Regional Leaders Summit RLS – Sciences
München, 14.7.2016

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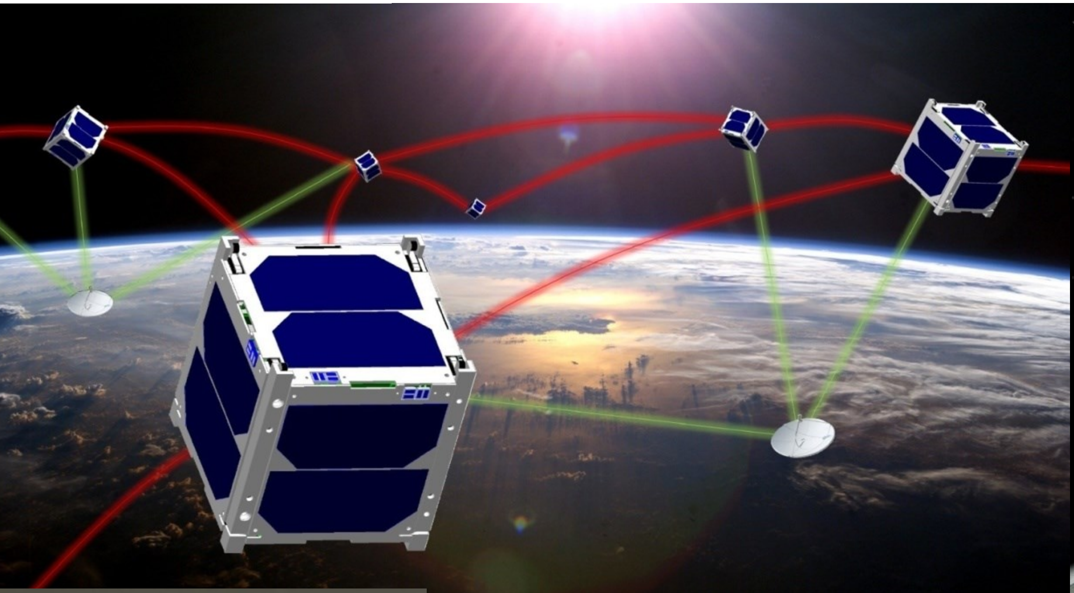

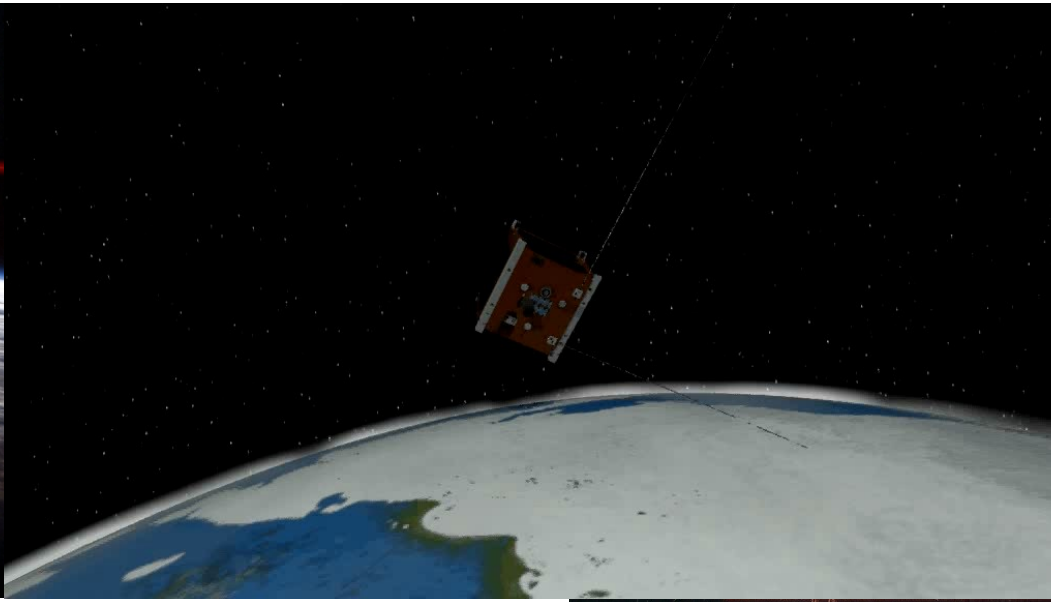

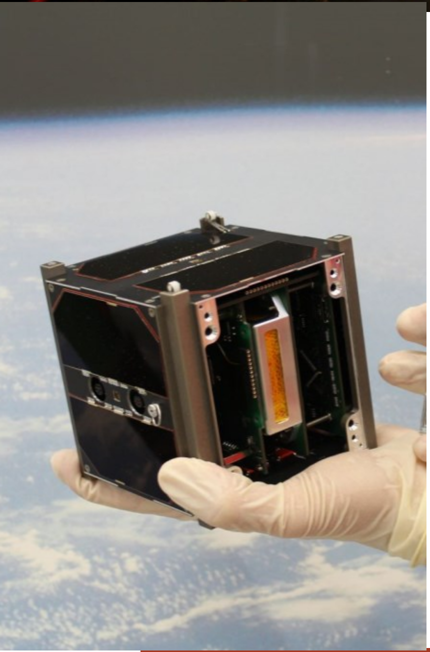

Formations of Small Satellites Offering Huge Cooperation Potential

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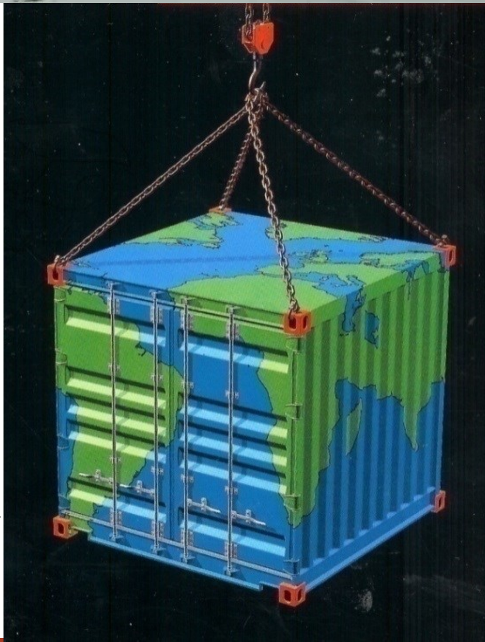

2014 *BREAKTHROUGH OF THE YEAR* | *RUNNERS-UP*

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High Scientific Profile

The journal "Science" selects every year the "Breakthroughs of the Year" and in addition also the 10 runner-ups for the most promising future scientific areas. Here the topic "Satellite formations" corresponds to two mentioned fields.

Two Earth-observing CubeSats (dark oblong objects) shoot from a satellite deployment device on the International Space Station.

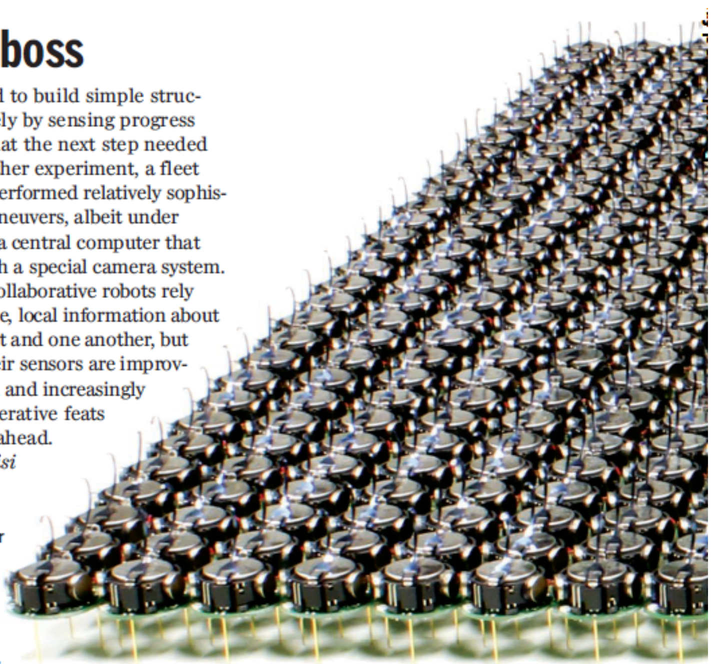
Cooperative 'bots' don't need a boss

Robots are getting better all the time at working with humans, but this year several teams demonstrated that these machines can also work together, without human supervision. At a time when roboticists are still struggling to improve how well individual robots sense their surroundings and respond to new situations, letting teams of robots execute their own missions may seem premature. But after years of work, researchers have come up with new software and interactive robots capable of cooperating on rudimentary tasks.

In one study, a thousand robots the size of U.S. quarter coins came together like a marching band to form squares, letters, and other 2D formations. The sheer scale required cheap, easy-to-run robots that could efficiently sense where other robots were. In another project, 10 quadcopters radioed their locations to one another and adjusted their paths to avoid collisions and fly in formation, creating a rotating circle. A third group of robots, inspired by termites, was programmed to build simple structures cooperatively by sensing progress and inferring what the next step needed to be. In yet another experiment, a fleet of robotic boats performed relatively sophisticated group maneuvers, albeit under the command of a central computer that tracked them with a special camera system.

So far, all the collaborative robots rely on relatively crude, local information about their environment and one another, but both they and their sensors are improving rapidly. More, and increasingly impressive, cooperative feats undoubtedly lie ahead.
–Elizabeth Pennisi

Small, disk-shaped robots that maneuver in formation are just one example of the year's progress in self-organizing machines.



IMAGES: (CLOCKWISE FROM TOP LEFT) NASA; SVEN LIDSTROM/ICECUBE/NSF; SYNTHORX, ADAPTED BY C. SMITH/SCIENCE

The rise of the CubeSat

A decade ago, CubeSats were just educational tools, a way for university students to place a simple Sputnik in space. Now these 10-centimeter boxes, built with off-the-shelf technology and costing hundreds of thousands of dollars rather than hundreds of millions, have taken off. More than 75 were launched this year, a record. What's more, the little boxes are starting to do real science.

Increased and affordable access to space is driving much of the boom. CubeSats can hitch a ride on commercial or government rockets carrying bigger spacecraft, or they can be pushed out the door of the International Space Station. The rapid-fire launch rate is encouraging something never before seen in space: risk-taking. Designers can tolerate a failure or two and quickly get back in the game. As technology advances, they can also swap in better solar panels, batteries, or processors.

Private money has taken notice, funding companies such as Planet Labs, which is monitoring Earth with a swarm of perennially replaced CubeSats. Their small telescopes take pictures with relatively poor spatial resolution—a few meters—but at frequent intervals. Spy agencies may not be seduced, but Planet Labs' data are plenty useful for monitoring deforestation, urban development, and river changes.

Coming up next: CubeSats that talk to one another while taking measurements. Among other things, such CubeSat constellations will be able to cover more area, faster, or monitor Earth's surface in several wavelengths at once. If they work, CubeSats will have demonstrated not only that small is beautiful, but also that the whole is greater than the sum of its parts. *–Eric Hand*

Commercial Perspectives for Small Satellites in Earth Observation

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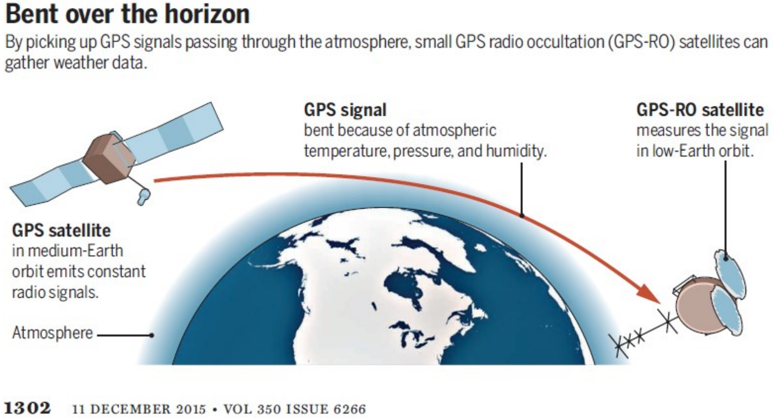
2016: launch of about 100 Dove satellites flying in a constellation is planned

Picture taken by Dove pico-satellites

Planet Labs produces pico-satellites with dimension 30 cm x 10 cm x 10 cm for Earth observation with about 5 m resolution



The companies **Spire** (San Francisco) and **PlanetiQ** (Boulder, Colorado) detect with a pico-satellite constellation atmospheric deviations of GPS-signals and infer weather characteristics (like temperature, pressure, humidity)

Emerging Markets for Pico-Satellites

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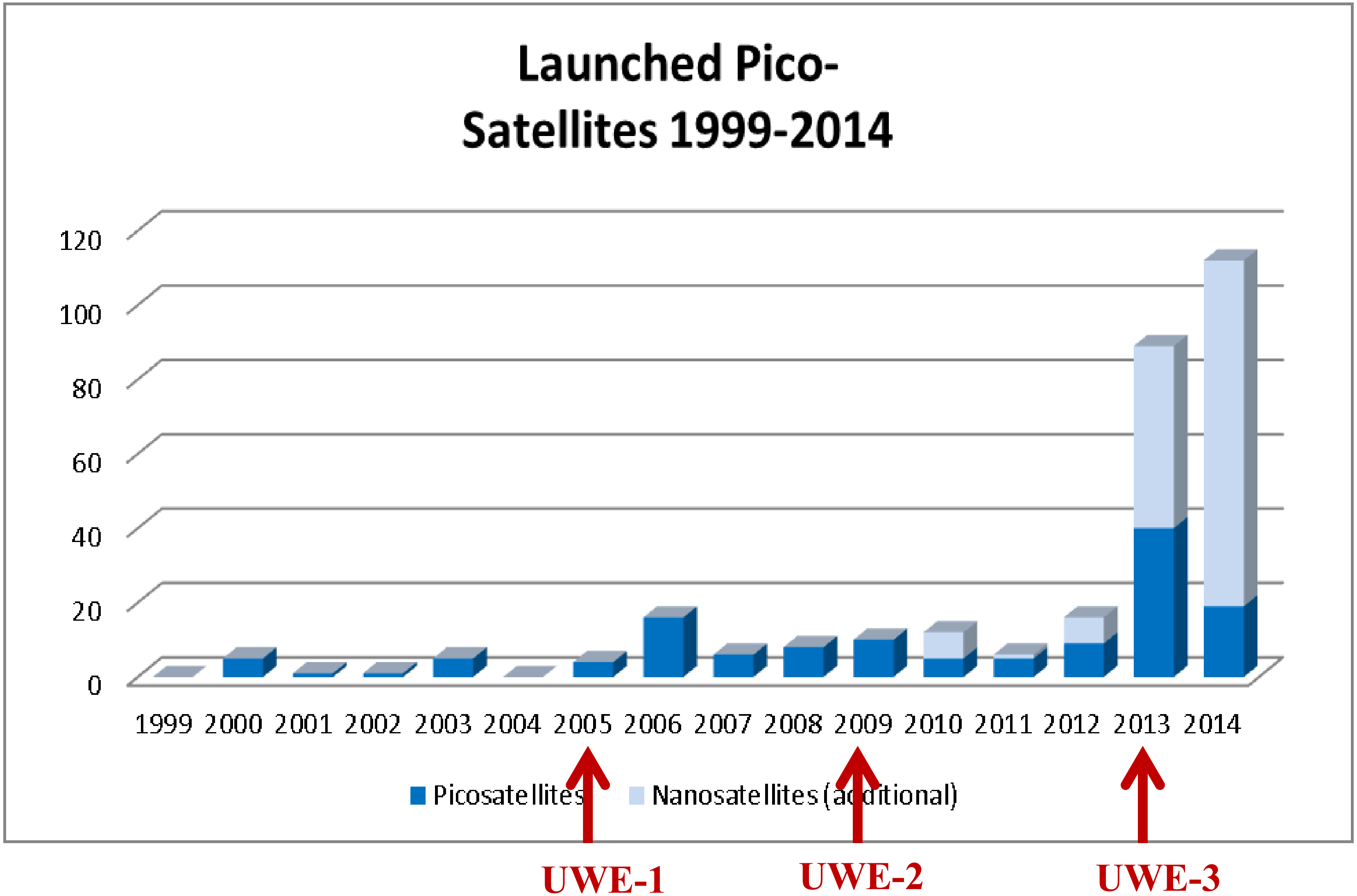


Worldwide launches of pico-satellites (mass ~ 1 kg) and nano-satellites (mass ~10 kg)

Emerging Markets in particular for pico-satellite formations

Constellation driving the smallsats' demand

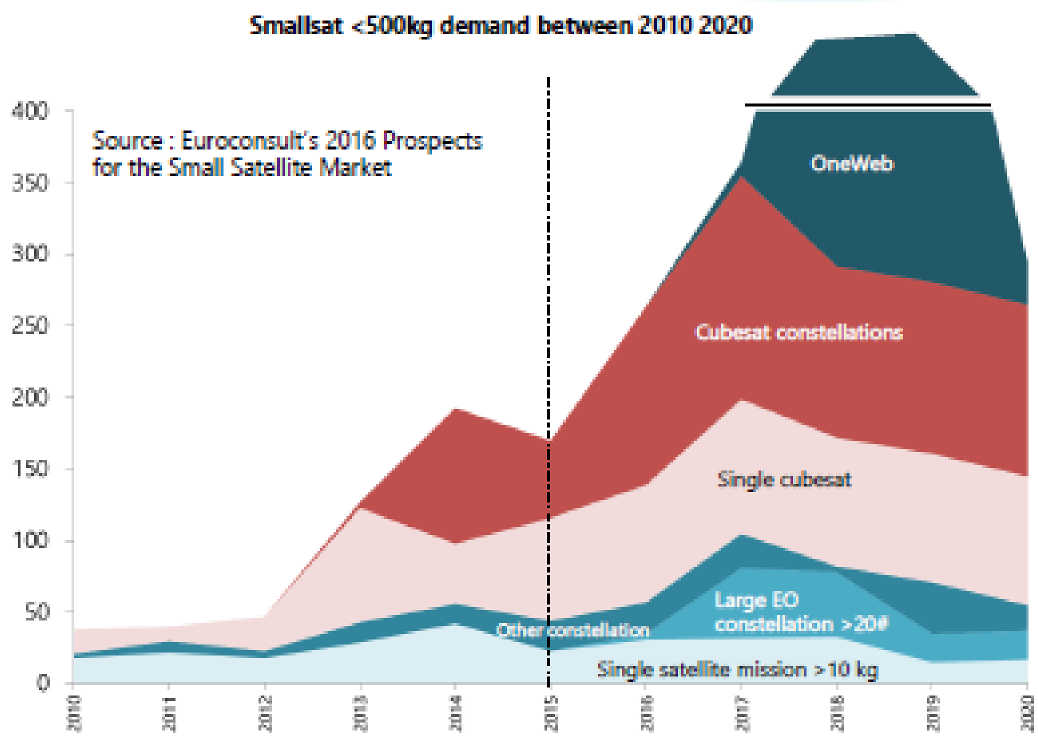
BY AVERAGE +16% GROWTH EACH YEAR IN THE PAST DECADE

> A total of 577 satellites (<500kg) have been launched over the past 5 years, 2200 are expected to be launched by 2020

> In the past three constellations for satcom and earth observation accounted for 35% of the total and should growth up to 67% in the next 5 years driven by several large projects

A TURNING POINT OF THE DEMAND

> Commercial operators will account for 86% of the future demand (40% in the past)



Small Satellite Formations will be the necessary next step to follow the constellations

Objectives: Realisation of a challenging, inspiring, motivating and affordable joint project

- All partner regions Georgia, Upper Austria, Quebec, São Paulo, Shandong, Western Cape, Bavaria host universities, companies or agencies with emphasis in space technology and participate.
- Universities from the partner regions are involved in leading edge research on pico-satellites, and operate already several satellites successfully in orbit.
- It is a symbolic perspective, when the partner regions extend their terrestrial cooperation to hig-htech demonstration in space to realize a system of cooperating small satellites based on technologies from the partner regions.
- Applications in Earth observation and environment monitoring will be addressed.

Space Activities in the Partner Regions

Québec

The Canadian Space Agency is located in Saint-Hubert, Québec

Space / small Satellite programs at

Regular Canadian Satellite Design Challenge (CSDC) to build small satellites

Bavaria hosts a broad spectrum of space activities at agency, industry and university level

Space Actitivities in the Partner Regions

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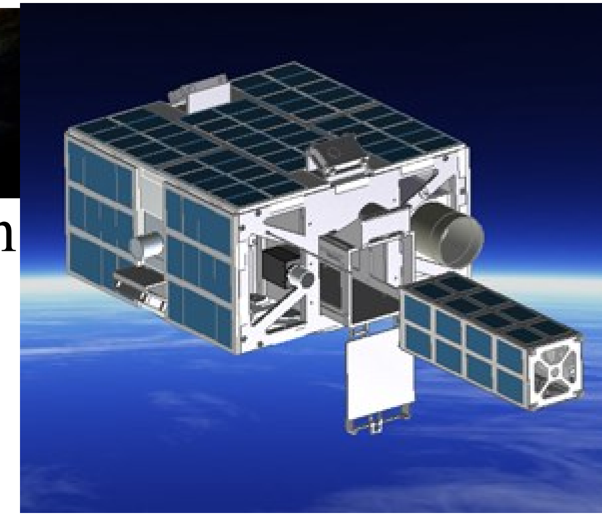
Georgia is home to more than 500 companies in the *aerospace*

Georgia Tech | Center for Space Systems

Prox-1 University Nanosat Mission



Western Cape

Cape Peninsula University of Technology

CPUT works on the ZACUBE-1 satellite

SumbandilaSat as starting point for SunSpace and now Spaceteq

SPACETEQ

São Paulo

INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS MCT INPE BRASIL

Upper Austria

JOHANNES KEPLER UNIVERSITÄT LINZ | JKU

Shandong

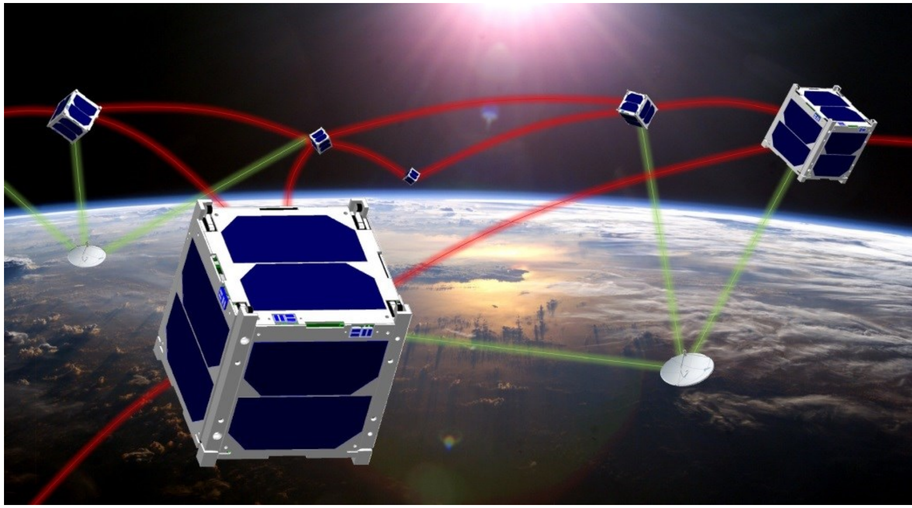
中国空间技术研究院 China Academy of Space Technology 中国航天

Shandong Institute of Aerospace Electronics

山东大学

Distributed networks of satellites support

- higher temporal / spatial resolution in observation data,
- higher availability,
- graceful degradation capabilities in case of failures



Miniaturization techniques enable

- realization of satellites at continuously smaller masses,
- decreased costs for launch

Further challenges for small satellites relate to

- relative navigation (position and attitude),
- inter-satellite communication in dynamic environments

Leading edge research supported by ERC Advanced Grant

(the highest valued European Research price)

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European Research Council

ZfT /Uni Würzburg: Roadmap for distributed networked pico-satellite systems

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(UWE = ***U***niversity ***W***ürzburg's ***E***xperimental satellites)

2017/18 NetSat-1 to NetSat-4 Formation Flying Mission
- **Distributed Computing Capabilities**
- **Formation Control**
- **DTNs, MANets**
- **…**

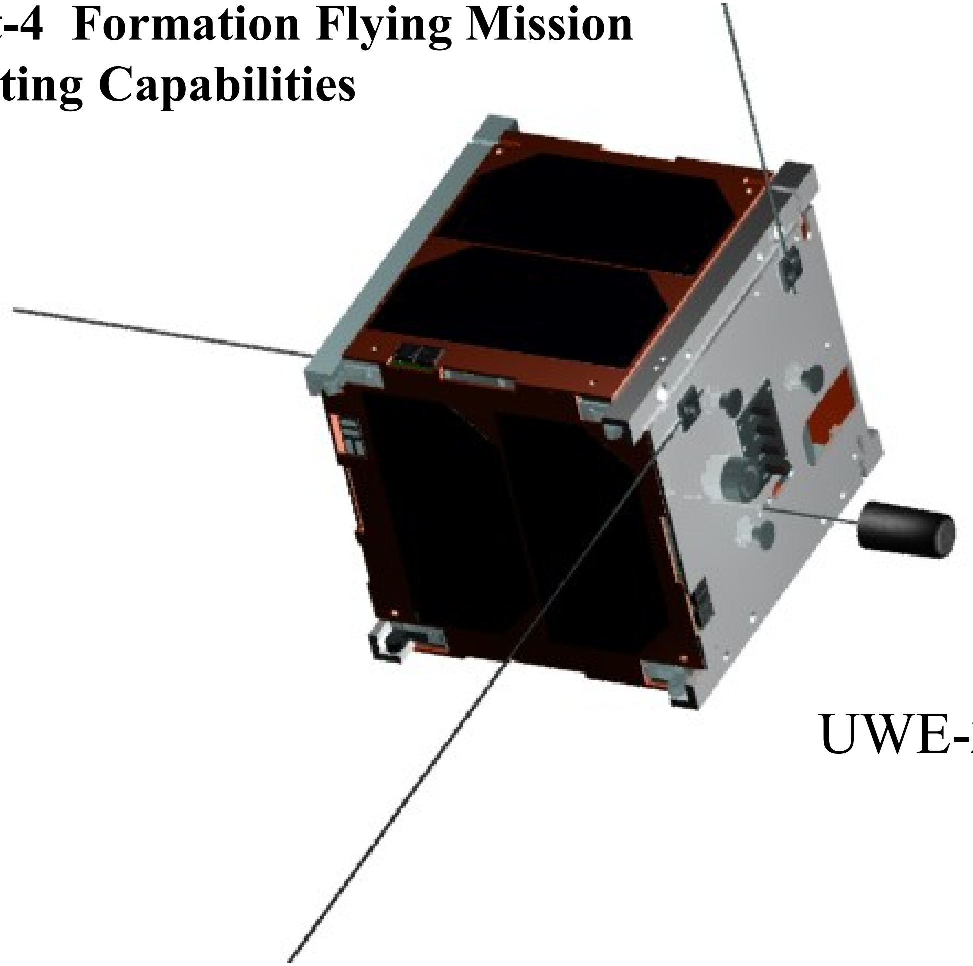
2016 TIM, TOM
- **Relative Navigation**

2016 UWE-4
- **Position Control**

2013 UWE-3
- **Attitude Control**

2009 UWE-2
- **Attitude- and Orbit Determination**

2005 UWE-1
- **Telecommunication "Internet in Space"**



UWE-2

Conclusions

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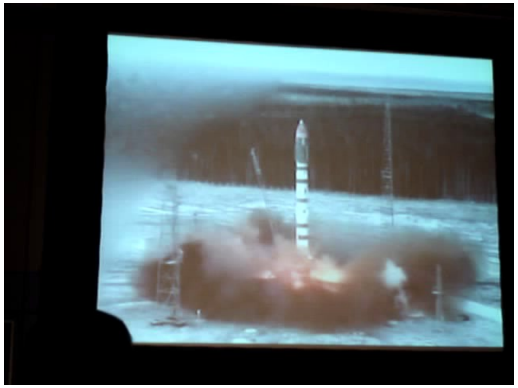
The paradigm shift from large spacecrafts with multiple payloads to cooperating distributed small satellite systems offers interesting application potential, topics for research and education, as well as for international cooperation.



Networked satellite systems offer efficient approaches

- for high spatial and temporal resolution of observation data
- for cooperatively solving complex tasks
- for higher fault tolerance and robustness of the overall system

- There are excellent opportunities for international partners to contribute specific components or instruments for integration into the satellites, but also to contribute a dedicated satellite to the network.
- Partnerships in ground station infrastructure offer participation of a broad audience

Due to the aerospace hightech emphasis in all the regional partner states, there are excellent cooperation opportunities for small satellite networks ! A project with high visibility