

RF Communications for 250 AU

Can we do better than Voyager?

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Communications With Voyager Today

- Voyager 1 currently at ~129 AU from Earth
- Voyager 2 currently at ~105 AU from Earth
- Communications supported by 70m Deep Space Network antennas only
- Voyager baselined an S/X-Band Communications System
 - S-Band (2 GHz) up/down for Command/Telemetry
 - Currently at 16 bits/second uplink command rate
 - X-Band (8.4 GHz) down for Science Data downlink
 - Currently at 160 Bits/Sec downlink data rate
- For comparison, your home Ethernet connection is ~10M to 100M bits/sec

Communications Key Technology Areas

State-Of-The-Art

- Travelling Wave Tube Power Amplifier
 - 1977: X-Band 20 Watts RF Power @ ~25 % efficiency (~80 Watts DC)
 - 2014: Ka-Band 250 Watts RF Power @ 50% efficiency (~500 Watts DC)
 - 2025: Ka-Band 500 Watts RF Power @ 50% efficiency (~1000 Watts DC)
- Antenna
 - 1977: 3.5 meter diameter, solid, spacecraft body mounted, 3 mrad pointing (X-Band)
 - 2014: 6 meter diameter, wire mesh, deployable (L-Band through Ka-Band)
 - 2025: 9m diameter, wire mesh, deployable, 0.35 mrad pointing (Ka-Band)
- Data Coding
 - 1977: Convolutional Coding with Concatenated Reed-Solomon Code
 - 2014-2025: Turbo Coding
- Deep Space Network
 - 1977: 64>70 meter S-Band and X-Band
 - 2014-2025: 34 meter X-Band and Ka-Band

Key Telecom Equipment Comparison (2025)

Mission	Element	Type	Mass (each)	Size	Performance	Telecom Performance
Voyager (8.4 GHz) (DSN: 70m)	Power Amplifier	TWTA	5.8 kg		18 Watts RF Power 72 Watts DC Power (~25% efficiency)	125 AU: 160 bits per second 250 AU: ~40 bits per second
	Antenna	Parabolic dish, body fixed, solid	53 kg	3.7m diameter (3 mrad pointing)	~48 dBi (8.4 GHz)	
	Data Coding	Convolutional Code with concatenated Reed-Solomon		Rate 1/2 (CC) with RS (255,223)	6 dB over an uncoded link (factor of 4 data rate improvement)	
Interstellar (32 GHz) (DSN: 34m)	Power Amplifier	TWTA	10.3 kg		500 Watts RF Power ~1000 Watts DC Power (~50% efficiency)	125 AU: ~56 kbps 250 AU: ~14 kbps
	Antenna	Parabolic dish, deployable, wire mesh	120 kg	9m diameter (0.35 mrad pointing)	~67 dBi (32 GHz)	
	Data Coding	Turbo		Rate 1/6	~3 dB over a concatenated CC-RS link (factor of ~2 data rate improvement)	

Data Rate Improvements (2025)

Techniques to improve downlink data rate above and beyond 14 kbps

Improvement Mechanism	Description	dB Increase	Percentage Increase	Cumulative Data Rate
Decrease JPL Mandated 3 dB margin at launch	JPL and Division 33 Flight Project Practices mandate 3 dB minimum at launch. Operate at a lower residual margin by decreasing this to 1 dB.	+2 dB	+58.5 %	22 kbps
Improved spacecraft pointing requirements	Requirement of 0.35 mrad can be tightened to <0.1 mrad. This is achievable today on many platforms while in quiescent states.	+1 dB	+25.9 %	28 kbps
Improved coding	Move from Turbo 1/6 code to Ultra Low-Rate 1/32 code.	+ 1 dB	+25.9 %	35 kbps
DSN 34 m arraying	Array together two DSN 34 meter stations to improve downlink SNR.	+2.5 dB	+77.8 %	62 kbps