OLFAR, A Radio Telescope Based On Nano-Satellites in Moon Orbit

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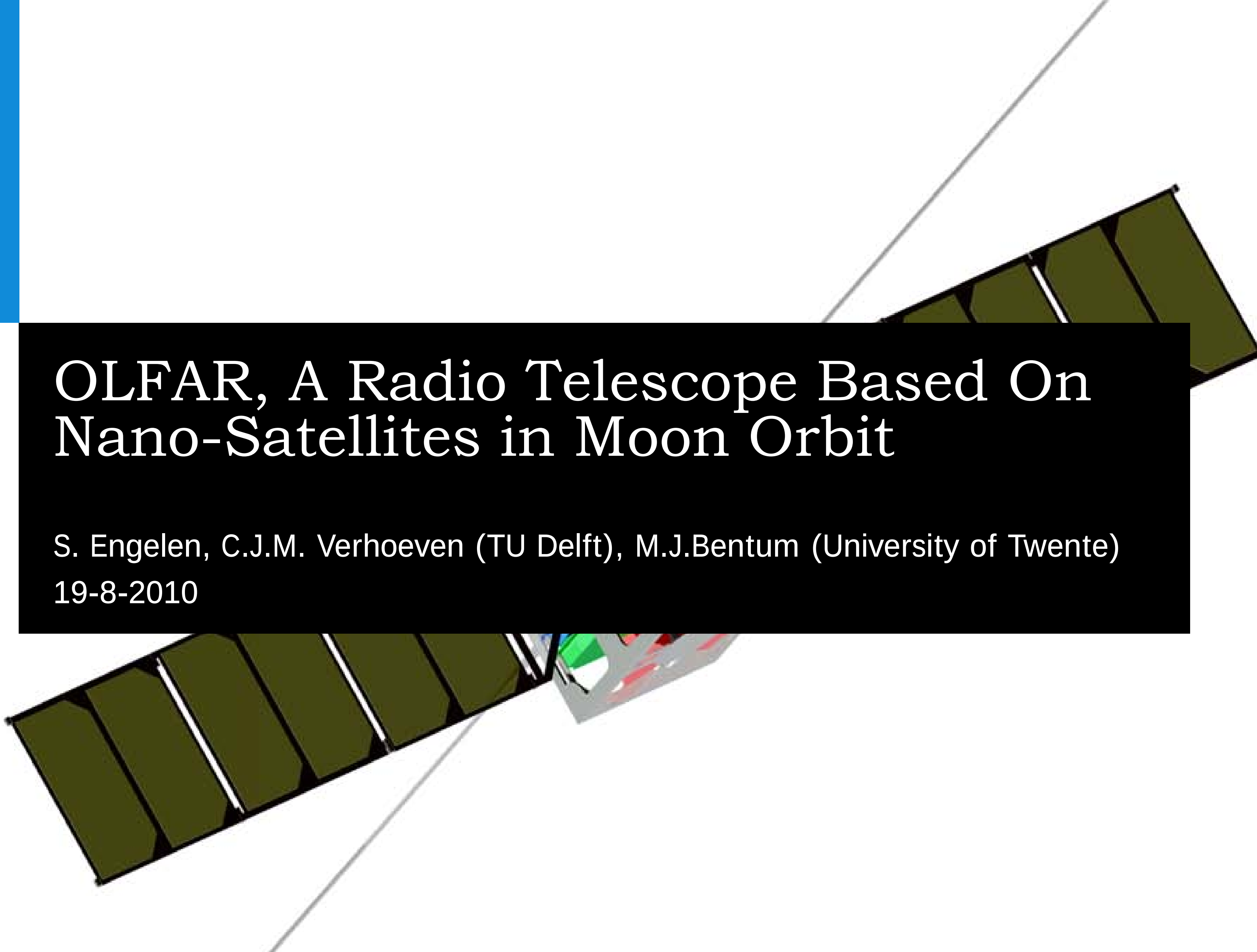


Overview

- Introduction
- Low frequency radio astronomy in space
- The space segment
- Project status

Introduction

The science case for OLFAR(1)

LOFAR: Low Frequency Array

- Range: 10-250 MHz
- Distributed sparse array
  - 26 stations on-line
  - 13 under construction
- Targets:
  - Epoch of Reionisation
  - Deep extragalactic surveys
  - Transient sources
  - Ultra high energy cosmic rays
  - Solar science and space weather
  - Cosmic magnetism

LOFAR node

Introduction

The science case for OLFAR(2)

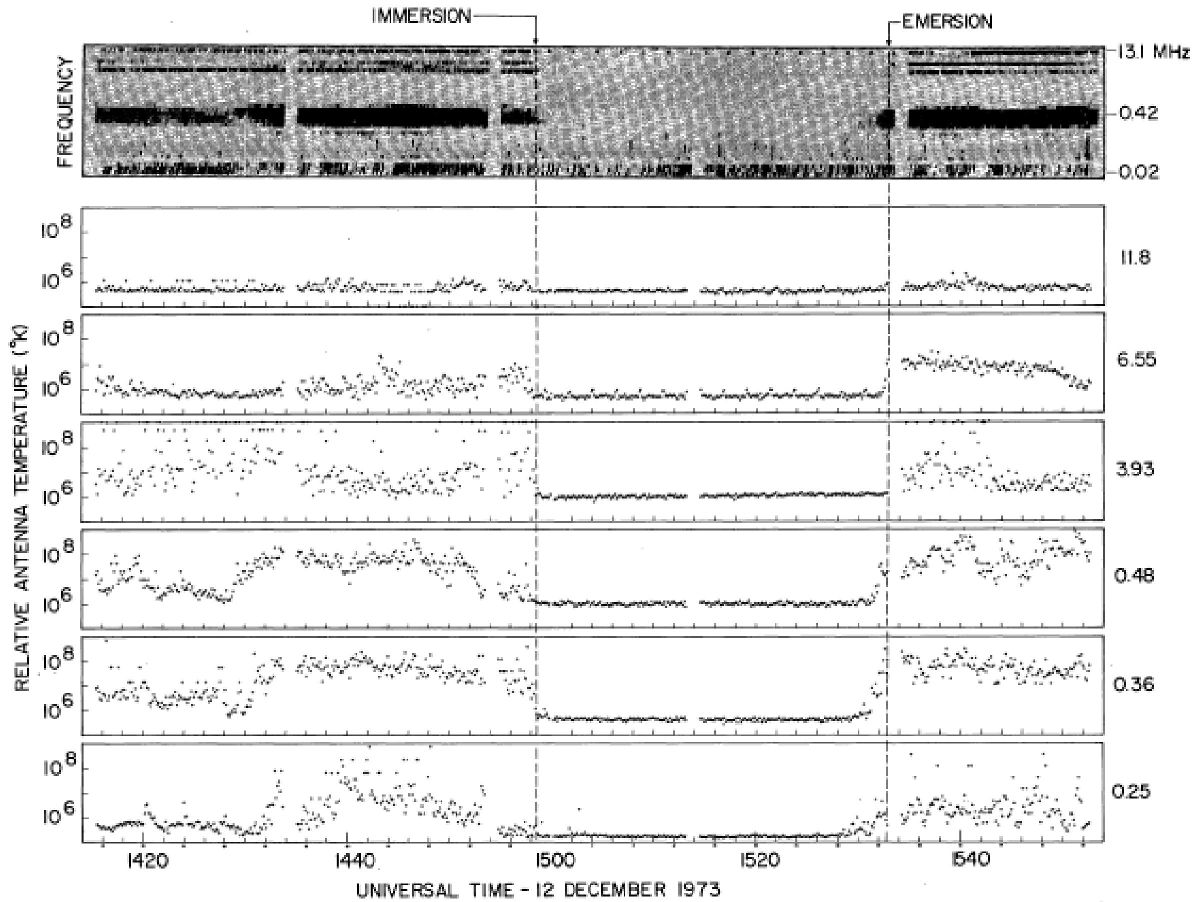
- Atmosphere not (fully) transparent for <30 MHz
    - Need for a space segment to augment the sensitivity of LOFAR at low frequencies

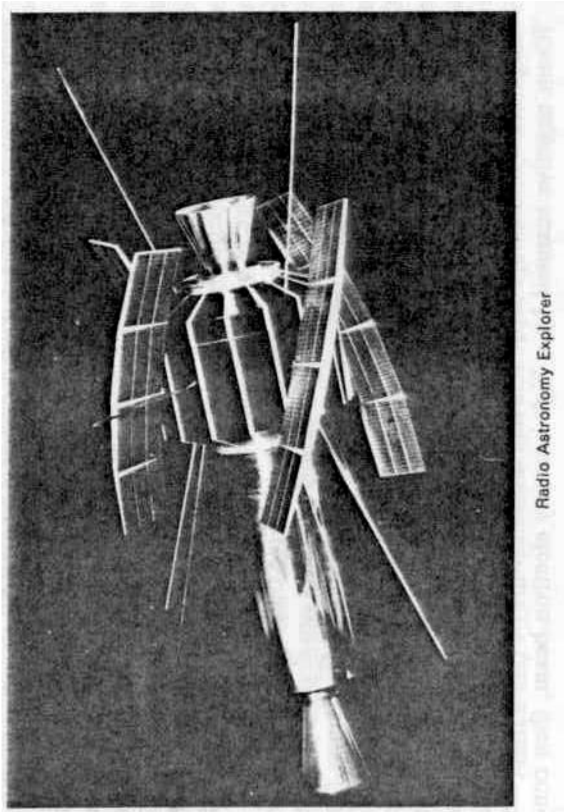
- NASA launched RAE-1 into earth orbit (1968)
    - Discovered the ionosphere is highly active
    - Earth emits very strong Kilometric Auroral Emissions

RAE-1

- RAE-2 launched into lunar orbit (1973)

Low Frequency science in lunar orbit





RAE-2

Source: J.K. Alexander et al. (1975)

The OLFAR space segment

The payload

Frequency range	1-30 MHz
Antennas	Dipole or tripole
Number of elements	50
Maximum baseline	Between 60 and 100 km
Spectral resolution	1 kHz
Processing bandwidth	100 kHz
Spatial resolution at 1 MHz	0.35 degrees
Snapshot integration time	1 s
Sensitivity	Confusion limited
Instantaneous bandwidth	TBD
Deployment location	Moon orbit, Earth-Moon L2 or Sun-Earth L4/5

The OLFAR space segment

The case for a nano-satellite swarm(1)

What is a swarm?

- A distributed system consisting of:
  - A large number of identical elemental satellites (nodes)
  - Simple rules within each satellite determine its behaviour
  - Emergent behaviour shows in the behaviour of the swarm as a whole
  - No local command structure is present – the swarm is controlled globally.
  - Elements are exchangeable and disposable
  - Cooperation is key

The OLFAR space segment

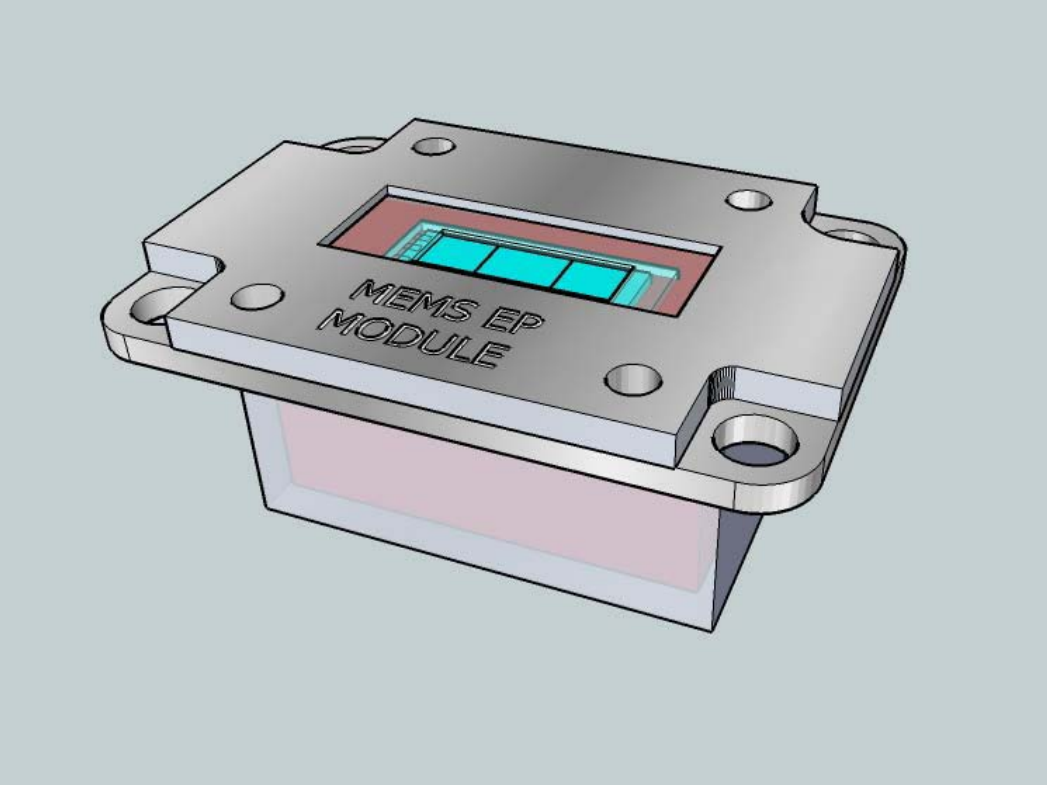
The case for a nano-satellite swarm(2)

	Formation flying S/C	Constellation	Fractioned S/C	S/C Swarm
Navigational accuracy	Very high	Moderate	Moderate	High
Orbital control precision per element	Very high	Moderate	High	Low
Position control of the virtual instrument	Very High	Moderate	High	High
Redundancy	Very low	Low	Moderate	**Very high**
Impact of the loss of an element	Loss of mission	Reduced functionality	Loss of specific function	Reduced coverage/ resolution
Element complexity	High	High	Moderate	**Very low**
System design complexity	High	Low	Moderate	High
Time-to-market	Very long	Long	Short	Short
Launch window flexibility	Low	Moderate	High	Very high
Maintainability	Low	Low	Moderate	High
Possibilities for extension /expansion	Low	Low	Low	**Very high**
Autonomy	Moderate	None	Low	**Very high**

The OLFAR space segment

The OLFAR swarm(1)

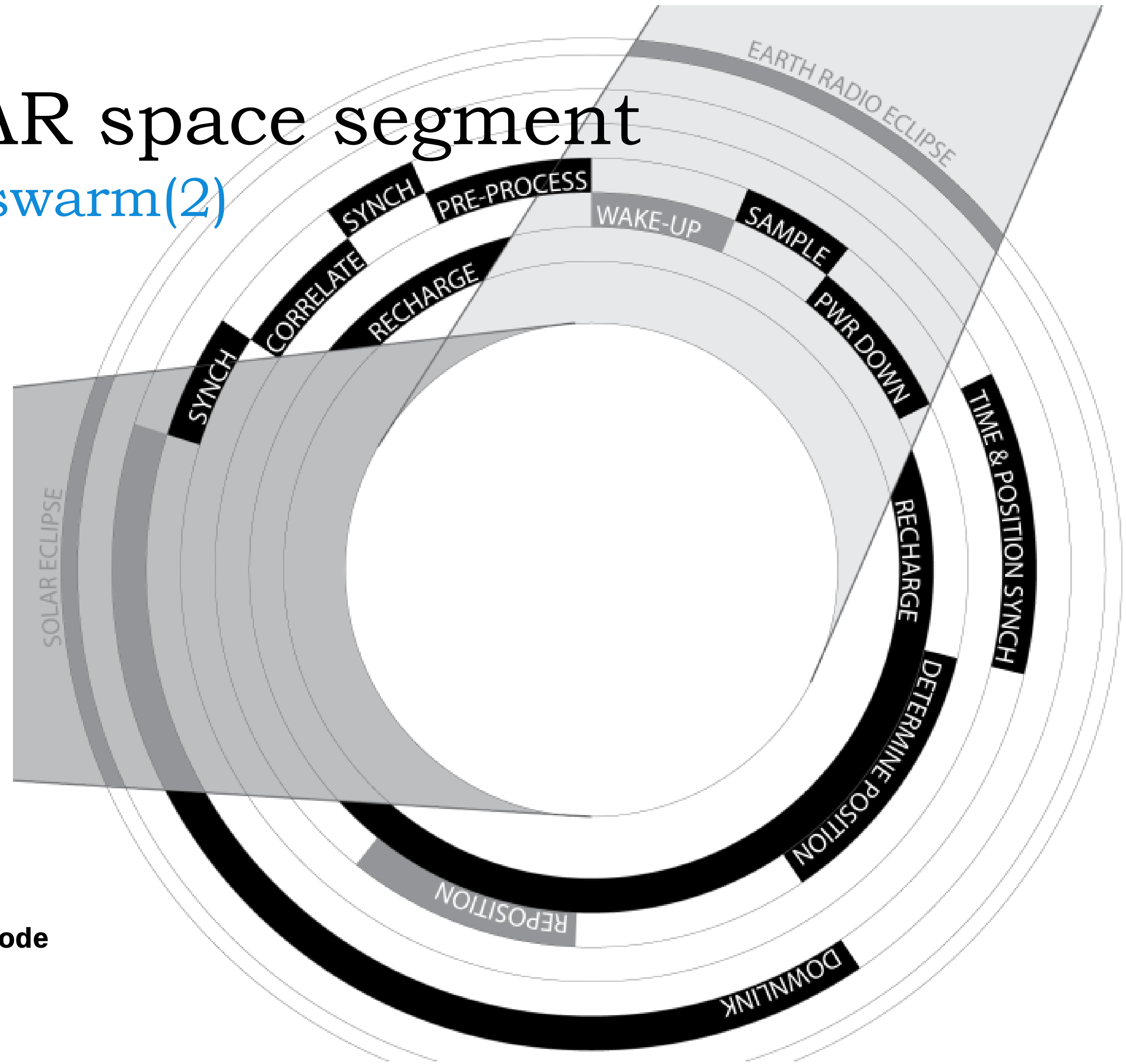
- 50 autonomous nano-satellites in lunar orbit
- Global swarm and science phase control by ground station operators
- Autonomous, individual lunar orbit insertion, using colloid thrusters – increases flexibility and expandability



TNO MEMS Colloid Thruster Module

The OLFAR space segment

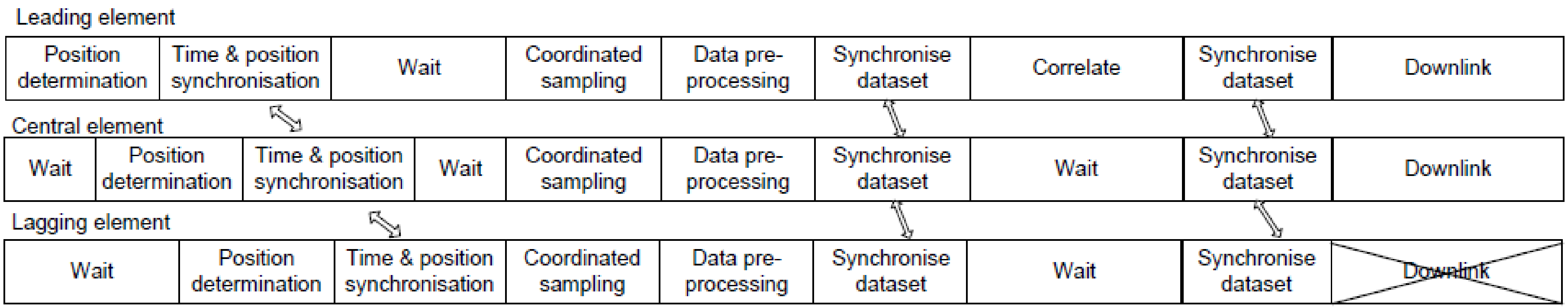
The OLFAR swarm(2)



Phase diagram of one single node

The OLFAR space segment

The OLFAR swarm(3)

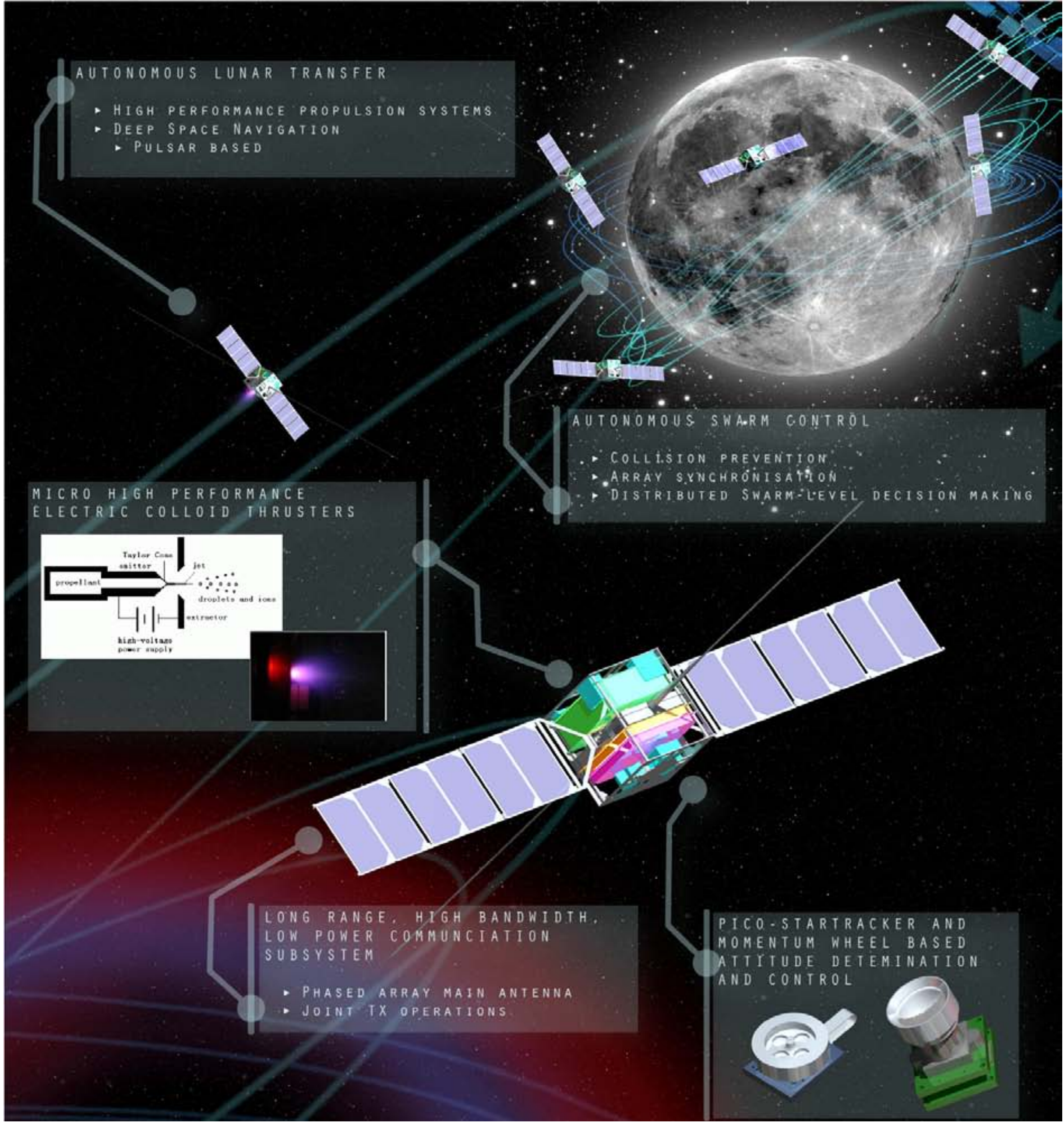


- Time-phase diagram of multiple nodes shows benefits of full element-level autonomy
- Inter-satellite communication is a must, though will have to be limited by ‘smart’ selection of protocols
- Redundancy is provided mostly through the high number of nodes

Project status

- The OLFAR project is already partly funded
- Research and development has started both at academia and research institutes, supported by industry.
- A LF radio-chip has been designed
  - To be launched on Delfi-N3XT in 2012
  - Frequency span: 30 kHz to 30 MHz
  - Output bandwidth: 50 kHz.
- Critical components of the space segment have been identified
- Missions and projects are being outlined focussing on their development.

Questions?


AUTONOMOUS LUNAR TRANSFER
▸ HIGH PERFORMANCE PROPULSION SYSTEMS
▸ DEEP SPACE NAVIGATION
▸ PULSAR BASED
AUTONOMOUS SWARM CONTROL
▸ COLLISION PREVENTION
▸ ARRAY SYNCHRONISATION
▸ DISTRIBUTED SWARM-LEVEL DECISION MAKING
MICRO HIGH PERFORMANCE
ELECTRIC COLLOID THRUSTERS
Taylor Cone
emitter
jet
propellant
droplets and ions
extractor
high-voltage
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LONG RANGE, HIGH BANDWIDTH,
LOW POWER COMMUNCIATION
SUBSYSTEM
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PICO-STARTRACKER AND
MOMENTUM WHEEL BASED
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