The 5th

Mission Idea Contest

Micro/Nano Satellites for Global Sustainable Development

UNISEC GLOBAL
University Space Engineering Consortium

19 November, Strasbourg France

INTERNATIONAL SPACE UNIVERSITY

Arid and Semi-Arid Lands Satellite (ASAL-SAT)

A LoRa ground sensor network for easing life in Sub-Sahara Africa ASAL areas

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Introduction

Era of "big" data

- Can remote areas benefit?
- How to collect this data?

Sub Sahara Africa

- Pastoralism
- Wildlife

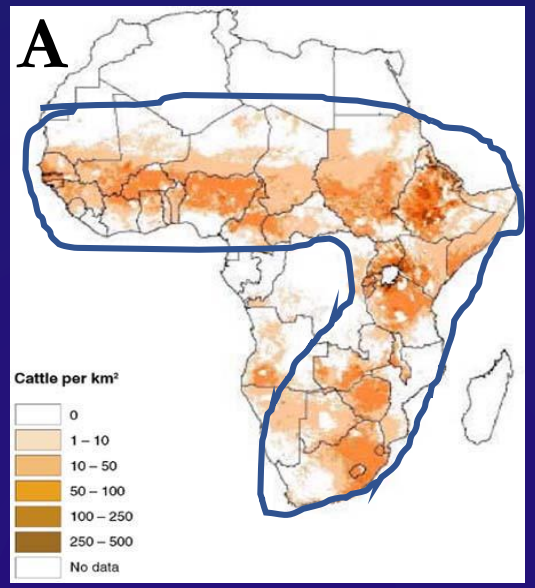


Image: FAO

Image: eLimu.org

A: Cattle distribution

B: Elephants distribution

C: Lion distribution

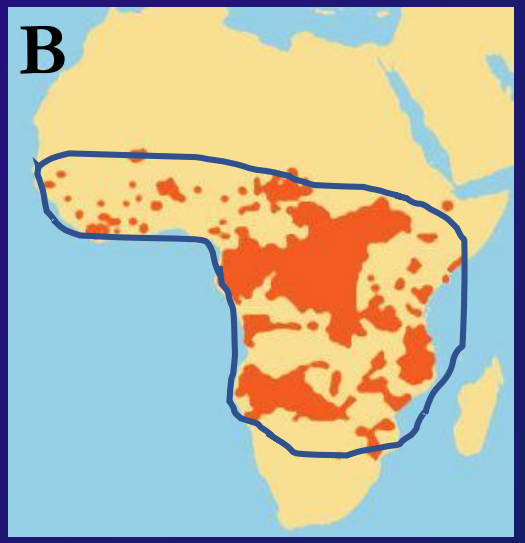


Image: Defenders of Wildlife

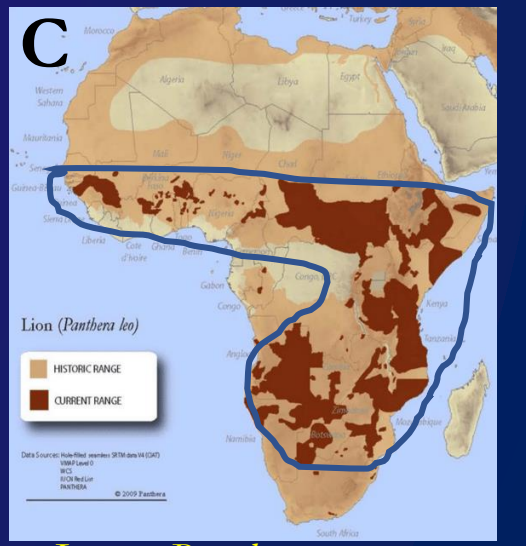


Image: Panthera.org

Human-Wildlife

- Co-Existence
- Pasture and Water Conflicts
- Endangered Wildlife

Kenya

Image: REUTERS/Goran Tomasevic

Image: REUTERS/Goran Tomasevic

A. Human-Wildlife Conflict, Laikipia Kenya, Feb 2017

B. Carcass of an elephant, Laikipia Kenya, Feb 2017

Disaster Management

Flash floods monitoring

Image: The Standard Newspaper, April 2018

A. Mandera Floods, Kenya, 2018

Image: The Nation, April 2018

B. Turkana Floods, Kenya, 2018

ASAL-SAT

Mission Objectives

- Wildlife and Livestock Population mapping, enumeration and tracking
- Vegetation cover surveillance, and pasture and water identification
- Disaster e.g. Flash floods warning system

How to achieve this?

- Very remote areas
- Lack of infrastructure – Power, communication
- Low population density

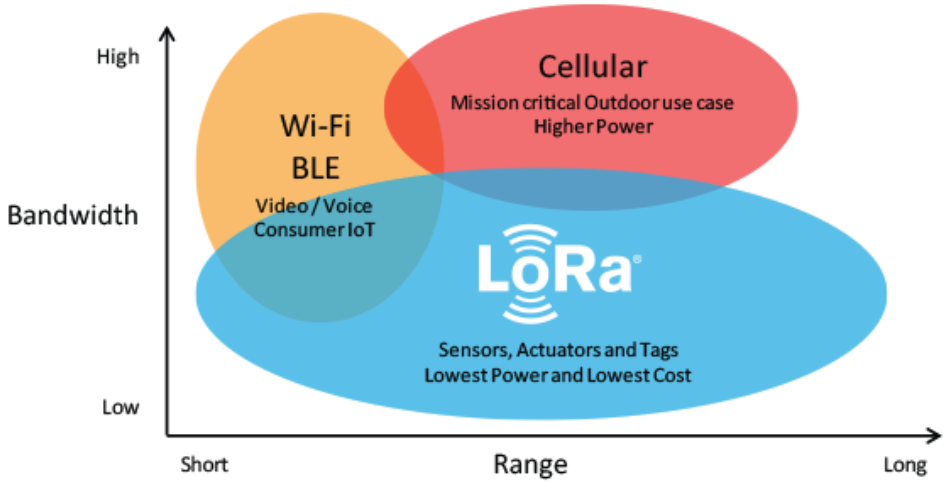
SDGs

LoRa and LoRaWAN Introduction

- LoRa - Chirp Spread Spectrum (CSS) modulation
- LoRaWAN - Communication Protocol built on the LoRa physical layer
- Link between gateways and backend servers?
  - GSM/Cellular; Fibre
  - ASAL-SAT

OSI Model

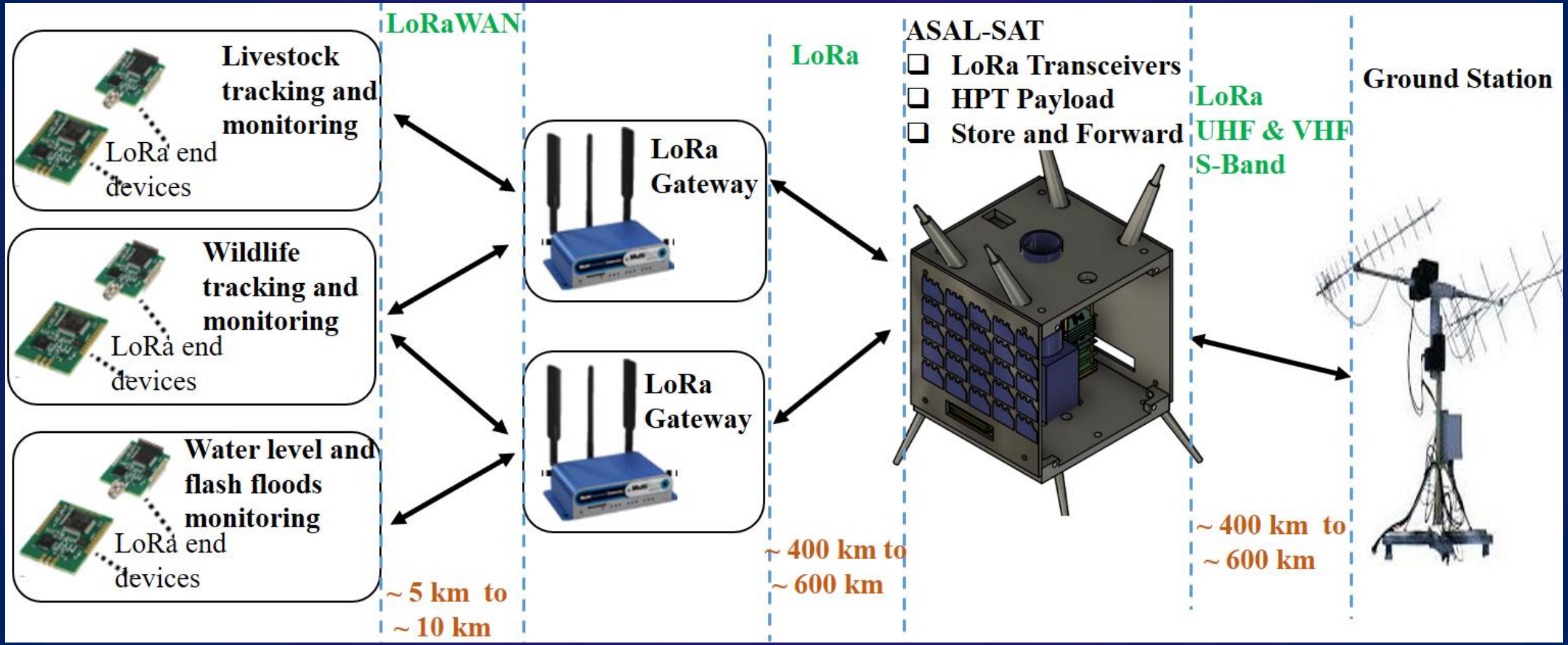
3	Network	LoRaWAN
2	Data Link	LoRaWAN
1	Physical	LoRa



LoRa and LoRaWAN - Attractive Features

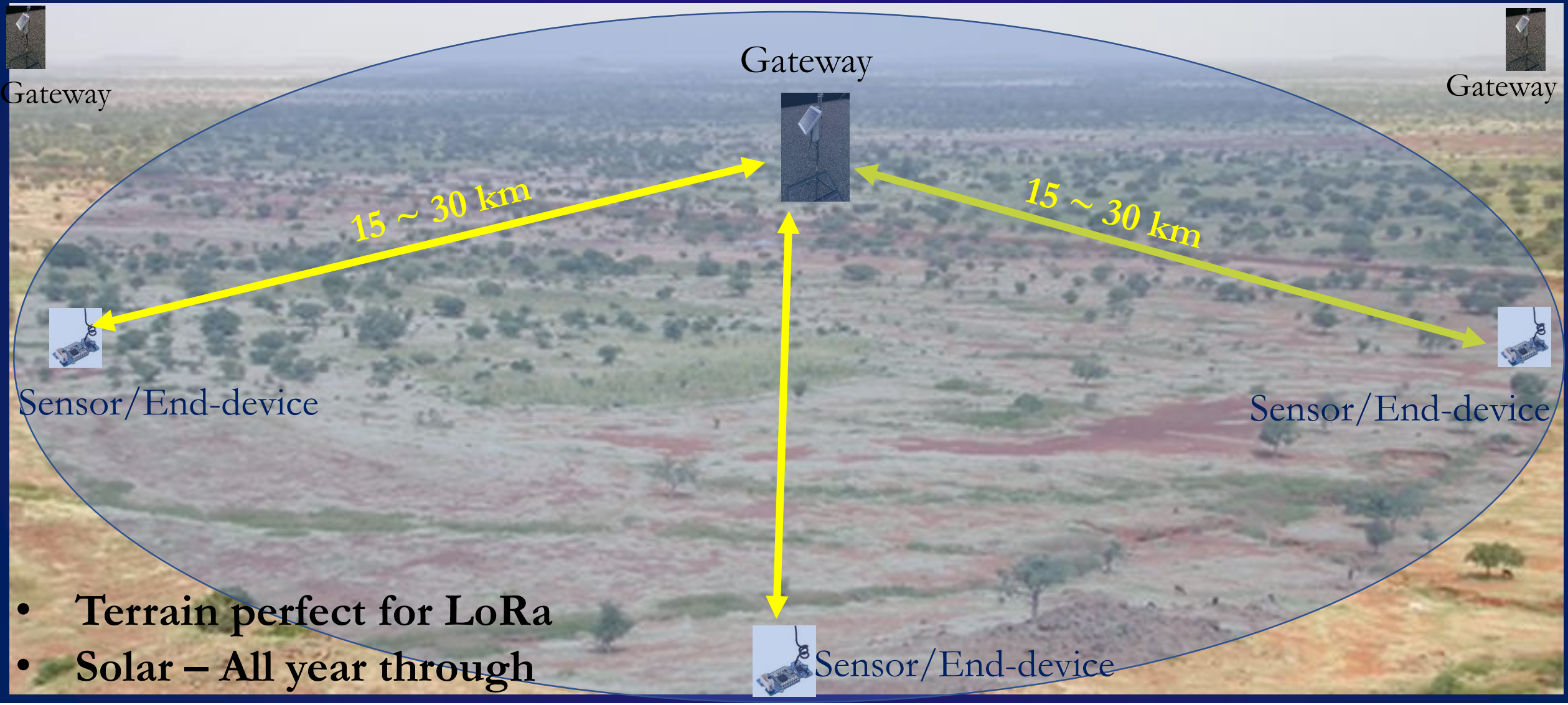
- Low power consumption (10 years of battery lifetime)
- Long communication range (2-5 km in urban centres and 15 km in rural areas)
- Operates in the license-free regulated ISM bands (between 166 to 1020 MHz)
- LoRa based devices are cheap and highly affordable

Concept of Operations



Mission Idea High Level

Ground LoRa-based Network



- **Terrain perfect for LoRa**
- **Solar – All year through**

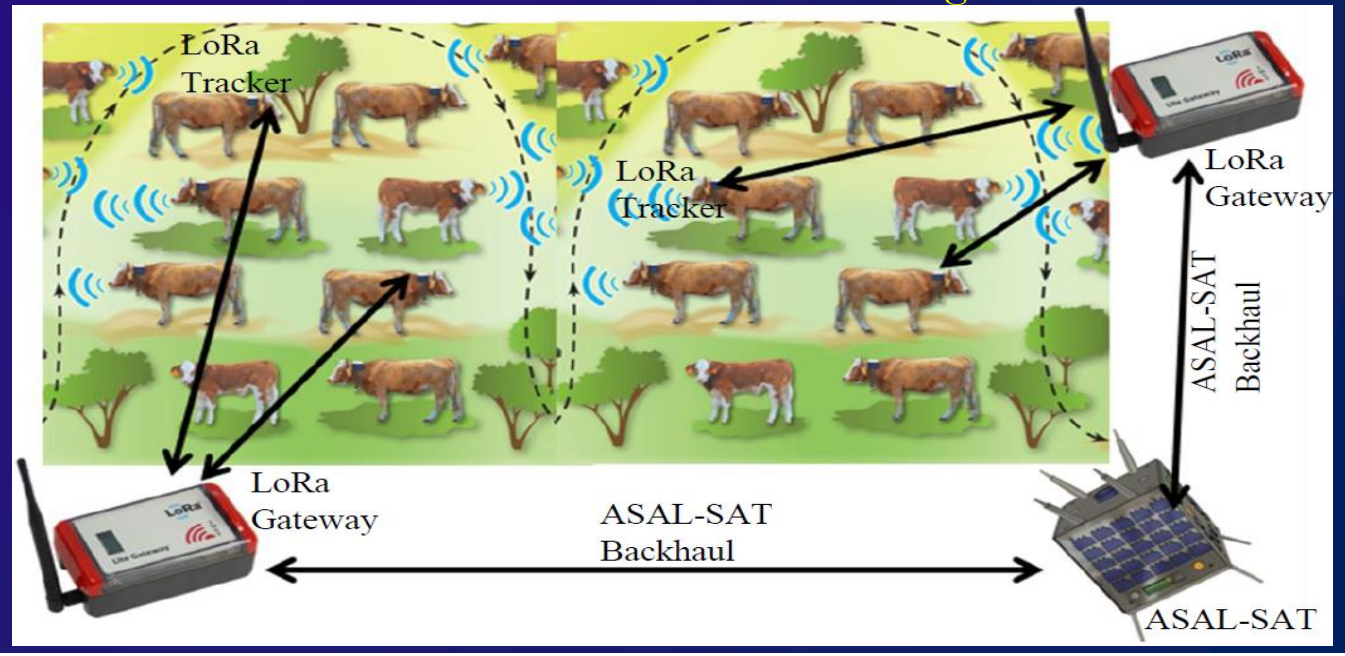
Livestock Tracking

- Nomadic Lifestyle
- Cattle rustling
- Real & Decoy LoRa bands

Improve this

Image: PRISE/Ray Morris

Image: CattleWatch



LoRa Ground Data Generation Estimation

- Area under consideration ~100 km^2

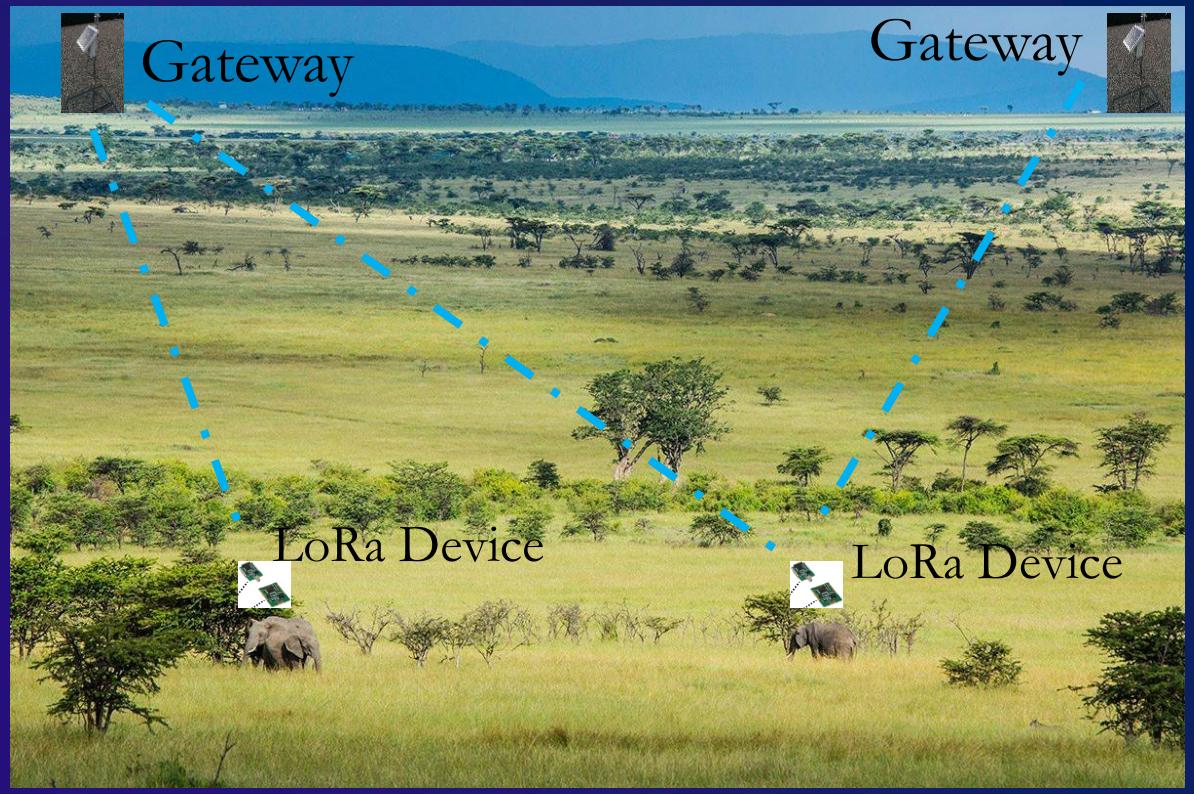
Population density	Average persons per Household	Households per 1 km^2	Total Households in 100 km^2
30/km^2	6	5	500
Average livestock per household	Livestock with LoRa tracker per household	Total animals with trackers in 100 km^2	
100	10	5000	
LoRaWAN overhead size per packet	Animal Identification and tracking data size	Total packet size per tracker	Total packet sizes in 100 km^2
13 bytes	5 bytes	18 bytes	9000 bytes

- Low Data size suited to LoRaWAN : 100 km^2 ~ 9 kB
- 100 km^2 ~ 10 gateways sufficient for 15 km radius
- More gateways ~ Increase robustness, minimize packet loss

WildLife Tracking

- Endangered Species
- Tracking and mapping

- Gateways can have GPS
- LoRa Triangulation for end devices



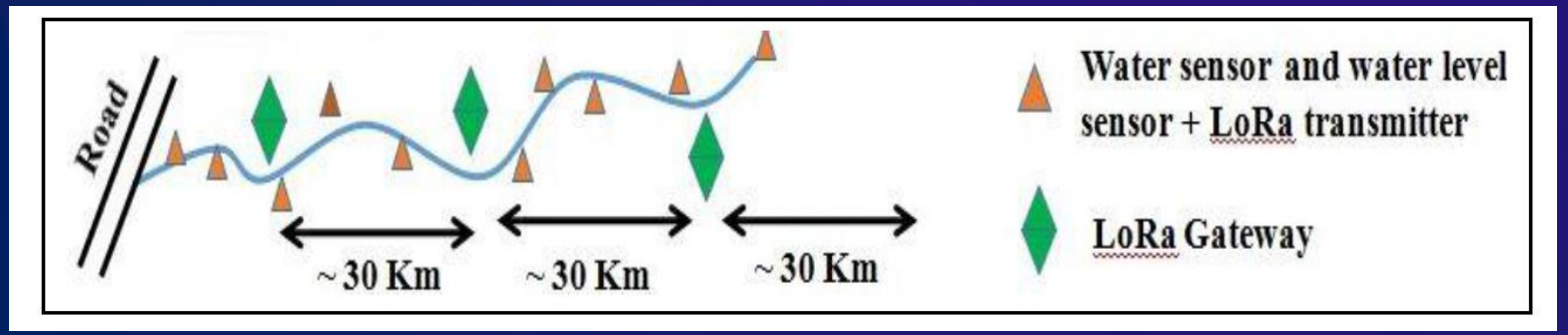
Comparison with Existing Solutions

	VHF Collars	GPS/GSM Collars	GPS Satellite Collars	LoRa + ASAL-SAT
Data Reception	Handheld radio & GPS recorder	GSM mobile phone coverage	Commercial Satellite	Gateways & ASAL-SAT
Batteries Lifetime	3 years	2 years	2 years	~ 10 years
Weight		300 – 500 g	400 – 700 g	< 100 g
Cost (USD $)	300 – 500	1000 - 2000	2500 - 4000	10 - 50

Flash Floods/Water Level Monitoring and Warning System

Image: decentLabs

C. LoRa Ultrasonic Water Level Sensor



A. Mandera Floods, Kenya, 2018

Image: The Standard Newspaper, April 2018

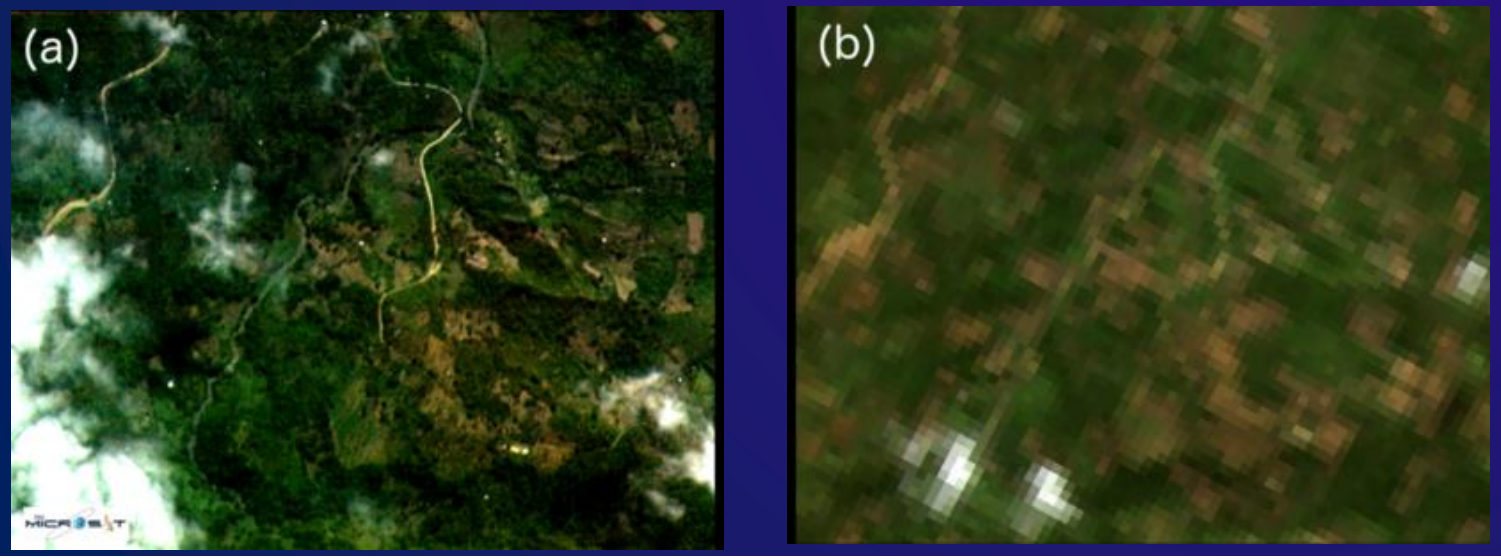
B. Turkana Floods, Kenya, 2018

Image: The Nation, April 2018

Vegetation Cover Surveillance

- Curb overgrazing, deforestation, desertification
- Assess grassland and savanna degradation
- Aid in pasture and watering points location

Image: The Philippines, Dept. Science and Technology



High Precision Telescope (HPT)

- By Tohoku and Hokkaido universities
- Philippines Diwata-1 satellite
- 5 meter spatial resolution

Image: HPT, Junichi Kurihara et. al

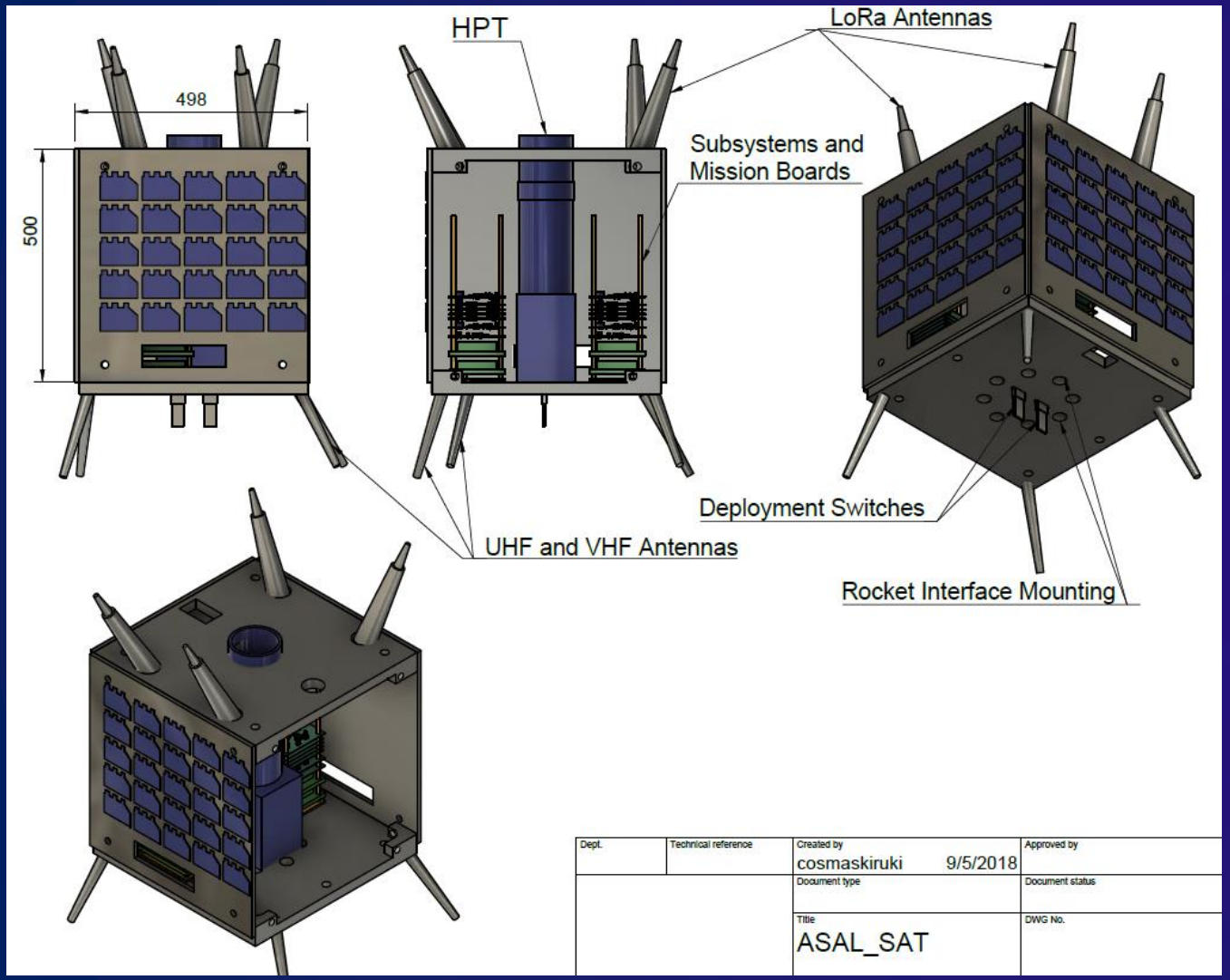
a) HPT on Diwata-1

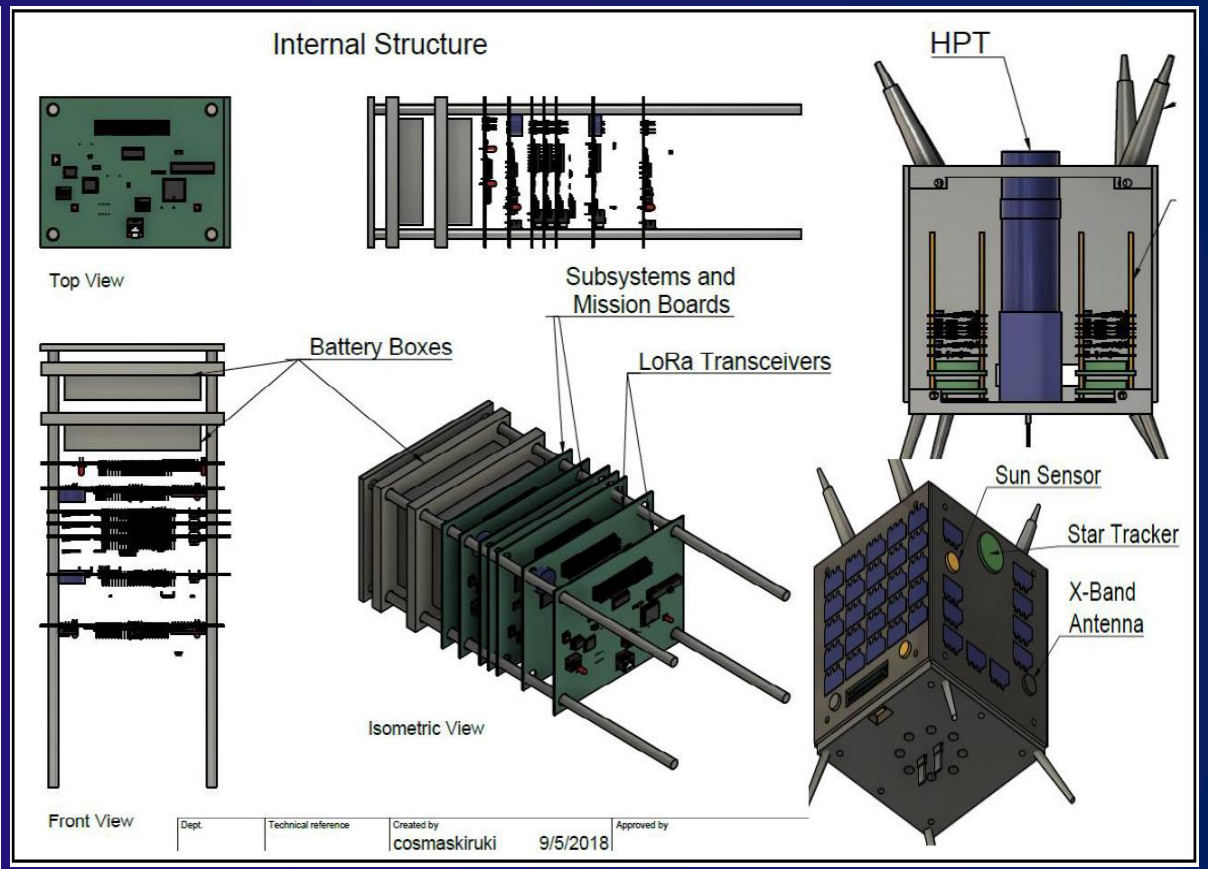
b) LandSat 8 : 15 meters (panchromatic); 30 meters (visible); 100 meters (thermal)

Key Performance Parameters

- Tracking updates – 30 minutes interval
- Flash Floods monitoring – 15 minutes update
- Ground Spatial resolution – 30 meters

Space Segment



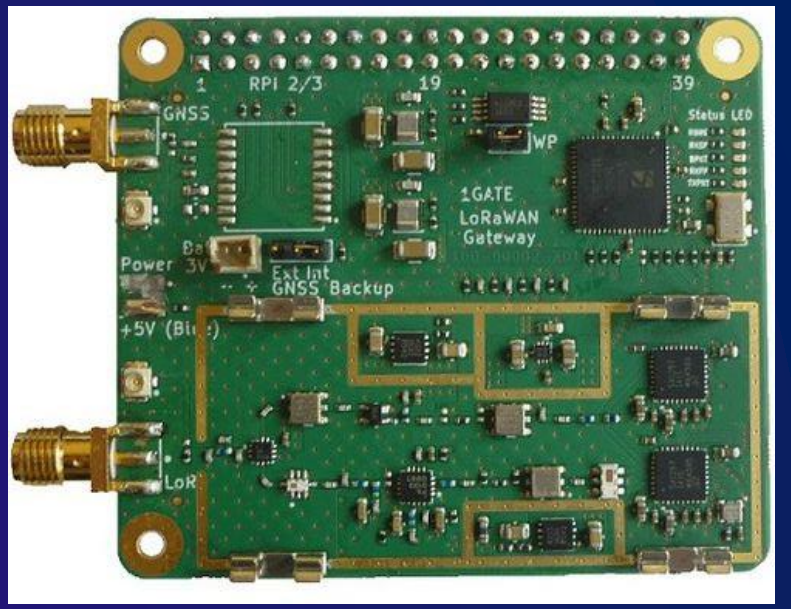


- 50 cm x 50 cm x 50 cm
- HPT- 38 cm × 16 cm × 13 cm.

Major Mission Payloads

LoRa Transceivers

- ASAL-SAT - 4 LoRa Transceivers
- Simultaneous on 8 channel; 6 SFs per channel = 48 ground gateways
- Half Capacity utilized – 25 ground gateways simultaneously (100 total)
- 10 byte packet takes about 741 ms – Time on Air (TOA)

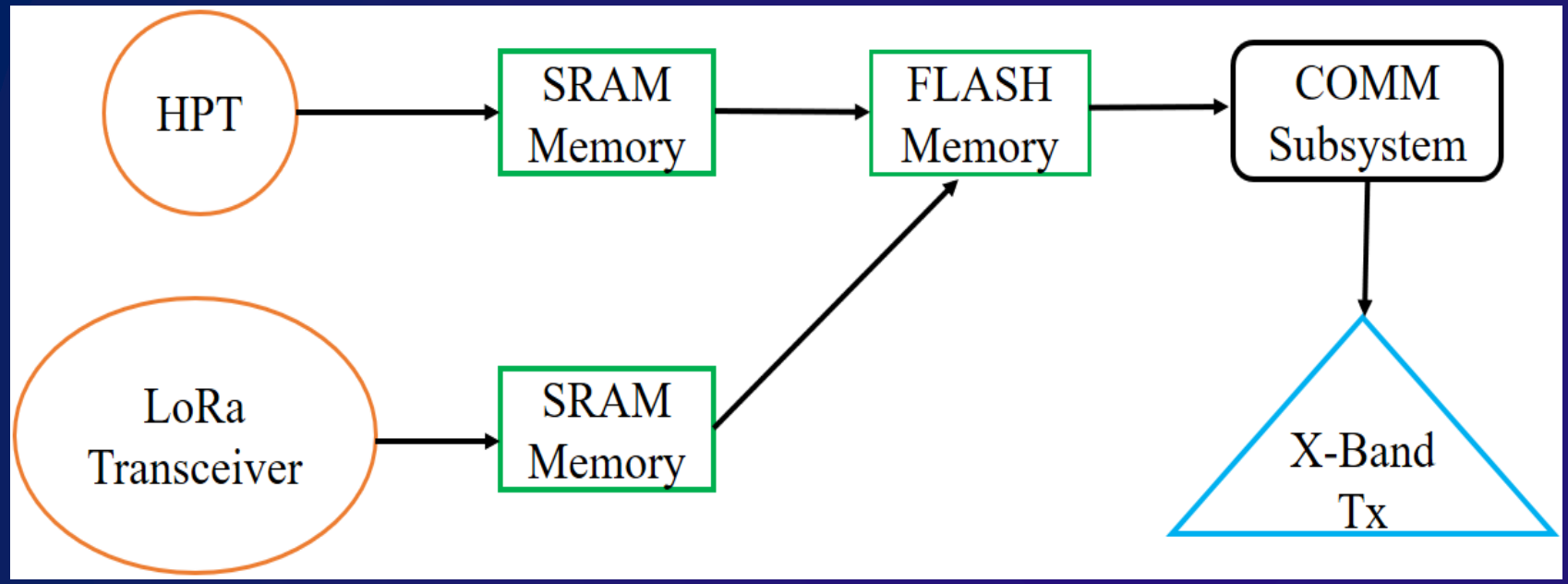


High Precision Telescope (HPT)

- Field of view of 0.28^o by 0.21^o
- 2 km x 1.5 km
- Temporary image storage - Static Random-Access Memory (SRAM)

Image: HPT, Junichi Kurihara et. al

Store and Forward



Other Subsystems

❑ ADCS

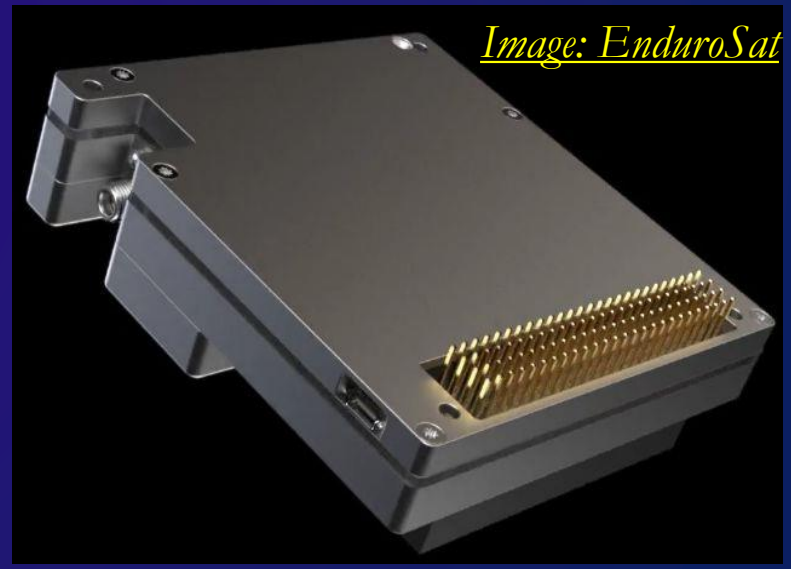
- Orienting HPT for desired location image capture
- Antenna pointing for ground LoRa network

- **Determination**: Sun sensor (coarse), Star Tracker Camera (fine); GPS (Earth-reference); Gyroscopes, Magnetometer

- **Actuators**: 3 – Axis stabilization by Reaction wheels; Magnetorquers

❑ Communication

- X- band
  - ➢ 8.3 GHz
  - ➢ Imagery telemetry, up to 50 Mbps
- UHF
  - ➢ TT & C



Endurosat X-band Transmitter

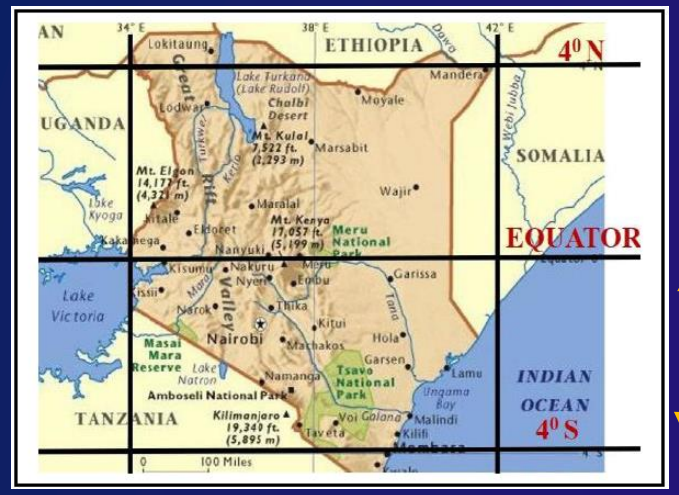
- 8.4 GHz
- 270 g

Subsystems Power and Mass Budget

No	Device	Mode	Power Consumption Idle (mW)	Power Consumption Peak (mW)	Mass (g)
1	4 LoRa Transceivers + Controller	RX and TX	500	3040	200
2	X-Band Transmitter	TX only	270	12000	300
3	UHF (TT&C)	RX	200	200	85
		TX	700	1700	100
4	HPT Imager		100	4000	3000
5	ADCS				
	Reaction Wheels	Idle	180	6000	760
	Star Tracker		100	7000	2200
	Sun Sensor		120	120	15
	GPS Receivers		240	950	47
6	OBC		400	2000	70
7	EPS, Solar Panels and Batteries			200	2500
8	Structure and harnesses				4500
	Total		**2810**	**37210**	**13777**

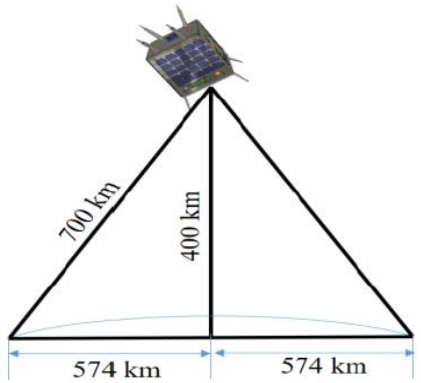
Orbit/Constellation Description

ASAL-SAT – Technology demonstration



~ 450 km

~ 450 km



$$FSPL\,(dB) = Link\ Budget - Link\ Margin = 151 - 3$$
$$= 148\ dB$$
$$20\ log_{10}(d) = 148 + 147.55 - 20\ log_{10}\,(868\ x\ 10^6)$$
$$= 116.78\ dB$$
$$d = 690\ 240\ metres \approx 700\ km$$

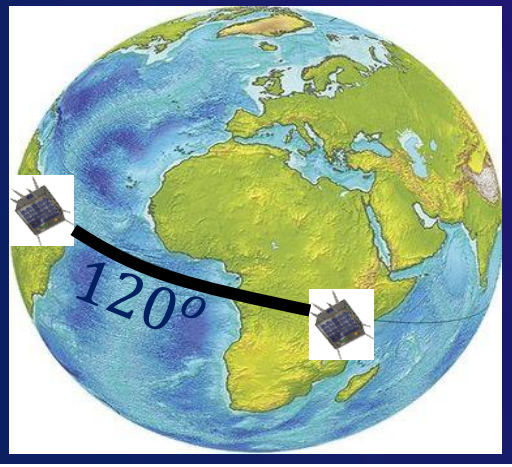
Thus, ground coverage distance from nadir point on the equator is

$$R = \sqrt{700^{\,2} - 400^{\,2}} = 574\ km$$

400 km, equatorial orbit – Kenya fully covered

Satellite Constellation

Image: RCMRD ,Kenya Map



Equatorial orbit – 14 revs per day (100 mins)

3 satellites (120^o) – revisit time 30 mins

Implementation Plan - Stakeholders

- ASAL-SAT – Kenya Chapter

Kenya Space Agency

- Ground Stations

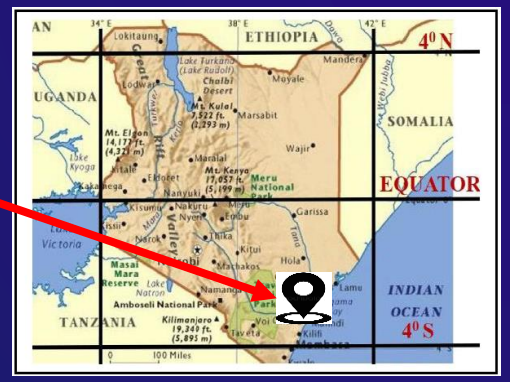


Image: Luigi Broglio Space Centre, Malindi Kenya

- X-Band station with a 6 m long parabola

- ASAL-SAT – Sub Sahara Adoption

HQ. Kenya

REGIONAL CENTRE FOR MAPPING OF RESOURCES FOR DEVELOPMENT

BOTSWANA, BURUNDI, COMOROS, ETHIOPIA, KENYA, LESOTHO, MALAWI, MAURITIUS, NAMIBIA, RWANDA, SOMALIA, SOUTH AFRICA, SOUTH SUDAN, SUDAN, ESWATINI, SEYCHELLES, TANZANIA, UGANDA, ZAMBIA, ZIMBAMBWE

- Data Dissemination

Govt. Kenya

County Govs.

Local Media Stations

GSM/USSD

Implementation Plan - Partners

Cost Schedule

Cost Center	Unit Cost (USD)	Total Cost (USD)
20 Kg Satellite Hardware and Assembly (3)	200,000	600,000
Satellite tests and transportation		200,000
Human Resource (Initial 3 years)		700,000
Launch (100 Kg class)		3,000,000
Operational Costs for 3 Years (after launch)		1,000,000
Total		**5,500,000**

Technology Demonstration Partners

Kyutech CeNT Test Facility

JAXA

ISS Kibo Module

Not Equatorial (51.6^0)

Equatorial Orbit

- H ~ 500 km
- L ~ 3 - 5 Yrs

Thank You