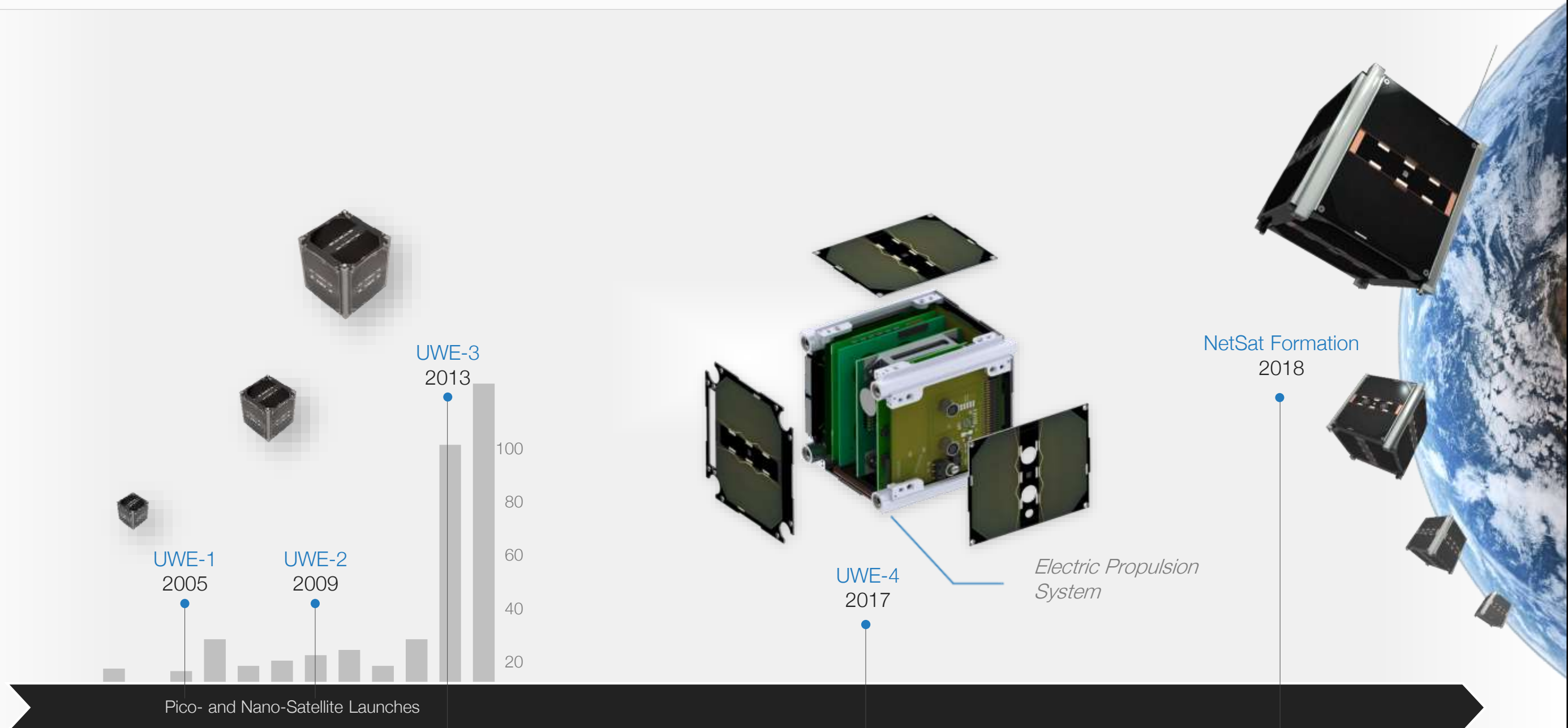


# Lessons Learned From More Than 10 Years CubeSat Activities in Wuerzburg, Germany

4th UNISEC Global Meeting  
October 18-23, Bulgaria

Stephan Busch • University of Würzburg • Oct. 2016

# Miniature Satellites from Würzburg (Germany)



## Performance

- Miniaturization limits available resources

## Durability

- Only 40-50% of miniature satellites reach their primary mission objective in orbit

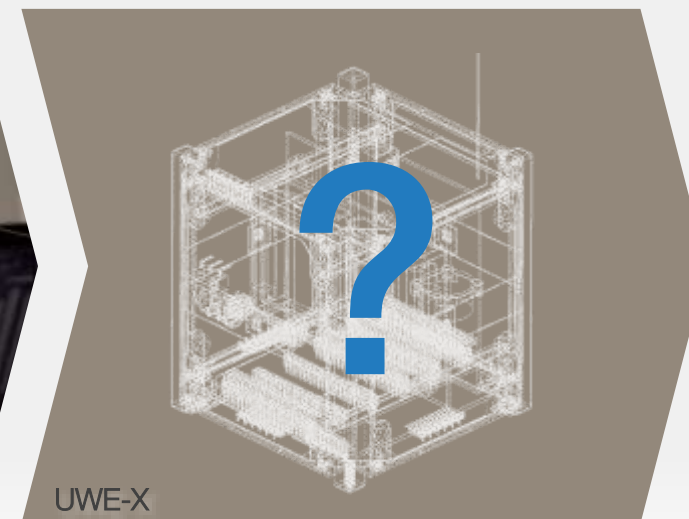
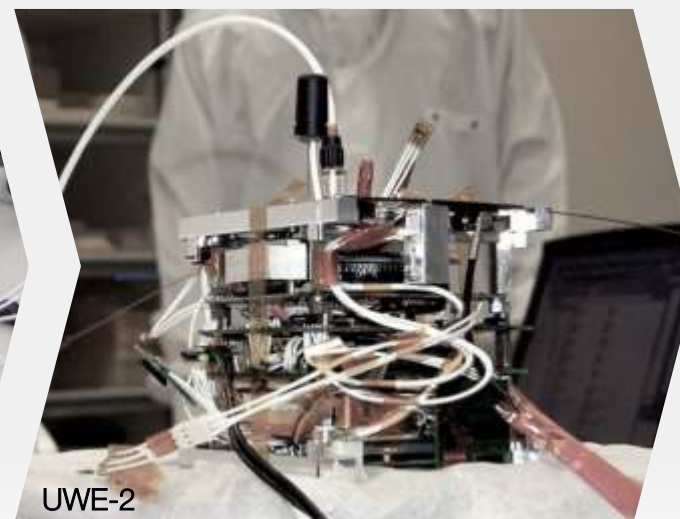
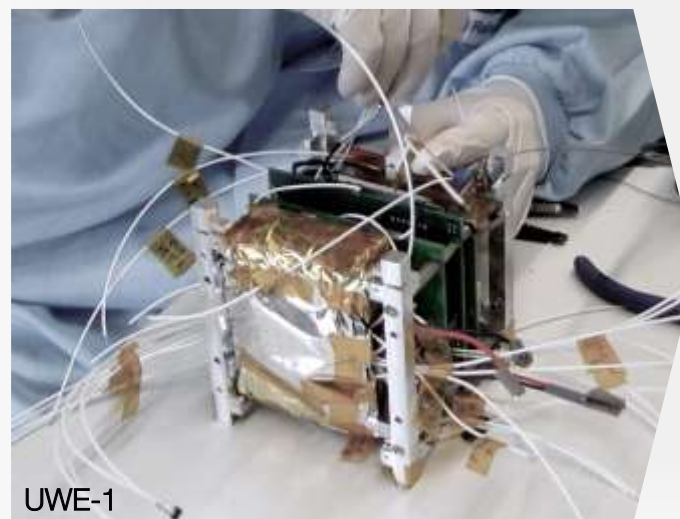
Bouwmeester und Guo, 2010; Swartwout, 2013

## Fast Development Cycle

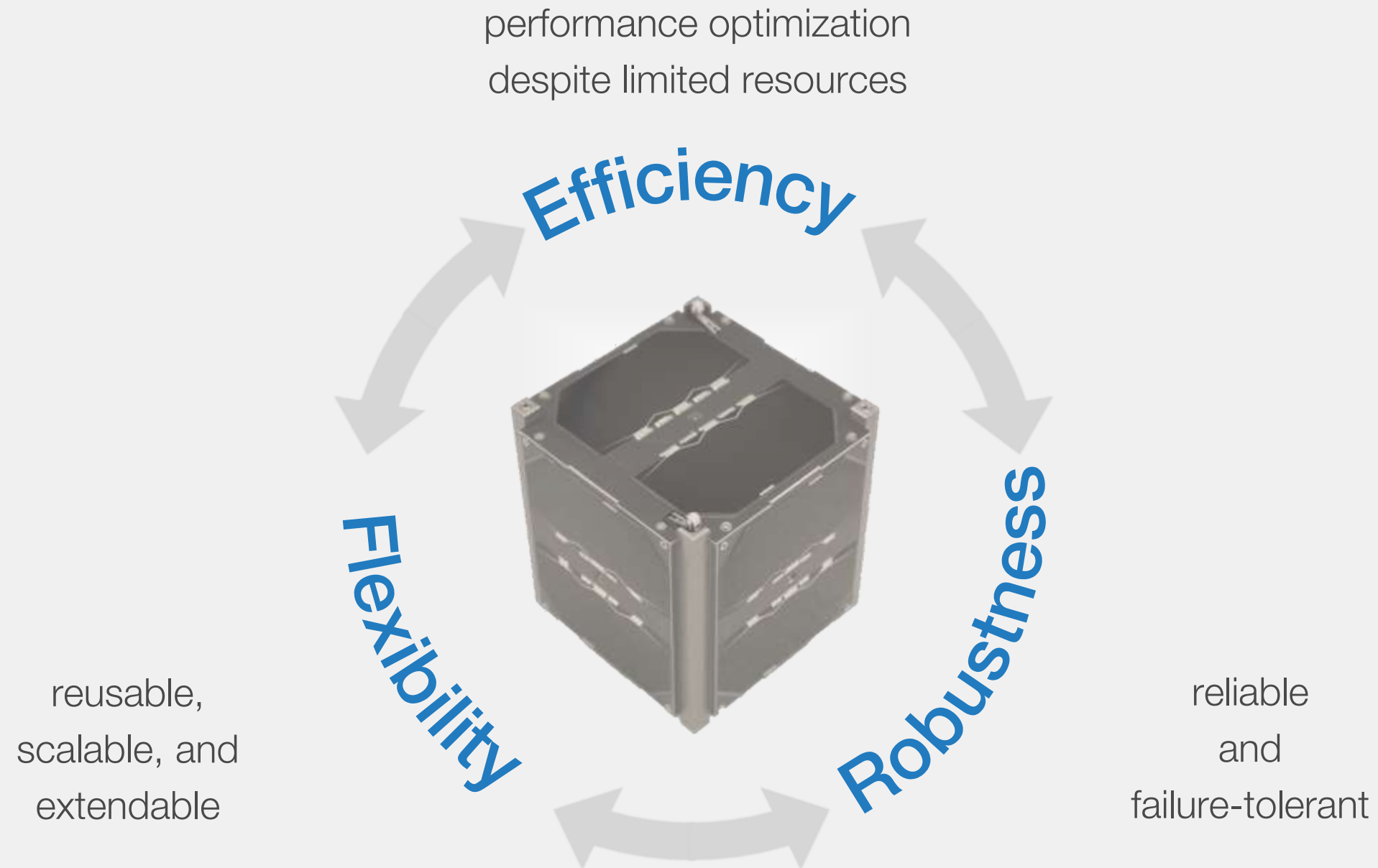
- Design iteration und launch within a few months: How to assure quality?

## Modern Production

- Production, Integration, and Test: from High-tech Manufactures to Batch Production



# Challenging Trade-Off





# Testability as Design Driver

## Access to Hardware

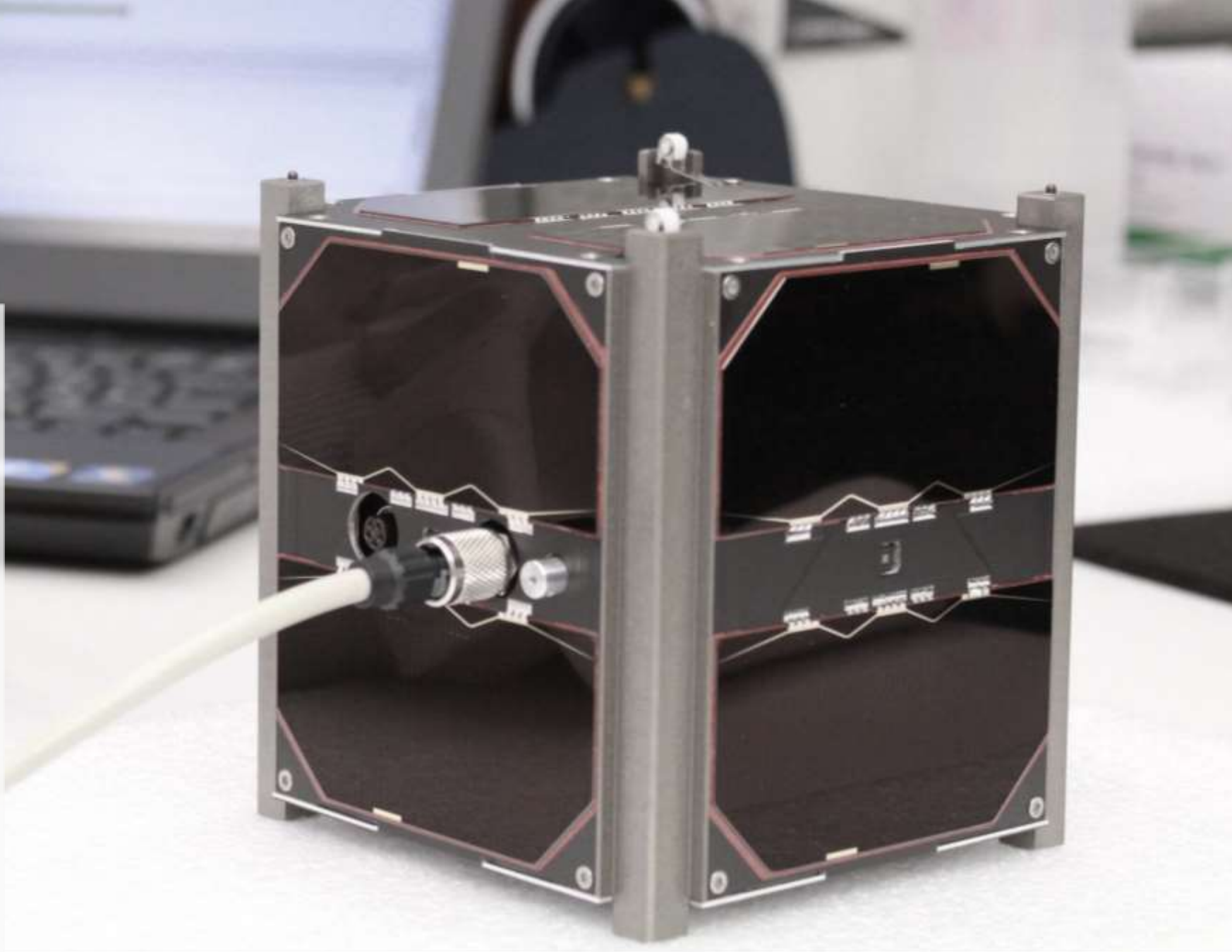
- fast and simple  
functional integration tests

## Access to Software

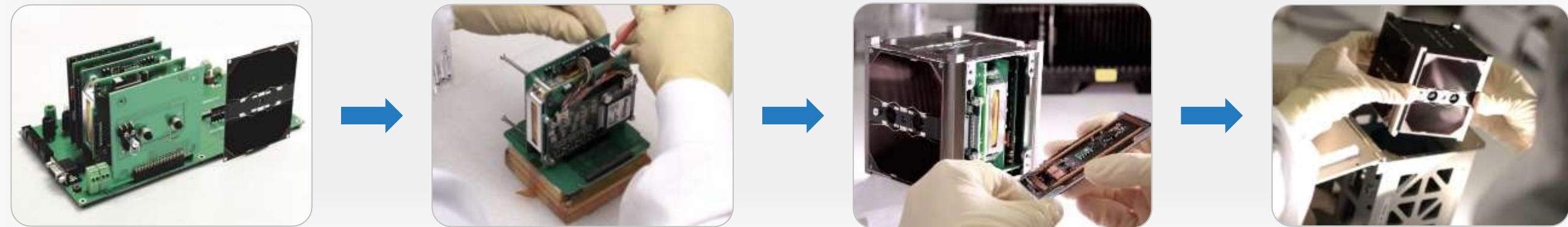
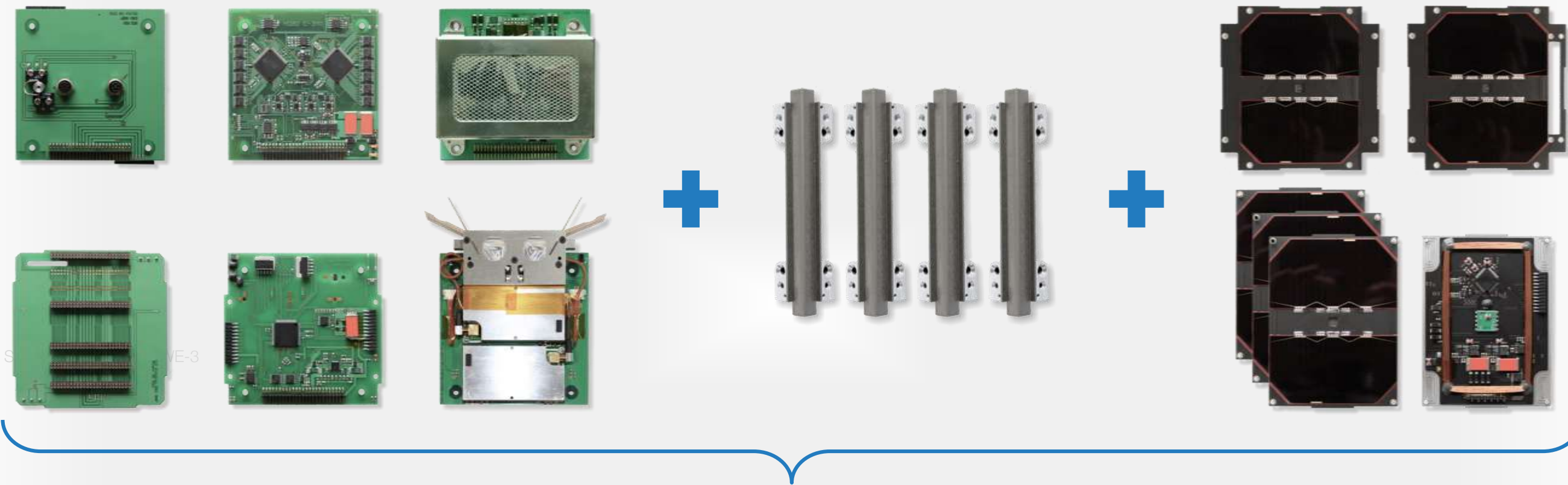
- embedded Unit tests
- generic parameter access

## Access to Test Equipment

- simple test setups for continuous  
automated verification



# Access to Hardware





# Testability as Design Driver

## Access to Hardware

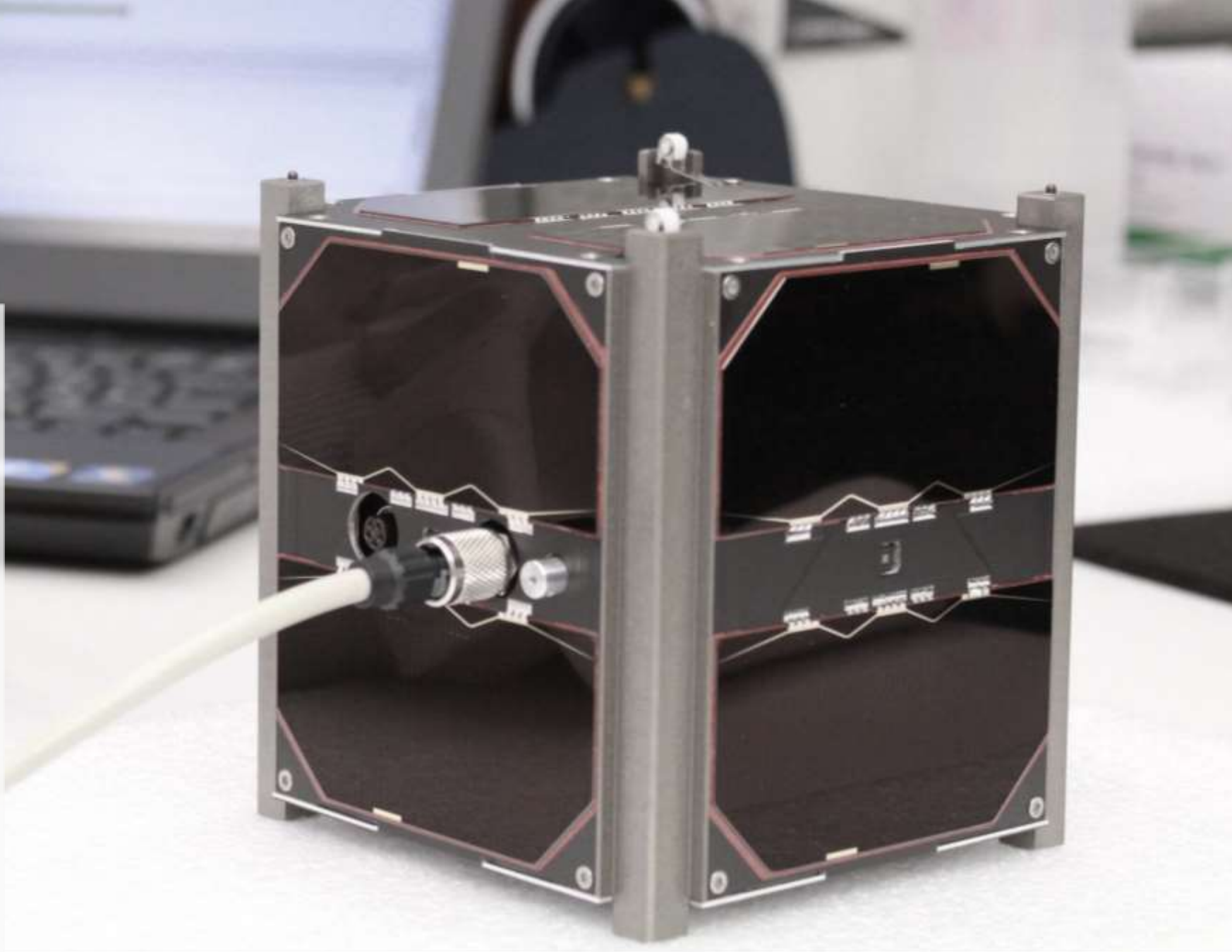
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## Access to Software

- embedded Unit tests
- generic parameter access

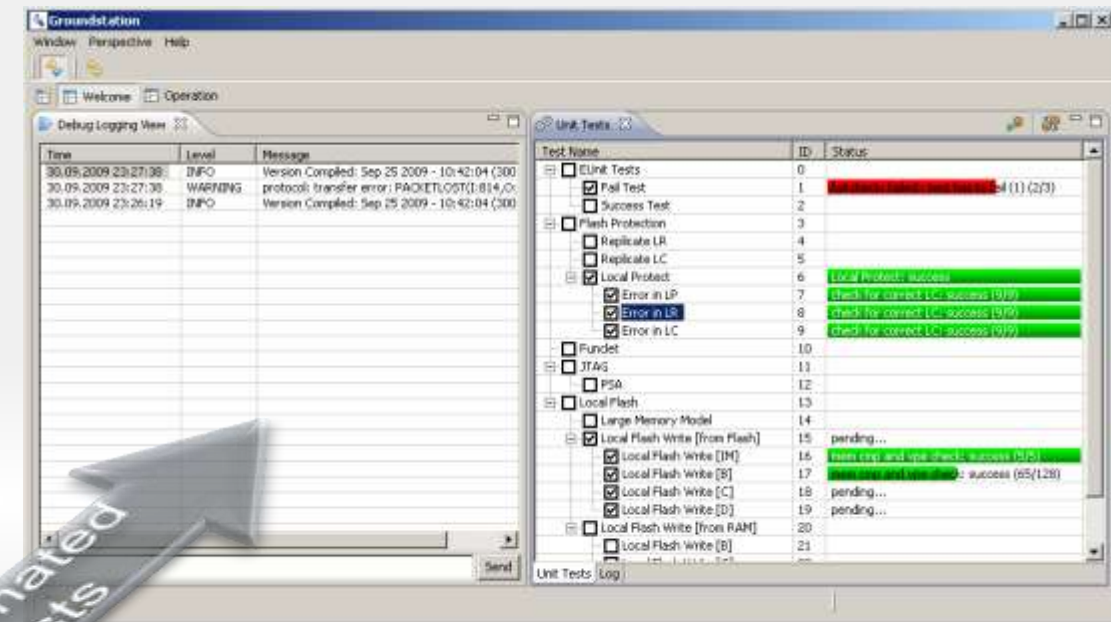
## Access to Test Equipment

- simple test setups for continuous  
automated verification



## Embedded Unit Testing

- simple, rapid to use
- continuous check of each single feature
- immediate detection of potential failures



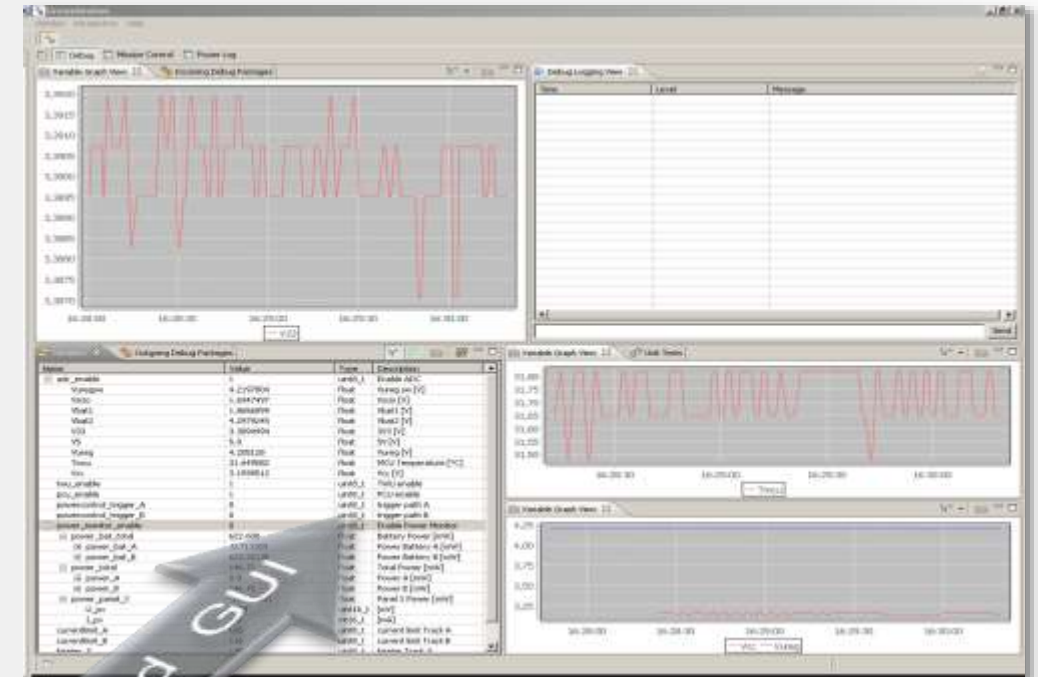
```
EUNIT_DEFINE(test, funclettest, "Funclet", 2, EUNIT_ROOT)
{
    uint8_t code[sizeof(Funclet_o)];

    //check location
    address_t addr;
    addr.u8_ptr = (uint8_t*)Funclet_o;
    EASSERT("funclet link location", addr.u32 > 0x5BFF, "
```



## Embedded Variable Synchronization

- simple, rapid to use one-line coding effort
- read/write sync
- automated GUI and data export



```
VARSYNC_DEFINE(var, U_B, uint16_t, "[mV]", "", (void*)0, (void*)0, $power_B)
VARSYNC_DEFINE(var, I_B, int16_t, "[mA]", "", (void*)0, (void*)0, $power_B)

VARSYNC_DEFINE(var, power_panel_X, float, "Panel X Power [mW]", "", (void*)0, (void*)0, $power_panel_X)
VARSYNC_DEFINE(var, U_px, uint16_t, "[mV]", "", (void*)0, (void*)0, $power_panel_X)
VARSYNC_DEFINE(var, I_px, int16_t, "[mA]", "", (void*)0, (void*)0, $power_panel_X)
```

# Testability as Design Driver

## Access to Hardware

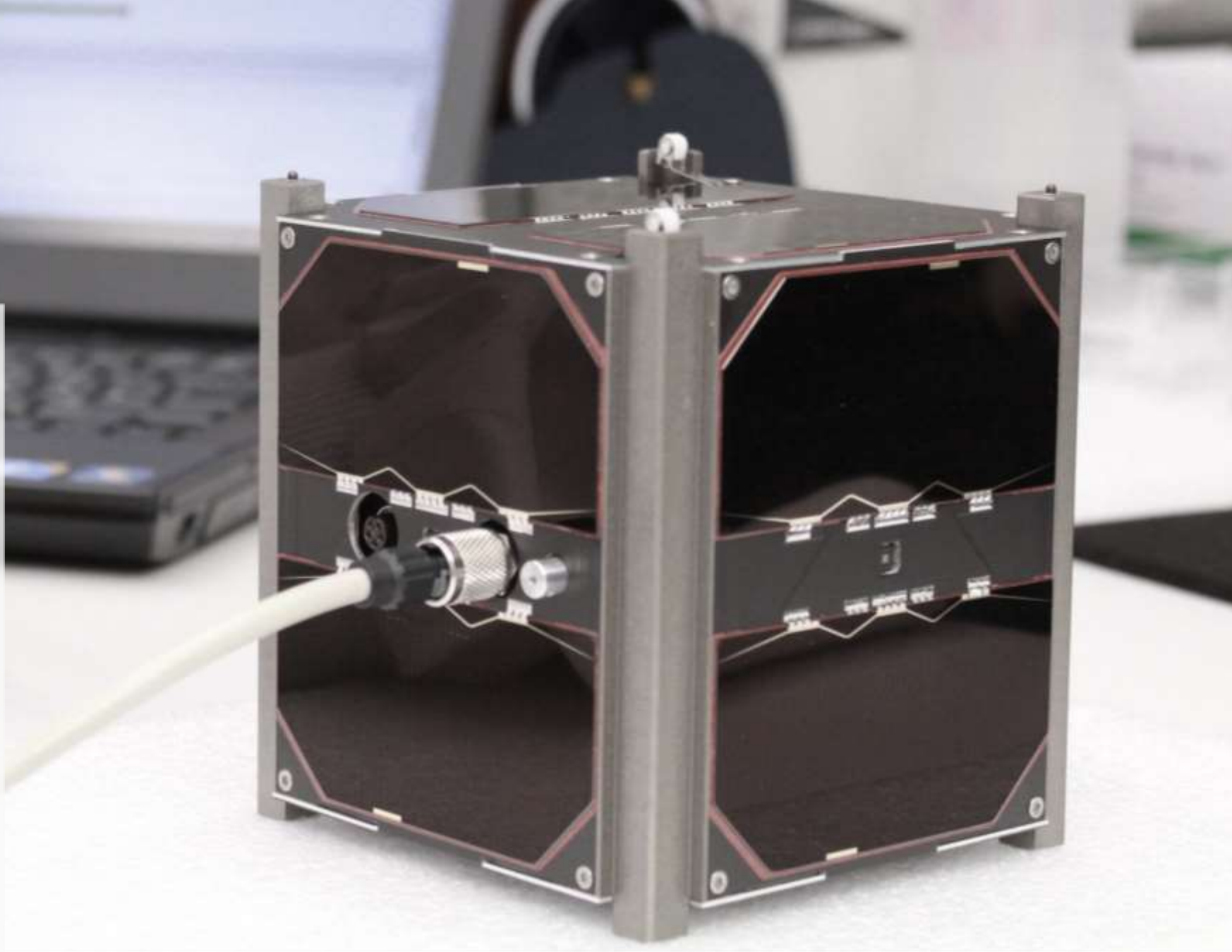
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- embedded Unit tests
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## Access to Test Equipment

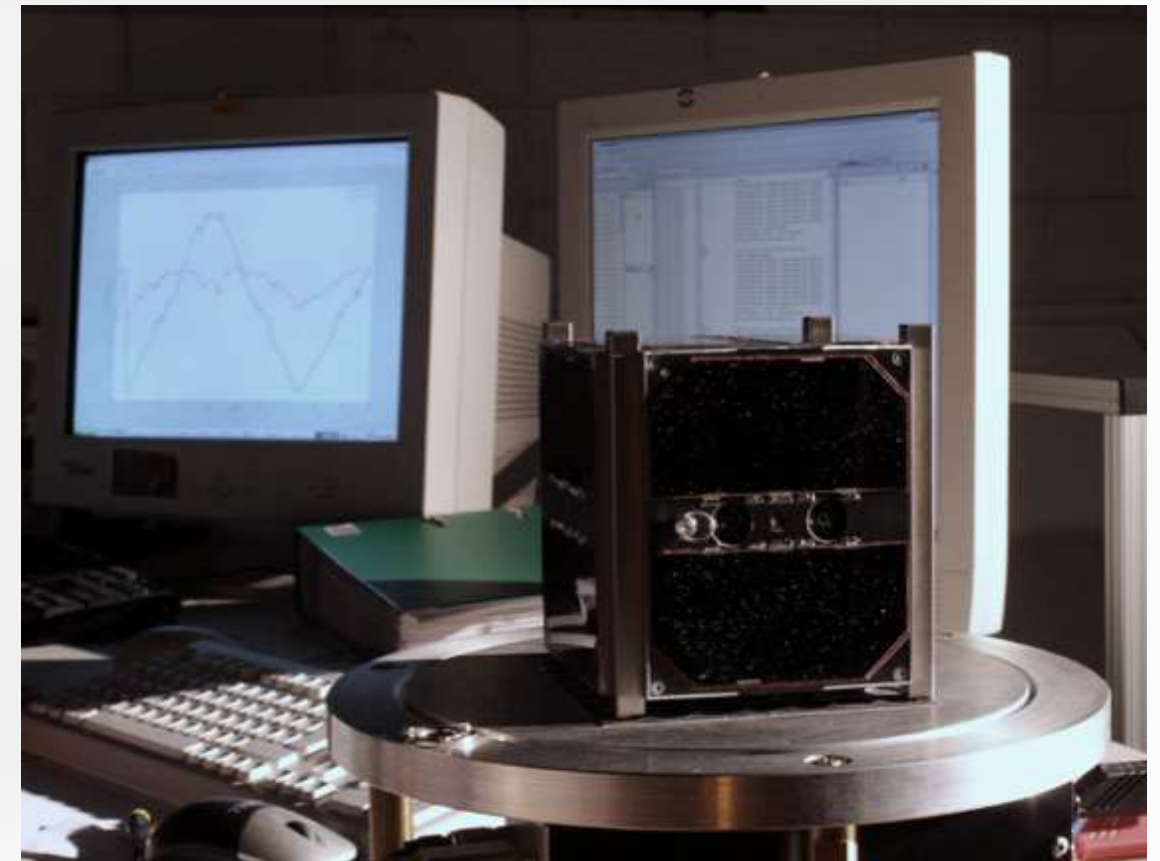
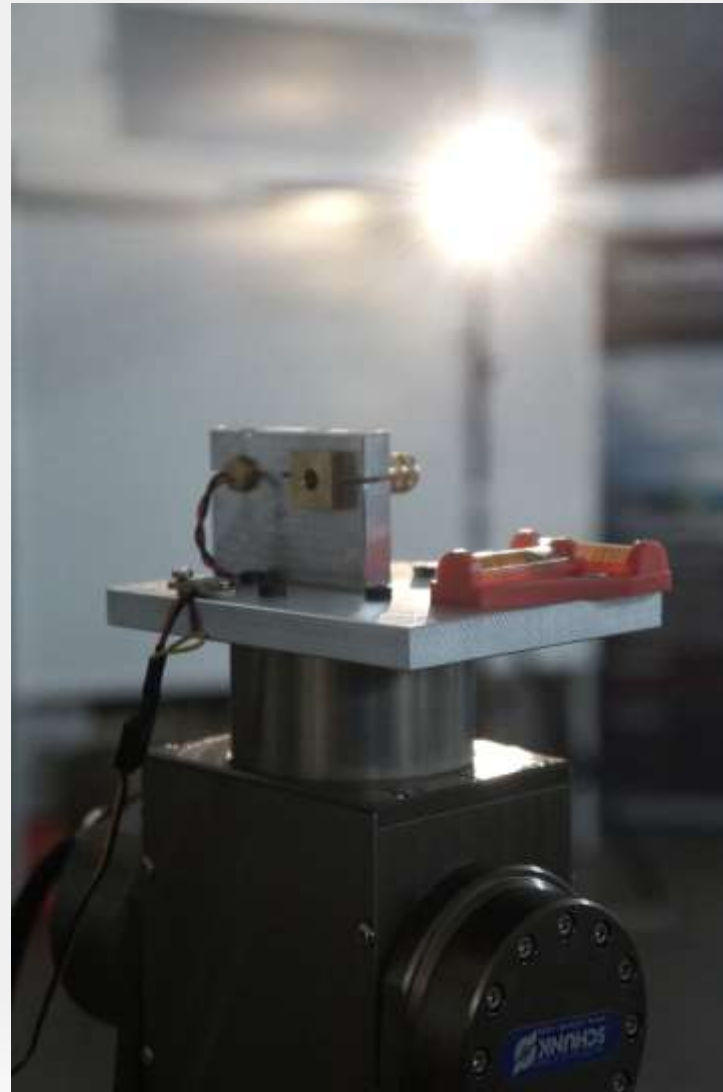
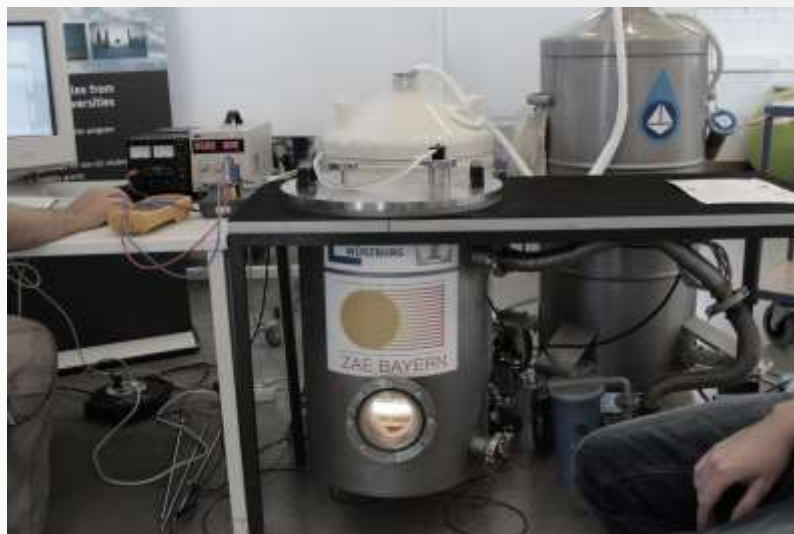
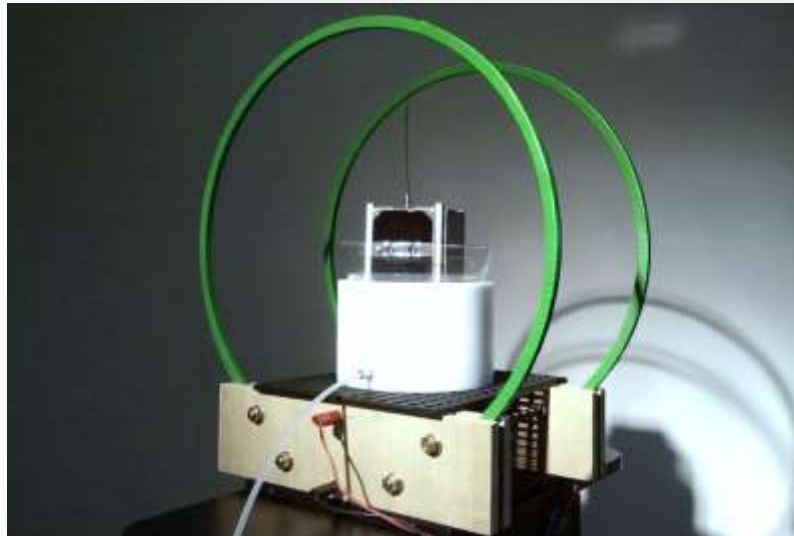
- simple test setups for continuous  
automated verification



# Access to Test Equipment

“...when you don't have access to traditional test facilities, then be creative!”

Mengu Cho (2016)

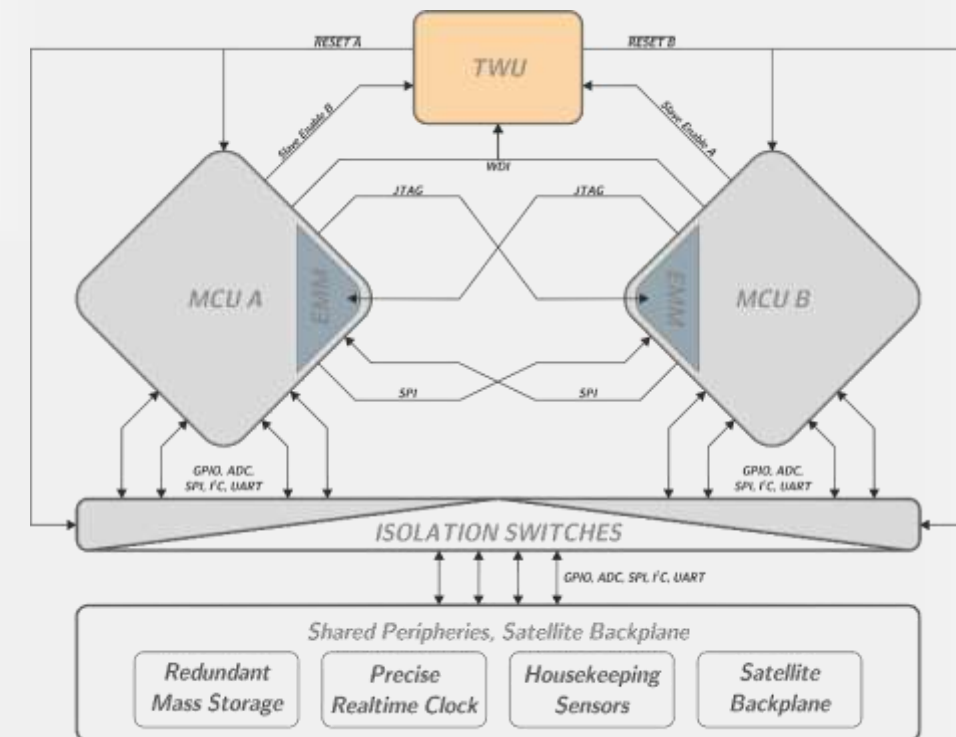
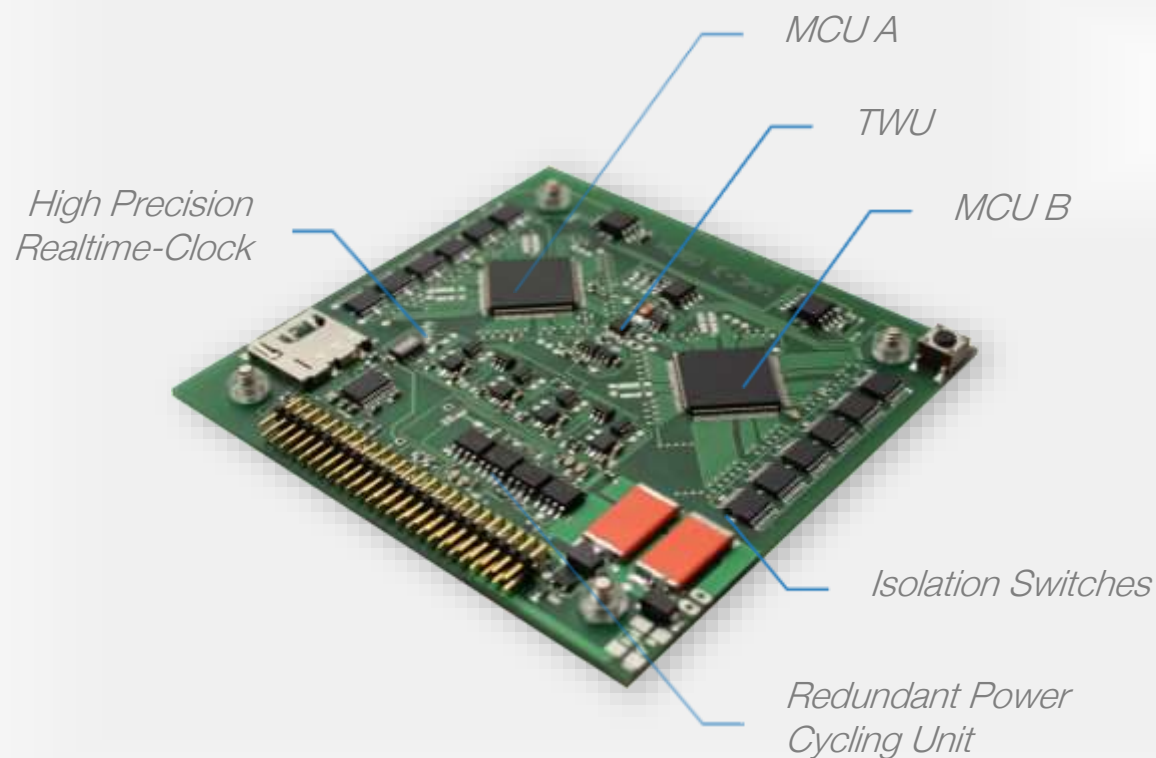




# ...be lean, but don't forget to be robust...

## Robust and Energy Efficient *OBDH* Core Module

- Optimized as dedicated housekeeping und autonomous FDIR module
- 2 redundant Microcontroller (MCU) in *warm-backup*
- Less than 10 mW total power consumption







## UWE-3 Launch – 21. Nov. 2013

- Yasny Launch Base, Russia
- Cluster Launch with 29 satellites, a.o.
  - DubaiSat-2
  - SkySat-1
  - Dove-3/4



Image credits: Kosmotras

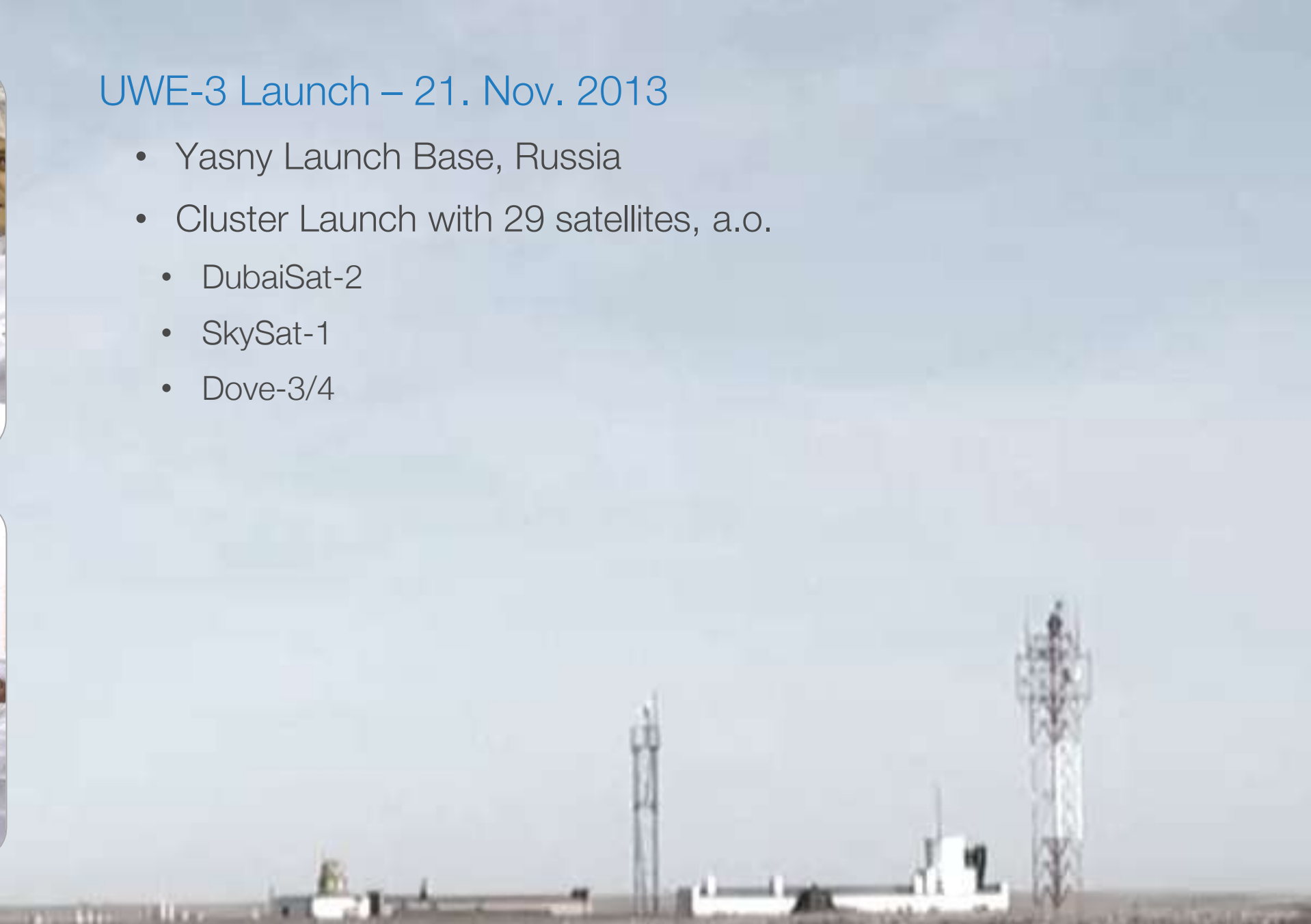




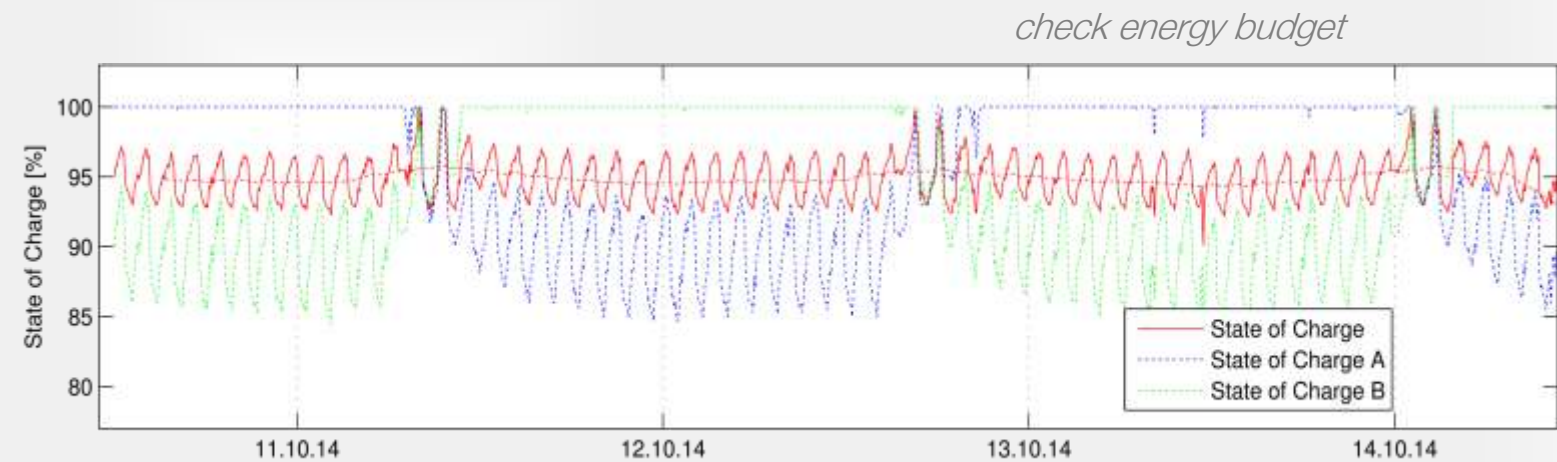
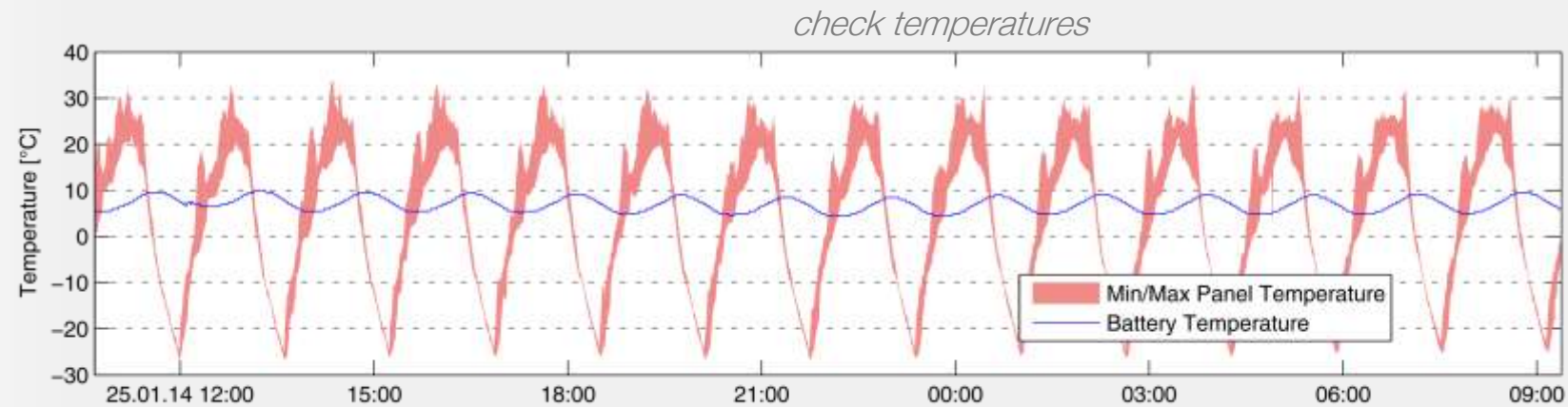
Image credits: Kosmotras

## UWE-3 Launch – 21. Nov. 2013

- Integration into Space Head Module of a decommissioned Dnepr intercontinental rocket



...don't forget what happens after launch...

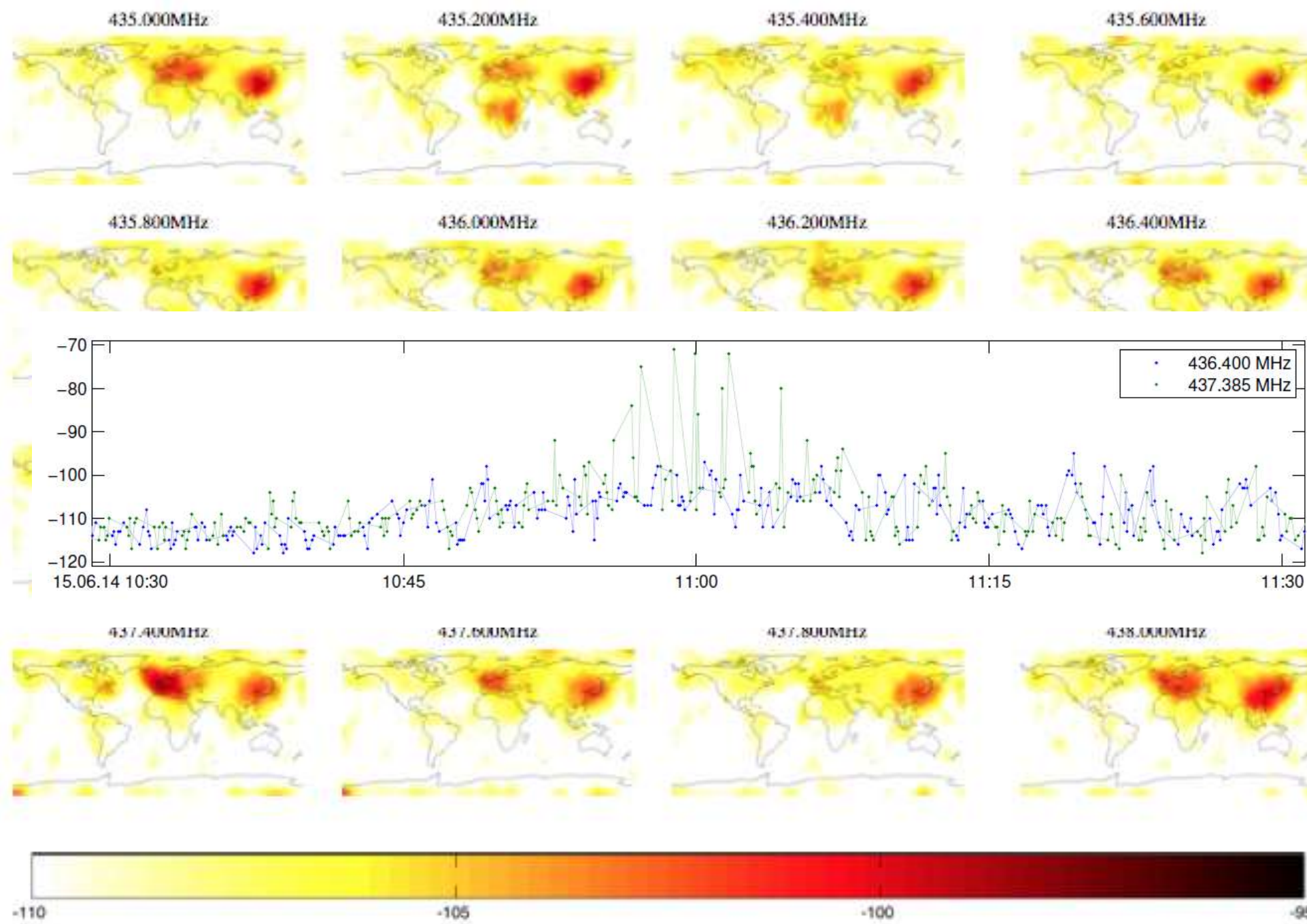


Launch  
Nov. 2013

Commissioning  
Dez. 2013



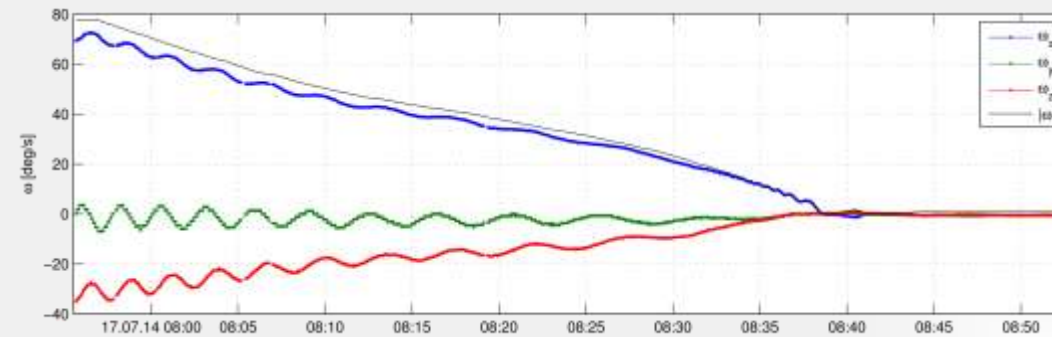
...dc



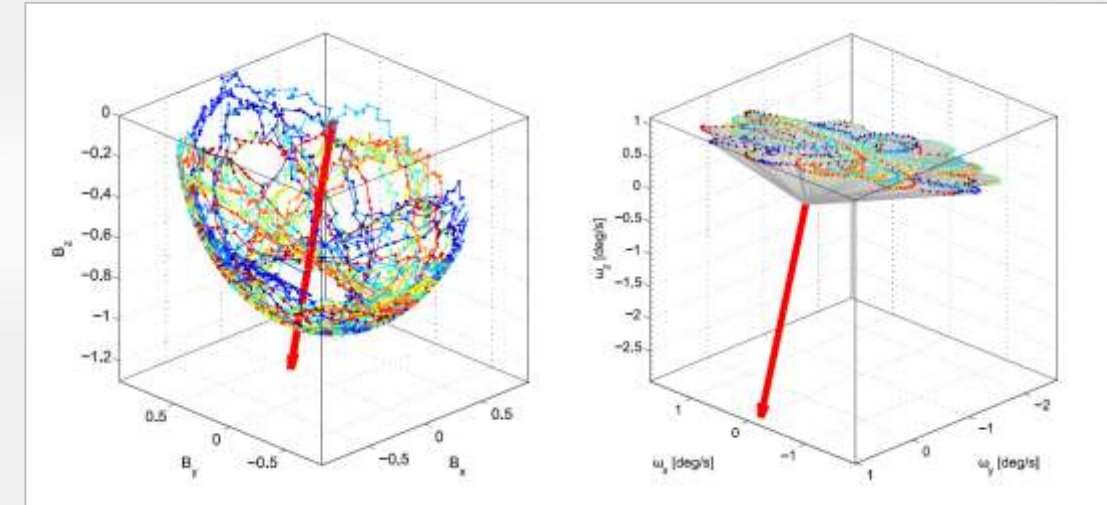


# ...don't forget what happens after launch...

*Rotation- and Rate-Damping Experiments*



*Residual Magnetic Dipole Estimation*



Launch  
Nov. 2013

UHF Interferenzanalyse  
2014

Inbetriebnahme  
Dez. 2013

Magnetic Disturbances?  
2014-2015

...don't think there are no challenges left...

## Mega-Constellations and Formations of Small Satellites

- Earth Observation
- Communication

### Examples

- OneWeb: 648
- SpaceX: 4024
- PlanetLabs: ~100



Image credits: NASA, PlanetLabs

# How to build, test, and operate hundreds of satellites?

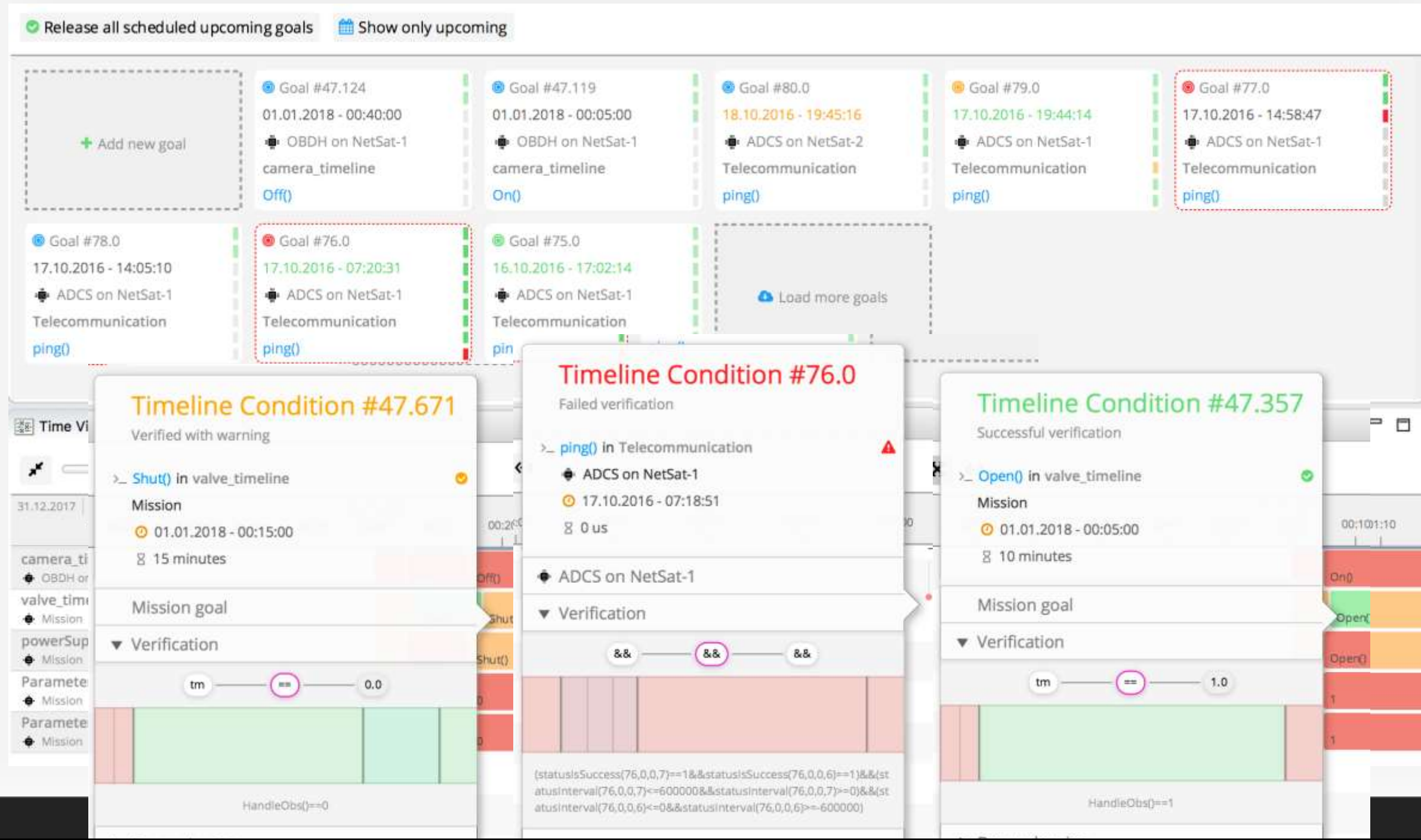
The screenshot displays a mission planning software interface. At the top, there are two buttons: "Release all scheduled upcoming goals" (with a green checkmark icon) and "Show only upcoming" (with a calendar icon). Below these, a grid of goal cards is visible, including "Goal #47.124", "Goal #47.119", "Goal #80.0", "Goal #79.0", and "Goal #77.0". Each card shows a date and time, a goal icon, and a description like "ADCS on NetSat-1" or "Telecommunication".

Two modal windows are open. The left modal, titled "Create a new goal", prompts the user to "Pick the type of goal to create:" with options "Direct" (selected) and "Planned". It shows a goal for "NetSat-1" with the action "rotateAround(...)" and a description "Rotates the satellite around a vector (X,Y,Z) by a given angle". The vector components are X: 2.0, Y: 1.0, Z: 3.0, and the angle is 45.0 degrees. There is also a checkbox for "Immediate default execution" and fields for "earliest start" and "latest start" dates. The right modal, titled "Goal #79.0", shows the goal's status and execution details. It includes a "Timeline condition" section with a checkmark and a "Status overview" section with three sub-sections: "Goal end status", "Execution status", and "Goal start status".

The background interface includes a "Time View" section on the left with a timeline for "camera\_timeline", "valve\_timeline", "powerSupply\_timeline", "ParameterA\_timeline", and "ParameterB\_timeline". The bottom right shows a "Any system" filter and a timeline view with colored bars representing different mission phases or states.



# how to build, test, and operate hundreds of satellites





# Thank You!

