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A Double CubeSat with an X Ray Detector for In Situ Environmental Measurements of QB50

Prof.Dr. Alim Rüstem Aslan, Ertan Umit
Space Systems design and Testing Lab, Dept. of Space Engineering
Istanbul Technical University, aslanr@itu.edu.tr, http://usl.itu.edu.tr

Co-Auhtors, Sponsors

- Emrah Kalemci, Sabancı University
- M. İlarslan, TurAFA/ASTIN
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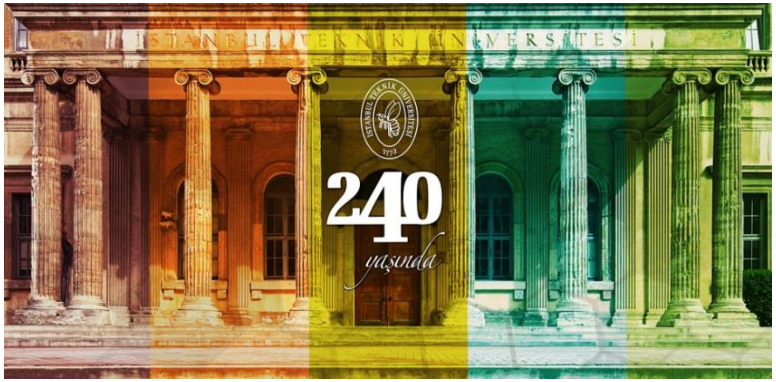
- TÜBİTAK, ASELSAN, TUSAŞ....

ISTANBUL

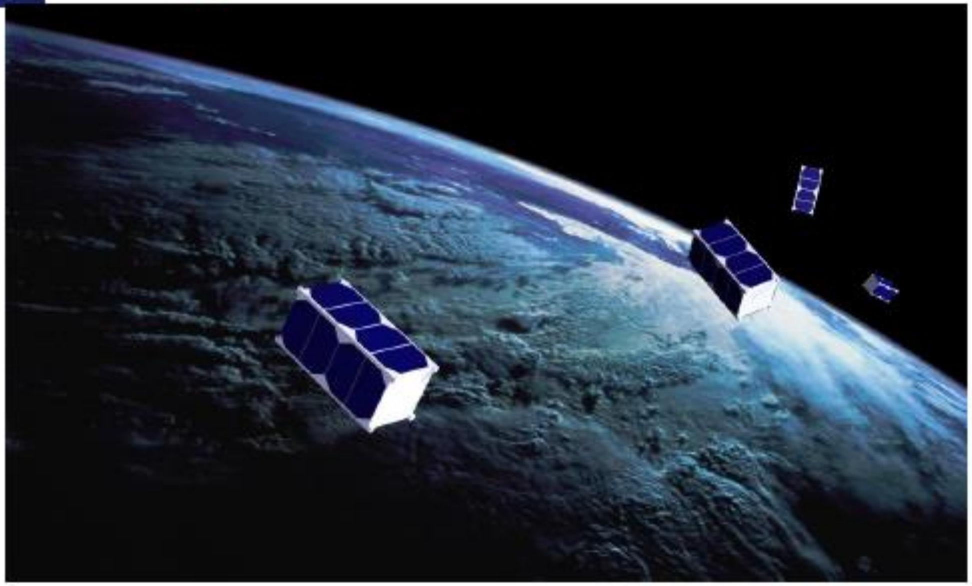


Content

- QB50 Project

- BeEagleSat Project

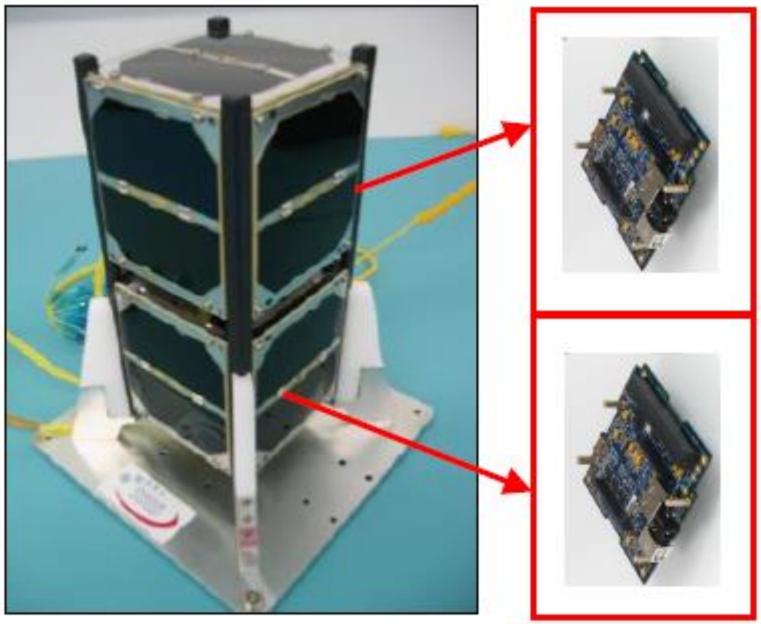
QB50 - THE IDEA



- An international network of 50 CubeSats for multi-point, in-situ, long-duration measurements and in-orbit demonstration in the lower thermosphere
- A network of *50 CubeSats* sequentially deployed
- Initial altitude: 350 km (circular orbit, high inclination)
- Downlink using the QB50 Network of Ground Stations

QB50 - The CubeSat

On a Double CubeSat (10 X 10 X 20 cm³):



Science Unit:

Lower Thermosphere Measurements

Sensors designed by MSSL

Standard sensors for all CubeSats

Functional Unit:

Power, CPU, Telecommunication

Optional Technology or Science Package

Universities are free to design the functional unit

Sensor Selection

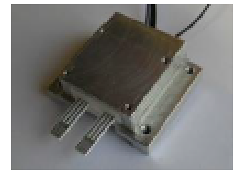
Set 1
Ion-Neutral Mass Spectrometer (INMS)
2 corner cube laser retroreflectors (CCR)*
Thermistors/thermocouples/RTD (TH)

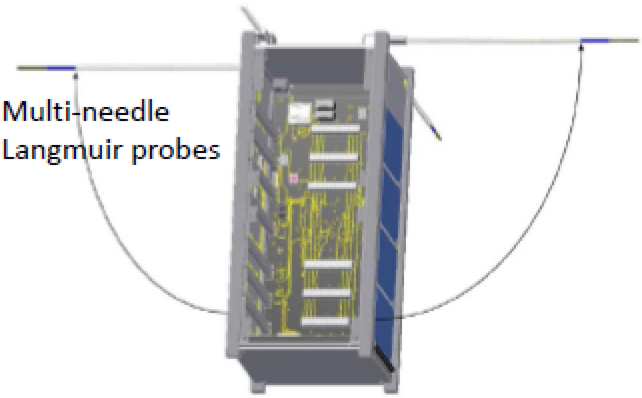
Set 2
Flux-Φ-Probe Experiment (FIPEX)
2 corner cube laser retroreflectors (CCR)*
Thermistors/thermocouples/RTD (TH)

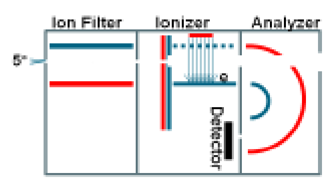
Set 3
A set of 4 Langmuir probes (MNLP)
2 corner cube laser retroreflectors (CCR)*
Thermistors/thermocouples/RTD (TH)

* Offered as an option

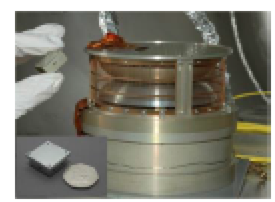
FIPEX sensor





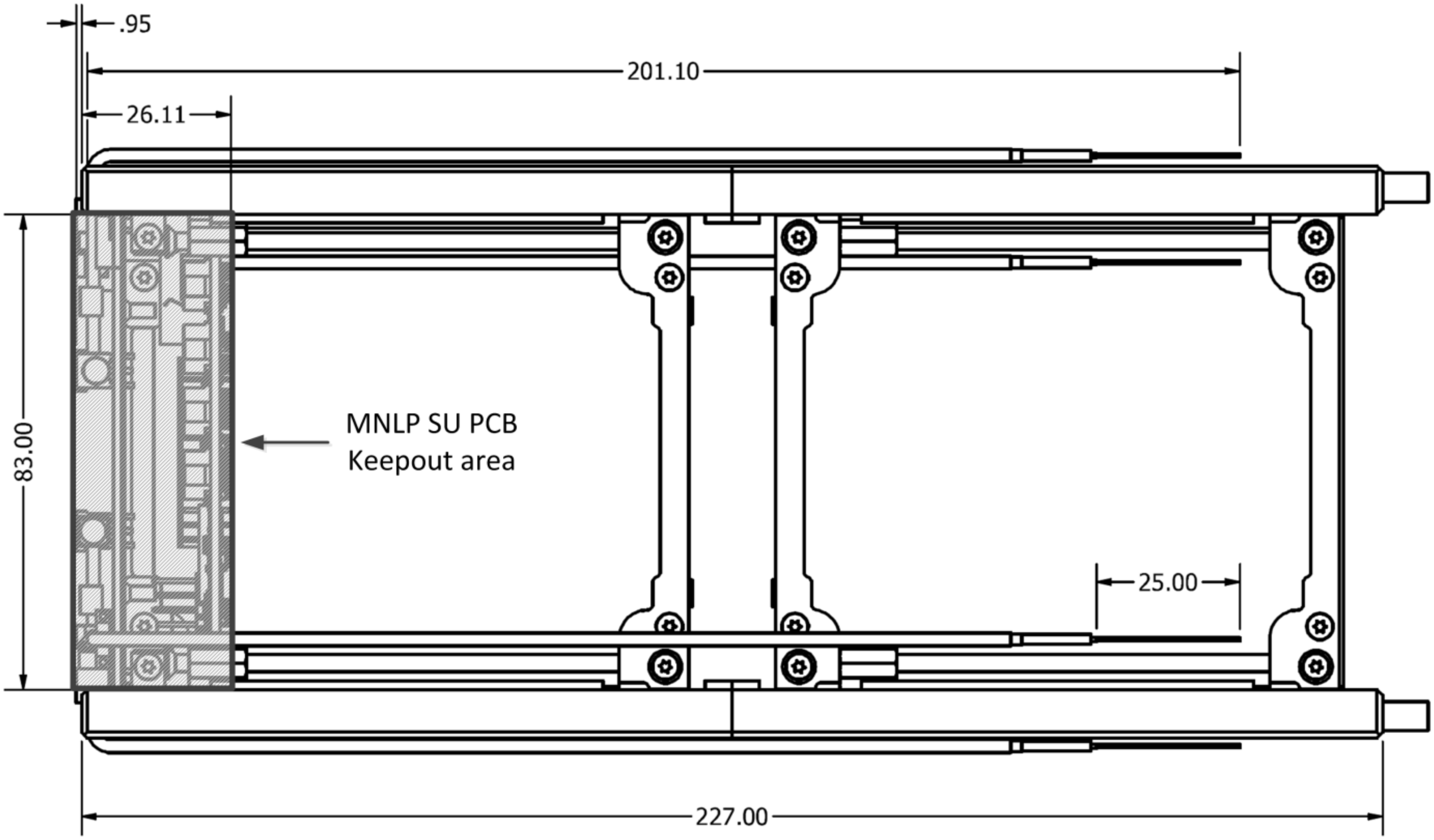


Schematic of the principle of working of the INMS

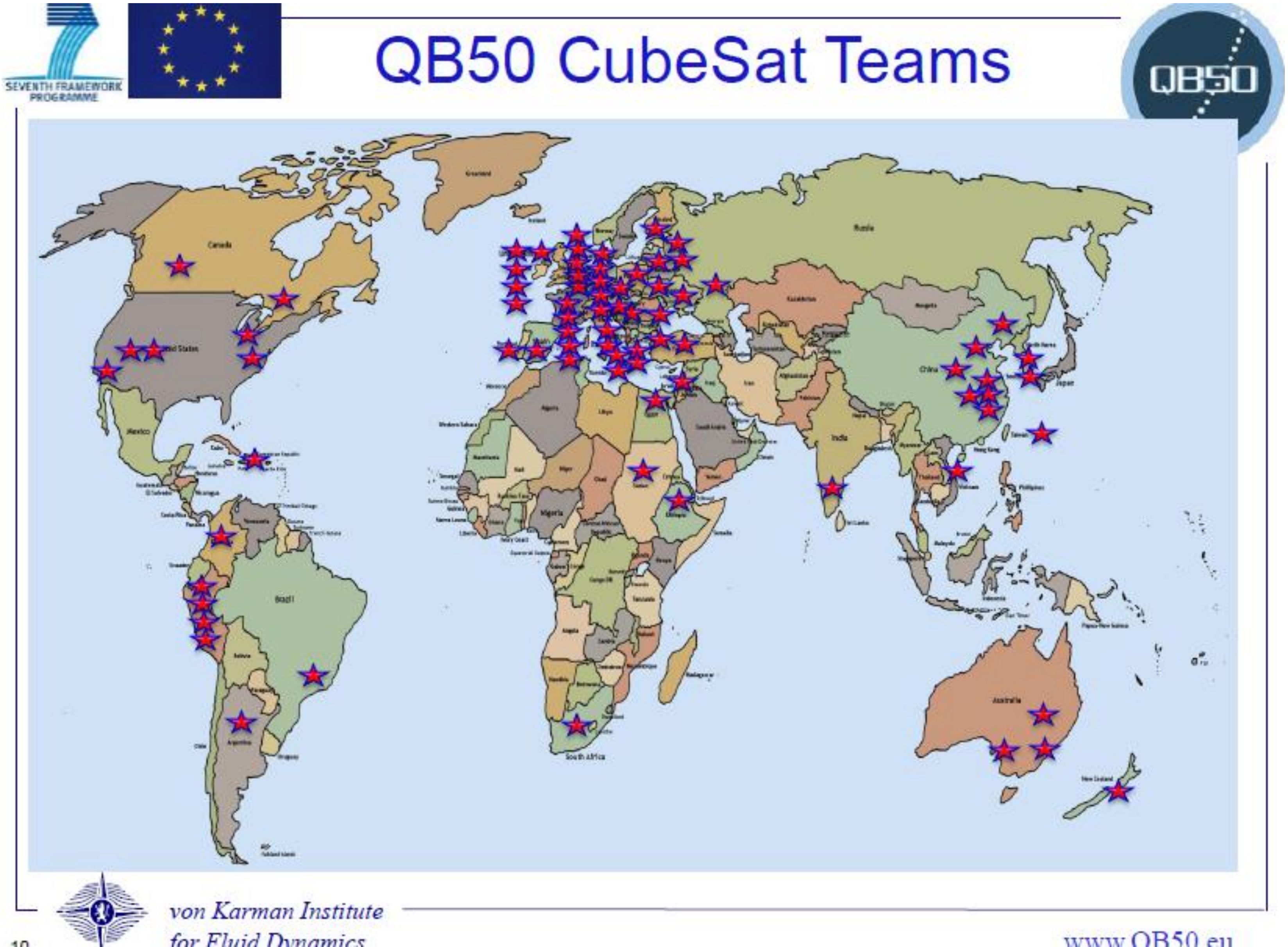


Miniaturised charged particle analyser along with the Improved Plasma Analyser

QB50 MNLP Sensor set



61 TEAMS


SEVENTH FRAMEWORK PROGRAMME
QB50 CubeSat Teams
QB50
Canada
Brazil
Russia
China
India
Australia
South Africa
von Karman Institute
for Fluid Dynamics
www.QB50.eu

Programmatic

Next steps

- Sign the **Contract** with VKI

- Register the QB50 “Space Object” in Belgium
    - less paper work for CubeSat teams
    - 3rd party liability on Belgian State
    - “registration” does not mean “ownership”

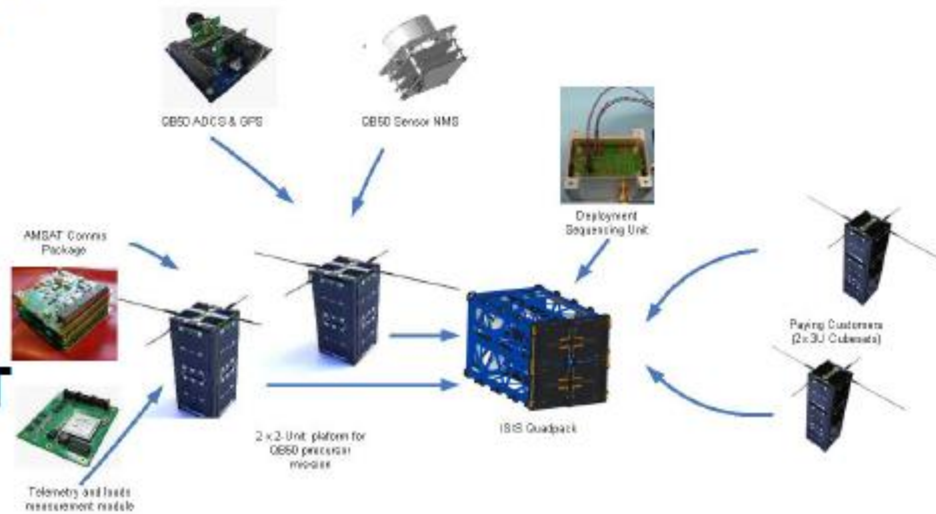
- Frequency allocation through Belgian Authorities
- Fill in and send the **Frequency Allocation Form**
- AMSAT is supporting QB50,
- Info on all **paperwork** (export license, ITAR, etc …)

Belgian Science Policy Office

belspo

The Precursor Flight

- **Objectives: flight demonstrate/risk reduce key elements of the main flight such as:**
  - **deployment building block Quadpack**
  - **common sensors**
  - **Surrey (SSC) ADCS**
  - **satellite control software**
  - **operations**
- **testbed for new AMSAT technologies**
- **managed by ISIS**
- **flight planned may 2014**
- **launcher: Kosmotras Dnepr**



von Karman Institute for Fluid Dynamics

www.QB50.eu

QB50 Requirements

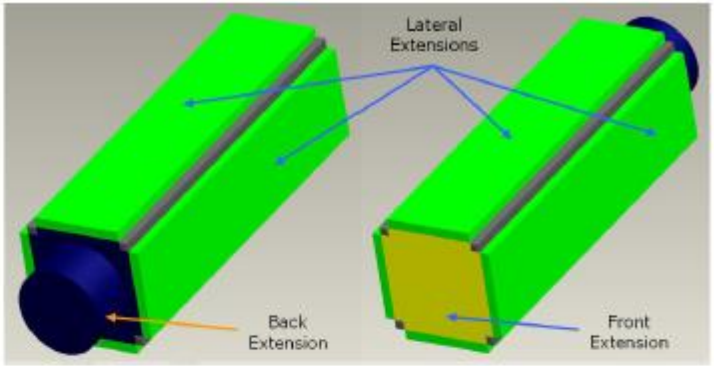
- CubeSat teams and VKI shall sign a Contractual Agreement
- CubeSat teams shall deliver their fully tested flight model CubeSats to ISIS no later than 4 months before the launch date.
- The CubeSats shall be launched into a circular orbit at 350 km altitude.
- CubeSats carrying the standard atmospheric sensors shall commence payload operations within 7 days after deployment, and secure the science sensors to look in the ram direction with a precision of ± 10º, and to operate for a minimum period of two months.
- CubeSat teams shall have access to a ground station with uplink (VHF-band) and downlink (UHF-band) capability.
- CubeSat teams shall provide selected science data (quick-look data) and key housekeeping data in real time to the Mission Control Centre and fully processed science data, key housekeeping data to the Data Processing and Archiving Centre (DPAC) within 3 after the end of the mission operational phase.

Structural Subsystem

- QB50-SYS-1.1.1.
  ...2U shall be 100 x 100 x 227mm
  ...3U shall be 100 x 100 x 340.5mm

- QB50-SYS-1.1.2.
  ...shall fit entirely within the extended volume...

- QB50-SYS-1.1.3.
  ...mass shall be no more than 2.0kg for 2U and 3.0kg for 3U



Attitude Determination and Control Subsystem

- QB50-SYS-1.2.1.
  ...shall be able to recover from tip-off rates of up to 10°/s within 2 days (TBC)

- QB50-SYS-1.2.2.
  ...shall have an attitude control with pointing accuracy of ±10° and pointing knowledge of ±2° from its initial launch altitude of 350km down to at least 200km (TBC)

Electrical Power Subsystem

- QB50-SYS-1.3.2.

  ...shall be able to survive in a powered-down state without battery charging, inspection or functional testing for a period of up to 2 months (TBC)

On-Board Computer and On-Board Data Handling

- QB50-SYS-1.4.2.
  ...shall collect whole orbit data and log telemetry every minute

- Satellite Control Software
  – Ground station interface software
  – CubeSat Control System
  – Operations User Interfaces software
  – Communications handling with the DPAC and MCC

On-Board Computer and On-Board Data Handling

- QB50-SYS-1.4.2.
  ...shall collect whole orbit data and log telemetry every minute

- Satellite Control Software
  - Ground station interface software
  - CubeSat Control System
  - Operations User Interfaces software
  - Communications handling with the DPAC and MCC

Telemetry, Tracking and Command

- QB50-SYS-1.5.1.

  ...shall use a downlink data rate of 9.6 kbps

- QB50-SYS-1.5.2.

  ...shall communicate a volume of at least 2 Megabits of science data per day....

- QB50-SYS-1.5.7.

  ...shall use an uplink data rate of 1.2 kbps

- QB50-SYS-1.5.9.

  ...CubeSat provider shall have access to a ground station.....to send telecommands....

Structural	ADCS	EPS	OBC / OBDH	TT&C	Thermal	General

Thermal

- QB50-SYS-1.6.1.

  ...shall maintain all its electronic components within its operational temperature range while in operation and within survival temperature range at all other times

General Requirements

- QB50-SYS-1.7.1.

  ...shall be designed to have a lifetime of at least 3 months....

- QB50-SYS-1.7.3.

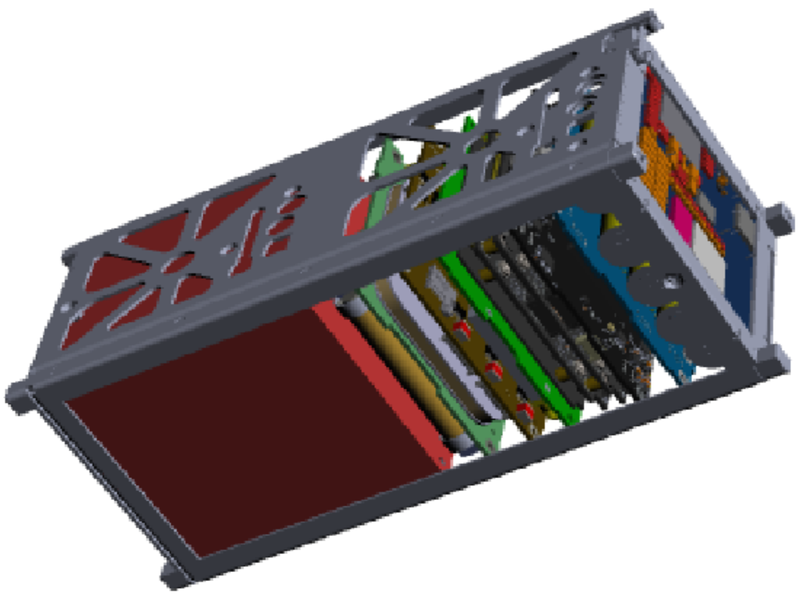
  All RBF items shall be identified by a bright red label....containing... “REMOVE BEFORE FLIGHT” or “REMOVE BEFORE LAUNCH” and the name of the satellite printed in large white capital letters

REMOVE BEFORE LAUNCH

QB50 – MYCUBESAT

BeEagleSAT of QB50

- BeEagleSAT is a joint project of Istanbul Technical University, Turkish Air Force Academy, and Sabanci University.
- One of possible 2U CubeSats of the QB50 Network



BeEagleSat Overview

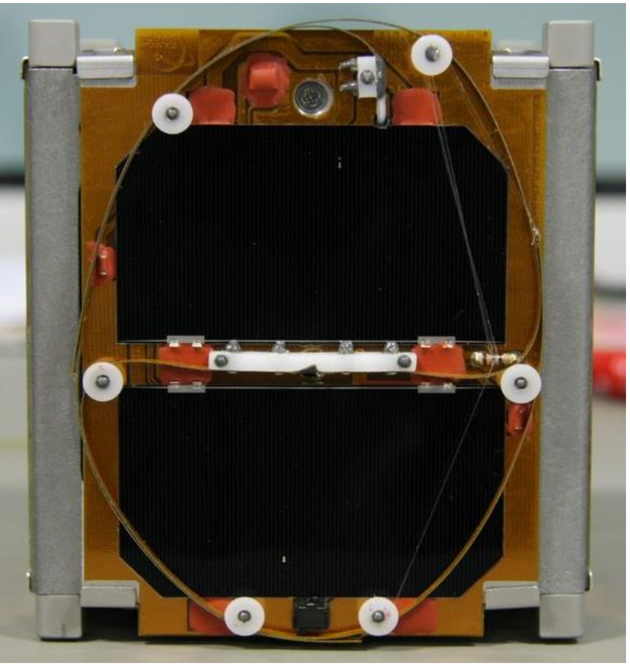
- A double CubeSat
- employing the Sensor Set #3 of QB50
  - “Multi Needle Langmuir Probe,
  - Corner Cubes and Thermistors”,
- in house developed systems
  - 2U structure,
  - ADCS system with magnetorquers and a momentum wheel, sun sensor, GPS
  - electrical power system,
  - on-board computer and MODEM and
  - the secondary payload, the X-Ray detector.

BeEagleSat Overview

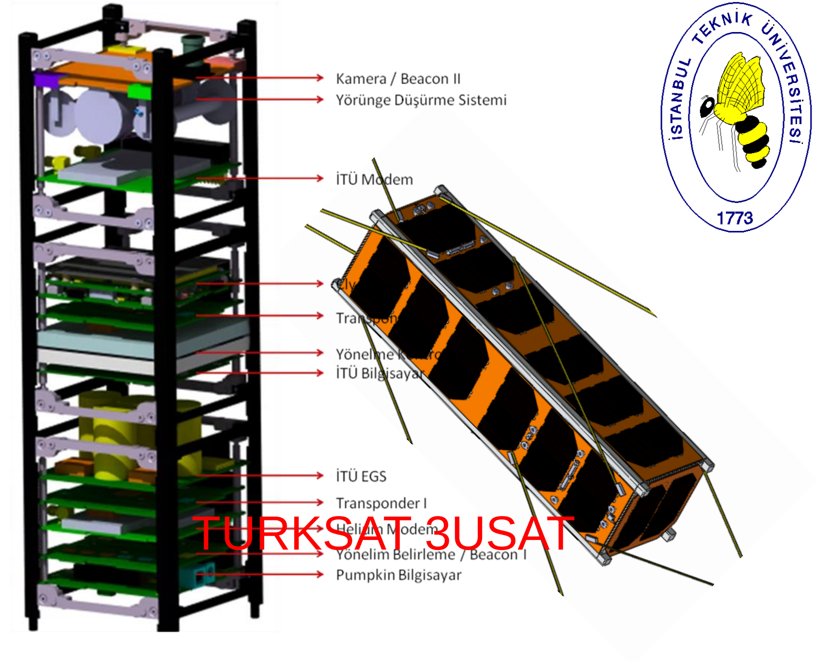
- developed to meet the mass, volume, link and pointing requirements of the QB50.
- The functional unit will provide the required link and power to the science unit and to the own experiments.
- All the tests will be carried out at existing ITU laboratories.
- X-Ray detector system is being developed by the Sabancı University team and the ITU project team.

ITU Development and Test Infrastructure

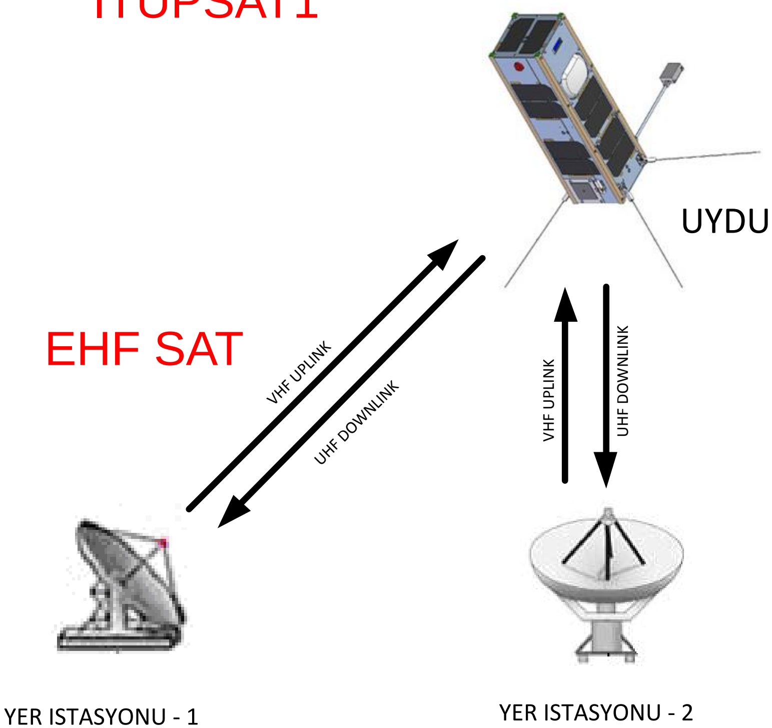
ITU-SSDTL CubeSat Projects



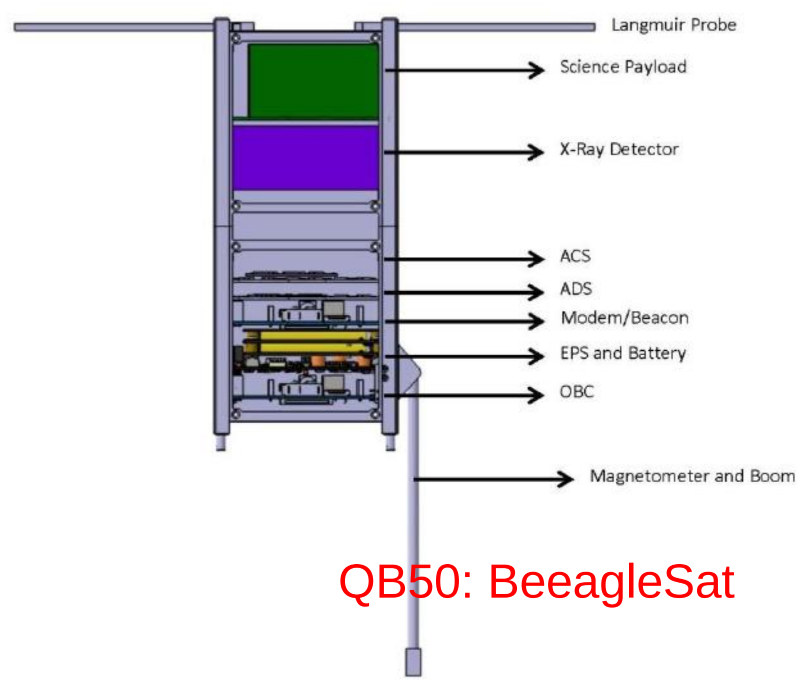
ITUPSAT1



TURKSAT 3USAT



EHF SAT



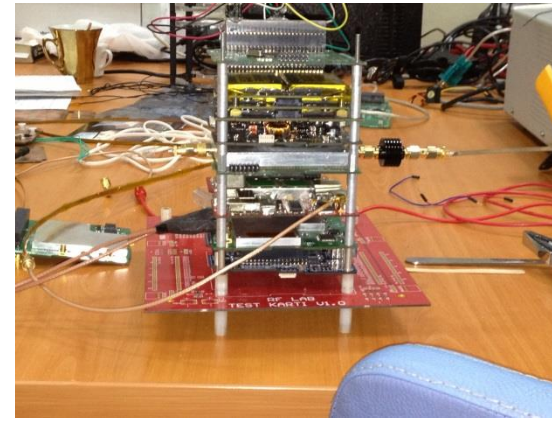
QB50: BeeagleSat

Design- Development phases

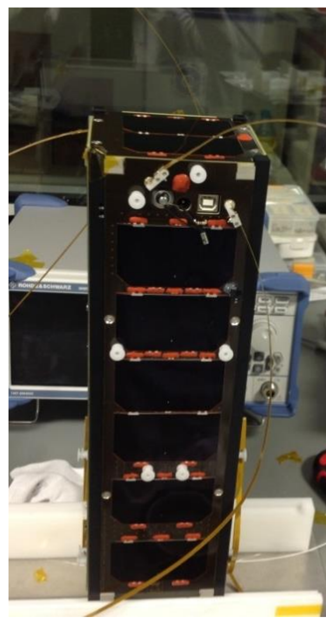
Satellite
Design / Analysis / Production

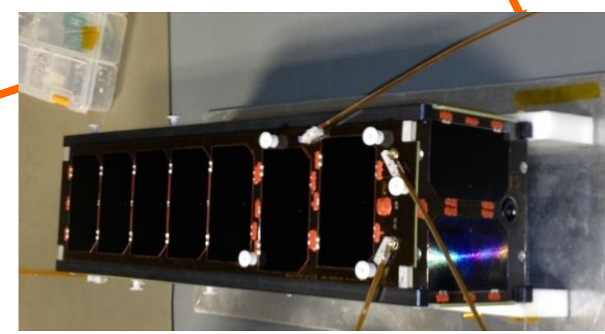
Test & Integration
Infrastructure / Payloads / Systems
Thermal Vacuum, Vibration, EMC

Ground Station

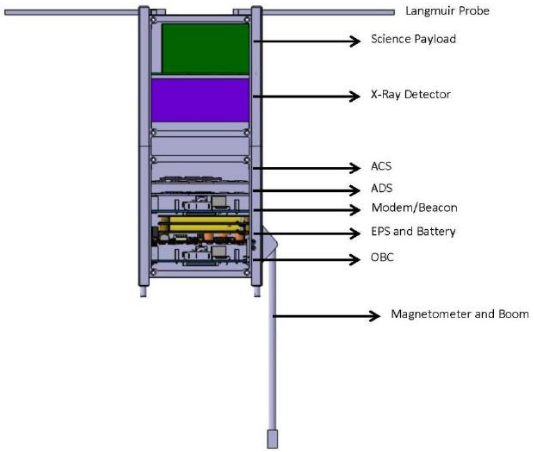


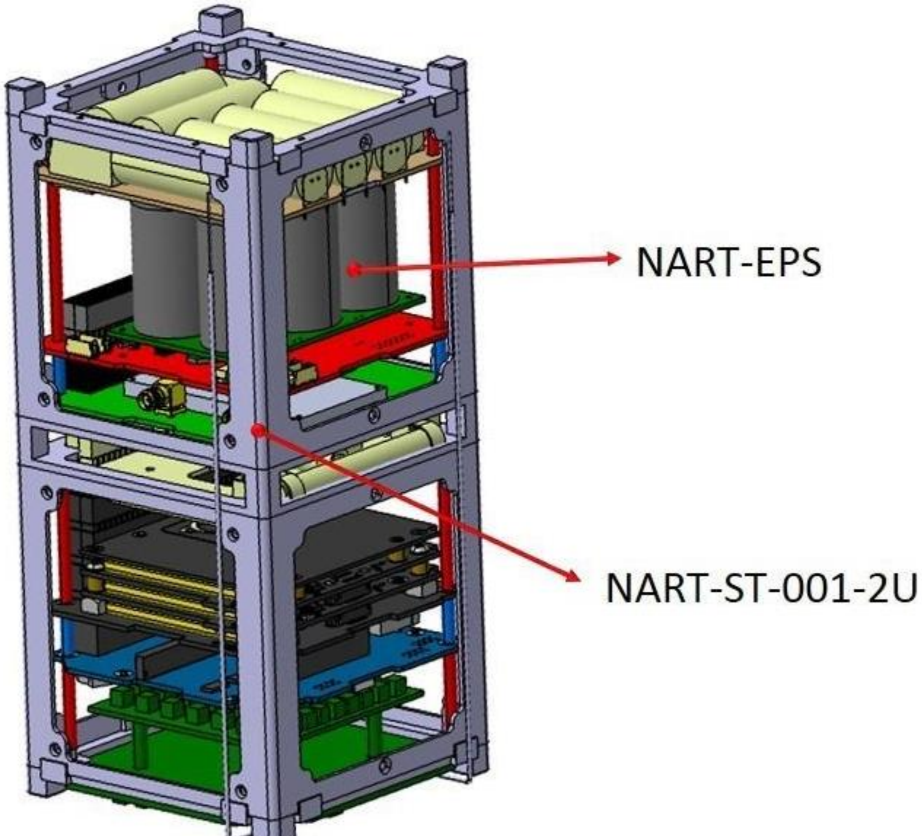
- Conceptual design
- Desktop model
- Engineering model
- Flight Model



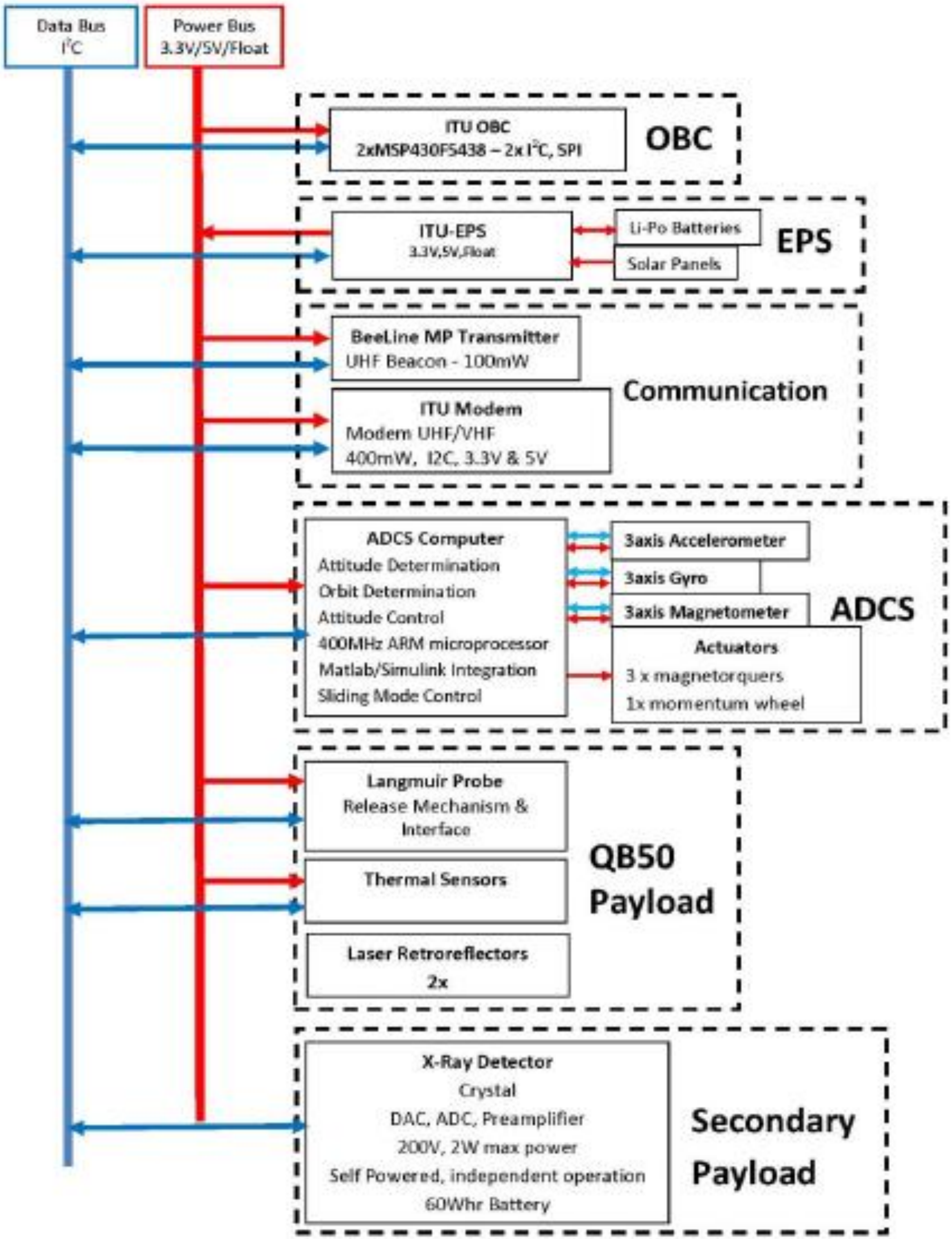


QB50: BeEagleSat (2015)





BLOCK DIAGRAM



STRUCTURE

ADCS of BeEagleSat

- employing sensor set #3
  - 5 degrees of determination accuracy and
  - 15 degrees of control accuracy
- between the altitudes of 380 and 200 km.
- Below 200 km, there are no accuracy requirements.
- A three-axis attitude control employing 3 magnetorquers and a momentum wheel is foreseen.
- Use of sun senors and GPS

ADCS of BeEagleSat

- Analysis and evaluations,
  - Accuracy
  - Ease of development
  - power and
  - cost

- Algorithms and software development

EPS

- Derived from the previously developed EPS of the 3U CubeSat, 3USAT
- Prepared to meet the QB50 requirements
- Limited power for tight pointing requirements.
- Power will be provided by COTS solar panels and batteries.

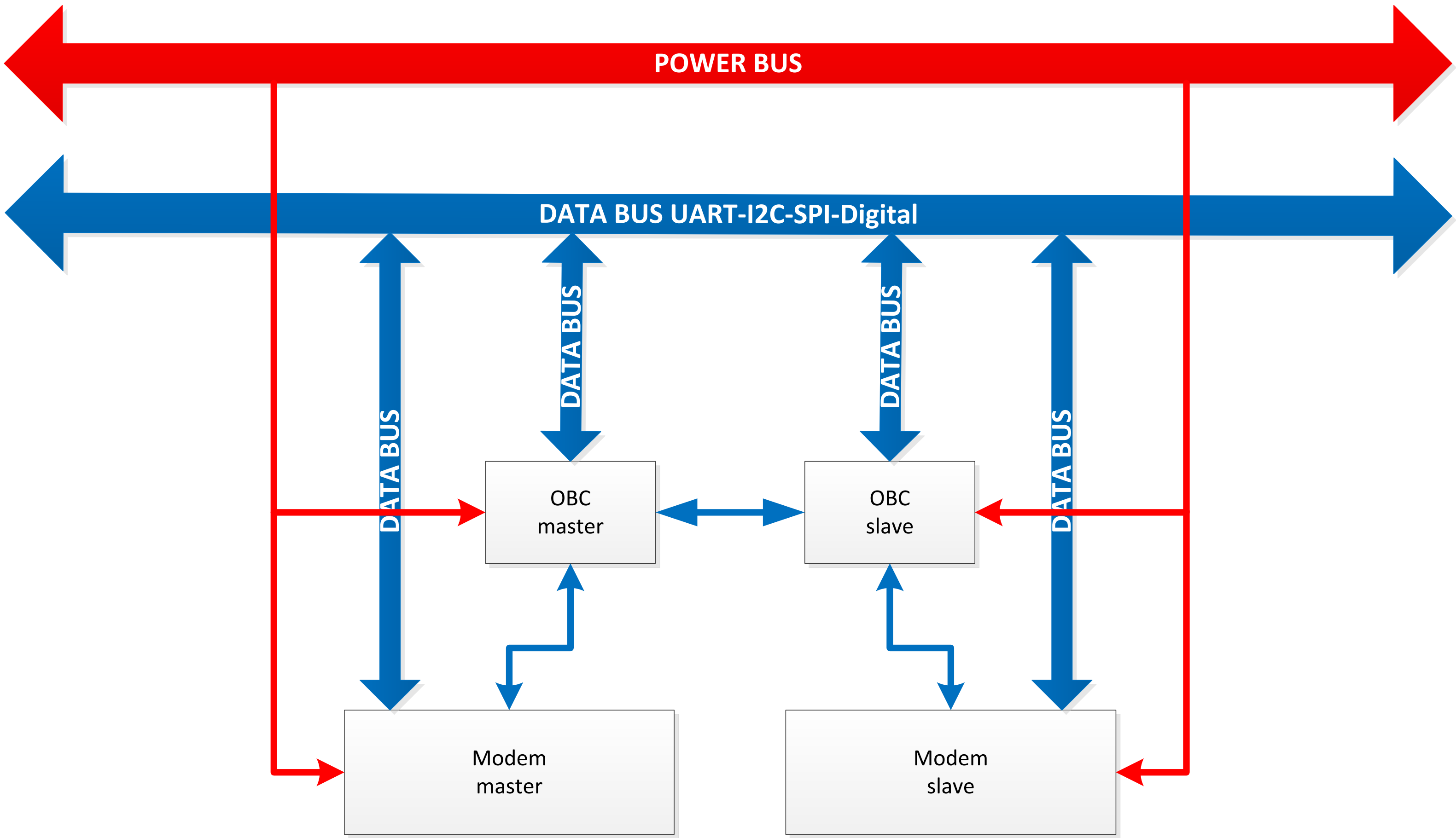
POWER BUDGET

	Power Consumption	Number of units on	Mode Safe	Mode De Tumble	Mode Operation
OBC	0,1	1	100	100	100
MODEM	1	1	4	10	10
RX	0,1		1	0,1	0,1
TX	1		3	9,9	9,9
ADCS	1	5	0	100	100
Measurement	0,05		0	100	100
Calculation	0,25		0	100	100
Actuation	0,7		0	100	50
Experiment Unit	0	1	0	0	20
Science Payload	2,7	1	0	0	22
Sum loads (W)			0,2	1,2	1,44
Efficiency			0,85	0,85	0,85
Power Consumed			0,235	1,412	1,6941176
Power Generated			0,55	1,72	1,72
Power Margin			0,315	0,308	0,0258824

OBC/OBDH and COMMS

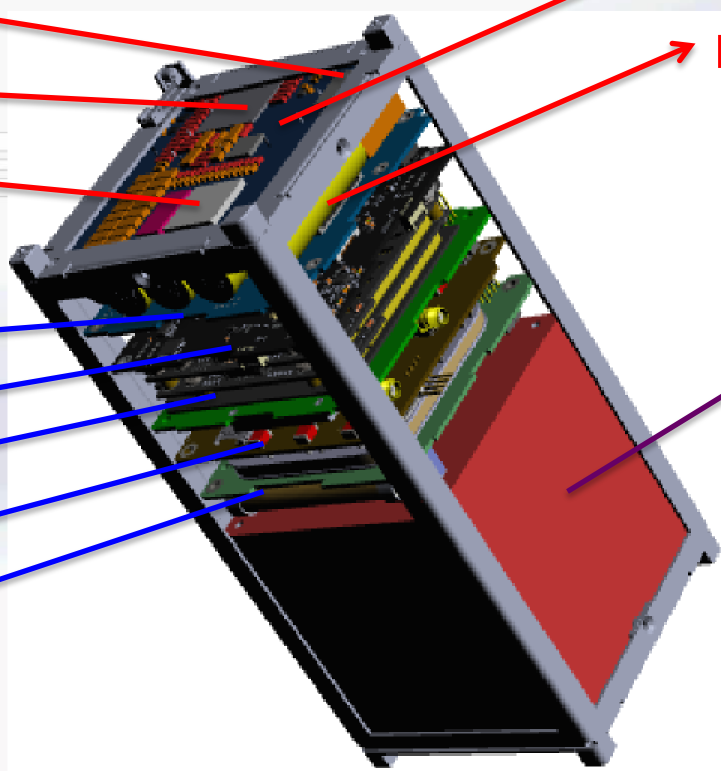
- Critical volume and mass budget,
- Gather electronic systems on a PCB together to meet mass requirement
- Combined OBC and MODEM transceiver on a single board is currently under development
- To increase reliability the system is designed in a redundant manner.
  - OBC will have dual microcontrollers and MODEM will have dual redundant transceivers

OBC-MODEM


POWER BUS
DATA BUS UART-I2C-SPI-Digital
DATA BUS
DATA BUS
DATA BUS
DATA BUS
OBC master
OBC slave
Modem master
Modem slave

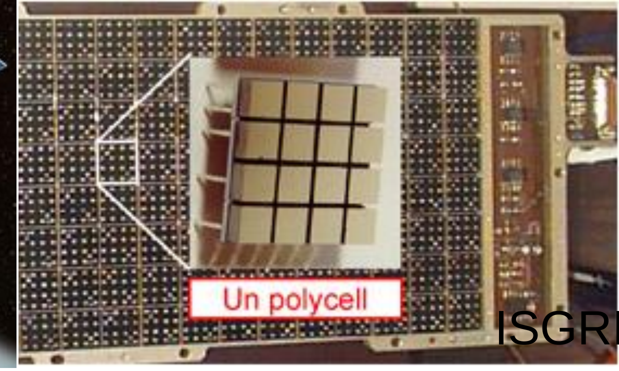
Ground Station, VHF/UHF

BeEagleSAT Control Unit and X-ray Detector Payload.



Preliminary drawing !

Motivation

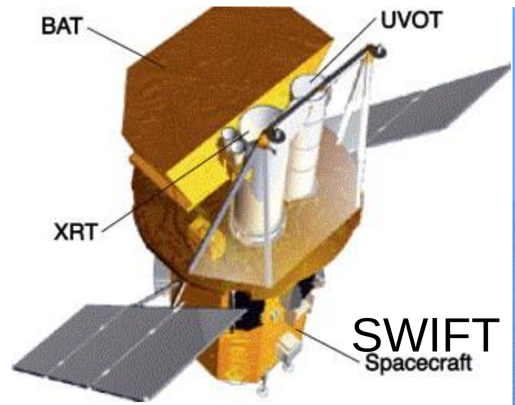


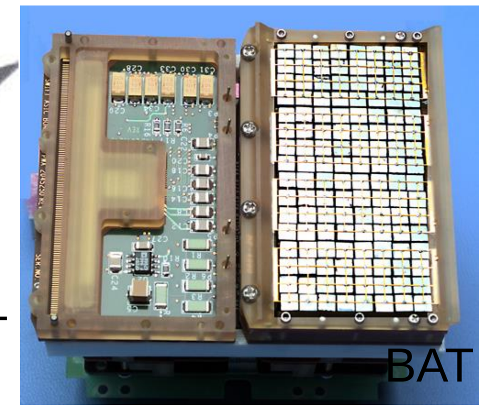
- Space heritage of single crystal CdTe and CdZnTe X-ray detectors:

ISGRI on INTEGRAL

BAT on Swift

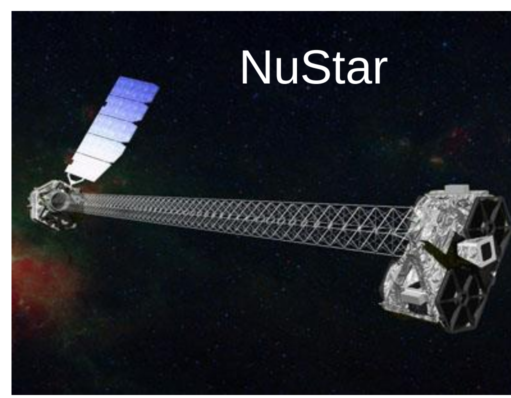
Coded mask imaging of large field of views above 20 keV.

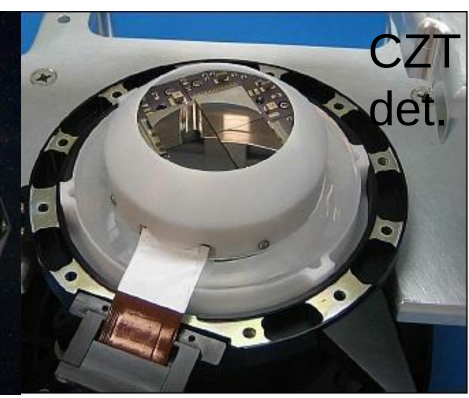




- Space heritage of pixellated, CdZnTe detectors: NuStar focal plane CCD with X-ray telescope.

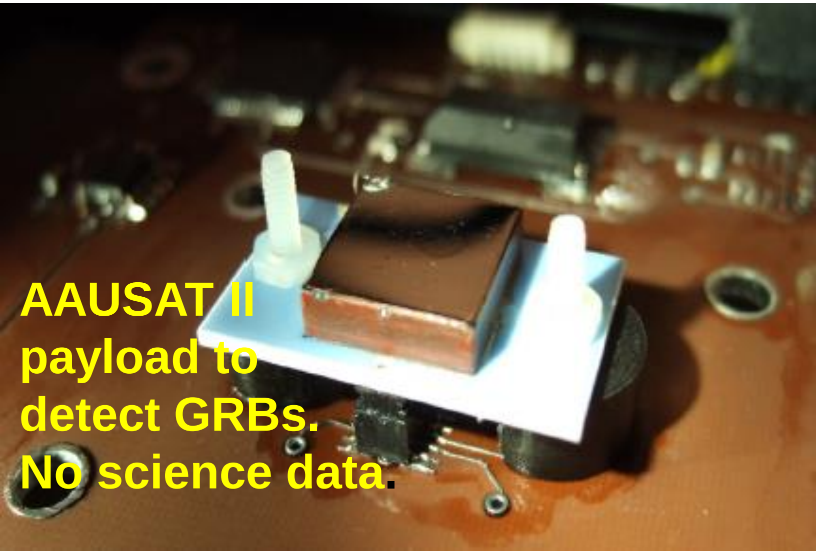
impressive minimum energy of a few keV – high resolution imaging up to 60 keV

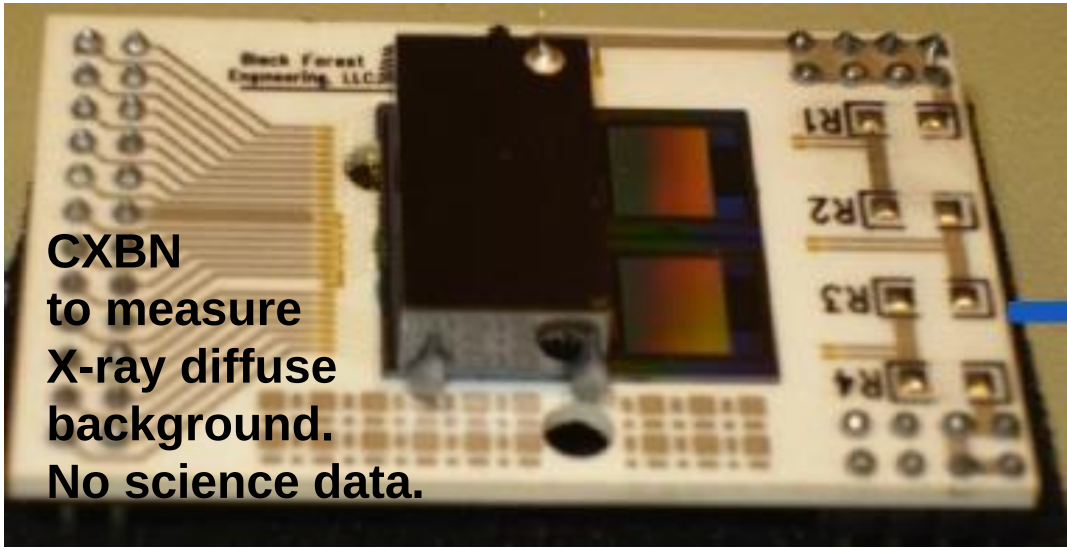




Motivation

- CdZnTe X-ray detector attempts on cubesats:





Space heritage of large crystal orthogonal strip detectors : NONE!

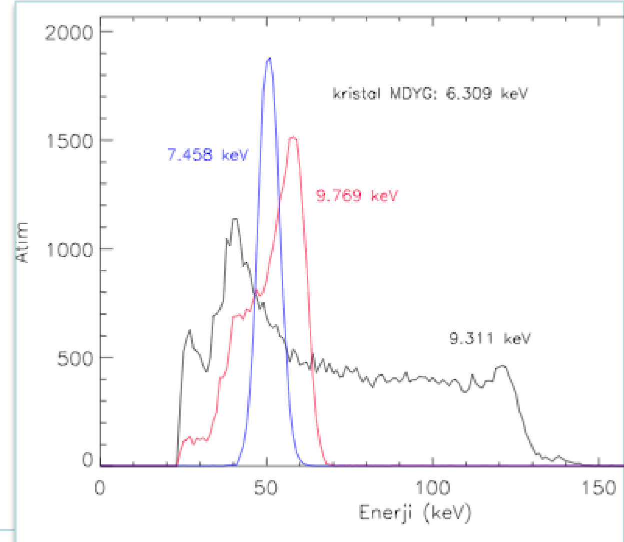
Other aims:

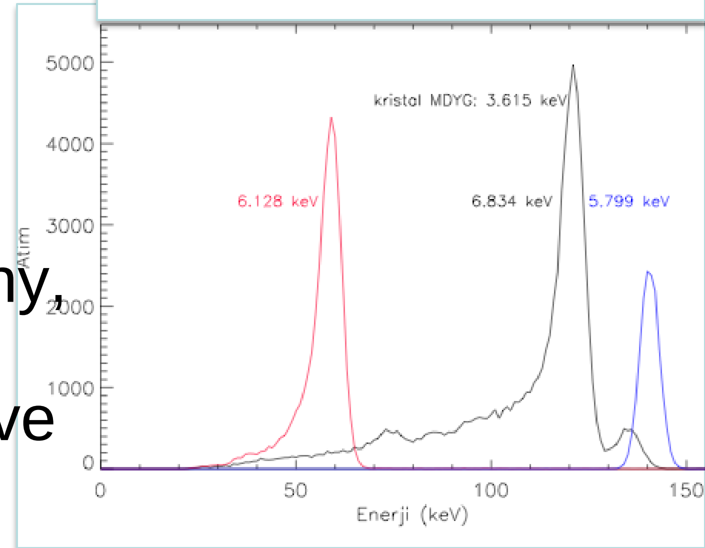
Test RENA 3 (NOVA R&D*) readout electronics in space
Measure X-ray background spectrum at very low Earth orbit.
Lay foundations of producing scientific space payloads in Turkey!

CdZnTe orthogonal strip X-ray and Gamma-ray detectors

- **Why CdZnTe?**
  - High band gap (~1.6 eV) semiconductor crystal allows room temperature operation!
  - High atomic number composition allows reaching a few hundred keVs with with a few mm thickness.
  - Moderate energy resolution (good enough for astrophysical continuum)

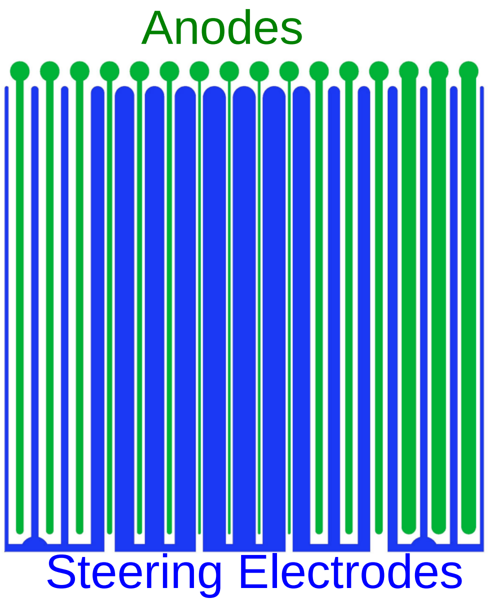
  major problem: poor hole transport properties. Solution: make anodes tiny, use large planar cathodes, and essentially make the detector sensitive only to electrons (small pixel effect)

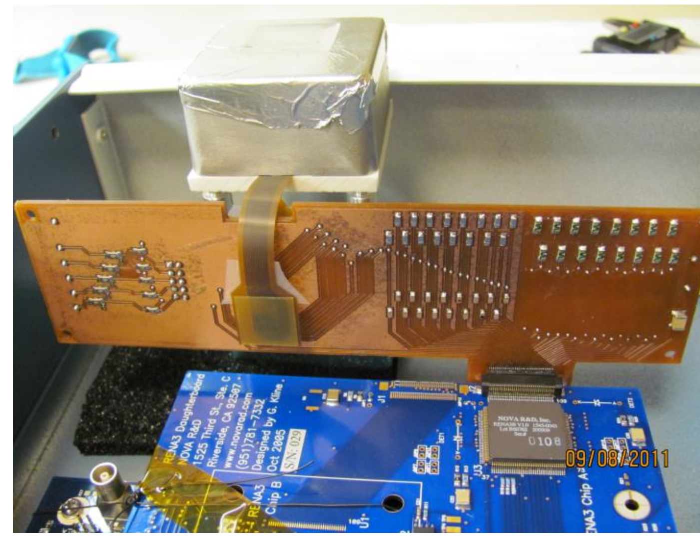


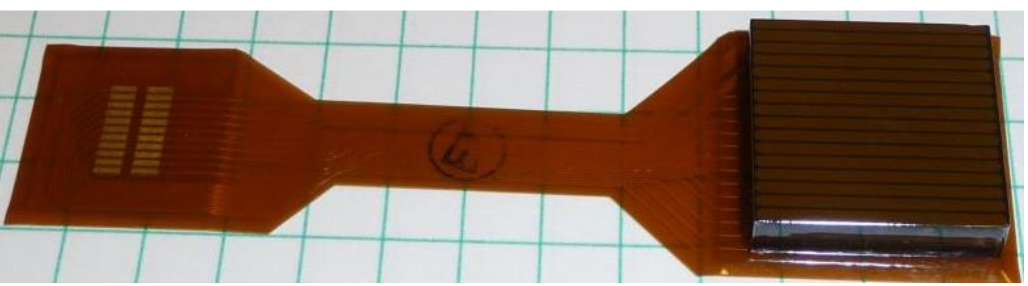


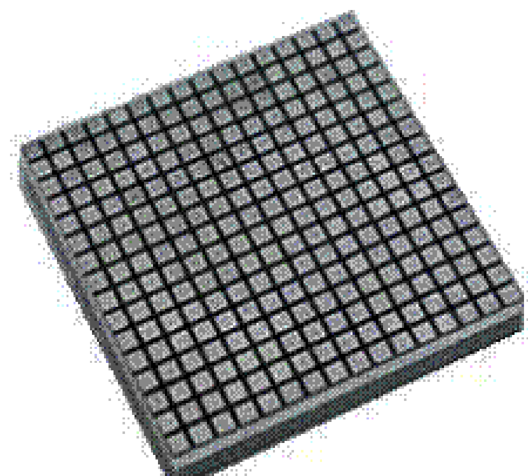
Cross-strip detector with steering electrodes

- Optimize anode/steering electrode/gap widths for best performance (energy resolution, charge collection efficiency, and noise!)



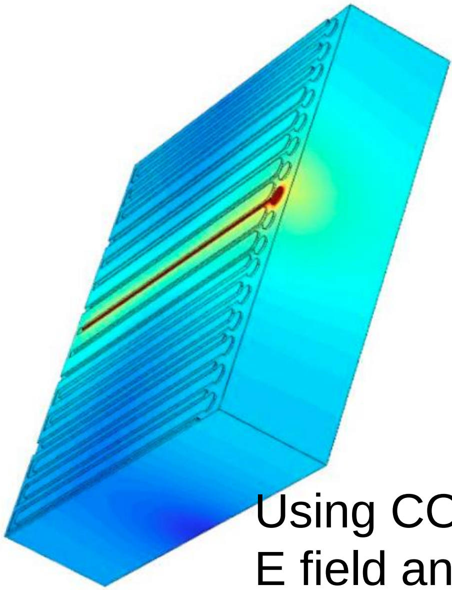




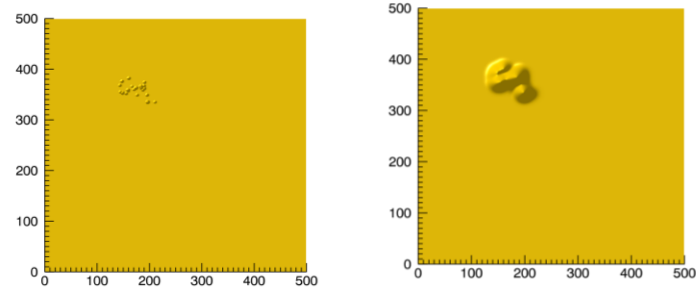


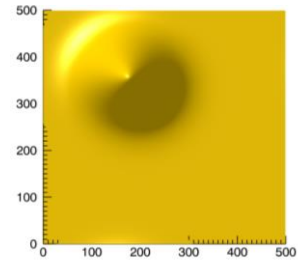
X – position from one (or multiple) anode strip(s)
y – position from one (or multiple) cathode strip(s)
Advantage: 2xN electronic channels for NxN resolution

Simulations

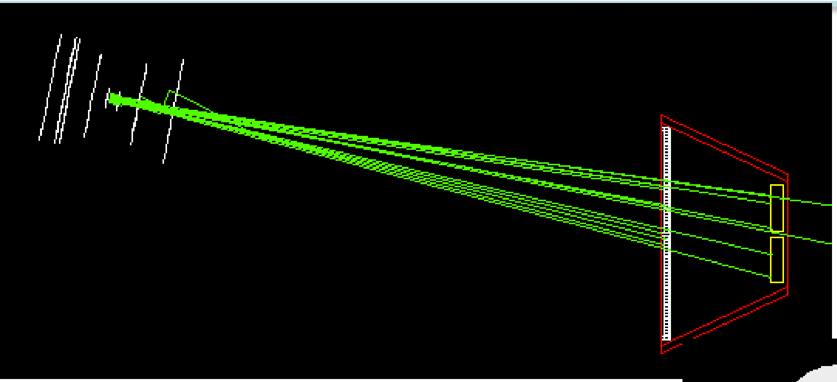


Using COMSOL determine
E field and weighting potentials
in 2D and 3D.

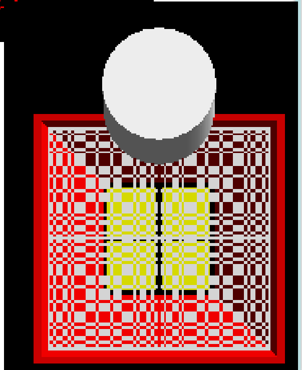




Create clouds of charges
(GEANT), follow their track
taking into account
diffusion and repulsion (IDL

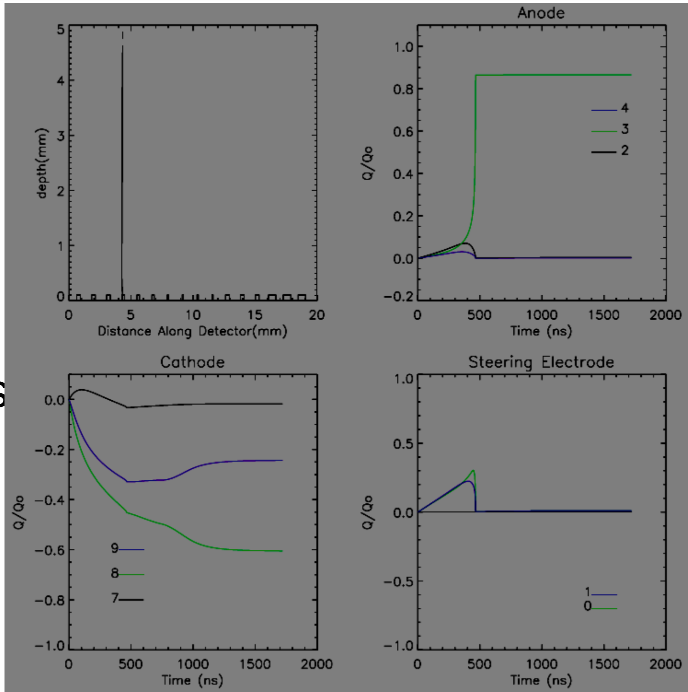


Using GEANT,
determine interaction
positions and
energies

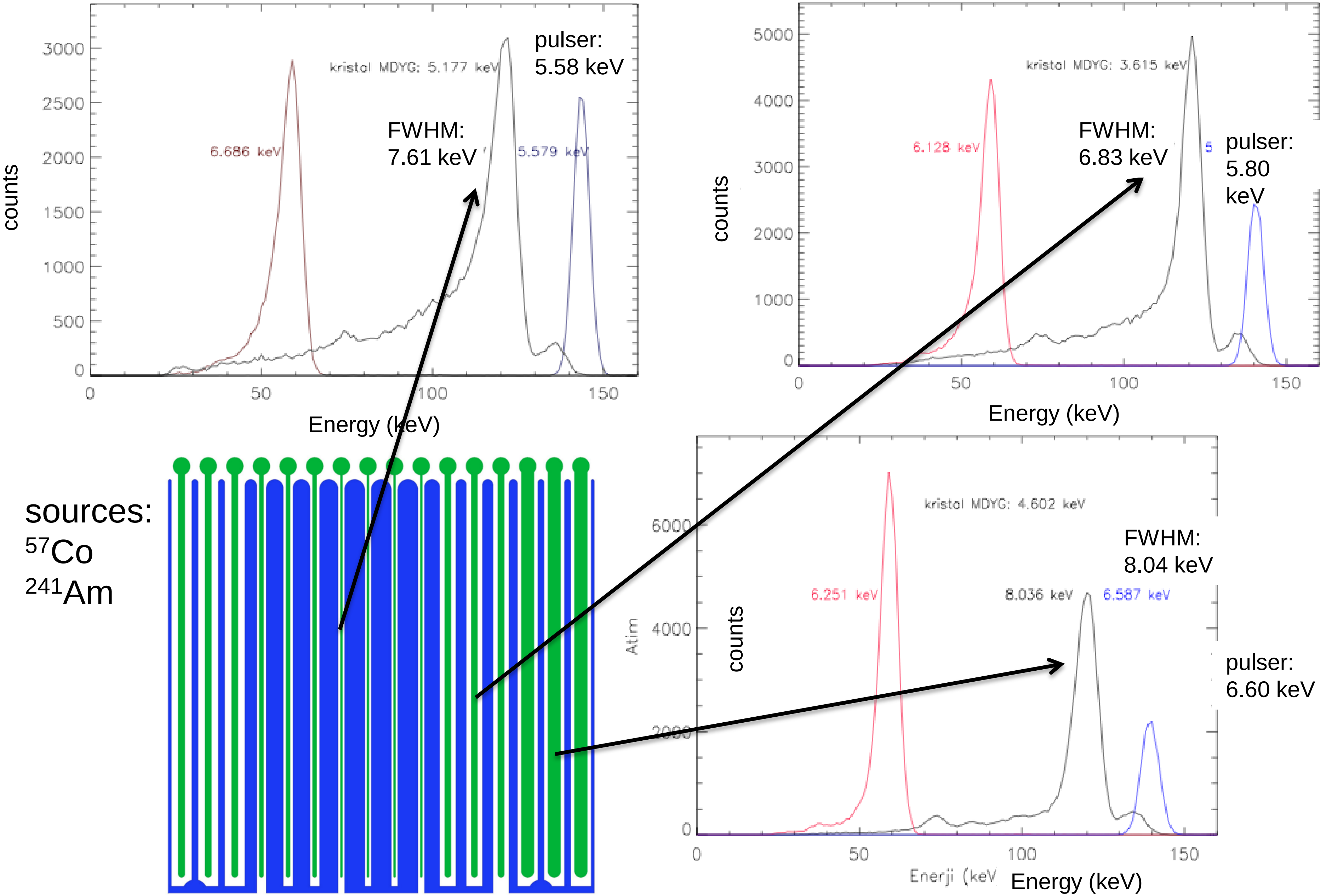


Obtain
induced
charges as
a
function of
time
for all strips
taking into
account
 trapping,

detrapping,

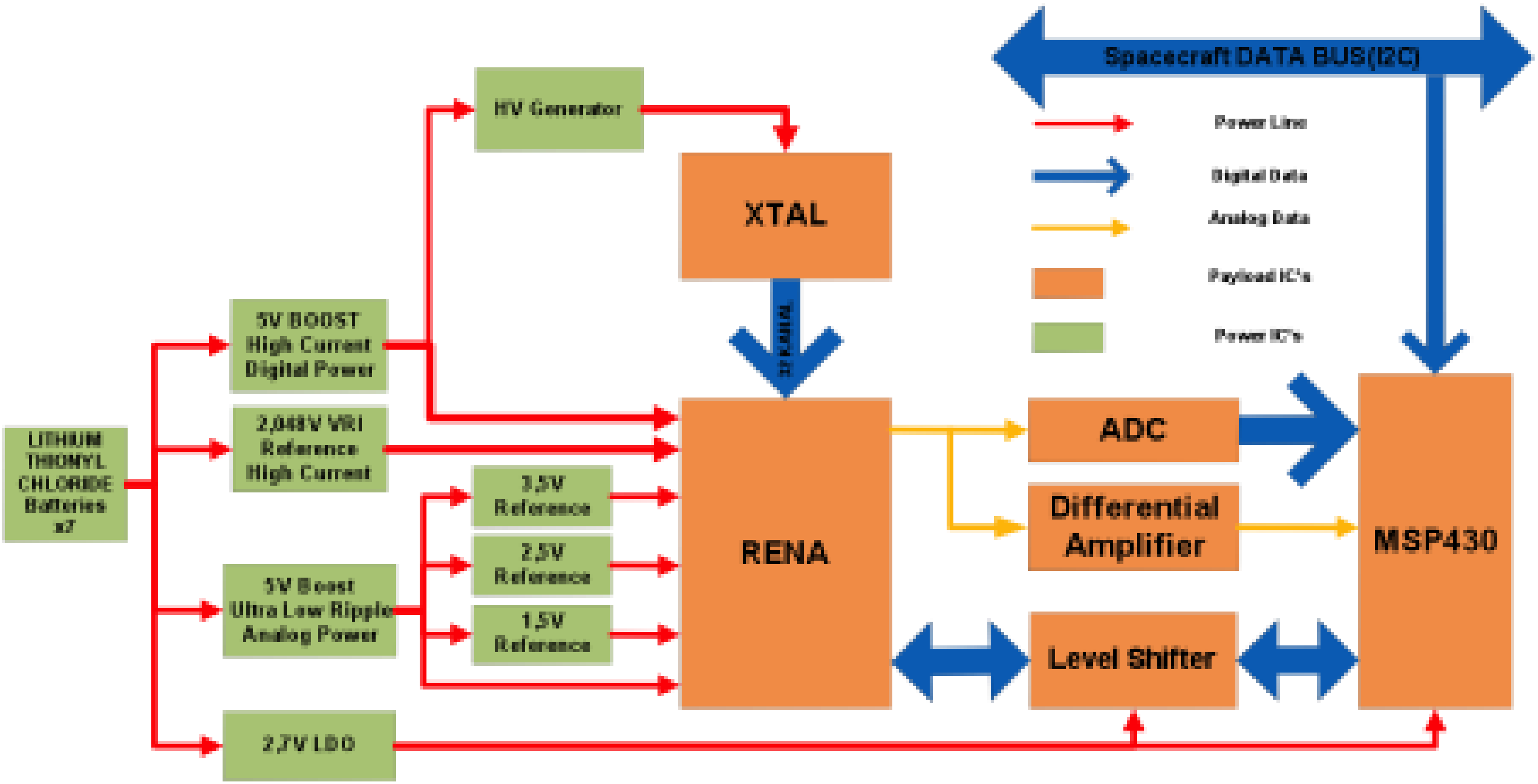


Results II – simulations face reality



Power Management of XRD

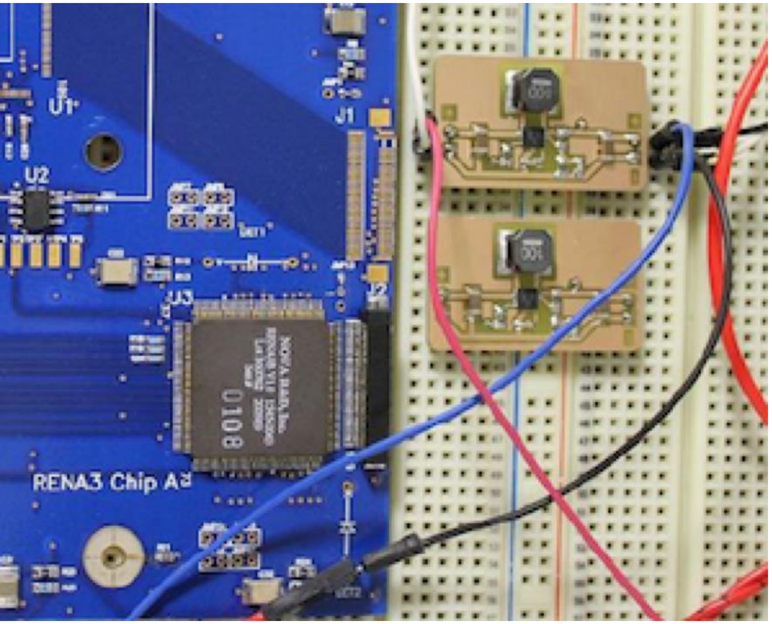
The payload will have its own battery and power system



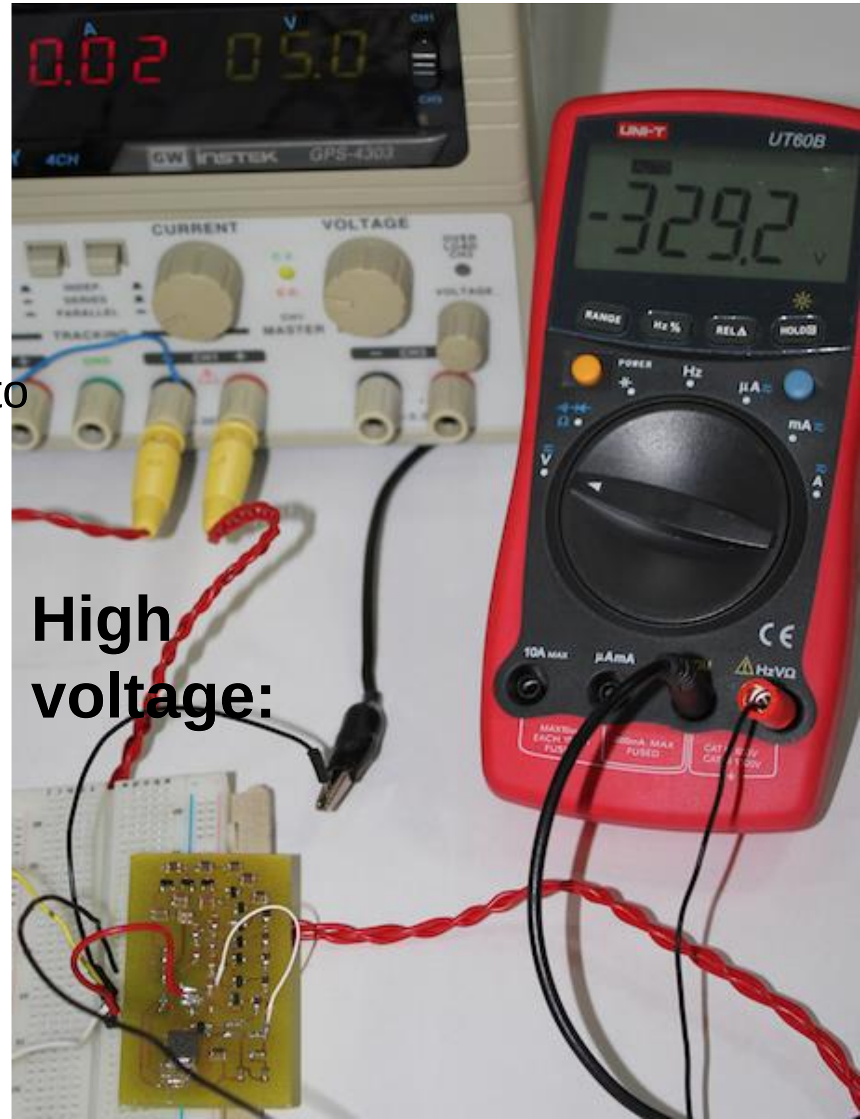
Power Management – current status

We first designed the circuits to produce necessary voltages from the battery, simulated them and finally produced prototype circuits. We obtain all required voltages, some ripple and noise measurements still underway.

1.5 V, 2 V, 3.3 V, 3.5V, 5V required for the ASIC to operate are produced from the battery



High voltage:

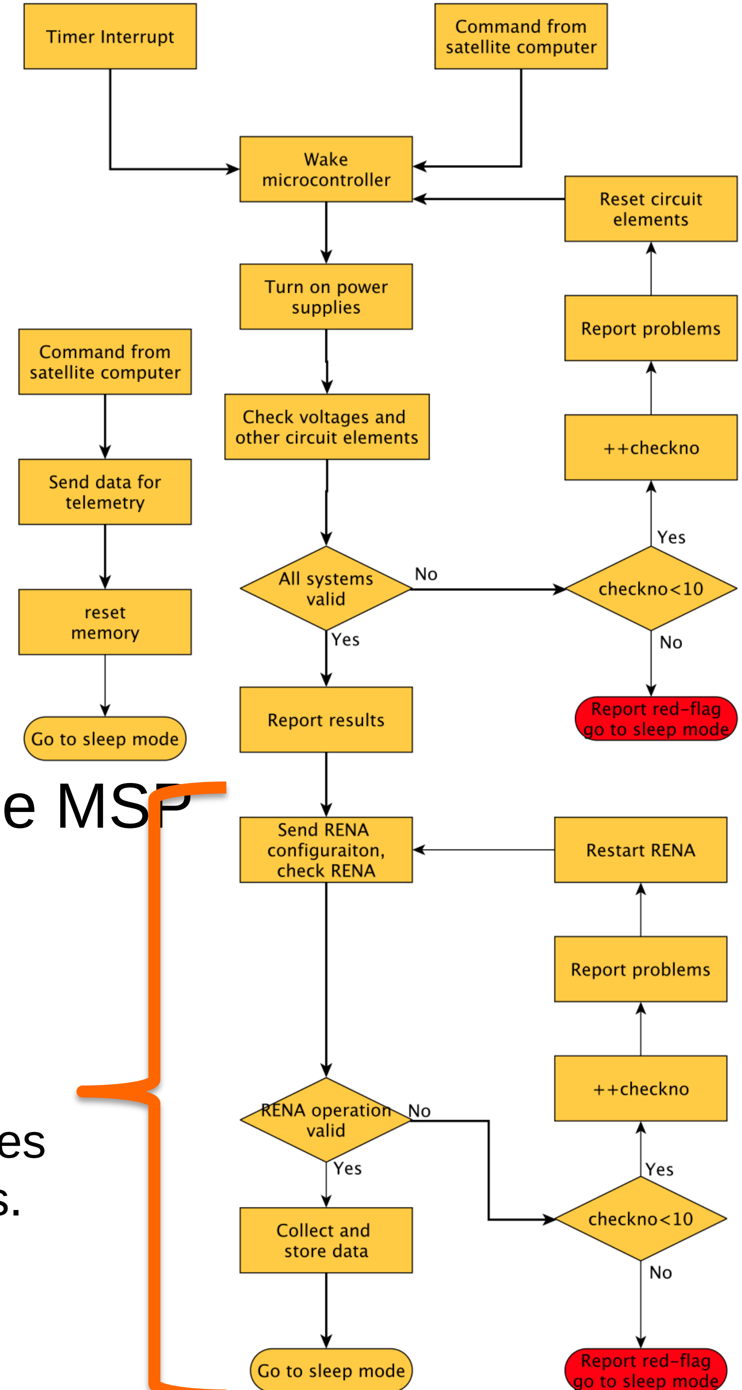


Signal Processing and storage

The payload has its own MSP430 microcontroller and storage unit, and will transfer data to satellite computer for telemetry when asked.

Current status: We are programming the MSP to work with the RENA 3 ASIC.

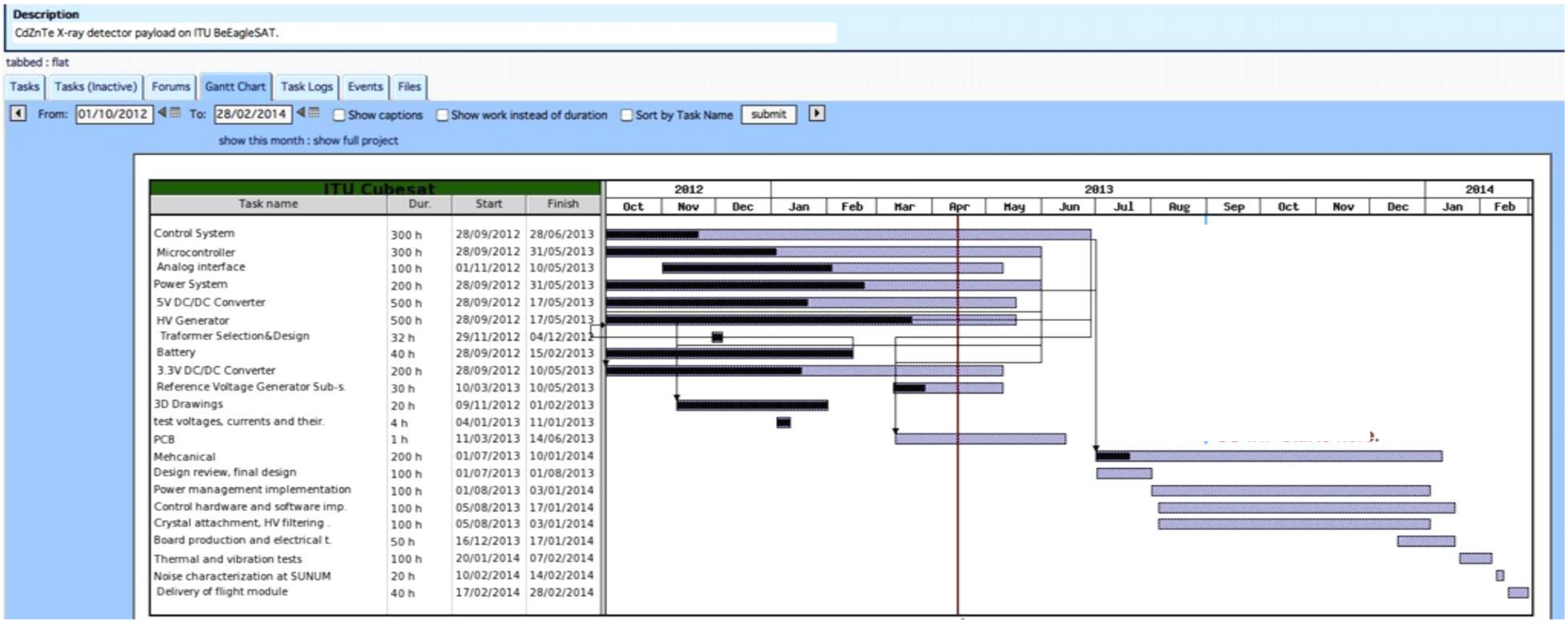
Due to power and telemetry constraints the system will be operated intermittently. The preliminary estimates show ~140 hours of available power from our batteries.



Challenges and work in progress

- Low noise power circuits for the ASIC, and the detector (300 V). Preliminary ripple and noise measurements are ok.
- Optimization of the data taking due to telemetry constraints (trade off issue)
- Attachment of the 3 mm thick, 20 mm x 20 mm CdZnTe crystal to the board and maintaining electrical contacts on the cathode side (next slide).

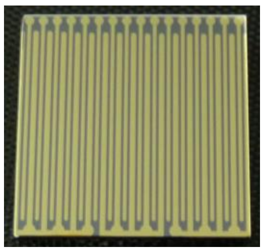
- **Project management and coordination** between Sabanci and ITU is handled by online project management tools and weekly meetings



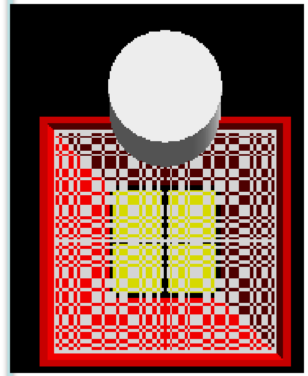
Outlook – prototype to real Imager

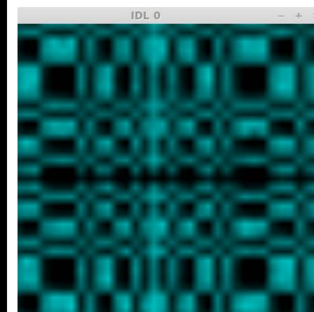
4 crystals, 40 mm x 40 mm area, 32 x 32 (equivalent) pixels read by 4 RENA 3b ASICs.

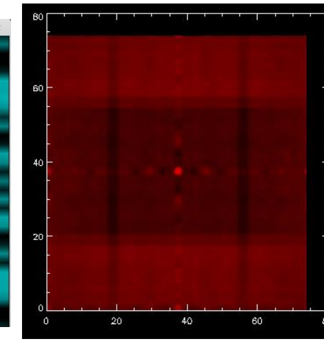
Strip thickness based on optimization



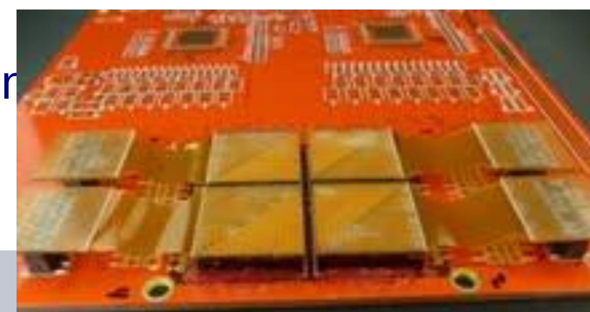
Simulations







Overall Design



Conclusions

- ITU, TurAFA and SU along with national space industry benefit from QB50.
- A 2U CubeSat with sensor Set 3 is being developed.
- A local X-Ray detector will be space tested.
- Students, through hands-on work, developing the necessary skills and experience to succeed in the space industry.
- Overall, the QB50 project providing an outstanding intercultural experience and a global network of students and engineers with the possibility of exchange and cooperation programs.

Thank You…

Alim Rüstem ASLAN
Istanbul Technical University
Department of Space Engineering
+90532 480 3449
aslanr@itu.edu.tr
usl.itu.edu.tr