



Nano-Satellite Constellation Collecting Global Pre-earthquake Signals for Space-borne Early Earthquake Detection

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- Collecting Pre-earthquake Signals
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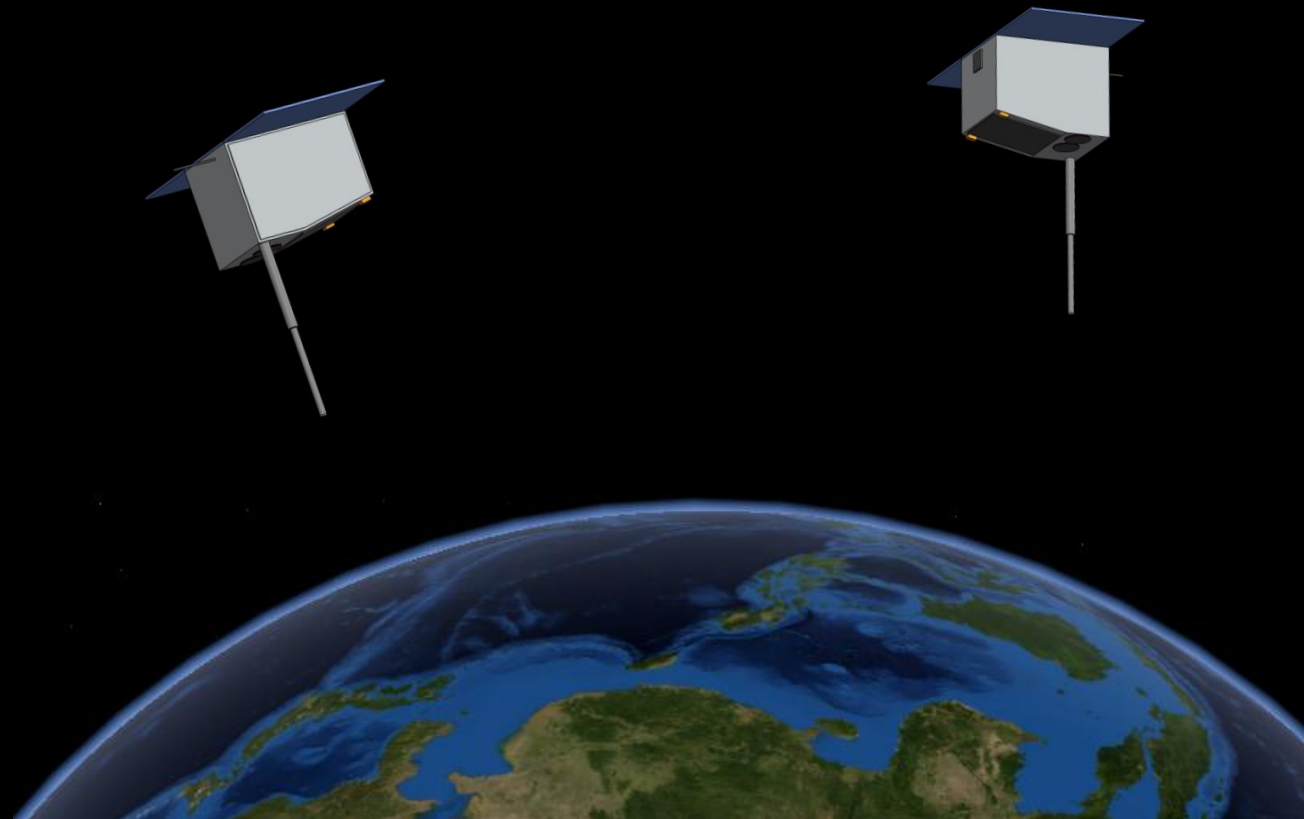
Mission Objective

A dedicated nano-satellite constellation

Collecting global pre-earthquake signals to create a public database

To facilitate the development of early earthquake detection technique

ELF magnetic field disturbance
Earthquake lights
Thermal anomaly
Ionospheric anomalies



Motivation

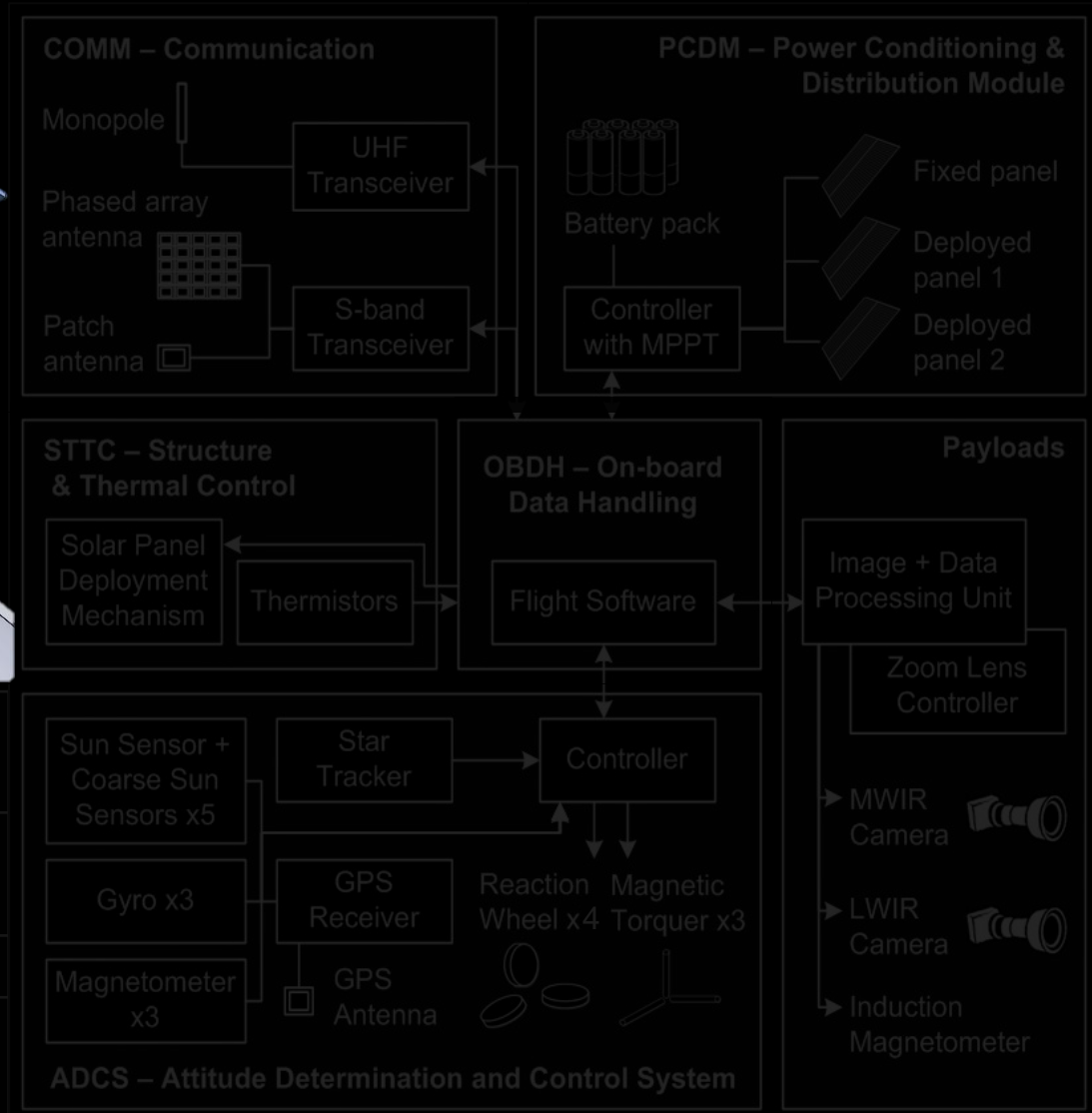
- 432,000 lives taken, 235 billion USD losses by Earthquakes (2008 – 2012)
- Previous ground based or space borne missions only provide single pre-earthquake signal
- Correlating of different data is difficult



Features

- Multiple instruments on a nano-satellite pair to record four pre-earthquake signals
- Public database for scientific community to research on early Earthquake detection

○ Nano-satellite Design



520 mm x 400 mm x 400 mm, 25.0 kg
62.4 W peak, 0.5 m² PV area

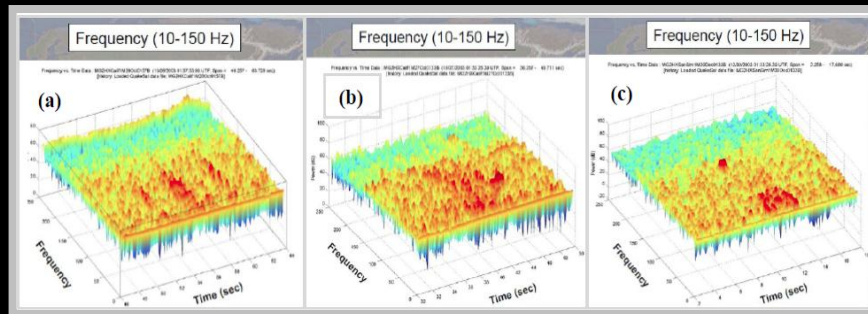
9600 bps UHF TT&C uplink/downlink
1 Mbps S-band data downlink

9600 bps S-band Ionospheric RF links

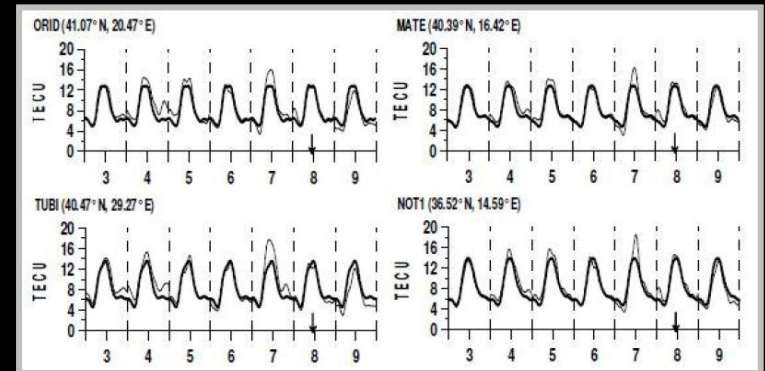
MWIR/LWIR cameras, Induction Magnetometer

Collecting Pre-earthquake Signals

Scientific payloads to collect different pre-earthquake signals globally ...



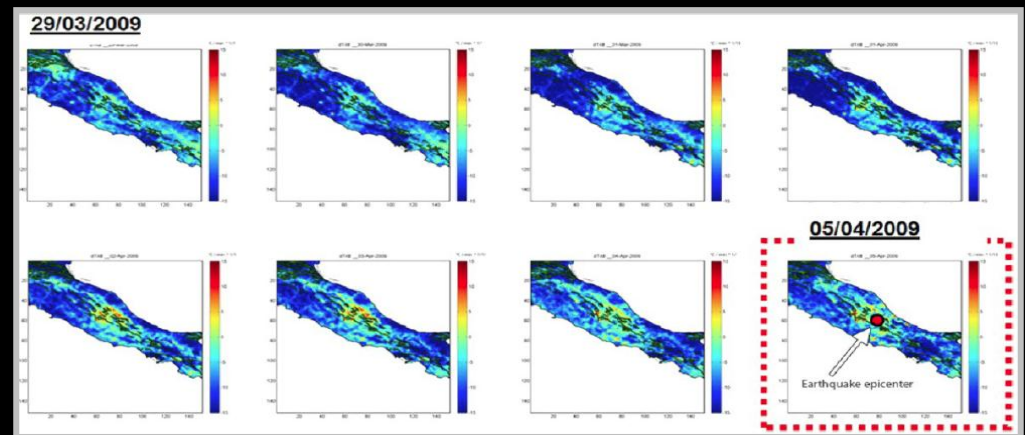
ELF observation by QuakeSat on San Simeon earthquake (a) 57 days before (b) 56 days before (c) 8 days after



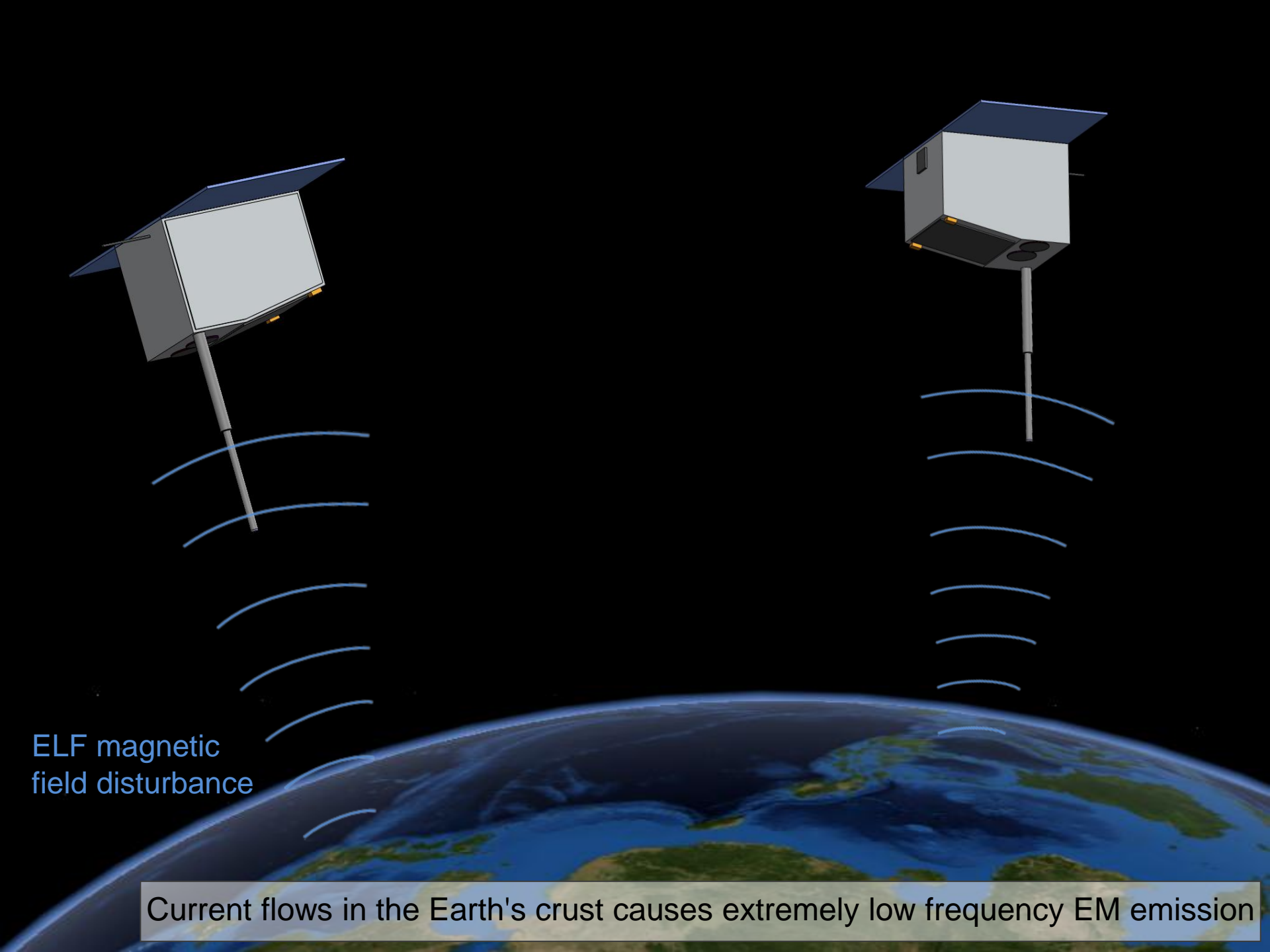
Variation of TEC for four GPS stations, arrow shows earthquake occurrence



Sketch of a luminous phenomenon as reported by witness

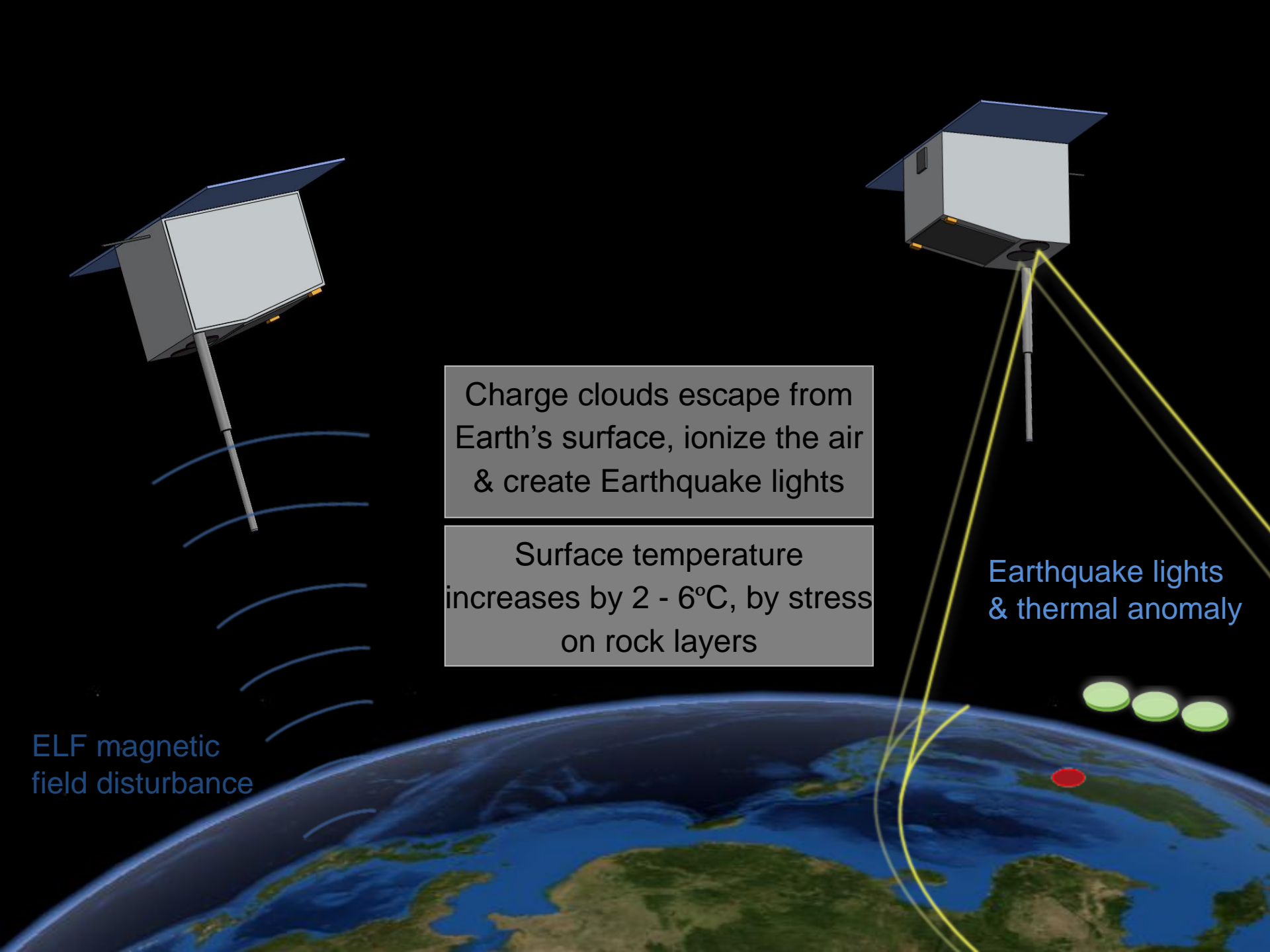


Night thermal gradient from 29th March to 5th April in Forli, Italy, caused by a magnitude 4.6 earthquake (photos by Meteosat)



ELF magnetic
field disturbance

Current flows in the Earth's crust causes extremely low frequency EM emission

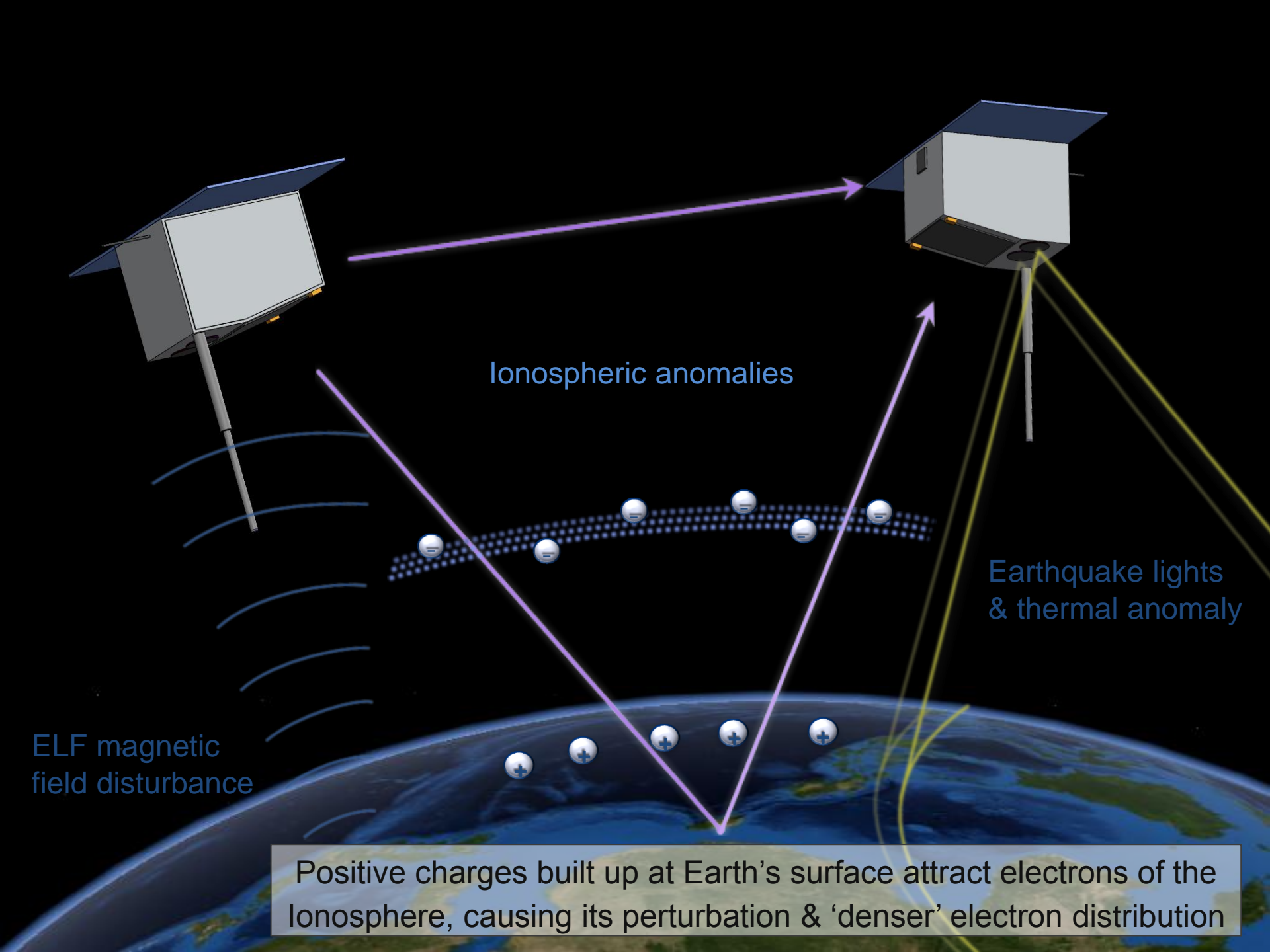


Charge clouds escape from Earth's surface, ionize the air & create Earthquake lights

Surface temperature increases by 2 - 6°C, by stress on rock layers

Earthquake lights & thermal anomaly

ELF magnetic field disturbance



ELF magnetic field disturbance

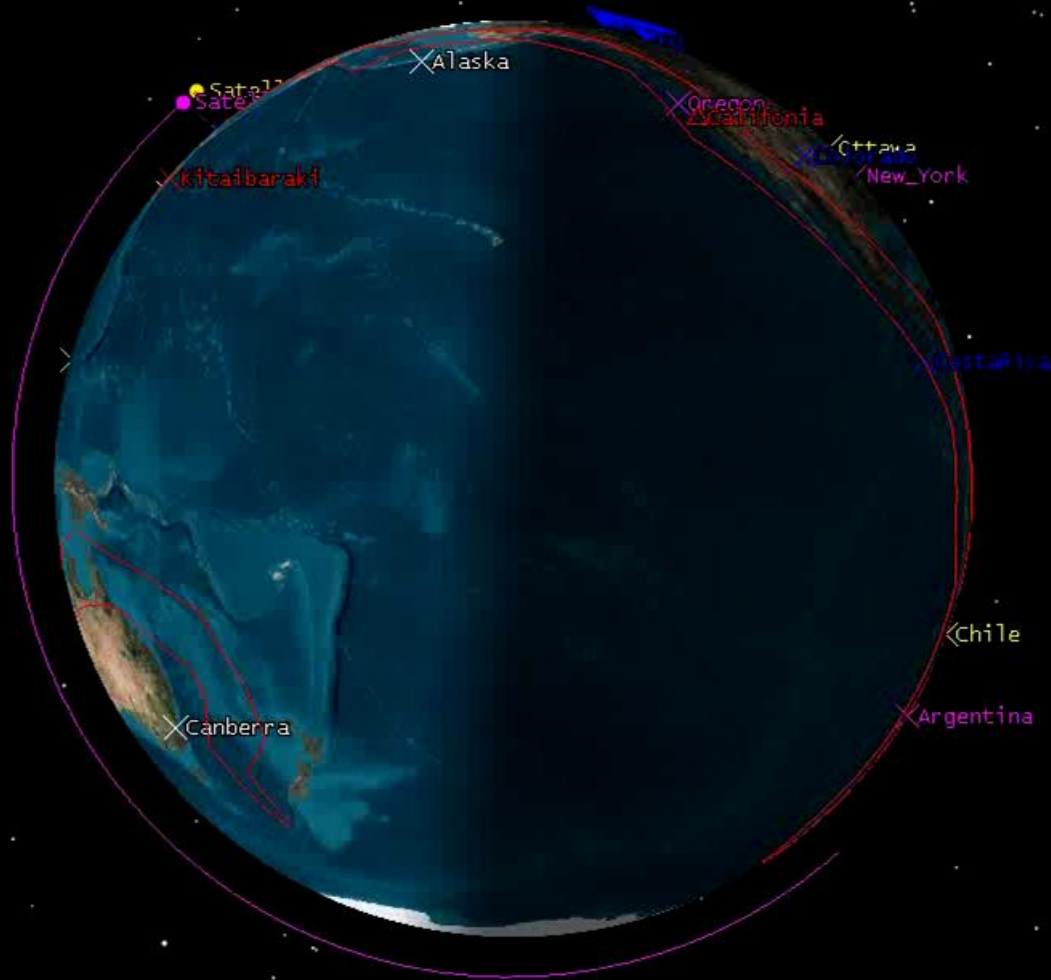
Ionospheric anomalies

Earthquake lights & thermal anomaly

Positive charges built up at Earth's surface attract electrons of the ionosphere, causing its perturbation & 'denser' electron distribution

Nano-satellite Constellation

Approved for MIC Use Only

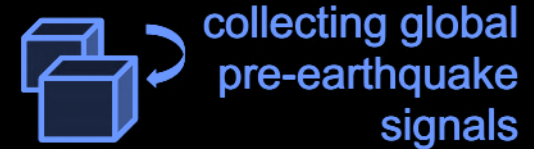


5ec

Sun-synchronous orbit at 600 km, 2° arc angle separation (243 km apart)

Concept of Operation

Earthquake Signals Satellites



data request +
missions upload

~ 15 M5.5+
earthquakes/month
Earthquake info


**USGS
Earthquake Data**


**Mission Control
Centre**

Earthquake
signals

selected data of
earthquake location

155 MB data/earthquake
for ± 15 days window

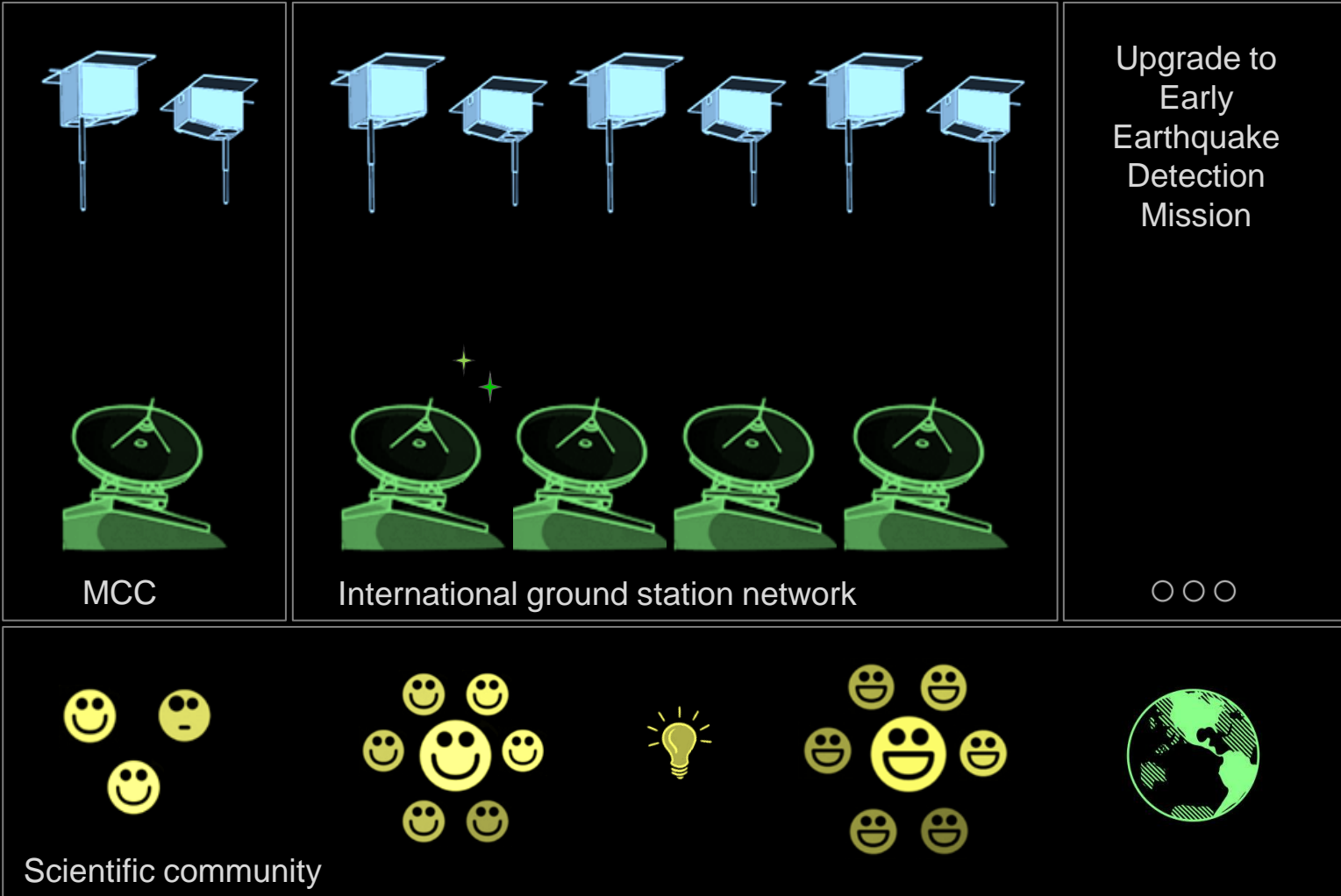
takes about 2 days to
download via 1Mbps link
1 GDSN can get data for
15 earthquakes/month

Earthquake
signals


**Earthquake
Signals Database**


Scientists

○ Implementation and collaboration



MCC

International ground station network

Upgrade to
Early
Earthquake
Detection
Mission

○ ○ ○

Scientific community

Conclusion

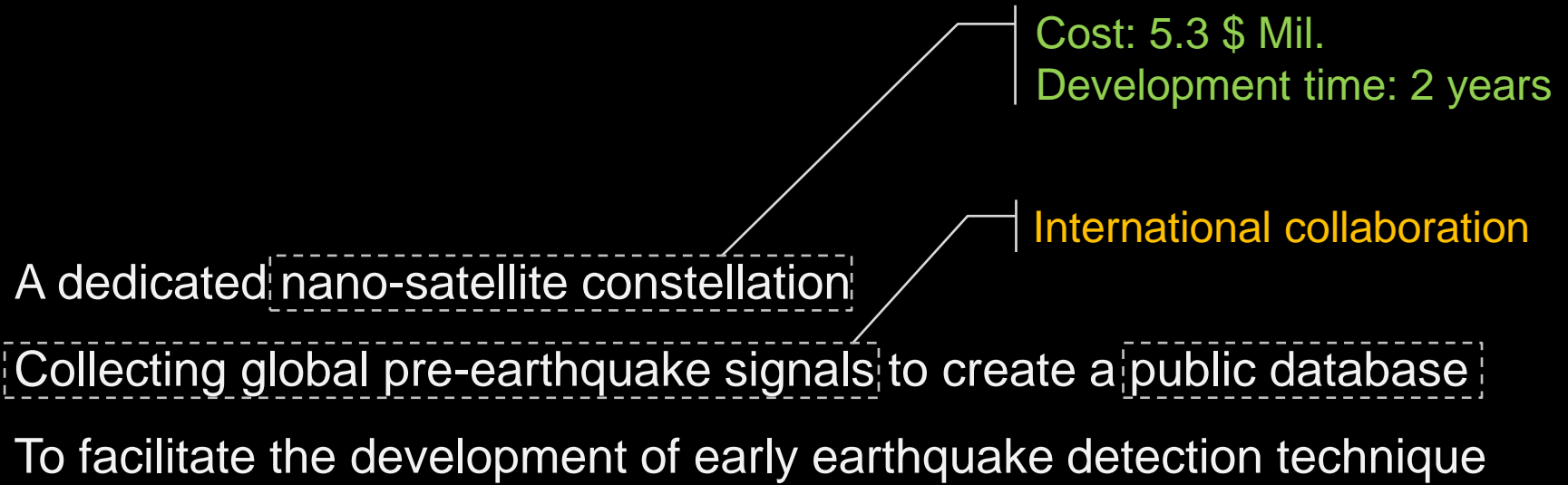
A dedicated nano-satellite constellation

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Conclusion

A dedicated nano-satellite constellation

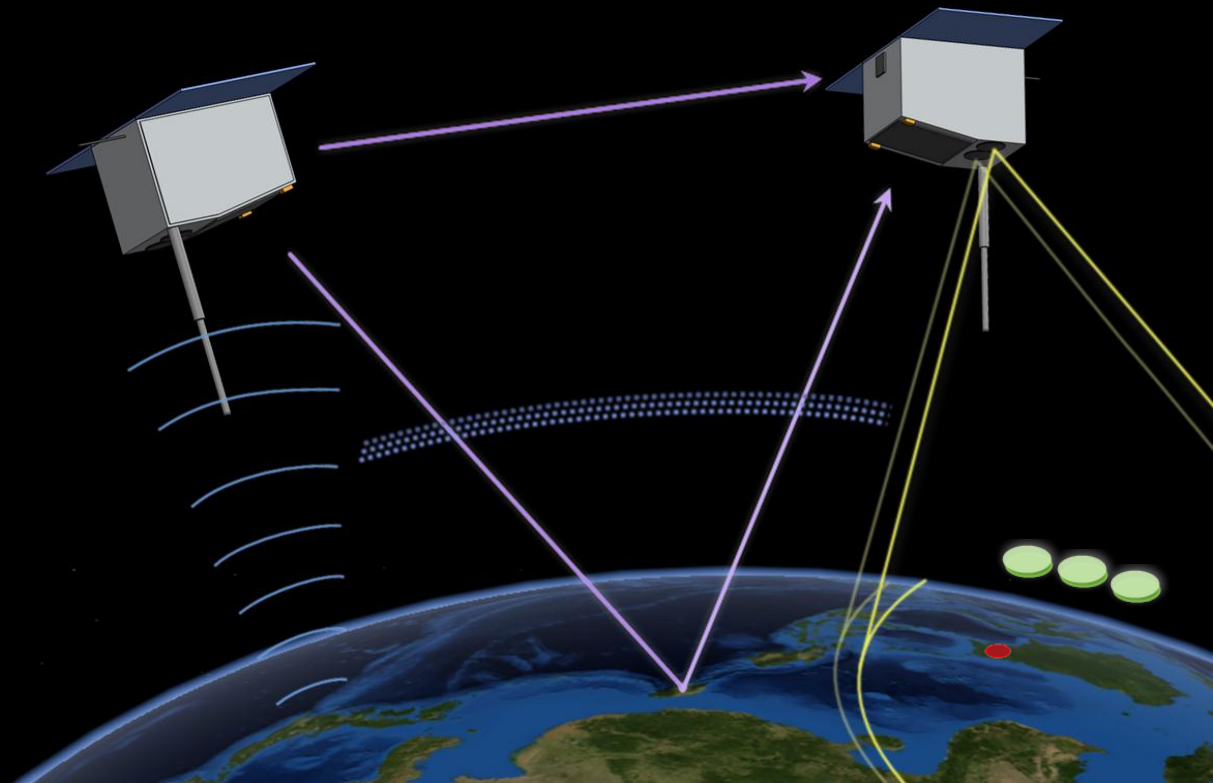
Collecting global pre-earthquake signals to create a public database

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Thank you !

Q&A

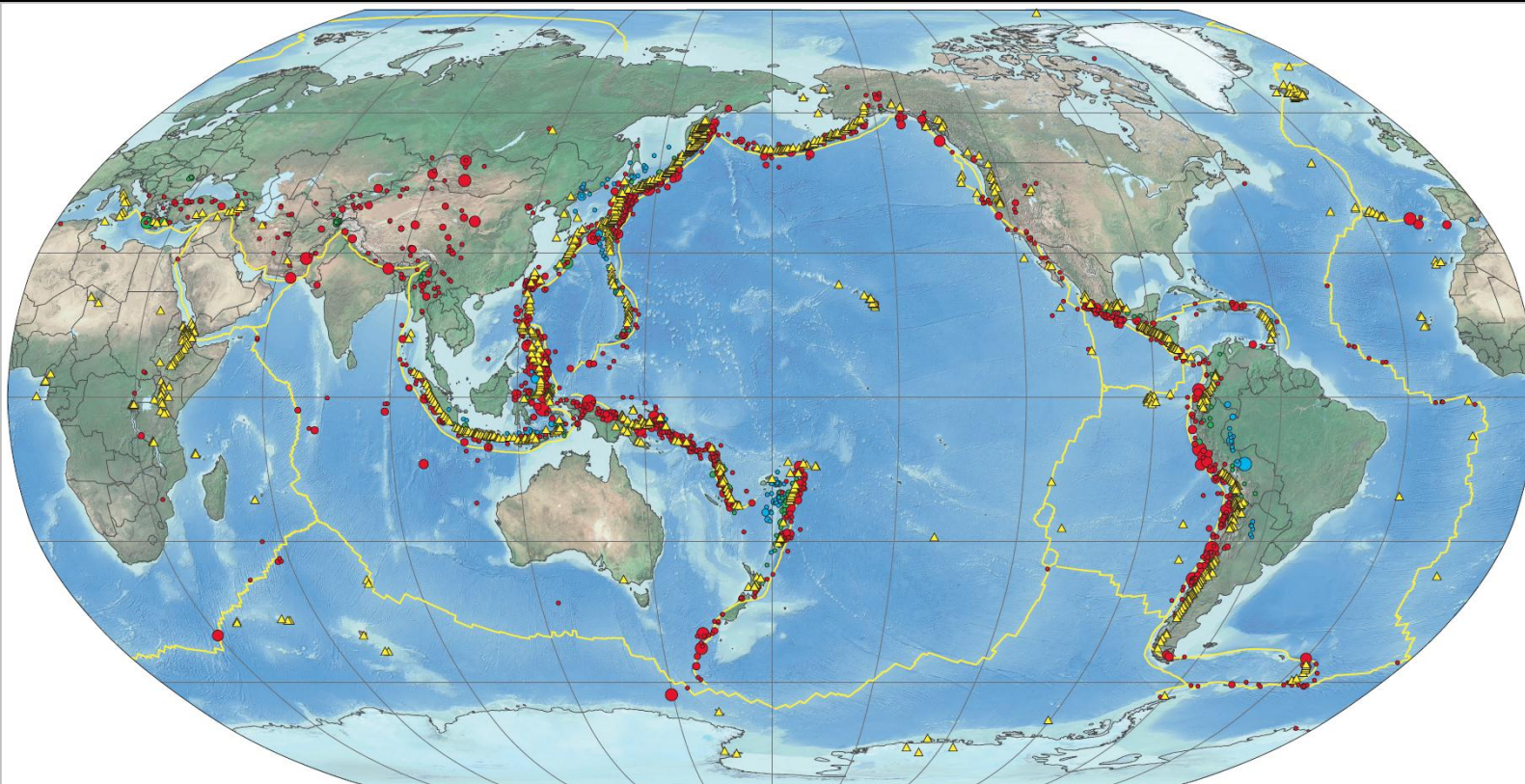


Extra slides



MAP EXPLANATION

- Magnitude classes
 - 4-5.9
 - 6-6.4
 - 6.5-6.9
 - 7-7.4
 - 7.5
 - 7.6
 - 7.7
 - 7.8
 - 7.9
 - 8.0
 - 8.1
 - 8.2
- Depth of focus
 - 0-69 km
 - 70-299 km
 - 300-700 km
- Nucleation points
- Rupture zones
- Active volcanoes
- Mean slab depth
 - 60 km
 - 100
 - 200
 - 300
 - 400
 - 500
 - 600
- Plate boundaries
 - Subduction
 - Transform
 - Divergent
 - Others

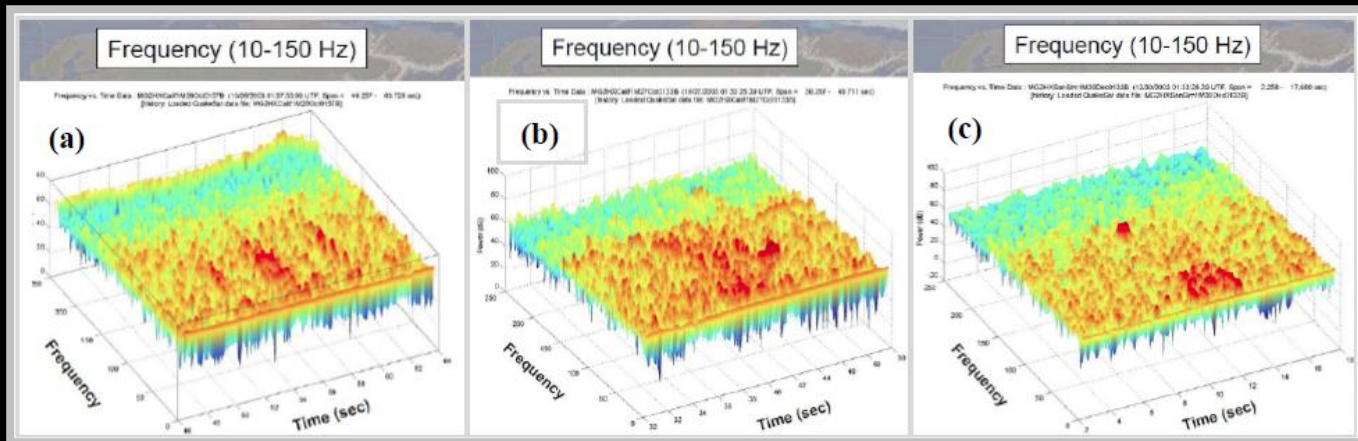


Earthquake map from USGS

Studies on Pre-earthquake Signals

- ELF Magnetic field disturbance

Current flows (positive holes flow horizontally & electrons flow vertically into lower crust) causes extremely low frequency EM emission ...



ELF observation by QuakeSat on San Simeon earthquake (a) 57 days before (b) 56 days before (c) 8 days after

Studies on Pre-earthquake Signals

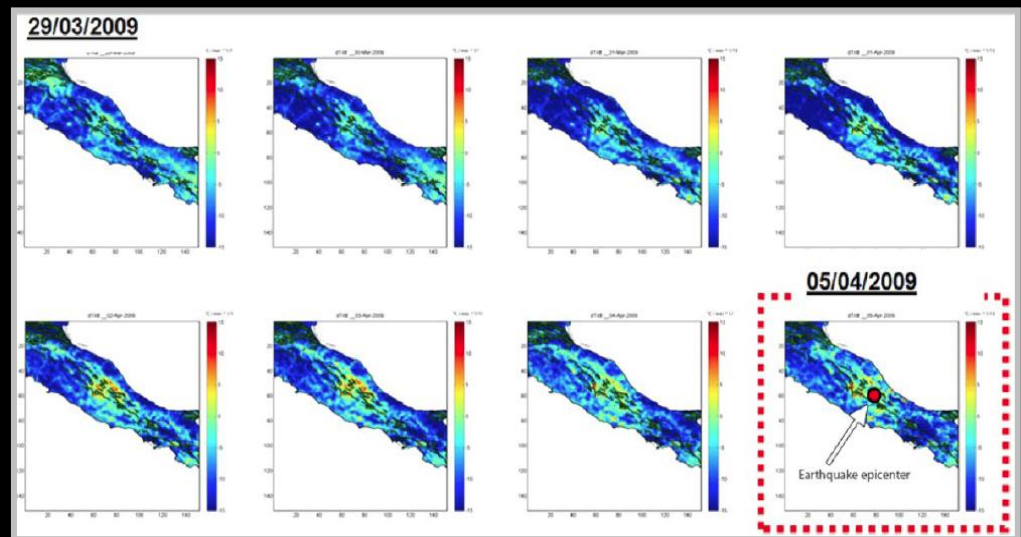
- Earthquake lights & thermal anomaly



Sketch of a luminous phenomenon as reported by witness

Up to 24 days before:
charge cloud escapes
Earth's surface, ionized the
air and create "aurora like"
lights, witnessed as far as
205 km from epicenter ...

6 - 24 days before Earthquake: Surface temperature increases by 2 - 6 degree C, by warm gas formation and rising ground water ...

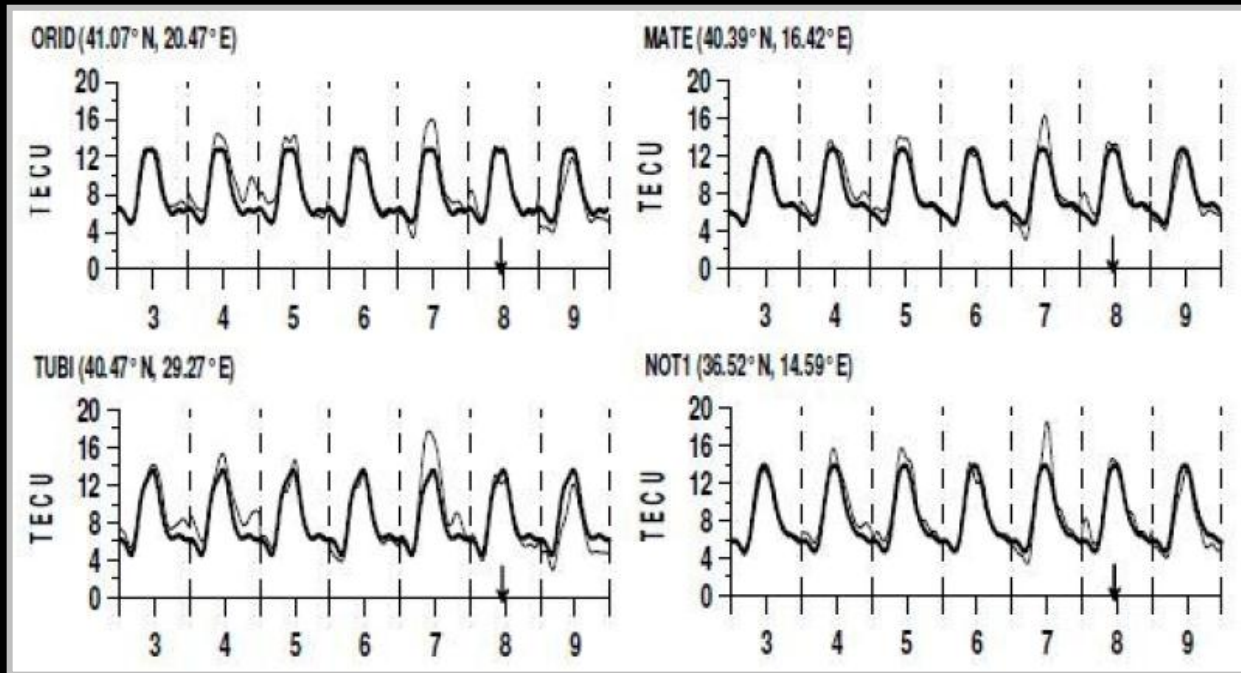


Night thermal gradient from 29th March to 5th April in Forli, Italy, caused by a magnitude 4.6 earthquake (photos by Meteosat)

Studies on Pre-earthquake Signals

- Ionospheric anomalies

Positive charges built up at Earth's surface attract electrons of the ionosphere, causes its perturbation and 'denser' electron distribution ...



Variation of TEC for four GPS stations. Thin line is TEC variation during Earthquake period, thick line is the median TEC variation, and arrow shows earthquake occurrence

Specification

Surveillance data	Description	Size (kB/sample)	No. of sample/day	Size (MB/day)
MWIR image	1024x768 pixels, 12-bit gray	1536	90	135.00
LWIR image	1024x768 pixels, 12-bit gray	1536	90	135.00
ELF measurement	Spectrum 1- 1000 Hz	8	10000	78.12
Ionospheric measurement	Link characteristics (power, phase shift, delays, etc.)	10	10000	97.66
Memory / satellite	4 x 8 GB SD cards	Data collected each day		445.78 MB
Storage	32 GB x 2	30-day archive (25% margin)		≈ 16.72 GB

Compiled data	Description of covered region around epicenter		Size (kB) / day
MWIR image	Reconstructed images of the 700 km x 700 km region		1200
LWIR image	Reconstructed images of the 700 km x 700 km region		1200
ELF measurement	Sample in a square grid of 24° longitude x 24° latitude		1280
Ionospheric measurement	Sample in a square grid of 24° longitude x 24° latitude		1600
Downlink rate	1 Mbps	Total	5280 kB
Downlink time	15 minutes/day	Data per earthquake (±15 days)	≈ 155 MB
RX data per day	110 MB	Transmission data size per day	77.5 MB

24° longitude = 2900 km @ 600-km altitude

6 images per orbit