AI for satellite communication

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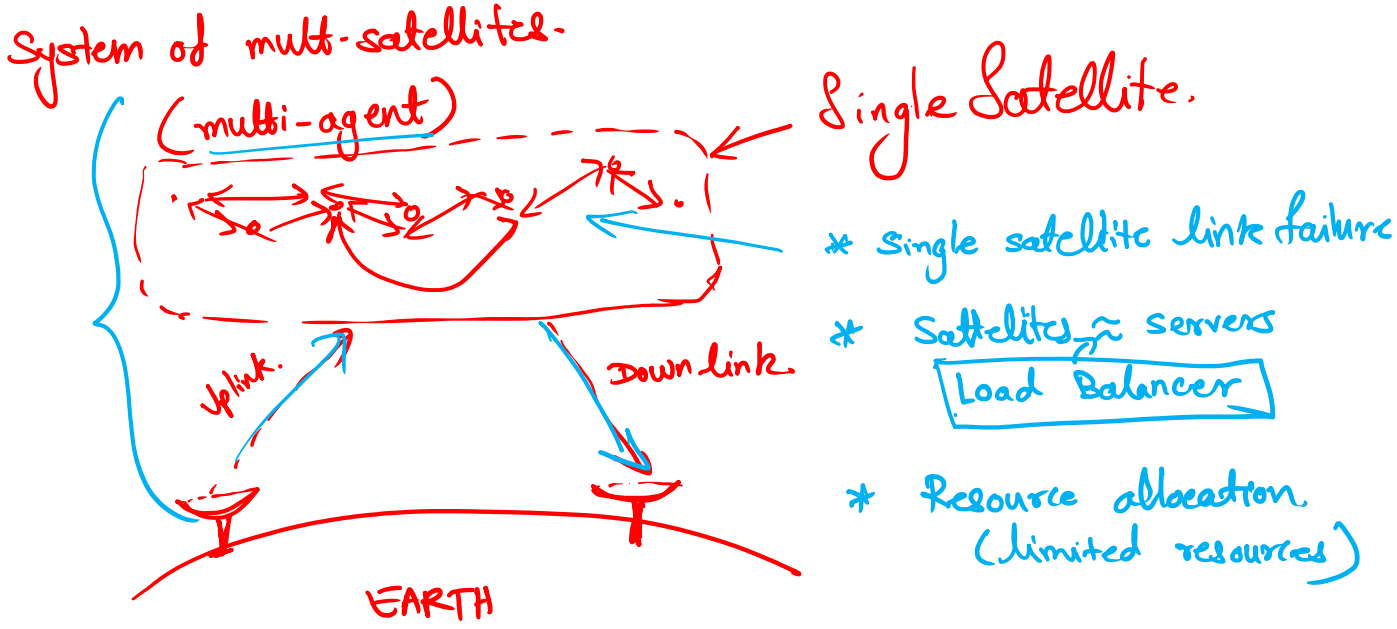

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Introduction

- The remarkable advancement of wireless communication systems, quickly increasing demand for new services in various fields, and rapid development of intelligent devices have led to a growing demand for satellite communication systems to complement conventional terrestrial networks to give access over uncovered and under-covered urban, rural, and mountainous areas, as well as the seas.

- In particular, the application of AI to a wide variety of satellite communication aspects has demonstrated excellent potential, including beam-hopping, anti-jamming, network traffic forecasting, channel modeling, telemetry mining, ionospheric scintillation detecting, interference managing, remote sensing, behavior modeling, space-air-ground integrating, and energy managing.

Sub Modules → optimization / fixed solution based systems ↔ N.N (DL)

- AI can aid in data collection, processing, and understanding using neural networks and deep learning through Computer Vision models to allow data users to better understand and handle data more efficiently in a timely manner, at spatial resolutions of 2cm through 15cm by Digital Aerial Photography and LiDAR, and from 15cm to 2.0m by a variety of Satellite sensors.

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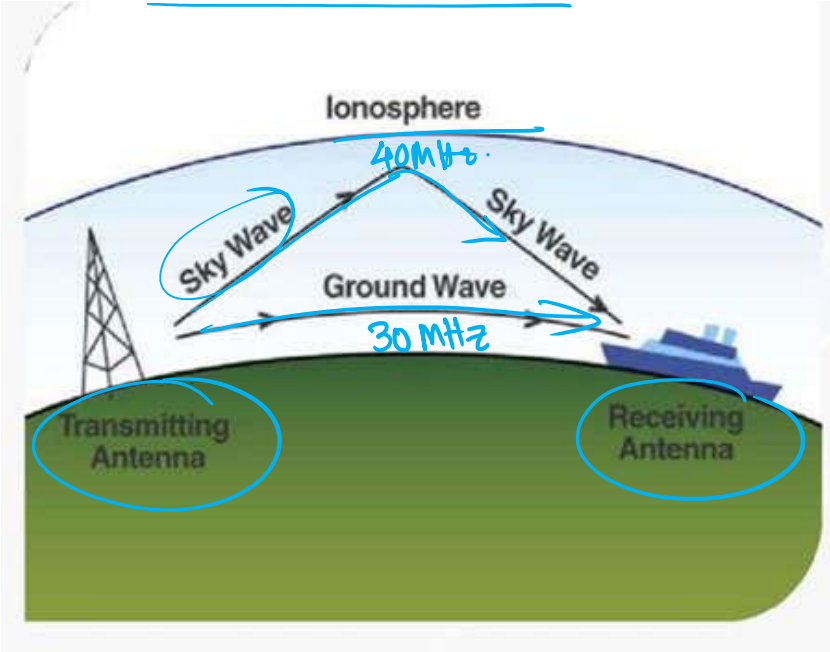
Satellite Communication Background

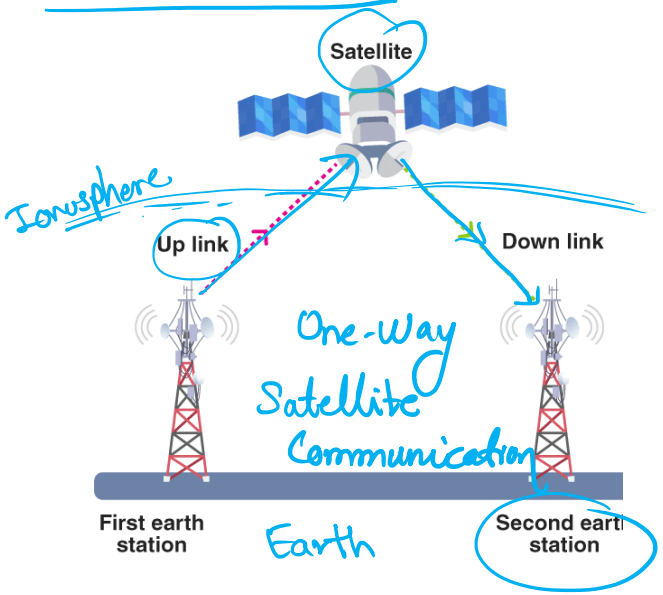
The following two kinds of propagation are used earlier for communication up to some distance.

- **Ground wave propagation** – Ground wave propagation is suitable for frequencies up to 30MHz. This method of communication makes use of the troposphere conditions of the earth.
- **Sky wave propagation** – The suitable bandwidth for this type of communication is broadly between 30–40 MHz and it makes use of the ionosphere properties of the earth.



How a Satellite Works

- A **satellite** is a body that moves around another body in a particular path. A communication satellite is nothing but a microwave repeater station in space. It is helpful in telecommunications, radio and television along with internet applications.
- There are two types of Satellites (i) One-way Satellite Communication, (ii) Two-way Satellite Communication
- In one-way satellite communication, the communication usually takes place between either one or multiple earth stations through the help of a satellite.
- The communication takes place between the transmitter on the first earth satellite to the receiver which is the second earth satellite.
  - Some common one-way satellite communication is:
  - Position location services are provided by the radio
  - Tracking is a part of space operations services
  - Internet services take place with broadcasting satellites



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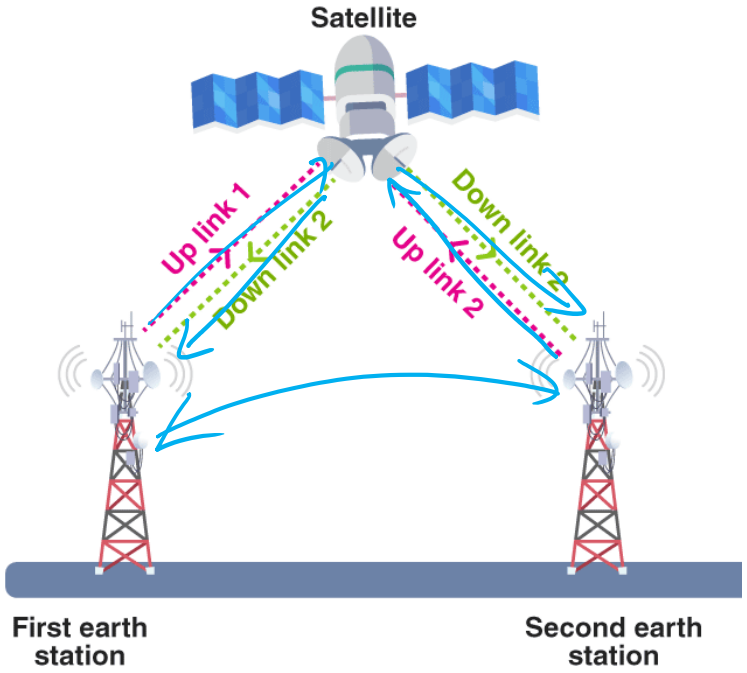
How a Satellite Works

- Two-Way Satellite Communication
  - In two-way satellite communication, the information is exchanged between any two earth stations. It can be said that there is a point to point connectivity.
  - The signal is transmitted from the first earth station to the second earth station such that there are two uplinks and two downlinks between the earth stations and the satellite.



AI in Satellite Communication

- The latest innovation to capturing precise and accurate geospatial data over large areas from satellite imagery has been the utilization of Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL) and Computer Vision (CV).
- AI can improve in the analysis of large areas of interest, to classify objects, detect and monitor land use, data fusion, cloud removal, and spectral analysis of environmental changes from satellite or aerial imagery.

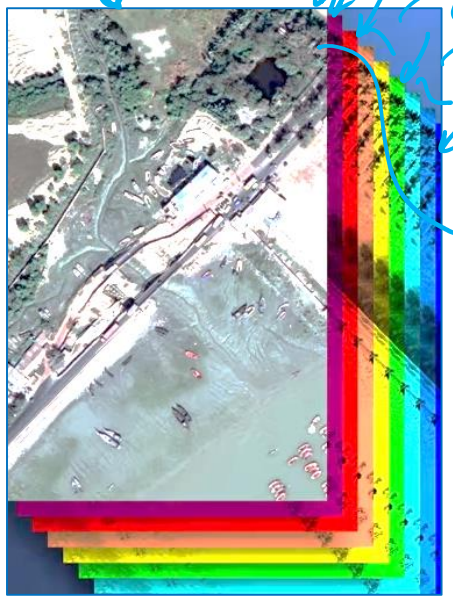
Received data
noise removal.

Source: https://www.defenseone.com/insights/cards/space-based-c4isr/8/?oref=d1-cards-continue

AI in Satellite Communication

- **Satellite in Agriculture and Drought areas:**

- Artificial intelligence and remote sensing can create Computer Vision models to better understand the data. Images collected by satellites or unmanned aerial vehicles (UAV), these models can provide near real-time reports for large scale sized areas with complex feature distribution such as in the applications of agriculture, urban planning, transportation, disaster management, climate change, and wildlife conservation.



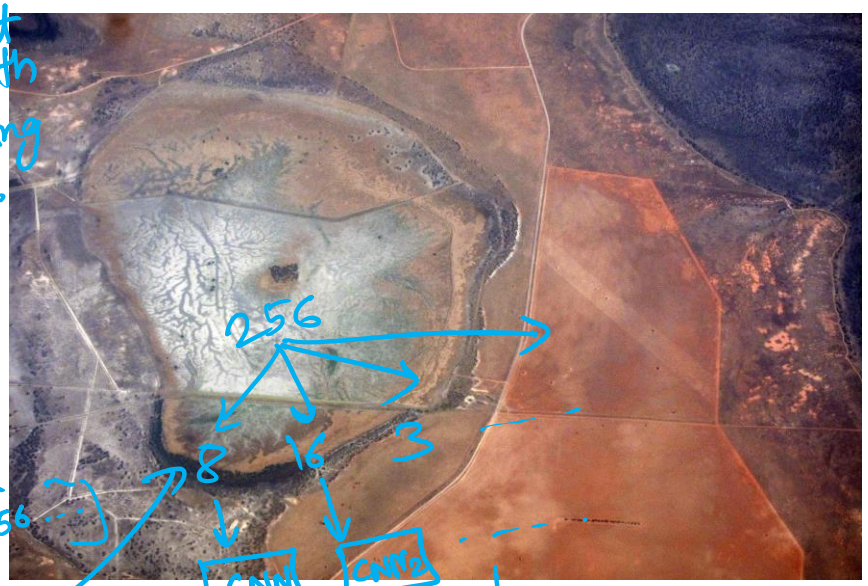


Fig: A satellite image from 2015 depicts a salt-affected water catchment area in drought-struck farmland in Australia, November 26, 2015.

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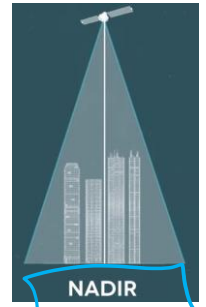
Issues

- Sun location



AI in Satellite Communication

- **Small, Smart Satellites:**
- While both the physical size and cost of satellites have decreased over the years, these smaller satellites are not (yet) equipped with features at the same level as those employed by larger satellites.
- This shortfall, however, can be negated if a group of hundreds or thousands of small satellites are launched as one network. Under this system, if one small satellite is damaged or knocked off course, the cost is minimal, and the system as a whole won't suffer.
- The same cannot be said of the older, larger satellites—a damaged WGS satellite is costly both in terms of financials (the eleventh WGS satellite will cost the U.S. government $605 million).

AI in Satellite Communication

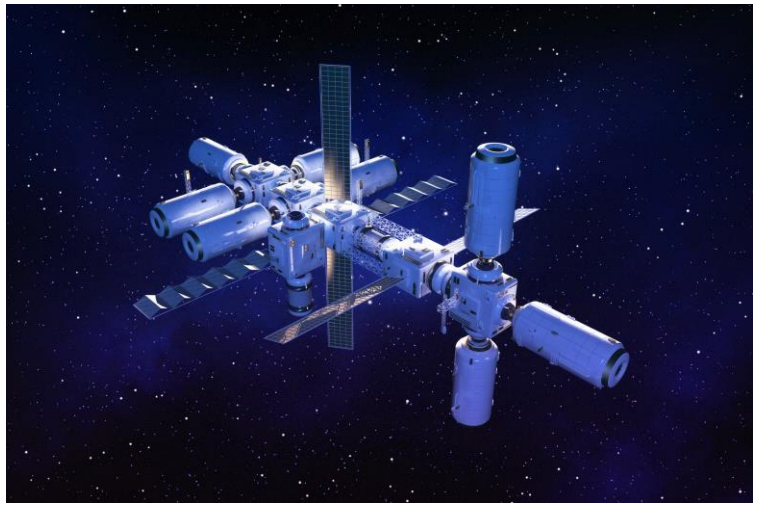
- **Satellite Hacking:**
- Another risk to current and future satellites is hacking. Carried out by foreign governments, non-state entities, or even individual actors, cyber attacks are relatively inexpensive endeavors. On top of that, tracing a cyber attack back to its source often proves difficult, if not impossible.
- The importance of satellites make them a critical part of any nation's infrastructure and attacking those satellites a strategy that most nations need to consider.
- Over the past decade, both China and Russia have launched cyber attacks against U.S. and NATO-affiliated satellites. Because both nations are rapidly incorporating cyber attacks into their military arsenal, the threat of similar instances will only increase.

AI in Satellite Communication

- **Space Force & Military Space Station:**

- Currently, most security-related space projects and missions are handled by the National Reconnaissance Office (NRO) and the Air Force Space Command. By creating a space-centric military branch, the United States is signaling to the world that space missions are at the forefront of its future security plan.

- Research Area:
  - NN based data encoder and encryption
  - Secure AI applications
  - Hybrid: secure and normal link (to reduce latency)



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AI in Satellite Communication

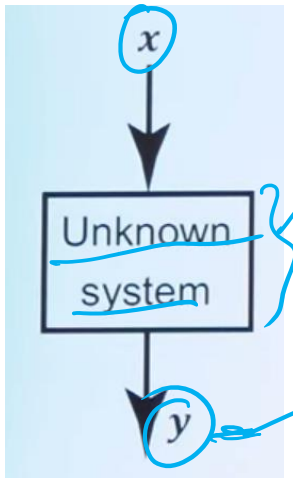
- **Artificial Intelligence & Satellites:**
- In addition to simply taking photographs, the military's newest investigation satellites use AI to **analyze and sort** captured images. Once this process has gone through the satellite's system, the sorted images are transmitted to ground stations on Earth. Here, machine learning allows the stations to compare the new images to a excess of others in the station's database. The compiled images in the database act as a control group, and differences found in the new images (such as a new structure being built or a plane following an unusual fight pattern) are brought to the attention of decision makers. → "attention based signal transmitter at satellite end"
- At the same time, new technology like the European Space Agency's **PhiSat artificial intelligence chip** allows satellites to quickly filter through images and discard the ones that aren't useful.

AI-Powered Rover “Pragyan”– Chandrayaan-2

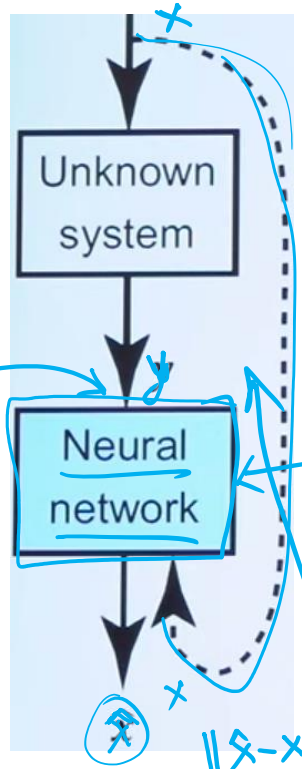
- Pragyan is an AI-powered rover that is part of Chandrayaan-2, India’s second moon mission. It will explore the lunar surface and search for water, minerals, and other resources.
- The rover has been designed to traverse the lunar surface and perform various scientific experiments. An AI system enables it to navigate autonomously and identify, analyze, and respond to its environment in real-time.

Sourse: https://www.springboard.com/blog/data-science/ai-space-exploration/#:~:text=AI%20algorithms%20were%20also%20used,virtual%20simulations%20for%20training%20astronauts.

DL based unknown system inversion



We've to invert this system



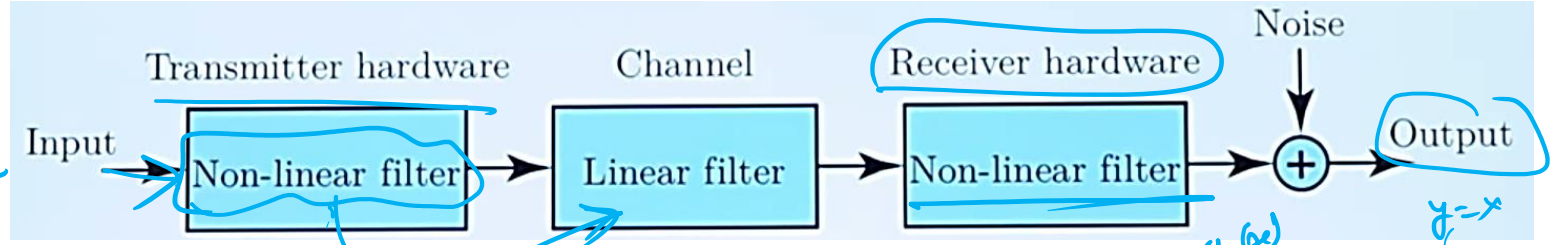
Backpropagated.

$\|\hat{x}-x\|_2$

We generate signals:
Easy to get a training set

Benefits
No need to approximate the system or invert an approximation
Capture real characteristics!

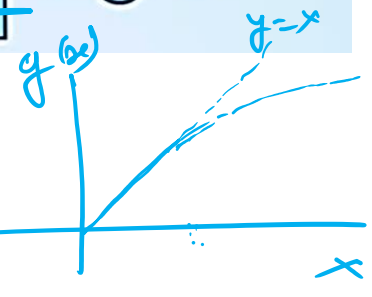
Drawback
Function might be time-varying
Approximation errors, outliers



Non-linear amplifier:

3rd order amp.

$$g(x) = x - \alpha x|x|^2$$

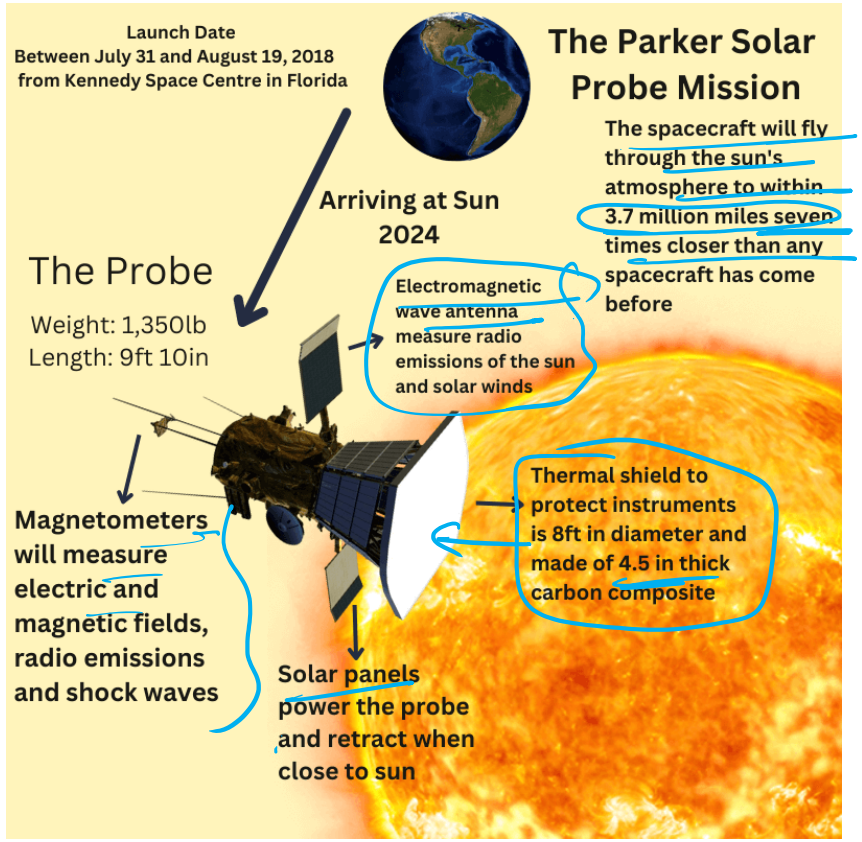


Future AI Satellite

- NASA's Parker Solar Probe mission is scheduled to arrive at the Sun's outer atmosphere in December 2024.

- The probe will be within 4 million miles of the Sun's surface and can tolerate temperatures as high as 2500°F (or 1370°C). It is equipped with a magnetometer and an imaging spectrometer that will help us understand how the Sun interacts with other planets in our solar system, thus allowing us to comprehend solar storms, which often interfere with communication technology on earth.

- AI is expected to improve our ability to monitor Earth-orbiting observation satellites and spacecraft on long-distance voyages.



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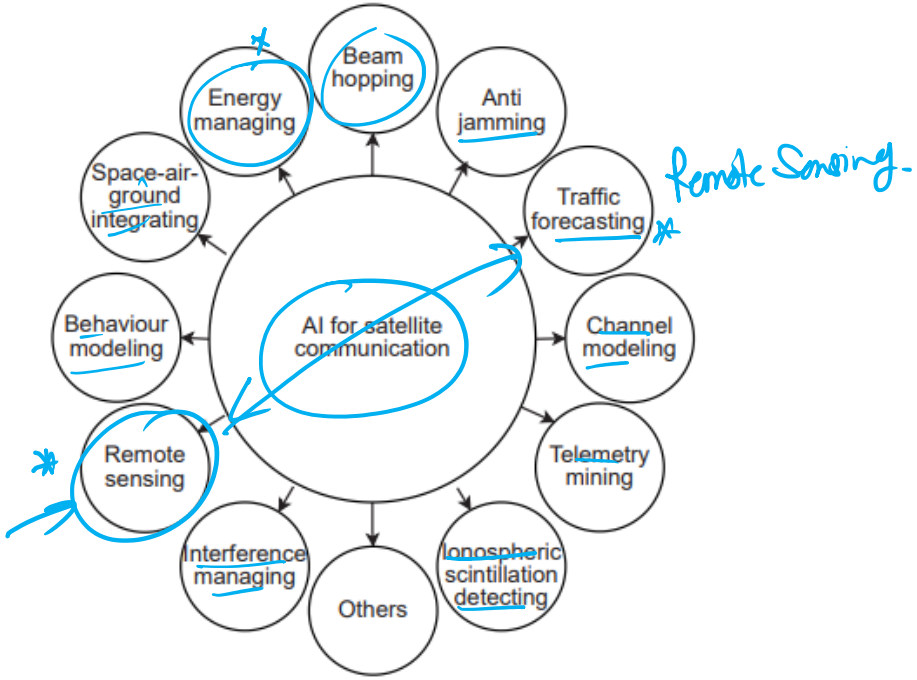
Applications of Satellite Communication:

- Satellite communication plays a vital role in our daily life. Following are the applications of satellite communication.
  - Radio broadcasting and voice communications
  - TV broadcasting such as Direct To Home (DTH)
  - Internet applications such as providing Internet connection for data transfer, GPS applications, Internet surfing, etc.
  - Military applications and navigations
  - Remote sensing applications
  - Weather condition monitoring & Forecasting



Thank you

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