Supplementary Material

Solar Sail Propulsion: A Theoretical Case Study of a Carrington-Class Encounter and Extension Towards the Net Operational Time

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Overview
This supplementary document provides the tabulated datasets, environmental proxy outputs, and analytical scaling arrays utilized to generate the figures and bounding limits presented in the main manuscript.

Section S1: Transient Acceleration Boost vs. CME Shock-Front Density
Description: Calculated acceleration enhancement percentage for the IKAROS-class architecture across a continuous sweep of Coronal Mass Ejection shock-front proton densities at a fixed 2,400 km/s velocity (corresponding to Figure 2).

Appendix A: Kinematic Acceleration Boost vs. Coronal Mass Ejection Density Simulation Engine: Analytical Derivation (Kinetic Dynamic Pressure Model)	
Shock front Density (n_{CME}) ($Protons/cm^3$)	**Acceleration Boost in Percentage (%)**
30	4.1331
35	4.8219
40	5.5108
45	6.1996
50	6.8885
55	7.5773
60	8.2662
65	8.955
70	9.6439
75	10.3327
80	11.0216
85	11.7104
90	12.3993
95	13.0881
100	13.777
105	14.4658
110	15.1546
115	15.8435
120	16.5323
125	17.2212

130	17.91
135	18.5989
140	19.2877
145	19.9766
150	20.6654
155	21.3543
160	22.0431
165	22.732
170	23.4208
175	24.1097
180	24.7985
185	25.4874
190	26.1762
195	26.8651
200	27.5539
205	28.2427
210	28.9316
215	29.6205
220	30.3093
225	30.9981
230	31.687
235	32.3758
240	33.0647
245	33.7535
250	34.4424
255	35.1312
260	35.8201
265	36.5089
270	37.1978
275	37.8866
280	38.5755
285	39.2643
290	39.9532
295	40.642
300	41.3309
305	42.0197
310	42.7085
315	43.3974
320	44.0862
325	44.7751
330	45.4639
335	46.1528
340	46.8416
345	47.5305
350	48.2193
355	48.9082

360	49.597
365	50.2859
370	50.9747
375	51.6636
380	52.3524
385	53.0413
390	53.7301
395	54.419
400	55.1078
405	55.7966
410	56.4855
415	57.1743
420	57.8632
425	58.552
430	59.2409
435	59.9297
440	60.6186
445	61.3074
450	61.9963
455	62.6851
460	63.374
465	64.0628
470	64.7517
475	65.4405
480	66.1294
485	66.8182
490	67.5071
495	68.1959
500	68.8848

Section S2: Total Sail Thrust Force vs. CME Shock-Front Density
Description: Calculated total thrust force combining baseline photon pressure and Coronal Mass Ejection kinetic pressure acting on the 196 m² membrane across a continuous density sweep (corresponding to Figure 3).

Appendix B: Total Sail Thrust Force vs. Coronal Mass Ejection Density **Simulation Engine: Analytical Derivation (Kinetic Dynamic Pressure Model)**	
Shock front Density (n_{CME}) ($Protons/cm^3$)	F_{Max} (N)
30	1.85E-03
35	1.86E-03
40	1.87E-03
45	1.89E-03
50	1.90E-03
55	1.91E-03

60	1.92E-03
65	1.93E-03
70	1.95E-03
75	1.96E-03
80	1.97E-03
85	1.98E-03
90	2.00E-03
95	2.01E-03
100	2.02E-03
105	2.03E-03
110	2.04E-03
115	2.06E-03
120	2.07E-03
125	2.08E-03
130	2.09E-03
135	2.11E-03
140	2.12E-03
145	2.13E-03
150	2.14E-03
155	2.15E-03
160	2.17E-03
165	2.18E-03
170	2.19E-03
175	2.20E-03
180	2.22E-03
185	2.23E-03
190	2.24E-03
195	2.25E-03
200	2.27E-03
205	2.28E-03
210	2.29E-03
215	2.30E-03
220	2.31E-03
225	2.33E-03
230	2.34E-03
235	2.35E-03
240	2.36E-03
245	2.38E-03
250	2.39E-03
255	2.40E-03
260	2.41E-03
265	2.42E-03
270	2.44E-03
275	2.45E-03
280	2.46E-03
285	2.47E-03

290	2.49E-03
295	2.50E-03
300	2.51E-03
305	2.52E-03
310	2.53E-03
315	2.55E-03
320	2.56E-03
325	2.57E-03
330	2.58E-03
335	2.60E-03
340	2.61E-03
345	2.62E-03
350	2.63E-03
355	2.64E-03
360	2.66E-03
365	2.67E-03
370	2.68E-03
375	2.69E-03
380	2.71E-03
385	2.72E-03
390	2.73E-03
395	2.74E-03
400	2.75E-03
405	2.77E-03
410	2.78E-03
415	2.79E-03
420	2.80E-03
425	2.82E-03
430	2.83E-03
435	2.84E-03
440	2.85E-03
445	2.86E-03
450	2.88E-03
455	2.89E-03
460	2.90E-03
465	2.91E-03
470	2.93E-03
475	2.94E-03
480	2.95E-03
485	2.96E-03
490	2.97E-03
495	2.99E-03
500	3.00E-03

Section S3: SPENVIS Solar Proton Fluence Data (ESP-PSYCHIC)
Description: Tabulated integral and differential solar proton fluence profiles across the 5-year Sub-L1 mission simulation. Data is provided for both the 95% and the bounding 99% confidence levels (corresponding to Figures 4 and 5 in the main text).
Methodological Note on Statistical Non-Monotonicity: As noted in the main manuscript, the integral fluence at the 99% confidence level ($2.737 \times 10^{12} cm^{-2}$) is marginally lower than the 95% confidence level ($3.044 \times 10^{12} cm^{-2}$) at the lowest energy thresholds (e.g., 0.1 MeV). This non-monotonicity is an inherent artifact of the SPENVIS ESP-PSYCHIC engine's compound stochastic formulation, which derives mission fluence by combining a lognormal fit of observed event fluences with Poisson-distributed event frequencies. Because this compound probability model does not guarantee strict monotonicity across all confidence levels and energy channels simultaneously, the specific 99% output values have been retained exactly as generated by the simulation engine to preserve absolute methodological fidelity.

Appendix C: Deep-Space Solar Proton Fluence (95% Confidence Interval) Simulation Engine: ESA SPENVIS (ESP-PSYCHIC Module)		
Energy (MeV)	**Integral Fluence (cm^{-2})**	**Differential Fluence ($cm^{-2}MeV^{-1}$)**
0.1	3.04E+12	1.88E+13
0.11	2.87E+12	1.64E+13
0.12	2.72E+12	1.43E+13
0.14	2.47E+12	1.12E+13
0.16	2.27E+12	8.97E+12
0.18	2.11E+12	7.39E+12
0.2	1.97E+12	6.22E+12
0.22	1.86E+12	5.33E+12
0.25	1.72E+12	4.34E+12
0.28	1.60E+12	3.61E+12
0.32	1.47E+12	2.90E+12
0.35	1.39E+12	2.51E+12
0.4	1.28E+12	2.02E+12
0.45	1.19E+12	1.67E+12
0.5	1.11E+12	1.40E+12
0.55	1.05E+12	1.20E+12
0.63	9.62E+11	9.67E+11
0.71	8.92E+11	7.95E+11
0.8	8.28E+11	6.54E+11
0.9	7.69E+11	5.40E+11
1	7.20E+11	4.54E+11
1.1	6.78E+11	3.88E+11
1.2	6.42E+11	3.38E+11
1.4	5.83E+11	2.65E+11
1.6	5.37E+11	2.12E+11
1.8	4.98E+11	1.75E+11

2	4.67E+11	1.47E+11
2.2	4.40E+11	1.26E+11
2.5	4.06E+11	1.03E+11
2.8	3.78E+11	8.82E+10
3.2	3.45E+11	7.74E+10
3.5	3.23E+11	6.90E+10
4	2.93E+11	5.48E+10
4.5	2.68E+11	4.46E+10
5	2.48E+11	3.93E+10
5.5	2.29E+11	3.55E+10
6.3	2.04E+11	2.79E+10
7.1	1.84E+11	2.35E+10
8	1.64E+11	1.98E+10
9	1.47E+11	1.57E+10
10	1.33E+11	1.36E+10
11	1.20E+11	1.20E+10
12	1.09E+11	1.01E+10
14	9.20E+10	7.54E+09
16	7.88E+10	6.01E+09
18	6.80E+10	4.78E+09
20	5.97E+10	3.91E+09
22	5.24E+10	3.30E+09
25	4.40E+10	2.53E+09
28	3.72E+10	2.02E+09
32	3.04E+10	1.49E+09
35	2.64E+10	1.22E+09
40	2.12E+10	9.09E+08
45	1.73E+10	6.87E+08
50	1.44E+10	5.29E+08
55	1.20E+10	4.20E+08
63	9.24E+09	2.97E+08
71	7.28E+09	2.14E+08
80	5.68E+09	1.55E+08
90	4.39E+09	1.11E+08
100	3.47E+09	8.01E+07
110	2.79E+09	5.87E+07
120	2.29E+09	4.50E+07
140	1.59E+09	2.85E+07
160	1.15E+09	1.83E+07
180	8.63E+08	1.23E+07
200	6.62E+08	8.61E+06
220	5.18E+08	6.29E+06
250	3.71E+08	4.11E+06
280	2.71E+08	2.79E+06
320	1.88E+08	1.68E+06

350	1.47E+08	1.20E+06
400	1.01E+08	7.34E+05
450	7.31E+07	4.66E+05
500	5.46E+07	2.73E+05

Appendix D: Deep-Space Solar Proton Fluence (99% Confidence Interval) Simulation Engine: ESA SPENVIS (ESP-PSYCHIC Module)		
Energy (MeV)	**Integral Fluence (cm^{-2})**	**Differential Fluence ($cm^{-2}MeV^{-1}$)**
0.1	2.74E+12	1.22E+13
0.11	2.62E+12	1.08E+13
0.12	2.52E+12	9.50E+12
0.14	2.35E+12	7.63E+12
0.16	2.22E+12	6.27E+12
0.18	2.10E+12	5.28E+12
0.2	2.01E+12	4.53E+12
0.22	1.92E+12	3.95E+12
0.25	1.82E+12	3.28E+12
0.28	1.73E+12	2.79E+12
0.32	1.63E+12	2.29E+12
0.35	1.56E+12	2.01E+12
0.4	1.47E+12	1.66E+12
0.45	1.39E+12	1.40E+12
0.5	1.33E+12	1.20E+12
0.55	1.27E+12	1.05E+12
0.63	1.20E+12	8.62E+11
0.71	1.14E+12	7.24E+11
0.8	1.08E+12	6.09E+11
0.9	1.02E+12	5.13E+11
1	9.75E+11	4.40E+11
1.1	9.34E+11	3.83E+11
1.2	8.98E+11	3.38E+11
1.4	8.38E+11	2.72E+11
1.6	7.89E+11	2.23E+11
1.8	7.49E+11	1.88E+11
2	7.14E+11	1.61E+11
2.2	6.84E+11	1.41E+11
2.5	6.46E+11	1.17E+11
2.8	6.14E+11	1.02E+11
3.2	5.76E+11	9.16E+10
3.5	5.49E+11	8.29E+10
4	5.12E+11	6.78E+10

4.5	4.81E+11	5.65E+10
5	4.56E+11	5.17E+10
5.5	4.30E+11	4.83E+10
6.3	3.95E+11	3.92E+10
7.1	3.67E+11	3.44E+10
8	3.37E+11	3.03E+10
9	3.10E+11	2.47E+10
10	2.88E+11	2.24E+10
11	2.65E+11	2.07E+10
12	2.46E+11	1.77E+10
14	2.16E+11	1.39E+10
16	1.91E+11	1.16E+10
18	1.70E+11	9.62E+09
20	1.52E+11	8.18E+09
22	1.37E+11	7.15E+09
25	1.18E+11	5.69E+09
28	1.03E+11	4.74E+09
32	8.62E+10	3.63E+09
35	7.64E+10	3.06E+09
40	6.30E+10	2.37E+09
45	5.26E+10	1.85E+09
50	4.45E+10	1.47E+09
55	3.79E+10	1.20E+09
63	2.98E+10	8.74E+08
71	2.40E+10	6.48E+08
80	1.90E+10	4.81E+08
90	1.50E+10	3.53E+08
100	1.20E+10	2.66E+08
110	9.63E+09	2.02E+08
120	7.91E+09	1.55E+08
140	5.50E+09	9.82E+07
160	3.98E+09	6.31E+07
180	2.97E+09	4.24E+07
200	2.28E+09	2.97E+07
220	1.79E+09	2.17E+07
250	1.28E+09	1.42E+07
280	9.36E+08	9.63E+06
320	6.47E+08	5.80E+06
350	5.05E+08	4.13E+06
400	3.49E+08	2.53E+06
450	2.52E+08	1.61E+06
500	1.88E+08	9.41E+05

Section S4: SPENVIS Total Ionizing Dose (SHIELDOSE-2)
Description: Tabulated Total Ionizing Dose (TID) attenuation data as a function of Aluminum-equivalent and Tissue shield thickness (corresponding to Figure 6).

Appendix E: Total Ionizing Dose (TID) for Aluminum and Tissue Targets Simulation Engine: ESA SPENVIS (SHIELDOSE-2 Module) Subsection - 1 Target Material = Aluminum (Al)		
Al Absorber Thickness (mm)	**Total Dose (rad)**	**Solar Protons Dose (rad)**
0	6.86E+06	6.86E+06
0.001	2.80E+06	2.80E+06
0.003	1.58E+06	1.58E+06
0.004	1.14E+06	1.14E+06
0.007	7.55E+05	7.55E+05
0.013	4.38E+05	4.38E+05

Appendix E: Total Ionizing Dose (TID) for Aluminum and Tissue Targets Simulation Engine: ESA SPENVIS (SHIELDOSE-2 Module) Subsection – 2 Target Material = Tissues		
Al Absorber Thickness (mm)	**Total Dose (rad)**	**Solar Protons Dose (rad)**
0	9.15E+06	9.15E+06
0.001	4.06E+06	4.06E+06
0.003	2.45E+06	2.45E+06
0.004	1.83E+06	1.83E+06
0.007	1.26E+06	1.26E+06
0.013	7.75E+05	7.75E+05

Section S5: SPENVIS Micrometeoroid Environment (Grün Model)
Description: Extracted data array detailing the inverse logarithmic relationship between cumulative particle flux and particle mass for the unshielded Sub-L1 proxy environment (corresponding to Figure 7).

Appendix F: Sub-L1 Interplanetary Micrometeoroid Cumulative Flux Simulation Engine: ESA SPENVIS (Grün Meteoroid Model) Altitude – 1.0$\times$ 10^6 km (almost 67% of the Sun-Earth L1 point distance) Earth shielding factor: 1.000 Gravitational Attraction Factor: 1.006			
Mass (g)	**Diameter (cm)**	**Density (g/cm^3)**	**Flux ($Impacts/m^2yr$)**
1.00E-12	9.85E-05	2	1.09E+03
1.26E-12	1.06E-04	2	1.01E+03

1.58E-12	1.15E-04	2	9.29E+02
2.00E-12	1.24E-04	2	8.56E+02
2.51E-12	1.34E-04	2	7.88E+02
3.16E-12	1.45E-04	2	7.26E+02
3.98E-12	1.56E-04	2	6.68E+02
5.01E-12	1.69E-04	2	6.14E+02
6.31E-12	1.82E-04	2	5.63E+02
7.94E-12	1.96E-04	2	5.17E+02
1.00E-11	2.12E-04	2	4.74E+02
1.26E-11	2.29E-04	2	4.34E+02
1.58E-11	2.47E-04	2	3.97E+02
2.00E-11	2.67E-04	2	3.64E+02
2.51E-11	2.88E-04	2	3.34E+02
3.16E-11	3.11E-04	2	3.06E+02
3.98E-11	3.36E-04	2	2.81E+02
5.01E-11	3.63E-04	2	2.58E+02
6.31E-11	3.92E-04	2	2.38E+02
7.94E-11	4.23E-04	2	2.20E+02
1.00E-10	4.57E-04	2	2.03E+02
1.26E-10	4.94E-04	2	1.88E+02
1.58E-10	5.33E-04	2	1.74E+02
2.00E-10	5.75E-04	2	1.61E+02
2.51E-10	6.21E-04	2	1.50E+02
3.16E-10	6.71E-04	2	1.39E+02
3.98E-10	7.24E-04	2	1.29E+02
5.01E-10	7.82E-04	2	1.20E+02
6.31E-10	8.45E-04	2	1.11E+02
7.94E-10	9.12E-04	2	1.03E+02
1.00E-09	9.85E-04	2	9.56E+01
1.26E-09	1.06E-03	2	8.83E+01
1.58E-09	1.15E-03	2	8.14E+01
2.00E-09	1.24E-03	2	7.49E+01
2.51E-09	1.34E-03	2	6.86E+01
3.16E-09	1.45E-03	2	6.27E+01
3.98E-09	1.56E-03	2	5.71E+01
5.01E-09	1.69E-03	2	5.17E+01
6.31E-09	1.82E-03	2	4.67E+01
7.94E-09	1.96E-03	2	4.20E+01
1.00E-08	2.12E-03	2	3.76E+01
1.26E-08	2.29E-03	2	3.34E+01
1.58E-08	2.47E-03	2	2.97E+01
2.00E-08	2.67E-03	2	2.62E+01
2.51E-08	2.88E-03	2	2.30E+01
3.16E-08	3.11E-03	2	2.01E+01
3.98E-08	3.36E-03	2	1.75E+01

5.01E-08	3.63E-03	2	1.52E+01
6.31E-08	3.92E-03	2	1.31E+01
7.94E-08	4.23E-03	2	1.12E+01
1.00E-07	4.57E-03	2	9.60E+00
1.26E-07	4.94E-03	2	8.16E+00
1.58E-07	5.33E-03	2	6.89E+00
2.00E-07	5.75E-03	2	5.80E+00
2.51E-07	6.21E-03	2	4.85E+00
3.16E-07	6.71E-03	2	4.04E+00
3.98E-07	7.24E-03	2	3.34E+00
5.01E-07	7.82E-03	2	2.76E+00
6.31E-07	8.45E-03	2	2.26E+00
7.94E-07	9.12E-03	2	1.84E+00
1.00E-06	9.85E-03	2	1.50E+00
1.26E-06	1.06E-02	2	1.21E+00
1.58E-06	1.15E-02	2	9.73E-01
2.00E-06	1.24E-02	2	7.79E-01
2.51E-06	1.34E-02	2	6.22E-01
3.16E-06	1.45E-02	2	4.94E-01
3.98E-06	1.56E-02	2	3.91E-01
5.01E-06	1.69E-02	2	3.08E-01
6.31E-06	1.82E-02	2	2.42E-01
7.94E-06	1.96E-02	2	1.89E-01
1.00E-05	2.12E-02	2	1.47E-01
1.26E-05	2.29E-02	2	1.14E-01
1.58E-05	2.47E-02	2	8.86E-02
2.00E-05	2.67E-02	2	6.84E-02
2.51E-05	2.88E-02	2	5.27E-02
3.16E-05	3.11E-02	2	4.05E-02
3.98E-05	3.36E-02	2	3.10E-02
5.01E-05	3.63E-02	2	2.37E-02
6.31E-05	3.92E-02	2	1.80E-02
7.94E-05	4.23E-02	2	1.37E-02
1.00E-04	4.57E-02	2	1.04E-02
1.26E-04	4.94E-02	2	7.88E-03
1.58E-04	5.33E-02	2	5.96E-03
2.00E-04	5.75E-02	2	4.50E-03
2.51E-04	6.21E-02	2	3.39E-03
3.16E-04	6.71E-02	2	2.55E-03
3.98E-04	7.24E-02	2	1.91E-03
5.01E-04	7.82E-02	2	1.43E-03
6.31E-04	8.45E-02	2	1.07E-03
7.94E-04	9.12E-02	2	8.03E-04
1.00E-03	9.85E-02	2	6.00E-04
1.26E-03	1.06E-01	2	4.48E-04

1.58E-03	1.15E-01	2	3.34E-04
2.00E-03	1.24E-01	2	2.49E-04
2.51E-03	1.34E-01	2	1.85E-04
3.16E-03	1.45E-01	2	1.38E-04
3.98E-03	1.56E-01	2	1.02E-04
5.01E-03	1.69E-01	2	7.59E-05
6.31E-03	1.82E-01	2	5.63E-05
7.94E-03	1.96E-01	2	4.17E-05
1.00E-02	2.12E-01	2	3.09E-05
1.26E-02	2.29E-01	2	2.29E-05
1.58E-02	2.47E-01	2	1.69E-05
2.00E-02	2.67E-01	2	1.25E-05
2.51E-02	2.88E-01	2	9.26E-06
3.16E-02	3.11E-01	2	6.84E-06
3.98E-02	3.36E-01	2	5.06E-06
5.01E-02	3.63E-01	2	3.73E-06
6.31E-02	3.92E-01	2	2.76E-06
7.94E-02	4.23E-01	2	2.03E-06
1.00E-01	4.57E-01	2	1.50E-06
1.26E-01	4.94E-01	2	1.11E-06
1.58E-01	5.33E-01	2	8.15E-07
2.00E-01	5.75E-01	2	6.01E-07
2.51E-01	6.21E-01	2	4.43E-07
3.16E-01	6.71E-01	2	3.26E-07
3.98E-01	7.24E-01	2	2.40E-07
5.01E-01	7.82E-01	2	1.77E-07
6.31E-01	8.45E-01	2	1.30E-07
7.94E-01	9.12E-01	2	9.59E-08
1.00E+00	9.85E-01	2	7.06E-08

Section S6: NIST PSTAR Proton Stopping-Power Data
Description: Interpolated proton projected range data for Kapton Polyimide (ICRU-49 composition) across the 0.010 MeV to 2.100 MeV kinetic energy sweep (corresponding to Figure 12).

Appendix G: Projected Proton Range in Kapton Polyimide (ICRU-49) Simulation Engine: NIST PSTAR Database Delimiter – Space				
Kinetic Energy (MeV)	**Projected Range (g/cm^2)**	**7.5 µm Threshold Line**	**Markers**	**Point Label**
0.01	2.51E-05	1.07E-03		
0.03	5.90E-05	1.07E-03	5.90E-05	~30 keV CME
0.06	9.99E-05	1.07E-03		
0.09	1.38E-04	1.07E-03		

0.12	1.76E-04	1.07E-03		
0.15	2.17E-04	1.07E-03		
0.18	2.60E-04	1.07E-03		
0.21	3.07E-04	1.07E-03		
0.24	3.57E-04	1.07E-03		
0.27	4.11E-04	1.07E-03		
0.3	4.68E-04	1.07E-03		
0.33	5.29E-04	1.07E-03		
0.36	5.93E-04	1.07E-03		
0.39	6.61E-04	1.07E-03		
0.42	7.32E-04	1.07E-03		
0.45	8.07E-04	1.07E-03		
0.48	8.84E-04	1.07E-03		
0.51	9.65E-04	1.07E-03		
0.54	1.05E-03	1.07E-03		
0.546	1.07E-03	1.07E-03	1.07E-03	Penetration Threshold
0.57	1.14E-03	1.07E-03		
0.6	1.23E-03	1.07E-03		
0.63	1.32E-03	1.07E-03		
0.66	1.41E-03	1.07E-03		
0.69	1.51E-03	1.07E-03		
0.72	1.61E-03	1.07E-03		
0.75	1.72E-03	1.07E-03		
0.78	1.82E-03	1.07E-03		
0.81	1.93E-03	1.07E-03		
0.84	2.04E-03	1.07E-03		
0.87	2.16E-03	1.07E-03		
0.9	2.28E-03	1.07E-03		
0.93	2.40E-03	1.07E-03		
0.96	2.52E-03	1.07E-03		
0.99	2.65E-03	1.07E-03		
1.2	3.60E-03	1.07E-03		
1.5	5.17E-03	1.07E-03		
1.8	6.98E-03	1.07E-03		
2.1	9.02E-03	1.07E-03		

Section S7: Thermal Equilibrium and Solar Irradiance Limits

Description: Dual-axis parametric sweep detailing continuous solar irradiance and the resulting steady-state operating temperature for the unshielded CP1/Aluminum sail architecture from 0.15 AU to 0.98 AU (corresponding to Figure 10).

Appendix H: Thermal Equilibrium and Irradiance Limits (0.15 AU – 0.98 AU) Simulation Engine: Analytical (Stefan-Boltzmann Parametric Sweep) Delimiter: Space		
Distance (AU)	**Temperature (C)**	**Solar Irradiance**
0.15	436.5	60488.9
0.16	413.9	53164.1
0.17	393.4	47093.4
0.18	374.6	42006.2
0.19	357.3	37700.8
0.2	341.4	34025
0.21	326.6	30861.7
0.22	312.8	28119.8
0.23	299.9	25727.8
0.24	287.8	23628.5
0.25	276.5	21776
0.26	265.8	20133.1
0.27	255.7	18669.4
0.28	246.3	17359.7
0.29	237.3	16183.1
0.3	228.6	15122.2
0.31	220.5	14162.3
0.32	212.7	13291
0.33	205.3	12497.7
0.34	198.2	11773.4
0.35	191.4	11110.2
0.36	184.9	10501.5
0.37	178.6	9941.6
0.38	172.6	9425.2
0.39	166.8	8948.1
0.4	161.4	8506.3
0.41	156.1	8096.4
0.42	151	7715.4
0.43	146.1	7360.7
0.44	141.2	7030
0.45	136.6	6721
0.46	132.1	6432
0.47	127.8	6161.2
0.48	123.5	5907.1

0.49	119.5	5668.5
0.5	115.5	5444
0.51	111.7	5232.6
0.52	108	5033.3
0.53	104.4	4845.1
0.54	100.8	4667.3
0.55	97.4	4499.2
0.56	94.1	4340
0.57	90.9	4189
0.58	87.8	4045.8
0.59	84.7	3909.8
0.6	81.7	3780.6
0.61	78.8	3657.6
0.62	75.9	3540.6
0.63	73.1	3429.1
0.64	70.4	3322.8
0.65	67.8	3221.3
0.66	65.2	3124.4
0.67	62.7	3031.8
0.68	60.2	2943.3
0.69	57.8	2858.6
0.7	55.3	2777.6
0.71	53	2699.9
0.72	50.7	2625.4
0.73	48.4	2554
0.74	46.3	2485.4
0.75	44.2	2419.6
0.76	42.1	2356.3
0.77	40	2295.5
0.78	38	2237
0.79	36.1	2180.7
0.8	34.1	2126.6
0.81	32.2	2074.4
0.82	30.4	2024.1
0.83	28.5	1975.6
0.84	26.7	1928.8
0.85	24.9	1883.7
0.86	23.2	1840.2
0.87	21.5	1798.1
0.88	19.8	1757.5
0.89	18.2	1718.2
0.9	16.6	1680.2
0.91	15	1643.5
0.92	13.4	1608

0.93	11.9	1573.6
0.94	10.3	1540.3
0.95	8.9	1508
0.96	7.4	1476.8
0.97	6	1446.5
0.98	4.5	1417.1

Section S8: Multi-Event Early Warning Time vs. Sentinel Distance

Description: Parametric early-warning time windows calculated across a continuous inner-heliospheric Sub-L1 sentinel domain for major historical space weather events, (corresponding to Figure 11).

Appendix I: Multi-Event Early Warning Time vs. Sentinel Distance Simulation Engine: Analytical Kinematic Model Delimiter: Space					
Distance (AU)	**1972 Ultra-Fast (2900 km/s)**	**1859 Carrington (2400 km/s)**	**2003 Halloween (2000 km/s)**	**1989 March (980 km/s)**	**2015 St. Patrick's (668 km/s)**
0.15	12.18	14.72	17.66	36.04	52.88
0.16	12.04	14.54	17.45	35.62	52.26
0.17	11.89	14.37	17.25	35.19	51.63
0.18	11.75	14.2	17.04	34.77	51.01
0.19	11.61	14.03	16.83	34.34	50.39
0.2	11.46	13.85	16.62	33.92	49.77
0.21	11.32	13.68	16.41	33.5	49.14
0.22	11.18	13.51	16.21	33.07	48.52
0.23	11.03	13.33	16	32.65	47.9
0.24	10.89	13.16	15.79	32.22	47.28
0.25	10.75	12.99	15.58	31.8	46.66
0.26	10.6	12.81	15.38	31.38	46.03
0.27	10.46	12.64	15.17	30.95	45.41
0.28	10.32	12.47	14.96	30.53	44.79
0.29	10.17	12.29	14.75	30.1	44.17
0.3	10.03	12.12	14.54	29.68	43.55
0.31	9.89	11.95	14.34	29.26	42.92
0.32	9.74	11.77	14.13	28.83	42.3
0.33	9.6	11.6	13.92	28.41	41.68
0.34	9.46	11.43	13.71	27.99	41.06
0.35	9.31	11.25	13.51	27.56	40.44
0.36	9.17	11.08	13.3	27.14	39.81
0.37	9.03	10.91	13.09	26.71	39.19
0.38	8.88	10.74	12.88	26.29	38.57
0.39	8.74	10.56	12.67	25.87	37.95
0.4	8.6	10.39	12.47	25.44	37.33

0.41	8.45	10.22	12.26	25.02	36.7
0.42	8.31	10.04	12.05	24.59	36.08
0.43	8.17	9.87	11.84	24.17	35.46
0.44	8.02	9.7	11.63	23.75	34.84
0.45	7.88	9.52	11.43	23.32	34.21
0.46	7.74	9.35	11.22	22.9	33.59
0.47	7.59	9.18	11.01	22.47	32.97
0.48	7.45	9	10.8	22.05	32.35
0.49	7.31	8.83	10.6	21.63	31.73
0.5	7.16	8.66	10.39	21.2	31.1
0.51	7.02	8.48	10.18	20.78	30.48
0.52	6.88	8.31	9.97	20.35	29.86
0.53	6.74	8.14	9.77	19.93	29.24
0.54	6.59	7.96	9.56	19.51	28.62
0.55	6.45	7.79	9.35	19.08	27.99
0.56	6.3	7.62	9.14	18.66	27.37
0.57	6.16	7.45	8.93	18.23	26.75
0.58	6.02	7.27	8.73	17.81	26.13
0.59	5.88	7.1	8.52	17.39	25.51
0.6	5.73	6.93	8.31	16.96	24.88
0.61	5.59	6.75	8.1	16.54	24.26
0.62	5.45	6.58	7.9	16.11	23.64
0.63	5.3	6.41	7.69	15.69	23.02
0.64	5.16	6.23	7.48	15.27	22.4
0.65	5.02	6.06	7.27	14.84	21.77
0.66	4.87	5.89	7.06	14.42	21.15
0.67	4.73	5.71	6.86	13.99	20.53
0.68	4.59	5.54	6.65	13.57	19.91
0.69	4.44	5.37	6.44	13.15	19.28
0.7	4.3	5.19	6.23	12.72	18.66
0.71	4.16	5.02	6.03	12.3	18.04
0.72	4.01	4.85	5.82	11.87	17.42
0.73	3.87	4.68	5.61	11.45	16.8
0.74	3.73	4.5	5.4	11.02	16.17
0.75	3.58	4.33	5.19	10.6	15.55
0.76	3.44	4.16	4.99	10.18	14.93
0.77	3.3	3.98	4.78	9.75	14.31
0.78	3.15	3.81	4.57	9.33	13.69
0.79	3.01	3.64	4.36	8.9	13.06
0.8	2.87	3.46	4.16	8.48	12.44
0.81	2.72	3.29	3.95	8.06	11.82
0.82	2.58	3.12	3.74	7.63	11.2
0.83	2.44	2.94	3.53	7.21	10.58
0.84	2.29	2.77	3.32	6.78	9.95
0.85	2.15	2.6	3.12	6.36	9.33

0.86	2.01	2.42	2.91	5.94	8.71
0.87	1.86	2.25	2.7	5.51	8.09
0.88	1.72	2.08	2.49	5.09	7.47
0.89	1.58	1.9	2.29	4.66	6.84
0.9	1.43	1.73	2.08	4.24	6.22
0.91	1.29	1.56	1.87	3.82	5.6
0.92	1.15	1.39	1.66	3.39	4.98
0.93	1	1.21	1.45	2.97	4.35
0.94	0.86	1.04	1.25	2.54	3.73
0.95	0.72	0.87	1.04	2.12	3.11
0.96	0.57	0.69	0.83	1.7	2.49
0.97	0.43	0.52	0.62	1.27	1.87
0.98	0.29	0.35	0.42	0.85	1.24