COMMS and Data Links

Robótica Aérea

Xin Chen/Manuel Barriopedro

Elements of UAS

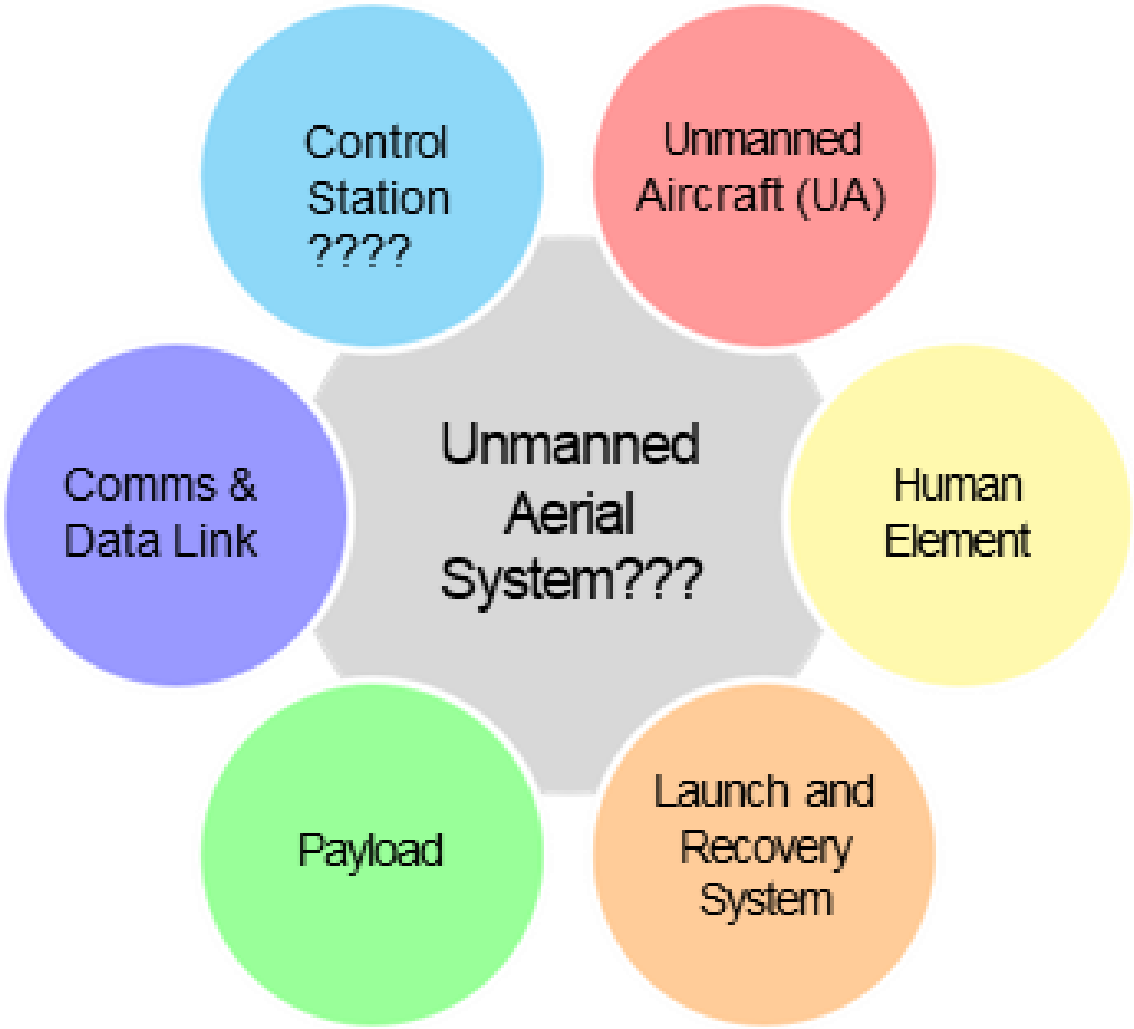
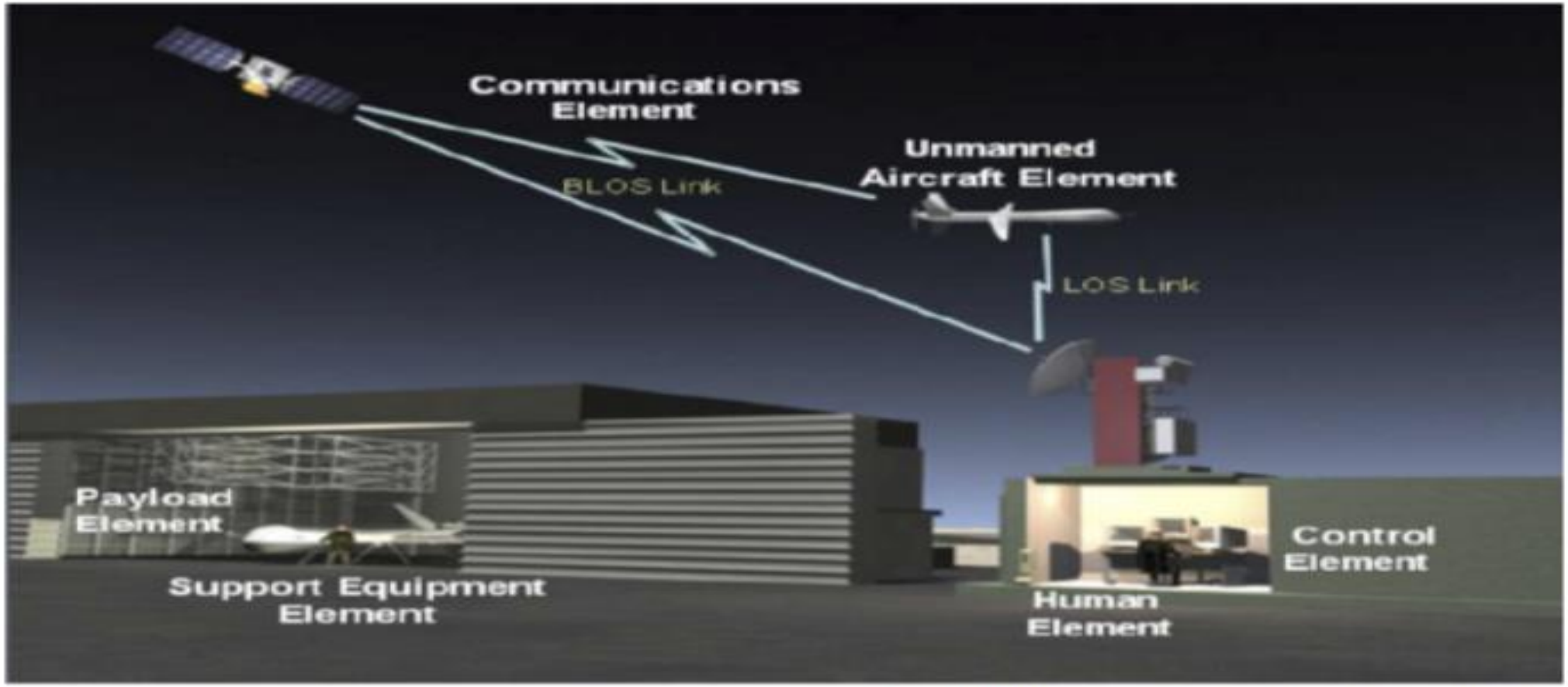


Figure: Elementos de UAS [Barnhart et al., 2012].

Why Data Links?

Data Links – Operational needs

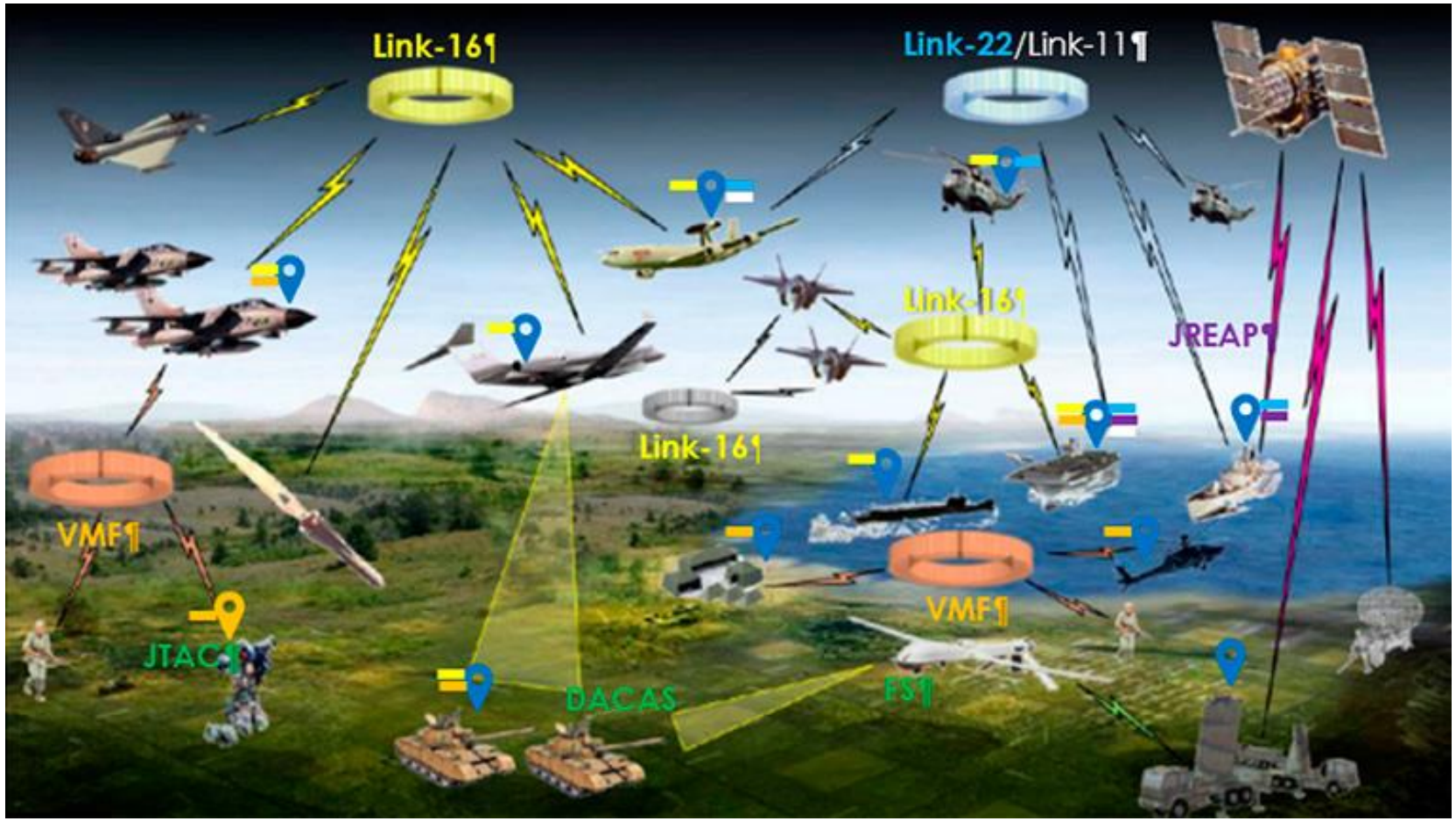
- Neither Pilot nor Payload Operators are onboard



Elementos UAS. Fuente JUAS COE CONOPS, Joint concept of Operation for UAS, capítulo 2 versión 1.5.

Data Links – Operational needs

- Data dissemination

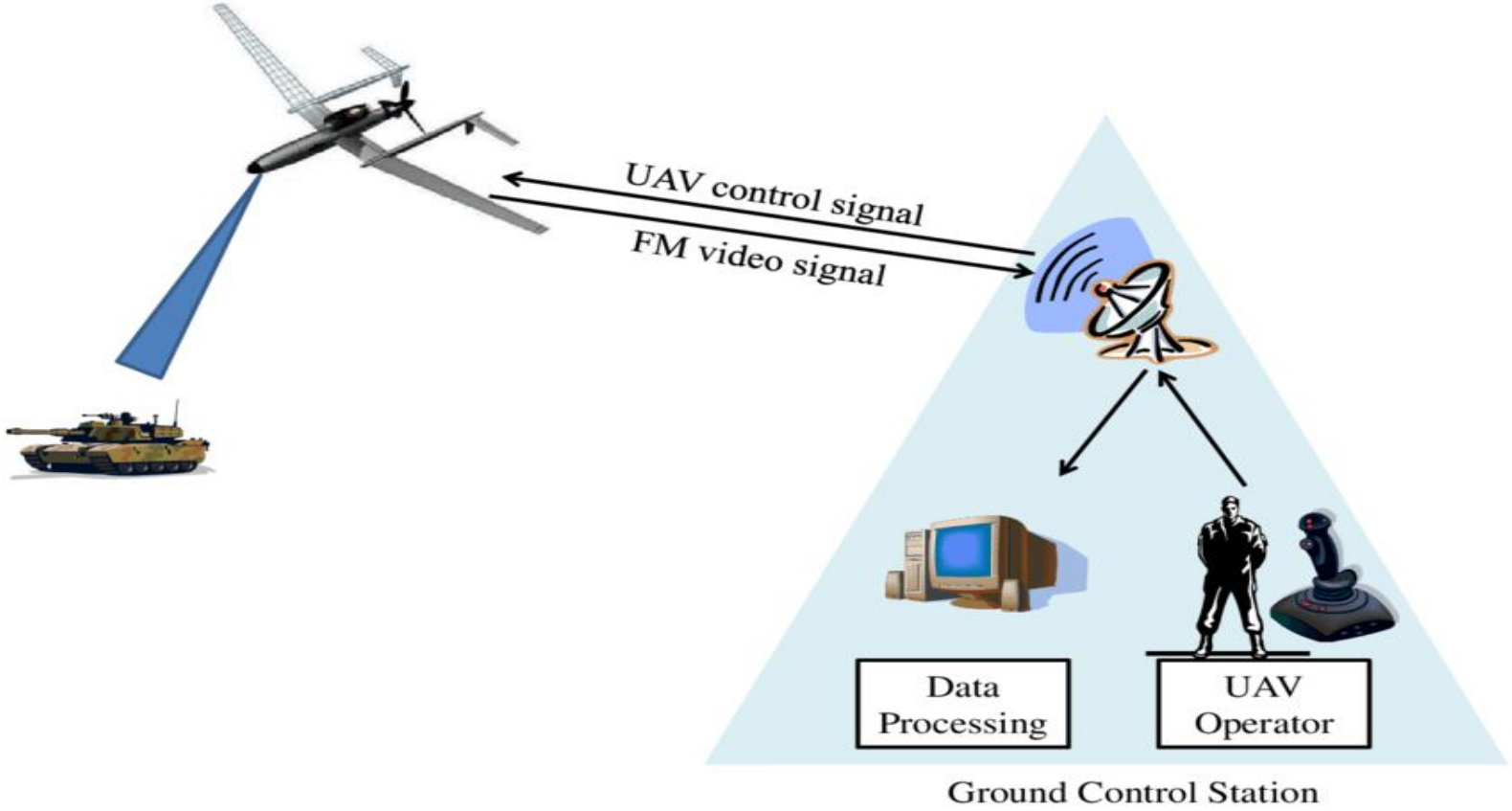


Source: Grupo Oesia
https://grupooesia.com/tactical-data-links/

Types of Communication

Data Links – Types of communication

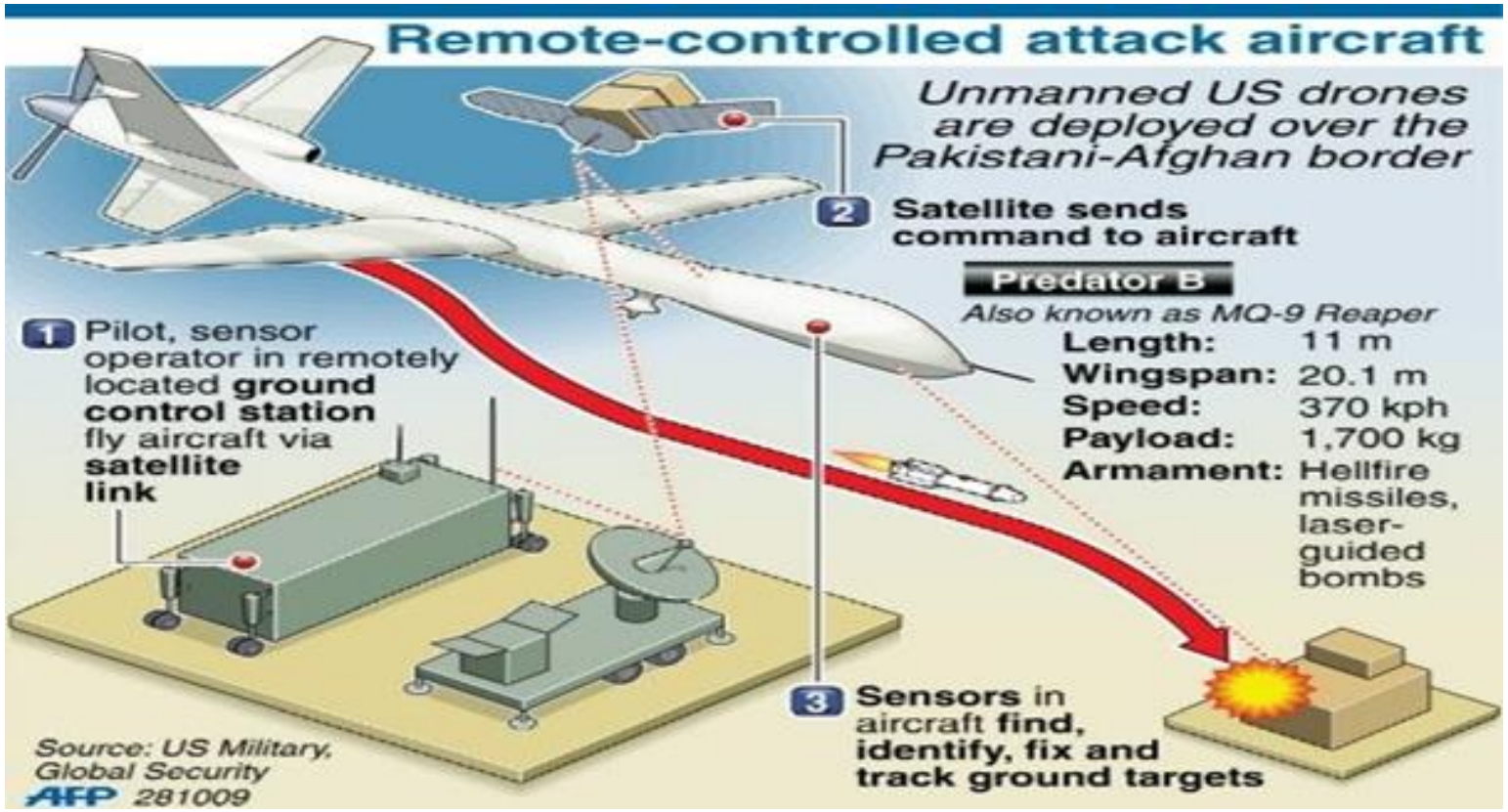
- LOS



Source: Unmanned aircraft systems in the cyber domain. https://kstatelibraries.pressbooks.pub/unmannedaircraftsystems/

Data Links – Types of communication

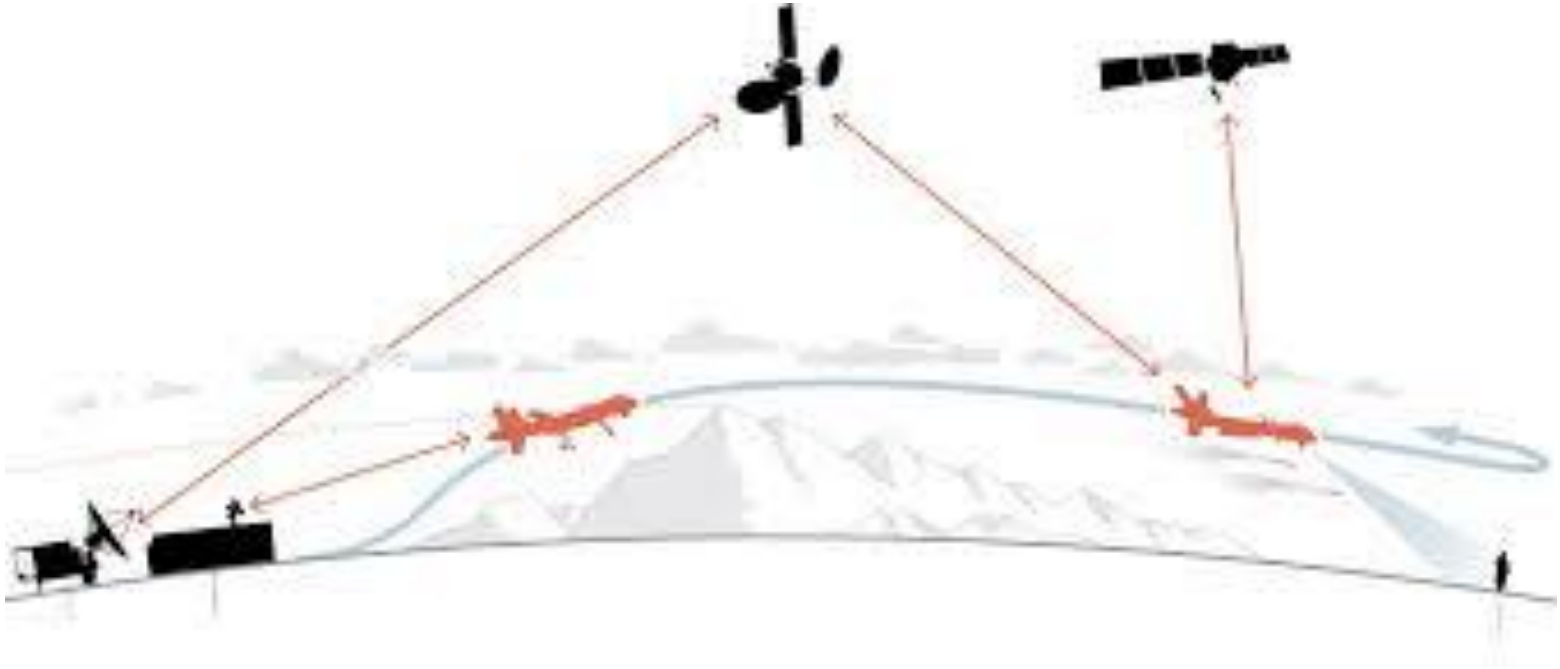
- BLOS



Source: Unmanned aircraft systems in the cyber domain. https://kstatelibraries.pressbooks.pub/unmannedaircraftsystems/

Data Links – Types of communication

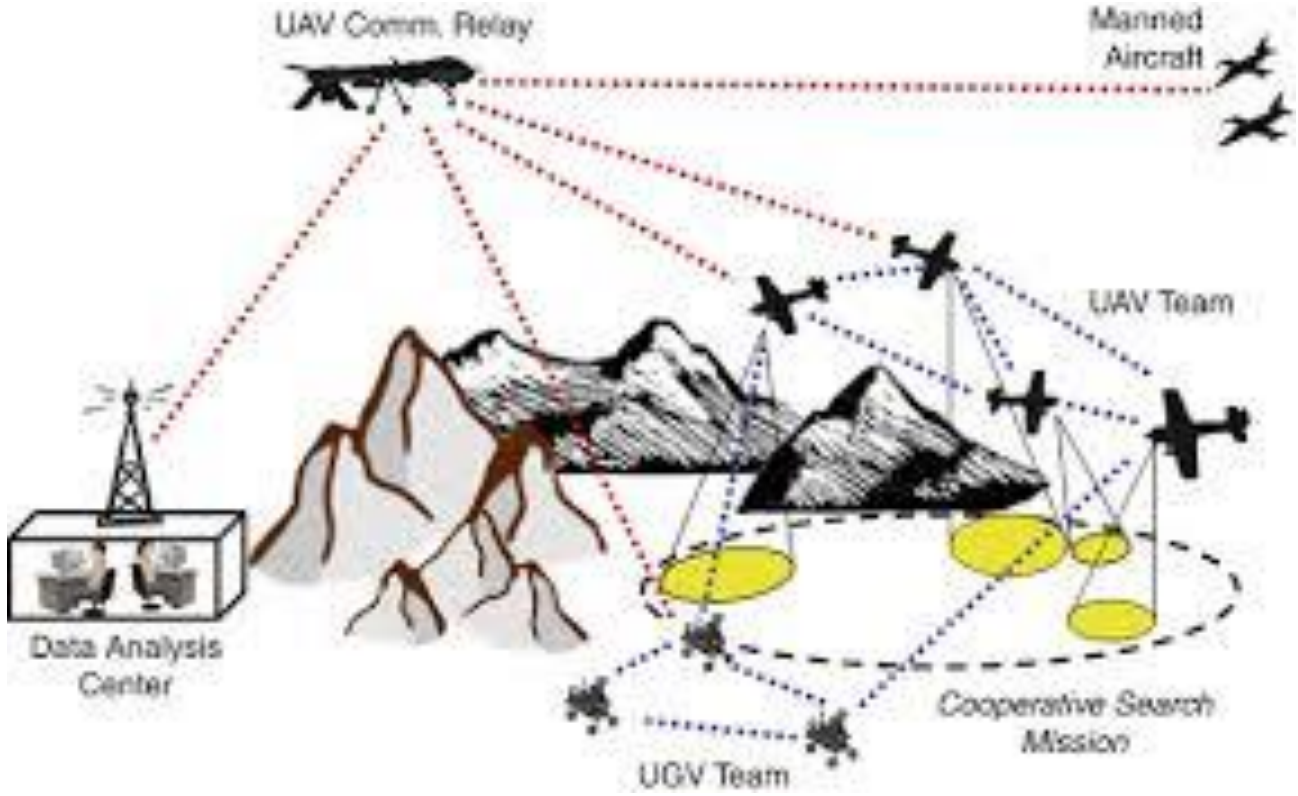
- LOS and BLOS



Source: Unmanned aircraft systems in the cyber domain.
https://kstatelibraries.pressbooks.pub/unmannedaircraftsystems/

Data Links – Types of communication

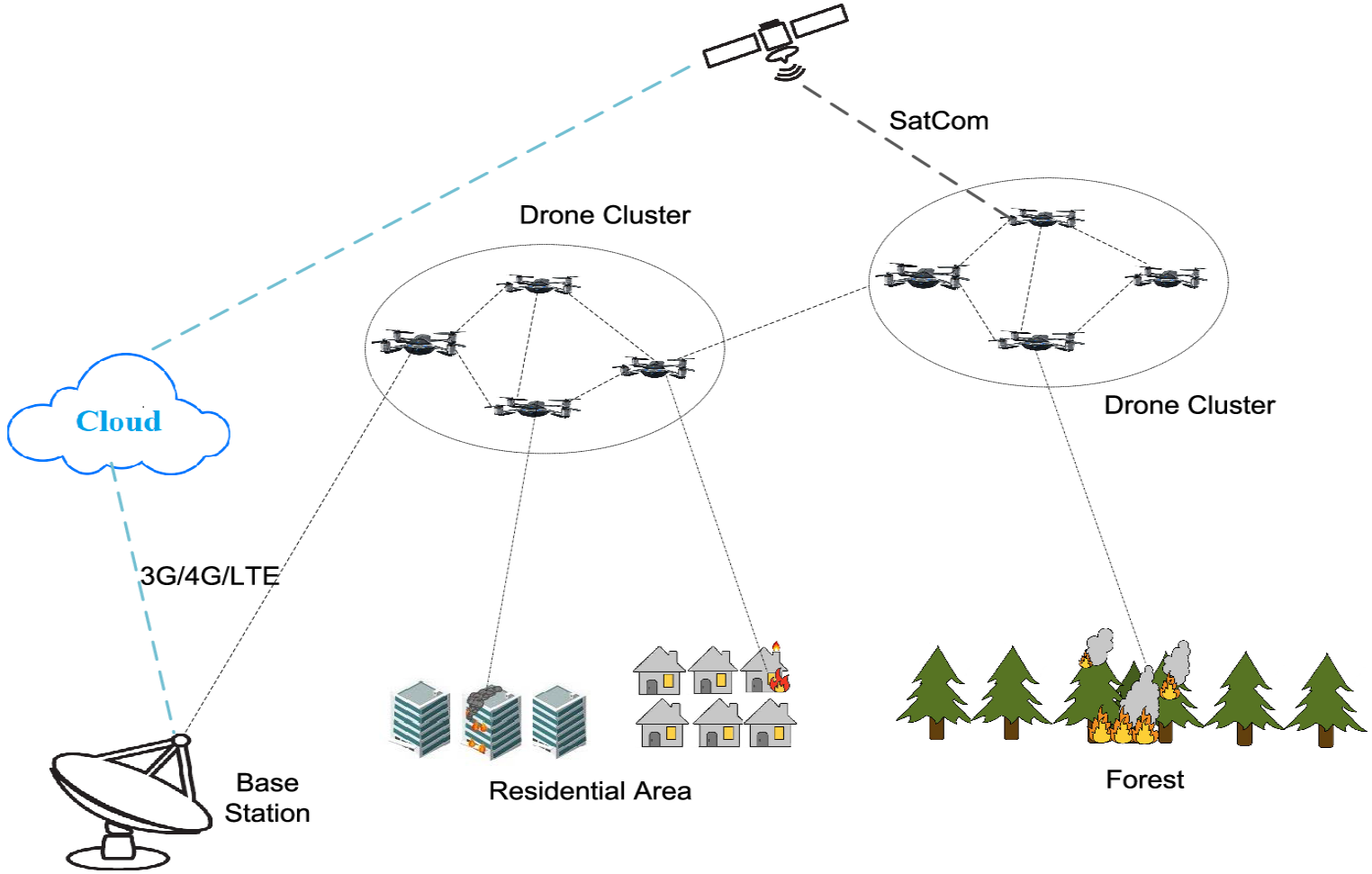
- BLOS with LOS means?



Source: Control of communication networks for Teams of UAV
https://link.springer.com/referenceworkentry/10.1007%2F978-90-481-9707-1_19

Data Links – Types of communication

- Civil operation – 3G/4G/5G/LTE: Utilización red telefonía: Future!!! – U-Space



Data Links – Types of communication

- Interoperability

Design Requirements

Data Links – Design Requirements

- Frequency
- Data Rate
- Range
- Interoperability
- Security
- Certification

Data Links

Frequency

Data Links – Frequency

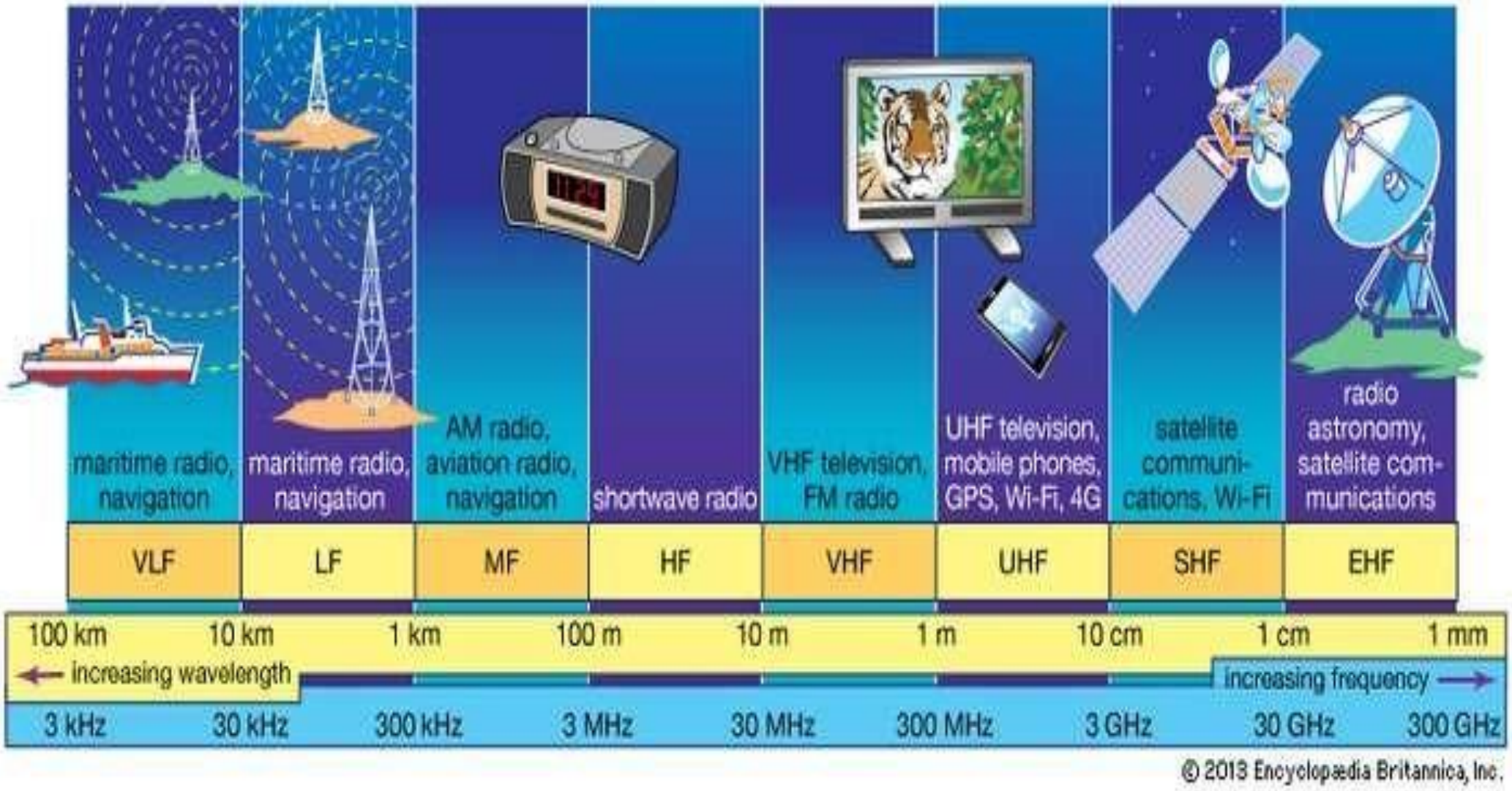
- What is Radio Frequency?
  - Electronic Magnetic Radiation (EMR) being used to transfer energy and information by radiowaves
  - A radio frequency (RF) signal refers to a wireless electromagnetic signal used as a form of communication

- How many RF are there?
  - As a matter of convention, the ITU divides the radio spectrum into 12 bands, each beginning at a wavelength which is a power of ten (10n) metres, with corresponding frequency of 3×108−n hertz, and each covering a decade of frequency or wavelength. Each of these bands has a traditional name.

Data Links – Standard Radio Spectrum Segments

TABLE 1: STANDARD DEFINITIONS OF RADIO SPECTRUM SEGMENTS		
Name	**Frequency range**	**Applications**
Low frequency (LF)	30 to 300 kHz	Navigation, time standards
Medium frequency (MF)	300 kHz to 3 MHz	Marine/aircraft navigation, AM broadcast
High frequency (HF)	3 to 30 MHz	AM broadcasting, mobile radio, amateur radio, shortwave broadcasting.
Very high frequency (VHF)	30 to 300 MHz	Land mobile, FM/TV broadcast, amateur radio
Ultra high frequency (UHF)	300 MHz to 3 GHz	Cellular phones, mobile radio, wireless LAN, PAN
Super high frequency (SHF), millimeter-wave range	3 to 30 GHz	Satellite, radar, backhaul, TV, WLAN, 5G cellular
Extremely high frequency (EHF)	30 to 300 GHz	Satellite, radar, backhaul, experimental, 5G cellular
Terahertz , tremendously high fequency (THF) or far infrared (FIR)	300 GHz to IR	R & D, experimental

Data Links – Frequency



Data Links – RF Band Designations

TABLE 2: MICROWAVE LETTER BAND DESIGNATIONS		
Band	**Frequency range**	**Applications**
L	1 to 2 GHz	Satellite, navigation (GPS, etc.), cellular phones
S	2 to 4 GHz	Satellite, SiriusXM radio, unlicensed (Wi-Fi, Bluetooth, etc.), cellular phones
C	4 to 8 GHz	Satellite, microwave relay, Wi-Fi, DSRC
X	8 to 12 GHz	Radar
K_u	12 to 18 GHz	Satellite TV, police radar
K	18 to 26.5 GHz	Microwave backhaul
K_a	26.5 to 40 GHz	Microwave backhaul, 5G cellular
Q	30 to 50 GHz	Microwave backhaul, 5G cellular
U	40 to 60 GHz	Experimental, radar
V	50 to 75 GHz	New WLAN, 802.11ad/WiGig
E	60 to 90 GHz	Microwave backhaul
W	75 to 110 GHz	Automotive radar
F	90 to 140 GHz	Experimental, radar
D	110 to 170 GHz	Experimental, radar

Data Links – RF Use

- What will you use normally for C2 and which for Payload Control?

- C2
  - Band C & L for LOS (low frequency, less impacted by weather!!! And no posible VHF/UHF, as they are too crowded)
  - Band Ku & Ka for BLOS

- Payload Control
  - Band C & Ku for C2
  - Band Ku & Ka for BLOS

Note: only C2 frequency regulated

Data Links

Data Rate

Data Links – Bandwith/Data Rate

- Narrow Band:
  - Signal bandwith less than the channel coherent bandwith (similar behaviour in a bandwith)
  - Low data rate transmission
  - Signals that are 100kHz or smaller in bandwith
  - Channel enough narrow to have a flat frequency response (smaller, so it behaves uniformously)
  - More robust, due to less possibility of overlapping with an interering signal
  - Easy channel to channel isolation
  - Lower transmit signal power is required
- Wide Band:
  - Signal bandwith exceeds the channel coherent bandwith
  - Channel enough wide to not have a flat frequency response (bigger, so it does not behave uniformously)
  - Signals that are 100kHz or smaller in bandwith
  - Less robust, due to more possibility of overlapping with an interering signal
  - Difficult channel to channel isolation
  - Higher transmit signal power is required

(*) Note:100Mbpps bandwith but 50Mbpps datarate

Data Links – Band/Data Rate

Which one for C2 and
which one for Payload Control?

Data Links

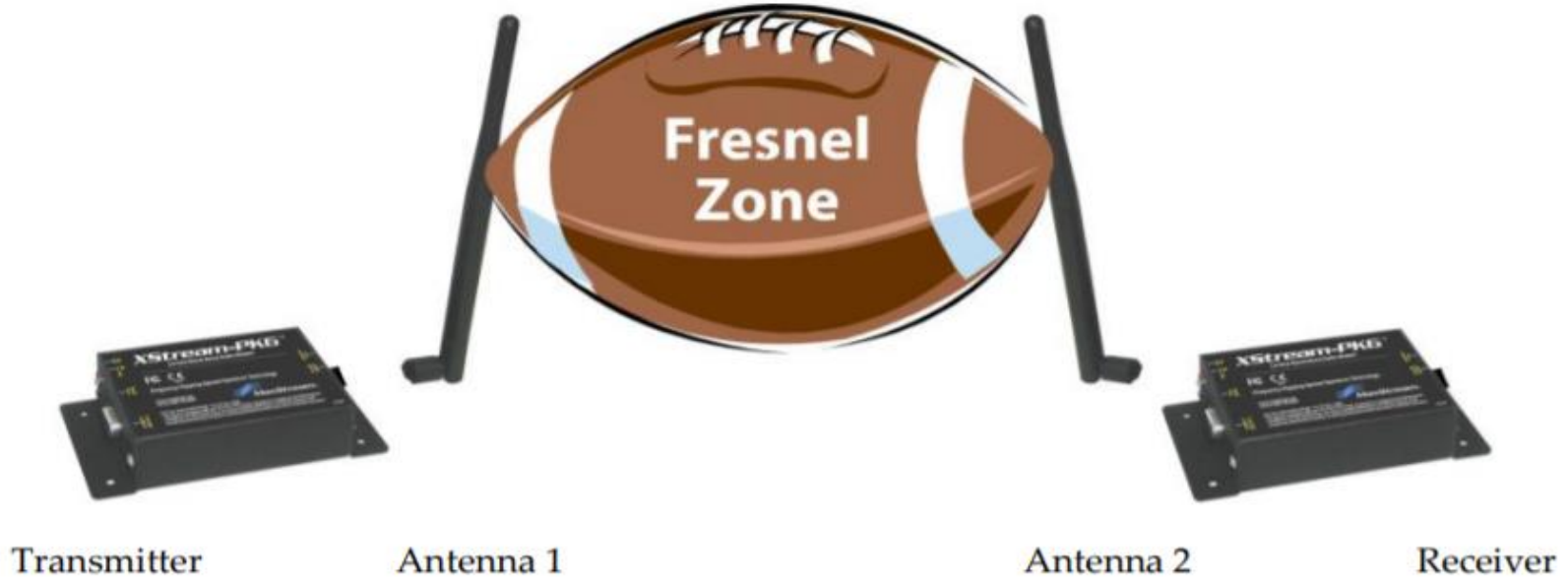
Range

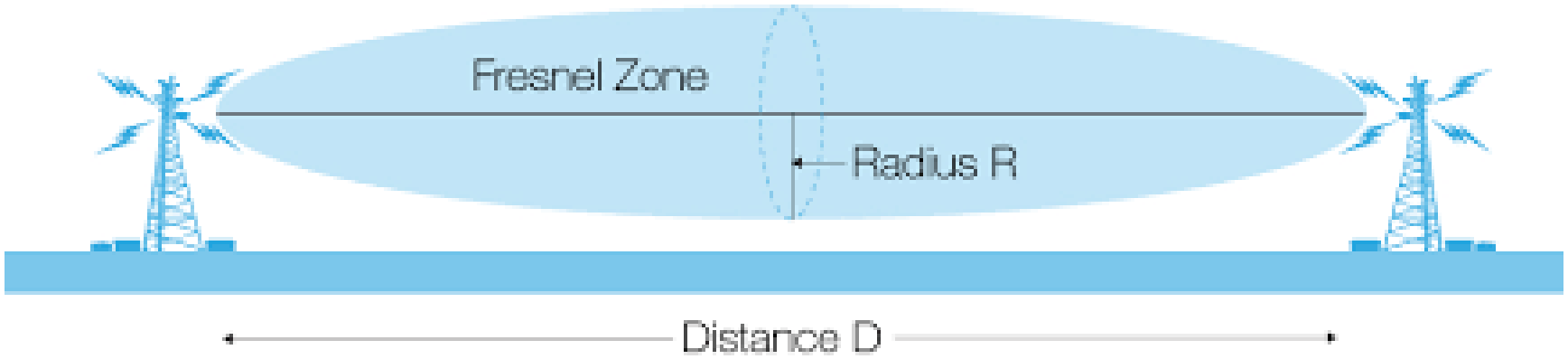
Data Links – Range

- LOS:
  - Line-of-sight transmission means the transmitting and receiving antenna can "see" each other as shown. The maximum distance at which they can see each other, dLOS, occurs when the sighting line just grazes the earth's surface

  - Attaining RF Line-of-Sight (LOS) between the sending and receiving antennas is essential in achieving long range in wireless communication systems. There are two types of LOS that are generally used to describe an environment:
    - Visual LOS is the ability to see from one site to the other. It requires only a straight linear path between two points.
    - RF LOS requires not only visual LOS, but also a football-shaped path free of obstacles for data to optimally travel from one point to another. This football-shaped path is called Fresnel zone.

Data Links – Range





Data Links – Range

Formula:

$$d_l = \sqrt{2Rh} \approx 3.57 * \sqrt{h}$$

$$d_r = 4.12 * \sqrt{h}$$

h = height of the antenna.
R = radius of the earth.
dl = total line of sight.
dr = radio horizon (actual service range)

Data Links – Range

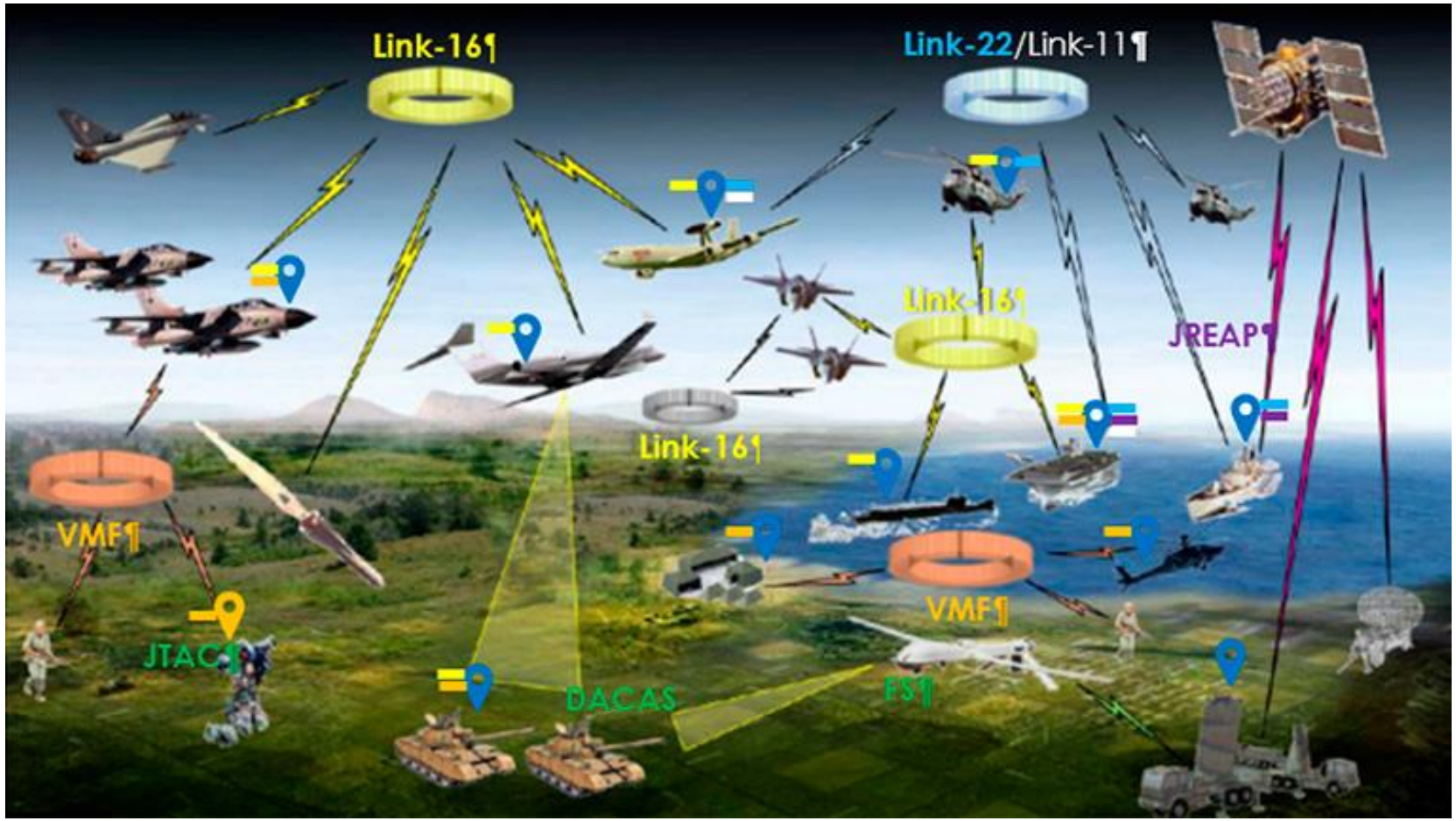
- BLOS:
  - Longer than line of sight
  - Problem of Latency: the greater the distance data must travel, the greater the latency

Data Links

Interoperability

Data Links – Interoperability

- Is it required to “talk” with other assets?



Source: Grupo Oesia
https://grupooesia.com/tactical-data-links/

Data Links

Security

Data Links – Security Threats

- Interception: the longer a source emits radiation, the greater the chance of interception
- Jamming: To drown out the conversation between a drone and its operator by blasting electromagneti noise at the radio frequencies that drone use to opérate.
- Spoofing: is a hack which essentially can alter or delay UAV commands via a malicious GPS signal and accordingly can cause collisions, faulty guidance and theoretically virtual UAV hijacking. This was used by the Iranian military to capture a United States military drone in 2011. Figure 13-7 Enemy Captured RQ-170
- Maldrone: malware is injected into critical áreas of the UAS operation system through security flaws in the Datalink
- Zigbee and Killerbee, which are essentially sniffing and penetration tools which when successful can cause a major threat to UAS by Denial of Service (DoS) Attacks

Data Links – Security Threats

Source: Opall-Rome, B. (February 12, 2018). Israel Air Force says seized Iranian drone is a knockoff of US Sentinel: https://www.defensenews.com/global/mideast-africa/2018/02/12/israel-air-force-says-seized-iranian-drone-is-a-knockoff-of-us-sentinel/

Data Links – Security Protection

- We want LPI (Low Probability of Intercept), but if done, we do not want to be neither interfere nor intervened

  - *Ground Station Handover Method. (GSHM):* Change GCS controlling the Air Vehicle

  - *Direct-sequence spread spectrum (DSSS):* using secure authentication codes. These codes can be a software embed in the ground station transmission to the satellite relay or UAV. Both the UAV and ground station will have encoding and decoding software to authenticate commands without direct modification to the uplink

  - *Frequency-hopping spread spectrum (FHSS):* is a method of transmitting radio signals by rapidly changing (hopping) the carrier frequency among many distinct frequencies occupying a large spectral band

  - *Dynamic power management. (DPM)*

Obviously, we need Communications Management

Data Links

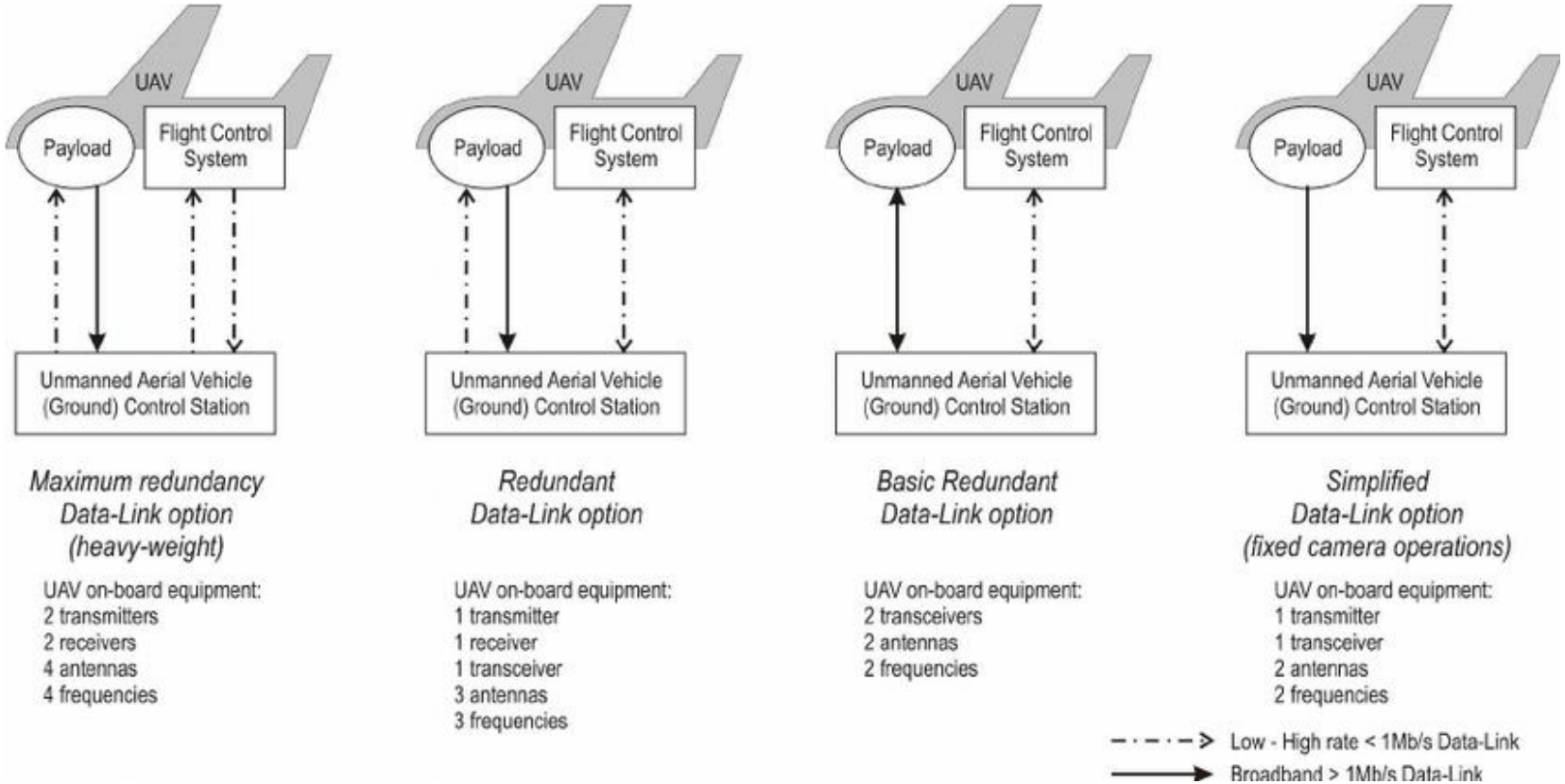
Certification

Data Links – Certification

- Data Link System considered normally as Major regarding Safety Aspects: o single point of failure allowed!!!
    - *Resilient Systems*
    - *Redundancies*
    - *Comms Manager to manage redundancy and back-up*

Data Links – Certification

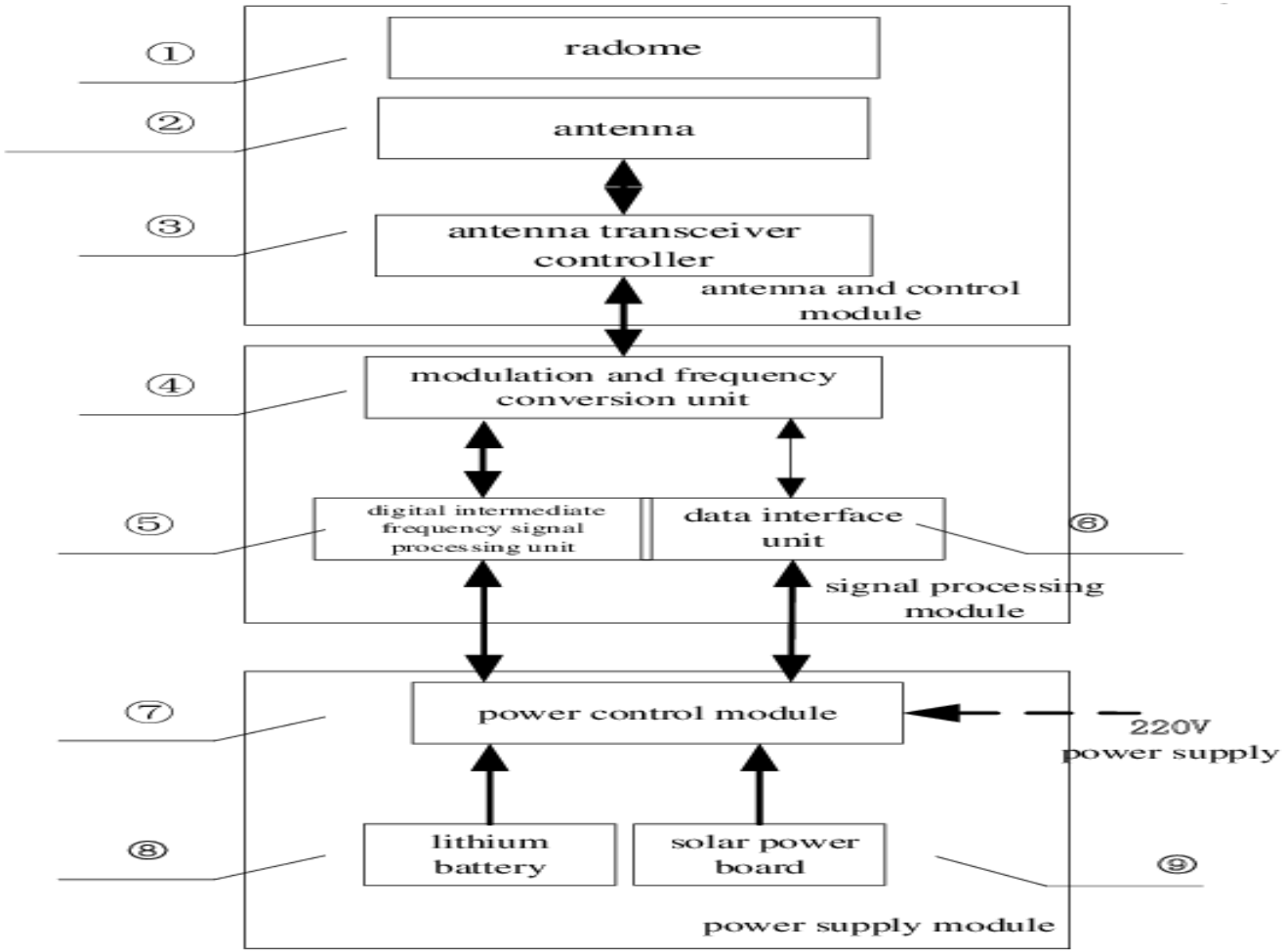
- Data dissemination



https://www.researchgate.net/figure/The-UAV-data-links-organization-options_fig1_244477850

System Elements

Data Links – Data link terminal block diagram

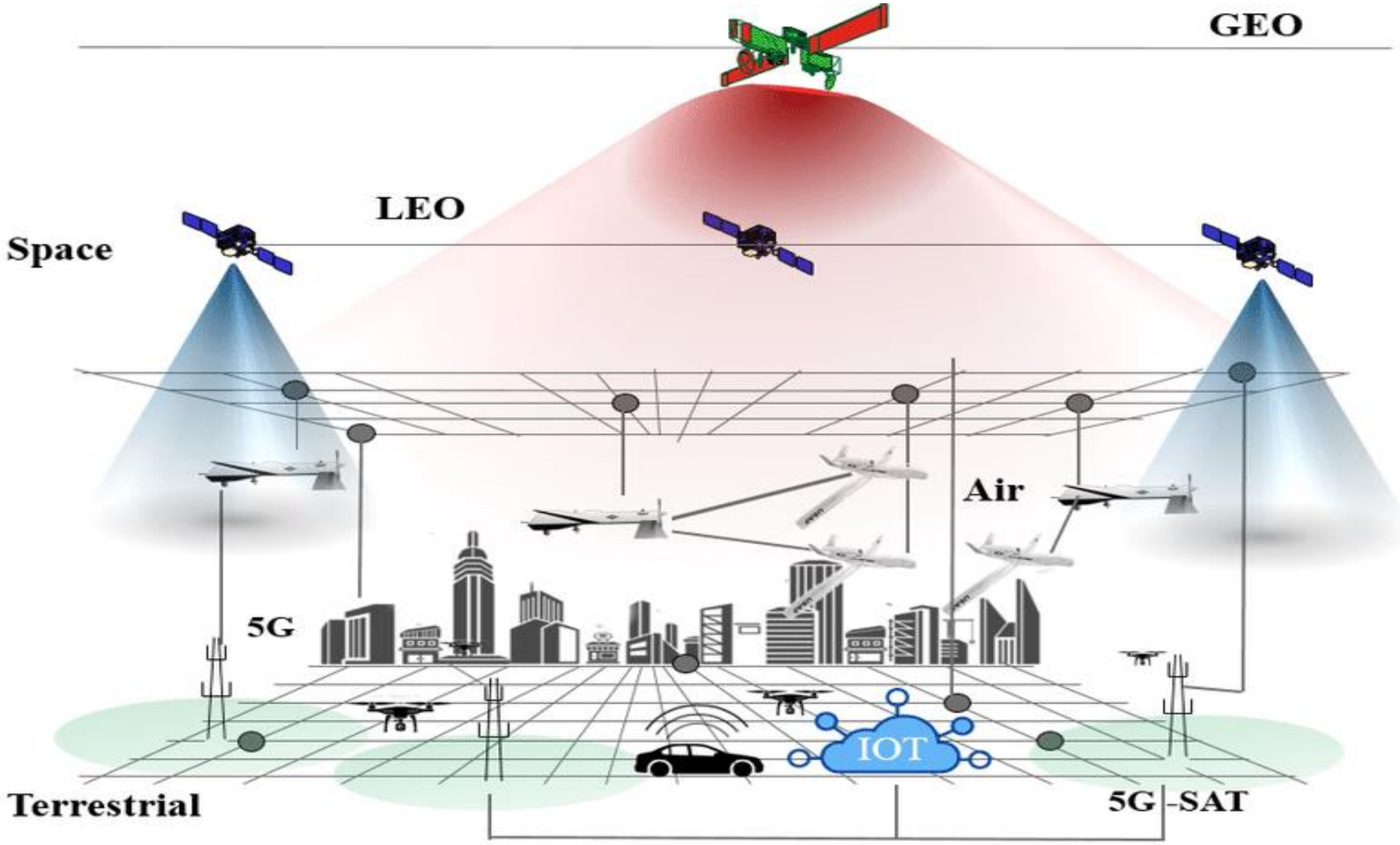


https://www.researchgate.net/figure/UAV-data-link-terminal-function-block-diagram_fig2_340734995

Data Links

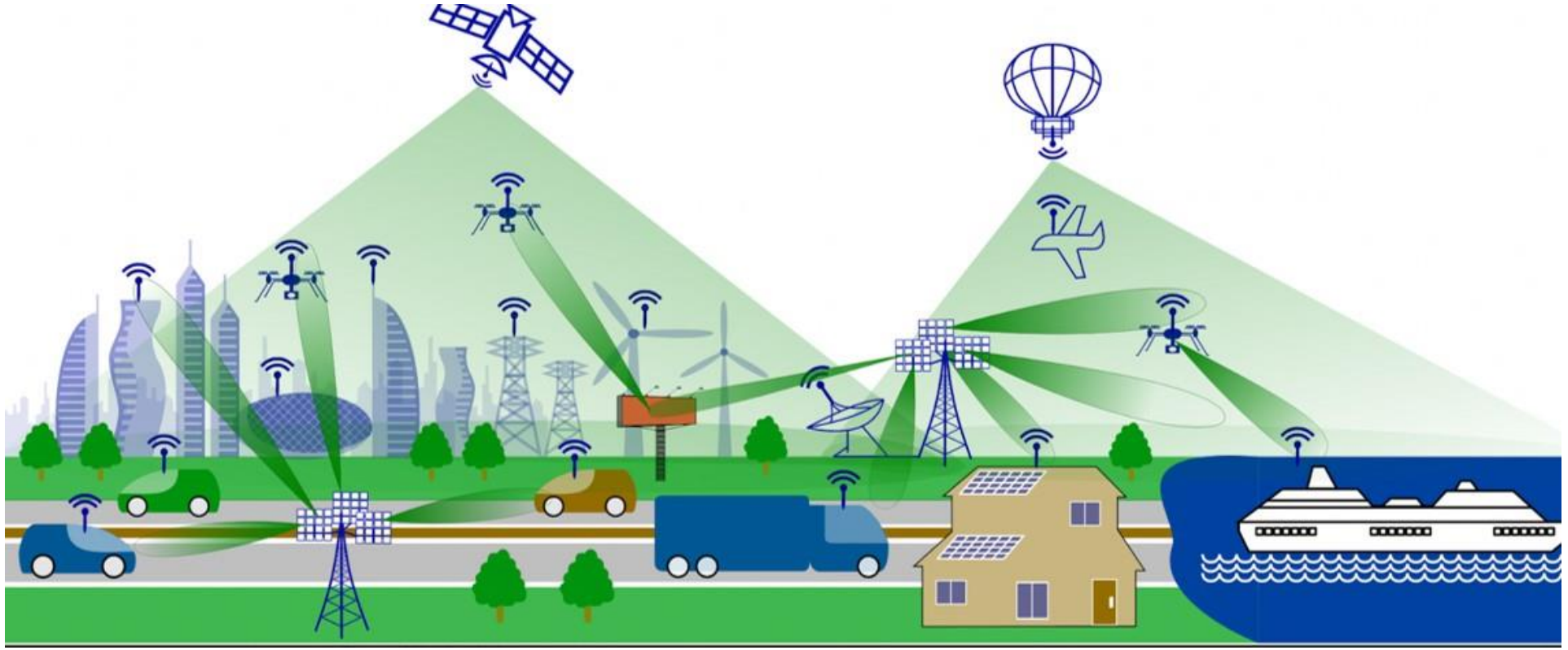
Future

Data Links - Future



https://www.researchgate.net/figure/UAV-communication-entities-including-ground-air-and-space-segments_fig1_329525679

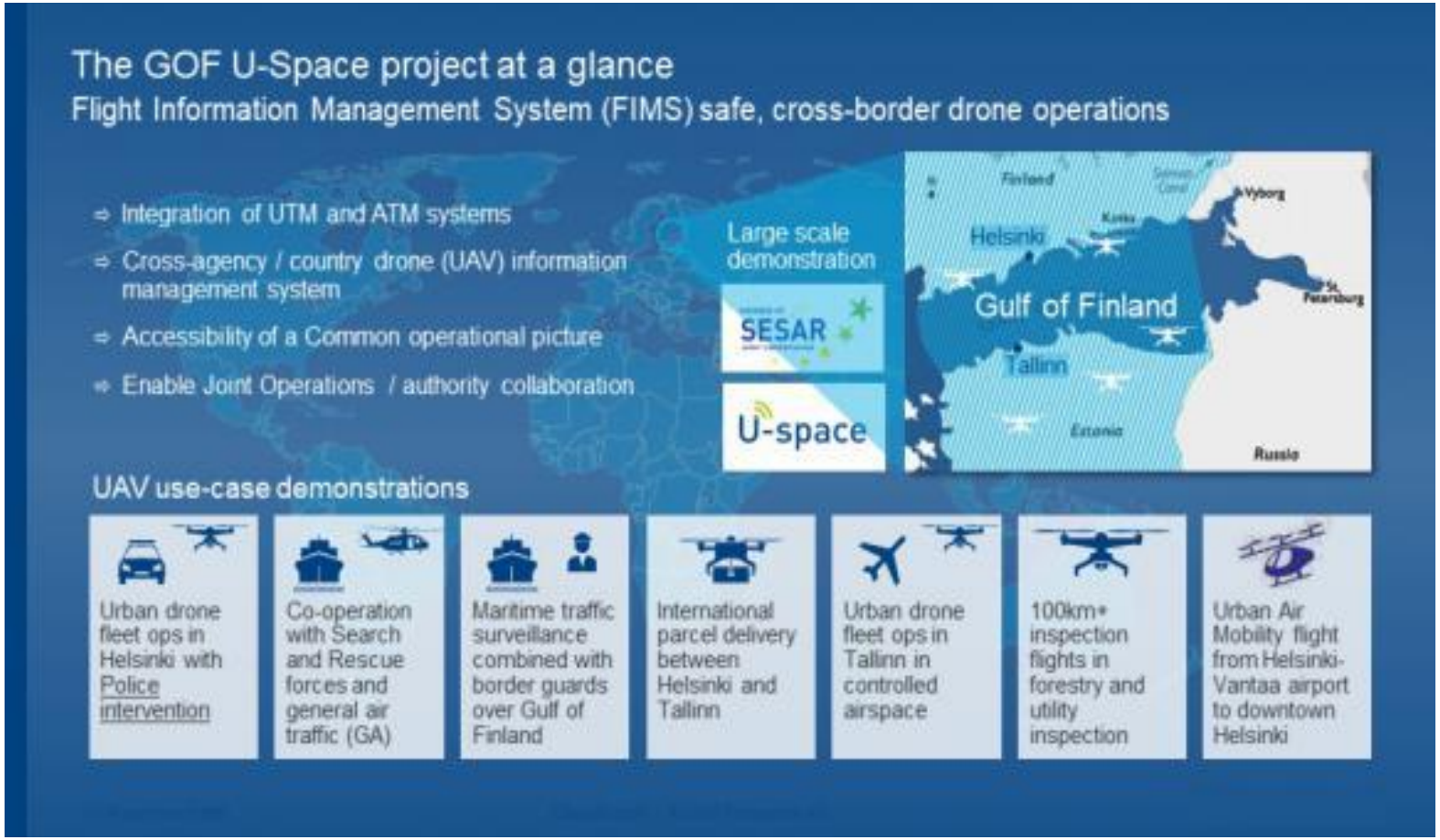
Data Links - Future



UAVs are expected to be fully integrated into the smart cellular network of the future (6G)

https://www.upf.edu/en/web/focus/noticies/-/asset_publisher/qOocsyZZDGHL/content/id/245870639/maximized

Data Links - Future



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https://www.frequentis.com/en/news/sesar-u-space-demonstrations-safe-drone-traffic-integration-gulf-finland-gof

Acrónimos

BLOS	Beyond Line Of Sight
GCS	Ground Control Station/System
GNC	Guidance, Navigation, and Control
HALE	High-Altitude, Long-Endurance
HTOL	Horizontal Take-Off and Landing
ISR	Intelligence, Surveillance, and Reconnaissance
LoA	Level of Autonomy
LOS	Line Of Sight
MALE	Medium-Altitude, Long-Endurance
MAV	Micro Air Vehicle
MEMS	MicroElectroMechanicalSystems
MUT	Manned/Unmanned Team
RF	Radio Frequency
RPAS	Remotely Piloted Aerial Systems
UAS/UAV	Unmanned Aerial System/Vehicle
VTOL	Vertical Take-Off and Landing