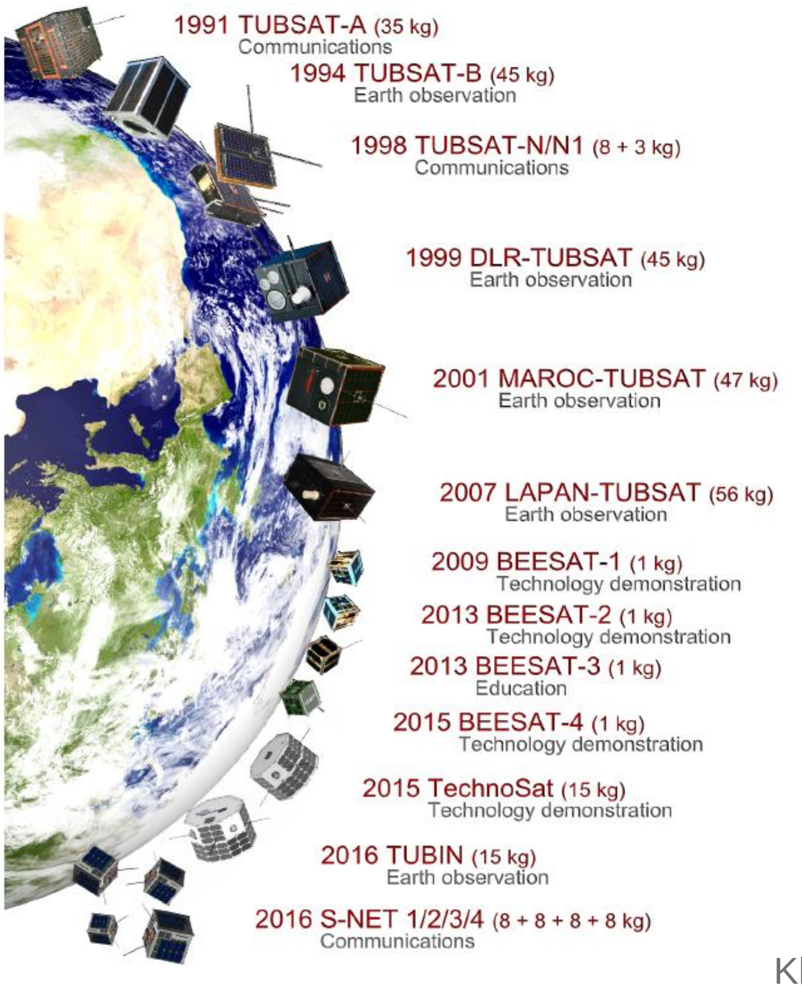


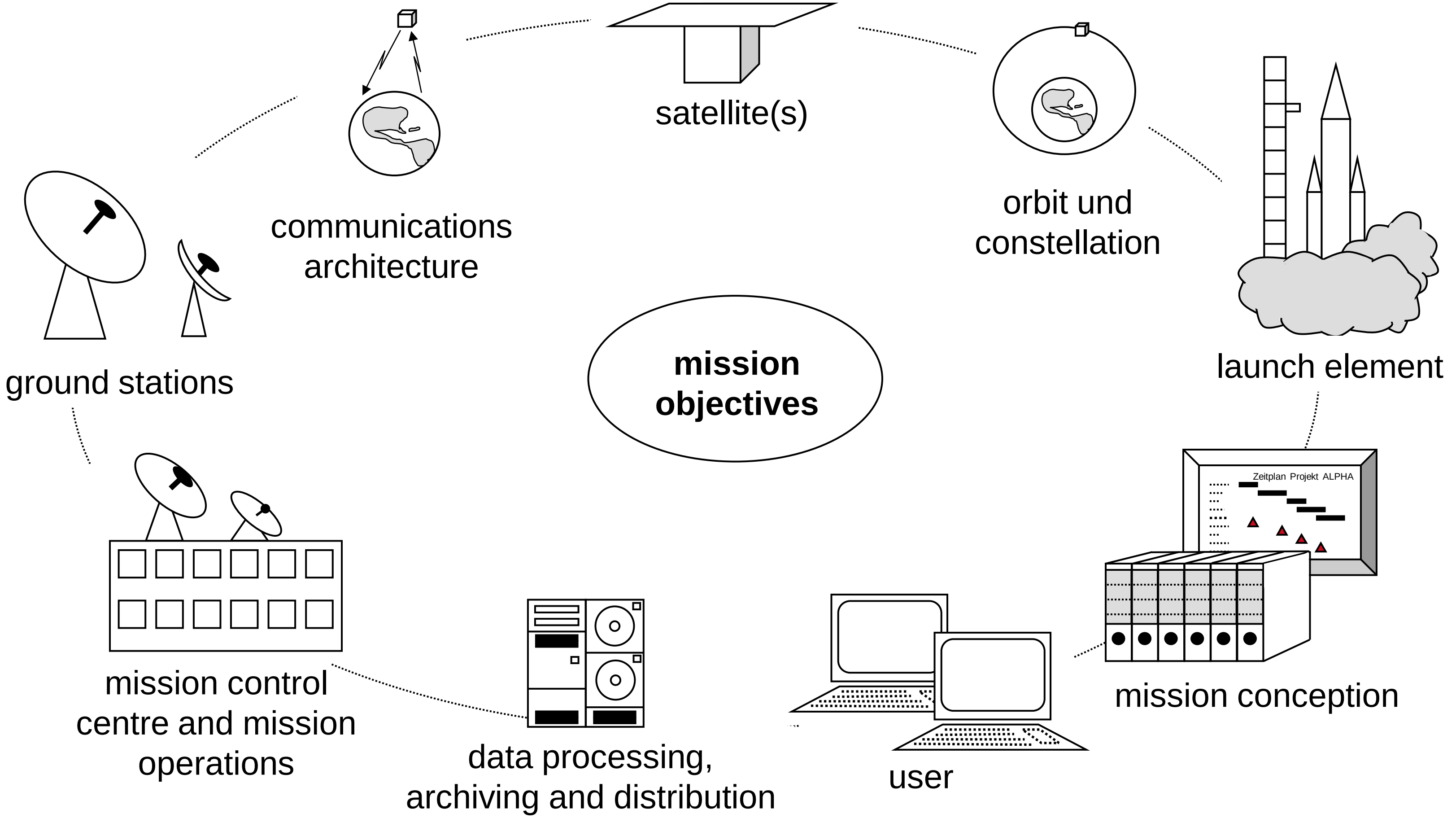
Satellites of Technische Universität Berlin 1991-2016

The Rise of Small Satellites

Klaus Brieß| Chair of Space Engineering| MOOC@TU9

For what do we need satellites?

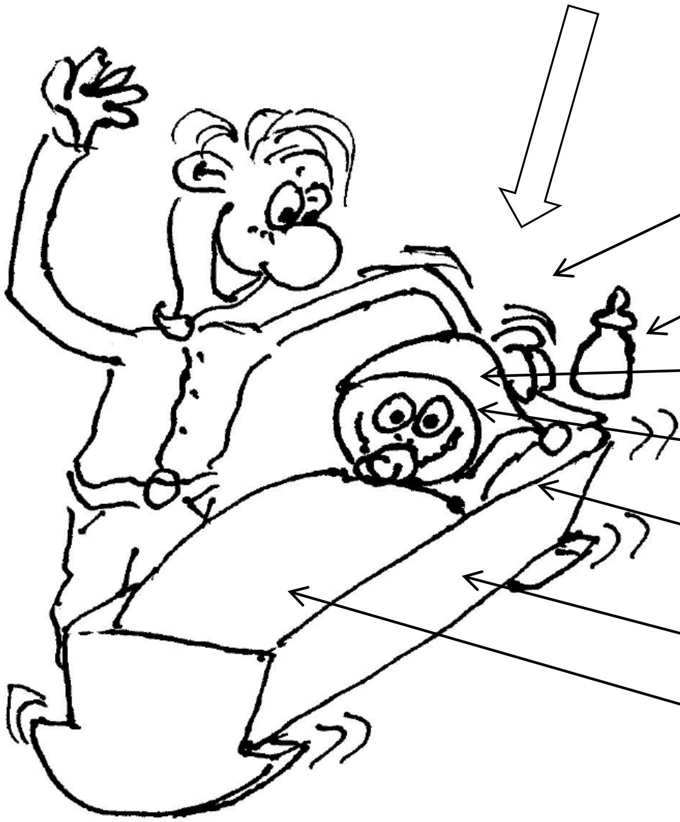
What a satellite needs - the elements of a satellite mission



What is a satellite?

satellitis, satelles (Lat.) = companion on the way

The satellite consists of 6 or 7 subsystems and a payload, for instance a camera.



Attitude control system

Power system

On-board data handling system

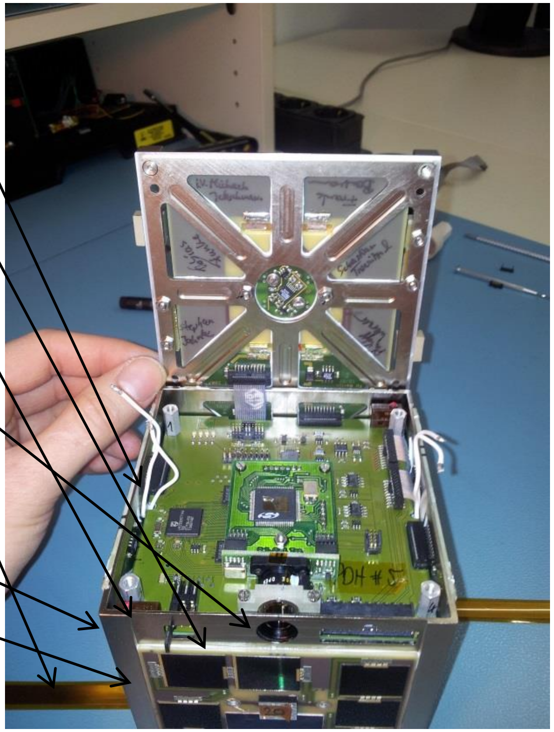
Camera

Communication system

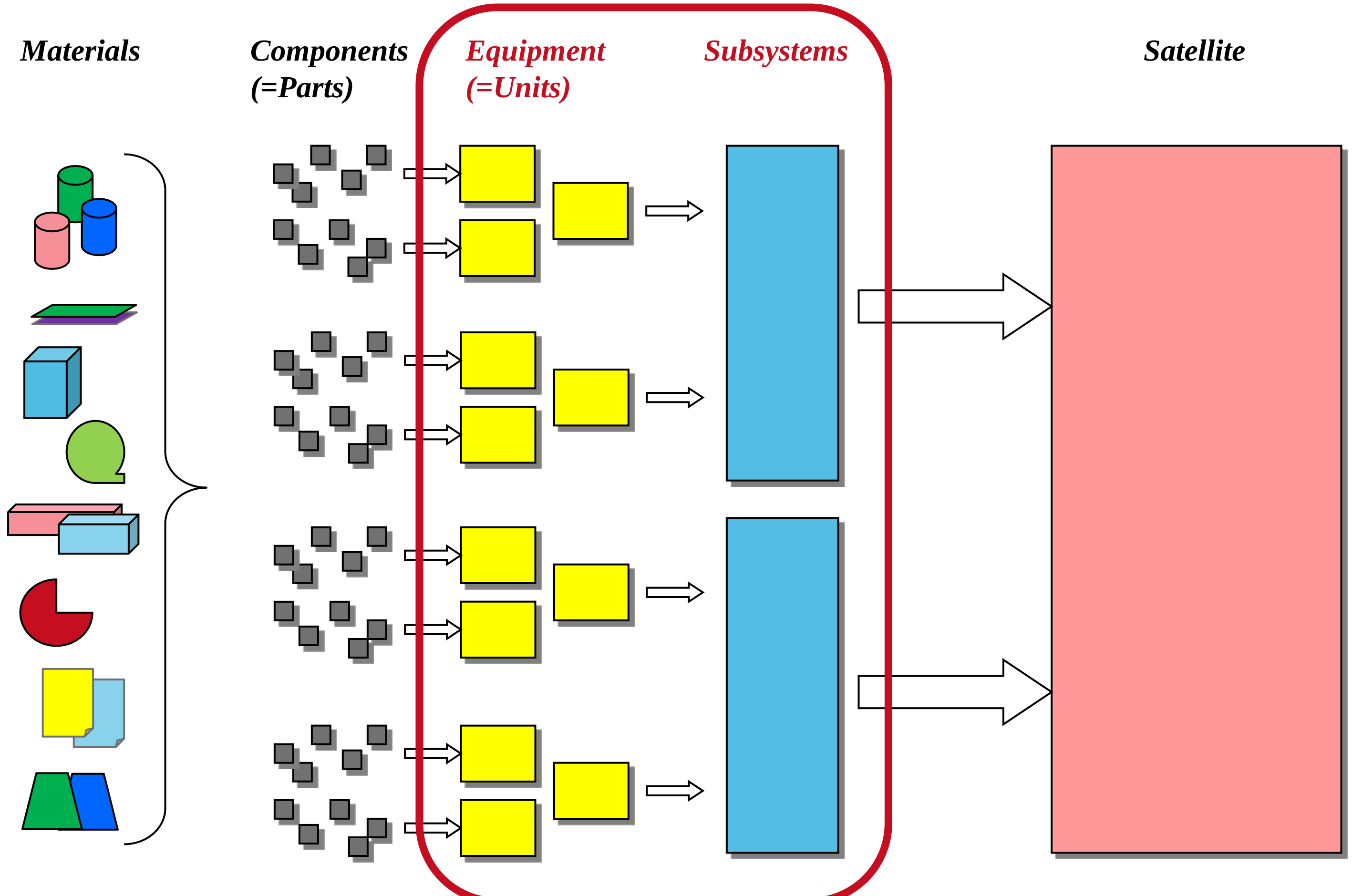
Structure

Thermal control system

Optional: propulsion system



System levels of a satellite



...are presented on the next slides

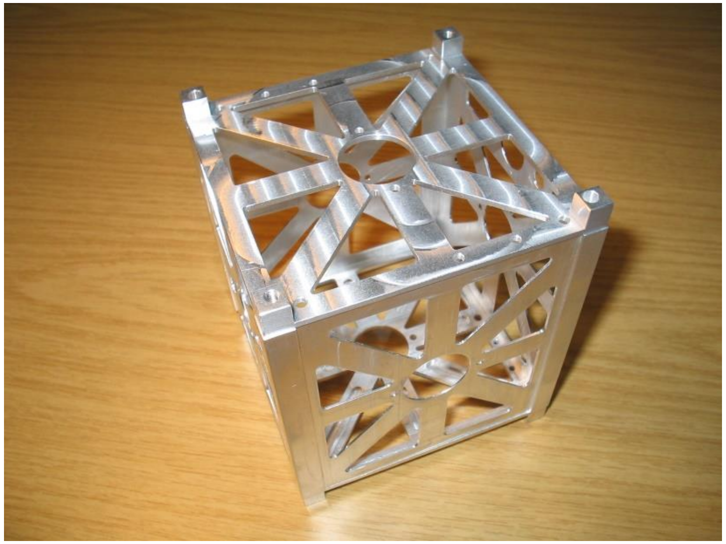
[Ber05, modified]

Structure and mechanisms

Function: to carry the payload and keep all subsystems together

Challenges:
a) launch loads: accelerations, sine vibrations, random vibrations, acoustic loads, shock loads
b) material stability in vacuum and during direct Sunlight radiation

Equipment	**Mass [g]**	**average Power [W]**
Basic Structure	140	-
Mounting parts	25	-



Basic structure of BEESAT satellite

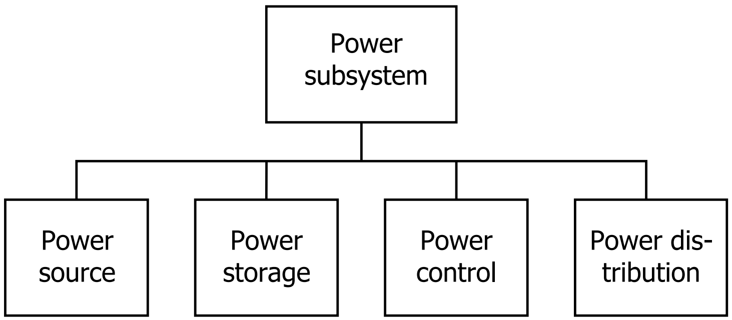
Electric power subsystem

Function: to generate, control, store and distribute electric energy

Challenges:
a) equipment qualified for vacuum and radiation environment
b) all equipment ON and loading battery at day, or
c) all equipment ON at night

Equipment	Mass [g]	average Power [W]
Solar arrays	80	N.A.
Batteries	200	0.02
Power distribution unit	40	0,10
Power control unit	20	0,04

N.A. Not applicable for power consumption



Main functions of the electric power subsystem

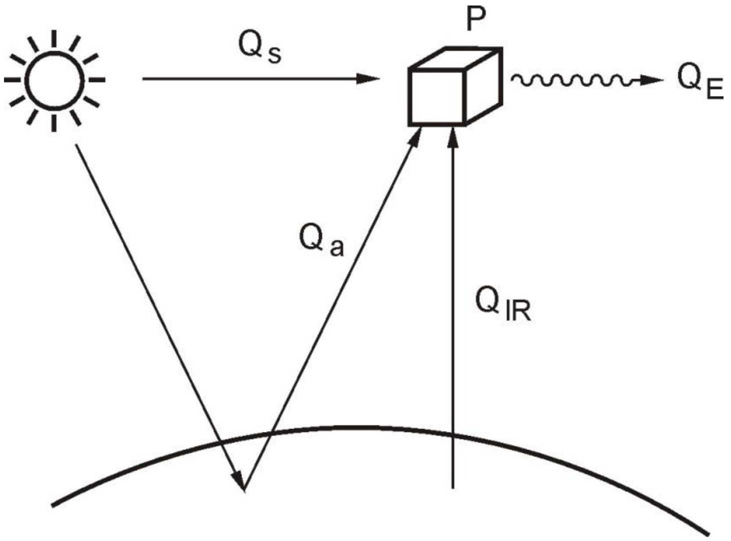
Thermal control subsystem

Function: to keep the temperature for all units in the allowed ranges

Challenges: a) all equipment ON during the longest direct sunlight radiation

b) most of the equipment OFF in the Earth shadow

Equipment	**Mass [g]**	**average Power [W]**
Temperature sensors	10	0,0001
Heat conductors	1	-
Radiator surfaces	-	-
Insulation material	-	-



Thermal radiation environment for a satellite

Q_S = thermal energy from the Sun,
Q_a = reflected thermal energy from the Sun (albedo)
Q_{IR} = thermal engergy from the Earth
P = thermal energy generated by the satellite
Q_E = radiated thermal energy by the satellite

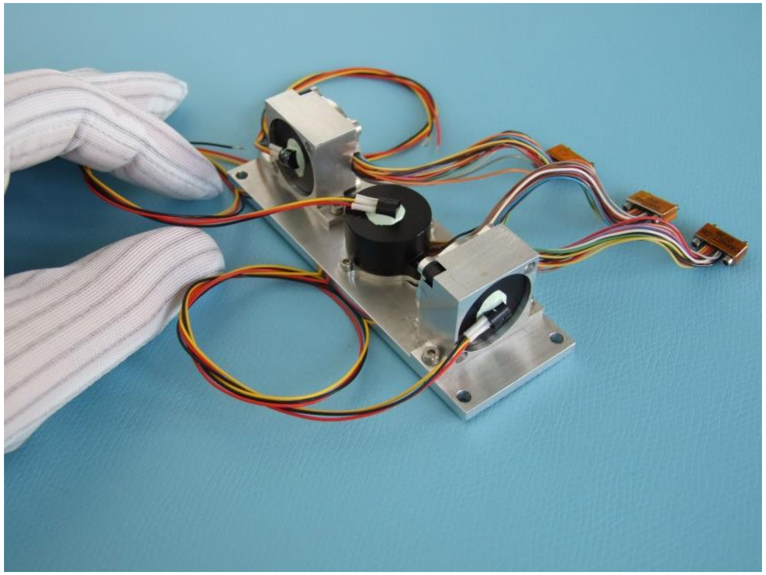
Attitude control subsystem

Function: to stabilise the attitude of the satellite and to direct satellite sides into desired directions

Challenges: a) equipment qualified for vacuum and radiation environment

b) compensation of disturbance torques

Equipment	Mass [g]	average Power [W]
magnet field sensors, rate sensors, sun sensors	20	0,07
Magnetic coil system	10	0,02
Reaction wheels	60	0,05
Reaction wheel electronics	30	0,03



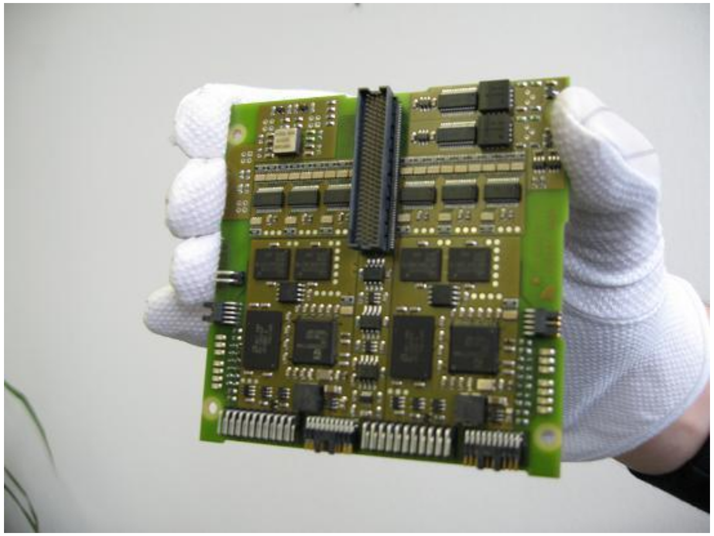
Reaction wheel assembly of BEESAT for attitude control

On-board data handling system

Function: to control the handling and storage of the telecommands, the health data (telemetry) and the payload data

Challenges: a) equipment qualified for vacuum and radiation environment
b) large camera data volume

Equipment	**Mass [g]**	**average Power [W]**
OBDH circuit board	60	0,15



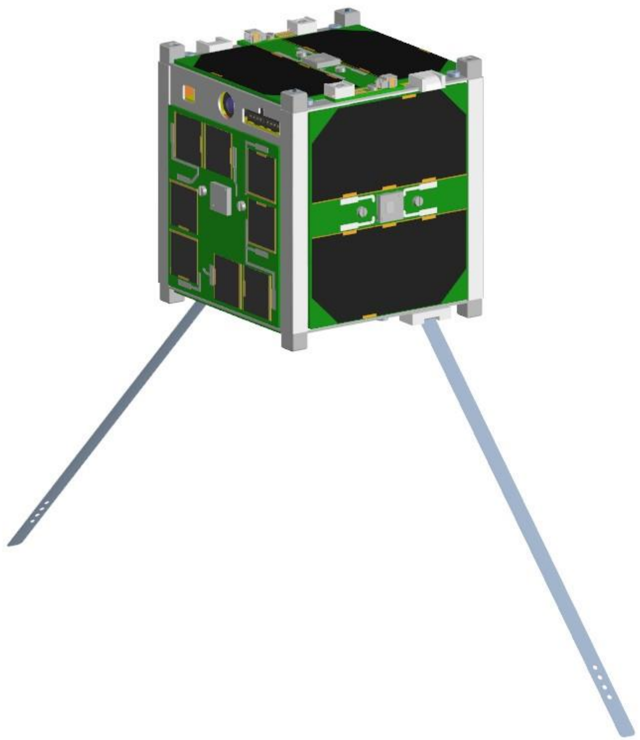
On-board data handling system of the BEESAT family

Communication subsystem

Function: to assure the communication between satellite and ground in up-link and down-link direction

Challenges:
a) equipment qualified for vacuum and radiation environment with very high reliability
b) stable link at high slant range

Equipment	Mass [g]	average Power [W]
UHF transceiver board	30	0,16
UHF transceiver board	30	0,16
Antennas, diplexer	5	-



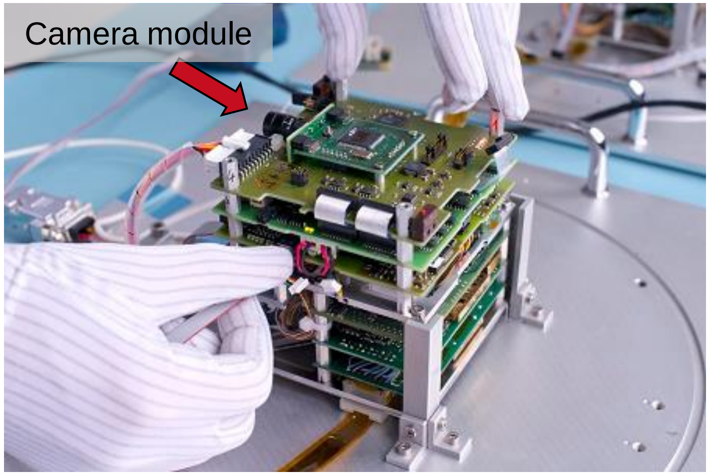
BEESAT-1 with unfolded antennas for communication in the UHF band

Payload: camera

Function: to perform the mission objectives, for instance remote sensing of the Earth

Challenges: a) equipment qualified for vacuum and radiation environment
b) high dynamic range, short integration time

Equipment	Mass [g]	average Power [W]
camera circuit board	50	0,001



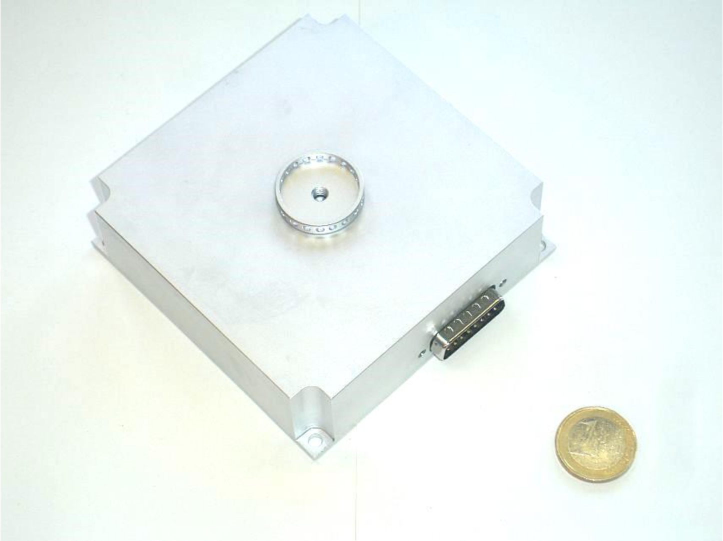
Camera module on-board of BEESAT

Propulsion subsystem (depending on mission)

Function: to perform orbit manoeuvres to keep or to change the orbit

Challenges: a) equipment qualified for vacuum and radiation environment

b) system complexity



Aquajet Resistojet Propulsion System launched in July 2012. [Credits: Aerospace Innovation GmbH, 2012]

Equipment	Mass [g]	average Power [W]
Aquajet Resistojet unit	500	100

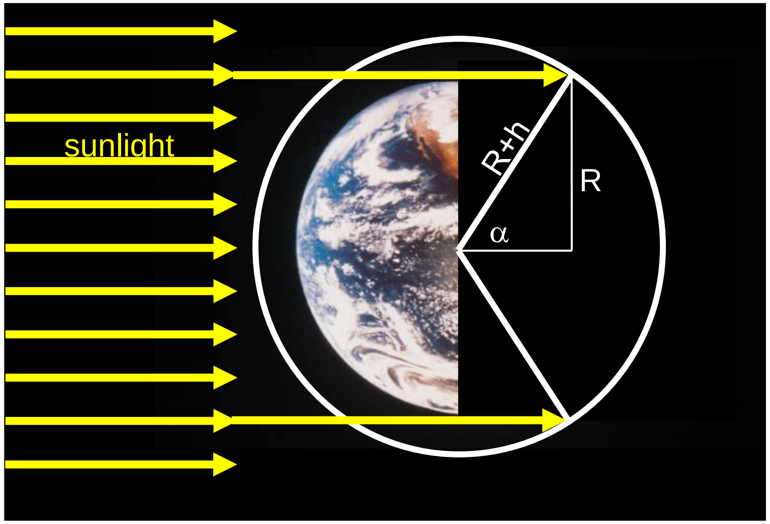
How many power P_{SA} do we have to generate?

T_d = time in sunlight (day)
T_e = eclipse time (night)
P_e, P_d = Power consumption (eclipse/day)
P_{SA} = Power generation by solar array
η_e, η_d = efficiency of the power subsystem (eclipse/day)
η_d = 0,85
η_e = 0,65

$$T = 2\pi\sqrt{\frac{(R+h)^3}{GM}}$$

$$T_e = \frac{T}{\pi}\arcsin\left(\frac{R}{R+h}\right)$$

$$P_{SA} = \frac{1}{T_d}\left(\frac{P_e T_e}{\eta_e} + \frac{P_d T_d}{\eta_d}\right)$$



Sunlight conditions for a satellite (schematic)

LEO = Low Earth orbit, h = 200km...2000km
T = Orbit period,
T_e = eclipse time
Given:
R = Eart radi (R = 6378 km),
h = Orbit hight (h = 500km)
GM = 398600 km^3/s^2