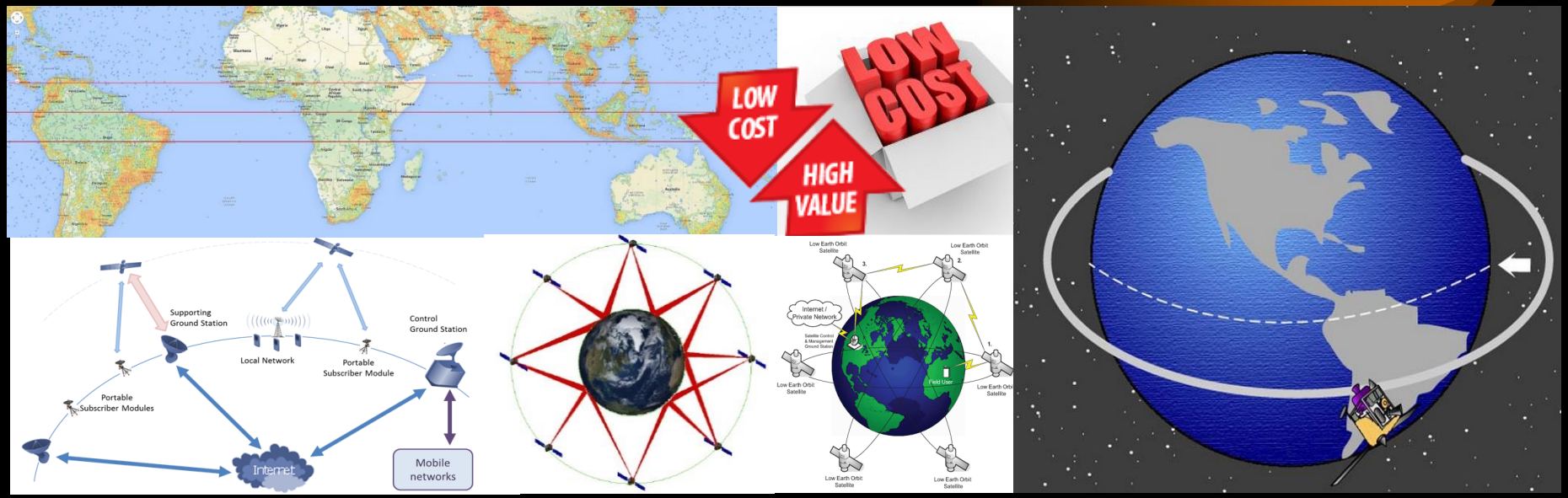
Low cost communication network for Equatorial remote areas



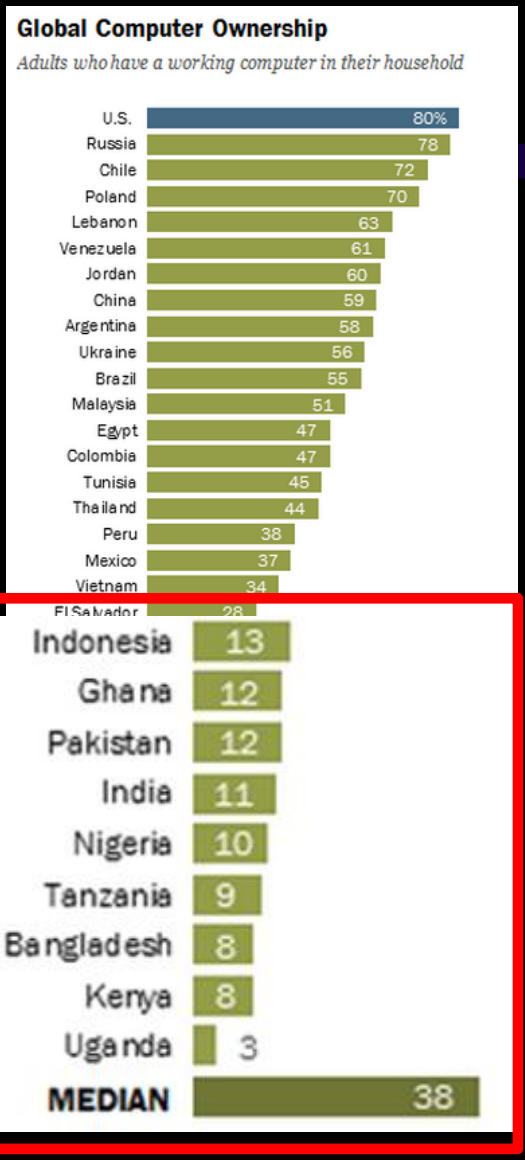
Pre-4th Mission Idea Contest, 3rd UNISEC Global Meeting
4 July 2015, Takeda Hall, Asano Campus
University of Tokyo, Japan

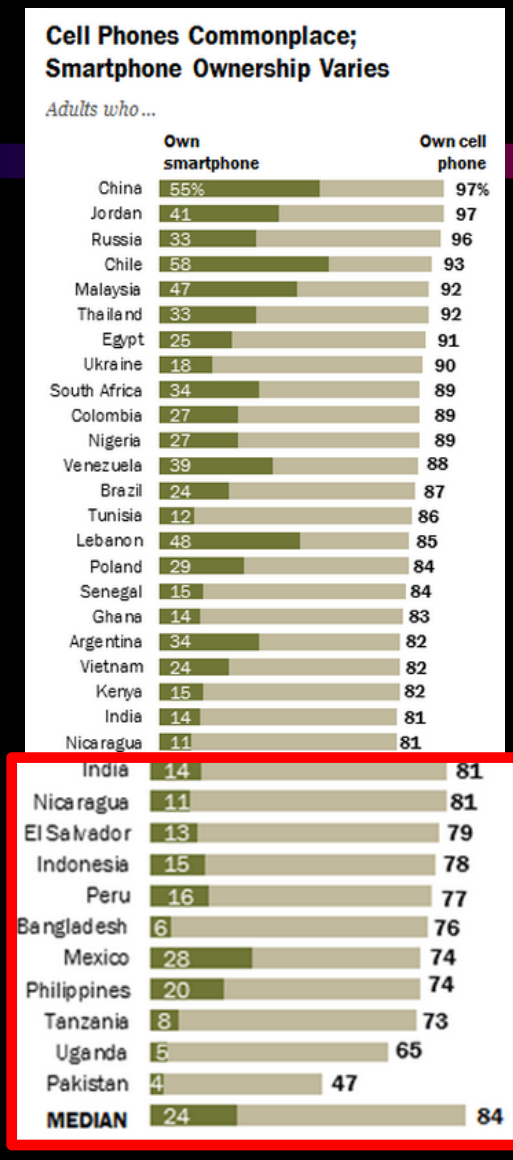
Presented by
BENDOUKHA, SIDI AHMED
DURAN, ADELAIDA CASTILLO

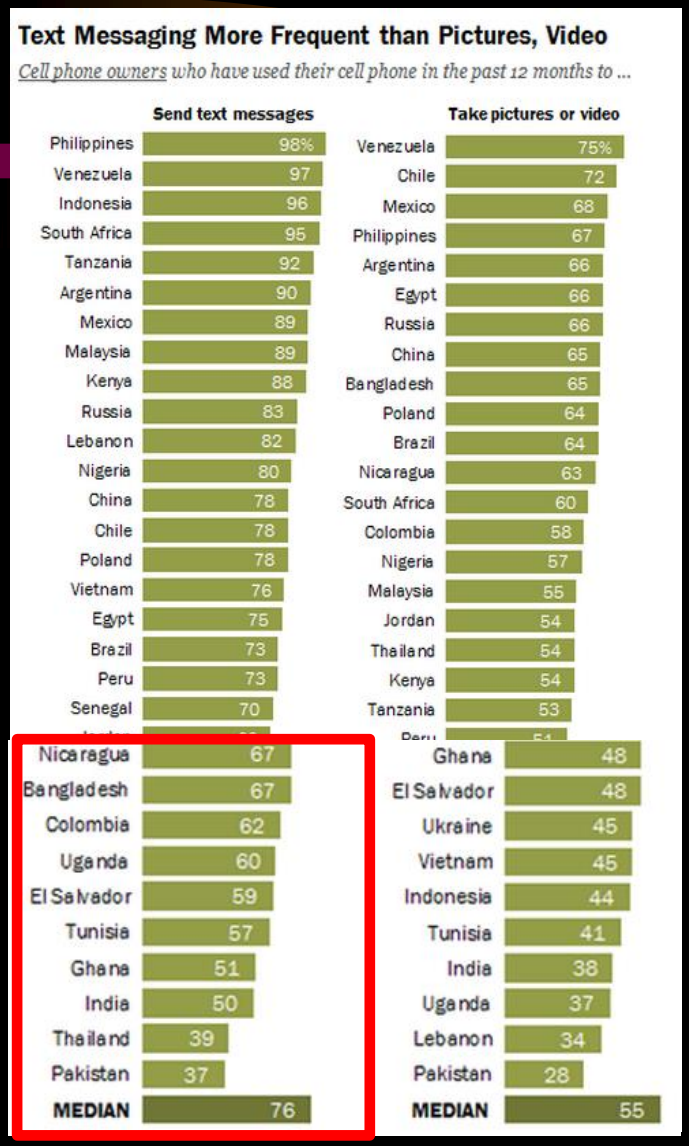
Outline of the Presentation:

1. Introduction
2. Mission Objectives
3. Concept of Operations
4. Orbit and Constellation Design
5. Mission key performance parameters
6. Space segment design
7. Implementation plan
8. Conclusion

Global Situation -- Access to Communication?

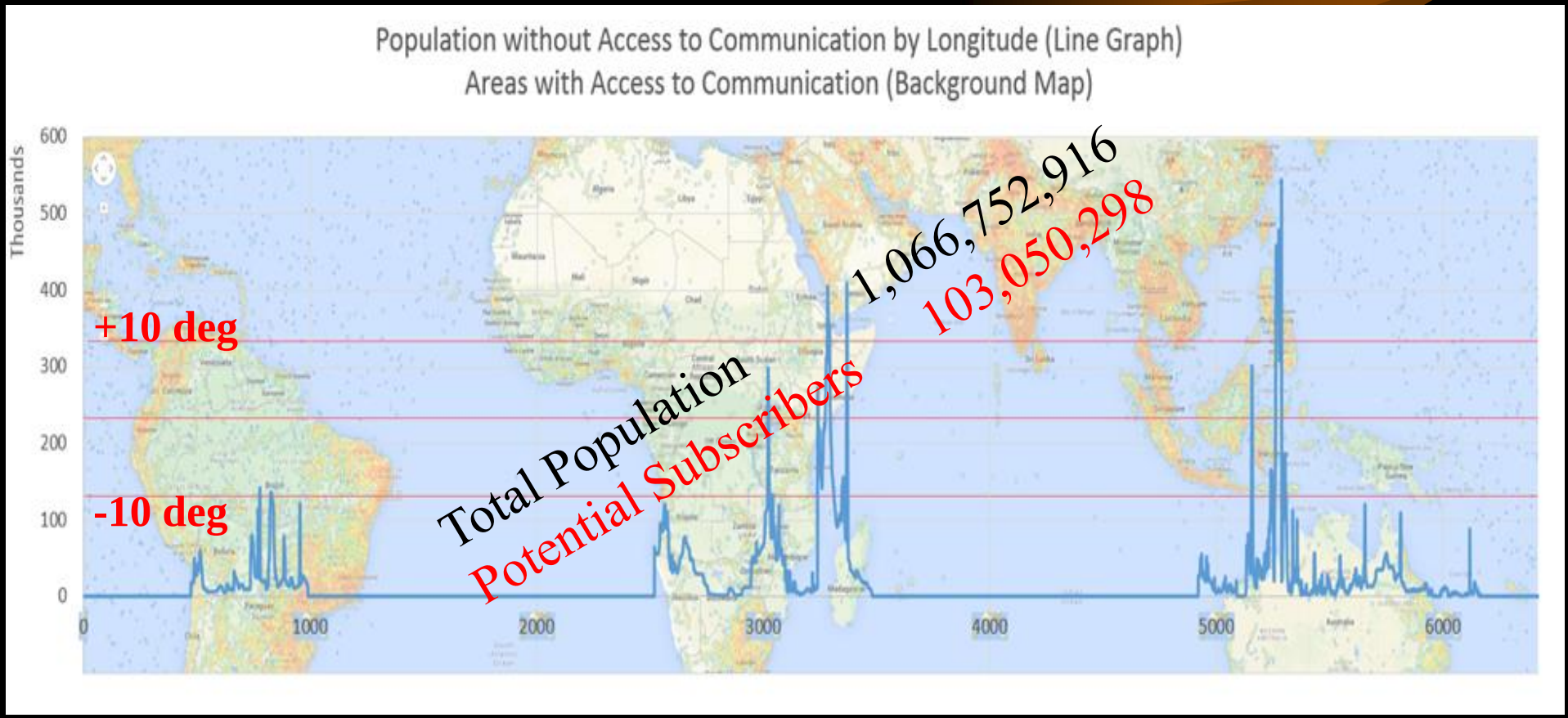






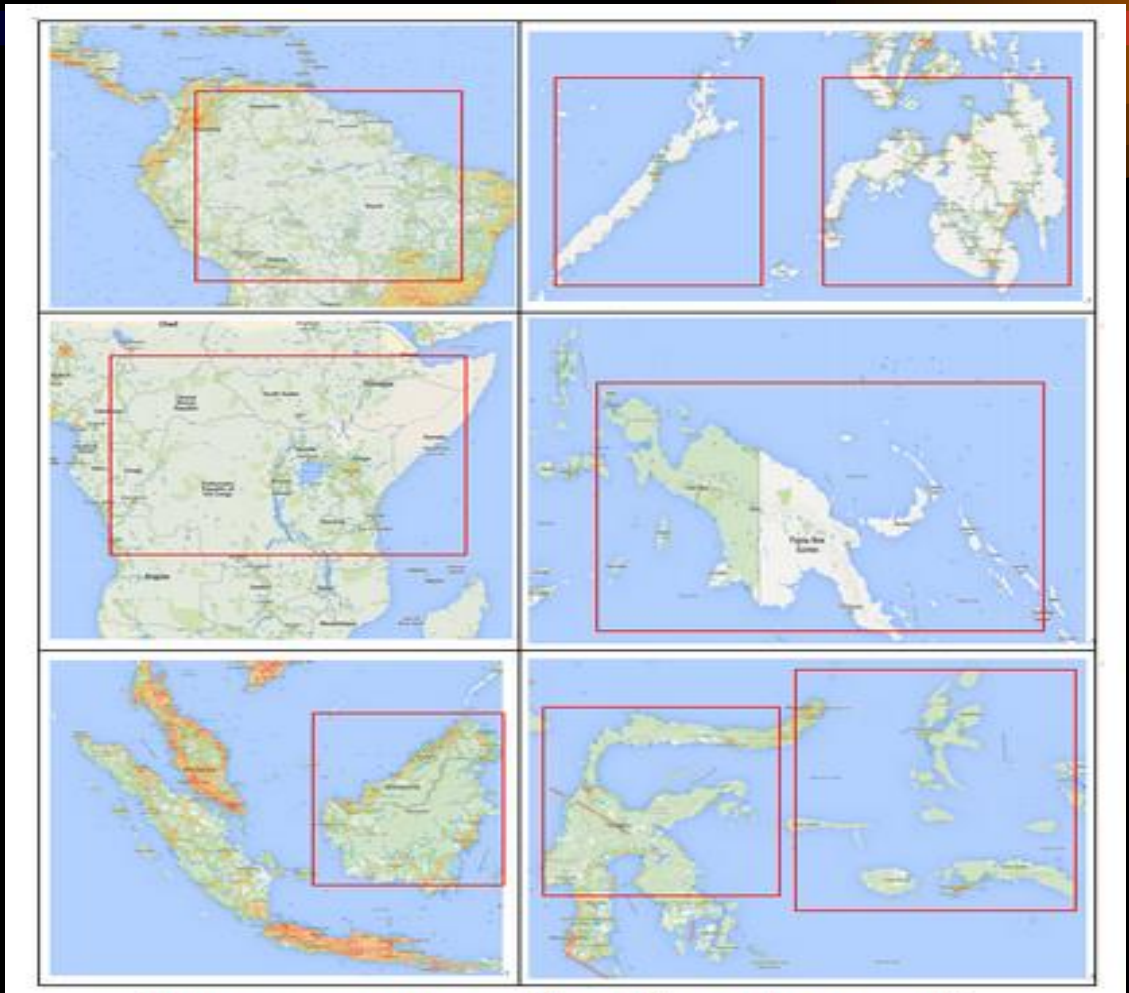
http://www.pewglobal.org/2015/03/19/1-communications-technology-in-emerging-and-developing-nations/

Population without Access to Communication ?

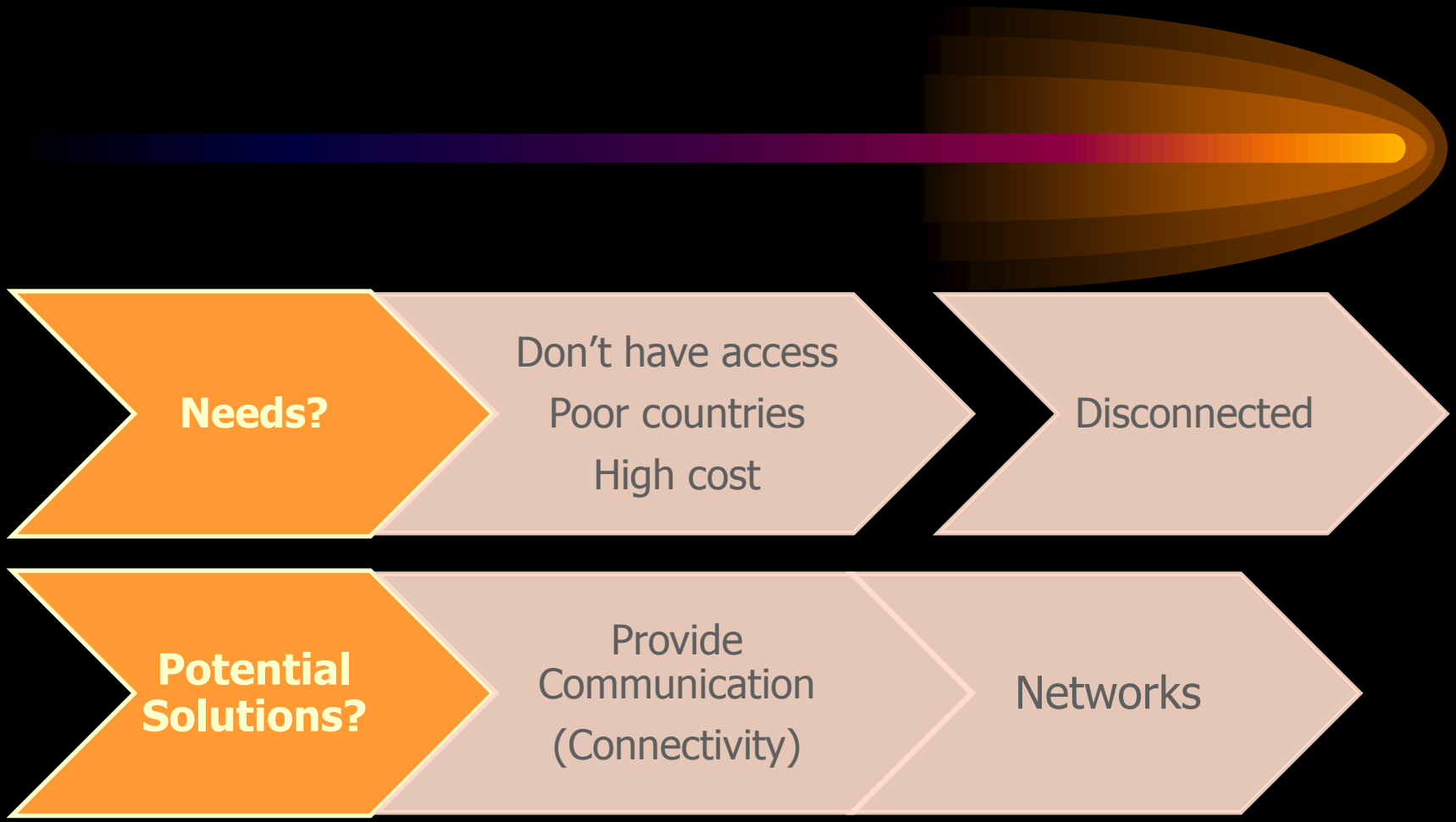


Source: SEDAC / EOSDIS and http://opensignal.com/

1. South America
2. Central and Southern Africa
3. Southeast Asia (Malaysia-Indonesia Peninsula, Southern Philippines)
4. Pacific Islands (Indonesia-Papua New Guinea Regions)



Target areas represented by red boxes (not to scale).
Considered only areas without access to Communications


Needs?
Don't have access
Poor countries
High cost
Disconnected
Potential Solutions?
Provide Communication (Connectivity)
Networks

How to solve the connectivity problem in Equatorial Region remotes areas?

- ✓ Wired and mobile communications
  -- fast, easy but limited coverage

- ✓ Communication via satellite
  -- good quality but high cost

Question that needs to be addressed -- Mission Idea?

How to provide a SMS/MMS communication at a relatively low cost for developing countries along the Equatorial Region?

Low cost communication network for Equatorial remote areas

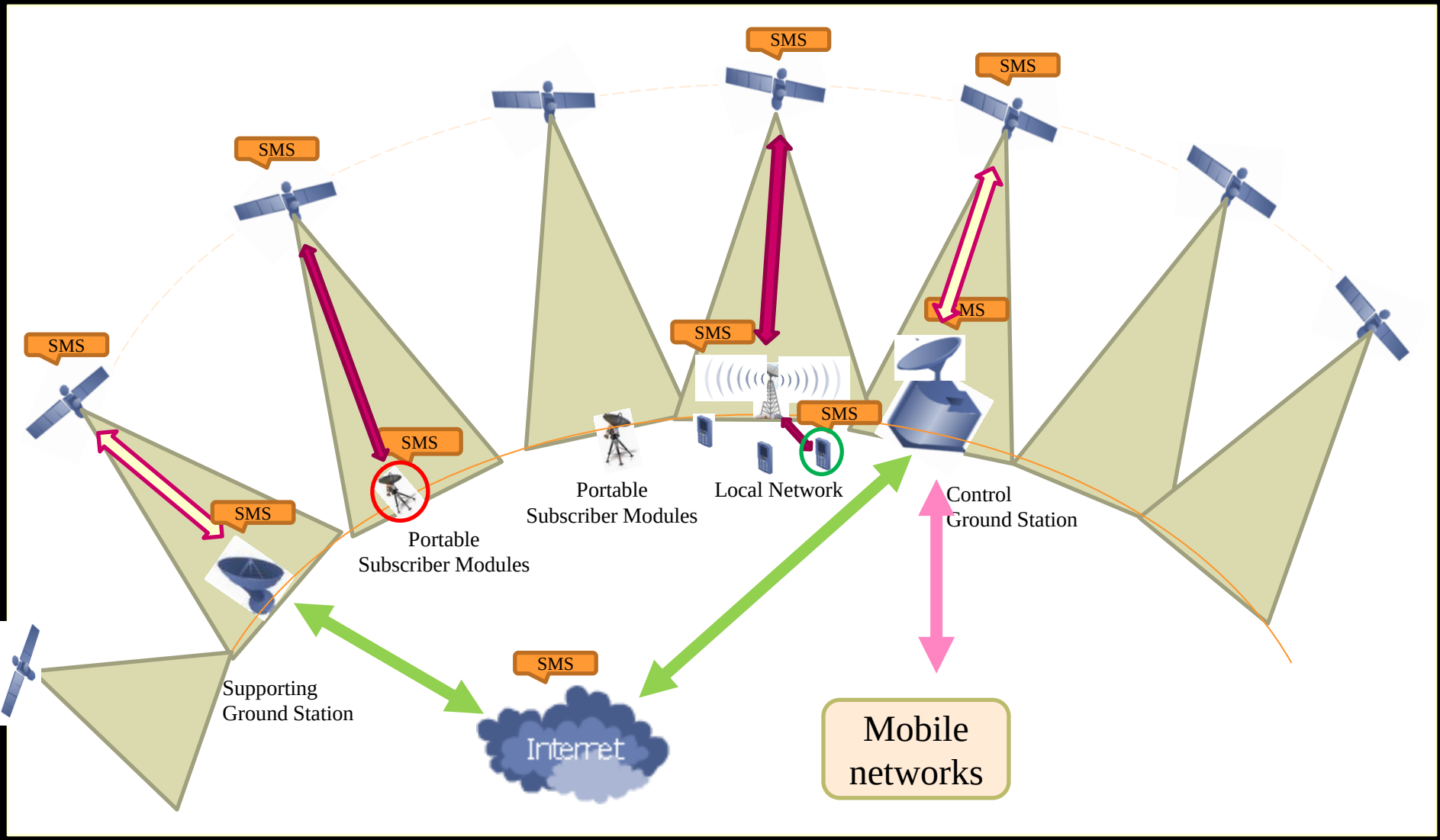
Dmytro Faizullin, Adelaida C. Duran, Rahmi Rahmatillah,
Rafael Rodriguez, Sidi Ahmed Bendoukha, Okada Yumiko,
and Fumito Kuroiwa

faizullindr@gmail.com, o595301d@mail.kyutech.jp, o350941r@mail.kyutech.jp, rafael@es.ise.kyutech.ac.jp,
ben.sid@hotmail.fr, o350908y@mail.kyutech.jp, o350912f@mail.kyutech.jp

Mission Objectives

- Demonstrate the capability of satellite constellation in equatorial region for providing stand-alone communication.
- Provide SMS and MMS services at low cost

Mission Concept



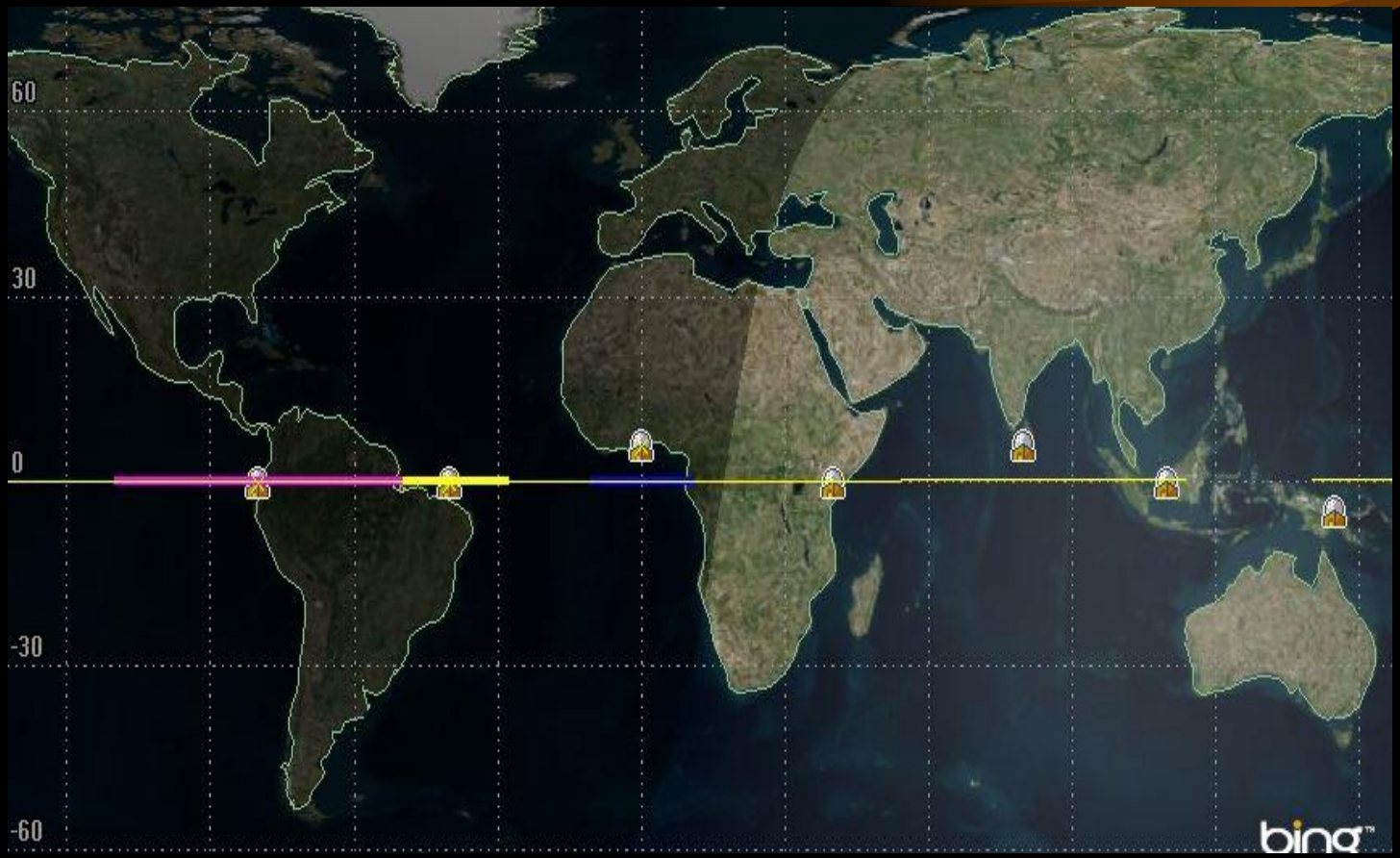
Orbit and Constellation Design

1. **Earth Coverage in terms of Latitudes**
   - ✓ Field of view of payload (FOV) ± 50 deg
   - ✓ Latitudes for coverage area bigger than 10 deg
2. **Time delay**

   Time delay less than 1 hour was chosen for current project, computed base on the following

   - ✓ Altitude of satellite (1000 km)
   - ✓ Number of satellites (04)
   - ✓ Number of ground stations (07) from -80 to +150 deg

Location ground segment: 07 ground stations located in Equatorial planeusing STK software for plot



Dependence of altitude from FOV of payload and covered area in terms of latitude

Altitude(h),km FOV(α). deg	500	600	700	800	900	1000	1100	1200	1300	1400	1500
30	2.6	3.2	3.7	4.2	4.8	5.3	5.9	6.4	7.0	7.6	8.1
35	3.2	3.9	4.5	5.2	5.9	6.6	7.3	8.0	8.7	9.4	10.1
40	3.9	4.7	5.5	6.3	7.2	8.0	8.9	9.8	10.7	11.6	12.6
45	4.7	5.7	6.7	7.7	8.8	9.9	11.0	12.2	13.3	14.6	15.9
50	5.7	6.9	8.2	9.6	10.9	12.4	13.9	15.5	17.2	19.1	21.1
55	7.1	8.7	10.4	12.2	14.2	16.4	18.8	21.7	25.1	26.1	27.1
60	9.1	11.4	14.0	17.1	20.3	21.6	22.9	24.0	25.1	26.1	27.1
65	12.8	15.8	17.5	18.9	20.3	21.6	22.9	24.0	25.1	26.1	27.1
70	14.0	15.8	17.5	18.9	20.3	21.6	22.9	24.0	25.1	26.1	27.1

Revisit time of a ground station by satellites

Altitude, km		500	600	700	800	900	1000	1100	1200	1300	1400	1500
FOV, deg		65	60	55	55	50	50	45	45	40	40	35
Number of satellites	1	101,3	103,6	106,0	108,5	110,9	113,4	115,9	118,4	121,0	123,5	126,1
	2	50,6	51,8	53,0	54,2	55,5	56,7	57,9	59,2	60,5	61,8	63,1
	3	33,8	34,5	35,3	36,2	37,0	37,8	38,6	39,5	40,3	41,2	42,0
	4	25,3	25,9	26,5	27,1	27,7	28,3	29,0	29,6	30,2	30,9	31,5
	5	20,3	20,7	21,2	21,7	22,2	22,7	23,2	23,7	24,2	24,7	25,2
	6	16,9	17,3	17,7	18,1	18,5	18,9	19,3	19,7	20,2	20,6	21,0
	7	14,5	14,8	15,1	15,5	15,8	16,2	16,6	16,9	17,3	17,6	18,0
	8	12,7	13,0	13,3	13,6	13,9	14,2	14,5	14,8	15,1	15,4	15,8
	9	11,3	11,5	11,8	12,1	12,3	12,6	12,9	13,2	13,4	13,7	14,0
	10	10,1	10,4	10,6	10,8	11,1	11,3	11,6	11,8	12,1	12,4	12,6

Time delay for transmitting message

Number of ground stations		1	2	3	4	5	6	7	8
Considered territory by longitudes, deg		360	360	-80 till +140	-70 till +150	-80 till +160	-80 till +120	-80 till +150	-80 till +140
Distance between ground stations, deg		360	180	110	80	60	40	40	35
Time between two ground stations, min		113,4	56,7	34,6	25,2	18,9	12,6	12,6	11,0
Number of satellites	1	226,8							
	2		163,3	153,9	125,6	106,7	87,8	87,8	83,0
	3		163,3	135,0	106,7	87,8	68,9	68,9	64,1
	4		135,0	97,2	97,2	78,3	59,4	59,4	54,7
	5		140,7	97,2	68,9	72,6	53,7	53,7	49,0

Cost Analysis

1. Cost of one satellite: 2M$
2. Cost of one ground station (GS): 350,000 $

Cost in Million Dollars		Number of Ground Stations							
		1	2	3	4	5	6	7	8
Number of Satellites	1	2.35	2.7	3.05	3.4	3.75	4.1	4.45	4.8
	2	4.35	4.7	5.05	5.4	5.75	6.1	6.45	6.8
	3	6.35	6.7	7.05	7.4	7.75	8.1	8.45	8.8
	4	8.35	8.7	9.05	9.4	9.75	10.1	10.45	10.8
	5	10.35	10.7	11.05	11.4	11.75	12.1	12.45	12.8

Efficiency coefficient of satellite communication system.

Efficiency = 1000/ (Cost * Time delay)

Efficiency		Number of Ground Stations							
		1	2	3	4	5	6	7	8
Number of Satellites	1	1.88	1.63	1.45	1.30	1.18	1.08	0.99	0.92
	2	1.01	1.30	1.29	1.47	1.63	1.87	1.77	1.77
	3	0.69	0.91	1.05	1.27	1.47	1.79	1.72	1.77
	4	0.53	0.85	1.14	1.09	1.31	1.67	1.61	1.69
	5	0.43	0.66	0.93	1.27	1.17	1.54	1.49	1.59

Mission Key Performance Parameters

1. Covered Area and message delivering time delay
   - ✓ Delivering time delay is maximum 60 minutes
   - ✓ Minimum Covered territory latitude is $\pm 10^{o}$
   - ✓ Revisit time of a ground station by satellites is 28.3 min
2. Data & Capacity
   - ✓ Data rate about 200 Kbps
   - ✓ SMS size is selected to be maximum 1kB
   - ✓ Capacity of one satellite is 25 messages per second

Listed key performance parameters using for the ground segment

3. Ground segment performance

Parameters	**Value**
Number of ground station	07
Location	80^{o} west and 150^{o} east longitudes
Distance between neighbor ground stations	40 degree along equator
Time passing between two GS Time passing stations	12.6 minutes 37.4 minutes
GS Antenna Type	Parabolic dish
Antenna efficiency	65%
Antenna gain	30dBi, -3dB beamwidth 2.9deg
Receiver sensitivity, BER	-138dB, 10^{-7}

User segment equipment has featuring continuous wave (CW) reception functions

4. User Segment

Parameters	Value
Power transmitted	02 watts
Internal antenna gain	16dBi
Bit rate of internal antenna	384kbps
Transmission rate Up to 1.5 Mbps	Connect to external antenna from terminal

To achieve all the operation it's important to have a suitable communication system

1. Communication System

- ✓ S- Band
- ✓ VHF/UHF Band

→ Link Budget Up& Down

2. C&DH

For this mission we need to consider a very reliable and redundant data storage system

- ✓ 200kbps data baud rate, provide 25 messages in 1 second, 2160000 messages in 1 day
- ✓ Equivalent to 2.16 GB transmitted data per day.

Space Segment Design

3. Attitude and Orbit Control System

- 3 axis stabilized.
- Attitude control accuracy has accuracy error for roll and pitch 0.0±0.5deg/3.0deg, for yaw 0.0±0.1deg/3.0deg

✓ AOCS consist of three parts:

- Sensors (3 Gyros, 1 GPS, 6 Sun-sensor, 1 Magnetometer)
- Microcontroller (Collects data from sensors)
- Actuators (4 Reaction wheels)

Space Segment Design

4. **Power System**

The power system shall be reliable and shall include redundancy for ensure the correct mission

- Satellite Consumption Power (100 Watts)
- Margin, 20% of power (20 Watts)

5. **Mass Budget**

The satellite mass requirements obtained by the mass budget estimation used as reference of design,

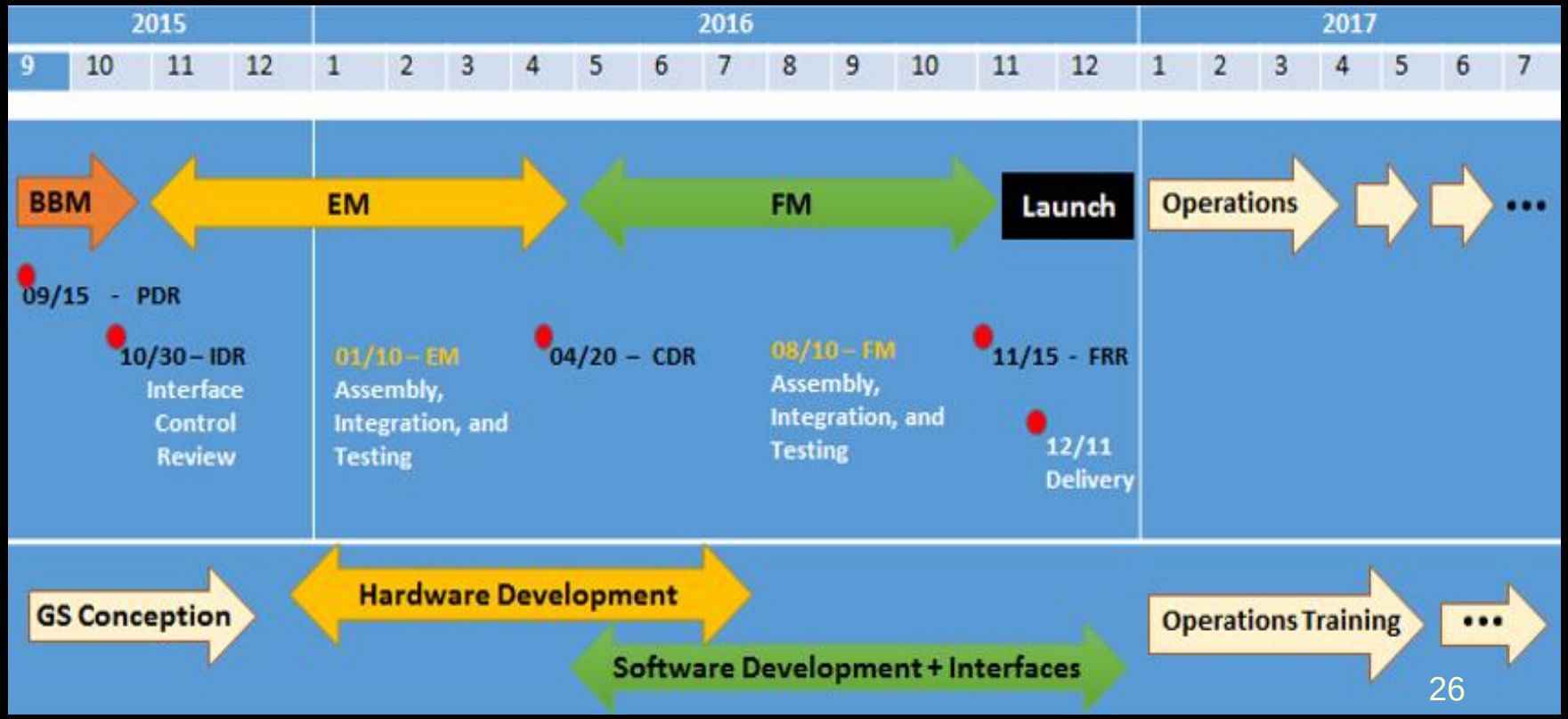
- Total mass (**40 kg**)

Implementation Plan

- Implementation of the project depends on multiple factors and consists of several steps
  - ✓ Technical part of project
    - Investigation of technical feasibility
    - Development
    - Production
  - ✓ Law regulation
    - Permission to build the ground stations
    - Frequency allocation
  - ✓ Service providers
    - Local government
    - Local network providers

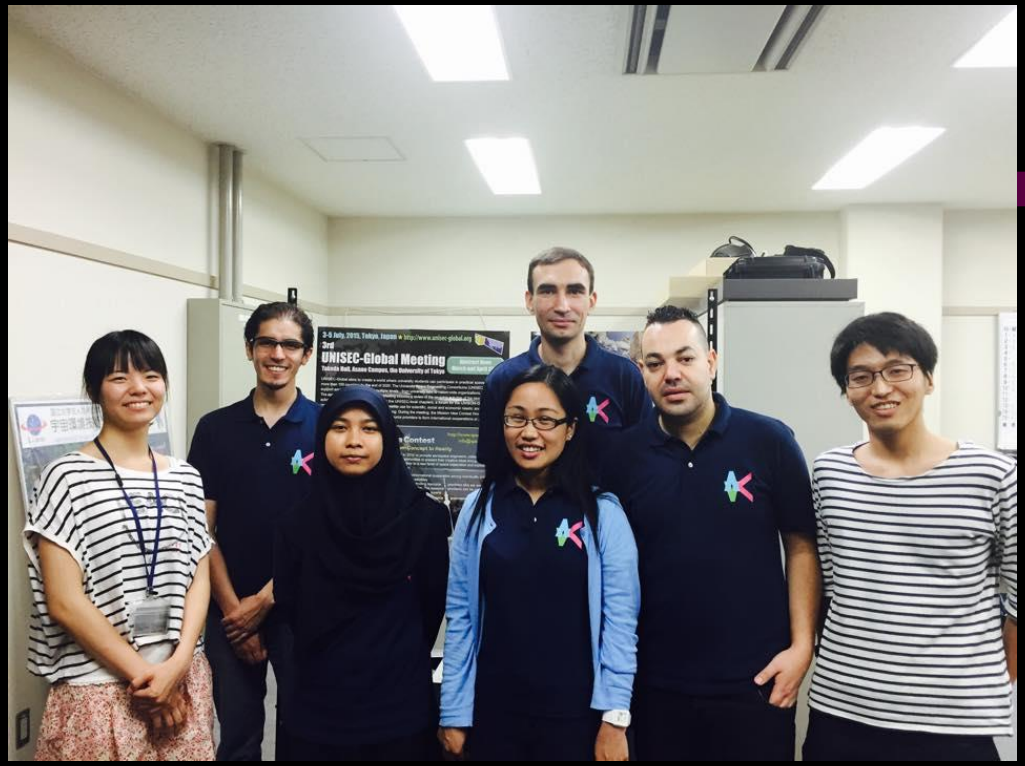
High level schedule for the proposed mission

- Plan presented in different steps classified in order including a feasibility study definition



Conclusion & Perspectives

- Opportunities for space science and satellites technology for developing countries(rural areas)
- Solving regional problems by international efforts
- The main purpose is having a minimum cost for communication that supports Equatorial region population
- The developed idea can be a performed by lean satellites because of the low cost and good enough technical capability



Thank you for your attention