Biarritz, 1-5 june 2026

We present current efforts among the HelioSwarm/iESA team to design synthetic solar wind ion data and how we use them to plan future operations. We start from Solar Orbiter/PAS data in the near-Earth environment and map them to iESA angular/energy resolutions. This synthetic dataset help us 1/ to assess the performance of the peak tracking strategy, 2/ to evaluate the scientific relevance of the different iESA modes (core, proton, alpha, full) depending on solar wind regimes, and 3/ test compression algorithms to match telemetry constrains. Visualization of distribution functions is performed with the newly developed Velocirap python library (see the related presentation).

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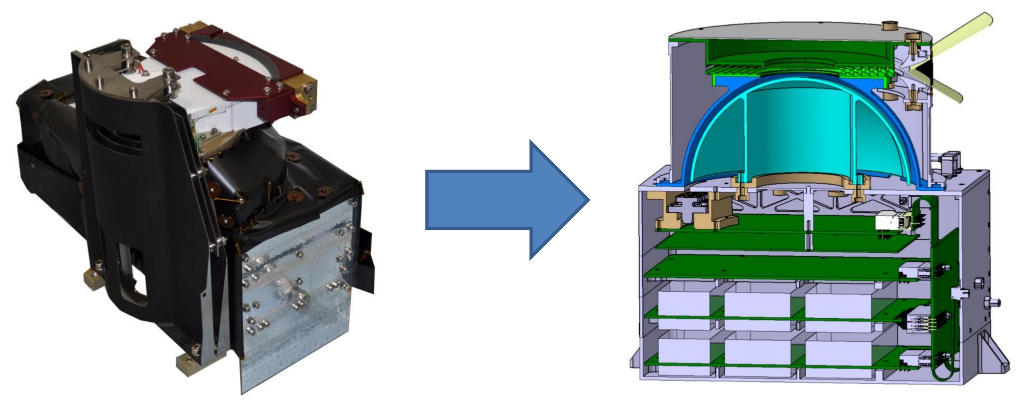
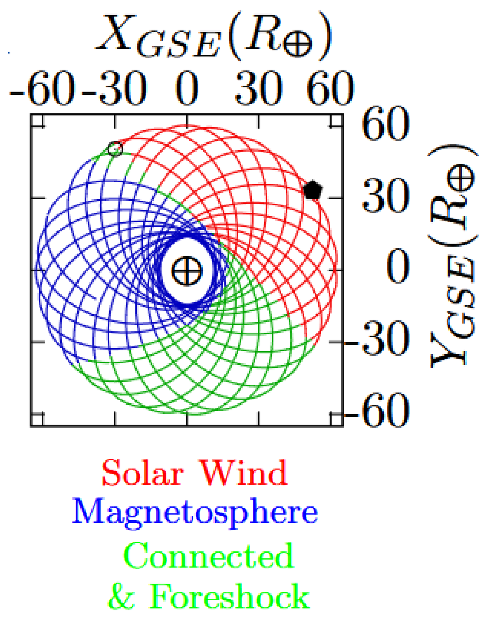
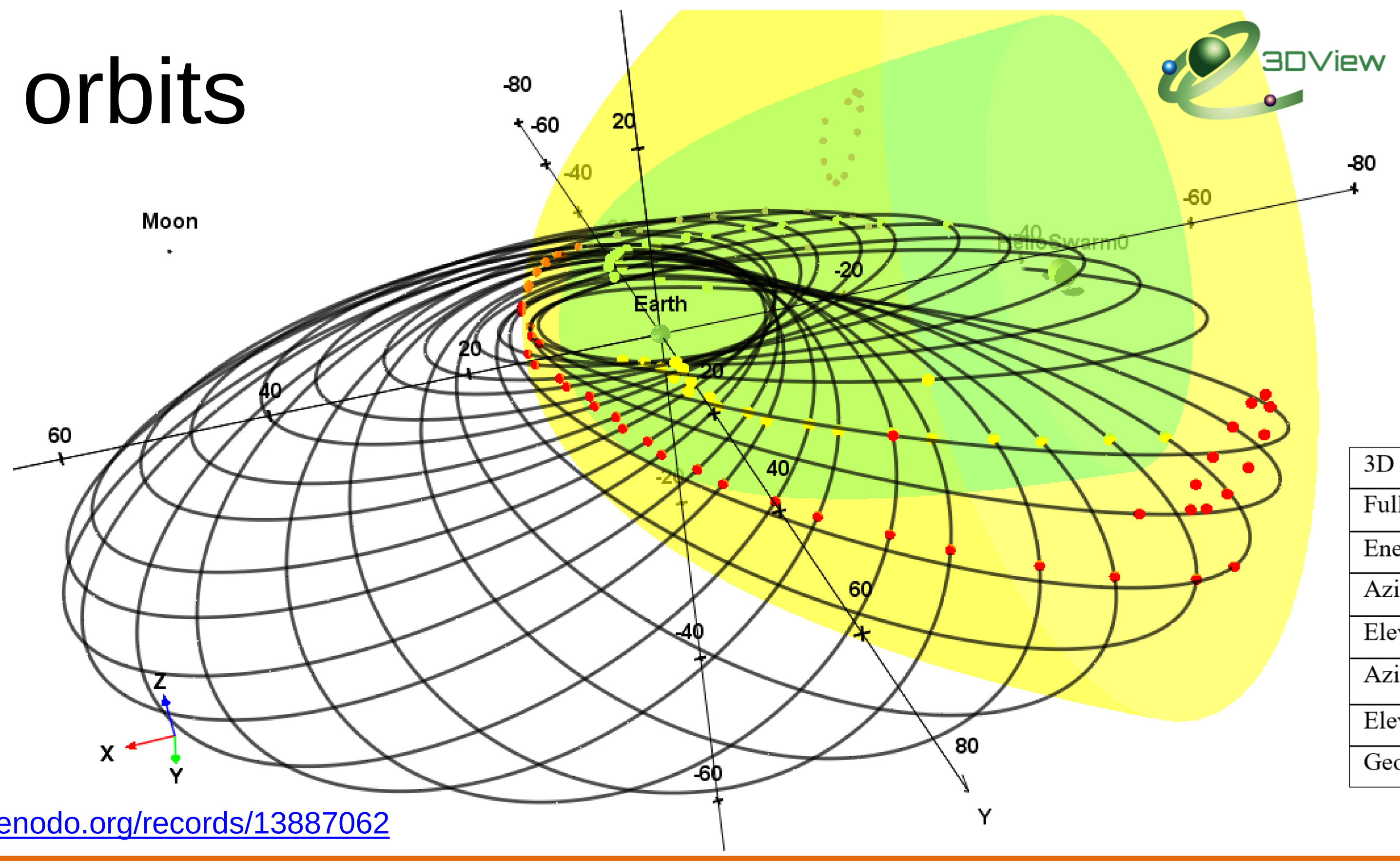
En mémoire d'Alain Barthe

Solar Orbiter / PAS to HelioSwarm / iESA synthetic data and operational modes



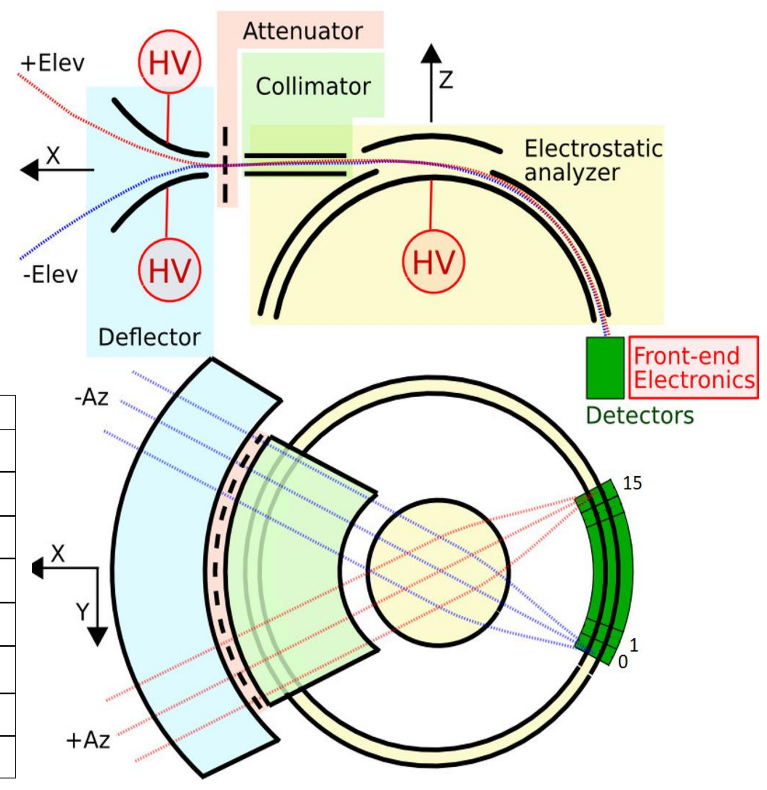
HelioSwarm orbits





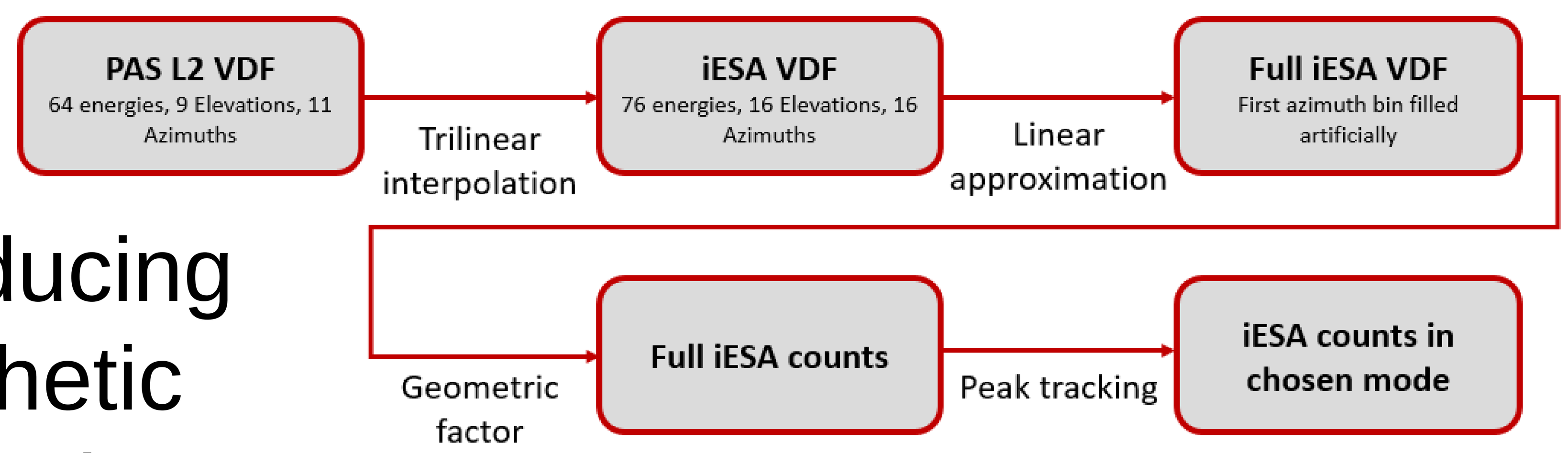
Full representative trajectories: https://zenodo.org/records/13887062

iESA concept

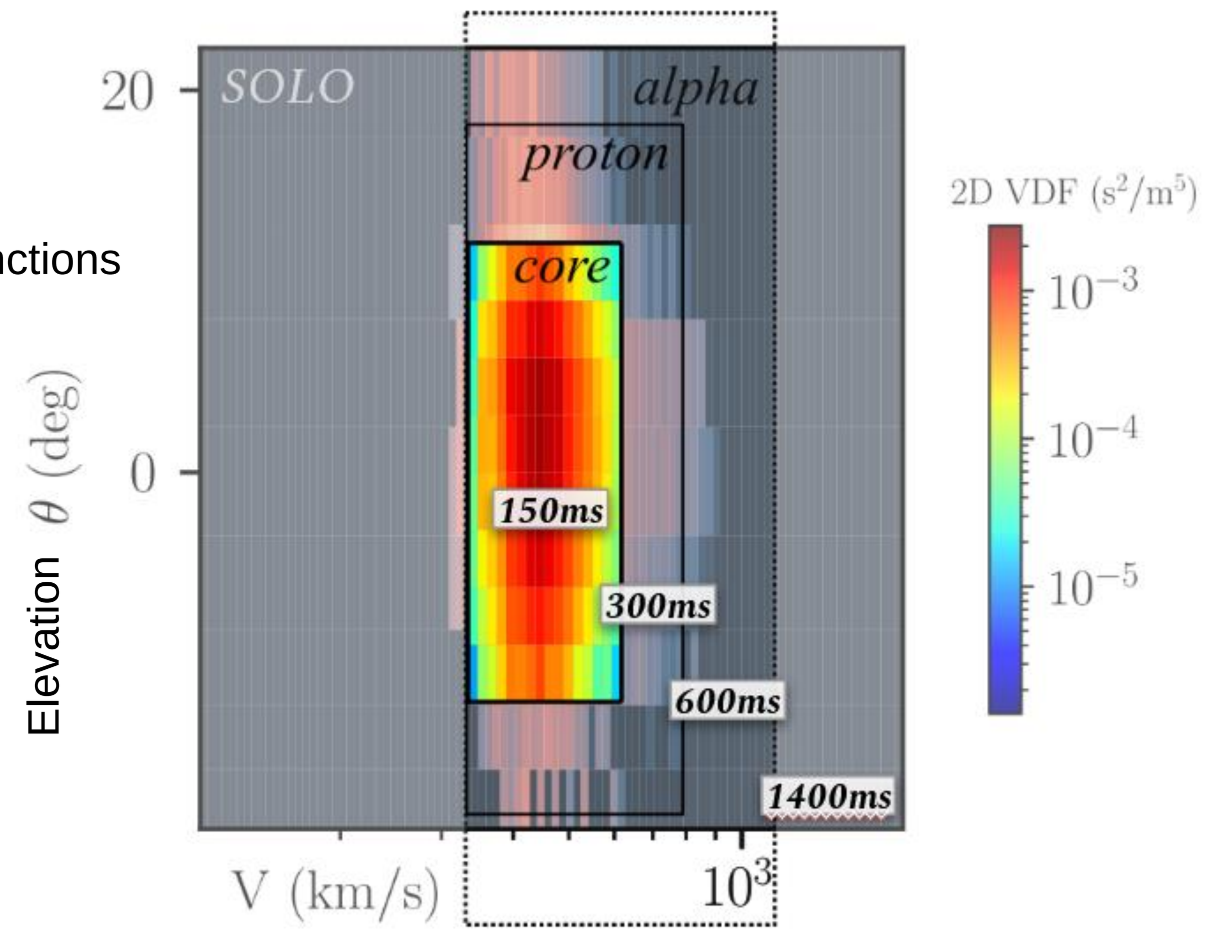


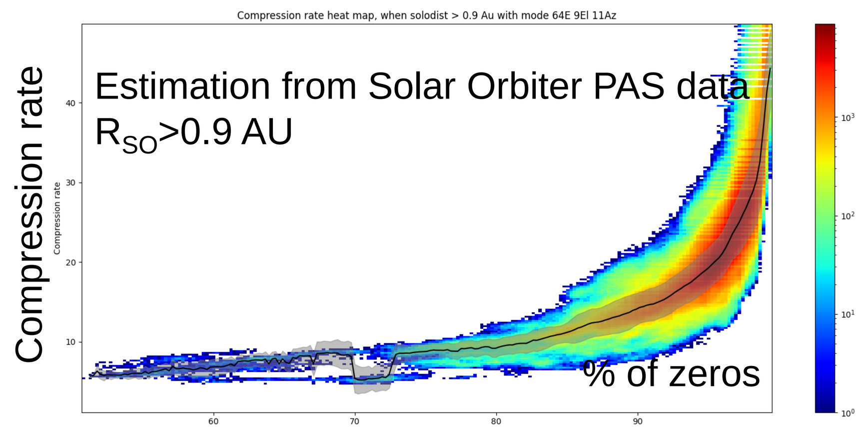
	Required	Designed
3D sampling time resolution	150ms	150 ms
Full energy range	326 eV – 6.7 keV	60 eV – 20 keV
Energy resolution $\Delta E/E$	9%	8%
Azimuth resolution	5°	3°
Elevation resolution	5°	3°
Azimuth range	±12°	±24°
Elevation range	±12°	±24°
Geometric Factor	1.0e-6 cm² sr eV/eV	3.0e-6 cm² sr eV/eV

Producing synthetic iESA data



PAS and iESA distribution functions in the different configurations



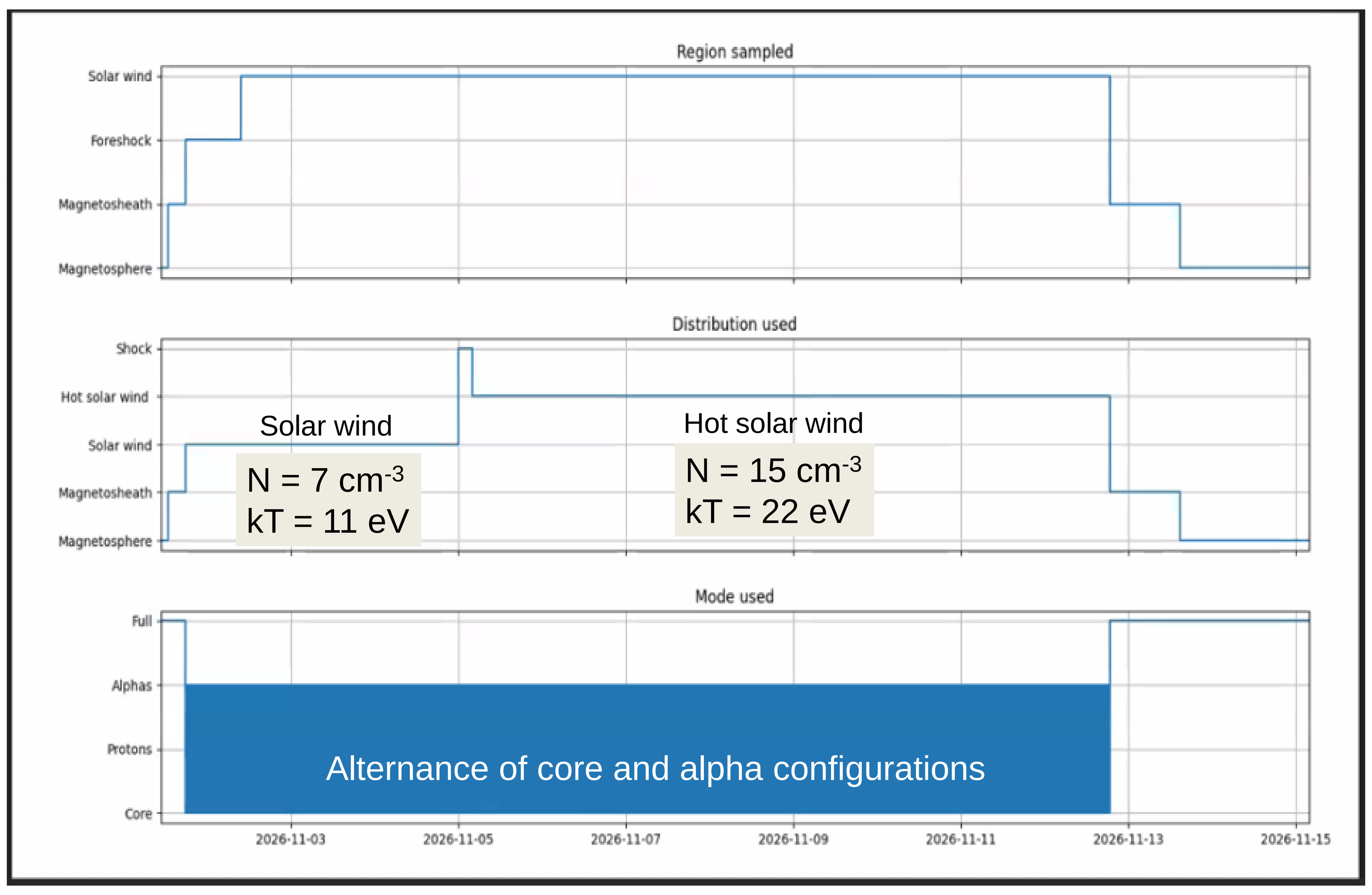


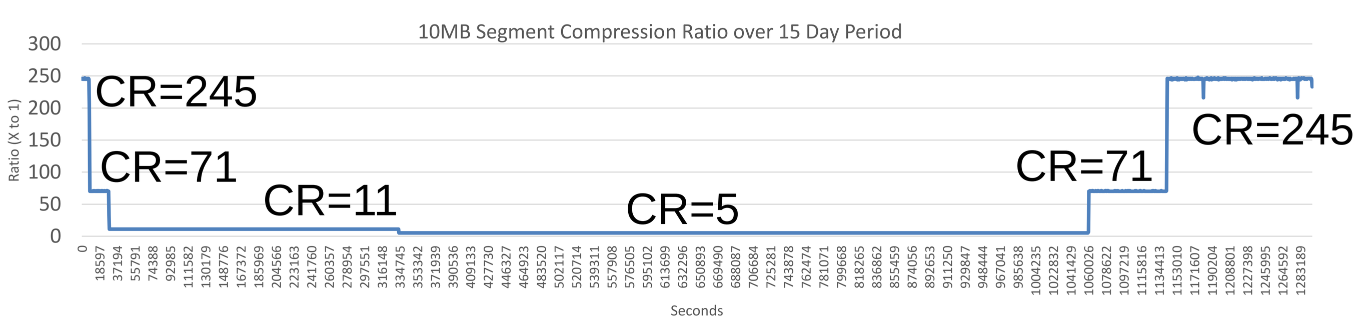
Proposed iESA configurations

Example of possible samplings with duration in s	Sampling dimension	Sampling size at Hub PU input, Bytes	SpW rate, kBytes/s (between iESA and Hub PU)
Core configuration 0.150 s	16 energies, 8 elevations, 16 azimuths	4548	29.8 + 0.1 (HK)
Proton configuration 0.297 s	22 energies, 12 elevations, 16 azimuths	9238	30.4 + 0.1 (HK)
Alpha configuration 0.600 s	34 energies, 16 elevations, 16 azimuths	18890	30.8 + 0.1 (HK)
Full configuration 1.341 s	76 energies, 16 elevations, 16 azimuths	42200	30.7 + 0.1 (HK)

Compression study over one typical HelioSwarm orbit

- For a given orbit (15 days) an iESA dataset has been generated from Solar Orbiter distribution functions in magnetosphere, magnetosheath and solar wind environments and iESA configurations
- 3 compression algorithms have been evaluated (DEFLATE, BZIP2, LZMA) on the full dataset, or by chunks of 10 MB / 10k records





10k Samples
Sample Count: 660

		DEFLATE	BZIP2	LZMA
Ratio[2] x to 1	Average	7.17	11.87	9.42
	Median	4.00	5.00	5.00
	Mode	4.00	5.00	5.00
	Mean (trim top/bottom 2.5%)	5.09	7.15	6.77
	Average (trim >=100)	5.36	7.49	7.13
	Min	4.00	5.00	5.00
	Max	114.00	260.00	144.00
Time[1] Seconds	Average	2.19	1.64	25.46
	Median	2.58	1.83	27.26
	Mode	1.05	0.88	17.28
	Mean (trim top/bottom 2.5%)	2.20	1.61	25.61
	Min	0.06	0.01	0.03
	Max	3.65	4.47	40.16
Size[1] Bytes	Average	8,701,850.70	6,040,085.94	6,169,332.61
	Median	10,227,370.00	7,321,637.50	7,324,167.50
	Mode	10229761	3523598	7328383
	Mean (trim top/bottom 2.5%)	8,815,815.85	6,128,553.33	6,244,470.03
	Min	245,486.00	151,708.00	170,453.00
	Max	10,245,838.00	7,336,646.00	7,338,027.00

10MB Sample Size
Sample Count: 3136

		DEFLATE	BZIP2	LZMA
Ratio[2] x to 1	Average	21.12	41.50	27.30
	Median	4.00	5.00	5.00
	Mode	4.00	5.00	5.00
	Mean (trim top/bottom 2.5%)	19.14	37.10	24.83
	Average (trim >=100)	8.00	12.51	10.78
	Min	4.00	5.00	5.00
	Max	114.00	248.00	144.00
Time[1] Seconds	Average	0.46	0.33	0.03
	Median	0.63	0.42	0.03
	Mode	0.27	0.06	0.03
	Mean (trim top/bottom 2.5%)	0.47	0.33	0.03
	Min	0.02	0.00	0.01
	Max	0.85	0.59	0.09
Size[1] Bytes	Average	1,831,770.99	1,272,481.29	1,309,960.24
	Median	2,582,125.00	1,849,261.00	1,866,046.00
	Mode	92136	899673	1883642
	Mean (trim top/bottom 2.5%)	1,856,933.18	1,289,025.72	1,327,270.55
	Min	17,605.00	9,401.00	14,201.00
	Max	2,616,753.00	1,874,668.00	1,890,500.00

- The 3 compression algorithms provide a trade off in compression time and compressed size
- For compression, BZIP2 and LZMA provided similar performance, with the worst cases being a 5:1 compression ratio during the Hot Solar Wind sections of the example data
- When not in Hot Solar Wind, the compression was often greater than 10 to 1 for both algorithms
- When considering time, BZIP2 provides the best compression time for large files
- It is recommended that the BZIP2 algorithm is implemented in HelioSwarm FSW
- There is an existing open-source C library for BZIP2 that could be utilized
- The main risk with using BZIP2 on HelioSwarm is that it would be new development
- BZIP2 is a slower algorithm that uses more memory than DEFLATE
- BZIP2 would require more testing to ensure it does not overwhelm processing time or memory capacity