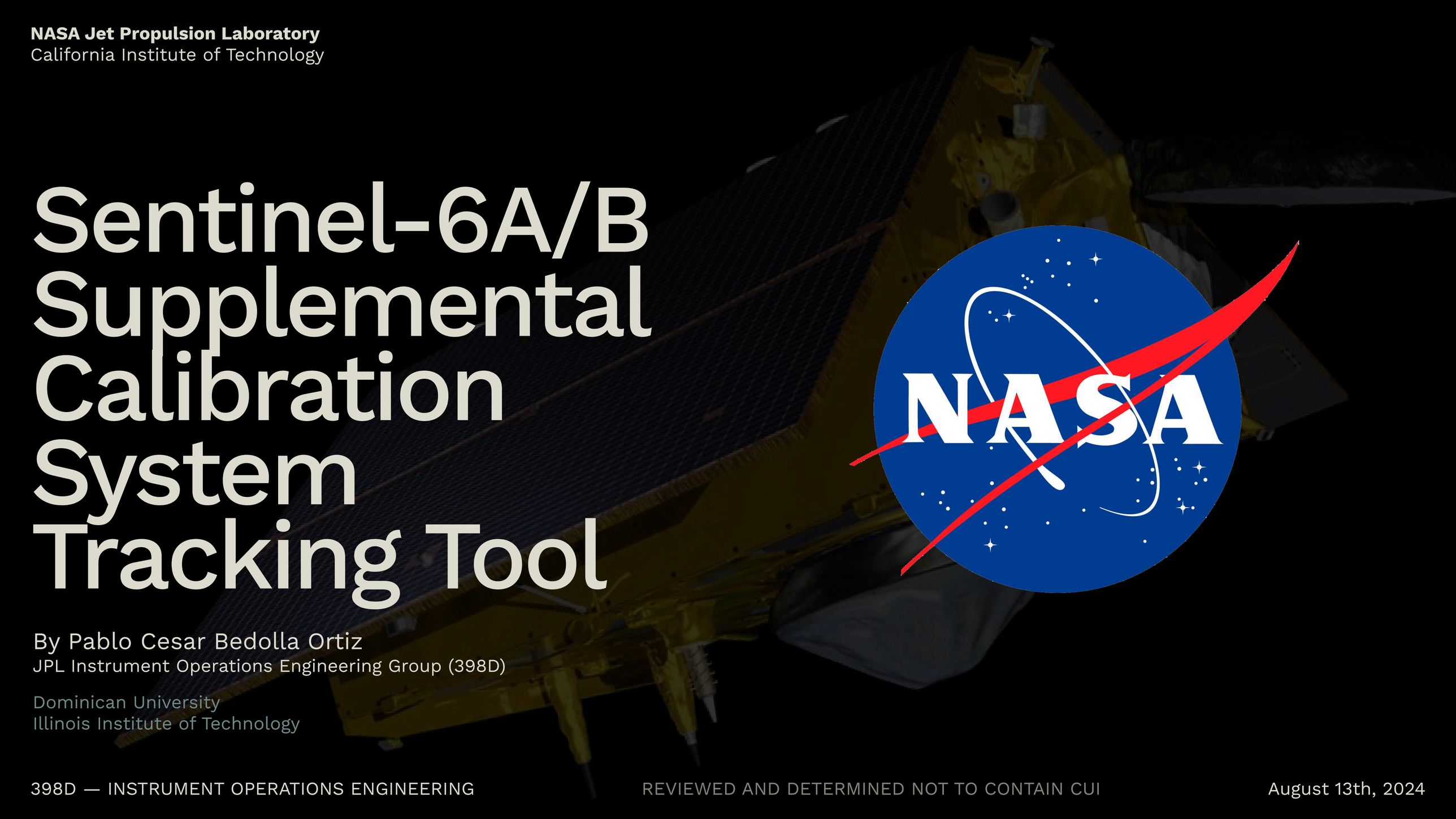
NASA Jet Propulsion Laboratory
California Institute of Technology

Sentinel-6A/B Supplemental Calibration System Tracking Tool



By Pablo Cesar Bedolla Ortiz
JPL Instrument Operations Engineering Group (398D)

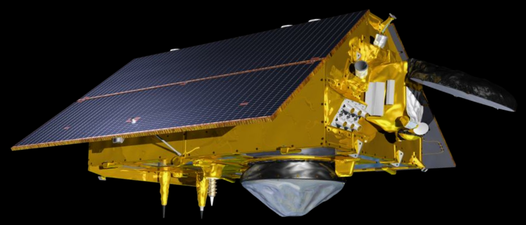
Dominican University
Illinois Institute of Technology

AGENDA

1. What is SCS?
2. What is SCS Subsetter?
3. Present Issues with SCS Subsetter
4. Statement of Objective & Scope
5. Introduction to SCS-KNIT
6. Purpose of SCS-KNIT
7. SCS-KNIT Feature A: Modularity
7. SCS-KNIT Feature B: Algorithms
7. SCS-KNIT Feature C: Efficiency
8. SCS-KNIT Results
9. Closing Statements

WHAT IS SCS?

SCS is an *internal calibration subsystem* meant to improve quality and measurement offset of radiometric calibration using two calibration targets of known values



Sentinel-6 Michael Freilich Satellite

←

AMR-C

Advanced Microwave Radiometer - Climate Quality (AMR-C)

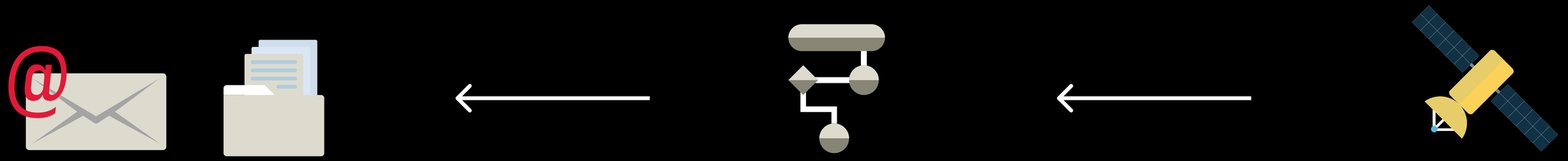
←

SCS

Supplemental Calibration System

WHAT IS SCS SUBSETTER?

SCS Subsetter is an internal script designed to query **SCS** datasets, process the data, and identify **SCS** movements to produce statistical outputs



Trend-plots & Spreadsheets

Querying, Processing, and Motion Detection

Gather SCS datasets (via Testing/ Flight)

NASA Jet Propulsion Laboratory
California Institute of Technology

Present Issues with Subsetter

ISSUES

01 Insufficient Runtime Speed

02 Insufficient Data Processing

03 Absence of Batching During Reading

04 Readability and Modularity

05 Extraction Anomalies

01 INSUFFICIENT RUNTIME SPEED

```python
pd.Index(
    Path(file).rglob(
        '*kwrd*.csv'
    )
).astype(str)

```

vs.

```
$ fd -e csv “VOLTS” .
```

Raw Recursion
Runtime: 2h 4m 55s

Parallelized Recursive Directory Traversal
Runtime: 0h 2m 4s

02 INSUFFICIENT DATA PROCESSING

[38]:

time_stamp	pkt_type	current	switch_status	status6

Original **VOLT** files accessed by the *subsetter* script

02 INSUFFICIENT DATA PROCESSING

Duplicates

	time_stamp	pkt_type	current	switch_status	status6
0	1980-01-06 00:00:00	3	0.0	238	0.0
1	1980-01-06 00:00:00.500000	3	0.0	238	NaN
2	1980-01-06 00:00:00	3	0.0	238	0.0
3	1980-01-06 00:00:00.500000	3	0.0	238	NaN
4	1980-01-06 00:00:00	3	0.0	238	0.0
...	...	...	...	...	...

Null Values

Original **VOLT** files accessed by the *subsetter* script

03 INSUFFICIENT DATA PROCESSING

```
...
AMR-C_Subsetter\Laptop-4\2019\01\11\20190111T210006_AMRC_EGSE_HA_1553__motor.csv
AMR-C_Subsetter\Laptop-4\2019\01\11\20190111T2...
AMR-C_Subsetter\Laptop-4\2019\01\15\20190115T182100_AMRC_EGSE_HA_1553__motor.csv
AMR-C_Subsetter\Lap
AMR-C_Subsetter\Lap
AMR-C_Subsetter\Lap
AMR-C_Subsetter\Laptop-4\2019\01\23\20190123T183338_AMRC_EGSE_HA_1553__motor.csv
AMR-C_Subsetter\Laptop-4\2019\01\23\20190123T1...
AMR-C_Subsetter\Laptop-4\2019\01\23\20190123T184744_AMRC_EGSE_HA_1553__motor.csv
AMR-C_Subsetter\Laptop-4\2019\01\23\20190123T1...
Length: 34364, dtype: object
```

AMR-C_Subsetter\Laptop-4\2019
Length: 34364, dtype: object
22__motor.csv

Lack of read & write verification (**REAL** skip file estimate: ~1700)

03 ABSENCE OF BATCHING DURING READING

1. Master *TGSE* File iteratively appends **VOLT** data
2. Master *Spacecraft* File iteratively appends **VOLT** data
3. No pre-processing (cleaning) of **VOLT** or **GNSSRO** data prior to motion extraction
4. Lack of parallelization for large repetitive tasks

03 ABSENCE OF BATCHING DURING READING

STACK OVERFLOW

Excessively deep recursion

got RAM?

Running out of RAM when loading vast data file

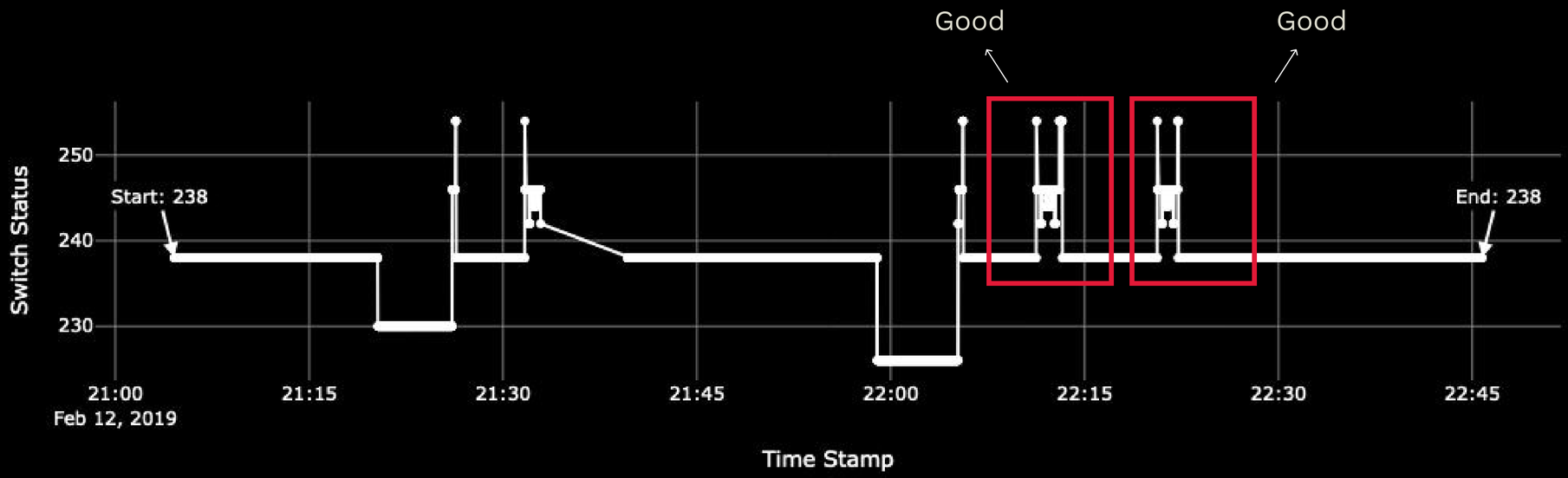
```
...
Stack overflow occurred: maximum recursion depth exceeded
>>>
```

Stack-overflow raised after maximum recursion depth is reached

04 READABILITY AND MODULARITY

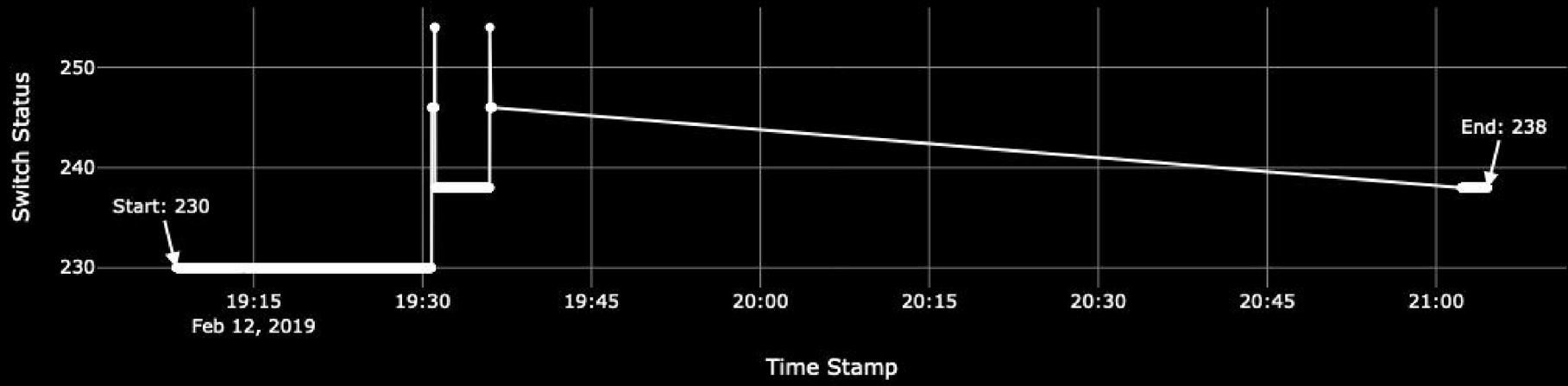
1. Lack of modularity decreases developer efficiency
2. DRY: Do **NOT** Repeat Yourself
3. Compile with all possible warnings active *(The Power of 10 Rules)*
4. Long and Complex Scripts are hard to follow
5. Reusability is King. Group data and methods as classes.

05 EXTRACTION ANOMALIES



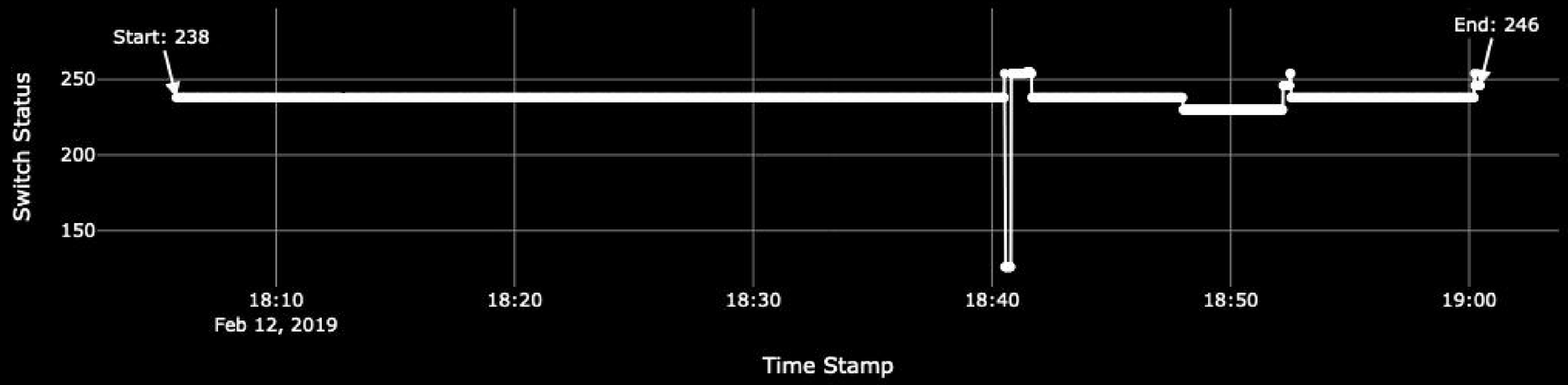
Extracted **Full Motion** containing all identifiable statuses

05 EXTRACTION ANOMALIES



Extracted **Full Motion** containing all identifiable statuses

05 EXTRACTION ANOMALIES



Extracted **Full Motion** containing all identifiable statuses

NASA Jet Propulsion Laboratory
California Institute of Technology

Statement of Objective & Scope

OBJECTIVE OF ASSIGNMENT

Refactor the **unmodular** and **error-prone** codebase to modularize and improve it, ensuring it is written in a way that other teams can utilize it effectively.

NASA Jet Propulsion Laboratory
California Institute of Technology

Introduction to SCS-KNIT

398D — INSTRUMENT OPERATIONS ENGINEERING

August 13th, 2024

SCS-KNIT

SENTINEL-6A/B SUPPLEMENTAL CALIBRATION SYSTEM (SCS)
KNOW, NAVIGATE, INTEGRATE, TRACK (KNIT)

Constants

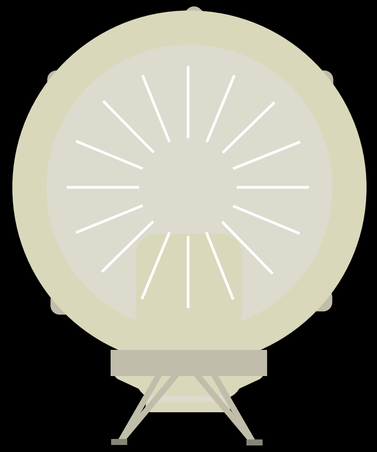
- Statuses
- Colors
- Helpers
- Paths

Models

- Motions
  - AB: Off
  - AB: Sci Moving
  - ....
  - AB: WCT

Utilities

- Generators
  - Algorithms
  - ...
- Helpers
  - Network Connector
  - ...
- ...



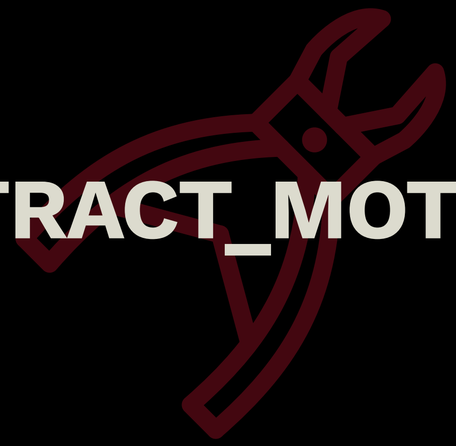
SCS-KNIT FEATURES: MODULARITY

SCS-KNIT extends SCS Subsetter beyond modularity

1. Offers extensive **Enum** constants for ease development
2. Efficient data processing functions for such files
3. Plotting & Console statistical tools
4. Data-classes for movement/motion extraction

SCS-KNIT FEATURES: ALGORITHMS

SCS-KNIT offers a new way to extract and store motions

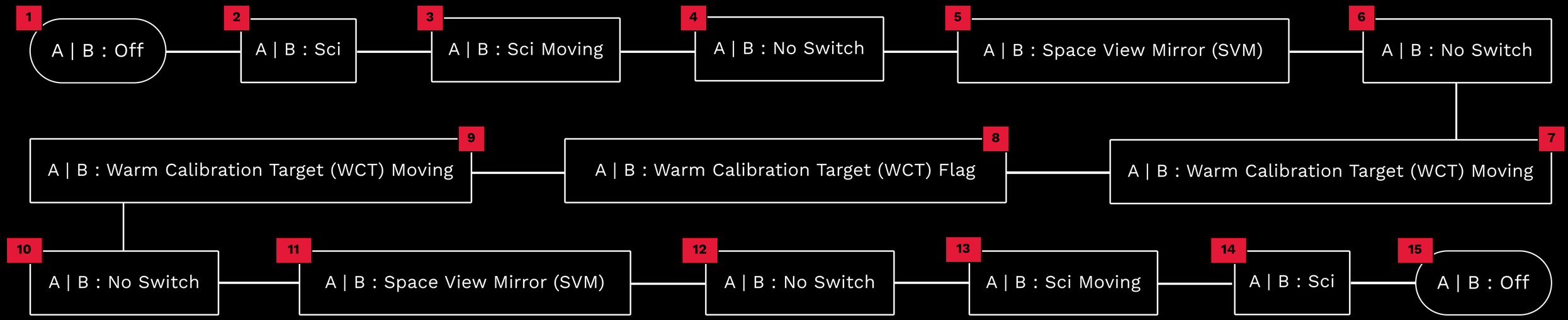


EXTRACT_MOTIONS →

NASA Jet Propulsion Laboratory
California Institute of Technology

FULL CALIBRATION COMMAND (A | B)

Full calibration command sequences for Supplemental Calibration System (SCS) A or redundant B

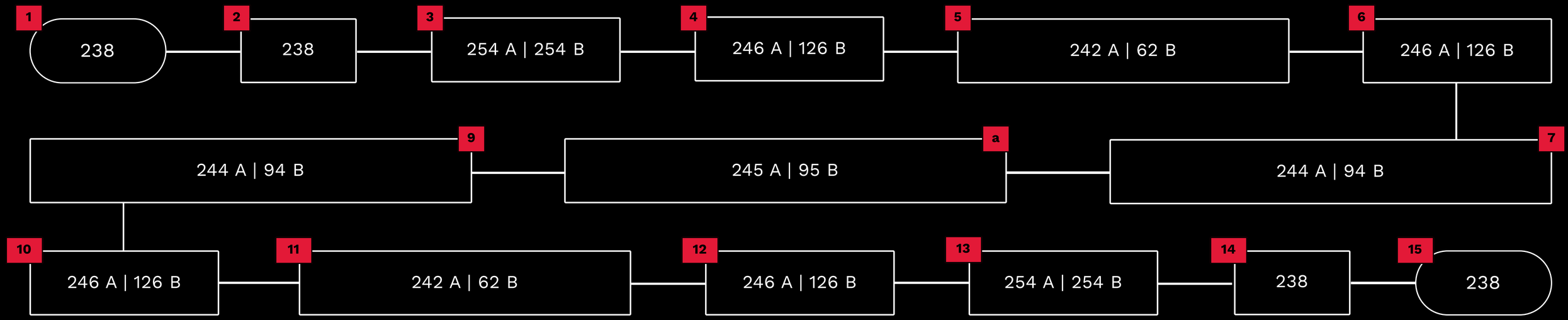


SWITCH STATUS IDENTIFIERS

NASA Jet Propulsion Laboratory
California Institute of Technology

FULL CALIBRATION COMMAND (A | B)

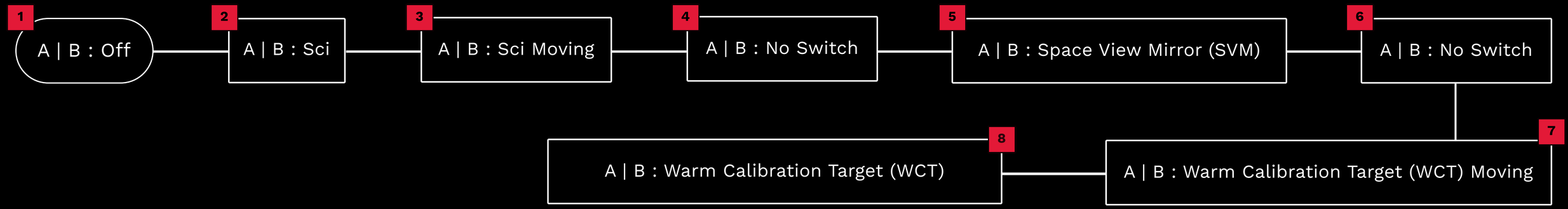
Full calibration command sequences for Supplemental Calibration System (SCS) A or redundant B



SWITCH STATUS CODES

HALF CALIBRATION COMMAND (A | B)

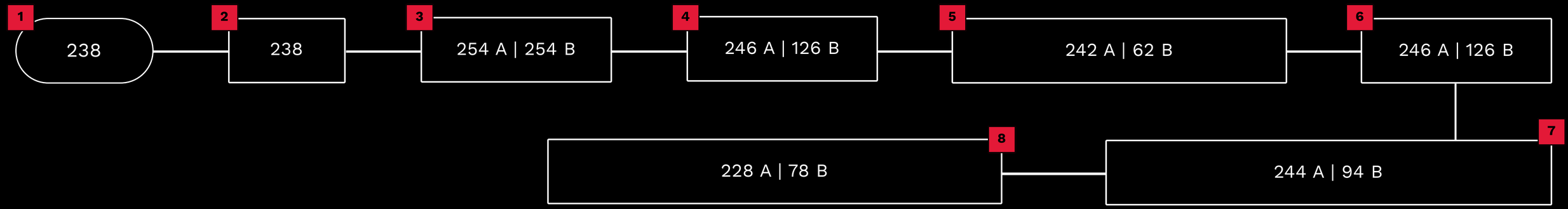
Half calibration command sequences for Supplemental Calibration System (SCS) A or redundant B.
Move the instrument to Warm Calibration Target (WCT).



SWITCH STATUS IDENTIFIERS

HALF CALIBRATION COMMAND (A | B)

Half calibration command sequences for Supplemental Calibration System (SCS) A or redundant B.
Move the instrument to Warm Calibration Target (WCT).



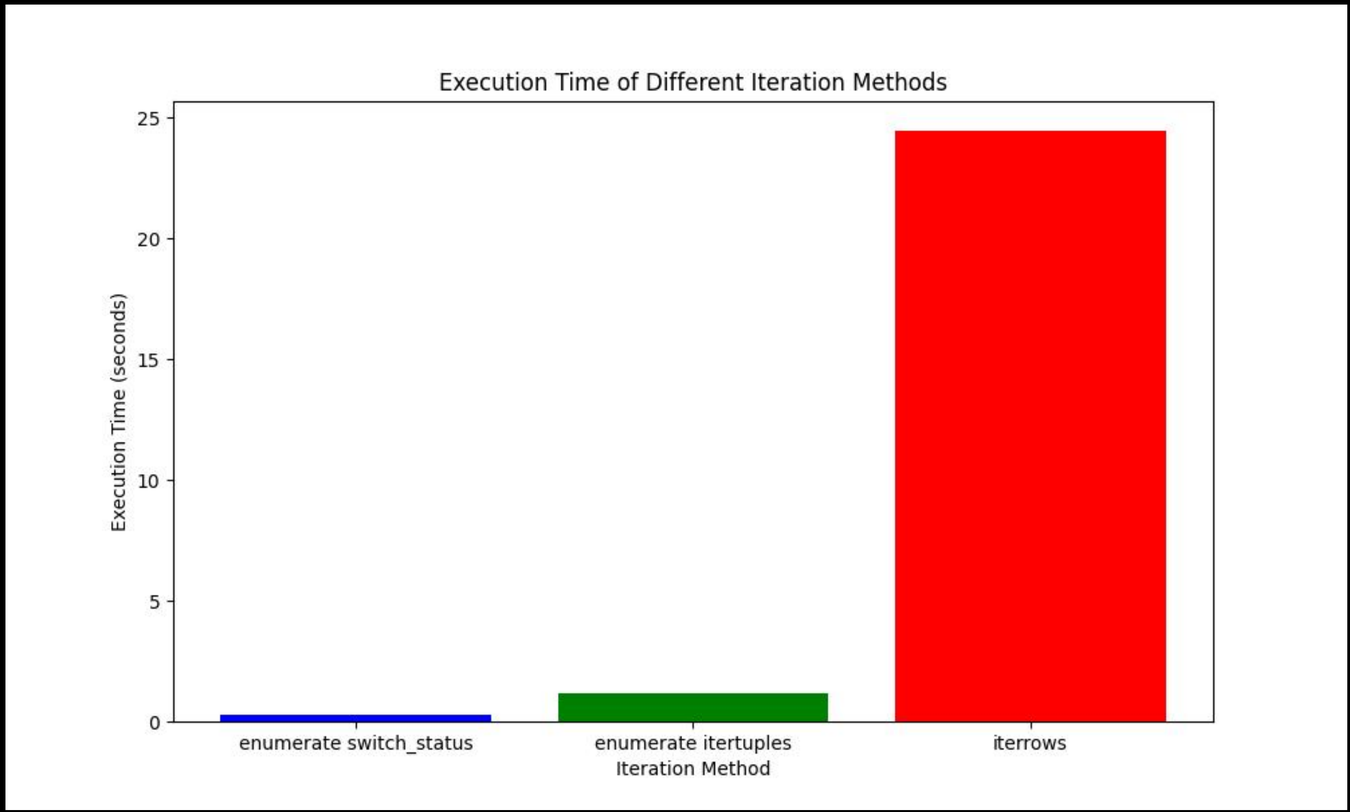
SWITCH STATUS CODES

SCS-KNIT FEATURES: EFFICIENCY

SCS-KNIT can operate at speeds significantly faster than the original code

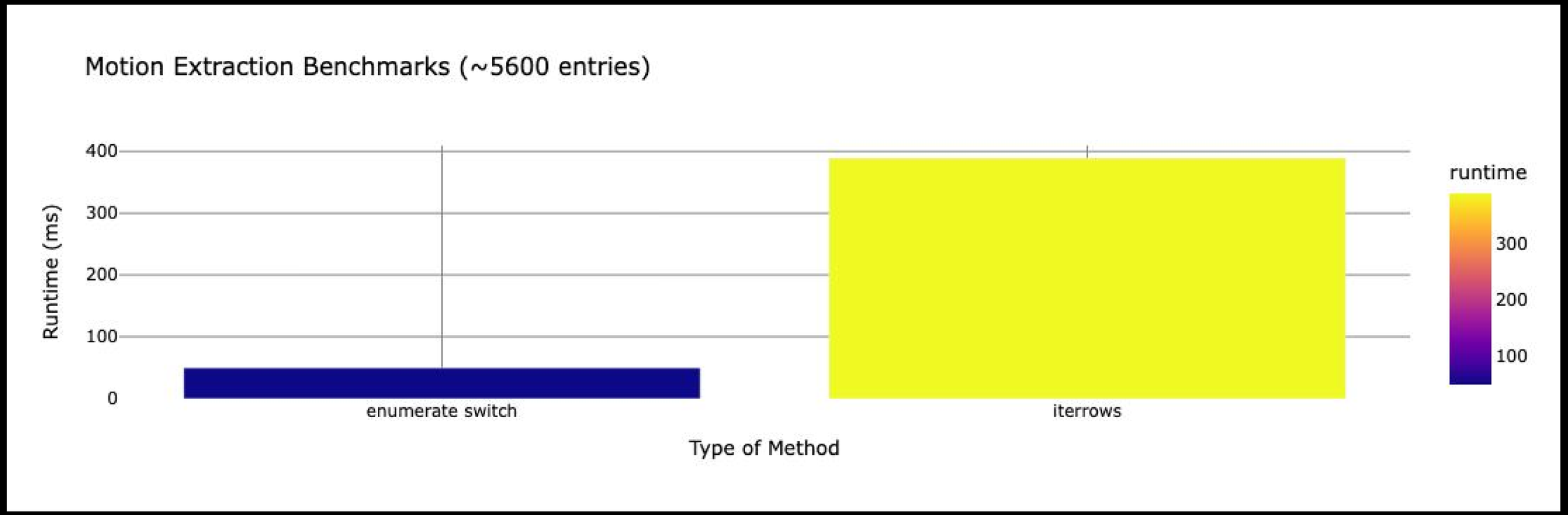
SCS-KNIT FEATURES: EFFICIENCY

Benchmarks of the three most effective search approaches for looping, which represent only a portion of overall efficiency improvements, and are still faster than the original.



SCS-KNIT FEATURES: EFFICIENCY

Benchmarks of the three most effective search approaches for looping, which represent only a portion of overall efficiency improvements, and are still faster than the original.



SCS-KNIT FEATURES: EFFICIENCY

Benchmarks of the original methods employed for extracting files with **VOLT** in their filenames

```
[19]: %%time
      pd.Index(Path(UnixPathsToData.TGSE_TEMPERATURE_DIRECTORY.value).rglob('*VOLTS*.csv')).astype(str)

      CPU times: user 20.4 s, sys: 1min 8s, total: 1min 28s
      Wall time: 2h 4min 55s

[19]: Index(['/Volumes/Sentinel-6/AMR-C/Laptop-1/2019/01/24/20190124T171515_AMRC_TGSE_VOLTS_.csv',
             '/Volumes/Sentinel-6/AMR-C/Laptop-1/2019/01/24/20190124T172151_AMRC_TGSE_VOLTS_.csv',
             '/Volumes/Sentinel-6/AMR-C/Laptop-1/2019/01/24/20190124T173012_AMRC_TGSE_VOLTS_.csv',
             '/Volumes/Sentinel-6/AMR-C/Laptop-1/2019/01/24/20190124T174032_AMRC_TGSE_VOLTS_.csv',
             '/Volumes/Sentinel-6/AMR-C/Laptop-1/2019/01/24/20190124T213929_AMRC_TGSE_VOLTS_.csv',
             '/Volumes/Sentinel-6/AMR-C/Laptop-1/2019/01/25/20190125T013529_AMRC_TGSE_VOLTS_.csv',
             '/Volumes/Sentinel-6/AMR-C/Laptop-1/2019/01/25/20190125T025349_AMRC_TGSE_VOLTS__Radiometric_Calibration.csv',
             '/Volumes/Sentinel-6/AMR-C/Laptop-1/2019/01/25/20190125T064950_AMRC_TGSE_VOLTS__Radiometric_Calibration.csv',
             '/Volumes/Sentinel-6/AMR-C/Laptop-1/2019/01/25/20190125T104550_AMRC_TGSE_VOLTS__Radiometric_Calibration.csv',
             '/Volumes/Sentinel-6/AMR-C/Laptop-1/2019/01/25/20190125T144149_AMRC_TGSE_VOLTS__Radiometric_Calibration.csv',
             ...
                                                                                                  MRC_TGSE_VOLTS__SDDA_Survival_degC.csv',
                                                                                                  MRC_TGSE_VOLTS__SDDA_Survival_degC.csv',
                                                                                                  MRC_TGSE_VOLTS__SDDA_Survival_degC.csv',
                                                                                                  MRC_TGSE_VOLTS__SDDA_Survival_degC.csv',
                                                                                                  MRC_TGSE_VOLTS__DDU_ThermalCycle_degC.csv',
             '/Volumes/Sentinel-6/~snapshot/daily.2024-08-06_0010/AMR-C_Bokeh-Plots/Laptop-1/2019/08/21/20190821T234615_AMRC_TGSE_VOLTS__DDU_ThermalCycle_degC.csv',
             '/Volumes/Sentinel-6/~snapshot/daily.2024-08-06_0010/AMR-C_Bokeh-Plots/Laptop-1/2019/08/22/20190822T034215_AMRC_TGSE_VOLTS__DDU_ThermalCycle_degC.csv',
             '/Volumes/Sentinel-6/~snapshot/daily.2024-08-06_0010/AMR-C_Bokeh-Plots/Laptop-1/2019/08/22/20190822T073814_AMRC_TGSE_VOLTS__DDU_ThermalCycle_degC.csv',
             '/Volumes/Sentinel-6/~snapshot/daily.2024-08-06_0010/AMR-C_Bokeh-Plots/Laptop-1/2019/08/22/20190822T100454_AMRC_TGSE_VOLTS__Return_Ambient_degC.csv',
             '/Volumes/Sentinel-6/~snapshot/daily.2024-08-06_0010/AMR-C_Bokeh-Plots/Laptop-1/2019/08/22/20190822T140054_AMRC_TGSE_VOLTS__Return_Ambient_degC.csv'],
            dtype='object', length=12793)
```

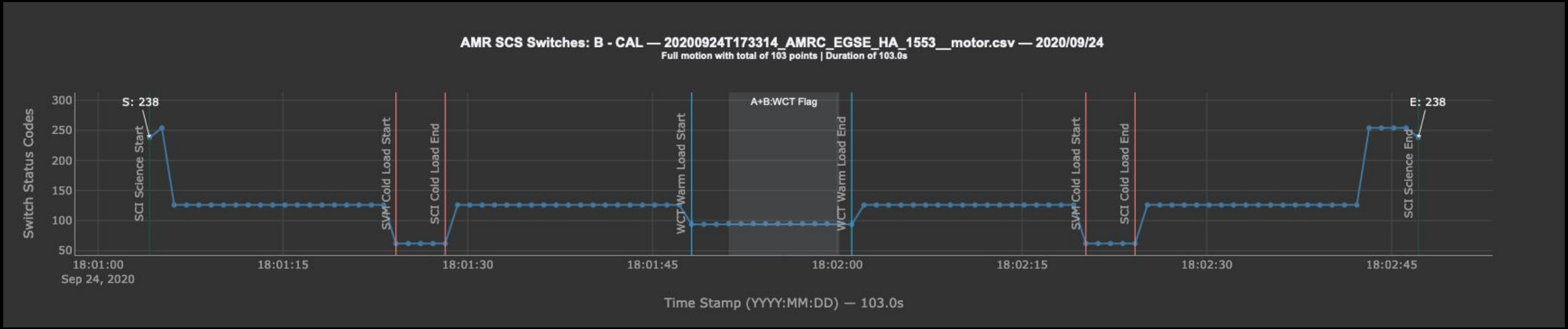
CPU times: user 20.4 s, sys: 1min 8s, total: 1min 28s
Wall time: 2h 4min 55s

SCS-KNIT FEATURES: RESULTS

SCS-KNIT provides comprehensive **statistical plotting** for any desired value (column), provided that the value is present.

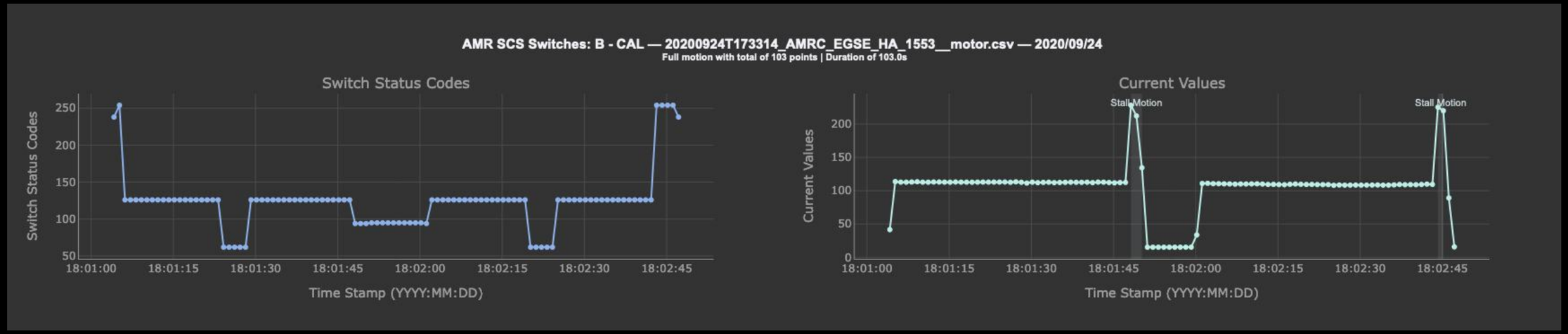
SCS-KNIT FEATURES: RESULTS

Full motion extraction of a **motor** file



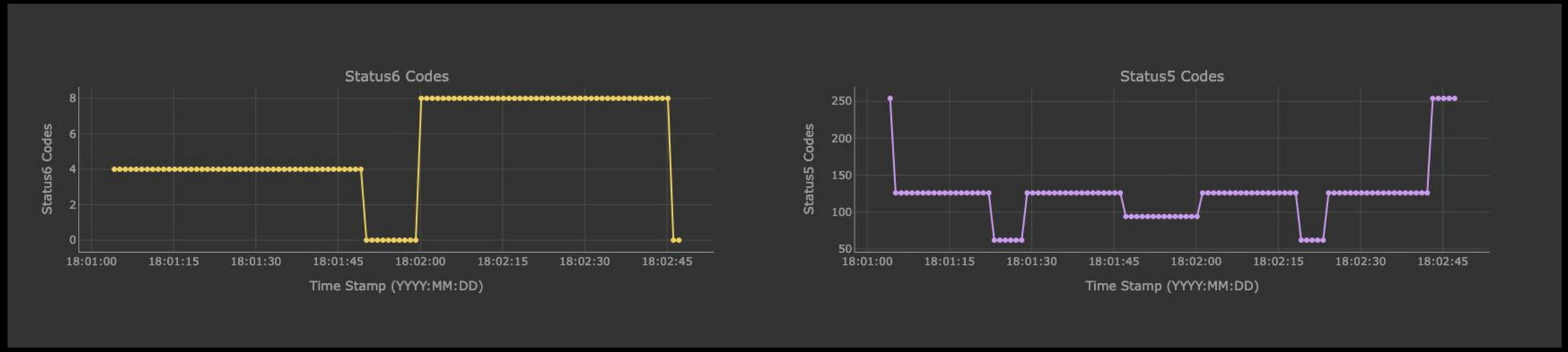
SCS-KNIT FEATURES: RESULTS

Full motion extraction features of a **motor** file



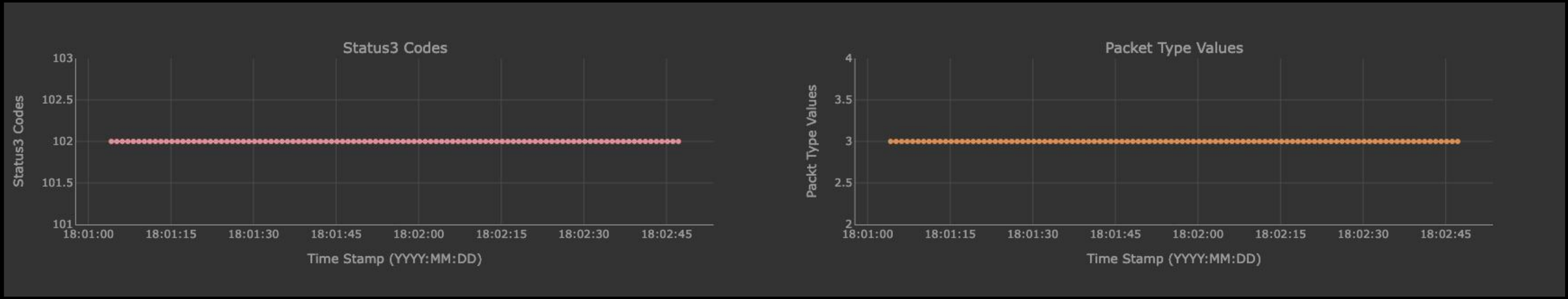
SCS-KNIT FEATURES: RESULTS

Full motion extraction features of a **motor** file



SCS-KNIT FEATURES: RESULTS

Full motion extraction features of a **motor** file



SCS-KNIT FEATURES: RESULTS

Full motion extraction of **all motor** file

SCS_Full_Motions.csv — Open with Microsoft Excel

	Motion_CSV	FM-A/B	EU	CMIE	Target	SCS_Mode	stall_Only_Track
0	/Volumes/SENTINEL-6/AMR-C_Subsetter/Laptop-1/2020/09/24/20200924T173314_AMRC_EGSE_HA_1553__motor.csv	A	H	B	WCT	Nominal	stall
1	/Volumes/SENTINEL-6/AMR-C_Subsetter/Laptop-1/2020/09/24/20200924T173314_AMRC_EGSE_HA_1553__motor.csv	A	H	B	Sci	Nominal	stall
2	/Volumes/SENTINEL-6/AMR-C_Subsetter/Laptop-3/2019/03/23/20190323T074828_AMRC_EGSE_VB_1553__motor.csv	A	V	A	WCT	Nominal	stall
3	/Volumes/SENTINEL-6/AMR-C_Subsetter/Laptop-3/2019/03/23/20190323T074828_AMRC_EGSE_VB_1553__motor.csv	A	V	A	Sci	Nominal	stall
4	/Volumes/SENTINEL-6/AMR-C_Subsetter/Laptop-3/2019/03/22/20190322T150540_AMRC_EGSE_HA_1553__motor.csv	A	H	A	WCT	Nominal	stall
5	/Volumes/SENTINEL-6/AMR-C_Subsetter/Laptop-3/2019/03/22/20190322T150540_AMRC_EGSE_HA_1553__motor.csv	A	H	A	Sci	Nominal	stall
6	/Volumes/SENTINEL-6/AMR-C_Subsetter/Laptop-3/2019/03/22/20190322T150540_AMRC_EGSE_HA_1553__motor.csv	A	H	B	WCT	Nominal	stall
7	/Volumes/SENTINEL-6/AMR-C_Subsetter/Laptop-3/2019/03/22/20190322T150540_AMRC_EGSE_HA_1553__motor.csv	A	H	B	Sci	Nominal	stall
8	/Volumes/SENTINEL-6/AMR-C_Subsetter/Laptop-1/2020/06/25/20200625T170259_AMRC_EGSE_HA_1553__motor.csv	A	H	B	WCT	Nominal	stall
9	/Volumes/SENTINEL-6/AMR-C_Subsetter/Laptop-1/2020/06/25/20200625T170259_AMRC_EGSE_HA_1553__motor.csv	A	H	B	Sci	Nominal	stall
10	/Volumes/SENTINEL-6/AMR-C_Subsetter/Laptop-1/2020/06/25/20200625T170259_AMRC_EGSE_HA_1553__motor.csv	A	H	B	WCT	Nominal	stall

SCS-KNIT FEATURES: RESULTS

Full motion extraction of **all motor** file

SCS_Full_Motions.csv — Open with Microsoft Excel

ert	initial_Time_Stamp	D_Motion [sec]	I_SVM_avg [mA]	I_SVM_max [mA]	I_SVM_min [mA]	D_stall [sec]	I_Stall_avg [mA]	I_Stall_max [mA]	I_Stall_min [mA]	T_HK_WCT_1_avg [degC]	T_HK_WCT_5_avg [degC]	T_HK_
2020/09/24	2020-09-24 18:01:04.176199	47.001	112.93	113.34	112.66	2.0	191.68667	228.32	134.48	-68.990625	-71.38000000000001	
2020/09/24	2020-09-24 18:02:00.176199	47.0	109.27	109.46	109.12	1.0	222.74	225.42	220.06	-69.65375	-75.6975	
2019/03/23	2019-03-23 09:19:52.851999	46.0	103.8	104.5	102.86	1.0	239.09	243.54	234.64	22.6375	23.87	
2019/03/23	2019-03-23 09:20:47.851999	45.0	102.22	102.78	101.38	2.0	215.40667	236.58	176.38	22.585625	23.79	
2019/03/22	2019-03-22 15:39:24.534799	45.001	106.29	106.9	105.6	1.0	239.59	239.68	239.5	21.60266666666667	21.43	
2019/03/22	2019-03-22 15:40:18.535799	45.995	103.8	104.56	102.34	2.0	206.94	238.38	146.08	21.602500000000006	21.45	
2019/03/22	2019-03-22 16:57:35.431799	45.0	86.54	87.14	86.04	1.0	229.23	231.08	227.38	24.04866666666667	22.9	
2019/03/22	2019-03-22 16:58:29.431799	44.995	86.04	86.44	85.46	1.0	223.32	225.54	221.1	23.984666666666666	22.85	
2020/06/25	2020-06-25 17:59:53.545199	46.999	109.3	110.1	108.68	2.0	195.02667	225.94	148.18	-76.635625	-159.8	
2020/06/25	2020-06-25 18:00:49.545199	46.0	104.36	105.28	103.28	2.0	215.3	217.12	214.22	-77.17375	-160.20999999999998	
2020/06/25	2020-06-25 18:15:57.548199	46.001	107.74	108.08	107.1	1.0	210.15	210.62	209.68	-76.79624999999999	-174.10750000000002	
2020/06/25	2020-06-25 18:16:52.549199	46.0	101.8	102.32	101.26	2.0	206.75333	216.38	190.52	-76.865	-159.5025	
2019/02/12	2019-02-12 22:11:14.904599	56.001	102.14	105.6	99.84	13.0	245.34857	251.52	238.56	19.301052631578944	19.278	
2019/02/12	2019-02-12 22:12:19.905599	56.995	102.72	103.68	101.76	12.0	239.18769	250.56	228.96	19.362105263157893	19.494	
2019/02/12	2019-02-12 22:20:36.893599	45.0	101.38	103.2	99.84	1.0	241.2	241.44	240.96	19.625	19.73	
2019/02/12	2019-02-12 22:21:30.894599	44.997	102.82	104.16	101.28	1.0	259.92	276.48	243.36	19.675000000000004	19.85	

SCS-KNIT FEATURES: RESULTS

Full motion extraction of **all motor** file

SCS_Full_Motions.csv — Open with Microsoft Excel

Motor Average Current Low Limit	Motor Average Current High Limit	Motor Average Stall Current Low Limit	Motor Average Stall Current High Limit	Motor Max Stall Current Low Limit	Motor Max Stall Current High Limit	Motion Duration Low Limit	Moti
85.47050846993477	128.20576270490216	603.8271784957556	838.6488590218828	603.8271784957556	838.6488590218828	75.98864443347112	92.8
44.91302137994982	67.36953206992472	639.5556922805018	888.2717948340303	639.5556922805018	888.2717948340303	79.85600918088586	97.6
78.62863780136854	117.94295670205278	207.15213008652648	287.71129178684237	207.15213008652648	287.71129178684237	39.80302333097803	48.6
78.65733308715721	117.98599963073579	207.17096291579003	287.7374484941528	207.17096291579003	287.7374484941528	39.793970849635436	48.6
79.35946563033276	119.03919844549914	207.96427077258008	288.8392649619168	207.96427077258008	288.8392649619168	39.5567558180414	48.3
79.3545359543736	119.03180393156038	207.95561565535516	288.82724396577106	207.95561565535516	288.82724396577106	39.5585236530787	48.3
78.95318873098446	118.42978309647668	207.41612005896658	288.0779445263425	207.41612005896658	288.0779445263425	39.697734586728984	48.5
78.96860333284323	118.45290499926483	207.43183335859845	288.09976855360895	207.43183335859845	288.09976855360895	39.692571553107356	48.5
-5718.197319485496	-8577.295979228244	1642.541674187633	2281.3078808161567	1642.541674187633	2281.3078808161567	193.71639440992087	236.
-5785.86279480358	-8678.794192205369	1648.8617881506182	2290.0858168758587	1648.8617881506182	2290.0858168758587	194.45097987519318	237.
-8434.862840388201	-12652.294260582303	1871.299708750507	2599.0273732645933	1871.299708750507	2599.0273732645933	220.3808837458689	269.
-5669.451544875747	-8504.177317313619	1637.964427695556	2274.9505940216054	1637.964427695556	2274.9505940216054	193.18446249269346	236.
79.81526037685805	119.72289056528706	209.08853654570666	290.40074520237033	209.08853654570666	290.40074520237033	39.39075261327419	48.1
79.7751725412707	119.66275881190603	208.9584273500149	290.2200379861318	208.9584273500149	290.2200379861318	39.40524815517901	48.1

SCS-KNIT FEATURES: RESULTS

Full motion extraction of **all motor** file

FULL EXTRACTED MOTIONS

Total: 627

PORTABILITY

JSON & CSV Extraction

MODULARITY

Extract TGSE, Spacecraft, HK,
or Motor files separately

NASA Jet Propulsion Laboratory
California Institute of Technology

Closing Statements

ROOM FOR IMPROVEMENT

SCS-KNIT would immensely benefit from

01 Additive statistics with motion generation and extraction

02 Enhanced modularity during motion extraction

03 Command-line execution capability

04 Stronger CSV/XLSX exportability

05 **STRICTER SOFTWARE/DATA STRUCTURE**

REFERENCES

NASA Jet Propulsion Laboratory (JPL). (n.d.). Sentinel-6 Michael Freilich Satellite. NASA Jet Propulsion Laboratory (JPL). https://www.jpl.nasa.gov/missions/sentinel-6

RECOGNITION AND APPRECIATION

Thank you to all my mentors, colleagues, the education office and peers. Thank you JPL!

ACKNOWLEDGEMENT STATEMENT

The material contained herein is based on work supported by the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the JPL Maximizing Student Potential in STEM program program and the National Aeronautics and Space Administration (NASA) (80NMD0018D0004).