Title: MENA Renewable Energy Source Mapping Via Nano-Satellite Mission
Primary Point of Contact (POC) & email: Ahmed Farid [1] – ahmed@farid-dev.net
Co-authors: Ahmed El Araby [2], Amr Sherif [1], Fatima Fouda [1]
Organization: [1] *October University for Modern Sciences & Arts (MSA)*, [2] *Cairo University*

Need

The demand for energy is increasing in the MENA region as populations continue to grow, and traditional energy sources as fossil fuels continue to be consumed. A clear long-term solution is to seek clean and renewable energy sources, but the locations to harvest the most amount of energy throughout the year are necessary. The proposed satellite mission aims to focus sensing capabilities to generate up-to-date climatic and spectral information solely for energy production purposes, given that currently known energy maps dating years back were produced by both large imaging satellites and relatively large meteorological stations.

Mission Objectives

Historical data of the region from 2008 to 2011 [1] show massively increasing electrical consumption, with generated energy from renewable sources not keeping up with such annual rise. Carbon emissions from usage of fossil fuels for energy are also on the rise.

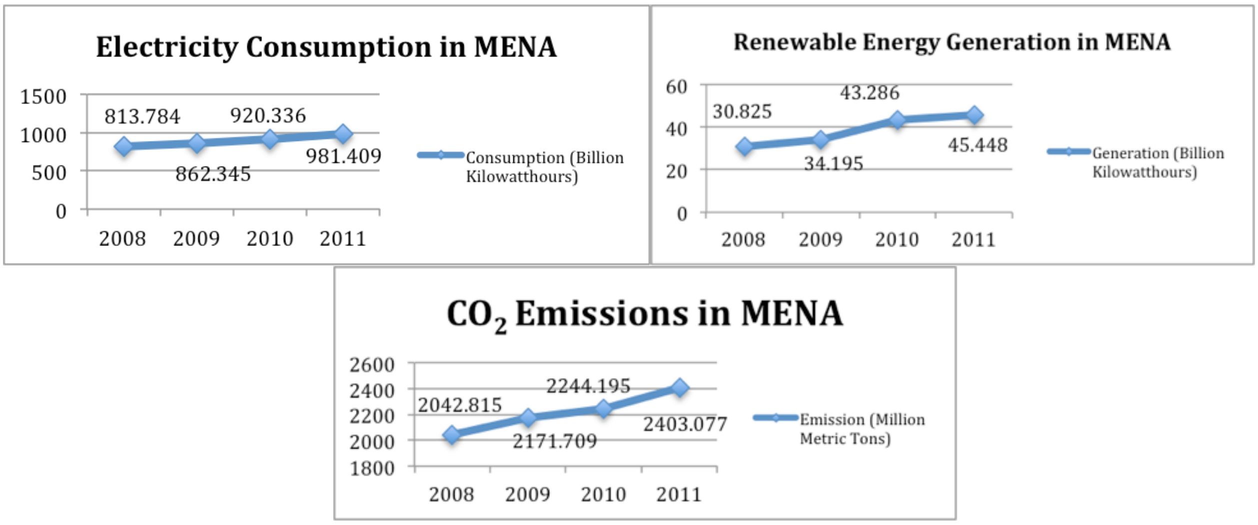

Figure 1: Computed Graphs of Energy Statistics in MENA Region

The need for energy sustainability and a cleaner environment are the driving factors behind the proposed mission of the following objectives:

- Providing all-year information of energy locations and capacities for wind, solar, and geothermal sources on an annual basis. This is to be attained with the help of IR-range imaging, and ground-based wind sensors.
- Manipulating satellite data for energy, municipal and possible estate business uses: Energy source replacement, extending population to new locations rather than centralizing in main cities, estate expansion and business opportunities in new remote locations.
- Overcoming political dispute over river water share, which affects both produced energy from river dams and water share [2]. Alternative energy sources can also be utilized for water desalination.

Concept of Operations

With the help of an orbiting satellite, ground sensors, and a network of receiving ground stations, renewable energy outputs can be quantified and mapped. The satellite, proposed to be of 3U size, will be launched by a P-POD launcher and will mainly capture spectral images within IR ranges for solar and geothermal hotspot detection, obtain wind sensors uplink, and downlink telemetry. The ground segment is comprised of miniature self-powered wind measurement stations suitable for detecting speed and direction on a ground surface, and a network of ground stations that will assist in data downlinks. Wind sensors ought to consist of a wind vane for direction detection, and an anemometer for speed measurement. They should also sustainably operate in remote places where power lines are mostly hard to reach, with the aid of solar panels and power generated from an installed wind turbine. The readings are to be sent as uplink via VHF communications to the satellite when in range, which is needed for obtaining wind readings in remote areas.

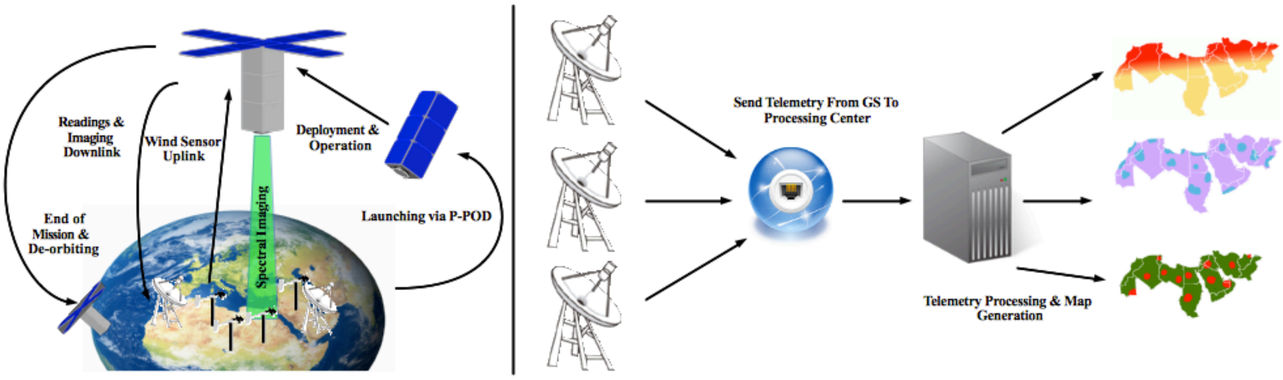

Figure 2: Concept of Operations

All received data from different ground-stations are then sent to a centralized data processing system, where energy output maps would be generated based on the analysis of the obtained satellite readings on an annual basis.

The space mission is proposed to last for 5 years, being consistent with expected nano-satellite lifetimes.

Key Performance Parameters

Given the requirement of obtaining solar and geothermal energy information with the help of remote sensing, a spectral camera is needed. Black body radiation can be utilized to determine geothermal heat in the form of enclosed heat; Earth's radiation spectrum is roughly 9–14 μm [3], which makes using an infrared camera with this spectrum ideal for detecting geothermal hotspots. Weather satellites are equipped with thermal or infrared sensors, which produce images that are analyzed to determine cloud heights and types, calculating land and surface water temperatures in the end. A weather satellite's spectrum is typically 10.3–12.5 μm [4], which can detect solar energy hotspots. As it just so happens that the spectrum needed for solar hotspot detection (10.3–12.5 μm) is within the geothermal spectrum (9–14 μm), only one spectral camera system with the latter's spectrum is enough to detect both.

Wind sensors must be placed strategically in sites of interest in which no obstruction is clearly present (i.e. mountains and forests). To provide good measurements, height of the wind sensor ought to be at least 10 m high. Given the desert nature of most countries in the MENA region, self-cleaning solar panels [5] is vital for the sustainable operation of the wind sensors throughout the mission.

With data obtained from several captured images and wind sensors on the ground, the need for faster downlink data rate is realized in the case of lesser ground stations. To be able to fulfill this, the satellite must make use of an S-band transmitter to send the data at 1 Mbps, ensuring no data carry-over scenarios.

Space Segment Description

The satellite is proposed to carry mainly two payloads:

- A spectral imager to obtain solar and geothermal information within 9-14 μm range, and a ground resolution of 500m for 500x500 km area for adequate accuracy.
- A VHF uplink receiver to obtain wind readings from ground sensors.

The system is designed to make use COTS components and fit in a 3U cube-satellite structure, allowing for standardized P-POD launching. The following shows a simple CAD representation of the satellite:

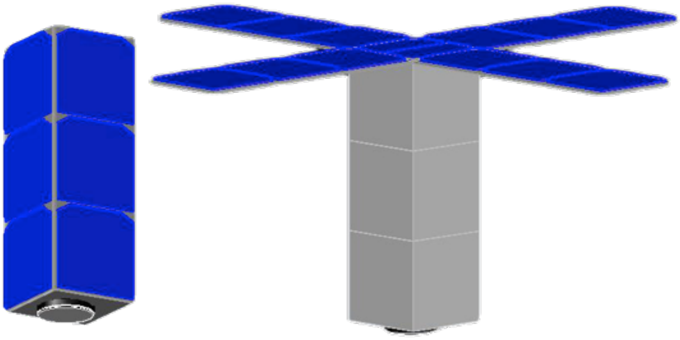

Figure 3: CAD Representation of Satellite

The satellite features a deployable solar array system to ensure continuous projection of the sun on a 3U area during operation (Minus the camera face). It also features a deployable air drag de-orbiter [6] as a measure to safely end the mission, and to help reduce the debris problem on low-Earth-orbits. The following table summarizes specifications with approximate values:

Table 1: Satellite Specifications

Mass	2 Kg
Peak Power Consumption	14.6 W
Solar Power Generation	25 W
Payloads	• 9-14 μm spectral imager • VHF uplink receiver
ADCS	Determination: • Magnetometer • Gyroscope • Sun sensor • GPS Control: • Magnetorquer
OBC	• ARM-based computer • Scheduling and multi-tasking • Storage unit for telemetry
Communications	• S-Band downlink transmitter at 1 mbps • VHF uplink receiver at 1200 bps • Deployable 4-way monopoles antenna
EPS	• Deployable solar arrays • Power distribution • Chargeable batteries
De-orbiting	Air drag sail de-orbiter

Orbit/Constellation Description

Using a single satellite, the orbit is desired to ensure the following:

- Ground track that covers most of the land for imaging purposes.
- Least location revisit time for sound climatic readings.

It should be noted that with the help of the imager's specifications of 500x500 km land area image, and the ground stations and sensors' communications reach, the need for exact ground track revisit is lessened and thus revisits can occur on marginal longitudinal distances to a ground object's actual physical location. It was found that the following orbital parameters would fulfill the requirements, shown with ground track simulation after 6 and 18 days respectively:

Table 2: Orbit Parameters

Altitude	604.5 km
Eccentricity	0
RA	Launching Position
Inclination	98.43°
Argument of Perigee	None
Ground Track Revisit Time	~ 6 days

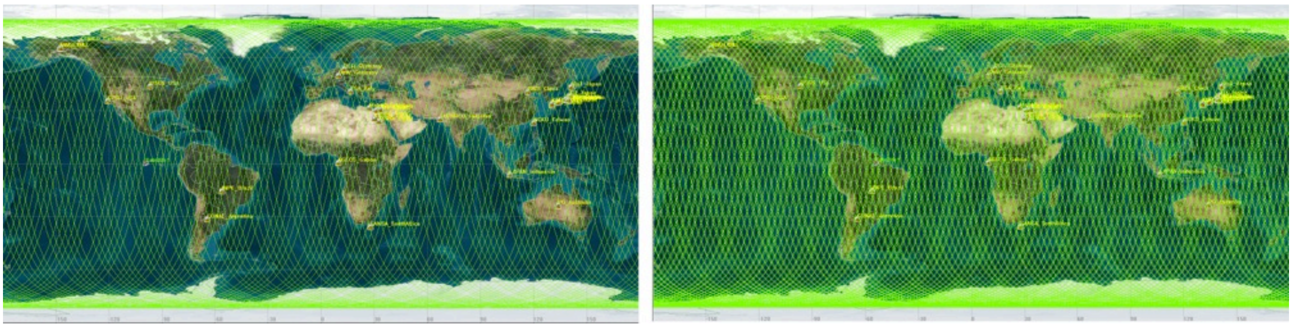

Figure 4: Orbit Ground Track After 6 & 18 Days From Deployment

Implementation Plan

The mission is aimed towards the sustainability of energy consumption and providing other solutions to the region. Thus, a consortium involving governments and energy agencies of countries is to be formed for regional cooperation. Member countries should coordinate the deployment and operation of a ground-station network for downlink coverage, deploy wind sensors network on land, and share received telemetry to a data processing center over an internet connection. The *Egyptian National Authority for Remote Sensing & Space Sciences* (*NARSS*) and the *Arab Organization for Industrialization* (*AOI*) can manage the manufacturing and assembly of the satellite and wind sensors, given development experience and mass production capabilities. The data processing segment is proposed to be centered at the *Egyptian Meteorological Authority* (*EMA*), given prior extensive research experience in meteorological data processing. The following is a tentative list of phases with involved peers and known costs (As per MIC cost model):

Table 3: Tentative Implementation Phases With Peers & Costs

Phase	Involved Peers (Not limited to)	Known Costs (M$)
Invitation to Renewable Energy Mapping Consortium & Planning	• Governments • Energy Agencies • Satellite Agencies	
Satellite & Wind Sensor Design	• *NARSS*	
Satellite & Wind Sensor Manufacturing, Assembly & Test	• *AOI* • *NARSS*	2.9 – for satellite (Shared cost) 0.0004/Sensor
Wind Sensor Delivery & Deployment	• *AOI* • Governments	
Ground Station Deployment	• Governments • Space Agencies	0.5/ground station development (If not present)
Satellite Launch	• Satellite Launching Agent	4 – to place on desired orbit
Mission Operation	• Space Agencies • *EMA*	0.2/year – for a ground station 1/year – for telemetry processing
Annual Map Publishing	• *EMA* • Governments • Energy Agencies	

(Note: Costs cannot be added up as it is subjective to number of member countries, needed sensors per country, and ground stations)

The following are identified risks that might hinder the implementation:

- Due to the Arab spring, political turmoil and reform in a given country may delay joining the consortium or even obstruct development/deployment of infrastructure.

- Though a country's membership is not a requirement at the initiation of the consortium, delays in joining would cause this country not obtaining 5 years (Mission's lifetime) worth of telemetry.

- Possible delays in importing needed materials for manufacturing and assembly of systems.

References

[1] International Energy Statistics (2014). Retrieved March 20, 2014, from http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm

[2] Maasho, A. (2014, April 23). Paying for giant Nile dam itself, Ethiopia thwarts Egypt but takes risks. *Reuters*. Retrieved from http://www.reuters.com/article/2014/04/23/us-ethiopia-energy-insight-idUSBREA3M0BG20140423

[3] Prakash, A. (2000). Thermal Remote Sensing: Concepts, Issues, and Applications. *International Archives of Photogrammetry and Remote Sensing*, Vol. XXXIII, Part B1, 239-243. Retrieved from http://www.isprs.org/proceedings/xxxiii/congress/part1/239_xxxiii-part1.pdf

[4] Infrared Atmospheric Sounding Interferometer (2014, January 28). Retrieved April 12, 2014, from http://smsc.cnes.fr/IASI/

[5] Friday, L. (2014, March 24). Self-Cleaning System Boosts Efficiency of Solar Panels. *Boston University*. Retrieved from
http://www.bu.edu/today/2014/self-cleaning-system-boosts-efficiency-of-solar-panels/

[6] Aerodynamic End-Of-Life DeOrbit System Fact Sheet. (2012, February 12). Retrieved April 18, 2014, from
http://www.clyde-space.com/documents/2765