Pico-Satellite Formations:
The Science & Technology Challenge in „New Space“

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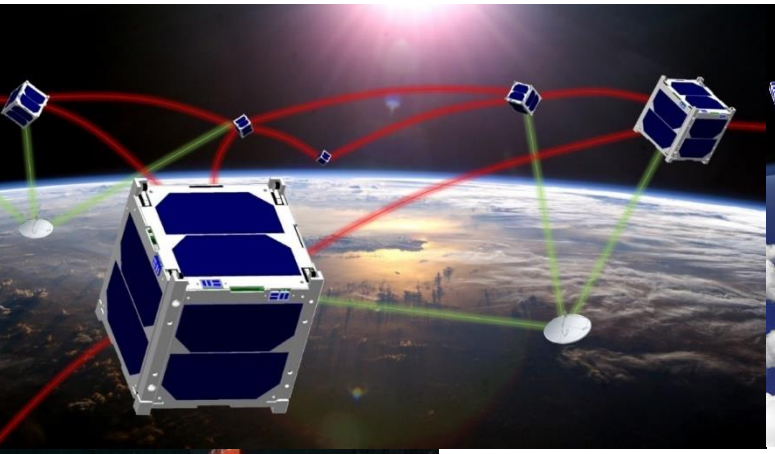
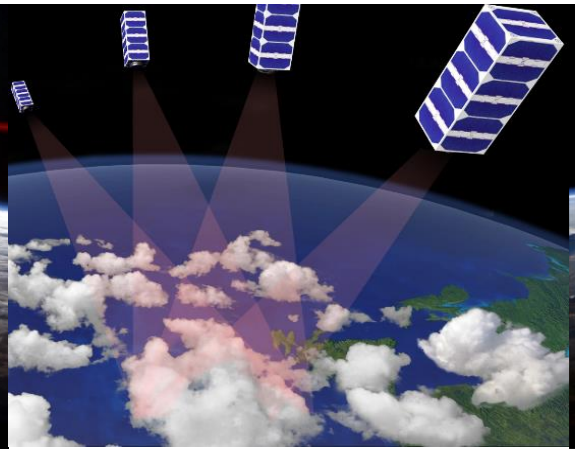
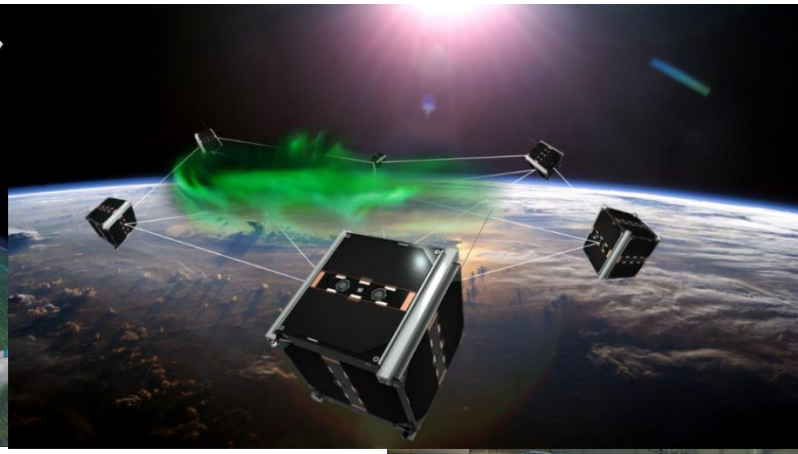

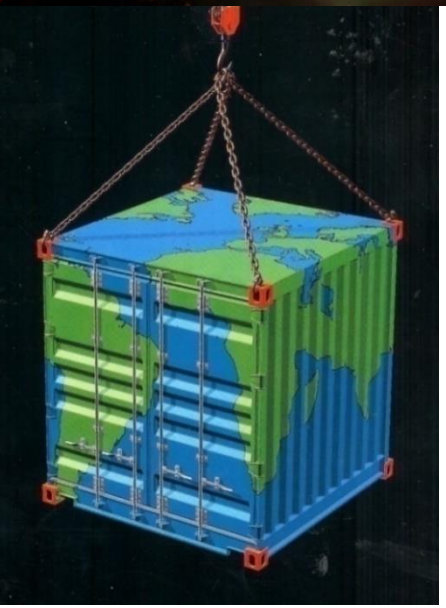

NetSat, the Future in Space : Smart, Small, and Cooperativ ?

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NetSat Launch Party, Würzburg 28.9.2020

Huge Perspectives for Small Satellite Formations

Developments in Computer Technology during 50 Years

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Mainframe computers 1970

- needed area complete halls
- fast disk storage of 10 MB
- magnetic tapes as mass storage

Developments in Computer Technology during 50 Years

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Today:

- small, networked smart phones act as computers in the cloud
- storage several GB

Satellite Evolution during my Professional Life

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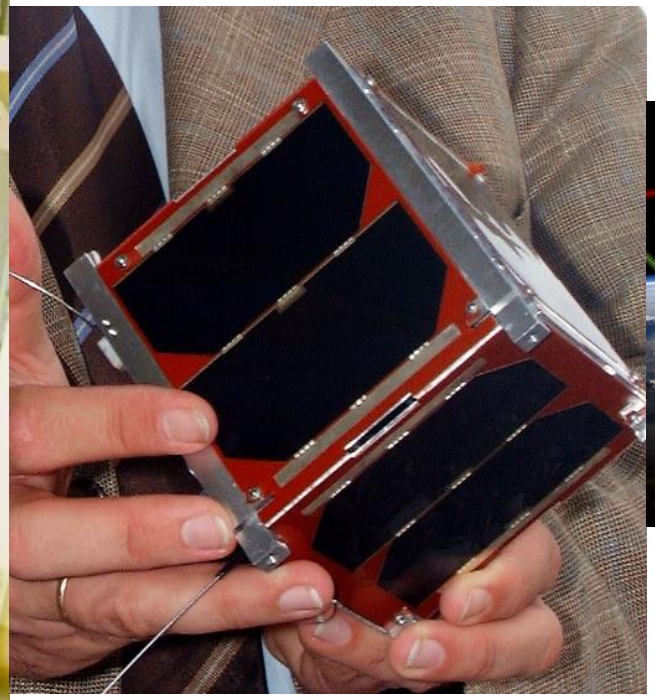
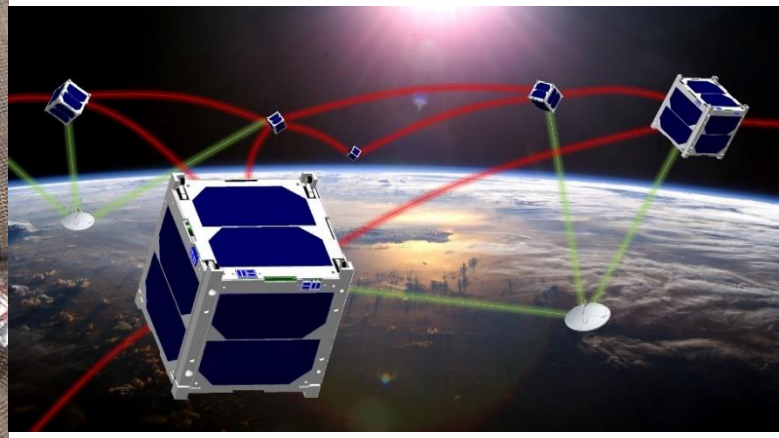
Cassini/Huygens by NASA / ESA to explore Saturn and Titan (initiated 1986)
6.7 m height / Ø 4 m
launch mass: 5.82 t

miniaturization



UWE-1 first German pico-satellite; 10 cm cube; mass<0,9 kg; for Internet from space; launch 27.10.2005

cooperation



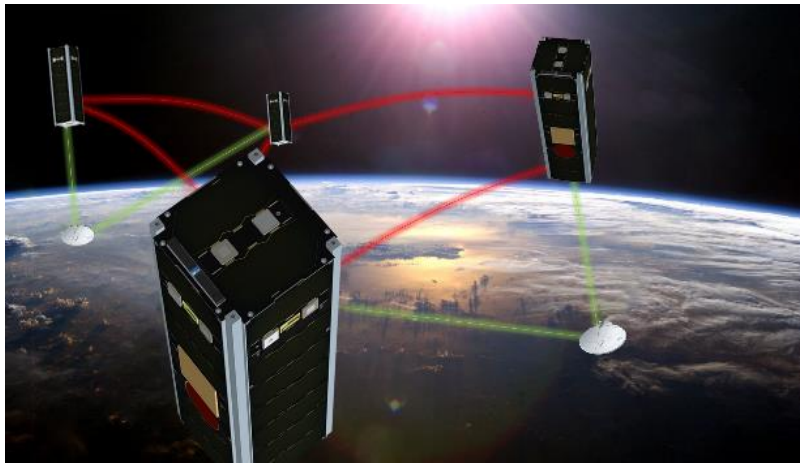
NetSat distributed, networked multi-satellite system; launch 28.9.2020

Huge Perspectives for Small Satellite Formations

NetSat Motivation

decentralized, distributed systems offer

- **higher fault tolerance and robustness** (after defects, the other satellites continue)
- **scalablility** according to application needs (additional satellites can be added to increase resolution and coverage)
- **better availability** for multi-satellite system



Research supported by an ERC Advanced Grant 2012

NetSat Control Challenges

Gefördert durch
Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie

- **self-organization:** inter-satellite links, networked control, cooperation
- **autonomous reactions:** relative navigation, fuel efficiency, collision avoidance
- **miniaturization :** control & FDIR software have to compensate noise

Formation Implementation

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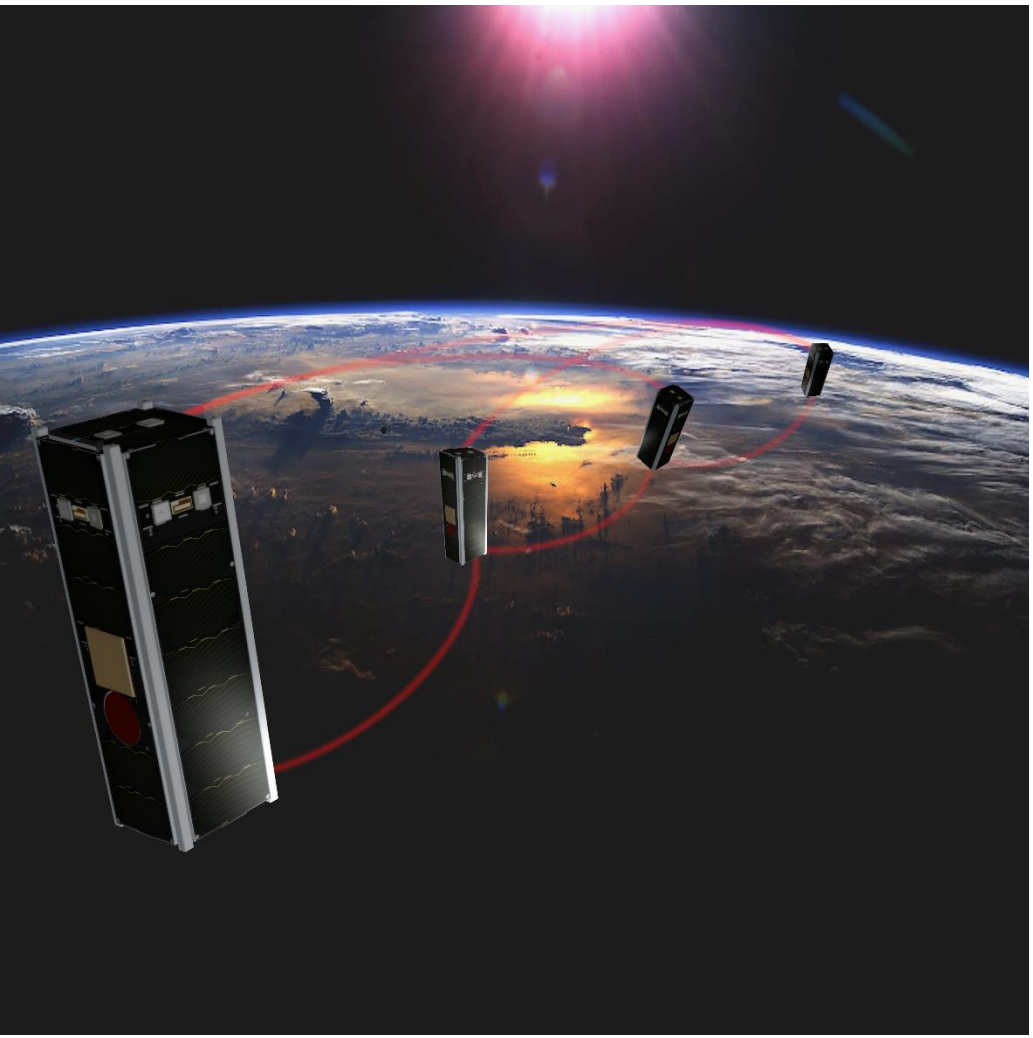
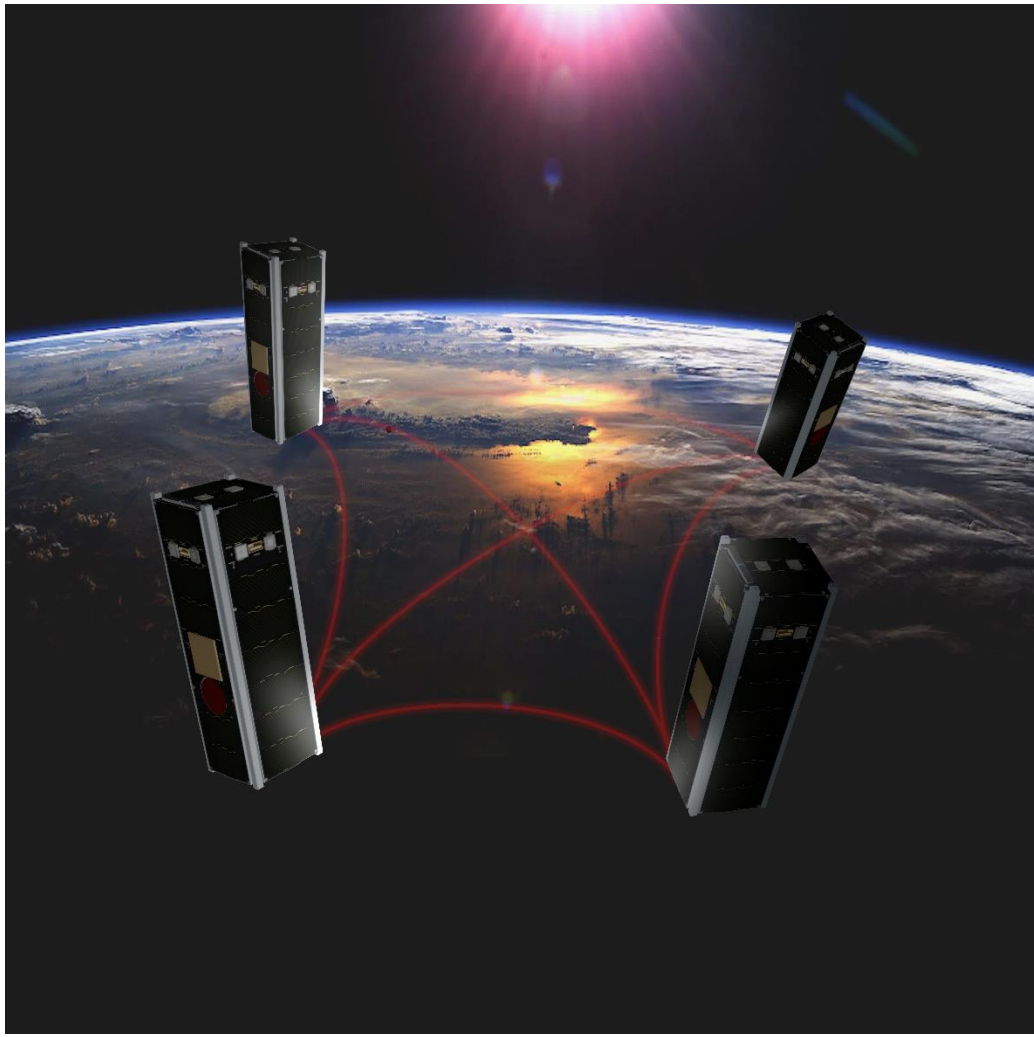


1-dimensional configuration
all satellites aligned in one line;
string of pearls

2-dimensional configuration
all satellites in one plane



NetSat Innovation

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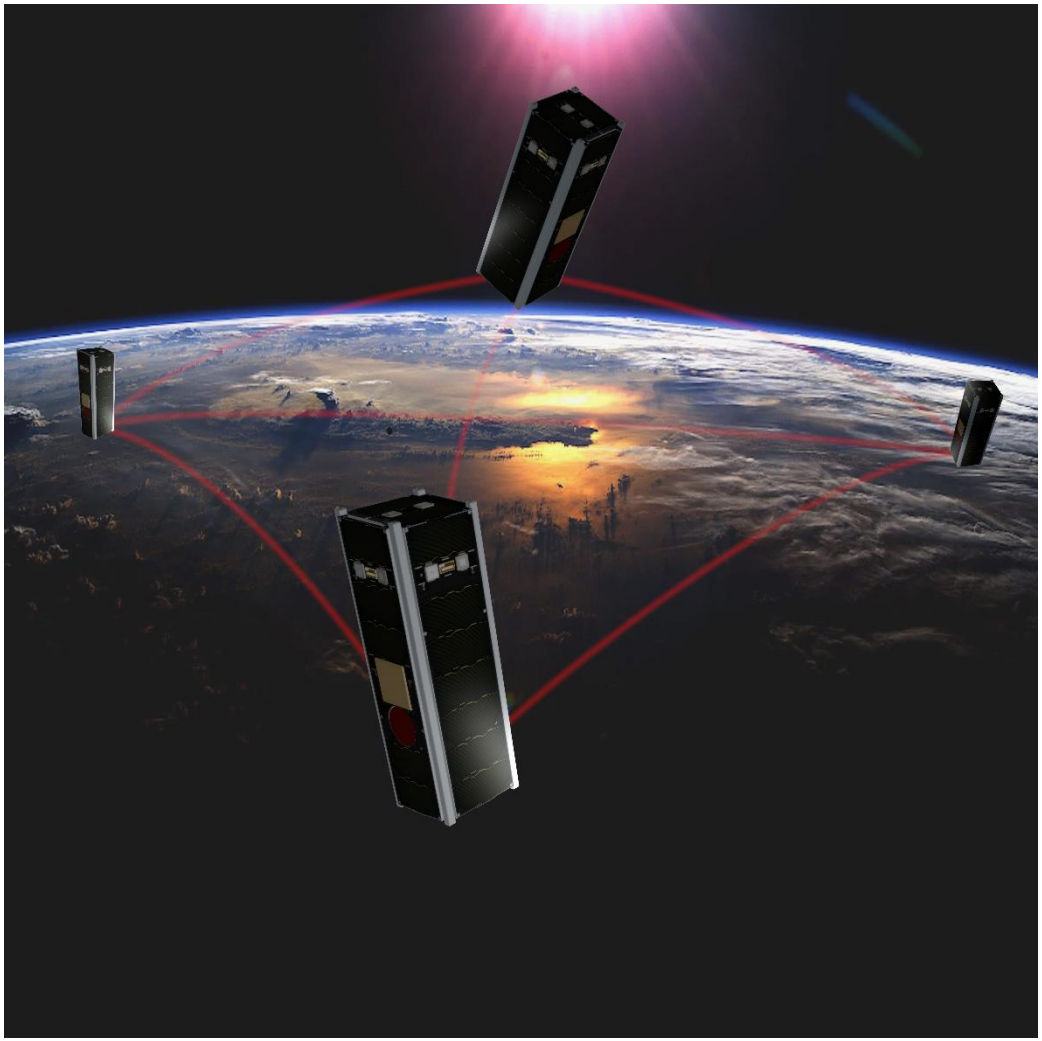

3-dimensional configuration
satellites distributed in 3D space
Shape of a tetrahedron

Space Dynamics: Cartwheel Helix Orbit 1

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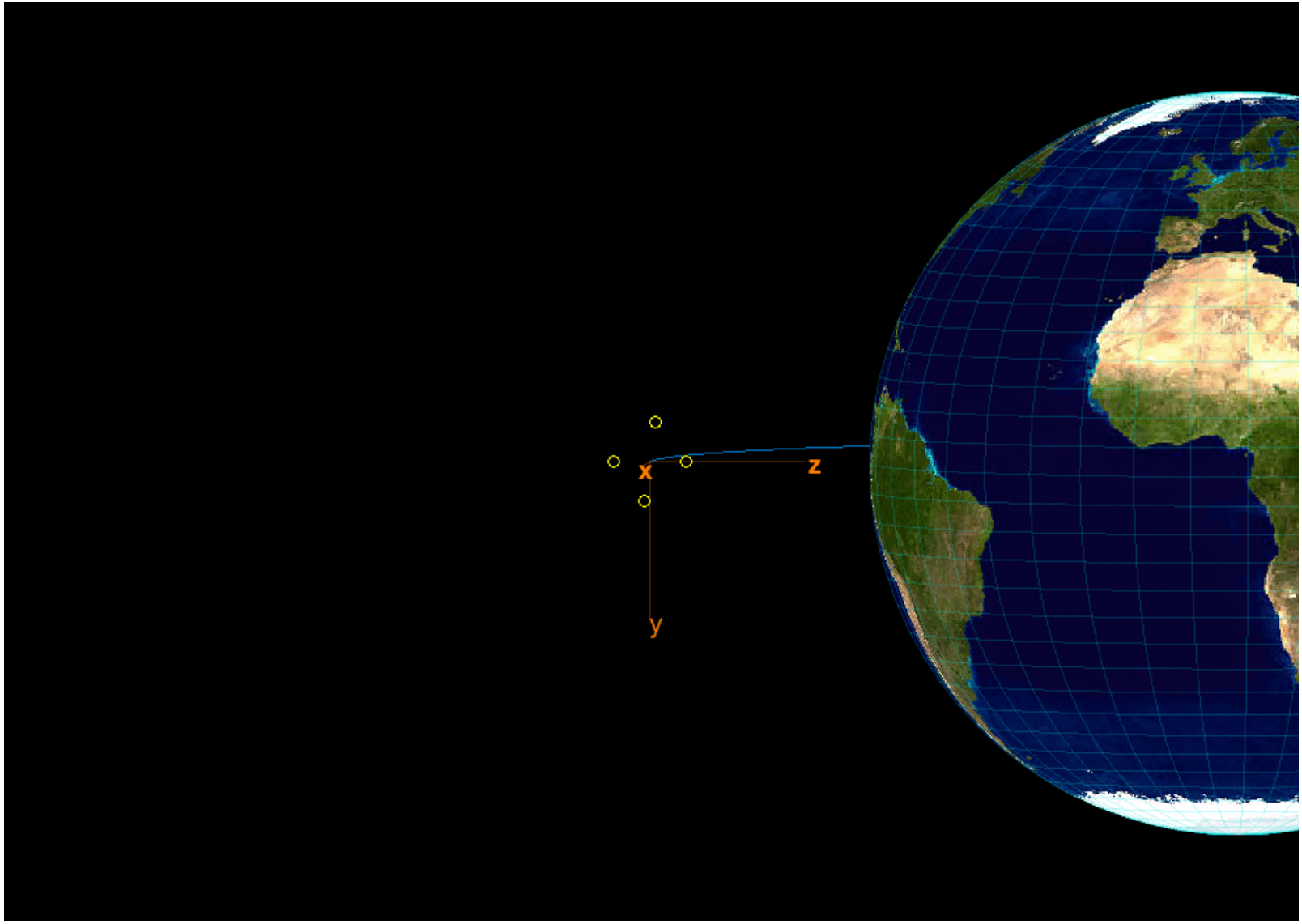

Space Dynamics: Cartwheel Helix Orbit 2

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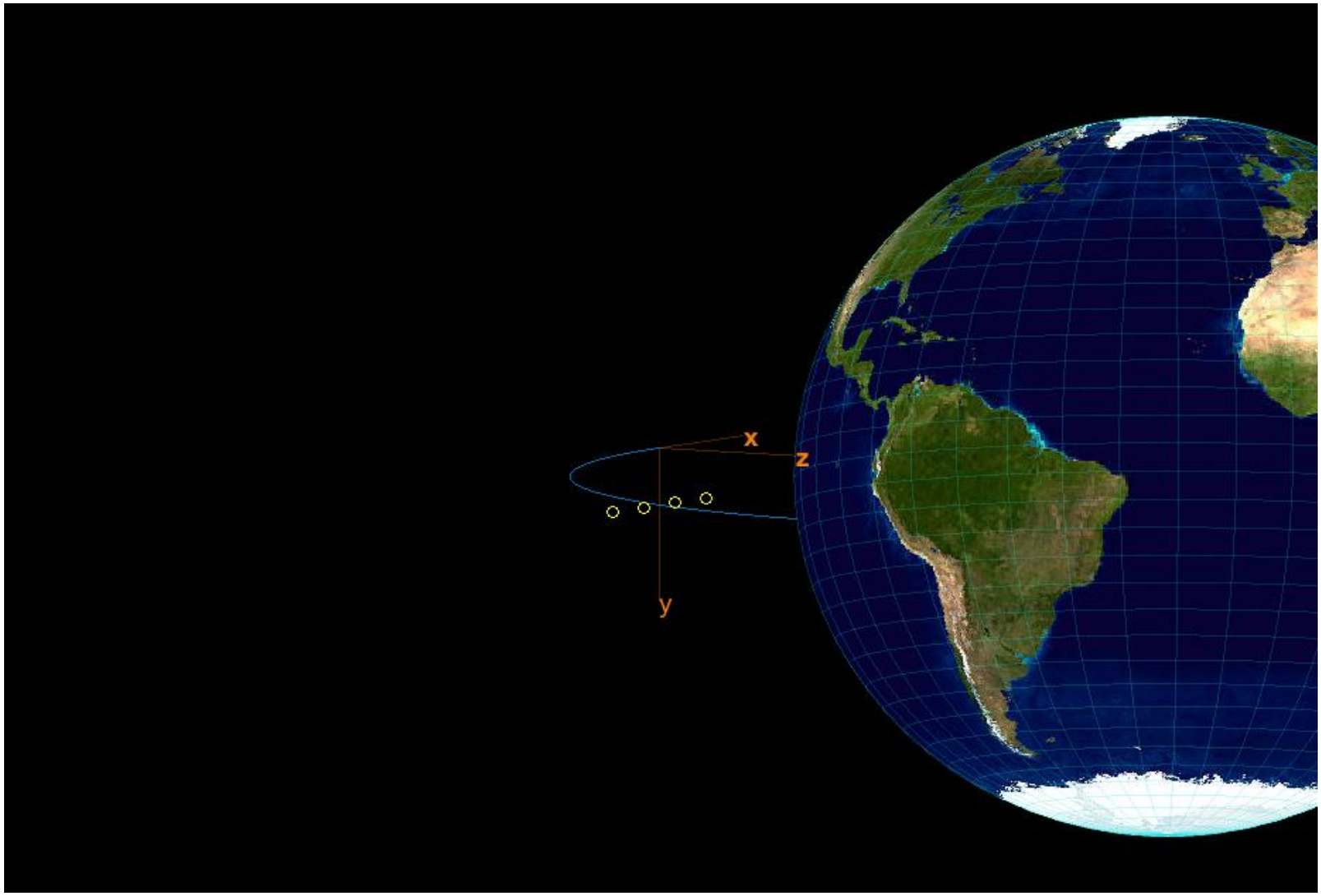


Forthcoming NetSat Experiments

- formation control for optimum observation configurations in 3D
- transitions between different formation topologies
- control strategies for autonomous formation maintenance
- distance reduction from 100 km in the beginning to 20 m at end of mission

Future Application of these Formation Technologies

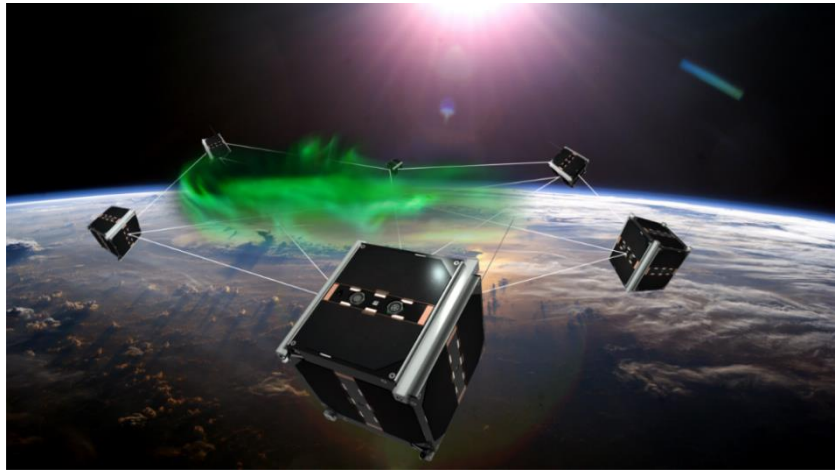
sensor networks for scientific observations

- multi-point, multi-perspective observations
- very long baseline data acquisition

traditional satellites for illumination, large small satellite detector networks as receiver

forming of virtual large antenna arrays for

- long distance data transmission
- high resolution detection



Future applications of satellite formations

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technology development for nano-satellite formations

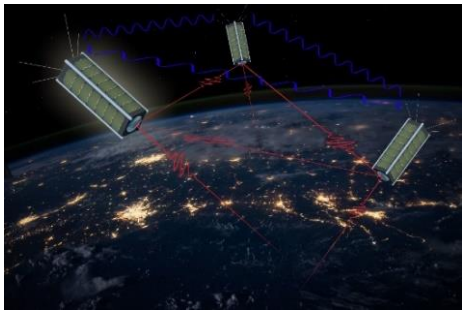
NetSat (launch now in one hour)
networked control, intersatellite links, and relative navigation technologies for small satellite formations

erc Advanced Grant 2012

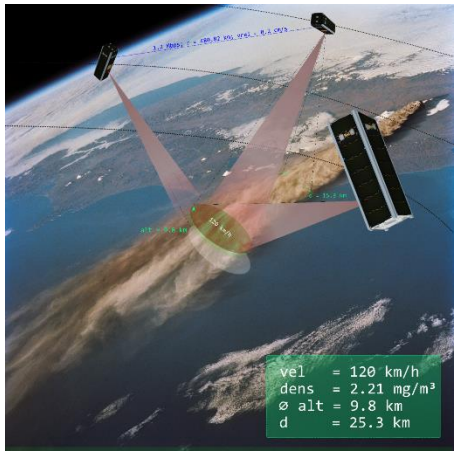
Excellent perspectives for scientific innovations in telecommunication and Earth observation networks !

erc Synergy Grant 2018

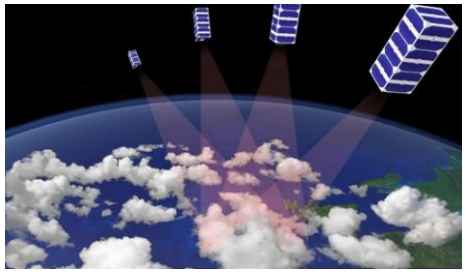
applications



QUBE (2021)
Quantum key distribution for secure communication



TIM / TOM (2021)
3D-Earth observation by photogrammetric methods



CloudCT (2022)
computertomo-graphy of clouds for improved climate predictions