Reconfigurable Channel Coding for Small Satellite High Speed Radios

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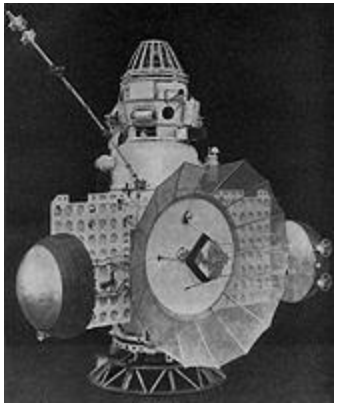
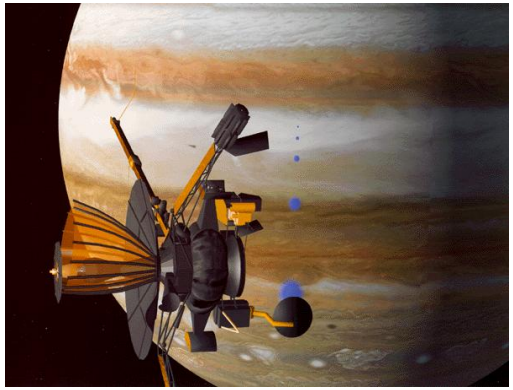
Risks

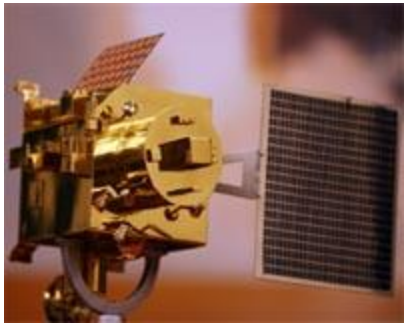
"This will ***NOT*** happen to ***MY*** spacecraft."

Radio-Induced Failures

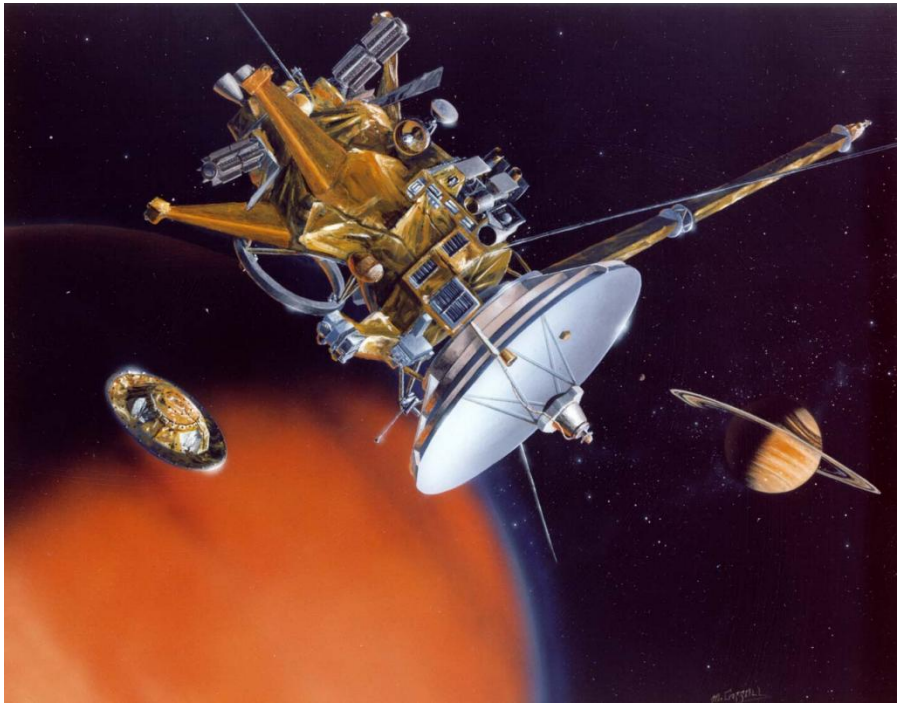


- Mars 1 (1962)
- Zond 2 (1964)
- Galileo (1989)
- Chandrayan (2009)



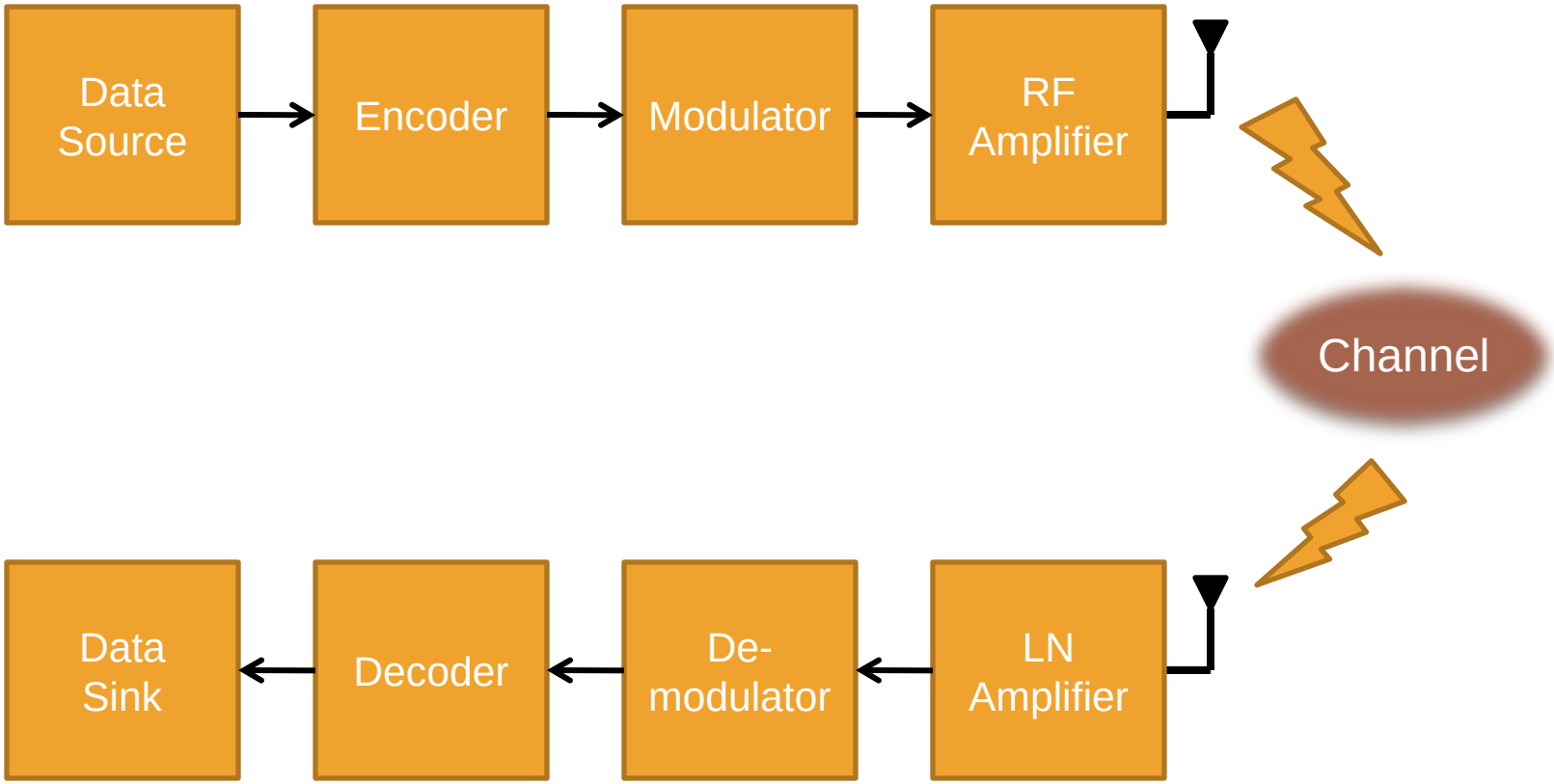


Huygens/Cassini Design Flaw

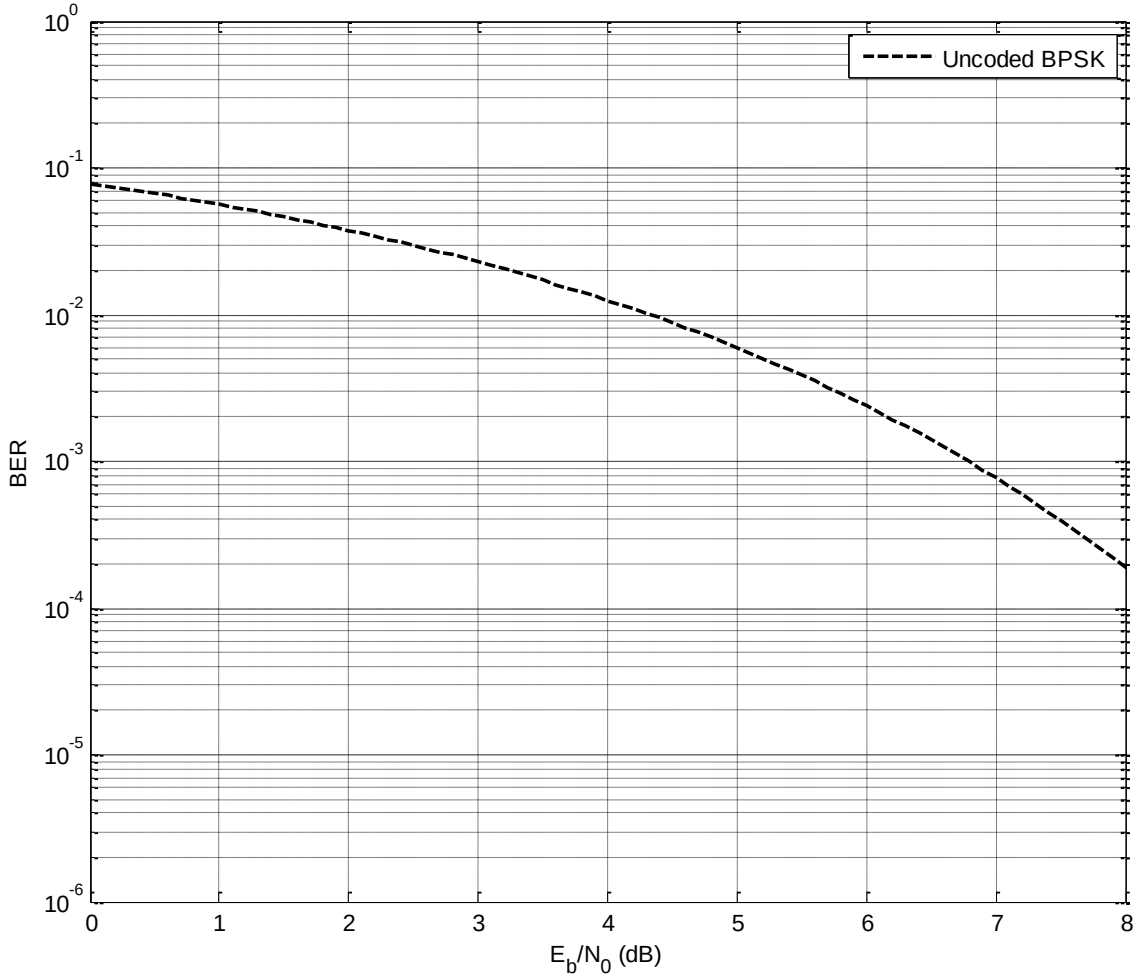


- Flaw → **All** Huygens data would be lost.
- Doppler **time**-shift not accounted for.
- Firmware **not** reprogrammable.
- Resolution → Change Huygens trajectory.

The Communications Channel



Channel Bit Error Rate (BPSK)



- High transmit power required.

Channel Encoding

- Add redundant information.
- Special mathematical constructs.
- Detect or correct transmission errors.

10 dB: *Jack and Jill ran up the hill to fetch a pail of water.*

7 dB: *Jack and Jill ran up the hill to fetkh a0pail of water.*

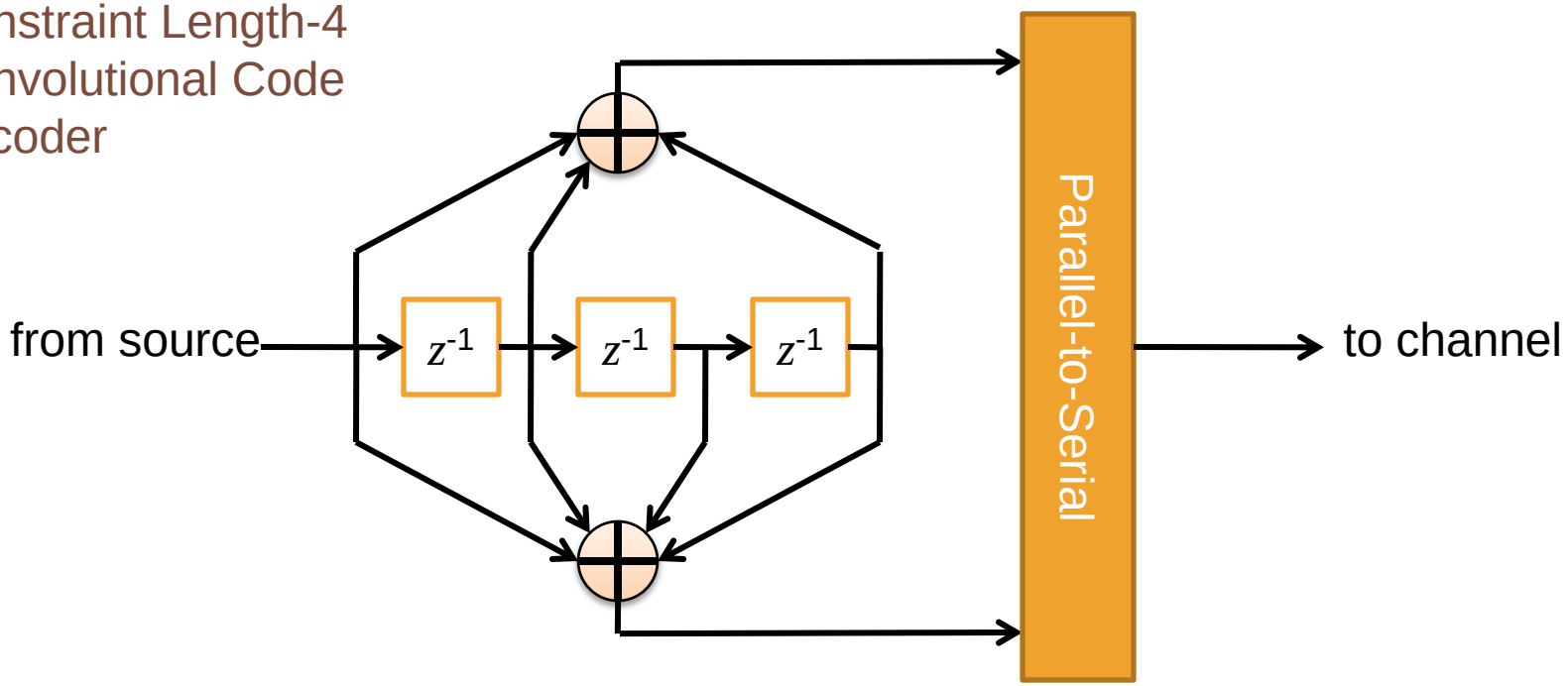
4 dB: *Jack!and Jill rin up the hill to fetch a pakl of water.*

1 dB: *Jas+ and Jidl ran up the hill ug $eteh ` pail ff w`dds.*

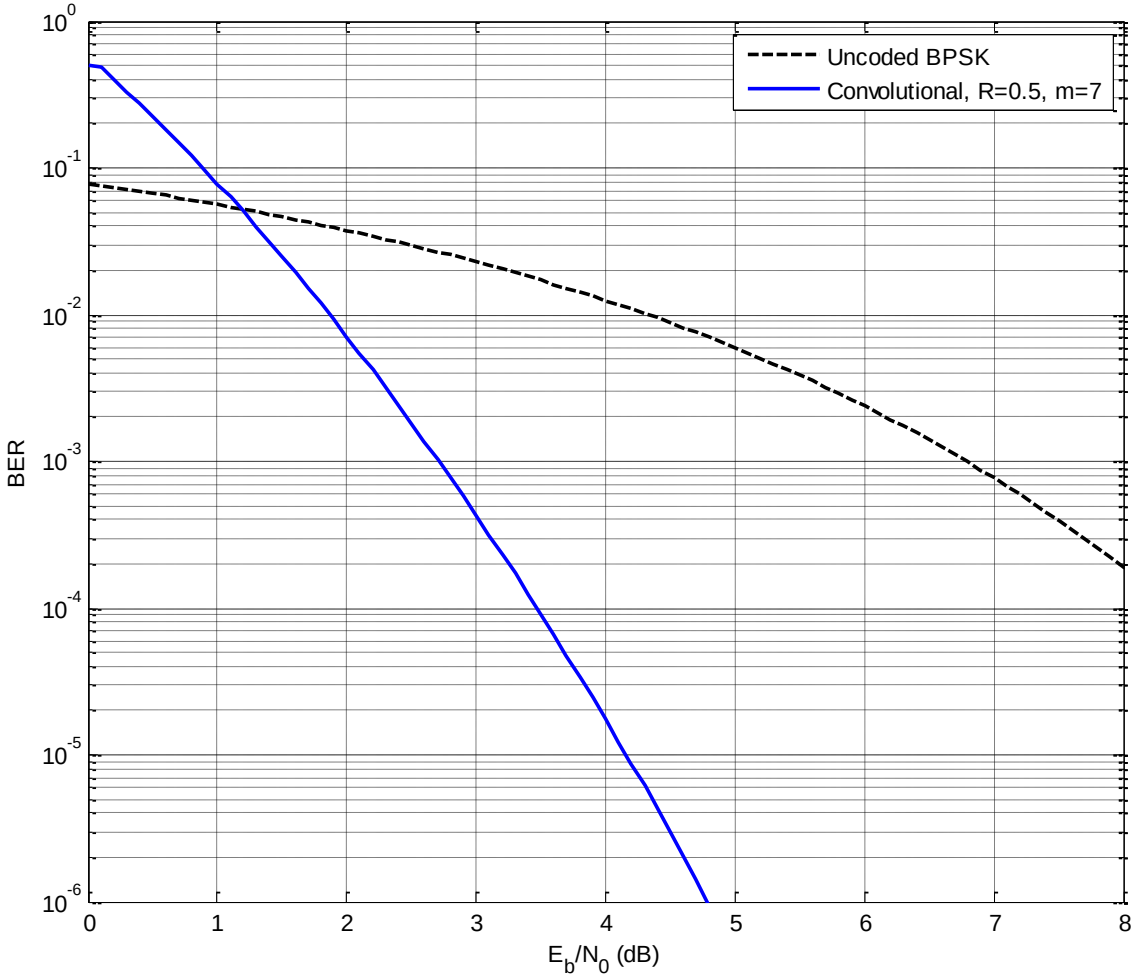
-2 dB: *JcK`aN| Bh<dccag8up Dh% lOln`u_ f'L2(abpak| Kb ⊏aVmr>*

Typical Channel Encoder

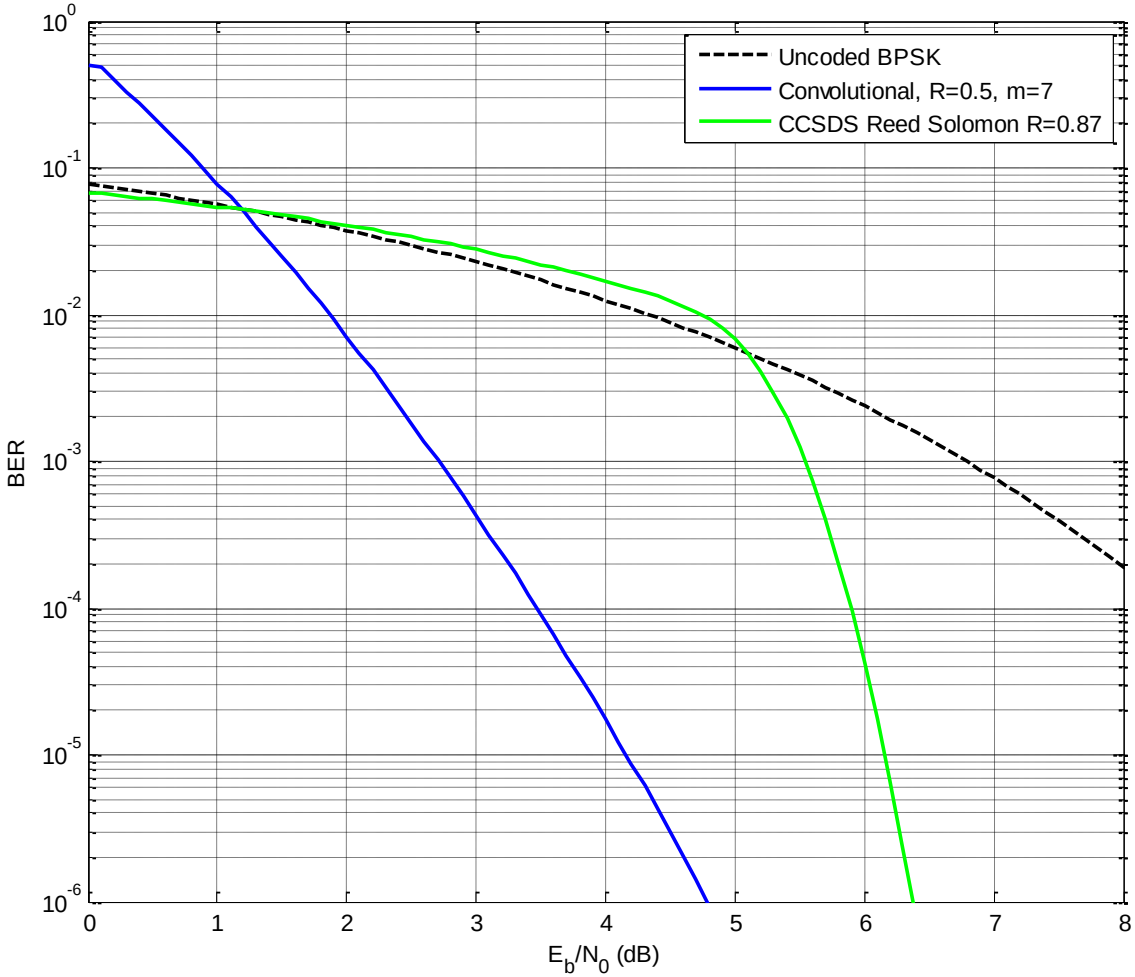
Constraint Length-4
Convolutional Code
Encoder



Rate ½ Convolutional Code

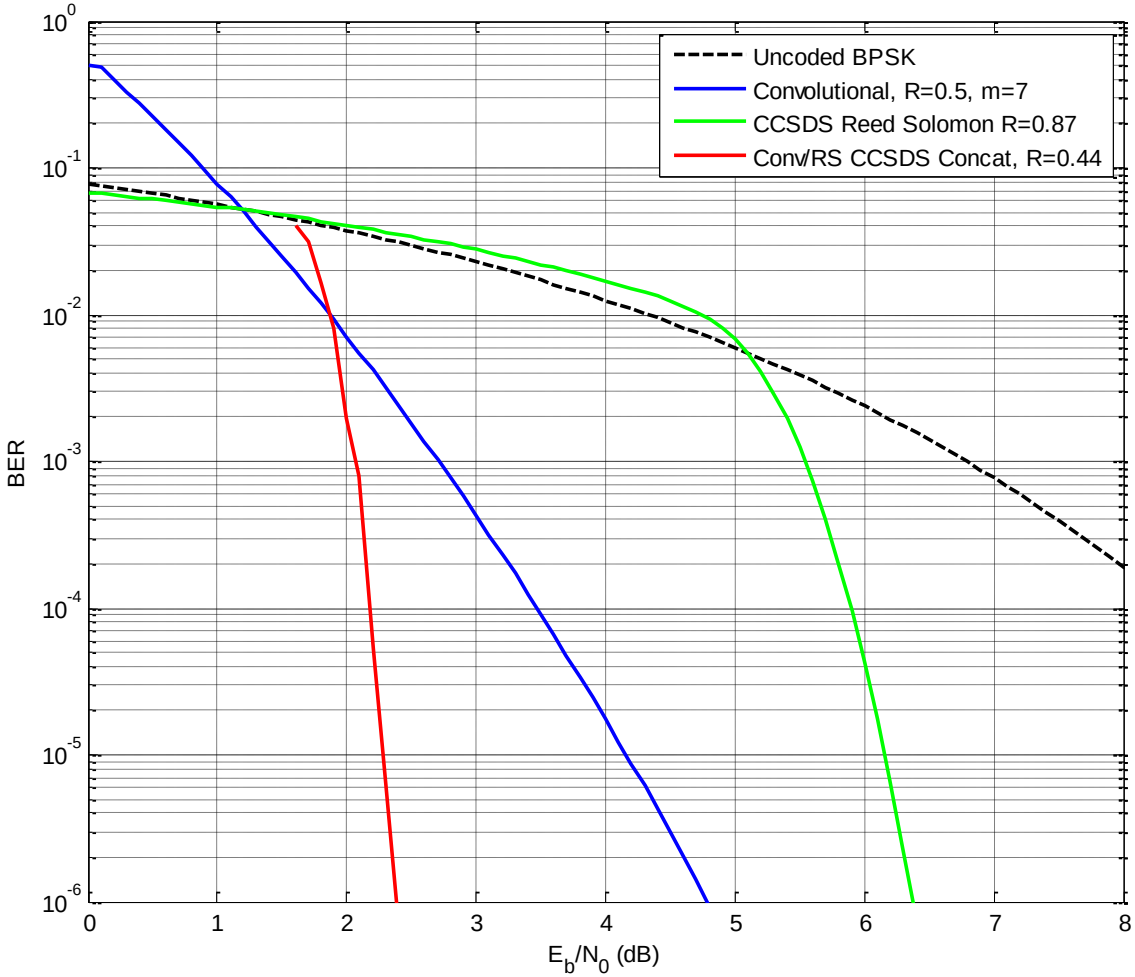


CCSDS Reed-Solomon Code

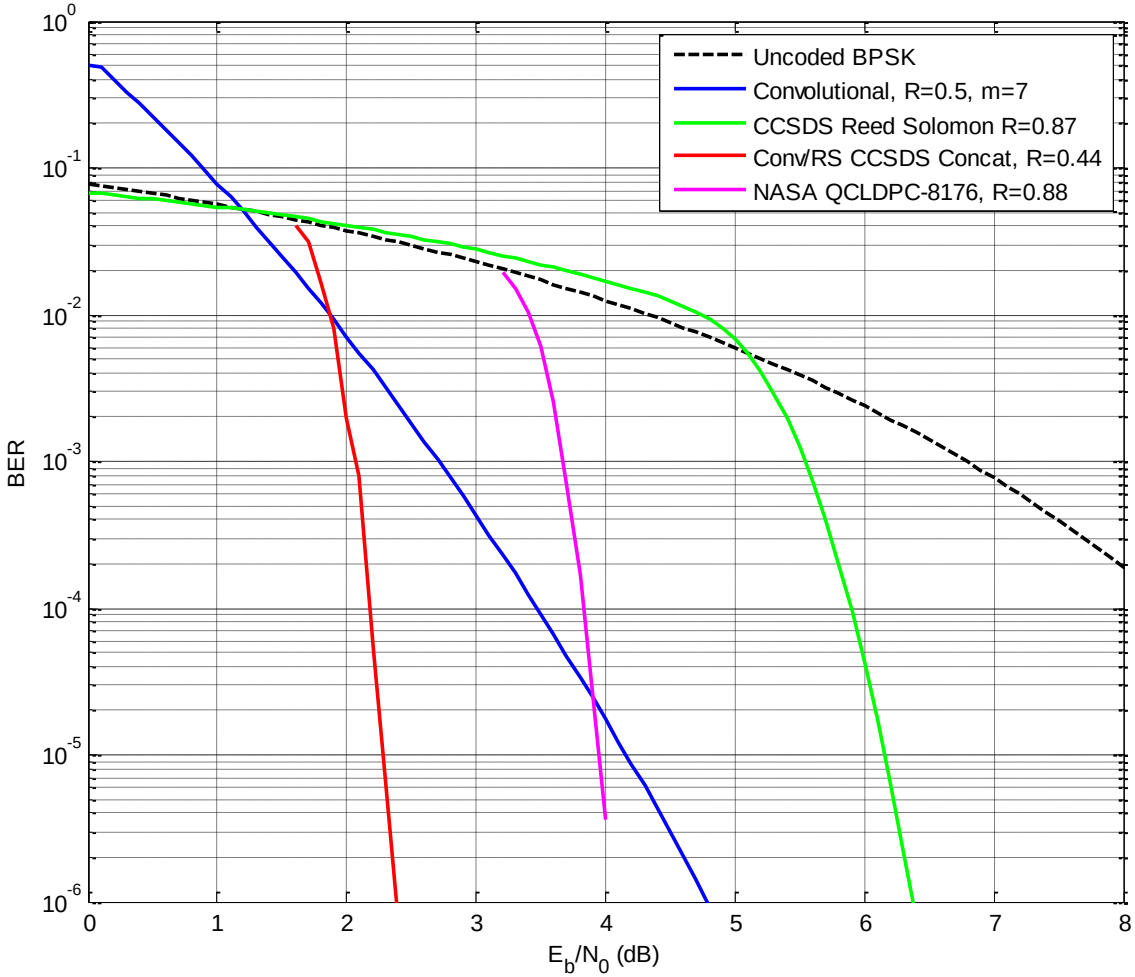


Channel Code Concatenation

Concatenated Convolutional/Reed-Solomon

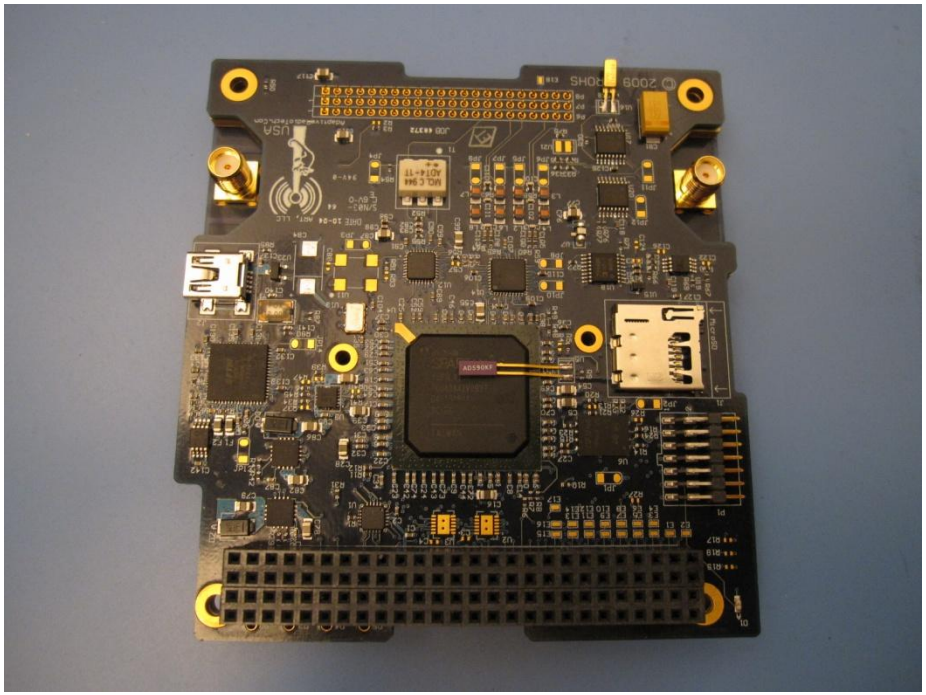


NASA GSFC-STD-9100 QCLDPC-8176

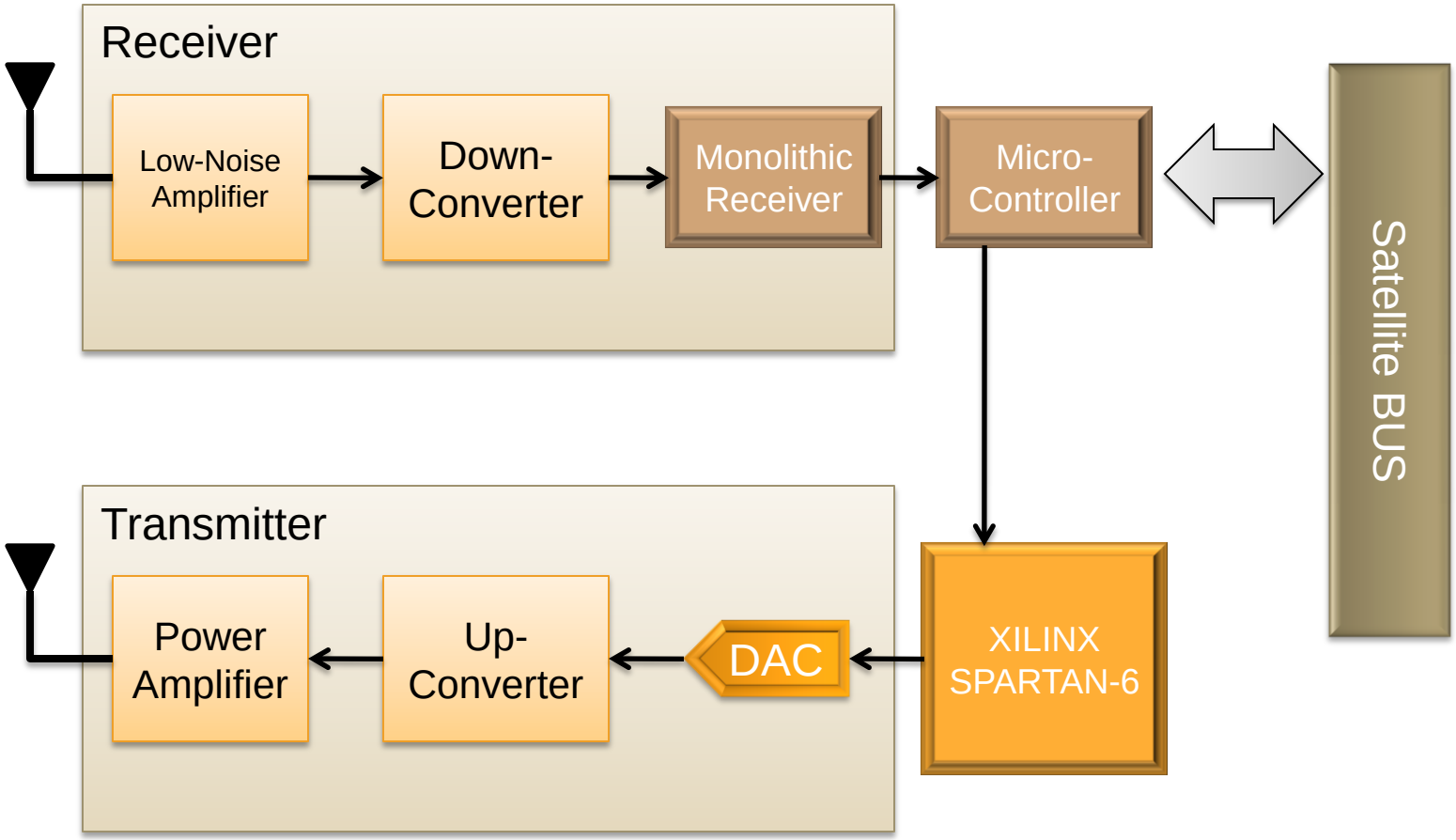


Firehose Software Defined Radio

- Satellite Radio
  - FPGA firmware
    - Baseband processing.
  - Non-volatile memory
  - Up/Down converter customizable

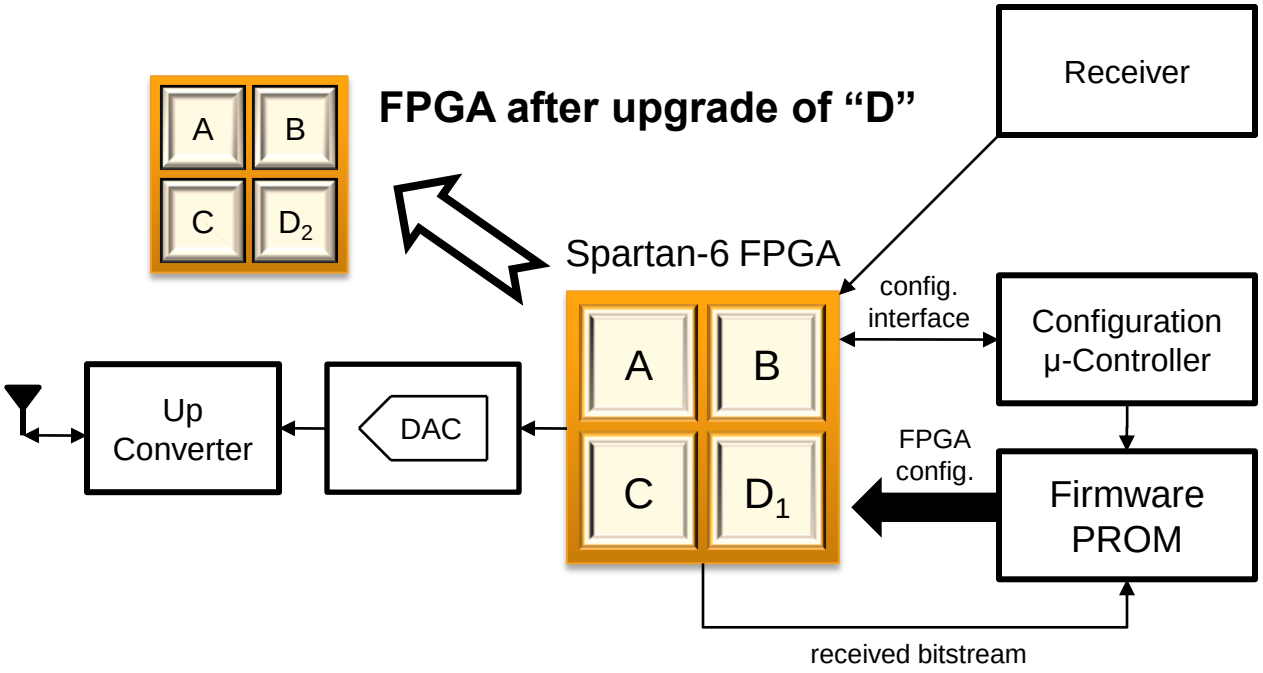


System Architecture

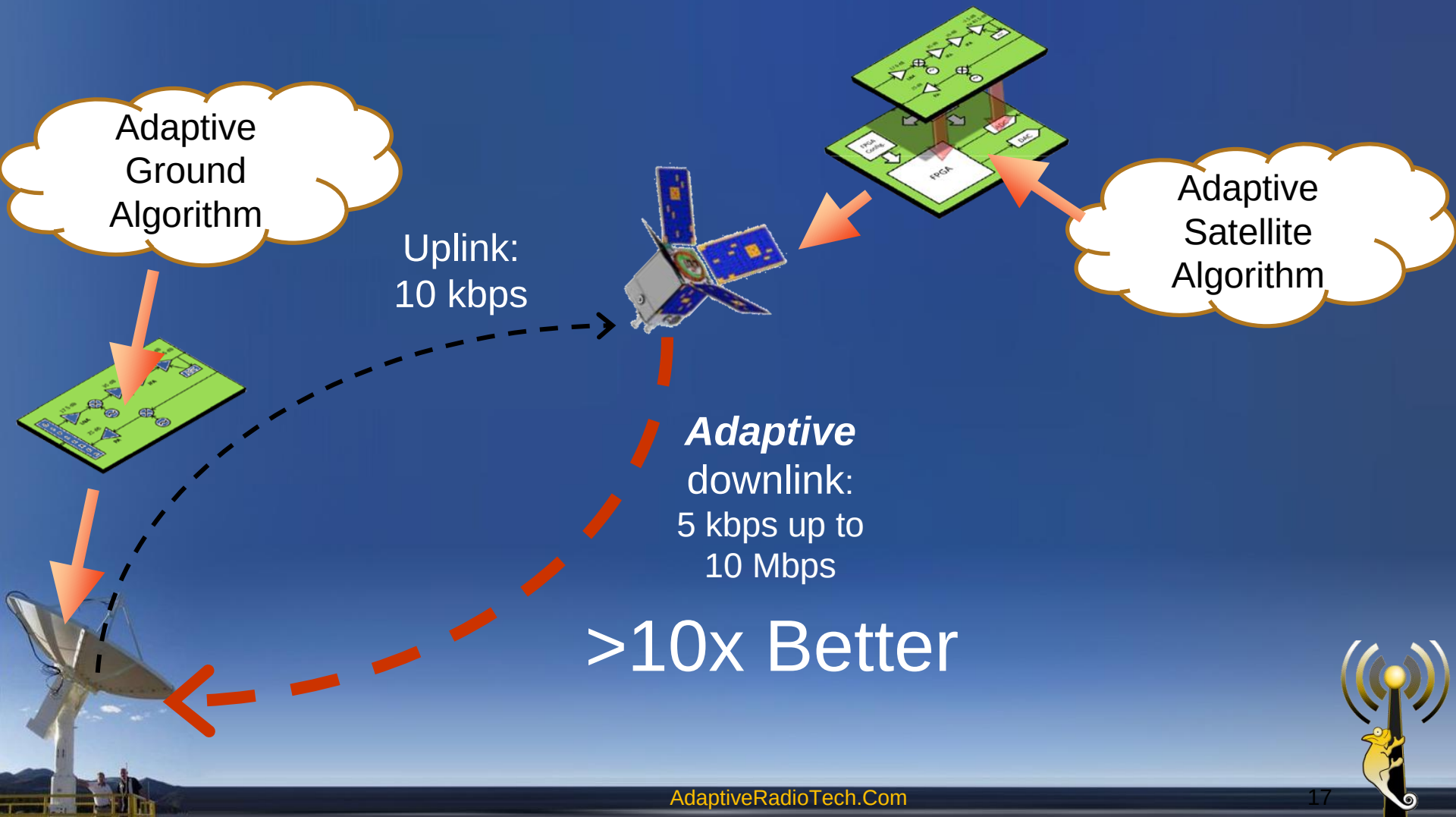


FPGA Reprogramming

- Partial Reconfiguration
- Post launch bitstream deployment
- Storing of multiple waveforms



Firehose
An Adaptive Waveform

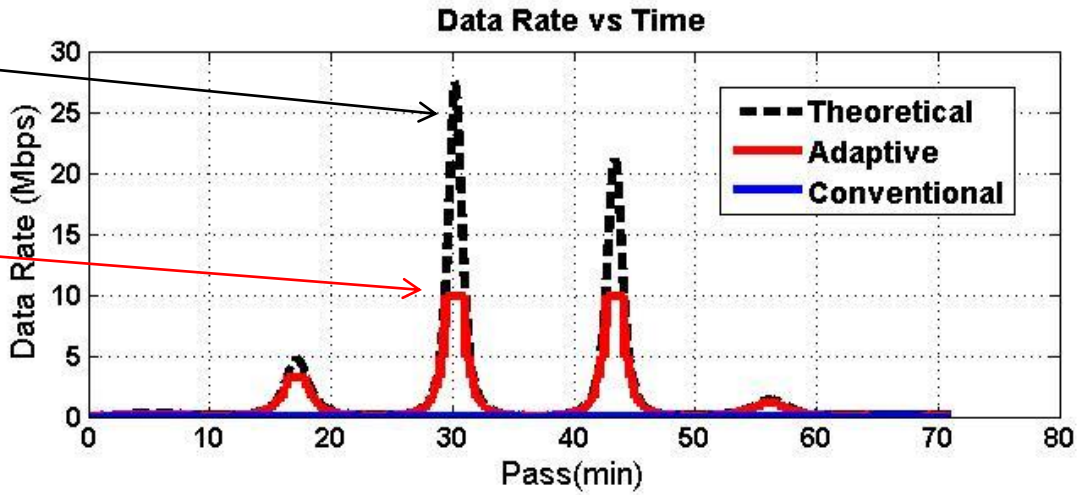


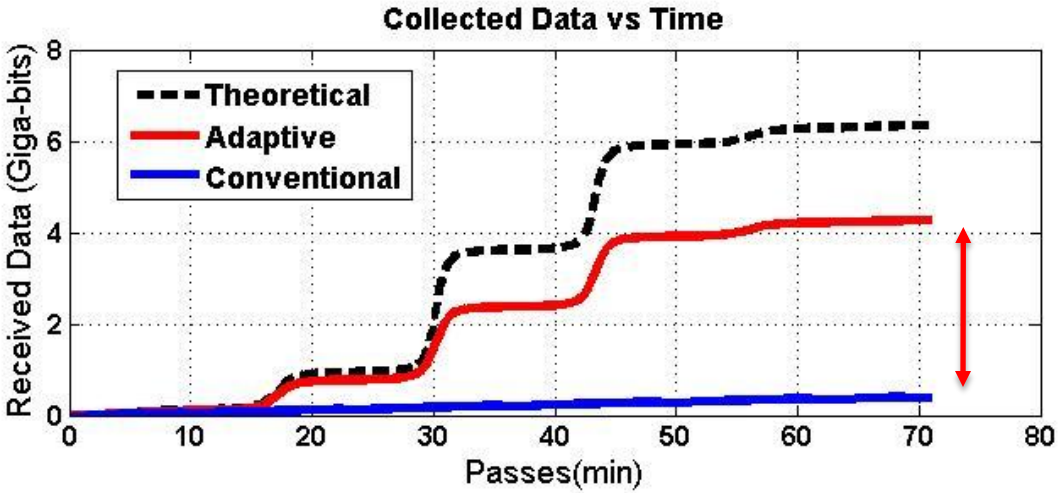
>10x Better

Firehose Waveform: How it works

Channel Bandwidth Limit
6 passes from a day in the life of CFESat

Link Optimization





>10x

<u>Channel varies:</u>

- Range
- Noise (El Angle)
- Pointing (pol/pattern)

<u>Rate changes</u>

- Auto-negotiated
- No user coding
- Instant
- Glitch free

Conclusion

- Post-launch reconfigurability
  - Resolve design flaws.
  - Overcome new challenges.
  - Migrate to new infrastructure
- Improved power efficiency
  - More bandwidth for very small satellites