Infrared Detector Read modes:

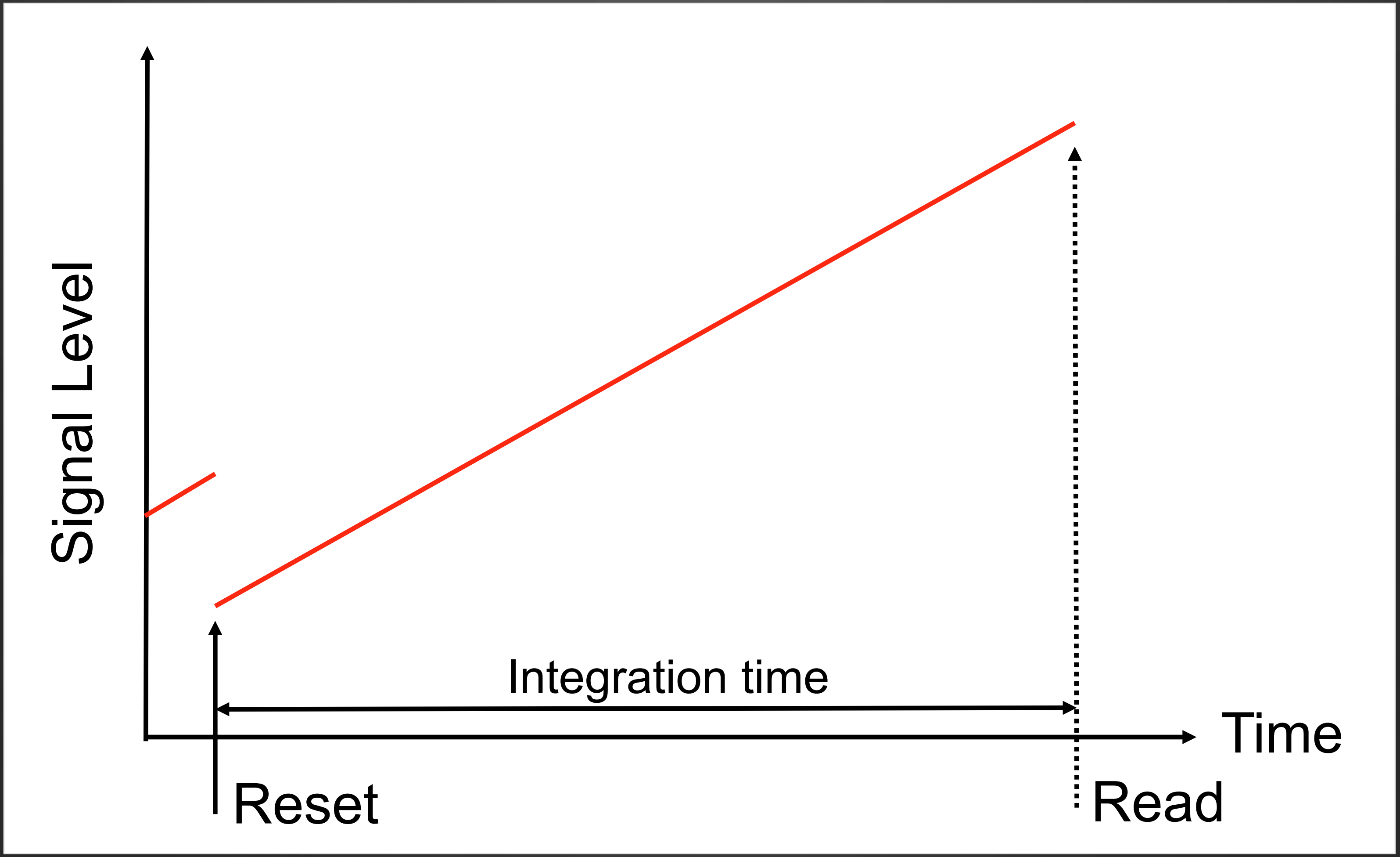
Why we do what we do on Webb

Version History:

2011: Rachel Anderson for RIAB Training

2009: Mike Regan for JWST Detector Course

Single Sample is CCD-like.



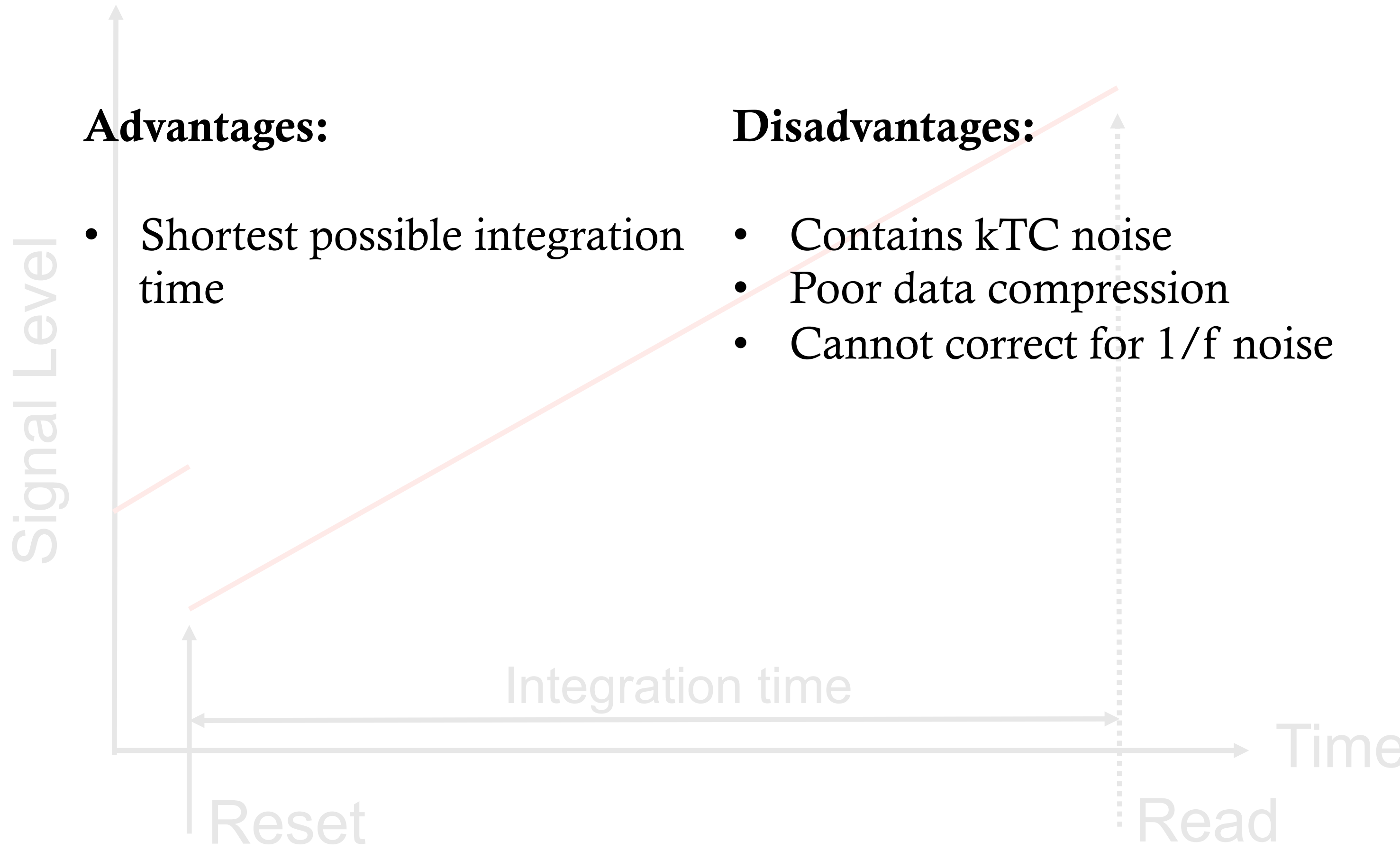
Single Sample is CCD-like.

Advantages:

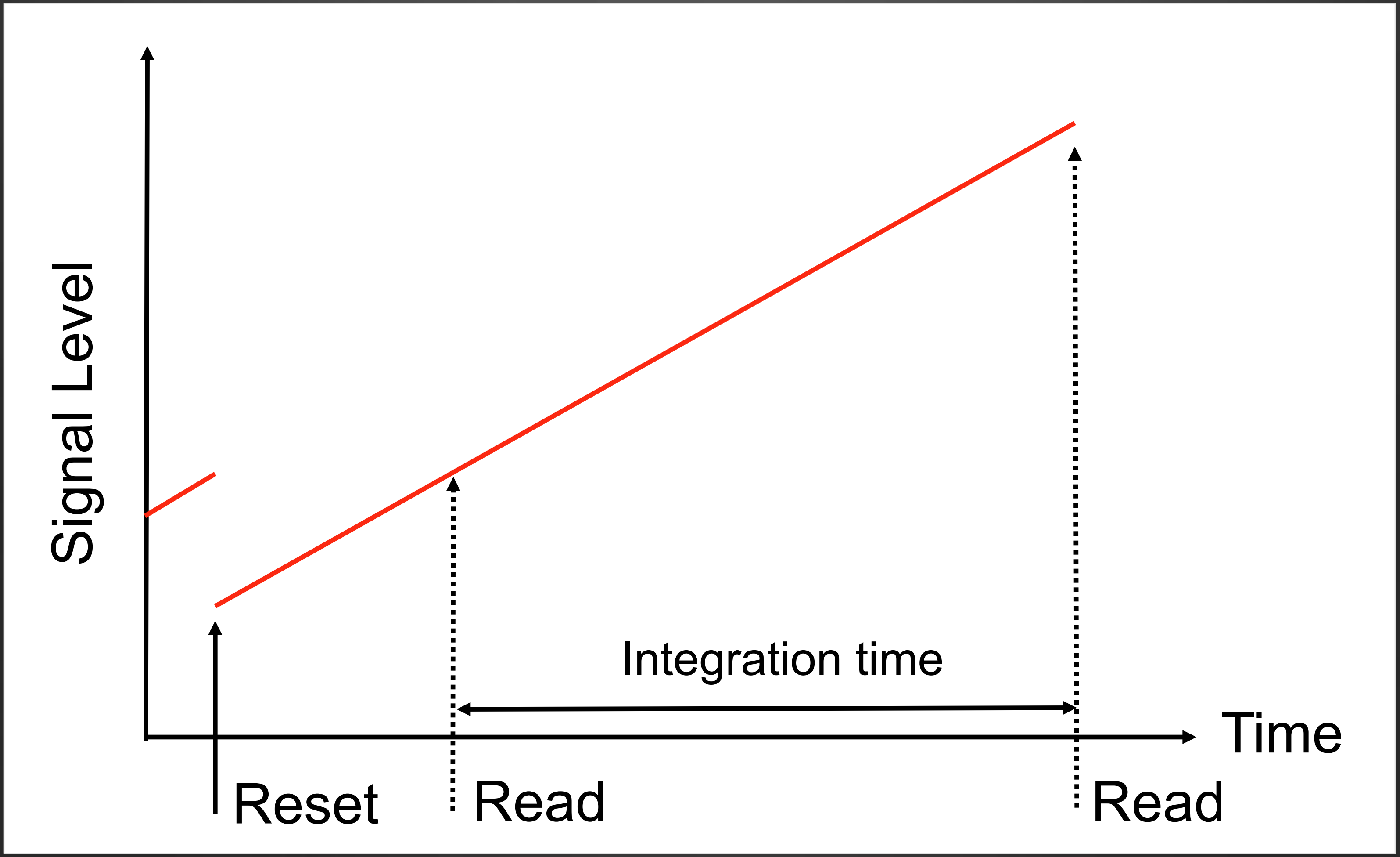
- Shortest possible integration time

Disadvantages:

- Contains kTC noise
- Poor data compression
- Cannot correct for 1/f noise



A Correlated Double Sample (CDS) is the difference between two frames.



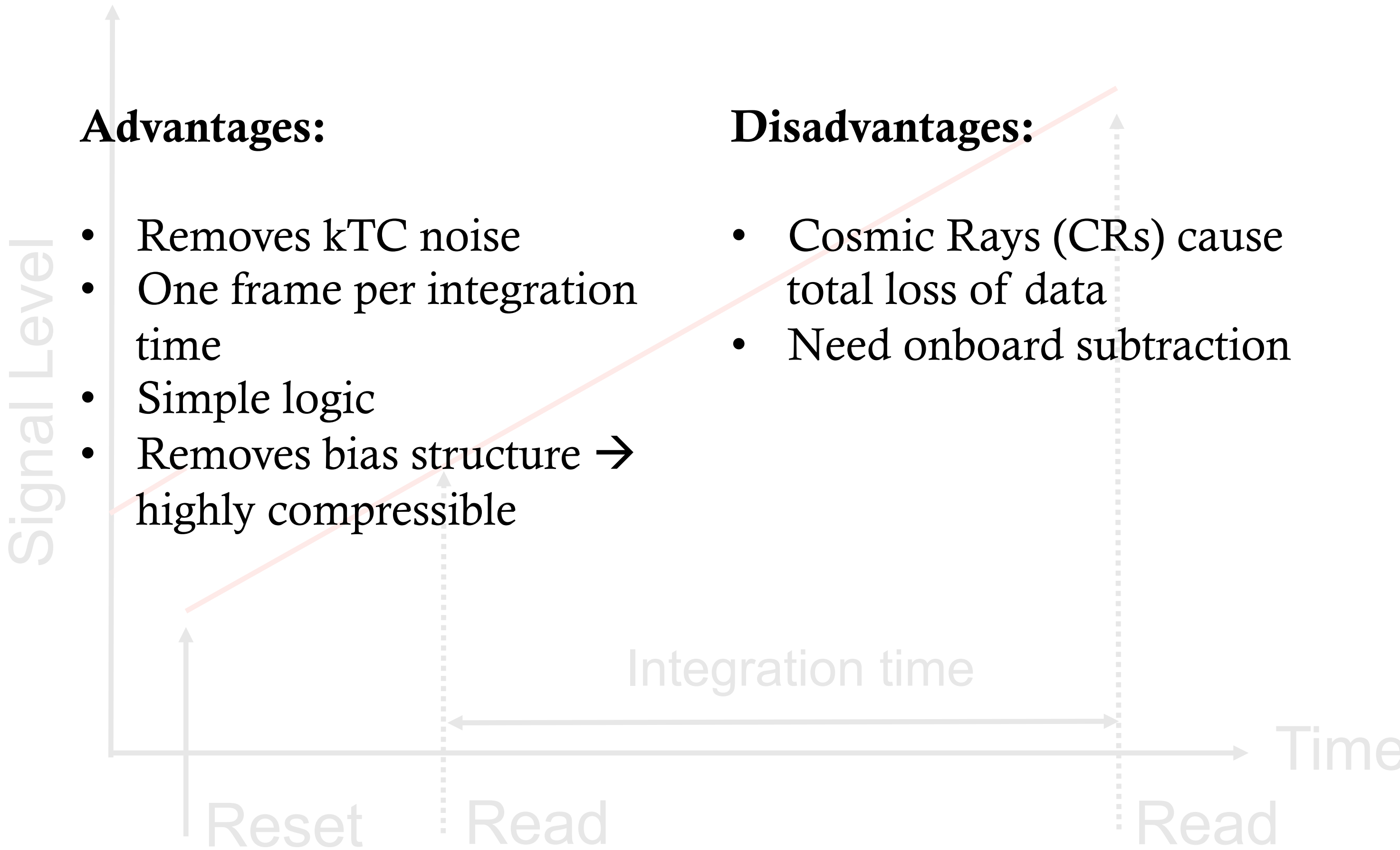
A Correlated Double Sample (CDS) is the difference between two frames.

Advantages:

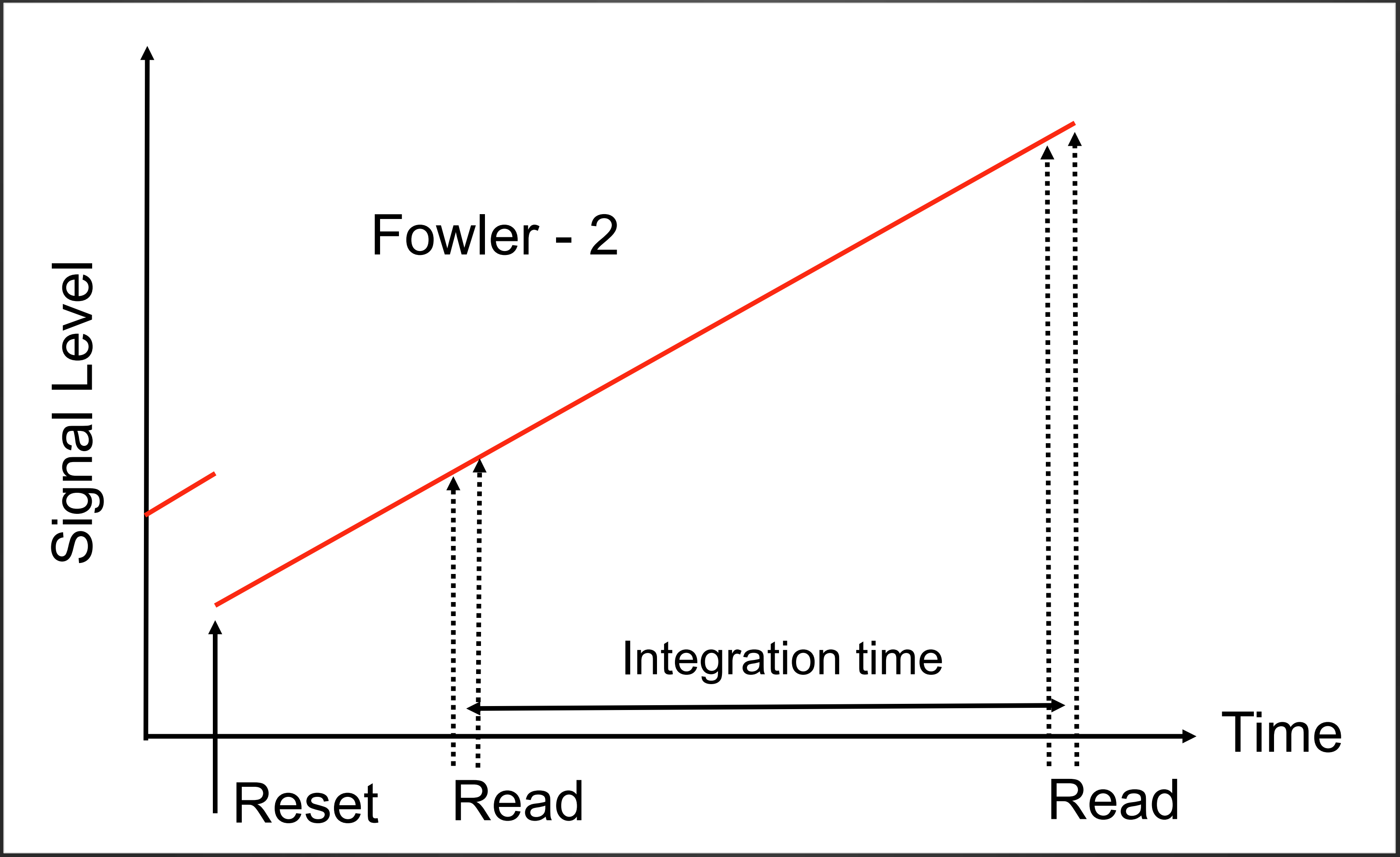
- Removes kTC noise
- One frame per integration time
- Simple logic
- Removes bias structure → highly compressible

Disadvantages:

- Cosmic Rays (CRs) cause total loss of data
- Need onboard subtraction



Fowler Sampling uses multiple reads at the beginning and end (average then sub)



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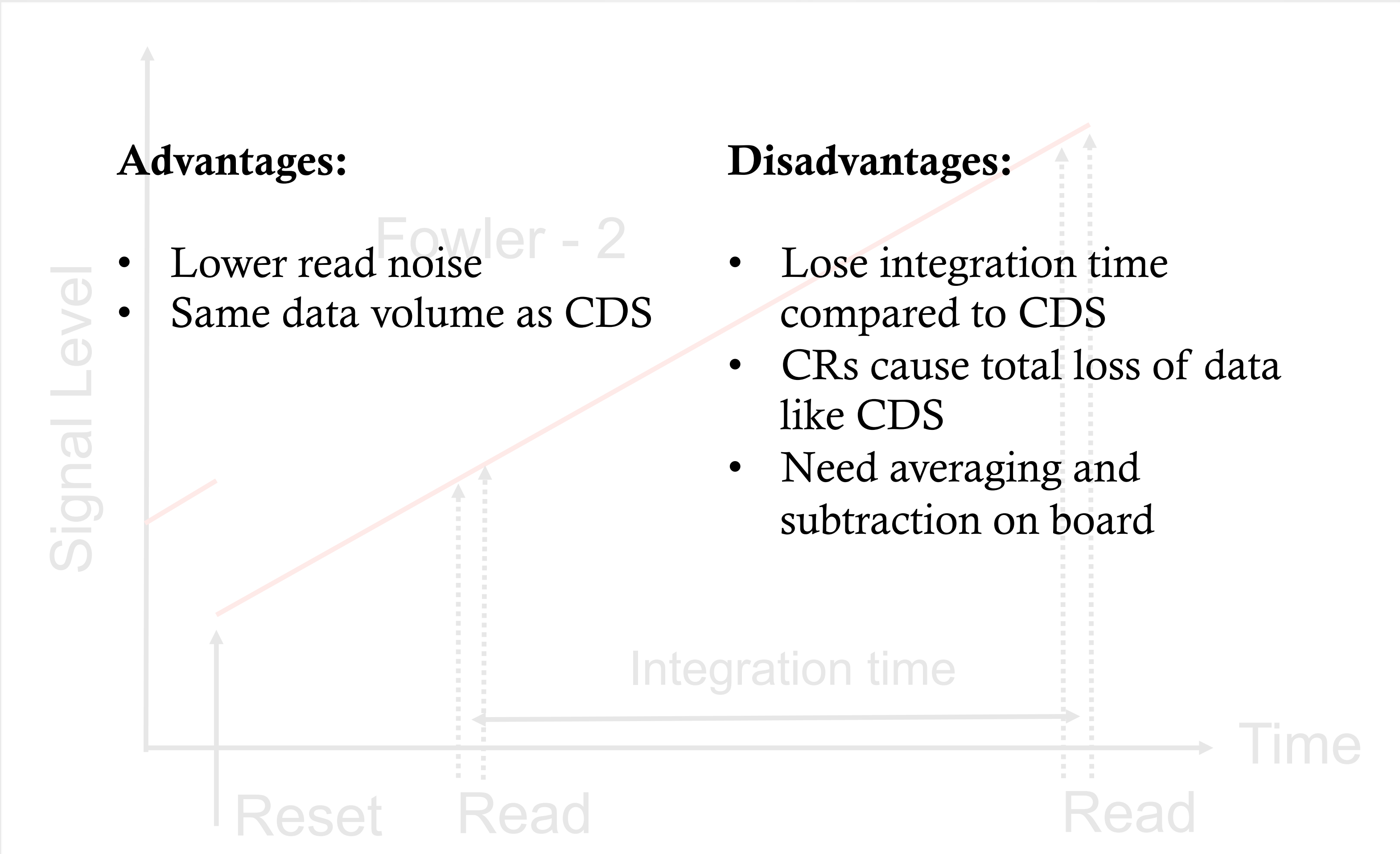


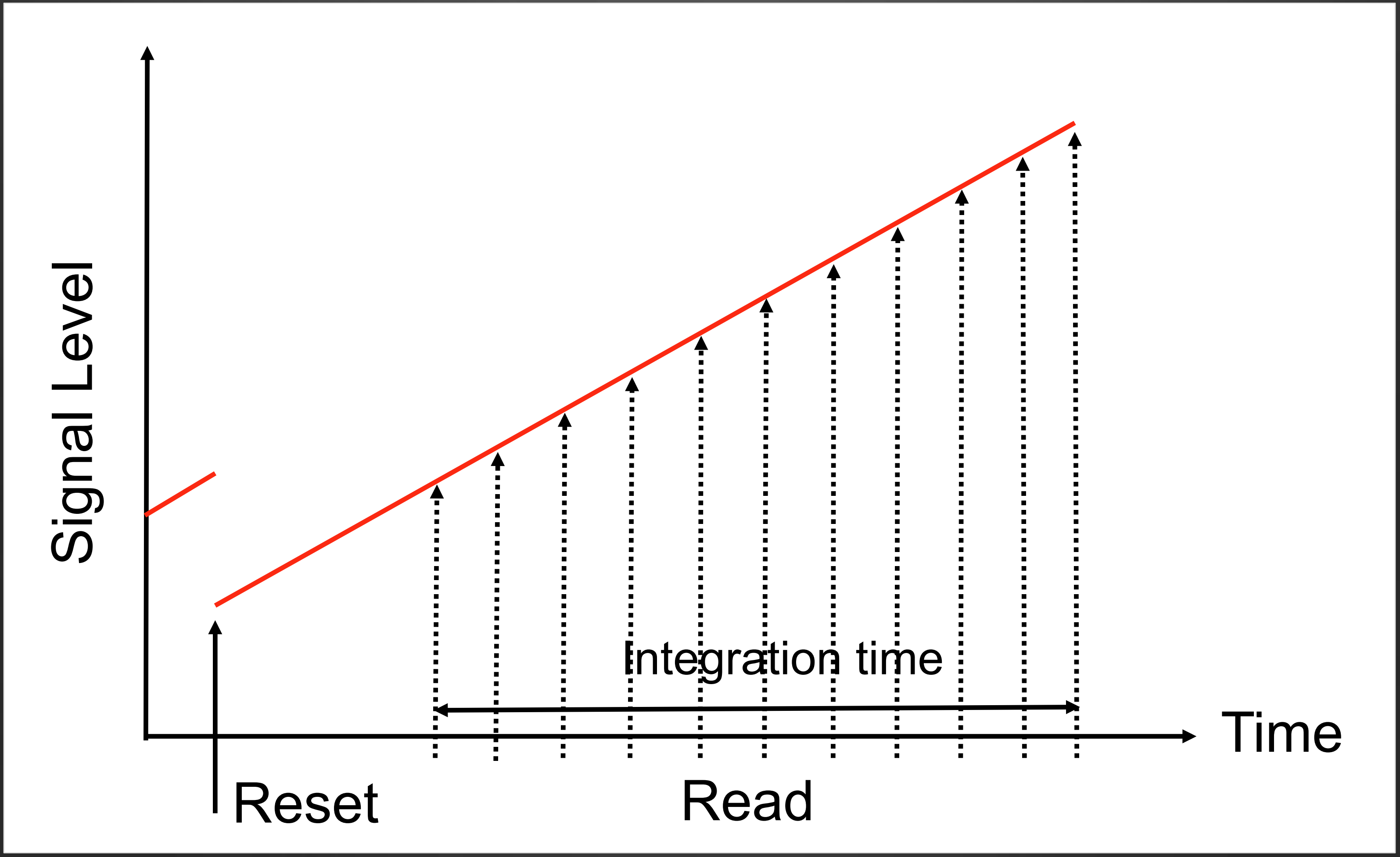
Advantages:

- Lower read noise
- Same data volume as CDS

Disadvantages:

- Lose integration time compared to CDS
- CRs cause total loss of data like CDS
- Need averaging and subtraction on board

Up-the-Ramp, Multiaccum, we solve for the slope (e^-/s) based on multiple samples.



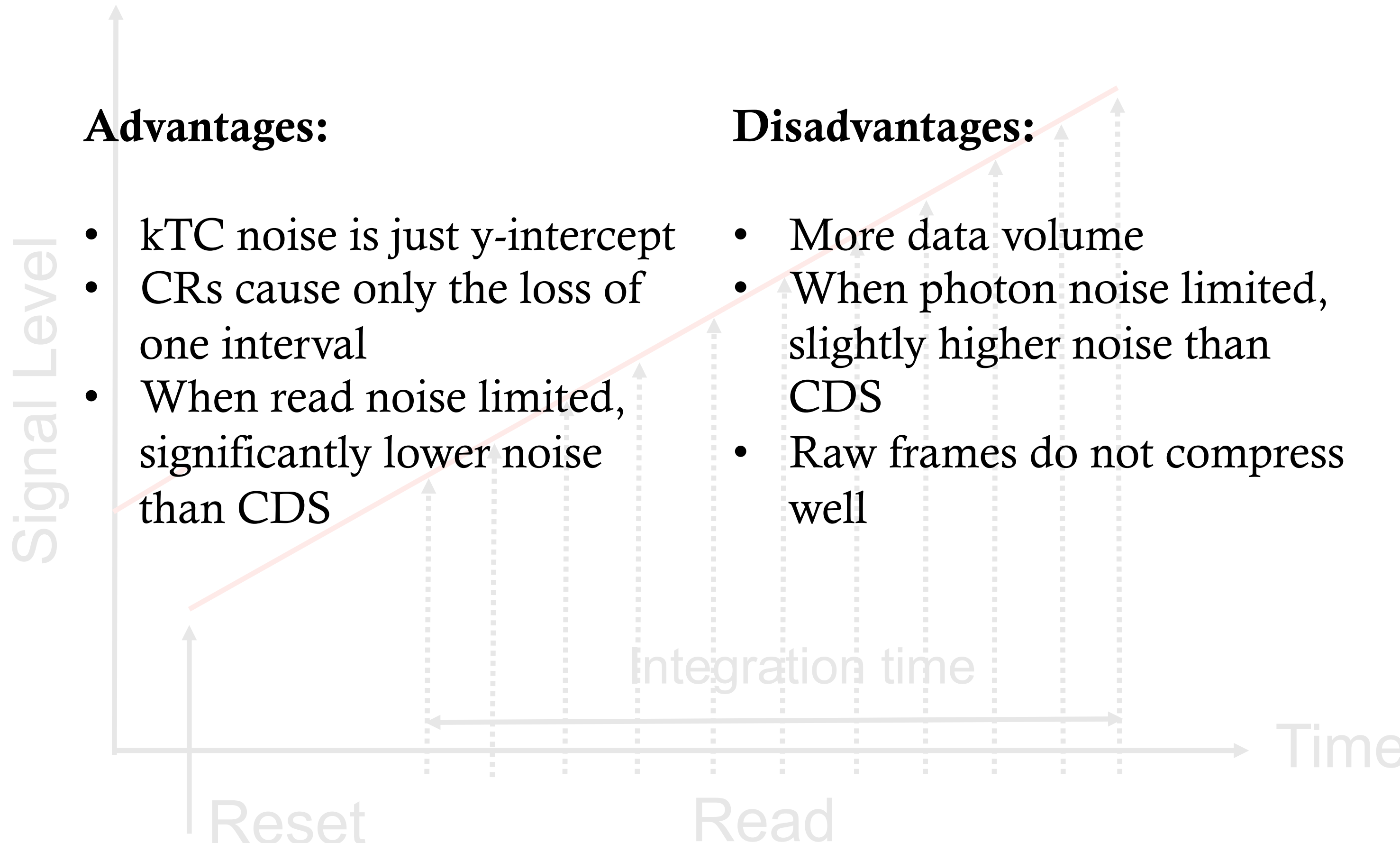
Up-the-Ramp, Multiaccum, we solve for the slope (e^{-}/s) based on multiple samples.

Advantages:

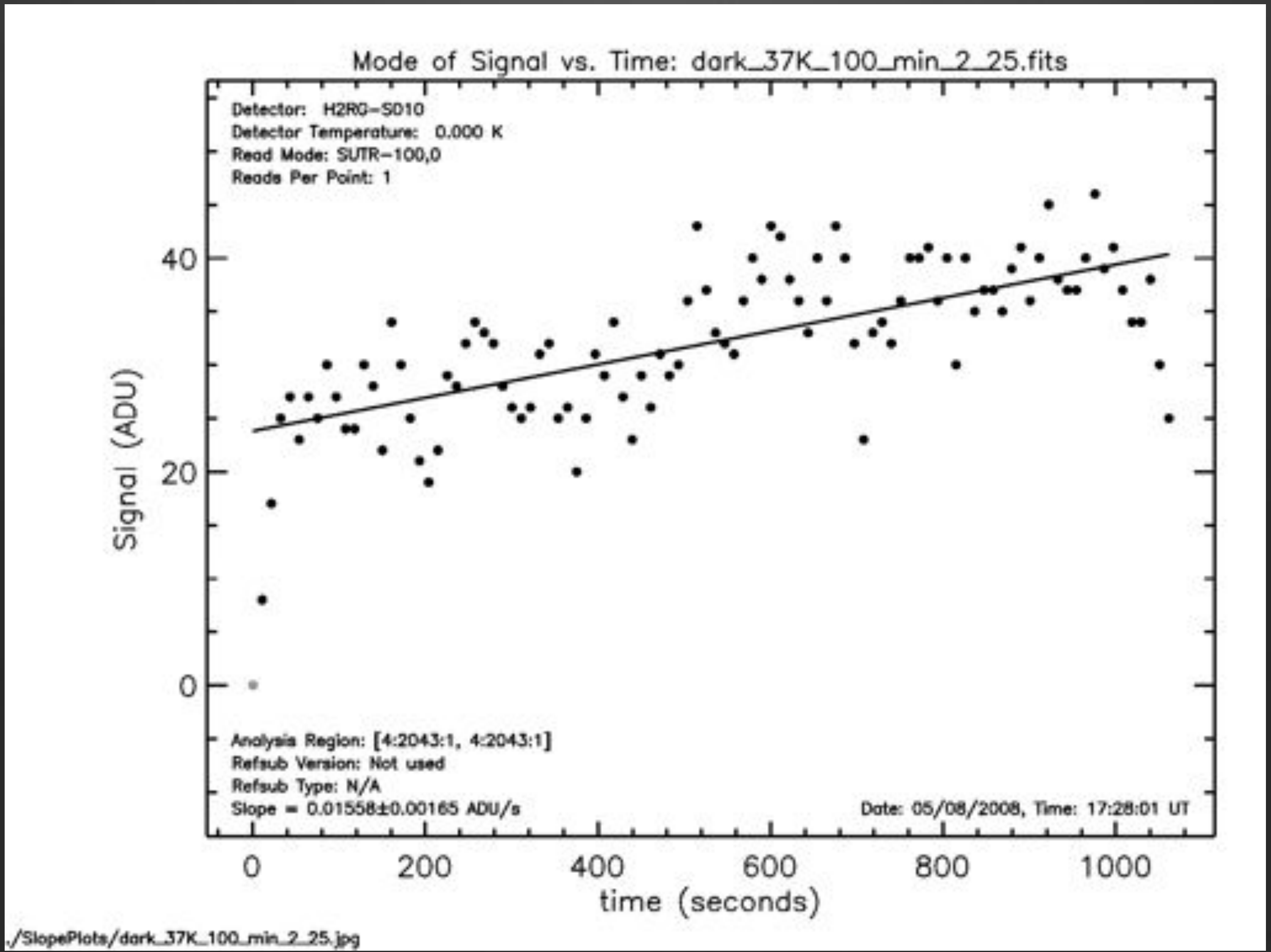
- kTC noise is just y-intercept
- CRs cause only the loss of one interval
- When read noise limited, significantly lower noise than CDS

Disadvantages:

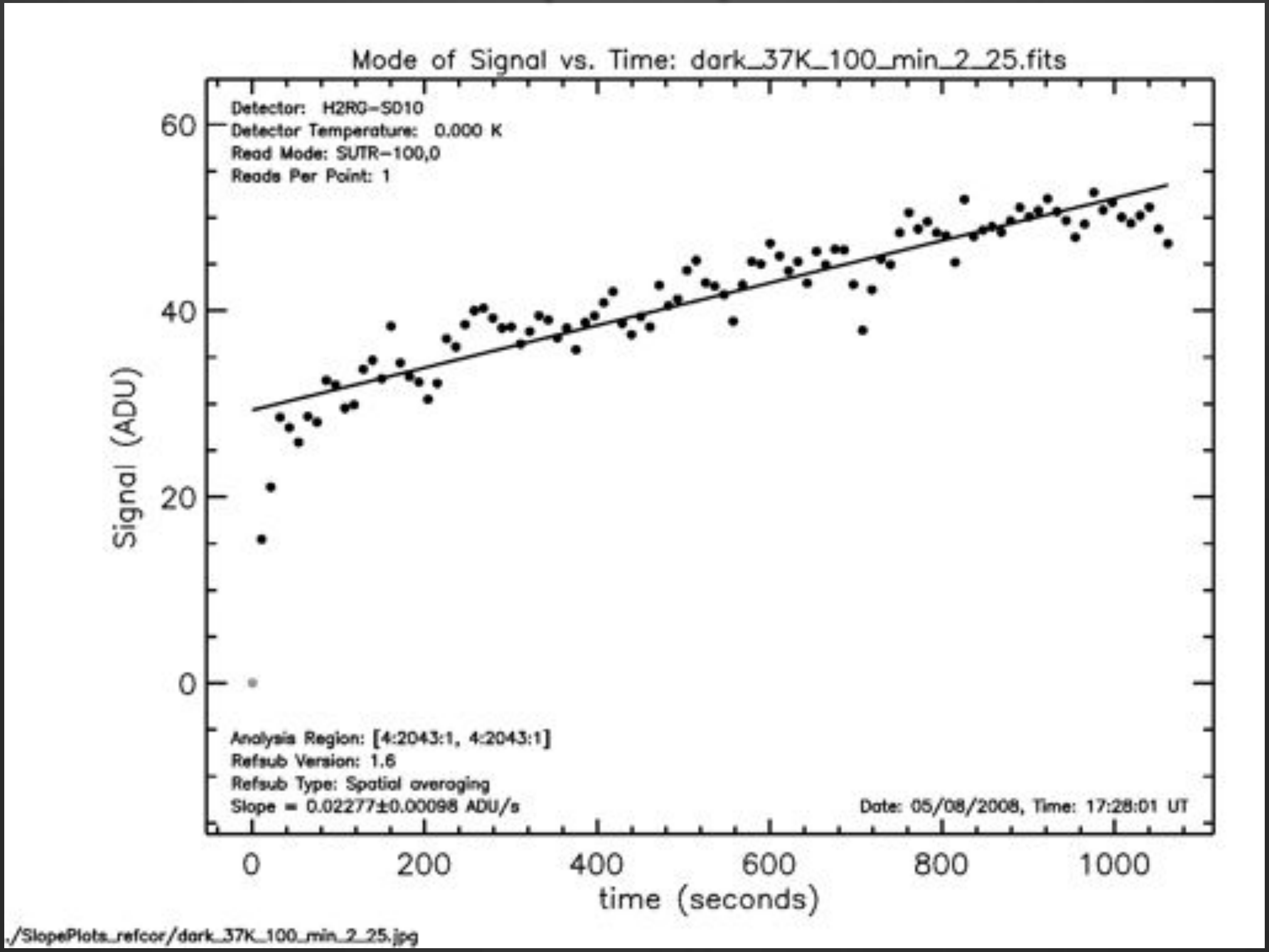
- More data volume
- When photon noise limited, slightly higher noise than CDS
- Raw frames do not compress well



Example from the Operations Detector Lab



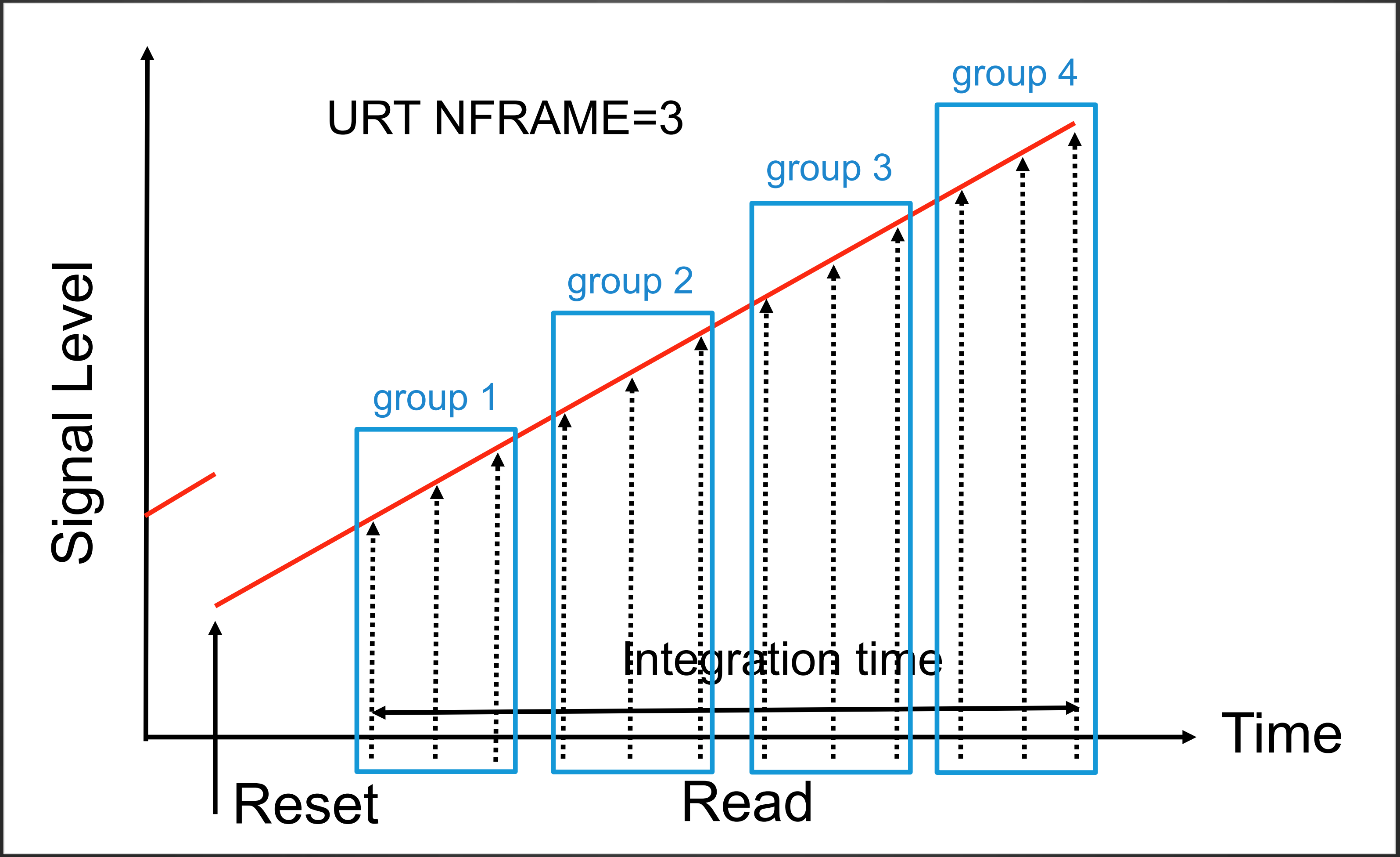
Example from the Operations Detector Lab (ref. pix. corrected)



Up-the-ramp is the JW baseline readout scheme but…

Instrument	SCA(s)	Amps/SCA	Total Amps	Pixels/sec/Amp	Bits/Pixel	bits/sec	Gbits/day
NIRCam	10	4	40	1.00E+05	16	6.4E+07	5530
NIRSpec	2	4	8	1.00E+05	16	1.3E+07	1106
MIRI	3	5	15	1.00E+05	16	2.4E+07	2074
NIRISS	1	4	4	1.00E+05	16	6.4E+06	553
FGS	1	1	1	1.00E+05	16	1.6E+06	138
					Total in 1 day =		**9400**
					Downlink in 4 hrs =		**230**
					Minimum Reduction Factor =		**41**

To reduce data volume, we average frames into groups.



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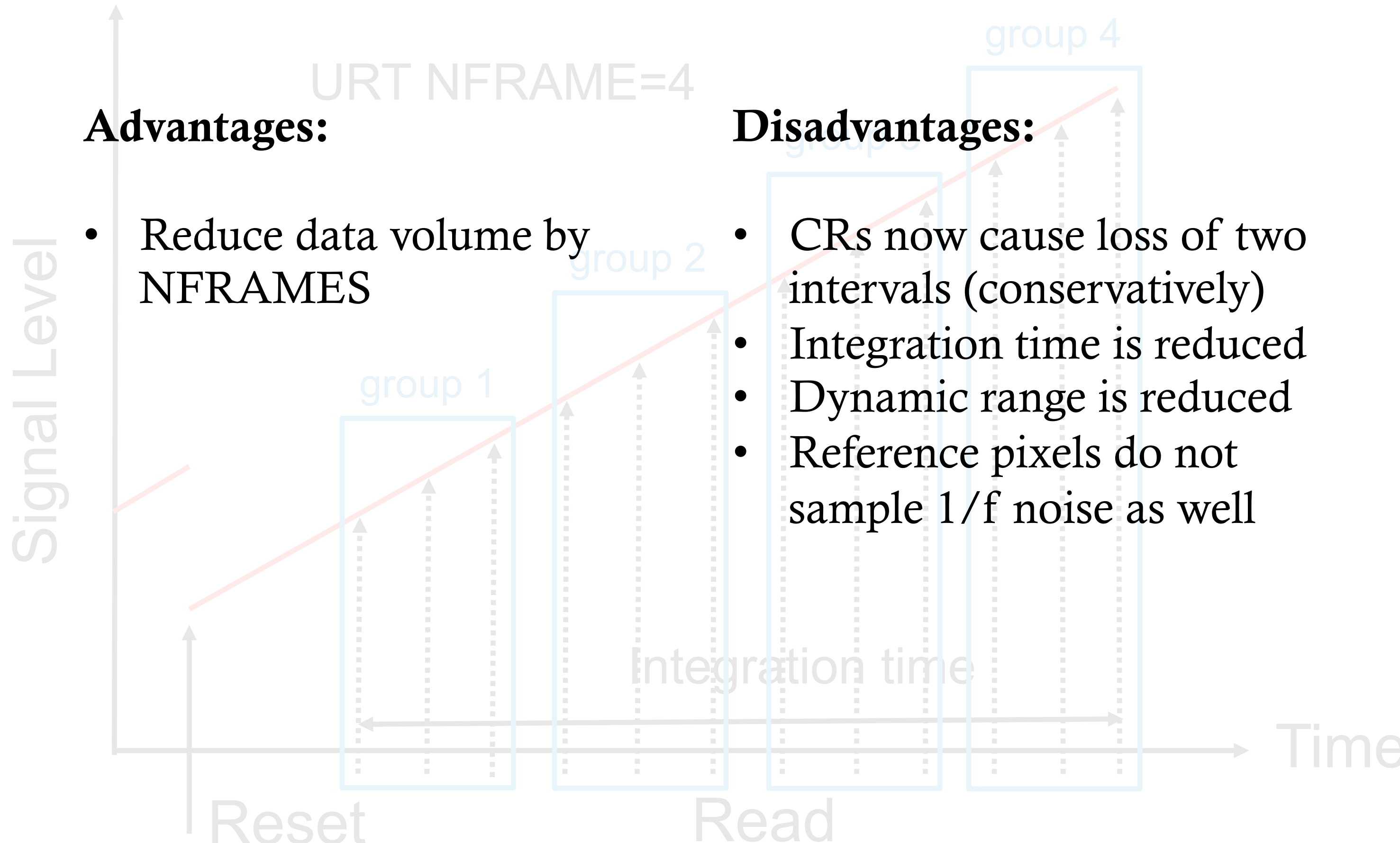


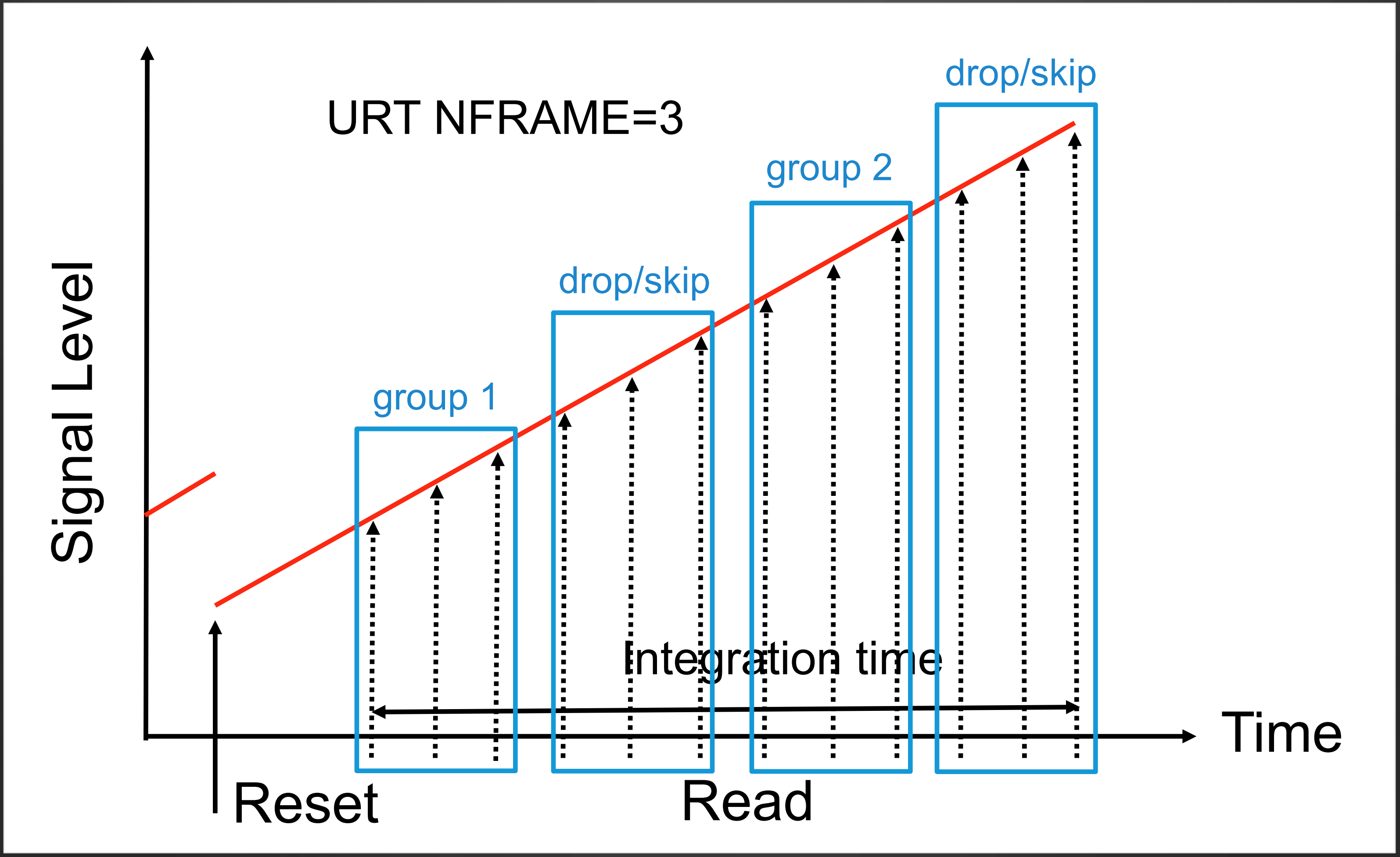
Advantages:

- Reduce data volume by NFRAMES

Disadvantages:

- CRs now cause loss of two intervals (conservatively)
- Integration time is reduced
- Dynamic range is reduced
- Reference pixels do not sample 1/f noise as well

To reduce the side effects of averaging, we drop some frames.



To reduce the side effects of averaging, we drop some frames.

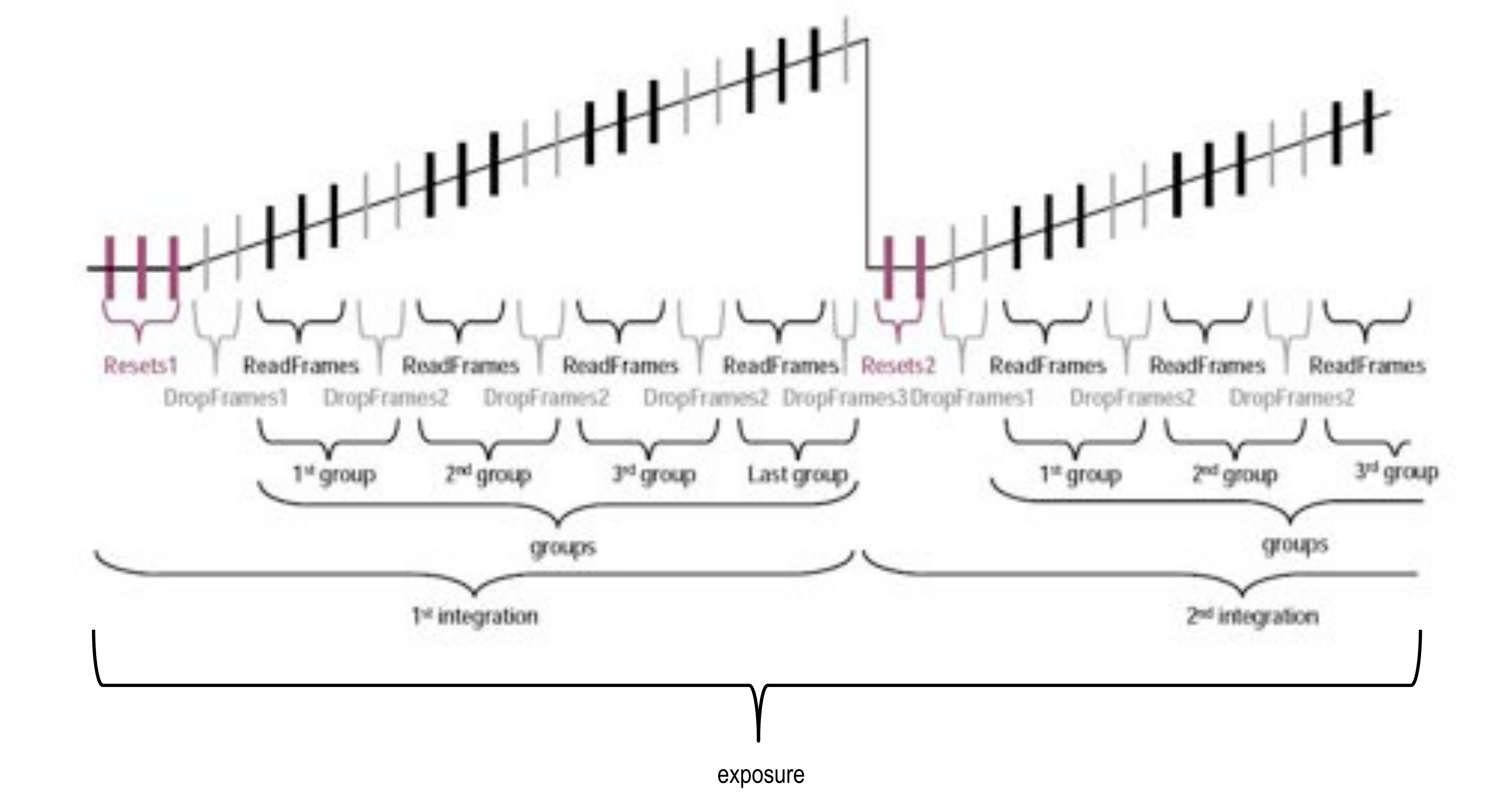
Advantages:

- Data volume reduction is (NFRAME × NSKIP)
- Loss of effective integration time is decreased
- Chance the CRs could cause the loss of only 1 interval of data
- Less dynamic range loss

Disadvantages:

- Not as much reduction in effective read noise
- Not clear we can only lose one interval due to CRs

The generic JW readout has many parameters.



In reality there are only two parameters that we change for most instruments

Instrument	Readmode	NFRAME	NSKIP	NSAMPLE
NIRSpec	NRSSLOW	4	0	
	NRSFAST	1	0	
NIRISS	NIS	4	0	
	NISRAPID	1	0	
MIRI	MIRISLOW	1	0	10
	MIRIFAST	1	0	

NIRCAM has nine readout modes that tradeoff data volume, dynamic range, and read noise

Instrument	Mode	NFRAME	NSKIP	Grouptime	Saturation Time
NIRCAM	DEEP8	8	12	212	84.8
	DEEP2	2	18	212	21.2
	MEDIUM8	8	2	106	84.8
	MEDIUM2	2	8	106	21.2
	SHALLOW4	4	1	53	42.4
	SHALLOW2	2	3	53	21.2
	BRIGHT2	2	0	21.2	21.2
	BRIGHT1	1	1	21.2	31.8
	RAPID	1	0	10.6	21.2

For all deep, medium and shallow modes, the first frame is stored, separate from the first group.

CLOCK	To address a particular pixel. “Clock” is a verb.
READ	The act of clocking and digitizing pixels in an SCA. “Read’ is a verb.
SAMPLE	The result of a single Analog to Digital conversion.
DWELL	Sample a pixel multiple times before clocking to the next pixel.
nsample	The number of A/D samples per pixel.
FRAME	The result of sequentially clocking and digitizing all pixels in a rectangular area of an SCA. "Full-fame readout" means to digitize all pixels in an SCA, including reference pixels. “Frame” also applies to the result of clocking and digitizing a subarray on an SCA.
GROUP	One or more consecutively read frames. There are no intervening resets. Frames may be averaged to form a group.
nframe	The number of FRAMES per GROUP.
INTEGRATION	The end result of resetting the detector and then non-destructively sampling it one or more times over a finite period of time. This is a unit of data for which signal is proportional to intensity, and it consists of one or more GROUPS.
ngroup	The number of GROUPS in an INTEGRATION.
INTEGRATION TIME	The time elapsed between when a pixel is first read and when it is last read in an INTEGRATION. This time interval is the time relevant for scientific analysis, but note that the actual elapsed time in an INTEGRATION is slightly longer, and it depends on the number and spacing of samples in the INTEGRATION. Using the time variables defined in §5.3.1.1, the integration time is t_{int} = ngroup × t_{group}, and the extra readout overhead is nframe × t_{frame}.
EXPOSURE	The end result of one or more INTEGRATIONS over a finite period of time.
nint	The number of INTEGRATIONS in an EXPOSURE. N.B., For NIRCam, NIRSpec, and the TFM, nint is always 1, and an EXPOSURE is equivalent to an INTEGRATION.
EXPOSURE TIME	The total time during an exposure spent accumulating signal from a source. The total elapsed time in an exposure is longer due to readout overheads at the end of each integration period.
TOTAL ELAPSED TIME	The total elapsed time during an exposure, or the “wall clock” time. The TOTAL ELAPSED TIME is the time interval from when the first pixel is read in the first integration to when the last pixel is read in the last integration in an exposure.