Signal Processing for Distributed Autonomous Systems

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Signal processing for Distributed Autonomous Systems

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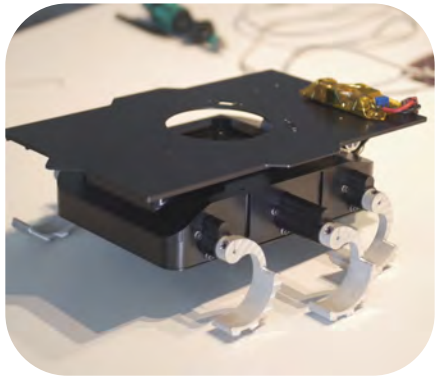
- EE4C11: Systems Engineering (Q1, MS)
- ET4386: Estimation and Detection theory (Q2, MS)

- Sensor fusion
- Distributed optimization

1 PostDoc
4 PhD
8 MS

TUD: Lunar Zebro (2022-)
Smallest and lightest Moon rover



NWO-NSO: PIPP-OLFAR (2018-)
Technologies for interferometry

EU-ECSEL: ADACORSA (2020-)
Autonomous Drone Navigation

TUD: CRANES (2021-)
Cooperative relative navigation

TUD: Sensor AI Lab (2022-)
Distributed AI for sensor networks

Technology Readiness Levels (TRLs)

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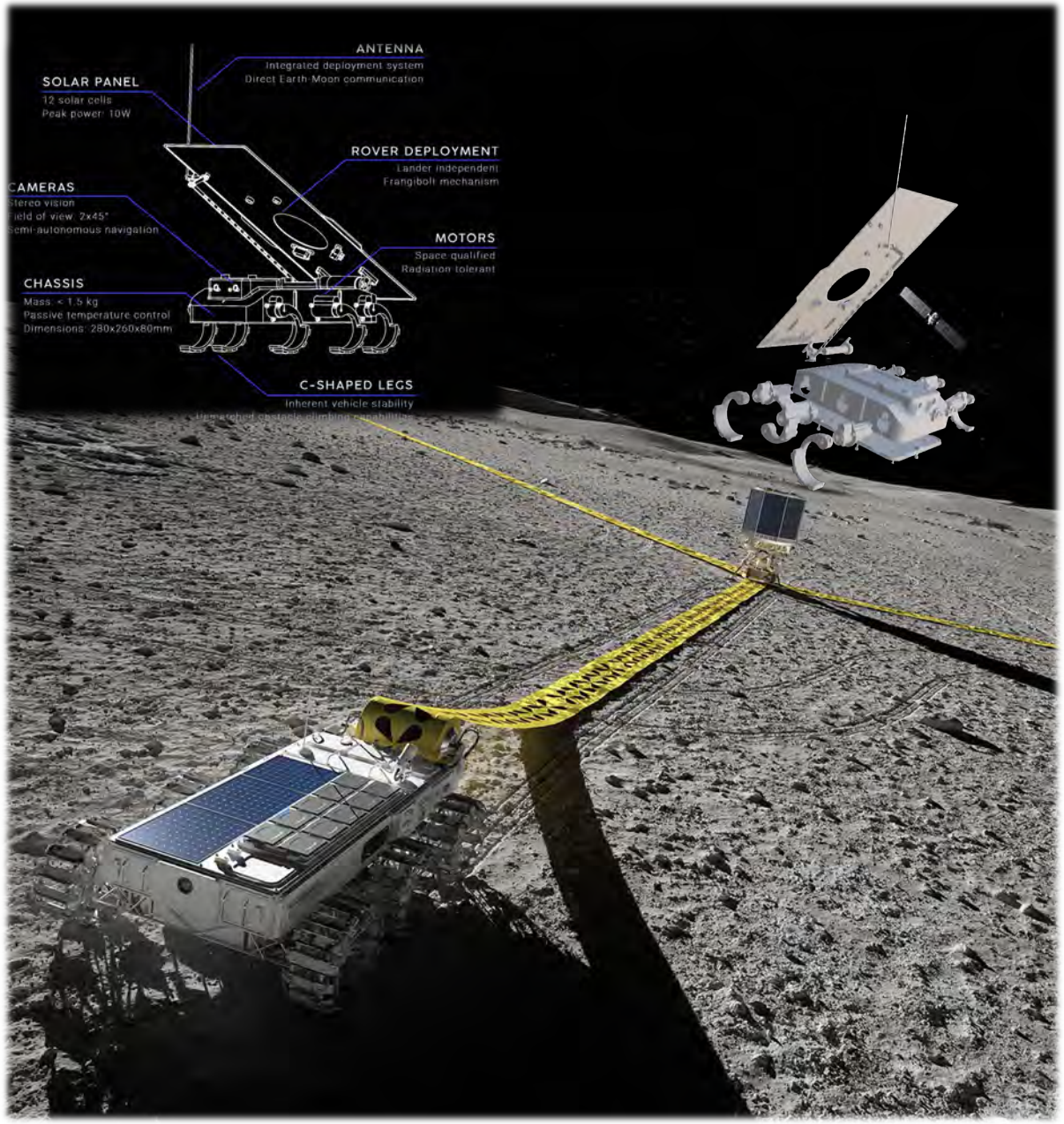
Lunar Zebro (LZ)

World's smallest interplanetary rover built by TUD students

- Aims to cover as much Lunar surface for as long as possible
- Science mission e.g., deploy antennas for radio astronomy

Lunar Zebro Team at the IAC 2022 conference



https://zebro.space/

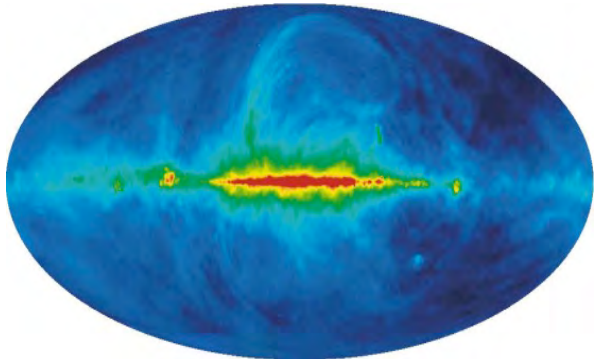
https://spectrum.ieee.org/rovers-will-unroll-a-telescope-on-the-moons-far-side

Burns, Jack, et al. "A Lunar Farside Low Radio Frequency Array for Dark Ages 21-cm Cosmology." (2021)

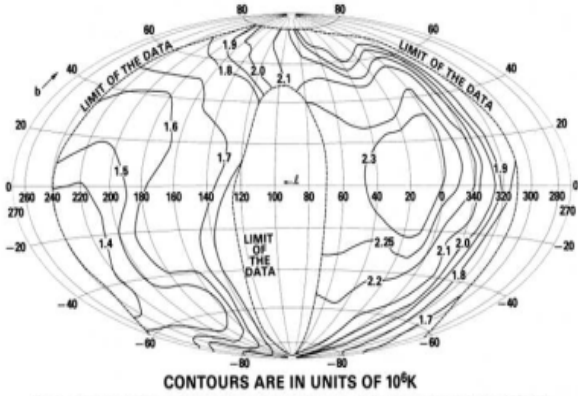
Space-based Interferometry

OLFAR: A satellite swarm for space-based interferometry

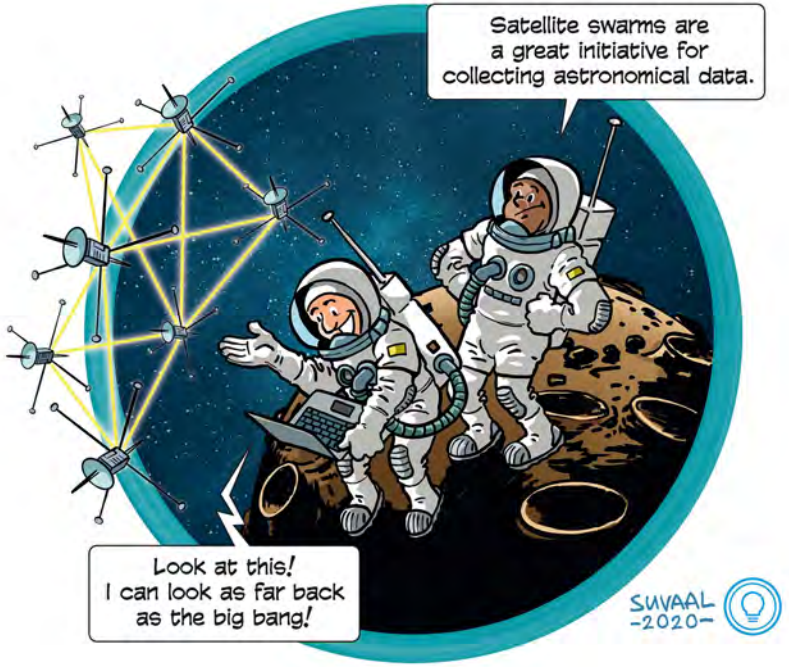
- Ground-based interferometry limited <30Mhz
- Deploy a satellite swarm on the far side of the Moon

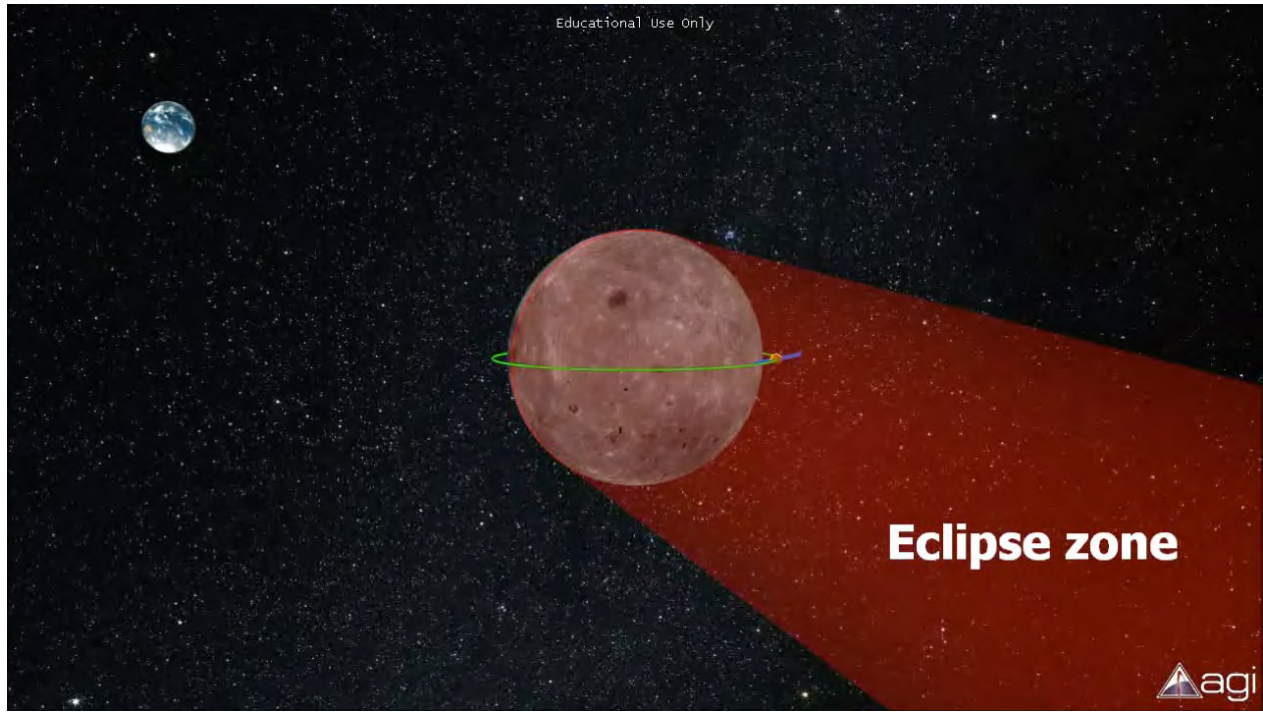


408MHz map made by Jordellbank + Parks + Effeslberg (Haslam et al 1982)



4.7 MHz map by Lunar orbiter Radio Astronomy Explorer 2 (RAE-2) (Novaco 1978)



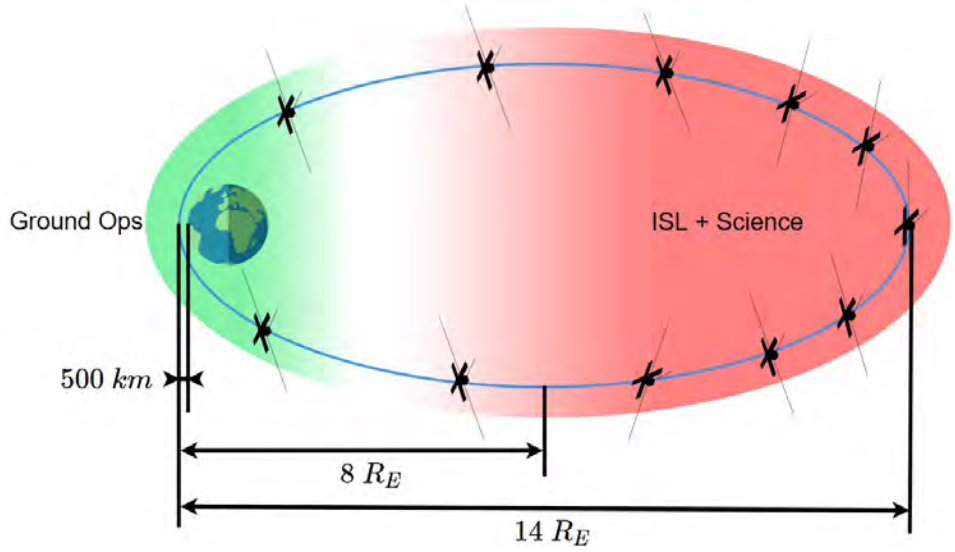


Bentum, M. J., et al. (2020) "A roadmap towards a space-based radio telescope for ultra-low frequency radio astronomy."
Rajan et.al., (2016) "Space-based Aperture Array For Ultra-Long Wavelength Radio Astronomy"

Space-based tomography

Monitor Earth's magnetosphere using satellite swarms

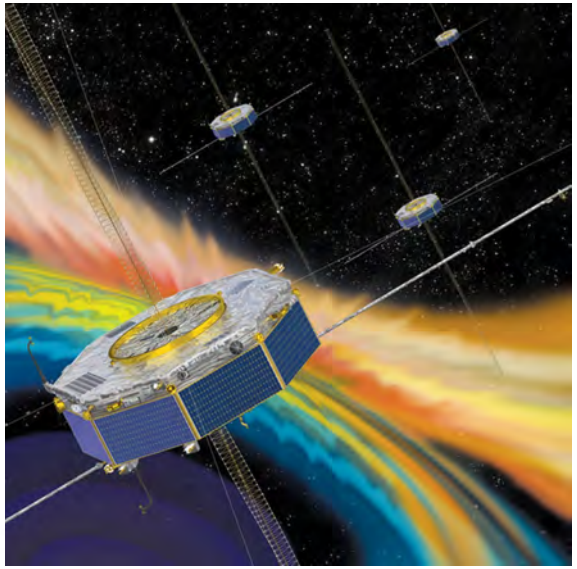
- NASA-MMS mission launched in 2015, with 4 satellites
- Current studies estimate the need for 20-60 satellites

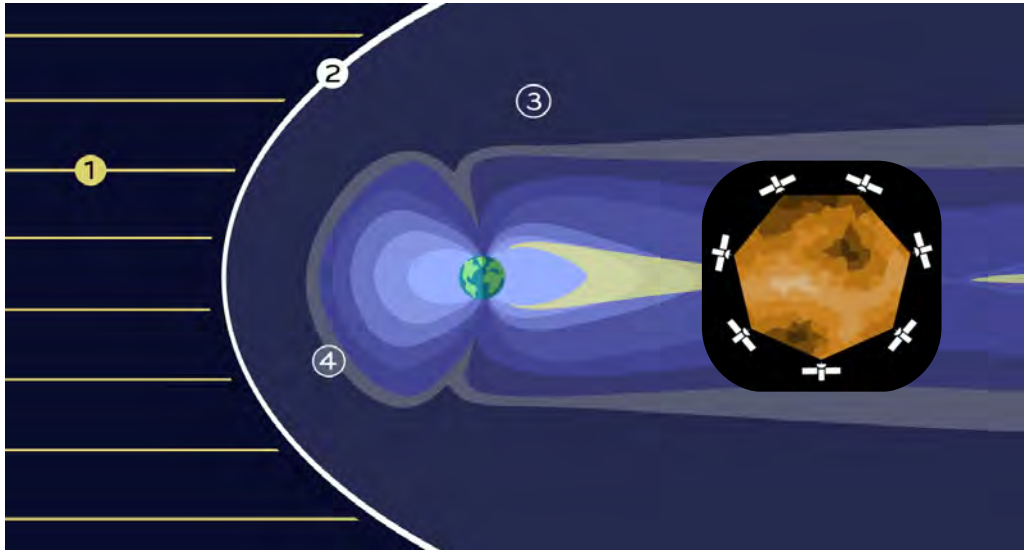


4 NASA Satellites to Launch on Magnetic Field Mission This Thursday

By Calla Cofield published March 10, 2015

The four MMS satellites were stacked and packed inside an Atlas V rocket fairing in a clean room at the Astrotech Space Operations facility in Titusville, Florida. MMS is set to launch into space at 10:44 ET on Thursday night (March 12). Image released Feb. 19, 2015. (Image credit: NASA/Ben Smegelsky)





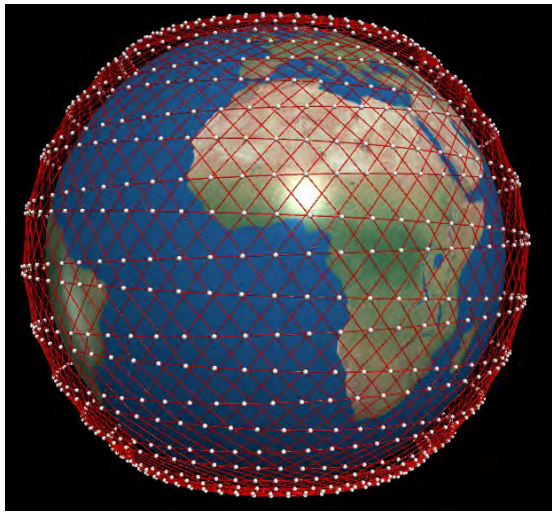
https://mms.gsfc.nasa.gov/

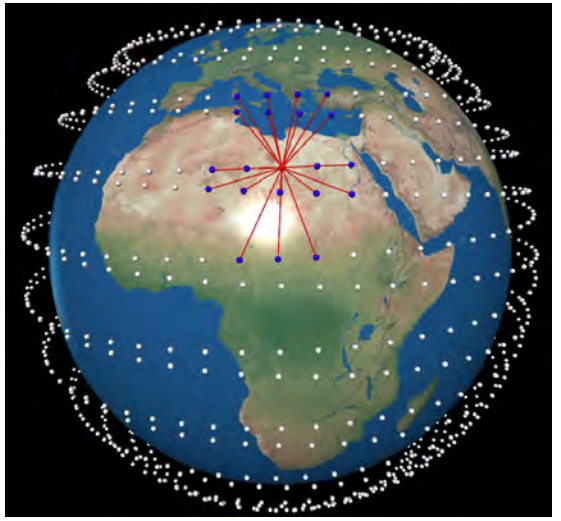
Rajan et.al., (2021) "Applications and Potentials of Intelligent Swarms for magnetospheric studies"

Starlink network

A satellite network to provide low-latency broadband internet

- Phase 1: 1584 satellites, 72 orbits, 550km altitude
- Currently relies on ground segments for positioning





SPACE

SpaceX launches first bunch of satellites for its Starlink mega-constellation

By Nick Lavars
May 24, 2019

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Falcon 9 on the launchpad ahead of the Starlink mission SpaceX

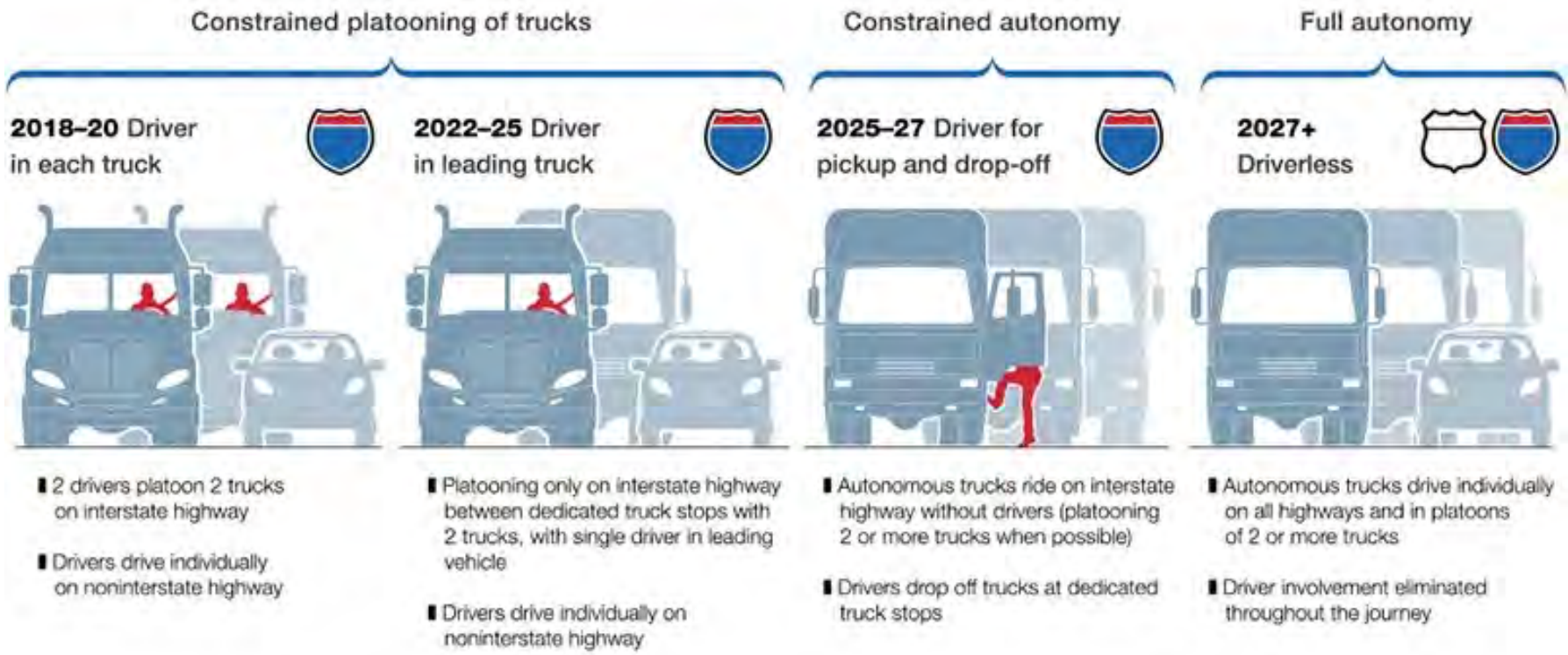
Sixty Starlink satellites packed into the nosecone of the Falcon 9 rocket SpaceX

C.Turner and R.T.Rajan “Performance Bounds for Cooperative Localisation in the Starlink Network” , In submission
https://newatlas.com/starlink-starlink-launch-mega-constellation/59838/

Autonomus truck platooning

Trucks coordinate their routes to conserve upto 20% fuel efficiency

How can we coordinate their paths ?



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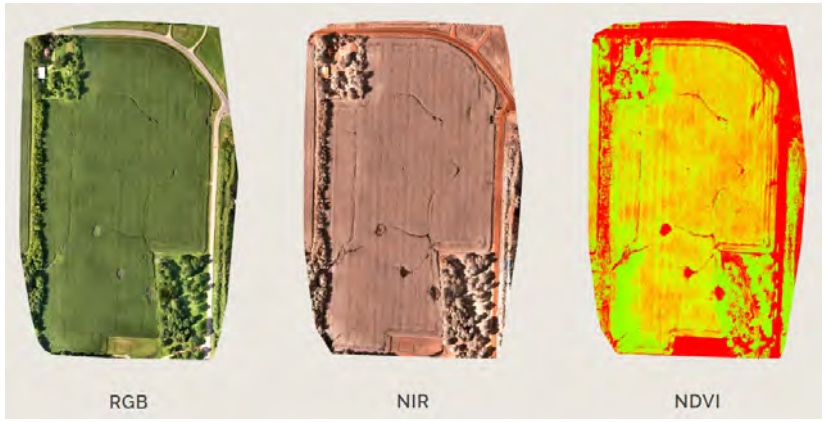
Zeng, Y., Wang, M., & Rajan, R. T. (2022). Decentralized coordination for truck platooning

Graphic: McKinsey & Co

Autonomous Drones

On-board sensor fusion and Robust navigation

Agriculture: Sentera - Phanton 4



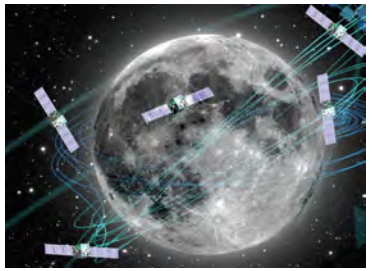
Logistics: Amazon Prime Air

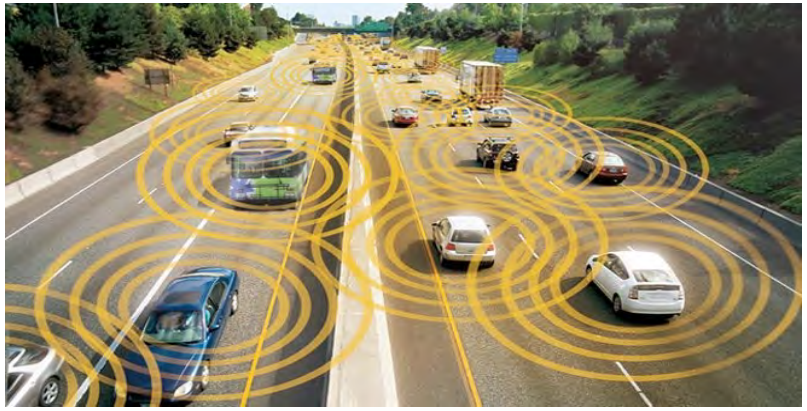
Surveillance: Airbus 'Hangar' Drone

Mohammadkarimi, M., Leus, G., & Rajan, R.T. (2022). Joint Ranging and Phase Offset Estimation for Multiple Drones using ADS-B Signatures.
* P.Zhai , R.T.Rajan (2022) " Distributed Gaussian Process for Multi-agent Systems
Graphic: https://www.statista.com/chart/17201/commecial-drones-projected-growth/

Distributed Autonomous Sensing Systems

- Networked Cyberphysical systems of hetrogeneous agents
- AI for multi-agent systems → Two key behaviors
  - Autonomous behavior → Sensor fusion
  - Cooperative behavior → Distributed optimization
- **Inaccessible/Intermittentenly accessible multi-agent systems**
  - Less dependence on external references or infrastructure
  - Need for physics-inspired inference and behavior
- **Signal processing challenges of multi-agent systems**
  - *Calibration*: Targetless camera calibration
  - *Timing:* Can we synchronize clocks without a reference ?
  - *Localization:* Is GPS-free/denied localization possible ?
  - *Control:* Can we coordinate a multi-agent anchorless network cooperatively ?
  - *Learning:* How to learn an unknown field in an unknown environment ?





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