

# Tech Brief: Earth Observation vs SAR

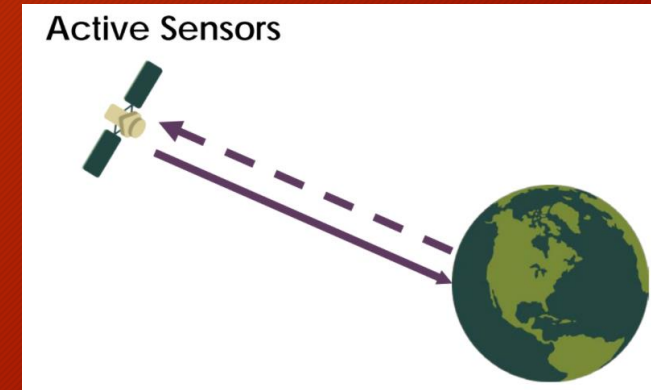
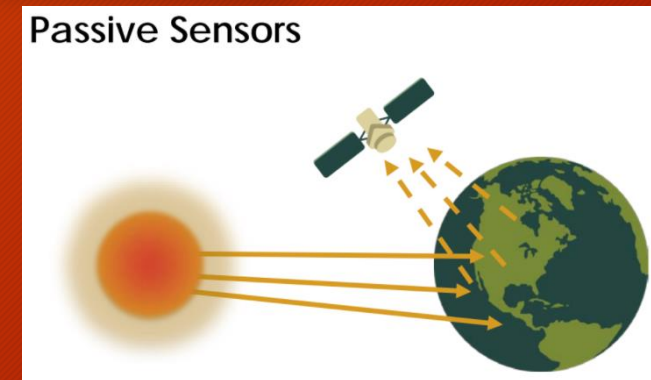
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# Earth Observation (EO) Introduction

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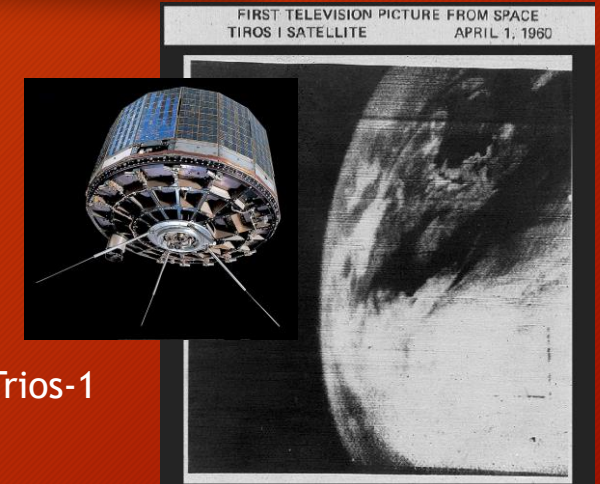
- Earth Observation is conducted using Active and/or Passive Sensors
  - Passive Sensors: Based on solar reflection in visible, infrared, thermal infrared, and uwave bands of EM spectrum.
    - Cloud coverage and night side of the earth can limit operation
  - Active Sensors: Based on satellite emitting and receiving reflected energy
    - Generally all-weather operation
- Key Systems Parameters for EO satellite
  - Spatial Resolution: size of object/features being measured
  - Spectral Extent: breadth of electromagnetic spectrum sensed
  - Radiometric Resolution: number of digital levels expressed in the data collected
  - Temporal Resolution: intervals between imagery acquisition



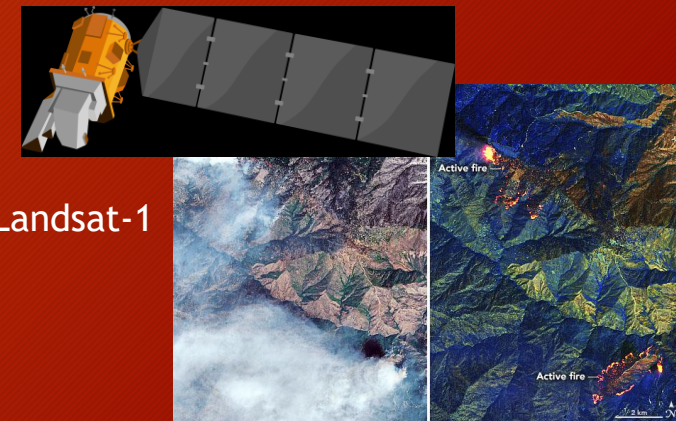
# Earth Observation a brief history

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- 1960 Tiros-1 weather satellite
  - 2 visible spectrum cameras - 10 satellites launched
- 1964 - Nimbus-1 to 1978 Nimbus 7
  - introduced multi-spectral scan (MSS) w/uwave for water vapor detection
- 1974 - Landsat 1 to 2013 Landsat 8
  - MSS progressed from 3 bands to 11 bands
- 1974 - GEOS series - 1<sup>st</sup> Geostationary orbit EO satellites
  - GEOS-17 launched 2018 -program on going
- 1980's Active Sensing imaging ... SAR introduced
- 1986 SPOT program - commercial earth observations
- 1990 -2010 sensor types expand
  - 10 countries/regions (EU) operate EO/meteorological satellites
- 2010's - Nano/cube Sats - miniaturization w/full capabilities



Tiros-1



Landsat-1

# EO Sensors Types

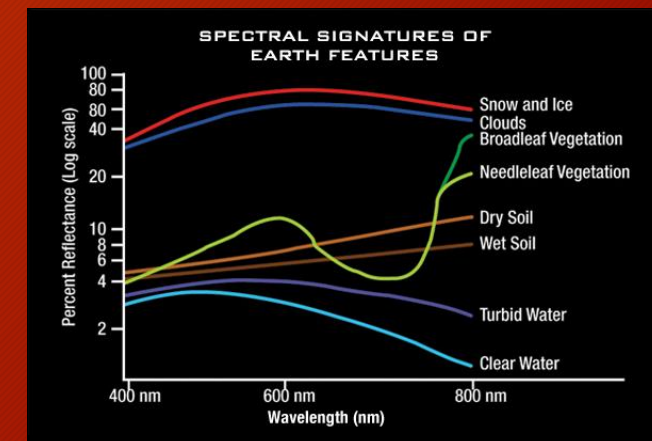
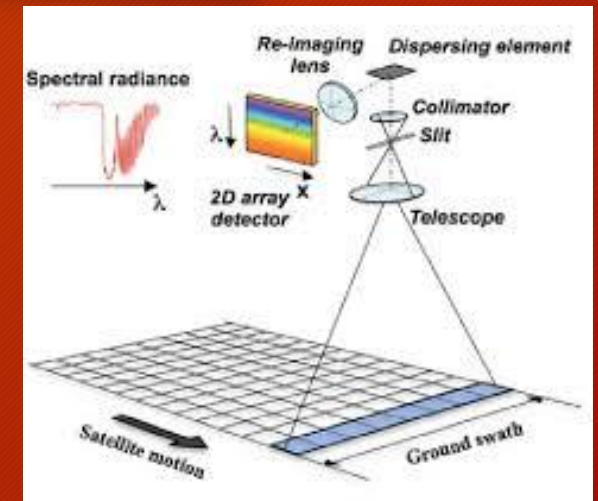
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- **Passive Sensors**

- **Radiometers:** multi and hyper spectral detecting radiation in 10's to 100's emission bands
- **Imaging Radiometer:** two-dimensional array of sensors scanned electrically or mechanically
- **Sounder:** measures vertical distributions of atmospheric parameters
- **Spectrometer:** uses a prism or grating for spectral discrimination

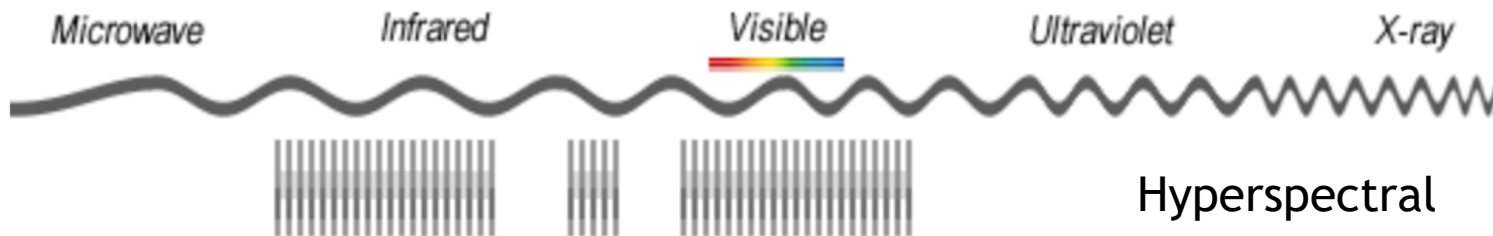
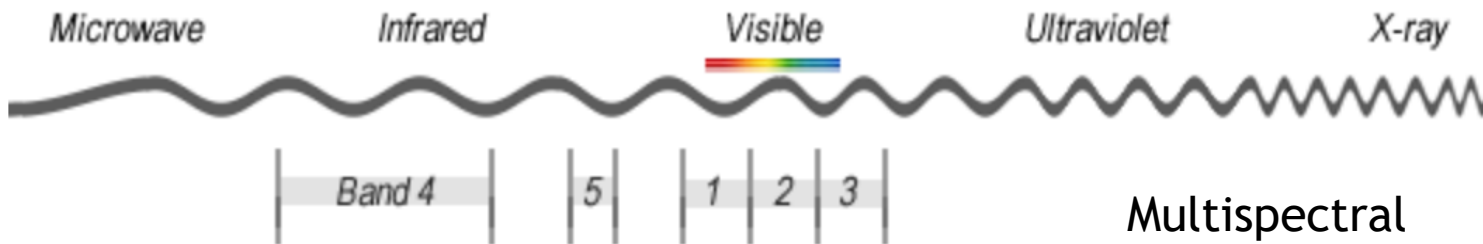
- **Active Sensors**

- **RADAR:** Sounding/altimeter, scatterometers, and SAR
- **LASER Based:** Altimeters and Lidar



# Technology Evolution: Multispectral to Hyperspectral

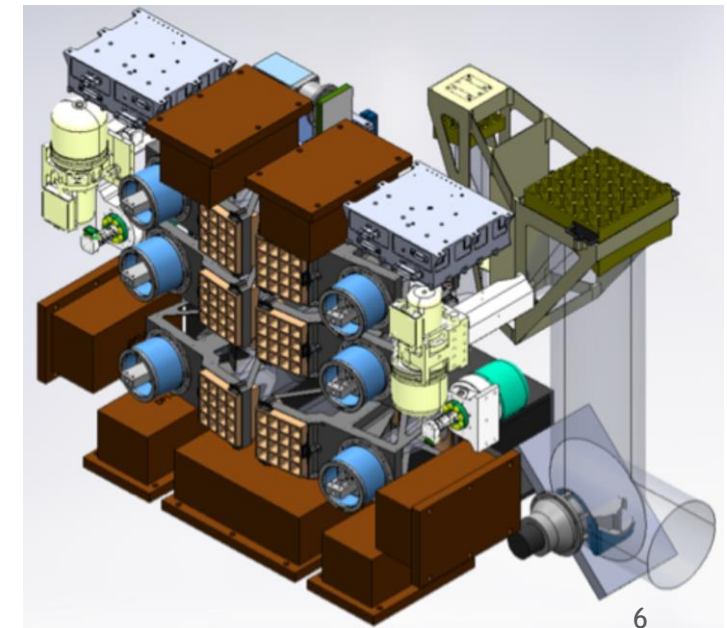
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- Multispectral: typically 3-10 frequency bands - relatively wide bands
- Hyperspectral: Hundreds of narrow bands
- Evolution through a multiple decades of technology advances
- Advantages of Hyperspectral:
  - Capture all data at one time
  - More accurate segmentation and classification of the image
- Disadvantages of Hyperspectral:
  - Cost and Complexity

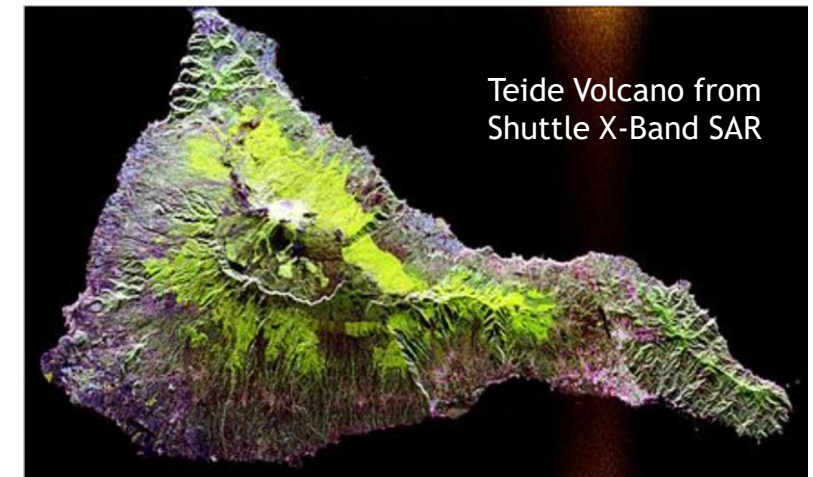
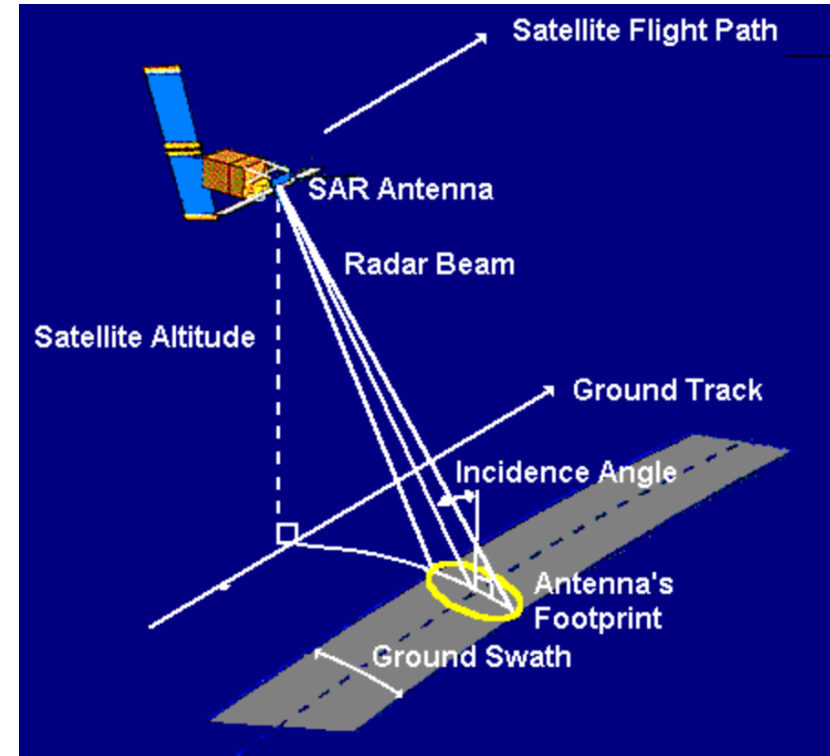
# NANO EO Satellite Revolution

- Historically, EO satellites have large multiple sensor platforms
  - Only a handful of countries had the technology to build and launch
- By 2010, the Nano/Cube satellite revolution created a disruption
  - Any country or company could launch and operate EO satellite
  - Despite the size, resolution and capabilities matched or exceeded the previous generation multi-sensor satellites
- NSA Jet Propulsion Lab CubeSat technology validation
  - GRIFEX: 3U, 2D spectrometer chipset and instrument
  - CubeRRT: 6U, 6-40 GHz radiometer w/real-time FPGA processing
  - TEMPEST-D: 6U, 82-183 GHz radiometer to study precipitation at cloud transitions
  - RACE: 1.5U package for 2U to 6U cubeSat, 183 GHz water vapor line radiometer.



# What is SAR?

- Synthetic-aperture radar (SAR) is a form of radar that is used to create two-dimensional images or three-dimensional reconstructions of objects, such as landscapes
- The distance the SAR device travels over a target in the time taken for the radar pulses to return to the antenna creates the large synthetic antenna aperture
- SAR can create high-resolution images with relatively small physical antennas - PERFECT for CubeSats
- LEO X-Band SAR can achieve resolutions < 1 meter
- Interferometric (InSAR) and differential Interferometric (D-InSAR) processing can approach GPS in accuracy



# Types of SAR Systems

- Stripmap mode

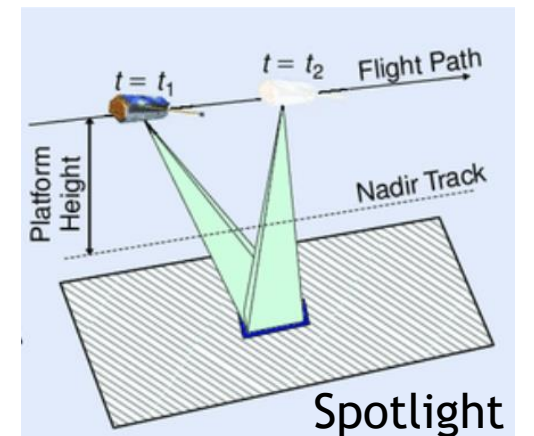
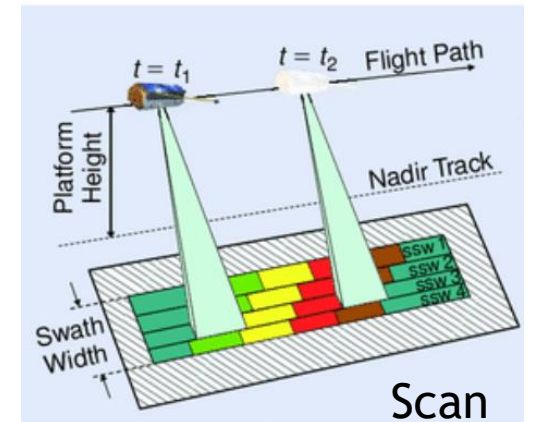
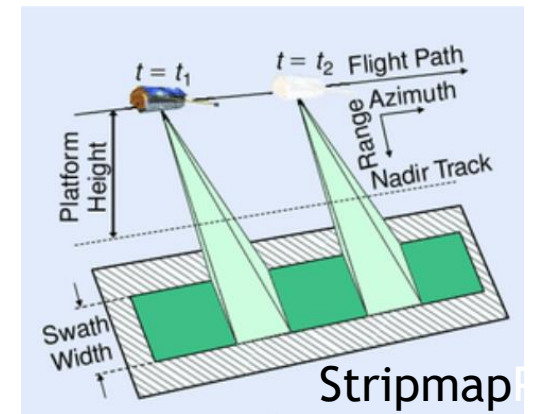
- Antenna remains fixed relative to the orbit path
- Terrain is illuminated with a pulse repetition radar signal
- Backscatter of radar pulses cumulatively added on a pixel-by-pixel basis to attain the fine azimuth resolution desired in radar imagery

- Scan mode:

- Antenna beam sweeps periodically and thus cover much larger area than the spotlight and stripmap modes
- Resolution is reduced but a far greater area is scanned

- Spotlight mode:

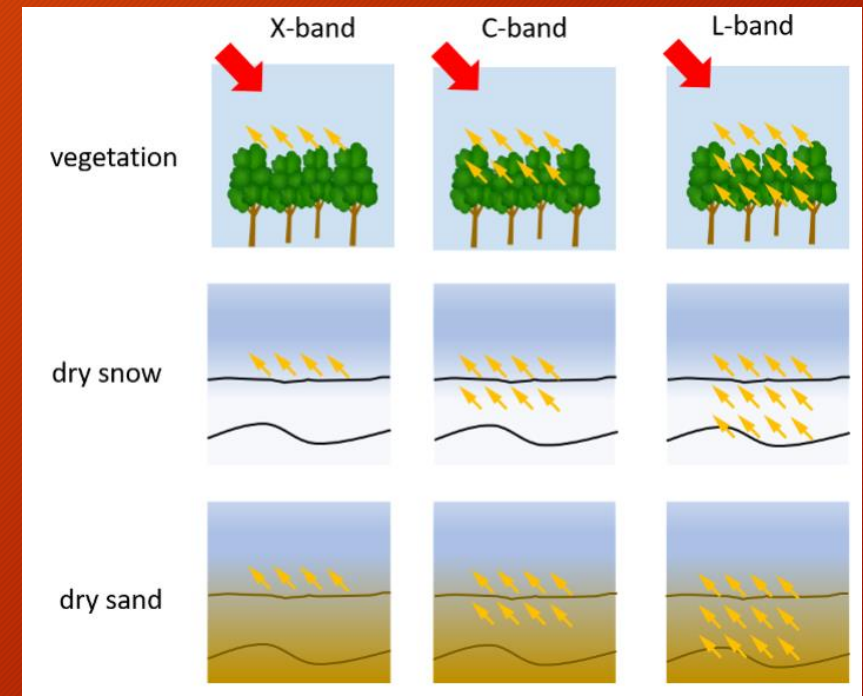
- Radar is steered at a fixed terrestrial point
- Radar dwell period is extended resulting high azimuth resolution



# SAR Frequency bands of operation

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Band	Frequency	Wavelength	Typical Application
Ka	27 – 40 GHz	1.1 – 0.8 cm	Rarely used for SAR (airport surveillance)
K	18 – 27 GHz	1.7 – 1.1 cm	rarely used (H <sub>2</sub> O absorption)
Ku	12 – 18 GHz	2.4 – 1.7 cm	rarely used for SAR (satellite altimetry)
X	8 – 12 GHz	3.8 – 2.4 cm	High resolution SAR (urban monitoring,; ice and snow, little penetration into vegetation cover; fast coherence decay in vegetated areas)
C	4 – 8 GHz	7.5 – 3.8 cm	SAR Workhorse (global mapping; change detection; monitoring of areas with low to moderate penetration; higher coherence); ice, ocean maritime navigation
S	2 – 4 GHz	15 – 7.5 cm	Little but increasing use for SAR-based Earth observation; agriculture monitoring (NISAR will carry an S-band channel; expands C-band applications to higher vegetation density)
L	1 – 2 GHz	30 – 15 cm	Medium resolution SAR (geophysical monitoring; biomass and vegetation mapping; high penetration, InSAR)
P	0.3 – 1 GHz	100 – 30 cm	Biomass. First p-band spaceborne SAR will be launched ~2020; vegetation mapping and assessment. Experimental SAR.

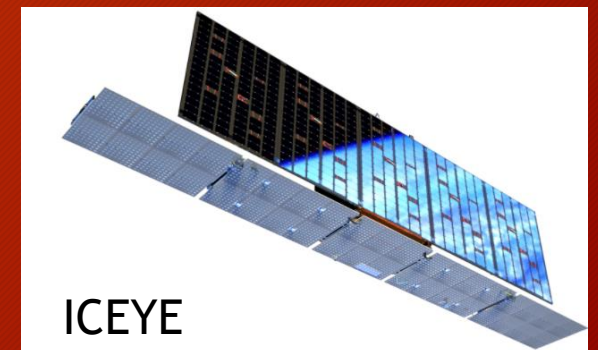
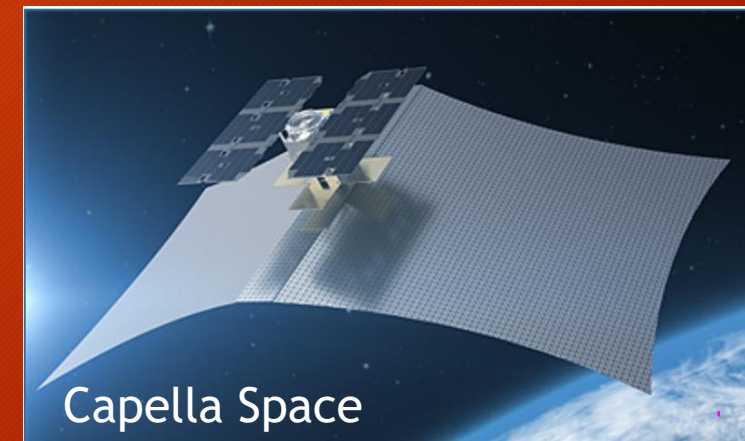


Penetration Capability by Frequency Band

# Nano Satellite SAR

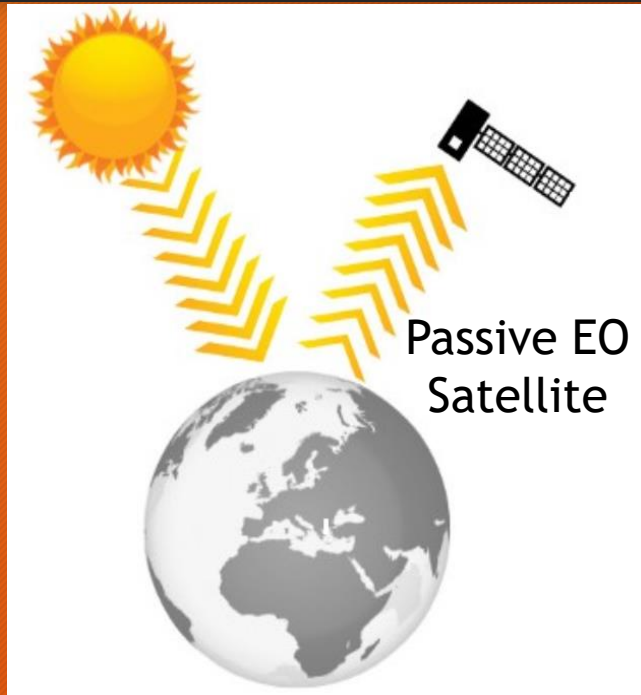
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- Like EO, SAR is undergoing rapid advances in technology/size/cost reduction
- New generation SAR Satellites - 10x reduction in size and weight from greater than 1000Kg less than 100Kg
- Examples of On Demand/As A Service SAR
  - Capella Space
    - 18 satellites planned - revisit time ~hourly
    - X band Radar resolution: ~0.5m
  - ICEYE
    - 3 satellites operational - adding 8 satellites next year , revisit time ~ 12 hours, moving ~1 hour.
    - X band Radar resolution: ~1m (spotlight mode)



# Comparison and Conclusions

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- Requires solar illumination & low cloud cover
- High resolution with low power
- Simple Interpretation & target identification



- Day & Night capability with cloud penetration
- Medium to high resolution- power is a major design issue
- Extensive processing required for imaging

# Thank You

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