laboratory realized they could pinpoint the location of the satellite by measuring the Doppler shift**





# 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





# Parallel Worlds



55 million B.C.

**Development and application of these technologies, for the most part, occurred in parallel**



1957

GPS



1897

Lasers



1740

IMU

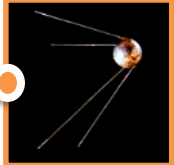


# GPS - Lightspeed Timeline



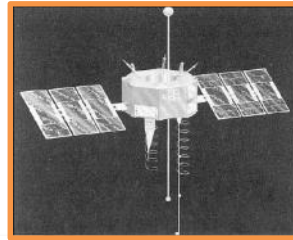
1957

Sputnik



1964

TRANSIT



1967

TIMATION



1978 - 2016

NAVSTAR



1983

2000

Selective Availability  
ON OFF



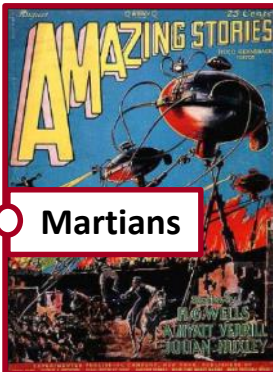




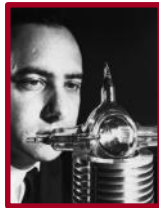
# Lasers/LiDAR - Lightspeed Timeline



1897

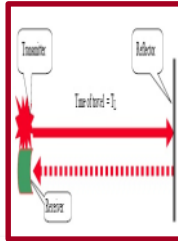


Martians



1960

Laser



1963

Laser  
Rangefinder  
Testing



1971

Laser Maps  
Moon



1970's – 1980's

NASA  
Airborne  
LiDAR

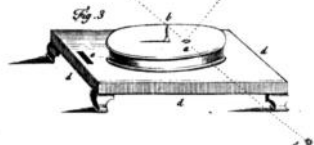


# IMU - Lightspeed Timeline



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

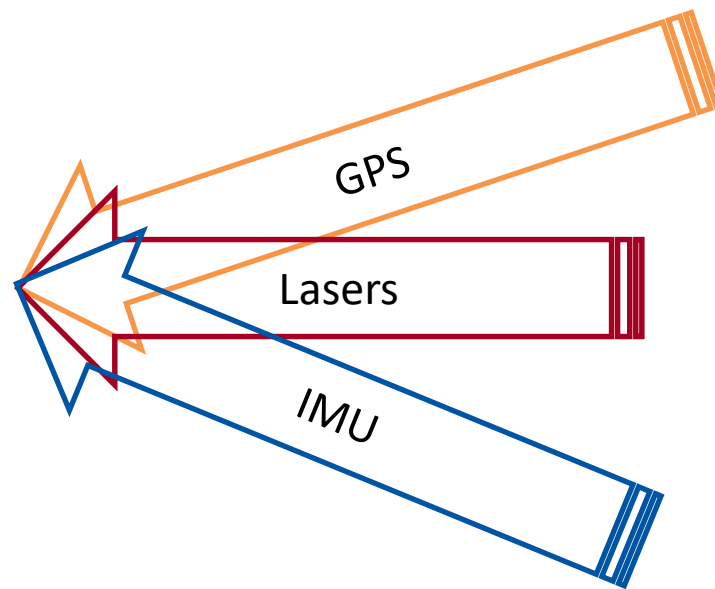




# 1999 Commercial LiDAR System

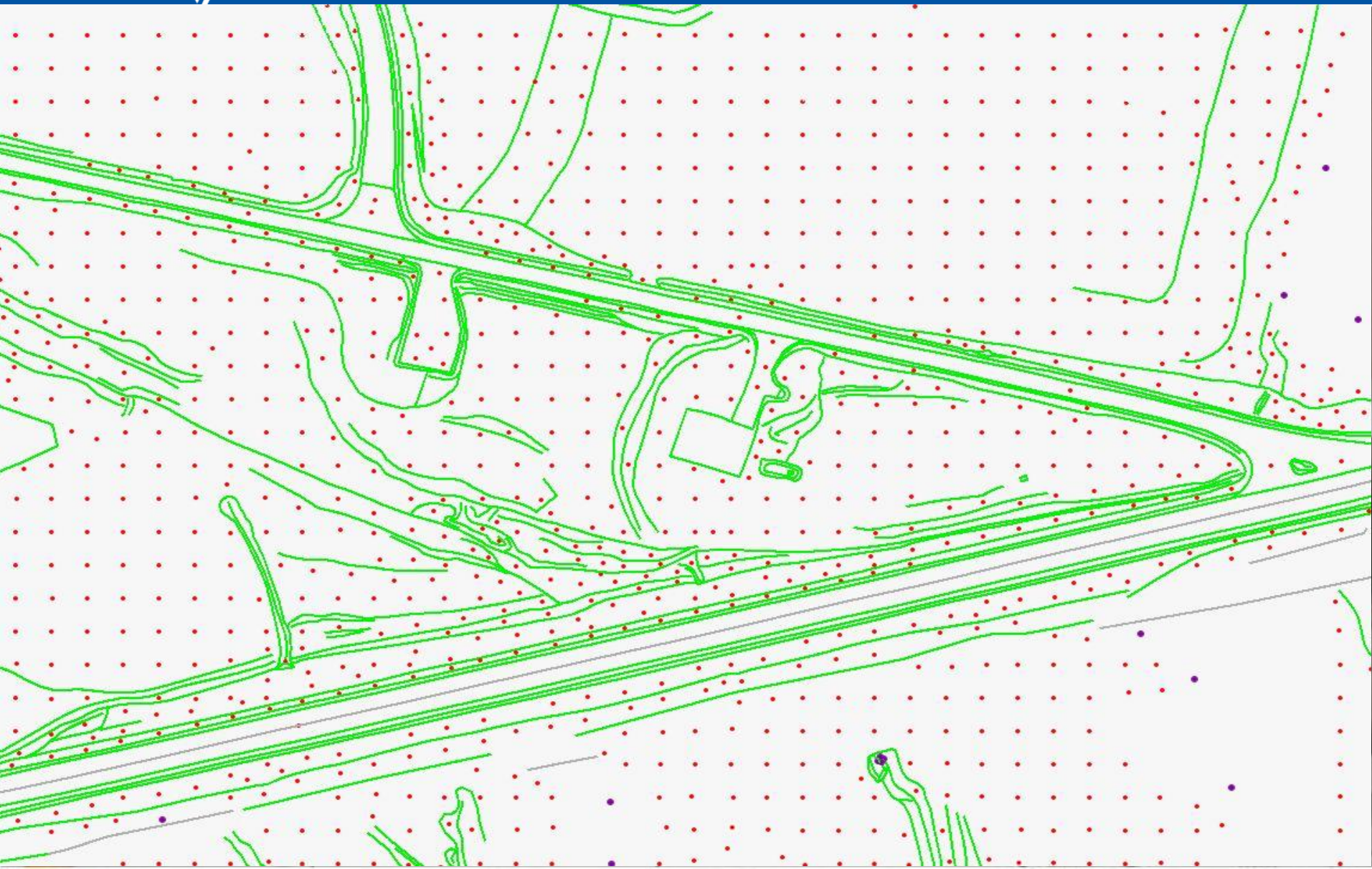


Source: Fugro EarthData





# FROM RELICS TO HIGH-SPEED TECH





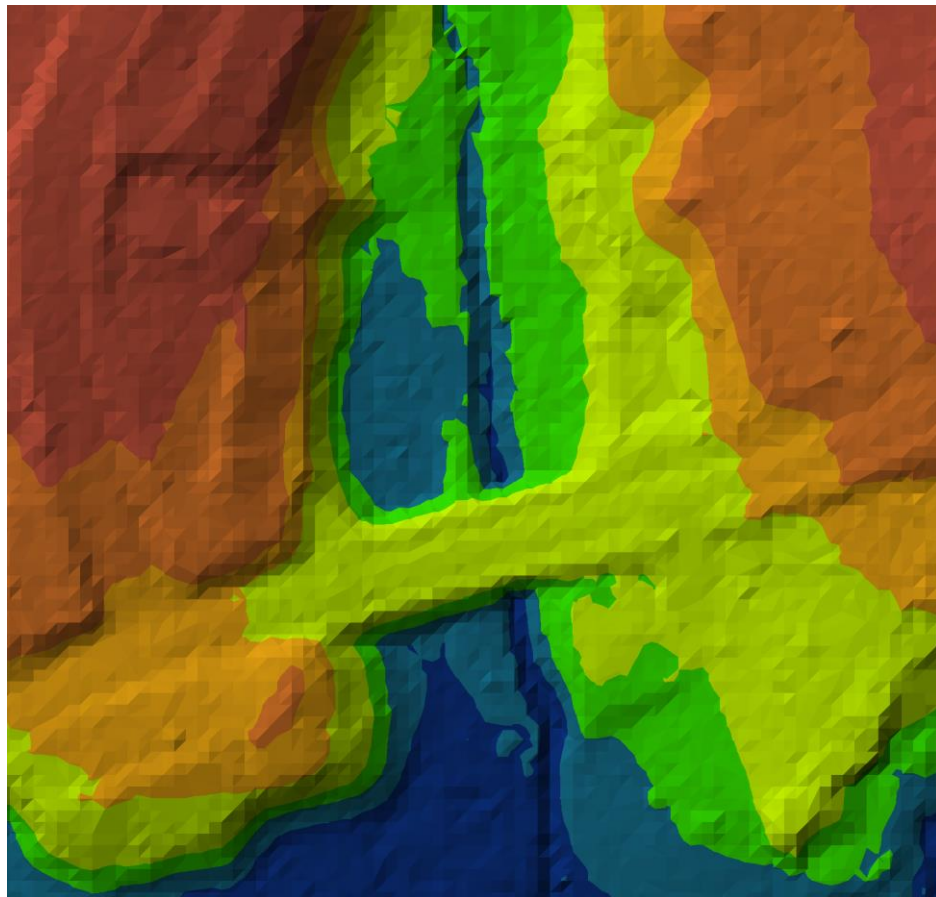
# Negative Press?

- Technology was met with some skepticism:
  - “It’s not accurate”
  - “It’s not reliable”
  - “It will never replace photogrammetrically-derived Digital Elevation Models (DEMs)”
  - It will blind forest animals?



# The First Statewide LiDAR Program

2000 - 2007





# The First Statewide LiDAR Program

- Up until this point:
  - NC received (on average) one 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

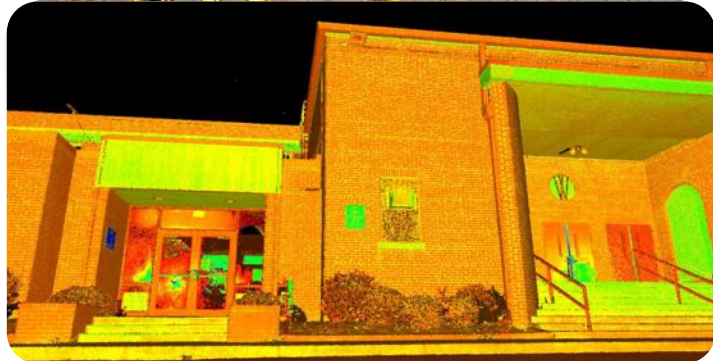
# THE STATE OF LIDAR TODAY



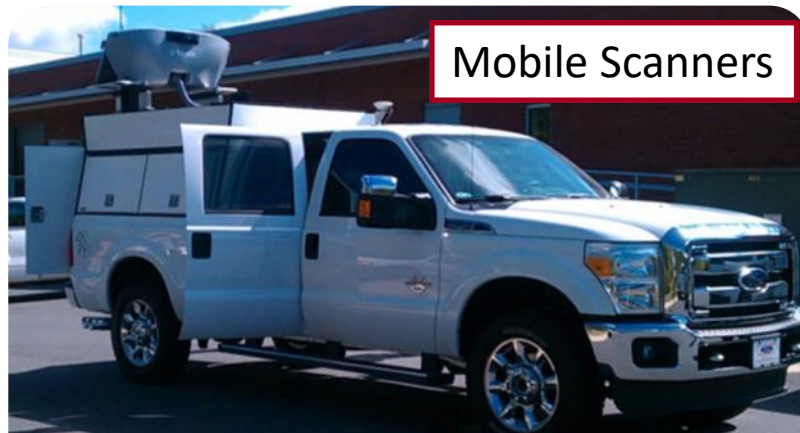


# LiDAR Today

Static Scanners



Mobile Scanners

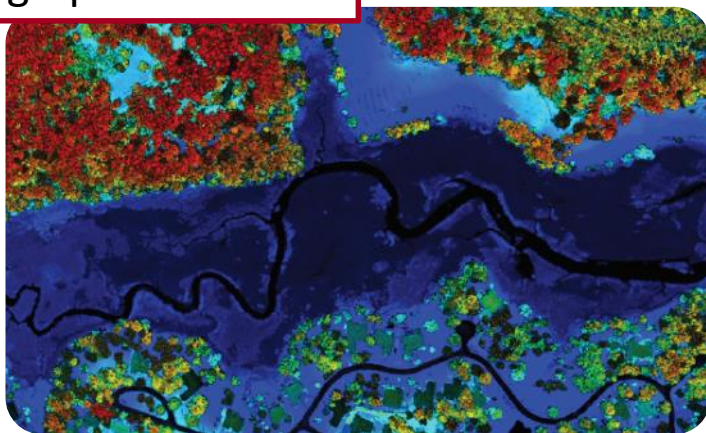




# LiDAR Today

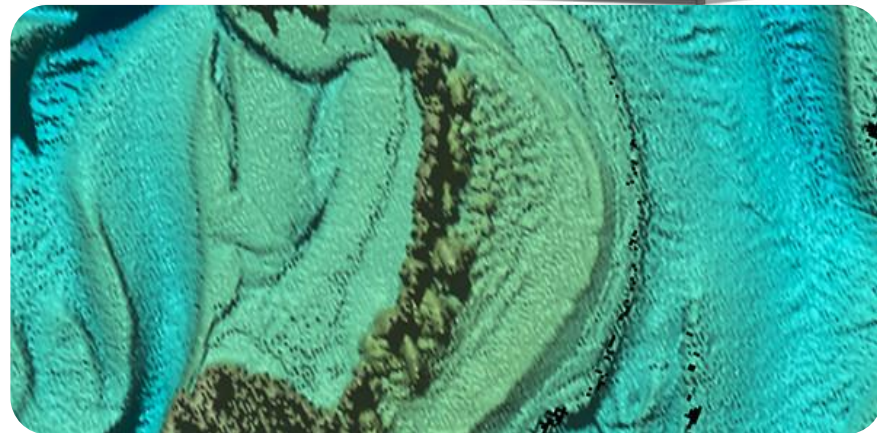


Topographic Scanners



Source: Teledyne Optech

Bathymetric Scanners



Source: Teledyne Optech



# LiDAR Today

DEM Models

Agriculture

Forestry

Flood Models

Land Classification

River Surveys

Utility Mapping

Transportation Mapping

Pollution Modeling

Coastline Management

Oil & Gas Exploration

Mining

Archeaology

Viewshed Analysis

Solar Energy Planning

Glacier Monitoring

Accident Scene Map

Architecture

Gaming

Historical Records

BIM

Cell Network Planning

Autonomous Vehicles

Watershed Delineation

Robotics

Meterology

Law Enforcement

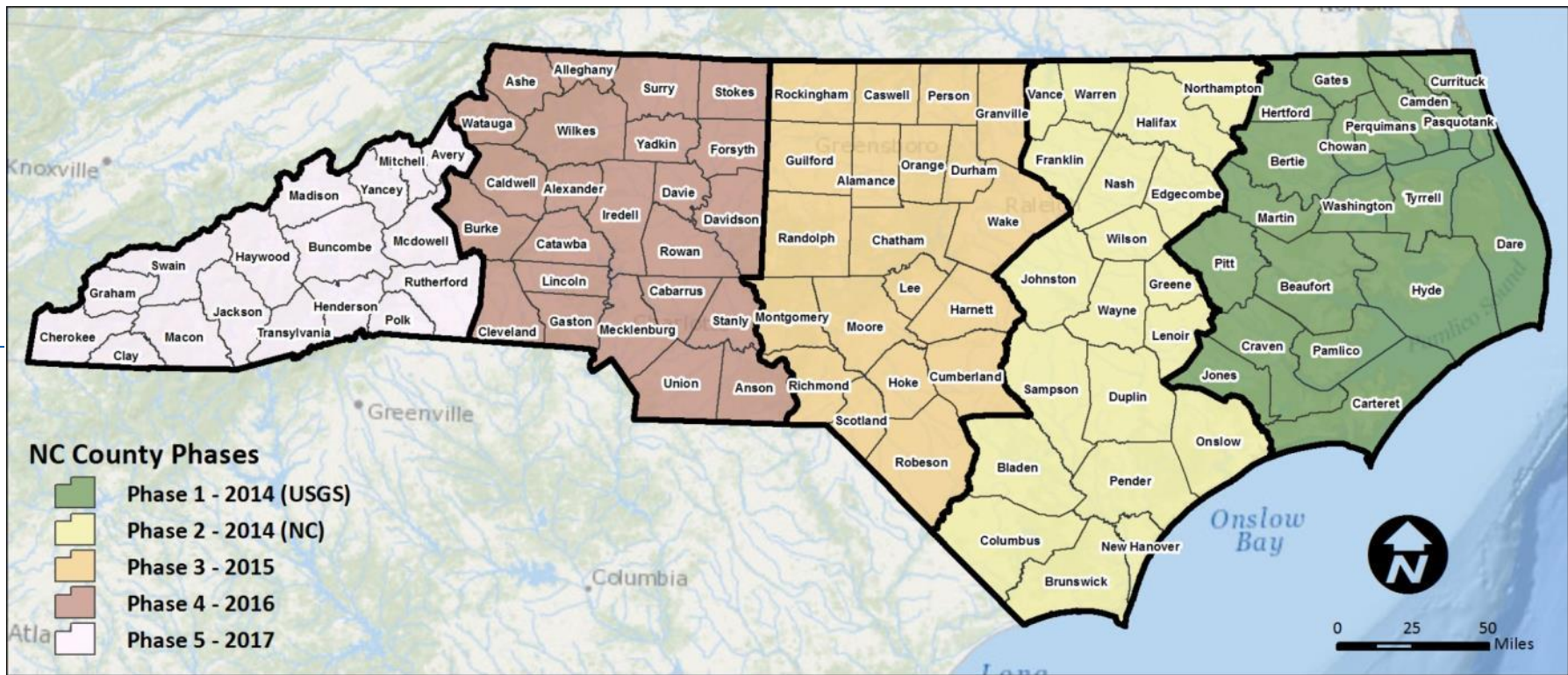
Military

Astronomy

Surveying



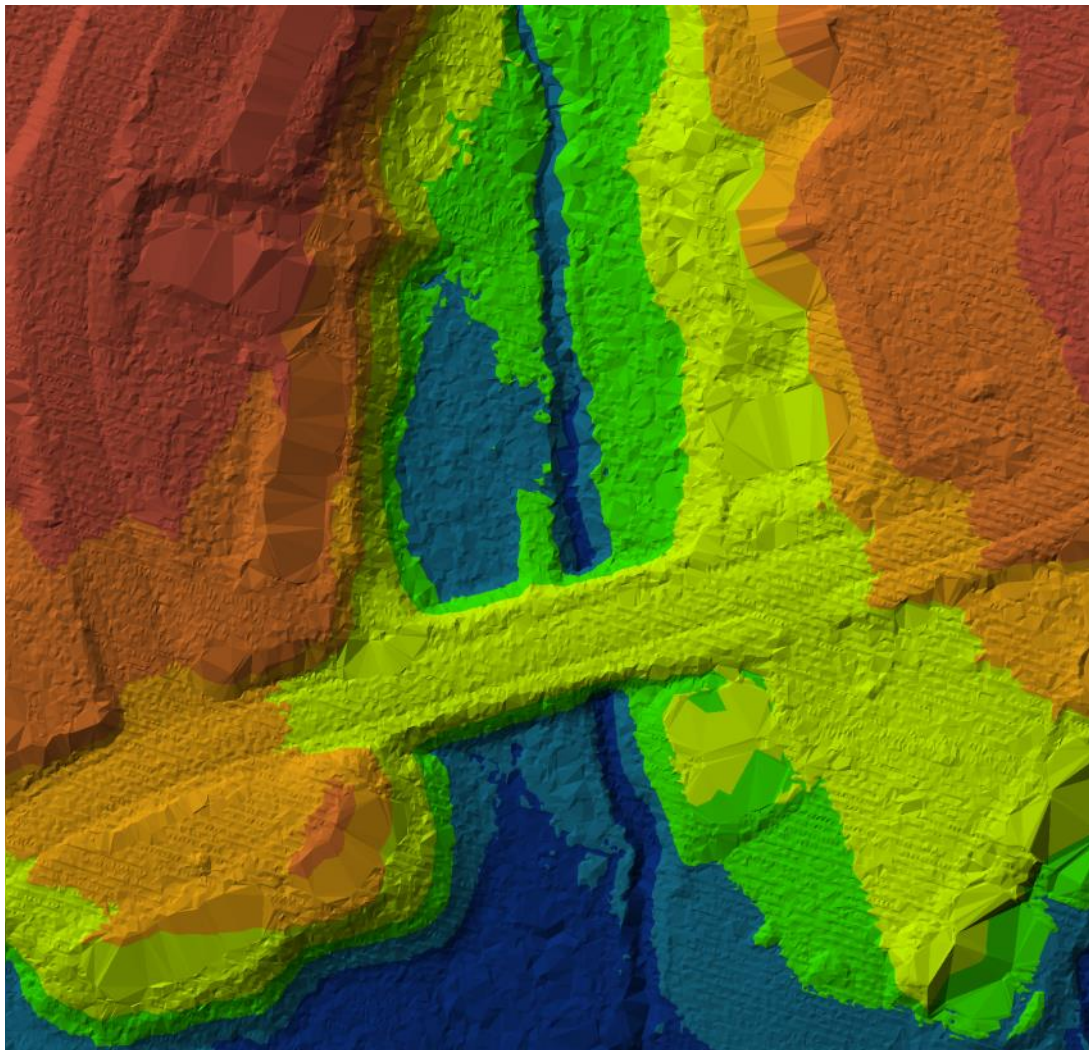
# LiDAR Today – NC Refresh





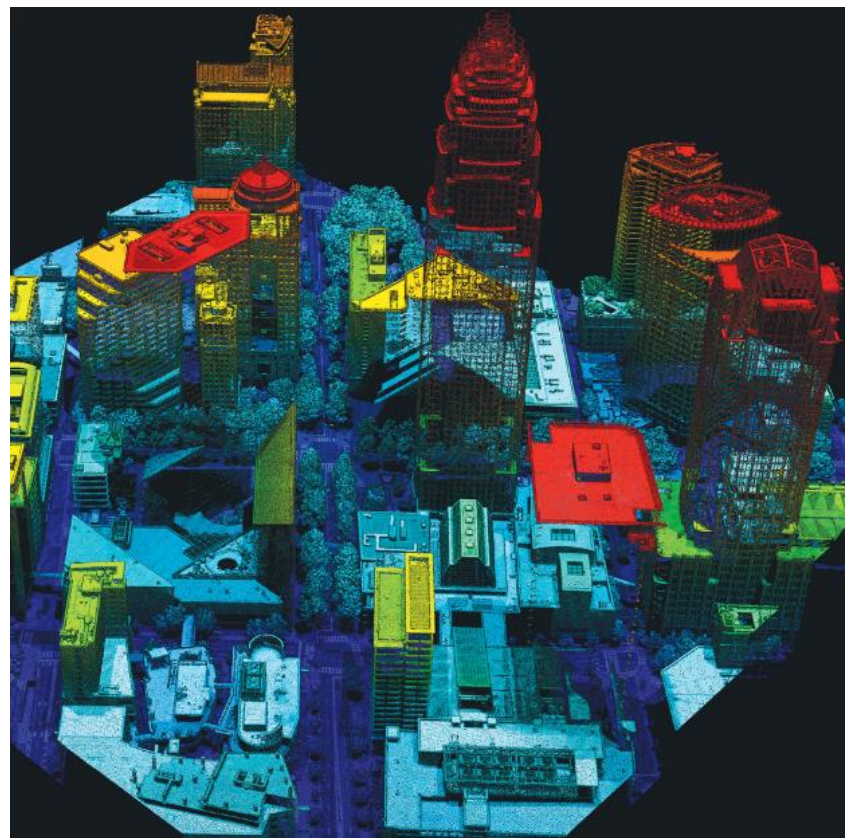
# LiDAR Today – NC Refresh

New QL2 Data





# NC Refresh – Next?



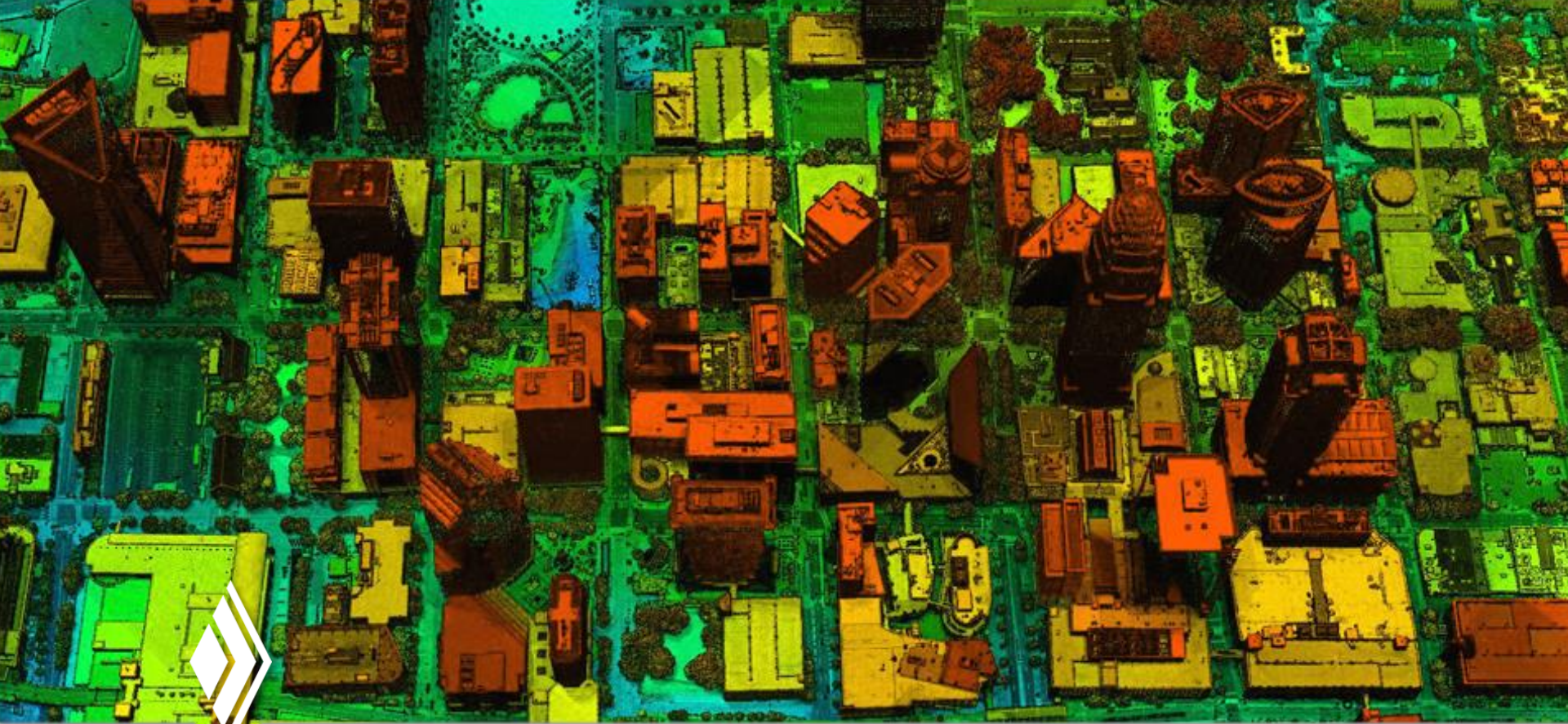




# PHOTONS?



Well...sort  
of...



# QUESTIONS?

