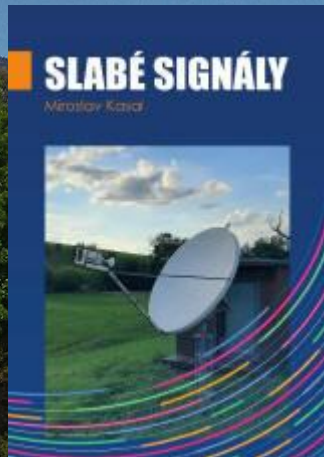


Experimentální radioelektronika jako životní krédo

Miroslav Kasal



E-mail: kasal@vut.cz

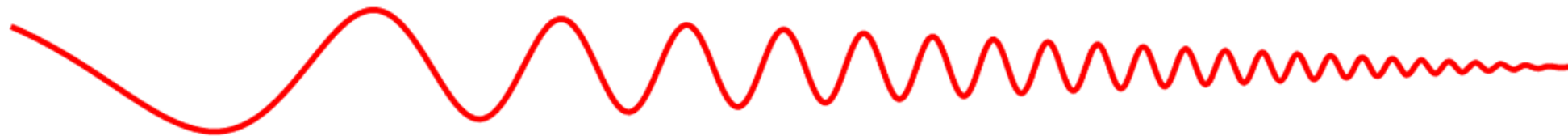
<http://www.urel.feec.vutbr.cz/esl/>



Advertising, as on this car radio demonstration vehicle in 1932, helped to make Motorola a familiar brand name.



Penetrates Earth's Atmosphere?



Radiation Type
Wavelength (m)

Radio
 10^3

Microwave
 10^{-2}

Infrared
 10^{-5}

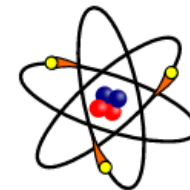
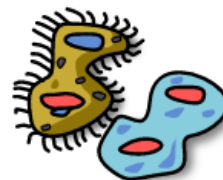
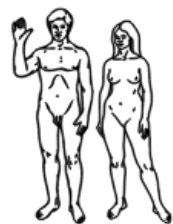
Visible
 0.5×10^{-6}

Ultraviolet
 10^{-8}

X-ray
 10^{-10}

Gamma ray
 10^{-12}

Approximate Scale
of Wavelength



Buildings

Humans

Butterflies

Needle Point

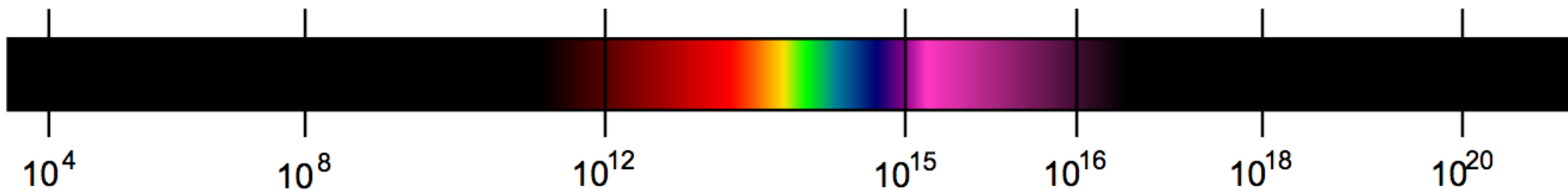
Protozoans

Molecules

Atoms

Atomic Nuclei

Frequency (Hz)



10^4

10^8

10^{12}

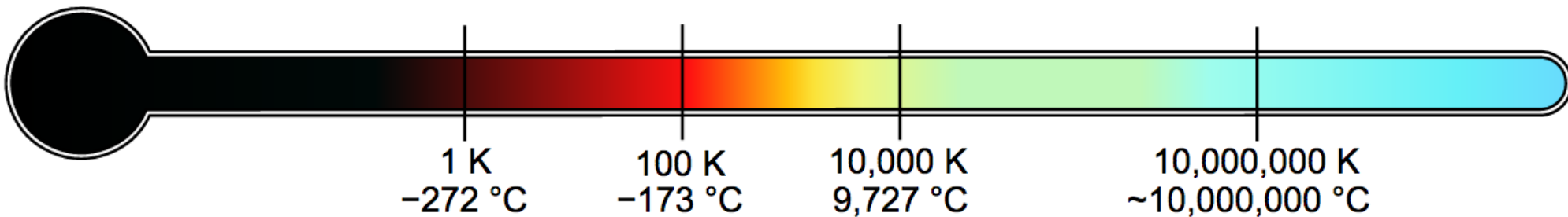
10^{15}

10^{16}

10^{18}

10^{20}

Temperature of
objects at which
this radiation is the
most intense
wavelength emitted



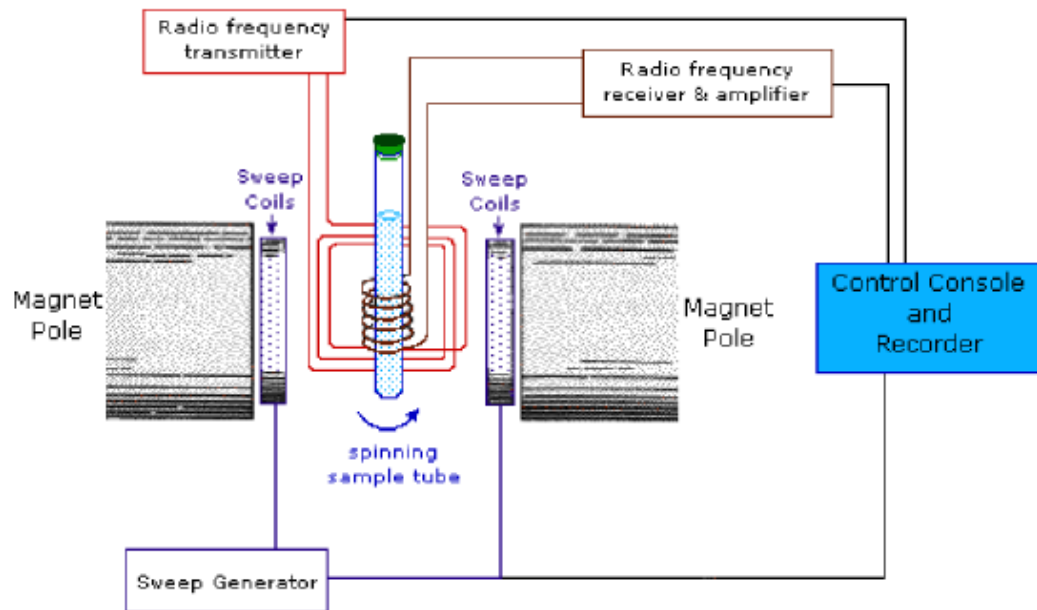
1 K
-272 °C

100 K
-173 °C

10,000 K
9,727 °C

10,000,000 K
~10,000,000 °C

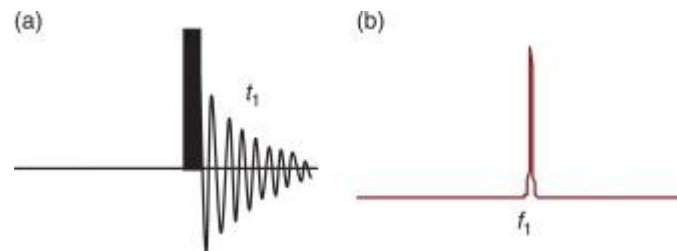
Ústav přístrojové techniky ČSAV 1970 - 2002



- **NMR CW Spektrometr s rozmítáním pole**

- **NMR CW Spektrometr s Time-Sharing**

^1H , ^{19}F , ^{31}P

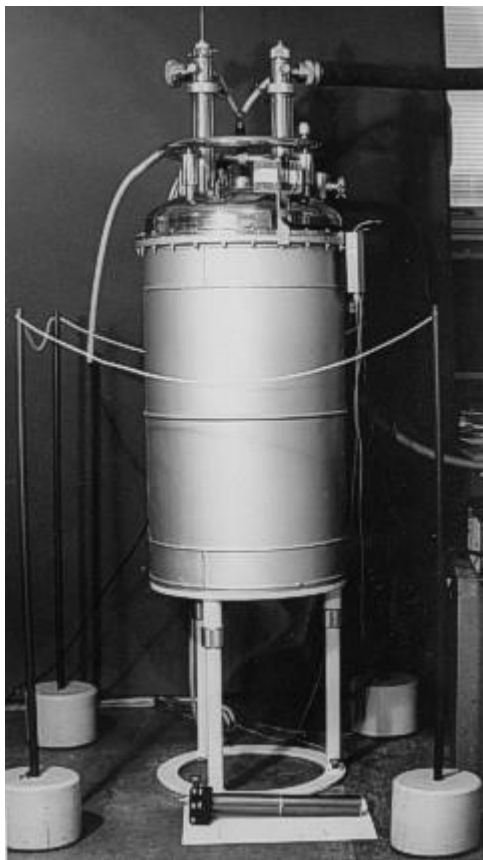


- **NMR Spektrometr s Fourierovou transformací**

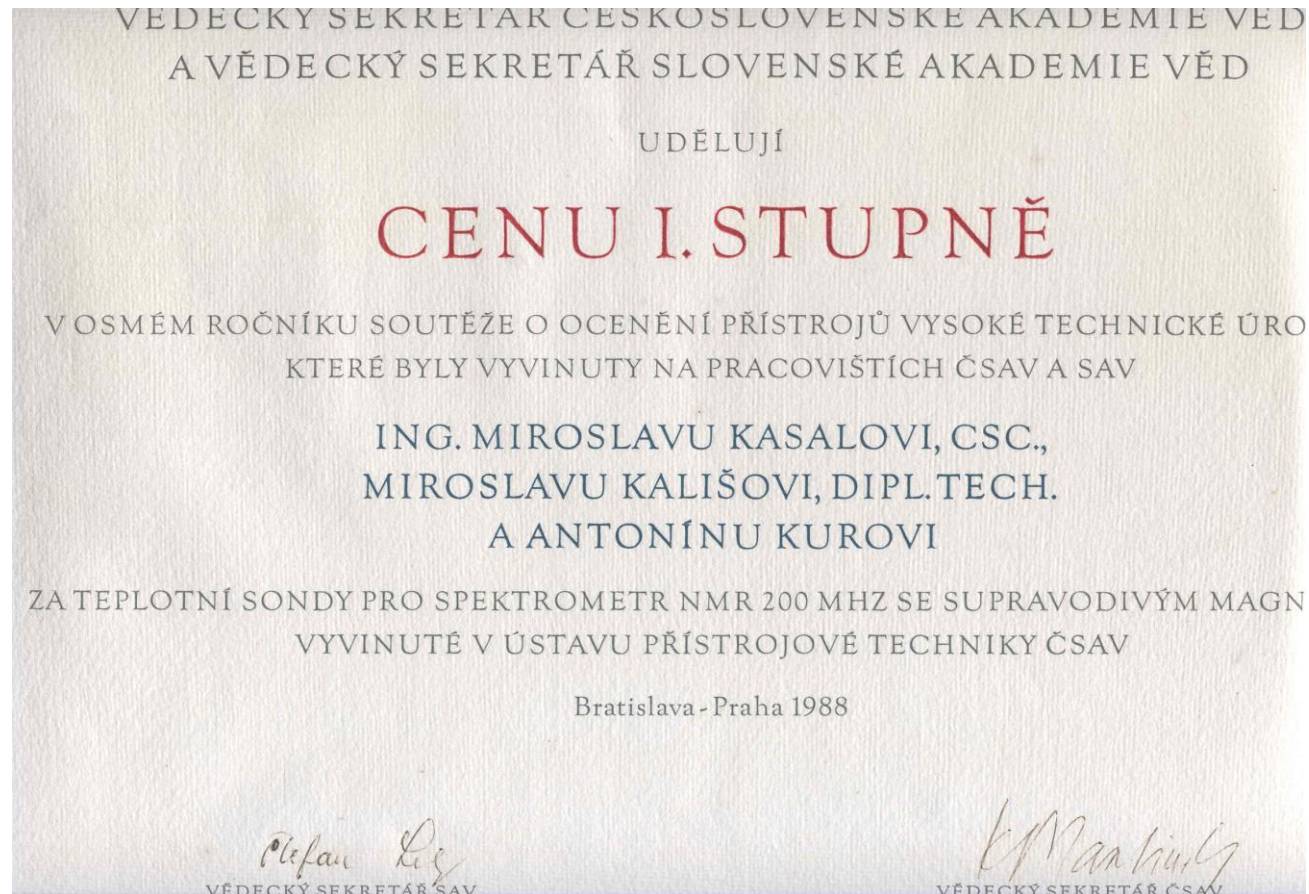
Impulsní buzení, vzorkování odezvy a FFT
 ^1H , ^{13}C

- **Širokopásmový NMR Spektrometr s FFT**

Širokopásmové vf výkonové zesilovače,
širokopásmový přijímač - vysílač
s polyfázovou sítí,
nízkošumové zesilovače - LNA,
teplotní sondy



Spektrometr NMR se supravodivým magnetem 4,7 T (^1H – 200 MHz)



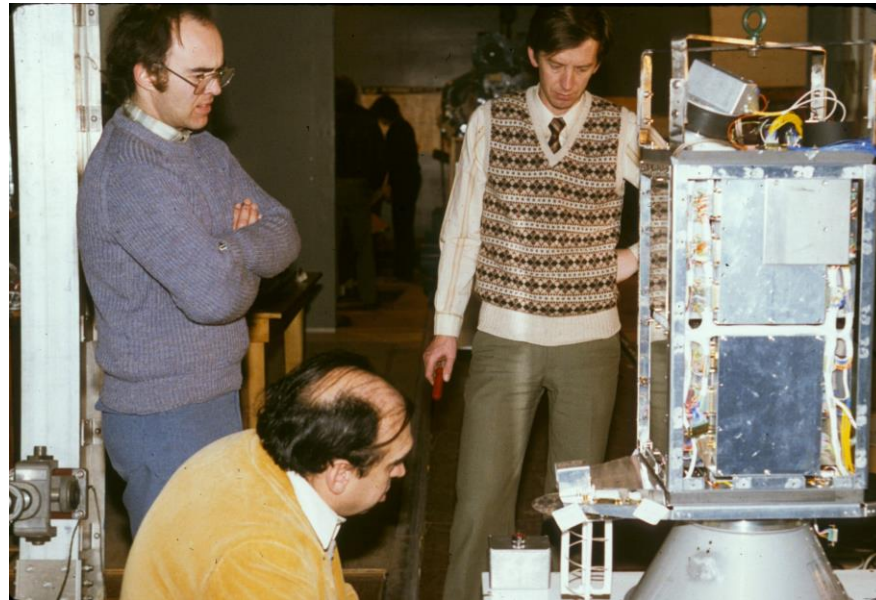
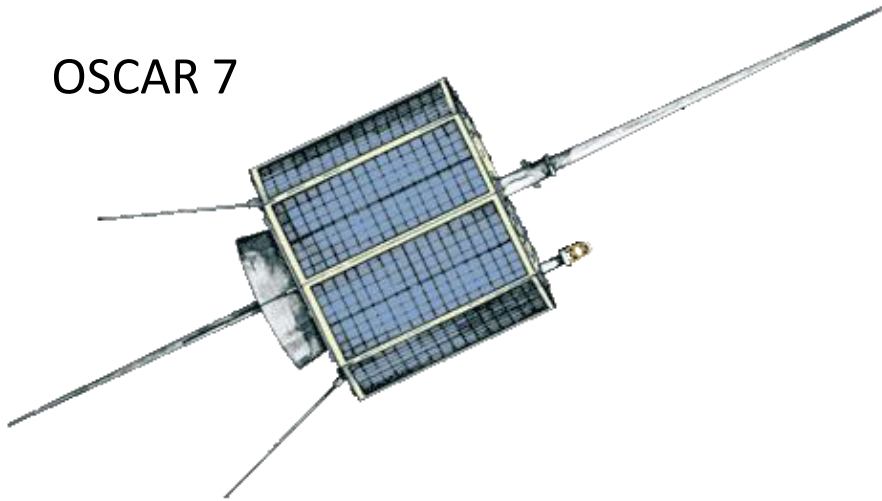
EXPERIMENTÁLNÍ DRUŽICE

AMSAT – Radio Amateur Satellite Corporation – USA – OSCAR 1 - 1961

Univerzita v Marburgu
– prof. K. Meinzer

Univerzita v Surrey
- prof. M. Sweeting

OSCAR 7



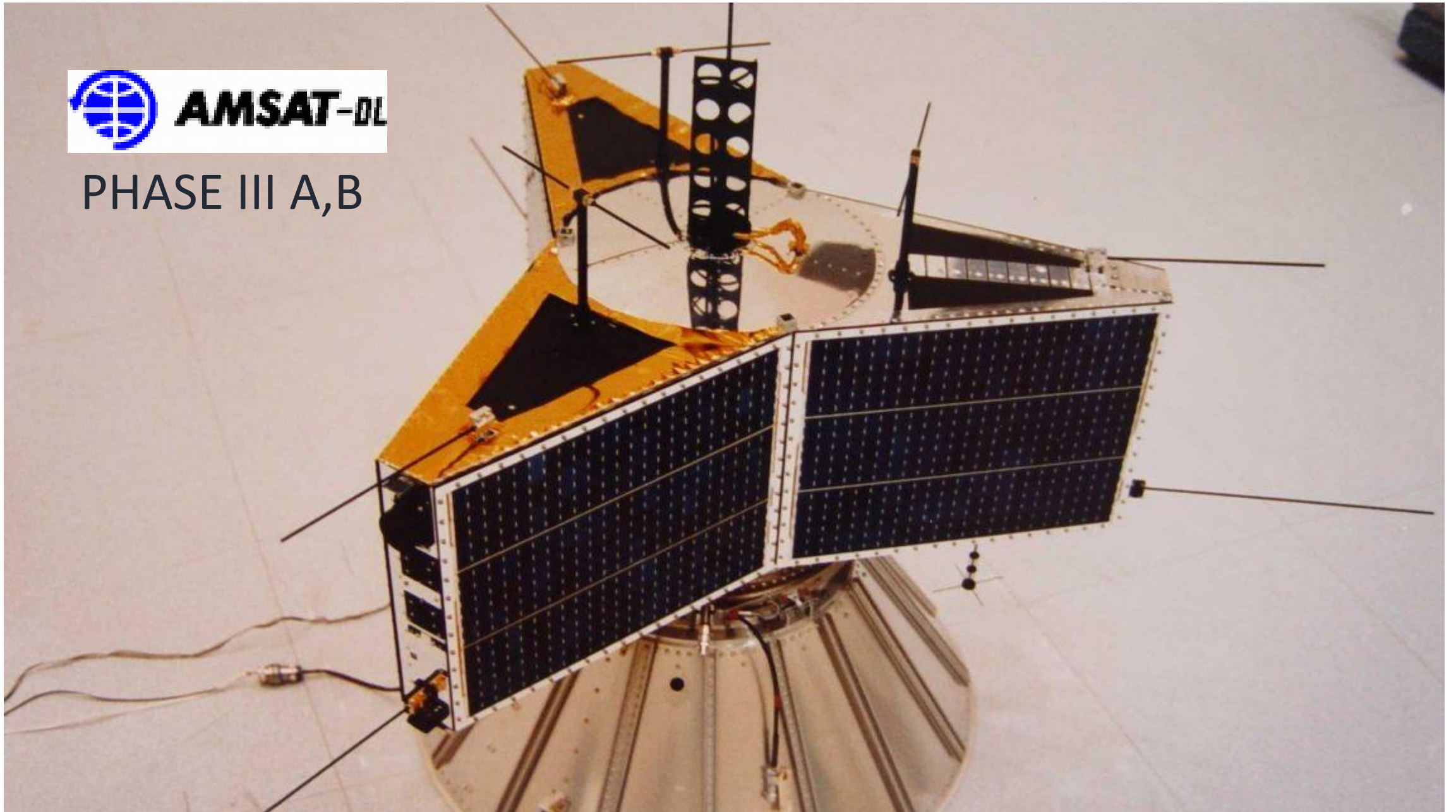
UoSAT 2





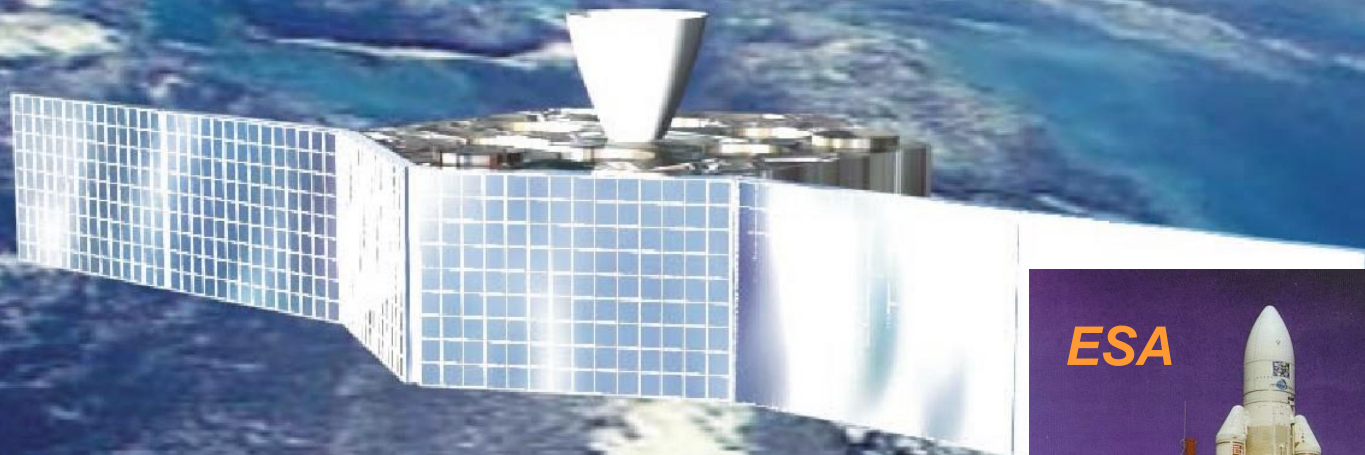
AMSAT-DL

PHASE III A,B



ÚREL FEKT VUT v Brně

Telemetrická a povelovací stanice



AMSAT

Phase 3-D Spacecraft

**CSG Kourou
Ariane 5**

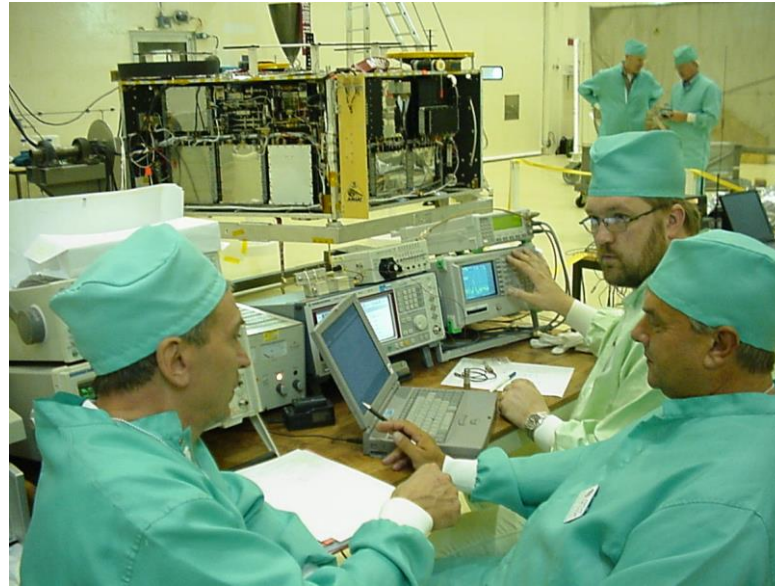
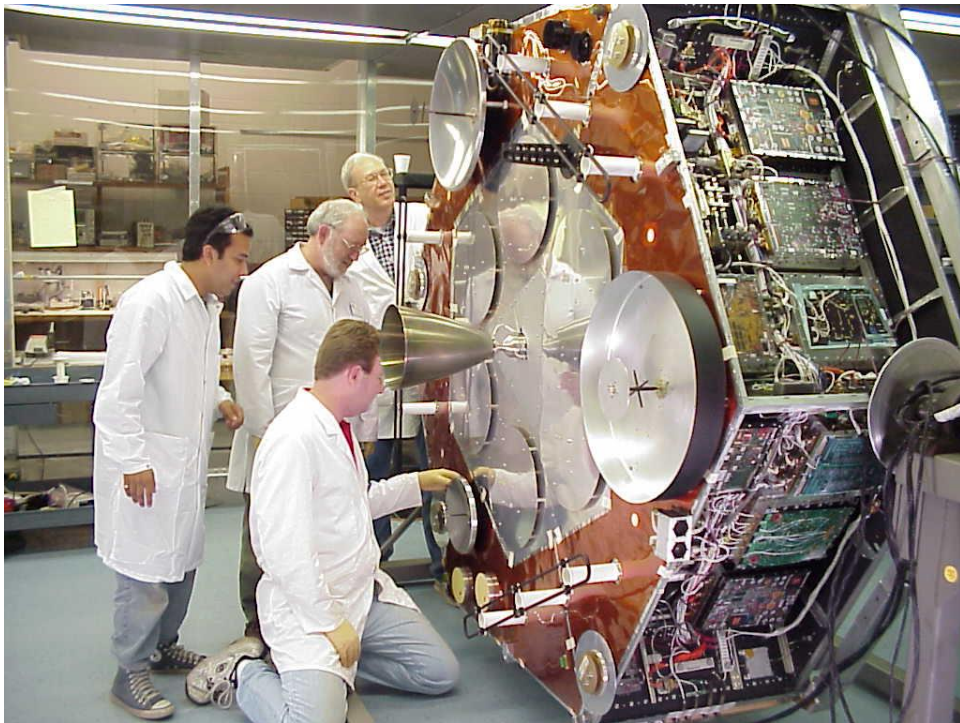


pictures: AMSAT-DL W.Gladisch

EXPERIMENTAL SATELLITE LABORATORY

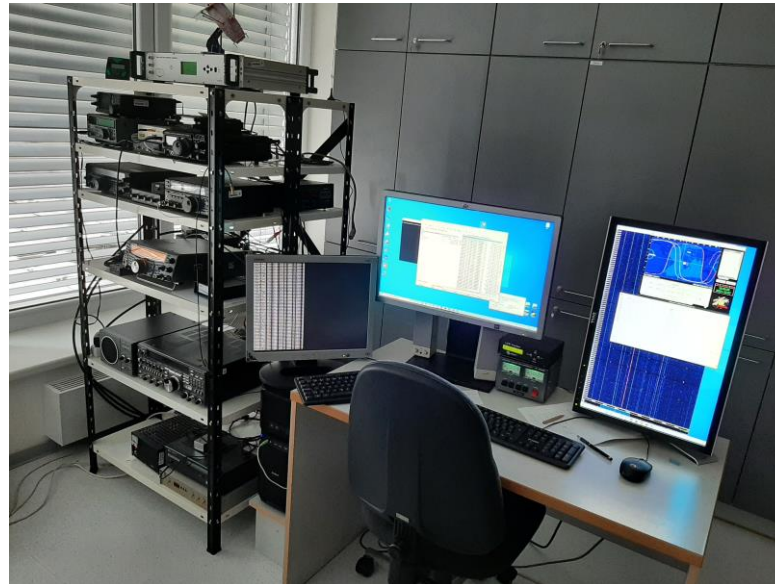
DREL FEKT BUT

AMSAT Phase IIID Satellite

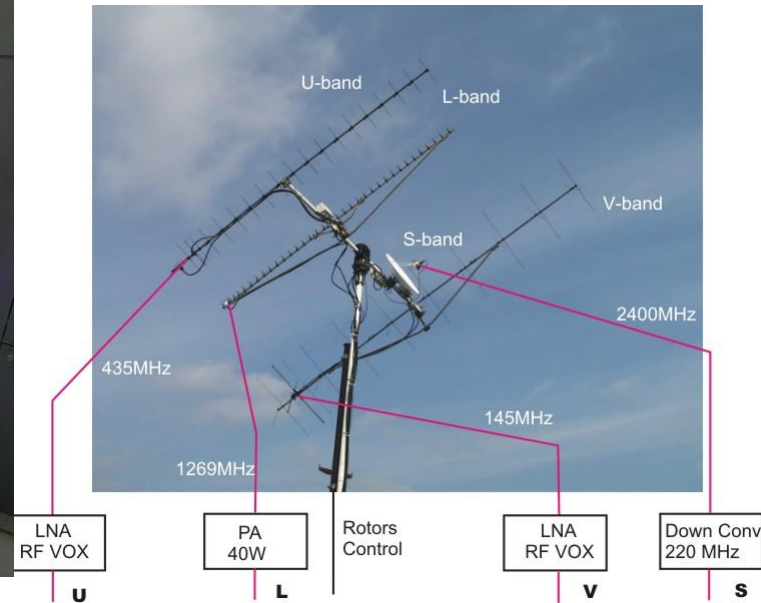


ESA Centre Spatiale Guyanais
Kourou 2000
*PIIID Satellite launch campaign
with Ariane V rocket*

ESL DREL FEKT BUT 2000 -2005
*Ground segment
Telemetry gathering and
satellite control*



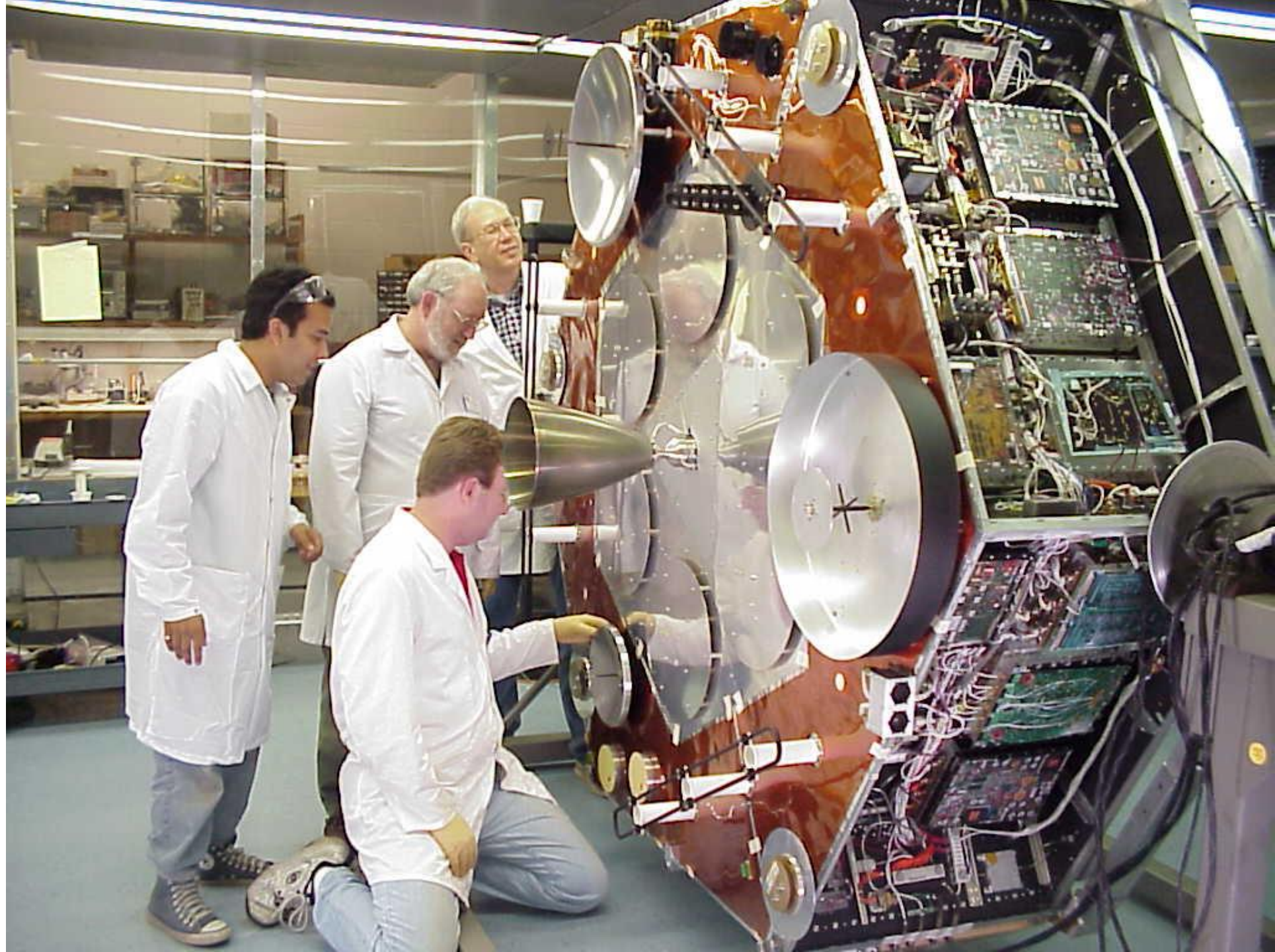
University Marburg 1995 - 1999
AMSAT Facility Orlando FL 1997 - 2000
ESL Brno 1994 - 2000
*Design and realization of L-band receivers,
Satellite integration*



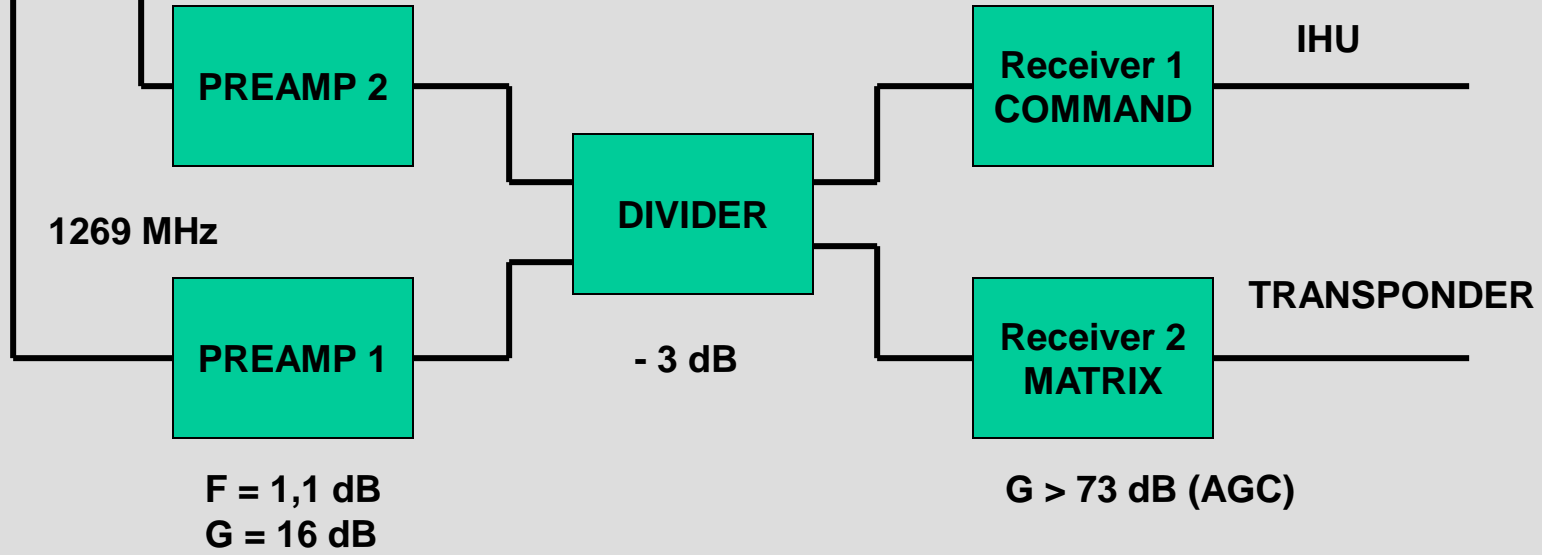
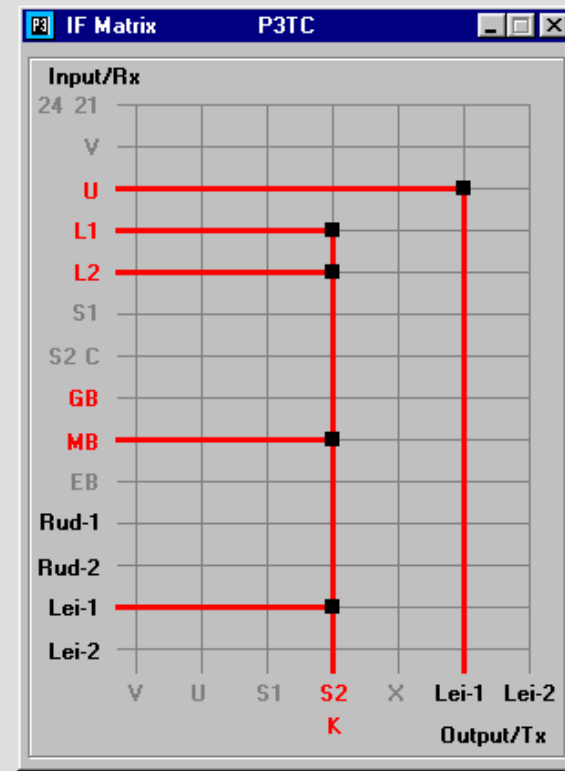
AMSAT Družice P3D

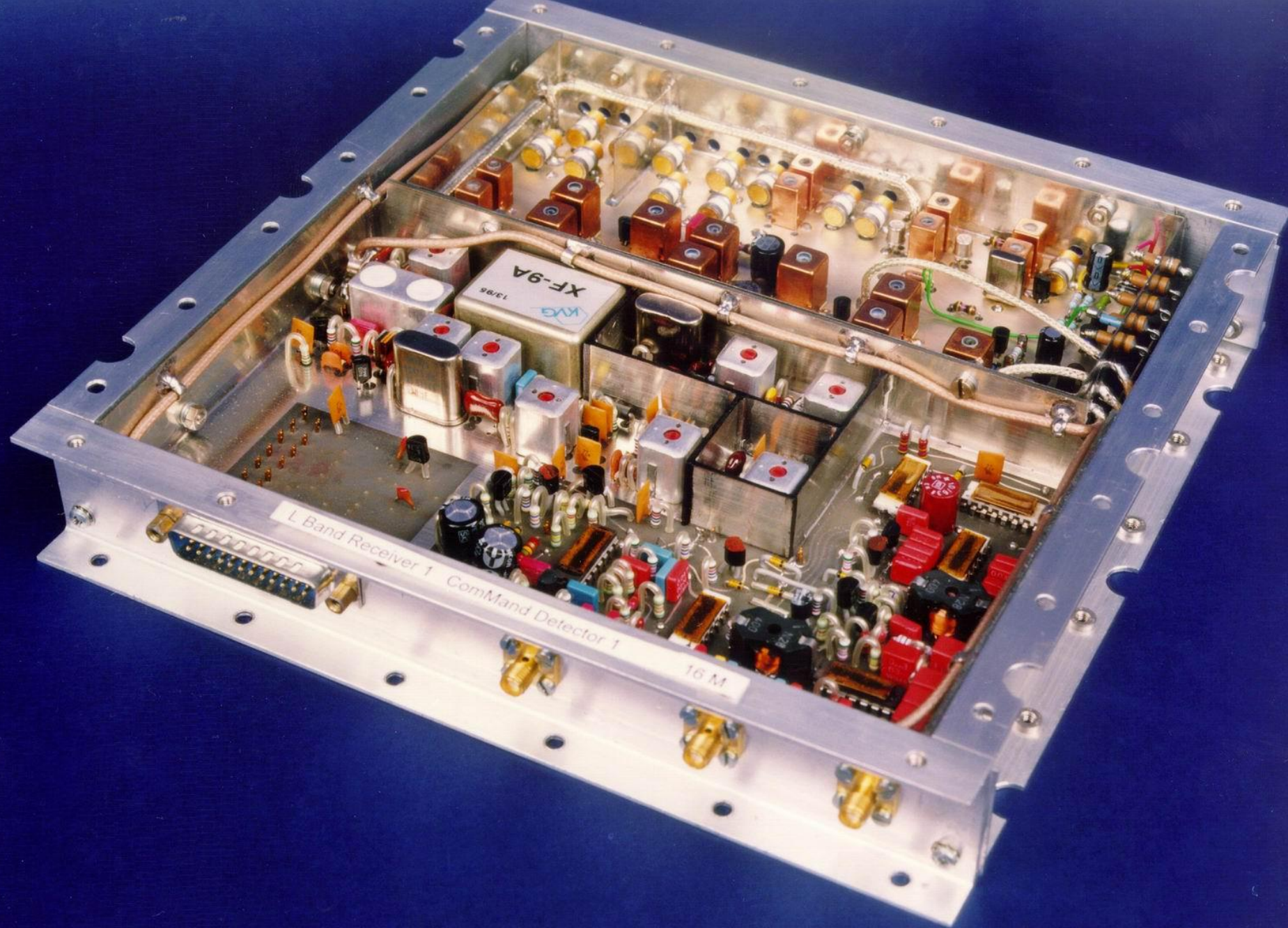
Prof. Dr. Karl Meinzer, University of Marburg

- Maticový transpondér
- Spinová a tří-osá stabilizace polohy družice na dráze HEO
- Tři gyroskopy s magnetickými ložisky
- Dvě barevné kamery s vysokým rozlišením
- GPS navigační systém (NASA)
- Arcjet – plasmový reaktivní motor 0,1 N
- CEDEX
- LASER experiment



AMSAT P3D L-Band Receivers Arrangement





GPS experiment

PRELIMINARY RESULTS OF THE GPS FLIGHT EXPERIMENT ON THE HIGH EARTH ORBIT AMSAT OSCAR 40 SPACECRAFT

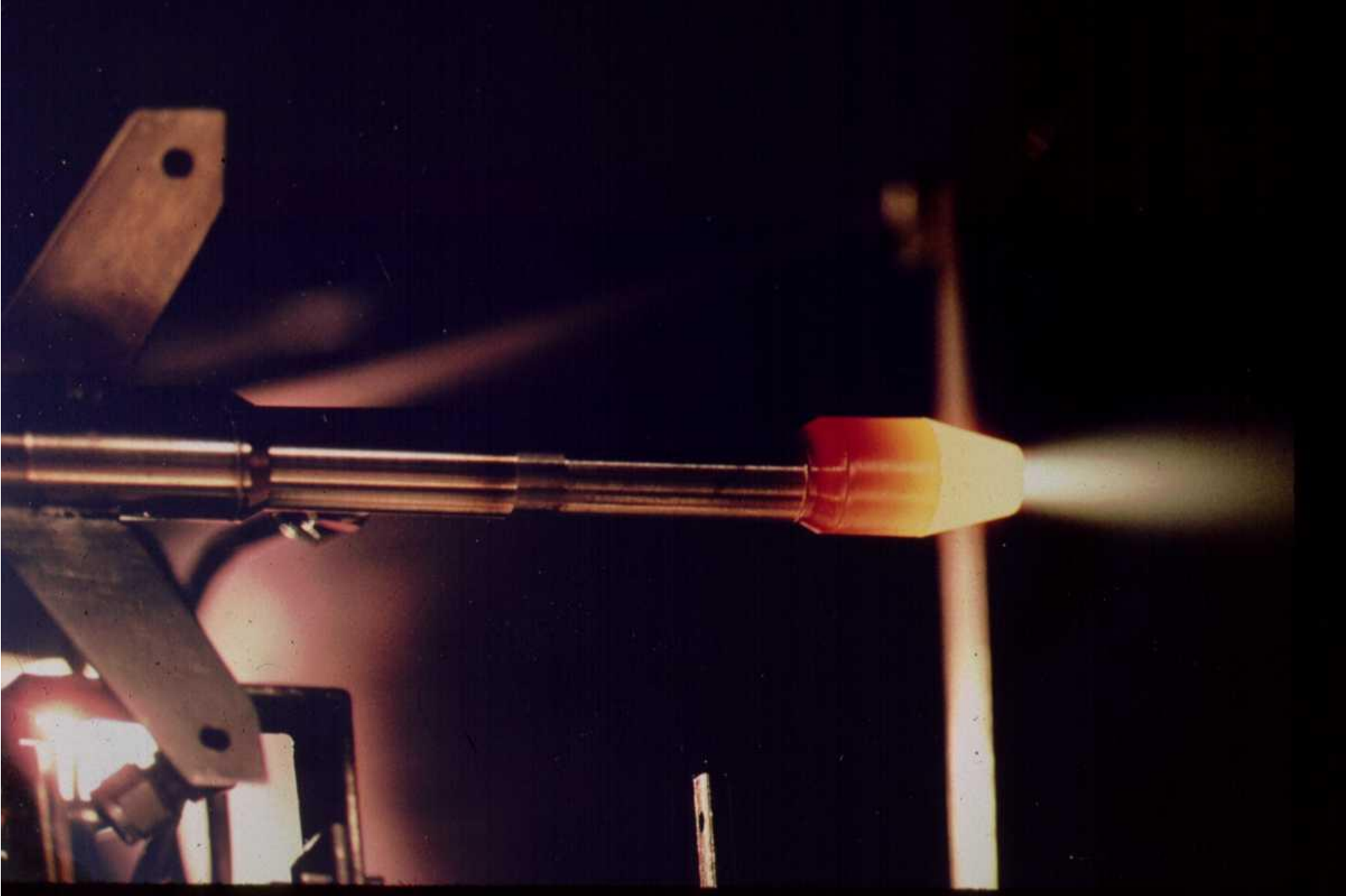
**Michael C. Moreau,* Frank H. Bauer,*
J. Russell Carpenter,* Edward P. Davis,*
George W. Davis † , and Larry A. Jackson ‡**

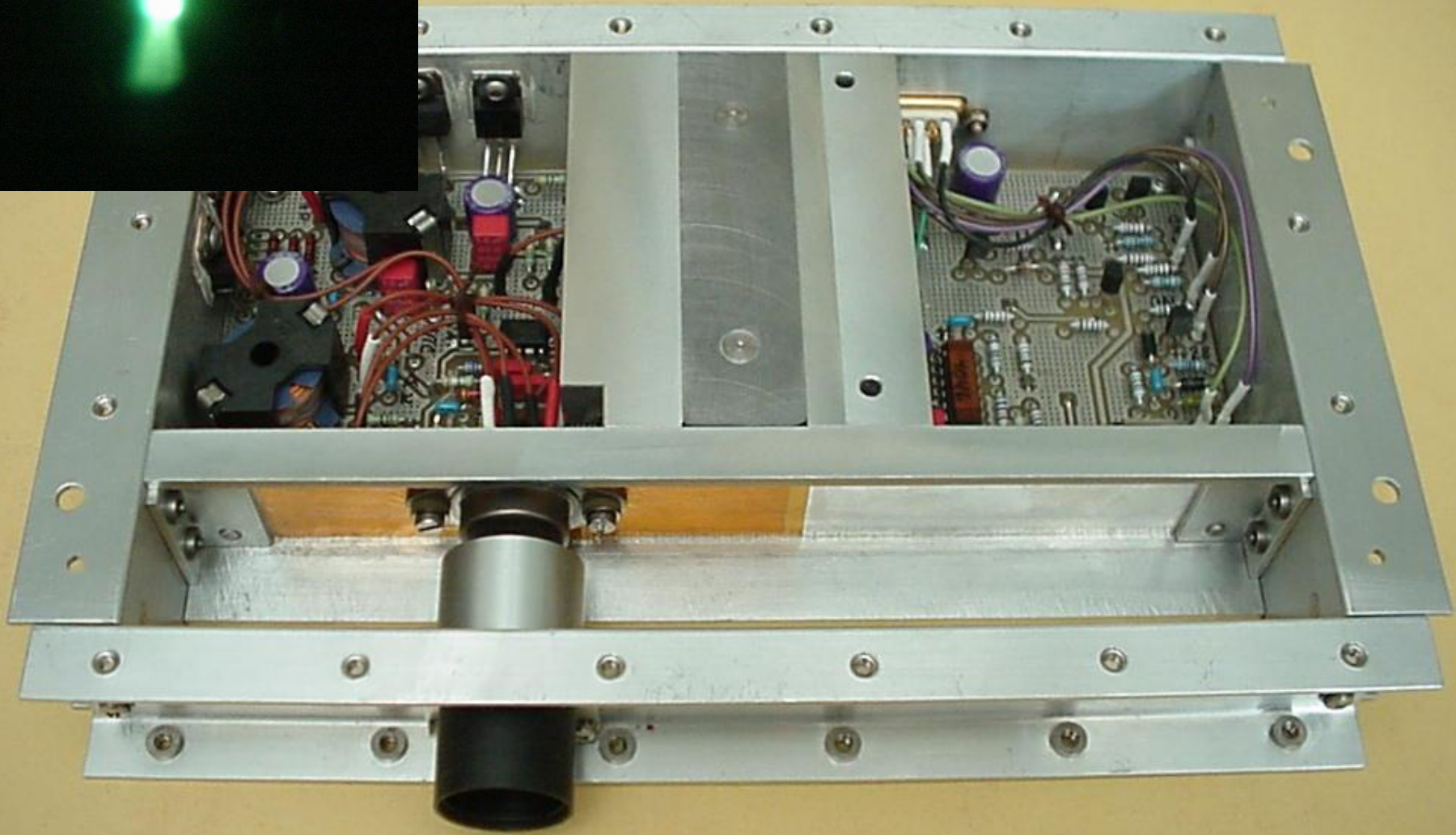
* Guidance, Navigation, and Control Center, NASA Goddard Space Flight Center, Greenbelt, MD 20771

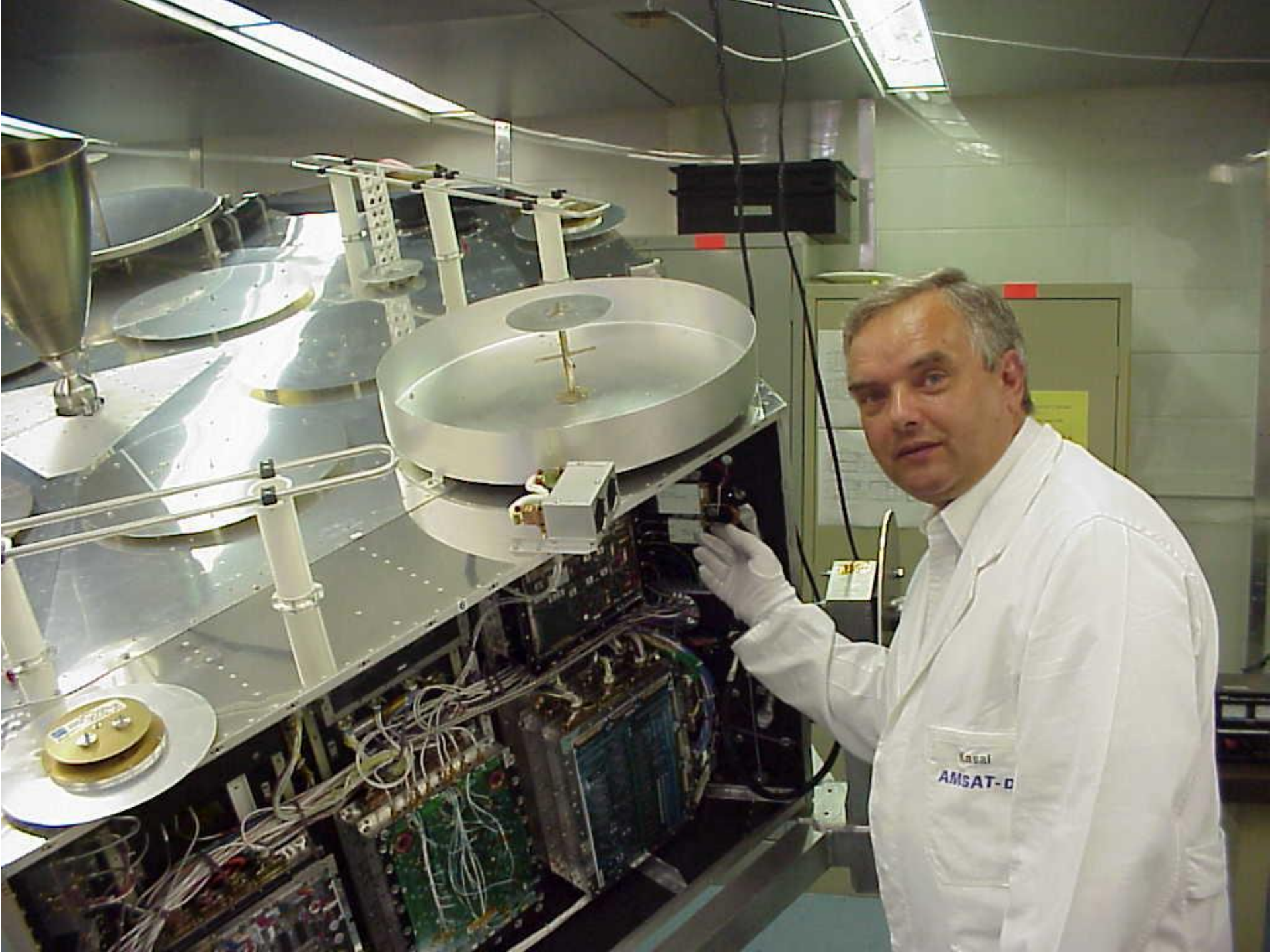
† Emergent Space Technologies, LLC, 3034 Old Channel Rd, Laurel, MD 20724

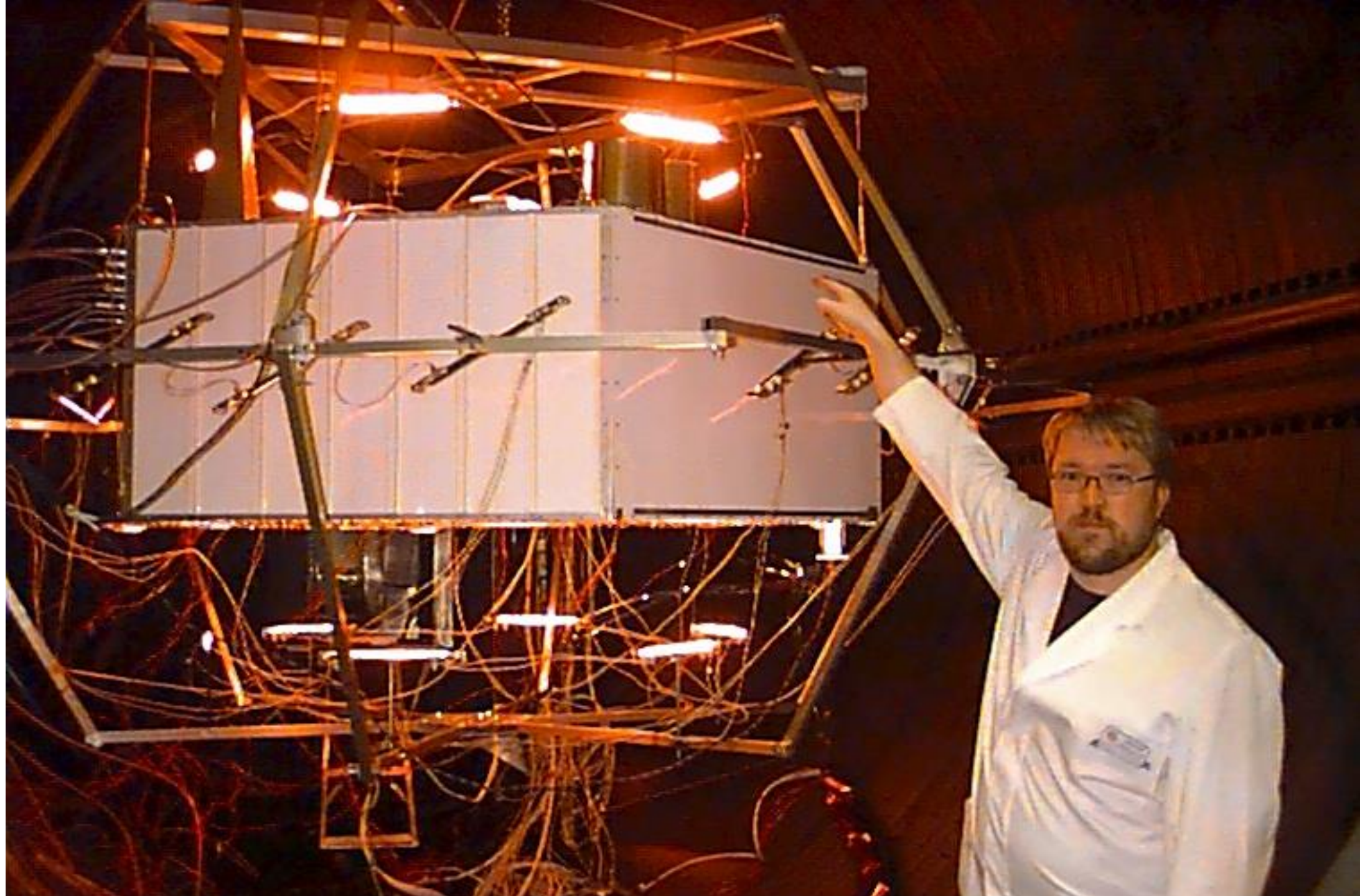
‡ Orbital Sciences Technical Services Division, 7500 Greenway Center Dr., Suite 700, Greenbelt, MD 20770

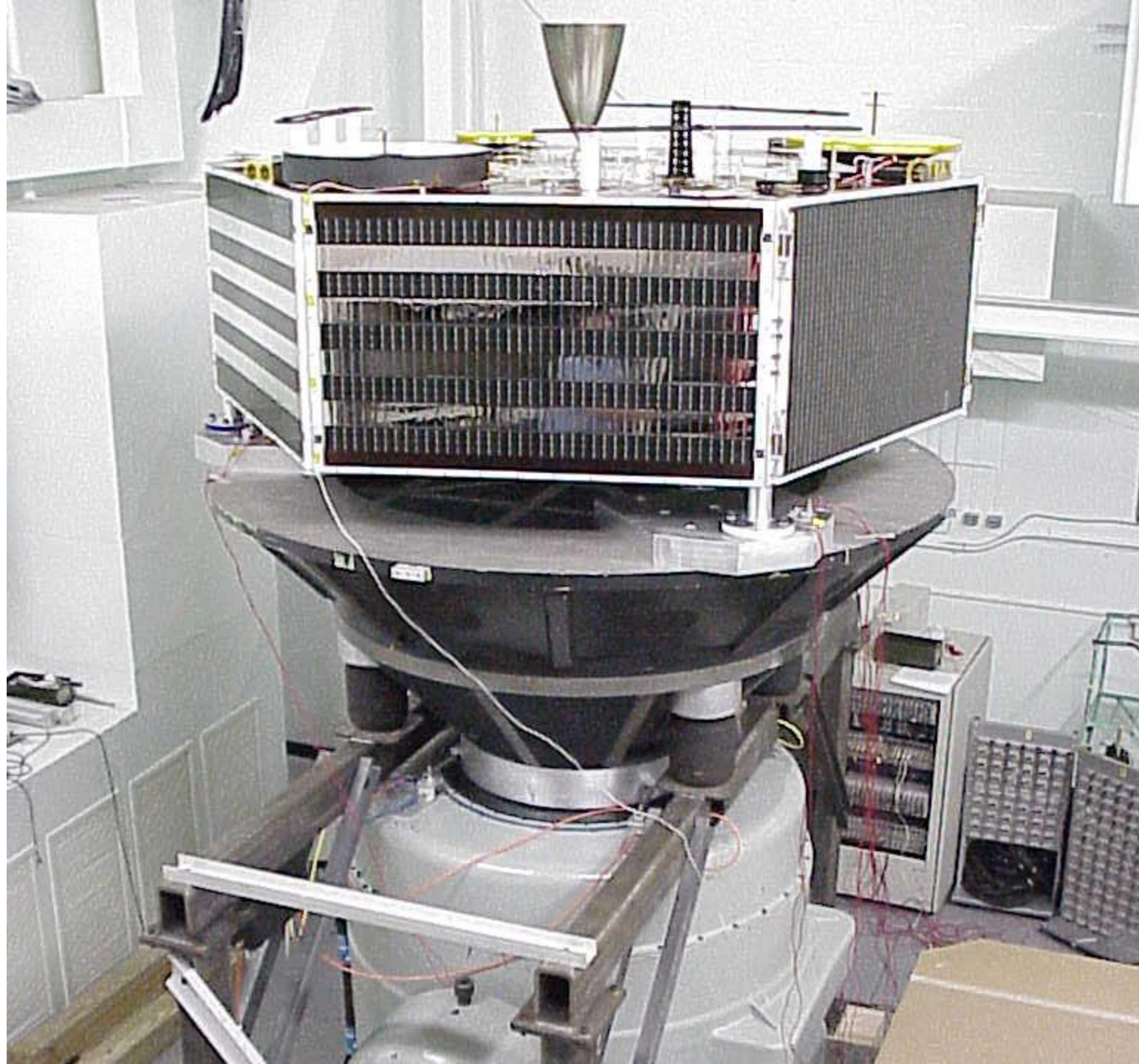
**25 th Annual AAS Guidance and Control Conference,
February 6-10, 2002, Breckenridge, CO 1**

















HOTEL DES ROCHES

BIENVENUE



Bienvenue ***Welcome***

CENTRE SPATIAL GUYANAIS

Port spatial de l'Europe
Europe's Spaceport





Centre Spatial Guyanais



M17290

15/09/04

M

AMSAT DL

038653

MIROSLAV

KASAL





S₃A

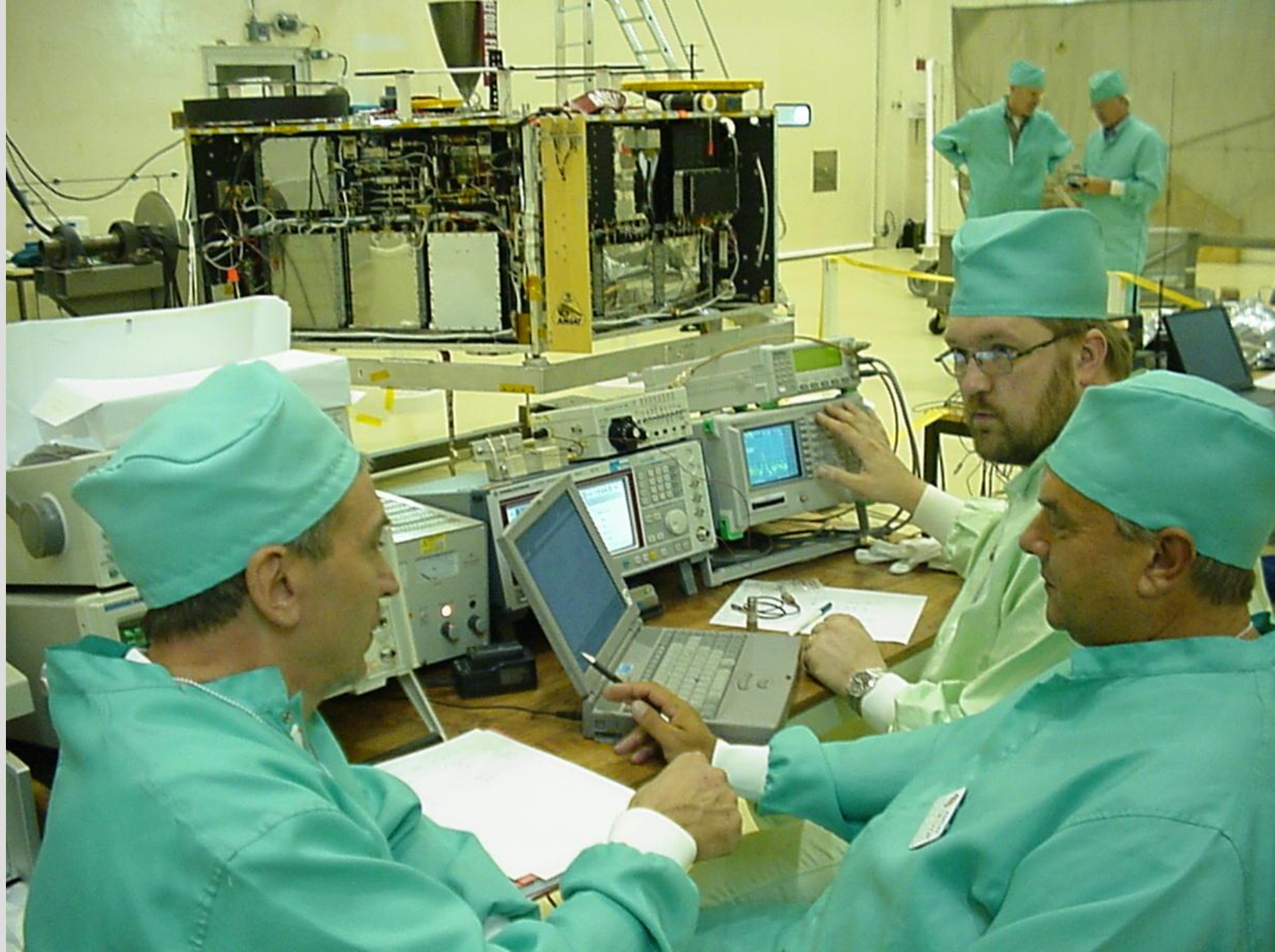
BATIMENT REEMPLISSAGE ET
ASSEMBLAGE SATELLITE
SPACECRAFT FILLING AND
ASSEMBLY BUILDING





ENTREE S3A

















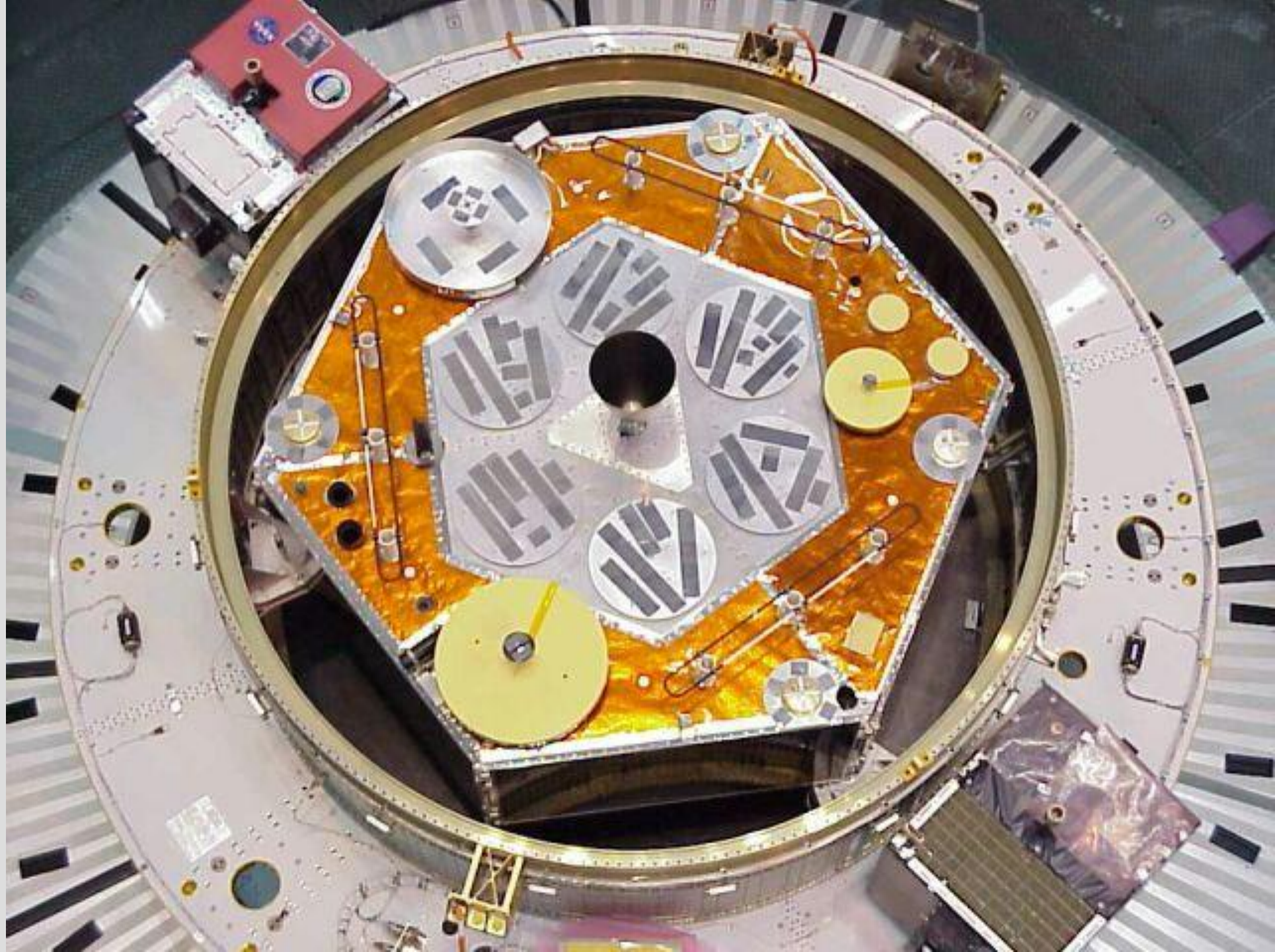
















00.15

arianespace



00.31

arianespace



02.32

arianespace

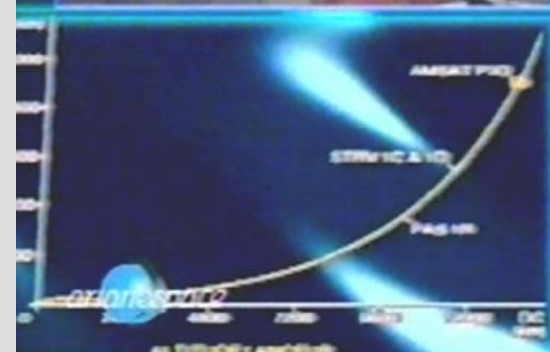
A = 73.6 km
V = 2.11 km/s
CINE



42.58

V 135
PAS 1R
AMSAT P3D
STRV 1C
STRV 1D

T = +2577 s
Moyen: C1S
S = 0.0 deg
A = 5382.1 km
V = 6.58 km/s





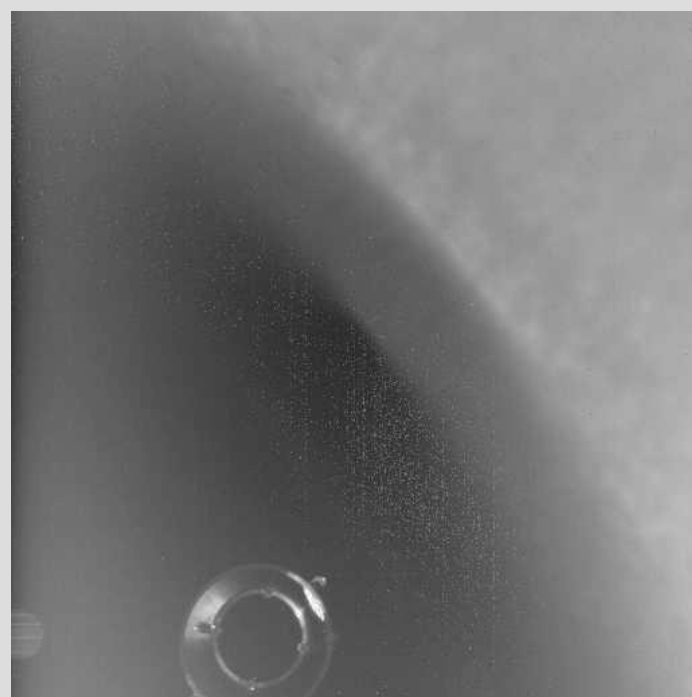
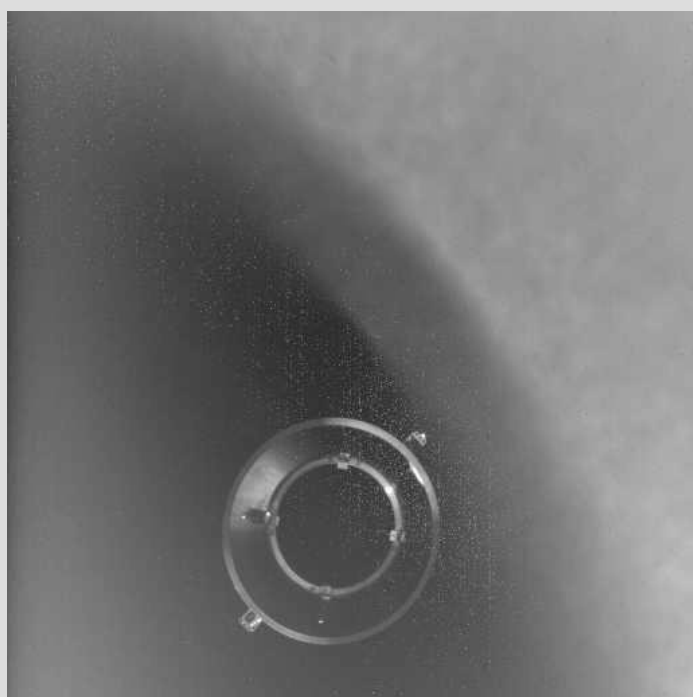
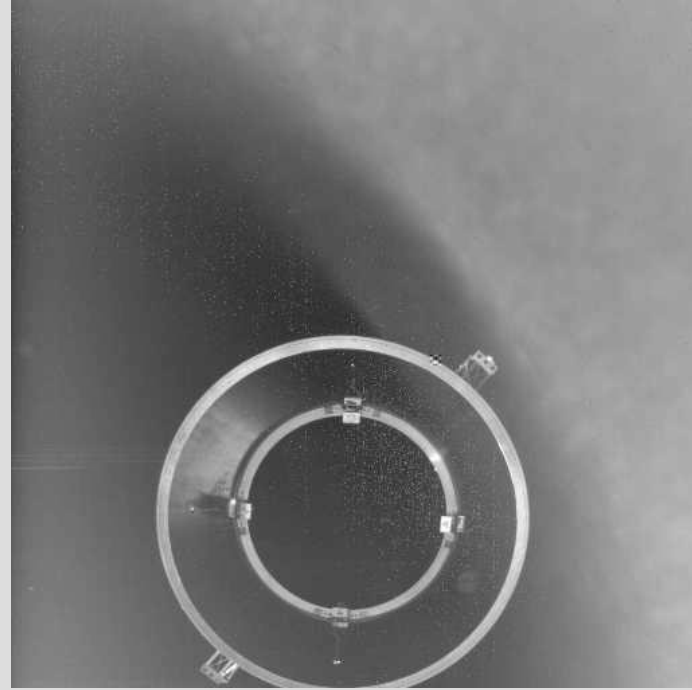
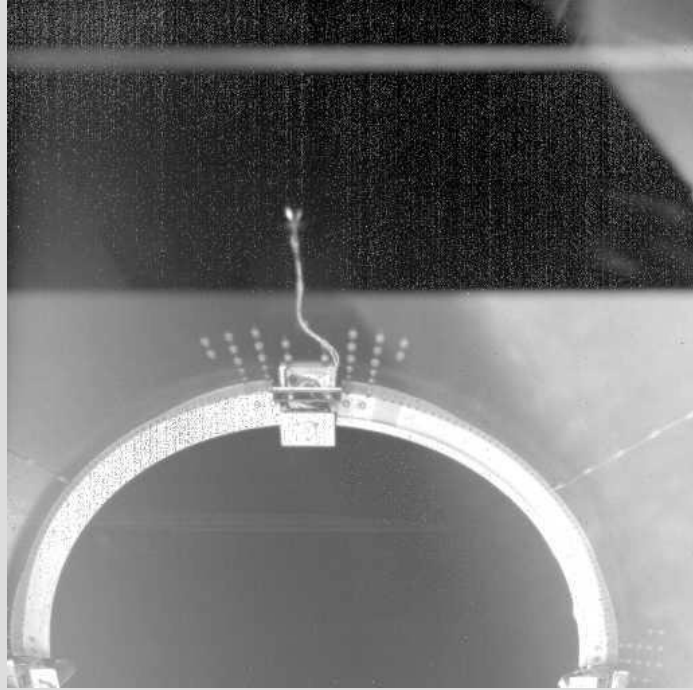
41.13

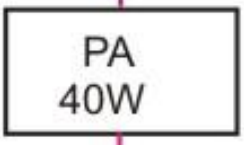
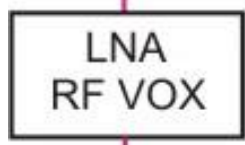
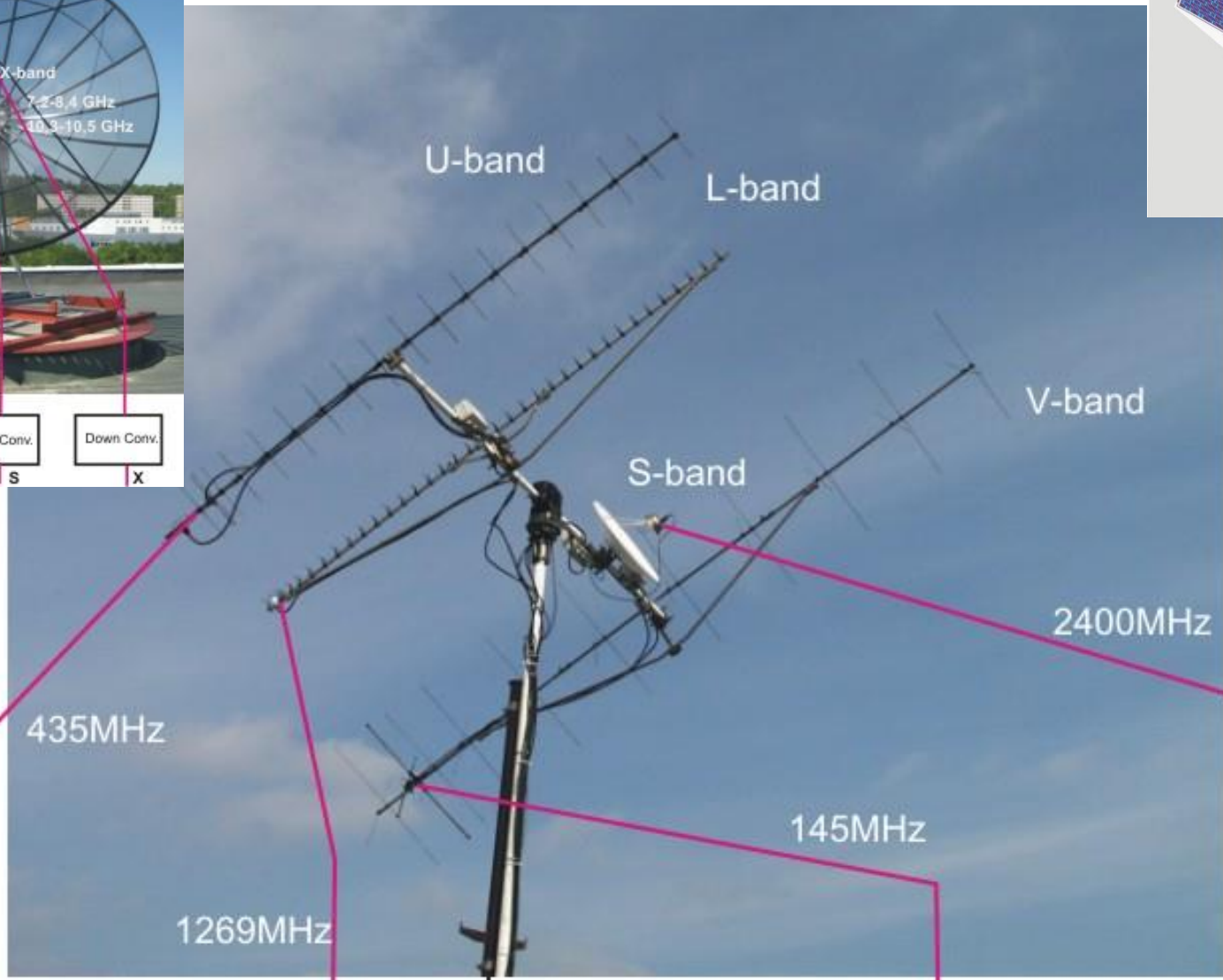
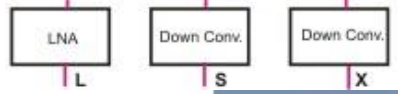
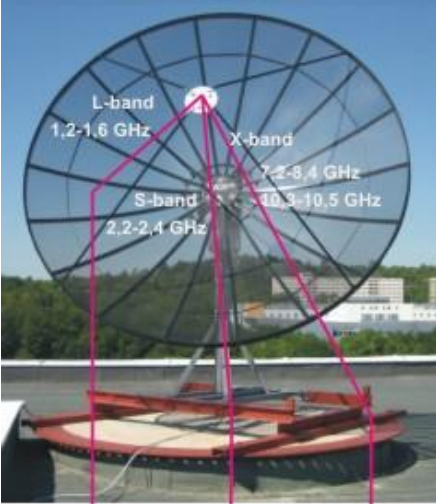


 arianespace

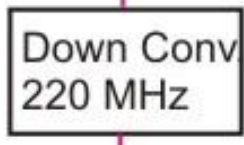
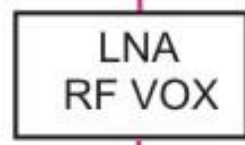
$A = 4939.7 \text{ km}$

$V = 6.78 \text{ km/s}$





Rotors Control

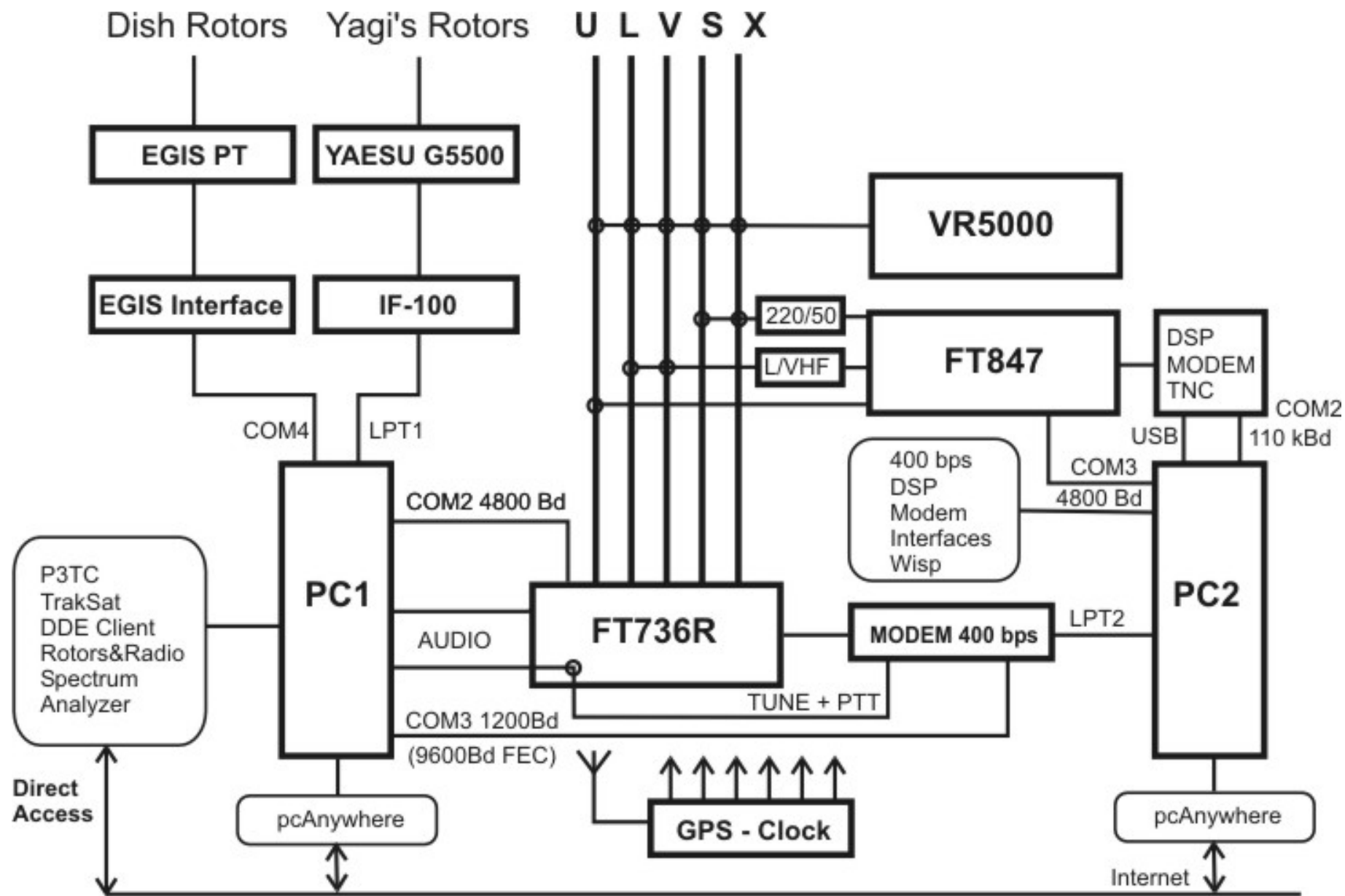


U

L

V

S





Telemetrické a povelovací pracoviště
ÚREL



Microsoft Excel - Commfcalc

File Edit View Insert Format Tools Data Window Help

Nápořádá

2401,3381	<Beacon>	2401,2944	Comm Fq Calculator by OK2AQK	
BRX display start	RX offset	NBF	NRXLO	Doppler down
221,3398	-0,0017	2401,323	2180,000	0,0151
BRX display actual	Comm Fq		TX display	Doppler up
221,2961	435,2000		435,1973	0,0027

for IF-100 and YAESU Transceiver(s)

Help

6 UP0000000000 --- DN0000000000 ---

Restore DDE link Close DDE link

Rotor

Azimuth: 201.1
Elevation: 030.6

Communication active

Auto update
 Manual control

Update rotor

Radio(s)

Uplink freq [MHz]: 1269.323
Downlink freq [MHz]: 221.29975

Mode: LSB
Mode: USB

Selected Radio: FT 736
Selected Radio: SatMode

CAT is off PTT
CAT is off

Auto update
 Manual control

Update TX Update RX

Update radios

AO-40
OK2AQK

2001 Nov 18 [Sun]
13:05:56 (UTC)

Azm: 201.0
Elev: 30.6
Rate: 3.57
Rng(k): 18541.6
Hgt(k): 16099.9

AOS: 12:22:43
LOS: 21:31:32
Max El: 36.2
Cntdwn: 08:25:36

Squint: 60.0
MA: 15.2
Orbit #: 484
Mode: S

Beac: 2401.2944
Azz: El:

TrakSat ConvKeys
AttHistC PlanSat
Wincmd32 Commfcalc

File

RX Freq 1600
TX Freq 1000

AFC
 Net
 BPSK
 QPSK (usb)

200 Hz Slow Zoom X1 3500 Hz

Spectrum Waterfall Input Data Sync Auto Text Select

00:10:54 5,20 0 X

P3 P3TC

Exit Menu Help

Input

Block

Byte

CRCC

Text

Raw

K M

L N

OFF

Data

Status

Matrix

Nav

Power

Temp

Events

P3 Status P3TC

A HI, THIS IS AMSAT OSCAR-40

2003-11-15 20:46:30

Amsat Day# 9449

Orbit# 1397 MA# 134

Cmd# #0B70 Event# #07DD

Current Amsat Day#: 9451

AGC / ALC

V-Tx: 41.0

V-Rx: ---

U-Rx: 0.1

U-Tx: ---

L1-Rx: 0.9

L2-Rx: ---

S1-Rx: ---

S2C-Rx: ---

S2 Tx: 78.0

X-Tx: #0A

HF Rx: 8.0

Rcv/Ant/Leila

21: off

24: off

V: off

U: ON/Hi

L1: ON/Hi

L2: off

S1: off

S2: off

C: off

R1: VUHi

Leila: #92D8

Experiments

Rudak: off

GPS: off

RFexp: off

CamA: off

CamB: off

Cedex: off

Ctrl: off

IHU-2 off

Cmd AFC

L1: ---

U/V: ---

Hz1: ---

Hz2: ---

Safety

Cmd: ---

Mag: off

E-Flg: #00

S/A: arm

S.Err: 1

LI/EP/AR

Instr. off

EPU: off

LIU: off

ARU: off

Beacons

GB: ON

Mod: psk/EB

MB: GB

EB: off

Laser: off

Trans/Ant

V: off

U: off

S1: off

S2: ON

X: off

K: off

PSU

Heat: off

Chrg: off

Bat: Main

P3TC

Earth Sensors

Sensitiv: 64

Pointing: side

Edge: neg

Lock Rng: 10

ES1 Top (HiG)

MA: 14

Orb#: 117

ES2 Bot. (omni)

MA: 14

Orb#: 117

ES1 (top): 245

Update: 0

ES2 (bot): 10

Update: 0

Spin Sun Sens.

SS1 cnt: 1

SS2 cnt: 25

Sol.Ang: 26.7

Treshld: 1.5v

Flags: 3

Spin

Raw#: 67

SEU: 2.8

P3 Power P3TC

Volts

Bat.Main: 28.5

Bat.Aux: 0.1

Bat.Off: 28.76

28v-S: 28.2

Amps

Tot. Bat: 0.8

EPU: 0.0

Main bus: 1.6

28v-S: 0.2

BCR: 3.1

SEU: 179

Tx Pwr/Cur

V Tx: 15.0

U Tx PA: 8.0

I-28v-S: 1.1

I-10v-S: 89.0

S1-A/mix: 8.0

S2 Pwr: 112

CS X-Tx: ---

Out X-Tx: ---

mA-Hel-X: ---

K-Tx: 9.0

I-K-Tx: 34.0

BCR #1

U-In: 24.2

I-SA-1: 17.3

I-SA-6: 17.3

Sol.Off: 21.1

BCR #2

U-In: 5.8

I-SA-4: 17.3

I-SA-5: 17.3

I-10vC1: 2.1

U-10vC1: 10.6

Sol.Off: 20.2

BCR #3

U-In: 20.0

I-SA-2: 17.3

I-SA-3: 17.3

I-10vC2: 2.1

U-10vC2: 10.6

Sol.Off: 20.1

Flow: ---

P3 Command P3TC

Upload

(A0-40 IHU KEPLERIAN ELEMENTS at perigee 954)
8272 ? ES ? 35744 ? A/F ? 21772 ? B/F ? -24 ? KO ?
1414 INCL ? 14524 RECTAS ? 21158 PERIGA ? 47 ? KW ?
13583 13433 #04A4 2 ?FK

P3

File

KEP

Block

1 / 1

Start

Stop

K

<<

<

>

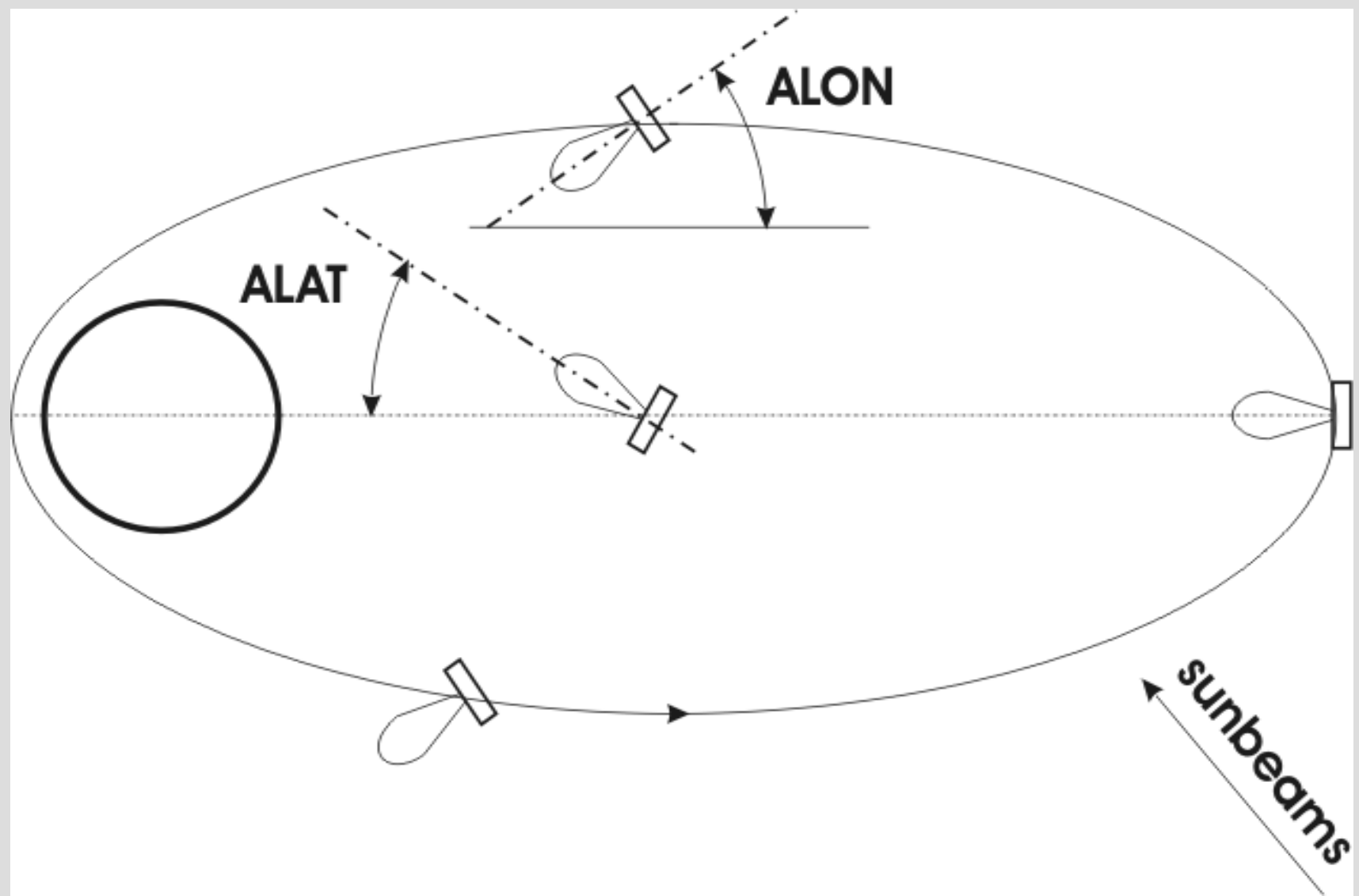
>>

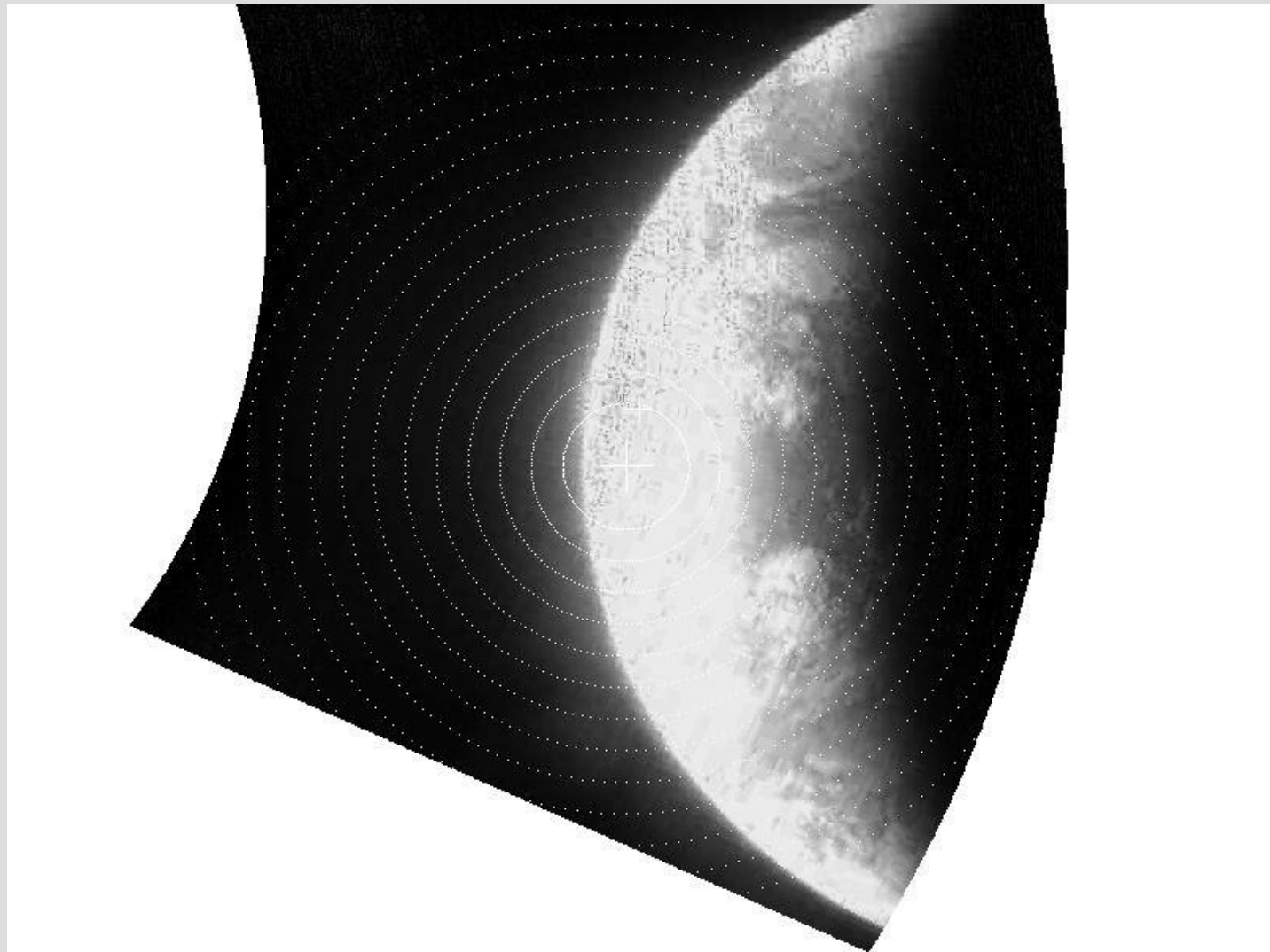
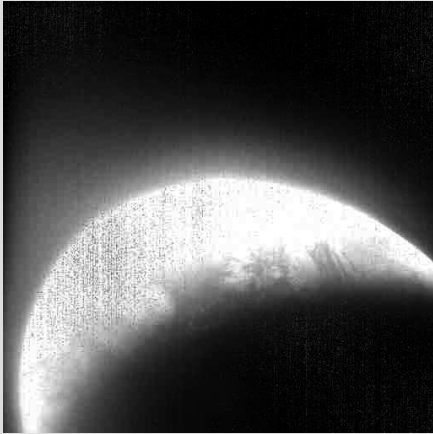
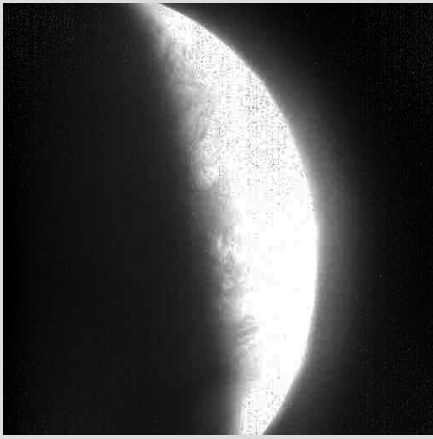
>

P3 Telemetry P3TC

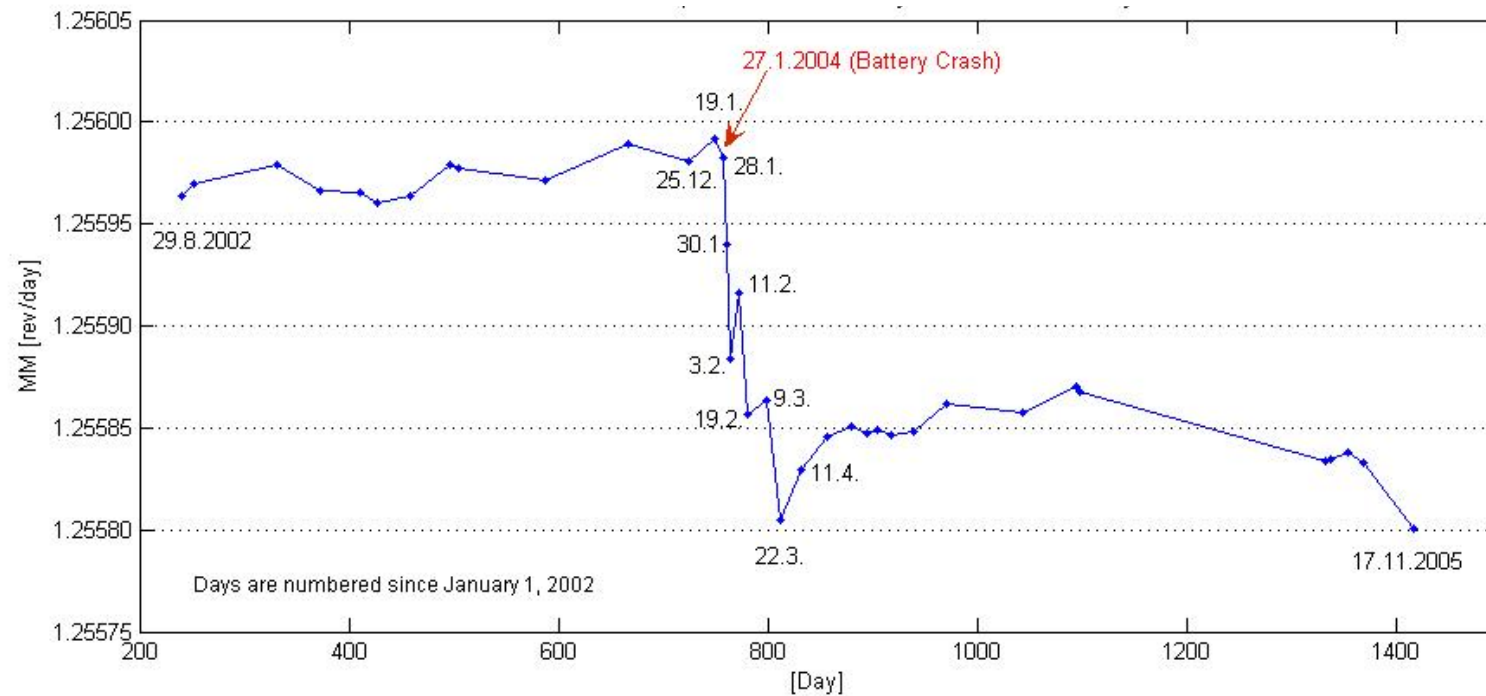
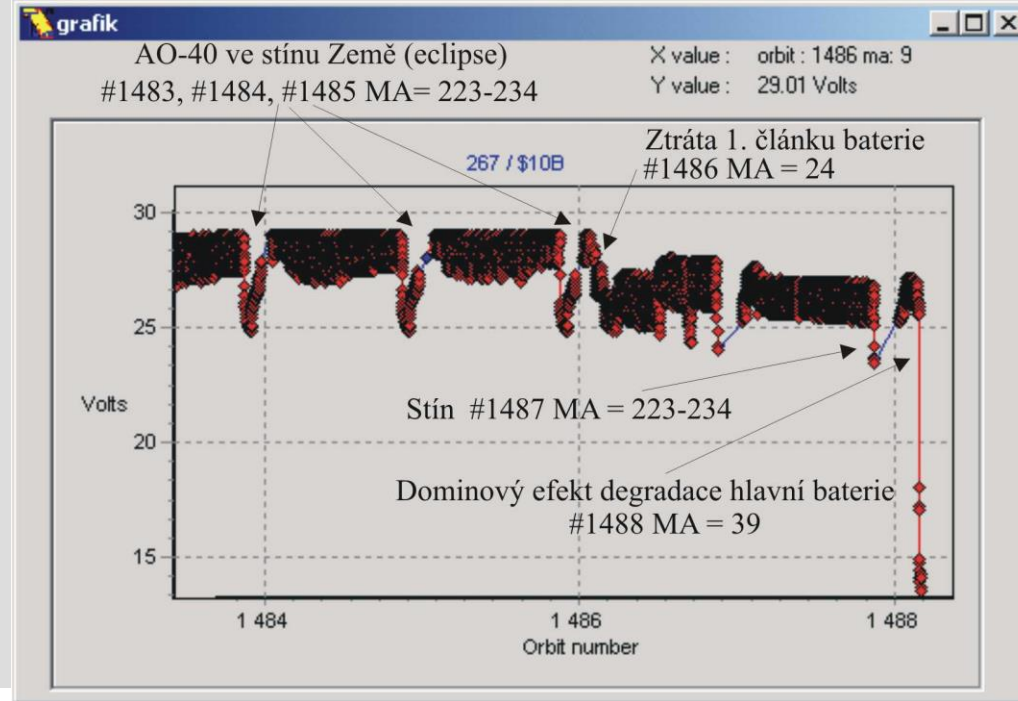
Replay

A HI, THIS IS AMSAT OSCAR-40 2003-11-15 20:46:30 #0B70
+-----+
| Hgt: 58710 km Lon: 70 Lat: 8 ALON: 37 ALAT: 0 |
+-----+
z %B @&, 3, S ((FDE) NG~+(pN 32 #
x ~2n n ~< <<< ~311111112 ~y.....
~ ~ ~ Q t X d " 6] p \$ @ P d t

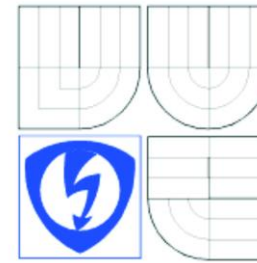
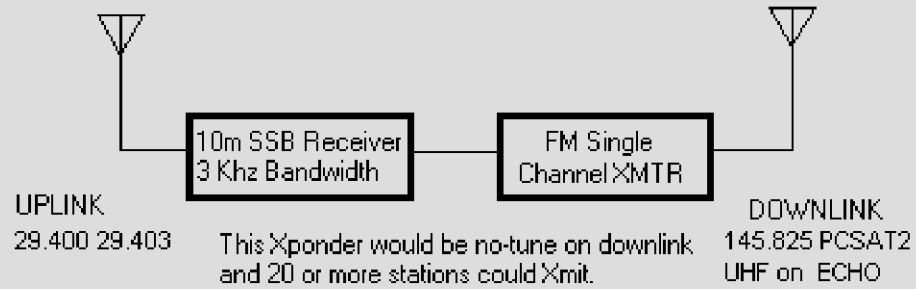




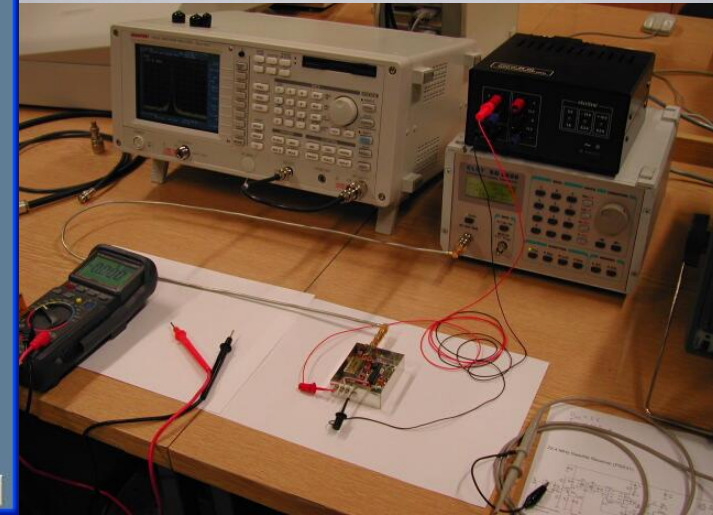
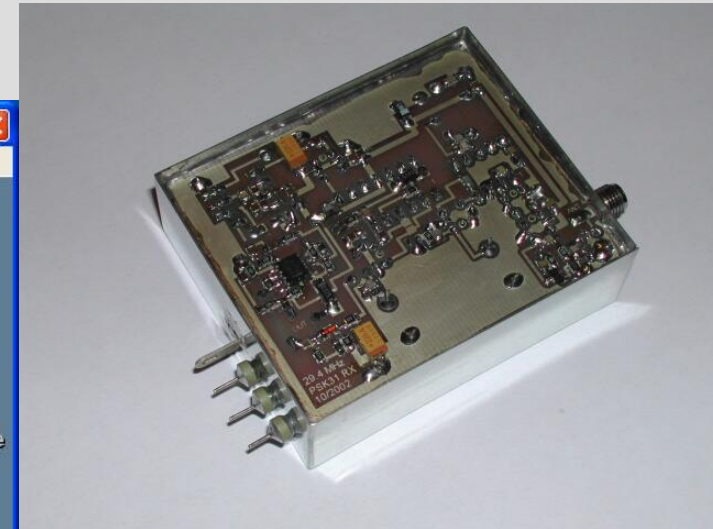
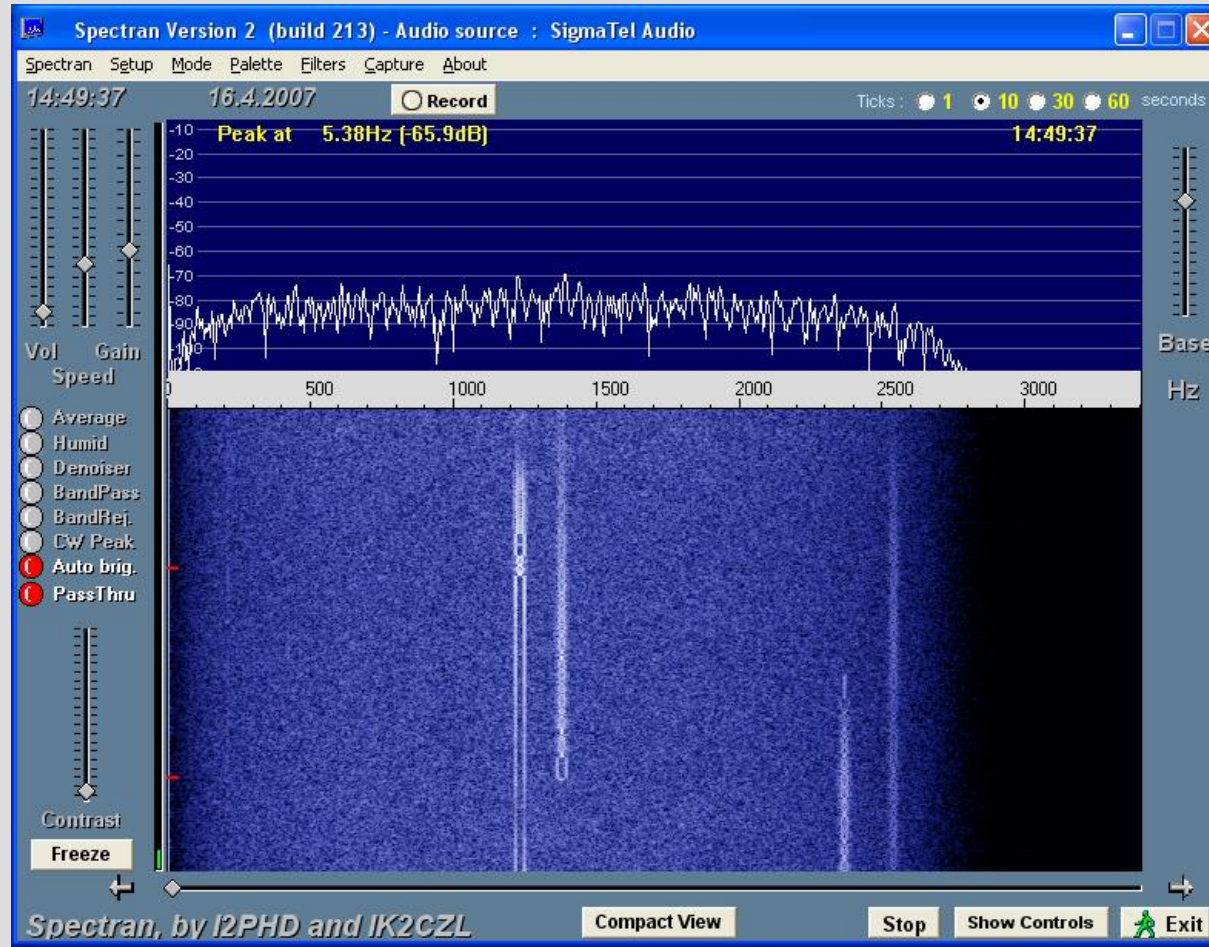
**Orbit no. 1394; 13.11.2003 18:52:41
Spin 3,388 rpm; Capture 1, 174 sec.**

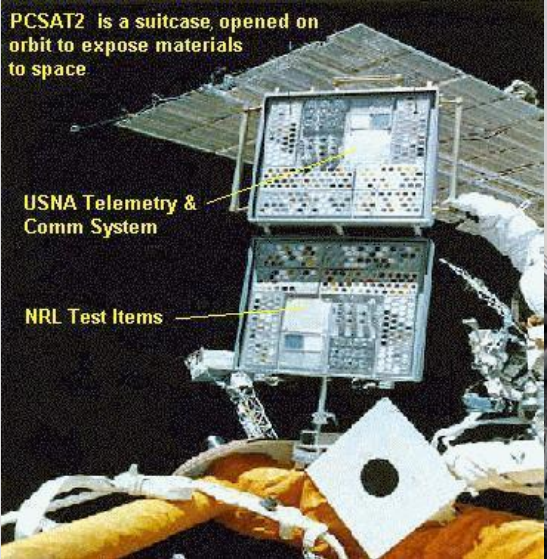


PSK-31 SSB=>FM Transponder

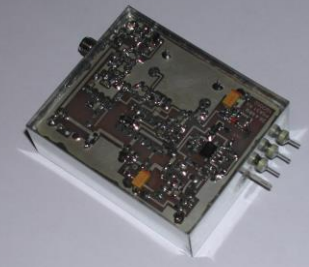


Brno University of Technology
Institute of Radio Electronics





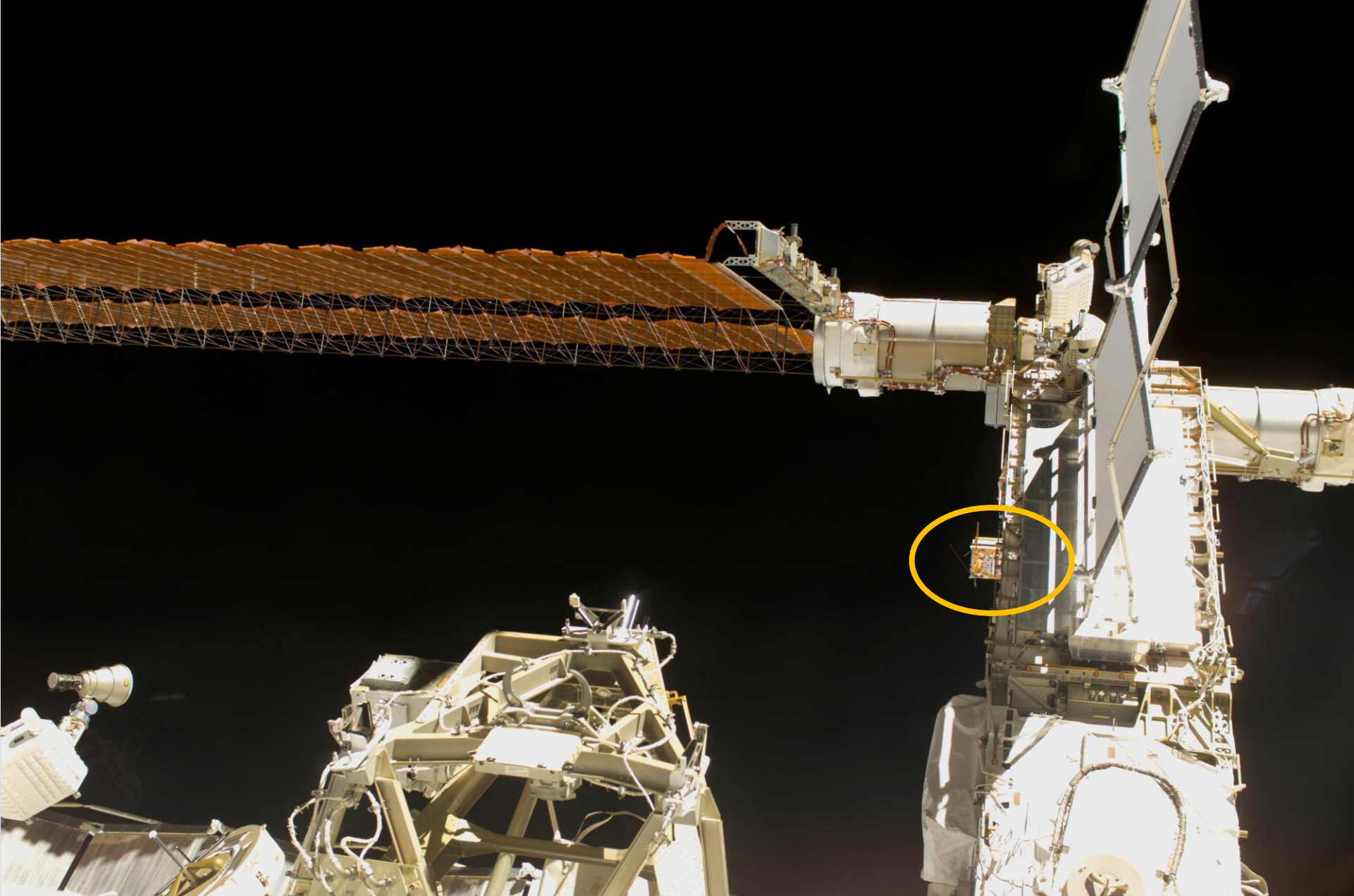
PCSAT 2



Úzkopásmový družicový transpondér pro pomalou datovou komunikaci – spolupráce s americkou Námořní Akademií

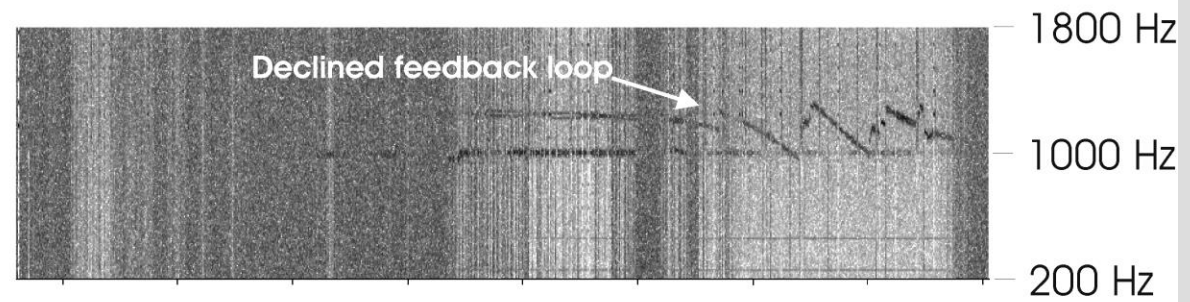
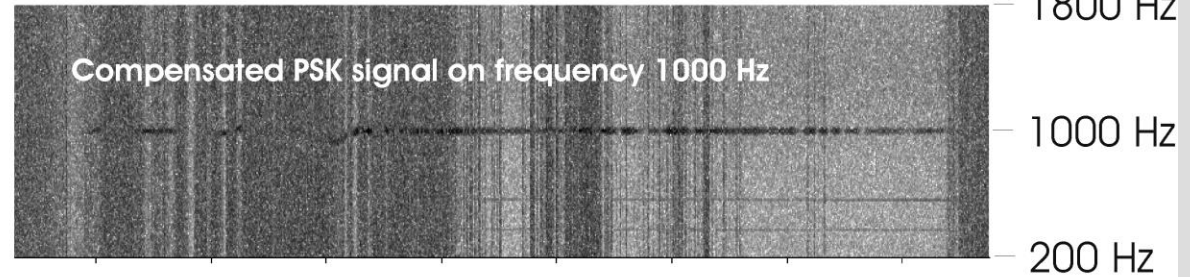
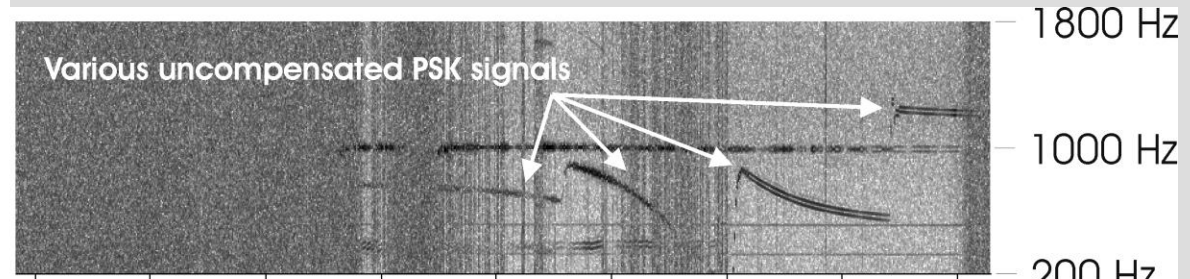
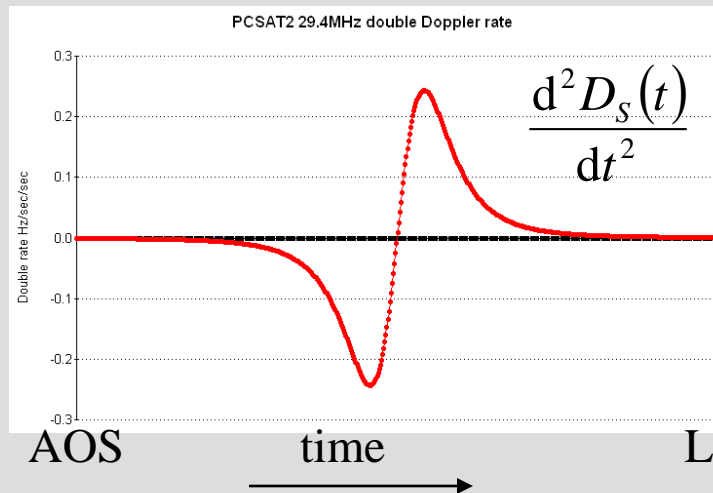
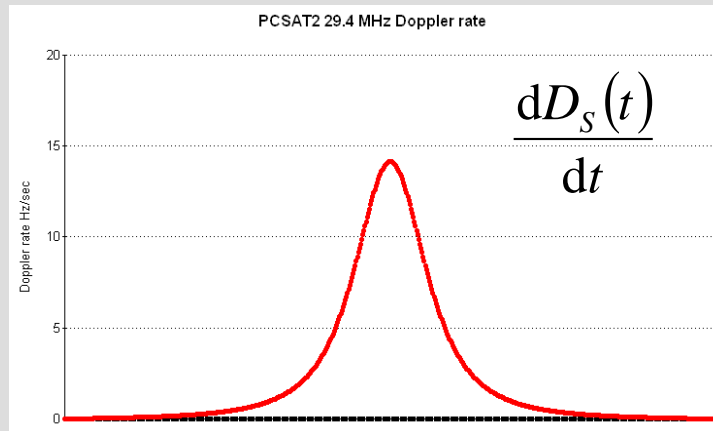
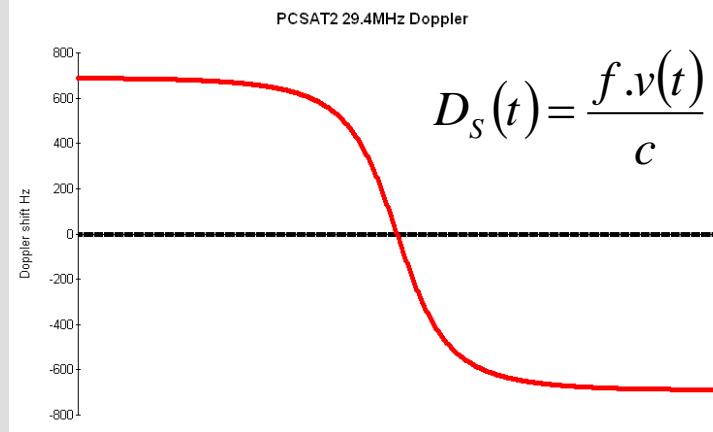


PCSAT 2



S114E7356

Dopplerův posuv v úzkopásmovém transpondéru na družici LEO



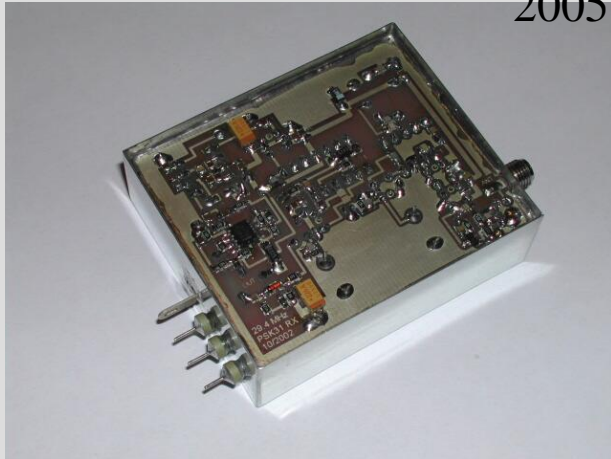
time [min]

AOS time LOS

EXPERIMENTAL SATELLITE LABORATORY

DREL FEKT BUT

US Naval Academy & ESL - PCSAT2
2005



US Naval Academy &
ESL

- PSAT 2015
- BriSat 2015
- Psat-2 2019



GRBAAlpha

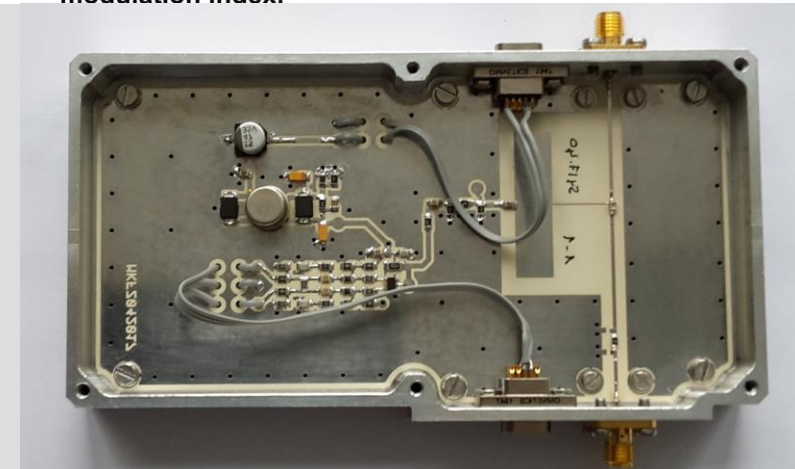
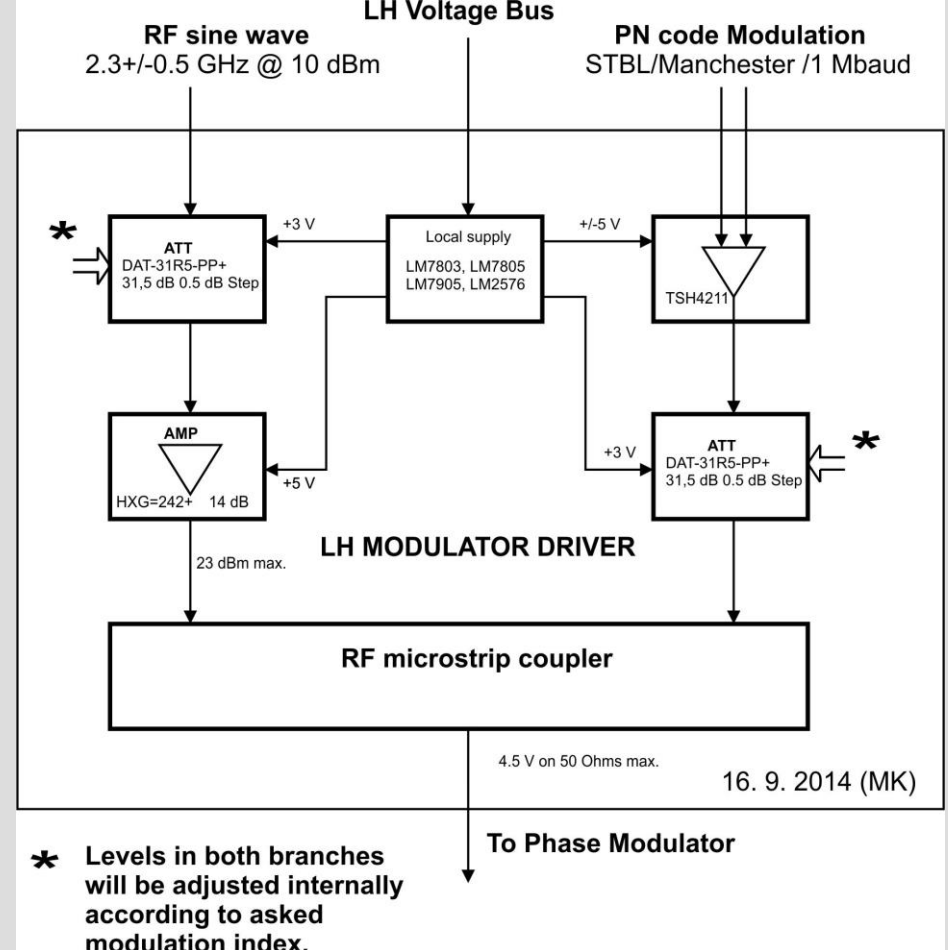
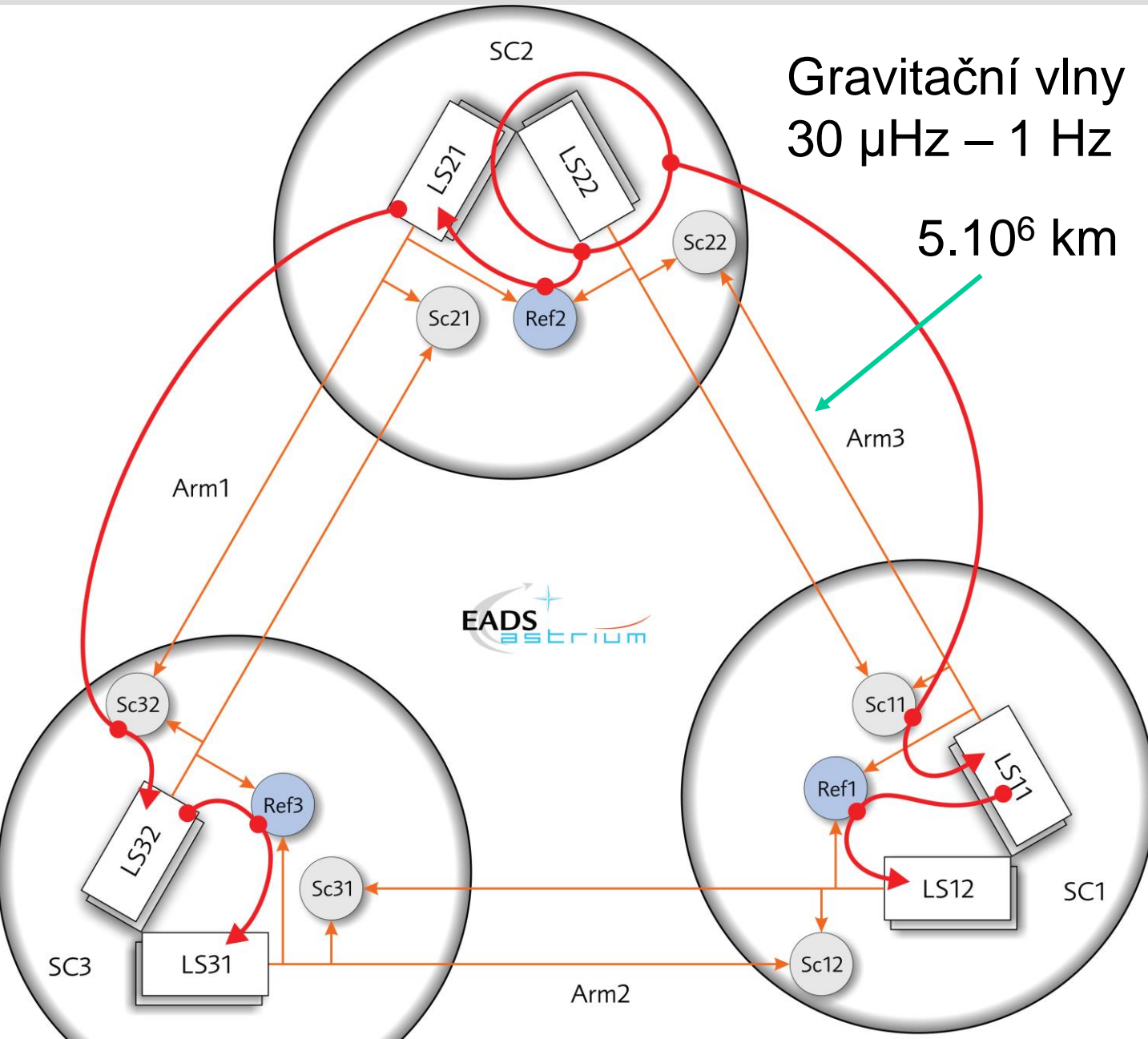


BDSat

ESL – Ground Segment 2021 – 2022

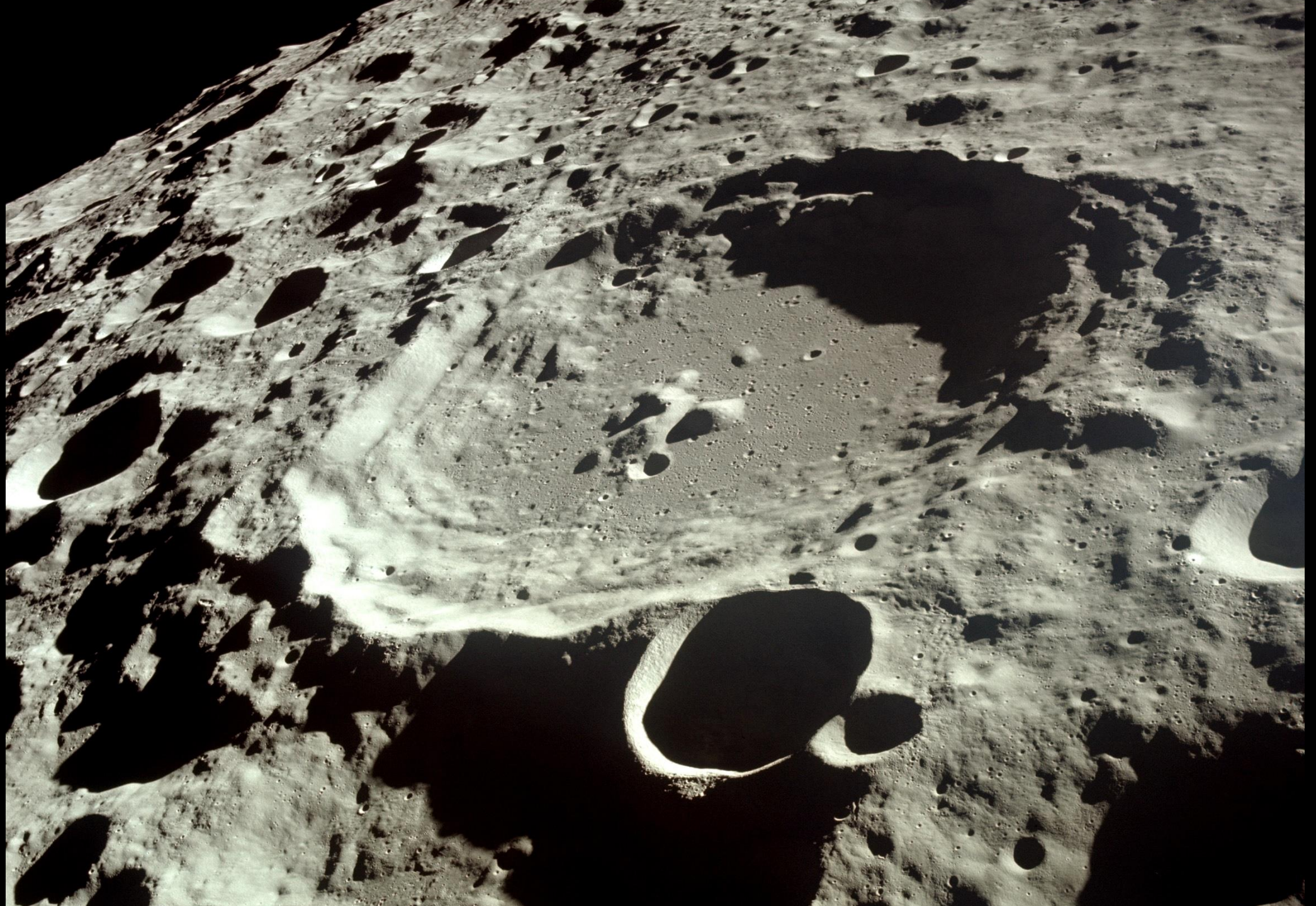


ESA – NASA projekt eLISA



MOON BOUNCE





- Koeficient odrazu $k = 0,065$
- Průměr Měsíce $d = 3500 \text{ km}$
- Efektivní průřez $s = 6,25 \cdot 10^{11} \text{ m}^2$
(ČR má rozlohu asi $7,9 \cdot 10^{10} \text{ m}^2$)

$$10 \log \left(\frac{P_r}{P_t} \right) = 10 \log \left(\frac{s \cdot \lambda^2}{(4\pi)^3 D^4} \right) \quad \lambda = 3 \text{ cm}$$

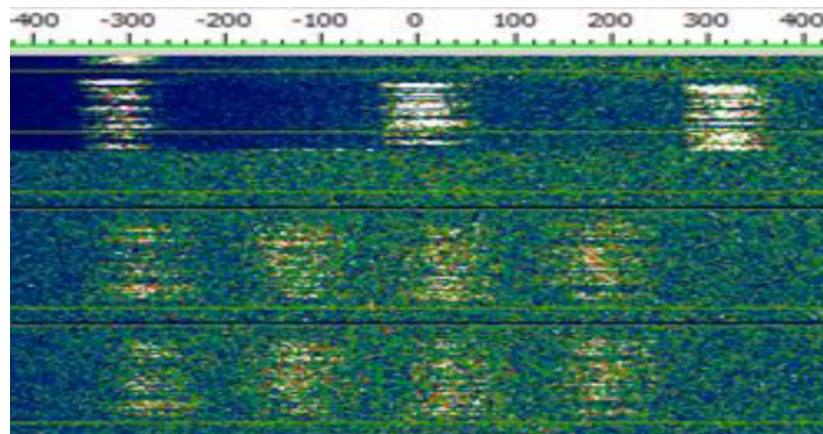
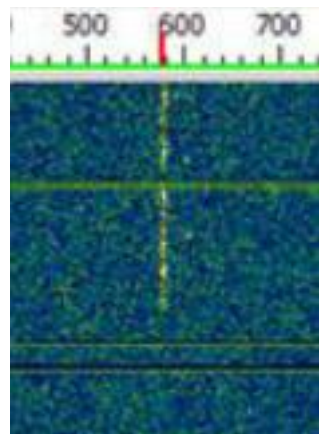
V perigeu je útlum EME $\sim 287,5 \text{ dB}$

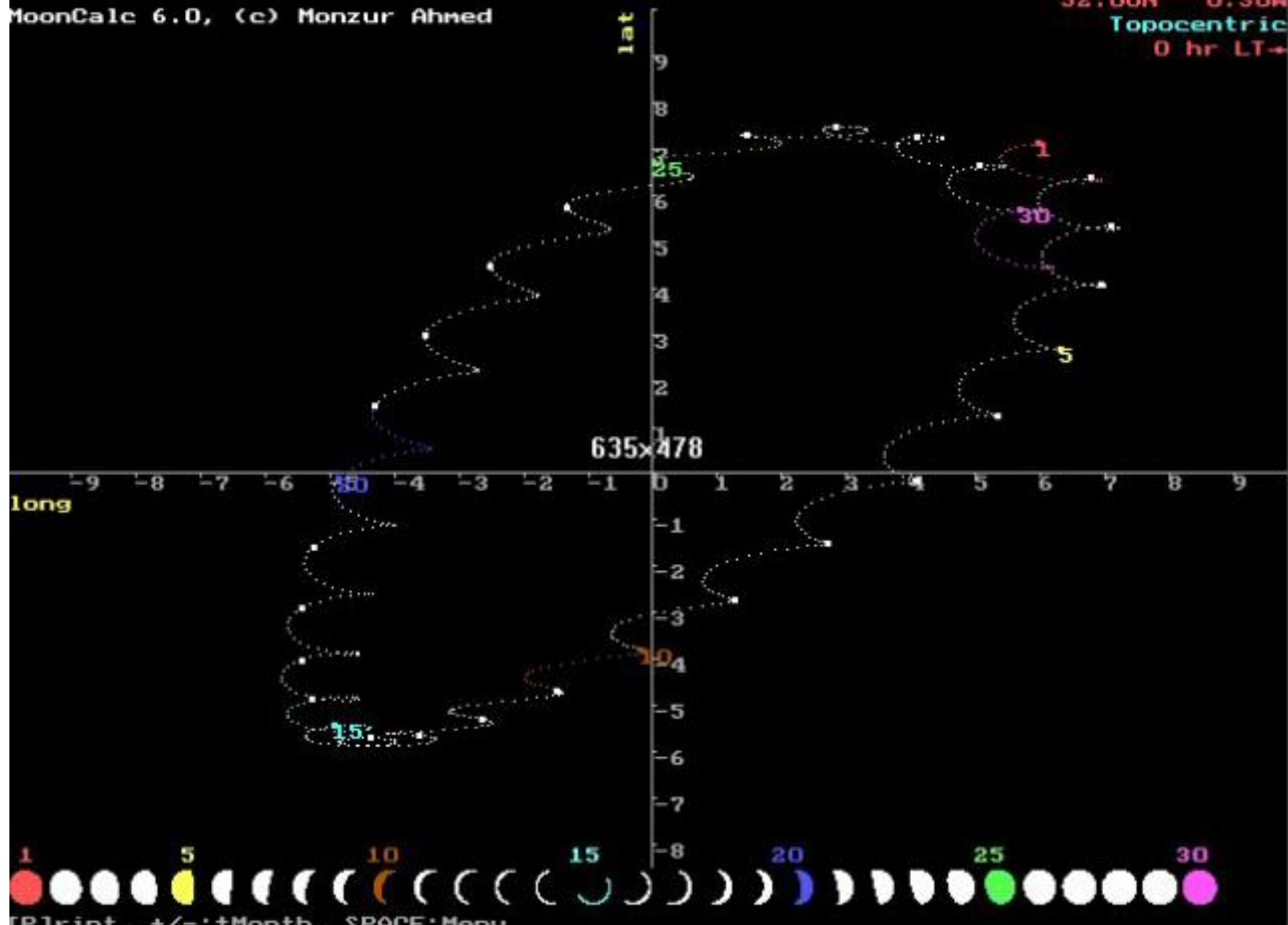
V apogeu je útlum EME $\sim 289,8 \text{ dB}$

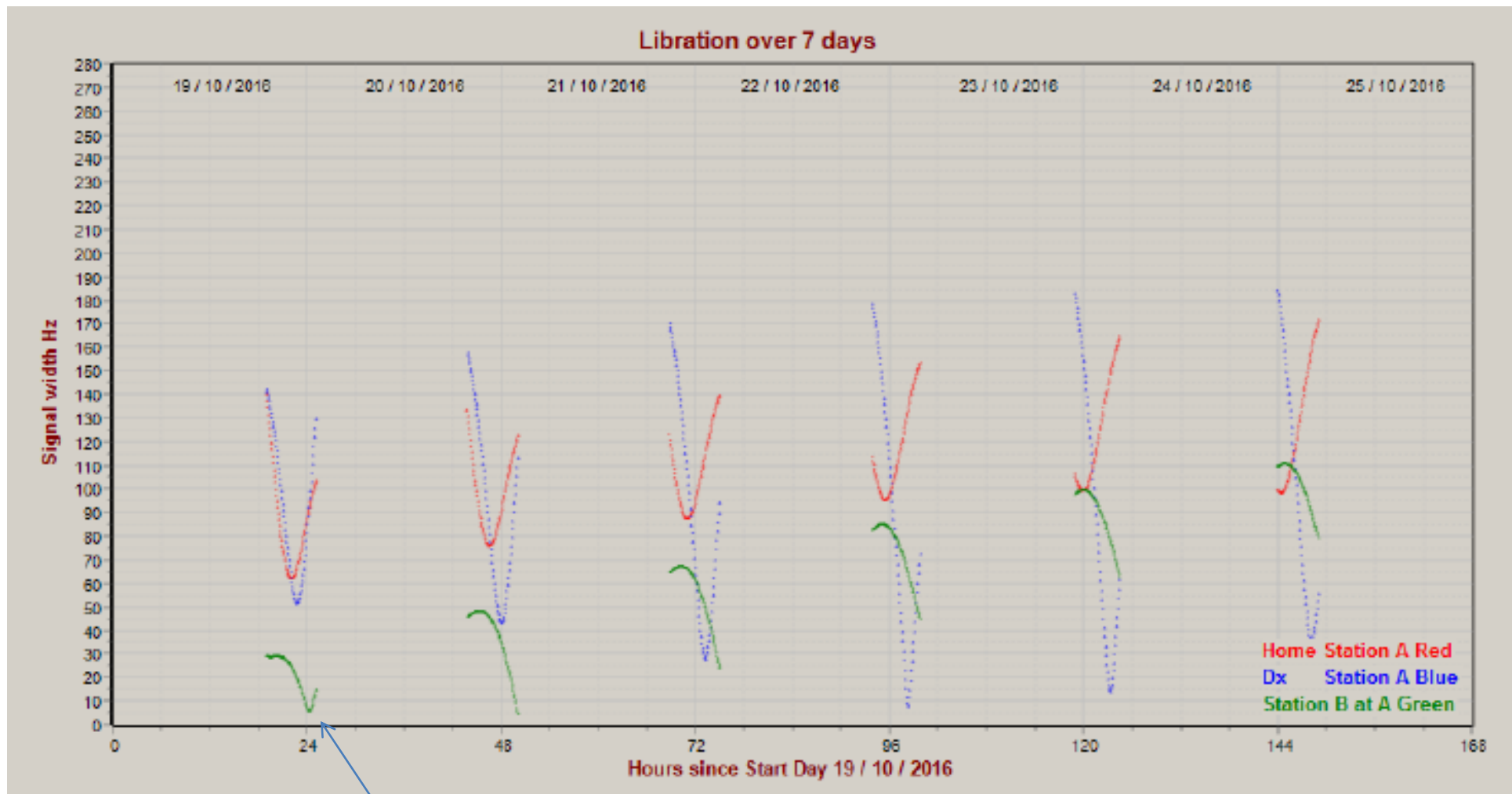
Rozšíření spektra odraženého signálu

Librace Měsíce

- délková (longitude)
- šířková (latitude)
- denní (diurnal)
- fyzická (physical)

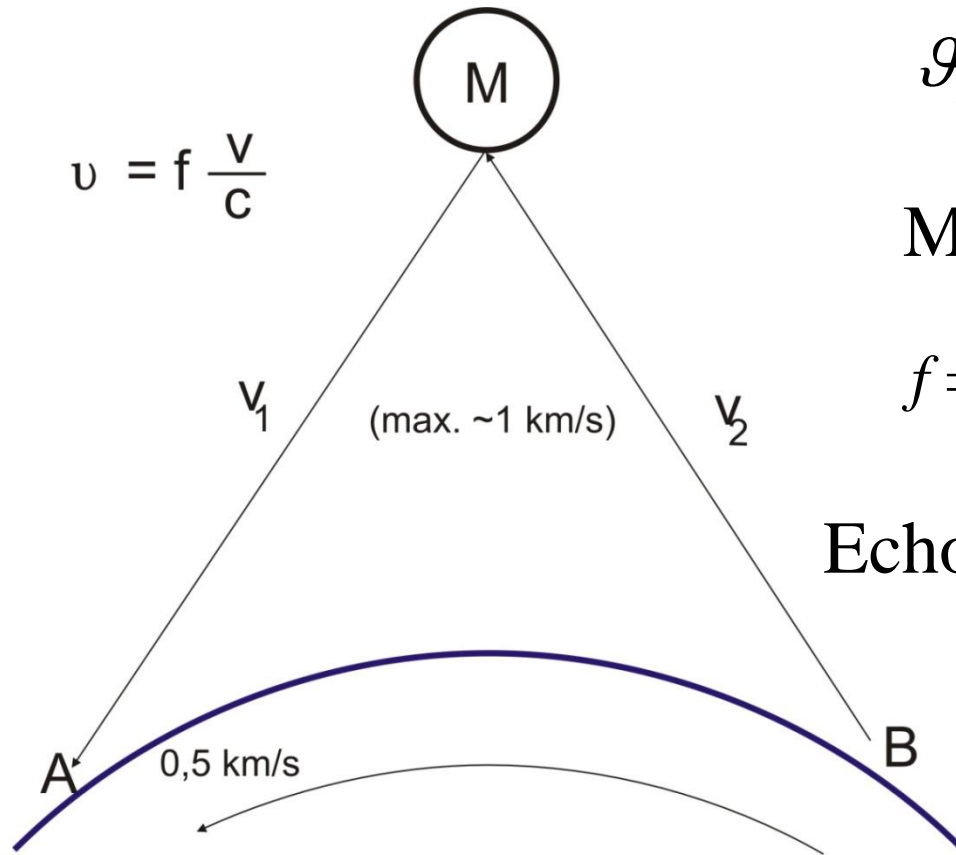






Nejmenší „spread“ pro protějšek v Japonsku

Dopplerův posuv



$$\mathcal{D}_1 = f \frac{v_1}{c} \quad \mathcal{D}_2 = f \frac{v_2}{c}$$

$$\text{Mutual} \Rightarrow \mathcal{D} = \mathcal{D}_1 + \mathcal{D}_2$$

$$f = 10,4 \text{ GHz} \quad DP = \pm 25 \text{ kHz}$$

$$\text{Echo B} \Rightarrow \text{Mutual} - \frac{\text{Echo A}}{2}$$

$$\text{Full Dopp} \Rightarrow F_{TX} - \mathcal{D} \text{ and } F_{RX} + \mathcal{D}$$

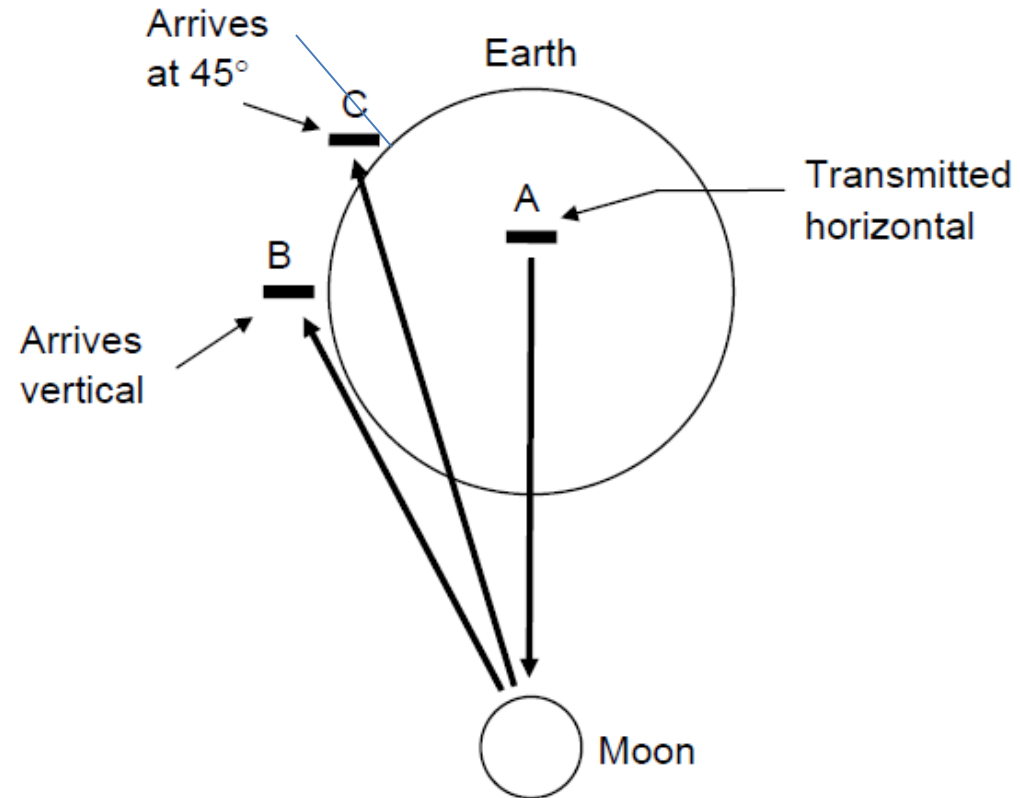
$$\text{Const Freq on the Moon} \Rightarrow F_{TX} - \frac{\mathcal{D}}{2} \text{ and } F_{RX} + \frac{\mathcal{D}}{2}$$

Polarizace signálů

Spatial Angle

CP-CP versus LP-LP

1,6 dB pro LP-LP
[6]



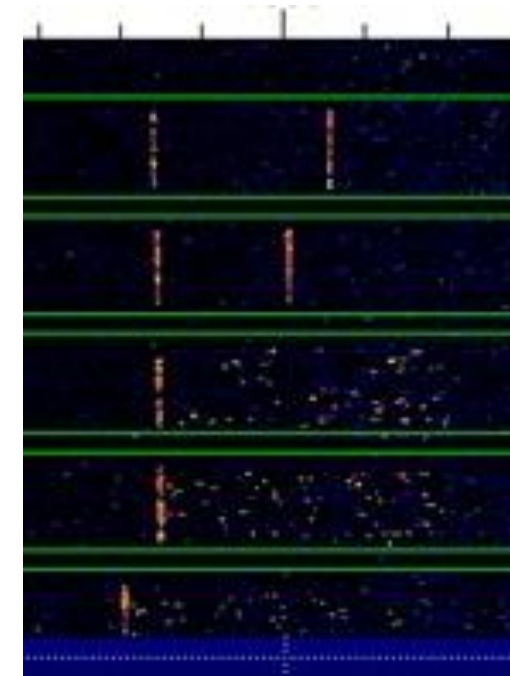
DIGITÁLNÍ KOMUNIKACE

Joseph H. Taylor, K1JT - NP 1993
WSJT (Weak Signal communications, by K1JT)

The screenshot shows the WSJT-X v1.7.0-devel interface. It features two main tables for decoded messages:

Single-Period Decodes						Average Decodes					
UTC	dB	DT	Freq	Message		UTC	dB	DT	Freq	Message	
2211	-13	2.3	1307	** CQ NC1I FN32	f	2212	Tx	900	#	NC1I OK2AQ JN89	
2213	-12	2.3	1306	** CQ NC1I FN32	f	2214	Tx	800	#	NC1I OK2AQ JN89	
2215	-10	2.3	1349	** CQ NC1I FN32	f	2216	Tx	800	#	NC1I OK2AQ JN89	
2217	-12	2.3	1347	** OK2AQ NC1I FN32 000	f	2218	Tx	800	#	RO	
2219	-12	4.4	1344	# RRR		2220	Tx	800	#	73	
2221	-12	2.8	1340	# 73		2222	Tx	800	#	73	

Below the tables are control buttons: Log QSO, Stop, Monitor, Erase, Clear Avg, Decode, Enable Tx, Halt Tx, Tune. The center panel shows a frequency display of 432.000 000, a signal strength indicator at 34.6 dB, and various settings like Tx/Rx frequencies, EME delay, and Submode B. The bottom status bar indicates 'Receiving', 'JT65 B', 'Last Tx: 73', 'Auto-Tx-Enable Armed', and '33/60 WD:6m'.



SNR až -28 dB ($B_n = 2500$ Hz) citlivost vůči CW je asi o 10 až 14 dB větší

Základní parametry módu Q65

T/R Period (s)	Symbol Length (s)	Tone Spacing (Hz)	Occupied Bandwidth (Hz)	Transmission Duration (s)	SNR (dB)	Max AP SNR (dB)
15	0.150	6.667	433	12.8	-22.2	-23.7
30	0.300	3.333	217	25.5	-24.8	-26.6
60	0.600	1.667	108	51.0	-27.8	-30.4
120	1.333	0.750	49	113.3	-30.8	-32.5
300	3.456	0.289	19	293.8	-33.8	-37.4

FSK 65 tónů

LDPC

Q-ary

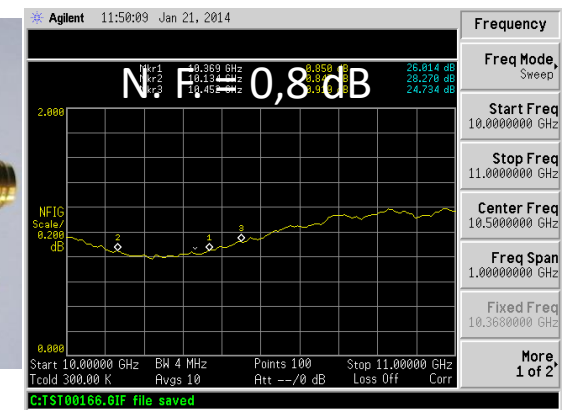
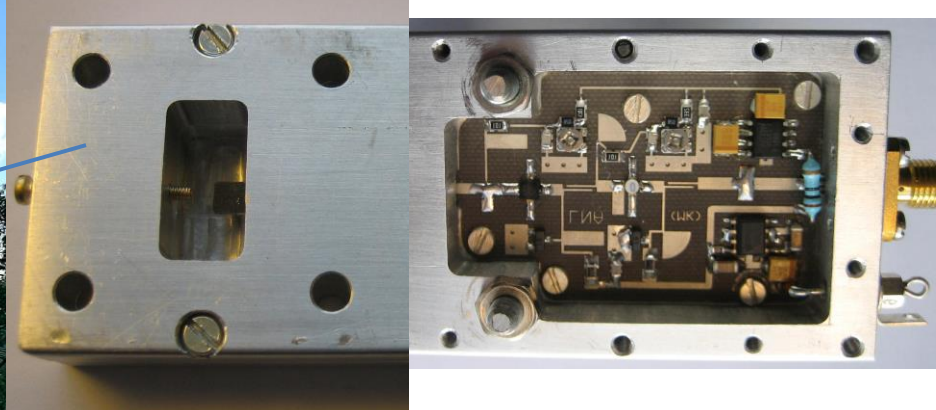
FEC

A priory information

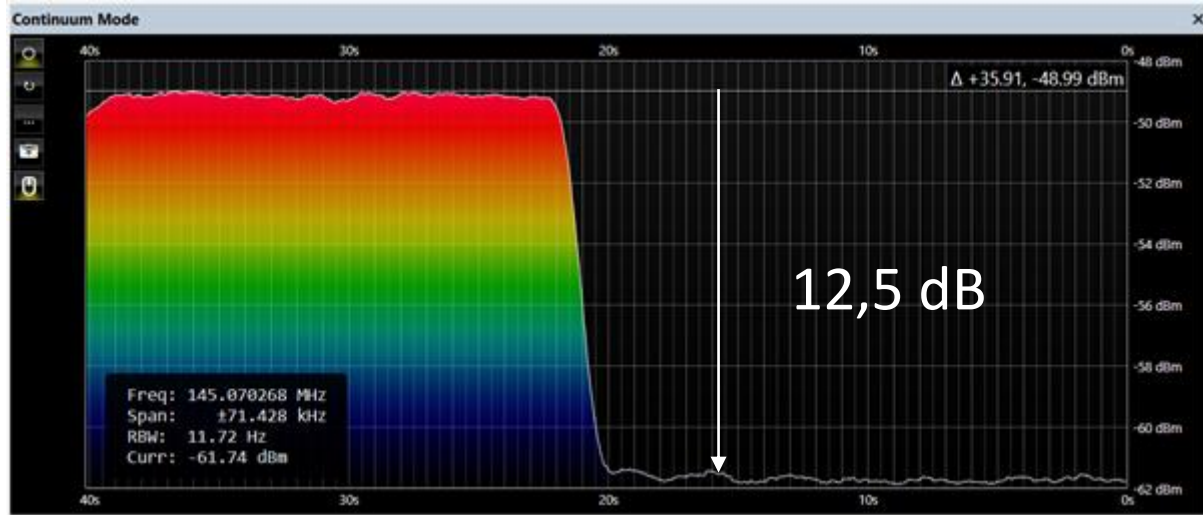
Averaging

Rozestupy tónů a šířka spektra módů Q65

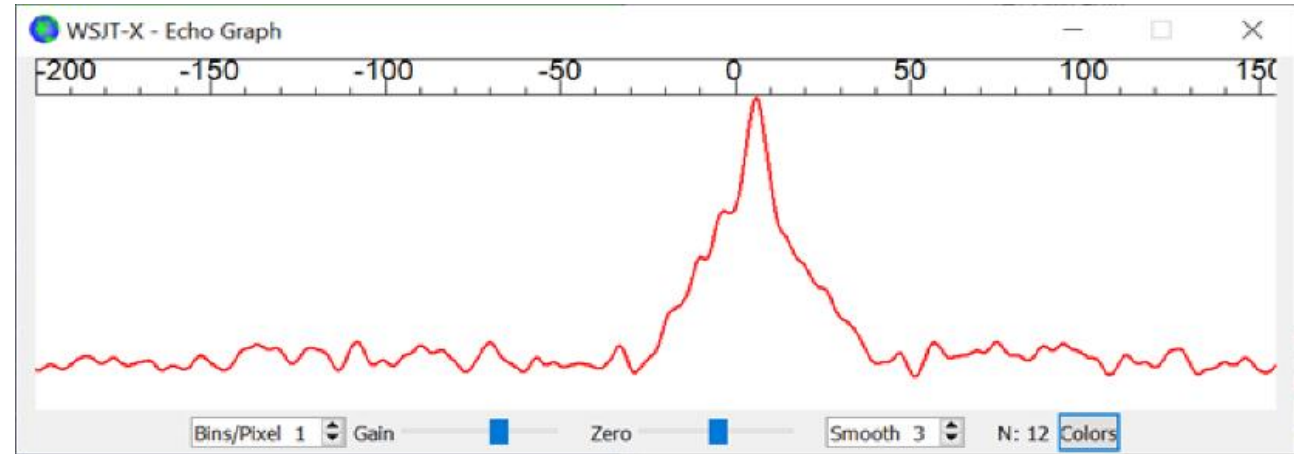
T/R Period (s)	B Spacing Width (Hz)		C Spacing Width (Hz)		D Spacing Width (Hz)		E Spacing Width (Hz)	
15	13.33	867	26.67	1733				
30	6.67	433	13.33	867	26.67	1733		
60	3.33	217	6.67	433	13.33	867	26.67	1733
120	1.50	98	3.00	195	6.00	390	12.00	780
300	0.58	38	1.16	75	2.31	150	4.63	301



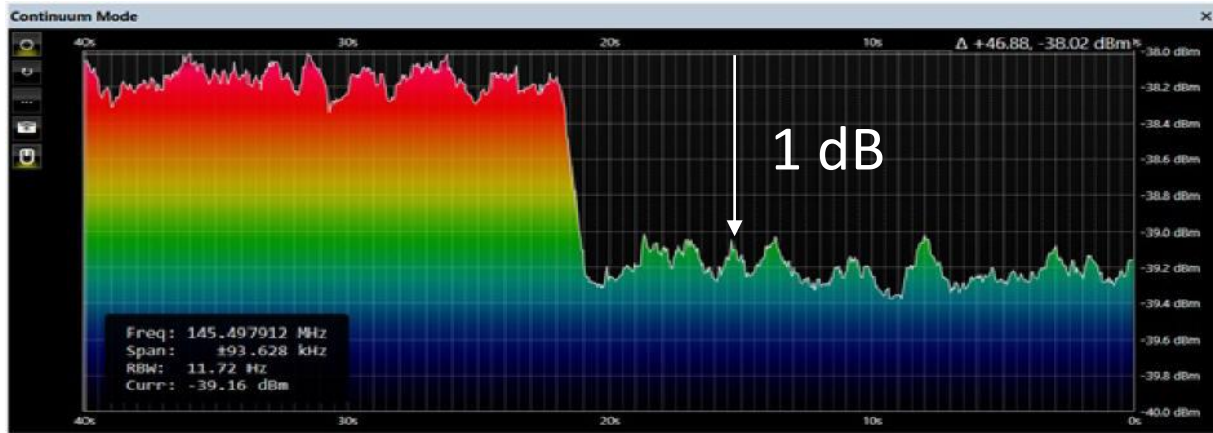
SN/CS 13. 8. 2023 SFU = 150



Vlastní ECHO N = 12



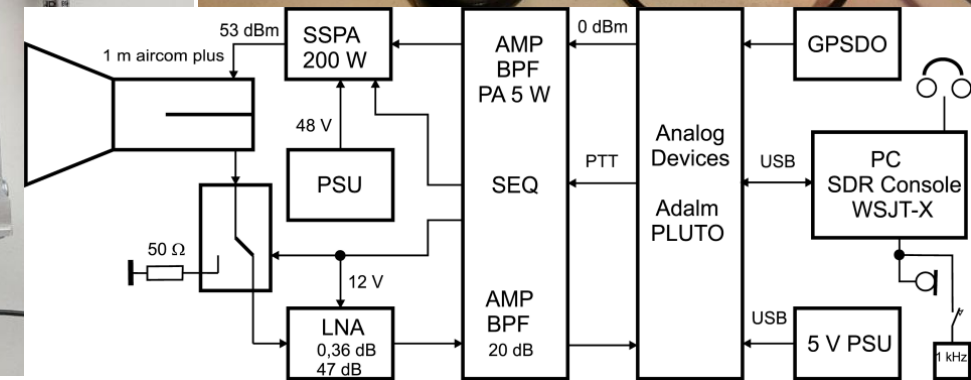
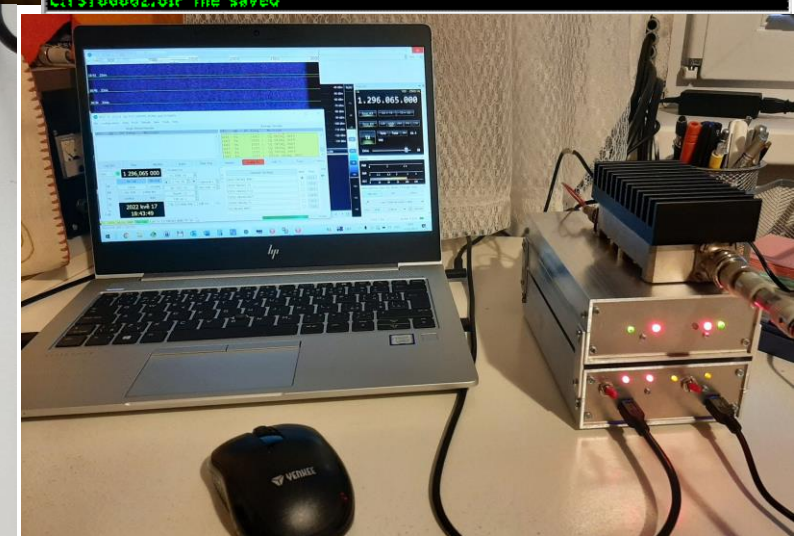
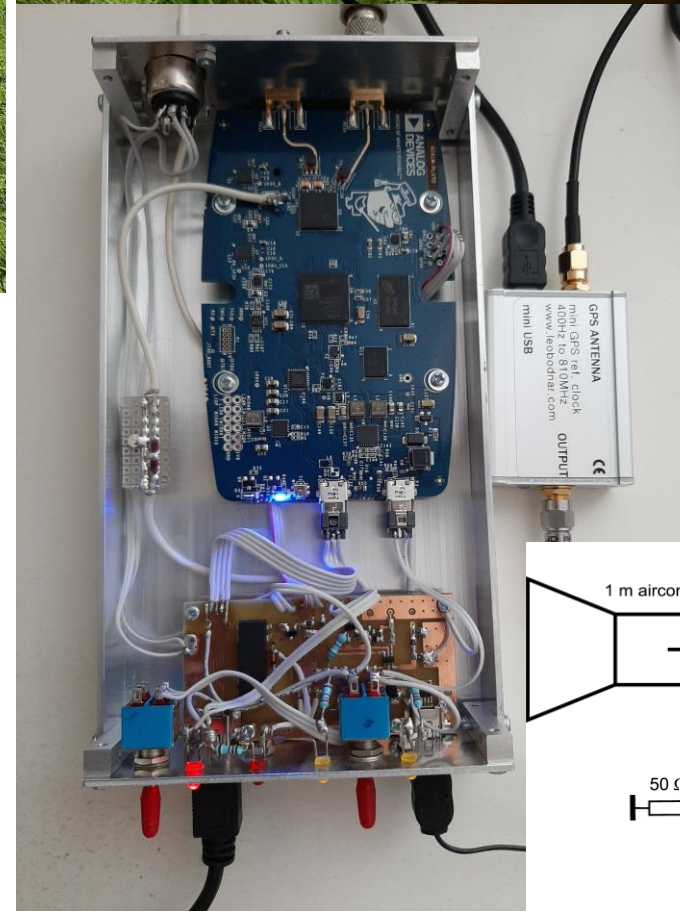
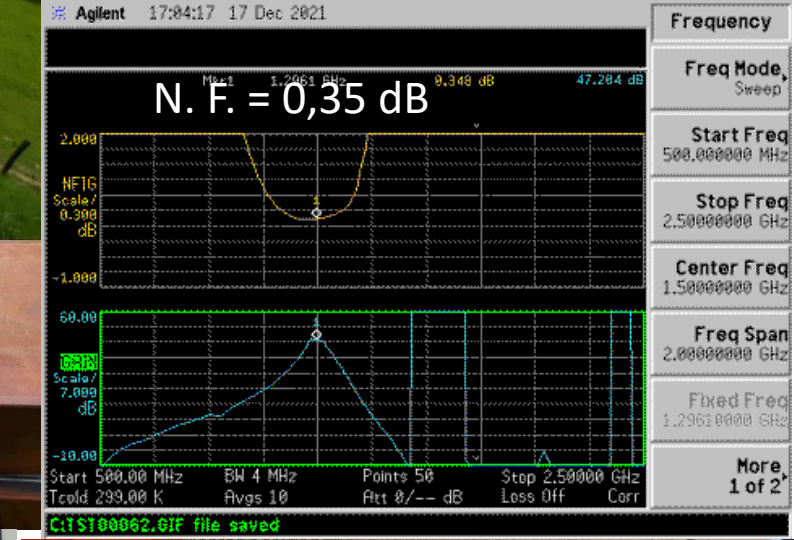
MN/CS 01.10. 2023 20:00 UTC



WSJT-X v2.6.0-rc3 by K1JT et al.

File Configurations View Mode Decode Save Tools Help

UTC	N	Level	SNR	dBerr	DF	Doppler	Width	Q
141629	1	56.4	-14.8	0.5	15.0	-17531	61.2	8
141635	2	56.5	-15.0	0.5	-1.8	-17531	61.2	10
141641	3	56.6	-15.8	0.5	5.1	-17531	61.1	10
141647	4	56.2	-15.8	0.5	5.1	-17530	61.1	10
141653	5	56.5	-15.9	0.5	5.9	-17530	61.0	10
141659	6	56.4	-16.1	0.5	5.9	-17530	60.9	10
141705	7	56.2	-16.2	0.5	5.9	-17529	60.9	10
141711	8	56.2	-16.0	0.5	6.2	-17529	60.8	10
141717	9	56.4	-16.0	0.5	6.2	-17529	60.8	10
141723	10	56.5	-16.1	0.5	5.9	-17528	60.7	10
141729	11	56.2	-16.0	0.5	5.9	-17528	60.7	10
141735	12	56.5	-16.0	0.5	5.9	-17528	60.6	10



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Cena ministra školství za výzkum - 2007

DĚKUJI VÁM ZA POZORNOST