

# Starten met Amateur Satellieten



Ivo Klinkert      PA1IVO  
Henk Hamoen      PA3GUO

Satellietdag Apeldoorn  
25 April, 2015

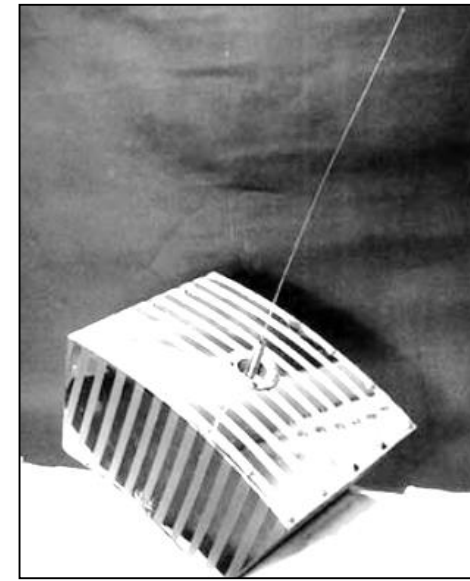
# Agenda

- **Amateur satellieten**
  - Geschiedenis
  - Wat zijn Cubesats ?
- **Satellietbanen**
  - Kepler sets & Tracking software
  - Doppler Effect
- **Apparatuur**
  - Antennes & rotoeren, voorversterkers & filters
  - Zenders & ontvangers, Computerbesturing
- **Verbindingen maken**
  - Spraak & digitaal, transponders & repeaters
  - Zendamateurs & Universiteiten & NASA
- **Vragen**



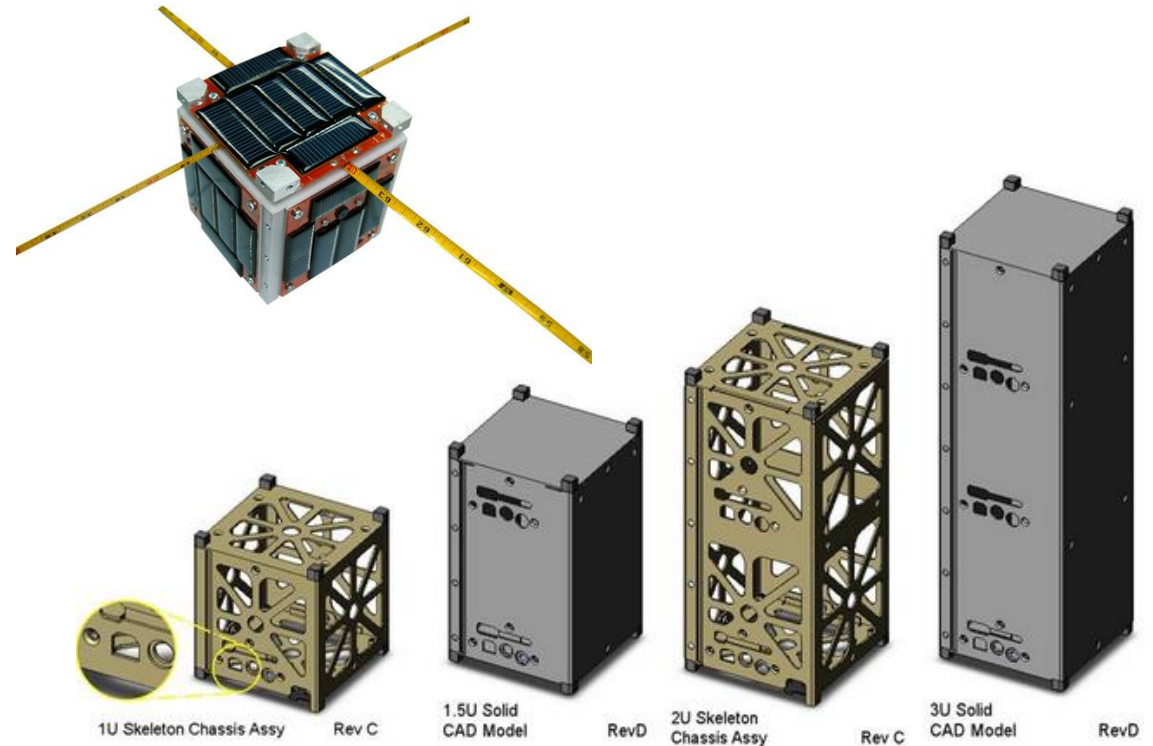
# Amateur satellieten

- Eerste: OSCAR-1 - 1961
- Oudst werkende: AO-7 - 1974
- Grootste: AO-40: 450kg - HEO - Ariane 5
- Duur → 2<sup>e</sup> payload
- Cubesats: kleiner & goedkoper
- Nederland: Delfi-C3, Delfi-n3Xt, AO-73 (FUNcube-1) !



# Wat zijn Cubesats ?

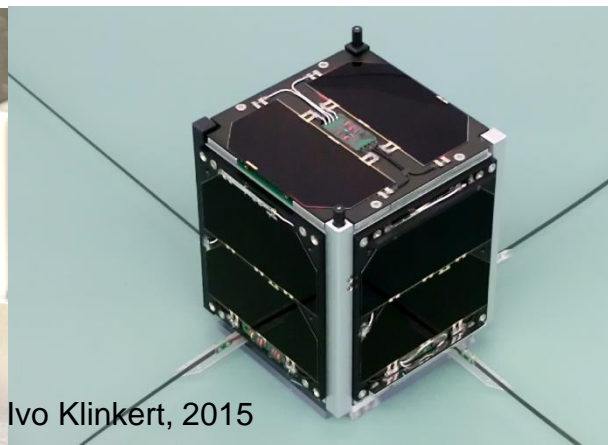
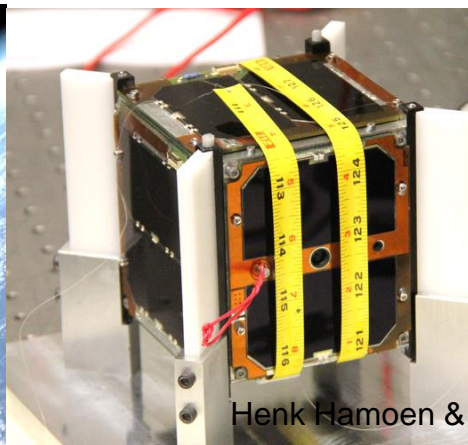
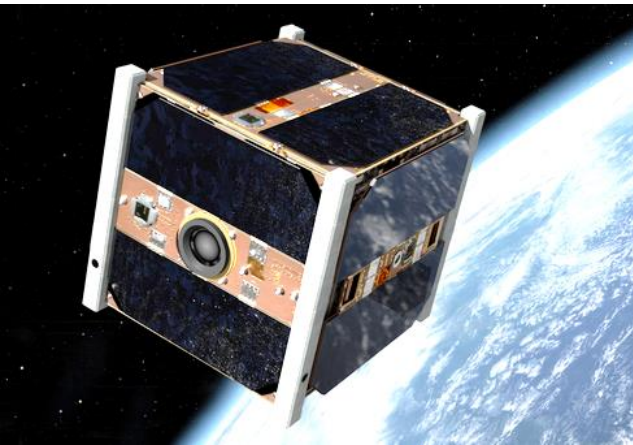
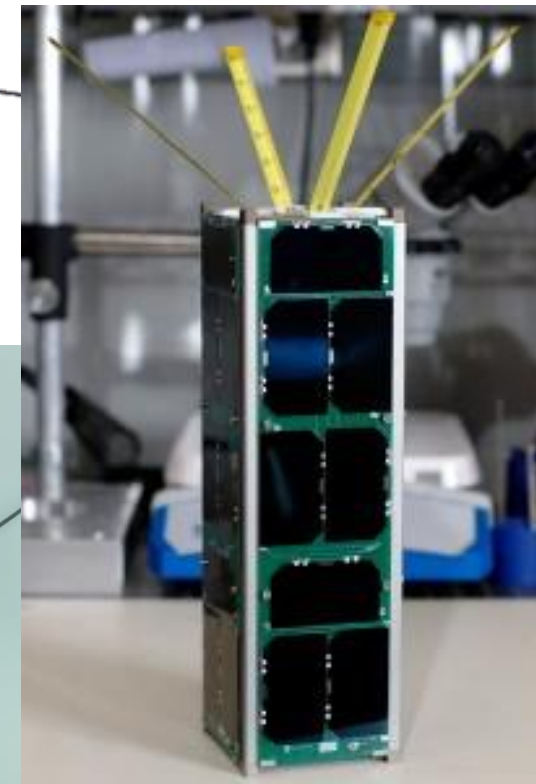
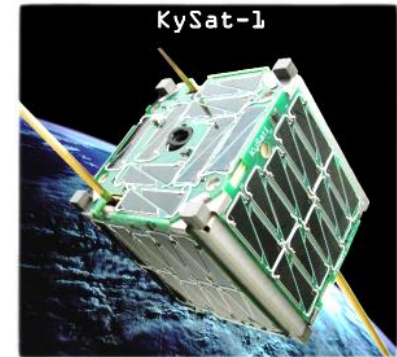
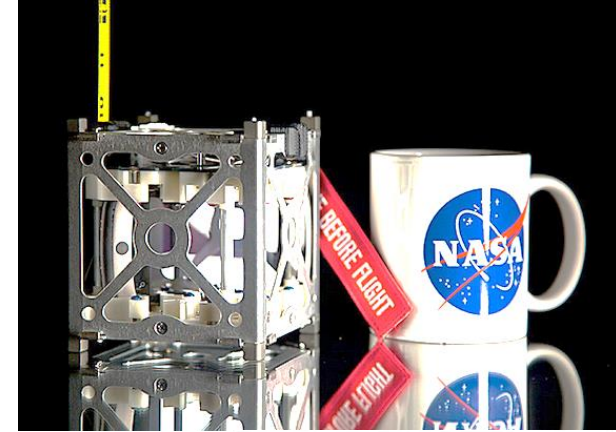
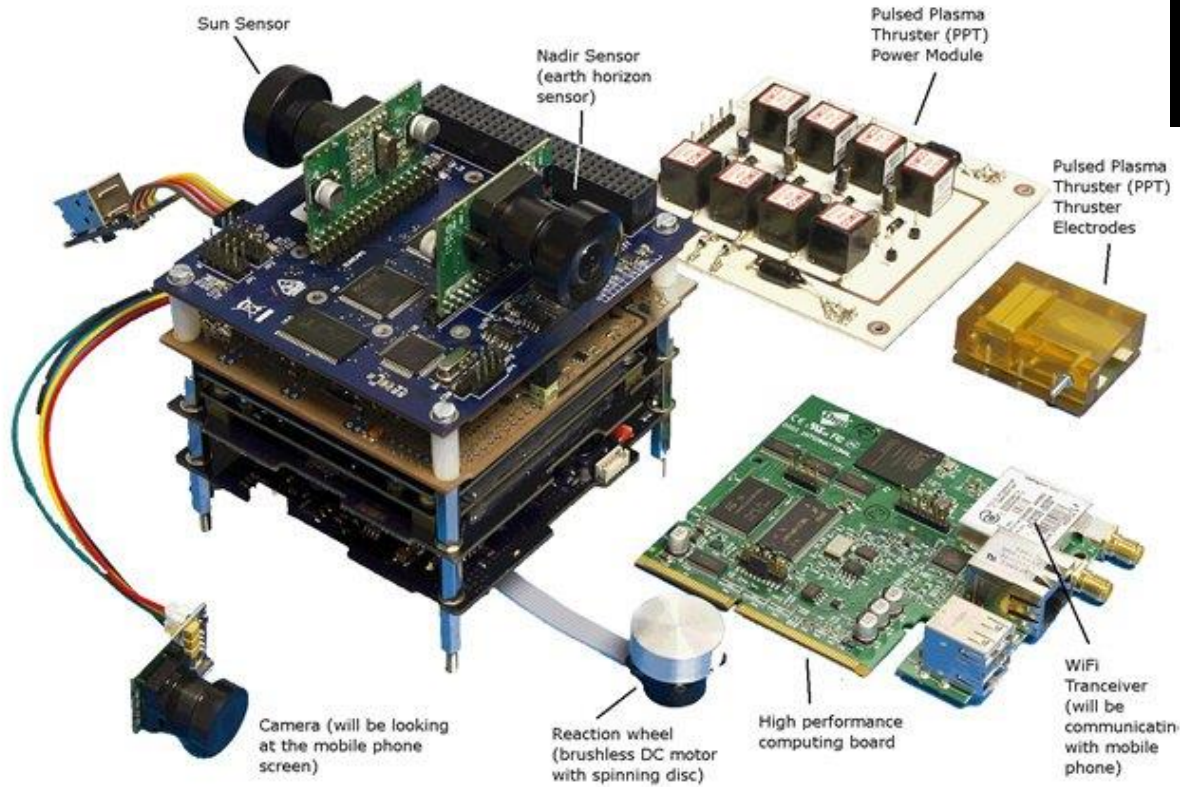
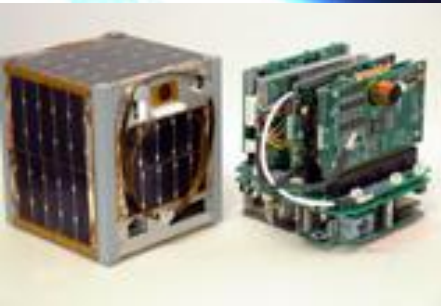
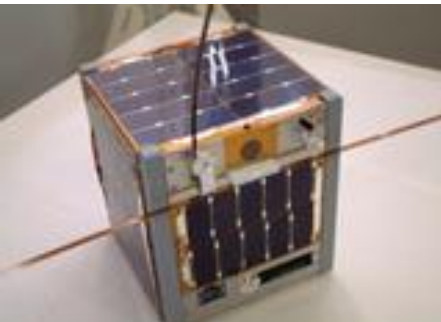
- Stanford University
- Prof. Twiggs - 1998
- <1.33 kg
- 10 x 10 x 10 cm units
- 1U, 2U, 3U, 6U, ...



- Eerste lancering: 30 juni 2003
- “Support Hands-on University-level Space Education”
- 50+ gelanceerd, 300+ in ontwikkeling



# Voorbeelden van Cubesats





# Cubesats in 2014 = \$\$\$

- Magazines
- NASA
- Internet

**CubeSatShop.com** | isispace.nl | isislaunch.com  
The one-stop-shop for all your CubeSat and nanosat systems...

Welcome to the CubeSatShop, the one stop webshop that offers a broad range of product nanosatellites in general. The webshop offers standardized, off-the-shelf components and subsystem manufacturers.

**Categories**

- CubeSat Structures
- Communication Systems
- Power Systems
- Control Systems
- Systems
- Computers
- Adapters
- Equipment
- Cameras
- Kits and Buses
- Stations

**SPACE.COM** | TECH SPACEFLIGHT SCIENCE & ASTRONOMY

TRENDING: Skywatching Guide // Space Webcasts // Mars Rover Curiosity // Solar Flares // Space Ph

## Big News about Small Satellites: Cubesats Rule!

by Leonard David, Senior Space Writer | September 28, 2005 06:59am ET

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**ISIS Innovative**

home about ISIS capabilities

**ISIS CubeSat Solutions**

ISIS offers a broad range of turn-key nanosatellite solutions, ranging from standard CubeSat solutions in the 1 - 4 kilogram range to 20 kilogram

National Aeronautics and Space Administration

**CUBESAT ELaNa VI LAUNCH ON L-36 Mission**

**CubeSat Deployment**

Four CubeSat projects were selected for the ELaNa VI mission. The NRO funded the Naval Postgraduate School to develop NPS-CUL, which can attach up to eight P-PODS to a single adaptor. This allows up to 24 single-unit (1U) CubeSats to be launched at one time. The CubeSats on OUTSats are sponsored by either the NRO Mission Support Directorate or NASA's Launch Services Program. The P-POD was designed and manufactured by the California Polytechnic State University (Cal Poly) to integrate CubeSats onto the launch vehicle. This P-POD design has flown previously on Defense Department, NASA, and commercial launches. For NASA, Cal Poly integrates the CubeSats with the P-POD and provides the entire assembly to the launch vehicle integrator.

After the main payload deploys, the CubeSats will separate from their P-PODs. After 45 minutes in orbit, the CubeSat transmitters will turn on and university ground stations will listen for their beacons, determine the small satellites' functionality and announce operational status. CubeSat mission durations and orbital life vary, but are anticipated to last at least 160 days. Upon mission completion, the CubeSats fall to Earth, burning up in the atmosphere.

**Mission Overview**

NASA is partnering with the National Reconnaissance Office (NRO) to launch small research satellites, or CubeSats, for four universities on the third installment of the Educational Launch of Nanosatellite (ELaNa) mission. The Launch Services Program at NASA's Kennedy Space Center in Florida manages the ELaNa missions. The CubeSats will be flown as part of the Operationally Unique Technologies Satellite, or OUTSat, an auxiliary payload aboard the Atlas V 401 rocket scheduled to lift off Aug. 2. Three Poly Picosatellite Orbital Deployers, or P-PODs, will carry and deploy the ELaNa VI CubeSats.

The ELaNa CubeSat Launch Initiative enables university students to obtain hands-on experience and gives private industry access to a low-cost vehicle. Since its inception in 2010, the program has selected more than 60 CubeSats from private and public institutions around the U.S., including six that were launched successfully on the ELaNa III mission. The ELaNa VI CubeSats were chosen from a prioritized list of universities that responded to two public announcements to NASA's CubeSat Launch Initiative in 2011. NASA will announce another call for proposals in mid-August. It will close in November.

**Basic CubeSat Facts:**

- Built to standard dimensions of 1 unit, or 1U, which is equal to 10x10x11 cm
- Can be 1U, 2U, 3U, or 6U in size
- Weigh less than 1 1/3 kg (3 lbs) per U—6U may be up to 12-14 kg
- Deployed from standard Poly-Picosatellite Orbital Deployers (P-POD)

**CPS was developed and built by the California Polytechnic State University in San Luis Obispo. Its primary purpose is to test a deployable spacecraft de-orbiting a thin-film mechanism consisting of a miniature solar sail. After the sail deploys, observations will be made from the ground to detect any altitude or velocity degradation of the spacecraft.**

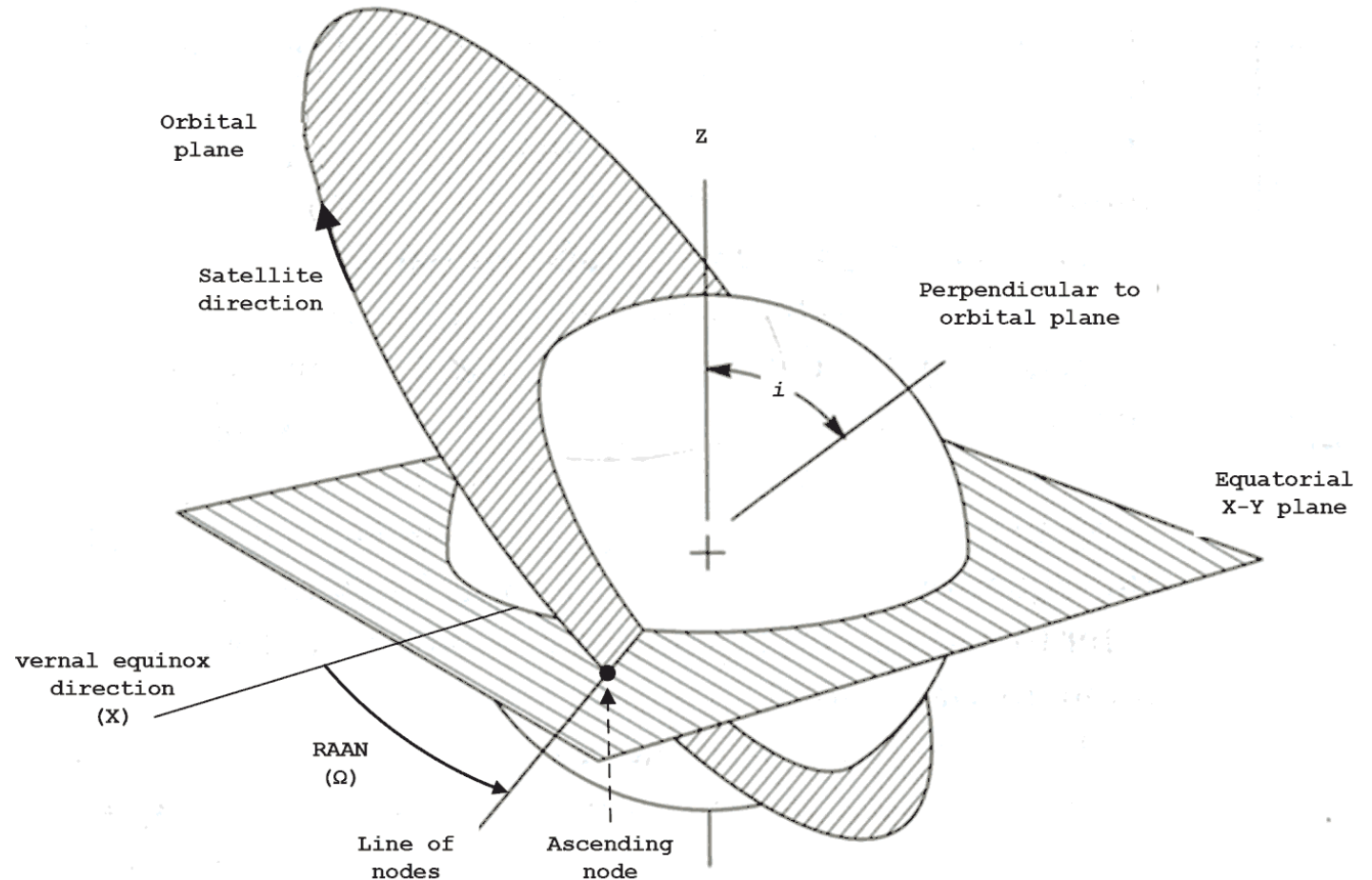
**NASAfacts**

# Satellietbanen

LEO = Low Earth Orbit  
HEO = High Earth Orbit

## 6 baan-parameters

- Soort baan:
  - Inclination
  - Mean Motion
  - Eccentricity
- Positie baan:
  - RAAN
  - Argument of perigee
- Positie satelliet:
  - Mean Anomaly
- AO13, AO40: Ellips-vormig
- LEO-satellieten: Cirkel-vormig ('rond')



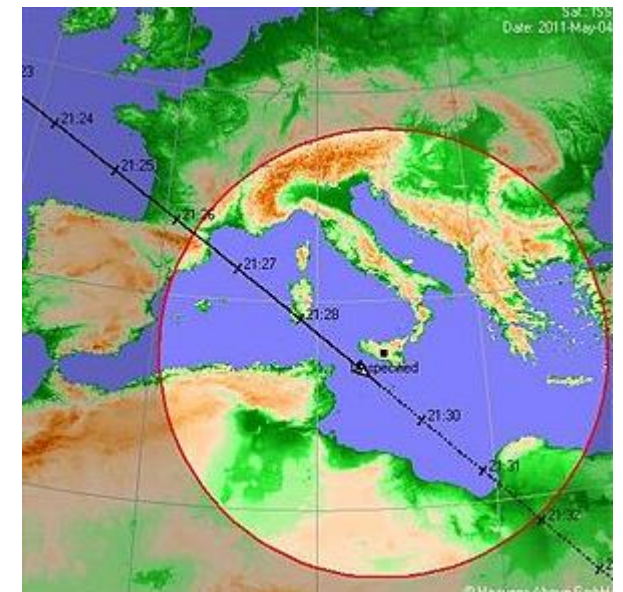
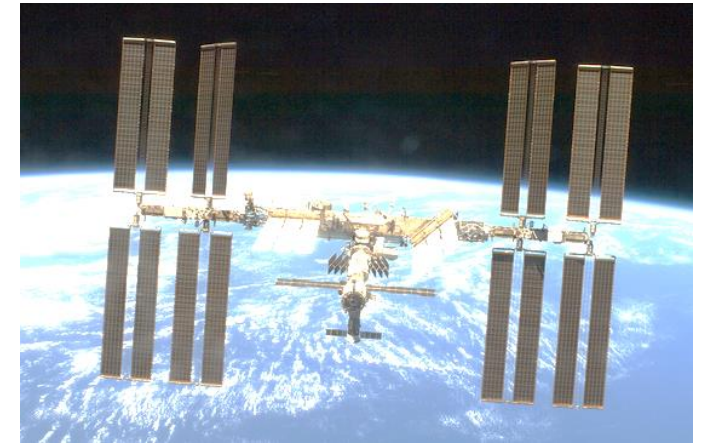
# LEO banen

## ■ Low-Earth-Orbit (LEO) banen

- Satelliet komt ongeveer elke 1,5 uur over
- Passage maximaal rond 15 minuten
- Ongeveer 3 tot 4 passages, dan weer tijdje 'niet-zichtbaar'
- Noord → Zuid of Zuid → Noord

## ■ Footprint

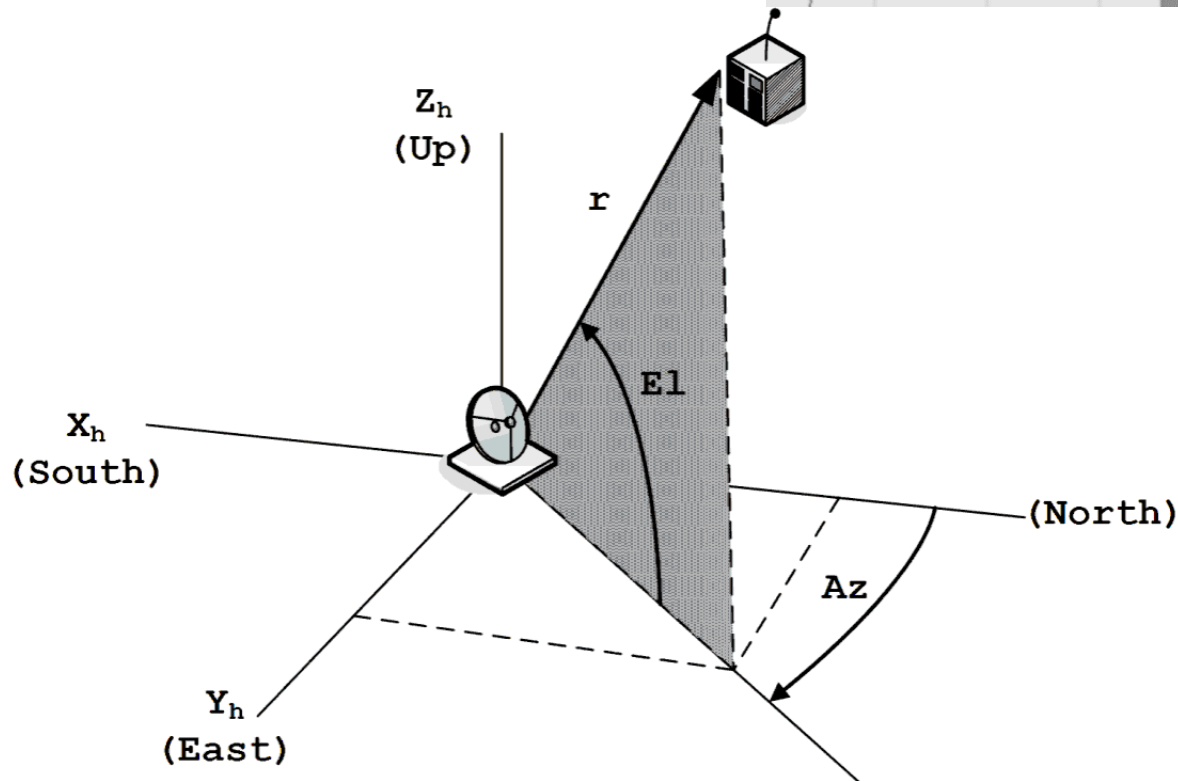
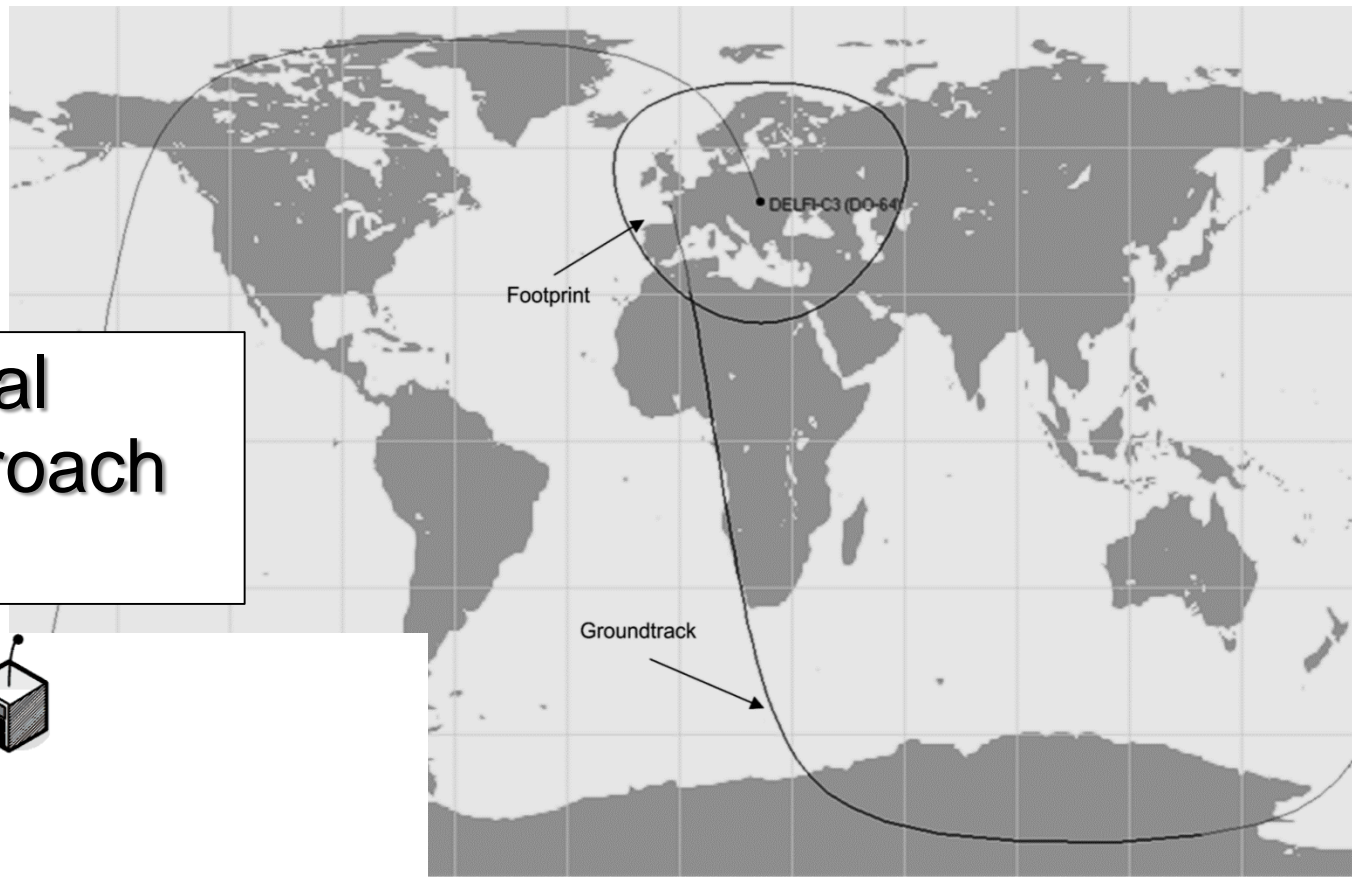
- Gebied waarin met de satelliet een verbinding gemaakt kan worden





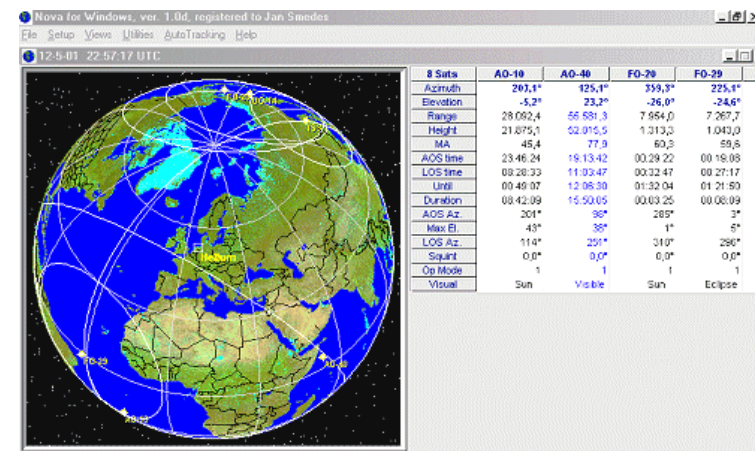
# Satelliet positie

AOS Aquisition of Signal  
TCA Time Closed Approach  
LOS Loss of Signal



# TLE's

- Two Line Elements (TLE)
- Software berekent de satelliet positie met TLE's



```
1 35004U 09028D 09156.84140383 .00003395 00000-0 87986-4 0 154
2 35004 40.4627 308.3133 0027431 81.4359 278.9560 15.39970114 2598
```

```
1 35004U 09028D 09156.84140383 .00003395 00000-0 87986-4 0 154
2 35004 40.4627 308.3133 0027431 81.4359 278.9560 15.39970114 2598
      incl      RAAN      e      argofper      MA      MM
```

- Beschikbaar op internet:

<http://www.celestrak.com/NORAD/elements/>

<http://www.amsat.org/amsat/ftp/keps/current/nasa.all>

...

# Tracking Software

- PC:

- Orbitron
- SATPC32
- HRD
- NOVA
- Gpredict
- MacDoppler



- Tablets:

- App's



- Online:

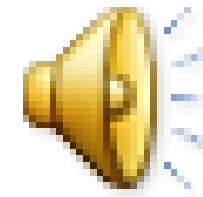
- www.Amsat.org
- Heavens Above

The collage displays several satellite tracking software interfaces:

- Orbitron (top right):** Shows a satellite search window with parameters like 'Search period: 2005-05-10 23:28:52' and a table of tracked satellites including IRIDIUM 53, 10, and 12. It also features a 'Predict' button and a 'Satellites Data' panel.
- SATPC32 (middle right):** Displays a table of satellite data with columns for Azimuth, Elevation, Magnitude, Range, and Azimuth/Elevation. It includes a 'Predict' button and a 'Rotor/Radio' control panel.
- HamSatDroid (bottom left):** Shows satellite coordinates for AO-51: 'Satellite Latitude: -63.06°', 'Satellite Longitude: -15.55°', 'Home Latitude: 34.16°', and 'Home Longitude: -117.99°'. It includes a world map showing the satellite's path.
- gisat (bottom right):** A 'Real-Time Satellite Tracking Display' showing a world map with satellite tracks and a detailed data panel for a selected satellite (PCSAT) with parameters like 'Latitude: 56.50 N', 'Longitude: 47.72 W', and 'Altitude: 2896.39 km'.



# Doppler Effect: Wat is het ?



Doppler Effect: Sirene

- Voorbeelden
  - Formule 1
  - Politie sirene
  - Trein bij overweg
- Frequentieverschuiving
  - Door snelheidsverschil  
bron  $\leftrightarrow$  waarnemer
  - Ook bij satelliet signalen!
- Typische LEO-passage:
  - 145 MHz  $\sim$ 3 kHz
  - 435 MHz  $\sim$ 9 kHz

$$f_w = f_b \left( \frac{v}{v - v_b} \right)$$

en bij verwijdering van de waarnemer:

$$f_w = f_b \left( \frac{v}{v + v_b} \right)$$

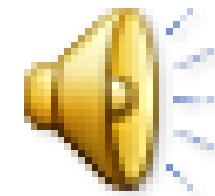
met

- $f_b$  de echte frequentie van de golf die de bron uitzendt,
- $v$  de voortplantingssnelheid van de golf in het medium en
- $v_b$  de snelheid waarmee de golfbron beweegt in de richting van de waarnemer,

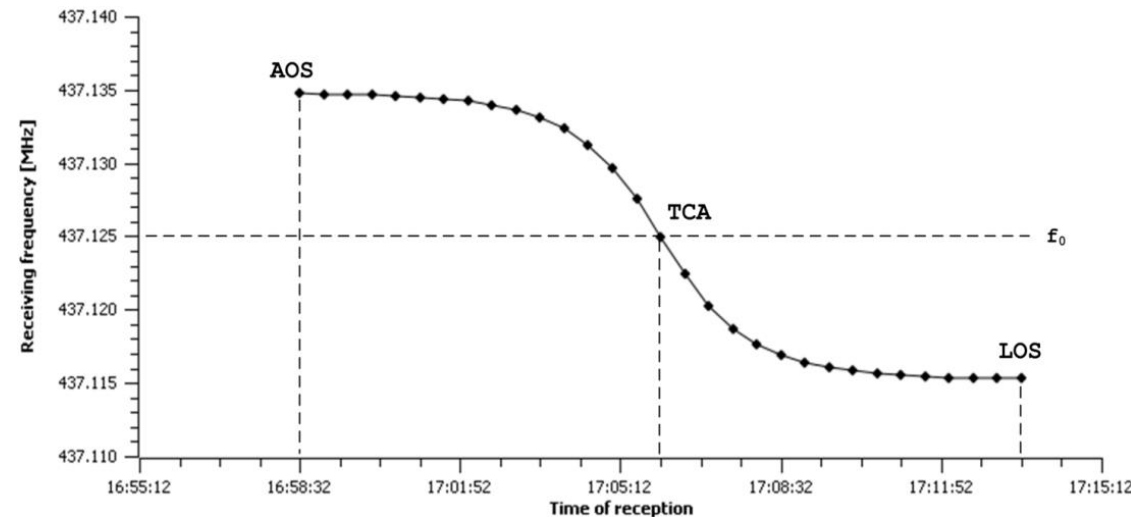
# Doppler Effect: Varieert tijdens een passage

- Goed te voorspellen als je weet:

- Waar jij (stil) zit
- Waar de sateliet is
- Hoe snel de satelliet gaat

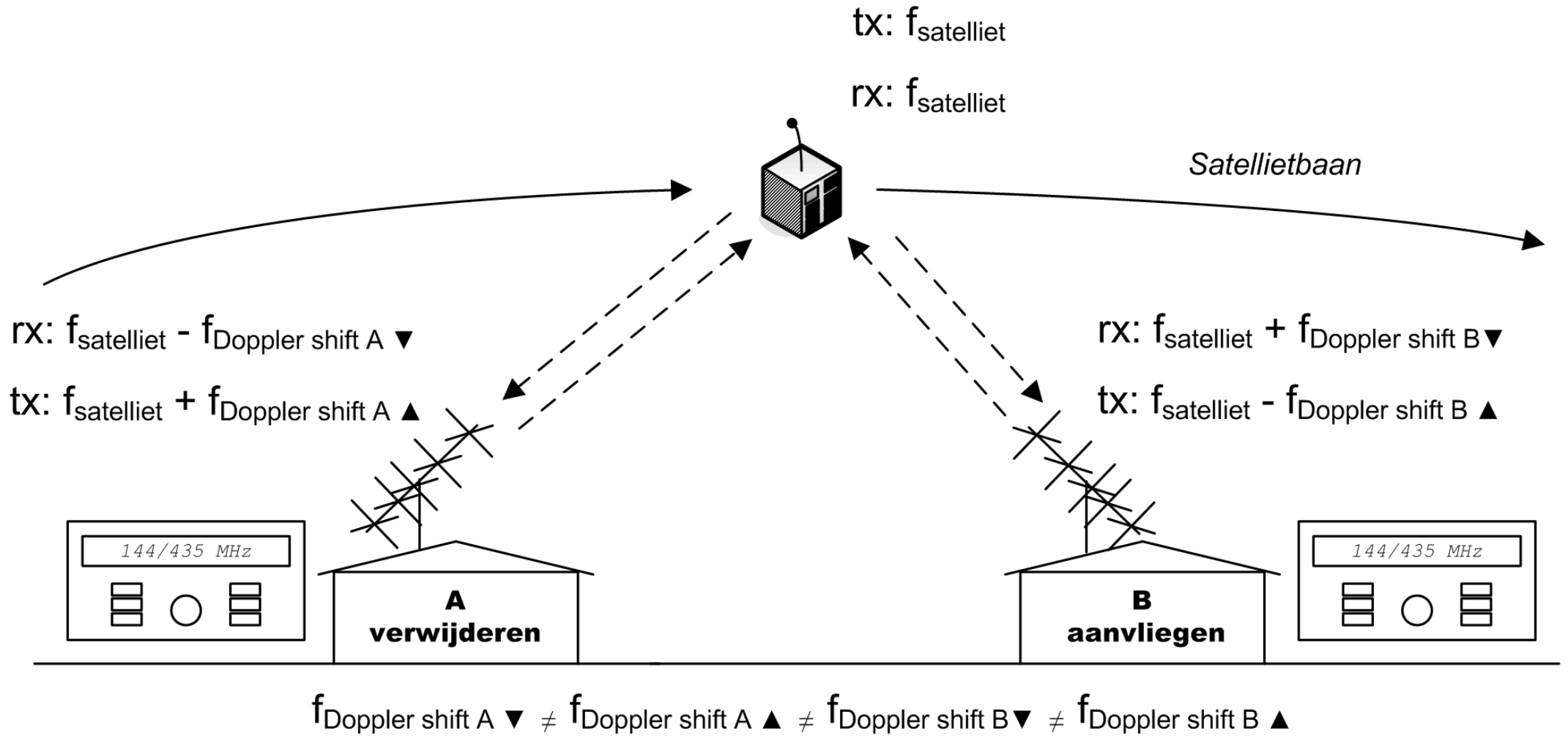


LO19 CW 437 MHz



- Grootst bij AOS en LOS
- Nul (slechts heel even) bij TCA
- Verandering van frequentie grootst bij TCA!

# Doppler Effect: Full duplex voorbeeld





# Apparatuur: Antennes

- $\frac{1}{4}$  golf rondstraler werkt 'aardig'
  - Bijvoorbeeld voor ISS (sterk)
  - Geeft zeker niet het beste resultaat

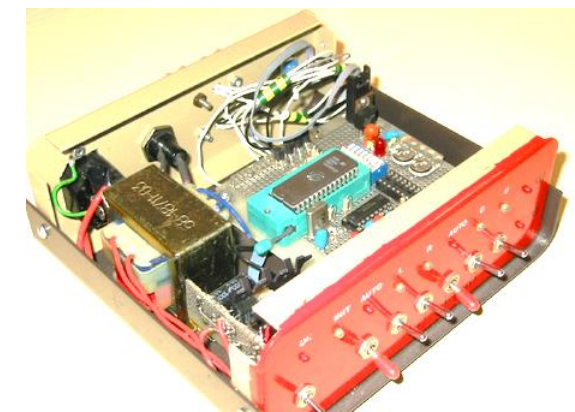


- Richtingsgevoelige antenne is beter
  - 4 elements (145 MHz) of 7 elements (435 MHz)
  - Meer elementen → meer winst  
maar: een kleinere openings hoek!
  - Voorbeelden: Arrow, DL6WU, DK7ZB



# Apparatuur: Rotoren

- Antenne moet de satelliet 'volgen'
  - Horizontaal (Azimuth:  $360^{\circ}$ )
  - Verticaal (Elevatie:  $90^{\circ}$ )
  - Redelijk nauwkeurig ( $5^{\circ}$ )
    - Openingshoek richt-antenne is klein
- Behoorlijk snel draaien:
  - $45^{\circ} \dots 90^{\circ} \dots 45^{\circ}$  elevatie in  $<5$  minuten
  - Optie: vaste elevatie op  $25^{\circ}$ 
    - Satelliet meeste tijd  $<40^{\circ}$  elevatie
- Hand of Computer besturing (interface)
  - Zelfbouw of bouw pakket (LVB tracker)



# Apparatuur: Filters, Coax, Voorversterkers

- 'Mode-J' filter

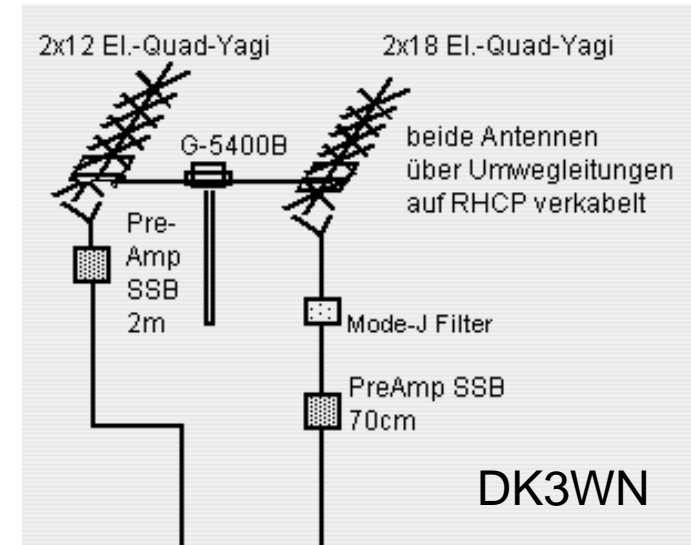
- Invloed TX op RX (harmonische)
- 145 MHz uplink bij 435 MHz downlink

- Antennekabel (coax)

- Portabele (<2 meter): gewoon RG58 gebruiken
- Vaste opstelling (rotor lussen etc. → 15 meter): goede coax

- Voorversterkers

- Niet nodig voor betere SNR (ontvangers goed genoeg)
- Compenseren verlies door lange antennekabels (coax)





# Apparatuur: Zenders & Ontvangers

## ■ Full-duplex?

- Geïntegreerde full-duplex set is fraai
- Maar twee losse sets gaat ook prima!
- All-mode 2m en 70cm beste eerste keus



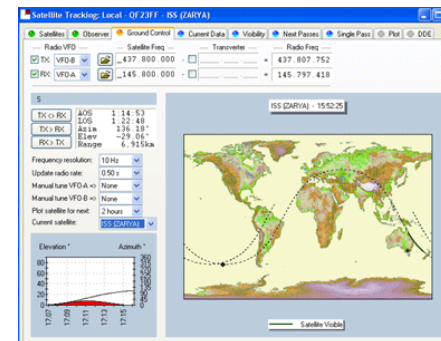
## ■ Wees creatief

- Zonder de nieuwste set kan het ook!
- SDR (FUNcube Dongle) + TX (FT817ND)



## ■ Doppler correctie

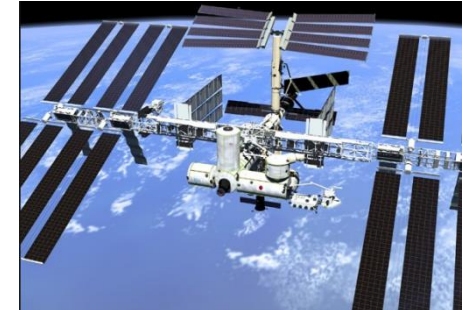
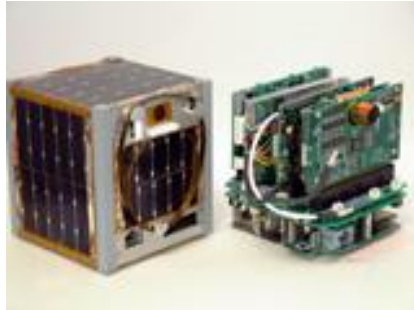
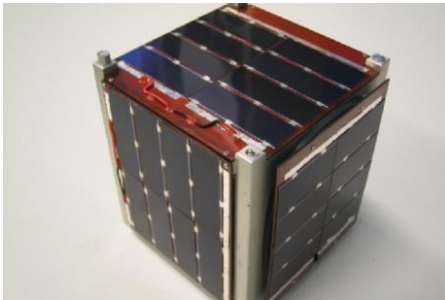
- Handmatig/geheugens of PC
  - SATPC32, HamRadioDeluxe, ..



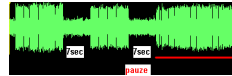
Memory	ISS freq (RX)
Mem A	145.827
Mem B	145.825
Mem C	145.823

# Verbindingen maken: 1<sup>e</sup> stap (leren ontvangen)

SEEDS II (CO-66)	437.485 MHz	CW	90mW
CU XI-V (CO-58)	437.465 MHz	CW	80mW



jqllygu seeds 📢



BJ1SA ... 📢



<b>Hope-1 (HO-68)</b>	435.790 MHz	CW	200mW
ISS	145.825 MHz	APRS	10-25W

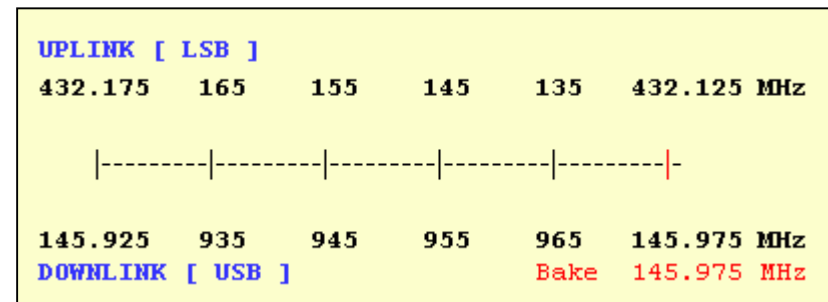
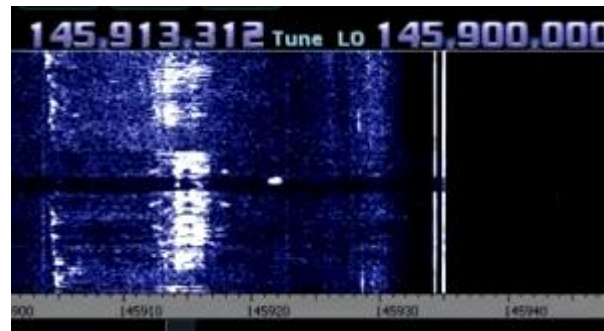
→ Ervaring met richten & grootte van antennes

→ Gevoel voor sterkte en verloop (doppler) van signalen

# Verbindingen maken: Spraak & Digitaal

## ■ Spraak

- FM repeater: net als een gewone 'land' FM repeater
- SSB transponder: als een stukje kortegolf band dat gekopieerd wordt (goed zichtbaar op een SDR)



Bron: DK3WN (AO7 Transponder)

## ■ Digitaal

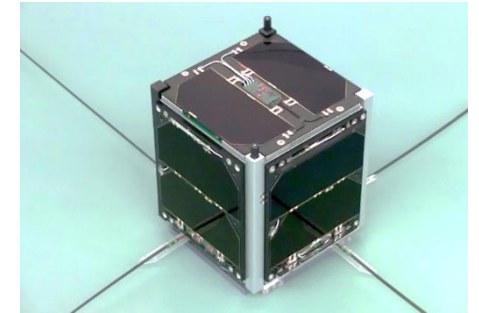
- ISS APRS: net als normaal APRS op 144.800 MHz
  - Settings: "HBAUD 1200" + "U CQ VIAARISS" op 145.825 (U/D)
  - Livestream: [www.ariss.net](http://www.ariss.net) en kijk op [www.issfanclub.com](http://www.issfanclub.com)
  - "chatten" via ISS: "Hello IK8ABC, 73's from Holland"


# Verbindingen maken: Repeaters & Transponders

**SO-50** Up 145.850 (FM + 67 Hz tone) Down 436.800 (FM)



**ISS** Up 145.825 (FM) Down 145.825 (FM)



**FO-29** Up 145.900 - 146.000 (LSB)  Down 435.800 - 435.900 (USB)

**AO-73** Up 435.150 - 435.130 (LSB) Down 145.950 - 145.970 (USB)

→ Tegelijkertijd antenne richten & een QSO maken (FM)

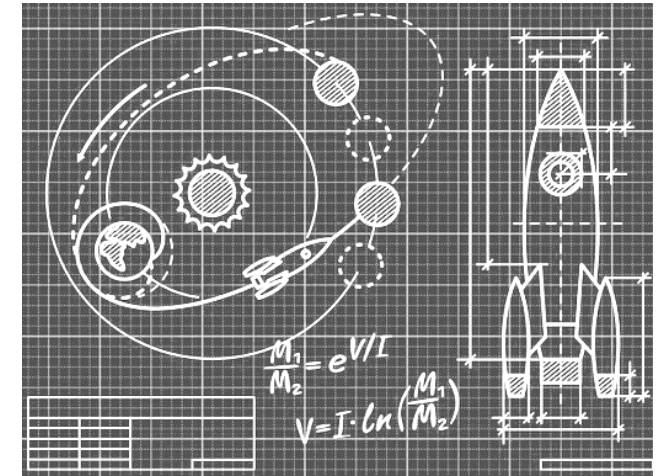
→ Nauwkeurig afstemmen, up & down tegelijk! (SSB)




# Zendamateurs en ruimtevaart

- OK... dus wat kunnen we doen BEHALVE gebruik maken van Amateur Satelieten?

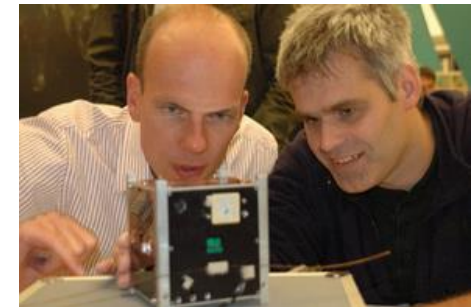
- Wetenschappelijke Experimenten!



- RAFT, ANDE1, ANDE2, ..
- RAX, Grifex, Nanosail, O/OREOS 
- Delfi, LithuanicaSAT01, .. (onderzoek + HAM radio!)
- + vele Japanese projecten

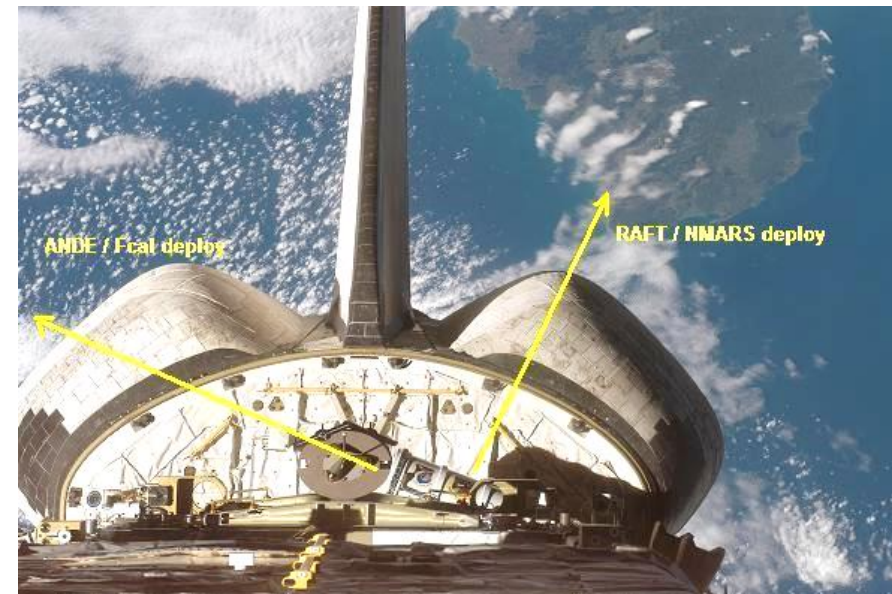
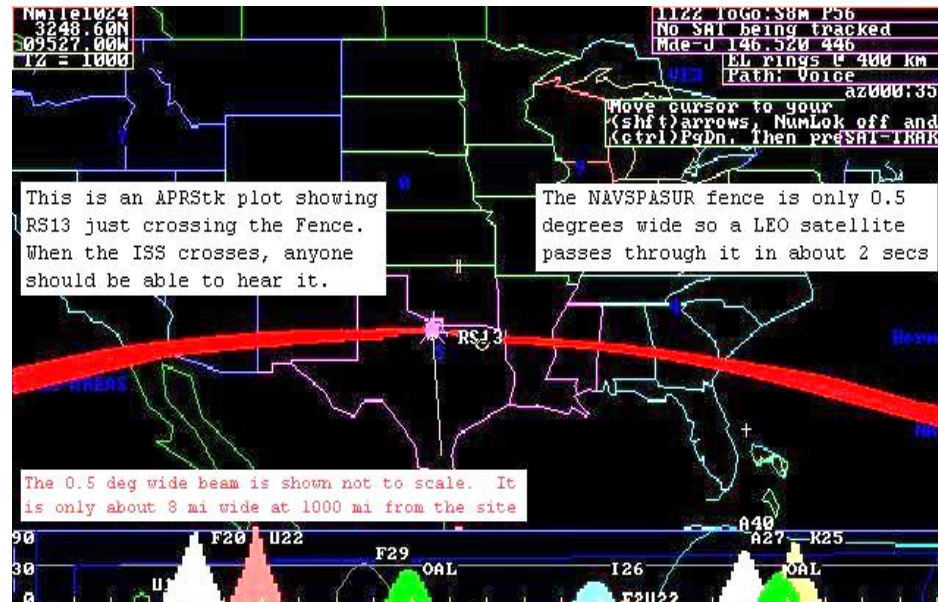
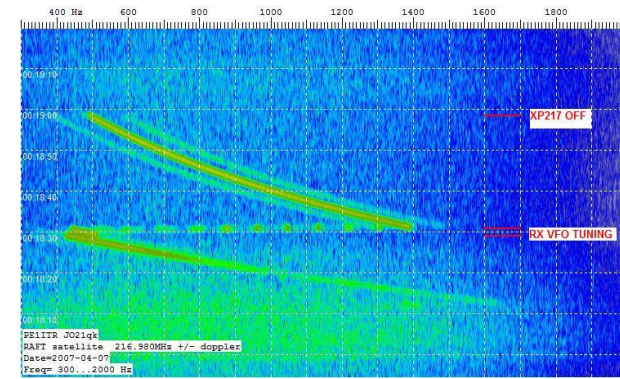
# Daarom zijn Radio Amateur belangrijk!

- Radiocommunicatie
  - Niet onderzoeks-hoofddoel van de universiteiten
  - Soms (vaak) zelf geen grondstation
- Footprint / access
  - Spannend moment: direct na lancering
  - Meer contacttijd: meer data
- Ervaring is beschikbaar
  - Bewezen radio-installaties & operators staan klaar, óók tijdens weekenden
  - Hulp bij bepalen van de juiste kepler set's na lancering



# RAFT, ANDE, MARS, FCAL

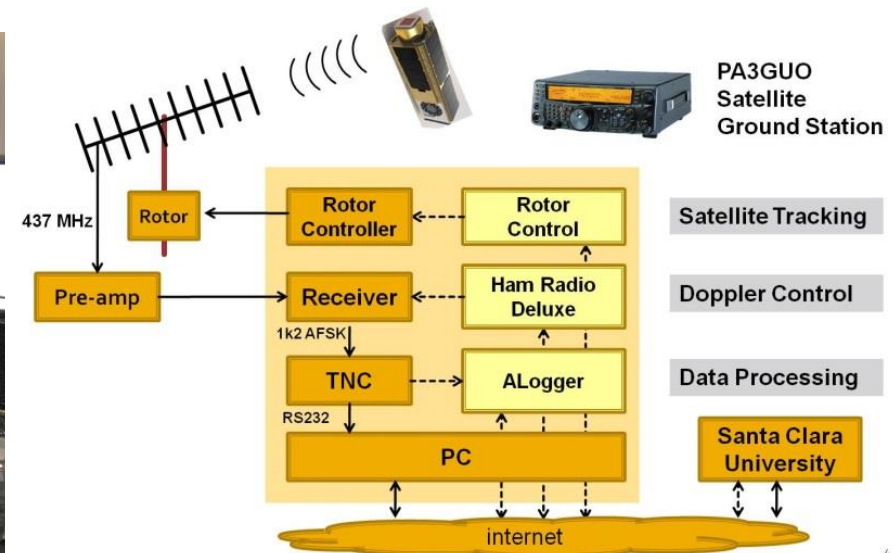
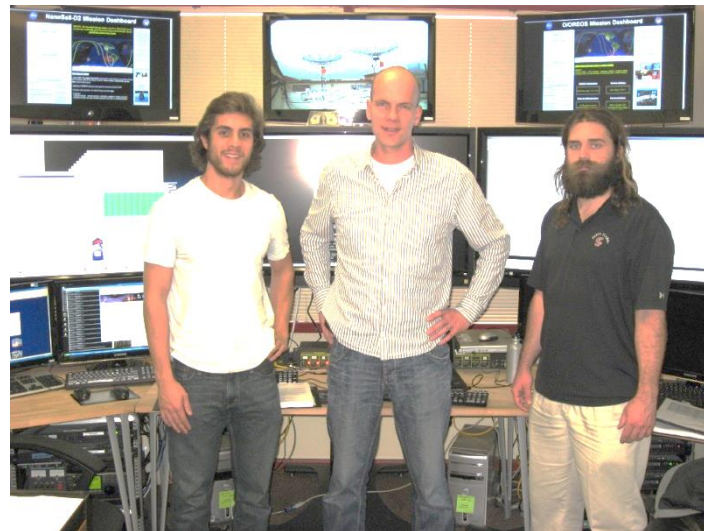
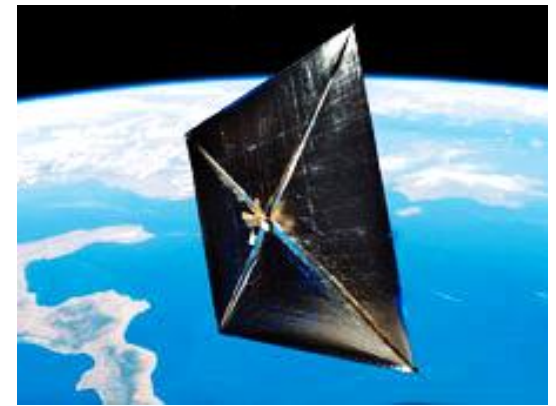
- USNA Satellite Lab, Bob Bruninga
- PE1ITR/Rob, DK3WN/Mike, PA3GUO/Henk
- RAFT moest bewezen worden boven US (vliegend door de 'radar fence')





# Nanosail & O/OREOS

- NASA projecten
- Ondersteund door SCU (San Jose, US)



- FASTSAT Lancering, geen 'deploy', toen 'her-ontdekt'
- Sail opende boven Spanje: alleen bereik vanuit Europa



# RAX, Mcubed, Grifex

- University of Michigan, James Cutler
- Onderzoek van Space Weather



**RAX2 Ground Station Client**

Altitude			Communications			External Panels		
Name	Value	Unit	Name	Value	Unit	Name	Value	Unit
RMI Mag Z	-0.1383	Gauss	LMP NCHD	12759	commands	A3 Current	25	milliamps
RMI Mag Y	-0.1421	Gauss	LMP Radio Temp	0	deg C	A4 Current	12	milliamps
RMI Mag X	-0.3355	Gauss	LMP RSSI	-105.3063	dBm	A7 Current	62	milliamps
Gyro X	-0.5125	deg/sec	Queue Status	0	packets	A8 Current	0	milliamps
Gyro Y	-0.6125	deg/sec	DMF # RX	862	bytes	A3 Voltage	15.8815	volts
Gyro Z	7.6125	deg/sec	DMF # TX	1359112	bytes	A4 Voltage	10.6744	volts
Gyro Mag X	0.558	Gauss				A7 Voltage	15.3985	volts
Gyro Mag Y	0.1365	Gauss				A8 Voltage	11.6291	volts
Gyro Mag Z	0.4305	Gauss						

Power System			Satellite State			Black Temperature		
Name	Value	Unit	Name	Value	Unit	Name	Value	Unit
3.3V Current (EPS)	76	milliamps	FB	Disabled		CPU Temp	19.3486	degrees C
5V Current (EPS)	155	milliamps	PIM	Disabled		EPS Output Reg Temp	18.6547	degrees C
Batt Current (EPS)	17	milliamps	IDPU	Disabled		Batt Board Temp	10.3078	degrees C
5V Voltage (BB)	4.96	volts	ADB	Enabled		PTB Board Temp	8.6	degrees C
3.3V Voltage (BB)	3.296	volts	PFB	Disabled		LMP Board Temp	8.0	degrees C
Batt Voltage	8.1694	volts	WOB	Enabled		ADB Board Temp	13.020	degrees C
			LMP	Enabled		IDPU Board Temp	14.6	degrees C
			Antenna Switch	L3Huan		PIM Board Temp	8.6	degrees C
			Polarization Switch	R1PCP				
			Command Queue	0	commands			

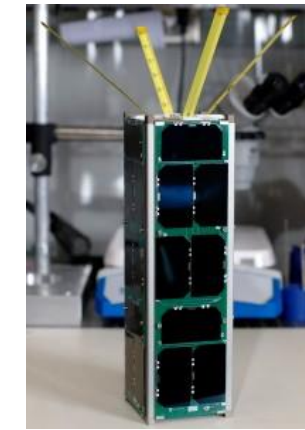
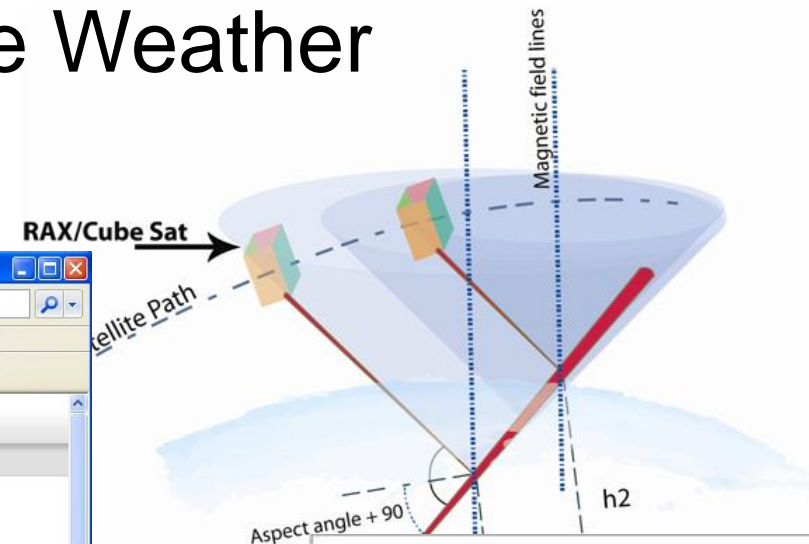
```

18 Nov 2011 10:54:27 GMT
18 Nov 2011 10:54:47 GMT
18 Nov 2011 12:23:46 GMT
18 Nov 2011 12:24:06 GMT
18 Nov 2011 12:25:06 GMT
18 Nov 2011 12:25:26 GMT
18 Nov 2011 12:25:46 GMT
18 Nov 2011 12:26:06 GMT
18 Nov 2011 12:27:27 GMT
18 Nov 2011 12:27:47 GMT
18 Nov 2011 12:28:07 GMT
18 Nov 2011 12:28:27 GMT
18 Nov 2011 12:29:07 GMT
18 Nov 2011 12:29:27 GMT
  
```

**RAX**

```

!S 12: 40:50 !RAX-1*>CQ:nvm8k|VMI!liigOG~s
!S 12: 41:10 !RAX-1*>CQ:nvm8k|[[CMn^nm fH-
!S 12: 41:31 !RAX-1*>CQ:nvm8k|[ M*PfgYp
!S 12: 41:51 !RAX-1*>CQ:nvm8k|UiMODcpp 3[
!S 12: 42:11 !RAX-1*>CQ:nv.m8k|Z J1(tggf
!S 12: 42:31 !RAX-1*>CQ:nvCm8rk|Z_JW
!S 12: 42:51 !RAX-1*>CQ:nvUm8k|T H7"ahh3
  
```



**Watching your feed!**

James Cutler <jwcutler@umich.edu>

U hebt dit bericht beantwoord op 28-10-2011 14:48.

Verzonden: vr 28-10-2011 14:45

Aan: Henk Hamoen

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Thanks, looks great!

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James Cutler, Assistant Professor  
University of Michigan  
Department of Aerospace Engineering

# Delfi-C3, Delfi-n3Xt



- Technische Universiteit Delft

- Delfi-C<sup>3</sup>

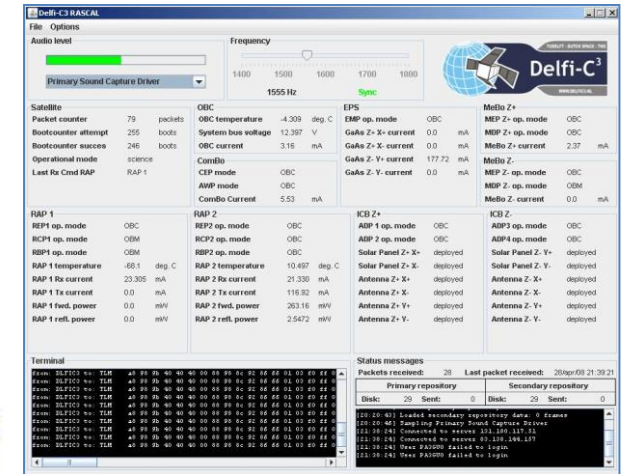
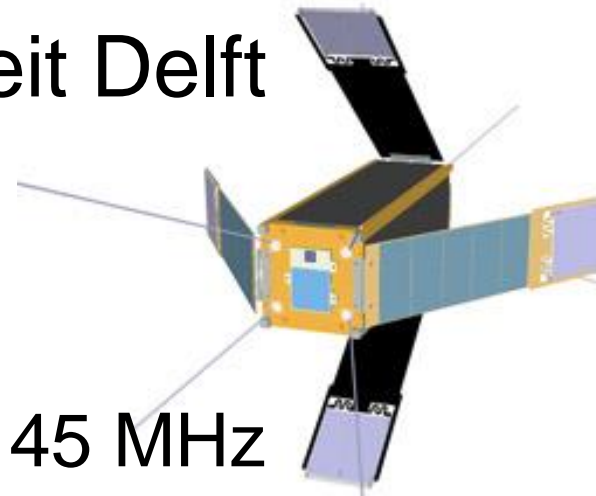
- Lancing: 2008
- Telemetry downlink: 145 MHz
- Transponder: niet meer functioneel (435 → 145 MHz)

- Delfi-n3Xt (2013)

- Lancing: 2013
- Telemetry downlink: 145 MHz

- Delfi-??

- Meer in de lezing van Nils !



# Meer informatie



<http://amsat.org/pipermail/amsat-bb> AMSAT wereldwijd bulletin board (BB)

[www.amsat.org](http://www.amsat.org)

Vooral nieuws uit US, meeste info niet actueel

[www.dk3wn.info](http://www.dk3wn.info)

Alle details over elke satelliet + sat blogs

[www.issfanclub.com](http://www.issfanclub.com)

Laatste nieuws, status ISS, discussie forums

[www.amsat-uk.org/](http://www.amsat-uk.org/)

Actueel satellite nieuws

[www.southgatearc.org](http://www.southgatearc.org)

Veel nieuws, prettig leesbaar, actueel

[www.ariss.net](http://www.ariss.net)

Real-time APRS data van het ISS

# Vragen ?