

How Distance Influences Interplanetary Data Transfer Rate With Relation To Education In ICT & Astronomy



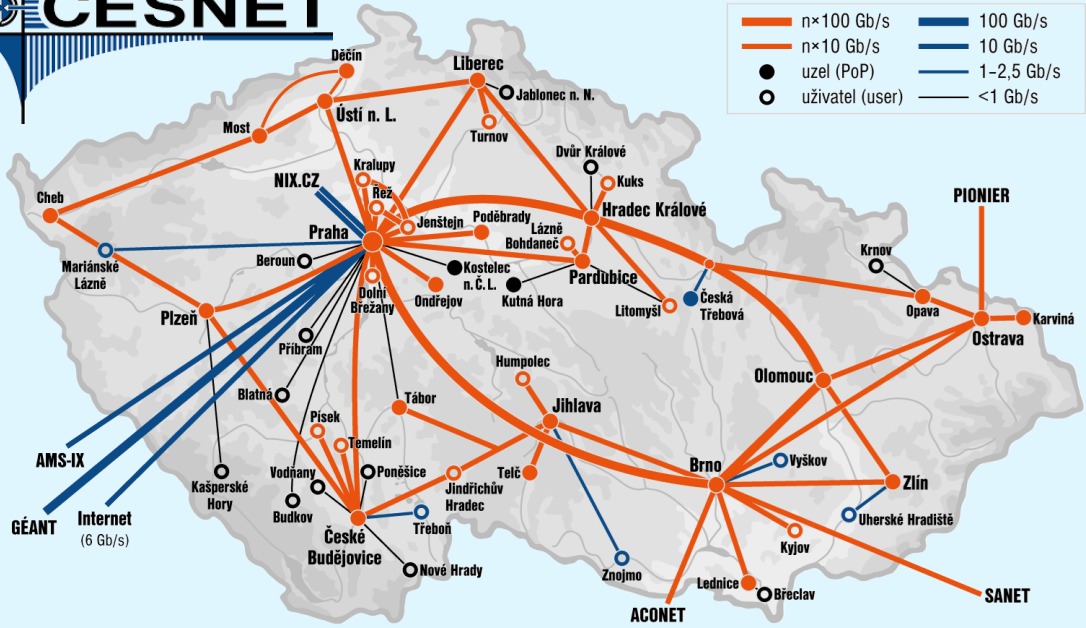
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Mbps, Gbps, ... W, kW, ...



1997: Wi-Fi, tens of Mbps

1991: 9.6 kbps

Wi-Fi power ~ 0.1 W – 2 W,
range of tens of metres

FM trans. power ~ 3.16 kW,
range of tens of kilometres

Why?





Space probes

16,560,000,000 km (111 au)

Is it sufficient
output power
to reach Earth?

20 W

160 bps

Voyager 2

Voyager 1

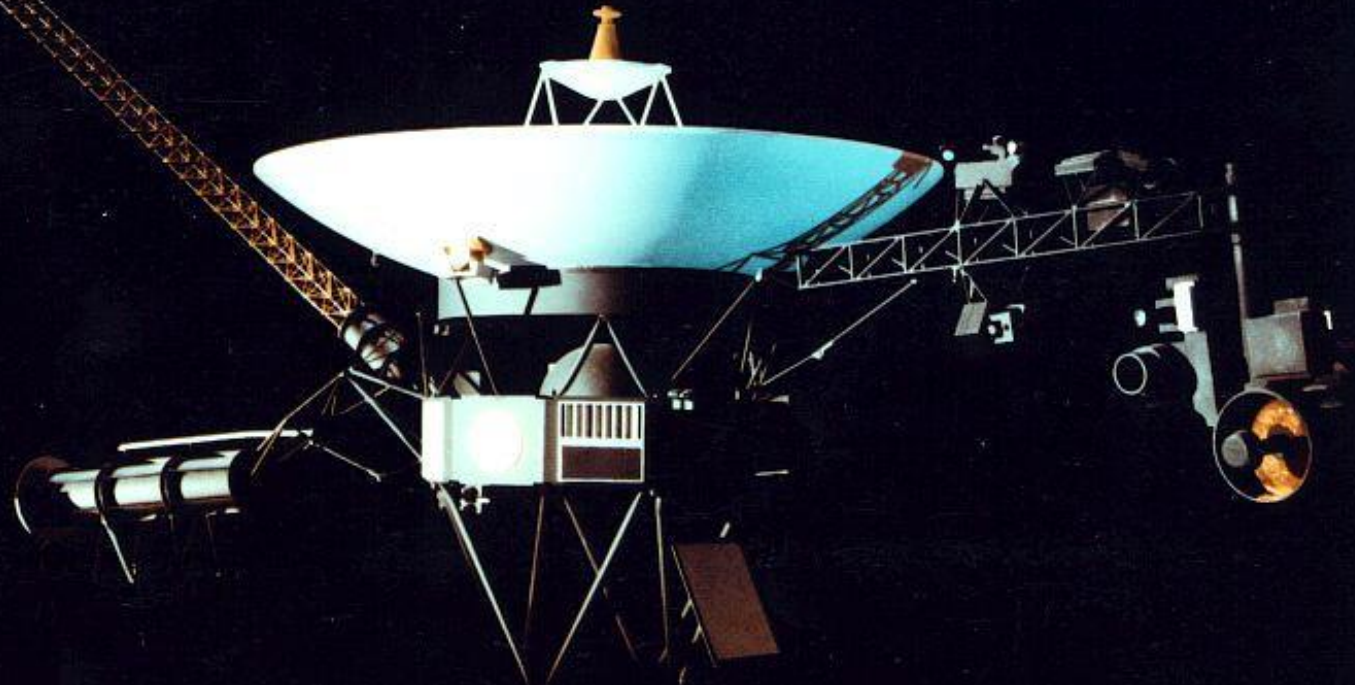
New Horizons

Cassini

Dawn

Rosetta

...



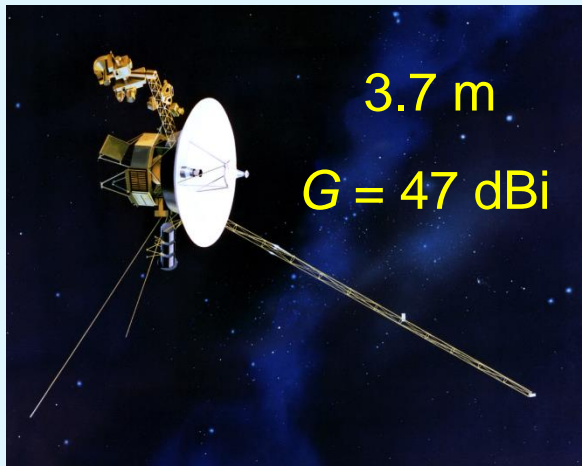


Inverse-square law in theory

$$I = \frac{P}{S} = \frac{P}{4\pi r^2}$$

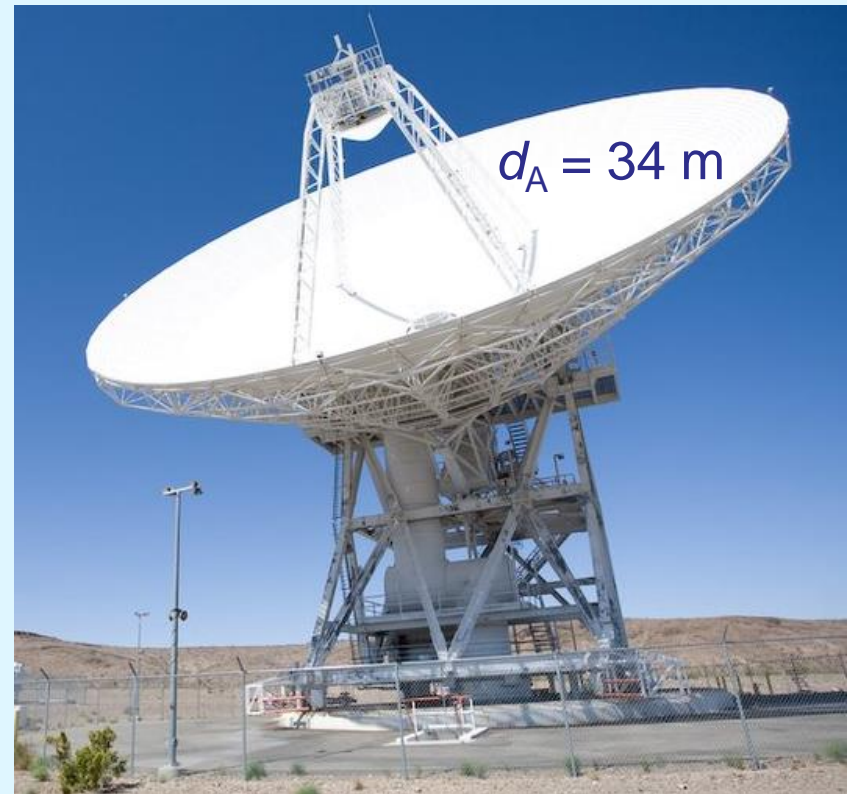
$$r_S = 16.56 \cdot 10^9 \text{ km}$$

$$P = 20 \text{ W}$$



$$EIRP = P \cdot 10^{\frac{G}{10}} = 1.0 \text{ MW}$$

Equivalent Isotropically Radiated Power



$$K = \frac{d_A^2}{16r_S^2} = 2.6 \cdot 10^{-25}$$

$$P_R = K \cdot EIRP$$

$$= 2.6 \cdot 10^{-22} \text{ kW}$$



Deep Space Network

eyes.nasa.gov/dsn/dsn.html

The screenshot shows the NASA Deep Space Network (DSN) website interface. The browser address bar displays `http://eyes.nasa.gov/dsn/dsn.html`. The page header includes the NASA logo, "Jet Propulsion Laboratory | California Institute of Technology", and "DEEP SPACE NETWORK NOW". A "DSN home" button and an information icon are also present. The page is updated with the text "LAST UPDATED: AUG 25 10:39 AM (UTC)".

The main content area is divided into three sections for different ground stations:

- MADRID:** Includes antennas JNO, SOHO, and STA with signal strength values 63, 65, 54, and 55.
- GOLDSTONE:** Includes antennas GBRA, CHDR, and DAWN with signal strength values 14, 15, 24, 25, and 26.
- CANBERRA:** Includes antennas CAS, NHPC, MRO, and M010 with signal strength values 43, 45, 34, and 35.

On the right side, the "TARGET" section is set to "CASSINI". It features a 3D model of the spacecraft and three buttons: "VIEW ANTENNA", "VIEW SPACECRAFT", and "VIEW WORLD MAP". Below these, a "CAS" tab is selected, and the "DATA" section displays the following information:

- DATA RATE: 124.42 kb/sec
- FREQUENCY: 8.43 GHz
- POWER RECEIVED: -127.38 dBm (1.83 x 10⁻¹⁹ kW)

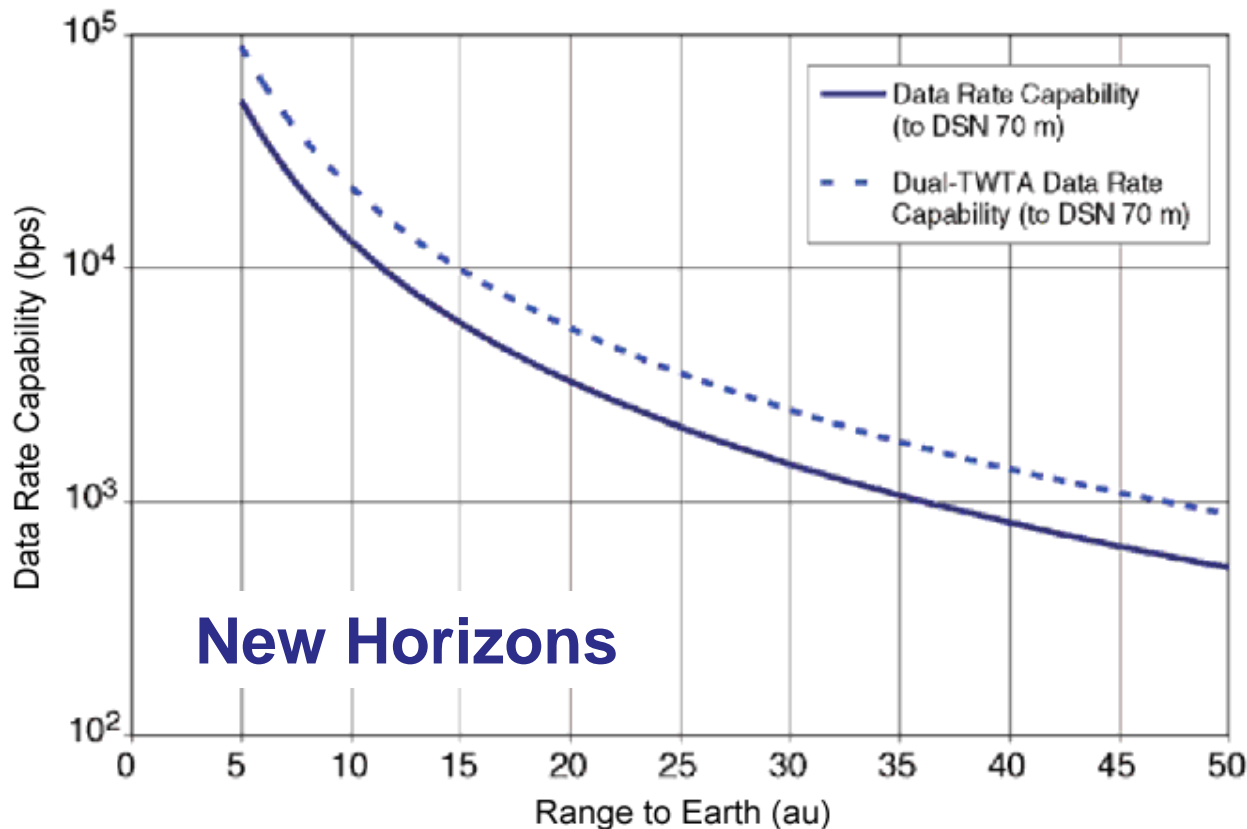
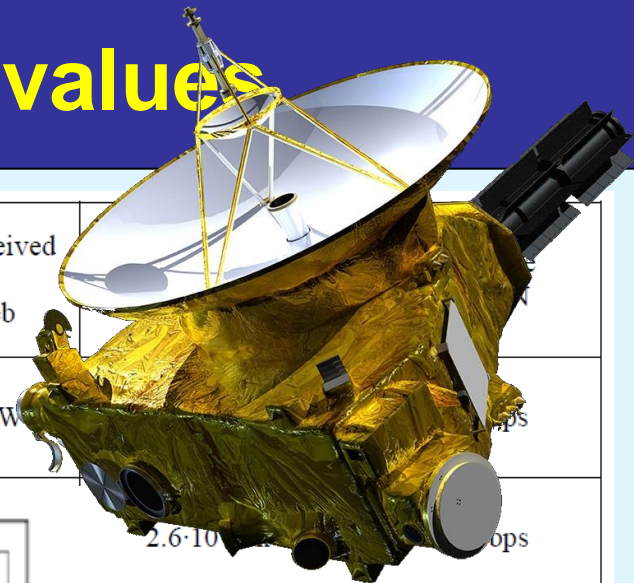
The "POWER RECEIVED" value is circled in red. At the bottom of the data section, there are links for "- less detail", "credits", and "contact us".



Calculated vs. measured values

Voyager 2
calculated

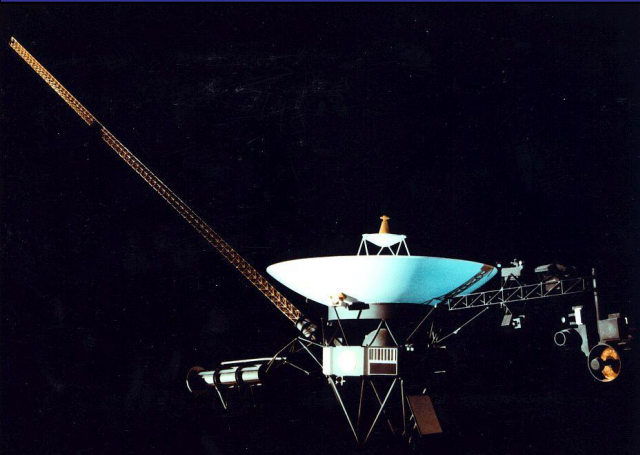
Space probe (Antenna gain, Power output) / DSN Antenna (Diameter)	Distance from Earth	Measured Received Power by DSN web
Voyager 1 (47 dBi, 20 W) / DSS 14 (70 m)	$20.08 \cdot 10^9$ km 134 au	$3.55 \cdot 10^{-22}$ kW



$2.6 \cdot 10^{-21}$ kW	4.21 kbps
$2.2 \cdot 10^{-21}$ kW	4.21 kbps
$3.6 \cdot 10^{-20}$ kW	22.12 kbps
$2.4 \cdot 10^{-19}$ kW	125 kbps
$2.1 \cdot 10^{-19}$ kW	52.42 kbps
$1.1 \cdot 10^{-18}$ kW	245.76 kbps
N/A	1.19 Mbps



Receiving antenna improvements



Voyager 2

64-m to 70-m upgrade



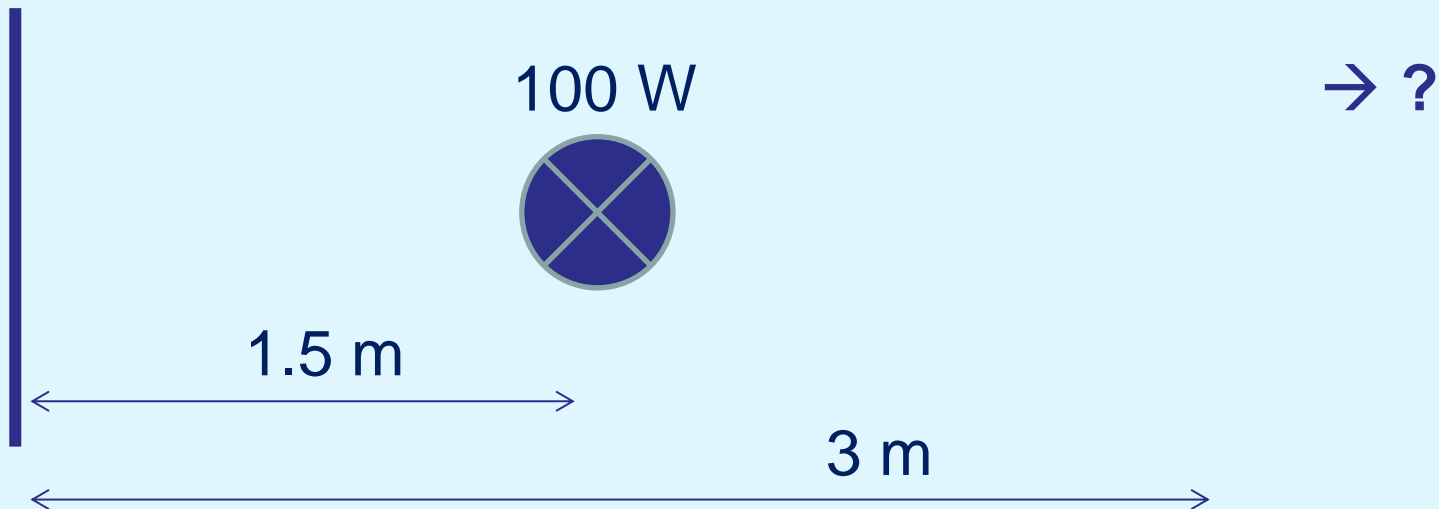
Encounter	Inverse Square (Distance)	Expected Rate (bps)	Achieved Maximum Rate (bps)
Jupiter	1/1 (5.2 au)	115,200 (ref.)	115,200
Saturn	1/4 (10 au)	~ 29,000	44,800
Uranus	1/13 (19 au)	~ 9,000	29,900
Neptune	1/36 (30 au)	~3,200	21,600



Questionnaire

15. A person is reading a newspaper while standing 5 feet away from a table that has on it an unshaded 100-watt light bulb. Imagine that the table were moved to a distance of 10 feet. How many light bulbs in total would have to be placed on the table to light up the newspaper to the same amount of brightness as before?
- A. One bulb.
B. Two bulbs.
C. Three bulbs.
D. Four bulbs.
E. More than four bulbs.

~ 200 students of various faculties, various grades of ZČU at Plzen

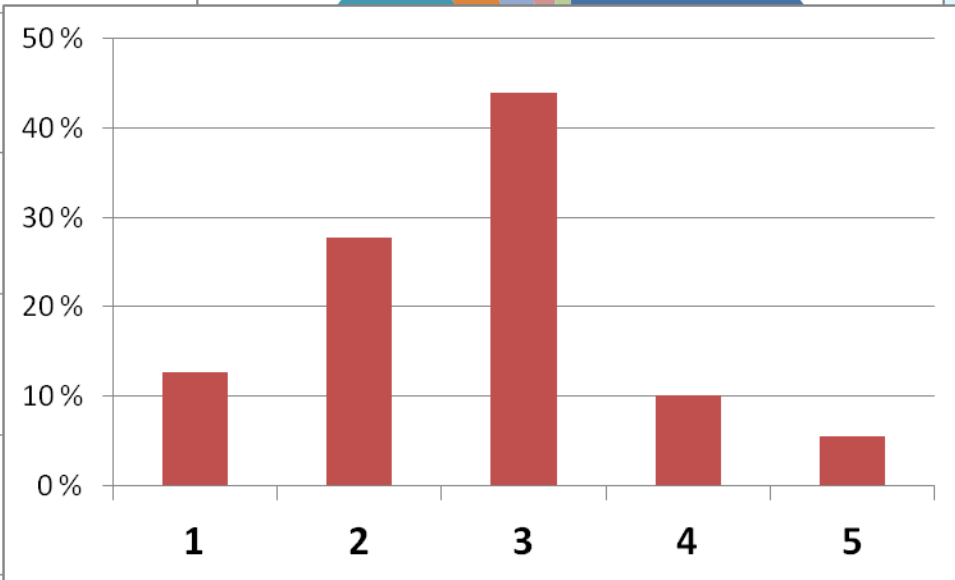
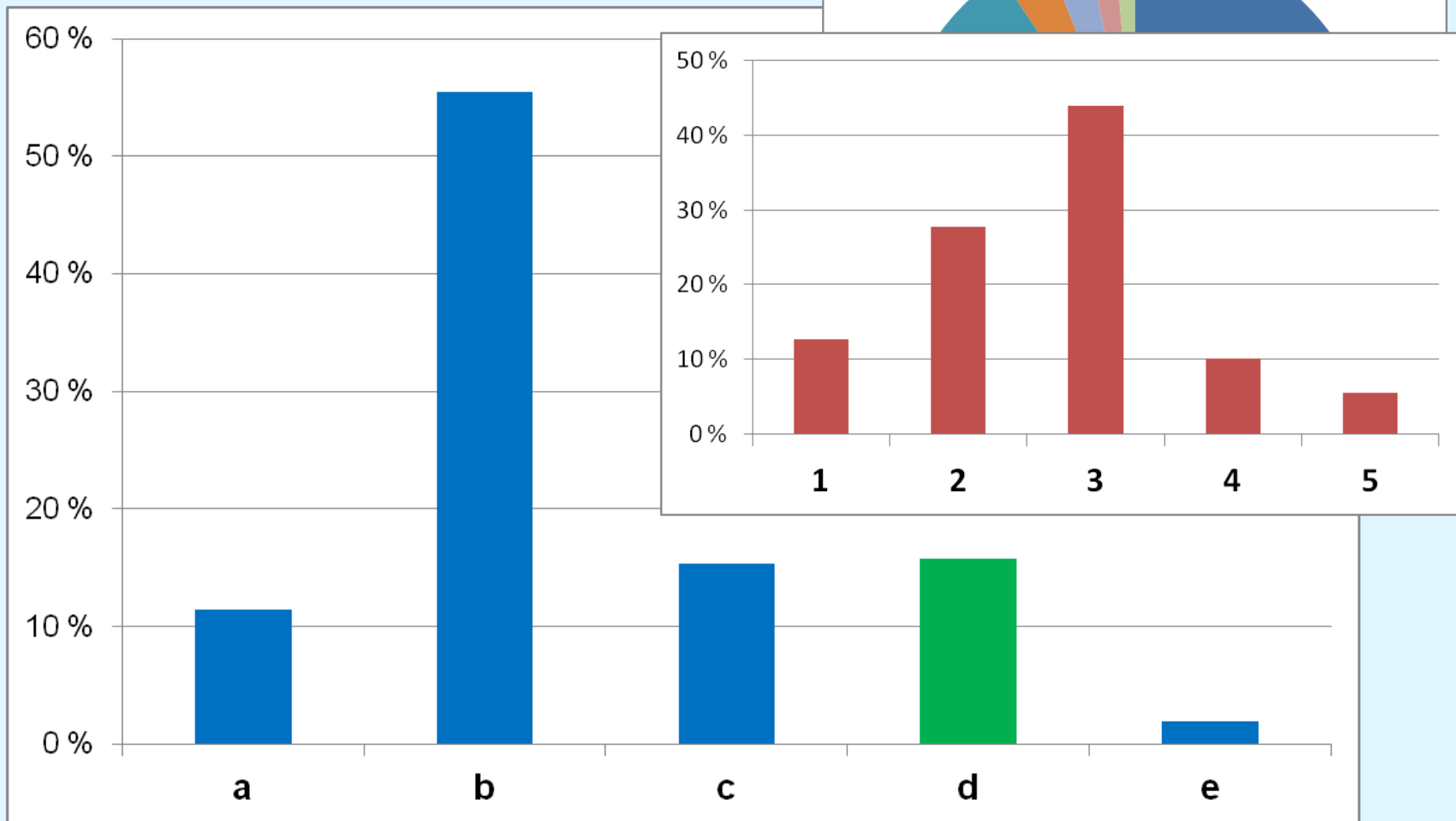




Student's result

FST 3 % FPR 2 % FEL 1 %

FUD 3 %



1

2

3

4

more

~ 200 students of various faculties, various grades of ZČU at Plzen



Practical activities for ICT

Sešit1 - Microsoft Excel nekomeřč

Domů Vložení Rozložení stránky Vzorce Data Revize Zobrazení

Calibri 11

B *I* U **A** **A**

Vložit

Schránka

Písmo

Zarovnání

Matematický

Číslo

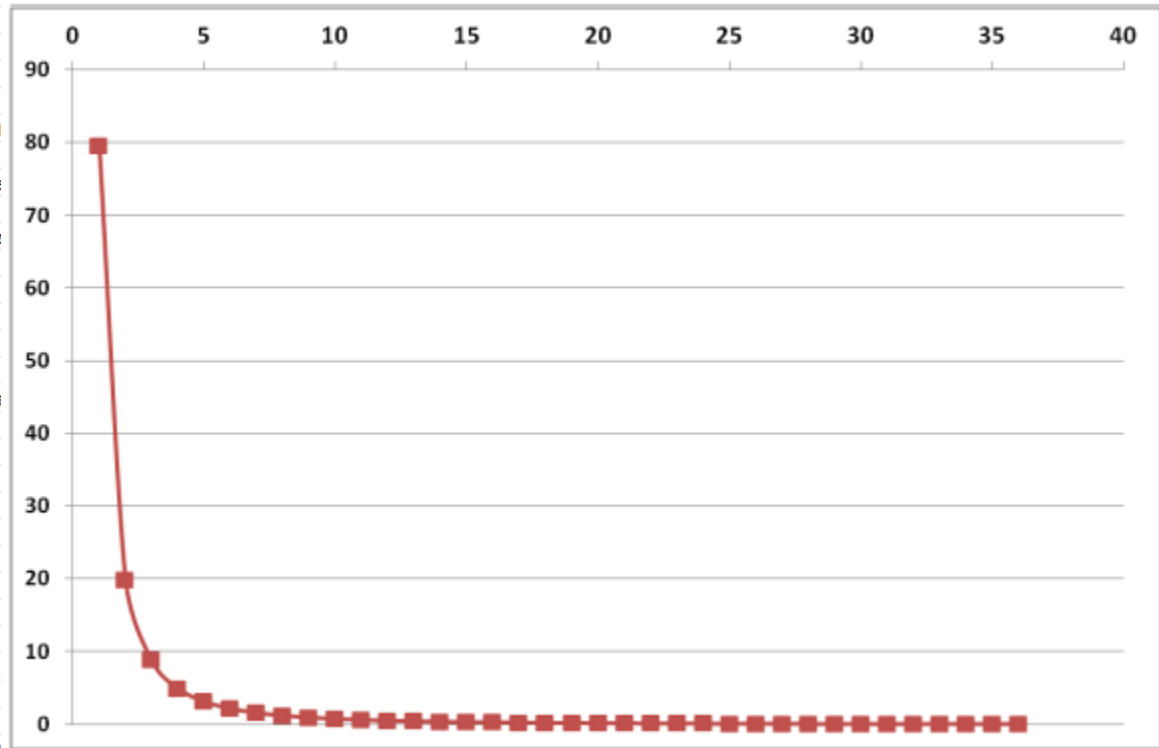
B5 f_x =B4*D4

	D	E	F	G	H	I	J
10							
11							
12		NH			Voyager 1		
13							
14		12 W			20 W		
15		42 dB			47 dB		
16		190187,2 W EIRP			1,00E+06 W E		
17							
18		9,14E-18 W received			3,55E-19 W re		
19							
20		5,2E+12 m vzdálenost			2,008E+13 m vz		
21							
22							
23		3,40E+26 m2			5,07E+27 m2		
24							
25		70 m			70 m		
26		3848,5 m2 anténa			3848,5 m2 i		
27							
28		2,2E-21 kW			7,6E-22 kW		
29							
30		2,677291			0,466283102		
31							
32		2					
33		1,584893					
34							
35							
36							
37							
38							

List1 List2 List3

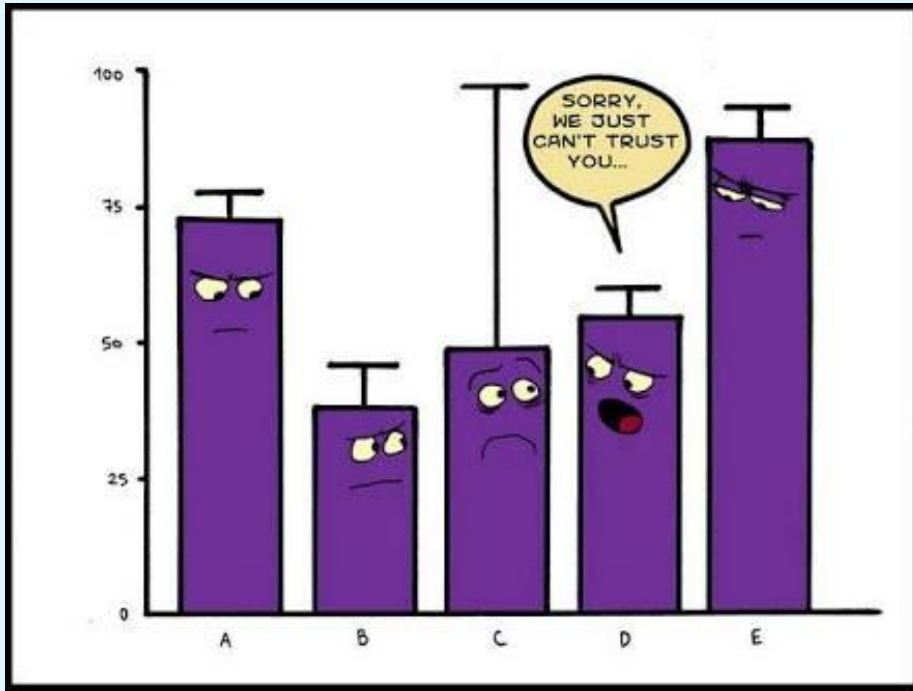
Připraven

85%

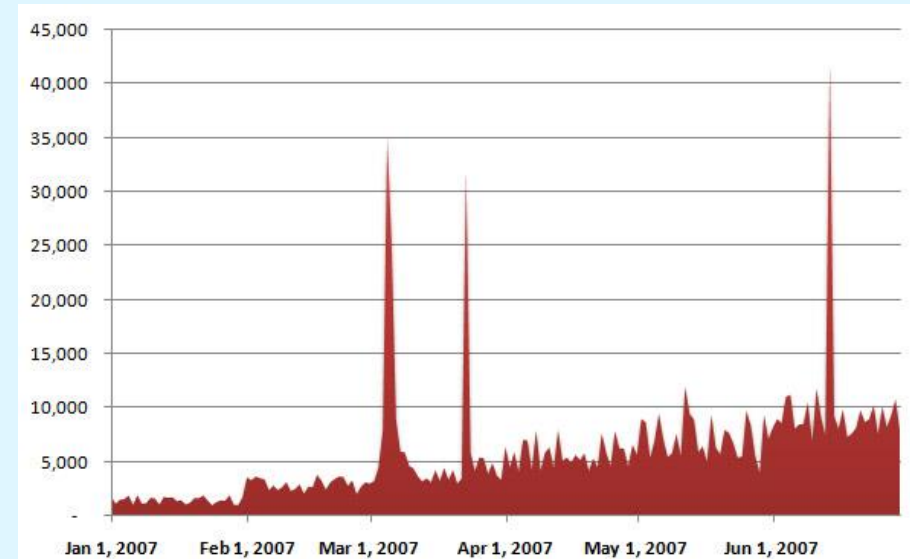
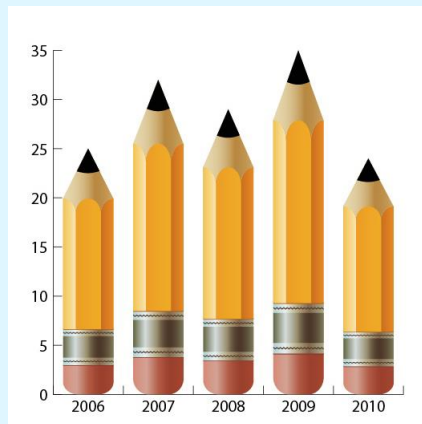
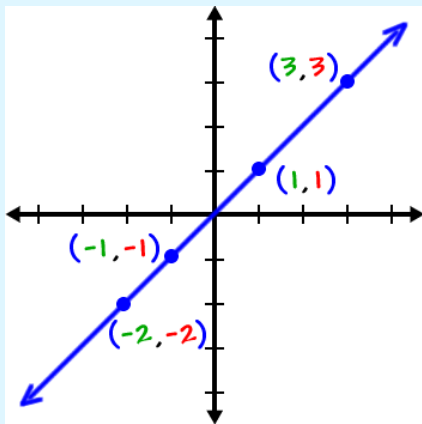




Graphs / plots / diagrams are everywhere...



**ICTE
2015**





Students' activities

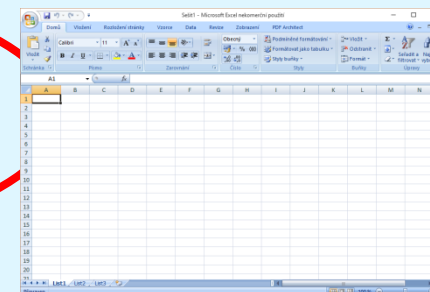


Real Data



Students

Application software



Graphs Visualization

**ICTE
2015**



Practical activity for Physics

inaudible distance estimation
3x distance measurement
mean distance

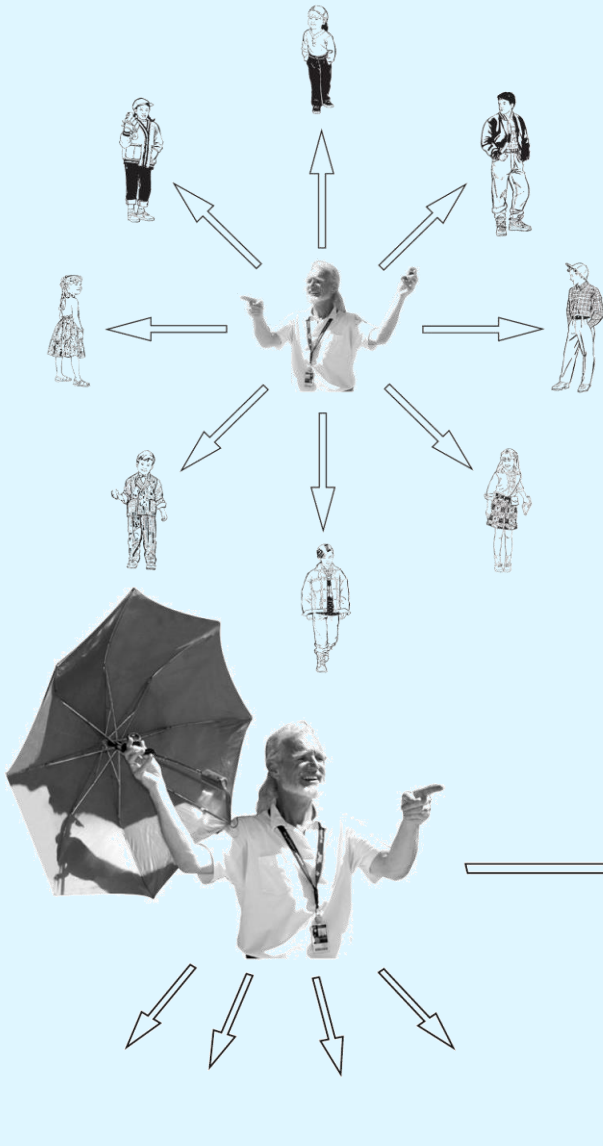
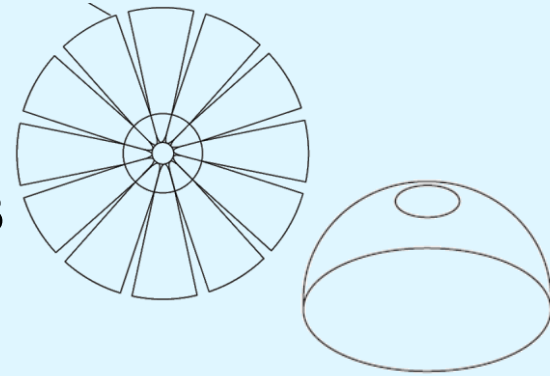
1 m

76 dB

inaudibly at **~160 m**

intensity (calculated) **~32 dB**

Recommendation:
*use lower sound volume
to have suitable distance of
inaudibility*





Moderní trendy v přípravě učitelů fyziky 8

Jak ICT ovlivňuje fyziku a naopak

Kdy? duben 2017 (upřesníme)

Kde? Kašp. Hory, hotel Šumava

Proč? kof.zcu.cz/ak/trendy/8/

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