Nano and pico satellites
hvorfor ?
hvordan ?
...

ganske kort om mig

Jens Frederik Dalsgaard Nielsen

MSc EE, PhD - på dansk civilingeniør indenfor elektroteknologi (1983)

CV

1959	:-)
1969	så Armstrong & Aldrin moon walke i 1969 (Apollo 11)
1978 - 1983	Civilingeniør - medicinsk teknologi
1983 - 1984	SW/HW, brovægte, doseringssystemer mm
1984 - 1985	PhD stud i medicinsk teknologi
.... - 1991	PhD indenfor regulering og automation
....	
2003 - idag	Satellitter og studentersatellitter på AAU

en lille reminder
det vigtigste - næste generation

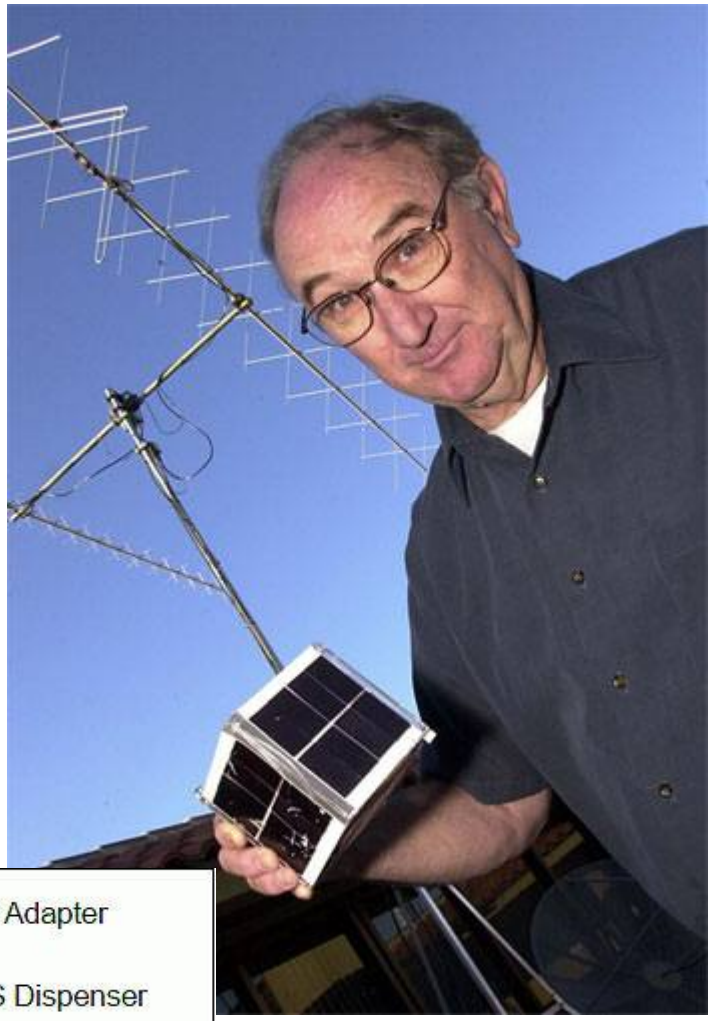
“my” CV in space
Det er 100% de studerendes fortjeneste

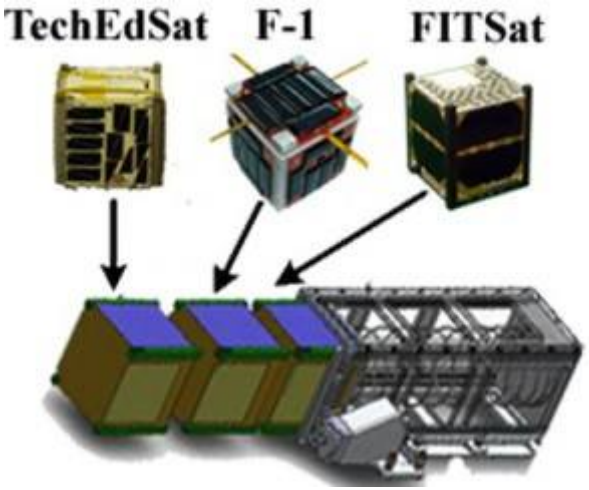
2001-2003	*AAU CUBESAT*	
2003-2005	ESA SSETI EXPRESS	(AAU: four subsystems)
2003-2009	AAUSAT-II	(launch 30. June 2008)
2004-2006	Baumanetz OBC	(Uni of Moscow lost during launch)
2006-2011	GENSO	(global ground station system)
2008-2009	AAUSAT3/BEXUS	(ballon flight)
2007-2014	AAUSAT3	(launch 2013 18 month operations)
2010-2012	AAUSAT3.5/DLR-AISAT	(payload on DLRs AISAT)
2012-2016	AAUSAT4	(launch by FYS ESA Education)
2012-2015	AAUSAT5	(launch 5.Oct 2015)

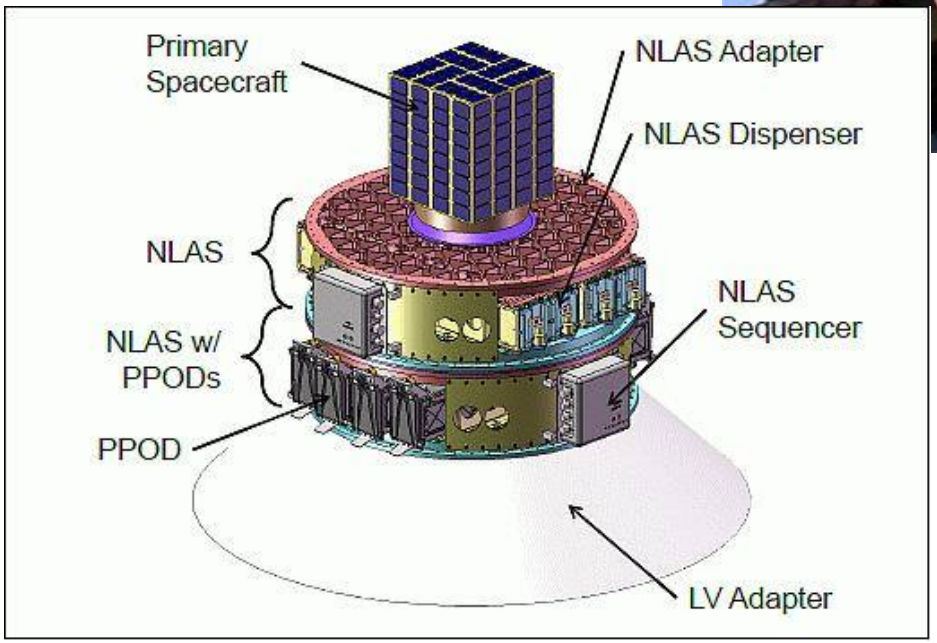
On way fælles missioner: DISCO1, DISCO2, DISCO3 (AU,AAU,SDU,ITU) 2021-2025

Satellit størrelse

- prof Bob Twiggs - manden bag standard størrelseide
- 1U, 2U, 3U, ... (U: unit)
- 1kg 2kg 3kg - i store tal
- populært sagt
- 10cm x 10 cm x (10,20,30) CM
- 6U, 12U
- POD - deployment







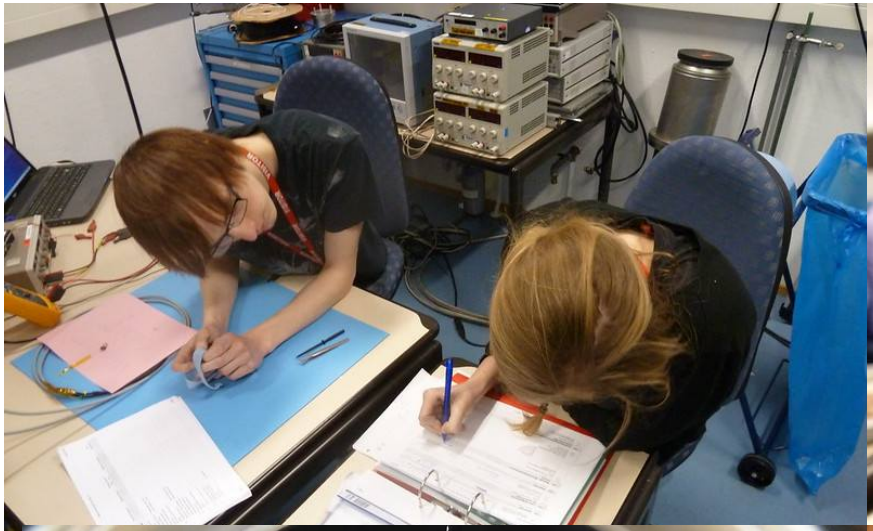
Birth of cubesat

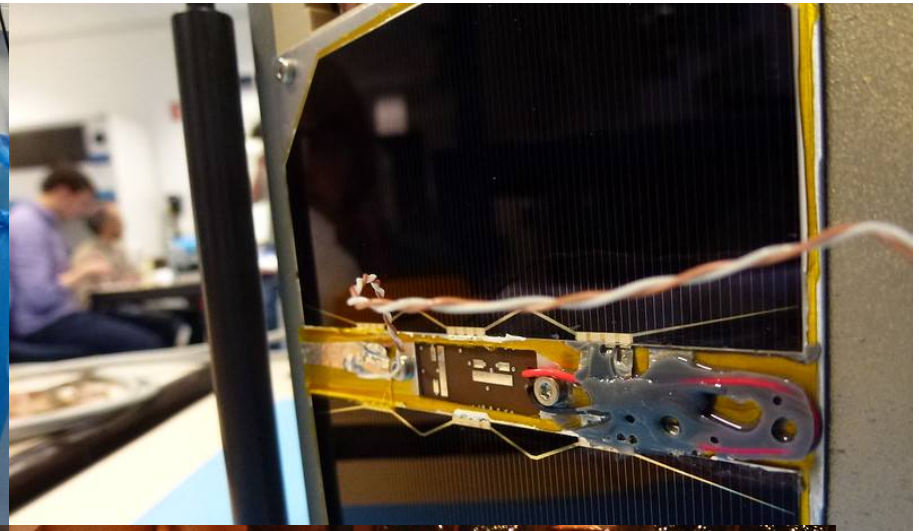
- Størstedelen af cubesat firmaerne er startet af studerende der arbejdede med studenter cubsats 2001-2010.
- ret ung industri. Før 2003 ingen opsendelser. Idag 3 cubesats i orbit om dagen
- Det var der INGEN der overhovedet havde overvejet
- Bare i Aalborg er der mere end 200 arbejdspladser i denne branche.
  - Langt de fleste har startet i AAU SATLAB :-)
- ...

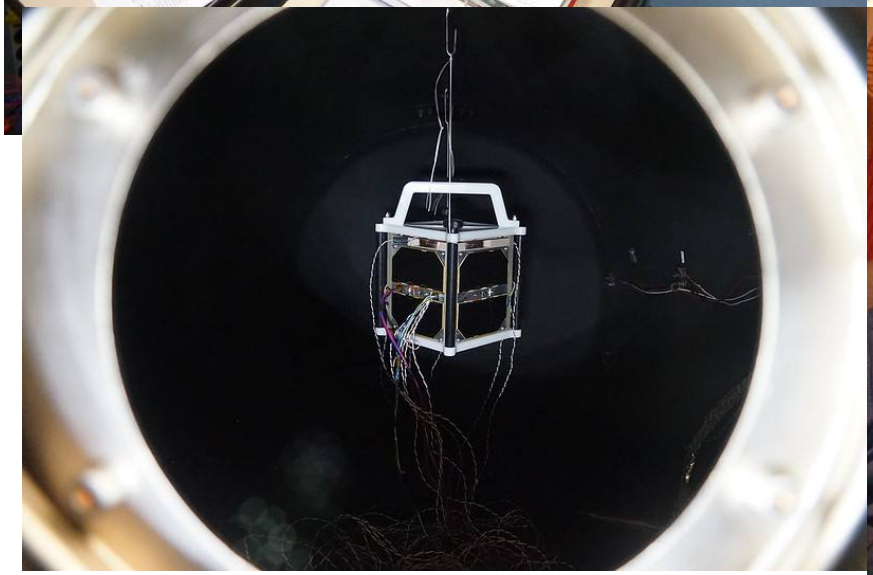
Name	COSPAR ID[44] SATCAT №	Type	Organisation	Mission	Mission status	Launch date (UTC)	Time	Launch vehicle	Reentry date	Remarks
AAU CubeSat[47]	2003-031G 27846	1U	Aalborg University	Imaging[48]	Failed	30 Jun 2003	14:15[49]	Rokot/Briz-KM		Battery problems, deactivated on 2003 Sep 22[50]
CanX-1	2003-031H 27847	1U	UTIAS	Technology demonstration[52]	Failed	30 Jun 2003	14:15[49]	Rokot/Briz-KM		No signal from spacecraft[53]
Cubesat XI-IV (Oscar 57)	2003-031J 27848	1U	University of Tokyo	Amateur radio	Active[54]	30 Jun 2003	14:15[49]	Rokot/Briz-KM		
CUTE-I (Oscar 55)	2003-031E 27844	1U	Tokyo Institute of Technology	Amateur radio	Active[55][56]	30 Jun 2003	14:15[49]	Rokot/Briz-KM		
DTUsat	2003-031C 27842	1U	Technical University of Denmark	Tether research[57]	Failed	30 Jun 2003	14:15[49]	Rokot/Briz-KM		No signal from spacecraft[57]
QuakeSat	2003-031F 27845	3U	Stanford University	Earthquake detection[58]	Active	30 Jun 2003	14:15[49]	Rokot/Briz-KM		
TUSat1		1U	Taylor University	Space Communication Research[59]		30 Jun 2003	14:15[60]	Rokot/Briz-KM		First Satellite from Indiana[60]

AAU* missioner

- ALT er designet, implementeret, loddet, samlet, testet og launched af studerende.





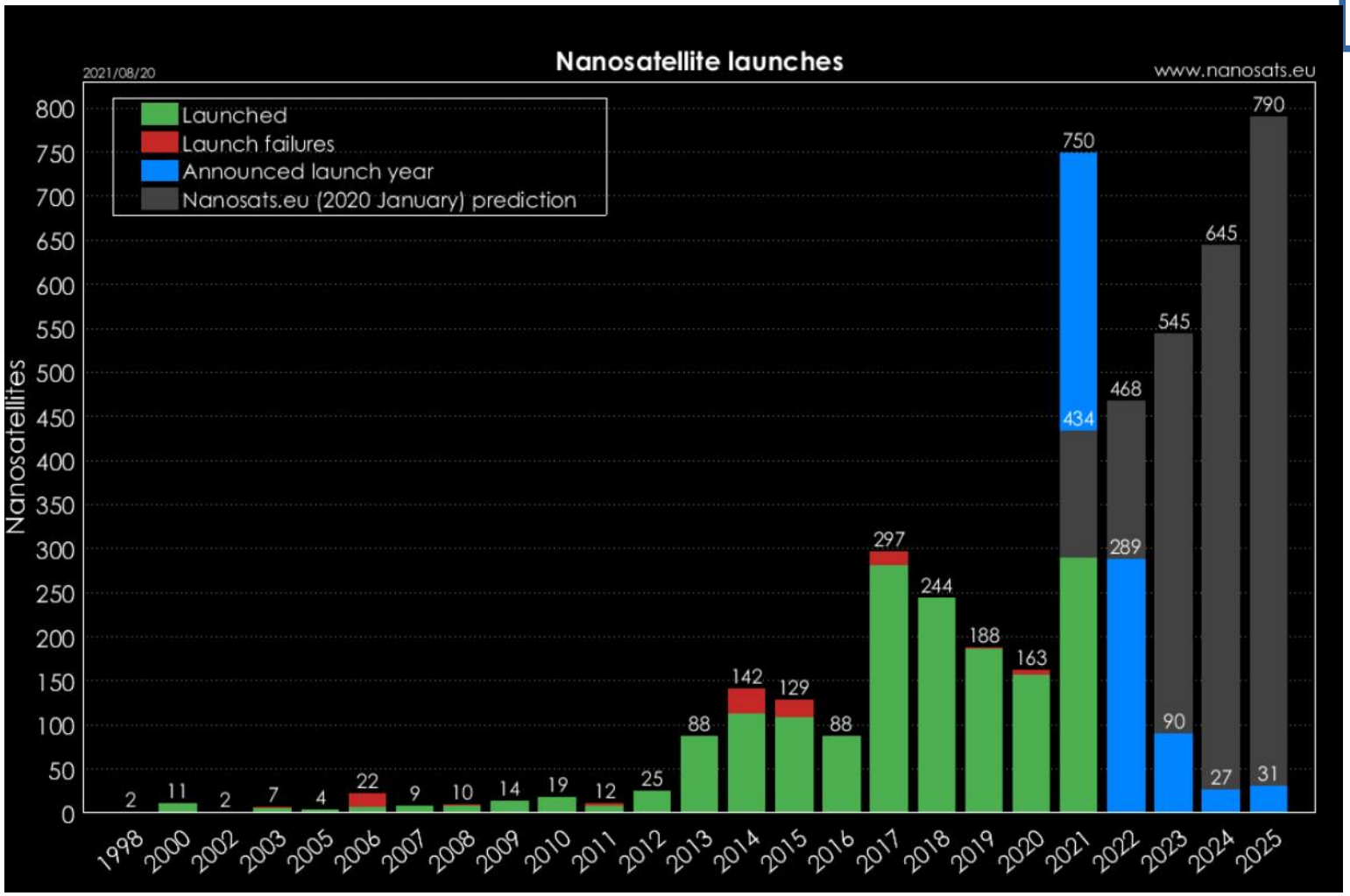


Min opslagstavle

nano & picosats & launches

- https://en.wikipedia.org/wiki/Small_satellite
- kan man stole på hvad man læser (wikipedia??)

Group name[1]	Mass (kg)
Large satellite	>1000
Medium satellite	500 to 1000
Mini satellite	100 to 500
Micro satellite	10 to 100
Nano satellite	1 to 10
Pico satellite	0.1 to 1
Femto satellite	<0.1



https://space.skyrocket.de/doc_chr/lau2020.htm

- mit forsigtige gæt for **2020 er ca 1000 små satellitter**

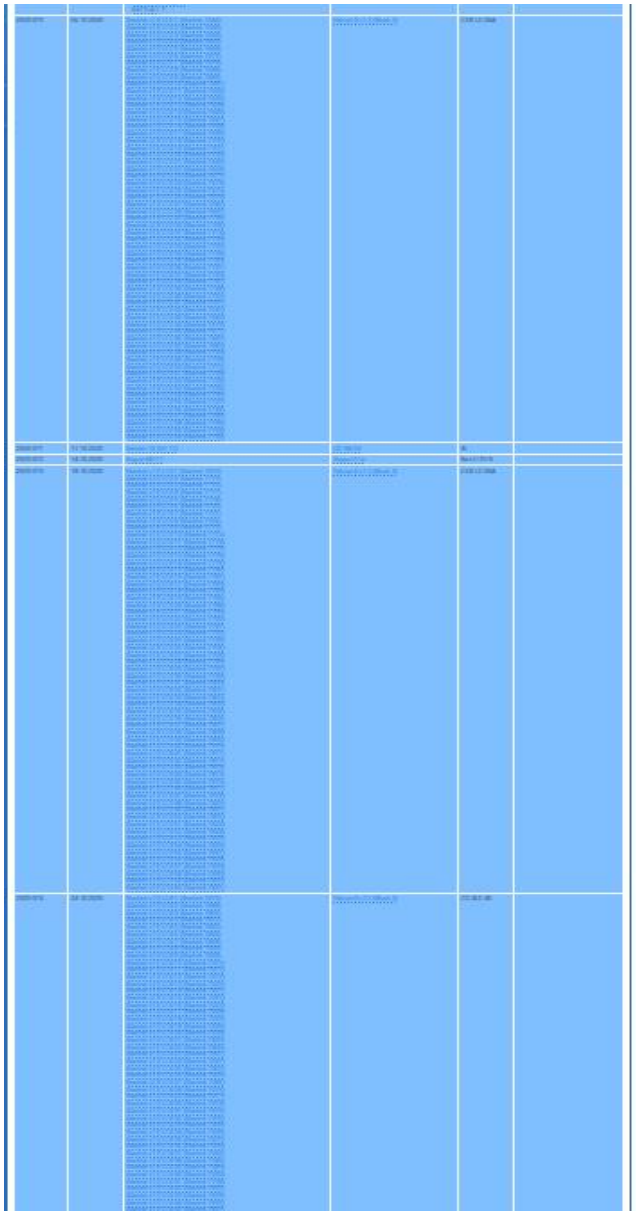
De store:

- Starlink series (SPACE-X) mål 12000 !
  - internet
- Flock (Planet Labs)
  - jordobservation
- OneWeb
  - internet

Det er blevet en helt dagligdags ting iløbet af mindre end 10 år.

Bestil en satellit (GomSpace, Space Inventor,...)
Bestil en opsendelse
Bestil servicering af satellit

Betal ved kasse 1 :-)



Min satellit
hvad skal der til ?

- En mission - payload
- Platform(satellit) til at supportere payload

- En launch provider med en fornuftig bane
- En jordstation

- En masse papir arbejde ...
- Få at få radiosendetilladelse
  - hos ITU > 1 år
  - hos IARU efterfølgende måneder

- For at få flyvetilladelse fra “EM”
  - måneder - mindst
- Test, test, test, test

ERHVERVSMINISTERIET

“Postordre” - Space Inventor - Aalborg

- Lignende fra Gomspace, ISIS(NL), Pumpkin(USA),...
- OG mange mange flere firmaer

POWER | OBDH | ADCS | COMMS | PANELS

MPPT-P3

Six plus one channel maximum power point tracker and battery charger module.

SEE MORE

PCDU-P3

Twelve channel power conditioning and distribution unit with channel allocation.

SEE MORE

BAT100-P3

8 Cell Lithium-Ion battery system designed for high battery lifetime, easy integration and safety.

SEE MORE

EPS-P3

Complete electrical power system consisting of MPPT-P3, BAT-P3 and PCDU-P3.

SEE MORE

EPS-1U

Complete electrical power system for integration in 1U cubesats.

SEE MORE

BAT600-P3

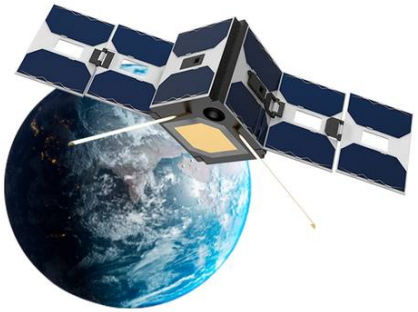
28V / 600 Whr battery system for micro satellites based on the BAT-P3 design.

SEE MORE

1U SATELLITE |

RELIABLE AND HIGH PERFORMING 1U CUBESAT WITH SEVERAL OPTIONS AVAILABLE TO ENHANCE PLATFORM CAPABILITIES

| **VERSION:** N/A | **STATUS:** COMPLETED | **TRL:** 9 | **FLIGHT HERITAGE:** YES |



FACT DATA

| **EM PRICE:** POR | **FM PRICE:** POR | + FLIGHT PROVEN |

FEATURES

- Highly configurable satellite built from our modular subsystems
- Allows for the easiest and most reliable integration procedure
- 360° access to internal systems
- Relies on thorough analysis, design and
- Uses shielded hi-rel subsystems
- Designed for extreme ruggedness
- Reliability: 5 years design lifetime

DESCRIPTION

1U CubeSat configured from our modular subsystems to enable buyers to tailor the satellite to your needs ranging from basic to advanced. A novel design approach reduces part numbers in the 1U CubeSat structure allowing for the easiest and most reliable integration procedure with 360° access to internal systems. Our satellites and sub-systems rely on thorough analysis, design and test to ensure successful operation in space.

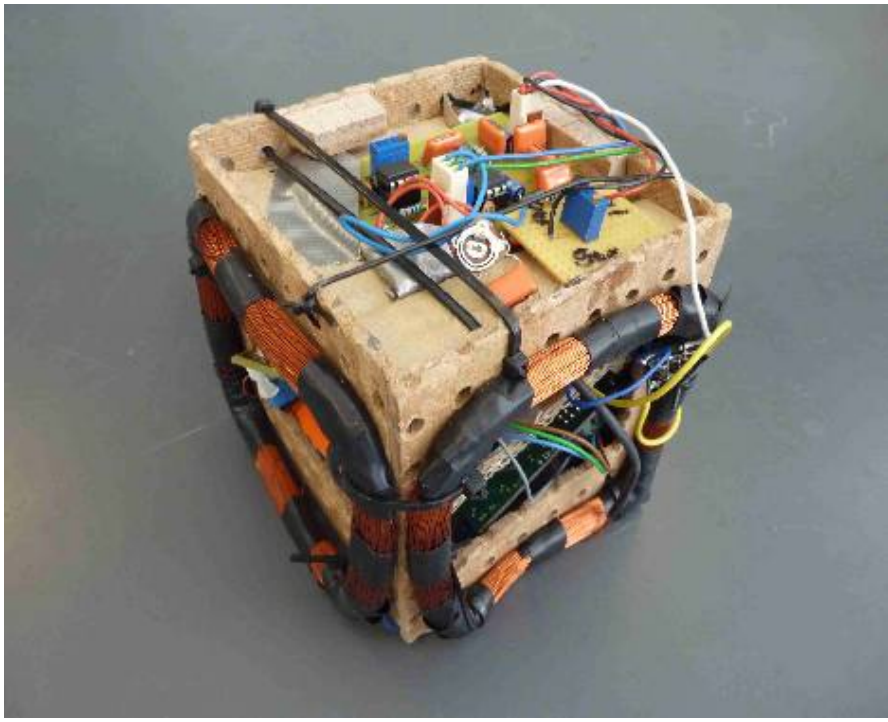
The satellite platform is designed with reliability and performance as the primary design drivers. It uses the shielded hi-rel subsystems: Batteries, power conditioning and distribution,

Min satellit
hvad skal der egentlig til ?

- En mission - payload
- Platform til at supportere payload

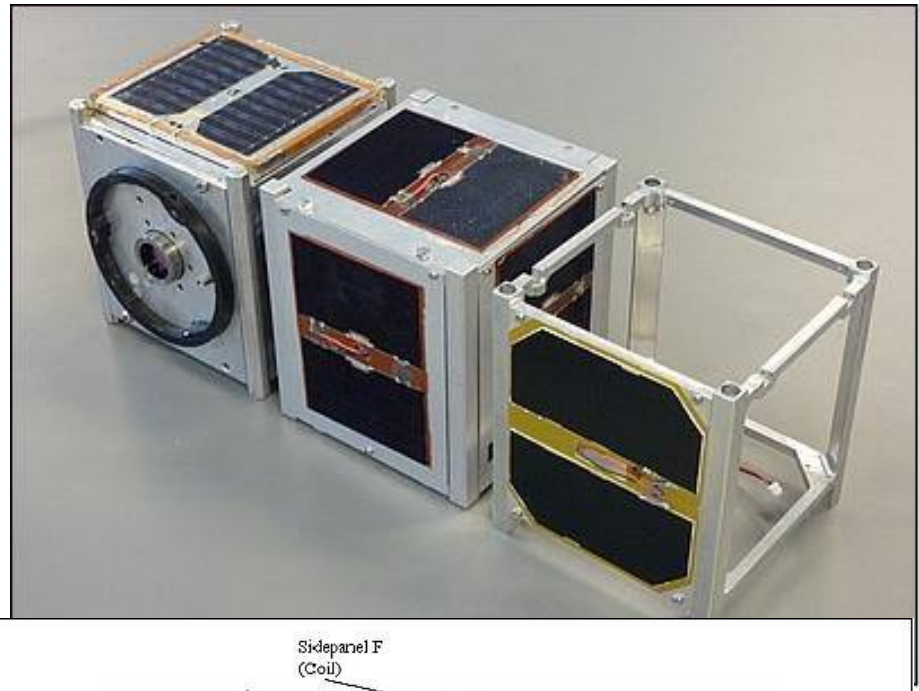
- Krav fra payload til platform
  - plads & placering
  - brug af satellit overflade
  - energiforbrug 24/7 og periodepeak
  - attitude (skal satellit pege på en bestemt måde)
  - kommunikation (data downlink)

- For missionen som helhed
  - Datalink budget
  - Orbit (hvor skal vi flyve?)

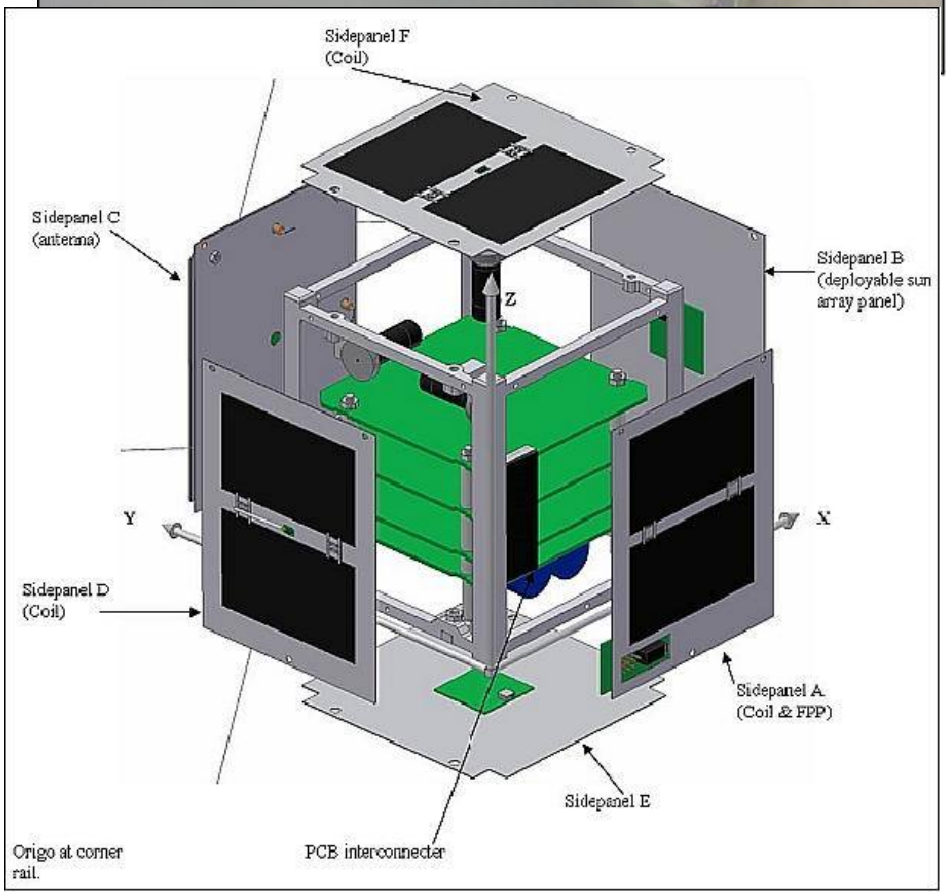


cubesat

- Kasse/ramme - aht POD interface
- Sidepaneler (6 ialt)
- Solceller i kamp om plads
  med payloads og antenner



- Solceller II
  - 8,0cm*4,0cm*0,1mm
  - areal 31,38cm2
  - effektivitet ~ 30%
- Solen ca 1400W/m2
- 1U: 1400 * 2 * 0,30*(31,82/10000) ~= **2,6W**
- Batterier mindst 2 stk
  - typisk 18650 type 3,7V a 2-3000mAh
  - “space” kvalitet



Det suveræn vigtigste system
Strømforsyning og solcelle

- Skal lade batterier
- Give strøm til subsystemer
- Overvåge deres strømbrug

- Koble subsystemer af hvis
  - de bruger for meget strøm
  - vi er "nede" på strøm

- Powercycle subsystems (genstart)
  - på kommando
  - fordi de ikke svarer på "pings"
  - ...

Strømforsyningen er "last man standing"

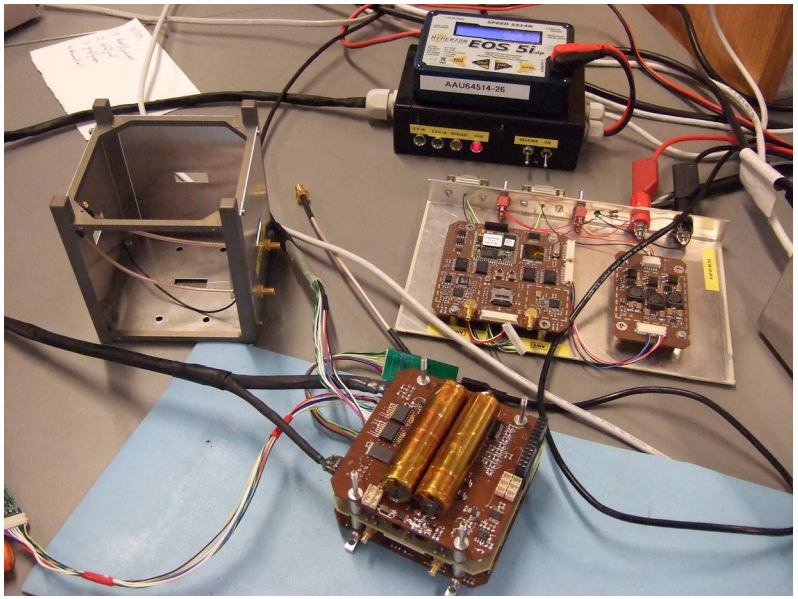
Skal kunne håndtere

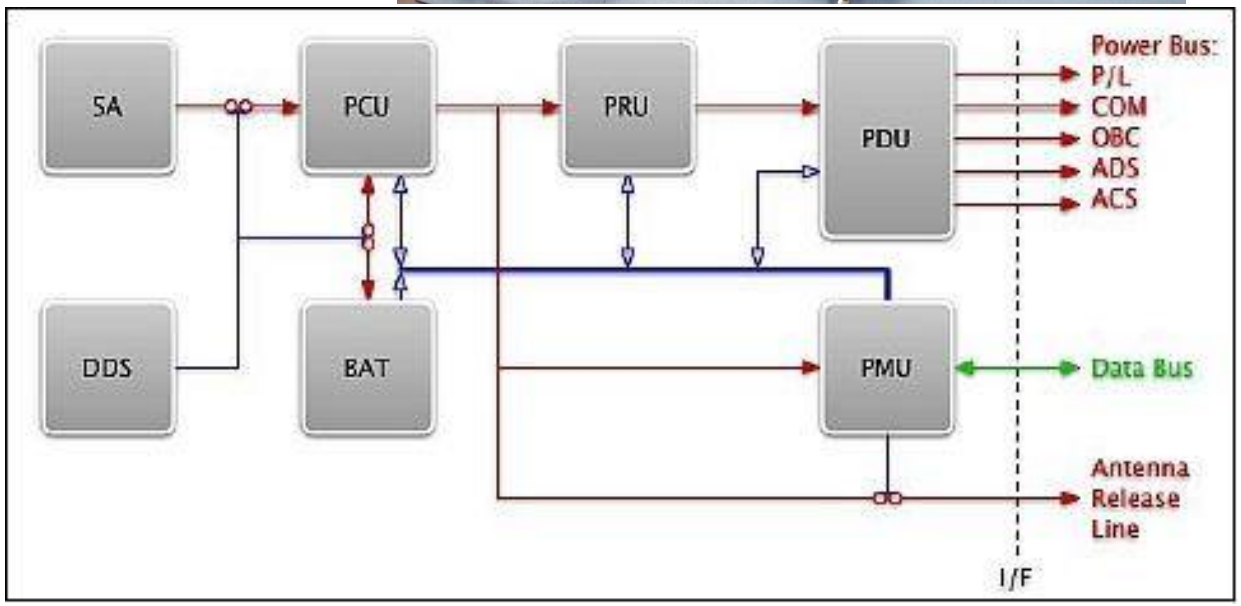
- beskadigede batterier
- beskadigede solpaneller
- tab af en eller flere solceller
- batteridegradering over tid

- undgå at batterier fryser (så går de til)

OG STRØMFORSYNINGS MICROCONTROLLER PROGRAM SKAL BARE VIRKE - ALTID ... !

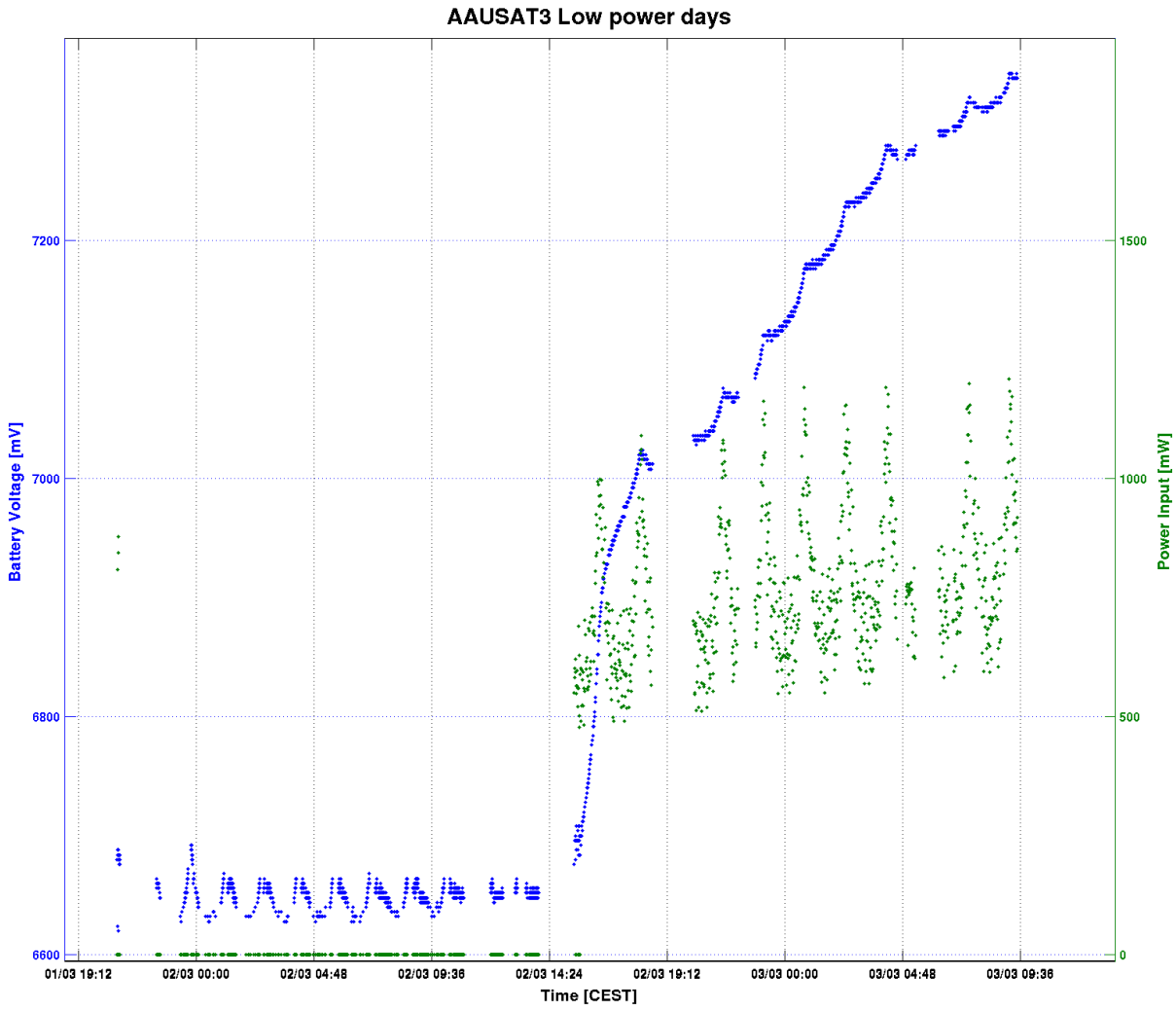
OG IKKE ALLE SITUATIONER KAN FORUDSES





AAUSAT3 - på trediedagen

- Solceller på 5 sider (6. var antenne)
- Fortegnsfejl ==>
- magnetfeltbremse var elmotor
- roterede med 2 Hz
- vendte blinde side mod solen
- og var jo spinstabiliseret
- hmmmmmm
- batteri blev fladt ret hurtigt
- 3000 reboots
  - lidt strøm
  - "hello" og ikke mere strøm
  - nede igen
  - gå til start ....
- MORALE: ikke alle scenarier kendes



Næstvigtigste subsystem - COM

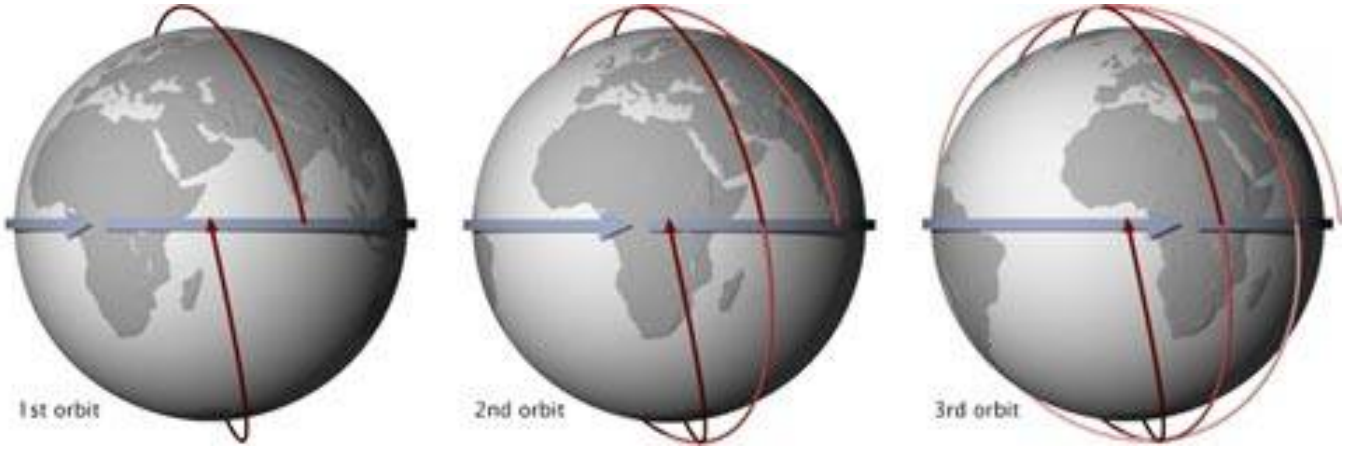
- Uden kommunikation kan det være lige meget.

Nogle tal

- 1W sendeeffekt
- for små antenner
- satellit peger måske ikke antenner mod jorden

- En orbit ca 90 min
- Et pass maks 12 min
- I DK 2 * 3-4 passes pr dag

- 2*4*8min = 64 min/døgn - hvis du er heldig



10 min pass

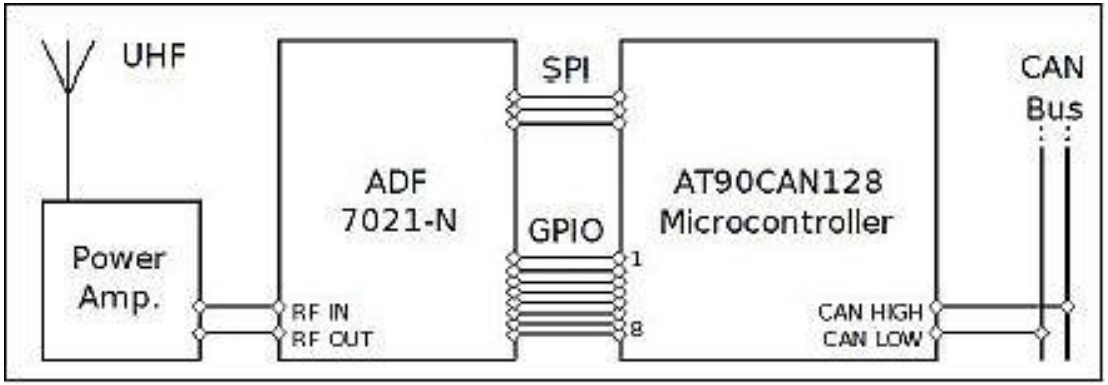
- ca 24000km/t så er 12 min lig 24000/6 = 4800 km !

- Vi har ofte haft kontakt fra Portugal op op til det nordlige Norge

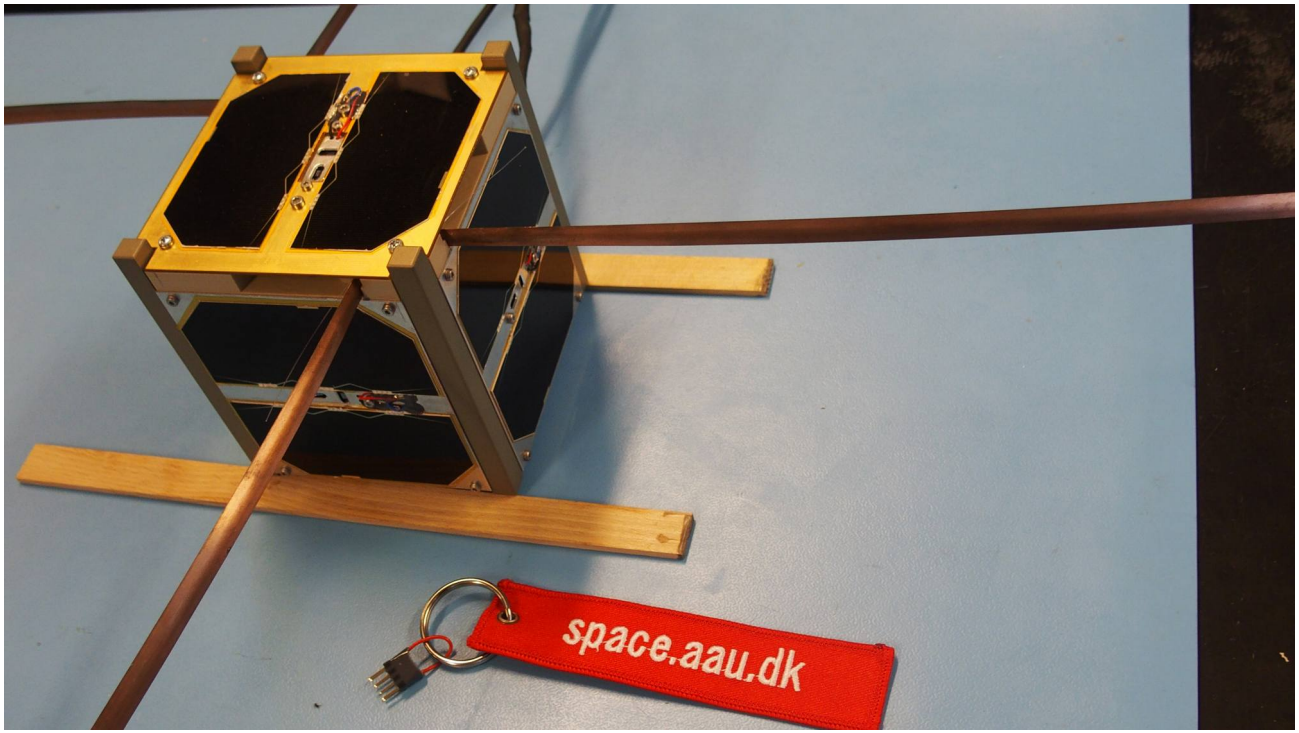
- på 1 W radio
- små antenner

AAU CUBESAT, AAUSAT3, AAUSAT-II

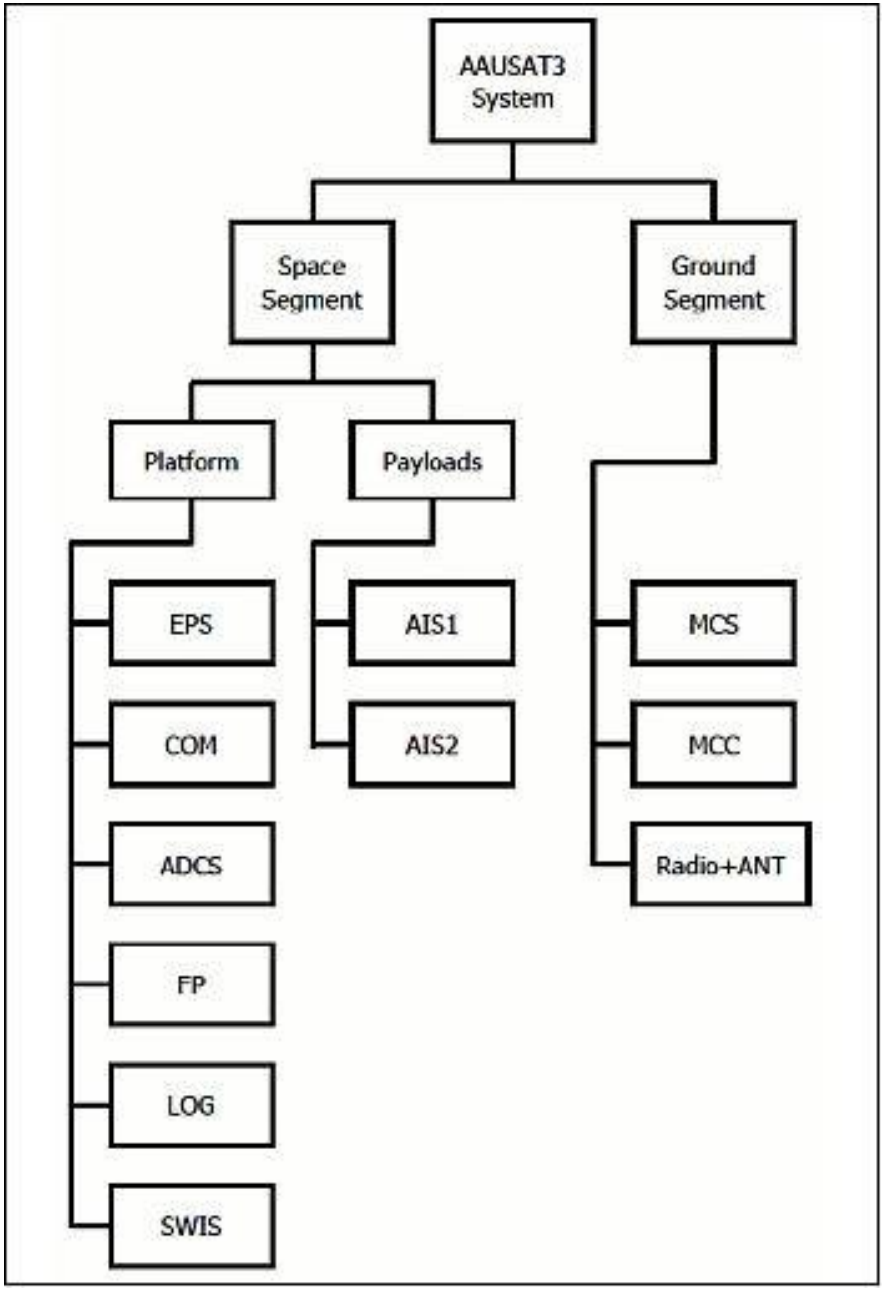
- baudrate 2400/4800/9600/19200
- +50% overhead aht fejlkorrektion

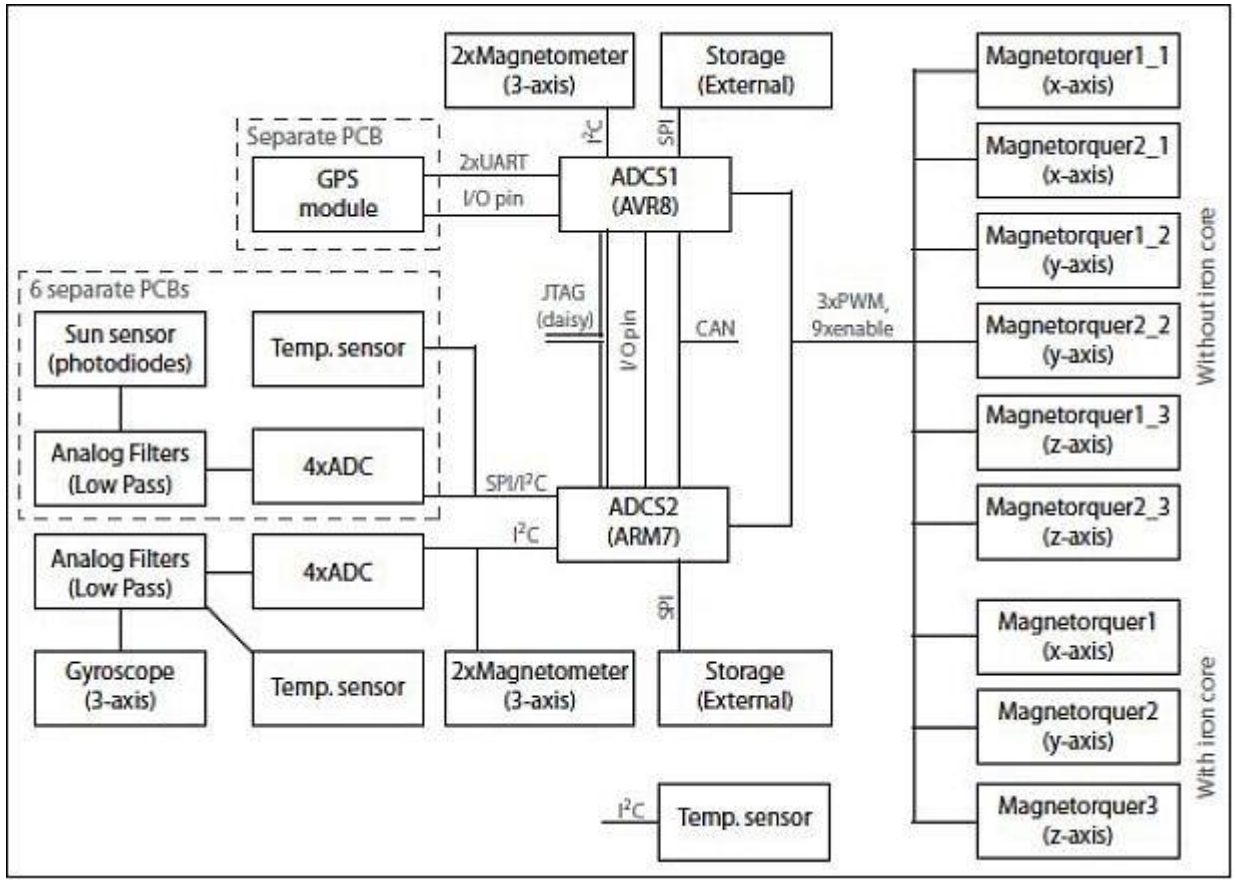


- 9600 bit/sec -> 4000 effektive bit
- 60min pr dag ...
- 60*60*4000/10 Byte ~= 1 MByte/dag



AAUSAT3


AAUSAT3 System
Space Segment
Ground Segment
Platform
Payloads
EPS
COM
ADCS
FP
LOG
SWIS
AIS1
AIS2
MCS
MCC
Radio+ANT

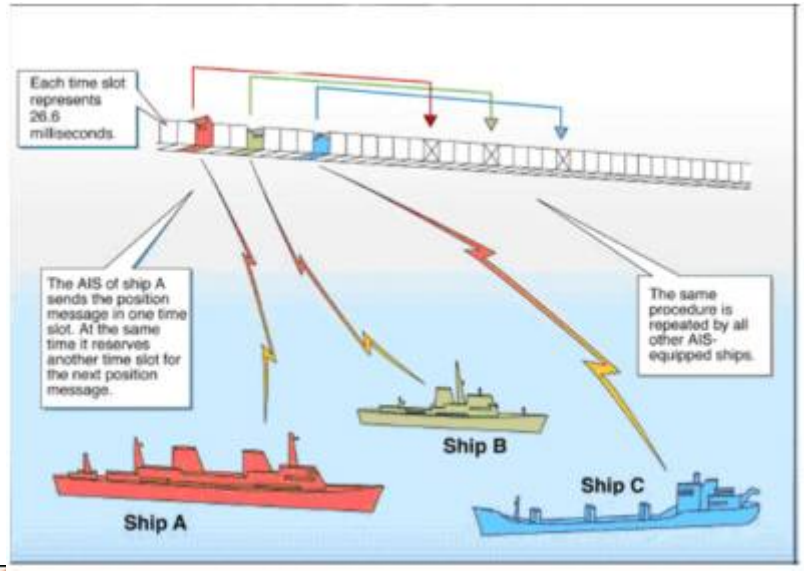

2xMagnetometer (3-axis)
Storage (External)
Separate PCB
GPS module
2xUART
I/O pin
I²C
SPI
ADCS1 (AVR8)
6 separate PCBs
Sun sensor (photodiodes)
Temp. sensor
Analog Filters (Low Pass)
4xADC
JTAG (daisy)
I/O pin
CAN
3xPWM, 9xenable
SPI/I²C
ADCS2 (ARM7)
I²C
Analog Filters (Low Pass)
4xADC
SPI
Gyroscope (3-axis)
Temp. sensor
2xMagnetometer (3-axis)
Storage (External)
I²C
Temp. sensor
Magnetorquer1_1 (x-axis)
Magnetorquer2_1 (x-axis)
Magnetorquer1_2 (y-axis)
Magnetorquer2_2 (y-axis)
Magnetorquer1_3 (z-axis)
Magnetorquer2_3 (z-axis)
Without iron core
Magnetorquer1 (x-axis)
Magnetorquer2 (y-axis)
Magnetorquer3 (z-axis)
With iron core

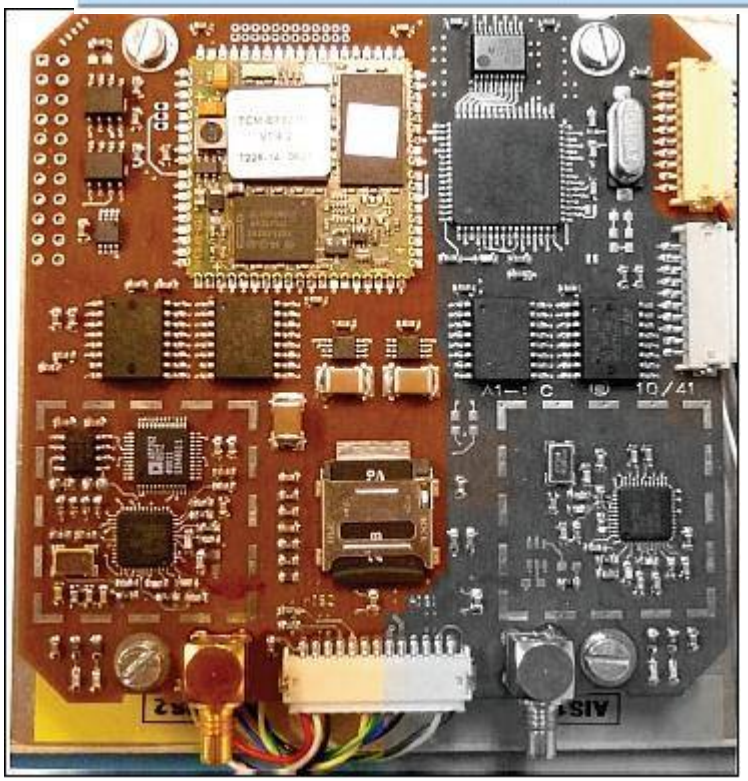
last - the payload - the mission

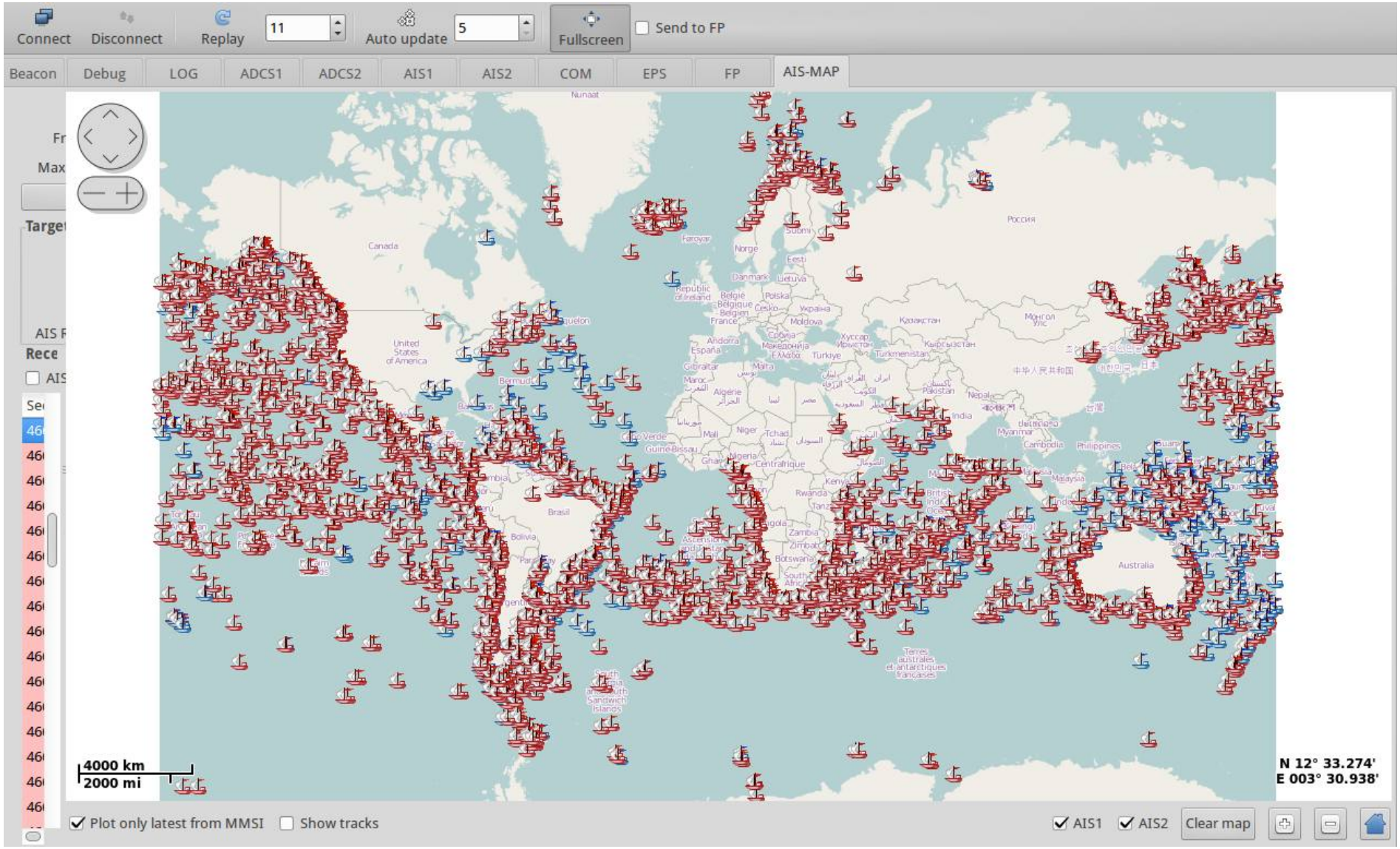
- Mission kan være bare at flyve
- camera - jordobservation
- monitor radiotraffik “fra oven”
- AIS (Automatic Identification Systems)

2 parallelle systemer

- robust simpelt system - ikke ret effektivt
- adv digitalt system - eksperiment
  - digitaliserer det rå radiosignal
  - signalanalyse
- Idag er der et firma i Aalborg der baserede deres produkter på det vi ser her
- og er kommet meget længere siden.






Connect
Disconnect
Replay
11
Auto update
5
Fullscreen
Send to FP
Beacon
Debug
LOG
ADCS1
ADCS2
AIS1
AIS2
COM
EPS
FP
AIS-MAP
4000 km
2000 mi
N 12° 33.274'
E 003° 30.938'
Plot only latest from MMSI
Show tracks
AIS1
AIS2
Clear map

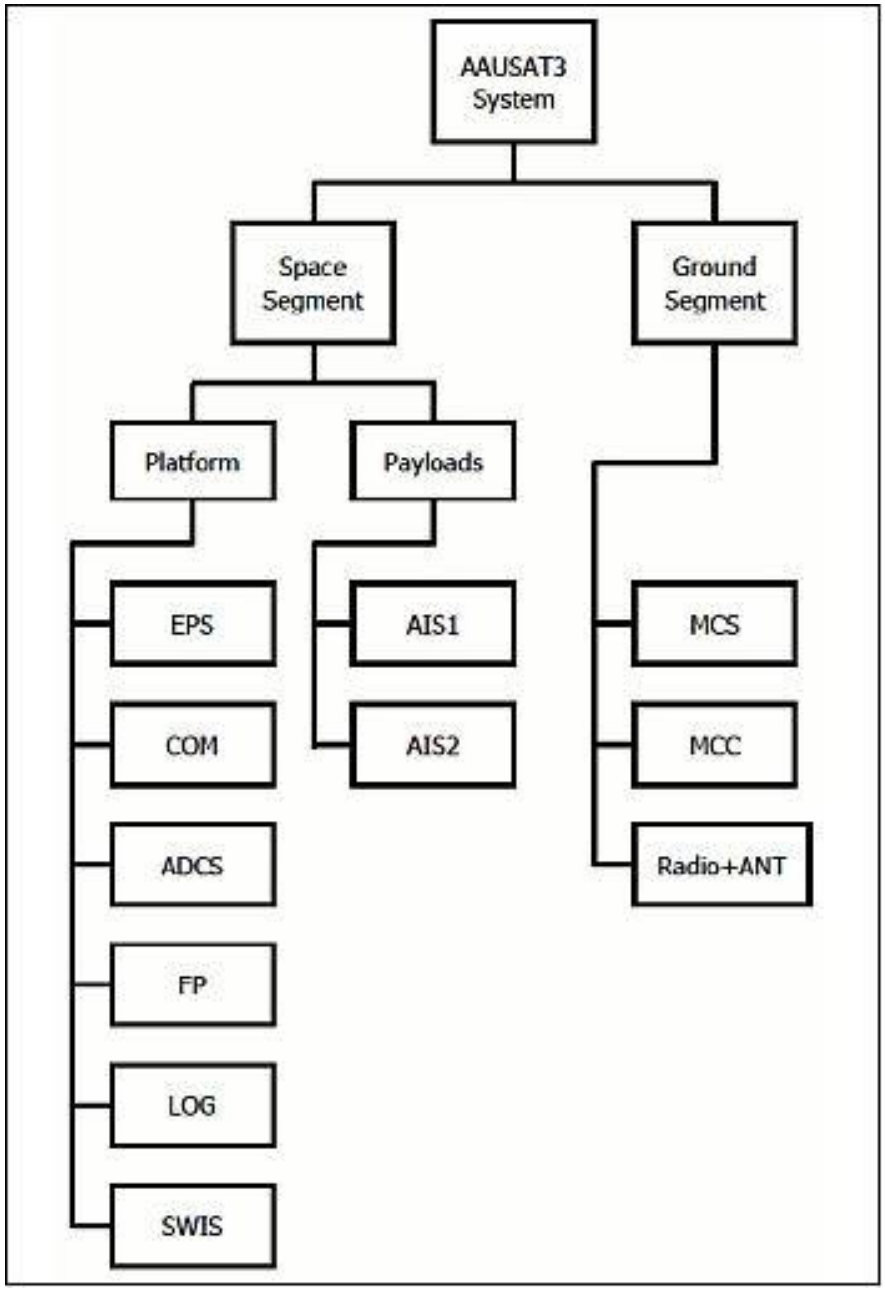
Typisk (?) system: AAUSAT3

- > 8 onboard computere/microcontrollers
- 8 Mhz til 600 MHz i klok
- 32 kByte lager til Mbyte
- Radiosystem

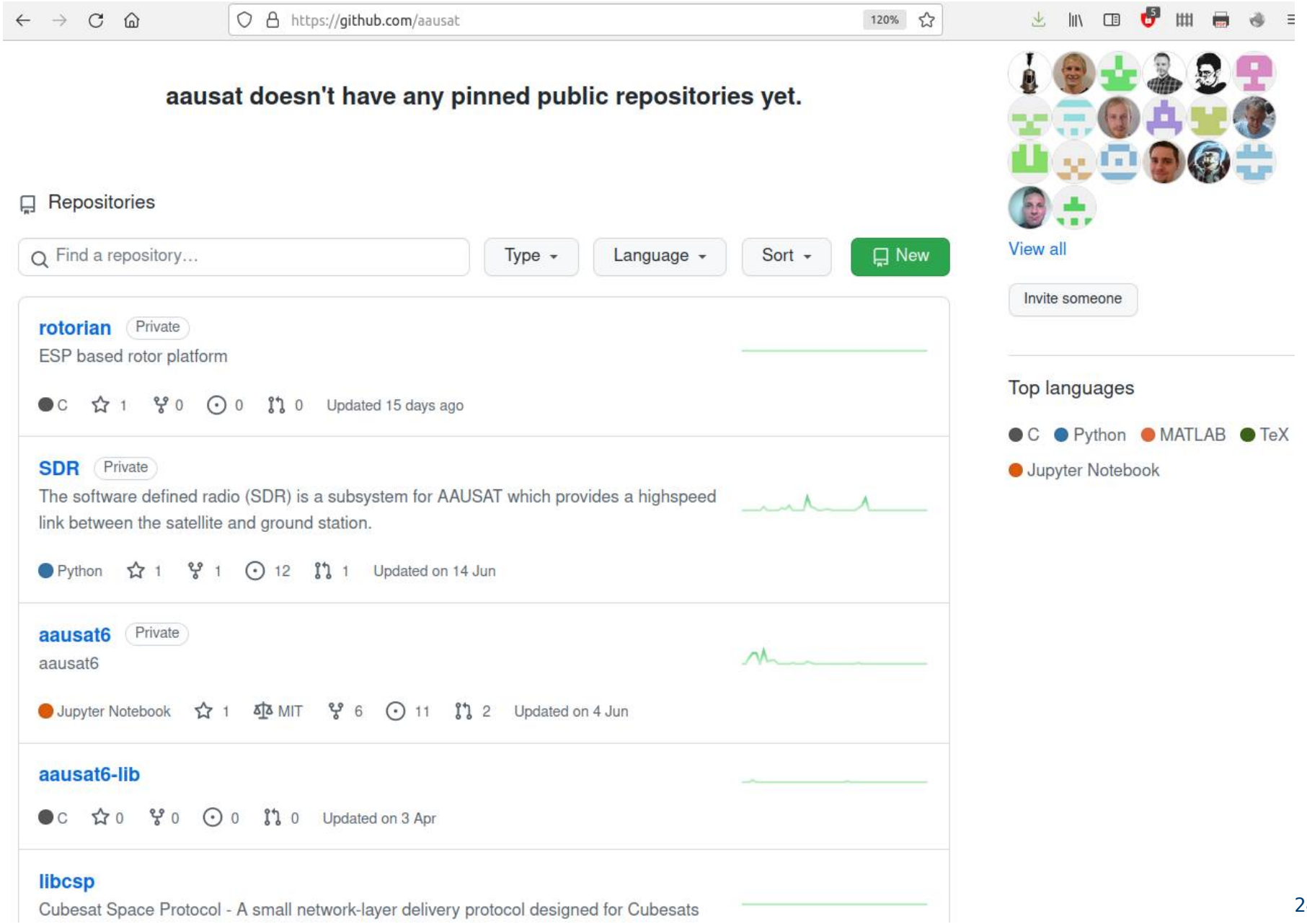
- OG alt skal drives af mindre end 2W i middel

Positionslyspære 12v5w

Varenummer 66605657700



SWSWSWSWSWSW og atter SW
mit gæt +2 mio linier kode



Kode

- Onboard spacecraft C & C++ 16/32 bit microcontrollers
  STM32,AT90CAN128,I167,...
  ALL FreeRTOS
- At ground C, python, sql
  PC, STM32,AT90CAN128
  ALL LINUX
  RTL SDR, Gnu SW, satnogs,...

- Client server based

  One GND : ground computet som varetager kommunikation

  Mange MCC Mission Control Client - brugergrænseflade

    ægte klient og som “listen only”

Succeskriterier

1) Blive klar til launch
2) Blive launchet - sat i orbit
3) 1 vejs kommunikation - At vi kan høre satellitten
4) 2 vejs kommunikation - at vi kan “snakke” med satellitten

5) At EPS virker OG lader (strømforsyning)
6) At resten af systemerne onboard virker
7) At payload virker

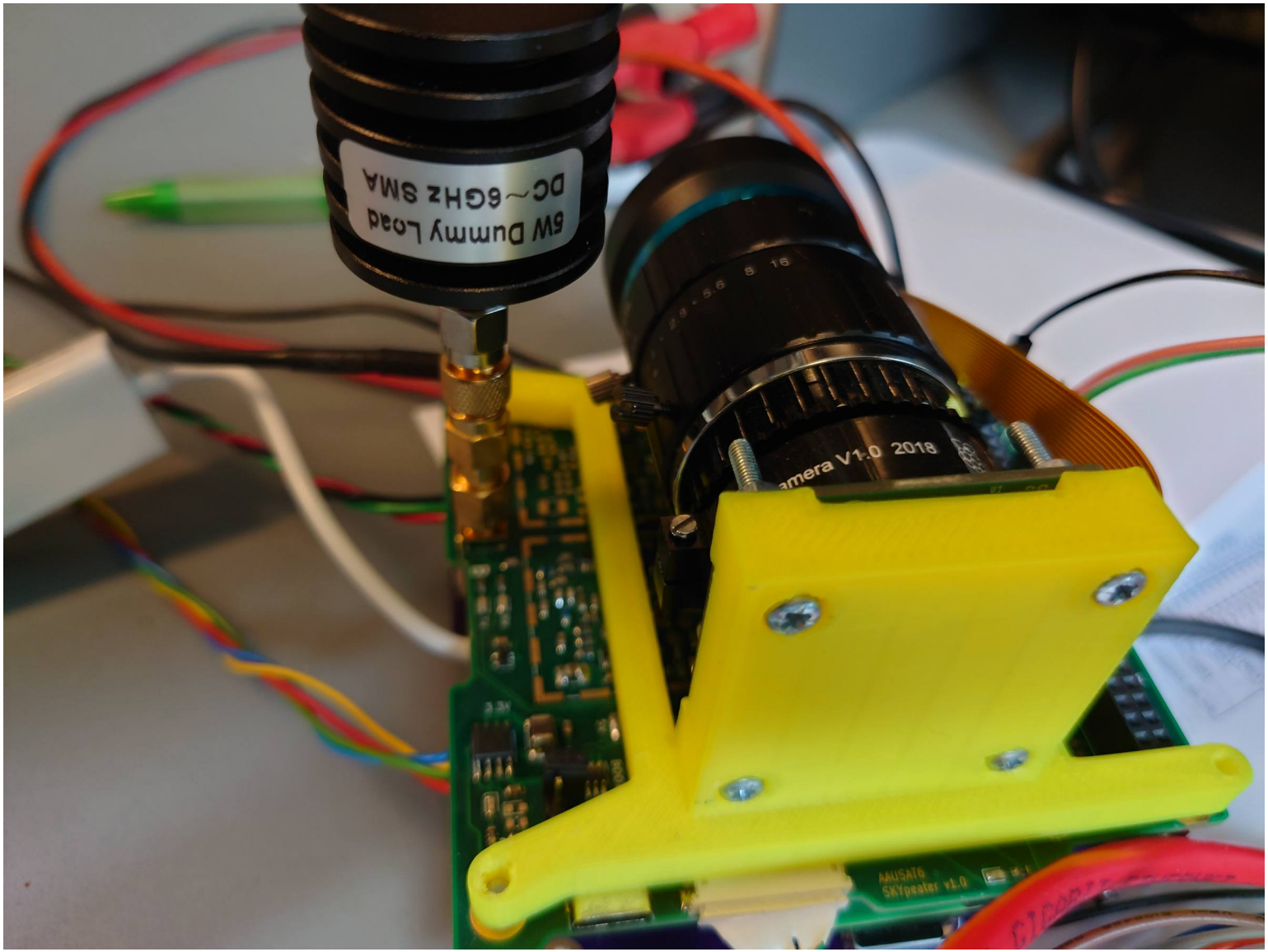
1. LEOP : Launch and Early OPerations - “afleveringsforretning”

   kan vare timer til dage. AAUSAT3 tog det kun eet pass (10min) (i grove træk)
   AAUSAT-II tog det et par måneder ...

2. OPERATIONS indtil EOL (EOL)

3. FINAL OPERATIONS ===> reentry (rumskrald)   < 25 år   (EU)

AAUSAT6
livestream from above



MEN husk Akins “love” (44 paragraffer ialt)

Akin's Laws of Spacecraft Design*

Space Systems Laboratory - Department of Aerospace Engineering - University of Maryland

Home

1. Engineering is done with numbers. Analysis without numbers is only an opinion.
2. To design a spacecraft right takes an infinite amount of effort. This is why it's a good idea to design them to operate when some things are wrong .
3. Design is an iterative process. The necessary number of iterations is one more than the number you have currently done. This is true at any point in time.
4. Your best design efforts will inevitably wind up being useless in the final design. Learn to live with the disappointment.
5. (Miller's Law) Three points determine a curve.
6. (Mar's Law) Everything is linear if plotted log-log with a fat magic marker.
7. At the start of any design effort, the person who most wants to be team leader is least likely to be capable of it.
8. In nature, the optimum is almost always in the middle somewhere. Distrust assertions that the optimum is at an extreme point.
9. Not having all the information you need is never a satisfactory excuse for not starting the analysis.
10. When in doubt, estimate. In an emergency, guess. But be sure to go back and clean up the mess when the real numbers come along.
11. Sometimes, the fastest way to get to the end is to throw everything out and start over.
12. There is never a single right solution. There are always multiple wrong ones, though.
13. Design is based on requirements. There's no justification for designing something one bit "better" than the requirements dictate.
14. (Edison's Law) "Better" is the enemy of "good".

43. You really understand something the third time you see it (or the first time you teach it.)

44. Space is a completely unforgiving environment. If you screw up the engineering, somebody dies (and there's no partial credit because *most* of the analysis was right...)

til slut

- lyder spændende - det er det
- mange mange timers arbejde
- meget er smidt væk og gendesignet og lave på ny
- meget meget frivilligt arbejde af studerende

og

al kredit skal gå til dem der er de reelle helte i denne historie

De studerende !

tak fordi I lyttede :-)

/Jens