Research and Educational Space Activities at AAU

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Axel Michelsen
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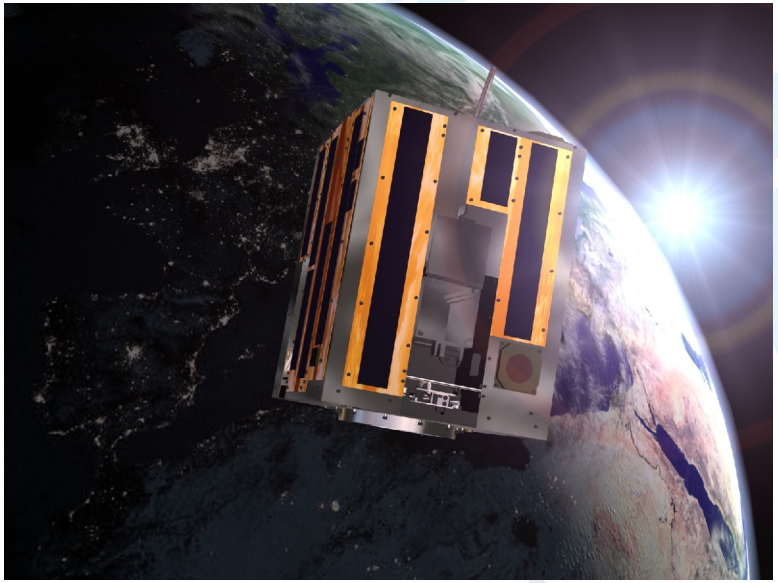
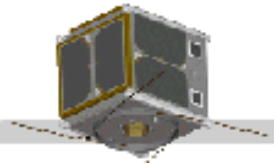
August 08



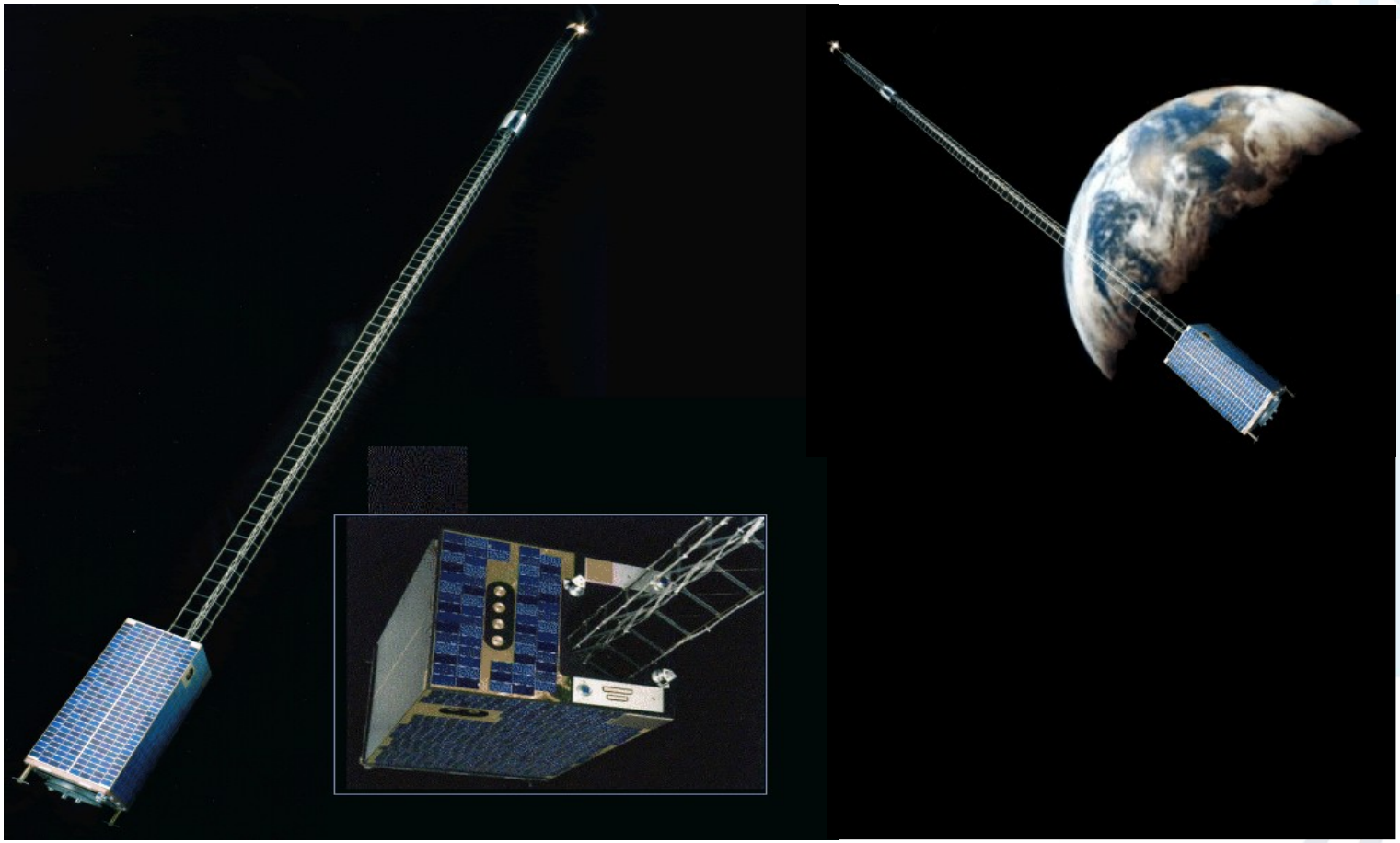


1997 Champ ACS study
- Intelligent Autonomous Systems (IAS) specialization
- ***TEAM***

Danish Satellite Program (cont.)
2000 Rømer Detailed Design
CubeSat Def. Phase
AAU CubeSat 2001
BEST summer school (25 sts.) 2002
AAU CubeSat launched (75 sts. 2003
- AAUSAT-II (+45 sts.)

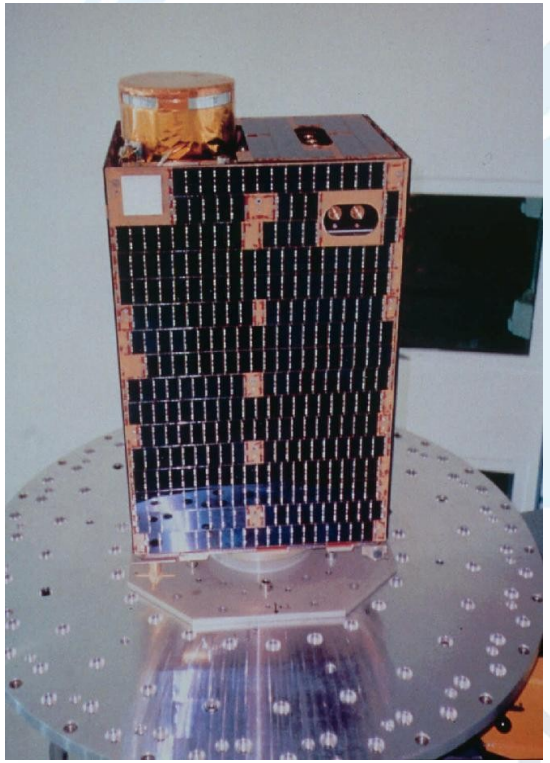
Advanced ACS+GPS
SSETI-Express (ESA) 2004
Baumanetz (Russia)
Baumanetz Launch
STEC05 Conference 2005
SSETI-Express Launch
AAUSAT-II 2008
AAUSAT3

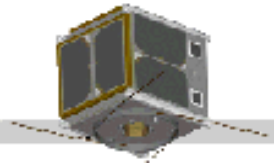
Ørsted – the first danish satellite



Satellites at Aalborg University – Ørsted

- Danish National Satellite Project
-
- Started: 1993
- Launch: February 1999
- Dimension: 34 cm x 45 cm x 68 cm
- Mass: 62 kg
- Payload: Magnetometers
- AAU main delivery: ACS

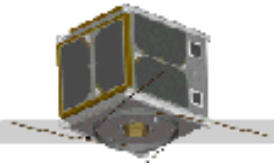




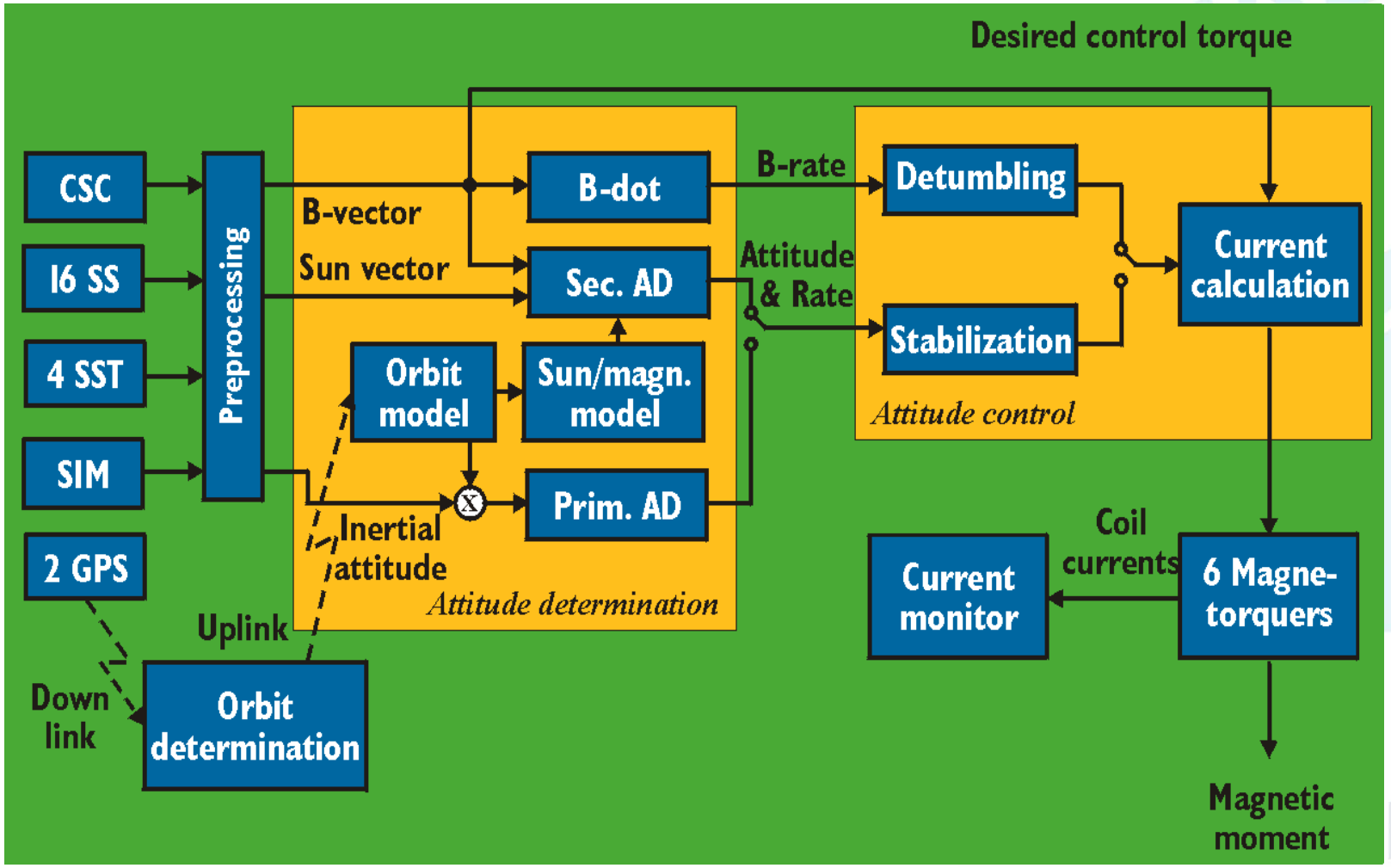
Ørsted purpose

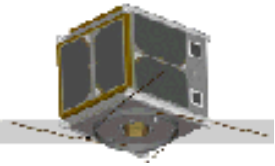
High precision measurement of earth magnetic field over place and time
Coil based attitude Control
100% danish project
20 millionUS$
Launched 1999
Still in full operation

- AAU ADCS – attitude determination and control



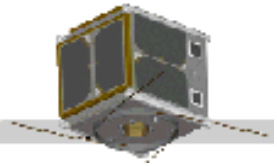
ACS control structure





AAU achievement

- Responsibility for analysis, design, implementation, verification of the ACDS system
- First proven control algorithm design based on use of only magnetorquer concept.
- Use of modular and hierarchical approach to facilitate easy verification and test.
- Several related Ph.D. work was conducted (ACS , ADS, Fault Diagnosis, Supervisory control)
- Has been complete success, In operation more than 7 years
- IT WAS HER IT ALL STARTED !



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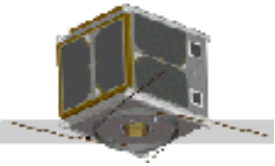
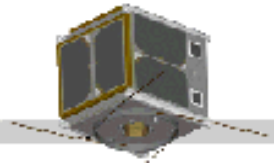


The Aalborg way of making Engineers

- Problem and Project Based Learning:
  - Solve a engineering problem within semester theme
  - Receive lectures for learning new theory and technology
- Mantra: Best Learning is by “Just Doing”
  - Math, Theory etc lectures them selves dont give anything
  - Same goes for Control, Realtime Systems, Power Eng,...
  - But are ! at the same time the knowledge basis for learning
  - Beware of keeping theorethical level high
  - ... solved by specific learning demands for examines



Students building Satellites

FOR FUN and NOT FOR FUN !!!

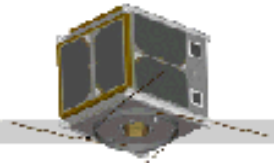
do it because it is fun

do it 100% because with must reach the goal

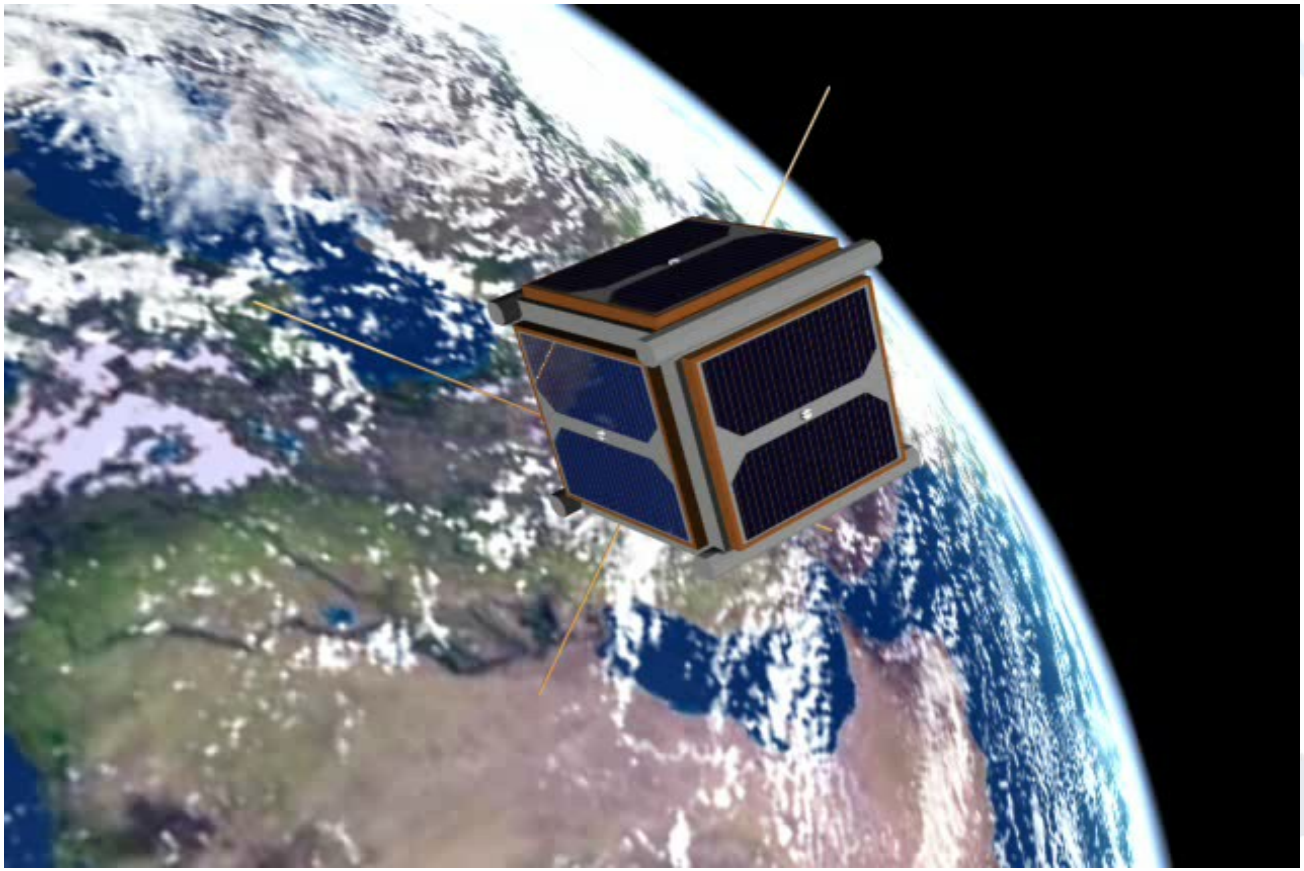
do it because you can afford the time for it

and remember ...

“Students only ! ”



AAU-Cubesat

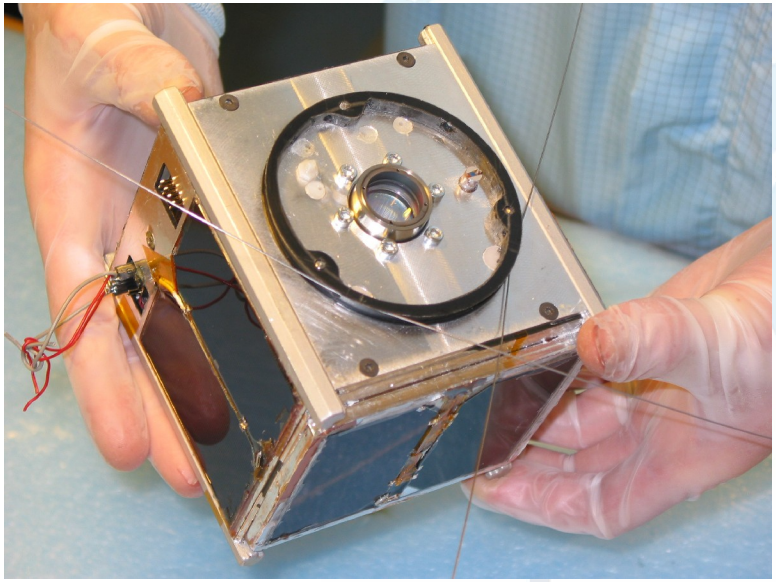


Student Satellites at Aalborg University AAU

CubeSat

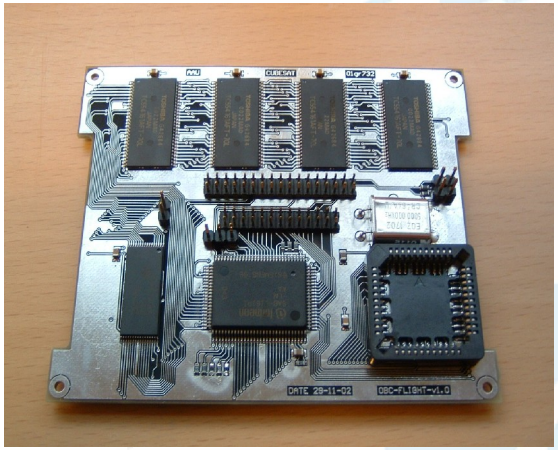
- Started: July 2001
- Launch: June 2003
- Dimension: 10 cm x 10 cm x 10 cm
- Mass: 1 kg
- Payload: Digital Camera

- **AAU Delivery: All**



Electrical subsystems:

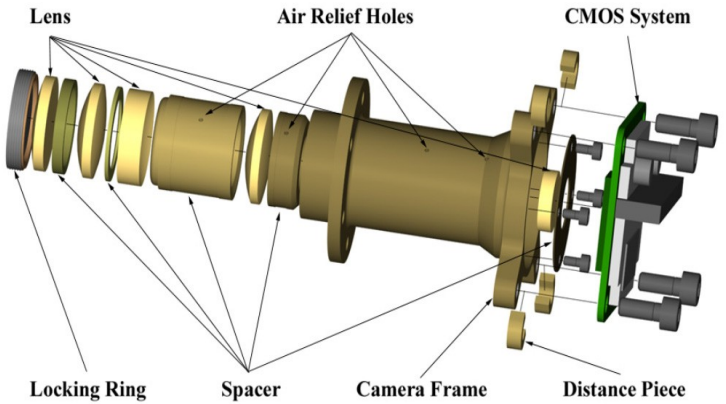
- Power supply unit
- On board computer
- Attitude determination and control system
- Communication unit

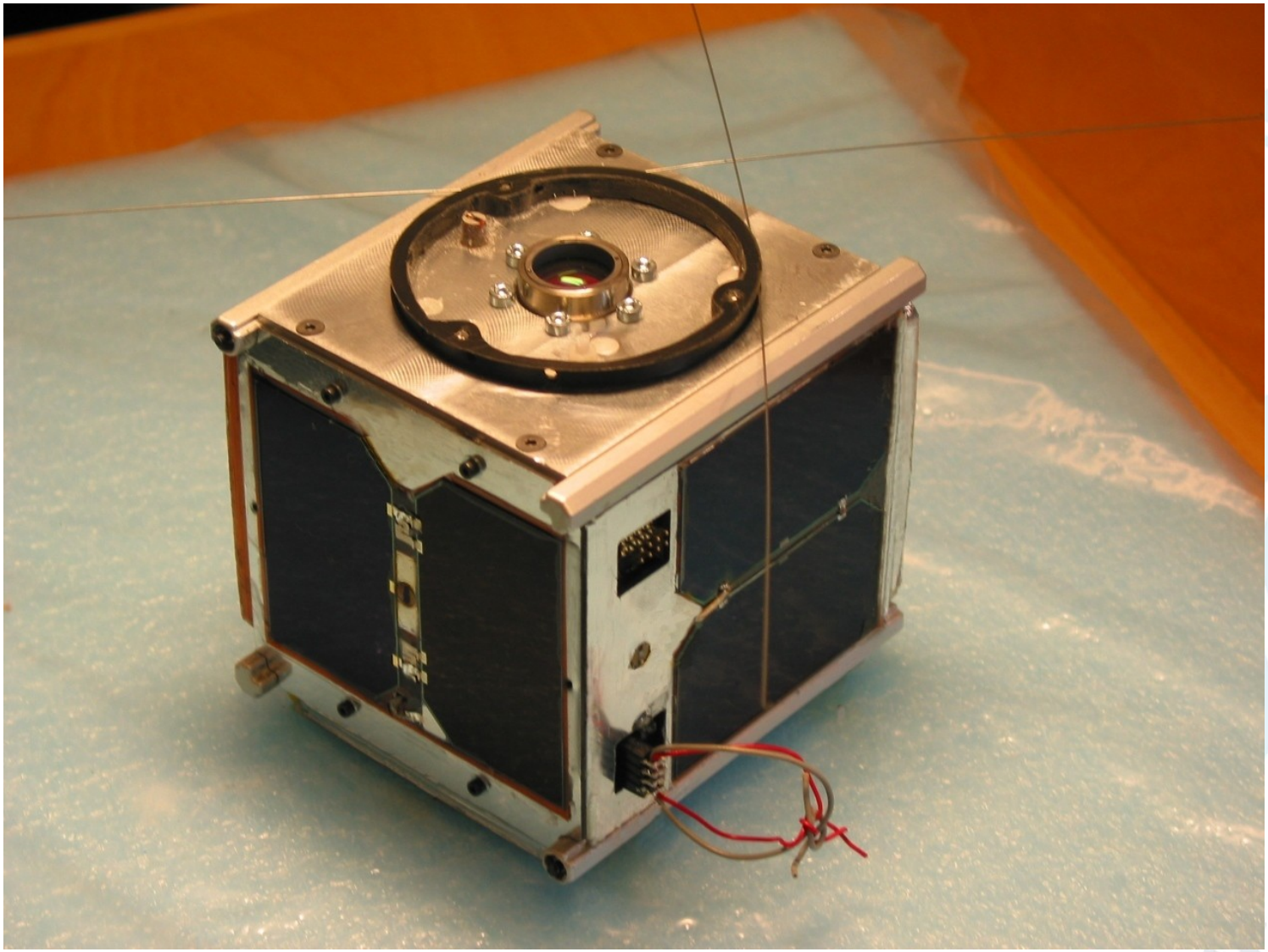


Other subsystems:

- Payload – Camera
- Mechanical structure
- Data handling system

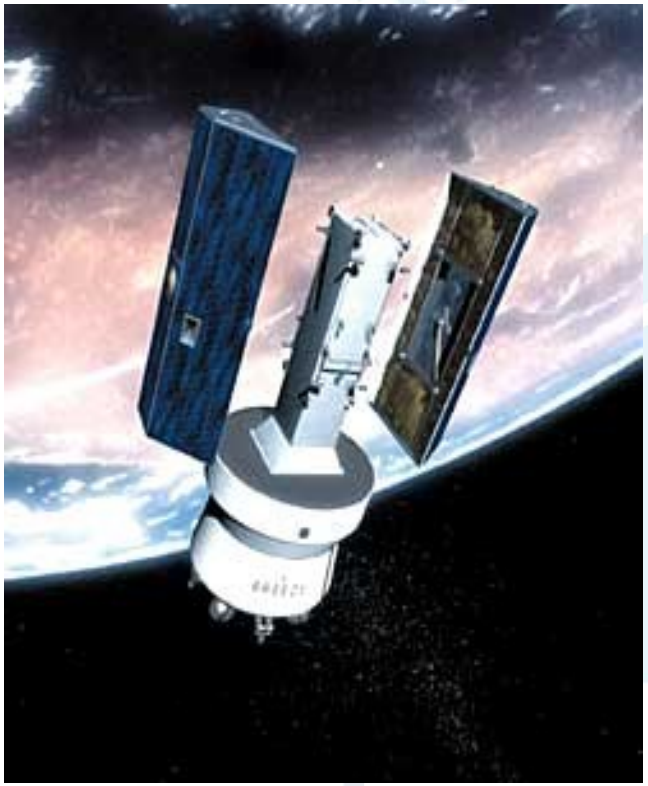
Ground segment





Launched on the 30th of June:

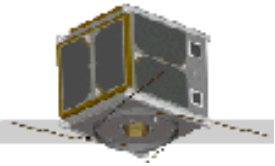
- Launched by Eurockot
- Close to sun-synchronous polar orbit
- 7 small satellites shared the launch



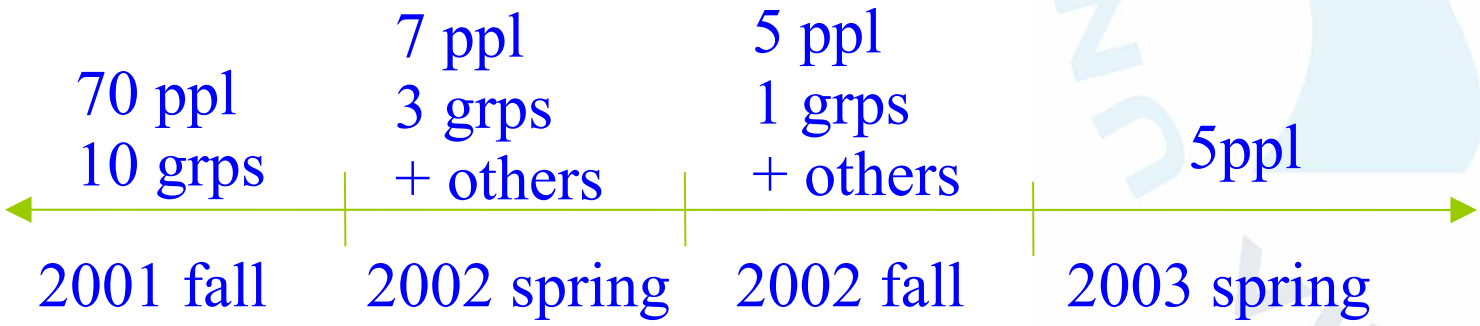
Results of operations:

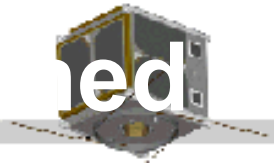
- Weak signal -> new ground station
- Battery lost capacity, close to inoperable
- Limited data acquired

Not all success criteria fulfilled, but the project is considered a great success



- Project initiated September 2001
- Definition and development phase ended June 2002
- Integration and test phase ended April 2003
- Operation phase from 30th of June 2003
- (End of project 25th of September 2003)



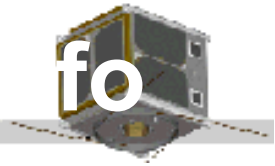


The Benefits for the Students:

- Very motivating work for students
- Challenging technical problems
- Experience with (inter-)group work
- It is FUN and PRESTIGOUS to be a part

What will we do different next time:

- Better handle students leaving the project
- Better utilize the outreach potential



In conclusion:

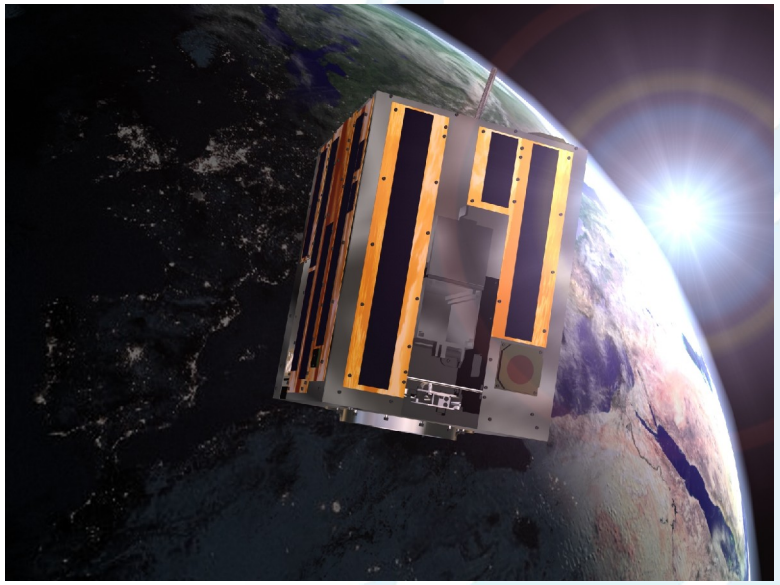
- Motivated and motivates many students
- Provided very good hands on training
- Experience with interdisciplinary work
- Experience with project management
- All at a price of about 200,000 Euro

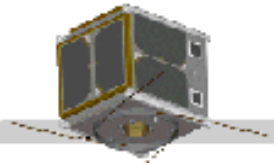
Student Satellites at Aalborg University

SSETI Express

- ESA coordinated student satellite (23 universities)

- Started: Jan 2004
- Launch: October 2005
- 60 cm x 60 cm x 80 cm
- Mass: 62 kg
- Payload: Digital Camera
- AAU Delivery:
  - ACS, OBC, P/L, COM,
  - GND





SSETI EXPRESS

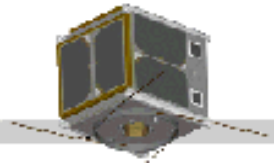
SSETI Express was launched on a

Cosmos-3M launch vehicle

from

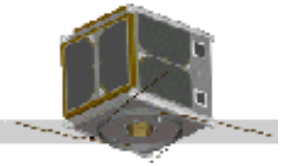
Plesetsk, Russia

on the morning of the 27th October 2005 at 06:52:26 UTC.



AAU responsibilities

ADCS
OBC, CDH
Camera Payload
Internal network onboard satellite
Official GND at AAU
Secundary GND at Svalbard :-) adn Copenhagen
Launch Campaign
The first 24 hours of operation



The result

Great success the first passes

Bad powersupply :-(

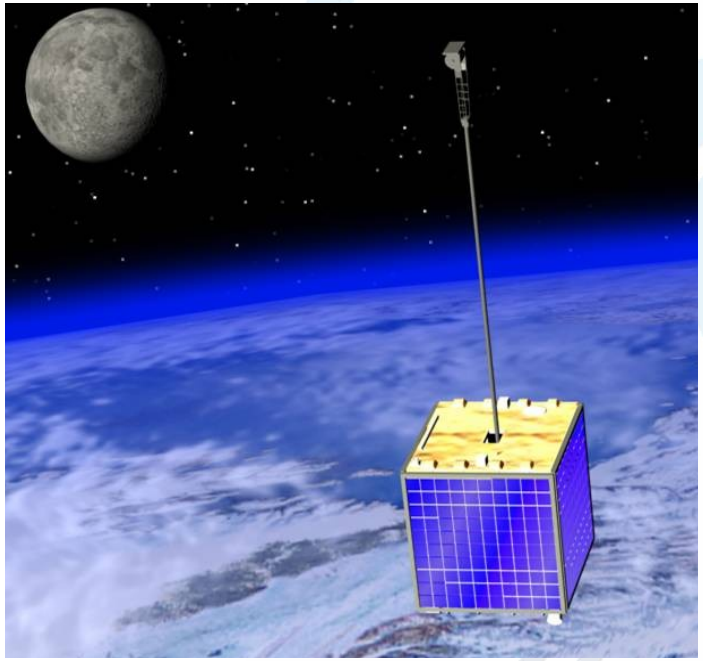
12 hours of operation

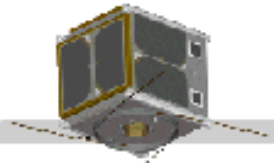
Satellites at Aalborg University

Baumanetz

- Bauman Moscow State Technical University

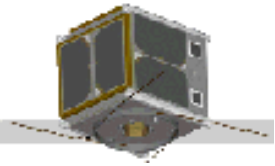
- student satellite
-
- Started: July 2002
- Launch: March 2006
- Dimension: 70 cm x 70 cm x 70 cm
- Mass: 100 kg
- Payload: IR Camera + (8 total)
- AAU Delivery: OBC





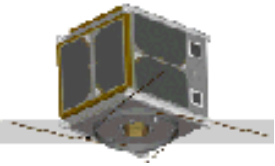
Launch failed – total disaster :-(

AAUSAT-II - The Motivating Factor



Problem Based Learning Concept (short)

- Duration: 1 semester (Sep-Jan and/or Feb-June)
- Final Master Project can be 1 or 2 semester
- 50% of time for courses/lectures
  - 4 hours lessons : 1.5 hours lecture. 2.5 hours exercise
  - 8:15-12:00 or 12:30 to 16:30, five days a week
  - 50% of courses has an examine
- 50% of time for the Project
  - The rest of their time :-)
  - University and labs open 24 * 7
  - (no staff after 1730 == unmanned labs :-)
  - Every project group has own office (6 prs 18 m2)
  - 1 staff as supervisor
  - Examine with external censor

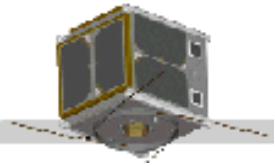


PBL

- Going for a Master is regarded as a full time job
- On Campus 5 days a week 35-50 hours (8am-5pm)
- Start of semester = many lectures
- From mid to end of semester = many hours in project

- Outcome:
  - Project report (100-300 p) - after 5th semester in english
  - Prototypes (may be located at industry – like a chicken stable)

- 1-8 semester projects for learning only
- 9-10 projects often has an industrial or research profile
- (more than 70% of all masters are industrial coop. based)

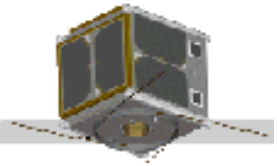


The generic project

- **Semesters are thematic**
  - Control Theory
  - GPS Systems and Kinematic Applications
  - Autonomous and Reliable Systems
  - … (http://www.esn.aau.dk) just one of several study boards

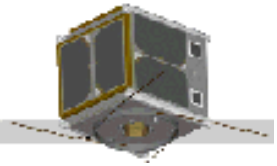
- A project shall cover

- Problem Definition (often in coop with companies)
- Problem Analysis
- Problem Demarcation
- Detailed Analysis
- Solution Proposal
- Development of Solution
- Simulation, **prototype implementation,…, iterations**
- Discussion and Results
- Further Work



Our next Challenge

- How to make better Engineers ?
- How to make even better Studies ?
- How to give them real Engineer Experience ?
- How to set extra tough demands on them ?
  - To fail is not an options !
- How to make them feel something Special ?
- How to give them a maybe one time life Experience
- How to make PR for our Engineer Education
- The Answer ???

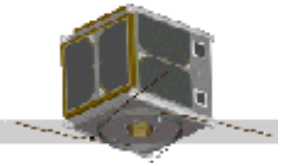


Phases / Schedule !!! - 2.5 year (minimum)

AAUSAT3 example

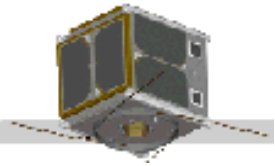
Pre07	Autumn 07	Selection of payload
PrephaseA	Spring 08	Prephase Study and final select.
Phase A/B	Autumn 08	Design phase 1 Detailed interface spec. System design, budgets
Detail design	Spring 09	Approved Engineering model
Ingration & Test		!
Launch		

3 year should be possible



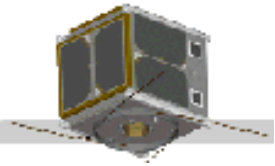
Short about Organisation

- Students are in Control
- VIP management is NOT primary management
- By “giving” them the responsibility they act responsible!
- Staff carry out “invisible” management and supervision for the student groups
- Staff (like me) has a Sentinel and Supervisor role
- It is students travelling to SFL (Canada) ISRO(India) ESA-ESTEC without staff.



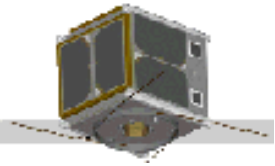
Incorporate Space Activities within Corriculum

- Easy within Study
  - Analysis, Design, Construction of Prototypes
- Can be within Study
  - Testing
- Problematic to be within Study
  - Carrying out real construction of a mature design
  - Iteration based on Testing
  - Launch Campaign
  - Operations
- **So to facilitate high quality development within a learning process**

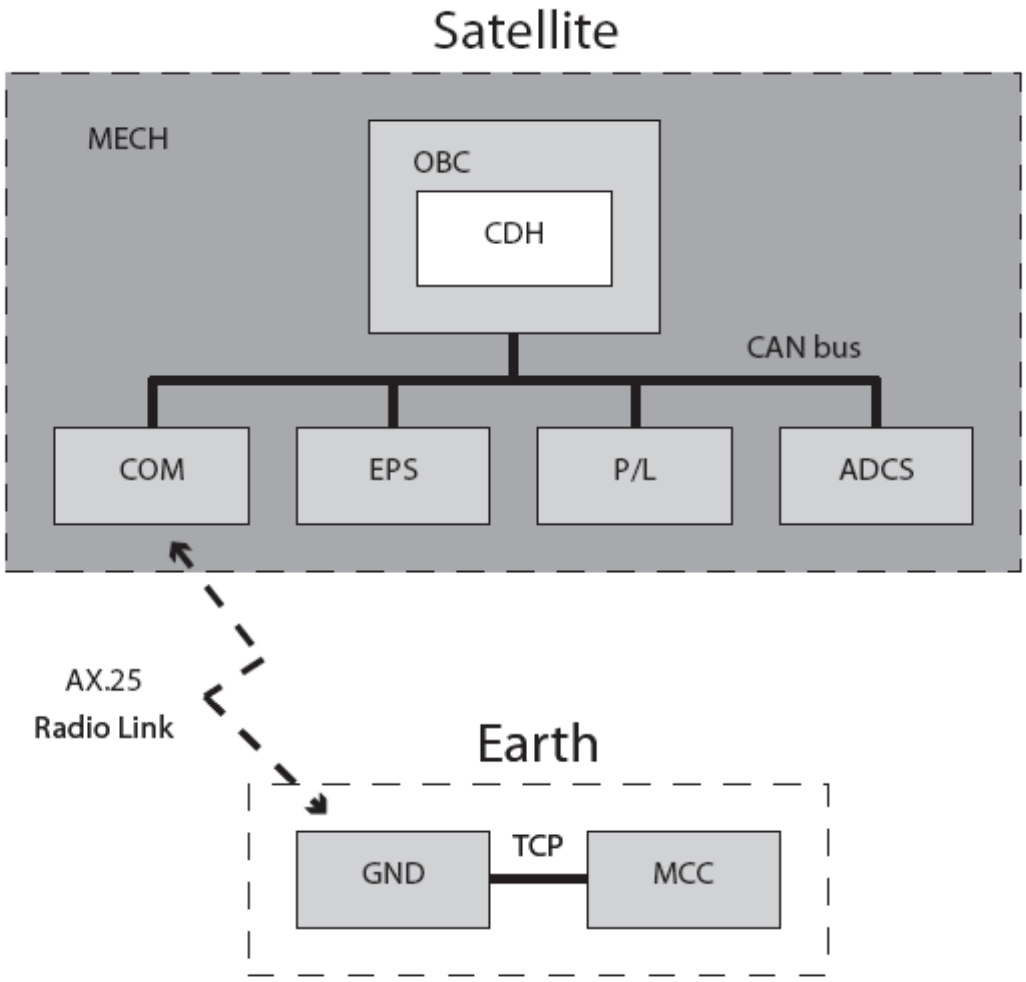


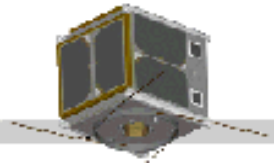
AAUSAT-II

- Start up in 2003
- Launched April 28th 2008
- More than 65 students involved – and has given birth to 3 PhD studies



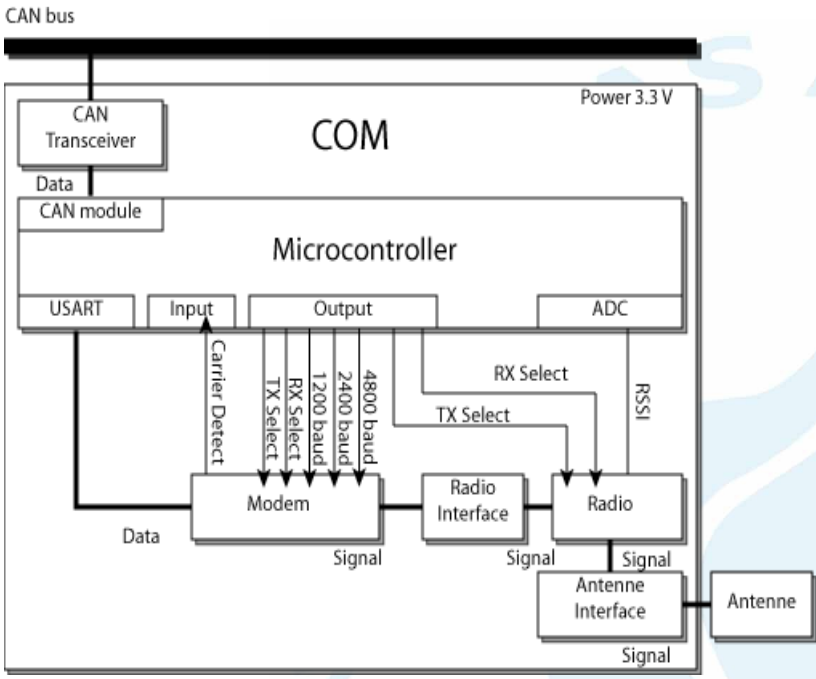
Overview


Satellite
MECH
OBC
CDH
CAN bus
COM
EPS
P/L
ADCS
AX.25
Radio Link
Earth
GND
TCP
MCC



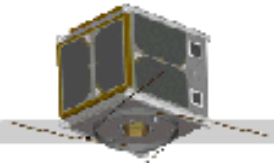
AAUSAT-II short

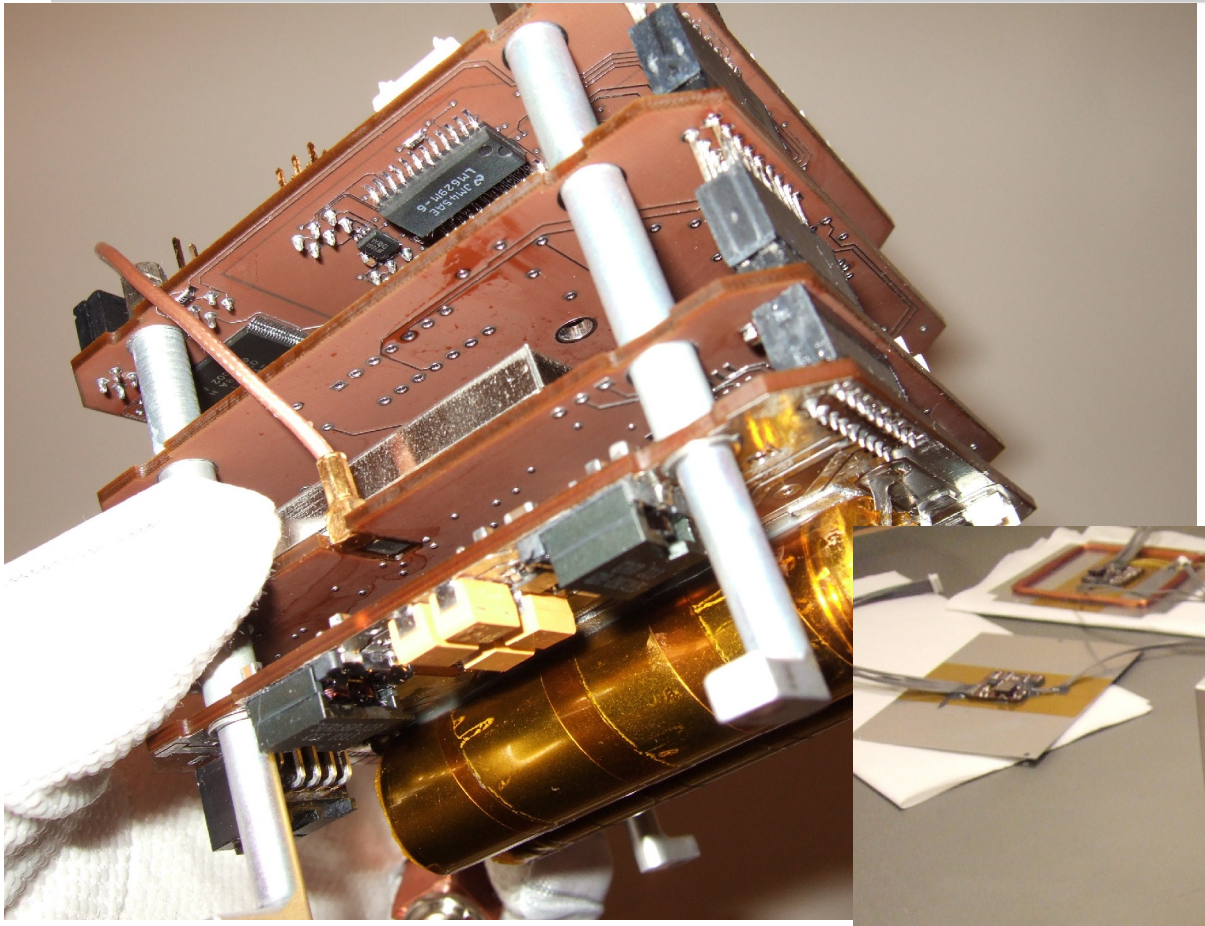
- OBC(ARM7) 2 * 4MB flash/2MB RAM
  - eCos
- EPS (PIC16) - master
  - No OS
- COM(PIC16) + SW on OBC
  - No OS eCos
- ADCS(PIC16) + SW on OBC
  - No OS
  - 3 mag coils and 3 momentum wheels
  - 3 axis magnetometer and 6 rate gyros
  - 6 sun sensors (photo diodes)
- PAYLOAD(PIC16) + SW on OBC
  - No OS

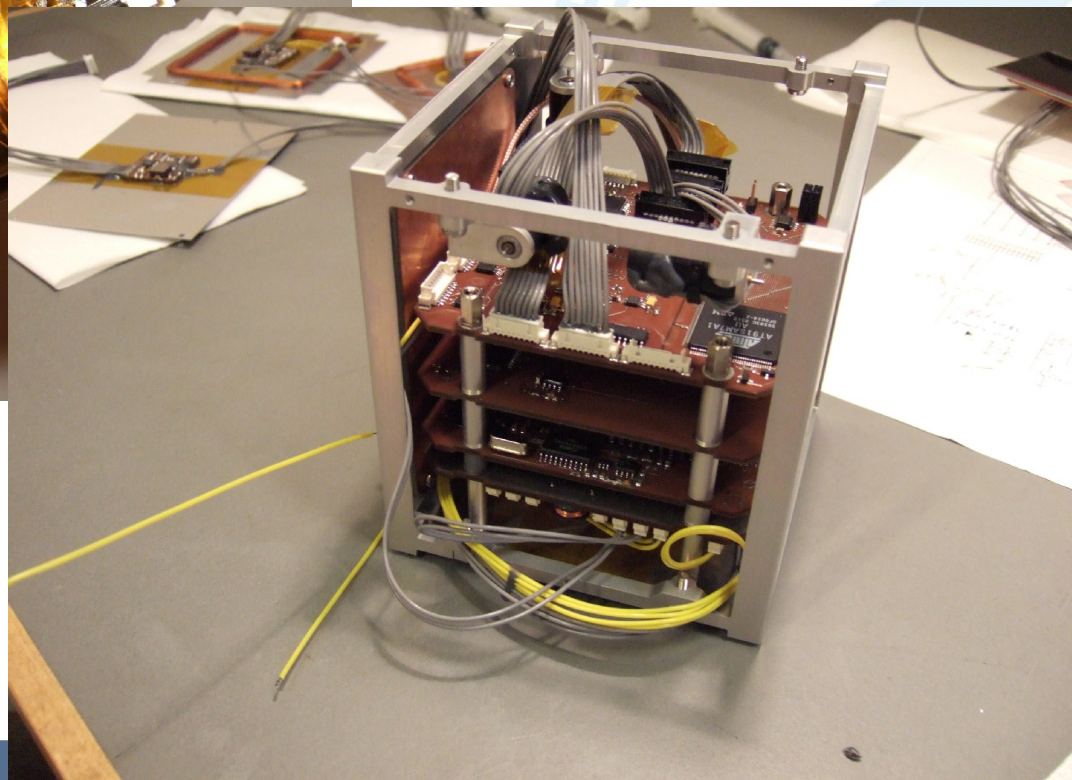


Single CAN 2.0B 125 kbit/s

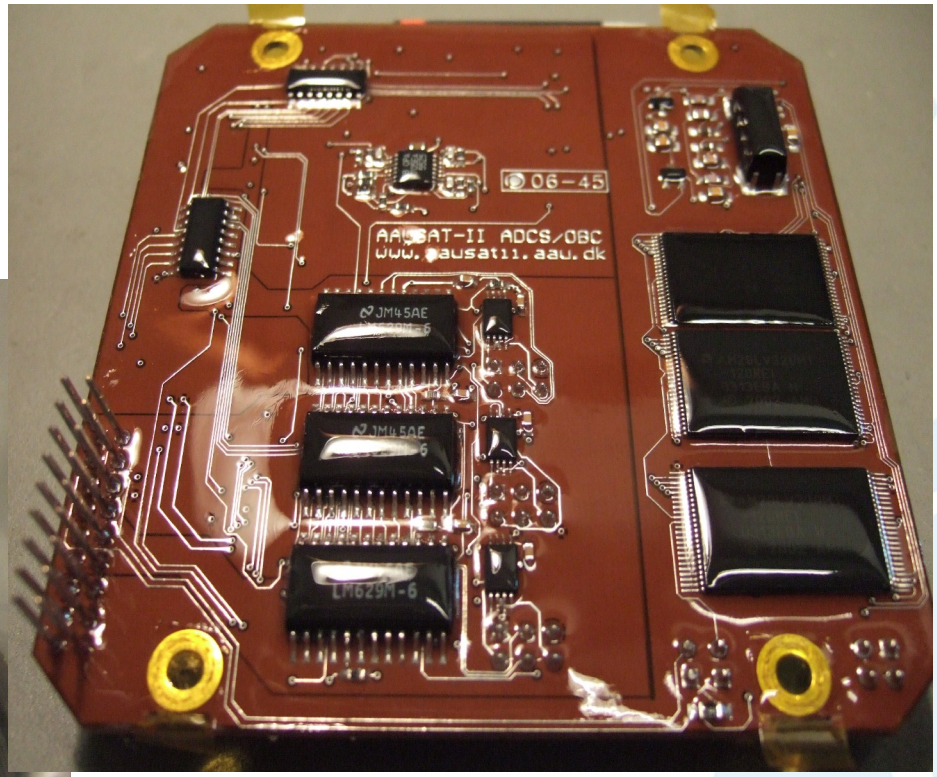
Student Space Program
at Aalborg University

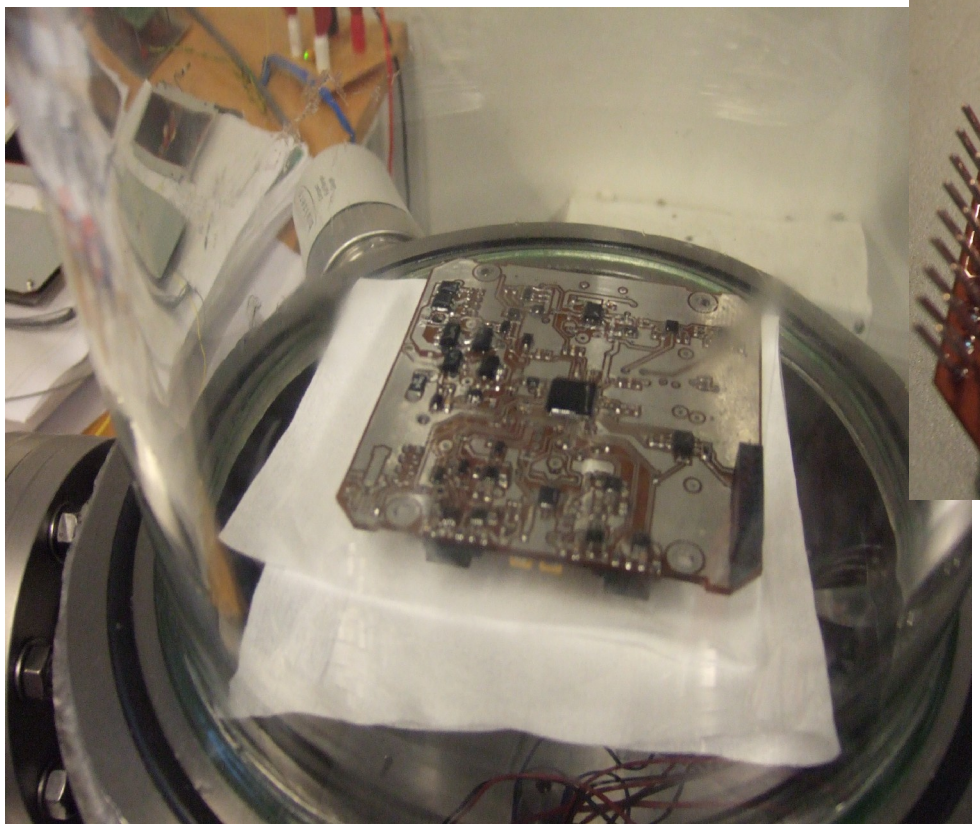


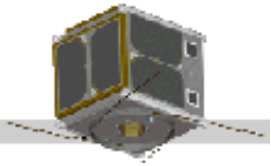


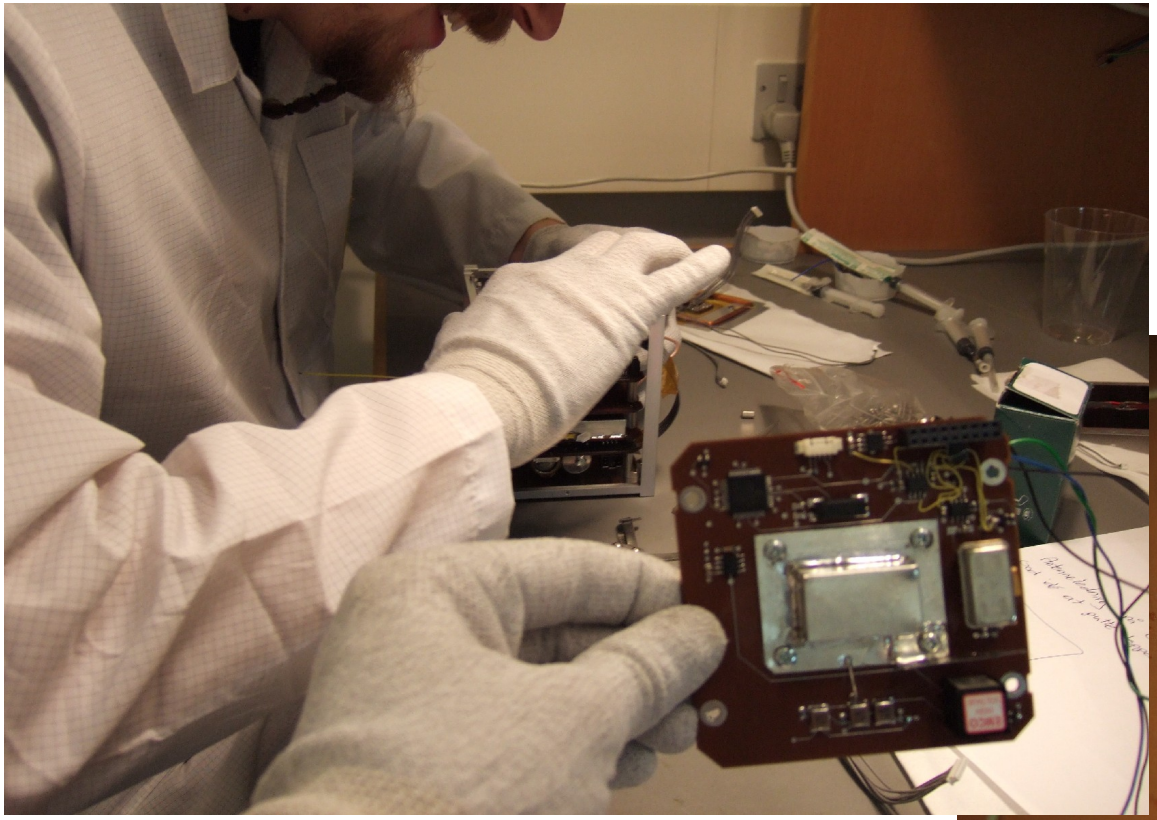


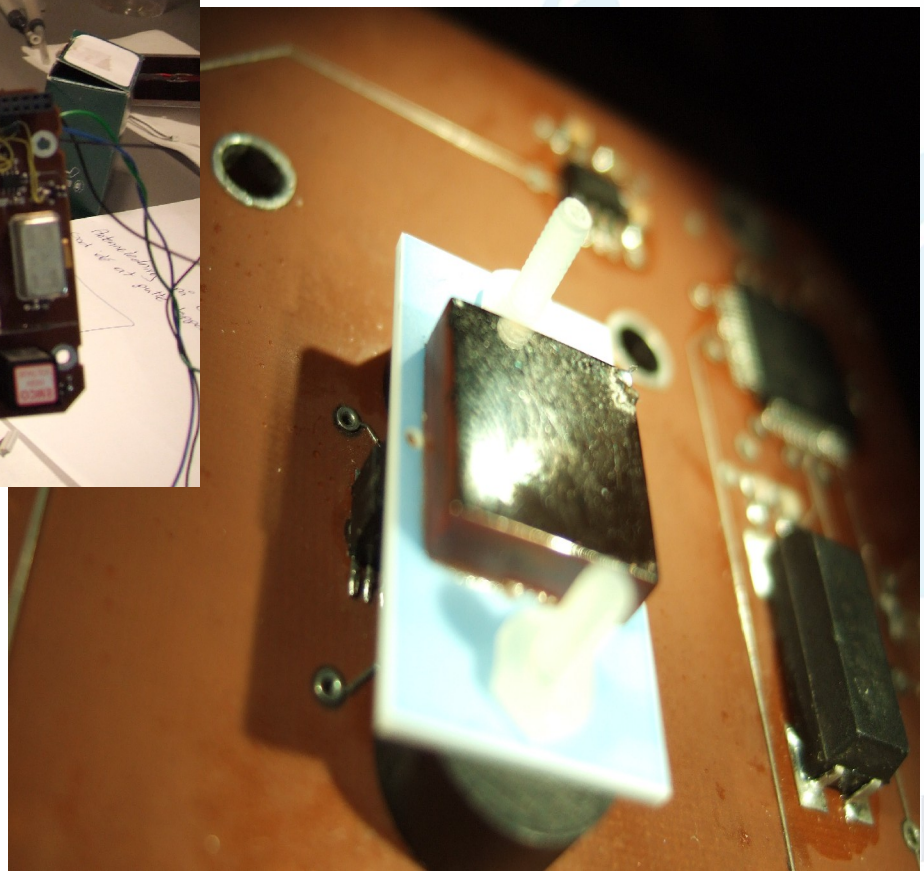
AAUSAT-II OBC & EPS

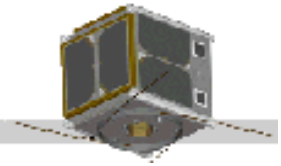






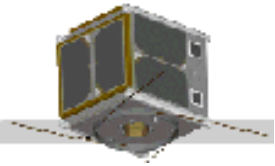






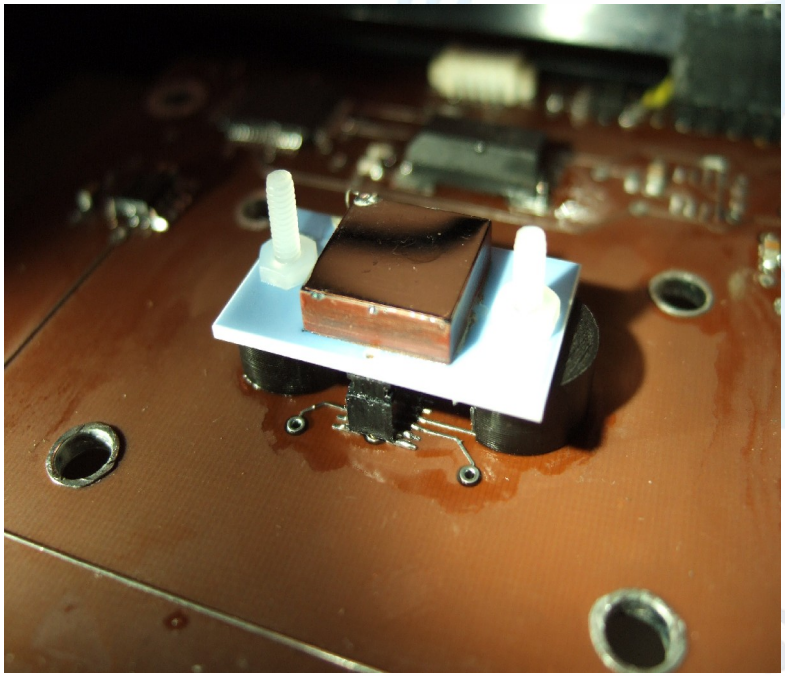
AAUSAT-II – Case Study – a costumer driven Sat

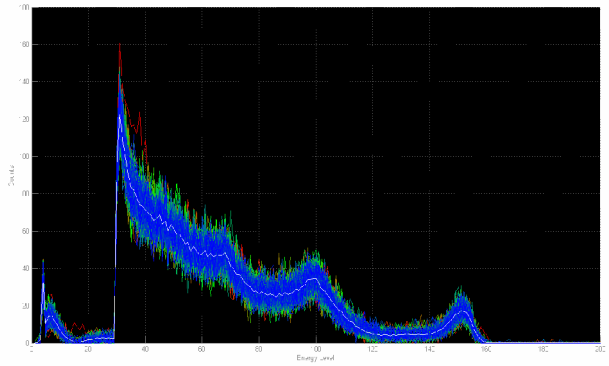
- Scientific Payload upon request from DTU Space
  - CdZnTe (Cadmium Zinc Telluride) crystal.
  - The size of the crystal is 10 x 10 x 4 mm, and weighs less then 5 grams.
  - This specific crystal has a detection range from 5 to 300 Kev with a resolution of 3 Kev at 60 Kev, making this small crystal a very usable scientific device.
- And … Surrounding Support Systems
  - EPS – Powersystem including solar panels
  - COM - including Radio System
  - ADCS – Attitude Control System
  - CDH & Flightplanner

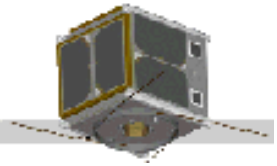


AAUSAT-II Payload – a science experiment

- New radiation sensor from Danish National Space Center
- First time in space
- Candidate for the ESA ASIM mission
- So it is not for fun only :-)
- All electronics by students!
- May be extra payload on coming satellite





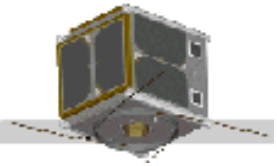


Criterias of Success

VERY Important to define in advance

It is a success ...

- **To have satellite accept for launch**
- **To get it in Orbit**
- **To receive Beacons**
- *To have experiments running autonomous*
- **To got acknowledge for uplink**
- To get in real contact
  - Very low speed – Morse ?!
  - Low speed - < 1200 baud or < 600/300 baud
  - Med speed 1200/2400
  - High speed ?
- Remember it is an educational activity
- And stick to them



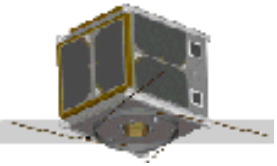
AAUSAT-II Launch campaign

- Launch April 28th 2008
- Still working on gettting into real contact
- Spirit is still quite high

- An overseen activity in a educational context !

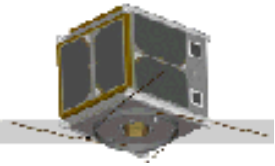
- We have problems with our spacecraft
- Now people are real learning about
  - Antennas
  - Transmission
  - How spacecraft real function inside
  - Mission Control Center
  - Command and Data Handling
  - Or just how to get spacecraft in business ...
  - Or - we are just getting familiar with our satellite

- Important to run many fake launches !!



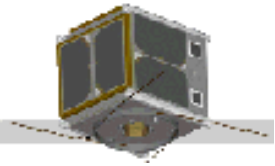
100 days in space today (Aug 06th)

- Still in operation :-)
- Spinning problems + 60 RPM
- A HUGE SUCCESS :-)



LL : Lessons Learned

- Students will be video recorded when discussing
  - Lessons Learned
  - “Features” in project/subsystems
  - …
- Will be part of education for next team (AAUSAT3)
- “Long term storage” of all kind of info is IMPORTANT !



Survival is highest Priority

which basicly means

- beware of using for much power
- beware of malfunction in sub systems
- beware of everything
- and dont rely on “Ground”
- Start/stop subsystems in a controlled way

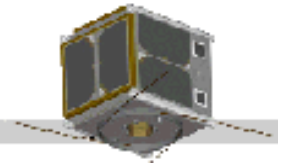
- Had very high priority in beginning
- Which gave birth to a simple roubust system design

- Which lead to subsystem detail design

- Whatif's (flat model) is invaluable

- Getting structure on distributed State System is nescessary

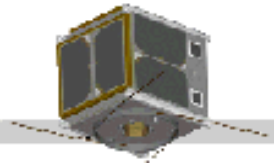
- *This is/will be a long fairytal*



KISS !!! !!! !!!

- KISS is the way to Success - no more less
- Better do a few things ok than many things !!
- Realize that when time goes by things get more complicated

- Who wants to build simple/stupid systems ?



Identification af Real Time “Locations”

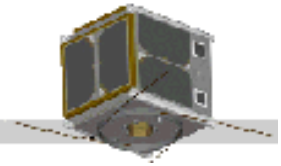
- ADCS
- Onboard Main Clock (which will run ADCS as well)
- Modem ?

- Rest is not time critical in control sense
  - No control loop stability issues !
  - Time out/delay requirements exist

- Normal (or not) ?

- Breaking of rules (like timing) leads normally to fall back procedures

- Satellite can live without detumbling



SIMPLE ??? KISS ???

Simple is not same as “just a PID”

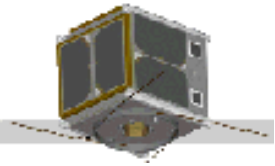
Simple means keep number of system states down

Simple means keep coding low

...

AAUSAT-II consists of more than 75000 lines of C code on 5 computers

Ground station consists of ???? lines of Java and C



The most important sub task: TESTING

We have being testing for month

Some errors did show up after 1.5 month 24 * 7 testing !

-> Formal tools will have a high priority in the future (Upaal)

Easy to have testing *development* as educational activity

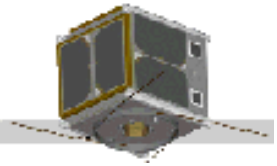
Difficult to carry out ... as an educational activity

Problem ?

Modelling/emulating the problematic issues:

- Link quality and noise
- Breakage of protocols
- Worst case temporal behaviour of (sub)systems

Again – Fake launches invaluable – but maybe not enough



OPERATION

Luanch sucessfull

Full contact obtained

Experiments went well

then ???

In advance define EOP (End Of Operation)

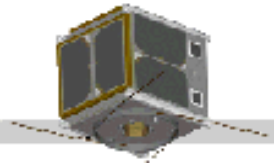
Stick to it

Have a Party :-)

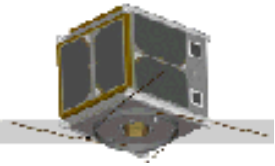
GENSO

Global Educational Ground Network for Satellite Operations

- ESA,NASA,CSA,JAXA joint student activity (ISEB members)
- AAU participate
- Now in Alfa test
- AAU has Genso ground station in 24h operation
- 25 students involved
- Until now a success
- in parallel with AAUSAT-II

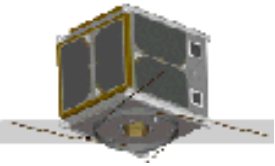


AAUSAT3



Mission

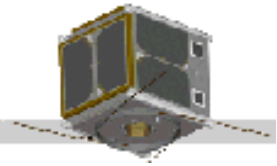
- Mission proposed by
  The Royal Danish Administration of Navigation in summer 2007
- Direct contact to Aalborg Student Space
- Is it possible to receive AIS signals from ships an SART equipment in polar regions ?
- at 161.975 MHz and 162.025 MHz GMSK 9600 bits/sec TDMA
- So ...
- Construct an AIS satellite and operate in the polar regions
- And have it launched in LEO



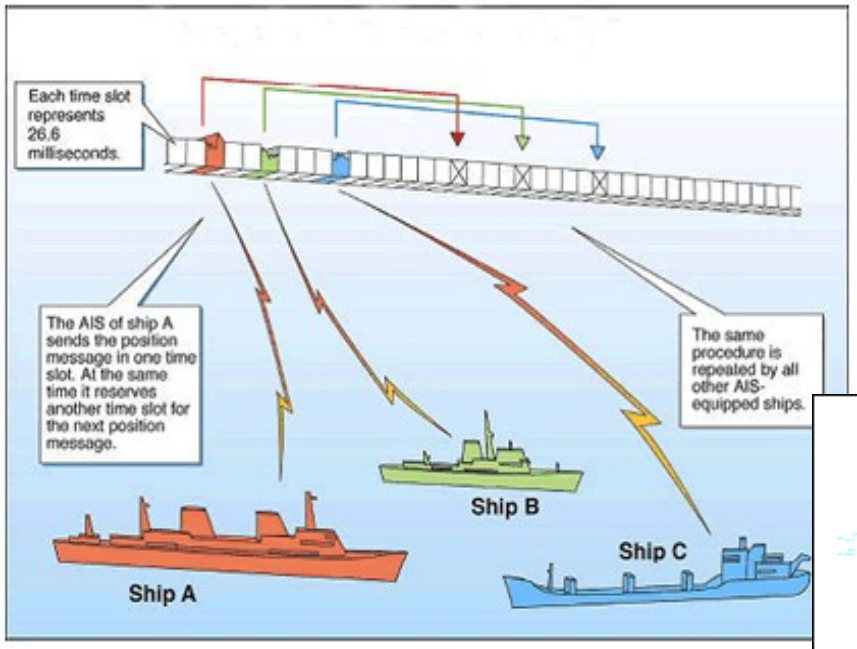
Why AAUSAT3 ?

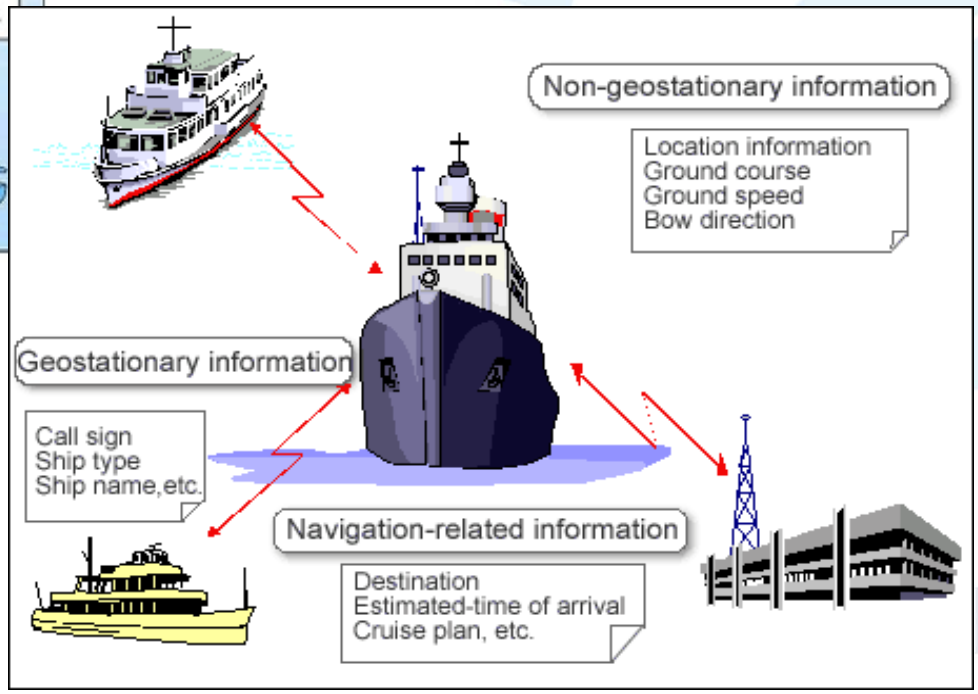
- Not only for fun – a real need
- Much “unknown” ship traffic in polar regions: around ...
  - Greenland(Denmark)
  - Iceland
  - Canada
- Basicly: National Authorities wants tot trace from space
  - For ships in “nominal mode” and in SART situations
- Scientific research between AAU Space Center, Danish and Canadian Naval Auth., Uni of Toronto and Uni. of Calgary is under establishment
- Extra driving force for students that their help is needed

AAUSAT3

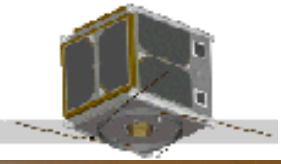


AIS – Shipborne Automatic Identification System





AAUSAT3



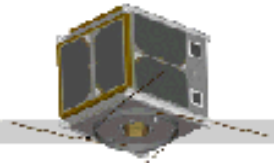
AAUSAT3

PhDs today

Own space company (with two other old sat stud)

Master students today

AAUSAT3

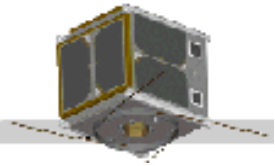


AAUSAT3 BUDGETS

- AAUSAT-II EM is used for training these days
- AAUSAT-II approx 150.000 Euro incl launch
- 50% as industry funding
- 50% as University double up

- AAUSAT3 budget is stipulated to 150.000 Euro all included
- 50% from Industry and 50% double up from University
- Supervision and management partly paid by University

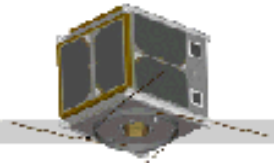
AAUSAT3



core team

- Prof PhD Jens Dalsgaard Nielsen
  - management
  - realtime, hw, sw, protocols,...
- Prof PhD Morten Bisgaard
  - Control, adcs, sys eng autonomous systems
  - AAU Cubesat , AAUSAT-II
- PhD students
  - Jesper A Larsen, Jakob Grunnet, Martin Kragelund, Axel Michaelsen, Kresten K. Sørensen
  - Karl K Laursen, Lars Alminde (on leave for starting space comp)
- Prof Hans Ebert
  - Radio systems, AIS, antennas, radio protocols,...
- Prof PhD Rafael Wisniewski
  - adcs, hybrid systems, adv control, sensors,...
  - Ørsted and AAU Cubesat
- and ... Prof Per Høeg
  - AIS, radio system
  - Participated in numerous ESA projects

AAUSAT3



EOS - End Of Slides

AAUSAT3