Fleets of micro, nano, pico space probes
High Speed Streaming Swarms
Mikro, nano pico szondák flottája
gyors áramló rajok

VIZI, P.G.[1]

[1] Wigner RCP, Hungarian Academy of Sciences H-1121 BUDAPEST, Konkoly Th. 29-33.
vizi.pal.gabor@wigner.mta.hu; H-1121 Budapest, Konkoly Thege Miklós út 15-17., Hungary

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Data remotely, Geoinfo close-up

Topic

- Streaming Swarm Concept
  - Micro and Nano Space Probes
  - Streaming Swarm
  - Sweeping Streaming Swarm

- Self organising network

- Sensors of Swarms – Remote and In-situ
  - Remote: Spectrum Scanner for micro probes or drones
    preprocessing for interest and big data solutions
  - In-situ: Multi sensors – spectral, acoustic chirp, capacitive chirp

- Analog situations - from last historical space mission events
  Rosetta and Philae

Introduction

- Recent technologies allegedly promise fast speed space devices - probes - accelerated by a launch base until to some percent of the speed of light. [1].
  Malcolm Ritter: Stephen Hawking joins futuristic bid to explore outer space, phys.org, April 12 2016, http://phys.org/news/2016-04-stephen-hawking-life-tiny-spacecraft.html
- Nano and micro technology is the applied science of the 21st century, not only in the Earth but in space and planetary technologies, too.
- Streaming Swarm of Nano Space Probes (SNP) as mission, instruments and payload concept.
- Smaller, cheaper and more efficient analytical methods for planetary space probes.
- moreover, as fleet operated - give opportunities to reach far objects in the Solar System with more developed skills then before.
- Micro and nano space probes sizes form dm mm
  (Micro and nano technology means the SI originated sizes.)
  We use both terminologies in their places.
- Hard challenges - Potential and promising concepts?
- It isn't possible to complete the mission nowadays!
- Author's earlier works described the Nano, Pico Space Devices and Robots (NPSDR) [2-4] and the fleet of Micro Sized Space-Motherships (MSSM) [5] which type or similar devices maybe can fulfil the requirements incidentally.

History and antecedents of Nano Devices 16

- **1950 NEUMANN**, János. Self reproducible robots with self evolution **Mathematics**
- **1954 LEM** Metal Insects by Stanislaw Lem: The Invincible **Sci-Fi**
- **1980** Advanced Automation for Space Missions, University of Santa Clara, USA: small self copier robot conception to the Moon, using local Moon matter to build new robots. **Science** -
- **1998 Vint Cerf** pinhead nanoships – (one of the original creators of the Internet,) envisions tiny nanoships that can explore not just the solar system but eventually the stars themselves []
- Idea and fantasy without technology till nineties, in 21st century available!
- Resources is now moving from a conceptual stage
- NIAC: NASA Institute for Advanced Concepts (1998 – 2007)
  2002 Mason Peck, Cornell University, USA,
  tiny "Sprites" – electromagnetic acceleration using foe example Jupiter's fields (billion electron volts)
- Michio Kaku: Physics of the Future . []
- 2007 - 2009 Pentagon's DARPA researches for military applications, e.g. monitoring positions of the enemy in battlefields. USA Air Force
- **2009**- My thesis , **2010** my first conference presentation about the topic: The Minimal Plan, **2012** NPSDR at NASA Goddard IPM conference,
  2013 , 2014, 2015 LPSC, Fleet of Micro Sized Space-Motherships (**MSSM**) with Nano, Pico Space Devices and Robots (**NPSDR**) Fleet of MSSM
- **2017** H-SPACE, 2017 LPSC Streeming Swarms of Fleet of NPSDR&MSSM

NPSDR 16



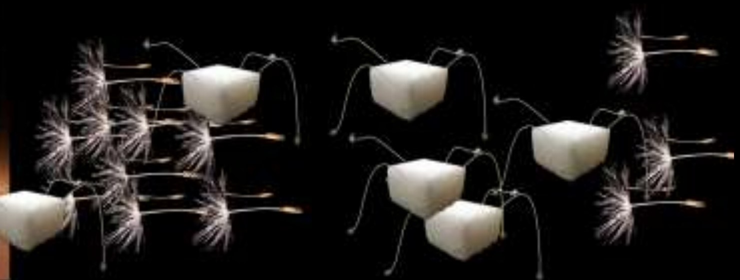

- **NPSDR** Earlier articles of authors (Vizi et al. 2012)[1] and (Vizi et al. 2013)[2] defined the concept of Nano and Pico Space Devices and Robots (NPSDR) and described the basic structures, functions, fields of the application possibilities.

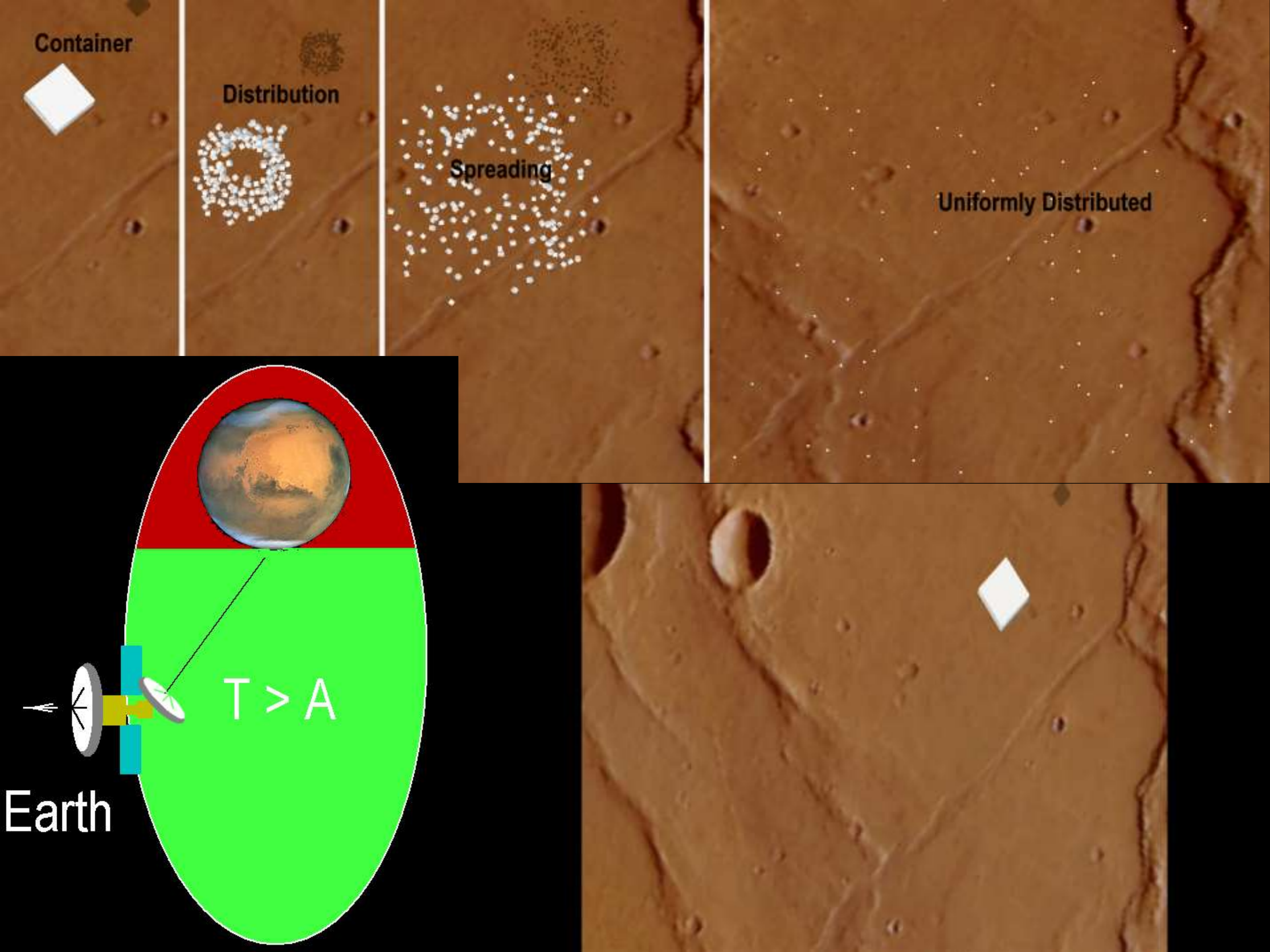
- Now we describe new concepts of solutions:
- - reduced micro sized space-mothership and fleet of them
- - swarm of nano probes as analytical sensor ships with wide spectrum of possible analytical sensors and with reduced smart telecommunication systems.

- [1] Vizi, P.; Horváth, A.; Hudoba, Gy.; Bérczi, Sz.; Sík, A. 'Lump Sugar and Salt Shaker'-Like Nano and Pico Space Devices and Robots 2012LPICo1683.1122V
- [2] Vizi, P. G.; Dulai, S.; Marschall, M.; Bérczi, Sz.; Horvath, A.; Hudoba, Gy.; Pocs, T.: Possible Identification Method for Martian Surface Organism by Using a New Strategy of Nano- Robots 2013LPI....44.2281V

Micro Sized Space-Mothership (MSSM) and **Fleet of NPSDRs**

- NPSDRs are deployable from
  - fleet of Micro Sized Space-Mothership (MSSM)
- Micro Sized Space-Mothership (MSSM):
  - to carry and distribute fleet of nano probes of NPSDRs
  - reduced nearly cubic decimeter
- NPSDRs:
  - wide spectrum of independent or multiplied sensors
  - fleet of analytical sensor ships –
  - reduced smart telecommunication systems.
- MSSMs gather, pack and transmit the collected data by NPSDRs to the Earth.
- Benefits:- cheap - abundant and redundant amount.




Container
Distribution
Spreading
Uniformly Distributed
T > A
Earth

Streaming Swarm Concept

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?

- Hard challenges - Potential and promising concepts?
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  as mission, instruments and payload concept.
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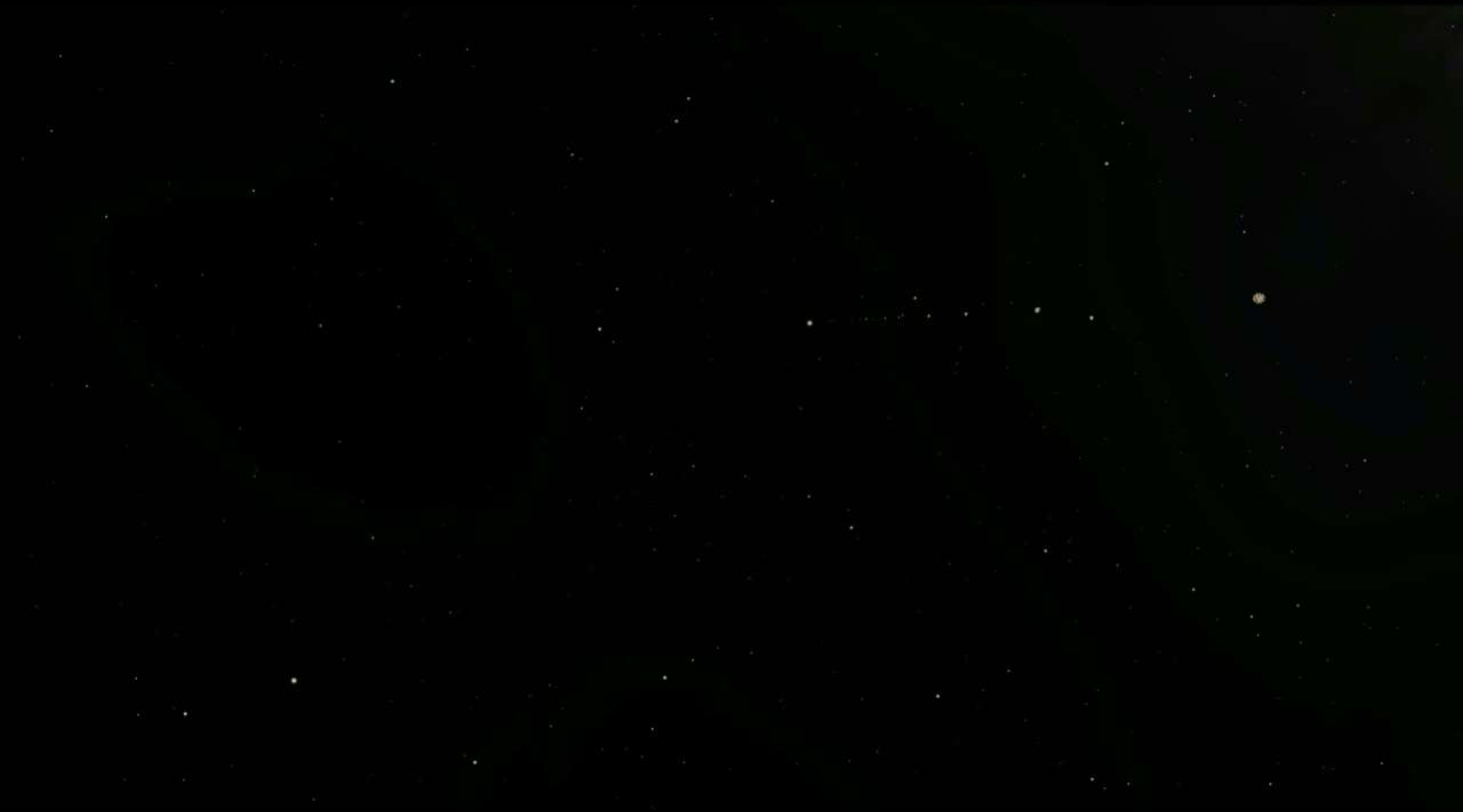
- OR MAGLEV STYLE ACCELERATING (estimated up to 100km/s)



Hard Troubles – Really Hard Troubles

Affecting a swarm and elements in case of high speed.

A. Accelerating

How can we accelerating up to order of magnitude of speed of light? In the vicinity of Earth it is maybe solvable to accelerate some type of space probes. Not solved, some ideas available, laser acceleration

B. Decelerating

How can we decelerate down the probes from the 'near speed of light'? **No how, no way**. Is any solution to use them **without decelerating**?.

C. Relativistic view and communications

According to different rates of Doppler effects new telecommunication systems needed.

Can we measure any characteristic at the target for example outgassing, magnetic fields and spectrums on a high speed?

D. Cosmic effects -Radiation

Extreme radiation affects the devices.

E. CONCEPTS AND POSSIBLE SOLUTIONS

Accelerating – Laser Accelerating

Mission	Laser Power	Veh. Mass	Accel.	Sail-screen Mirror size	Max speed (in percent of c [%])
1. Overflight	65 GW	1 t	0.036 g	3.6 km	0.11 - 0.17 lightyear
2. Meeting					
Acceleration Phase	7,200 GW	785 t	0.3 g	100 km	0.21 - 2.1 lightyear
Deceleration Phase	26,000 GW	71 t	0.2 g	30 km	0.21 - 4.3 lightyear
3. Manned					
Acceleration Phase	75,000,000 GW	78,500 t	0.3 g	1000 k m	0.50 - 0.4 lightyear
Deceleration Phase	17,000,000 GW	7,850 t	0.3 g	320 km	0.50 - 10.4 lightyear
Return Section	17,000,000 GW	785 t	0.3 g	100 km	0.50 - 10.4 lightyear
Deceleration Phase	430,000 GW	785 t	0.3 g	100 km	0.50 - 0.4 lightyear

R.L. Forward: Forward, R.L. (1984) "Roundtrip Interstellar Travel Using Laser-Pushed Lightsails," J. Spacecraft and Rockets, Vol. 21 , Mar-Apr, pp. 187-195

Some little calculation and counting

1t 0,1c 100 billion KWh = 1011 kWh
c = 300.000 km/s;

Ideal case:
p = E_0 / c, p' change on mirror, Δp to mirror,
Ideal nanobot 10^{-3} cm^3 $m_0 = 10^{-2}$ g -Δp **p=mv => Δv**

- $\Delta v = 2 * E_0 / (m_0 * c)$

for low speeds above for relativistics below

$$m \frac{v'}{\sqrt{1 - \frac{v'^2}{c'^2}}} = m_0 \frac{v}{\sqrt{1 - \frac{v^2}{c^2}}} + 2 \frac{E_0^0}{c}$$

Some little calculation and counting

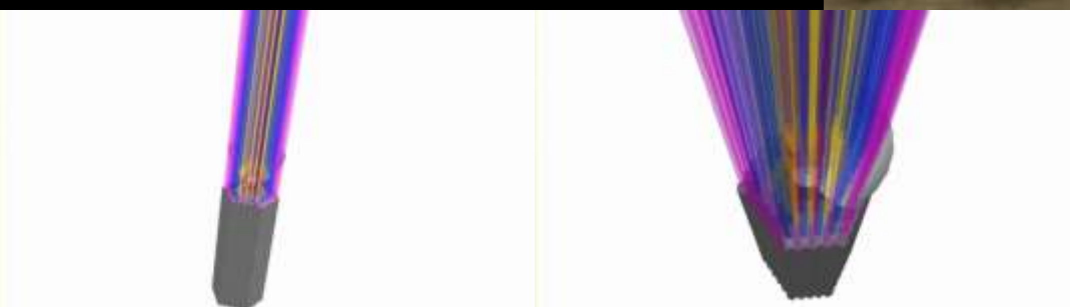
- ELI laser, where IL = 10^{23} W/cm^2, time is femtosecundum = 10^{-15} s
- From above for 1 cm^2 E = 10^{23} W * 10^{-15} s = 10^7 Ws = 10 MWs
- perform calculations with 1MWs laser
- E_0 = 1 MWs = 10^6 Ws = 10^6 J
- The length of the laser pulse temporal order of millisecond account: 10^{-3} s
-
- Dv = 2* E_0 / (m_0 * c) = 2 * 10^6 Ws / (10^{-5} kg * 3* 10^8 m/s) = 2/3 * 10^3 m/s
-
- Approximately 1 km/s.
- With a composite beam approximatelly: 1000 times faster in 1 secundum
- Δ v = 1000 km/s ideal
- from 0 km/s to 1000 km/s it is average 500 km/s
- Acceleration is in space only!
- **For planetary missions it is 10 times faster than speeds of nowadays O.K. for Overflight Passing Through missions**

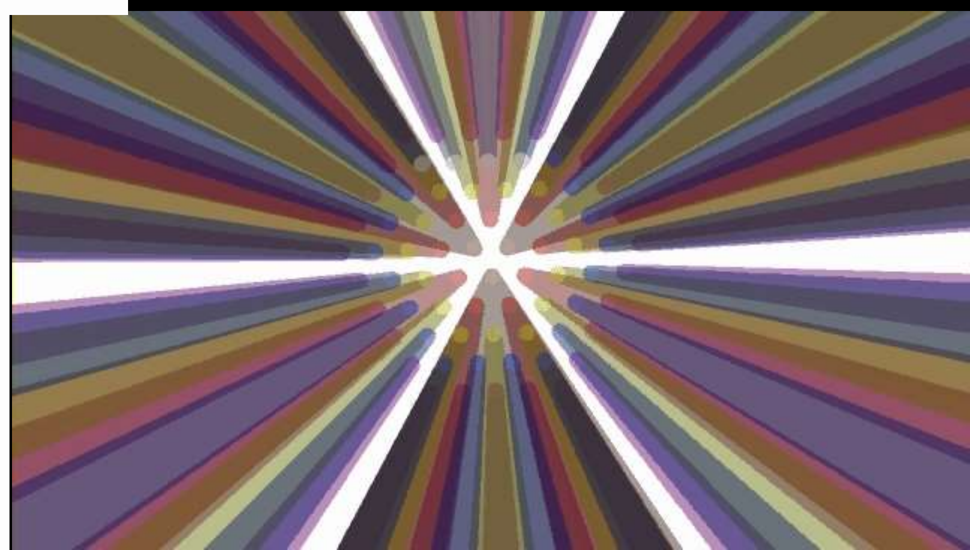
A. Accelerating

Sheaves of laser ideas, **not solved**

Hawking (2016) up

Vizi (2009) below





B. Decelerating

NO HOW, NO WAY

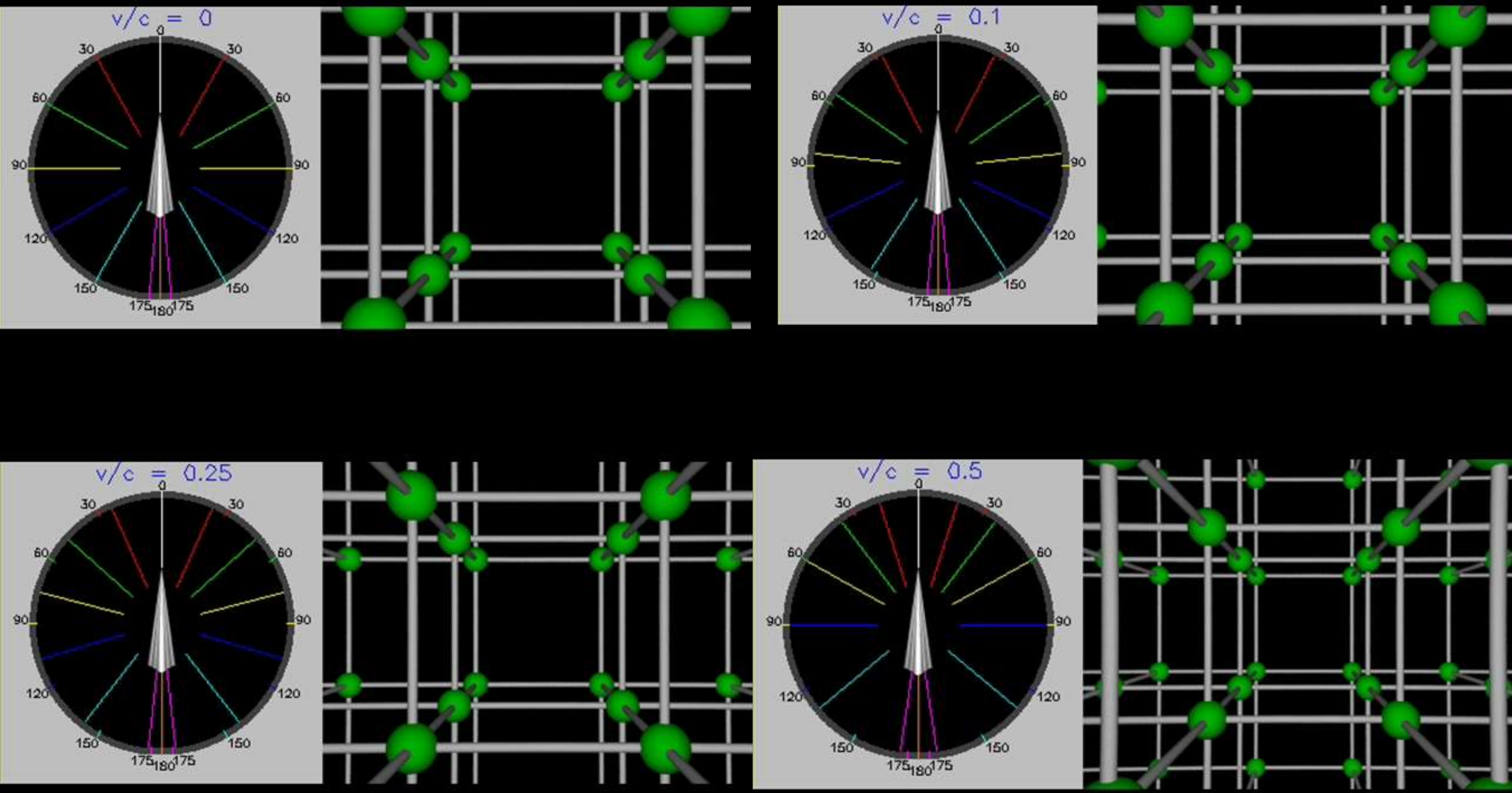
Overflight

Is any solution to use them without decelerating?

(see later)

C. Relativistic View Deformation

View distortion forward at different percent of light speed



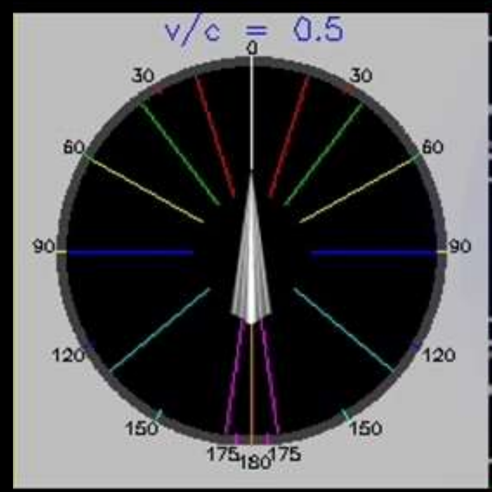
C. View deformation

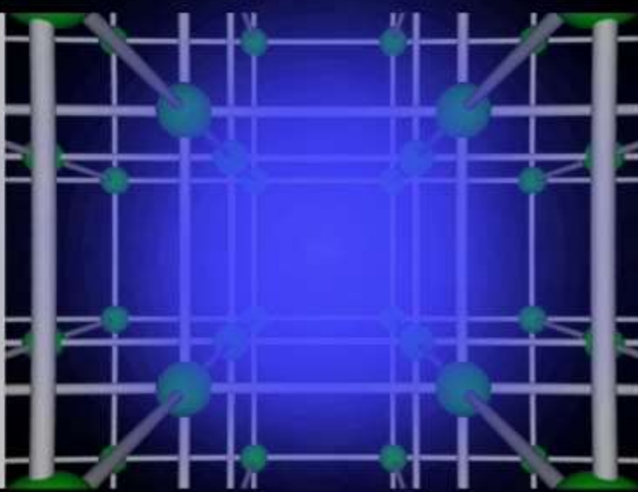
According to emitted or reflected incoming light different relativistic sensing effects

First case Lorentz-Contraction otherwise additional virtual rotation also

In the target direction everything will be lighter blue, back direction darker red

Anisotropic view will be





D. Cosmic effects - Radiation

Collision with particles
Considerations:
Average 7 nucleuses (plasma) / m^3 in Solar System
Cubesat sized $1dm^2$ cross section
sweeps 1 m^3 10^3 dm^3 , 10^1dm in 1 m -> 10^2 m = 100 m
Nanosat sized $1cm^2$ cross section
sweeps 1 m^3 10^6cm^3 10^2cm in 1 m -> 10^4 m = 10 km

D. Solutions to Cosmic Effects

NASA Ames article: D.-I. Moon1 et al. Sustainable Electronics for Nano-Spacecraft in Deep Space Missions Center for Nanotechnology, NASA Ames Research

Center, Moffett Field, CA, USA, 2016 IEEE

- An on-the-fly self-healing device is experimentally demonstrated for sustainability of space electronics. A high temperature generated by Joule heating in a gate electrode provides on-chip annealing of damages induced by ionizing radiation, hot carrier, and tunneling stress. With the healing process, a highly scaled silicon nanowire gate-all-around device shows improved long-term reliability in logic, floating body DRAM, and charge-trap Flash.
- Radiation hardening strategy: ChipDesing

D Brave Concept of NASA Ames

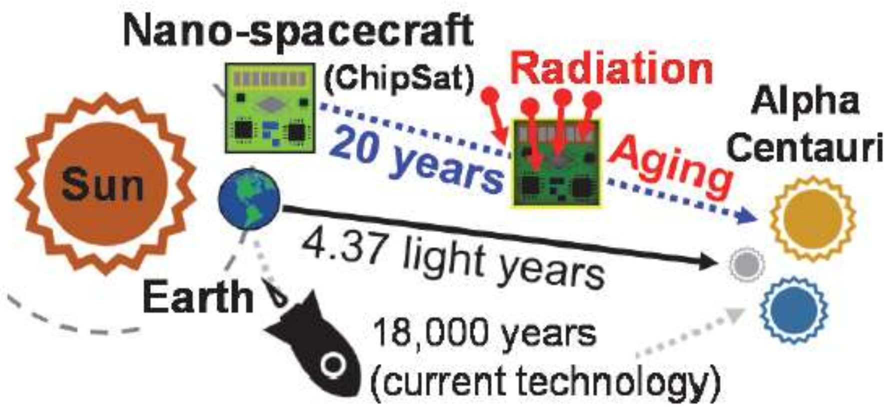


Fig. 1. A nano-spacecraft such as ChipSat, which consists of solar cells and functional blocks in a printed circuit board, would face a high risk of damage from radiation and aging issues on a flight into deep space. Especially, most of functional blocks such as microcontroller, memories, sensors, and communication system are semiconductor-based chips.

Lifetime of COTS chips ~ 10 years

➔ Deep space mission > 20 years

Radiation hardening strategy			
	Flight path control	Radiation shielding	Chip design
Voyager	O	O	O
ChipSat	X	X	O

Fig. 2. International standard for a lifetime of terrestrial commercial off-the-shelf (COTS) chips is set to target for 10 years, whereas many deep space missions require longer than that period. Furthermore, the intermittent radiation exposure alters the designed function of the chip, leading irrecoverable aging and even catastrophic failure.

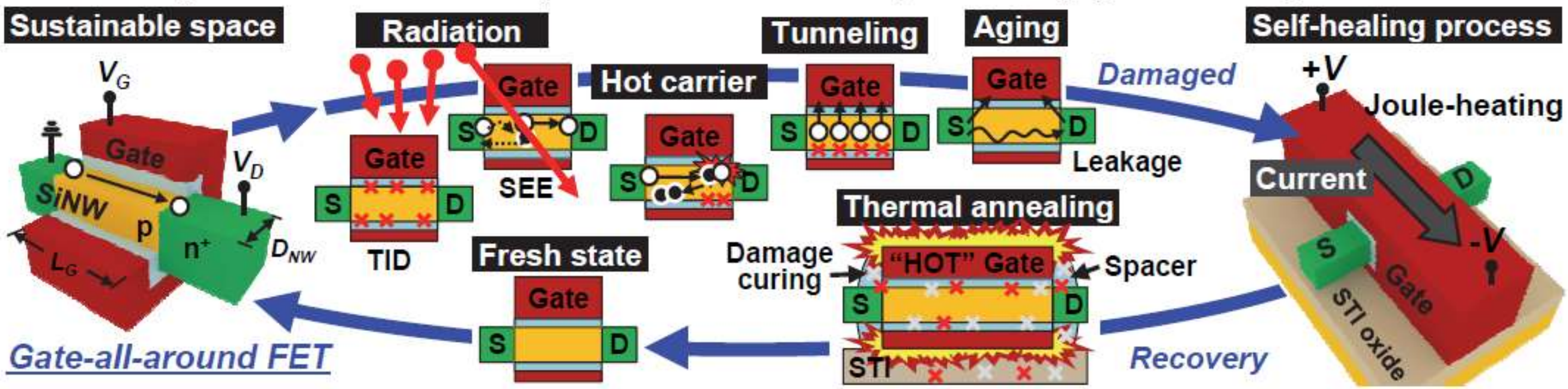


Fig. 3. Schematics to show the self-healing effect in the lifetime limited factors of space applications: radiation, hot carrier, and tunneling stress. High energy particles generate fixed charges and interface traps. Also, device and memory operational point of view, hot carrier and tunneling stress cause reliability issues. These aging mechanisms lead failure of semiconductor-based electronics. By applying voltage to the gate electrode, the gate dielectric and isolation dielectric are annealed by the high temperature generated by Joule heat, and the damaged device can be recovered to a fresh state. With the iterative self-healing process, the lifetime of space electronics can be extended to satisfy long term deep space mission.

D. Concept for the self-healing

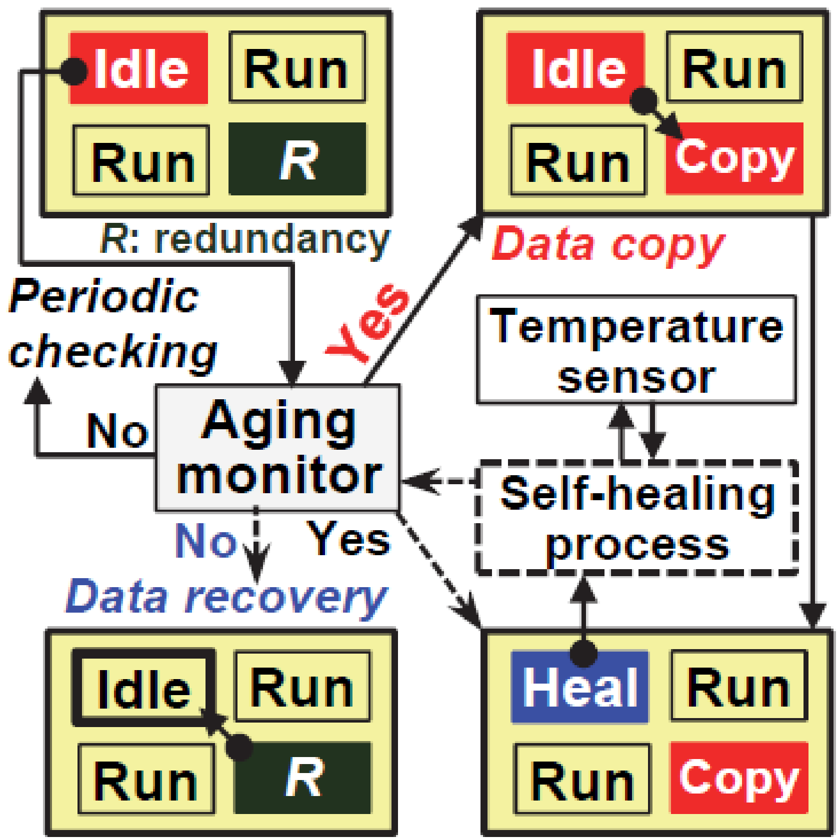
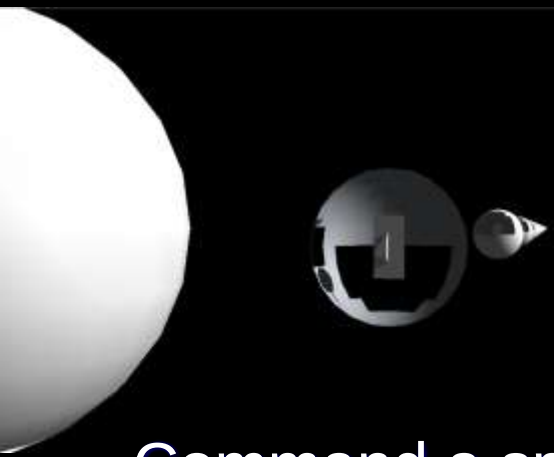


Fig. 20. Operational concept for the self-healing process. A sustainable electronic system is composed of the built-in gate heater, aging monitor, and temperature sensor.

E. CONCEPTS AND POSSIBLE SOLUTIONS



Command a special part of the swarm to do a specific job inside a space interval. Let we divide the space into sectors near the target – a moon, planet or star.

Particular space intervals demand definite activities.

Classical probe is orbiting the target and makes measurements in circulating or near rounding orbit.

A high speed streaming swarm couldn’t orbit the target. But we can **command** the part of them at just the target area to **make the same measurements at the same position where classical probe made.**

Single Space Probe vs. Stream of Swarm

A planet's atmosphere could be clear or cloudy …

A **single space** probe which can turn on and off experiments and sensors in accordance with the conditions expected.

The result must be the same like in case streaming swarm

Just exactly at that time then the elements of the stream which have arrived earlier can inform the next elements of the stream to set up they sensors to getting ready to use a fitted settings of parameters for the specific measuring.

To find the best balance between the available time and electrical power and the importance of significant measuring.

Flowchart and Timetable as Procedures

Location dependent tasks during approaching, nearby and beyond the target (like a procedure oriented program)

Approaching
- Before destination
  - place of pre measuring

At destination
- place of main measuring
- common computing for interest - sending backward and forward and parallel
- focusing on interest - sending backward to the next part of swarm

After Destination
- Sending back precomputed main data after parallel computing
- Trying to send back all data several times repeatedly as long as run out of energy

Proportional weighting between tasks
- during planning the mission program HW&SW, predefined in situ analyzing and result dependent actions
- from the collected data at destination result dependent actions, according to predefined program but from the results

Communication in Stream of Swarm

It is necessary to communicate each other inside of the swarm. First parts of the stream collect measurements, start to preprocess data and send back to the next part of the stream relevant information as a negative feedback for better settings to help to collect data more precisely

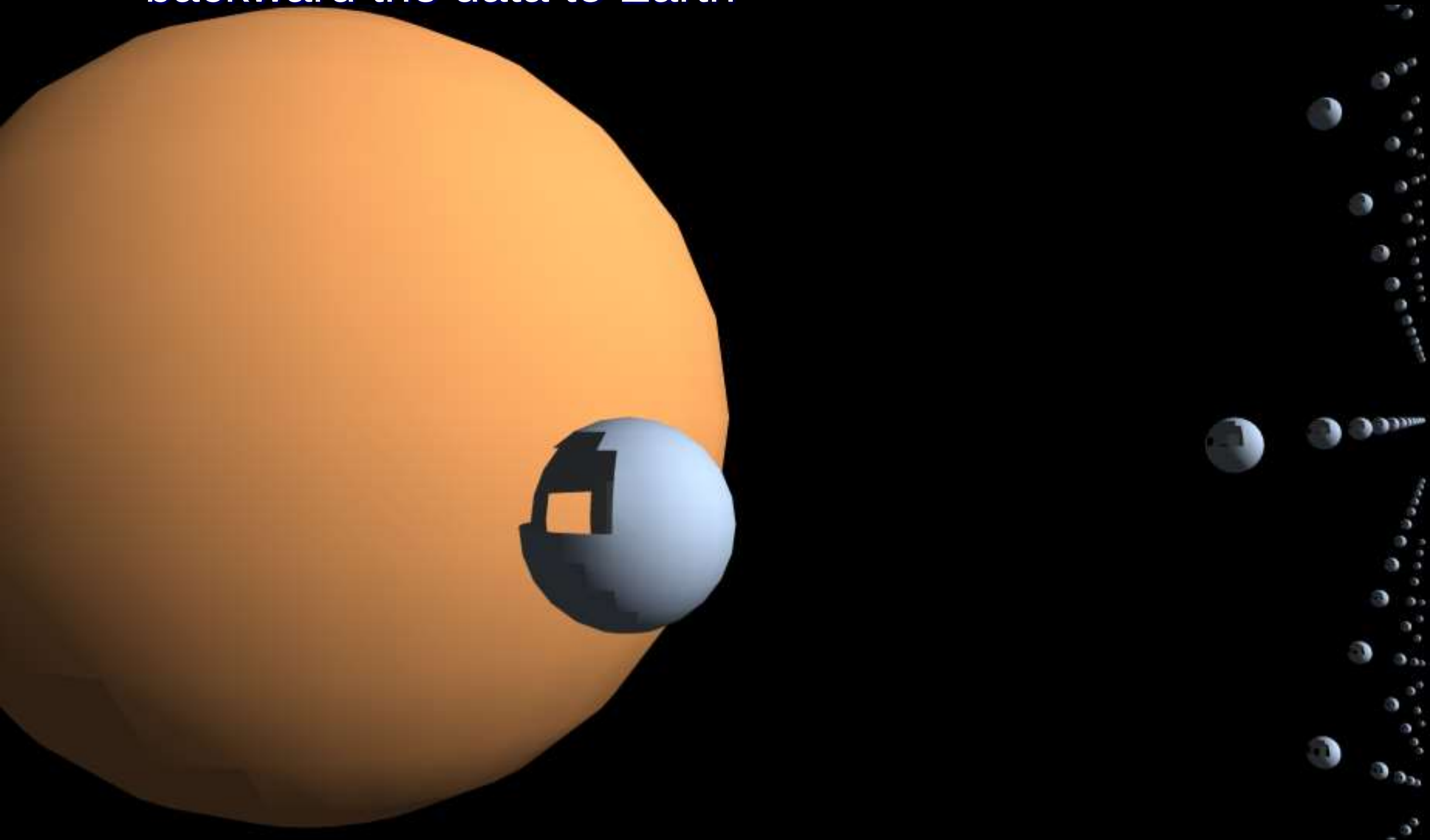
A. Negative feedback to next part of Swarm

It is a key opportunity to modify, to correct and to involve the behavior of the next part of the stream according to results of the first part of the stream. The kth parts of the stream make measurements and start to process the data. According to the results, the kth part of the stream could send feedback to the k+1th part of the stream and so on step by step. It is a theoretical possibility to pinpoint the next new specific measuring according to the preprocessed data. Swarm can send back the whole collected data in one time together to the Earth with the united power of the Stream at cornerstones of mission.

Flowchart and Timetable as Procedures at Sectors and Communication

To fall behind to relay the data

- Proportionally fall behind, to lag at the end of the stream as telecommunication relay element as a concept to relay backward the data to Earth



Power sources[16]

- Batteries for operation for
  - long term slow consumption and for
  - short term high energy demand.
- for long term slow consumption operation:
  - space qualified small battery cells.
- for short term high energy demand:
  - from two component power sources
  - shortly like a spark
  --for example during transmission of collected scientific data
- Two components usually means one solid and one liquid component, according to pressure, mainly independently if we keep them in a closed space in a vessel, which can hold enough pressure until activating the liquid, without sublimation.

Possible target objects

- Planets with magnetic field or without
- Planetary object size: different requirements in point of view of size, ranging from
  - asteroids
  - comets
  - rocky planets
  - gas giant sized planets.
- Dusty fields: Dusty places e.g. comets or rings of planets which are around of gas giants usually.
- Combined: Gaseous big planets have moons, magnetosphere, dusty halo with particle shower together with huge particle streams

Environment Friendly and Ethic Questions

Is this ethic to spread streams of swarms of nano probes

non invasive – just passing through

Invasive – deploy some part of probes into atmosphere and other parts are measuring the results remotely also

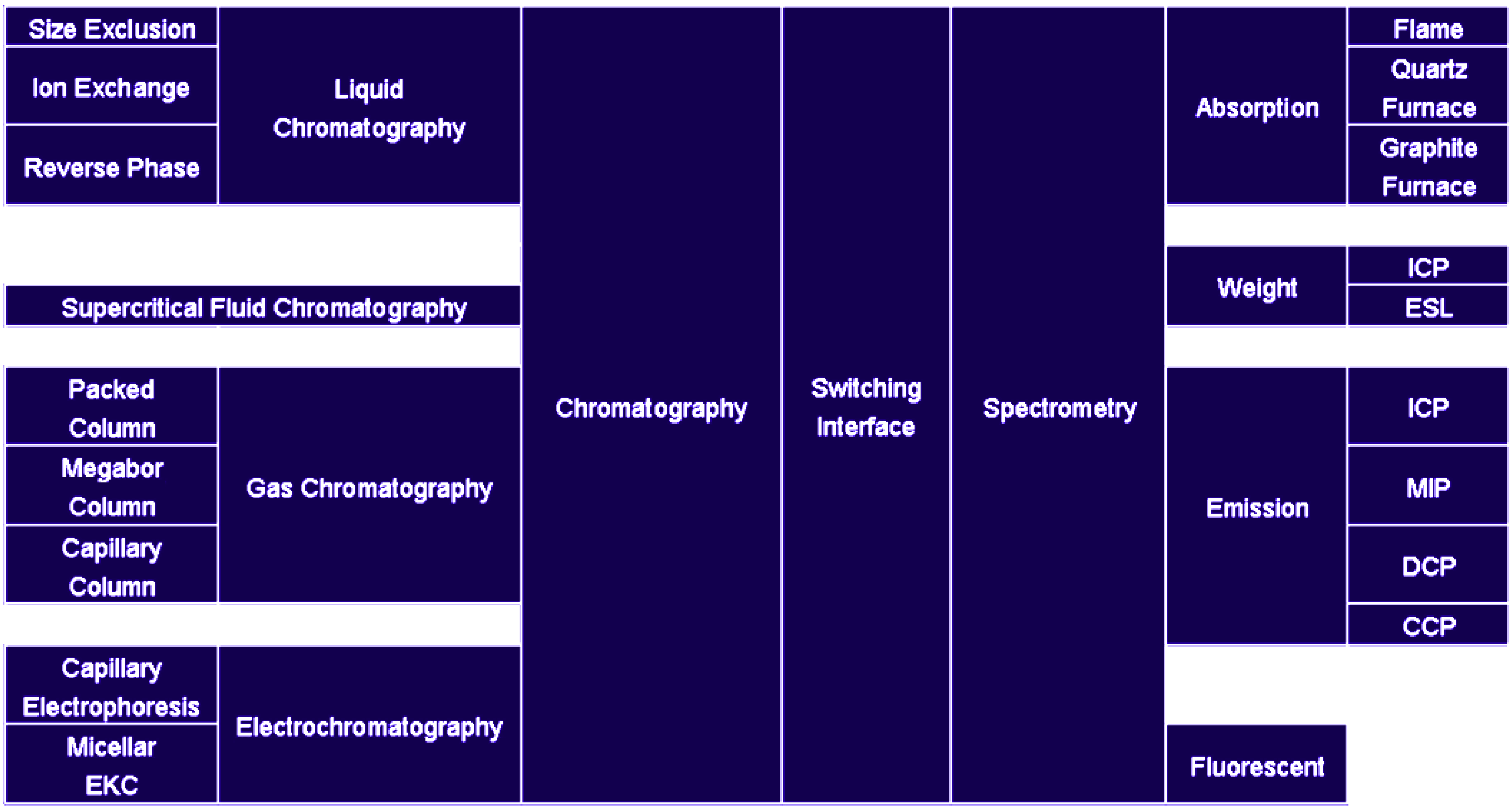
Near remote sensing by other parts of stream

Remote sensing from Earth

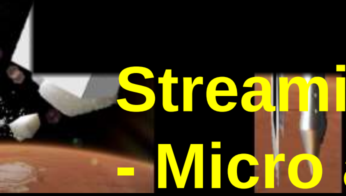
- Spectral from infra to gamma and
- Radio frequency spectrum

Variety of analytical methods

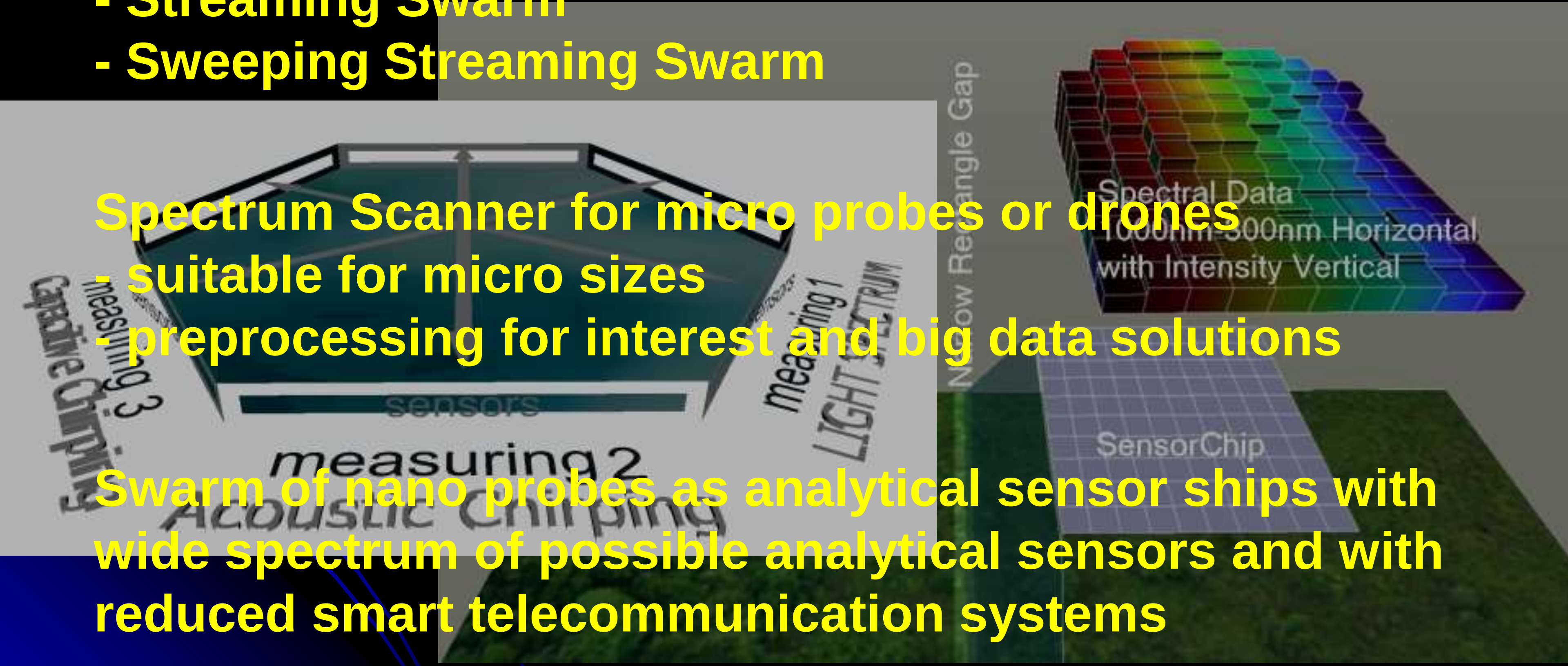
- Mainly classical measuring principles/ideas, but the new aspect is the micro devices, which is deployable?



Sensors of Swarm Stream as Technology Research on Nano Scale



Streaming Swarm Concept
- Micro and Nano Space Probes
- Streaming Swarm
- Sweeping Streaming Swarm



Spectrum Scanner for micro probes or drones
- suitable for micro sizes
- preprocessing for interest and big data solutions

Swarm of nano probes as analytical sensor ships with wide spectrum of possible analytical sensors and with reduced smart telecommunication systems

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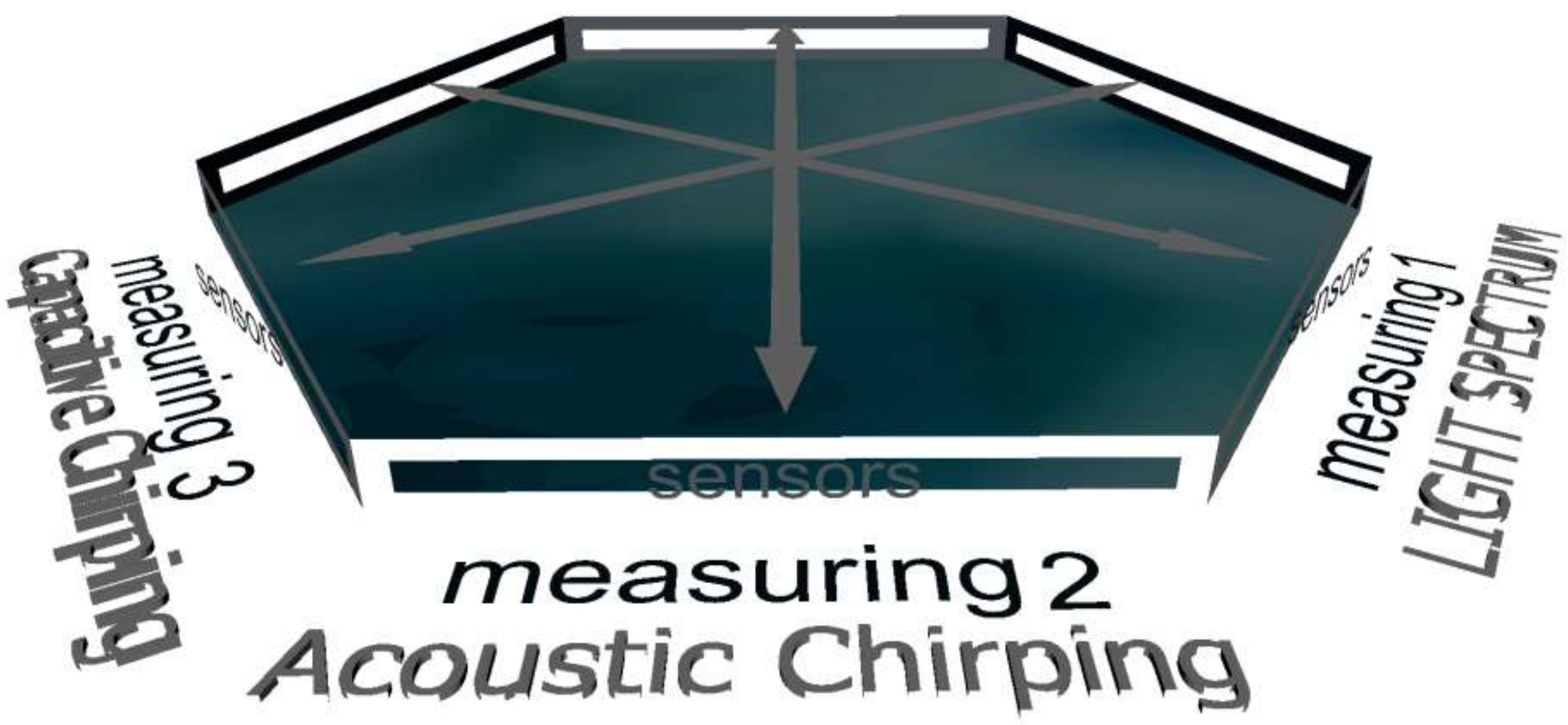
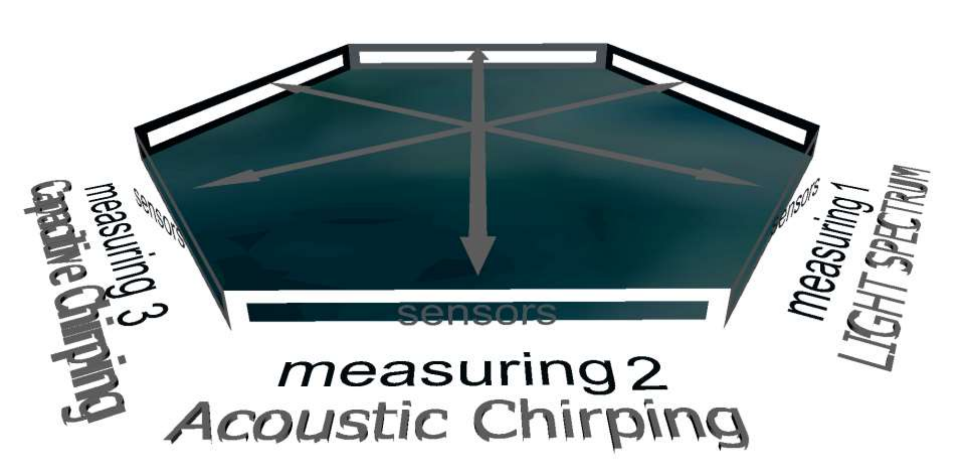
[1]MTA Wigner RCP H-1121 BUDAPEST, Konkoly Th. 29-33. vizi.pal.gabor@wigner.mta.hu

Block template of a Sensor Chamber Complex in a Nano Probe

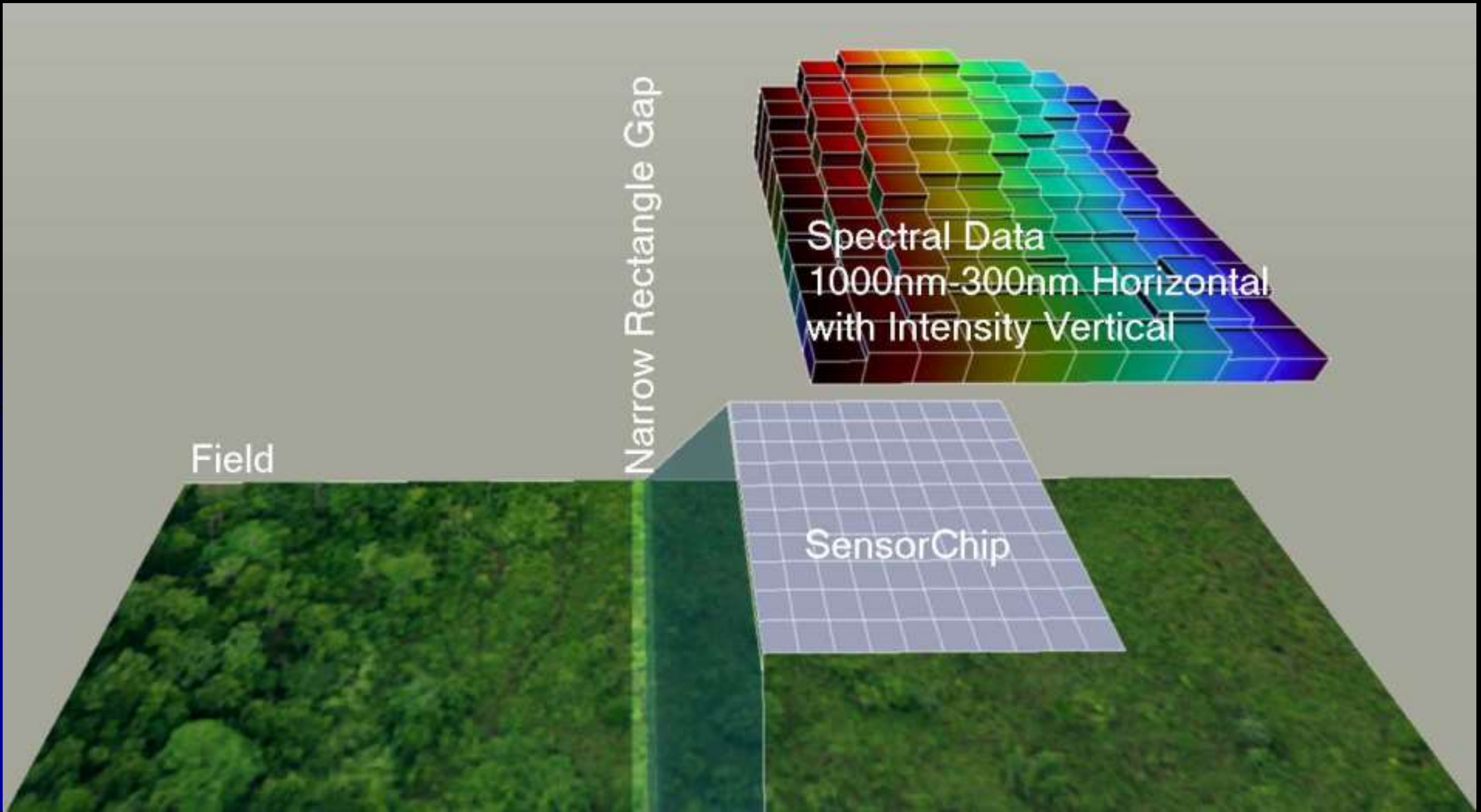


Measuring order in the Sensor Chamber Complex

- The Nano Probe contains a Sensor Chamber Complex (Vizi 2017, 2018), which can collect, hold and analyze samples from the tartget field.
- Measuring starting from a non invasive measuring, without modifying the sample. Measurings are light spectrum analyzing, acoustic chirping and capacitive chirping.
- According to measuring target and the collected matter - to keep the sample in original state – the order of light spectrum analyzing and acoustic chirping can be changed in order to keep the measurement non invasive, to keep the sample in original intact state. (Vizi 2017)
- Phase of the capacitive measurement usually invasive and may be modifying the sample. It can be advantageus for the result to broke into componenets, ions and beneficial to collect more data about components of the sample.



Block template of a Full Spectrum Scanner Field Scanning - One Narrow Rectangle CCD and the Spectrum



Távoli térinformatika, térképezés

- A Csurjumov-Geraszimnekó üstökös nyaki része 2014.08.20.

Távoli térinformatika, térképezés

- Final place of Rosetta mission’s Philae lander on the surface of Comet Churyumov-Gerasimenko 67P
- A Rosetta misszió Philae leszállóegységének végső helye a 67P Csurjumov-Geraszimenkó üstökösön
- Video: PhilaeRestplace

CONCLUSION

- Special philosophy HW and SW plans
- In case of smarter but more expensive elements measuring and transmitting can be turned really efficient.
- The **redundancy** is also coming from the large amount of **abundance** of the Streaming Swarm of Nano Space Probes (SNP).
- In case of a streaming swarm mission **a weighted distribution of tasks** necessary to elaborate during developing and deploying
- The whole streaming fleet necessary to **behave like one big organization** as one big integrated space system

Thank you very much for your attention!

References:

- [1] Malcolm Ritter: Stephen Hawking joins futuristic bid to explore outer space, phys.org, April 12 2016, http://phys.org/news/2016-04-stephen-hawking-life-tiny-spacecraft.html
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