

DAPCOM
Data services

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What is DAPCOM?

DAPCOM Data Services S.L. is a **technological spin-off company**



UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH



UNIVERSITAT DE
BARCELONA

Founded in February 2013

Strong background on **Space research**

8 co-founders, all of them
from **Gaia@Barcelona**



Main field: **Software and Data Science**

**Space
data
handling**

**Massive
data
processing**

**Efficient
data
compression**

Main customers (so far)



IEEC (Gaia/DPAC):

IDU (Intermediate Data Updating)

Massive re-processing of accumulated raw data
(>1 trillion images, >100TB raw data)

ESA (Gaia/DPAC):

XM (Cross-Matching)

Determination of **source catalogue** (>1.5 billion)
from >100 billion on-board detections



High-quality and specialized software engineering

Main customers (so far)

Mind the Byte (SaaS for drug discovery)

Consultancy on efficient, massive data transfers for genomic data processing on the Cloud



Meteowhizz (for IAC)

Tailored software platform (backend + web frontend) for improved meteorological predictions in astronomical observatories



Spire Global Inc.

Adaptation of our data compression technology to their **nanosatellites constellation** (radio occultation data)



Data compression for Space systems

Consultative Committee for Space Data Systems (CCSDS):

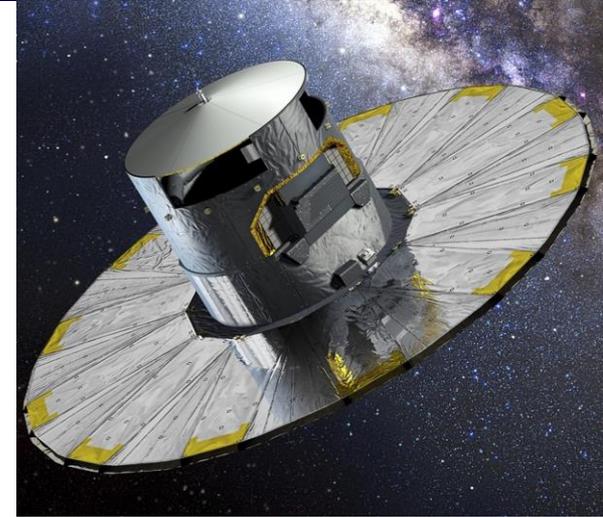
Several recommendations for onboard data compression

- 121.0: Lossless data compression
One may define and implement any data predictor
- 122.0: Lossless + lossy greyscale image data compression
Discrete Wavelet Transform (~JPEG2000)
- 122.1: Lossless + lossy multi-band image data compression
Extension of 122.0 for colour images
- 123.0: Lossless hyperspectral data compression
Aimed at low complexity
- 123.1 (in prep.): Near-lossless hyperspectral compression

See www.ccsds.org for more details

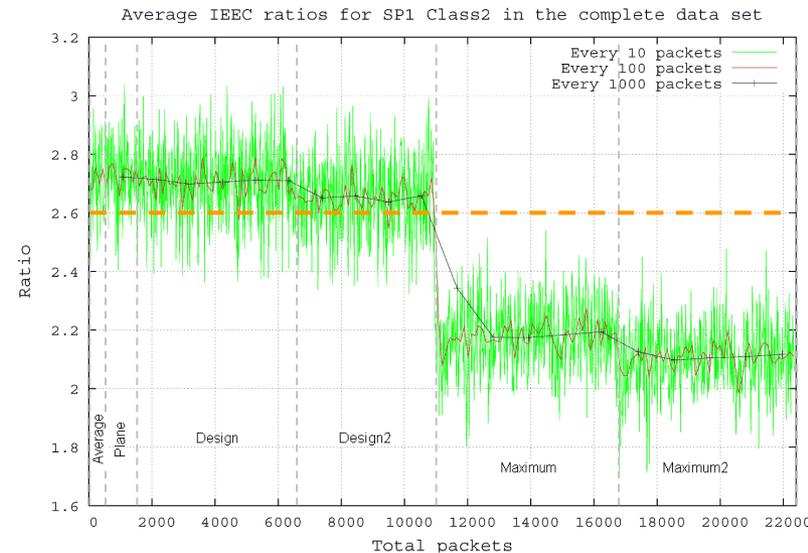
Data compression for Gaia

- Gaia: ESA cornerstone mission
 - 3D catalogue of >1 billion (10^9) stars
 - Downlink: 60GB/day (from 1.5M km)
 - High-performance on-board data compression (tailored to Gaia, software on PowerPC, C language)



- GOCA: Gaia Optimum Compression Algorithm

- ESA TRP Study: IEEC + GTD
- Initial (contractor) baseline: Rice entropy coder. Many problems with *outliers* (prompt particle events)
- IEEC solution: PEC (Prediction Error Coder)



FAPEC: Our own data compression technology

ESA TRP study: Gaia Optimum Compression Algorithm (GOCA)
→ PEC (Prediction Error Coder), later Fully Adaptive PEC (**FAPEC**)

US patent 9,002,913 B2

License transferred
to DAPCOM

Method for fully adaptive calibration of a prediction error coder

Abstract

Method for fully adaptive calibration of a prediction error coder, comprising a first step of initialization; a second step of reception and accumulation of block-size data samples wherein for each received value, it is added one to the histogram bin associated to that value; a third step of analysis of the histogram and determination of the coding option; a fourth step of analysis of the histogram and determination of a coding table; a fifth step of output a header with the prediction error coder coding table determined; and wherein previous steps are repeated if more samples need to be compressed. It is useful as a data compression technique, with the advantage of being faster and more robust than the current CCSDS lossless compression standard.

US20120166503A1
UNITED STATES OF AMERICA

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Inventor: Jordi Portell I De Mora, Enrique Garciaberro Montilla, Xavier Luri Carrasco, Alberto González Villafranca, Jorge Torra Roca

Current Assignee: Universitat de Barcelona, Universitat

Main FAPEC benefits:

Better compression resiliency on **statistical outliers**

Fast and self-calibrated operation

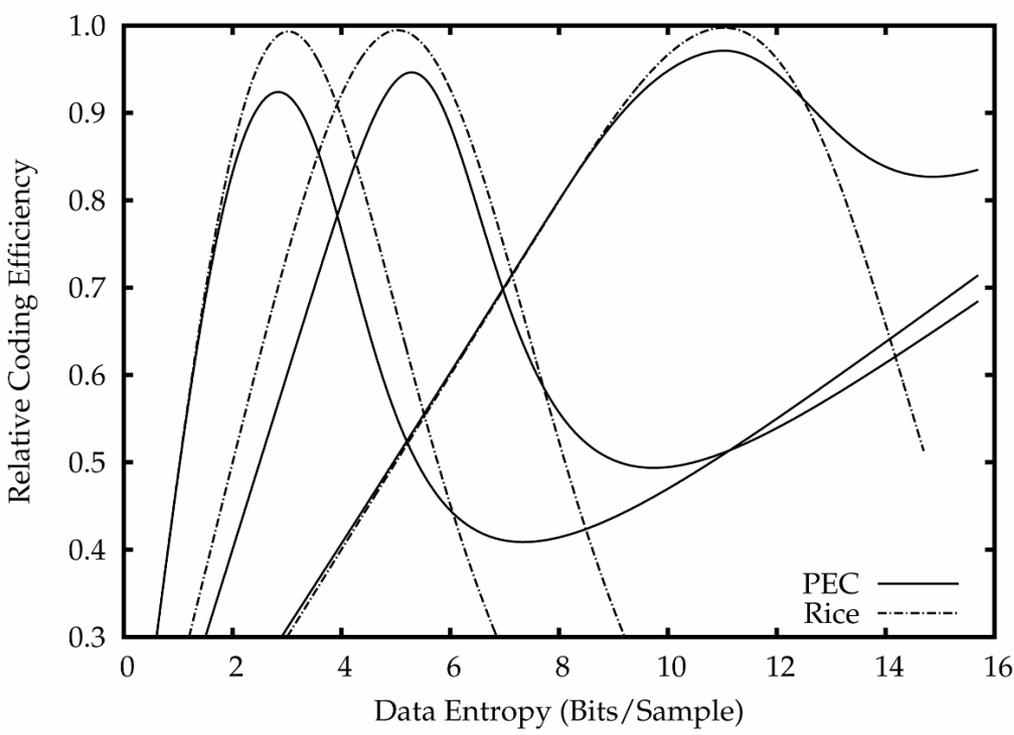


ESA Business Incubation Centre (BIC) in Barcelona

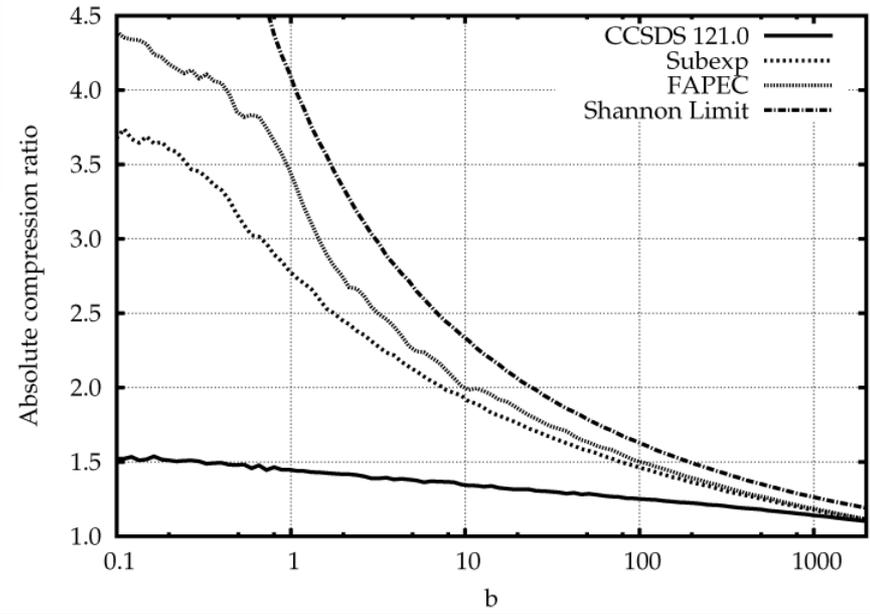
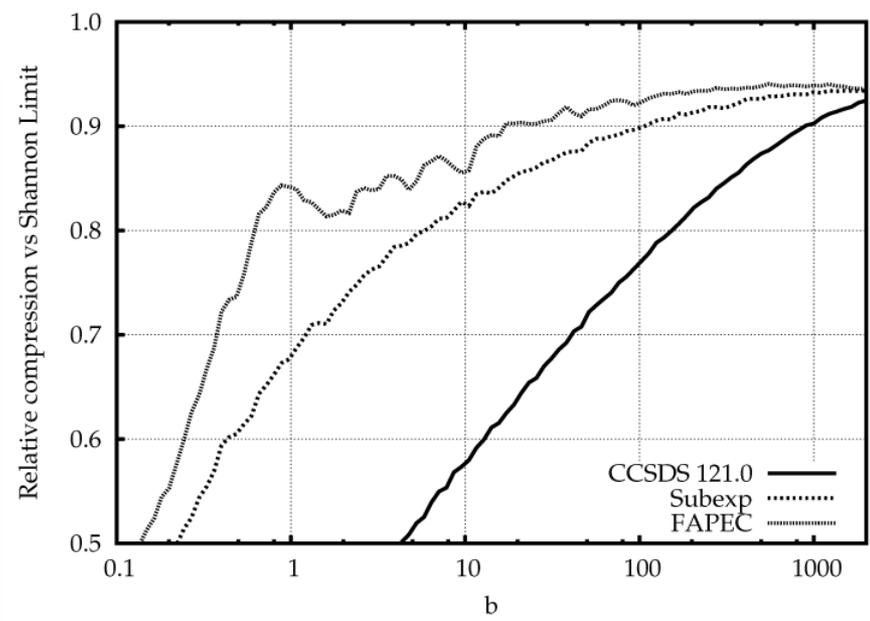
Transfer this technology to the non-Space market

**business
incubation
centre**
Barcelona

Entropy coding performance: Rice vs. PEC/FAPEC



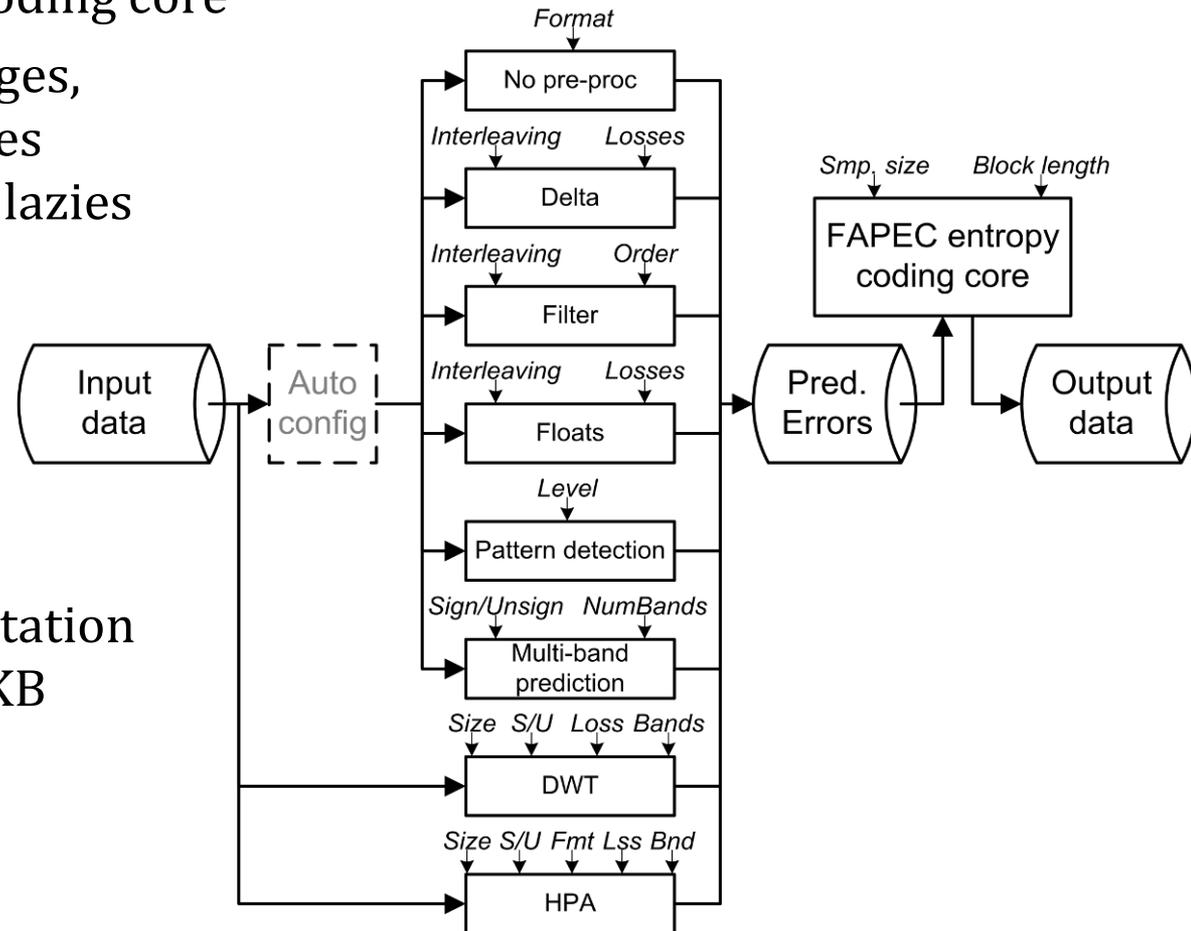
$$H = \sum_i P(i) \log_2 \frac{1}{P(i)}$$



The FAPEC data compressor

Versatile data compression solution (onboard + onground applications)

- Based on FAPEC entropy coding core
- Suite of pre-processing stages, including multi-band images and auto-configuration for lazies
- 8 to 24 bits per sample (and beyond: interleaving)
- Lossless and lossy
- Typically fast operation
- ANSI C software implementation
Code footprint can be <50KB
- Error-resilient file format
- Encryption, multi-thread
- Easy to add new tailored stages

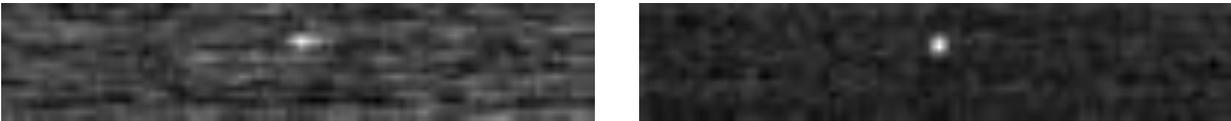
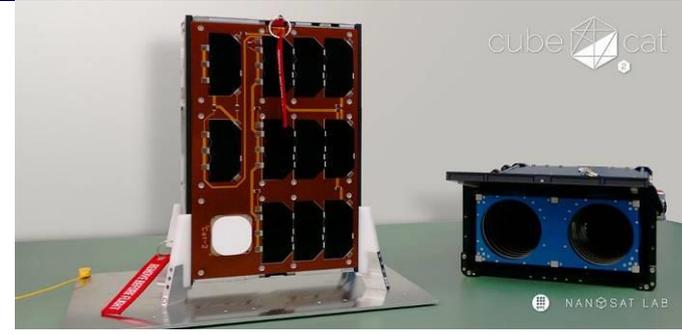


Implementation complexity

	Pre-processing stage	Data used	SS	Ratio	bps	IPS
• Tests with <i>Valgrind</i> tool	None (signed)	Solar image	8	1.03	7.76	68
	None (unsigned)	Solar image	8	1.05	7.62	72
	Delta	Planetary image	8	1.07	7.48	65
	Delta (auto-configured, 327-kB file)	Planetary image	8	1.07	7.48	92
• FAPEC compression is typically in the 50-150 IPS range	Delta	Telecommand file	8	1.15	6.96	61
	Delta	Meteorological image	8	1.44	5.55	55
	Delta	Stellar image	16	2.98	5.37	54
	Delta (<i>decompression</i>)	Stellar image	16	2.98	5.37	96
	Delta interleaving 4	Stellar image	16	2.76	5.80	69
	Delta interleaving 224	Hyperspectral image	16	2.01	7.96	74
	Delta lossy 4 LSB	Stellar image	16	6.94	2.31	58
	Delta lossy + interleaving	Stellar image	16	6.19	2.58	58
	3 rd order linear filter	Stellar image	16	2.92	5.48	80
	Filter + interleaving	Stellar image	16	2.59	6.18	87
• Decompression as well (note dictionary decompression IPS!)	Floats	Radioastronomy data	32	1.15	27.8	160
	Floats + interleaving	Radioastronomy data	32	1.15	27.8	168
	Dictionary level 0	Telecommand file	8	2.30	3.48	59
	Dictionary level 2	Telecommand file	8	2.62	3.05	104
	Dictionary level 2 (<i>decompression</i>)	Telecommand file	8	2.62	3.05	32
	3 bands prediction	Meteorological image	8	1.97	4.06	71
	3 bands prediction (auto-conf, 5.1MB file)	Meteorological image	8	1.97	4.06	73
	224 bands prediction	Hyperspectral image	16	2.34	6.84	98
	DWT 1 band	Solar image	8	1.30	6.15	131
	HPA 1 band	Solar image	8	1.26	6.35	118
• Compressible data leads to fewer instructions	DWT 3 bands	Meteorological image	8	1.82	4.40	110
	HPA 3 bands	Meteorological image	8	2.48	3.23	99
	DWT 224 bands	Hyperspectral image	16	2.41	6.64	157
	HPA 224 bands	Hyperspectral image	16	2.47	6.48	115
	DWT 1 band lossy	Solar image	8	3.79	2.11	134
	HPA 1 band lossy	Solar image	8	3.50	2.29	144
	DWT 3 bands lossy	Meteorological image	8	9.50	0.84	113
	HPA 3 bands lossy	Meteorological image	8	6.06	1.32	131
	DWT 224 bands lossy	Hyperspectral image	16	31.0	0.52	152
	HPA 224 bands lossy	Hyperspectral image	16	20.8	0.77	134

(Almost) operations: ³Cat-2

- First satellite using FAPEC
 - Launched 15-Aug-2016
- GNSS-R (reflectometry)
 - Tiny (100x20x16bpp) and noisy images



- Original baseline for on-board compression: PNG (Zip-like)
- FAPEC was accepted as the new baseline
 - Better ratios, faster operation
 - Lossy option chosen (noisy data)
 - Also chosen for experimental star tracker images!

<i>Simulated data:</i>	Worst ratio	Best ratio
PNG (original baseline)	0.94	0.99
Lossless delta FAPEC	1.08	1.20
4 LSB lossy delta FAPEC	1.48	1.72

Acknowledgements:
R. Olivé and A. Camps
UPC NanoSat Lab
www.tsc.upc.edu/nanosatlab

NANOSATLAB



UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Departament de Teoria del Senyal
i Comunicacions
RSLab

Tests: OPS-SAT

- ESA technology demonstrator
- Powerful payload:
 - Dual-core ARM9 800MHz
 - 1 GB RAM + 8 GB SD
 - 2048x1944px camera (Bayer)
 - Fine ADCS, GPS, SDR...
- Several experiments
 - FAPEC included

```

mkyer Editra Visualiza Puntu Arranjament Ajuda
ThumbEE CPU extension supported.
Registering SWP/SWPB emulation handler
Waiting for root device /dev/mmcblk0p2...
dwmac_socfpaga ff784988.dwmac0: data FIFO error (status=00000000)
mmc0: problem reading SD Status register.
mmc_host mmc0: Bus speed (slot 0) = 125000000Hz (slot req 125000000Hz, actual 125000000Hz div = 0)
mmc0: new high speed SDHC card at address aaaa
mmcblk0: mmc0:aaaa S588G 7.48 GiB
mmcblk0: p1 p2 p3 p4
kjournald starting. Commit interval 5 seconds
EXT3-fs (mmcblk0p2): using internal journal
EXT3-fs (mmcblk0p2): recovery complete
EXT3-fs (mmcblk0p2): mounted filesystem with ordered data mode
VFS: Mounted root (ext3 filesystem) on device 179:2.
devtmpfs: mounted
Freeing unused kernel memory: 348K (8868f000 - 866e4000)
INIT: version 2.88 booting
Error opening /dev/fb0: No such file or directory
Starting uddev
udev[87]: starting version 182
Starting Bootlog daemon: bootlogd.
Configuring network interfaces... eth0: device MAC address 40:d8:55:17:cd:ef
udhcpc (v1.21.1) started
Sending discover...
libphy: stmmac-0:03 - Link is Up - 1000/Full
Sending discover...
Sending select for 192.168.78.54...
Lease of 192.168.78.54 obtained, lease time 86400
/etc/udhcp.d/50default: Adding DNS 161.116.78.1
done.
Starting rpcbind daemon...NET: Registered protocol family 10
done.
net.ipv4.conf.default.rp_filter = 1
net.ipv4.conf.all.rp_filter = 1
Starting atd: OK
INIT: Entering runlevel: 5
Starting system message bus: dbus.
Starting OpenBSD Secure Shell server: sshd
done.
creating NFS state directory: done
NFS daemon support not enabled in kernel
Starting system log daemon...0
Starting kernel log daemon...0
Starting Lighttpd Web Server: Lighttpd.
Starting crond: OK
Stopping bootlog daemon: bootlogd.

Poky (Yocto Project Reference Distro) 1.5.1 mityom-5cax /dev/tty00
mityom-5cax login:
    
```



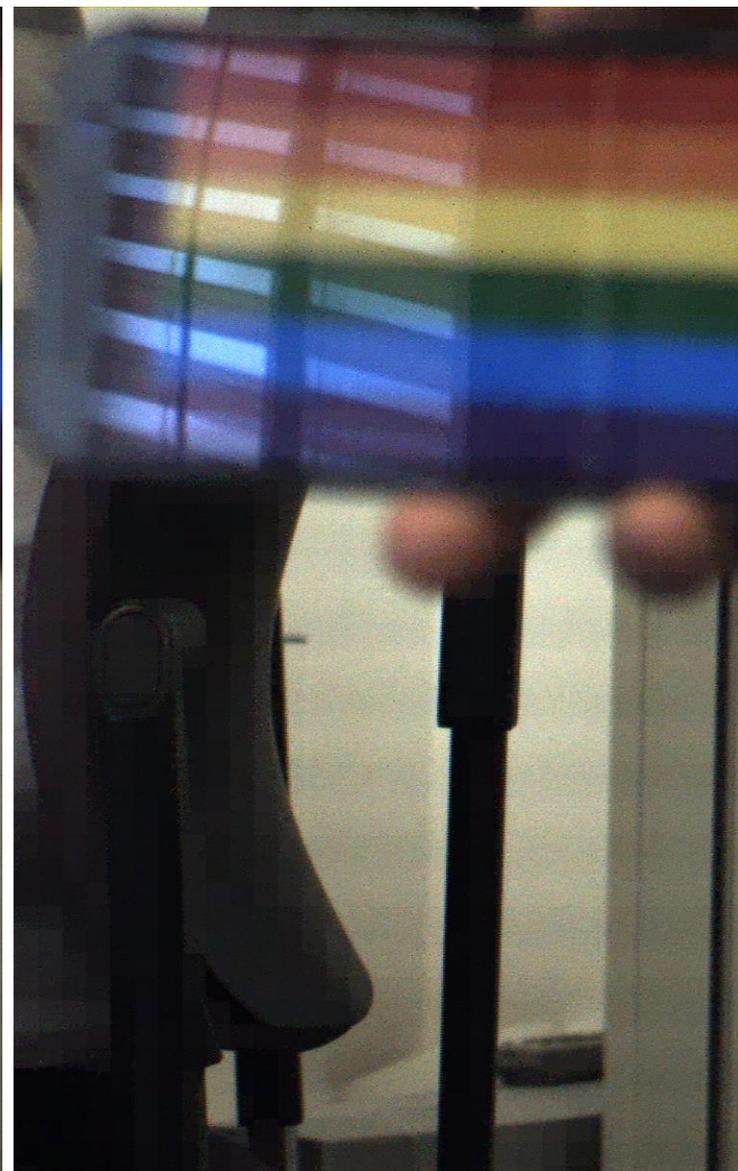
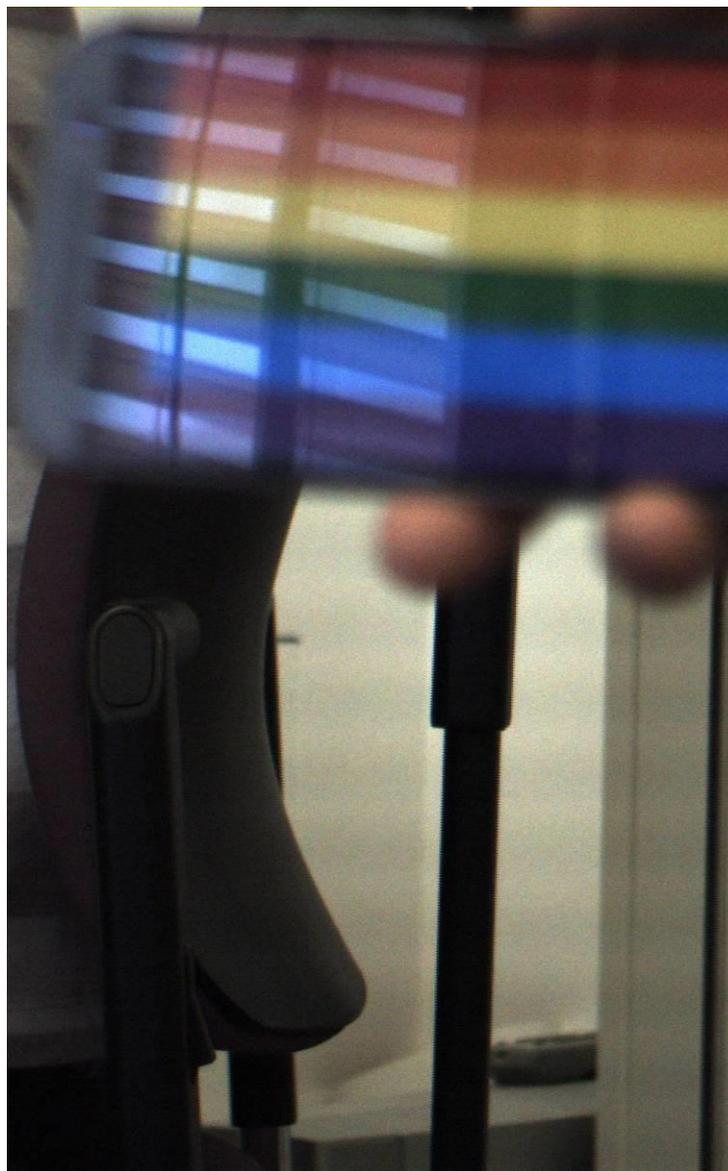
	Lab 1 image		Lab 2 image	
	Ratio	Speed	Ratio	Speed
Lossless delta	2.05	15.4 MB/s	2.74	17.6 MB/s
4 LSB lossy delta	4.24	18.6 MB/s	7.6	21.2 MB/s
Lossless HPA	2.01	9.3 MB/s	2.70	9.9 MB/s
Level 4 lossy HPA	2.73	7.8 MB/s	4.18	8.0 MB/s
Level 7 lossy HPA	5.36	8.0 MB/s	12.2	9.0 MB/s

Tests: OPS-SAT

Lossy tests

Left:
original

Right:
HPA ratio 12



Tests: Euclid

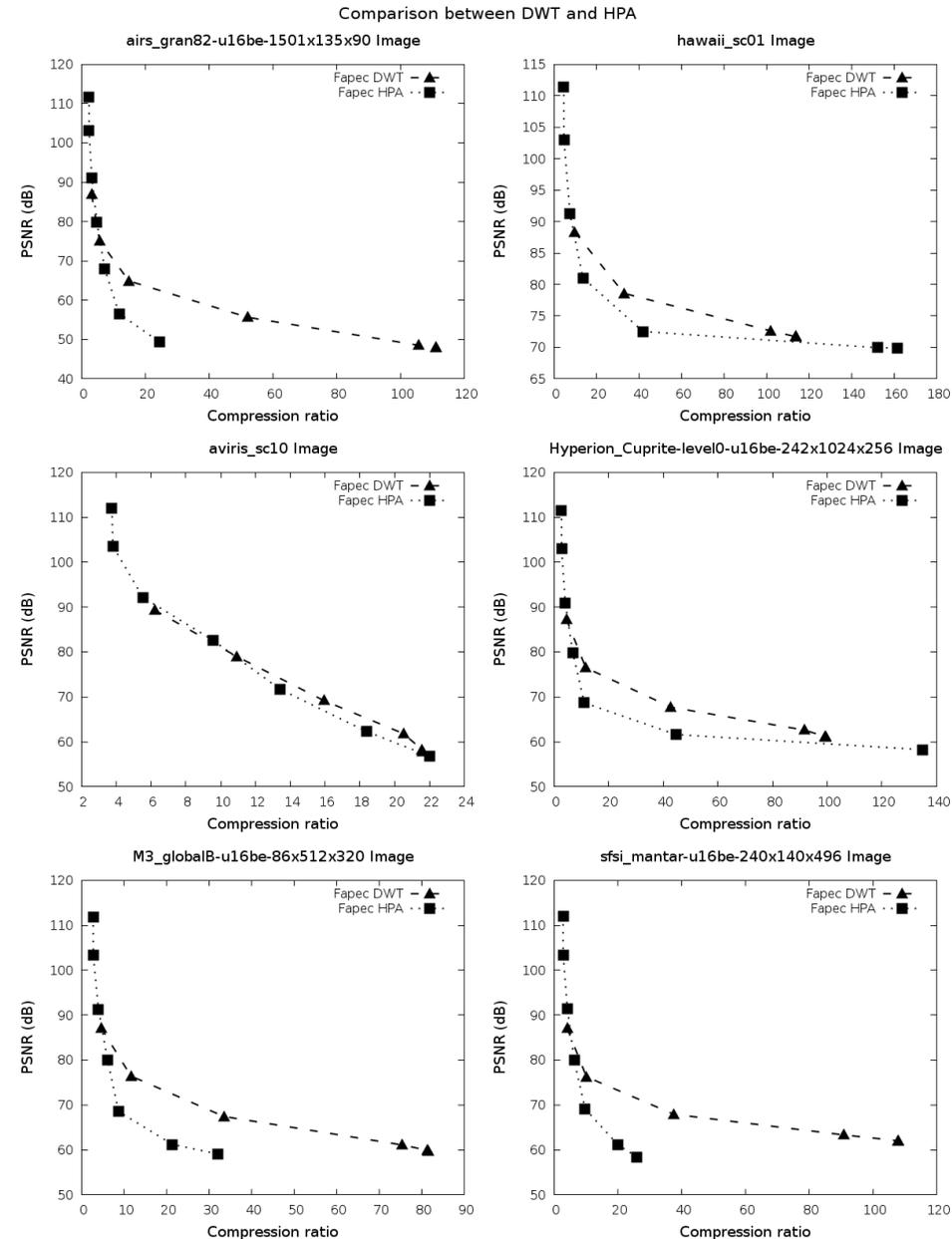
- ESA mission
- FAPEC tested on VIS + NISP simulated data
- Also integrated in the VIS engineering model board
 - Better ratios + slightly better times than Rice baseline



	Rice	FAPEC Delta	FAPEC 2 nd order filter
Charge inj.	4.60	4.73	4.92
Charge rel.	2.72	3.07	3.10
Flat field	1.34	1.32	1.35
Star field 1	2.55	2.80	2.84
Star field 2	2.75	3.17	3.15

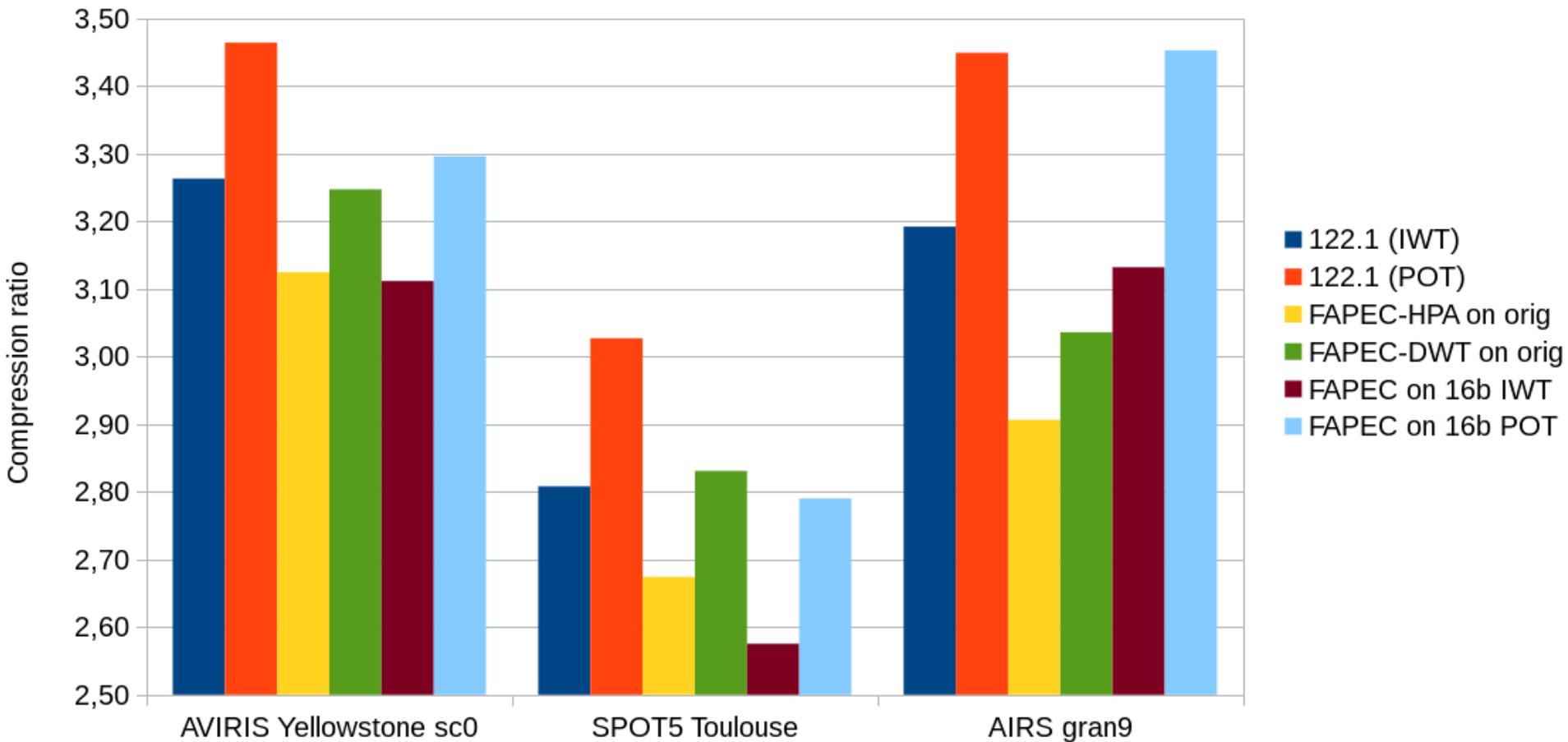
Tests: Lossy hyperspectral (I)

- FAPEC tests to compare its DWT and HPA stages
- DWT outperforms HPA for high ratios
- HPA provides smoother lossless-to-lossy transition
- HPA supports more coding formats
- HPA uses inter-band correlation also for few bands
- HPA typically faster



Tests: Lossless hyperspectral (II)

Lossless compression of multi/hyper spectral data



Tests: “onboard” compression speed

C3SatP (IEEC transversal initiative):

- High-performance **on-board computer**, **data handling** and SDR platform
- Aimed at **cubesats**
- On-board data handling: Xilinx Zynq UltraSCALE+ (**4 ARM cores, up to 1.5GHz**)
- Max power consumption: **~8W (TBC)**

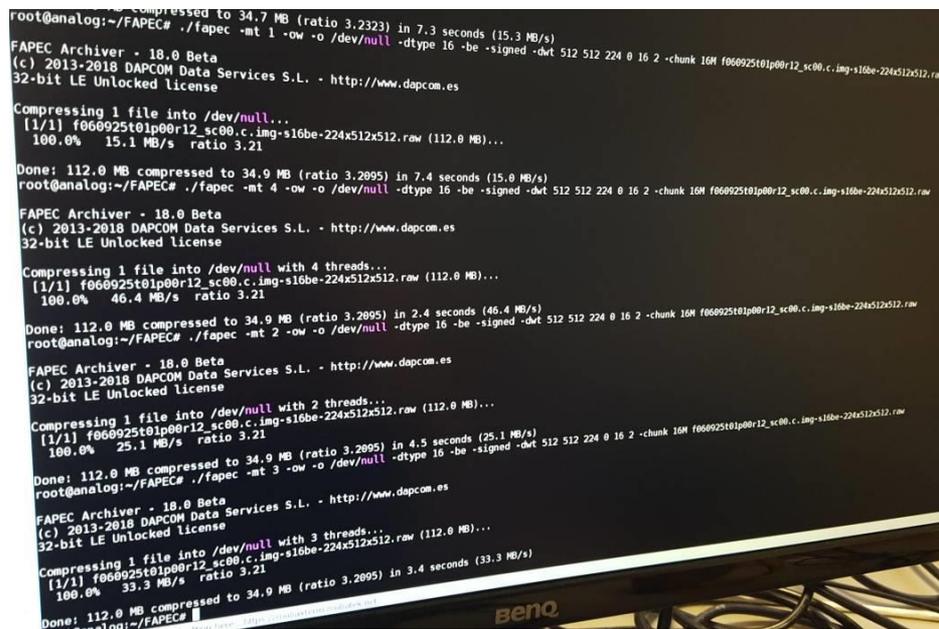
Multispectral Earth Observation is an excellent use case for this platform
→ test hyperspectral data compression here



Tests: “onboard” compression speed

FAPEC-DWT compression test on AVIRIS file (C software as-is):

- Single-chunk (single-thread): **15.7 MB/s (7.8 Msamples/s)**
→ full AVIRIS 512x512x224 scene in ~7s
- Additional tests with ~16MB chunks (ratio reduced from 3.25 to 3.21):
 - 2 threads: 25 MB/s (x1.6)
 - 3 threads: 33 MB/s (x2.1)
 - 4 threads: 46 MB/s (x2.9)
→ up to 23 Msamples/s
- Reminder: ~90 MB/s (x5.7) on a laptop (Intel Core i7 2640M 2.8GHz), single-thread
- CCSDS **122.1** hardware reference (RTAX2000S, VHDL): 18.4 Msamples/s
- Another hardware reference (**FAPEC** on ProASIC M1A3P1000L, VHDL, only entropy coding core): 12 Msamples/s



```
root@analog:~/FAPEC# ./fapec -mt 1 -ow -o /dev/null -dtype 16 -be -signed -dwt 512 512 224 0 16 2 -chunk 16M f060925t01p00r12_sc00.c.img-s16be-224x512x512.raw
FAPEC Archiver - 18.0 Beta
(c) 2013-2018 DAPCOM Data Services S.L. - http://www.dapcom.es
32-bit LE Unlocked license
Compressing 1 file into /dev/null...
[1/1] f060925t01p00r12_sc00.c.img-s16be-224x512x512.raw (112.0 MB)...
100.0% 15.1 MB/s ratio 3.21
Done: 112.0 MB compressed to 34.9 MB (ratio 3.2095) in 7.3 seconds (15.3 MB/s)
root@analog:~/FAPEC# ./fapec -mt 2 -ow -o /dev/null -dtype 16 -be -signed -dwt 512 512 224 0 16 2 -chunk 16M f060925t01p00r12_sc00.c.img-s16be-224x512x512.raw
FAPEC Archiver - 18.0 Beta
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Compressing 1 file into /dev/null with 4 threads...
[1/1] f060925t01p00r12_sc00.c.img-s16be-224x512x512.raw (112.0 MB)...
100.0% 46.4 MB/s ratio 3.21
Done: 112.0 MB compressed to 34.9 MB (ratio 3.2095) in 2.4 seconds (46.4 MB/s)
root@analog:~/FAPEC# ./fapec -mt 2 -ow -o /dev/null -dtype 16 -be -signed -dwt 512 512 224 0 16 2 -chunk 16M f060925t01p00r12_sc00.c.img-s16be-224x512x512.raw
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Compressing 1 file into /dev/null with 2 threads...
[1/1] f060925t01p00r12_sc00.c.img-s16be-224x512x512.raw (112.0 MB)...
100.0% 25.1 MB/s ratio 3.21
Done: 112.0 MB compressed to 34.9 MB (ratio 3.2095) in 4.5 seconds (25.1 MB/s)
root@analog:~/FAPEC# ./fapec -mt 3 -ow -o /dev/null -dtype 16 -be -signed -dwt 512 512 224 0 16 2 -chunk 16M f060925t01p00r12_sc00.c.img-s16be-224x512x512.raw
FAPEC Archiver - 18.0 Beta
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32-bit LE Unlocked license
Compressing 1 file into /dev/null with 3 threads...
[1/1] f060925t01p00r12_sc00.c.img-s16be-224x512x512.raw (112.0 MB)...
100.0% 33.3 MB/s ratio 3.21
Done: 112.0 MB compressed to 34.9 MB (ratio 3.2095) in 3.4 seconds (33.3 MB/s)
root@analog:~/FAPEC#
```

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