The 8th
Mission Idea Contest
for Multiple Nano-satellites

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

CUBESAI

CUBESAI: CubeSat-based Sensing and AI for Disease Prediction

THE TEAM

Alper Güvercin
METU Aerospace Engineering
3rd Grade

İpek Ölmez
METU Aerospace Engineering
2nd Grade

Yunus Emre Özdemir
METU Aerospace Engineering
2nd Grade

Duru Ceren Cerit
METU Aerospace Engineering
4th Grade

Introduction

- Vector-borne diseases (VBD) are human illnesses caused by parasites, viruses, and bacteria that are transmitted by vectors.
- Malaria, dengue, chikungunya, yellow fever, plague and Zika.

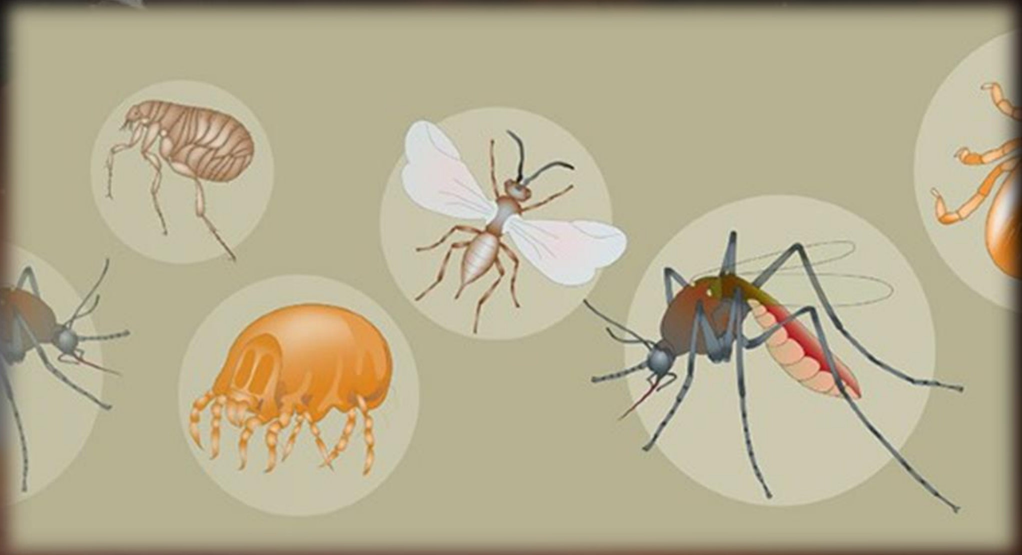
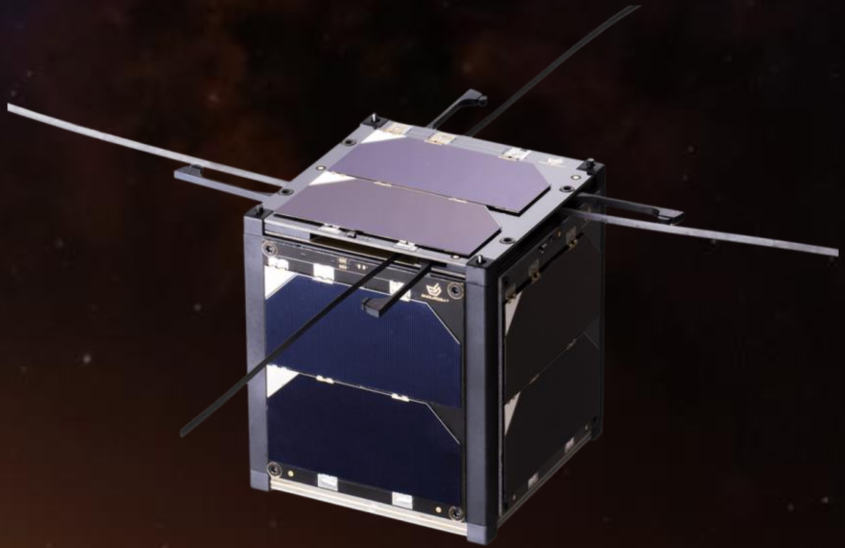


Fig.1. Vector-Borne Pathogens

- VBD causes more than **700.000** deaths every year.
- **80%** of the world's population are at risk of one or more of them [1].

Introduction

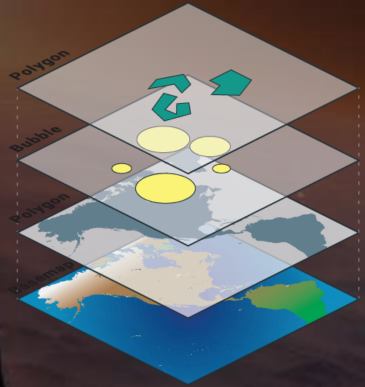


Primary aim of the project is

early detection and prediction

of VBDs by using:

- Remote Sensing
- Geographical Information System
- Artificial Intelligence



THE NEED

- Climate directly impacts the transmission of VBDs

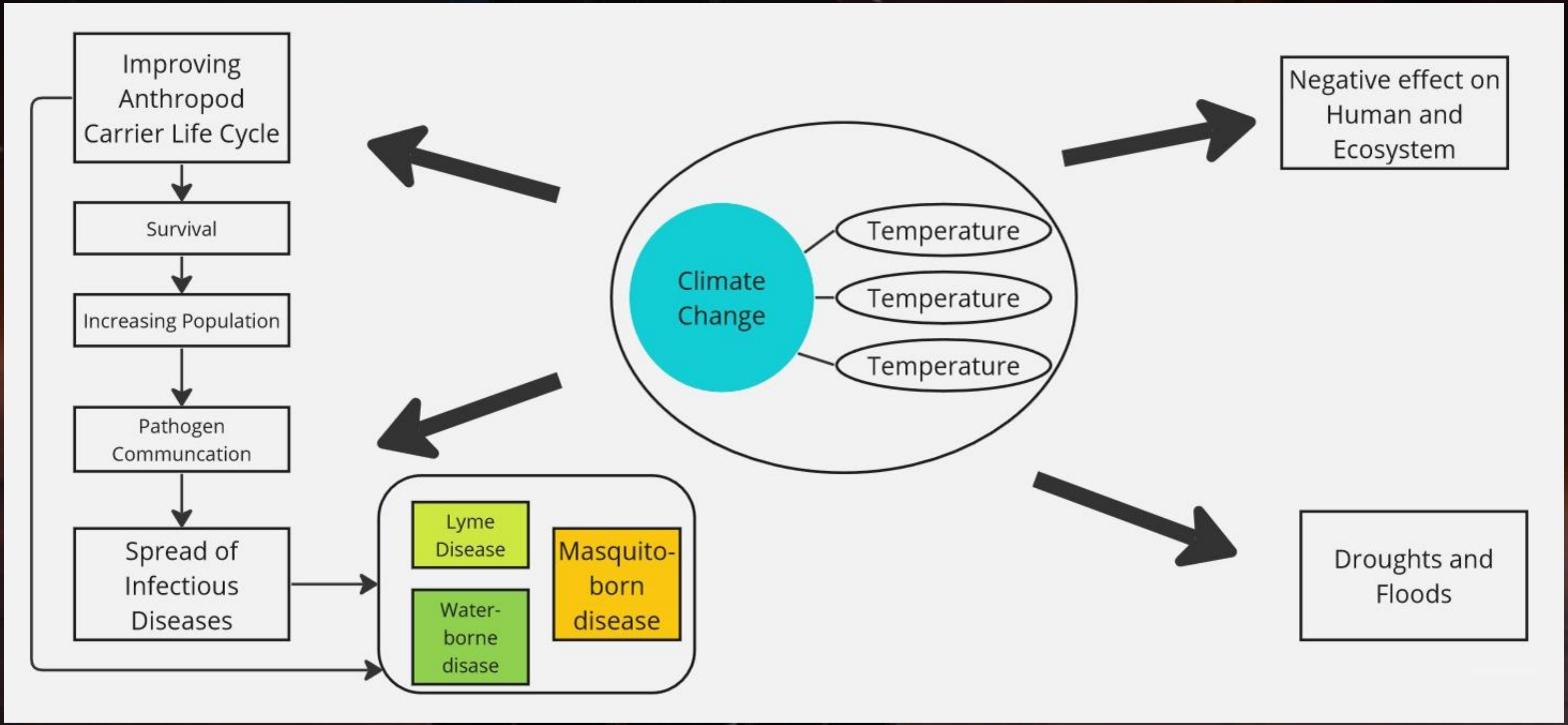


Fig.2. Environmental Factors Affecting VBDs

FURTHER INVESTIGATION NEED

Coinfection between COVID-19 and Vector Borne Diseases

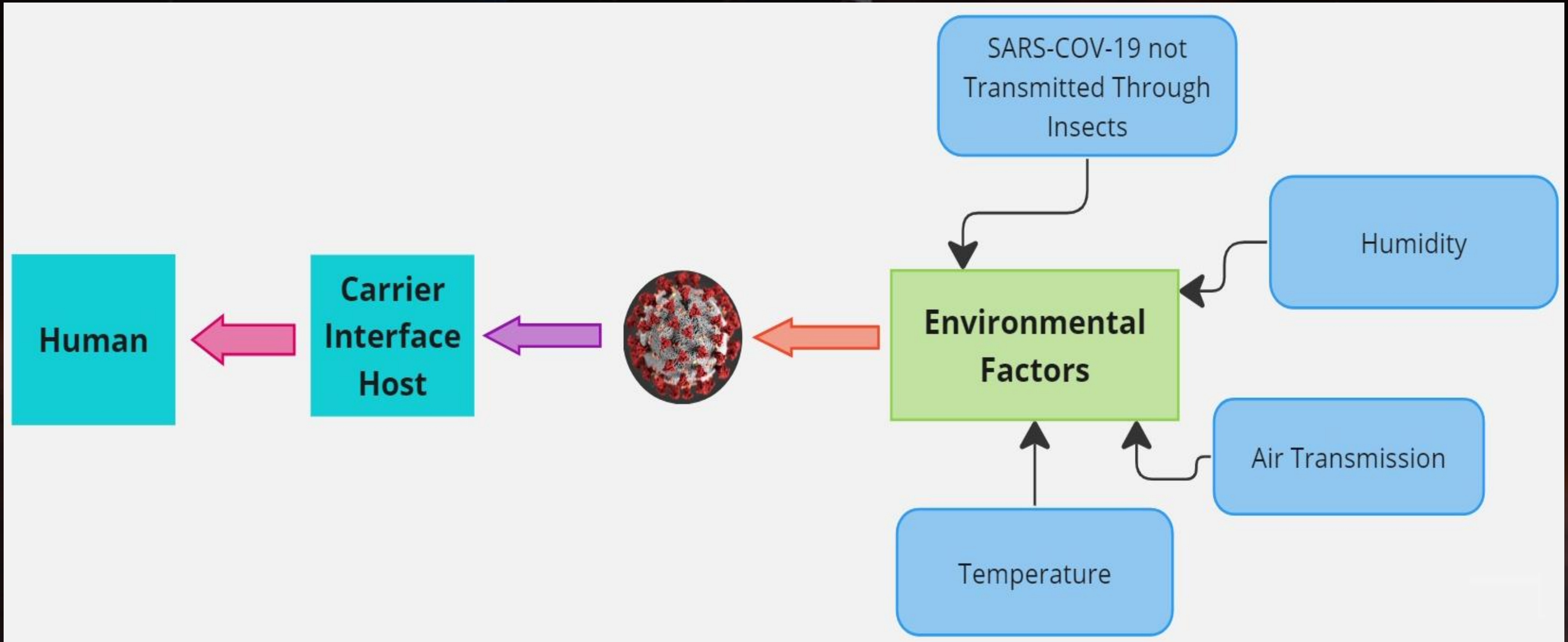


Fig.3. Coinfection between COVID-19 and VBD

Mission Objectives

Primary Objective

-Near-real-time data for detecting VBDs

-Creating a risk map of VBD

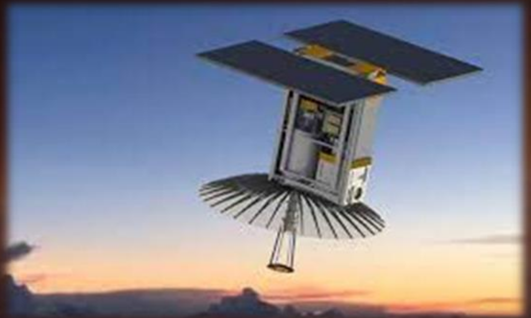


Fig.4. RAINCUBE Demonstration [2]

Secondary Objective

-Backup for heavy rainfall or dense cloud coverage.

-Demonstrating SAR within a 6U CubeSat

Third Objective

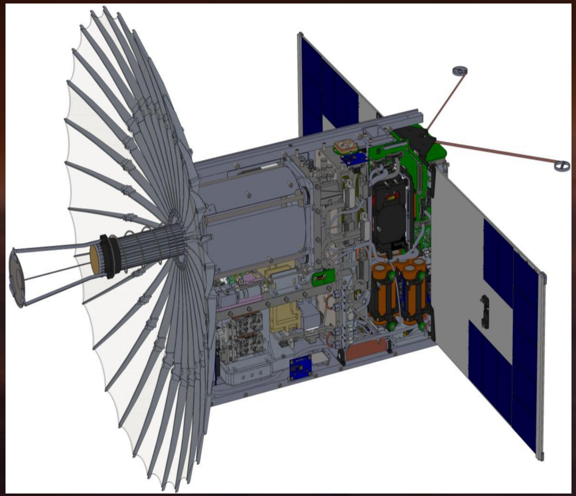
-Enhanced data processing and interpretation using AI

-Gathering data despite spatial and temporal constraints.

Concept of Operations

Space Segment and System Overview

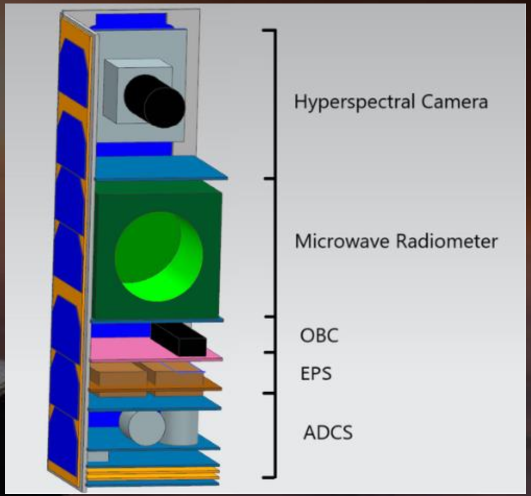
CUBESAI-A (x3)



- 6U CubeSat
- Active Sensors
  -Synthetic aperture radar (SAR)
- Temperature, precipitation, vegetation, H2O vapor

Fig.5. Drawing of the RAINCUBE [3]

CUBESAI-P (x3)



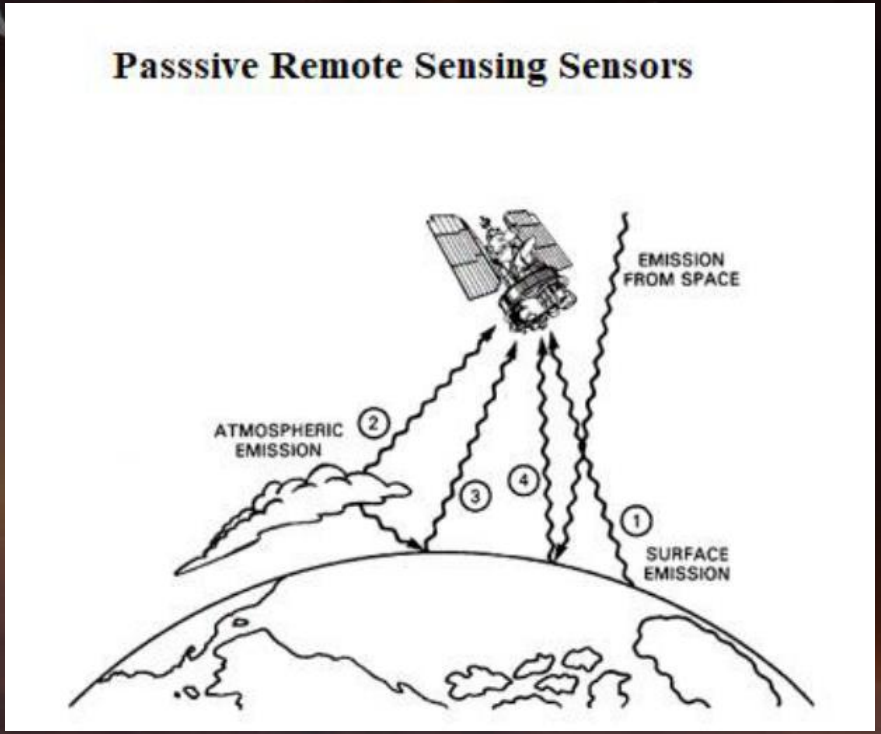
- 3U CubeSat
- Passive Sensors
  -Hyperspectral Camera
  -Microwave Radiometer
- Temperature, humidity, precipitation, wet zone, sky clearness.

Fig.6.CAD drawing of the CUBESAI-P

Concept of Operations

Why are active and passive sensors separated?

- Observation of the Earth's surface and atmosphere.
- Operates in dark conditions
- Can penetrate clouds, generate 3D images



- Global observations of the Earth and it's atmosphere
- Requires less power
- For identifying land cover, mapping vegetation, detecting atmospheric gases

Concept of Operations

Ground Segment

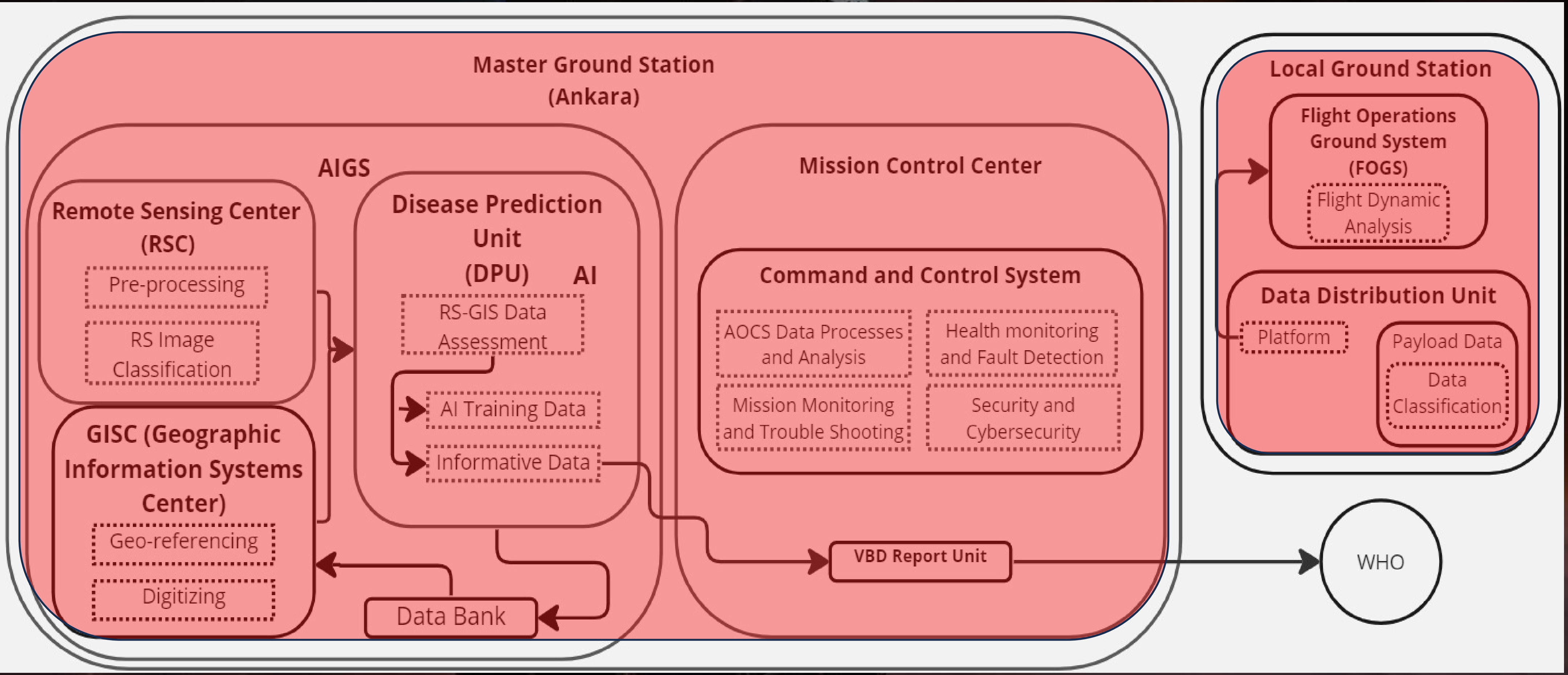


Fig.7. Ground Segment Operations

Concept of Operations

Mission Operations

Tasks	1/24	2/24	3/24	4/24	5/24	6/24	7/24	8/24	9/24	10/24	11/24	12/24	1/25	2/25	3/25	4/25	5/25	6/25	7/25
Pre-Launch Operations																			
Concept Development and Mission Definition	■	■																	
Merit and Feasibility Reviews		■	■																
System Design and Technology Development		■	■	■	■	■													
CUBESAI-A, CUBESAI-P Hardware Fabrication						■	■												
Component/Equipment Acqusition and Test						■	■	■	■										
Ground Station Design, Development, and Test								■	■	■	■	■	■						
Environmental Testing												■	■	■	■				
Regulatory Licensing														■	■				
Launch and Deployment																			
CubeSat to Dispenser Integration and Test																■			
Launch and Separation																■	■		
Activation and Initialization																	■	■	■
Mission Operations																			

Fig.8. Pre-deployment Phase Gantt Chart

Concept of Operations

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

Mission Operations

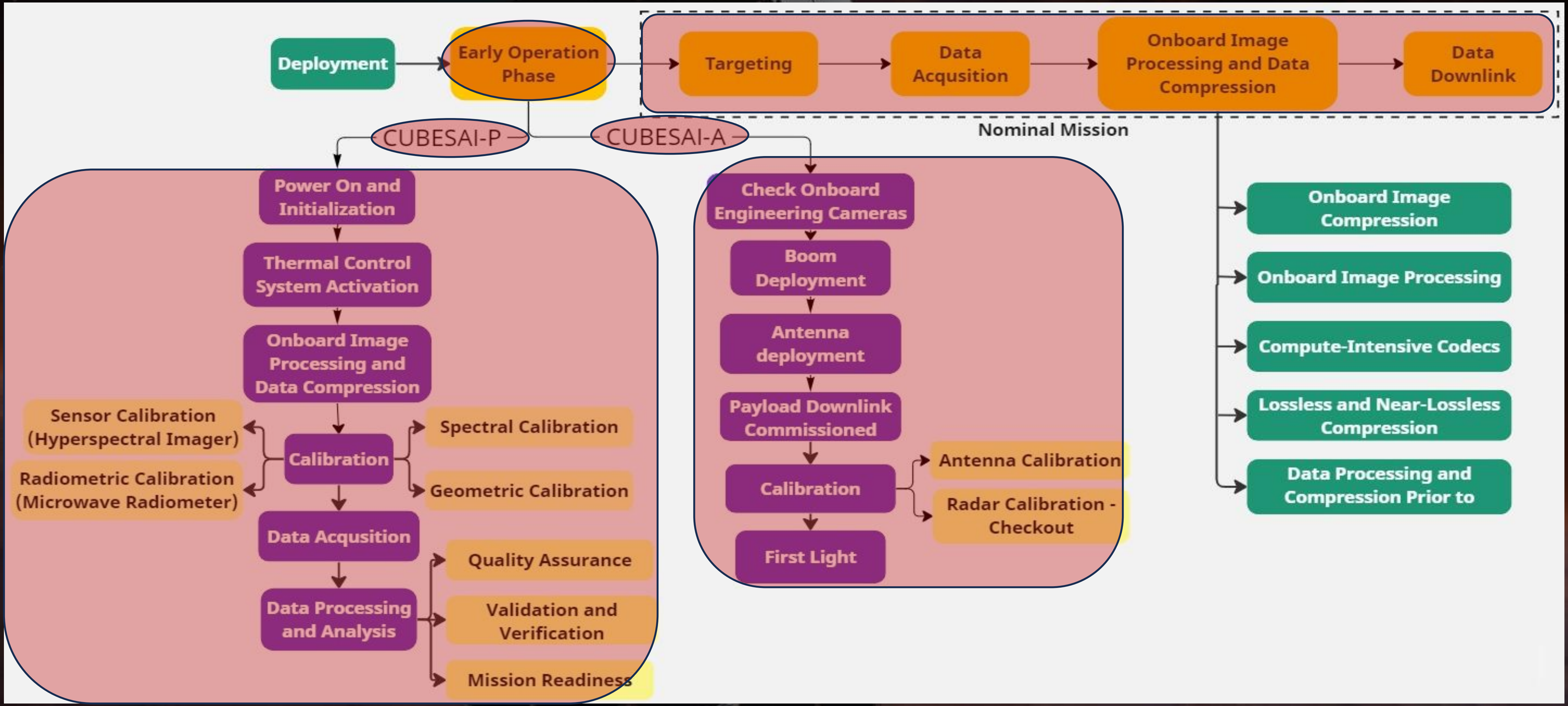
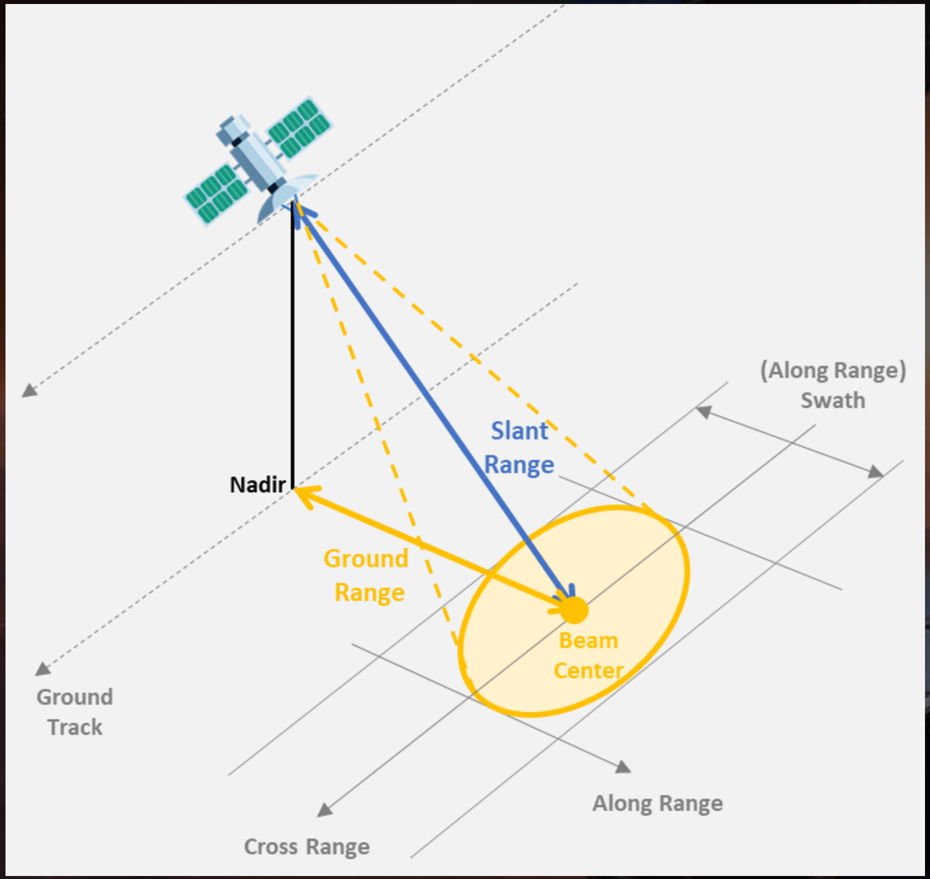


Fig.9. Detailed Operational Scheme

Key Performance Parameters

Synthetic Aperture Radar (SAR)



- High Coverage (318 km) Swath Width
- Minimized Power Consumption
- 6.5 kg

Antenna

- X-band
- 39.6 dB gain at 8.4 GHz
- 1.5 m x 1.5 m
- deployable reflect array antenna

Key Performance Parameters

Data Transformation

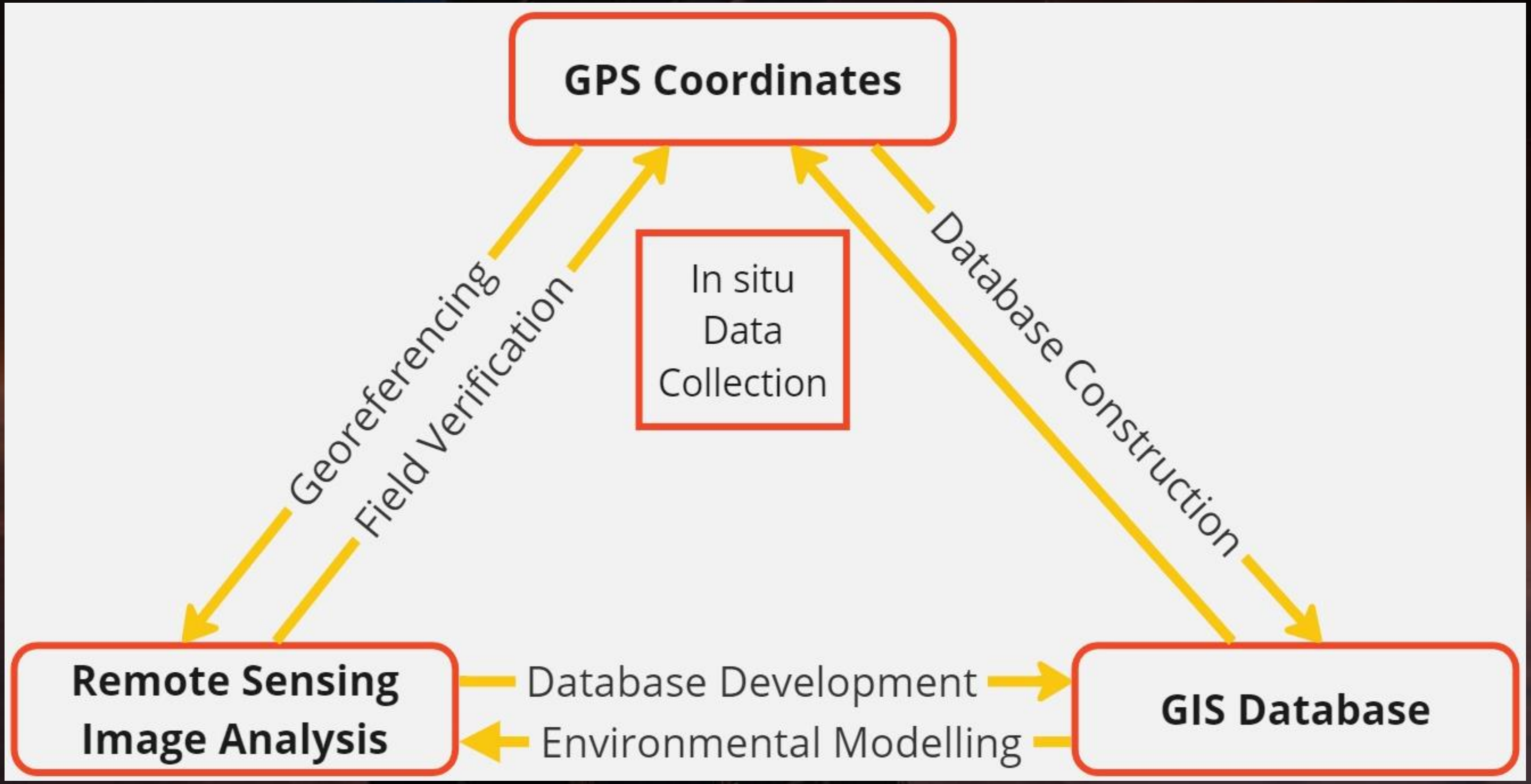


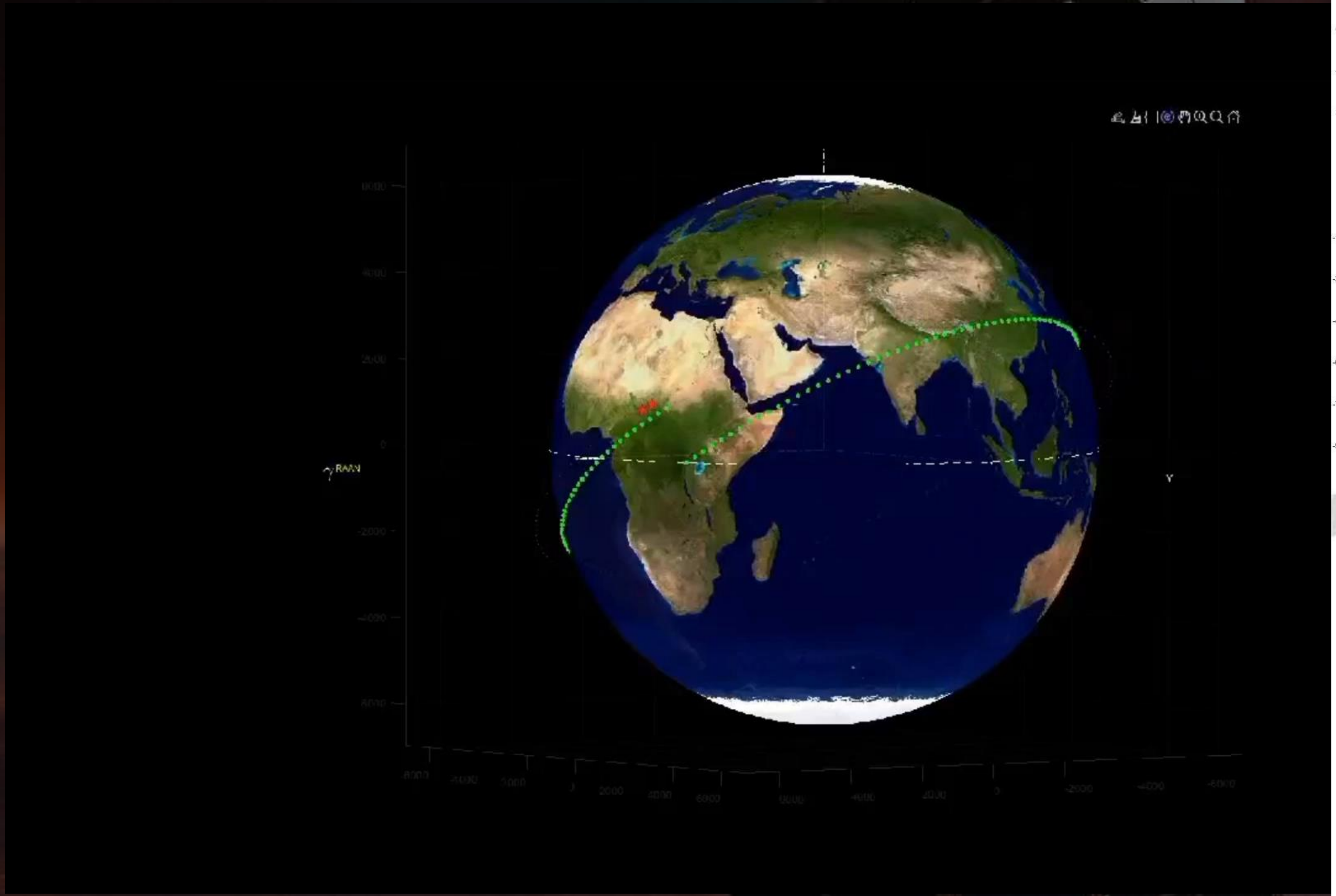
Fig.10. Anomaly Detection with AI-GIS-RS

SPACE SEGMENT DESCRIPTION

Instruments and Payloads	Mass (g)	Size (m × m × m)	Power Consumption (W)	
TT&C (EnduroSat)	270	0.01 × 0.01 × 0.004	0.5 - 2	CUBESAI-P and CUBESAI-A
OBC (EnduroSat)	180	0.01 × 0.01 × 0.005	0.27 - 0.55	
ADCS (CubeADCS)	780	0.09 × 0.09 × 0.057	0.12 - 0.2	
Hyperspectral Camera (HyperScape50)	440	0.095 × 0.09 × 0.117	2.7 - 7	CUBESAI-P
Microwave Radiometer	1330	0.01 × 0.01 × 0.01	16 - 21	
SAR	8200	0.2 × 0.2 × 0.1	22 - 28	CUBESAI-A

Fig.11. Summary of Components

ORBIT/CONSTELLATION DESCRIPTION



Animation of the orbit of a CUBESAI

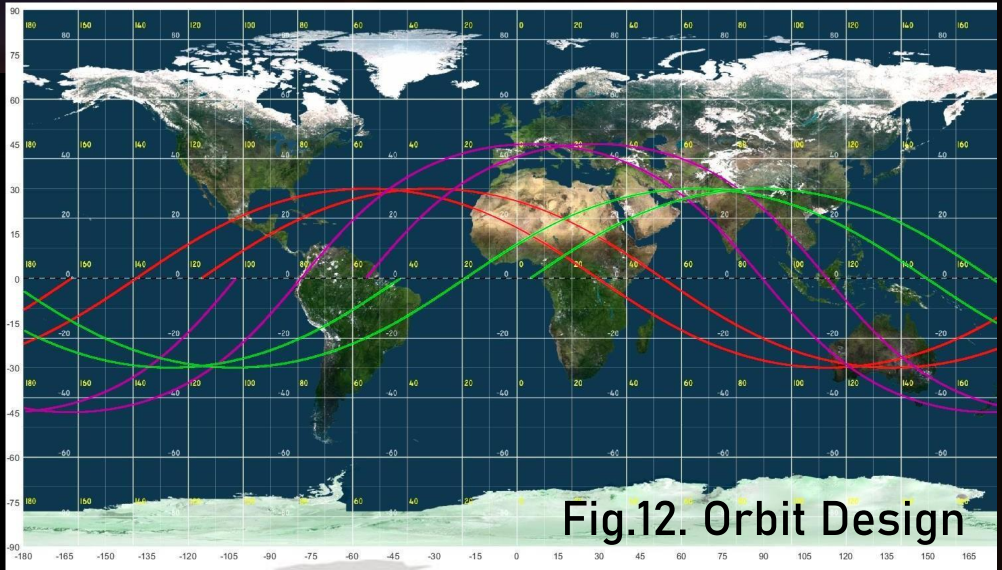


Fig.12. Orbit Design

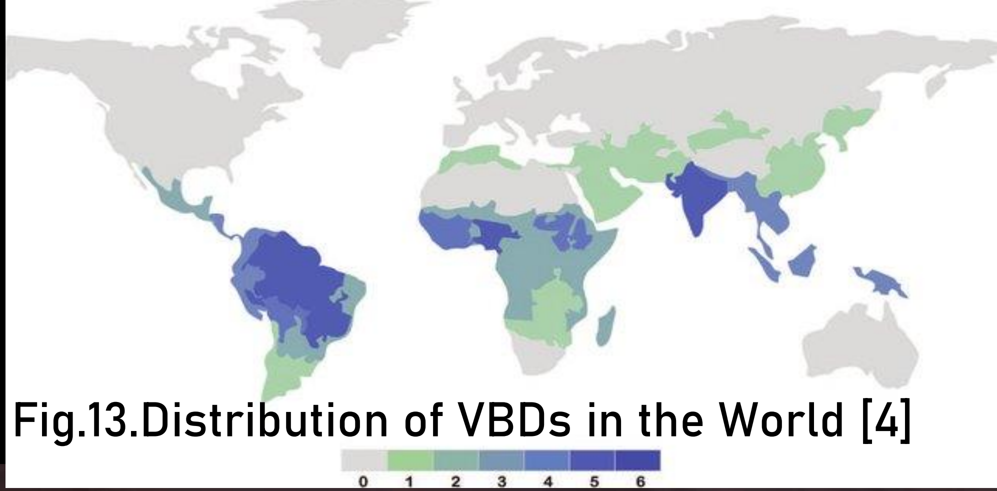


Fig.13.Distribution of VBDs in the World [4]

IMPLEMENTATION PLAN

- World Meteorological Organization (WMO)
- World Health Organization (WHO)
- Turkish Space Agency (TUA)

Main Mission Risks

1. Power system and attitude control failure
2. Communication system failure
3. Payload and sensor failure
4. Mechanical failure
5. Data handling failure

TOTAL COST: ~1.5 MILLION DOLLARS [5]

Thank you so much for the assistance!

ODTÜ
METU

Assoc. Prof. Dr. Halil Ersin Söken

PLANS

The 7th
Mission Idea Contest
For Deep Space Science and Exploration

Cansu Yıldırım and **Semra Sultan Uzun** from the Winner Team (PARS) of MIC7

Thank you for your attention.

Do you have any questions?

REFERENCES

[1] Vector-borne diseases (2020) World Health Organization. Available at: https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases#:~:text=Vector%2Dborne%20diseases%20are%20human,that%20are%20transmitted%20by%20vectors.

[2] https://www.jpl.nasa.gov. "New CubeSats to Test Earth Science Tech in Space." NASA Jet Propulsion Laboratory (JPL), www.jpl.nasa.gov/news/new-cubesats-to-test-earth-science-tech-in-space.

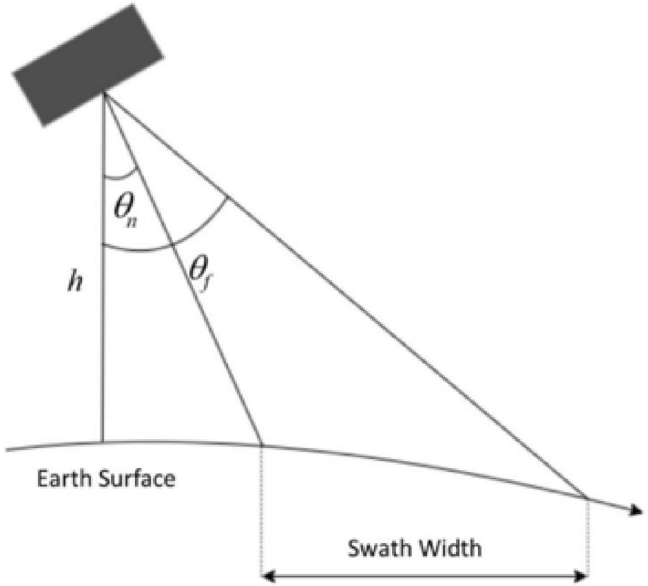
[3] "RaInCube (Radar in a CubeSat) - EoPortal." Www.eoportal.org, www.eoportal.org/satellite-missions/raincube.

[4] Golding, Nick & Wilson, Anne & Moyes, Catherine & Cano, Jorge & Pigott, David & Velayudhan, Raman & Brooker, Simon & Smith, David & Hay, Simon & Lindsay, Steve. (2015). Integrating vector control across diseases. BMC Medicine. 13. 249. 10.1186/s12916-015-0491-4.

[5] Golding, Nick & Wilson, Anne & Moyes, Catherine & Cano, Jorge & Pigott, David & Velayudhan, Raman & Brooker, Simon & Smith, David & Hay, Simon & Lindsay, Steve. (2015). Integrating vector control across diseases. BMC Medicine. 13. 249. 10.1186/s12916-015-0491-4.

APPENDIX

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY



$$SW = h\,(\tan\theta_f - \tan\theta_n) / n_{pol}$$

where,
SW = swath width (318.0148829 km)
h = altitude (500 km)
n_{pol} = number of polarizations (single)
θ_n and θ_f = near and far range look angles (20°, 45°)

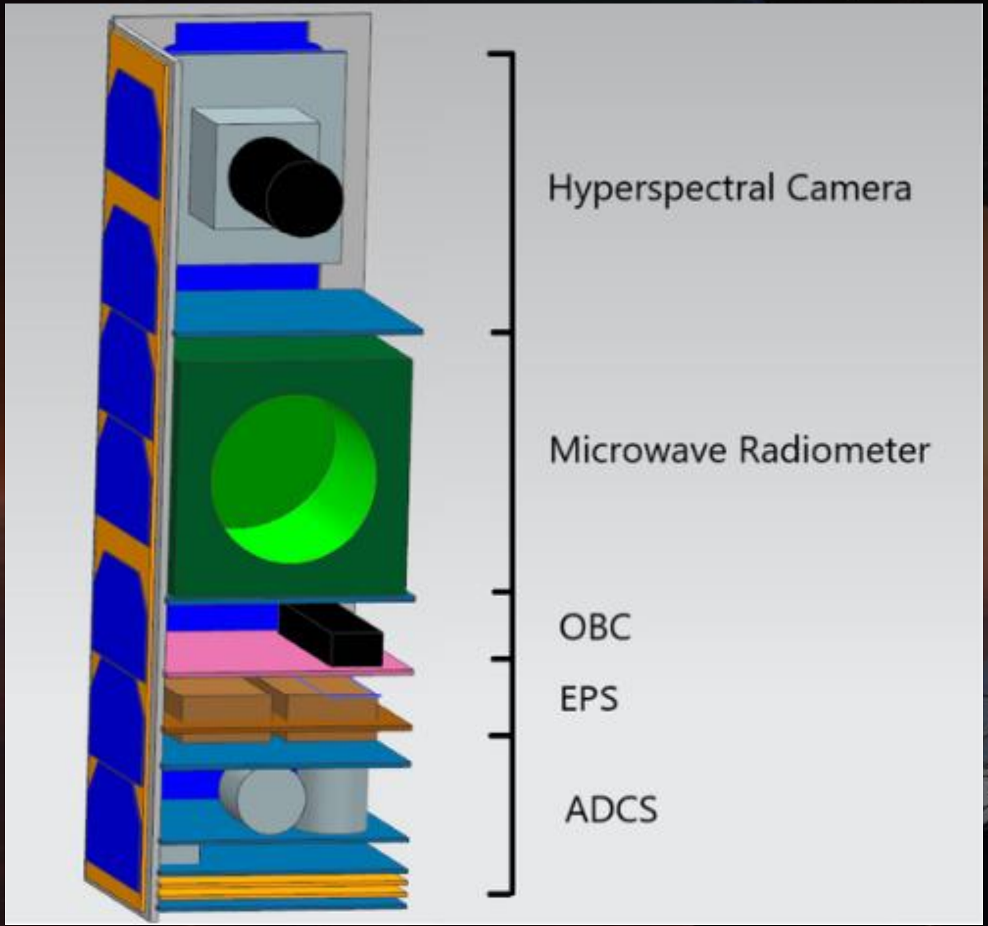
$$PRF_{min} = 2V_s / L_{az} = 20.3 \text{ KHz} \quad \& \quad \tau_p = L_{az} / 2V_s = 49.3\ \mu s$$

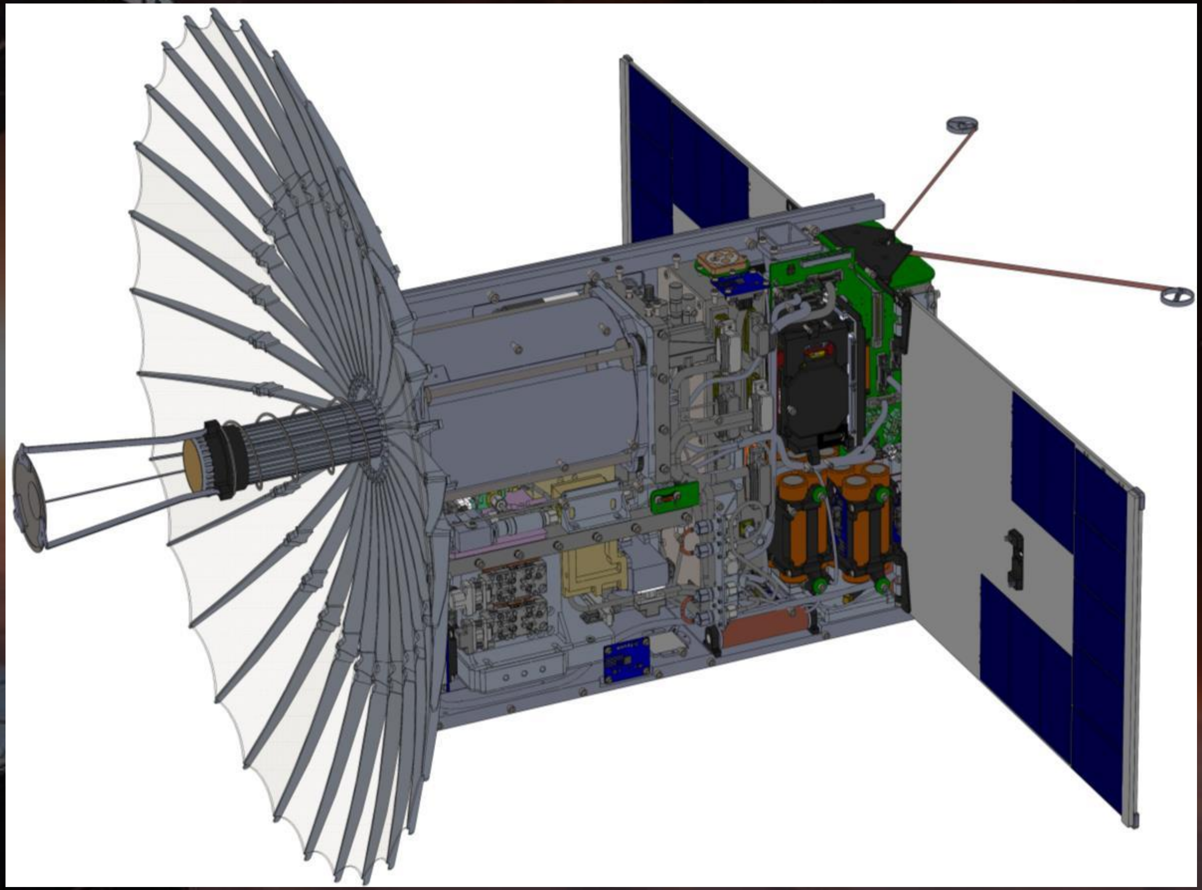
where,
PRF_{min} = minimum required PRF
V_s = orbital velocity (7.6 km/s)
L_{az} = azimuth dimension of the antenna (0.75 m)
τ_p = maximum pulse duration

APPENDIX

Instruments and Payloads	Mass (g)	Size (m × m × m)	Power Consumption (W)
TT&C (EnduroSat)	270	0.01 × 0.01 × 0.004	0.5 - 2
OBC (EnduroSat)	180	0.01 × 0.01 × 0.005	0.27 - 0.55
ADCS (CubeADCS)	780	0.09 × 0.09 × 0.057	0.12 - 0.2
Hyperspectral Camera (HyperScape50)	440	0.095 × 0.09 × 0.117	2.7 - 7
Microwave Radiometer	1330	0.01 × 0.01 × 0.01	16 - 21
SAR	8200	0.2 × 0.2 × 0.1	22 - 28

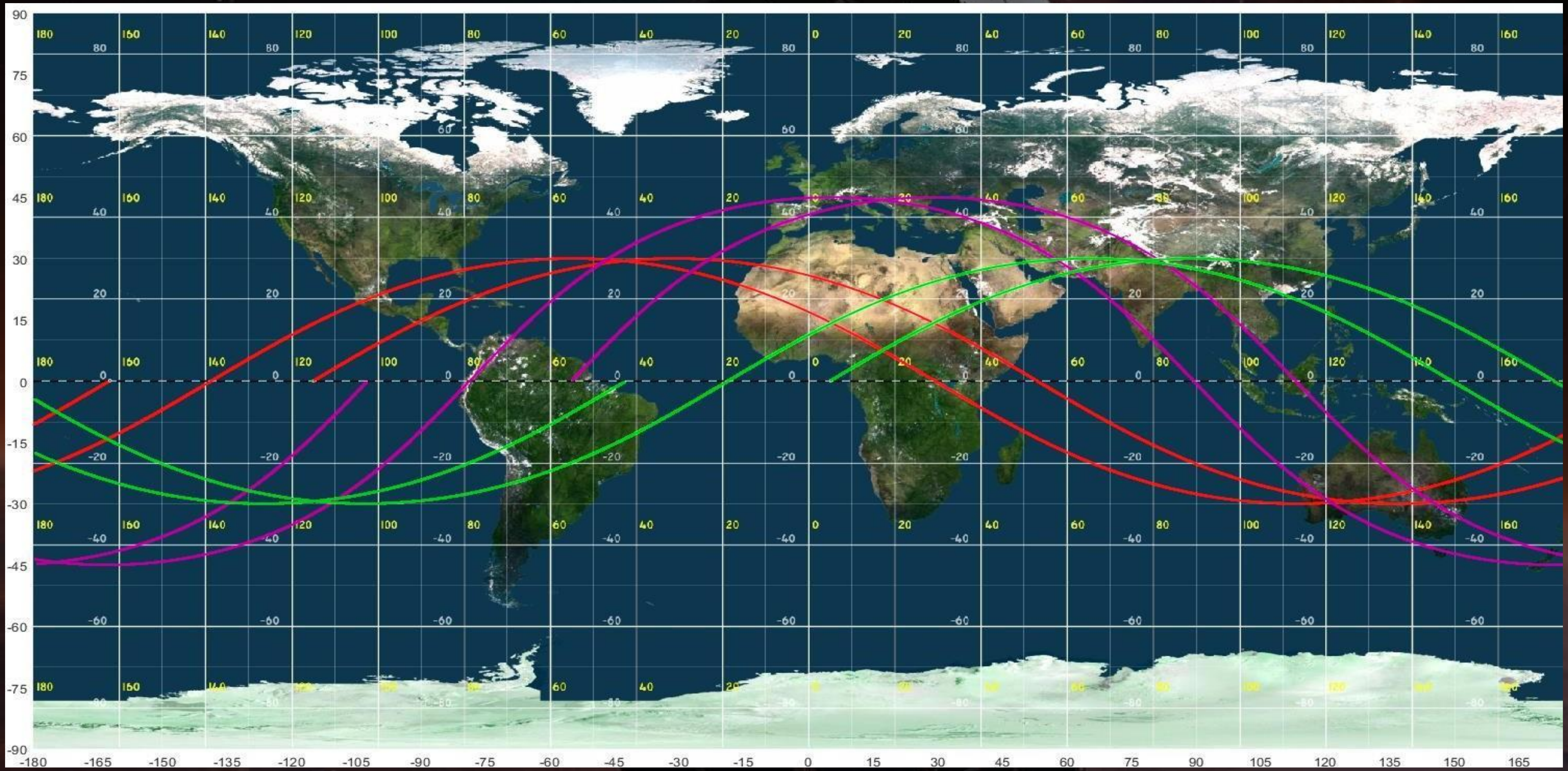
APPENDIX





APPENDIX

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY



- Altitude: 500 km
- Semimajor Axis: 6871 km
- Eccentricity: 0
- Inclinations: 30 degrees for two, 45 degrees for one
- RAANs: 0, 60 and 120 degrees
- Period: 5668.2 s (1.57 h)