Mission, Instrument, and Performance of a combined DAIA/SULFRO/LUWISA mission

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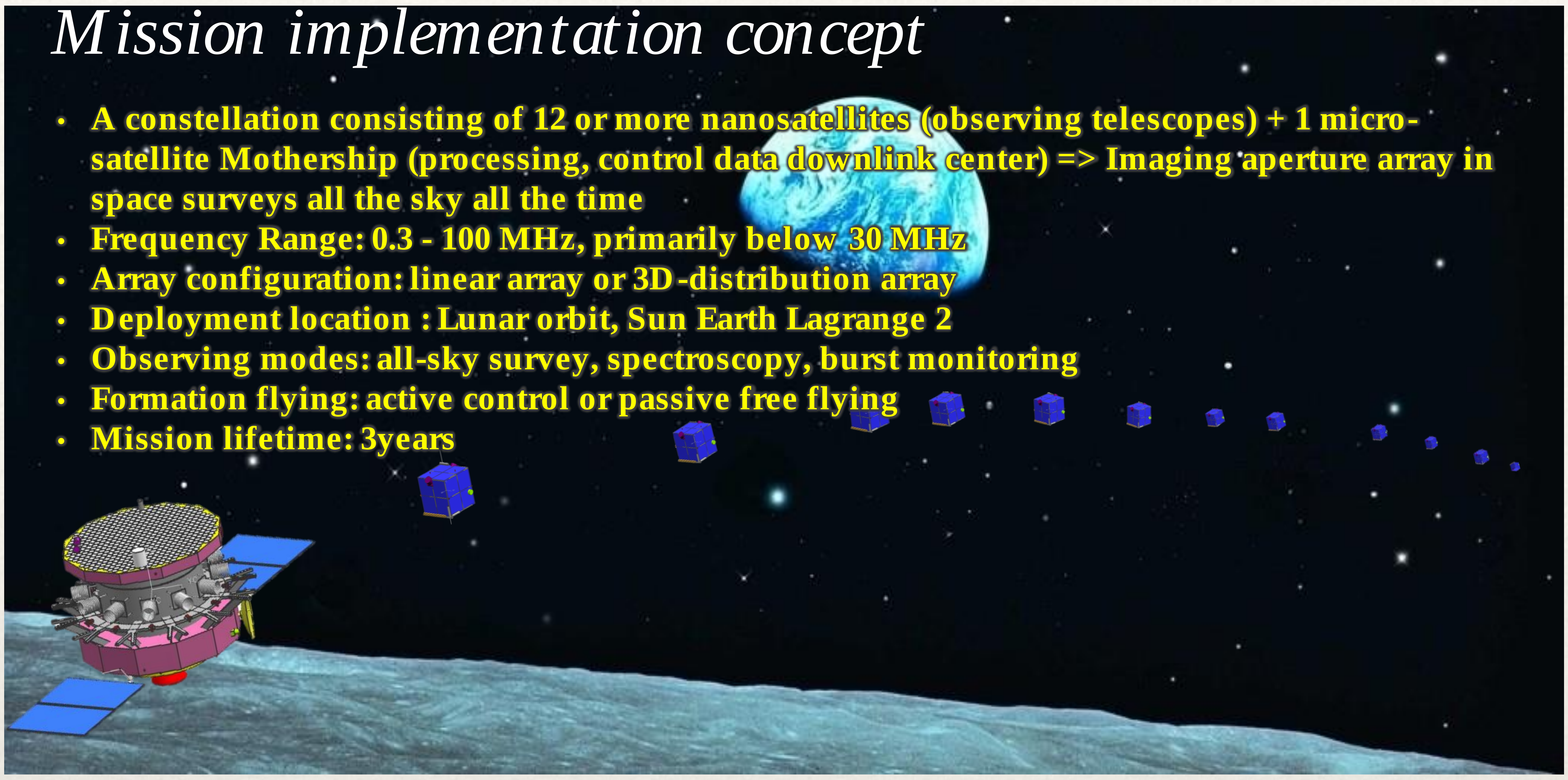
Abstract: We present preliminary study results on mission, instrument, and observational performance of a small mission as a pathfinder and an important first step to open up the hitherto inaccessible ultra-long wavelength spectral window. The mission concept is mainly originated from DAIA and LUWISA proposals with input from SULFRO. The receiver and antenna design has heritage of previous cooperation. Sensitivity, sky coverage, and angular resolution are estimated based on mission and instrument parameters.



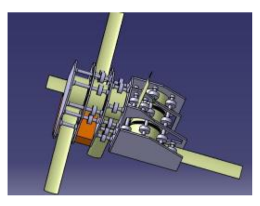
Mission implementation concept

- A constellation consisting of 12 or more nanosatellites (observing telescopes) + 1 micro-satellite Mothership (processing, control data downlink center) => Imaging aperture array in space surveys all the sky all the time
- Frequency Range: 0.3 - 100 MHz, primarily below 30 MHz
- Array configuration: linear array or 3D-distribution array
- Deployment location : Lunar orbit, Sun Earth Lagrange 2
- Observing modes: all-sky survey, spectroscopy, burst monitoring
- Formation flying: active control or passive free flying
- Mission lifetime: 3years

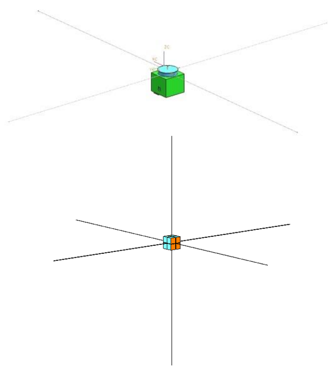
Receiver and Antenna System

Requirements

FoV	Ominidirectional
Galactic noise-limited	$T_{rec} < 1/10\ T_{sky}$
Frequency	0.3~30 MHz
Bandwidth	> 1MHz
Power Consumption	< 3 W ?
Weight	< 1 kg



Possible deployment mechanism. Korsak 2010

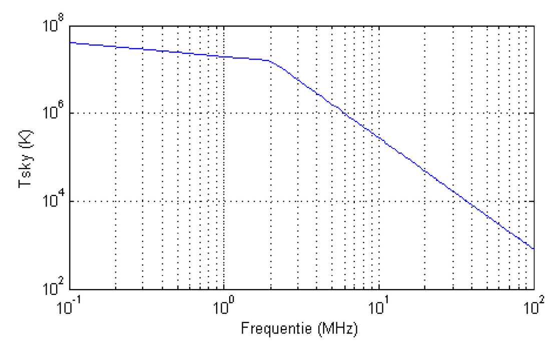


Cross dipole and tripole antenna

Antenna Simulation

The sky temperature can be approximated by

$$T_{sky} = \begin{cases} 16.3\times 10^6\,K\left(\frac{\nu}{2\,\mathrm{MHz}}\right)^{-2.53} & \text{at } \nu > 2\,\mathrm{MHz} \\ 16.3\times 10^6\,K\left(\frac{\nu}{2\,\mathrm{MHz}}\right)^{-0.3} & \text{at } \nu \le 2\,\mathrm{MHz}. \end{cases}$$



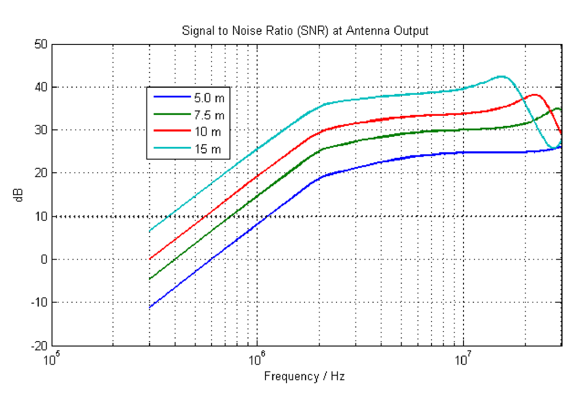
(S. Jester, H. Falcke, 2008)

Total noise temperature for the antenna at the output of LNA,

$$T_{ant} = \left(\eta T_{sky} + (1-\eta)T_{amb} + T_{rec}\right)G_{LNA}$$

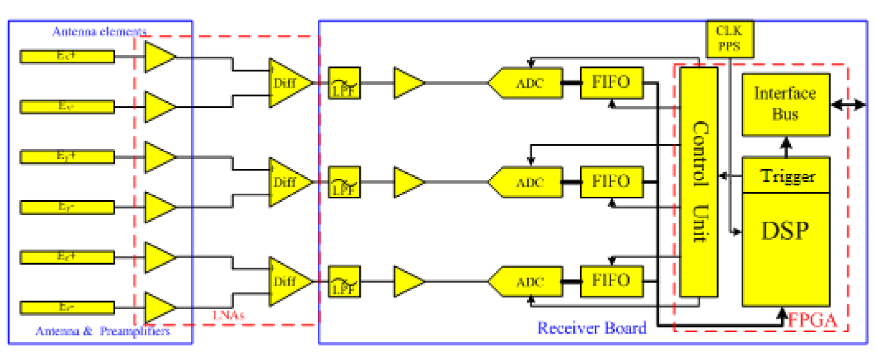
For the Galactic noise limited requirement,

$$\mathrm{SNR} = \frac{\eta T_{sky} G_{LNA}}{\left[(1-\eta)T_{amb} + T_{rec}\right]G_{LNA}} \ge 10$$



Simulations show that 7.5-meter Tripole antenna is feasible.

Receiver System



Left: Block diagram showing the active antenna with the receiver unit.

Power Dissipation Estimation

Preamplifier (LNA)	153 mw per channel
Differential driver for ADC	10 mW per channel
16 bits ADC @65 MSPS	60 mW per channel
Low-Power Flash FPGA	<400 mW
Total Power	<1.2 W

Dynamical range

High system dynamical range is achieved with improved receiver design and taking advantage of the period when terrestrial, solar, and jovian emissions are shielded by the Moon.

Performance Estimation

Parameters

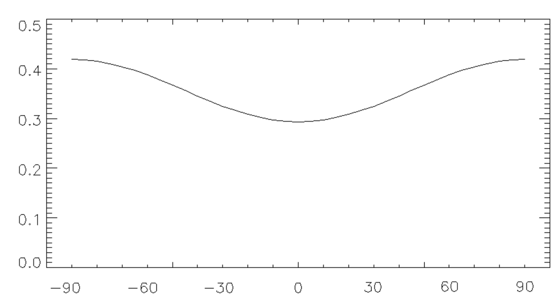
The following parameters are used for the lunar orbit array

Number of antenna	12
Number of simultaneous baseline	66
Longest baseline	100 km
Number of polarization	3
Orbital period	2.3 hours
Operation time	3 years
Lunar shielding time fraction	0.3
Antenna effective area [a,b]	$3*\lambda^2*\varepsilon/(\pi*8)$
Integration bandwidth	1 MHz (provisionary)

[a] Woan 1997
[b] We assume ε = 0.7 @ 1 MHz and ε = 0.95 @ 10 MHz

Sky Coverage

For every orbit of observation around the Moon, the directions perpendicular to the orbit plane has the best u-v coverage. Cross-dipole antennas are mounted so that their dual-lobe shaped main beam also points to the same directions. The antenna beam limits instantaneous field of view of the observation made in an orbit. The array uses orbital precession to cover the full sky in about 16 months. The figure to the right shows the simulation result of the efficiency of a line of sight at a given latitude in the procession coordinates, with beam shape and scanning action considered. The efficiency is ~1/3.



Latitude (degree)

Sensitivity

Flux sensitivity

$$\sigma_s = \frac{2kT_{sys}}{A_e\sqrt{2n(n-1)\Delta\nu\tau n_p}}(Jy)$$

Temperature sensitivity

$$\sigma_t = \frac{D^2 T_{sys}}{A_e\sqrt{2n(n-1)\Delta\nu\tau n_p}}(K)$$

Sensitivity after 3 years considering all factors

Flux sensitivity (Jy)		Temperature sensitivity (K)	
1MHz	10MHz	1MHz	10MHz
0.15	**0.15**	**5.4 E+05**	**5.7 E+05**

Angular resolution

The shortest and the longest baselines are ~30m and 100 km, respectively. At 0.5 MHz and 10 MHz, the array angular resolution is 25 arcmin and 1.2 arcmin, respectively.